

## **FINAL REPORT**

## FHWA-WY-10/03F

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# VOLUME 2 GRAVEL ROADS MANAGEMENT: IMPLEMENTATION GUIDE

By:

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Abstract This report establishes procedures for managing dirt and counties, that must manage their roads with very limited re- implementing asset and pavement management principle management software. The overall effort required to implement a gravel roads ma- efforts must be limited and the analysis must be simple ar- maintenance history, and condition monitoring. This report is divided into three volumes. FHWA-WY-10/03F Volume 1 "Gravel Roads Managemenn Organization, Analytical Methods, and Summary and Con- FHWA-WY-10/03F Volume 2 "Gravel Roads Managemenn departments with implementation or improvement of a gravel with acquiring the necessary information to develop an inf	gravel roads, with a primary focus on sma esources. The report strives, first, to guid s and, second, to encourage and facilitate anagement system (GRMS) for local ager and transparent. The four basic steps are: t." This section outlines the Background, clusions. t: Implementation Guide." This section is avel roads management system. It is writ formation systems process	aller agencies, such as le and assist smaller a e the development of g ncies must be minimal assessment; inventor Problem Statement, C e designed to assist loc ten primarily for road n	s Wyoming Igencies by gravel roads . Data collection y; cost and Dbjectives, Report cal road and street nanagers tasked
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#### **INTRODUCTION**

Development of this unsealed dirt and gravel roads management implementation guide was driven by the simple fact that the cost of diesel is going up and the cost of information is going down. Given this fact, it makes sense to increase our use of information to reduce our use of diesel. This guide tries to help small agencies' road managers make this transition.

This guide is designed to assist local road and street departments with implementation or improvement of a gravel roads management system (GRMS). Much of the advice in this guide will apply to developing management systems in general. It is written primarily for road managers who realize that their agencies could operate more efficiently, and that they could present a clearer picture of their operations to elected officials and the public if they did a better job of collecting, managing, analyzing, using, and presenting information.

This guide is prepared in partial fulfillment of a project funded by the Wyoming Department of Transportation (WYDOT) and the Mountain-Plains Consortium (MPC) to address the lack of a GRMS designed for small, local government agencies. For further guidance on the issues raised in this guide, refer to the final report submitted to WYDOT and MPC on the Wyoming  $T^2/LTAP$  Center's website. A companion guide, the Programming Guide, provides advice to programmers who may be writing software to assist road and street departments with the implementation of a GRMS.

This guide is process oriented. The first section, ASSESSMENT, describes some of the preliminary actions road managers should go through when trying to improve their information management processes. The DATA MANAGEMENT section addresses some of the information handling issues agencies may be facing, and it suggests some possible ways of improving data management processes. The INVENTORY section describes basic elements of an unsealed road network that should be assembled before other roadway management functions can take place. The DATA COLLECTION section discusses ways of collecting data and how to avoid some pitfalls. Analyses that may be performed are described in subsequent sections, including CYCLIC MAINTENANCE SCHEDULING, TRIGGERED MAINTENANCE SCHEDULING, NETWORK LEVEL OUTPUTS, SAFETY ASSESSMENTS, and DRAINAGE ASSESSMENTS. Finally, the REFERENCES AND OTHER SOURCES section provides sources for some of the statements in this document and further reading for those who wish to learn more about this topic. The goal of this guide is two-fold: First, it strives to help road managers assess their current management processes.

#### ASSESSMENT

There are several basic questions a road manager should answer when contemplating implementing or improving a gravel roads management system (GRMS):

- How are we collecting, analyzing, and using information about our unsealed roads network?
- What resources do we have to improve the situation?
- What should we do next to improve our unsealed roads management?

The goal of this guide is to provide managers with an answer to the last question. To do this, the first two questions must also be answered. The following discussions try to provide managers with advice on how to answer these questions.

#### **Current Information Management Practices**

The first step a road manager should take when trying to improve their asset and information management processes is to assess their current strengths and weaknesses. There are many questions the road manager should ask themselves when undertaking this assessment, with some suggestions in the following paragraphs.

#### Five Core Questions about Infrastructure Management Systems

In workshop materials developed by the United States Environmental Protection Agency 'Five Core Questions' relating to asset management are raised:

- 1. What is the current state of our assets?
  - What do we own?
  - Where is it?
  - What condition is it in?
  - What is its remaining useful life?
  - What is its economic value?
- 2. What are the required levels of service?
  - What is demanded by users and stakeholders?
  - How do actual conditions differ from those desired?
- 3. Which assets are critical to performance?
  - How do they deteriorate and fail?
  - What is the likelihood of failure?
  - What is the consequence of failure?
- 4. What are good O&M (operation and maintenance) and CIP (capital improvement plan) strategies?
  - What management options exist?
  - Which are most feasible for our agency?
  - How do they impact level of service?
- 5. What is a good long-term funding strategy?
  - Does it align with my agency's policy goals? (Allbee 2007)

These questions are applicable to infrastructure assets in general. In many cases, applying these questions to unsealed roads may lead one to the conclusion that the efforts needed are so great and the task of answering them is so daunting that unsealed road managers may feel overwhelmed and discouraged. Still, asking these questions will help identify some of the hurdles faced when managing unsealed roads. For example, when establishing the condition of unsealed roads, their rapidly changing nature may make it difficult to answer these questions; when addressing failure of an unsealed road, we

first need to define 'failure,' also a difficult task. These issues and more demonstrate the need for alternate ways of thinking about unsealed roads.

#### **Questions from Australia about Unsealed Roads Management**

In the 'Unsealed roads manual' (*Giumarra 2009*), five questions are posed to help practitioners arrive at a suitable GRMS:

- 1) How much of the road network conforms to desired standards and community expectations for each road class?
- 2) Is the condition of the road network improving or deteriorating over time?
- 3) What potential safety problems, risks and liability issues are currently present in the network?
- 4) Is maximum value being obtained from current resource allocations?
- 5) Is the current level of resource allocation able to provide sustained operations?

Given that these questions are tailored specifically to unsealed roads, they begin to hit closer to the mark for gravel roads management. Most road managers could provide subjective answers to the first two questions, though having actual data to back them up would add a lot of credibility when they try to answer them for elected officials. Safety issues on local roads are often subordinate to cost issues. Without a mechanism for identifying safety problems, solutions will not be found, so it is road managers' duty to do their best to identify and solve safety issues. Questions about the value and sustainability of a road network and its management, like the first two questions, may be answered in subjective terms, but without data to back up any such statements, they also lack credibility. The following discussions tackle these questions individually in an effort to assist unsealed road managers in identifying their information management practices' most pressing needs.

#### Standards and Community Expectations

The goal of a GRMS should be to keep the customers happy. This may be impossible, but we should still try. In order to keep the public and their elected officials as happy as possible, we need some standards. One quantitative approach is to minimize user costs. For unsealed roads, user costs may be put into four categories:

- Travel time
  - How long it takes to get from place to place
- Vehicle operation costs
  - o Fuel
  - Filters and lubricants
  - Tires and suspension
  - Others
- Transitability
  - Access in all seasons and weather conditions
- Safety
  - Property damage
  - o Injuries

• Fatalities

In theory, one might develop mathematical ways of addressing and assessing each of these issues. However, from a practical point of view, few agencies will be able to conduct in-depth user cost studies, so they must make some sweeping generalizations about quantifiable minimum standards which the agency should strive to meet.

The most basic decisions address 'transitability.' Can a road be traveled in all seasons and weather conditions? In all vehicles? Will snow be plowed? These questions should be answered for all an agency's roads.

Next, acceptable road quality must be addressed, with travel time, safety, and vehicle operating costs defining road quality, perhaps along with ride comfort, though vehicle operating costs and travel times will mirror comfort issues. For each road section, a minimum acceptable surface condition should be established; the goal should be to perform maintenance when roads reach this condition, referred to as the 'maintenance intervention level.' These assignments should be presented to elected officials as a way to reduce maintenance costs, with the understanding that some roads may receive less maintenance and be in worse condition than they are now, potentially leading to more complaints from those who use them. Elected officials need to understand the implications of their fiscal decisions, and assigning 'maintenance intervention levels' is a way to demonstrate the consequences of budget constrictions and a way to prioritize maintenance and rehabilitation activities.

All these issues add up to the necessity to establish 'maintenance intervention levels' for each road section. Though in an ideal world, road managers would undertake sophisticated analyses to arrive at a minimum acceptable surface condition for every road section in their network, for smaller agencies this will be cost-prohibitive. Therefore subjective 'maintenance intervention level' assignments should be made, considering the factors described above.

#### Changes in Network Conditions with Time

Unlike sealed roads, unsealed roads change quickly with time, traffic, and weather, making it difficult to answer the question of whether the overall network condition is getting better or worse. Methods for assessing overall network condition include gravel thickness measurements and surface condition surveys, either visual or automated. Road managers should, at a minimum, ask themselves how they might evaluate the overall condition of their network, recognizing that answering this question may be difficult. (For more on this topic, see the DATA COLLECTION, Condition Data: *How does the road perform?* section.)

#### Safety, Risk and Liability

Safety issues should also be considered, though in many instances safety will compete for funds with transitability and ride quality. Road managers should use systematic approaches to identifying safety issues and should advocate their resolution in the most cost-effective ways possible, including seeking funding at the State and Federal levels. Accomplishing this will, in most cases, require the local agency to have data on the safety and liability issues on their road network. Fundamentally, the public expect roads to be safe in spite of existing conditions that make this a very difficult goal.

In spite of the relatively low traffic volumes on most unsealed roads, they are often dangerous. Instituting systematic safety and risk evaluation processes, along with the resolution of issues as they are identified and resources allow, will provide a good measure of legal protection in the event that the agency is sued over any failures to meet accepted safety standards. Also, lives will be saved. (For more on this topic, see the SAFETY ASSESSMENT section.)

#### **Optimizing Resource Allocation**

The fundamental question of whether resources are achieving maximum value is really a question of spending funds in the most cost-effective manner. This goes right to the core of asset management: It is the use of objective standards to provide the best possible service at the least cost. Fundamental questions involve materials selection, equipment purchases, routine maintenance (blading) frequency, periodic maintenance (reshaping, regraveling and dust suppression) frequency, snow plowing policy and other decisions that impact both the cost of maintaining unsealed roads and the standards to which they are maintained. Many agencies now make these choices based on the road supervisor's subjective judgment, with elected officials frequently making significant decisions that substantially influence and change the supervisor's plans.

Data from a GRMS should help supervisors justify their plans. Hopefully information from a GRMS helps them persuade elected officials to make the best possible decisions for the long-term health of their unsealed roads network. Indeed, if the data are good enough and presented well enough, the case might be taken directly to the public and the media, thereby influencing elected officials by demonstrating that decisions made to balance a budget may be providing a long-term disservice to the general public, leading to the short-sighted politicians losing their next election.

