COST EFFECTIVENESS
OF
SELECTED ROADWAY DUST CONTROL METHODS
FOR
EAGLE RIVER, ALASKA

FINAL REPORT

by

Matthew Reckard
Research Engineer

Alaska DOT&PF Research Section
2301 Peger Road
Fairbanks, Alaska 99709

July 1988

prepared for

STATE OF ALASKA
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
3220 Hospital Drive
P.O. Box O
Juneau, Alaska 99811-1800

TABLE OF CONTENTS

LIST OF TABLES

1. INTRODUCTION

The U.S. Environmental Protection Agency has set air quality standards for airborne particulates with diameters equal to or less than ten microns ("PM_{10}" particulates). These particulates have been correlated with respiratory illnesses. The primary standards for long term (annual) and short term (24 hour) PM_{10} concentrations are 50 and 150 micrograms per cubic meter of air, respectively.

The short term concentrations have been exceeded on several occasions in both Eagle River near Anchorage and in the Mendenhall Valley of Juneau. Consequently, the Alaska Department of Environmental Conservation has undertaken a program to determine the sources of the particulates in these areas and potential ways to reduce them. This report is part of that effort.

A previous study (1)* estimated the quantities of emissions from various sources in both areas. This study is referred to in this report as "the inventory". Roadways, both paved and unpaved, were found to be the source of substantial amounts of particulates in both cases. This report presents the final results of an effort to determine the cost effectiveness of various strategies for reducing these particulate emissions from roadways in the Eagle River area. A companion report addresses the problem in the Mendenhall Valley.

An preliminary report for this study (2) presented rough estimates of the costs and benefits of a variety of emission reduction strategies. Of the strategies presented in that report, six were selected for more detailed analysis. Three of these are strategies for unpaved roads. These include:

- The use of surface application of asphalt emulsion as a dust palliative ("road oiling")
- The use of calcium chloride for the same purpose
- Paving

*numbers in parentheses refer to references listed in Section 7.

The other strategies apply to paved roads. These include:

- Paving driveways and other areas near paved roads (to reduce the amount of mud tracked onto the paved roads)
- Using "cleaner" sand as a winter traction aid
- A combination of the use of less sand and more effective spring cleanup

Strategies which were considered in the initial report but have not been given further examination include:

- Watering paved and unpaved roads during dry periods
- Using "Coherex" (a proprietary petroleum-derived dust palliative)
- In-place mixing of asphalt emulsion with the top several inches of roadway
- Substituting rock salt for winter traction sand
- Substituting calcium/magnesium acetate (CMA) for winter traction sand
- Vehicle speed restrictions on paved and unpaved roads
- Using heated sand to reduce the quantity of traction sand
- Regraveling unpaved roads at regular intervals

2. DISCUSSION OF THE PROBLEM

Air quality violations in Eagle River have been limited to two times of the year: in the spring following breakup, and in the fall near the end of October. While two springtime violations occurred in 1986, none have been recorded in the past two years. There were three autumn violations recorded in 1985, four in 1986, and one in 1987. There have been a number of readings approaching the standard during all of these periods.

All of the violations have been recorded at a single site adjacent to the Old Glenn Highway in the downtown area. Dust monitoring on the perimeters of Eagle River has found little particulate matter, indicating that the dust is being generated within the community. Monitoring at additional sites within Eagle River has not recorded any violations to date (3). It is therefore possible that the problem area is quite limited in size. This should become clearer in the future as additional monitoring is performed.

Examination of weather records from nearby stations indicates that high readings in springtime may be associated with windy weather; this does not appear to be the case with the autumn violations. Loose material subject to being windblown may remain on all surfaces as the snow melts. This is particularly true of sanded streets, and may help account for the high readings in spring. The reason for the more severe autumn problem is not clear. Road maintenance crews normally try to grade unpaved roads just before freezeup, so they will be in good condition during the winter. This leaves the road surface loosened. It has been suggested that a dry period immediately following this extensive grading might result in large amounts of dust generation on unpaved streets.

