ARIZONA TRUCKING ASSOCIATION

December 9, 2025

Pima County Board of Supervisors
130 W. Congress Street
Tucson, AZ 85701

RE: *2025 Unpaved County Roads, Health Standards and Air Quality Ordinance Version 2*

Dear Chairman Scott and Members of the Board:

I am following up on my previous letter outlining the many ways the original draft of your proposed ordinance violated the U.S. Constitution, federal law, and state law. After reviewing the revised ordinance distributed on November 24, 2025, it is now even more apparent that the County is not attempting to solve a dust-control issue. Instead, the updated language confirms that trucking is being used as an avenue to limit mining activity—an objective pursued in clear violation of well-established commercial-vehicle access laws.

The Revised Ordinance Confirms an Unlawful Objective

Nothing in the revised ordinance suggests an effort to align with federal or state requirements. To the contrary, the revisions strengthen the very features that render the ordinance unlawful and reveal a policy aimed at restricting lawful economic activity under the guise of air quality regulation.

Severe Economic Exposure — Including the Potential to Bankrupt the County

The consequences of adopting such an ordinance should not be underestimated. **Your actions could bankrupt the County.** The mine's projected production of **92,000 tons of copper per year** during its first decade allows for straightforward calculation of the economic loss caused by any County-imposed restriction on lawful operations—losses that easily reach into the billions. These impacts would extend beyond mining, affecting construction, agriculture, manufacturing, and all freight-dependent industries.

For the trucking industry, the legal basis is equally strong. The revised ordinance is plainly unlawful, meaning the Arizona Trucking Association and affected carriers would be positioned to succeed on the merits in any resulting litigation. The County would face significant financial consequences, including economic damages, injunctions halting enforcement, and prevailing-party attorney's fees.

Legal Violations Reaffirmed and Expanded in the Revised Ordinance

- **Federal Law (STAA & Supremacy Clause):** Federal law guarantees reasonable access for STAA-dimension trucks and expressly prohibits local governments from imposing permit requirements or trip limitations on legal-size commercial vehicles. The revised ordinance is even more clearly inconsistent with federal supremacy in this area. Noncompliance with the STAA also places federal transportation funding at risk.

- **The County's Actions Constitute an Abuse of Police Power:** Where a county claims to regulate dust yet knowingly declines to use effective dust-control methods while pursuing a policy designed to achieve unrelated outcomes, courts view this as pretext. Here, trucking and road access are being used as a proxy battleground for disputes over mining—dragging drivers and carriers into a conflict that has little to do with dust control.

- **State Law — A.R.S. § 28-1092:** This statute prohibits counties from denying access or requiring permits for legal-size vehicles. The revised ordinance moves in the opposite direction and further entrenches noncompliance.

- **State Law — A.R.S. § 28-1106:** Section 28-1106 does not authorize air-quality-driven vehicle restrictions. The statute concerns roadway safety and structural protection, not dust policy or production limitation.

- **The Roadway Is a Major Arterial Street Under A.R.S. § 28-1106(E):** Under § 28-1106(E), a county may not restrict use of a major arterial street unless it conducts a test drive or applies a vehicle template demonstrating that legal-size vehicles cannot safely operate on the road. Santa Rita Road meets the definition of a major arterial street. The County has conducted no such engineering analysis. By allowing up to seventy-five trucks per day, the County necessarily concedes that legal-size vehicles can operate safely. Under § 28-1106(E), **if the road is safe for one lawful truck, it is safe for all**

lawful trucks, and the County lacks authority to impose access restrictions.

- **The County Has No Authority to Issue Special Permits to STAA Vehicles:** The ordinance repeatedly relies on "special permits," but **A.R.S. § 28-1104 applies only to overweight or overdimensional loads**, not trucks of legal size and weight. STAA vehicles do not require special permits, and no county may create such a scheme. Moreover, § 28-1104 requires local procedures to conform to **A.A.C. Title 17, Chapter 6**, which Pima County acknowledged when it adopted **Pima County Code Chapter 10.36** in 2017. The revised ordinance ignores these statutory limits and the County's own established framework—**reflecting a fundamental failure to conduct even the most basic legal analysis before advancing a measure with profound financial implications.**

The County's Own Memo Relies on Speculation, Not Evidence

The County's memo states only that increased truck traffic *may* contribute to dust and *could* lead to non-attainment. This speculative language fails to meet the evidentiary threshold required for restricting lawful commerce. Non-attainment designations require monitoring, modeling, coordination with ADEQ, and EPA analysis. None of those prerequisites are present.

The Ordinance Conflicts with FHWA Federal Best Practices for Dust Mitigation

Attached for your review is the Federal Highway Administration's *Unpaved Road Dust Management: A Successful Practitioner's Handbook*. FHWA emphasizes engineering, maintenance, proper road design, and chemical dust suppressants as the proven, effective tools for dust control. Nowhere does FHWA recommend restricting lawful truck traffic, capping daily trips, or adopting discretionary permitting schemes. Even if dust control were justified, the County is obligated to pursue the **least restrictive effective means**, not the most intrusive and least lawful option.

The Revised Ordinance Creates Arbitrary and Discriminatory Access Restrictions

By transforming lawful truck access into a scarce, permission-based quota, the County invites arbitrary, discriminatory, and economically distortive outcomes. Version 2 compounds—not cures—the legal deficiencies of the original draft. If the County proceeds on this path, the resulting legal and financial consequences will be unavoidable.

ATA Supports Lawful, Effective Dust-Control Measures — Not Unlawful Access Limits

As stated previously, the Arizona Trucking Association fully supports lawful, data-driven dust-mitigation strategies. Nothing in this letter should be mistaken as opposition to genuine dust control. Our objection is to an unlawful vehicle-access scheme masquerading as dust policy. We remain ready to work collaboratively with Pima County, PDEQ, ADEQ, and affected industries to implement real solutions grounded in engineering, science, and federal best-practice standards. But the ordinance as drafted—and as revised—cannot withstand legal scrutiny and will cause substantial harm to the County, the region's economy, and the public interest.

For these reasons, I respectfully urge the Board to permanently withdraw this ordinance and provide a written response to the issues raised in this letter so that the County's official position is clear and part of the public record.

Respectfully,

Tony Bradley
President & CEO

Attachment: *Unpaved Road Dust Management, A Successful Practitioner's Handbook*, Federal Highway Administration, January 2013

cc: Jan Lesher
Kathryn Skinner
Jennifer Toth

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UNPAVED ROAD DUST MANAGEMENT
A Successful Practitioner's Handbook

Publication No. FHWA-CFL/TD-13-001 **January 2013**

U.S. Department of Transportation
Federal Highway Administration

CTIP

Federal Lands Highway
Commitment to Excellence

Central Federal Lands Highway Division
12300 W. Dakota Ave.
Lakewood, CO 80228

FOREWORD

The Federal Highway Administration (FHWA) encourages programs that protect both the environment and the life of the roadway. Fugitive dust from unpaved roads threatens air, soil and water quality and roadside flora and fauna. This loss of material cause road surface deterioration, increases maintenance cost, and adds to the complexity of managing a network of unpaved roads.

This FHWA report called *Unpaved Road Dust Management, A Successful Practitioner's Handbook* offers broad programmatic-level guidance for managing a cost-effective unpaved road program. This handbook is for all managers of unpaved roads who seek to stretch their budgets to provide an acceptable level of service while minimizing risks to air, soil and water quality, vegetation and wildlife.

Michael Davies, P.E., Director of Project Delivery
Federal Highway Administration
Central Federal Lands Highway Division

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15. Supplementary Notes

COTR: Roger Surdahl, FHWA-CFLHD. For a list of the Dust Scan Steering Committee members please see Appendix A. This project was funded under the FHWA Federal Lands Highway Coordinated Technology Implementation Program (CTIP).

16. Abstract

This handbook provides broad programmatic aspects of unpaved road management. It is based on observations made during a national scan tour and provides useful and insightful excerpts of real-world examples and includes practical how-to instructions for determining what type of treatment may be needed for different situations. It ultimately strives to encourage road managers to think broadly about the process of unpaved road management rather than just focusing on a specific type of chemical treatment.

17. Key Words	18. Distribution Statement
FUGITIVE ROAD DUST, DUST CONTROL, CHEMICAL TREATMENT(S), UNPAVED, GRAVEL, UNSEALED ROADS, PALLIATIVES, STABILIZATION, UNPAVED ROAD MANAGEMENT	No restriction. This document is available to the public from the sponsoring agency at the website http://www.cflhd.gov.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	Millimeters	mm
ft	feet	0.305	Meters	m
yd	yards	0.914	Meters	m
mi	miles	1.61	Kilometers	Km
		AREA		
in^2	square inches	645.2	Square millimeters	mm^2
ft^2	square feet	0.093	Square meters	m^2
yd^2	square yard	0.836	Square meters	m^2
ac	acres	0.405	Hectares	ha
mi^2	square miles	2.59	Square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	Milliliters	mL
gal	gallons	3.785	Liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	Grams	g
lb	pounds	0.454	Kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	Lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	Newtons	N
lbf/in^2	poundforce per square inch	6.89	Kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	Inches	in
m	meters	3.28	Feet	ft
m	meters	1.09	Yards	yd
km	kilometers	0.621	Miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	Hectares	2.47	Acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	Milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	Gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	Ounces	oz
kg	kilograms	2.202	Pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	Poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380 (Revised March 2003)

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ACKNOWLEDGMENTS

The authors acknowledge all who put forth their efforts towards this Unpaved Road Dust Management, A Successful Practitioner's Handbook. The Dust Scan Steering Committee was composed of more than 20 experts (Appendix A) who volunteered many hours advising, planning, writing and/or traveling on the Scan. We are grateful for the energy and wisdom they shared.

We extend a heartfelt thank you to the following individuals and their agencies and staff who hosted the Scan travel team: (Idaho) Joe Wuest and Verlin Van Zee of the Lakes Highway District, Ryan Luttman of Bonner County Road and Bridge; (Montana) Joe Hughes and Steve Monlux (Retired) of the U.S. Forest Service, Erik Dickson of Missoula County; (Arkansas) Gary "Mac" McElroy of Ozark-St. Francis National Forest; (Colorado) Randy Teague of Douglas County Department of Public Works, Dale Miller of Larimer County Road and Bridge, Josh Holbrook and Mel Everhart of Weld County Public Works, and Ted Plank of Boulder County. We also acknowledge the logistical prowess of Traci Ulberg of Meetings Northwest, LLC, and Matt Duran and Carrie Plasters of EnviroTech Services.

Finally, we thank the staff at the Western Transportation Institute for their administrative support.

PHOTOGRAPH CREDITS

The authors acknowledge the following individuals for allowing the use of their photographs in this handbook.

Photographer	**Figure numbers**
David Jones:	1, 2, 6–9, 11–17, 20–34, 20–34, 36–46, 48–50, 52–55, 57–60, 62–74, 77, 78, 80–86, 88–91, 93–95, 97, 98
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OVERVIEW

KEYS TO SUCCESS

Following good management processes is the key to any successful road program. When practitioners focus on broad, fundamental programmatic elements, the details are easier to conceive and manage. By spending the time and the money up front to design and refine site-specific best practices, beneficial results will follow over the life of roadways.

Conversations about how and what chemical treatments can be used to enhance unpaved road management programs often center on a search for a single "one-size-fits-all" product. Such an easy solution is yet, and is unlikely, to be developed. Numerous factors must be considered when managing unpaved roads, including the engineering of the road, who uses the road and why, politics, economics, environmental impacts, training, staffing, cost, and the satisfaction of the customers being served.

KEY INSIGHTS

The work of a successful road manager is not simply crunching numbers in financial statements any more than it is simply identifying a chemical treatment that works well. The successful road manager knows that a chemical additive will only work well when it's applied to a properly engineered roadway, the road is appropriately maintained, and the treatment is rejuvenated at optimal time intervals.

Figure 1. Photo. Good unpaved road.

Figure 2. Photo. Poor unpaved road.

The most successful management programs are those that consider not just the price tag of chemical applications on a single stretch of road, but that factor in all costs and benefits involved in maintaining the entire network of roads in a jurisdiction over time. This includes identifying the price, both economic and environmental, of doing nothing, which can lead to higher costs "down the road" to remediate a bad situation. The public expectation placed on the road manager is to preserve and maintain the road system by keeping the roads dust free, properly shaped, providing a safe driving surface, limiting material loss, and quickly responding to citizen concerns (Figure 1 vs. Figure 2). Chemical treatments, when carefully selected, applied, and maintained, can provide a cost-effective means of satisfying these expectations. While some practitioners differentiate between "dust control" (typically spray-on applications to the surface) and "road stabilization" (typically mixed-in applications) practices, the two are closely linked and the decision to use one or the other is best based on an assessment of the problem and resources at hand to address it.

PURPOSE OF THE HANDBOOK

This handbook identifies key issues to consider when using chemical dust control and stabilization additives as part of an unpaved road management program. It covers economic justification, evaluating the road, selecting an appropriate additive, applying the additive, and considering the environmental implications.

> "I think that the genius of the road manager's clear success was that he did what only one percent of managers do—manage the decision-making process by communicating the cost of *not* doing what he was recommending."
> *– A Scan Team member*

BACKGROUND TO THE HANDBOOK

This handbook has been developed from observations made during the *2010 National Scan of Best Practices for Chemical Treatments on Unpaved Roads* sponsored by the Federal Highway Administration's Central Federal Lands Highway Division and coordinated by the Western Transportation Institute at Montana State University and Meetings Northwest, LLC. The driving force behind this Scan was a recognition that road dust and the chemicals used to control it pose engineering, economic, regulatory, health, safety, and environmental challenges, and that these need to be quantified and approaches developed to address them.

This is the work of more than 20 individuals, listed in Appendix A, with unique expertise and backgrounds from government, academia and industry who joined together on three efforts, namely assessing the national state of the practice with regard to chemical treatments on unpaved roads (Kociolek, 2013) and identifying host sites for the Scan; visiting selected sites that offered examples of best practices in Arkansas, Colorado, Idaho, and Montana; and authoring this handbook.

DUST SCAN FOCUS

The Scan began with the objective of identifying a clear set of best practices to share with the nation's road practitioners. It soon became evident that "best" means what's appropriate to a particular situation, and the Scan team agreed that a clear plan and management strategy for any unpaved road network is more important than simply focusing on the "best" chemical additive. While numerous questions were asked of the road managers who hosted the Scan at each of the sites, the Team's ultimate focus was to find the answers to three key questions:

1. Is the practice working?
2. Is there a satisfactory balance between minimizing environmental impacts and maximizing road user and road agency benefits?
3. Is the practice cost effective?

The team followed a consistent process for each set of roads visited on the Scan:

1. Listen to the host practitioner's story—challenges and successes, management methods and operations, and advice for others (Figure 3);
2. Drive a section of each showcase road to get a subjective "feel" for the effectiveness of the dust control, the ride condition and comfort level of speed, and identify perceived or potential problems and clear benefits (Figure 4);
3. Objectively evaluate several sections of the physical road and adjacent roadside following a standardized visual assessment form shown in Appendix B (Figure 5);
4. Close out each visit with the Hosts by sharing the Team's observations on the answers to the three key questions above.

As such, there was no time for "research" during the Scan. Each evaluation was a snapshot in time—a chance to get an overall perspective of the road condition at one stage of its treated life. The process provided the opportunity for an independent review of practices, including what appeared to be working and what could use improvement. With 10 perspectives, the team's goal was not to achieve consensus, but rather to capture the range of observations for what makes an effective practice and program.

The travel team visited nine sites to observe the operations and results of unpaved road practitioners' programs as listed in Table 1.

Most of the host site roadways were considered low volume, carrying between 50 and 400 vehicles per day. Two of the roadways were more traveled—one had a seasonal count of about 1,200 vehicles per day (Figure 6) and the other had about 800 per day, 15 percent of which were large trucks. Similar to the state of the practice nationally (Kociolek, 2013), all hosts used magnesium chloride ($MgCl_2$) or a magnesium chloride blend on some or all of their roads, with the exception of one who used an enzyme.

Figure 3. Photo. Listening to the practitioner.

Figure 4. Photo. Driving a road section.

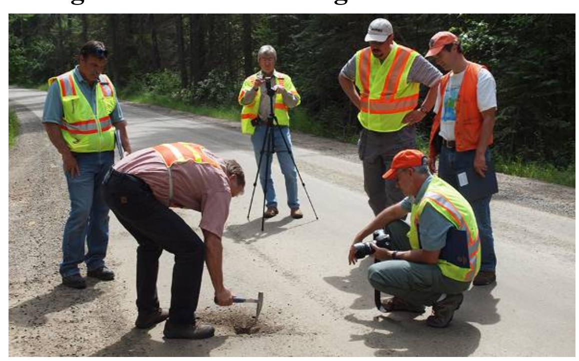

Figure 5. Photo. Evaluating the road.

Figure 6. Photo. Unpaved road traffic.

Table 1. Scan Tour Host Sites.

General Location	Agency	Chemical Treatment
Northern Idaho	Lakes Highway District	Chloride
Northern Idaho	Bonner County	Chloride
Idaho/Montana Border	Lolo National Forest	Chloride
Western Montana	Missoula County	Chloride
Northwestern Arkansas	Ozark-St. Francis National Forest	Enzyme
Northern Colorado	Larimer County	Chloride/lignin blend
Northern Colorado	Weld County	Lignin and chloride/lignin blend
Northern Colorado	Boulder County	Chloride/lignin blend
Northern Colorado	Douglas County	Chloride/lignin blend

Rather than simply producing a recap of scan tour observations, the travel team decided to write a document that melds together scan tour observations with other best practices and basic technical information. What makes this handbook unique is that it represents a culmination of intensive contemplation and debate by a team of experts who willingly engaged on this effort to identify the complex challenges of managing an unpaved road network. It should not be considered a stand-alone guideline for designing, constructing, maintaining and managing an unpaved road, but rather a handbook that supplements existing excellent references on the topic.

UNPAVED ROAD DUST BEST MANAGEMENT PROCESS

To best manage unpaved roads, an intentional and sustainable program is recommended that includes the following components:

1. The Big Picture: Understand the benefits to controlling dust and address it at a program level. (Chapter 1)
2. Identify, document, and justify both project level and program level costs in a defensible and manageable budget. (Chapter 2 and Appendix C)
3. Provide ongoing staff education and implement best work practices to deliver well-maintained roads with an efficient use of time, equipment, and materials. (Chapter 3 and Appendix D)
4. Systematically assess road condition and prioritize improvements and maintenance of the system using discrete, identifiable, and manageable segments. (Chapter 4 and Appendix B)
5. For each segment in a system, classify the roadway material, geometry, traffic level, and climatic zone and select the best chemical treatment for these conditions. (Chapter 5 and Appendix E)
6. Reestablish the roadway's correct geometry and cross-sections, and then properly apply the selected chemical treatment. (Chapter 6)
7. Be knowledgeable of the chemical compositions of the selected treatments and apply them responsibly for the least impact to the environment. (Chapter 7 and Appendix E)
8. Stay in touch with other current dust control activities. (Chapter 8).

POINTS TO CLARIFY

A fundamental misconception that needs to be corrected is that this handbook is about identifying the best product to use; it is not. Nor is it a comprehensive evaluation of the performance of all available dust palliatives and soil stabilizers. Neither is it an endorsement of the products used at the sites that were visited on this Scan, nor is it intended to convey that these products are the only ones recommended for use. Rather, this handbook is about identifying and intentionally following a process to best manage an unpaved road system using chemical treatments, either sprayed directly onto the road to control dust, or mixed into the surface layer to improve the material properties, to improve all-weather passability, as well as to reduce dust levels.