#### **Operational Sustainability**

The issue of operational sustainability is related to the one of whether the overall network condition is improving or deteriorating, though it also incorporates the issues of maintenance and rehabilitation optimization. It might be demonstrated that current funding levels are adequate *if*, for example, an agency is willing to spend the additional money up front to purchase better quality gravel, or if the agency is willing to allow some very low traffic volume roads to be maintained to a lower standard. To address these issues, one must have some way of monitoring conditions and projecting future conditions with a variety of maintenance and rehabilitation strategies. Only by collecting condition, maintenance and cost data for an extended period of time can this issue be accurately addressed.

#### **Information Management Assessment Summary**

When evaluating the current information management practices of a road or street agency, two primary factors, agency costs and user costs, should be kept in mind at all times. The following questions may help consolidate and clarify a road or street manager's evaluation of their gravel roads management practices:

- How are cost data tracked, stored, analyzed, used and presented?
- How are network conditions assessed, used and presented?
- How are maintenance strategies established for each road section?

- How are maintenance and rehabilitation tasks scheduled and prioritized?
- Is information provided to the public and elected officials that lets them understand unsealed road and street management well enough to make good decisions regarding funding and other higher level management decisions.
- Is the unsealed roads network managed as efficiently as practical?

Hopefully, by answering these questions road managers will identify those areas within their own information management practices that, if improved, will yield the greatest benefit to their agency and the traveling public.

#### **Available Resources**

Once the need for improvement has been established, the next step is to perform a reasonable assessment of the agency's resources, both financial and otherwise. The following discussions provide guidance in this assessment.

#### Support

Without the political will to carry through with implementation of a GRMS, any effort to establish such a system may be wasted. Therefore road managers need to convince their crews and others involved in the agency's information management of the value of a GRMS, and if additional funding or cooperation from other departments within the agency are needed, elected officials and other decision makers may also need to be convinced.

One problem many agencies will face is that it may take some time to collect data upon which good decisions can be based. Thus, there will need to be considerable effort expended before a management system shows many rewards. This reality must be understood both by those who will fund the effort and by those who will do the work. Identifying areas where benefits can be achieved quickly, such as instituting needs-based maintenance scheduling, may help get an agency through the early period when initial data are being collected. Support for an asset management program must be maintained throughout this early period while historical data are being accumulated.

#### **Financial Resources**

It's easy to agree in principle to better manage one's assets, but it is quite another thing to be willing to put forward the time and money needed to carry out a plan. To this end, it should be kept in mind that an agency should proceed with small steps, correcting those problems that may inhibit better management of their unsealed roads. Much of the initial assessment should be geared towards identifying those next steps that will be most cost-effective. Implementing a GRMS does not have to be expensive, but it has to be well thought out and designed to work within an agency's financial restraints.

#### Hardware, Software, GPS and GIS

Though for most agencies the greatest investment they will make in a GRMS will be their employees' time, computer expenditures may also be needed. Fundamental computer equipment will be the geographic information system (GIS) software and a computer to run it on, not to mention a person skilled at running the software. Global positioning system (GPS) units may also be useful. However, it is

more important to understand how to develop an effective GRMS with equipment that's already available than it is to have particularly high tech computer, GIS, or GPS equipment. It's better to start out with a simple system that can be run on a spreadsheet than it is to get in over one's head with a complex system that is too difficult to maintain.

If a commercial software package is in use, perhaps cost tracking software, then its appropriateness and effectiveness should be assessed. Agencies may determine that they have the right software in place, but it is not being used to its fullest potential due to poor selection of budget line items or to poor division of the road network into sections.

#### Information

An early step in developing a GRMS should be to assess what information is already available. Information may be available within the agency and it may be available elsewhere, perhaps from the State Department of Transportation or other sources.

The simplest information is a map or other location-based information. Most agencies will have an existing map of their roads. Other related information includes road lengths, distances between intersections, top widths, surface types and ownership. For additional guidance, see the list of fields in the INVENTORY section below.

Another type of information that should be not only collected but evaluated is historical cost and maintenance data. This information should be evaluated as to whether it is being collected in a way that provides the greatest value. In many cases, data are collected in ways that are important to accountants but are of limited value for road managers. For many agencies, an early step will be to adjust and clarify how maintenance and cost data are collected. The Maintenance and Cost Tracking section below provides additional guidance in evaluating historical data, while the Maintenance Task Definitions section defines those maintenance tasks that are of interest to road managers.

The following list contains some of the types of information that might be useful when establishing a GRMS:

- Condition data
- Traffic data
- Safety or crash data
- Drainage data
- Roadway location and length data
- Aerial and other photos
- Classification data, such as functional classes
- Maintenance history data
- Cost data
- Soil type data
- Legal and Right-of-Way data

In addition, good metadata should be obtained. (Metadata is information about the data, such as how they were collected, when they were collected, what the various fields or columns represent, what units are used, and so on.) As information is collected, it should be kept in standard formats whenever possible so transfer to a standard platform can take place as different uses for the information become apparent.

#### Personnel

Having people on staff with the willingness, understanding, and skills to make a management system work is critical. All the money, computers, and software in the world won't be of much use if the people operating them don't understand and believe in what they are doing. The first factor is whether they understand why they are changing how they operate. They need to see the potential benefits of a management system. Many experts in the field were willing to volunteer their time to this collaborative effort. Clearly they see the potential for success in managing unsealed roads. Those responsible for maintaining and managing these roads must also understand what they are doing and why they are doing it.

In addition to understanding what they are doing, personnel will need certain skills to help with the implementation of a GRMS. Those skills fall into three classes: Computer skills, preferably with GIS, though spreadsheets will do; GPS skills; and unsealed roads skills. Of these, probably the most unique and difficult to acquire are the roads skills. Fortunately most agencies initiating an unsealed roads management program already have these skills. GPS units have become relatively easy to operate, and many people currently use them for outdoor recreational pursuits. Probably the most challenging personnel issue will be finding those with the computer skills to implement a GRMS. However, a well planned management system does not need a full-time GIS expert to make it work. It *does* need at least one conscientious person to make sure the database, even if it is only a system of index cards, is well managed and up to date.

#### **Assessment Summary**

The first step in implementing or improving a GRMS is to evaluate the agency's current information management practices as they relate to unsealed roads. Once this has been done, the agency should be able to identify the areas where improvement will yield the most positive results. Then, by combining this knowledge with the skills of their personnel and other available resources, an agency may proceed with improving its information management using the guidance provided in the following sections.

#### **DATA MANAGEMENT**

There are numerous ways unsealed roads data can be managed. An early decision will be whether to purchase a commercial software package, obtain a free package, or develop software internally. Each has its pros and cons. A review of the results of the assessments described above should provide some indication as to whether an agency should purchase commercial software or develop it internally from a spreadsheet, database, or GIS package.

Most data management systems can be assigned to one of these three general types:

- Manual
  - File cabinets, manila folders, and so on
- Databases or spreadsheets
  - o Tables of information stored in a computer
- Geographic information systems (GIS)
  - Databases with a mapping function

In the most general terms, the larger the road network, the more advantageous it will be to work towards the bottom of this list. A small town with two miles of streets and thirty sections may do very well with a manual system, especially if it is already established and working well, while an agency with a thousand miles of roads and hundreds of sections may be frustrated without the mapping capacity provided by a GIS system.

In addition to the size of the network, an agency's level of available expertise, particularly computer expertise, should also play into the decision-making process when selecting the means of managing information. If an agency has an under-utilized GIS programmer available, by all means put them to work setting up a gravel roads management system (GRMS), at least in the earlier stages. It may be worthwhile to work with a commercial software provider, particularly if an agency is preparing to institute a better system for tracking costs and maintenance tasks. Any agency contemplating instituting a GRMS should make their information management decisions based on both their needs and their resources.

#### **Manual Data Management Systems**

For all but the very smallest agencies, a manual system is not practical. Unless you can list from memory every sign and culvert in your jurisdiction, it is probably time to at least learn how to use a spreadsheet. If this isn't going to happen, you should pattern your filing system on those described below for spreadsheets and databases.

#### **Spreadsheet and Database Management Systems**

At a minimum, there should be two tables in a spreadsheet or database-type system, one with static fields, the inventory as described in the INVENTORY section below, and another table with changing fields to record maintenance and condition monitoring. Realistically, once a system develops any sophistication at all, additional tables will be desirable. There should be a table with static, inventory-type data; a table to record maintenance performed and its costs; and a table to record conditions. One might also have tables recording material costs, including the costs associated with crushing and stockpiling gravel, whether by agency or contracted forces. Equipment costs might have their own table; there are entire fleet management systems available. A number of spreadsheet functions, such as filters, sorts, and lookups may be useful, not to mention macros and software code that may be used for

fairly sophisticated applications, though programming time can quickly add up. There will always be a trade-off pitting ease of operation and simplicity against flexibility and sophistication.

Final decisions on what tables or sheets should be created should be made by programmers with a good understanding of both the principles and practices described in this report and with the agency's operations and existing information management procedures. The following tables are simplistic suggestions:

- Static Inventory
  - As described in the INVENTORY section
- Maintenance performed, including costs
  - Possibly derived from a Work Orders system
  - Possibly derived from Time Cards
- Condition and Performance Data
  - Traffic counts
  - Safety data and conditions
  - Drainage conditions
  - Surface condition ratings
  - o Gravel thicknesses

More detailed and advanced discussions are in the Programming Guide.

#### **Geographic Information Systems (GIS)**

Most of what was said in the preceding Spreadsheet and Database Management section also applies to a GIS; a GIS is a database with a mapping component. Given the geographic nature of road networks, this can be a tremendous advantage, both for road and street crews carrying out their daily activities and for elected officials and the public who are trying to understand what the agency is doing.

There are two main drawbacks to using a GIS system instead of a spreadsheet system. First, fewer people are familiar with GIS software than with spreadsheet software, and, second, GIS software is more complex so both programming and data analysis are more difficult. However, with that said, GIS systems have become much easier to use, and commercial packages are becoming available that utilize GIS functionality. In spite of some drawbacks, GIS should be used whenever practical, and spreadsheet or database systems should be switched over to GIS if the resources to do so are available.

#### **INVENTORY**

An inventory is simply a list of assets and a few fundamental, static attributes of the assets, unsealed roads in this instance. Without the structure an inventory provides, other more sophisticated steps in a gravel roads management system (GRMS) are not possible.

At the very least, the following aspects of an unsealed road network should be collected and stored:

- > Unique Section Identification: Road Name and/or Number
  - Each section of road should be uniquely identified. Many agencies will only have road names or numbers. Some provision should be made within a database scheme to split existing roads into smaller sections should such needs arise.