3. LIMITATIONS OF THE STUDY

Both the costs and the benefits discussed in this report are narrowly defined. The costs given are only immediate construction or treatment costs; indirect costs are ignored. Calcium chloride, for example, increases corrosion of vehicles (although probably less when used for dust control than for melting snow). The calculated benefits are limited to air quality as measured by PM_{10} levels. Other benefits, such as lowered vehicle operating costs which result from paving roads, have not been considered.

Neither the estimates of costs or emissions reductions presented in this study are precise. J.M.Hoover, a leading authority on road dust control, has lamented that "quantitative measurements of dust from roads have been practically nil. Yet it is quite impossible and borders on the absurd to assess the economics and lasting value of dust palliation methods without monitoring the dust" (4, p. 27).

This uncertainty was recognized in the emissions inventory, on which this study relied heavily. The inventory used the "best available techniques", yet for some important emissions categories this provided only "generally good order-of-magnitude" accuracy (1, pp. xii-xiii).

Much of the difficulty in making estimates of emissions generation and reduction is that both are very dependant on site-specific soils types, weather, and other factors.

The costs of dust reduction methods are also variable. Road construction costs, for example, are dependent on local soils and drainage conditions, and to examine these on an individual street basis would far exceed the scope of the study. Emissions vary with traffic volume, yet traffic counts could not be performed on all of Eagle River's streets.

Estimates of emissions reductions were made for this report on an annual basis rather than a seasonal one. It should be noted that the best procedure for reducing annual emissions may not be the best for reducing the emissions in a particular season. Changes in the type and quantity of winter traction sand, for example, are more likely to affect springtime emissions levels than those in the fall.

4. SUMMARY OF FINDINGS

The estimated costs and emissions reductions are shown in Table 1. The figures for techniques applicable to unpaved streets are given on a per mile basis, while those for paved roads are given on an areawide basis. It should be noted that the emissions reductions listed are not additive, that is if two strategies are implemented simultaneously the benefit will not necessarily be the sum of the benefits of the two individually.

The figures shown for the paving of unpaved streets are based on paving a limited number of streets with higher than average traffic volumes. The figures shown for oiling or calcium chloride application, on the other hand, are based on an "average" unpaved street. The cost effectiveness of the latter two techniques would be more favorable if they also were applied only to selected busier streets.

Of the options considered for paved streets, those which deal with sand used for winter traction would have a greater effect on reducing springtime emissions than those in the fall. Their effectiveness at reducing fall season emissions (compared to paving driveways, etc.) would thus be less than they are for reducing annual emissions, which is reflected in the table.

The paving of driveways, lots, and street approaches to the main paved roads was examined for this report. The possibility of oiling or applying calcium chloride to these areas, however, was not. Based on the favorable cost effectiveness of these techniques as applied to unpaved roads, however, this might be a cost effective dust reduction strategy.

Most of the dust palliating effect of both oil and calcium chloride is lost when the treated road is regraded. Some of the effect of calcium chloride is regained after a short period, although this tends not to be the case with oiled roads. The dusty road conditions created by grading just prior to freezeup thus might still occur, especially on oiled roads. It has been suggested that these dusty conditions are a major cause of the autumn air quality violations in Eagle River. If this is true, oil and calcium chloride may not be as effective at reducing the number of autumn violations as they are at reducing the total annual emissions.

This tends to make paving a more attractive option. In this regard, it should be noted that much of the paving planned for Eagle River is in the immediate vicinity of the monitoring site where air quality violations have been recorded. As noted above, it is possible that the air quality problem area is limited to a fairly small area near this site. If this is true, the planned paving may be very effective at reducing the fall violations.

Furthermore, the Eagle River Road Service Area's use of cleaner sanding material, the reduced amount of sand used, and the introduction of spring street sweeping may have already had a substantial effect on spring dust levels. This reduction is indicated in Table 1, and may be largely responsible for the lack of springtime air quality violations in the past two years. The steps already taken or planned in Eagle River, therefore, may go a long way towards eliminating the dust problem in the community.