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CHAPTER 1 – INTRODUCTION

The compelling incentive for this handbook on *Unpaved Road Dust Management*, and the earlier *2010 Survey and National Scan of Best Practices for Chemical Treatments on Unpaved Roads*, was the recognition that road dust, and the chemicals used in its control, pose difficult engineering, economic, regulatory, health, safety, and environmental challenges. These challenges need to be better understood and overcome so that chemical treatments are used appropriately across the nation. This handbook is aimed at practitioners who deal with such challenges on the ground and whose individual challenges may be unique to their region.

Even though this document touches on road management issues at the program level, it is not a blueprint for project level unpaved road construction and maintenance. It is not a prescription for determining the correct type and quantity of dust abatement chemical to apply to roads. It is not a checklist for measuring how one county's program ranks against others across the nation, and it is not a research reference documenting the effectiveness of chemical treatments used in experiments and field trials. While the authors find value in these goals and believe that some warrant further study, they are not within the scope of this work because:

Figure 7. Photo. Low volume access road.

Figure 8. Photo. High volume haul road.

- Different types of roads require different levels of service (Figures 7 and 8).
- Each locale faces different challenges in terms of subgrade soil types, climate, topography, availability of wearing course aggregates and chemical additives, population and traffic demands, etc.—all of which affect the longevity of a road and the durability of its treatments.
- Different agencies have different equipment fleets.
- Different funding mechanisms require different approaches to road management and, in the end, dictate what is possible for road improvement efforts.

For example, most chemical treatments rely on mechanical and/or chemical reactions with the soil to be effective. Roads constructed with geologically young glacially deposited material are going to behave very differently from roads constructed with highly weathered basalt materials with high clay contents. Consequently, different road management approaches and different chemical treatment programs will need to be followed.

A wide variety of generic and vendor-specific chemical treatments are available to road practitioners. Although it would be nice to identify the single best cost-effective chemical treatment on the market, guaranteed to work the first time, every time, on the more than one million miles of unpaved roads constructed in the 3,141 counties in America, there are just too many variables for that to be a realistic goal. With balanced judgment of their effectiveness, availability, cost, and safety, practitioners will find that more than one product will probably provide efficient and effective road dust management solutions for a given set of conditions.

What's possible in Bonner County, Idaho, where property valuation reaches $6 billion and the road network totals 700 miles with 425 miles of unpaved roads, is probably not achievable in Woodbury County, Iowa, with a road network twice that size and little more than a tenth the property valuation.

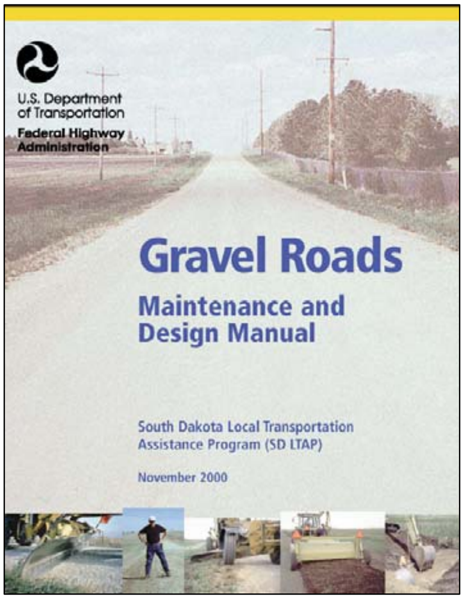
WHY CHEMICAL DUST CONTROL?

Depending on the situation, treating an unpaved road with an appropriate additive generally limits the fines loss. Fines are the "glue" that holds the larger aggregates of an unpaved road together to form the surface layer. Keeping fines in the road leads to:

- Reduced dust levels;
- Improved safety and driver experience;
- Improved air and water quality by reducing particulate matter and sediment runoff;
- Improved quality of life of nearby residents;
- Extended intervals between gravel replacement needs;
- Reduced maintenance costs through extended intervals between grader blading needs; and
- Reduced public complaints.

PURPOSE OF THE HANDBOOK

This handbook is offered as a guide that supplements existing manuals and guidelines to creating sustainable, long-term management programs for maintaining unpaved roads in counties, and on federal lands, forests, mines, farms, and other jurisdictions. Sustainable is meant as meeting objectives and being affordable, cost-effective, and with minimal environmental impact, both in terms of the chemical treatment applied and the aggregate retained through conservation of fines and road shape. It also means providing a level of service to road users that affords them safe and comfortable transportation and a nuisance-free environment, not simply to reduce complaints but also to assure their continued willingness to fund effective road management efforts through their tax dollars.



IT'S THE PROCESS, NOT JUST THE PRODUCT

One of the aims of this handbook is to elevate road managers' thinking to a broader scope about the *process* of unpaved road management using chemical treatments as a road management tool, not just focusing on the use of a specific chemical treatment or product. Understandably, once a certain treatment is used, it can be difficult to redirect from the inertia. But focusing on one product can be risky. What happens when market demand drives up prices, a supplier goes out of business, a local supply is used up, or new research flags a favored product as potentially unsafe or toxic? The point is even with experience and a treatment that seems to work, it is always a good idea to stay abreast of other available additives, technologies, and techniques.

> "I conduct product testing with vendors. I tell them I'll pay if it works as they say it will. If it doesn't, at least I learned something." - *Scan tour host*

Experimenting with different products can be worthwhile, but only if new information is gathered, a basic scientific procedure is followed in the evaluation (that is, comparing a new approach with the existing approach and/or an untreated control), and the process is documented. In a similar way, hard-won knowledge gained from experience is often lost when staff members move on or retire. Careful thought should be put into succession training for employees to maintain continuity and ensure that valuable wisdom stays in the shop. While it may be necessary due to limited budgets for one person to do it all, a better program consists of a team of individuals, who document what they do, how they do it, and what they learn (both good and bad experiences). All of this thinking about process will help justify the costs and savings.

It's not enough to hear "it works," "it's environmentally friendly" or "it's cheap." When the vendor or contractor is required to meet product and/or aggregate specifications, there should be follow up to see that these have been met. Furthermore, product specifications and Material Safety Data Sheets (MSDS) should be verified with an independent accredited laboratory. Colleagues in neighboring jurisdictions, peer-reviewed research and relevant associations can be great sources of information. At the base of it all, succeeding in the process of unpaved road management using chemical treatments requires a solid understanding of quality road construction because a product is only as good as the road on which it is applied.

Key Terminology

Different words mean different things to different people in different parts of the country. In this handbook the following general terminology is used:

Product – chemical treatment, additive, palliative or stabilizer applied for the purpose of dust control (that is, fines retention) and/or stabilization (that is, improved all weather passability).

Material – aggregate, gravel or soil to which the product is applied.

Unpaved – unsealed, unsurfaced or gravel roads.

The terms **Dust Control** and **Road Stabilization** – Keeping the fines on the road (dust control) helps maintain the cementitious matrix needed to keep the road aggregate in place (road stabilization).

SUGGESTED READING

The following documents provide guidance on all aspects of unpaved road design, construction, and maintenance. Most of the documents include discussion of dust control and unpaved road stabilization. All of the documents can be downloaded from the Internet. Full references are provided at the end of the document.

1. Dust Palliative Selection and Application Guide. (Bolander and Yamada, 1999).
2. Dust Control Guidance and Technology Selection Key. (Gebhart, Denight, and Grau, 1999).
3. Gravel Road Management: Implementation Guide. (Huntington and Ksaibati, 2010).
4. Chemical Treatments on Unsealed Roads: Establishing a Chemical Treatment Program. (Jones, 2008).
5. Chemical Treatments on Unsealed Roads: Additive Selection Guide. (Jones, 2008).
6. Chemical Treatments on Unsealed Roads: Unsealed Road Evaluation Guide. (Jones, 2008).
7. Chemical Treatments on Unsealed Roads: Protocols for Researching the Performance of Additives. (Jones, 2008).
8. Chemical Treatments on Unsealed Roads: Fit-for-Purpose Certification of Additives. (Jones, 2008).
9. Dust Control Field Handbook: Standard Practices for Mitigating Dust on Helipads, Lines of Communication, Airfields, and Base Camps. (Rushing and Tingle, 2006).
10. Gravel Roads Maintenance and Design Manual. (Skorseth and Selim, 2000).
11. Guidelines for Cost Effective Use and Application of Dust Palliatives. (Smith, Makowichuk and Carter, 1987).
12. Unsealed Roads: Design Construction and Maintenance. (Paige-Green, et al, 2009).
13. Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT $\leq$ 400), 1st Edition.

CHAPTER 2 – JUSTIFYING THE COSTS

INTRODUCTION

Unpaved roads are an integral and strategic part of the national road network and successfully function for years when properly constructed and maintained. But they don't stand up to traffic without some occasional maintenance; therefore light, regular re-grading (Figure 9) and less frequent but more intensive regravelling and reshaping should all be part of a formally planned and adequately budgeted program. Proper budgeting requires accurate documentation of the extent of the road network, its current condition, a reasonable estimate of its maintenance needs over a long time period, and a thorough understanding of the costs of achieving a range of performance levels as well as the costs of not meeting them.

Figure 9. Photo. Grader maintenance.

THE PROBLEM

While those in charge of allocating funds may prefer to hand them out on an annual basis, road department operations require attention to longer-term needs in order to use those funds most efficiently, especially if gravel preservation and reduced maintenance through chemical treatment is being considered. Along with typical line items for construction and maintenance work, multiple-year road maintenance budgets also need to include allocations for training and retaining qualified employees, buying and depreciating equipment, and contracting for supplies of appropriate quality materials. Multiple-year programs that successfully plan and account for these eventualities need to be assembled to justify annual requests and provide greater assurance of continued funding for manpower, machinery and materials expenditures. However, there are no standard approaches to road maintenance budgets being followed by unpaved road managers.

LEARNING POINTS FROM THE SCAN TOUR

The scan tour found various approaches to justifying chemical treatments on unpaved roads. The most successful were those that used a simple spreadsheet-based management system to clearly demonstrate savings in terms of gravel replacement and road maintenance when compared to not treating the road. Levels of detail varied, with the most comprehensive showing details of, for example, downsizing equipment fleets, redeploying labor to other important functions, and reassigning funds saved on maintenance of treated roads to other roads that require upgrading.

RECOMMENDED APPROACH

Evaluate and Record the True Costs

Treating roads with an appropriate chemical additive will cost more up front compared to leaving them untreated, but the quantifiable benefits usually justify those extra costs in terms of

Figure 10. Photo. Unpaved road accident.

preserving materials (extending the interval between gravel replacement) and reducing maintenance (extending the interval between grader blading). Other benefits such as reduced environmental impact associated with controlling the loss of fines (dust), and improved safety (Figure 10) and reduced environmental impact are more difficult to quantify economically but important to point out. Accurately tracking all costs in a detailed spreadsheet provides compelling evidence when justifying budgets with individuals or groups who allocate funds (e.g., supervisors, employers, or governing boards/commissioners). Table 2 shows a cost comparison between chemical treatment and routine (untreated) maintenance, prepared by a scan tour host and used in justifying chemical treatment as an appropriate, cost-effective unpaved road management practice.

Table 2. Case study cost comparison of treated versus untreated roads.

The Lakes Highway District in Northern Idaho determines all of its costs, resulting in a clear picture of the true cost of road construction and maintenance.	
Untreated	**Treated**
1. Aggregate a. Crushed to specification b. Reapplication 2. Average price of haul to roadway a. Equipment and supplies (fuel, oil, tires and the truck) b. Operator (loaded rate) 3. Placement (also used for ongoing maintenance) a. Motor grader i. Prorated hourly rate ii. Fuel, tires, oil and cutting edges iii. Operator (loaded rate) b. Roller i. Prorated hourly rate ii. Fuel and oil iii. Operator (loaded rate) c. Water truck i. Prorated hourly rate ii. Fuel, oil and water iii. Operator (loaded rate) 4. Salary a. Supervisor b. Crew c. Office staff	For a newly treated roadway at a $MgCl_2$ shot rate of ½ gallon/square yard of roadway and a cost of $92.20/ ton, the treatment to the roadway was $3,501/mile. For a retreated roadway, ¼ gallon was used, which cut the cost in half to $1,750/mile. Additional costs included preparation/ maintenance of the roadway with a grader, water truck and roller (twice per year at a cost of $480/mile). **First year costs**: Spring maintenance: $480/mile $MgCl_2$: $3,500/mile Fall maintenance: $480/mile Total Cost = $4,460/ year **Second year costs:** Spring grading: $480/year Rejuvenation at ¼ gallon $MgCl_2$: $1,750 Fall grading: $480/year Total cost = $2,710/year
Average cost per untreated mile = $8,980/year* *This roadway required blading 18 times per year to maintain an acceptably safe and comfortable ride. Additional pro-rated costs per year are added for the replacement of gravel (item 1)	Average cost per treated mile**: 1st year = $4,460/year 2nd year = $2,710/year ** Does not factor in replacement gravel, which will be needed, but at much lower frequency than untreated roads

Completely and accurately measuring the true costs of untreated versus treated roads and using consistent criteria to compare results from different chemical treatments and maintenance practices enables confident decision-making about the most economical choice for a particular situation. It also helps determine the better option when upgrading a particular road section to an asphalt or concrete surface.

Prepare a Defensible Budget

Preparing a detailed budget with defendable entries is a key component of the process. Appendix C provides a complete and detailed example of one county engineer's annual funding request to county officials. Road managers can use this spreadsheet with their own numbers to justify a chemical treatment program. In doing this, recognize that in most instances, the true benefits of most chemical treatment programs will only be realized after three or four years when the initial costs are recouped through savings in gravel replacement, routine maintenance, and lower application rejuvenations.

Demonstrate Success – Small Projects First

A small demonstration on a selected representative link in the road network is often helpful to prove local effectiveness of chemical treatments to both the road user and to those with the purse strings (Figure 11). Documenting and demonstrating the success by comparing a treated section of road against an untreated control section can provide the justification needed to fund the treatment of more roads in the following year. These smaller projects also pose less risk to the road manager than a larger commitment to a locally unproven technique that might produce unsuccessful results. But each county, forest, mine or federal land does not need to do its own research on dust control. There is a wealth of information and experience available to guide road managers through the process. Techniques can be replicated and adapted elsewhere as long as the process is documented and available.

Figure 11. Photo. Dust control experiment.

Sell the Process to Managers/Supervisors/Employers/Governing Boards/Commissioners

For road managers, a credible relationship with the people who approve annual budgets and allocate funds can establish the level of mutual trust and respect that is critical to budgetary consensus. These individuals, especially if they are public servants, want reasonable and rational justifications for each disbursement. For instance, a request for greater immediate operating funds may be better received if it can be shown that it will result in reduced future funding needs. Also, demonstrating that past funding levels were used to do more than simply maintain a status quo and actually improved the quality of the road network will be seen as evidence of good stewardship and can encourage the approval of funding requests. Road managers who understand organizational objectives and who can clearly communicate their own specific needs in meeting those objectives will prevail as effective program managers. Maintaining some form of gravel road management system to keep track of costs and performance, and sharing experiences with other unpaved road managers in neighboring jurisdictions (that is, not “reinventing the wheel”), are also important parts of this process.

CHAPTER 3 – STAFF EDUCATION

INTRODUCTION

Unpaved road maintenance is an evolving business. Roadway designs and aggregate specifications have improved. However, trucks are getting bigger and faster and the loads they haul are heavier, resulting in greater impacts to the road structure. Good quality aggregate is getting harder to obtain and more expensive as it must be hauled over longer distances. Motor graders are also bigger and more powerful, and have hydraulic steering controlled with joysticks, articulated blading, and air conditioned cabs with electronic gauges. Some people adjust to these changes better than others, but continuing education and training is necessary for everybody in order to optimize resources and productivity.

THE PROBLEM

Blading a road with a chemical treatment (Figure 12) often requires a different methodology from that to which most motor grader operators are accustomed. After gaining some experience with the mechanisms of dust control and soil stabilization, operators must adjust their practices to accommodate them or they may do more harm than good. This is easier said than done. Old habits die hard, and the fact that unpaved roads are no longer maintained the way they used to be, or as often, may be difficult for some to absorb. Consequently, one of the biggest challenges when trying new techniques—including the materials used and road preparation methods discussed in this handbook—is to get everybody (managers, superintendents, supervisors, operators, crews, etc.) to buy in to the idea.

Figure 12. Photo. Crust on road treated with magnesium chloride.

LEARNING POINTS FROM THE SCAN TOUR

Resistance to change by operators accustomed to blading untreated roads in a specific way, the fear that the use of chemical treatments and consequent reduced maintenance requirements would result in layoffs, and the difficulty of maintaining an acceptable level of service in the face of high staff turnover were key learning points from the scan tour. Road managers said they often hear from operators whose perspective is, "I have bladed the road this way for 30 years. Why should I change?" Another Scan host shared that the life of his chemical treatment was reduced because contracted maintenance staff, who were not under his direction, continued to blade the road weekly despite his requests to reduce the frequency.

One practitioner visited on the Scan noted that his best motor grader operator was the water truck driver because he would do what was asked of him to prepare the road for dust treatment and not let preconceptions developed through his own experience get in the way.

RECOMMENDED APPROACH

Managing Staff Effectively

For a successful unpaved road improvement program, road managers should be in full control of the road maintenance staff and should communicate, through a formal training program, the purposes and benefits of new and improved unpaved road management practices. Address fears regarding layoffs, noting that chemical treatment makes better network-wide use of available resources and rarely entails any staff reduction. Include equipment operators in field reviews, demonstrations, early planning and formal training programs in advance of starting a chemical dust control program. Provide opportunities for your operators to visit with operators from other agencies who have programs in place. This can help address any concerns about trying new methods. Motivate operators by reminding them that their work helps to reduce public complaints, improve safety for all drivers, and reduce impacts to the environment. Successful chemical treatment programs also mean freeing up more funds to upgrade other roads in the network, which can further motivate employees by demonstrating forward progress in achieving unit, county or district goals. Achieving staff buy-in with clear expectations and some flexibility will go a long way to building a successful program.

Training

There are four points to accentuate when training staff.

1. The road must be appropriately prepared prior to application of the product. Emphasize that chemical treatments don't make a bad road good; they only keep a good road good. Quality surfacing materials and a well-shaped road that easily sheds water are critical to the performance of all unpaved roads, and those receiving chemical treatment are no exception.
2. Adhere to the correct application procedure for the selected additive is imperative. Different additives require different application methods (typically spray-on or mix-in [Figures 13 and 14]) and the additive supplier must provide detailed instructions and guidance on how to do it correctly. Note that some spray-on applications require a series of light applications to achieve the desired penetration as opposed to a "single shot," which could run off into side drains (Figure 15), where it serves no purpose and could have negative environmental consequences.

Figure 13. Photo. Spray-on treatment to well-prepared road.

Figure 14. Photo. Mix-in treatment.

3. Unscheduled maintenance can do more harm than good. Most chemical treatments form some type of crust and if this is unnecessarily broken up, it will lead to increased levels of dust, rapid deterioration of ride quality, moisture loss, loose aggregate (which can cause windshield damage), and ultimately washboarding—all of which mean additional gravel will be needed sooner, greatly increasing the cost of maintaining the road.
4. The periodic maintenance typically associated with chemical treatments (that is, usually once or twice a year on roads with typical unpaved road traffic) should not simply cover surface distresses with material from the sides of the road. Instead, the surface crust should be softened with a water spray and then reshaped to restore the crown and remove any deformation (or this can be done after light rain) (Figure 16). Applying a water spray also allows remixing of the surface material and prevents a "biscuit" layer from forming. Biscuit layers rapidly break up under traffic, leading to a rough ride (Figure 17). Other chemical treatments form more permanent non-water-soluble surfaces, which require the use of scarifiers or rotomilling to break up the surface. Again, different types of treatment require different maintenance techniques and the additive supplier must provide clear guidance and training.