#### Location

- This may be as simple as having references to a map or as complex as a computerized geographic information system (GIS), or it may be a verbal description stored in a file cabinet or spreadsheet.
- The location of each section should be described, preferably with data from a global positioning system (GPS), and road networks should be divided into sections as described below in the Dividing a Road Network into Management Sections section.

#### > Surface Type

- The road's surface type should be identified and recorded. The following list contains suggested road types that may be applied to an entire unsealed road network.
  - Earth: unformed
    - Few or no drainage provisions
  - Earth: formed
    - Drainage improvements present
  - Gravel
    - Gravel only
    - Gravel with isolated dust control
    - Gravel with dust control
    - Stabilized gravel
    - Stabilized gravel with dust control
- Each agency should determine their own surface type classes, though those above should be sufficient for most agencies.
- This may be integrated into an overall agency road inventory that also includes sealed roads.
- > Length
  - The section's length should be recorded as accurately as possible. This may be complicated by uncertainty as to where an agency's roads truly begin and end.

Without this very basic information, no formal road network management can take place.

In addition to the fundamental inventory elements listed above, there are a number of other desirable elements to an inventory. Some of these are straightforward and easy to obtain, others take additional monitoring effort, while still others may require varying degrees of decision-making. The following list in approximate order of importance includes other elements of a GRMS inventory that an agency should consider collecting:

#### Road Name and Number

 In addition to the unique road section identifier described above, the name and number of the road should also be included in the inventory. It should be noted that one road may be split into several sections, each with its own unique section ID. With road names and numbers also in the inventory, searches on information about an entire road may be made even if the road is split into several maintenance management sections.

#### > Top Width

• Measurement of the typical usable width of the traveled way on tangents, between the hinges of the shoulder

#### Inventory Date

• When the initial inventory data was compiled

#### Inventory Data Collector

• Name or initials of the individual who compiled the inventory data

#### > Owner

• The legal status of the road should be described, including whether the agency has an easement, a right-of-way, or whether the legal status is uncertain. Additionally, if a road is owned by one agency but maintained by another, this should be indicated. Each agency should compile a list of possible ownership statuses.

#### Right-of-Way or Easement Width

- Functional Class
  - This assignment is made for a variety of reasons including the determination of appropriate geometry as described in the 'Green Book' (AASHTO 2004) and in the 'Very Low Volume Design Guide' (AASHTO 2001), and for a variety of funding applications.
  - Functional Classification may be the basis for the assignment of a section's maintenance intervention level and maintenance strategy as described below.
  - The following functional classifications based on the AASHTO guides are recommended, with those defined in the 'Green Book' in **bold italics** and those defined in the 'Very Low Volume Design Guide' in **bold**.
    - 1. Rural major collector roads
    - 2. Rural minor collector roads
    - 3. Rural major access roads
    - 4. Rural minor access roads
    - 5. Industrial/commercial access roads or streets
    - 6. Agricultural access roads or streets
    - 7. Recreational and scenic roads or streets
    - 8. Resource recovery roads or streets
    - 9. Urban collector streets
    - **10.** Urban major access streets
    - **11. Urban residential streets**

- Most agencies will not want to use all of these functional classes, though as the standard means of categorizing roads, local agencies should adhere to these classes so they may compare their network to others.
- Though traffic levels are not assigned to these classifications, there should be a general correlation between traffic levels and functional classifications, with higher classifications having more traffic. Additionally, the industrial, agricultural, and resource recovery roads will usually have a substantially higher proportion of heavy vehicles.

#### Maintenance Intervention Levels

- If a cyclic maintenance program is to be implemented, each road section should have an assigned minimum acceptable surface condition, referred to as its 'maintenance intervention level.' When a road's surface condition is worse than this minimum, maintenance should be performed as described below in the Maintenance Intervention Levels section.
- An agency might decide to assign all road sections within a given functional class to a
  particular maintenance intervention level. Table 1 suggests possible maintenance
  intervention levels, though it should be kept in mind that local considerations may
  change these.

#### Maintenance Strategy

• If a maintenance intervention level is assigned and a cyclic maintenance program is planned, then at some point the agency will need to assign a maintenance strategy to each road section, as described below in the Assign Road Sections to a Maintenance Strategy section.

#### Maintenance District

• Typically a maintainer will be responsible for a group of road sections, their district. This identifies the district each section is in.

#### Traffic Volumes

- Measured
  - ADT Average Daily Traffic
    - Cumulative traffic in vehicles per day, both directions
    - Should be corrected for season, day of the week, and time of day
  - Percent trucks > 10,000 lbs
    - Any effects of intermittent operations should be accounted for

# Table 1 Suggested MaintenanceIntervention Levels by FunctionalClass

	Maintenance
	Intervention
<b>Functional Class</b>	Level
Rural major collector	7 - Good
Rural minor collector	7 - Good
Rural major access	6 - Fair
Rural minor access	5 - Fair
Industrial/commercial	5 - Fair
Agricultural	3 - Poor
Recreational/scenic	3 - Poor
Resource recovery	4 - Poor
Urban collector	8 - Good
Urban major access	7 - Good
Urban residential	6 - Fair

- o Estimated
  - The ADT may be estimated if actual counts are not available
  - Percent trucks may be estimated if actual counts are not available

#### > Traffic Speeds

- o Posted
- Statutory
- Measured
  - Mean
  - 85<sup>th</sup> percentile
- o Design

#### > Transitability

- Dry season only
- o All seasons
  - Snow plowed
  - Snow not plowed

#### > Utilities

- о Туре
- Location
- Contact information
- Legal agreements

#### Legal Documentation

 This is related to the 'Owner' classification above, though one might go into more detail including references to legal documents. One might reference particular documents, including dates, such as commission minutes, or one might reference scanned electronic files.

#### Survey Information

 This may also be related to the 'Owner' classification above. References to any surveys performed might be useful, particularly if issues arise regarding legal status and right-ofway. Such references might include surveyor, date, and type, as well as links or references to any electronic files.

#### Subgrade Type(s)

• List, using AASHTO or USCS soil classification systems

#### Roadway Prism Height

- Above natural grade
  - <1½′ [0.5 m]
  - 1½' to 3' [0.5 1.0 m]
  - 3' to 5' [1.0 1.5 m]
  - >5′ [>1.5 m]
- At natural grade
- Below natural grade

#### **>** Road Uses: Social and Economic Benefits

- o Residential
- Public transit route
- School bus route
- Postal route

- o Emergency access
- o Industrial
- Agricultural
- Recreational
- Resource recovery
  - Mining
  - Logging
  - Oil and gas drilling
  - Wind farm
- o Other uses
- Through traffic

#### Land Use

- o Urban
- Rural (serves residences)
- Remote (does not serve residences)

#### > Terrain

- o Flat
- o Rolling
- o Hilly
- o Mountainous

#### > Photographs

- Other Roadway Features
  - o Intersections with public roads
  - Approaches
    - By type
  - Bridges
  - Box culverts
  - Large pipe culverts
  - Small pipe culverts
  - Low water crossings
  - Cattleguards
  - o Railroad crossings
  - Fencing
  - Snow fences
  - o Signs and delineators
  - Roadside vegetation type
  - o Crash data
  - o Others

Many features, particularly those listed in 'Other Features' above, may be monitored and managed by other management systems.

Agencies should weigh the benefit of having each of the above pieces of information against the cost of obtaining and managing that information. When setting up a database, it may be wise to include blank fields even if it is not the intent to collect more data right away, thereby avoiding major software rewrites in the future.

#### **Dividing an Unsealed Road Network into Management Sections**

Once an initial inventory including roads, surface types, and lengths is in place, it will usually be advantageous to subdivide the roads into fairly uniform sections. With that said, there will always be a trade-off between the value of having very specific information and the cost of obtaining and managing that information. As a general recommendation, most agencies will not need to further subdivide most of their roads if they have an existing inventory, though the following discussion may shed some light on when further subdivisions should be made.

The purpose of splitting a road into maintenance management sections is to track information by sections that receive the same maintenance and improvement treatments. Other assets, such as a parking lot, might also be considered a 'section.' Section lengths could vary from as little as a few hundred yards to a dozen miles or more. The trade-off between cost and benefit should be kept in mind at all times. The more sections there are, the more data that will need to be collected. However, if sections are too long, portions of a road that should be managed separately may be analyzed together, limiting the value of outputs from the management system. If, with time, it becomes apparent that a section is too long, it should be possible to subdivide the section.

There are a number of factors that may influence the division of a road into appropriate sections. A fundamental consideration will be whether a section has been maintained as a single unit in the past. Often this information will be easily obtained by asking the maintainer. They will usually be the person responsible for establishing the beginning and ending points of sections within their district. The following factors should be considered when splitting a road network into sections:

- Typical surface condition
- Maintenance history
  - Typical maintenance beginning and ending points
  - o Treatment beginning and ending points
- Construction history
  - Structural characteristics
  - Surfacing types
- Traffic
  - o Type
  - o Volume
  - o Speed
  - o Heavy vehicles
- Road use
  - Subdivisions and other residences

- Intersections
- Gravel pits and other extractive and industrial activities
- Agricultural operations
- o Recreational activities
- Land use
  - o Urban
  - Rural (serves residences)
  - Remote (does not serve residences)
- Subgrade Type
- Terrain

#### **DATA COLLECTION**

Once an inventory is established, there are three types of data collected as part of a gravel roads management system (GRMS) which answer these questions:

- What is done to the road?
  - Maintenance
  - o Rehabilitation
  - o Drainage
- What happens to the road?
  - o **Traffic**
  - Weather
  - Subgrade
- > How does the road perform?
  - Surface conditions
  - Crash data

If these three questions are answered completely, the road can be analyzed and managed very efficiently. Unfortunately, answering these questions costs money and it is not cost-effective to try and answer them all completely. The following sections provide some insights into deciding how much and which data are worth collecting. Fundamentally one must assess the costs of collecting, storing and analyzing data and compare these costs to the value obtained from these data.

There are logistical questions that need to be answered before beginning the process of collecting data:

- Who collects the data?
- How are the data collected and stored?
- When do we collect condition data?

The following sections provide guidance in answering these questions.

#### Historical Data: What is done to the road?

This task involves tracking the agency's unsealed roads maintenance and rehabilitation activities. Many agencies already track their activities and tasks, though they may not be tracked in such a way that the information is as useful as possible from a management point of view.

It has become apparent that one impediment to managing unsealed roads is the way in which information about them is currently tracked. While many agencies track costs, they generally do so according to a system developed by accountants to track money. It is important from a management point of view to also track costs and tasks in terms of how the road itself is treated. For example, it matters to accountants whether gravel is hauled in a contractor's truck or in the agency's truck, but from a road management point of view, the owner of the truck is irrelevant. However, it *is* important to know whether the hauled gravel is used to repair a soft spot or to regravel the entire section; many systems set up by accountants do not make this distinction. Data need to be collected in a way that is useful to road supervisors and engineers as well as to accountants. The next section describes maintenance tasks that should be the basis of an unsealed roads cost tracking system.

