Dust Control Field Guide

for

Gravel Driving Surfaces

Alaska Department of Transportation, Research, Development & Technology Transfer

Alaska Local Technical Assistance Program

Alaska University Transportation Center

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July 2015
Fairbanks, Alaska

Contents

1. Introduction for the Manager or Operator

This field guide is intended for readers who have been assigned the task of dust control or dust control management. Here is what you need to know:

- Why dust control is important.
- Road design and condition is an important part of dust control.
- Selecting the right dust palliative and proper application are job-specific and are vitally important.
- How to judge dust control success in terms of mechanical effectiveness and economics.

Be aware that various terms are used when generally referring to dust control materials, i.e., the "stuff" that one applies to a gravel road surface to aid in controlling dust. Because many source documents were used to create this field guide, and sometimes simply for the sake of word variety, the following general terms are intended essentially as synonyms: dust control chemicals, agents, palliatives, products, materials.

In all sections of this field guide, the term "road" will be used as an expedient way of representing all types of driving surfaces.

The principal reference for this field guide is Barnes and Connor, 2014.

1.1. Why is Dust Control Important?

Because Alaska is predominately a rural state, unpaved surfaces are the norm for a major portion of the state's roadways, streets, and runways. Loss of fine particles—dust—from unpaved driving surfaces produces three significant problems:

- Degradation of the road surface itself: fine soil particles act somewhat as a binder. Corrugations, potholes, and rutting are all evidence of loss of the fine particles, ultimately producing uncomfortable and unsafe driving conditions. Loss of fines from the surface requires frequent, expensive maintenance.
- Poor visibility: large, nearly opaque clouds of dust lofting from behind vehicles can quickly (sometimes completely) obscure a driver's vision for several seconds or longer.
- Health and quality of life: ambient particles of 10 micrometers (µm) or smaller in aerodynamic diameter (PM10) can penetrate deep into the respiratory tract, resulting in respiratory health issues. High levels of fine particles in the air create a general nuisance that degrades the quality of life as this material invades all living spaces and eventually settles on, under, and into *everything.*

PM10 is particulate matter having an aerodynamic diameter less than or equal to 10 micrometers (µm). This size fraction of particulate matter is used as a measure of fugitive dust. The regulatory standard in the United States for PM10 established by the U.S. Environmental Protection Agency (U.S. EPA) is 150 $\mu g/m^3$ averaged over a 24-hour period. An area meets this standard if the 24-hour PM10 concentration does not exceed 150 $\mu g/m^3$ more than once per year, on average, over a three-year period (Federal Register, 2013). The U.S. EPA has adopted methodologies to assess whether or not an area meets this standard (U.S. EPA, 1999).

It may be difficult to escape some dust problems. The smallest of particles in road dust can be held in the atmosphere for hours or even days. As a result, each passage of a vehicle can add additional fine particles to the atmosphere, making the total particle concentration cumulative. Small dust particles can be transported miles away from their source.

Yes. Dust control is important!

2. Condition of Roadway Before Dust Control Application

Good dust management starts with a good road. Dust control measures work best on well-prepared roadways with the right gravel surface course material. The better the initial condition of your road, the more likely it is that higher quality, longer lasting dust control materials will provide good service. Therefore, you need to know how to judge the initial condition of your existing gravel road.

It is your responsibility to do a basic assessment of the existing road condition before selecting a dust control material. You don't need special engineering skills to assess the general quality of a gravel road and determine whether it might be a good candidate for using the best dust control materials.

Key characteristics of a good gravel road related to dust control and problems this prevents:

- The right surfacing materials (well-graded gravel) are strong and stable. Incorrect surfacing gravel will not support traffic well and tends to produce huge quantities of dust.
- The right cross section (crown) removes water from road surface to roadside. Too much crown can be hazardous and insufficient crown allows water to remain on the road surface and soften it.
- Good drainage (ditch, culvert, etc.) removes water away from the roadside. Poor roadside drainage can soften the road embankment and driving surface.
- Good year-to-year stability (foundation and embankment stable enough to support a permanent driving surface). Unstable embankment or foundation conditions will lead to road deformation and many problems, some of which involve dust production.

Each of the above points is discussed in detail later in this section.

If the existing road has not been properly designed or maintained, good dust control chemicals will likely do a poor job. Problems with any of the above key characteristics can require frequent regrading and/or releveling, which in turn may require the addition of new gravel surfacing materials. New gravel surfacing will, in turn, require wasteful additions of more dust control agent. Combinations of these problems only make matters worse.

Improper maintenance will rapidly negate many of the benefits of even the best engineering and construction—and reduce the probability of successful dust control.

Note: (1) coverage of design and construction technology necessary to make a bad road good is beyond the scope of this field guide (see references pertaining to this section), and (2) this field guide provides no instructions regarding operation, control, and/or safety associated with activities or equipment necessary to evaluate road materials and conditions or to upgrade those materials and conditions.

2.1. Good Surfacing Material

Ideally, surface course materials are gravels composed of a well-graded mixture of aggregate particles that are hard, durable, and can be easily compacted to a relatively high density of about two tons per cubic yard.

In its 2015 *Standard Construction Specifications for Highways*, the Alaska Department of Transportation and Public Facilities (ADOT&PF) offers two excellent gravel surfacing gradations. These are listed as gradings E-1 and F-1 in Section 703-2.03 *Aggregate for Base and Surface Course* as indicated in Table 2.1 below. The gradations are similar, and either gradation will work; however, it may be easier to obtain or produce one or the other. Surfacing material must also meet the quality requirements for base course in Section 703-2.03, shown here in Table 2.2. Poor quality surface course material can break down to the point where it can no longer carry traffic or actually become muddy during rainfall.

Table 2.1. Gradation requirements for gravel surfacing (from Table 703-2, Standard Specifications for Highway Construction, *2015)*

Sieve	Gradation			
	Base Course		Surface Course	
	C-1	D-1	E-1	F-1
1½ in.	100			
1 in.	70–100	100	100	100
¾ in.	60–90	70–100	70–100	85–100
⅜ in.	45–75	50–80	50–85	60–100
No. 4	30–60	35–65	35–65	50–85
No. 8	22–52	20–50	20–50	40–70
No. 50	6–30	6–30	15–30	25–45
No. 200	0–6	0–6	8–15	8–20

Table 2.2. Quality requirements for gravel surfacing (from Table 703-1, Standard Specifications for Highway Construction*, 2015)*

Property	Base Course	Surface Course	Test Method
L.A. Wear, %	50, max.	45, max.	AASHTO T 96
Degradation Value	45, min.	45, min.	ATM 313
Fracture, %	70, min.	70, min., 1 face	ATM 305
Liquid Limit	---	35, max.	ATM 204
Plastic Index	6, max.	10, max.	ATM 205
Sodium Sulfate Loss, %	9, max. (5 cycles)	9, max. (5 cycles)	AASHTO T 104

Rules of Thumb for Gravel Surface Course Materials in Alaska

- Use well-graded gravel with a maximum particle size of 1 inch
- The P_{200} content should be in the 10 percent to 14 percent range, although ADOT&PF allows 8 percent to 20 percent depending on grading.
- The best natural surface course materials contain a small percentage of natural clay (not more than 2 to 4 percent).