Figure 15. Photo. Excess runoff of chemical treatment.

Figure 16. Photo. Maintenance of treated road.

Figure 17. Photo. Broken crust.

Once operators learn that different treatments may result in different stabilizing mechanisms, they will be able to properly adjust their maintenance practices to the treatments applied. Additional training topics are listed in Appendix D.

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CHAPTER 4 – PLANNING AN UNPAVED ROAD IMPROVEMENT PROGRAM

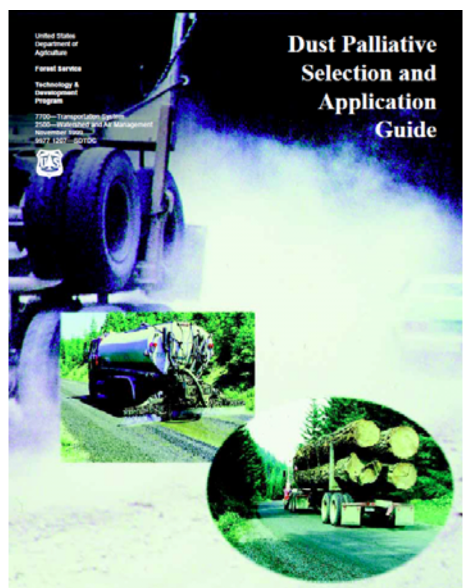
INTRODUCTION

Designing and implementing an unpaved road improvement program requires a comprehensive understanding of specific site, road, and traffic characteristics and, depending on how a practitioner goes about it, can lead to different decisions about what is the most appropriate dust control solution for an unpaved road.

THE PROBLEM

Finding and accessing readily available, user-friendly published information on establishing an unpaved road improvement program incorporating dust control appears to be an unmet need and concern for many unpaved road managers. Consequently, managers often rely on additive suppliers and vendors for guidance who, understandably, will encourage the use of their product even though it may not be the best solution for a particular section of road. Competing suppliers and vendors may also provide conflicting advice, leaving the road manager in doubt as to which approach to take.

LEARNING POINTS FROM THE SCAN TOUR



Road manager experience in establishing unpaved road improvement programs varied considerably across the locations visited. In some locations, road managers had researched the topic, typically following the US Forest Service *Dust Palliative Selection and Application Guide* and experience and/or recommendations from other experienced managers in neighboring jurisdictions. In other locations road managers relied on information and recommendations from suppliers and vendors. Most scan tour hosts were unaware of how additives were categorized, the full extent of available additives, or how to select an appropriate additive with confidence for a particular situation.

RECOMMENDED APPROACH

Data Gathering

The first task in establishing an unpaved road improvement program, with specific emphasis on using chemical treatments, is to document the features of the unpaved roads in the network. This includes a survey of the road and adjacent land, and possibly working with the road users and those who live next to it to understand public perceptions of problems with the road.

Information that needs to be collected includes:

- Road alignment and geometry (Figure 18), including drainage and the presence of shoulders, and highlighting any areas that typically require additional maintenance and/or repairs, or that are considered accident "black spots." The steepness of the grade may limit the choice of chemical treatment.
- Adjacent land use, such as residential, crops, forest, and wetland (Figure 19).
- Road condition, (poor, average or good) with a reason for the rating (no or poor aggregate, inadequate drainage, dust, surface distresses of washboarding, potholes, ruts, erosion, and weak subgrade). Problems should be divided into those that can be corrected using routine maintenance and those that will require reconstruction and/or regravelling.
- The thicknesses of the wearing and base courses (Figure 20) and their material properties (that is, using simple laboratory tests that determine the particle size distribution [grading] and plasticity [Atterberg Limits]. If passability problems are experienced in wet conditions, strength tests [California Bearing Ratio] should also be conducted). Interpretation of the results is covered in Chapter 5. Wearing course thickness should typically be greater than 4 in. (100 mm), while base course thickness must be sufficient to raise the road above surrounding ground level and to "protect" the subgrade from rutting.
- The ability of the road to shed water (that is, is there sufficient crown?). A crown of between 4 and 5 percent is adequate for water to flow off the road (Figure 21). Less crown typically results in ponding of water along the centerline, leading to potholes and ultimately softening of the material resulting in passability problems. More crown often leads to erosion and dangerous driving conditions (truck trailers can slide off the crown). Side drains need to take the water away from the road to prevent ponding on the sides that can lead to softening of the subgrade and resulting poor passability.

Figure 18. Photo. Super-elevation on sharp curve.

Figure 19. Photo. Mixed adjacent land use.

Figure 20. Photo. Insufficient, poor quality gravel.

Figure 21. Photo. Road with good drainage.

- The average daily traffic volume (Figure 22), primary users (for example, commuters or haul vehicles), types of vehicles (that is, percentage of trucks and cars), seasonality of traffic (that is, are there peak periods during harvesting?), and whether there is loaded truck traffic in one direction and unloaded in the other (fast moving empty trucks tend to cause more rapid deterioration on unpaved roads than slower moving loaded trucks).
- Average speed of the vehicles and what governs this speed (for example, road condition, dust, enforcement, etc.). The road manager will need to predict whether speeds will increase after dust control and whether this will lead to unsafe driving conditions.
- Known problem areas that require constant maintenance/repair or that constantly generate public complaints and the reason(s) for the problem (Figure 23).
- The current regravelling and grader maintenance program and frequencies.
- The current funding levels and whether additional funding can be made available if chemical treatments can be justified, and whether a multi-year program will be considered to optimize spending in the longer term.
- An acceptable level of dustiness (Figure 24). Complete dust control is generally only achieved by upgrading a road to a paved standard, the costs of which are often prohibitive and unjustifiable for low traffic volumes. Road users and adjacent property owners will often gladly accept a percentage of dust reduction. Ask these individuals to rate what an acceptable level of dust control is.
- The long-term plan for each road (that is, will it continue to experience current average daily traffic [ADT] and usage types or is ADT increasing? Will it be closed or paved in the next few years? Will improving it with a chemical treatment attract more traffic?).
- Climatic conditions, including rainfall distribution and intensity of storms, annual humidity ranges, freeze/thaw conditions, and maximum temperatures.

Figure 22. Photo. Truck on treated road.

Figure 23. Photo. Potholes caused by poor drainage.

Figure 24. Photo. Acceptable dust level.

Ranking

Based on the data collected, the road manager will need to rank the roads for improvement. The criteria used for this condition ranking will initially depend on the type and levels of distress, but may also be influenced by public complaints, political intervention, and/or funding mechanisms. Not all roads will require chemical treatment. When considering chemical treatment, it is often best to first treat those roads that have adequate gravel thickness and are in good condition (that is, keep the "good roads good" [Figure 25]) and then to improve and treat the poorer quality roads (Figure 26). This strategy is usually more cost-effective in the long run and will ultimately bring all roads to an acceptable standard faster than by adopting a "worst first" strategy (fixing bad roads first costs a lot, leaving limited or no funds to maintain the good roads, which will quickly deteriorate to a poor condition).

Figure 25. Photo. Keeping a good road good.

Figure 26. Photo. Road requires upgrade before treatment.

CASE STUDIES

Example case studies are provided in Figure 27.

CASE STUDIES

1) **A logging road in the Pacific Northwest has heavy seasonal traffic of lumber haul trucks (high average daily traffic [ADT]), considerable dust generation in the summer, is subject to freeze/thaw cycles in winter and spring snow melt as well as seasonal rains in spring and fall, with the base and surface courses worn below minimums and with significant washboarding.** Dust control is clearly needed to alleviate the safety issues related to reduced visibility for haul trucks and prevent dust falling into streams. Before any chemical dust control is applied, a cost-effective solution for this road would likely be to apply and grade new base and surface courses to the specified thicknesses, followed by incorporation of a durable or regionally proven stabilizer/dust control additive into the surface course.

Figure 27. Case studies illustrating the need for appropriate strategies for local conditions.

CASE STUDIES	
2) **A campground/trail head access road in the Southwest is dry most of the year, has seldom freeze/thaw cycling, with a low ADT of mostly light-duty vehicles, occasional heavy summer monsoon rains and occasional mild frontal winter rains. The road is seldom, if ever, re-graded. Only limited, thin surface course is present, which is in fairly good condition with dust needing to be controlled for aesthetic and environmental reasons.** In this case, a topical application and minimal road preparation may be sufficient.	
3) **A rural road in the Midwest has moderate ADT, mixed traffic types including light duty vehicles and seasonal farm equipment, some rutting and ponding of water on the road surface is known to occur, freeze/thaw cycling in winter, significant spring precipitation can be expected. Summer dust control is needed because of nuisance dust affecting residents in adjacent homes and businesses and because of road safety issues. The road is periodically graded to restore the crown and remove the potholes and minor rutting.** In this situation, an incorporation method, applied in concert with the annual regrading and road reshaping, may be the best approach.	

Figure 27. Case studies illustrating the need for appropriate strategies for local conditions (*cont.*).

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CHAPTER 5 – SELECTING A CHEMICAL TREATMENT

INTRODUCTION

There are more than 150 proprietary unpaved road additives on the market in the United States, ranging from general purpose dust palliatives that work well under a range of conditions to soil-specific stabilizers that have been developed to improve the properties of certain high clay content soils. There is also a growing tendency to combine two or more additives into a single product to enhance performance. Most additives can be categorized, based on chemistry, to aid selection for a specific additive. To properly select an additive for a roadway, the material properties, geometry, traffic levels, and climate must be known.

THE PROBLEM

The variety of choices of unpaved road chemical treatments available to the road manager is overwhelming given the extremely wide range of proprietary products available, the lack of specifications, and the lack of published scientific research comparing the various additive categories and additives within categories. Consequently, road managers invariably have to rely on the limited experience of others or the recommendations of additive suppliers and vendors who often provide conflicting information. Secondly, road managers usually only do limited testing of road materials and consequently choices of chemical treatment are often not compatible with the materials in the wearing course, leading to poor performance. In these instances, the chemical treatments are usually incorrectly blamed for the poor performance, whereas the lack of knowledge/information leading to inappropriate choices is usually the culprit.

LEARNING POINTS FROM THE SCAN TOUR

Road manager experience in selecting chemical treatments varied considerably across the locations visited. Magnesium chloride was the treatment of choice in many areas (Figure 28), this being attributed to a proven track record and cost-effectiveness, ready availability, and ease of application. There were, however, growing concerns about potential long-term environmental impacts associated with annual applications. In some locations, road managers had again researched the topic and considered alternatives such as lignosulfonate (Figure 29), typically following the US Forest Service *Dust Palliative Selection and Application Guide* and experience and/or recommendations from other experienced managers in neighboring jurisdictions. Cooperation also existed between some road managers and suppliers to "engineer" additives to better resolve the needs of a particular road

Figure 29. Photo. Lignosulfonate road.

condition. Most scan tour hosts were unaware of the full performance capabilities of available additives or how to select an appropriate additive with confidence for a particular situation. Most road managers were concerned about the lack of specifications for unpaved road chemical additives, dealing with the proprietary nature of many treatments, and how to incorporate chemical treatment requirements into their documents and specifications. One vendor noted that they were occasionally asked by road managers to help write bid specifications to suit their specific additive!

RECOMMENDED APPROACH

The performance of unpaved road chemical treatments is primarily influenced by how well the treatment is matched to the material properties of the wearing course materials. Traffic volume and type, road geometry and climate are of lesser importance, but will still influence the choice and need to be considered before any final decision is made. The approach recommended in this handbook advocates first understanding the materials, which requires inexpensive testing and simple interpretation of the test results, and then selecting an additive category considering the material properties, traffic, geometry, and climate.

Know Your Materials

Users of unpaved roads are fundamentally unhappy with dust and poor ride in dry conditions, and slippery, impassable roads in wet conditions. Meanwhile, practitioners are mainly focused on minimizing costs while providing a safe and acceptable level of service. All of these issues are a function of material properties and the way the road is constructed and maintained.

It is important to note that aggregate gradation specifications for the riding surface of unsurfaced roadways are not the same as those for hot mix asphalt, portland cement concrete pavement, or even those of the base course.

A finished road is only as good as the materials that form the riding surface. Most unpaved roads in the United States have some form of imported aggregate base and wearing course. Much of this aggregate comes from commercial sources that also supply contractors and various departments of transportation. Consequently, the aggregate supplied for unpaved roads will usually meet the specifications of the supplier’s greatest need; typically asphalt concrete, portland cement concrete, or aggregate base for paved roads (Figure 30). Many practitioners mistakenly believe that if materials meet the specifications for aggregate base in a paved highway, it will also work well as an unpaved road wearing course. **This is an incorrect assumption!** Aggregate base used in paved roads is confined by the chip seal, asphalt or concrete on the surface and gradings are optimized for strength alone as it is not directly exposed to traffic abrasion or the weather. A different set of material specifications is needed for unpaved road wearing courses to compensate for the lack of surface containment.

Figure 30. Photo. Aggregate for asphalt concrete.

Figure 31. Photo. Plasticity test.

Key material properties influencing unpaved road performance include the grading or particle size distribution, the fines content, the clay content, and the material shear strength. These are determined from basic material indicator tests including a grading analysis (for example, AASHTO T 27 or ASTM C136), a plasticity test (Atterberg Limits [AASHTO T 89 and T 90 or ASTM D4318] or bar linear shrinkage [Caltrans CT 228 or Texas Tex-107-E]), and a strength test (for example, California Bearing Ratio [CBR, AASHTO T 193 or ASTM D1883]), all of which are simple to do and cost very little (Figure 31). In fact, the costs are negligible in terms of the costs of gravel replacement and selecting the correct chemical treatment and are recovered many times over in the extended life of the road and reduced maintenance requirements. The small savings enjoyed up front by skipping material testing will invariably mean higher costs later on because of early replacement of gravel and the need for more frequent maintenance. Most specifications are based on these or similar tests and typically provide an envelope of parameters for each, which the aggregate supplier or practitioner needs to meet.

Understand How Material Properties Influence Performance

There are a range of recommendations, guidelines, and specifications for unpaved road base and wearing course materials. Most need to be adapted to suit local conditions and material availability. Many chemical treatments can be used to overcome limitations in material properties. However, many road managers have difficulty in interpreting test results, especially with regard to understanding performance if a grading envelope and a single plasticity criterion cannot be met by an aggregate supplier or in gravel located on the road owner's property. The following simple three-step procedure, based on research in southern Africa (Technical Recommendations for Highways, No.20) and adapted for international use, can be used to interpret key test results, assess the applicability of local material specifications, and understand how unpaved roads will perform if a particular material is used. It can also be used to make a decision regarding material choice, road design specifications, and chemical treatment selection. This procedure is a guide only and NOT a new specification, nor is it intended that it replace existing specifications. It may need to be refined for particular situations and calibrated for local conditions.

Step 1 – Test Result Analysis

- **Grading Analysis**
  In this recommended approach, only four key sieve sizes are required for the grading analysis. These are the 1.0 in., #4, #8, and the #40 (25 mm, 4.75 mm, 2.36 mm, and 0.425 mm) sieves. The first three are used to check for the correct mix of coarse, intermediate, and fine particles using the following simple formula known as the grading coefficient (G_c):

G_c = ((P1.0 in. – P#8) x P#4) / 100 or

G_c = ((P25 mm – P2.36 mm) x P4.75 mm) / 100

Where P is percent passing

Although the grading coefficient is determined using material passing the 1.0 in. (25 mm) sieve, a maximum size of 1½ in. to 1¾ in. (40 mm to 45 mm) is preferable to provide adequate all-weather passability. The use of aggregates larger than this will reduce ride quality, make it noisy to travel on, and cause problems for the maintenance grader operator.

The percentage material passing the #200 (0.075 mm or 75 µm) sieve is also a useful indicator of how an unpaved road will perform and can influence the decision of what treatment to use. High percentages of material (that is, >20%) passing this sieve imply that the road will be dusty when dry and may become slippery when wet. Low percentages (that is, <10%), imply that the road will washboard and require regular grader maintenance. Many unpaved road wearing course specifications based on paved road base course specifications limit this fines content to about 5 percent in the mistaken belief that this will reduce dust. Determination of the percent passing the #200 sieve (usually done using a wet process as part of a standard grading analysis) is, however, not as simple as determining the percent passing the #8 sieve (which can be done dry if necessary when checking aggregates in the field). Consequently for understanding general performance, the #200 material is factored into the grading coefficient equation as part of the #8 sieve material. However, the percent passing the #200 sieve is required for optimal chemical treatment selection.

The angularity of the aggregate should also be checked during the sieve analysis. Cubicle material (Figure 32) has better interlock than rounded material (e.g., uncrushed alluvial aggregates) and consequently rounded aggregate (Figure 33) should be crushed to obtain at least two fracture faces to enhance interlock and prevent raveling.

Figure 32. Photo. Cubicle aggregate.

- **Clay Content**
  The percent passing the #40 sieve is used together with the bar linear shrinkage (BLS), or plasticity index (determined from the Atterberg Limit tests if the BLS test cannot be undertaken), to optimize the clay content using the following simple formula known as the shrinkage product (S_p):

  S_p = BLS x P#40 if the bar linear shrinkage is used, or

  S_p = (PI x 0.5) x P#40 if plasticity index is used

Figure 33. Photo. Rounded aggregate.

(Note that using the bar linear shrinkage (Figure 34) to determine the shrinkage product is more accurate than using the plasticity index, especially for silty non-plastic or slightly plastic materials. These materials often have a plasticity index of zero, and consequently also a shrinkage product of zero if the above formula is used. However, they will usually have some shrinkage [that is, BLS > 0], thereby providing a number to work with to better estimate expected performance).

Figure 34. Photo. Bar linear shrinkage test.

- **Bearing Capacity**
  The California Bearing Ratio (CBR) performed on material in the laboratory is the most commonly used bearing capacity test. No formulas are required to interpret the results from this test.

Step 2 – Test Result Interpretation

Optimal unpaved road performance will usually be achieved when the wearing course materials meet the following:

- The grading coefficient is between 15 and 35. Although not directly measured in the grading coefficient formula, a fines content (material passing the #200 sieve) of between 12 and 15 percent is typically required to meet the grading coefficient requirements.
- The shrinkage product is between 100 and 365 (or between 100 and 250 if dust is a major concern and no dust control treatment is planned). Many unpaved road specifications based on paved road base course specifications limit or even exclude any clay content in the mistaken belief that this will also reduce dust.
- Assuming that the road has a quality base course with adequate CBR, the soaked CBR of the wearing course should be above a minimum of 15. If the traffic is predominantly trucks and the road is in a high rainfall area or storms of high intensity are common, a higher CBR may be desirable if passability problems are an issue. However, higher CBR materials tend to have low clay contents and consequently washboarding may be a problem. Therefore, a balance between CBR and shrinkage product needs to be determined for optimal performance for specific traffic type and volume.

When these optimal grading coefficient and shrinkage product limits are met, good performance is achieved as shown below in a simple performance prediction chart in Figure 35. The chart also demonstrates the likely consequences of not meeting the criteria.

The factors that contribute to each of these predicted material performances are discussed below.