#### Maintenance Task Definitions

Many agencies now collect cost and other data about unsealed roads (and other assets) using systems set up by accountants. When preparing to implement a maintenance and cost tracking system, serious consideration should be given to how costs and tasks will be assigned and classified. The line items to which costs are assigned should fulfill the needs of both accountants and engineers. Frequently, cost-tracking systems are established by and for accountants.

The following definitions are proposed for describing tasks performed on the surface of unsealed roads. They are very similar to those in *(NACE 1992)* with minor adjustments and clarifications to avoid confusion when used in a GRMS. The process of assigning work to one of these tasks is diagrammed in Figures 1 and 2.

#### Blading (Surface Smoothing; Dragging)

- *Purpose*: Remove surface defects; minor crown restoration
- *Equipment*: Motor grader, and possibly but not typically a compactor or water truck
- *Extent*: Limited to the driving surface and shoulders, going only deep enough to remove surface defects, such as ruts, washboards, and potholes; throughout the length of the section or in extensive areas greater than 20% of the section length where surface defects are significant, ignoring those areas without significant surface defects.
- Reshaping (Pulling shoulders; Cleaning ditches; Blending gravel)
  - *Purpose*: Improve drainage; recover material from the foreslope or ditch; blend surface gravel; restore crown; remove surface defects; correct defects in the road's crosssection
  - *Equipment*: Motor grader, and possibly but not typically a compactor, water truck, or vegetation removal equipment

• *Extent*: Greater than that for 'Blading;' to a depth greater than surface defects to blend the gravel, and/or the foreslope and ditch; throughout the length of the section or in extensive areas greater than 20% of the section length where such work is necessary, ignoring those areas that don't need reshaping.

#### Regravel

- *Purpose*: Restore structural capacity; improve quality of surfacing gravel; replace lost gravel
- Equipment: Motor grader, haul trucks; typically but not always compactor, water truck
- *Extent*: Typically the entire section length and at least 20% of the section length. Does *not* include the preparatory work of reshaping the road before placement of additional gravel; this work should be classified as 'Reshaping.' Also, it does not include dust suppression or soil stabilization.

#### Dust Control

- *Purpose*: Reduce emanation of fugitive dust
- Equipment: Distributor, and often motor grader, haul truck, and compactor
- *Extent*: Entire driving surface of the roadway for at least 20% of the section length. Generally applied topically.

#### Stabilization

- *Purpose*: Improve structural capacity; reduce routine maintenance frequency
- Equipment: Motor grader, distributor, haul truck, compactor, and sometimes a reclaimer or pugmill
- *Extent*: Entire driving surface of the roadway for at least 20% of the section length. Generally blended into the road surface with a reclaimer, pugmill, or motor grader.
- Isolated Repairs (Spot gravel, Patching, Soft spot repair)
  - *Purpose*: Correct isolated defects in a roadway
  - *Equipment*: Varies, but often includes motor grader, skid steer, haul truck, compactor, water truck, backhoe
  - *Extent*: All activities normally classified as 'Routine Blading,' 'Reshaping,' 'Regravel,'
     'Dust Suppression,' or 'Soil Stabilization' and other repairs with a total cost less than
     \$50,000 per mile per repair event which are performed on less than 20% of the roadway.
- Major Work (Major Repairs, Realignment, Rehabilitation, Reconstruction)
  - *Purpose*: Correct major structural or functional flaws
  - Equipment: Highly variable
  - *Extent*: Above and beyond that described for other activities, with surface and structural roadway repairs costing more than \$50,000 per mile per event excluding work that falls into one of the other maintenance tasks, and repairs that don't fall into any other category but that take place on 20% or more of the section length.

#### Drainage

- *Purpose*: Restore drainage and water flow; prevent scour, erosion, and piping
- Equipment: Variable, but often including shovels and backhoes

• *Extent*: Shoulders, foreslopes, ditches, backslopes, culvert ends

The values above of 20% of the section length and \$50,000 per mile are suggested values. They are used to determine whether a road's maintenance plan should be reassessed.

Figures 1 and 2 consist of a maintenance type decision tree, a flowchart that shows how maintenance costs should be assigned to the tasks listed above, with the exception of drainage maintenance. It is apparent from this chart that two of these tasks, 'Isolated Repairs' and 'Major Work,' are basically catchall classifications, while the other five tasks, 'Blading,' 'Reshaping,' 'Regravel,' 'Dust Suppression,' and 'Soil Stabilization' are specifically defined maintenance tasks that should be programmed in an effective GRMS.

When establishing or changing maintenance and cost tracking systems, one should have a clear idea as to how establishing such a system will improve the agency's operations. From an unsealed roads management point of view, all costs should be attributable to an individual road section and to one of the eight tasks described above.

#### **Time Cards**

One option for obtaining maintenance and cost information is from employees' time cards. If they simply indicate which, if any, of the eight tasks described above in the Maintenance Task Definitions section they worked on and which road sections they did the work on, one would have very useful maintenance data. A drawback might be that time cards only include labor costs, but not materials, supplies, or equipment costs.

#### **Work Orders**

Another possible source of information might be work orders, particularly if an agency is planning to change or implement a work order system. Like time cards, this is a form of paperwork that might only need minor adjustments to provide more useful information about what maintenance was performed on which road sections and how much it cost.

#### **Field Reports**

Another option might be to have crew foremen fill out forms describing the work their crews carry out; maintainers might file similar paperwork each time they maintain a road. These reports should provide a way of tracking both the maintenance tasks performed and the cost of performing these tasks, along with the road sections they were performed on.

#### Situational Data: How do precipitation, traffic and subgrade affect the road?

Two main environmental impacts on unsealed roads are precipitation and traffic. A related impact comes from below as the subgrade supports or fails to support the roadway.

Traffic monitoring should take place on as many sections in a network as practical, though the higher volume roads should have the highest priority, with estimates of traffic as an alternative on lower volume roads if actual counts aren't available.



Figure 1 Maintenance cost task assignments: Part A



Figure 2 Maintenance cost task assignments: Part B

Precipitation can dramatically affect the performance of unsealed roads. Unfortunately agencies will rarely have local precipitation data, and even if they did, the precipitation at one end of the section may be dramatically different from that at the other end. Generally, GRMSs will have to be able to function without weather data. However, consideration may be given to the time of year and freeze-thaw cycles.

Subgrade type critically affects the performance of unsealed roads. While it would be helpful to have detailed laboratory tests on every subgrade, a simple rating on a scale from Excellent to Failed might provide useful information. When one road is performing better or worse than another, the subgrade type may be causing such a discrepancy. It would be helpful to recognize this by having an evaluation of the subgrade.

#### Condition Data: How does the road perform?

Safety concerns should be addressed by a separate safety management effort addressing issues such as crash rates, signing, and so on. The SAFETY ASSESSMENTS section below addresses some simple safety issues that should be addressed as part of a GRMS.

It has been said that "If you can't measure it, you can't improve it." Assessing the condition of unsealed roads is difficult, but a GRMS should have the conflicting goals of providing the best possible service at the lowest possible cost. The quality of the driving surface is the primary measure of 'the best possible service' so ultimately we want some measure of surface conditions.

In establishing a condition monitoring program, one should determine what the data will be used for. The two fundamental reasons for collecting surface condition data are, first, to use condition data as the trigger for scheduled maintenance, and, second, to determine the overall condition of the network.

Condition data may be collected visually from within the vehicle, a 'windshield' survey method; it may be collected manually by getting out of the vehicle and measuring; or it may be collected using automated devices such as roughness meters and ground penetrating radar (GPR).

Once an inventory is established and a road network's history is being recorded, the next step in gravel roads management is monitoring the road sections' conditions. By evaluating road surface conditions in a systematic way, maintenance and repair schedules can be generated. Such schedules will lead to a wide variety of outputs, including cyclic and triggered maintenance programs and assessments of how a road network's overall condition is changing with time. However, there is a trade-off – it takes time and money to collect and manage data. In addition there are several logistical problems with monitoring the surface condition of unsealed roads:

- Rapid Deterioration
  - Unsealed road surfaces deteriorate much more quickly than sealed roads, even under the best of circumstances. The fact that they do so means a road that is in very good shape today may look quite different next week, making condition data suspect at best and irrelevant at worst.
- Weather and Precipitation

- Unsealed roads are highly susceptible to weather changes, particularly precipitation and freeze/thaw. No matter how good the road's crown and drainage, some moisture remains on or in the road after rain or snowmelt, softening it and making it more prone to ruts and potholes.
- Maintenance
  - Unsealed roads are maintained much more frequently than sealed roads. In order to collect meaningful condition data, one must coordinate condition data with maintenance data.
- Vehicle Path
  - When driving down an unsealed road, most drivers will try to miss potholes, washboards and ruts. Often one can substantially increase speeds by dodging most of the road's distresses. This consideration makes even automated monitoring of unsealed road conditions suspect.

In spite of these problems, it may be possible to obtain meaningful condition data. The rapid deterioration and maintenance issues may be addressed by considering the time since the most recent maintenance when assessing condition data. Recording the moisture condition of the road along with condition data may provide some insights into the true typical condition of the road. Having a single driver operate an automated test vehicle may reduce the impacts of different drivers taking different paths down an unsealed road. These issues need to be considered before undertaking an unsealed roads condition monitoring effort.

There are several methods for evaluating the quality of an unsealed road's surface as perceived both by the traveling public and by those who work on those roads. Simply put, the public is concerned with conditions now, while agency employees are concerned with the maintenance the roads will need and how current conditions predict future conditions.

There are several options when contemplating monitoring surface conditions of an unsealed roads network, each with its own strengths and weaknesses. Most agencies will decide upon one or more of these data collection techniques, depending on the purposes to which the data will be applied.

- Visual surveys
  - Driving the road and evaluating its condition based on visual observations
  - Loss of crown and shape
  - Supplement with digital photographs
- Manual measurement of distress severities and extents
  - Sampling road sections and performing measurements to determine a condition index
- Automated condition surveys
  - Use of a vehicle that routinely travels a road network to automatically collect roughness data
- Gravel thickness measurement
  - Excavation

- Ground penetrating radar (GPR)
- Reasonable travel speeds
  - Limited by surface roughness
  - Limited by alignment
  - Limited by sight distance

For any of these methods, the data collector should be trained. This is essential to gathering consistent data. Overall instructions to data collectors need to be explicit. Should the data collector record the current condition of the road or the typical condition? Ideally, for long-term network level uses and for regraveling or dust suppression issues, the typical condition should be recorded. If adjusting routine maintenance schedules is the objective, current conditions may be the most important. In all cases, the training and methods of data collection should be appropriate for the data's application.

The following discussions attempt to describe the pros and cons of several approaches to unsealed road condition data collection.