Lack of natural cohesion is a problem common to most Alaska gravel materials with respect to use as gravel surfacing. Lack of cohesion means that even gravel surfaces made using well-graded, densely compacted material will likely produce a lot of dust. A small amount of natural clay provides cohesion.

Research is proving that the performance of certain dust control agents may be optimized if used with gravels having a specific range of fines (percent of material passing the #200 sieve). **Make sure that the material that is or will be on your road surface is compatible with the dust control palliative you choose!** You must know any special gradation, mineralogical, or other materials properties required by a specific palliative. If possible, it is a good idea to discuss compatibility issues directly with the supplier of the palliative. An even better approach might be to provide the supplier with a sample of your surface course material for evaluation, as a way of verifying compatibility and establishing the best dosage rate for a given dust control chemical. Some companies prefer to evaluate your material as a way of ensuring proper selection and use of their product. If possible take advantage of this service—the company wants you to be successful.

Finally, use common sense when considering dust control options. Advanced technology cannot solve all problems. For example, if the existing road is nothing more than a dirt-surfaced four-wheeler path with poor drainage—and you cannot improve its present condition—you may have to consider the practicality of simply using periodic water applications or tolerating the dust. In this situation, an expensive dust control material will be wasted when the first storm event turns the road into a muddy mess.

2.1.1. Use of the Existing Surfacing Material

It is best to add a new layer of surface course material before using your dust control agent. However, availability and cost of new surface course material may be prohibitive. If the surface course material is close to the desirable gradations indicated in Table 2.1, adjustments in grading, application rates, and frequency of maintenance will provide acceptable results. For example, it may be possible to scarify several inches of the existing surfacing material, add a “calculated” quantity of better aggregate, then road-mix the two materials. You may need to hire the engineering expertise needed to evaluate available materials and the practicality of improving your existing surfacing.

If the surface course varies significantly from the desired gradation, an understanding of the compatibility between your gravel material and a specific dust control product becomes critical. The less ideal the existing gravel surface course, the more important it is to discuss product use directly with the supplier. Some dust control products may be able to stabilize and thereby effectively control dust production from surfacing materials that are considerably different from Table 2.1 gradation requirements.

2.2. Good Cross Section

The cross section of the roadway is critical to the performance of the roadway, including the amount of dust produced. The correct amount of crown greatly helps retain the intended shape and smoothness of a gravel road. **The recommended gravel road crown is 4 percent.**

A crown less than 4 percent will promote water ponding on the road surface. Water ponding leads to potholing, which requires frequent maintenance grading. Potholes make driving uncomfortable and can influence safety. With respect to dust control, motor grading can destroy the effectiveness of surface-applied palliatives by mixing the surface and lower gravel layers. Without frequent grading, the bumpy ride caused by potholes pounds the road surface and tends to maximize dust production and also produces more potholes.

A crown significantly higher than 4 percent may negatively influence safety. With respect to dust control, a very high crown may increase water runoff velocity during rain or rapid seasonal thawing events, and some kinds of dust control agents may be flushed away.

Getting the proper crown requires a trained motor-grader operator. There are simple aids to help the operator achieve the proper crown. Figure 2.1 (top) shows a slope indicator (Slope Meter No. 2) that can be attached to the grader blade to help the operator set the blade at the correct 4 percent grade.

Figure 2.1 (bottom) illustrates an indicator for checking the crown of the road after grading. The simple indicator can be created using a torpedo level and a straight edge such as a 2x6 with a block of wood attached to one end. For example, a 10-foot-long straight edge raised at one end with a 4 ¾-inch block can be used to indicate a 4 percent grade, as shown in Figure 2.1.