- <u>Erodible materials</u> are typically fine grained and have some plasticity. They generally perform well when used in roads on flat terrain or in areas of very low rainfall. In other areas they will quickly erode during rainfall, leaving channels in the road that are dangerous and unpleasant to drive over and expensive to maintain. Examples of roads built with materials falling in this area of the chart are shown in Figure 36 and Figure 37. The eroded material usually ends up where it is not wanted (for example, blocking drains or flowing into streams or onto adjacent land).

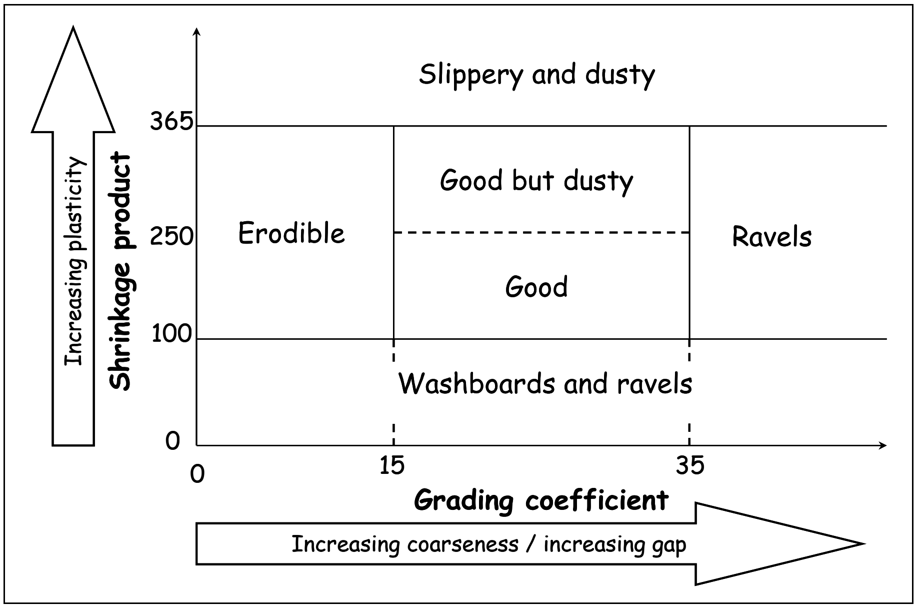

Figure 35. Chart. Material performance predictor chart (adapted from Paige-Green 1989).

Figure 36. Photo. Transverse erosion.

Figure 37. Photo. Longitudinal erosion.

- Materials that washboard (corrugate) and ravel are usually poorly graded or gap-graded (absence or insufficient quantities of certain sizes leading to poor aggregate interlock) and lack fines and plasticity. Consequently the particles do not bind together, leading to washboarding, raveling and, ultimately, gravel loss, and thus a poor and unsafe ride on a surface requiring regular maintenance. These materials are also prone to erosion during rainfall. Examples of roads built with materials falling in this area of the chart are shown in Figure 38 and Figure 39.

Figure 38. Photo. Washboarding (corrugation).

Figure 39. Photo. Washboarding and raveling.

- Materials that ravel have some plasticity, but are gap-graded. The presence of clay usually limits washboarding but does not prevent raveling. Examples of roads built with materials falling in this area of the chart are shown in Figure 40. Windshield damage is a major problem on these roads.
- Materials that are slippery when wet and very dusty when dry typically have high fines and clay contents. Examples of roads built with materials falling in this area of the chart are shown in Figure 41 and Figure 42. Increasing clay content also results in decreasing CBR, leading to poor passability in addition to the slipperiness Figure 43).

Figure 40. Photo. Raveling.

Figure 41. Photo. Dusty when dry.

Figure 42. Photo. Slippery when wet.

Figure 43. Photo. Impassable.

- Well-graded materials with moderate clay contents will perform well, but may be dusty during dry conditions. Examples of roads built with materials falling in this area of the chart are shown in Figure 44.
- Finally, well-graded materials with some clay will perform well with a minimum of maintenance. Examples of roads built with materials falling in this area of the chart are shown in Figure 45.

Figure 44. Photo. Good but dusty.

Figure 45. Photo. Good material.

Step 3 – Material Selection Decision

If materials falling within the good performing area on the chart are readily available, the decision is easy. Use these materials to construct a good road! If they are not readily available the practitioner needs to decide on an appropriate course of action as follows:

- Weigh the consequences with the probability of occurrence:
  - Erodible materials can be used in flat areas and areas with low rainfall or low intensity rainfall events.
  - Materials that washboard or ravel can be used on roads with low-traffic volumes traveling at low speeds. They can also be used if the practitioner is prepared to regularly blade or drag the road. The costs of this maintenance should be compared with importing better gravel from elsewhere. If the road is generally only used to access residences, the homeowners may be willing to tow a simple tire drag themselves to smooth washboarding and raveled areas.

  - Materials that are slippery or impassable can be considered on low traffic volume roads in low rainfall areas if the road can be closed during problem events.
  - Good but dusty materials can be used with appropriate speed restrictions or a suitable dust palliative.
- Use the material "as is," but adjust maintenance programs accordingly:
  - Blade the road more frequently to remove erosion channels or washboarding and redistribute raveled material.
  - Close the road during slippery or impassable conditions.
- Seek alternative aggregate suppliers who can provide the requested material.
- Blend two materials to meet the required grading coefficient and shrinkage product. This usually requires the addition of small amounts of clay if commercially obtained aggregate is used.
- Use a dust palliative or stabilizer to provide additional binding to the material, but remember that it is usually cheaper to use fines to fill voids (that is, meet the grading coefficient and shrinkage product requirements) than to use a chemical.

Selecting an Appropriate Chemical Treatment

Additive Types

Although there are more than 150 proprietary chemical treatments available on the market through as many additive suppliers, vendors, and distributors, most can be categorized into one of seven main categories (See Appendix E for a detailed summary of the categories). There is, however, a growing trend to blend additives from two or more categories to optimize performance for specific road conditions. The seven categories are:

- Water Absorbing. These treatments function by absorbing small quantities of water from the atmosphere, which agglomerates the fines and holds the aggregate matrix together through suction forces. The most common products in this category are magnesium chloride (Figure 46) and calcium chloride (Figure 47), both of which are commonly used for dust control in the United States. There is a considerable published record on the use of these additives and a significant history of application. Marginal increases in strength are possible, mostly due to improved compaction. They are water soluble and do not provide sufficient strength improvement to warrant consideration as soil stabilizers. Roads treated with these additives can be maintained with conventional unpaved road techniques (that is, grader blading after light rain or water application).

Figure 46. Photo. Magnesium chloride.

Figure 47. Photo. Calcium chloride.

- Organic Non-Petroleum or Natural Polymers. These treatments act as "glue" that agglomerates the fines and coarser particles together. This category includes lignosulfonates (Figure 48), tree resins, tree oils, vegetable oils and molasses-based products. They are by-products from plant-based industries including sulfite processes commonly used in pulp and paper industries, vegetable oil and tannin extraction, ethanol production, and sugar refining. Their composition is variable and depends on the plant matter and chemicals used during processing. Most are water soluble. They are effective dust palliatives but do not provide sufficient strength improvement for consideration as soil stabilizers. Treated roads can be maintained with conventional unpaved road techniques.

Figure 48. Photo. Lignosulfonate.

- Organic Petroleum and Petroleum Resins. Organic petroleum treatments are typically diluted asphalt emulsions that provide both strength improvement and dust control through a cementing action. They do not leach out during rainfall, but are difficult to maintain with conventional unpaved road maintenance equipment if a hard crust forms. Petroleum resins (Figure 49) are usually a blend of natural polymers and petroleum-based additives. They have a similar binding action to natural polymers but are more resistant to leaching by water. They are effective dust palliatives, but usually do not provide sufficient strength improvement for consideration as soil stabilizers when applied at economical application rates. They are difficult to maintain with conventional unpaved road maintenance equipment if a hard crust forms. Mineral oils and base oils are effective for dust suppression, but not for stabilization. They are not water soluble, but can be displaced from the soil particles by water. They usually do not form a crust and treated roads can be maintained with conventional unpaved road maintenance equipment.

Figure 49. Photo. Petroleum resin.

- Synthetic Polymer Emulsions. Synthetic polymer emulsions (Figure 50), or polymer dispersions, are suspensions of synthetic polymers in which the monomers are polymerized in a dominantly aqueous medium. Once the aqueous medium has evaporated, the active ingredients glue the aggregate particles to each other. Numerous formulations have been developed for various soil-conditioning applications. Depending on the formulation and application rate, they are effective in both

Figure 50. Photo. Synthetic polymer.

dust control and strength improvement (stabilization) applications. Roads treated with these additives are usually difficult to maintain using conventional unpaved road techniques because of damage to the skin/crust that forms on the surface.

- Synthetic Fluids. These treatments include synthetic base fluids and unique formulations of synthetic iso-alkanes (Figure 51). They are effective dust palliatives, but do not generally provide sufficient strength improvement for consideration as soil stabilizers. They can be modified with other binders if strength improvement is required. Roads treated with synthetic fluids can be maintained with conventional unpaved road techniques. Maintainability of roads treated with synthetic fluid blends will depend on the formulation and application rate and method.

Figure 51. Photo. Synthetic fluid.

- Electrochemical/Sulfonated Oils. Electrochemical additives (Figure 52), sulfonated oils (Figure 53), sulfonated petroleum products (SPPs) or ionic stabilizers rely on ionic exchange reactions to perform their expected functions satisfactorily. Their "active ingredients" are mostly hydrocarbon mineral oils modified with sulfuric acid to form a sulfonic acid. Sulfonated oils are all "surface active agents" (surfactants) and have the ability to fix, displace, or replace exchange cations in clays and to make the soil materials (particularly clay minerals but not necessarily only clays) hydrophobic by displacing adsorbed water and water of hydration, and preventing re-adsorption of this water. They are highly susceptible to ion exchange reactions in which appropriate inorganic ions present on mineral surfaces (particularly clays) and in clay interlayers are replaced by, or attached to, the organic molecules. This reduces the mobility of the ions and functionally reduces the plasticity of the material. Once an ion exchange reaction has occurred and the sulfonic acid is attached to a mineral particle, the so-called hydrophobic tails of the sulfonated oils are directed away from the particle and form an oily protective layer around it. In theory, this has the effect of reducing the thickness of the electrical double layer and of preventing water from gaining access to the clay mineral particle. With this reduced double layer thickness, it now becomes theoretically possible to achieve a greater degree of compaction

Figure 52. Photo. Electrochemical additive.

Figure 53. Photo. Sulfonated oil.

in the material and also to reduce the possible water absorption of the material in the long term. They can be maintained with conventional unpaved road techniques.

- Enzymes. As with sulfonated oils, enzymes (Figure 54) are proprietary products, the formulations of which are not made public. Little useful documentation on the exact process of stabilization is available, although some form of microbial activity to neutralize the activity of clay is a central theme of some product brochures. Material requirements (in terms of clay content and plasticity), application rates, and method and performance claims are similar to those advocated by the suppliers of electrochemical/sulfonated oils. Enzyme-treated roads can be maintained with conventional unpaved road techniques.

Figure 54. Photo. Enzyme.

Additive Selection

After optimizing the aggregate material, a suitable chemical treatment can be considered to further prevent the loss of fines, reduce dust levels, improve all-weather passability, and extend intervals between maintenance. Dust palliatives and stabilizers are usually developed to address specific problems, and contrary to some undocumented claims, there is no one chemical treatment that addresses all unpaved road problems. The recommended procedure for selecting the most appropriate additive for a given situation is as follows:

1. Using the chart in Table 3, select the additive category that will work best in terms of the specific traffic (numbers of cars and trucks per day), road geometry (presence of steep grades and/or sharp curves with super-elevation), climate (humidity levels and storm intensity), and soil chemistry. More than one category may be suitable.
2. Refine the selection to subcategories using the chart in Table 4, or the expanded version of the chart provided in Appendix E, both of which are based on the US Forest Service *Dust Palliative Selection and Application Guide* method. Choosing one additive category over another will depend on specific conditions and cost will require some engineering judgment, experience, and advice from experienced users, suppliers and vendors. Simple abrasion (mechanical brush [Figure 55]) and erosion tests can be considered to assess effectiveness of different additives under specific conditions, to compare additives, and to refine application rates.
3. Check material compatibility based on test result interpretation discussed earlier in this chapter and using the expanded performance predictor charts in Figure 56. Guidance on how various additives perform in terms of the material grading coefficient and shrinkage product is provided below.

Figure 55. Photo. Abrasion resistance test.

Table 3. Category Selection Chart

Additive Category	Traffic Limitations		Road Geometry Limitations		Climate Limitations		Soil Chemistry Limitations
	Cars	Trucks	Steep Grades	Sharp Curves/ Super-elevation	Humidity	High Intensity Rain	
Water absorbing	A	B[1,2]	B[3]	B[1,2]	C	B[5]	B[6]
Organic non-petroleum	A	B[1,2]	B[4]	C[1,2]	A	C[4]	A
Organic petroleum	A	B[1,2]	A	B[1,2]	A	A	B[7]
Petroleum resins	A	B[1,2]	A	B[1,2]	A	A	
Mineral oils	A	B[1,2]	A	B[1,2]	A	B[4]	
Synthetic polymer	A	B[1,2]	A	B[1,2]	A	A	A
Synthetic fluids	A	B[1,2]	A	B[1,2]	A	A	A
Electrochemical	A	B[1,2]	A	B[1,2]	A	A	C[8]
Enzyme	A	B[1,2]	A	B[1,2]	A	A	C[8]

A = No significant influence of performance B = Some influence on performance C = Significant influence on performance

[1] Empty trucks and trailers at high speed may break crust and accelerate washboarding and raveling
[2] CBR must be increased with increasing number of trucks to ensure all-weather passability
[3] May be slippery when wet
[4] Likely to leach out or down into lower layers with heavy rainfall
[5] May leach down into layer, but dry-back plus light rejuvenation will return it to surface
[6] Can react with some elements if abundant in soil to form non-hygroscopic compounds (e.g., iron chloride in soils with vey high iron content)
[7] Choice of anionic or cationic emulsion may influence performance on certain soils
[8] Requires specific clay minerals for satisfactory reaction

Table 4. Chart for Refining Additive Selection

Additive Category	Traffic			Surface Material								Climate During Traffic		
	Vehicles per Day			Plasticity Index/ Shrinkage Product			Fines (% passing No.200 Sieve [75 µm])							
Dust Palliative	<100	100-250	>250[1]	<5 / <50	5-15 / 50-365	>15 / >365	<5	5-10	10-20	20-30	>30	Wet	Damp to Dry	Dry[2]
Water absorbing														
Calcium Chloride	A	A	B	C	A[3]	C[3]	C	B	A	B[3]	C[3]	C[3,4]	A	C
Mag Chloride	A	A	B	C	A	B[3]	C	B	A	B[3]	C[3]	C[3,4]	A	B
Organic petroleum/Mineral oils														
Asphalt emulsion	B	B[5]	B[5]	A	B	C	B[6]	B	B[5]	C	C	B	A	A
Petroleum resin	A	B[5]	B[5]	A	B	C	B[5]	B	A	C	C	B	A	A
Mineral oil	A	B	B	B	A	C	C	B	A	B	C	B	A	A
Organic non-petroleum														
Lignin	A	A	B[5]	C	A	B[3,5]	C	B	A	B[3,5]	B[3,5]	C[4]	A	A
Tall oil	A	B	C[5]	A	B	C	C	B	A[5]	B[5]	C	B	A	A
Vegetable oil	A	C	C	B	A	C	C	B	A	C	C	C	A	B
Bio-Fluids	A	A	B[5]	C	B	A	C	C	A	A	C[3]	C[3,4]	A	C
Synthetic polymer emulsion														
Synthetic polymer[5]	A	B[5]	C[5]	A	A	C	C	A	A[5]	C	C	A	A	A
Synthetic fluids														
Synthetic Fluid[7]	A	A	B[5]	B	A	B	C	A	A	A	B	B	A	A
Electrochemical/Enzyme														
Electro-Chemical[5,8]	A	A	B	C	B	A	C	C	A	A	A	B	A	A
Enzyme[5,8]	A	A	B	C	B	A	C	C	A	A	A	B	A	A
Other (mechanical)														
Clay Additives[5]	A	B	C	A	B[3]	C	A	B	B	C	C	C[3]	A	A

Performance relative to unpaved road with no chemical treatment: A = Good B = Fair C = Poor

[1] Higher application rates/more frequent rejuvenation required for high truck traffic
[3] May become slippery in wet weather if shrinkage product >250
[5] Mix-in treatment usually required
[7] EPA Definition
[2] >20 days with less than 40% relative humidity
[4] May leach out in heavy rain
[6] SS-1 or CSS-1 with only clean, open-graded aggregate
[8] Requires reactive (usually expansive) clay minerals to react with

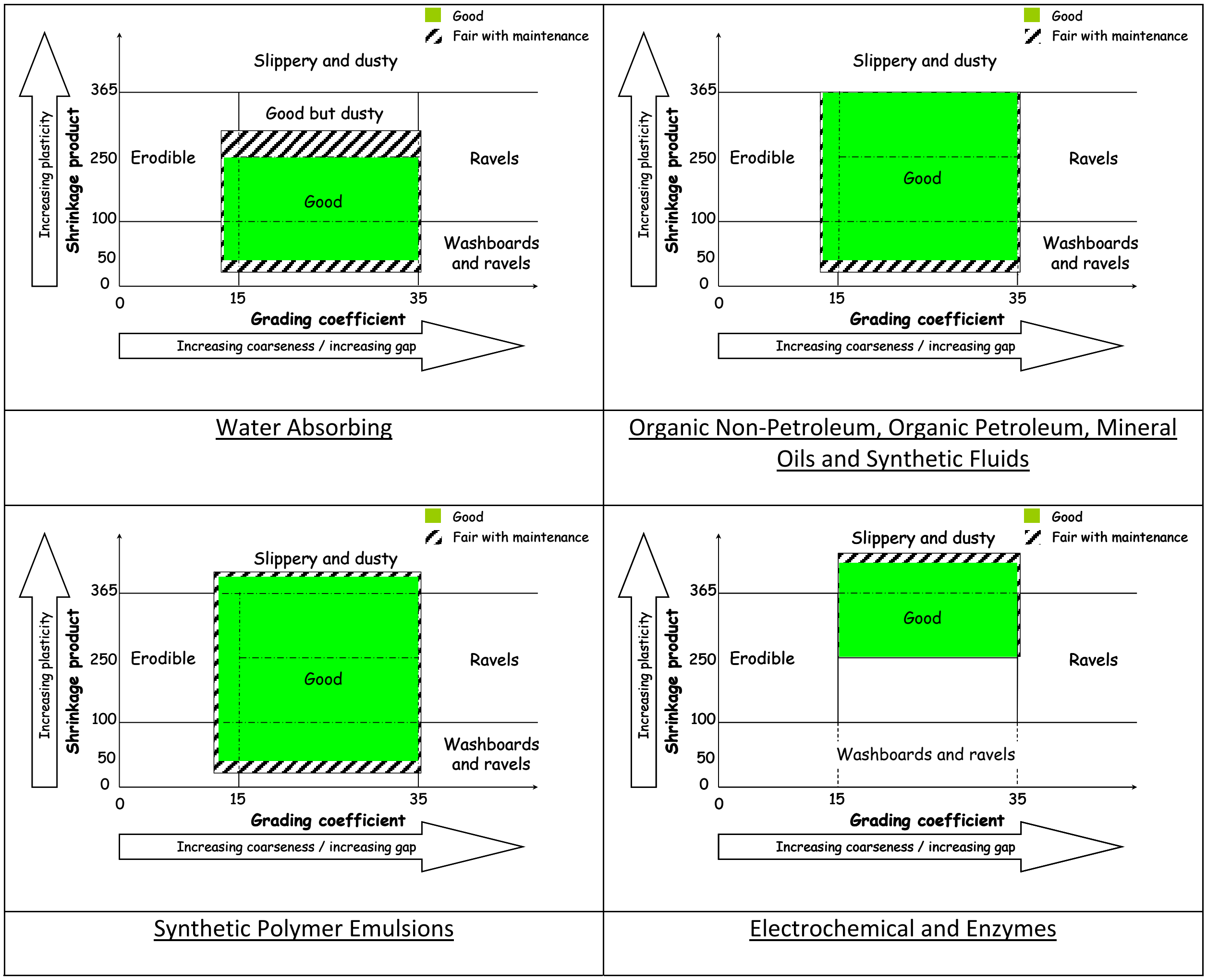

Figure 56. Chart. Additive selection guide linked to material performance.
(Adapted from Jones, 1999)

- Erodible materials: The problem with erodible materials is usually grading and/or drainage related, and consequently it is difficult to overcome with a chemical treatment. Non-water-soluble polymer emulsions or bituminous-based products can be tried on gentle to moderate slopes in combination with drainage improvements. Water-soluble products (for example, chlorides and plant-based polymers such as lignosulfonate) will reduce dust, but will not prevent erosion. Neither will sulfonated oils/ionic stabilizers or enzymes, as the clay content is usually insufficient for a reaction that will bind the particles satisfactorily to prevent the shear action of flowing water.
- Materials that corrugate and ravel: These materials lack fines and plasticity. Chemical treatments are generally ineffective if the shrinkage product is less than 50 because uneconomically high application rates are required to fill the voids between the particles. Wind- and tire-shear forces usually also exceed the binding ability of the treatments used under these circumstances, leading to continued problems. If the shrinkage product is above 50, a variety of chemical treatments can be used to improve the materials by enhancing binding, leading to significant reductions in dust and washboarding. Chlorides, plant-based polymers, synthetic fluids, synthetic polymer emulsions, mineral oils, resins,

and combinations of these products can all be considered. Sulfonated oils/ionic stabilizers and enzymes are generally unsuitable as there is insufficient clay to support a reaction. Incorporating fines, often readily available from adjacent land owners or waste piles at quarries, can be considered to raise the shrinkage product to 50, before applying an appropriate chemical.