#### **Subjective Visual Survey**

The simplest method of evaluating a road's surface is to drive it and subjectively rate it. The PASER system *(Walker 1989)* takes this approach, though it provides an overall rating that combines surface conditions with drainage characteristics. Training and quality control procedures are critical to maintaining consistency using a subjective visual survey.

Using a subjective rating of the road surface condition has both advantages and disadvantages. The main advantage is that it is quick and inexpensive to perform. The main up-front expense is training, a critical step to getting consistency from evaluator to evaluator. This leads into the main disadvantage; it is difficult to get consistent ratings, not just from evaluator to evaluator, but even a single individual may have some drift in their standards, depending on uncontrollable variables such as how much sleep they got last night (more sleep, better condition ratings) and whether they had time for a third cup of coffee (more coffee, worse condition ratings). It is difficult to rate roads the same way from day to day. In spite of these problems, a simple subjective rating of a road's surface condition, particularly when the evaluator is focusing on current ride quality alone, can provide good, repeatable results at a very low cost. This is particularly true if evaluators receive both classroom and field training in rating unsealed road surface conditions.

When using such a system, one should adopt a ten-scale, with the following verbal descriptions of the surface condition:

- 1. Failed
- 2. Very Poor
- 3. Poor (closer to Very Poor)
- 4. Poor (closer to Fair)
- 5. Fair (closer to Poor)

- 6. Fair (closer to Good)
- 7. Good (closer to Fair)
- 8. Good (closer to Very Good)
- 9. Very Good
- 10. Excellent

The PASER ratings only evaluate on a five-scale (Excellent, Good, Fair, Poor, Failed), but when using a five scale, one is often torn between Fair and Good or between Poor and Fair. By using a ten-scale, the evaluator generally has enough flexibility to make their best estimate of the condition without feeling too constrained by the rating system or scale.

#### **Unsurfaced Road Condition Index**

The United States Army Corps of Engineers (USACE) has developed a method of deriving an unsurfaced road condition index (URCI) using extent and severity measurements to determine deduct values, resulting in an URCI between 0 and 100 *(Eaton and Beaucham 1992)*. This method is too time-consuming to be used on most road networks on the order of hundreds of miles, though it may have some value as a check of other data collection methods or as part of a sampling condition assessment procedure.

Manual measurement of distress severities and extents are fairly reproducible, though, like with visual surveys, there is also a considerable degree of subjectivity and judgment when employing a method such as the one proposed by the USACE. Unlike visual surveys, these distress measurement methods take considerable time to carry out, so they are not practical for agencies that maintain large networks with very few employees.

#### **Automated Data Collection**

At least two automated roughness measurement devices for unsealed roads are available and in use by a number of jurisdictions around the globe. They have been used effectively to adjust maintenance schedules when used continuously. One is described by (*Brown et al 2003*); another is used in Australia (*Giumarra 2009*). As global positioning system (GPS) and other related systems become more sophisticated, automated data collection is becoming more viable, perhaps even for small, local agencies. For such a system to be most cost effective, continuous data collection systems should be mounted on a vehicle that will be traversing the road network whether or not it is collecting data. While a dedicated data collection event could be carried out with an automated system, the problems of a rapidly changing surface may reduce the usefulness of data collected occasionally with an automated roughness measurement system. One advantage they have is that they can be used to continuously monitor road conditions on a vehicle that is routinely traveling the road(s) being evaluated and managed. Thus the additional cost involves only the equipment and download costs since the monitoring vehicle will be traveling the monitored road regardless of whether or not it carries the roughness measuring equipment.

Automated data collection methods have considerable promise, though initial costs may make them impractical for very low volume roads. On county road networks, they would need to be mounted on vehicles that routinely drive the county roads, such as parcel or mail delivery vehicles, propane delivery trucks, or electric meter readers' vehicles. These vehicle types all serve residences. Other vehicles, such as fuel trucks, might be used to monitor remote industrial roads, such as those serving oil and gas drilling operations.

#### **Gravel Thickness**

Though the traveling public doesn't care how thick the gravel is, for agency employees it is a critical indicator of both the time until the next regraveling and the road's future performance. In an ideal world, an agency would always know not only the thickness of the gravel but also its current gradation and plasticity index. Though all this information will never be available, we may be able to occasionally assess the thickness of some unsealed roads.

Measuring the thickness of unsealed roads is usually determined with a skid steer and auger such as a fencing crew might use, though other methods of digging may also be used. A hole is punched 3 or 4 inches into the road and the operator looks inside to see how thick the surfacing gravel is. Often, one may simply enter 'thicker than 4 inches' and consider that to be enough information. Unfortunately, any road will have some variety in its lift thicknesses, and this is probably more pronounced for unsealed roads. Therefore, thicknesses should be checked in several places within a road section. This information provides a method to estimate the remaining life of an unsealed road surface, with 'remaining life' defined as the time until the most expensive unsealed roads maintenance procedure, regraveling, needs to be performed.

Gravel thicknesses will be fairly labor-intensive data to collect. For a given road section, several holes should be dug to get a representative value for the remaining gravel thickness. It takes a trained eye to discern lifts in unsealed roads since the lift lines are generally not as distinct as they are for other pavement types. Given the labor-intensive nature of collecting thickness data, an agency should use some discretion when deciding where to collect this data. The highest volume roads, those that receive periodic regraveling the most often, should be the top priority for this measurement, while those with very low volume may not ever need to be measured.

Alternatively, thickness data may be collected using ground penetrating radar (GPR).

The purpose of collecting these data is likely to be two-fold. First, regraveling can be programmed based on existing thicknesses, rather than on the time since the road was last regraveled, and, second, this information can be used to generate a 'remaining service life' (RSL) for each road and for the network as a whole.

#### Timing of Condition Data Collection: When do we collect condition data?

Timing condition data collection is a particularly vexing issue, since surface conditions may change so often and so quickly.

If a system-wide data collection effort is to be undertaken, it should be done at a time when most roads are in a relatively static condition. This might take place in late fall when the last rain has already fallen but before the roads' surfaces are covered with snow and ice. In any case, from a network-wide point of view, most of the roads should have been maintained neither too recently nor too long ago – they should be in 'typical' condition.

The other type of data collection will be ongoing data collection – that which takes place largely as a part of an agency's other activities. Generally, the timing of this data collection will be driven by the availability of labor. Still, some consideration should be given to recent precipitation and maintenance activities. Generally, we should try to rate roads when they have neither been maintained nor rained on too recently so their current ride is typical of that throughout much of the year.

An exception to this generalization occurs if data are used to determine when to perform routine maintenance. For this purpose, we want to know the current condition, particularly the quality of the riding surface, so we should simply rate the current conditions. This type of data will most likely be collected automatically, since one generally can't collect data fast enough to establish routine maintenance schedules with a non-automated system.

An option to consider would be to have a prioritized list of roads to be evaluated. Roads with higher volumes and functional classes would receive the highest priority, as would those that have gone the longest since they were last evaluated.

#### Data Collectors: Who collects the data?

There are several options when it comes to deciding who will collect unsealed roads data, and many agencies may choose to collect data in several ways. Operators, supervisors, and other regular agency employees may evaluate roads, either during the course of their other activities or as a separate task. Dedicated data collectors may be hired to evaluate roads. Recent agency retirees are obvious people to hire since they have a good knowledge of the road network and of unsealed roads in general.

Condition data, particularly the ride-related distresses of potholes, ruts, and washboards, can be rated by anyone with experience driving unsealed roads and sufficient diligence to provide consistent data. Other data, such as drainage and safety ratings, should be collected by skilled individuals. These elements of a road are not necessarily obvious to the general public.

Thickness data should be collected by individuals who have the equipment at their disposal, a skid steer with an auger or other suitable equipment, to quickly dig holes in the road to estimate gravel thickness. They must also have sufficient experience with unsealed roads to discern lift lines from a core hole.

The least expensive data will be those which are collected as a part of someone's usual routine. An operator might take an extra minute and evaluate the surface conditions of the road section he or she is about to maintain.

Intermediate in cost will be the data collected by agency employees, generally during a slow period. They are already hired and on the payroll, so keeping them productive during slow times by sending them out to perform visual surveys may save money in the long run by allowing the supervisor to make better resource allocation decisions when things get busy. The most expensive data will be those which are collected by people hired or equipment purchased specifically for the purpose of collecting data. These data will also be the most consistent since there will be fewer individuals collecting data, and since they are dedicated data collectors they should be well trained and focused on the task of gathering information.

#### **Operator-Collected Data**

Having operators collect condition data has one primary advantage – they are already out there, so the cost of data collection is very low, both in terms of time and money. No specialized equipment is needed so initial costs are limited to training. Data may be collected at the time of routine maintenance. Operators may also collect data during the performance of their other duties as they traverse the agency's unsealed roads. Of course, this type of data collection is subject to the disadvantages described earlier, particularly the weather, path, and maintenance concerns. If data are collected as part of routine blading, they will be collected at roughly the time when the road is assumed to be in its minimum allowable condition, particularly if a cyclic maintenance schedule is implemented. This is the condition we are most concerned with when programming maintenance, so, in some ways, this is the ideal time to perform data collection, another advantage of this data collection method.

#### **Dedicated Data Collectors**

Hiring or assigning dedicated road evaluators has one main advantage: The data will be collected by a few evaluators, so it will be more consistent. The obvious disadvantage is that by dedicating someone to just collecting data, the cost of the data will be substantially higher, though by using knowledgeable part-time employees, such as recent retirees from the agency's road or street crew, costs may be kept within reason.

Additionally, in cold regions roads change little during the coldest months when the road is frozen. If there is little enough snow on the roads, they may be rated during this time as well, since it may represent the 'typical' road condition fairly well.

Using dedicated data collectors raises issues with the timing of data collection, though there are solutions to these problems, as well. If retirees wanting to supplement their retirement checks are hired, they may be flexible as to when they work. At least in semi-arid climates, routine maintenance is often put off until there is sufficient moisture naturally present in the road surface. If considerable time has passed since an agency's roads have been maintained, the roads may be as near as they ever get to being in 'typical' condition. This might be a good time for dedicated road evaluators to spend a week or two rating the agency's roads, particularly the higher volume roads where accurate condition data are most important.

If costs can be kept within reason and evaluations can be timed so that they provide reasonably valuable information, hiring or assigning dedicated data collectors may be a viable alternative. Data collection methods would probably be either with a visual survey method, with an automated roughness measurement device, or both.

#### **Supervisor or Other Agency Personnel Data Collectors**

Data collected by agency personnel other than those who collect the data as an aside to their usual activities will have similar issues to those described above for Dedicated Data Collectors. However, having people already on staff will save the cost of hiring additional personnel, though it may detract from some of their other work.