Table 1: Costs and Benefits of Selected Roadway PM_{10} Emission Control Techniques for Eagle River

Technique	PM_{10} Emissions Reduction (tons/year)	Cost ($/year)	Cost per ton ($)
Unpaved Streets			
1. Paving - 2" hot asphalt pavement (per mile) (Note 1)	130.0	17,850	137
2. Paving - Bituminous surface treatment (per mile) (Note 1)	130.0	13,650	105
3. Oiling Streets (per mile) (Note 2)	76.2	3,675	48
4. Calcium Chloride Application (per mile)	76.2	2,580	34
Paved Streets			
1. Paving Driveways, Lots, and Street Approaches (Note 3)	310.0	33,700	109
2. Use of Cleaner Sand	84.0	5,000	59
3. Reduced Sanding/Better Cleanup (Note 4)	622.0	-0-	-0-

Notes:
1. Figures are based on paving about 20% of unpaved roads in the inventory area (see text). Cost effectiveness would be reduced for paving of additional, less travelled roads.
2. Figures are based on the use of CSS-1 emulsified asphalt. If waste oils were available, costs would be reduced.
3. Figures are for paving areas adjacent to the Old Glenn Highway, Eagle River Loop and Eagle River Road only (see text).
4. Figures are for actions already taken in the past two years (see text).

5. DETAILED FINDINGS

5.1 PAVING GRAVEL ROADS

To engineers a "pavement structure" usually means not only a road surface but the base and subbase layers of gravel. The word "pavement" as used in this report means just the waterproof road surfacing. Almost all pavements in Alaska are one of two types.

The least expensive of these is a "bituminous surface treatment", or BST. To build the most common type of BST, a layer of asphalt thinned with water ("emulsified asphalt") or asphalt thinned with a light petroleum product such as kerosene ("cutback asphalt") is sprayed onto a prepared gravel surface. Gravel screened to a uniform size ("chips", usually about 1/2 inch in diameter) is then spread over the asphalt and pressed into it with compactors. The asphalt hardens as the thinning agent evaporates out of it. A second layer of asphalt is then sprayed and a layer of smaller chips (about 1/4 inch in diameter) is applied. The resulting pavement is thin, but can be quite durable under light traffic if the underlying road embankment is strong and well drained. The BST described is the most common type in Alaska, but other types are possible using different size stones, a different number of layers, etc.

The other principal type of pavement used in Alaska is a "hot asphalt pavement", or HAP. This is also known by a confusing array of other names, such as asphalt cement concrete ("AC" or "ACC") or simply "hot mix". In this type of pavement the aggregate - a mixture of different sized sands and gravel - and the asphalt are both heated and mixed together in a central plant. The resulting mix is then trucked to the construction site and spread on the prepared roadway with a paving machine. The new pavement is compacted ("rolled") while still hot, and hardens upon cooling. The pavement layer is normally two to three inches thick, but in heavy traffic areas several layers can be placed to build up a thicker pavement. For the gravel roads in residential areas considered in this study, however, a minimum thickness would be needed.

Pavement Costs

It was hoped that about 4-1/2 miles of road would be "strip paved" in Eagle River for $400,000 in 1988. The engineer's estimate for the final design of this work, however, is $687,000 (5), or about $153,000 per mile. This is a fairly low cost for road paving, which is due to several reasons. Most importantly, the roads have been previously upgraded, and little new gravel will be added to them at this time. In addition, the roads are generally narrow; the average pavement width will be less than 24 feet. Some of the preparatory work (ditch cleaning, etc.) will be performed under a maintenance contract; the cost of this is not included in the above figures. Design and surveying work is also being kept to a minimum.

The Eagle River program, then, will include little other than a 2" layer of HAP. No significant improvements will be made to the road structure or drainage. This minimization of initial costs may result in higher than average maintenance costs on these roads in the future (5).

In contrast to the Eagle River program is that in the Mendenhall Valley near Juneau, which is a similar residential community. Three "paving" projects will be built there in 1988 for about $525,000, including design, inspection, and administrative costs. The total amount of pavement, however, is equivalent to only about 1-1/3 mile of 24' wide roadway. These much higher "paving" costs, however, include substantial new drainage improvements, a lot of utility work (adjusting manhole elevations etc.), replacement of old culverts, seeding of bare soil, excavation, and miscellaneous other work.