- Materials that ravel: Chemical treatments are generally ineffective on these materials because of the coarse or gap grading. They will keep the dust down initially, but won't prevent the raveling. Some success may be achieved at very high application rates (that is, using the chemical to fill the voids before a satisfactory bond is obtained). Alternatively, the addition of the gap material can be considered to adjust the grading coefficient before treatment. Dust levels will increase as the material gets displaced to the side of the road.
- Slippery or impassable materials: Additives used on these materials need to either chemically alter the clay minerals to reduce the plasticity or "waterproof" the clay particles to prevent them from expanding/shearing when wet. Synthetic polymer emulsions, mineral oils, resins, sulfonated oils/ionic stabilizers and enzymes can be considered. Atterberg Limits and soaked CBR tests should be carried out to check that a suitable reduction in plasticity and sufficient increase in shear strength is achieved with the selected product before it is applied on the road. Chlorides and other water soluble products should not be considered to treat these materials.
- Good and good but dusty materials: Chemical treatments can be effectively used on roads with these materials to minimize dust and limit fines loss, reduce the rate of gravel loss, and increase the intervals between grader maintenance. Chlorides, plant-based polymers, synthetic fluids, synthetic polymer emulsions, mineral oils, resins, and combinations of these products can all be considered. Clay contents are typically too low for sulfonated oils and enzymes to work effectively.

EVALUATING NEW PRODUCTS

New dust palliatives and unpaved road stabilizers are continuously being introduced to the market. Some of these are combinations of existing additives that have been engineered to meet specific project requirements or to counter undesirable properties of certain additives. Examples include mixing magnesium chloride with lignosulfonates to reduce the chloride content of applications or mixing petroleum products with lignosulfonates to reduce leaching. New products are also being developed to meet specific soil stabilization or environmental requirements. Examples include specific synthetic polymer emulsions, mineral oils, and synthetic fluids. New industrial processes can also lead to the production of by-products that may have an application in unpaved road maintenance. Examples include the growing ethanol production in certain states, which produces organic non-petroleum by-products. Finally, existing additives are often "repackaged" under a new name to elicit renewed interest, or to counter the effects of bad publicity from unsuccessful applications.

A cooperative but restrained relationship should be maintained with product vendors and their product track records should be evaluated independently (for example, by searching the Internet for reviews and experiences). Vendors should be quizzed on product attributes (both existing products and new ones) and asked to provide evidence of scientific research (laboratory tests and monitored field experiments [Figure 57]) to support their claims. Example questions to ask the vendor include, but are not limited to:

Figure 57. Photo. Additive experiment.

- <u>About the product in general:</u>
  - Are construction specifications available? Are they generic, or targeted specifically to one vendor's product?
  - Why has the product been developed and what makes it better than other currently available additives? Is it new, or is it a repackaged currently available additive? Is it a blend of currently available products, and if yes, which product, if any, dominates?
  - How long has the product been available, how much has been sold and who uses it? How long have individual users been applying it? Phone other users to get an independent opinion about the product, performance limitations, and cost-effectiveness.
  - What is the target use of the product? Is it aimed at improving all-weather passability (that is, strength improvement and aggregate binding) or simply as a surface treatment to bind surface fines together and reduce dust?
  - Is a guideline document (not a glossy brochure) available to guide the user on how to make an informed decision about where to use the product, how to justify its use in terms of life-cycle cost, how to apply it, how to maintain it, and how to determine optimum rejuvenation intervals and rates?
  - What technical support is provided to road owners and managers?
- <u>About environmental compatibility/impact:</u>
  - What is the product composition and what are its properties? What generic category does it fit into? Check these in the MSDS and other technical guidelines that the supplier must provide.
  - What is the product's impact on the environment? Has independent environmental testing been carried out? Are there any environments where the additive should not be used? Ask for a copy of the environmental testing report.
  - What is the product's regulatory impact? Are there special storage, handling or reporting requirements if stored on site? Ask for any requirements needed to conform with the US EPA Spill Prevention, Control and Countermeasure Rule. Check that product distributors are aware of these requirements.
- <u>About the economics:</u>
  - How will this product help save time, money and resources? More specifically, what is the initial cost per mile, predicted longevity, number of applications per year? What can be expected regarding road life-cycle maintenance and regravelling costs? Ask for back-up data from experiments, not just an opinion.
- <u>About performance:</u>
  - Are warranties, performance guarantees, and/or "fit-for-service" certifications provided?
  - How are performance and effectiveness measured? What defines a success or a failure? What remedies are provided for failures?

  - Is the product expected to perform better than current products? For example, does it resist moisture, is it less slick, is it easier to maintain, does it give measurable improvement in strength (California Bearing Ratio), abrasion resistance, or rate of gravel loss? Does it have any limitations in terms of traffic, climate or soil chemistry? Again, ask for back-up data and check whether reasonable comparative testing has been carried out.
  - What type of aggregate properties does it work best on? How does it match up in terms of the discussion above on materials and what simple tests can be done to get an idea of how well it will work? Where does the product fit on the performance predictor chart (discussed earlier in this chapter) and what impact will the product have on washboarding, raveling, rutting, gravel loss, erosion and slipperiness? Check field performance data to verify this and never trust anyone who says their product will prevent potholes (because that's a road/shape drainage issue that no chemical treatment can solve!).
- <u>About application:</u>
  - How is the product applied for best performance? Should it be sprayed on as a topical application, or does it require to be mixed in? What are the implications of applying it as a spray-on treatment if a mix-in application is recommended?
  - What can be expected when the road needs to be bladed? Is there residual performance after blading or is a full or partial reapplication necessary? Is it easy or difficult to rework? Does the road require watering before blading? Check the duration of field trial evaluations and whether maintenance procedures are documented.
  - What changes in current practices are recommended for best performance with the new product?
- <u>About the stage of development of the product:</u>
  - Is the product still considered to be experimental? If yes at what stage of the development cycle is it and when will it no longer be considered experimental?
  - Is independent scientific testing focusing on quantifying performance in terms of reduced dust, reduced rate of gravel loss, improved passability, cost–benefit, etc?
  - Are applications in the foreseeable future part of this research and if yes, is there a benefit to the road owner?
  - If the test fails, will the vendor be willing to re-treat at no cost or provide an alternative product?
  - Who else has tested/is testing the material? Can testimonials from other customers be provided? What volumes of the product have been used?
  - Will there be vendor representation at the test application and will assistance be provided to monitor performance throughout the application life of the product?

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CHAPTER 6 – CONSTRUCTION AND ADDITIVE APPLICATION

INTRODUCTION

Preparing the road for a chemical treatment and the process followed when applying it are critical for successful performance. Different additives are applied in different ways, usually either sprayed directly onto the prepared road surface, or mixed in during regravelling or in a reworking of the surface. Spray-on applications are the most popular because they are the least expensive for initial application. However, rejuvenation frequencies are usually higher because of the limited penetration of some additives and consequently may work out to be more expensive than mix-in treatments in the longer term. Mix-in treatments are generally required if chemical treatments are being used to both reduce dust and improve all-weather passability, or as clay stabilizers, since the additive needs to be distributed through the top two inches (50 mm) of material for dust control additives and top four to six inches (100 mm to 150 mm) of material for clay stabilizers and/or improving all-weather passability. Some chlorides can be applied in pellet or flake form, which can be spread on the road surface.

THE PROBLEM

The preparation of roads before applying chemical treatments generally follows standard road construction procedures and uses standard road construction and maintenance equipment. However, standard practice is often overlooked or has been "forgotten," and consequently, sub-standard construction is accepted, which leads to less than satisfactory performance.

LEARNING POINTS FROM THE SCAN TOUR

Figure 58. Photo. Poor gravel selection for treated road.

Magnesium chloride was the additive of choice in many areas and most applications were simple spray-on treatments. However, the level of effort afforded to road preparation and knowledge of the consequences of inadequate preparation, inappropriate application procedures, and optimizing rejuvenation intervals varied across the locations visited. On roads where mix-in treatments were used, tighter control over construction could have resulted in better long-term performance. Key problems noted included selection of lower quality aggregate (Figure 58), insufficient crown and drainage, poor compaction, spraying additives onto dry surfaces, and spraying the full dose of additive in a single pass. Many equipment operators had learned their skills from others on the job and had consequently inherited inappropriate techniques with no understanding of the consequences. Most scan tour hosts used construction specifications based on those of the state road agency. The lack of specifications and comprehensive guidelines for selecting and applying additives was repeatedly identified as an unmet need.

RECOMMENDED APPROACH

As with materials, the performance of unpaved road chemical treatments is also influenced by how well the road is prepared before application and then how appropriately it is applied. The approach recommended in this handbook advocates following conventional road construction and additive application procedures, with adjustments and additional steps to suit the specific additive being used. Road managers are encouraged to request detailed road preparation and application guidelines from additive vendors. A number of key issues are introduced in this section of the handbook, including drainage, road shape, wearing course thickness, road geometry, application rates, and application techniques. Road managers are also encouraged to employ additional information and knowledge from readily available guidelines (for example, the FHWA *Gravel Roads – Maintenance and Design Manual*).

Prepare the Road Before Application

Spraying dust control treatments onto unprepared roads is a waste of time and money. The dust control effect will be short lived, ride quality will not be improved, and the road will soon require some form of maintenance, which will reduce the life of the treatment (Figure 59). Prior to any spray-on application, shape the road to ensure an adequate crown is present, and then blade to provide a quality driving surface. Open drainage ways and culverts to ensure that water can be channeled away from the road during rain events. If the chemical treatment is going to be applied as part of a regravelling activity, incorporate the additive into the compaction water and mix this in with the aggregate.

Figure 59. Photo. Chloride applied to poorly prepared road.

Drainage

Good drainage is imperative for optimal performance of unpaved roads, especially in terms of all-weather passability, reducing slipperiness and erosion, and preventing potholes. Drainage includes two components.

- First the water must drain off the road as quickly as possible without eroding the surface. This is a function of road shape and providing an adequate crown is very important. A target crown of 5 percent (± 1%) (Figure 60) assures that the road surface will shed rain. A crown of less than 4 percent can lead to water ponding on the road (Figure 61), which is dangerous for road users and will create soft spots, which will quickly turn into potholes. A crown of

Figure 60. Photo. Good crown (4 to 6%).

more than 6 percent will exacerbate erosion during runoff and may cause truck trailers to slip off the road (Figure 62). Crown requirements should be relaxed on steep grades and super-elevations to maintain safe driving conditions but still prevent water from running down the road. Water velocities should be kept to a minimum at all times. Target crowns must be maintained during all subsequent maintenance.

- Second, water should not be allowed to pond next to the road. This will lead to water ingress, material softening, and ultimately impassability (that is, vehicles will get stuck). Culverts, ditches, and miter drains need to be included in the road geometry to channel this water away, but practitioners must understand and manage where the water goes.

Figure 61. Photo. Too little crown (<4%).

Figure 62. Photo. Too much crown (>6%).

Shaping a Road Before Spray-On Applications

Never shape a road when it is dry as this will loosen up sections of crust, segregate the materials, break down softer aggregates, and invariably result in a thin "biscuit" layer on the surface (Figure 63), which will break down quickly and ravel to the side, leading to rapid loss of the new crown. Instead, spray the road surface with water to bring the top two inches (50 mm) to about near optimum moisture content. This can be determined either using a microwave oven on site and comparing the moisture contents to those determined in a laboratory, or simply by doing the "squeeze" test (that is, a handful of material, when squeezed in the hand should hold the shape of a ball without exuding water [too wet, leaving a sheen of water on the skin], or crumble [too dry] when released [see Figure 64]).

Figure 63. Photo. Effect of biscuit layer on treated surface.

Once the material is adequately moistened, use a motor grader equipped with a slope meter or electronic grade control to achieve/maintain the required crown (typically five percent). If available, compact the road with a rubber-tire roller, smooth drum steel roller (no vibration) or even a grader-mounted roller (Figure 65) to consolidate the material and seal the surface. The grader blade should have good, new, straight edges to avoid rounding the surface.

[a] [b] [c]

Figure 64. Photo. Squeeze test for assessing moisture content.
([a] too dry, [b] too wet, and [c] acceptable)

Material from the side drains should NOT be bladed onto the road since it is typically silt and will result in a dusty "biscuit" layer that will be displaced by traffic in a short time. Uniformity of depth of the surface material should be maintained.

A good, compacted crown will reduce the need for frequent reshaping and blading and will extend the life of a treated road.

Figure 65. Photo. Grader-mounted roller.

Understand Wearing Course Thickness Requirements

Applying chemical treatments to unpaved roads where the surface has worn away is a waste of time and money. This is because the fines content is typically either too low or too high (remember that the fines are the "glue" that holds a wearing course together), the aggregate grading is usually poor (that is, probably more suited to base material in a sealed road than to a wearing course in an unsealed road), the subgrade is often exposed, and the road surface is often level with or below the natural ground level, which leads to drainage problems. Also, always remember that dust palliatives and surface stabilizers will not make a bad road good—they should only be used to keep a good road good.

Consider importing a suitable roadway surfacing aggregate when dealing with worn surfaces. In the case of subgrade exposures, a new base and wearing course will need to be imported, while in the case of base exposures, only a new wearing course will be needed. Surface thickness of the wearing course will depend on a number of factors including available funds, height of the existing road above the natural ground level (Figure 66), and traffic volumes. A "thicker-the-better" approach is generally best because of the high labor and equipment costs associated with

Figure 66. Photo. Road below natural ground level.

construction, and the need to have sufficient material to work with during routine maintenance. At a minimum, the road structure (that is, gravel material covering the natural subgrade) should be at least 12 inches (300 mm) above natural ground level, and higher in high rainfall regions and areas with weak subgrade (that is, subgrade CBR is less than five or dynamic cone penetrometer [DCP] penetration is more than 32 mm/blow). The following simple formula can be used to calculate the minimum thickness of gravel required:

$$T = t + (1 + C_t / 100) \times (GL \times L)$$

Where: T = design thickness (in inches or mm)

t = minimum thickness required for subgrade protection (e.g., 12 in. [300 mm]). See FHWA *Gravel Roads Maintenance and Design Manual* for method to determine this thickness.

C_t = traffic induced compaction (percent) (up to 20 percent for poor compaction/ incorrect compaction moisture content)

GL = expected annual gravel loss

L = expected regravelling frequency (years)

Example (US units)	Example (metric)
$T = t + (1 + C_t / 100) \times (GL \times L)$	$T = t + (1 + C_t / 100) \times (GL \times L)$
T = 12 + (1 + 10 / 100) x (0.5 x 5)	T = 300 + (1 + 10 / 100) x (12.5 x 5)
T = 12 + (1.1 x 2.5)	T = 300 + (1.1 x 62.5)
T = 14.75, rounded up to <u>15 in.</u>	T = 369, rounded up to <u>370 mm</u>

If the existing gravel thickness is less than 75 percent of the design thickness, regravelling should be considered before using a chemical treatment. Wearing course materials should be at least 4 in. (100 mm) thick, but preferably at least 6 in. (150 mm) thick to ensure a good crown and to facilitate maintenance activities.

Road Geometry

Optimizing the road geometry is best considered during the design of new unpaved roads, but very few of these are being constructed at present. In most instances, very little can be done about improving the geometry of existing city, county, and state unpaved roads and roads on federal lands because of property ownership and/or environmental issues (for example removal of trees and rehabilitating the old roadway). However, small improvements where feasible and appropriate can have a positive impact on safety, road performance, and on reducing road management costs including the number of grader passes and the amount and frequency of regravelling.

In some instances, the width of very wide roads (usually caused over time by blading material from the sides of the road onto the crown [Figure 67]) can be reduced by reworking the shape and moving the side drains (consider re-vegetating the reclaimed areas). This will improve overall road

Figure 67. Photo. Very wide road.

shape, minimize the potential for pothole formation, and reduce maintenance requirements (number of grader passes required). Small changes can also be made to reduce the severity of sharp curves (Figure 68) by providing a super-elevation, and some widening of very narrow roads may be possible with land owner agreement. Improving a road surface by better material selection and use of a chemical treatment will invariably result in increased vehicle speeds and additional signs may be required to warn motorists of sub-standard geometry. Road managers should use every opportunity to improve road geometry where feasible to improve road safety and increase maintenance productivity. Maintenance issues are often related to poor geometry (for example, raveling on sharp curves, erosion on steep grades and super-elevations, water ponding in dips, etc.). Guidance on road geometry is available in the American Association of State Highway and Transportation Officials (AASHTO) *Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT ≤ 400)* and the FHWA/South Dakota LTAP *Gravel Roads Maintenance and Design Manual*. When using chemical treatments on wider roads or roads with shoulders, apply to the full width to prevent loose material from being sucked onto the treated surface by moving vehicles and because shoulders will occasionally be subjected to traffic and water flow (Figure 69).

Figure 68. Photo. Very sharp curve.

Figure 69. Photo. Untreated shoulder.

General Information about Applying Chemical Treatments

Additive applications at the end of the rain season are usually the most effective. Do not apply additives if rain, strong winds, or hot and dry conditions are imminent.