#### **CYCLIC MAINTENANCE SCHEDULING**

Once an agency has an inventory of their unsealed roads, including some sort of prioritization using techniques involving functional classes, maintenance intervention levels, maintenance strategies, or other means, they may begin to develop prioritized lists of roads to receive maintenance ranging from routine blading to stabilization and regraveling. Figure 3 illustrates how such a system might work, including initial inputs, the routine maintenance cycle, and optional condition-based feedback.

#### Inputs

At the top of the flowchart in Figure 3 are two fundamental inputs, dividing the network into road sections and developing maintenance strategies, which are combined when a maintenance strategy is assigned to each road section.



Figure 3 Cyclic maintenance scheduling

#### **Road Sections**

An initial inventory is the starting point for a gravel roads management system (GRMS). Once an inventory is established, the road network should be broken down into maintenance maangement sections.

Often county road data are collected and organized by road name or number. In many cases, it will not be worth the additional effort to further subdivide a road network into smaller maintenance sections, particularly early in the implementation process. Breaking a road network into smaller sections provides better information, but it also means more time and effort must go into collecting the data. The process of splitting a road network into sections should seek a balance between the value of the information and the cost of obtaining and managing the data.

#### **Maintenance Intervention Levels**

Once the network is broken into sections, the agency should determine the worst tolerable surface condition for each section, its maintenance intervention level at which each road section's surface conditions need to be improved. A number of considerations should go into the decision of how to assign maintenance intervention levels, including the following:

- Traffic Volume
- Functional Class
- Road Usage
- User Costs
- Political Considerations

Considering these factors, a maintenance intervention level should be assigned to each section on a tenscale from 1-Failed to 10-Excellent.

#### **Maintenance Strategies**

Each agency should describe and document the standard maintenance strategies they currently use, along with any other maintenance strategies they would like to program into their GRMS. This could be based on historical maintenance data or simply on the knowledge of agency personnel. The goal of this assignment is to keep each road section in at least its minimum acceptable surface condition, the maintenance intervention level, as described in the preceding section. The following maintenance patterns are suggested options:

- > N: No maintenance
  - Some earth roads may never be maintained. They will generally be jeep or 4WD trails traversable only during the dry season.
- > **D**: Drainage maintenance
  - Some earth roads will only receive occasional drainage maintenance. They will generally be open seasonally and be inaccessible to many passenger cars.
- **BD**: Routine blading and drainage maintenance

- Some very low volume earth roads will receive only routine blading and simple drainage maintenance, such as clearing culvert ends.
- **BDS**: Routine blading, drainage maintenance, reshaping
  - A few low volume earth roads may never receive additional gravel, particularly if they are placed on high quality subgrade, but they will need occasional blading and reshaping along with drainage maintenance.
- **BDSG**: Routine blading, drainage maintenance, reshaping, regraveling
  - This will be the typical, basic maintenance applied to many gravel roads.
- **BDSGI**: Routine blading, drainage maintenance, reshaping, regraveling, isolated dust suppression
  - This will be the typical, basic maintenance applied to some gravel roads with the addition of dust suppression in localized areas where dust is an environmental concern.
- **BDSGU**: Routine blading, drainage maintenance, reshaping, regraveling, dust suppression over the entire section
  - This will be the typical, basic maintenance applied to some gravel roads with the addition of dust suppression over the entire section.
- **BDSGT**: Routine blading, drainage maintenance, reshaping, regraveling with stabilization
  - This will be the typical, basic maintenance applied to a few gravel roads with the addition of a soil stabilizer.
- **BDSGTU**: Routine blading, drainage maintenance, reshaping, regraveling with soil stabilization, dust suppression
  - This will be the typical, basic maintenance applied to a few gravel roads with the addition of a soil stabilizer when the section is regraveled and periodic dust suppression.

Agencies should select their own list of possible maintenance strategies.

Figure 4 graphically represents one of the nine maintenance strategies in Table 2, with the lines pointing down indicating the cost of maintenance tasks performed. Note that some tasks are also included in higher level tasks; for example, in Figure 4 'Drainage' is not performed at years 0, 8 or 16 since 'Drainage' is assumed to be included in 'Reshaping.' Table 3 shows the secondary tasks assumed to be included in each primary task.

Though the timeline shown in Figure 4 is labeled from 0 to 20 years, the time frames could be extended or compressed, depending on characteristics of each road section, such as material quality, subgrade, and traffic.

#### **Assign Road Sections to a Maintenance Strategy**

The goal of a maintenance strategy assignment should be to maintain the section in at least the maintenance intervention level which is economically appropriate for the traffic it receives, as described above in the Maintenance Intervention Levels section. For each section, the agency should make their best estimate of which maintenance strategy should be assigned to each road section. Usually, this will closely approximate the maintenance the section has typically received. Based on estimates of factors

that affect the maintenance frequency necessary to provide this service level, the frequency at which various elements of the maintenance pattern are to be performed should be assigned to each road section. Table 2 shows example maintenance frequency assignments based on functional classes and maintenance intervention levels. These frequency assignments should be based on agency personnel's best estimates of the maintenance frequencies needed to keep the road in conditions better than the maintenance intervention level. It would be easy to have a standard frequency, with the entire schedule expanded for roads expected to perform better and compressed for those expected to perform worse.

	Exa	mple	Freque	ncies,	Events	s per Y	ear	
Strategy	Drainage Maintenance	Routine Blading	Reshaping	Regravel	lsolated Dust Suppression	Section Dust Suppressoin	Soil Satbailization	Maintenance Interevention Level
N	0	0	0	0	0	0	0	1 - Failed
D	0.1	0	0	0	0	0	0	2 - Very Poor
BD	0.1	0.1	0	0	0	0	0	3 - Poor
BDS	0.2	0.4	0.05	0	0	0	0	4 - Poor
BDSG	0.267	2	0.133	0.067	0	0	0	5 - Fair
BDSGI	0.267	2	0.133	0.067	0.5	0	0	5 - Fair
BDSGU	0.2	1	0.1	0.05	0	0.5	0	6 - Fair
BDSGT	0.2	0.6	0.1	0.1	0	0	0.1	7 - Good
BDSGTU	0.2	0.6	0.1	0.1	0	0.4	0.1	7 - Good

 Table 2 Example Maintenance Strategies and Frequencies

Making these maintenance frequency assignments for each unsealed road section completes the input portion of the cyclic maintenance scheduling process. These are examples only, and maintenance frequencies should be influenced by a variety of factors, particularly traffic volumes.

#### **Cycle Initialization Points**

The final input needed to enter the cyclic maintenance process addresses when within its assigned maintenance schedule each road section is currently, that is: When on the timeline such as the one in Figure 4 should each section start the maintenance cycle? Maintenance records should be used to establish this, with the time of the last blading, reshaping, regraveling, and dust suppression being the main entries.

#### **Maintenance Cycle**

The central maintenance cycle shown in the middle of Figure 3 should be used to direct maintenance tasks for both individual maintainers, particularly blading and reshaping tasks, and for the agency as a whole for drainage, regraveling, dust suppression and soil stabilization tasks.



#### Figure 4 Strategy DBSG: Drainage, Blading, Reshaping and Regravel

			Inc	luded	Tasks		
Primary Task	Drainage	Blading	Reshaping	Regravel	lsolated Dust Supression	Section Dust Supression	Soil Stabilization
Drainage	Х						
Blading		Х					
Reshaping	Х	Х	Х				
Regravel		Х		Х			
Isolated Dust Suppression					х		
Section Dust Suppression					х	Х	
Soil Stabilization		Х			х	Х	Х

Table 5 Tasks included with Each Prindry Task	Ta	able	3	Tasks	Included	with	Each	Primary	/ Task
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#### **Prioritize Next Maintenance Tasks**

The first step in developing a prioritized list of maintenance tasks is to determine what the next tasks are for every section and when they are due, as shown in the upper two rectangles in the 'Cycle' trapezoid

in Figure 3. To do this, one needs to know when each task was last performed and the task's scheduled interval between task performances. For example, Table 4 shows the calculations that might be performed for a road receiving strategy DBSG, drainage, blading, reshaping and regravel, as shown in Figure 4. The current time in this example is 2011.0, January 2011. The 'time of last performance' indicates when each of the four programmed tasks was last performed; the 'scheduled time between task performances' comes from the selected maintenance strategy for the road section. The 'time since last performance' is the current time minus the 'time of last performance.' Dividing the 'time since last performance' by the 'scheduled time between task performances' yields a percentage, the 'current percent of scheduled time.' In this example, 'reshaping' at 123% of the scheduled time is due to be performed. If no maintenance is performed on this section until 2011.7, August 2011, the numbers will change, as demonstrated in Table 5. Now, blading at 180% of the 'scheduled time' is the highest priority task, followed by reshaping at 133%. Ideally, the road would now be reshaped which would also include

blading, though this section might only receive blading now if other sections have tasks at more than 133% of their scheduled time, moving them higher on the prioritization list.

This process would be repeated for every section within the network, an impossibly laborious task if done by hand, but an procedure with а properly easv programmed computer. It would yield a list for maintainers, perhaps after a rain or whenever it was determined that blading or reshaping are to be performed. The list would show the roads most in need of blading and reshaping. The maintainer would then combine this information with his or her knowledge of the district's geography to plan a route that gets to the top priority roads as quickly as possible. It would also generate a prioritized list for supervisors indicating which roads need drainage maintenance, regraveling,

|--|

Task	Time of Last Performance	Time Since Last Performance	Scheduled Time Between Task Perfromance	Current Percent of Scheduled Time
Drainage	2004.8	6.2	7.0	89%
Blading	2010.8	0.2	0.5	40%
Reshaping	2002.4	8.6	7.0	123%
Regravel	2002.4	8.6	14.0	61%

Table 5 Example Strategy DBSG at Time 2011.7

Task	Time of Last Performance	Time Since Last Performance	Scheduled Time Between Task Perfromance	Current Percent of Scheduled Time
Drainage	2004.8	6.9	7.0	99%
Blading	2010.8	0.9	0.5	180%
Reshaping	2002.4	9.3	7.0	133%
Regravel	2002.4	9.3	14.0	66%

stabilization and dust suppression. The maintenance crews could then be guided by this needs-based list, rather than simply responding to complaints or following a set cycle.

#### **Perform Maintenance Tasks**

Once the maintainers and supervisors have their prioritized lists in hand, they will maintain the roads.

The system as proposed does not directly provide a sequence for the maintainers since going right down the list might cause maintainers to spend too much time moving the motor grader from section to section. Maybe someday someone with considerable expertise in fleet management, vehicle tracking systems and GIS programming will combine this method with geographic information to come up with a route for each maintainer. Until then, it is envisioned that the maintainer will use the prioritized list to adjust his or her schedule, with the final geographic planning being performed by the maintainer, perhaps in consultation with the supervisor.