These examples illustrate the difficulties of making a general estimate of paving costs. The examples do not even include many other expensive road improvements that are often made at the same time as paving. As long as the road is being paved, the argument goes, why not widen it? Why not straighten it? Why not add curbs and gutters, or sidewalks, or median strips? Why not plant trees? It is thus often difficult to isolate "paving costs" from historical records.

The table below presents estimated unit costs for work items associated with paving. The figures were developed from estimating factors used by the Municipality of Anchorage (6). The cost of a BST is an exception; the figure cited is about 60% of the cost of a 2" HAP, an approximate ratio determined for Alaska in a previous DOT&PF study (7). The costs of engineering, inspection, and quality control by the contracting agency is estimated as 30% of the basic contract costs, and is included in the figures in the table.

Table 2: Unit Costs for Residential Street Paving

ITEM	APPROXIMATE COST ($/square foot)
1. Existing roadbed preparation	0.09
2. 4" crushed gravel base course	0.29
3. Bituminous surface treatment (BST)	0.55
4. 2" hot asphalt pavement (HAP)	0.92
5. Adjust manholes, catch basins etc.	0.25 - 0.45
6. Excavation of poor material, per foot depth	0.30
7. Common gravel fill (borrow), per foot depth	0.98

As the table indicates, the cost of the pavement itself may be only a fraction of the total project costs. As a minimum, the existing roadbed is normally prepared and a new base layer of several inches of high quality crushed gravel placed on the road. As noted above, however, little new gravel will be used this year in Eagle River.

The minimum paving costs including a new base course (items 1, 2, and 3 from the table) are equivalent to about $98,000 per mile for a BST 20 feet wide, which is a rather narrow pavement for a two lane road. The Municipality of Anchorage rarely uses BSTs, however, and normally paves at least a 24' width. A 24' wide HAP, using the figures from the table, would cost a minimum of about $165,000 per mile.

major structural road improvements may also be needed. Thin pavements, especially BSTs, have very little strength in themselves. Pavements like this placed on thin, soft, wet embankments in Alaska have fallen apart completely during the first breakup. It may thus be necessary to raise the grade by as much as two or three feet, or to remove this much poor soils and replace them with better material. Estimated unit costs for such work are included in the table. New culverts, ditches, and other drainage improvements may also be necessary. The need for and cost of such improvements is very site specific and cannot be estimated on a unit cost basis. Such work, however, can cost several times as much as the pavement itself.

Utilities within the roadway add to the cost of paving, as in the example of the Mendenhall Valley. Not only are manholes, catch basins, valve boxes, and the like difficult to work around, but it may be necessary to adjust their height or rebuild them entirely. This too can be very expensive.

Few if any of the gravel surfaced roads in Eagle River, however, have this type of utility improvements. Drainage is also generally fairly good in Eagle River. A typical cost for upgrading and paving a road in Eagle River might thus be about $265,000 per mile for a 24' wide surface. This includes $100,000 per mile in addition to the "minimum" cost given above. This amount would, for example, pay for excavation of 1' of poor material and a new 6" borrow layer (in addition to a 4" base and a 2" HAP) throughout the entire mile of road. It is more likely, however, that the additional money would be spent on a combination of excavation and borrow in selected areas, ditch and culvert work in others, etc.

For this report, it is assumed that $140,000 of the $265,000 is a permanent improvement while the remaining $125,000 has a 15 year life (that is the road will need repaving for $125,000 per mile every 15 years). Assuming a 4% real cost of money these capital expenditures are equivalent to an annual cost of about $16,850 per mile. Increased maintenance costs on a paved road may add about $1,000 to this figure, for a total cost of $17,850 per mile per year. If a BST were used instead of HAP, this might be reduced to about $13,650 per mile per year.

Dust Reduction from Paving Streets

The inventory figure for PM_{10} fugitive dust emissions from paved local streets, adjusted for the sanding and sweeping changes made by the Service Area (see the "Reduced Sanding/Better Cleanup section of this report), is 313.5 tons per year, or 0.031 lb/VMT. The corresponding figure for unpaved roads is 0.689 lb/VMT. The implied emissions reduction from paving is 95% for each vehicle mile travelled.