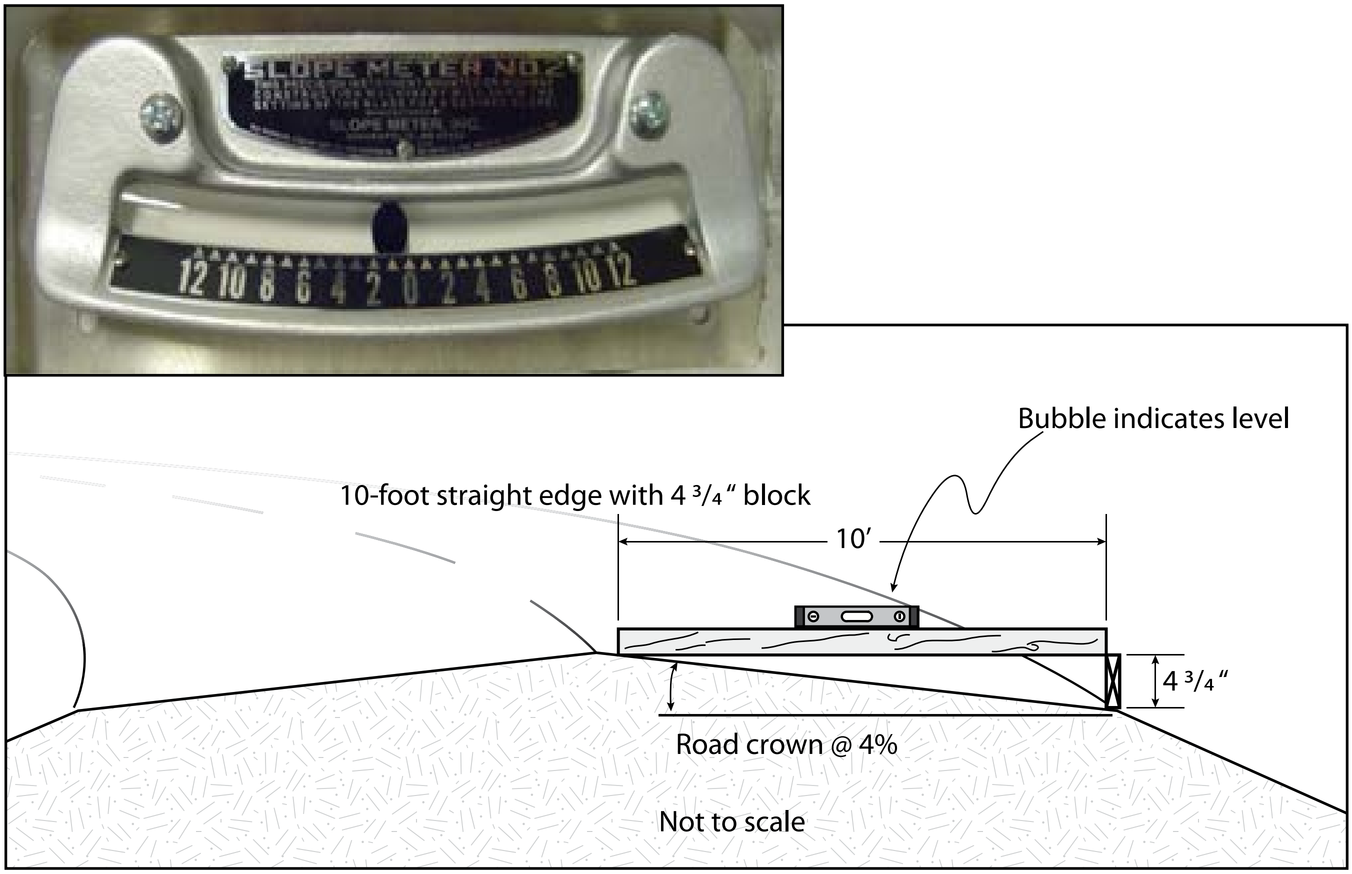

Figure 2.1. Tools for measuring road crown

Rules of Thumb for Getting Water Off of the Road Surface

Proper cross section for a road surface includes:

- A crown with 4 percent cross slope (crown). A good crown and correct superelevation must *always* be maintained.
- Allow no berms to form along downhill edges of roadway shoulders:
  during summer, because of rain,
  and during spring, because of snow/ice melt.

2.3 Good Roadside Drainage

The recommended 4 percent crown helps move water from the road surface to the edge of the roadway where roadside drainage then becomes the important factor. Good roadside drainage in the form of properly designed ditches and culverts moves water away from the roadway. **Good drainage is critical!** If water is allowed to stand adjacent to the road's driving surface, the strength of the surfacing and underlying materials can be weakened by water saturation. Vehicle-caused hydraulic pulses will then create potholes. Beware of creating drainage problems through poor maintenance practices, such as by filling in ditches or building berms along the edge of the roadway. Very poor drainage will actually allow ponded water to encroach on the road surface and thereby negate any advantage of a good crown. Figure 2.2 shows examples of drainage problems due insufficient ditching and poor maintenance. Note that the water is being directed onto the roadway in these photos.

Rule of Thumb for Drainage

- The three most important points regarding preservation of a gravel road are "DRAINAGE, DRAINAGE, DRAINAGE" (H. R. Cedergren).

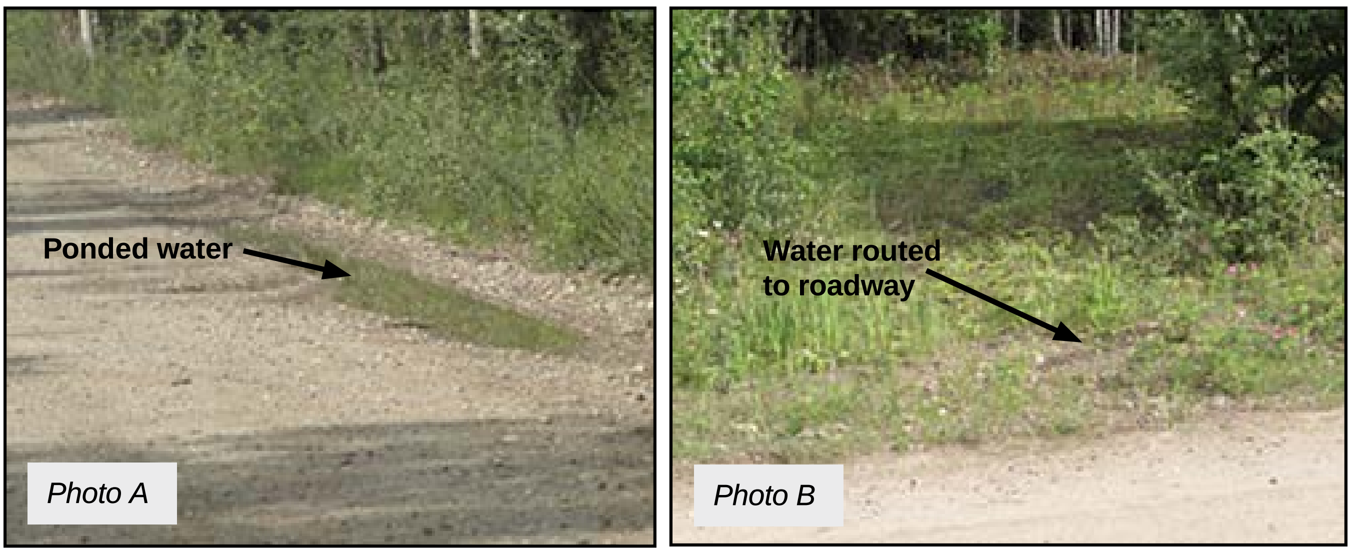

Figure 2.2. Photo A shows ponding due to improper ditching and Photo B shows a ditch blocked by poor maintenance.

The best times to examine a gravel road and recognize drainage problems are:

- during or immediately after a heavy rain event (to evaluate drainage), and
- during spring thaw (to evaluate drainage and thaw-related problems in particular).

It makes sense to examine the gravel road during both conditions for a complete evaluation of drainage.

You are expected to examine the roadway and adjacent areas to decide whether the existing system of drainage is handling water well. You may even recognize obvious problems that can be cured by a few hours of ditch cleaning or brush removal. Proper design of culvert and ditch improvements is an area of engineering outside the scope of this field guide—hire a professional. The State of Alaska's *Alaska Highway Drainage Manual* is available, as of this publication date, at http://www.dot.state.ak.us/stwddes/desbridge/pop_hwydrnman.shtml.

Rules of Thumb for Getting Water Away From the Road

- A good ditch is one of the road's best friends.
- Design to ensure freeboard greater than two feet.
- Select a good ditch shape and maintain it. A flat or V bottom is best.
- Culverts must be compatible with ditch design and remain free of blockage.
- Keep ditches clean.
- Be aware of environmental issues associated with ditch runoff: whatever the requirements today, they will be more strict tomorrow!

3. Determining Dust Control Benefits

3.1. Short-Term Versus Long-Term Evaluation of Dust Control

Whether or not dust control provides long-term economic benefits to a community or agency is simple to discuss in principle and extremely difficult to determine in practice. We know that it has community health, safety, and aesthetic benefits, although such benefits may not be economically quantifiable with convincing accuracy. The reality is that most dust control programs are initiated by policy (mandate), politics, or public demand and without regard for long-term economics. Such disregard creates a big potential for bias in calculating long-term economic benefits. Bias can occur when dust control managers or funding agencies seek to “prove” that popular (or perhaps mandated) dust control programs have had quantifiable, positive economic benefits. The following questions and comments shed additional light on why a standard engineering analysis of long-term benefits may be something of a waste of time.