Safety and Environment

Prior to working on the roadway, insure that appropriate traffic control and safety devices are in place to inform the driver on what to expect ahead. These devices need to be installed in accordance with all of the agencies requirements, which may include the *Manual of Uniform Traffic Control (MUTCD) requirements for Workzone Traffic Control*.

Take appropriate safety precautions during application based on the recommendations in the vendor’s guidance document and in the Material Safety Data Sheet (MSDS). Take care to ensure that the application is restricted to the road surface and that there is no runoff. Any chemical ending up off of the traveled way, in drains or on roadside vegetation is a reduction in both the application rate and potential effectiveness of the program and could have undesirable impacts on vegetation and surface water.

Road Closures

Always follow the supplier's recommendations for applying the chemical treatment. Some treatments (e.g., synthetic polymer emulsions, organic petroleums and petroleum resins) may require a road closure while the product is applied and for the duration of curing (typically 15 minutes to two hours). Even when not required by the supplier, where possible, ask the road users to wait at the start of the section until spraying is complete. This will limit unsafe driving conditions and reduce product adhering to vehicles.

Application Rates

Application rates depend on a number of factors including whether it is an initial application or a periodic rejuvenation, material properties, traffic volume and speeds, and climate. Always follow the supplier's recommendations. Avoid dilution of the products themselves beyond the manufacturer's recommended values since excessively diluted applications will not survive or remain in service as well or as long, will be subject to more rapid degradation (Figure 70) and runoff during rainfall events and, even when freshly applied, may not control fines or dust effectively when compared to the recommended dilution.

Figure 70. Photo. Insufficient additive application.

In some cases, a residual build-up of the product in the roadway will provide an opportunity to reduce the reapplication rates and still restore the road to its original full first-application performance. The product supplier should have researched application rates in detail and should provide guidance in the form of charts along with the chemical. If they cannot, it means that the road manager will be doing research on their behalf and consequently any performance claims that the supplier has made should be considered with care. No recommendations on specific products' application rates are made in this handbook.

Spray-on Applications

For spray-on applications, always follow the supplier's recommendations, but consider the following:

- First dampen the road surface (typically considered as the top 2 in. [50 mm]) with water to assist penetration of the additive. Applying treatments to dry roads results in a concentration at the surface, which will be quickly removed by traffic (see Figures 71 and 72 for the different results seen between no pre-wetting and pre-wetting). Avoid over-watering as this may lead to ponding and/or runoff. Lightly scarifying the road at the same time also helps the additive to penetrate.

Figure 71. Photo. Poor penetration without pre-wetting.

Figure 72. Photo. Penetration with pre-wetting.

- Most chemicals are best applied in a series of applications (typically three) rather than in a single shot. Allow a sufficient amount of time between applications to promote penetration to an appropriate depth and even distribution through the material. Avoid over-spraying to ensure that the product does not puddle or run-off and is not picked up by vehicle tires (additive adhering to a vehicle is additive that is lost for controlling dust) (Figure 73). Dividing the application over more than three applications should be considered on heavier trafficked roads (for example haul roads) or roads with high fines (that is silt and clay) contents. Be cautious on sandy materials to avoid penetration that is too deep. On mine haul roads, where constant deposition of dust from the air and from trucks is common, frequent (weekly, fortnightly or monthly depending on traffic and operating conditions) very light applications are usually required to maintain satisfactory dust control.

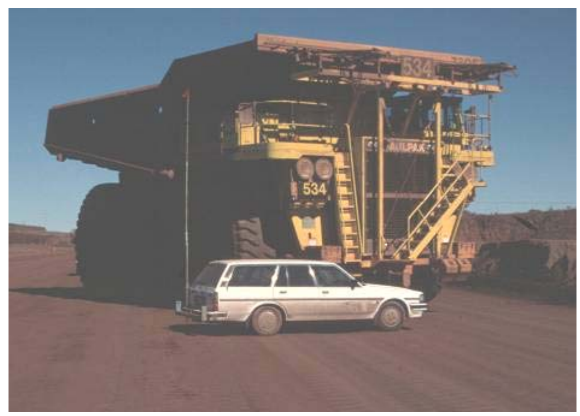

Figure 73. Photo. Additive stuck to vehicle.

Figure 74. Photo. Follow-up rejuvenation applications.

- If feasible, split the initial application over a longer period, with the initial application as described above and then a final light application (approximately 15 to 20 percent of the total application rate) approximately two to three weeks after the first application (Figure 74). This allows the initial application to penetrate and uniformly treat the layer, with the follow-up application treating lean areas and providing a new seal after any early traffic disturbances that have occurred while the road was drying out/curing. Slippery conditions are often also reduced if this approach is followed. The road surface must be dampened before each application.

- Use a tanker with a calibrated, pump-driven spray bar to apply the chemical. Avoid gravity fed bars as the distribution is too uneven leading to areas of over- and under-application. Application rates can be checked by leaving a pan in the road and measuring the product depth/volume after each distribution pass.
- Compact the road after the final application, preferably with a smooth drum steel roller (no vibration) followed by a rubber-tired roller to seal the surface and limit traffic compaction and wheel tracks that can become permanent if a crust forms.
- For chloride applications in dry areas, occasional light applications of water may be required during periods of low humidity to keep the product in the upper layer of the road and prevent dusting and raveling on the surface.
- Follow the supplier's recommendations for traffic closures and curing of the product.

Applications of Flake- or Pellet-Form Chlorides

Calcium and magnesium chloride can also be applied in flake or pellet form (Figure 75). These can either be dissolved in a water tanker and sprayed on to the road as discussed above. Beware that this is an exothermic reaction and significant and possibly dangerous temperatures may be reached depending on the dilution ratio. Alternatively, they can simply be spread onto the road surface. Always follow the manufacturer's recommendations, but consider the following for applications by spreading:

Figure 75. Photo. Flake application of calcium chloride.

- Spray the road surface with water until the top one inch (25 mm) is moist (not wet – use the squeeze test to decide).
- Prepare the road surface appropriately and lightly scarify the surface to promote penetration.
- Spread the flake or pellet at the design rate, checking with a tray to ensure that there is no under- or over-application. Over-application will usually lead to slippery and even impassable conditions.
- Depending on humidity levels, spray another light application of water to speed up flake dissolving and to promote penetration. Do not overwater as this can lead to runoff or over-penetration.
- Restrict vehicles from driving on the road until the flakes or pellets have dissolved.
- Follow-up light applications of water may be required to distribute the additive through the upper layer of material. Do not overwater.

Mix-in Applications

A mix-in process will typically provide effective dust abatement and/or gravel retention for longer periods than spray-on applications. The additional costs incurred during construction will usually be offset by extended rejuvenation intervals, by improved performance, and by less frequent road maintenance. Mixing depths will depend on the type of chemical treatment being used and the purpose of the treatment. For dust control treatments, mixing depth is typically one to two inches (25 mm to 50 mm). For soil stabilization treatments, mixing depth is typically four to six inches (100 mm to 150 mm) depending on the thickness of the layer, the type of additive used, truck traffic, and the purpose of the application. Clay stabilization and applications to improve all-weather passability on roads with high volumes of truck traffic are usually deeper.

For mix-in treatments, consider the following:

- Use a recycler to apply the product, with the additive pumped through the recycler's mixing chamber (Figures 76 and 77). The costs of using this equipment are usually offset by the speed, accuracy and efficiency of the process compared to a rip-and-recompact operation using a grader. Strictly control the mixing depth to ensure that the correct application rate is adhered to (deeper than planned mixing equates to lower than designed application rates).
- If a recycler is not available, rip the road surface to the required depth with a grader (Figure 78). Break down large cohesive lumps of material and remove large stones (> 3.0 in. [75 mm]).
- Dilute the product to an appropriate level in the water that will be applied to bring the roadway material up to its optimum moisture content (also known as compaction water.) This is sprayed onto the ripped material (Figure 79) in a series of applications and mixed with the grader, disc plough or other mixer. On completion of the application, the moisture content should be as close as possible to the optimum moisture content (note that the existing material moisture content needs to be determined prior to application and factored into the amount of fluid that is applied). If too low, spray a little more water to raise the moisture content to the required level. Check moisture contents using the "squeeze" test described earlier.
- Compact the road with a smooth drum or a rubber-tired roller (Figure 80) until refusal density (that is, density checks with a nuclear gauge or similar device after each roller pass reveal no further increases) is

Figure 76. Photo. Equipment-mounted recycler.

Figure 77. Photo. Full-depth recycler.

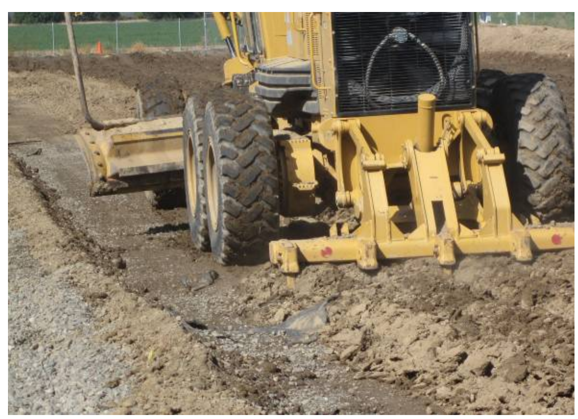

Figure 78. Photo. Ripping with a grader.

achieved rather than just aiming for a percentage of a laboratory determined density. Avoid aggregate breakdown through over-compaction. Remember that higher density results in higher bearing strengths, slower rate of gravel loss and greater resistance to road shape degradation, rutting, potholes, and moisture ingress.

- Apply a final light application of product (about 25 percent of the total application rate) to seal the surface (Figure 81). Avoid pooling or run-off of the product.

It's worth repeating that compaction is key to getting a tight road surface of the proper shape that will shed water and resist traffic loads. If the procedures above cannot be followed, or if the recommended equipment is not available, expect reduced performance of the product. It's always a good idea to close the road to traffic until the final application has penetrated into the road surface to prevent vehicles from picking up the additive.

Figure 79. Photo. Spraying the additive.

Figure 80. Photo. Compaction with rubber-tired roller.

Figure 81. Photo. Completed road.

Adding New Gravel

If new gravel is imported as part of the chemical treatment program, care must be taken to ensure that it meets the required specification (see discussion in Chapter 5) and that it is placed to the best possible construction standard. Detailed guidance on construction is beyond the scope of this handbook, but key processes include:

- Scarify or tine the existing surface to a depth of one to two inches (25-50 mm) to ensure a good bond between the old and new surface.
- Spread the new material evenly to achieve a consistent thickness, ensuring that there is no segregation of the fine and coarse aggregates.
- Dilute the chemical treatment into the compaction water and use this to raise the moisture content to optimum.
- Mix the material thoroughly and uniformly throughout the total stabilization depth using a recycler, rotivator, disc plough or grader.
- Properly shape and compact the road.
- Apply a final light application of product (about 25 percent of the application rate) to seal the surface. Avoid pooling or run-off of the product.

I'VE GOT A GOOD ROAD, NOW WHAT?

To protect your investment and record the improvements, it makes sense to conduct periodic drive-by inspections to evaluate the short-term and long-term effectiveness of the applications. After the application has cured, observe how the road surfaces respond to traffic and survey road users and adjacent land owners. Determine acceptable levels of dust reduction (an 80 to 90 percent reduction in dust levels compared to those on an untreated road will satisfy most road users and is often much cheaper than trying to achieve 100 percent dust control). Figure 82 through Figure 85 provide a guide for evaluating the effectiveness of dust control treatments.

Figure 82. Photo. No dust.
(1 on a scale of 1-5).

Figure 83. Photo. Acceptable level of dust.
(2 on a scale of 1-5).

Figure 84. Photo. Average level of dust.
(3 on a scale of 1-5).

Figure 85. Photo. Unacceptable level of dust.
(5 on scale of 1-5).

Use photographs from your roads to refine the evaluation process. Make arrangements to evaluate dust levels, gravel loss (using a dynamic cone penetrometer [Figure 86], by digging holes to measure layer thickness [Figure 87], or measuring stone protrusion [Figure 88], assuming that the tops of stones were level with the road surface after construction), shape retention (using a level, Figure 89), and ride quality.

Figure 86. Photo. Checking layer depths with dynamic cone penetrometer.

Figure 87. Photo. Checking gravel thickness.

Figure 88. Photo. Estimating gravel loss from stone protrusion.

Figure 89. Photo. Checking crown with a simple level.

Document your observations on an appropriate form (examples in Appendix B, visual assessment guideline available in Reference No 8) for easy reference at a later date and keep a photographic record of before and after images (Figures 90 and 91) as a reminder of the level of improvement. This information will help determine if the treatment method and application rate are appropriate to meet the intended dust control objective and whether the exercise will result in program savings. Consider doing rejuvenations before dust levels are unacceptable as application rates will be much lower compared to later full-dose applications that will be needed. Most products will build up a residual level over time and application rates will be reduced and rejuvenation intervals will increase over time, thereby reducing annual maintenance costs. Use this information to prove to your Managers/ Supervisors/Employers/ Governing Boards/ Commissioners and road users that the dust control program is cost effective.

Figure 90. Photo. Road before treatment.

Figure 91. Photo. Road after treatment.

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CHAPTER 7 – ENVIRONMENTAL CONSIDERATIONS

INTRODUCTION

When practitioners think about dust control and soil stabilization for unpaved roads, concern about environmental issues is often overshadowed by the practical need for useful and cost-effective solutions. However, like any product intentionally introduced into the environment, dust palliatives and soil stabilizers have the potential to negatively affect natural resources and public health. There is a trade-off between water and air quality when constructing unpaved roads, with or without dust suppressants. Environmental considerations must be central to any unpaved road management program for many reasons, but most importantly because practitioners have *a responsibility to the public*. This responsibility includes maintaining safe, drivable roads while safeguarding human health and protecting the quality of the air, soil, water, vegetation and wildlife near the roadway (Figure 92). Practitioners also have a legal responsibility to comply with environmental regulations—both those prompting dust control programs in the first place (for example, the Environmental Protection Agency's $PM_{2.5}$ and PM_{10} air pollution standards) and those that address the effects of carrying out road maintenance activities (for example, Section 303(d) of the Clean Water Act and associated Total Maximum Daily Load limits). By adopting approaches to minimize environmental impacts at the initiation of a project, practitioners not only reduce the likelihood of regulatory actions, but also improve public perception of their programs and minimize citizen complaints.

Figure 92. Photo. Road near lake.

THE PROBLEM

Estimating the environmental impacts of applying dust palliatives is complex and difficult. Much of this difficulty is attributable to three main issues:

- Lack of product information and usefulness/consistency of the information provided in Material Safety Data Sheets (MSDS)
- Lack of guidance on which environmental impacts to monitor, and how to do so, and
- The difficulty of balancing negative impacts of applying a chemical treatment (potential for damage to flora, fauna, and surface or ground water) with the positive impacts of applying a chemical treatment (improved road safety, reduced gravel loss and reduced maintenance requirements), while keeping in mind the potential costs of a "do nothing" approach.

LEARNING POINTS FROM THE SCAN TOUR

Road manager concerns with regard to the potential environmental impacts of using chemical treatments differed across the locations visited. All road managers were aware of the debate on the potential impacts of chlorides on the environment, but were concerned that no similarly priced alternative appeared to be available that would provide the same level of service and have no significant potential environmental impacts of its own. Most road managers were concerned about the lack of consistency in MSDSs, specifically the quality and variation of environmental information among manufacturers. Although no environmental testing was undertaken during the scan tour, no visible negative environmental impacts were observed, apart from some leaf discoloration on a thistle growing in a side drain that had an accumulation of fine material eroded from the wearing course (Figure 93). No similar observations were made on any of the other roads visited, including those where magnesium chloride had been rejuvenated on an annual basis for up to the past 22 years (Figure 94). One of the product developers visited was placing considerable focus on trying to develop new products, testing blends of magnesium chloride with other types of additive to reduce the introduction of chlorides into the environment, and engineering new products for specific site conditions (that is material type and characteristics, climate, and traffic) (Figure 95).

Figure 93. Photo. Concentrated chloride in side drain.

Figure 94. Photo. Road with regular annual magnesium chloride applications.

Figure 95. Photo. Engineered dust control treatment.

RECOMMENDED APPROACH

Collect Product Information

One of the first steps to improving knowledge of environmental impacts of unpaved road chemical treatment is improving knowledge about the products themselves. A lack of product information begins at the most basic level—the manufacturing process—and is because of two main reasons:

- Many dust palliatives are recycled from the waste streams of other industries and the exact product composition is often not well-documented. Depending on the process, the level of batch-to-batch variability can be significant.
- Chemical composition is often considered proprietary and not available to the end-user.

Do the following to overcome these issues:

- Ask vendors for detailed MSDSs covering both worker safety issues and potential environmental impacts, as well as verification of product composition and consistency. In some cases, a non-disclosure agreement (NDA) may be necessary. Do not consider the product if the vendor is unwilling to or cannot provide this information.
- Ask for any requirements needed to conform with the US EPA Spill Prevention, Control and Countermeasure Rule. Check that product distributors are aware of these requirements and adhere to them.
- Be wary of vendors who claim that chlorides have serious negative environmental impacts, but at the same time cannot provide adequate proof that their product is environmentally "safe".

Perform Environmental Testing

A second step is to ask for test results from an independent laboratory showing that the product will not have any significant potential safety or environmental impacts to crews, road users, fauna, flora, surface and ground water quality, or to aquatic organisms. Environmental tests should include chemical composition to verify if a formulation contains hazardous substances or heavy metals that may leach into surface or ground water, and tests to assess any potential negative impacts to aquatic organisms (typically fish and water flea [Figure 96]) and to roadside vegetation. Suggested environmental tests are provided in Table 5. Also be aware that “inactive ingredients” and additives such as surfactants can also create environmental risks. For example, the addition of a surfactant can dramatically change both the toxicity of a bio-based oil product and its movement in the environment. Again, the product should not be considered if the vendor is unwilling to or cannot provide this information.

Figure 96. Photo. Environmental Testing.

Table 5. Recommended Environmental Tests for Unpaved Road Additives.

Test	Method number
Volatile Organic Compounds (VOC)	EPA 8260
Semi-volatile Organic Compounds (Semi-VOC)	EPA 8270
Heavy metals	Various methods
Modified Synthetic Precipitation Leaching Procedure (SPLP)	EPA 1312
Acute toxicity tests with fish, macro-invertebrates and amphibians	ASTM E729
Three-brood, renewal toxicity tests with *Ceriodaphnia dubia*	ASTM E1295

It is also important to know what happens to a product after it is introduced into roadside ecosystems. Although dust palliatives are designed to bind to road materials, products can and do enter the environment through several pathways. During initial application, products can be over-sprayed onto adjacent roadside habitats, or be washed away if rain occurs before curing is complete. After curing, products bound to soil particles can still be washed or blown away. How and at what rate products enter and move through ecosystems will differ between different products and in different environments. A basic understanding of the chemistry of the product (for example, water solubility, molecular size, and chemical composition) and the mechanism of action will provide clues as to the potential migration pathways of the product. Information is also needed on how products weather and break down once exposed to rain, UV-radiation, and temperature fluctuations. Products in the original and weathered forms may have the potential to be picked up by organisms and then be transferred throughout the food chain, although almost no research has been done on understanding and quantifying this issue. Given the lack of data, the best strategy is to minimize opportunities for the product to enter the environment in the first place through a combination of wise product selection and responsible application (Figure 97).

Figure 97. Photo. Road preparation to minimize environmental impact.