The inventory's PM_{10} emissions estimate for unpaved roads averages 95.3 tons per mile annually. A 95% reduction from paving a mile of "average" gravel road would therefore be 90.5 tons annually. The emissions are dependent on traffic levels, however, and the first gravel roads to be paved will generally be those with heavier than normal traffic. Traffic counts have not been made on the local streets in Eagle River, however, so precise estimates for particular streets cannot be made.

As stated above, it was hoped that 4 1/2 miles of streets in Eagle River would be paved this summer, although budget constraints may reduce this figure. There are more than three additional miles of street paving within the inventory area in various stages of design. The combined total is a little over 20% of the unpaved mileage in the inventory area, but probably carries closer to 30% of all the traffic on unpaved roads. Assuming the latter figure is correct and that a 95% emissions reduction is achieved, the average reduction for the roads currently planned for paving would be about 130 tons per mile annually, which is the figure used in this report.

This estimate is in reasonable conformance for results found in other locations. On unpaved roads in Iowa, for example, dust generation was found to be 1 ton/mile/year/vehicle of average daily traffic (4). Assuming that 42% of the dust generated is PM_{10} sized material (as was done in the inventory) the 130 tons per mile emissions reduction estimate implies an average daily traffic of about 325, which is reasonable for the busier local streets under consideration.

5.2 ROAD OILING

Road oiling can refer to a range of treatments using various materials. At its most extensive it refers to what was termed an "emulsion road mix" in the interim progress report prepared for this study (2). Here the top three or four inches of a gravel road are loosened, bladed into a windrow, and heavily sprayed with an oil, a cutback asphalt, or an emulsified asphalt. The material is then worked back and forth in the road to mix it thoroughly, spread and shaped to crown and grade, and then compacted. The result can appear similar to a pavement.

In this report, however, road oiling refers to a simple process in which a relatively small amount of oil is sprayed onto a damp road surface. This is done immediately after grading, while the surface gravel is still somewhat loose, so that the oil will penetrate further.

In the past, waste oil (used crankcase oil, etc.) was frequently used for this purpose. This was both cheaper than using new oil and a convenient way to dispose of a waste product. Toxic materials were sometimes present in waste oil, however, creating a health hazard when sprayed on roads (the entire town of Times Beach, Missouri had to be abandoned for this reason). Waste oil must now be extensively tested before it can be used on roads, adding considerably to its expense. It is rarely used on roads any more. Therefore only the use of new products are considered in this report (specifically slow-setting asphalt emulsions).

Road Oiling Costs

The Anchorage Public Works Department does a considerable amount of road oiling, which it refers to simply as "dust control". They apply 0.3 gallons of CSS-1 emulsified asphalt per square yard of road surface early in the summer. This provides adequate control for the summer on roads with relatively little traffic (8).

The Public Works Department estimates the labor and equipment costs to apply oil at about $425 per mile (9). This does not include the cost of grading the road, since it is assumed that the roads would be graded whether they were oiled or not. CSS-1 emulsified asphalt costs about $185 per ton in Anchorage (10). For a treated surface 24 feet wide, this is equivalent to about $3,250 per mile at 0.3 gallons per square yard.

Dust Reduction from Road Oiling

A number of sources discuss the use of road oiling as a dust suppressant (e.g., 4, 11, 12, 13). Most quantitative testing has been made at industrial sites with heavy truck traffic, which is not representative of the roads under consideration. They indicate, however, that results can be variable. Road oiling at a rate of 1/2 gallon per square yard on a low traffic public road in Arizona was found to be 96% effective at controlling dust one month after application, and was still 95% effective five months later (12). Another source (13) cites a test on a public road where oil mixed to a depth of several inches continued to be over 95% effective after several weeks.

Due to the reported variability of results and the smaller application rate assumed for this study, it is assumed that only 80% effectiveness would be achieved in Eagle River. Average PM_{10} emissions for unpaved roads were found to be 95.3 tons per mile annually. An 80% reduction is therefore equal to 76.2 tons per mile annually.