1. Does your selected dust palliative work?
   - It may work well, but there may be a better alternative that you never tested or a better one that becomes available in the near future.
   - A good palliative today may become unavailable tomorrow.
   - A favorite palliative’s formulation may change with time and reduce its effectiveness.
2. Does your selected dust palliative do any harm to people and/or property?
   - Something considered environmentally acceptable today may be considered quite unacceptable in the future—maybe after great quantities of the palliative have accumulated over many years.
   - Equipment damage may be subtle and either not noticed or not correlated with use of a particular palliative for years.
3. Does your department have the financial resources to support long-term dust control?
   - This is a much better short-term than long-term question, e.g., see item 2 above.
   - Palliative selection/specification is inherently too variable for valid long-term economic analyses of specific palliatives, e.g., see item 1 above.
4. Do you possess data concerning benefits and/or costs for road users or nearby residents regarding your dust control activities?
   - Such data is critically important for a valid determination of long-term economics, but is usually unavailable.

Is it possible to calculate the very long-term physical and economic desirability of any particular dust control method? Do the above points suggest that it may be a wasteful exercise? A subjective assessment of short-term benefits, as explained below, may be the best practical course of action for evaluating dust control economics.

3.1.1. *Some Long-Term Analysis May be Useful*

Some long-term economic predictions can be useful if input values are based on reliable data. Section 3.3 presents a very brief introduction to life cycle cost analysis (LCCA) and includes a simple example. LCCA can be used to evaluate the economics of some long-term costs based on reliably estimated or actual applicable historic data. Such costs might include periodic grading, surface course replacement, and/or dust palliative re-applications. A valid LCCA requires good input data. It is commonly accepted knowledge that a minimum of about 12 years of maintenance records from a particular site may provide the necessary foundation of data for a reliable long-term LCCA. LCCA input data not based on actual maintenance experience and/or records should never be used. Remember: bad guesses = bad input = bad output.

3.1.2. *Short-Term Evaluation of Dust Control*

Based on the four points discussed at the beginning of Section 3, **this field guide stresses short-term evaluation of dust control methods.** As presented here, short-term evaluation of dust control consists of the two elements briefly summarized below and fully explained further on.

1. **Quantified Measurement of Dust (Section 3.2).** There need to be quantified measurements of dust before and after application of a selected dust control material. Dust concentration measurements are usually quantified in terms of weight of particles per volume of air, i.e., micrograms per cubic meter ($\mu g/m^3$). Conceptually speaking, the difference between the dust concentration before and after dust control application represents the immediate apparent benefit of the dust control application. For example we might say that cutting the dust concentration in half will reduce road surface maintenance costs by half. The economic benefit of reducing the dust concentration by half might be reinforced or might actually disappear when other important factors are considered.
2. **Determining the Initial Viability of a Dust Control Candidate (Section 3.3).** This is a mostly subjective evaluation of candidate dust control materials at your field site. This field guide presents a simple method for determining whether a dust control agent is viable at a specific field site and how it might directly compare with other dust control candidates.

3.2. Quantified Measurement of Dust

Measurements of fugitive dust from your gravel roads are necessary for developing a strategy to reduce dust concentration in your area. Monitoring dust from unpaved roads has three main goals:

1. Assess if an area is in compliance with regulatory standards.
2. Quantify dust emissions from unpaved roads.
3. Determine if your dust management strategy is effective.

To accomplish these goals, particulate sampling methods may include simplistic visual assessments, deposition monitors, stationary noncontinuous and semicontinuous monitors, and mobile monitors. In this field guide we concentrate on goal 3. We will now discuss two monitoring methods for addressing that goal.

3.2.1. Estimating Dust Concentration Using a Visual Method

Visual assessments of dust levels are based on the capability of the human eye to detect contrast between an object and its surroundings. Using a stationary object such as a sign or tree is an effective method. The clarity of an object seen through a cloud of dust will be perceived differently from person to person, so visual monitoring is a subjective measurement (Watson, 2002). However, over a common range of airborne dust concentrations, a visual scale is good enough to provide a useful monitoring tool. South African researchers (Thompson and Visser, 2007) developed a useful visual scale that has been modified for this field guide and presented here as Table 3.1.

Table 3.1 allows anyone to roughly estimate the PM10 content of a vehicle-produced dust cloud. Dust Intensity Factors (DIF) listed in the Dust Levels column represent quantitative approximations of relative PM10 content of the dust clouds depicted in each photo.

The relatively higher dust content of the Table 3.1 Degree 4 photo (DIF = 14) compared to the Degree 2 photo (DIF = 4) is simply 14 ÷ 4 = 3.5. In other words, the PM10 content of a Degree 4 dust cloud is quantified as being approximately 3.5 times higher than that of the Degree 2 dust cloud.

Table 3.1. Standard photos for visual estimation of dust concentration (modified from Thompson and Visser, 2007)

Dust Reference Photos	Degree of Dust Cloud Opacity	Dust Levels (approx. µg/m³ For PM10 size)	Qualitative Descriptions
	Degree 1	< 3,500 µg/m³ Dust intensity Factor = 1	Minimal Dust
	Degree 2	3,500–23,500 Dust Intensity Factor = 4	Dust just visible behind vehicle
	Degree 3	23,500–45,000 Dust Intensity Factor = 10	Dust visible, no oncoming driver discomfort, good visibility
	Degree 4	45,000–57,500 Dust Intensity Factor = 14	Notable dust, windows closed in oncoming vehicles, visibility just acceptable, overtaking/ passing hazardous
	Degree 5	> 57,500 µg/m³ Dust Intensity Factor = 16	Significant amount of dust, windows closed in oncoming vehicle, visibility poor and hazardous, passing not possible

3.2.2. Estimating Dust Concentration Using a Machine

Visual estimates of dust intensity are useful but not very precise or accurate. Fortunately, there are reasonably priced instruments that measure PM10 content of the air in a way closely analogous to the visual method previously described, but with very good precision and accuracy. However, it would first be necessary to purchase several pieces of equipment and then learn how to use and maintain them; this may be beyond your needs and organizational responsibility.

Light scattering nephelometers are instruments that take advantage of reflectance of light by particles in the air. The instrument draws air into a measurement cell where a light beam is focused onto the sample. The amount of light reflected from the particles correlates with the concentration of particles in the air stream. Filters or special inlets upstream of the measurement exclude dust particles that are too large. The nephelometer is not considered by the U.S. EPA to be a federal equivalent method (FEM) or a federal reference method (FRM). It is not sanctioned by the U.S. government as an official dust monitoring tool. Despite that, nephelometers are readily obtainable, reasonably accurate, and easy to use in the field. Versions of this equipment type have been recently used in several University of Alaska gravel road dust studies.