Monitor Impacts

Another critical environmental knowledge gap involves uncertainty about which environmental impacts are the most important to consider. Very little well-documented, long-term scientific monitoring of the impacts of dust control and road stabilization exists anywhere in the world. Therefore, in addition to working with accredited environmental testing laboratories, practitioners should undertake some monitoring of their own (Figure 98) until more formalized and representative environmental testing procedures

Figure 98. Photo. Monitoring roadside vegetation.

are developed and adopted. The final chapter of this Handbook notes that the U.S. Geological Survey is performing work on this issue. Environmental performance monitoring is complicated by variability both in product composition and geography. Different types of products (for example, chloride- versus hydrocarbon-based) will have different impacts on the environment, while concerns in arid habitats in the southwestern United States will be very different from those for a forested, stream-rich habitat in the northwest. Despite this variability, however, a basic list of impacts to be on the lookout for is provided in Figure 99. It requires being observant, noticing changes, and basically keeping your eyes open. Also provided is a list of 10 things that practitioners can do to strive for environmental excellence, despite not knowing all the answers (Figure 100).

BE ON THE LOOKOUT FOR THESE IMPACT INDICATORS

- Yellowing, browning or wilting of leaves or needles
- Unexplained loss of leaves or needles
- Presence of product residue or treated dust on leaves/needles, fence posts or mailboxes
- Abnormal corrosion of equipment, signs or other roadside structures
- Patches of bare ground—where vegetation might once have been—with obvious product presence
- Visual evidence that a product or treated material is moving from the roadway
- Treated road material accumulating in ditches or at culvert outlets
- Change in appearance or odor of water near roadway
- Presence of dead, dying, or abnormally behaving aquatic organisms
- Wildlife attracted to components of product (e.g., deer attracted to salt-based treatments)

Figure 99. List. Visual signs of environmental impacts from chemical treatments.

Balancing Negative and Positive Impacts of Dust Control Programs

Balancing the negative and positive impacts of dust control programs is a difficult undertaking, given our incomplete understanding of the potential negative impacts of different products. Road managers should also remember that a "do nothing" approach may also have significant negative environmental impacts (for example, increased loss of fines and aggregate into roadside habitats). Until such time as this issue has been adequately researched and documented, it is suggested that practitioners and road managers request the results of the independent laboratory environmental tests discussed above, determine what actions can be taken to minimize the impacts (for example, understanding material properties and determining appropriate application rate, mixing in as opposed to applying as a surface treatment, compacting the road, not applying close to environmentally sensitive sites, etc.) and then weigh any potential negative impacts against the benefits of improved road safety, improved health and living conditions, reduced airborne particulate matter, reduced particulate matter in streams, reduced gravel replacement and reduced maintenance. Depending on the type of additive used, mitigated negative impacts can often be tolerated in the light of the positive impacts of treatment in all but the most sensitive locations.

TEN DO'S – AND THE REASONS WHY

1. Build the road right
A well-built road requires less maintenance, less product, and is less likely to lose fine material and the palliative products bound to that material. Thus, it is less likely to create environmental problems.

2. Choose an appropriate product
Selecting a product that is appropriate for your climate and material, type and characteristics will maximize effectiveness of the treatment, as well as minimize product leaching from the road surface. Make sure that the vendor can provide a detailed MSDS, results of environmental tests from an independent laboratory, documented proof that the additive performs as claimed, details on what materials and under what conditions it should be used, and details on how to apply, maintain and rejuvenate the product.

3. Do a walk-through prior to application
Identify any potentially sensitive areas (for example, stream crossings, roadside wetlands, unique habitats). Think beyond the sides of the road. Take photographs of how the vegetation looks before application.

4. Apply the product responsibly
Apply at the recommended rate and use appropriate precautions (for example, when applying, use windrows or berms near sensitive areas to limit runoff, and do not apply over bridges or cattle guards). Apply during dry weather conditions to minimize runoff of any uncured or unbound product. Be careful not to apply more product than is needed. Shape and compact the surface appropriately.

5. Clean up responsibly
Spills or discharges of products have the greatest potential for toxic environmental effects. Do not empty or wash application equipment near water bodies or storm drains. Always have an emergency spill plan and materials to absorb spills.

6. Do a post-application walk-through
Evaluate the application and document any issues (for example, note any overspray on roadside vegetation or runoff of excess product).

7. Reseed or revegetate buffers
Plantings will help stabilize soil and create a line of defense between the road and adjacent habitat. Be sure to plant species that are native to the area!

8. Be aware of any signs of negative effects
These include leaf burn or discoloration, animals licking the road, product residues in drains, on stream banks or on rocks in streams. Early detection is key to minimizing overall impacts.

9. Optimize your maintenance program
Doing so will ensure you've done everything you could to keep costs (monetary and ecological) down.

10. Monitor performance
Following application, visit the site periodically and document any indications of potential environmental impacts.

Maintaining such records is extremely useful for this growing body of knowledge. If you are systematic about it, such data can be good supporting evidence for the products you choose to use or not use.

Figure 100. List. Ten actions to minimize environmental impacts.

CHAPTER 8 – ONGOING EFFORTS

THE ROAD DUST INSTITUTE

The Road Dust Institute (RDI) is an association (Figure 101) dedicated to improving road dust management in rural areas by collecting, storing and distributing information, discussing challenges and needs, and conducting research related to road dust, its consequences and its control. The RDI is now in the formative stage, but its website (www.roaddustinstitute.org) already provides information related to road dust and its treatment, and will soon engage the road dust abatement community as a whole.

The RDI seeks to advance the state of the practice by promoting research and technology transfer to improve unpaved road performance while reducing fines loss and minimizing environmental impacts. All of this will ultimately help reduce the cost of maintaining the national unpaved road network and reduce the environmental impacts (air, water and biological) associated with dust and fines loss.

ROAD DUST INSTITUTE PARTNERS

Federal Highway Administration – Federal Lands Highway Division
Western Transportation Institute at Montana State University
University of California – Davis (UC Pavement Research Center)
University of Nevada – Las Vegas
University of Alaska – Fairbanks

Figure 101. List. Organizations that formed the Road Dust Institute in 2010.

CURRENT RESEARCH

Significant gaps still exist in our understanding of the environmental impacts of dust control additives and surface stabilizers, but several studies have attempted to find some answers. Examples include:

- An EPA-sponsored expert panel in Las Vegas in 2002 identified data needs and a path forward for assessing the environmental impacts, and the subsequent report summarized existing knowledge of impacts for several dust palliative categories (EPA 2004).
- Steevens et al. (2007) provided a summary of the properties and potential environmental exposure pathways for six new commercial dust palliatives of interest to the military. This report also included a freshwater toxicity comparison of these newer products with older, petroleum-based stabilizers.
- Irwin et al. (2008) undertook work for the Environmental Protection Agency, providing a summary of the research to assess the impacts of six different chemical treatments on water quality and aquatic life relative to use of water alone.
- A current study by the U.S. Geological Survey (funded through the Federal Lands Highway Refuge Roads Program) is comparing the freshwater toxicity of more than 15 dust palliatives, in both the original (as shipped) form, and a weathered form exposed to ultra violet radiation. This study also includes testing on a variety of aquatic and

terrestrial organisms, including several plants. Field applications of selected products and monitoring of roadside habitats are underway at a National Wildlife Refuge in Texas, and additional field sites are being considered.

There is still the need for guidance on weighing the impacts of dust, gravel loss, frequent maintenance, hazardous driving, etc., against the impacts of the additives. It's always a question of how do we choose the right balance?

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APPENDIX A – DUST SCAN STEERING COMMITTEE

Last Name	First Name	Agency	Title
STEERING TEAM			
Albert	Steve	Western Transportation Institute - Montana State University	Director
Armstrong	Amit	Federal Highway Administration - Western Federal Lands Highway Division	Technology Deployment Engineer
Barnes	David	University of Alaska - Fairbanks	Civil Engineering Department Head
Bolander[(1) (2)]	Peter	USDA Forest Service	Geotechnical/Pavement Engineer
Drewes[(1) (2)]	Bruce	Idaho Technology Transfer Center	Center Manager
Duran[(2)]	Matt	EnviroTech Services, Inc.	Vice President of Sales and Marketing
Fay[(2)]	Laura	Western Transportation Institute - Montana State University	Research Scientist
Finger	Susan	US Geological Survey	Program Coordinator
Huntington[(2)]	George	Wyoming Technology Transfer Center - University of Wyoming	Senior Engineer/Transportation Training Coordinator
James[(2)]	David	University of Nevada - Las Vegas	Associate Vice Provost for Academic Programs
Jones[(1) (3)]	David	University of California Pavement Research Center - Davis	Associate Director/Principal Investigator/Research Engineer
Little[(1)]	Ed	US Geological Survey	Branch Chief
Main	Melvin	Midwest Industrial Supply, Inc.	Technical Support
Milne[(2)]	Clark	Alaska Department of Transportation and Public Facilities	Northern Region Maintenance Engineer
Nahra[(1) (2)]	Mark	Woodbury County, Iowa	County Engineer
Ramos-Reyes	Isabel	Federal Highway Administration - Eastern Federal Lands Highway Division	Technology/Safety Engineer
Rushing	John	U.S. Army Engineer Research and Development Center	Research Civil Engineer
Skorseth	Ken	South Dakota Local Technical Assistance Program - SD State University	Field Services Manager
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Vitale[(1) (2)]	Bob	Midwest Industrial Supply, Inc.	CEO Markets Manager
Williams[(1) (4)]	Bethany	US Geological Survey	Biologist
Yamada	Alan	US Forest Service	Civil Engineer
Coordination & Logistics			
Kociolek[(1) (2)]	Angela	Western Transportation Institute - Montana State University	Coordinator/Research Scientist
Scott[(1) (2)]	Andrew	Western Transportation Institute - Montana State University	Editor/Driver
Ulberg	Traci	Meetings Northwest, LLC	Logistics Support

(1) Traveled on the Scan (2) Co-Author of this Handbook
(3) Lead Author of this Handbook (4) Co-Author of the Handbook (Chapter 7)

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APPENDIX B – SCAN TOUR ASSESSMENT FORMS

UNSEALED ROAD ASSESSMENT FORM - UNTREATED										
Evaluator							Date			
Road No			Section							
Start km			End km							
Segment No				Start km			End km			
Photos	1		2	3		4	5		6	
Construction records?	Yes		No	Construction costs?			Yes		No	
Maintenance records?	Yes		No	Maintenance costs?			Yes		No	
Traffic information?	Yes		No							
General performance	1	2	3	4	5	Moisture	Wet		Dry	
Gravel quantity	1	Plenty	2	Sufficient	3	Isolated exposures	4	Extensive exposures	5	None
Gravel quality	1	Very good	2	Good	3	Average	4	Poor	5	Very poor
Influencing factors		Clay		Sand		Gravel/stones				
Road profile/shape	1	Very good (4%)	2	Good (2%)	3	Flat	4	Uneven	5	Very uneven
Drainage from the road	1	Well above ground	2	Slightly above	3	Level with ground	4	Slightly below	5	Canal
Riding quality/safety	1	Very good (>100 km/h)	2	Good (100 km/h)	3	Average (80 km/h)	4	Poor (60 km/h)	5	Very poor (40 km/h)
Influencing factors	Corrugation		Loose material	Stoniness		Potholes	Ruts		Erosion	
Dust	1	None	2	No visibility loss	3	Some visibility loss	4	Major visibility loss	5	Dangerous visibility loss
Slipperiness	1	Acceptable	5	Unacceptable	Passability		1	Acceptable	5	Unacceptable
Isolated problems	Potholes		Subgrade exposure	Transverse erosion		Longitudinal erosion	Rough area		Slipperiness	
Maintenance action	Local repairs		Routine blading	Heavy blading		Regravelling	Reshaping		Drains	
Notes										
Inventory check										
Material	Basic Crystalline		Acid Crystalline	High silica		Arenaceous	Argillaceous		Diamictite	
	Metaliferous		Carbonate	Pedocrete		Fer	Cal	Gyp	Sil	Transported
Road width	<8 m		8-10 m	>10m	Road type		Gravel	Earth		Treated

Visual assessment form used on Scan to assess untreated road sections. (Developed by David Jones).

UNSEALED ROAD ASSESSMENT FORM – TREATED/STABILIZED							
Evaluator					Date		
Road No		Section					
Start km		End km		Additive			
Segment No			Start km		End km		
Photos	1	2	3	4	5	6	
Construction records?	Yes	No	Construction costs?	Yes	No		
Application records?	Yes	No	Application costs?	Yes	No		
Rejuvenation records?	Yes	No	Rejuvenation costs?	Yes	No		
Maintenance records?	Yes	No	Maintenance costs?	Yes	No		
Traffic information?	Yes	No	Additive selection info?	Yes	No		
General performance	1	2	3	4	5	Moisture	Wet / Dry
Gravel quantity	1 Plenty	2 Sufficient	3 Isolated exposures	4 Extensive exposures	5 None		
Gravel quality	1 Very good	2 Good	3 Average	4 Poor	5 Very poor		
Influencing factors	Clay	Sand	Gravel/stones				
Road profile/shape	1 Very good (4%)	2 Good (2%)	3 Flat	4 Uneven	5 Very uneven		
Drainage from the road	1 Well above ground	2 Slightly above	3 Level with ground	4 Slightly below	5 Canal		
Riding quality/safety	1 Very good (>100 km/h)	2 Good (100 km/h)	3 Average (80 km/h)	4 Poor (60 km/h)	5 Very poor (40 km/h)		
Influencing factors	Corrugation	Loose material	Stoniness	Potholes	Ruts	Erosion	
Dust control	1 None	2 No visibility loss	3 Some visibility loss	4 Major visibility loss	5 Dangerous visibility loss		
Slipperiness	1 Acceptable	5 Unacceptable	Passability	1 Acceptable	5 Unacceptable		
Isolated problems	Potholes	Subgrade exposure	Transverse erosion	Longitudinal erosion	Rough area	Slipperiness	
Maintenance action	Local repairs	Routine blading	Heavy blading	Regravelling	Reshaping	Drains	
Additive action	None	Water spray	Light rejuvenation	Full rejuvenation	New spray application	New mix-in application	
Notes							
Inventory check							
Material	Basic Crystalline	Acid Crystalline	High silica	Arenaceous	Argillaceous	Diamictite	
	Metaliferous	Carbonate	Pedocrete	Fer / Cal	Gyp / Sil	Transported	
Road width	<8 m	8-10 m	>10m	Road type	Gravel	Earth	Treated

Visual assessment form used on Scan to assess treated road sections. (Developed by David Jones).

APPENDIX C – EXAMPLE COUNTY ROAD BUDGET PROPOSAL

WOODBURY COUNTY, IOWA UNPAVED ROAD MAINTENANCE PRACTICE, COST ANALYSIS, AND BUDGET REQUEST

This spreadsheet was prepared as an example of an unpaved road maintenance program. It includes a worksheet for calculating the cost of alternative road maintenance strategies.

In Iowa, granular surfaced roads have either gravel or crushed limestone for surfacing material. Other crushed rock or recycled products can be substituted for these aggregates provided they have an appropriate grading of coarse to fine material.

Standard county practice for maintenance of unpaved roads is to blade the roads every one to three weeks depending upon traffic and weather conditions, with gravel replacement as needed. This requires approximately 1.0 to 1.5 tons of gravel per mile per vehicle of the average daily traffic per year to maintain roads in an acceptable condition. Gravel loss is caused by traffic abrasion, loss of fines through dust and erosion, and by snow removal activities.

Woodbury County policy requires that roads with more than 200 vehicles per day or more than 12 houses per mile receive a dust palliative treatment. No efforts are made to stabilize the road. The example cost comparison in the attached spreadsheet does not include the cost of this surface treatment dust palliative. The addition of this palliative would influence the break even point for maintenance with no treatment vs. that with treatment. The cost of maintaining gravel roads increases with increasing traffic, especially when counts exceed 150 vehicles per day.

EXAMPLE COST COMPARISON MODEL SHEET

The following should be noted in the attached cost comparison model sheet:

- This is an example only. When using this worksheet, practitioners will need to use their own numbers for wages, equipment costs, equipment productivity, and material costs. Carefully check the spreadsheet cells to be sure that values are carried forward in the correct order in the calculations.
- Calculations of expenses should include all expenses anticipated for road maintenance and construction.
- Full cost of staff including wages, benefits, and payroll taxes should be included.
- Machine costs, if not documented, should be taken from a reliable source.
- Comparative calculations should be adjusted for local construction prices.
- Only direct agency costs are considered. Accident reduction and road user cost savings (e.g., vehicle operating costs) are not factored into the analysis, nor is the value of not having to deal with public complaints (with reduced maintenance and dust control provided by improved gravel roads, road administrators receive fewer complaints about road conditions).
- Cost savings can be directed to improving other segments in the network.
- Cost savings per mile increases with traffic count. Based on experience with other counties reviewed, gravel replacement may not be necessary for in excess of 15 years.
- The life of treated roads, when treatment is done annually and fines are kept on the road surface, can exceed 20 years.