5.3 CALCIUM CHLORIDE

Calcium chloride is a salt which has been widely used as a dust control agent on unpaved roads. It retards evaporation of water from the road surface and will also absorb water from the air at relative humidities above about 30%. Much of the dust reduction is thus achieved by keeping the road surface slightly damp. It also acts as a binder, producing a smooth, hard surface (although one which can still be graded if necessary).

Calcium chloride is supplied in flake or pelletized form. It can be spread in this form by sanding equipment, in which case enough water must be sprayed on the road to dissolve the salt. It may also be dissolved in water and applied with a water truck through a spray bar. It is normally applied immediately after road grading, and the road is usually compacted with a roller after treatment.

Calcium chloride has been used extensively in the Yukon Territory on higher traffic gravel roads. It has also been used for several years on city streets in Haines and some parts of the Dalton Highway.

Calcium Chloride Costs

On high speed roads (e.g., the Dalton and Alaska Highways) eight to ten tons of calcium chloride per mile are often used annually for dust control (14,15). About half this much has proved adequate on slower speed roads. About 3-1/2 tons per mile are used in Haines, with selected areas requiring a second treatment at this rate late in the summer (16). For this report the 3-1/2 tons per mile rate is assumed; it is further assumed that 20% of the roads would require two applications per year. Recent prices for calcium chloride delivered to DOT&PF maintenance stations have been about $450 per ton in 2,000 pound bladders and about $500 per ton in 80 pound sacks (17). The latter price is assumed here, yielding an average material cost of $2,100 per mile annually.

Labor and equipment costs are estimated to be about $400 per mile per application, or an average of $480 per mile annually. This is based on typical "Rental Rate Blue Book" (18) costs for two water trucks and a roller, two operators at $25 per hour (including benefits, overhead, etc.) and a foreman at $30 per hour. A grader and a third operator would also be required, but these costs are not counted as it is assumed that the road would be graded anyhow. This is the crew size and equipment used in Haines. Productivity is assumed to be 2 crew-hours per mile, also about what has been reported in Haines (16) and slightly less than road oiling crew productivity estimated for Anchorage (9).

Dust Reduction from Calcium Chloride

A number of sources discuss the use of calcium chloride for dust suppression. Most quantitative measurements have been made at industrial sites whose conditions are not similar to those on local roads in Eagle River. One source (11) which reports on a calcium chloride test on a low traffic public road indicates that over 90% effectiveness was maintained for an extended period. Another source (13) cites a test where calcium chloride treatment of a public road was 74% effective after several weeks. The effectiveness in Haines has not been measured quantitatively, but it is reported that the treatment gives "almost complete" dust control (16). For this report it is assumed that calcium chloride effectiveness is 80%, the same as road oiling. This is equivalent to 76.2 tons per mile of PM_{10} emissions reduction annually.

5.4 PAVING DRIVEWAYS, LOTS, AND GRAVEL STREET APPROACHES

Substantial dust can be generated on paved roads if they are dirty from having mud and debris tracked onto them from unpaved areas. The calculations made for the emissions inventory for Eagle River, for example, indicated that dust generated per vehicle mile travelled on dirty, sanded paved roads in springtime are about 1,000 times as great as they are on the same roads after sweeping (and about a quarter as great as for unpaved roads). While this estimate may be exaggerated, it is clear that if "carryout" mud can be reduced dust emissions on paved roads will be also greatly reduced.

One strategy for reducing dust emissions, then, is to pave what are currently unpaved approaches to the high traffic roads in the area. These approaches include driveways, parking lots, and intersecting streets. Paving the intersecting streets for the first 100 feet, for example, could greatly reduce mud carryout, although some amount of mud may be carried for as much as 1000 feet (19). Similarly, it might not be necessary to pave all of a large unpaved parking lot, but rather that portion which is adjacent to the paved high traffic street.

The streets in Eagle River included in this "high traffic" category for this report include Old Glenn Highway between Eagle River Road and the North Eagle River Access Road, Eagle River Loop Road, and Eagle River Road between the Old Glenn Highway and Eagle River Lane.