Nephelometer equipment can be placed on stationary mounts to sample the dust particle content of dust plumes produced by passing vehicles, i.e., similar in concept to, but more accurate than, the visual method. Measurements of fugitive dust using a stationary monitor represent the average dust production on a defined and uniform section of roadway for a given set of vehicle, road surface, and atmospheric variables over a specific time of measurement. Stationary monitoring represents the simplest use of nephelometer equipment.

Nephelometer equipment can also be mounted on a vehicle to quantify fugitive dust produced along an unpaved road. Use of a mobile monitor simply involves driving along the road while taking frequent measurements. There are several advantages of using mobile monitors over stationary monitors to quantify the fugitive dust produced from unpaved roads. The obvious advantage of a mobile setup is to actually assess dust production along the entire road length. Mobile monitoring methodology appears to be most useful for assessing the effectiveness of dust control strategies (Barnes and Connor, 2014). The main disadvantage of mobile monitoring is that there is currently no standard methodology. However, the University of Alaska Fairbanks developed a practical (though nonstandard) mobile nephelometer system (DUSTM II) for use in the field.

DUSTM II, shown in Figure 3.1, was developed for the measurement of fugitive road and runway dust in remote rural communities (Eckhoff, 2012). DUSTM II used a commercially available nephelometer, a TSI DustTrak aerosol monitor, model 8530, with an intake mounted behind the rear tires of a small all-terrain vehicle (ATV), opposite the exhaust side.

It is important to consider that the DUSTM II system was designed using only a single sampling intake (located behind one of the rear wheels). A single sampling intake requires use of only a single-channel model 8530 unit. This sampling setup assumes that the dust concentration measured by the unit is created solely by the ATV's tires. However, other vehicles in addition to the ATV testing system may be operating on the same road surface at approximately the same time, thus creating a "background" dust concentration that adds to the dust concentration measured by the 8530 unit. Minimize this problem by (1) prohibiting operation of other vehicles during use of the ATV system and (2) allowing for dissipation of dust from previous vehicles by waiting for several minutes before using the ATV system.

Figure 3.1 shows the ATV with attached DustTrak housed in a protective case, the rigid mounting frame that attached the intake to the DustTrak unit, and a close-up of the dust sample intake and plastic tube that connects the intake to the nephelometer. The model 8530 was equipped with a PM10-selective inlet for all field work conducted by UAF researchers. Further details about the system are contained in Eckhoff's 2012 master's thesis. Information concerning the status, location, and possible availability of UAF's DUSTM II unit can be obtained by contacting the UAF Department of Civil and Environmental Engineering.

Figure 3.1. University of Alaska Fairbanks DUSTM setup (left) and dust intake detail (right) (from Eckhoff, 2012)

As of this publication date, an ATV of a type similar to the basic Polaris four-wheeler shown in Figure 3.1 is easily available in any of the larger Alaska cities for under $10,000 new. A single channel TSI DustTrak aerosol monitor, model 8530 (DustTrak II) is available through TSI Incorporated, 500 Cardigan Road, Shoreview, MN 55126. An unofficial quote provided to the author on January 16, 2015, indicated availability of the basic model 8530 (new) for around $6,000. TSI Incorporated will provide technical expertise as required for mounting and operating DustTrak monitors. Therefore, it appears that an operational equivalent to the UAF DUSTM II system can be assembled using new components for substantially less than $20,000 at this time. This figure assumes the cost of an ATV, an aerosol monitor, plus additional costs of required mountings, connections, and additional hardware or electronics that may be needed to facilitate operation of the system.

3.2.3. EPA Dust Measuring Methods Beyond Casual Monitoring

Regulatory agencies use more complex monitoring techniques to assess compliance with air quality regulations. These are discussed only briefly. You may encounter such equipment and should be aware of its purpose as well as a few important terms associated with this more rigorous ("official") air monitoring technology. These are the methods that the U.S. EPA designates as FRMs and FEMs. These methods are used to rigorously assess fugitive dust from unpaved roads. They are the methods required to develop emission standards or verify compliance with regulations.

U.S. EPA established a federal reference method for monitoring PM10 compliance (Federal Register, 1987a). Filter method systems fit the requirements for the federal reference method (FRM). The FRM involves measuring the quantity of PM10 collected by the system within a given period of time. A common FRM method used in the United States is the high volume sampling (HiVol) method. Details of this monitoring method can be found in U.S. EPA (1999) and Chow (1995). U.S. EPA can also approve PM10 monitoring methods that are equivalent to the FRM. These methods are classified as federal equivalent methods, or FEMs (Federal Register, 1987b). Approved FEMs include several semi-continuous type systems.

Several kinds of filter method systems and several kinds of semicontinuous systems **are** accepted by the EPA. Nephelometers such as the DustTrak aerosol monitor are of the semicontinuous type (as mentioned in the previous section of this field guide), but they are **not** EPA certified.

3.3. Determining the Initial Viability of a Dust Control Candidate

Before committing to a dust control program using any particular dust control product, you may first want to perform short-term tests using limited amounts of several products. The initial concern is whether one or more of the tested products becomes a candidate for further evaluation or continued use. The initial decision can be based on the following questions.

- **Short-term effectiveness:** Is the dust control agent acceptably effective?
- **Initial cost estimate:** Can you afford the cost of the dust control material, considering the manufacturer's recommended reapplication schedule?
- **Apparent handling issues:** Are there known short- or long-term negatives associated with use of the dust control material with respect to transportation, application, and/or health?

Table 3.2 is a useful tool for evaluating dust control materials as viable candidates for further testing or continued use.

Table 3.2. Initial evaluations of dust control methods

Name of Dust Control Agent	Short-Term Effectiveness (Good/OK/Poor)	Initial Cost ($/Year-Mile)	Known Handling Issues (Yes/Slight/No)		
			Transport	Application	Health
Agent No. 1	OK	$530	No	Slight	Slight
Agent No. 2	Poor	$750	Yes	No	Yes
Agent No. 3	OK	$610	No	Slight	Slight
Agent No. 5	Good	$660	No	No	No

An example of calculating initial cost of dust control agent No. 1 for Table 3.2 is as follows:

Given

1. Cost of concentrated liquid dust control agent is $25/gallon
2. One gallon, properly diluted, treats 200 centerline-feet of roadway
3. Manufacturer generally recommends additional dust control treatment every two years
4. One mile of roadway can be treated (including dilution of concentrated agent) in two hours for $400 in equipment and operator costs.

Calculate

[(($/200 feet) (number of 200-foot intervals per mile)) + equipment and operator cost] [half cost for application every 2nd year]

= [(($25) (5,280/200)) + $400] [1/2] = [(($25) (26.4)) + $400] [0.5] = $530/Year-Mile

Select dust control candidates for further testing using your (mostly subjective) opinions and a selection aid such as Table 3.2. Example:

- Eliminate Agent No. 2 first because it is both expensive and not effective in controlling dust.
- Select Agent No 1 for further testing because its effectiveness is "OK" and it is lowest cost.
- Reject Agent 3 because it works no better than Agent 1 and is significantly more expensive.
- Select Agent No. 5 for further testing. Although Agent No. 5 is more expensive, it appears to work best and has no handling (especially health) issues.