#### **Record Maintenance Tasks**

As maintenance is performed, the work performed on each section will be recorded and this information will be stored in a database. This could be done with time cards or, if an organized system of work orders is in place, the work order system could also be used to record the work performed for the higher priority road maintenance tasks.

This new information is used to generate new priority lists and the cycle continues. An option might be to generate work orders for the high priority tasks identified by the cyclic maintenance schedule generated as described in the Prioritize Next Maintenance Tasks section above. On such a work order, the maintainer might indicate the time spent performing the task and the equipment used, including both actual work time and the time it takes to get to the job site each day.

#### **Optional Surface Condition Evaluation**

The frequencies at which maintenance is performed may be adjusted based on the maintainers' evaluations as they maintain the road. As shown in Figure 3, there is an optional approach in which the maintainer records the surface conditions at the time maintenance is performed, perhaps based on observations made while setting up traffic control signs. Such evaluations would be subjective ratings, perhaps based on the PASER system, though it seems advantageous to rate the surface conditions on a ten-scale, such as the one described above in the Subjective Visual Survey section.

Since each section should have a targeted minimum surface condition rating based on the type and volume of traffic it receives, the targeted minimums can be compared to the observed surface conditions when maintenance is performed. A road that consistently is in better condition than its desired minimum, the maintenance intervention level, could have its time between maintenance tasks extended, while one generally in worse than the desired condition could have its time between maintenance costs and keeping all roads in adequate condition with very minimal field data collection.

#### **TRIGGERED MAINTENANCE SCHEDULING**

Two methods of triggered maintenance scheduling, the use of condition data to program maintenance, have been discussed, though other methods might also be possible. One is the use of a continuous monitoring device to program routine blading, while the other is the use of gravel thickness data to program regraveling. The Canadian automated evaluation and rating system is documented elsewhere

(Brown et al 2003), while the use of gravel thickness as a maintenance trigger is not known to be well documented.

The principles of any triggered maintenance program are simple. Maintenance intervention levels are established. When conditions fall below them, maintenance is performed. It is unclear whether any proactive maintenance might be beneficial, analogous to preventive maintenance of asphalt pavements. If such proactive approaches are shown or believed to be advantageous, systems could be developed to, for example, regravel whenever surfacing gravel thickness drops below two inches, or add soil stabilizer to roads with over 200 vehicles per day. The future of triggered maintenance programs is not well defined, though as more sophisticated and inexpensive data collection, particularly automated systems, become more prevalent, triggered maintenance may become more commonplace.

#### **NETWORK LEVEL OUTPUTS**

There are likely to be two types of outputs from a gravel roads management system (GRMS). One will be the routine outputs, derived by simply clicking a button. These will include statically programmed outputs such as the cyclic maintenance schedules described above in the Cyclic Maintenance Scheduling section, as well as a host of other reports such as those described in the next few sections. The other type of outputs will be flexible reports generated to answer specific questions and performed by individuals with considerable familiarity with the software who are able to perform queries and other data manipulations to come up with desired outputs. The following discussions describe some of the outputs that might be derived from software used to operate a GRMS.

There is another way of splitting outputs into two types. One type consists of reports that are useful for external communication with elected officials and the public. Justifying various practices and expenditures is a necessary part of managing a road network, and an effective GRMS will be useful in fulfilling this function. Another report type contains information that lets the agency provide better service at a lower cost by using more cost-effective practices and by making better decisions. Both of these report types may be either pre-programmed or generated by individuals skilled at extracting and presenting data from the GRMS.

#### **Network Level Condition Monitoring**

A primary objective of a road management system is to provide an overall assessment of the network's condition. Such assessments and other agency-wide information are referred to as 'network-level' management. One of the most basic pieces of information that will be of interest to elected officials and the general public is whether the overall network condition is improving, staying the same, or getting worse. With sealed roads, there are numeric ways of quantifying average network condition using instruments that measure IRI (international roughness index). While there are similar instruments available for unsealed roads, there are systematic problems, mainly the weather, and secondarily maintenance practices, that may easily cause substantial network-wide bias in condition data collected during a single data collection event.

An agency may predict the remaining service life (RSL) of the network as a whole using estimates based on maintenance frequency as it is modified due to the conditions observed at the time of maintenance combined with gravel thickness and gravel loss rates. Though such methods are not thoroughly developed here, there are some basic principles that should govern the development of algorithms that could assess the RSL of a network, as described in the next section.

#### **Remaining Service Life (RSL) and Gravel Thickness**

A good assessment of an unsealed road network's long-term condition and RSL is gravel thickness. For a sealed road, the situation is much simpler. Surface conditions change slowly and in a predictable manner, so they may be used to generate RSL predictions. While, in an ideal world, frequent condition monitoring might yield overall condition assessments, until very inexpensive means of collecting and processing a lot of real-time data become available, a proxy, such as gravel thickness, is needed to assess an unsealed road network's current typical condition.

It should be kept in mind that using a RSL approach for unsealed roads is different than it is for sealed roads. A properly maintained unsealed road, it may be argued, has an infinite service life. The term RSL should be used to indicate how far ahead an agency is in terms of the average time until regraveling is needed next. A decreasing average surfacing gravel thickness means a shorter time until the average road needs more gravel, and it provides an indication that the network as a whole is falling behind. If an agency used thickness measurements to estimate the RSL of its higher volume roads, cyclic maintenance assumptions could be made for the lower volume roads, allowing an agency to arrive at reasonable values for the network-wide RSL without having to measure the thickness of every section. A final step when using thickness as a proxy for RSL would be assuming a rate of gravel loss, probably based on traffic and, if the information is available, on gravel properties such as the percent passing a #200 (75  $\mu$ m) sieve, the plasticity index, and the presence of a soil stabilizer or dust suppressant. Probably the best assessment of how much service life is left in an unsealed road network is to measure gravel thicknesses.

Using the procedure described in the Cyclic Maintenance Scheduling section, one can easily derive the time until the next regraveling is scheduled. As time passes and more data are collected, this estimate will become better and better if some of the feedback and modification mechanisms described above in the Optional Surface Condition Evaluation section are employed. This information could be used as the basis for RSL estimates. If thickness data are available, they could be used to generate estimates of the RSL, particularly for the higher volume roads that need the most gravel replacement. Perhaps combining the time until the next scheduled regraveling with thickness data could generate a more refined RSL, possibly one that could be derived without too much time spent measuring actual thicknesses.

#### **Financial Tables**

Financial tables will describe where the money is being spent. The three fundamental variables are:

- Maintenance and Rehabilitation Tasks
- Road and Road Section

#### Time Frame

Hopefully, the costs could be determined, for example, for 'blading' and 'regraveling' for all roads of a given type over a ten year period. Other costs would probably also be included, such as sign, culvert, bridge and asphalt road costs. Such tables would provide a good overall picture of where and how an agency is spending its money. What these tables will *not* tell you is whether these expenditures are yielding good results. Indeed, this is the crux of the 'accountants problem' described above in the Maintenance Task Definitions section. We want to know not only what we are spending our money on, but also if we are spending it correctly and effectively.

#### **Road Maintenance History Tables**

A simple output for any road or road section is its maintenance and rehabilitation history, hopefully including costs. These have several functions. If questions come up, either from elected officials or the public, as to what work has been performed on a given road section recently, this question could be easily answered with the click of a button. Plans for a given road will usually be predicated on what work has been done to it in the past. Such a function could provide this information quickly and easily. Finally, different road sections, particularly those fulfilling similar functions, could be compared. This might be useful, for example, to assess the performance of gravel from different sources under similar circumstances.

To generate these histories, a network inventory would be needed and maintenance history would have to be available. To be useful, the maintenance history would have to be coded to identify maintenance tasks that are of interest, such as blading, dust suppression, and regraveling.

#### **Road Work Maps and Tables**

If a GIS based system is used, maps could be generated showing where a given type of work has been performed over a set period of time. If maps are not possible, tables could list where different types of maintenance have been performed over a given time. For example, one might want to show where dust suppressants have been applied during the past two years. A map might be generated to display this, perhaps to justify applying dust suppressants to some roads but not to others. Another use might be to map which roads have been bladed within the past month. There could be a wide variety of applications for such maps and tables, both as a tool for communicating with elected officials and the public and for internal decision-making.

To generate these maps, maintenance histories and a simple inventory must be available within a GIS.

A related set of maps or tables could show how much money per mile is being spent throughout a road network. This might be used to answer questions about relative expenditures on roads throughout a network.

Yet another related map or table might show how many tons of gravel per mile-year have been applied to each road section throughout the network. Though of little value to the general public, this might be very useful for agency personnel, particularly if they could relate this information to the performance of different gravel sources or maintenance practices, such as dust suppression or soil stabilization.

#### **Condition Maps and Tables**

If condition data are collected, an agency might be able to generate maps of the current and past surface conditions. Of course, for such maps to be meaningful, data would have to be collected in such a way that they accurately reflect the true 'typical' surface conditions. This issue is discussed more thoroughly in the Condition Data section above.

#### **Condition Projection Maps and Tables**

As more data are accumulated and unsealed roads modeling becomes more sophisticated, it may become possible to accurately predict the future condition of an unsealed road network given various funding scenarios. Unfortunately the tools to make such predictions are not yet available, but this situation may change soon, making realistic predictions possible, particularly if a number of agencies collect unsealed roads data in useful ways as described throughout this report.

#### **SAFETY ASSESSMENT**

The safety component of this effort should compliment other safety efforts, such as those based on crash data, road safety assessments, and other formalized safety improvement procedures. This effort is primarily tailored to roads with too little traffic for crash data to be statistically useful and it should address safety issues that can be improved at low cost, such as minor geometric improvements made while pulling shoulders and reshaping ditches.

Safety assessments should be undertaken on a regular schedule, probably every few years or so. Since much of the safety focus in this project relates to making the roadway prism geometry as safe as possible, and since this is established mainly during reshaping, it makes sense to schedule safety inspections just before reshaping is performed. A road section safety summary could be presented to maintainers so they might correct as many safety defects as possible during the reshaping operation.

These evaluations should be performed by dedicated data collectors. The information collected using this method should be used by maintainers and supervisors to evaluate where additional safety efforts might be applied to improve the overall safety of the unsealed road network. It might also be used to modify some maintainers' practices so they leave a road safer after maintenance, particularly when reshaping the roadway prism. Some training would be needed to teach evaluators what to look for, such as obstructions within the clear zone and overturning hazards caused by culvert end treatments.

In addition to the proactive, routine inspections described above, safety inspections could also be reactive if a particular location has a crash history that indicates it should be examined in more detail. Such inspections should assess both the cause of any crashes and any factors that may impact the likelihood and severity of future crashes.

Safety issues on unsealed roads include the need for maintainers to understand the safety implications of their operations, both the immediate threats posed by their presence and the long-term effects of the way they leave the roadway, particularly shoulder steepness, edge drop-offs, clear zone width,

immovable objects and overturning hazards within the clear zone, and proper crowns and superelevations.