Summary of Results

Period	Annual Costs (2013 $)	
	Untreated	Treated
First Year	$ 45,283	$ 45,259
5 Years	$ 13,574	$ 10,629
10 Years	$ 10,013	$ 6,848
15 Years	$ 8,827	$ 5,426
20 Years	$ 8,233	$ 4,714

Construction Data Sheet

Construction - Assumptions									
Road has adequate base									
5" of gravel placed per mile									
Calcium chloride used in example calculations									
0.25 gal/sq.yd applied late summer first year									
Labor, Equipment and Materials for Construction	**Hourly Pay or rate**	**Hourly Benefits**	**Total Pay & Benefits**	**Hours or Tons Per Year**	**Price**	**Tons Per Year**	**Sq.Yds Treated**	**Gallons Per Sq.Yd**	**Annual Maint. Cost**
Motor Grader Operator	$ 19.24	$ 6.36	$ 25.60	16					$ 410
Truck Driver	$ 19.24	$ 6.36	$ 25.60	208					$ 5,328
Tanker Driver	$ 19.24	$ 6.36	$ 25.60	16					$ 410
Roller Operator	$ 19.24	$ 6.36	$ 25.60	16					$ 410
Motor Grader	$ 75.00	$ -	$ 75.00	16					$ 1,200
Dump Truck	$ 60.00	$ -	$ 60.00	208					$ 12,487
Water Tanker	$ 60.00	$ -	$ 60.00	16					$ 960
Roller	$ 35.00	$ -	$ 35.00	16					$ 560
Gravel (per ton)					$ 6.50	3122			$ 20,292
First Year Construction Cost - Untreated									$ 42,056
Calcium chloride (per sq.yd)					$ 0.35		14080	0.65	$ 3,203
First Year Construction Cost - Treated									$ 45,259

Maintenance Data Sheets

Untreated Road Maintenance - Assumptions								
Maintenance is 50% in first year								
Weekly blading - 15 minutes per mile								
Annual rock hauled to road to replace loss 1 ton/ADT								
April 1 to November 15 maintenance blading								
AADT is 200								
1 hour round trip for gravel hauling								
Labor, Equipment and Materials	**Hourly Pay or rate**	**Hourly Benefits**	**Total Pay & Benefits**	**Hours or Tons Per Year**	**Price**	**Tons Per Year**		**Annual Maint. Cost**
Motor Grader Operator	$ 19.24	$ 6.36	$ 25.60	23.89				$ 612
Truck Driver	$ 19.24	$ 6.36	$ 25.60	13.33				$ 341
Roller Operator	$ 19.24	$ 6.36	$ 25.60	13.33				$ 341
Motor Grader	$ 75.00	$ -	$ 75.00	23.89				$ 1,792
Dump Truck	$ 60.00	$ -	$ 60.00	13.33				$ 800
Water Tanker	$ 60.00	$ -	$ 60.00	13.33				$ 800
Roller	$ 35.00	$ -	$ 35.00	13.33				$ 467
Gravel (per ton)					$ 6.50	200		$ 1,300
Annual Maintenance (Untreated)	Construction	Maintenance	Total Cost					$ 6,453
Costs in first Year	$ 42,056	$ 3,227	$ 45,283					$ 45,283
Costs over 5 Years	$ 42,056	$ 25,812	$ 67,868					$ 13,574
Costs over 10 Years	$ 42,056	$ 58,078	$ 100,134					$ 10,013
Costs over 15 Years	$ 42,056	$ 90,343	$ 132,399					$ 8,827
Costs over 20 Years	$ 42,056	$ 122,609	$ 164,665					$ 8,233

Treated Road Maintenance - Assumptions									
Grader maintenance once per year at rejuvenation									
0.40 gal/sq.yd annual rejuvenation									
Labor, Equipment and Materials	**Hourly Pay or rate**	**Hourly Benefits**	**Total Pay & Benefits**	**Hours or Tons Per Year**	**Price**	**Tons Per Year**	**Sq.Yds Treated**	**Gallons Per Sq.Yd**	**Annual Maint. Cost**
Motor Grader Operator	$ 19.24	$ 6.36	$ 25.60	4					$ 102
Roller Operator	$ 19.24	$ 6.36	$ 25.60	2					$ 51
Truck Driver	$ 19.24	$ 6.36	$ 25.60	1					$ 26
Motor Grader	$ 75.00	$ -	$ 75.00	4					$ 300
Roller	$ 35.00	$ -	$ 35.00	2					$ 70
Water Tanker	$ 60.00	$ -	$ 60.00	1					$ 60
Gravel (per ton)					$ 6.50	0			$ -
Calcium chloride (per sq.yd)					$ 0.35		14080	$0.40	$ 1,971
Annual Maintenance Cost	Construction	Maintenance	Total Cost						$ 2,580
Costs over 5 Years	$ 45,259	$ 7,885	$ 53,144						$ 10,629
Costs over 10 Years	$ 45,259	$ 23,224	$ 68,483						$ 6,848
Costs over 15 Years	$ 45,259	$ 36,126	$ 81,385						$ 5,426
Costs over 20 Years	$ 45,259	$ 49,028	$ 94,287						$ 4,714

Input Data Sheets

Benefit Rate Calculation	**Days Per Year**	**Hours Per Day**	**Pay Rate**	**Hours per Year**	**Percentage or value**	**Hourly Rate**			
FICA			19.24		0.0765	$ 1.47			
Retirement			19.24		0.0807	$ 1.55			
Vacation	15	8	19.24	2080		$ 1.11			
Holiday Pay	10	8	19.24	2080		$ 0.74			
Sick Leave	12	8	19.24	2080		$ 0.89			
Life Insurance				2080	$ 120.00	$ 0.06			
Disability Insurance				2080	$ 1,126.00	$ 0.54			
Hourly Benefit Value:						$ 6.36			
Construction Productivity	**Hours Per Mile**	**Tons per Load**	**Hours per Load**	**Tons per Mile**	**Truck Hours**				
Motor Grader	16								
Water Tanker	16								
Roller	16								
Dump Truck		15	1	3122	208				
Materials	**Width**	**Thickness**	**Length**	**Unit Weight**	**Tons**	**Square Yards**			
Gravel per mile	25	0	5280	110	3122				
Treated Square Yards	24		5280			14080			
Maintenance Productivity: Untreated Road	**Weeks Per Year**	**Hours Per Week**	**Hours Per Year**	**Grader Hours**	**Tons per Load**	**Hours per Load**	**Tons per Mile per Year**	**Loads per Year**	**Truck Hours**
Motor Grader Hours-Maintenance Blading	32	0.33		10.56					
Motor Grader Hours-Rock Spreading/Shaping			13.33	13.33					
Total Motor Grader Hours per mile				23.89					
Roller Hours			13.33						
Truck Hours					15	1	200	13.33	13.33
Water Tanker Hours					15	1	200	13.33	13.33
Maintenance Productivity: Treated Road	**Hours Per Mile**	**Tons per Load**	**Hours per Load**	**Tons per Mile**	**Truck Hours**				
Motor Grader	4								
Roller	2								
Water Tanker	1								

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APPENDIX D – TRAINING TOPICS

1. Air quality
    a. Travel distances associated with dust
        i. Wind patterns and intensity
        ii. Distance to the point of interest
    b. Human health
        i. Respiratory issues
        ii. Residences coated with dust, possibly leading to other health issues
        iii. Accident risk due to drivers' reduced visibility
    c. Livestock (and game) health
        i. Increased dental wear due to chewing vegetation coated in dust
        ii. Respiratory issues
    d. Crops (and other vegetation)
        i. Problems related to coating crops with dust
    e. Equipment and Vehicle Damage
        i. Reduced life of air filters
        ii. Damage related to dust throughout any machine exposed to dust
2. Water Quality
    a. Runoff into adjacent waterways
    b. Over-application of chemicals
    c. Spills
3. Reduced Agency Costs
    a. Less frequent routine blading due to stabilizing effects
    b. Less surfacing material loss
    c. Lowered dust loss, leading to less frequent regravelling
4. User Costs
    a. Wet-weather performance issues
        i. Increased rutting due to higher moisture contents in the presence of hydrophilic treatments
        ii. Increased accident risk due to slippery conditions
    b. Dry-weather performance issues
        i. Improved visibility leading to safer travel
        ii. Better crust formation reduces washboards (rhythmic corrugations)
        iii. Retention of fines, preventing washboarding and raveling
        iv. Tolerate some roughness but preserve a durable, drainable crust.
5. Understanding materials
    a. The importance of testing
    b. How material properties influence performance
    c. Deciding between sources
6. Choosing an appropriate chemical treatment
    a. Understanding additive categories
    b. Choosing the right chemical treatment
    c. Dealing with suppliers
7. Applying chemical treatments
    a. Preparing the road

   b. Safety and environmental considerations
   c. Spray-on application process
   d. Mix-in process
8. Maintaining treated roads
   a. Preventing damage to crusts
   b. Preparing the road
   c. Rejuvenation treatments

Training Tip: Use pictures in addition to words when training

APPENDIX E – BASICS ABOUT ROAD DUST SUPPRESSANT CATEGORIES

Dust Suppressant Category	Attributes	Limitations	Application	Origin	Environmental Impact
Water and Water Absorbing					
Water	- Agglomerates the surface particles together - Normally, readily available	- Evaporates readily - Controls dust generally for less than a day - Generally the most expensive and labor intensive of the inorganic suppressants	- Frequency depends on temperature and humidity; typically only effective from 1/2 to 12 hours	- Any water source	Depends on water source
Calcium chloride (deliquescent)	- Ability to absorb water is a function of temperature and relative humidity; for example, at 25°C (77°F) it starts to absorb water from the air at 29% relative humidity and at 38°C (100°F) it starts to absorb water at 20% relative humidity - Significantly increases surface tension of water film between particles, helping to slow evaporation and further tighten compacted soil as drying progresses - Treated road can be regraded and recompacted with less concern for losing moisture and density	- Requires minimum humidity level to absorb moisture from the air - Doesn't perform as well as $MgCl_2$ in long dry spells - Performs better than $MgCl_2$ when high humidity is present - Slightly corrosive to metal, highly to aluminum and its alloys, attracts moisture thereby prolonging active period for corrosion - Rainwater tends to leach out highly soluble chlorides - If high fines content in treated material the surface may become slippery when wet - Effectiveness when less than 20% solution has performance similar to water	- Generally 1 to 2 treatments per season - Initial application; - Flake @ 0.5 to 1.1 kg/m^2 (1.0 to 2.0 #/sy), typical application 0.9 kg/m^2 (1.7 #/sy) @ 77% purity - Liquid 35 to 38% residual @ 0.9 to 1.6 l/m^2 (0.2 to 0.35 g/sy), typical application is 38% residual concentrate applied undiluted @ `1.6 l/m^2 (0.35 g/sy) - Follow-up:@ 1/2 to 1/3 initial dosage	- Brine - By-product in the form of brine from manufacture of sodium carbonate by ammonia-soda process and of bromine from natural brines - Three forms: - Flake, or Type I @ 77 to 80% purity - Pellet, or Type II @ 94 to 97% purity - Clear liquid @ 35 to 38% solids	- Water quality impact: generally negligible if the proper buffer zone between treated area and water - Fresh water aquatic impact: may develop at chloride concentrations as low as 400 ppm for trout up to 10,000 ppm for other fish species - Plant impact: some species susceptible such as pine, hemlock, poplar, ash, spruce, and maple - Potential concerns with spills of liquid concentrate

Dust Suppressant Category	Attributes	Limitations	Application	Origin	Environmental Impact
Magnesium Chloride (Deliquescent)	- Starts to absorb water from the air at 32% relative humidity independent of temperature - More effective than calcium chloride solutions for increasing surface tension, resulting in a vary hard road surface when dry - Treated road can be regraded and recompacted with less concern for losing moisture and density	- Requires minimum humidity level to absorb moisture from the air - More suitable in drier climates - In concentrated solutions very corrosive to steel (note: some products may contain a corrosive-inhibiting additive), attracts moisture thereby prolonging active period for corrosion - Rainwater tends to leach out highly soluble chlorides - If high fines content in treated material the surface may become slippery when wet - Effectiveness when less than 20% solution has performance similar to water	- Generally 1 - 2 treatments per season - Initial application: 28 to 35% residual @ 1.4 to 2.3 l/m^2 (0.30 to 0.5 g/sy), typical application is 30% residual concentrate applied undiluted @ 2.3 l/m^2 (0.50 g/sy) - Follow-up: @ 1/2 initial dosage	- Occurs naturally as brine (evaporated)	- Water quality impact: generally negligible, function of the buffer zone between treated area and water - Fresh water aquatic impact: may develop at chloride concentrations as low as 400 ppm for trout up to 10,000 ppm for other fish species - Plant impact: some species susceptible such as pine, hemlock, poplar, ash, spruce, and maple - Potential concerns with spills
Sodium Chloride (Hygroscopic)	- Starts to absorb water from the air at 79% relative humidity independent of temperature - Increases surface tension slightly less than calcium chloride - Can be reworked with a grader if surface is moist	- Requires minimum humidity level to absorb moisture from the air - Moderately corrosive to steel in dilute solutions - Tends not to hold up as well as a surface application	- Generally 1 - 2 treatments per season - Higher dosages than calcium treatment	- Occurs naturally as rock salt and brines	- Same as calcium chloride

Dust Suppressant Category	Attributes	Limitations	Application	Origin	Environmental Impact
Organic, Non Petroleum					
Lignin Derivatives	- Binds surface particles together - Greatly increases dry strength of material under dry condition - Retains effectiveness during long dry periods with low humidity - With a high amounts of clay, it tends to remain slightly plastic permitting reshaping and additional traffic compaction - Can be reworked with a grader if surface is moist	- May cause corrosion of aluminum and its alloys - Surface binding action may be reduced or completely destroyed by heavy rain, owing to solubility of solids in water - Becomes slippery when wet, brittle when dry - Difficult to maintain as a hard surface, but can be done under adequate moisture conditions - Performance varies depending on tree species and extraction process	- Generally 1 to 2 treatments per season - Initial: 10 to 25% residual @ 2.3 to 4.5 l/m^2 (0.5 to 1.0 g/sy), typical application is 50% residual concentrate applied undiluted @ 2.3 l/m^2 (0.50 g/sy) or - 50% residual concentrate applied diluted 1:1 w/water @ 4.5 l/m^2 (1.0 g/sy) - May be advantageous to apply in two applications - Also in powdered form mixed at 1kg to 840 liters (1 lb to 100 gallons) of water and then sprayed	- Water liquor product of sulfite paper making process, contains lignin in solution - Composition depends on tree species and chemicals used to extract cellulose; active constituent is neutralized lignin sulfuric acid containing sugar	- Water quality impact: none - Fresh water aquatic impact: BOD may be high upon spills/leaching into a small streams - Plant impact: none - Potential concern with spills
Tall Oil Derivatives	- Adheres surface particles together - Greatly increases dry strength of material under dry conditions	- Surface binding action may be reduced or completely destroyed by long term exposure to heavy rain owing to solubility of solids in water - Difficult to maintain as a hard surface	- Generally 1 treatment every few years - Initial: 10 to 20% residual solution @ 1.4 to 4.5 l/m^2 (0.3 to 1.0 g/sy); typical application 40 to 50% residual concentrate applied diluted 1:4 w/water @ 2.3 l/m^2 (0.50 gal/sy)	- Distilled product of the kraft (sulfate) paper making process	- Water quality impact: unknown - Fresh water aquatic impact: BOD may be high upon spills/leaching into a small streams - Plant impact: none - Potential concern with spills
Molasses/Sugar Beet Extract	- Provides temporary binding of the surface particles - Can be reworked with a grader if surface is moist	- Limited availability	- Not researched	- By-product of the sugar cane and sugar beet processing industry	- Water quality impact: unknown - Fresh water aquatic impact: unknown - Plant impact: unknown, none expected
Vegetable Oils	- Agglomerates the surface particles - Can be reworked with a grader if surface is moist	- Limited availability - Oxidizes rapidly, then becomes brittle	- Generally 1 treatment per season - Application rate varies by product, typically 1.1 to 2.3 l/m^2 (0.25 to 0.50 g/yd^2) - The warmer the product, the faster the penetration - Follow-up: apply at reduced initial dosages	- Some products: canola oil, soybean oil, cotton seed oil, and linseed oil	- Water quality impact: unknown - Fresh water aquatic impact: some products have been tested and have a low impact - Plant impact: unknown, none expected

Dust Suppressant Category	Attributes	Limitations	Application	Origin	Environmental Impact
Bio-fluids (Hydroscopic)	- Agglomerates surface particles - Can be used in freezing temperatures - Can be reworked with a grader if surface is moist	- Requires minimum humidity level to absorb moisture from the air - Pricing closely tied to bio-diesel and grain markets, therefore volatile	- Generally 2 to 6 treatments per season - Initial: 0.3 gal/sq yd depending on road surface condition, and product - Frequency depends on temperature and humidity	- Can be manufactured or a by-product of bio-diesel manufacturing - Plant or animal based, is renewable resource - Glycerin	- Water quality impact : none - Fresh water quality impact: none - Plant impact: none
Organic Petroleum/Petroleum Resins/Mineral Oils					
Asphalt based	- Binds and/or agglomerates surface particles because of asphalt adhesive properties - Serves to waterproof the road	- Under dry conditions some products may not maintain resilience - If too many fines in surface and high in asphaltenes it can form a crust and fragment under traffic and in wet weather - Some products are difficult to maintain	- Generally 1 to 2 treatments per season - Initial: 0.5 to 4.5 l/m^2 (0.1 to 1 g/sy) depending on road surface condition, dilution, and product - Higher viscosity emulsions are used for more open-graded surface materials - Follow-up: @ reduced initial dosages	- Cutback asphalt: SC-70 - Asphalt emulsion: SS-1, SS-1h, CSS-1, or CSS-1h mixed with 5+ parts water by volume - Modified asphalt emulsions - Petroleum oils	- Water quality impact : none after curing - Fresh water quality impact: none after curing - Plant impact: none, provided no direct application to plants - Beware spills - May have regulatory storage and reporting requirements
Petroleum Resins	- Binds and/or agglomerates surface particles - Petroleum additives reduce moisture sensitivity	- Crust is difficult to maintain	- Generally 1 to 2 treatments per season - Initial: 0.5 to 4.5 l/m^2 (0.1 to 1 g/sy) depending on road surface condition, dilution, and product	- Combination of lignin and petroleum	- Water quality impact : none after curing - Fresh water quality impact: none after curing - Plant impact: none, provided no direct application to plants - Beware spills - May have regulatory storage and reporting requirements
Mineral oils and base oils	- Agglomerates surface particles - Applied neat – does not require dilution with water - Treated road can be re-graded and re-compacted without reapplication	- Many products fall under this category – lack of test data - Temporary dust control	- Generally 1 to 2 treatments per season - Initial: 0.3 gal/sq yd depending on road surface condition, and product - Follow-up: @ reduced initial dosages	- Derived from crude oil solely through a physical separation process - Emulsified oils - Mineral oils - Can also be industrial waste	- Wide variety of ingredients in these products - “Used” products are toxic - Oil in products might be toxic - Need product specific analysis - Potential concerns with spills and leaching prior to the product “curing” - May have regulatory storage and reporting requirements

Dust Suppressant Category	Attributes	Limitations	Application	Origin	Environmental Impact
Synthetic Polymer Emulsions					
Synthetic Polymer Emulsions (Acrylates, polyvinyl acetates, polyvinyl chlorates, etc)	- Binds surface particles through adhesive properties - Can increase shear strength of material - Can be used in stabilization and dust control applications	- Difficult to maintain as a hard surface - Can break down under UV light - Performs best if mixed in	- Generally 1 treatment every few years - Initial: 5 to 15% residual solution @ 1.4 to 4.5 l/m^2 (0.3 to 1.0 g/sy); typical application is 40 to 50% residual concentrate applied diluted 1:9 w/water @ 2.3 l/m^2 (0.50 gal/sy)	- Can be by-product of the adhesive manufacturing process - Specifically formulated prime products to meet engineered specifications - Typically 40 to 60% solids	- Water quality impact: none - Fresh water aquatic impact: generally low - Plant impact: none - Need product specific analysis
Synthetic Fluids					
Synthetic Fluids ("Synthetic" defined by EPA environmental regulatory testing requirements [40 CFR 435])	- Adhesive and cohesive binding mechanism - Increases shear strength - "Waterproofs material - Dust control and material stabilization - Does not require dilution with water - Performs at extreme temperatures - Can be reworked with a grader	- None documented	- Generally 1 treatment per season - Initial: 0.2 gal/sq yd depending on road surface condition, and product - Follow-up: @ reduced initial dosages	- Manufactured specifically for dust control and surface stabilization - Produced by the reaction of specific chemical feedstock	- Water quality impact – none - Fresh water quality impact - none - Plant impact – none Meets EPA environmental based criteria for synthetic (sediment toxicity, biodegradability, PAH content, aquatic toxicity, and oil sheen free)
Electrochemical/sulfonated oils and Enzymes					
Electrochemical derivatives, sulfonated oils, ionic stabilizers, and enzymes	- Changes characteristics of clay size particles - Generally effective regardless of climatic conditions - Good compaction aid	- Performance dependent on fine clay mineralogy - Needs time to "set-up", that is react with the clay fraction - Difficult to maintain if full strengthening reaction occurs - Limited life span	- Generally diluted 1 part product to anywhere from 100 to 600 parts water - Diluted product then used to compact the scarified surface	- Proprietary, sulfonated oils and ionic stabilizers are often sulfuric acid based	- Need product specific analysis - Some products are highly acidic in their undiluted form
Other, Mechanical					
Clay Additives (Bentonite is most common)	- Agglomerates with fine dust particles - Generally increases dry strength of material under dry conditions	- The surface may become slippery when wet if too much is added and soil fines content increased to above 20%	- Generally 1 treatment every 5 years - Typical application rate is at 1 to 3% by dry weight	- Mined natural clay deposits	- Water quality impact: unknown - Fresh water aquatic impact: none - Plant impact: none