Result: Select Agents No. 1 and No. 5 for further testing.

Rational and careful initial evaluation of materials is a valuable first step in a good dust control program. Necessarily, all of this is based on short-term observations, opinions, costs, etc. It takes time and several years of documented usage before the next step of economic evaluation, life cycle cost analysis, is appropriate.

3.4. Life Cycle Cost Analysis

For the purpose of this field guide, life cycle cost analysis is defined as a way of comparing the long-term costs of two or more acceptable courses of action. This discussion is based on a much abbreviated and simplified version of life cycle cost methods presented by Ming, McHattie, and Liu, 2013.

Life cycle cost analysis (LCCA) can be done a number of different ways. In this field guide LCCA is done by calculating and comparing the total present values (PV) of several possible options. With PV analysis we calculate costs, in today's dollars, for the total amount to be spent on one or more events that will occur over time until some future date—until, let's say, 20 years into the future. PV analysis makes it possible to compare costs of several different, acceptable courses of action on an equal basis, by directly comparing the so-called total present costs of the alternatives. An example, with the required PV equation, is provided to help make this concept clear.

The formula for calculating the discounted present value (PV) of money spent in the future is:

$$PV = \frac{CF}{(1+i_{dis})^n}\text{, where}$$

PV = Present value,
CF = Cash flow at year n,
i_{dis} = discount rate in decimal form, and
n = year at which cash flow occurs.

The following example with tables illustrates how the method works by comparing two fictitious dust control alternatives. The alternatives are compared for only five years in this example. The recommended time period for road project analysis is usually 20 to 30 years. This analysis assumes that we truly know enough about future expenditures to enter them into a life cycle cost analysis. The discussion at the beginning of section 3 explains that there may be rather profound problems with such assumptions.

Table 3.3. Cash flow for dust control alternatives (example)

Dust Control Alternative 1 Input		
Purpose	**End of Expenditure Year**	**Expenditure (Cash Flow)**
Grading & palliative application	0 (time zero)	$5,000
Palliative	1	$2,000
Grading	2	$1,000
Palliative	3	$2,000
Grading	5	$1,000

Dust Control Alternative 2 Input		
	End of Expenditure Year	**Expenditure (Cash Flow)**
Grading & palliative application	0 (time zero)	$6,000
Grading	2	$1,000
Grading	3	$1,000
Palliative	4	$4,000

Note that the cash flows indicated above are stated in real or present-day "time zero" dollars because a real discount rate will be assumed, i.e., 4 percent (i_{dis} = 0.04). Use of a real discount rate is intended to account for predicted inflation and true cost increases.

Table 3.4. Present value analysis for two dust control alternatives (example)

Dust Control Alternative 1 PV Analysis			
Treatment	**Year**	**Cash Flow**	**PV**
Grading & palliative	0	$5,000	$5,000
Grading & palliative	1	$2,000	$1,923
Grading	2	$1,000	$925
Grading & Palliative	3	$2,000	$1,778
Grading	5	$1,000	$822
Sum of Present Values			$10,448

Dust Control Alternative 2 PV Analysis			
Treatment	**Year**	**Cash Flow**	**PV**
Grading & palliative	0	$6,000	$6,000
Grading	2	$1,000	$925
Grading	3	$1,000	$889
Grading & palliative	4	$3,000	$2,564
Sum of Present Values			$10,378

In this example, alternative 2 might be chosen by virtue of its slightly lower calculated total PV. An additional advantage of alternative 2 is the fact that it requires one less grading activity during the five-year analysis period. This is an added advantage for alternative 2 in terms of reduced user costs for delays and hazards associated with grading operations and palliative application. Note that no user or environmental costs were included in the example. Barnes and Connor (2014) indicated that, although critical, **both user and environmental costs may be very difficult to account for in any economic analysis**.

4. Dust Control Methods and Selection

Researchers have conducted many studies on the common palliatives: water, hydroscopic salts, and lignosulfonates. Only a handful of studies have been conducted on more recent additions to the selection of palliative types: polymers and synthetic fluids. In addition, multiple studies have shown the influence that vehicle speed has on the amount of fugitive dust created.

4.1. Vehicle Speed

Vehicle speed has a very significant influence on the amount of fugitive dust produced. Recent research found that PM10 production was reduced from 30 to as much as 80 percent by reducing vehicle speed from 30 to 15 mph. The increase in dust generation is evident in Figure 4.1 as vehicle speed increases from 15 to 45 mph.

A reduction in vehicle speed also means that dust control palliatives placed on the road will last longer. Lowering vehicle speeds also reduces vehicle-related forces that create road damage such as corrugations, potholes, and aggregate loss.

Figure 4.1. Fugitive dust created by a vehicle at different speeds (photos courtesy of Tom Moses)

Rule of Thumb for Producing Less Dust

Take advantage of low hanging fruit. It is a simple fact that lower vehicle speeds on gravel roads mean less dust. Lower speeds not only reduce dust production but reduce the general need for surface maintenance regardless of other variables. Dust from high-speed gravel surfaces such as runways must be controlled in other ways.

4.2. Introducing Types of Dust Control Palliatives

Table 4.1 summarizes important facts about many of the dust palliative types in use now. Palliatives are listed by suppressant category. Each suppressant category is defined in terms of attributes, limitations, usual application mode, origin, and environmental Impact.

Table 4.1 was extracted from the useful document published by the U.S. Department of Agriculture's Forest Service, *Dust Palliative Selection and Application Guide*. The table provides a fairly comprehensive list of commonly available materials that have been used for dust control on gravel roads. The purpose of the table is to let you know something about the full range of possibilities; it is not intended as a stand-alone palliative selection guide. A systematic method of palliative selection is covered in Section 4.3.

Note that the lignosulfonates (or lignosulphonates) mentioned elsewhere in this field guide are identified as "organic nonpetroleum: lignin derivatives" in Table 4.1.