It is the intent of this guide to focus on unsealed roads management and maintenance issues. Other safety issues on unsealed roads, such as signing and delineation, should be addressed, but they are outside the scope of this project.

Several features that might be rated as part of an effort to tailor maintenance activities in a way to make the roads safer might include the following:

- Foreslopes: Overturning Potential
  - o Severity
    - Steeper than 3:1
    - 3:1 to 4:1
    - 4:1 to 5:1
    - Flatter than 5:1
  - o Extent
    - >50%
    - **20% 50%**
    - 5% 20%
    - 2% 5%
    - <2%
    - None
- > Isolated Overturning Hazards within the Clear Zone
  - Severity
    - High, Medium, Low
  - o Extent
    - >10 per mile
    - 5 to 10 per mile
    - 2 to 5 per mile
    - <2 per mile</p>
    - None
- Immovable Objects within the Clear Zone
  - o Severity
    - High, Medium, Low
  - o Extent
    - >10 per mile
    - 5 to 10 per mile
    - 2 to 5 per mile
    - <2 per mile</p>
    - None
- Clear Zone Width
  - o Width

- <2′
- 2' to 5'
- 5' to 8'
- 8' to 12'
- 12' to 16'
- >16'
- o Extent
  - >50%
  - 20% 50%
  - 5% 20%
  - 2% 5%
  - <2%
  - None

The following potential problems do not lend themselves to easy rating as do the situations above, so they should be noted and described:

- Geometric Issues
  - Horizontal curves
  - Vertical curves
  - Blind driveways/approaches
  - Limited sight distance intersections
  - Inconsistent design: surprise curves, dips, and so on
  - Superelevations and crowns
- Surface Issues
  - Potholes and ruts
  - Corrugations/washboards
  - Slippery when wet
  - Loose material
  - o Dust
- Edge drop-off
- Bridge approaches
- Soft shoulders
- Signage and delineation
- Vegetation
- > Animals

Before collecting safety data, an agency should have a commitment not only to identifying safety problems but also to correcting problems as they become aware of them. To this end, it would be wise for agencies to focus on identifying issues that they have the resources to improve, rather than simply identifying all safety problems. For this reason, with the *'Geometric Issues'* and *'Other Issues'* above, the evaluator is only instructed to describe the issue. Such descriptions might be used for a preliminary

evaluation of areas for improvement as funding becomes available. The other four problem areas rated, *'Vehicle Overturning Hazards: Steep Shoulders and Foreslopes,' 'Isolated Overturning Hazards within the Clear Zone,' 'Immovable Objects within the Clear Zone,' and 'Clear Zone Widths'* may be improved by altering maintenance practices or by other minor, low cost actions. Since these last four areas are potentially very extensive, they may also be subject to quantitative analysis so it is worthwhile to enter quantitative values into a database.

#### **DRAINAGE ASSESSMENT**

As for safety above, drainage inspections should take place just before reshaping since drainage problems may be corrected during this procedure. Drainage inspection should also take place after an exceptional runoff event, both because it is easier to see how drainage performs during or just after these events and because these events may reveal problems that either weren't apparent or didn't exist before the flooding event.

Drainage should be rated to identify sections with significant problems, particularly those related to maintenance, and to provide insights as to why a given road may be performing poorly. It should assist maintainers with identifying areas where better or additional maintenance is needed.

This effort only addresses those culvert issues that can be corrected by routine maintenance practices though culverts should have their own management system that evaluates factors that can only be mitigated by replacement or other major work, such as proper placement, flow, erosion prevention, and scour resistance.

Bridges should also be managed, though their management is beyond the scope of this effort.

The following drainage features should be rated for severity and extent. Suggested extents for all these are: >50%; 20% - 50%; 5% - 20%; 2% - 5%; <2%; and None.

- Surface Drainage: Crown
  - *Very Good*: 4% to 5% cross slope, well-defined 'rooftop' shape; very good superelevations
  - Good: 3% to 6% cross slope; good 'rooftop' shape, minor flattening at the centerline; good superelevations
  - *Fair*: 1½% to 3% or >6% cross slope; generally has reasonable crown shape with limited flat spots at the centerline; minor superelevation deficiencies
  - *Poor*: 0% to 1½% cross slope; significant and extensive areas with deficient crown and flattening at the center; significant superelevation problems
  - Very Poor: 0% to inverted cross slope; generally lacks crown; poor or no superelevations
  - Failed: inverted cross slope; primary drainage is within the traveled way
- Surface Drainage: Shoulders

- *Good*: Shoulders adequately and consistently carry water to the foreslope without obstruction
- *Fair*: Occasional diversion of water away from the ditches by high shoulders, leading to limited erosion
- *Poor*: Significant channeling of water above the ditches due to high shoulders, leading to extensive erosion
- *Very Poor*: Extensive channeling of water in secondary ditches caused by high shoulders, leading to extensive and dangerous erosion
- Subsurface Drainage: Ditches
  - *Very Good*: No or negligible ponding or obstructions within ditches; depth of ditches at least 3' below the edge of the shoulder
  - *Good*: Only minor obstructions and ponding less than 6" deep within ditches; depth of ditches and any standing water at least 2' below the edge of the shoulder
  - *Fair*: Some ponding less than 1' deep within ditches; depth of ditch and any standing water at least 1' below the edge of the shoulder
  - *Poor*: Extensive ponding or blockages within the ditches; intermittent areas without ditching and extensive areas with ditches less than 1' deep
  - *Very Poor*: Water frequently standing by much of the roadway; ditches often not present or very shallow
  - Failed: Ditches generally not present; water is channeled onto the road surface
- Subsurface Drainage: Culverts
  - *Very Good*: Culvert ends clean and resistant to scour; barrel has less than 10% of its depth blocked
  - *Good*: Culvert ends in adequate condition with only minor susceptibility to scouring; only minor barrel blockage for less than 25% of the culvert's depth
  - *Fair*: Some damage to culvert ends; significant scour potential; significant barrel blockage up to 50% of the culvert's depth
  - *Poor*: Significant damage to culvert ends; significant risk of scour and piping; barrel blocked up to two-thirds of the culvert's depth
  - *Very Poor*: Culvert's capacity a small fraction of its original capacity due to blockage or damage; high risk of scour
  - *Failed*: No flow through culvert

Due to the relatively time consuming nature of collecting these data, they are designed to be collected on dedicated data collection efforts, rather than as part of routine activities. For ratings performed during routine activities, two simple evaluations could rate the surface and the subsurface drainage as *Very Good, Good, Fair, Poor, Very Poor,* or *Failed*, perhaps using the methods described in the drainage manual developed in Wisconsin (*Walker 2000*).

#### MANUALS

In the author's experience, four manuals stand out as providing the best guidance for those responsible for taking care of unsealed roads: They are the 'Gravel Roads Maintenance and Design Manual' by the South Dakota LTAP (*Skorseth and Selim 2000*), the 'Low Volume Roads Engineering: Best Management Practices Field Guide' by the USDA's Forest Service (*Keller and Sherar 2003*), Pennsylvania's 'Environmentally Sensitive Maintenance for Dirt and Gravel Roads' (*Gesford and Anderson 2006*), and the Australian 'Unsealed Roads Manual: Guidelines to good practice' (*Giumarra 2009*). Simply put and in the author's opinion, the South Dakota manual is for maintainers, the Forest Service and Pennsylvania manuals are for those responsible for design and construction, and the Australian manual is for managers. While there are other good manuals out there, these documents contain a wealth of information assembled by some of the top experts in our field. The influence of these manuals is throughout this report, particularly the American manuals. The Australian manual has verified many of the conclusions presented in this report, since it didn't get into the author's hands until much of this report was already written. Just to provide some scale, the South Dakota manual is about ¼" thick, the Forest Service manual is about ½" thick, the Pennsylvania manual is about 1" thick, and the Australian manual is about 3 cm thick.

#### South Dakota Manual

The SD-LTAP publication, *Gravel Roads: Maintenance and Design Manual, (Skorseth and Selim 2000)* provides guidance for those directly responsible for maintaining gravel roads. It begins with directions for maintainers, covering the basics of the gravel roadway prism and shape. It discusses drainage considerations and the properties, procurement, handling, and placement of good surfacing gravel. It discusses stabilization and dust control. It also goes over some of the newer techniques for working gravel roads. The appendixes discuss thickness design, gradation and plasticity, quantity calculations, the decision of when to pave a gravel road, and the walk-around motor grader inspection including a checklist. It is concise, well written, and well illustrated. As such, it is very accessible for those directly responsible for maintaining unsealed roads.

#### **Forest Service and Pennsylvania Manuals**

The USDA's Forest Service publication, *Low-Volume Roads Engineering: Best Management Practices Field Guide, (Keller and Sherar 2003)* and the Pennsylvanian manual *Environmentally Sensitive Maintenance for Dirt and Gravel Roads (Gesford and Anderson 2006)* both provide comprehensive and explicit guidance on the most important aspect of road construction, drainage. They also provide specific design information on virtually all aspects of low-volume unsealed road construction.

#### Australian Manual

The ARRB Group's publication, *Unsealed Roads Manual: Guidelines to good practice (Giumarra 2009)* is perhaps the most comprehensive unsealed roads management manual available. It covers a wide variety of topics necessary to the successful management of a unsealed roads network, including maintenance, materials, design, and construction. It also covers asset management and economic evaluation, as well as environmental and safety concerns.

#### **GLOSSARY**

#### **Chemically Treated Road**

Any road with dust suppressant (other than water) or soil stabilizer applied recently enough to bind the surfacing materials or significantly alter surfacing material's properties.

#### Earth (or Native Soil) Road

Any road surfaced with material that has not been transported.

#### **Formed Road**

Any road with ditches and other drainage features.

#### **Gravel Road**

Any road surfaced with processed, generally crushed and screened, imported granular aggregate.

#### **Gravel Roads Management Systems (GRMS)**

When referring to management systems, historically such systems have been referred to as 'gravel roads management systems' or 'gravel roads maintenance systems.' In keeping with this precedent, the term 'gravel roads management or maintenance system' (GRMS) is used to refer to systems designed to plan and program unsealed roads maintenance and improvement processes.

#### **Improved Road**

Any road with ditches and other drainage features and an imported aggregate surface.

#### **Sealed Road**

Any road with a semi-permanent, water-resistant surface.

#### **Surface Treated Road**

Any road with a bituminous or other sealant applied on top of a granular aggregate base, forming a semi-permanent top surface.

#### **Unformed Road**

Tracks laying on the natural ground surface without drainage features.

#### **Unimproved Road**

Any road that does not have drainage features and an imported aggregate surface.

#### **Unsealed Road**

Any road that does not have a semi-permanent, water-resistant surface.

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