Table 4.1. Road dust suppressants (Bolander and Yamada, 1999)

Dust Suppressant Category	Attributes	Limitations	Application	Origin	Environmental Impact
Water	• agglomerates the surface particles • 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 ½ to 12 hours	• any potable water source	• none
Water Absorbing: Calcium Chloride (deliquescent)	• ability to absorb water from the air is a function of temperature and relative humidity; for example, at 25°C (77°F) it starts to absorb water 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 in long dry spells • performs better than MgCl 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 preseason • initial application: **flake:** @ 0.5 to 1.1 kg/m² (1.0 to 2.0 lb/y²), typical application 0.9 kg/m² (1.7 lb/y²) @ 77% purity; **liquid:** 35 to 38% residual @ 0.9 to 1.6 L/m² (0.2 to 0.35 g/y²), typical application is 38% residual concentrate applied undiluted @1.6 L/m² (0.35 g/y²) • follow-up: apply @ ½ to ⅓ initial dosage	• byproduct 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 exists 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

(continued)

Dust Suppressant Category	Attributes	Limitations	Application	Origin	Environmental Impact
Water Absorbing: 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 very 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 to 2 treatments preseason • initial application: 28 to 35% residual @ 1.4 to 2.3 L/m^2 (0.30 to 0.5 g/y^2), typical application is 30% residual concentrate applied undiluted @ 2.3 L/m^2 (0.50 g/y^2) • follow-up: apply @ ½ initial dosage	• occurs naturally as brine (evaporated)	• water quality impact: generally negligible if the proper buffer zone exists 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
Water Absorbing: 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	• requires minimum humidity level to absorb moisture from the air • moderately corrosive to steel in dilute solutions • tends not to hold up well as a surface application	• generally 1 to 2 treatments preseason • higher dosages than calcium treatment	• occurs naturally as rock salt and brines	• same as calcium chloride

(continued)

Dust Suppressant Category	Attributes	Limitations	Application	Origin	Environmental Impact
Organic Petroleum Products	• 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 • 0.5 to 4.5 L/m^2 (0.1 to 1 g/y^2) depending on road surface condition, dilution, and product • the higher viscosity emulsions are used for the more open-graded surface materials • follow-up: apply at 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 • emulsified oils • mineral oils	• 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”
Organic Nonpetroleum: Lignin Derivatives	• binds surface particles together • greatly increases dry strength of material under dry conditions • retains effectiveness during long dry periods with low humidity • with high amounts of clay, it tends to remain slightly plastic, permitting reshaping and additional traffic compaction	• may cause corrosion of aluminum and its alloys • surface binding action may be reduced or completely destroyed by heavy rain, due 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	• generally 1 to 2 treatments preseason • 10 to 25% residual @ 2.3 to 4.5 L/m^2 (0.5 to 1.0 g/y^2), typical application is 50% residual concentrate applied undiluted @ 2.3 L/m^2 (0.50 g/y^2) or 50% residual concentrate applied diluted 1:1 w/ water @ 4.5 L/m^2 (1.0 g/y^2) • may be advantageous to apply in two applications • also comes in powdered form that is mixed 1 kg to 840 L (1 lb. to 100 gal.) of water and then sprayed	• water liquor product of sulfite papermaking process, contains lignin in solution • composition depends on raw materials (mainly wood pulp) and chemicals used to extract cellulose; active constituent is neutralized lignin sulfuric acid containing sugar	• water quality impacts: none • fresh water aquatic impacts: BOD may be high upon leaching into a small stream • plant impacts: none • potential concern with spills

(continued)

Dust Suppressant Category	Attributes	Limitations	Application	Origin	Environmental Impact
Organic Nonpetroleum: Molasses/Sugar Beet Extract	• provides temporary binding of the surface particles	• limited availability	• not researched	• byproduct of the sugar beet processing industry	• water quality impact: unknown • fresh water aquatic impact: unknown • plant impact: unknown, none expected
Organic Nonpetroleum: 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, due to solubility of solids in water • difficult to maintain as a hard surface	• generally 1 treatment every few years • 10 to 20% residual solution @ 1.4 to 4.5 L/m^2 (0.3 to 1.0 g/y^2); typical application is 40 to 50% residual concentrate applied diluted 1:4 w/ water @ 2.3 L/m^2 (0.5 gal/y^2)	• distilled product of the Kraft (sulfate) paper making process	• water quality impact: unknown • fresh water aquatic impact: unknown • plant impact: unknown
Organic Nonpetroleum: Vegetable oils	• agglomerates the surface particles	• 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/y^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
Electrochemical Derivatives	• changes characteristics of clay-sized particles • generally effective regardless of climatic conditions	• performance dependent on fine-clay mineralogy • needs time to set up, i.e., 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 also used to compact the scarified surface	• typical products: sulfonated oils, ammonium chloride enzymes, ionic products	• need product-specific analysis • some products are highly acidic in their undiluted form

(continued)

Dust Suppressant Category	Attributes	Limitations	Application	Origin	Environmental Impact
Synthetic Polymer Derivatives	• binds surface particles because of polymer's adhesive properties	• difficult to maintain as a hard surface	• generally 1 treatment every few years • 5 to 15% residual solution @ 1.4 to 4.5 L/m^2 (0.3 to 1.0 g/y^2); typical application is 40 to 50% residual concentrate applied, diluted 1:9 w/ water @ 2.3 L/m^2 (0.50gal/y^2)	• byproduct of the adhesive manufacturing process • typically 40 to 60% solids	• water quality impact: none • fresh water aquatic impact: generally low • plant impact: none • need product-specific analysis
Clay Additives	• agglomerates with fine dust particles • generally increases dry strength of material under dry conditions	• if high fines content in treated material, the surface may become slippery when wet	• 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

4.3. Selecting a Dust Control Palliative

Selecting the right palliative for your application is critical. Table 4.2 is an adaptation of a method proposed by Jones and Surdahl (2014) and modified by Alaska experience (Barnes and Connor, 2014). Selection criteria based on surface coarse plastic index have been omitted from Jones' and Surdahl's original table because very few Alaska surface course materials have a measurable plastic index.

You can use Table 4.2 to create a total score for each of the six palliatives listed in the left-hand column. For each palliative listed in the left column, select the appropriate value under each of the four areas of roadway/locality characteristics (average daily traffic, climate, fines content, and geometry) and then sum the values for that palliative in the right-hand column. The palliative with the *lowest* score is tentatively selected, realizing that final selection of a palliative may be heavily swayed by other important considerations.

Table 4.2. Selecting palliatives from those previously used in Alaska (adapted from Jones and Surdahl, 2014). Selection is based on road characteristics defined in four areas.

	Area 1			Area 2			Area 3				Area 4		
Palliative	**Average Daily Traffic**			**Climate**			**Fines Content**				**Geometry**		**Sum**
	<100	100–250	>250	Wet	Damp	Dry	<8%	8–15%	15–25%	>25%	Steep Grades	Sharp Curves	
Water	7	50	50	1	7	1	50	1	7	10	7	1	
Water + Surfactant	7	50	50	50	7	1	50	1	7	50	1	1	
Salts (CaCl)	1	1	7	50	1	50	50	1	1	50	1	7	
Organic nonpetroleum (lignosulfonate)	1	1	7	50	1	1	50	1	1	10	1	7	
Organic petroleum (synthetic fluids)	1	1	7	7	1	1	7	1	7	50	7	7	
Polymer	1	7	50	7	7	1	7	1	7	10	7	7	

Notes:

- Salts may not perform well when the relative humidity is less than about 35 percent.
- If the palliative is to be stored over the winter unheated, ensure the product can withstand freezing.
- The table addresses the most common palliatives used in Alaska. If other products are being considered, refer to Jones and Surdahl, 2014.

An example for water: if the average daily traffic is less than 100, the climate is damp, the fines content is 15 to 25 percent, with flat terrain and straight roads, the sum for water would be 21. Since there are no steep grades or sharp curves, the values for the Area 4 characteristics (geometry) would both be 0. Repeat this process for each palliative and order the values from smallest to largest. The most appropriate palliative would be the one with the smallest value and the least appropriate palliative would be the one with the largest value. Ranking of palliatives according to Table 4.2 is a good starting point for the selection process. It is a guide that may require adjustment based on local conditions and additional data. For example, if corrosion is an issue, as for runways, calcium chloride and lignosulfonate would not be appropriate regardless of Table 4.2 scores. Another palliative selection aid is obtained from the U.S. Forest Service's *Dust Palliative Selection and Application Guide* (Bolander and Yamada, 1999). Compare selections made using both Table 4.2 and Table 4.3.

Table 4.3. Palliative selection Chart (from Bolander and Yamada, 1999)

	Traffic Volumes, Average Daily Traffic			Surface Material								Climate During Traffic		
				Plasticity Index			Fines (Passing 75µm, No. 200, Sieve)							
Dust Palliative	**Light <100**	**Medium 100 to 250**	**Heavy >250** (1)	**<3**	**3–8**	**>8**	**<5**	**5–10**	**10–20**	**20–30**	**>30**	**Wet &/or Rainy**	**Damp to Dry**	**Dry** (2)
Calcium Chloride	✓✓	✓✓	✓	✗	✓	✓✓	✗	✓	✓✓	✓	✗ (3)	✗ (3,4)	✓✓	✗
Magnesium Chloride	✓✓	✓✓	✓	✗	✓	✓✓	✗	✓	✓✓	✓	✗ (3)	✗ (3,4)	✓✓	✓
Petroleum	✓	✓	✓	✓✓	✓	✗	✓	✓	✓ (5)	✗	✗	✓ (3)	✓✓	✓
Lignin	✓✓	✓✓	✓	✗	✓	✓✓ (5)	✗	✓	✓✓	✓✓	✓ (3,6)	✗ (4)	✓✓	✓✓
Tall Oil	✓✓	✓	✗	✓✓	✓	✗	✗	✓	✓✓ (5)	✓ (5)	✗	✓	✓✓	✓✓
Vegetable Oils	✓	✗	✗	✓	✓	✓	✗	✓	✓	✗	✗	✗	✓	✓
Electrochemical	✓✓	✓	✓	✗	✓	✓✓	✗	✓	✓✓	✓✓	✓✓	✓ (3,4)	✓	✓
Synthetic Polymers	✓✓	✓	✗	✓✓	✓	✗	✗	✓✓	✓✓ (5)	✗	✗	✓	✓✓	✓✓
Clay Additives (5)	✓✓	✓	✗	✓✓	✓✓	✓	✓✓	✓	✓	✗	✗	✗ (3)	✓	✓✓

Legend

✓✓ = Good   ✓ = Fair   ✗ = Poor

Notes:

(1) May require higher or more frequent application rates, especially with high truck volumes
(2) Greater than 20 days with less than 40 percent relative humidity
(3) May become slippery in wet weather
(4) SS-1 or CSS-1 with only clean, open-graded aggregate
(5) Road mix for best results

4.4. Alaska Experience with Dust Palliatives

There are a large number of palliatives available, each having its essential characteristics and usage as indicted in Table 4.1. The ADOT&PF has had experience with several of the different palliatives as shown in Table 4.4.

Table 4.4. Dust palliative categories (after Bolander and Yamada, 1999) with comments on ADOT&PF experience

Palliative	Products	Applied in Alaska in the Past
Water	Fresh and saline	Yes
Salts and brines	Calcium chloride and magnesium chloride	Calcium chloride
Petroleum-based organics	Asphalt emulsion, cutback solvent, dust oils, modified asphalt emulsion	Yes
Nonpetroleum based organics	Vegetable oils, molasses, animal fats, ligninsulfonate, tall oil emulsions	Ligninsulfonate
Synthetic polymers	Polyvinyl acetate, vinyl acrylic	Several proprietary products
Electrochemical products	Enzymes, ionic products (e.g., aluminum chloride), sulfonated oils	EMC2, Permazyme
Clay additives	Montmorillonite	Yes
Mulch and fiber mixtures	Paper mulch with gypsum binder, wood fiber mulch mixed with brome seed	Polyolyfin fiber reinforcement

The palliatives most commonly used in Alaska to date have been water and calcium chloride. Recent Alaska research (Barnes and Connor, 2014) indicates a short list of palliatives deemed to be most attractive for use in Alaska. These are:

- water
- calcium chloride
- synthetic fluids
- polymers

Experimental applications of synthetic fluids and polymers have been the subject of research in Alaska for the past few years. Although these materials show much promise as useful dust control agents, there is not a sufficient history of Alaska use under various conditions to warrant further discussion in this field guide. Detailed discussion of experiments with these materials is included in Barnes and Connor (2014) and in the Eckhoff's (2012) masters thesis. A basic problem with both synthetic fluids and polymers is that they are sold as proprietary materials that are poorly defined or essentially undefined as to their composition. Obviously, it can be problematic if future changes are made to secretively protected formulas of palliatives that past research found useful.

Water is a commonly used in Alaska. It is an effective palliative but acts only short-term because of evaporation. Of the three materials remaining on the list, the ADOT&PF has accumulated significant experience only with calcium chloride.

4.4.1. Alaska Experience with Calcium Chloride

Calcium chloride has been the palliative of choice for multimile stretches of highway where dust must be dependably controlled. Many miles of gravel road are treated annually with $CaCl_2$ in Alaska. $CaCl_2$ is a strongly hygroscopic material that draws moisture directly from the air into the aggregate chloride mix and thereby dampens it. The strength and dust-free nature of the damp chloride/aggregate mixture derive from the same mechanical forces that keep a freshly watered gravel surface dust free. In the damp aggregate mixture, capillary forces bind particles together, creating apparent cohesion as when water alone is used as the palliative. This works well in surface course materials specified for use in Alaska with a fines (–#200) content higher than 10 percent.

For the Dalton Highway, the ADOT&PF typically applies 8 to 9 tons per mile to previously untreated surface course material. In years two and three, respectively, the rates are 6 then 4 tons per mile. Year five starts the cycle again, beginning with 8 tons per mile (Barnes and Connor, 2014). The rates may vary depending on aggregate type and location. Chlorides can be applied as a solid or in brine form as long as the total required amount of the salt is used.

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