Cost of Paving Driveways, Lots, and Gravel Road Approaches

The cost per square foot of placing pavement on small areas like driveways is more than that for paving entire roads. On the other hand, much less associated work is generally needed since strength requirements are less and drainage is usually less of a problem. Typical costs to provide some gravel base material and pave drives and small lots are about $1.50 to $2.00 per square foot (20,21). For a small residential driveway (12' wide and 60' long) this translates to about $1250.

For this report it is assumed that paving costs are $1250 for small driveways, $2500 for larger, commercial driveways, and $5000 for an apron on a gravel road extending 100 feet back from the paved road. Paving parking lots is assumed to cost $1.75 per square foot. An inventory made of these features along the major paved collector roads in Eagle River is summarized below.

Table 3: Inventory of Unpaved Areas Adjoining Major Paved Roads in Eagle River

Road	Number of Unpaved Approaches Residential	Commercial	Streets	Approximate area of unpaved lots (ft_2)
Eagle River Road (Old Glenn Highway to Eagle River Lane)	4	5	5	70,600
Eagle River Loop (Old Glenn Highway to Eagle River Road)	11	11	8	139,000
Old Glenn Highway (Eagle River Road to North Eagle River Access Road)	1	4	7	158,400
Total	16	20	20	368,000

The cost to pave all these areas is estimated at $814,000, almost 80% of it for the unpaved lots. Some of these lots do not appear to be in use, however. Moreover, many are very large and it would be unnecessary to pave them entirely to prevent tracking mud out onto the paved roads. By limiting paving areas to 10,000 square feet per lot and not counting unused ones the lot area to be paved would be reduced by over two thirds, and the total cost for paving the lots, drives, and street approaches would be reduced to about $375,000. Assuming a 4% real cost of money and a 15 year life, this is equivalent to a $33,700 annual cost.

Dust Reduction from Paving Drives, Lots, and Street Approaches

The inventory estimated fugitive dust from paved roads to be about 1717 tons per year, of which sanding material is estimated to have contributed

571 tons per year (see the "Reduced Sanding/Better Cleanup" section of this report). The remainder, 1136 tons per year, is assumed to come principally from mud carryout.

The program considered here applies only to unpaved areas adjoining the major paved roads - The Glenn Highway, the Old Glenn Highway (as far as Northgate Drive), Eagle River Loop, and Eagle River Road (as far as Eagle River Lane). Emissions were estimated based on vehicle miles travelled; about 70% of the vehicle miles travelled on paved roads are on these major streets. Thus emissions due to mud carryout on these major roads is estimated to be about 795 tons per year.

It is difficult to estimate how effective the suggested program would be at reducing mud carryout; no good guidelines have been found in the literature. If one assumes that it would reduce mud tracked onto these major roads by 75%, the reduction in PM_{10} emissions would be 596 tons per year.

In reality this program would have no substantial effect on emissions from the (new) Glenn Highway, which accounts for almost half of the vehicle miles travelled on the major roads considered here (22). The argument can therefore be made that mud carryout onto the Glenn Highway should neither have contributed to the emissions inventory nor can it be reduced by the program considered here. If calculations are adjusted based on this reasoning, the initial inventory emissions were overestimated by 381 tons per year, while the emissions reduction listed above is overestimated by 286 tons. An adjusted emissions reduction figure of 310 tons is used in this report.

5.5 CHANGING SANDING MATERIAL SPECIFICATIONS

Dust sized particles may be present in sanding material when it is applied, or they may be produced by the breakdown of larger particles under the effects of traffic. The harder and more durable the material, the less likely it is that the latter will occur. Unfortunately, standard laboratory tests for durability apply only to coarse sand and larger particles. Durability specifications therefore would have no influence on most of the sanding material applied in Eagle River (unless new tests were devised). Harder material, moreover, would be more abrasive to pavements, producing more dust-sized particles from that source. It is thus unclear that durability specifications would have a large effect on airborne particulates.

Size specifications (gradations) do apply to small particles, however, and can be changed. Testing is normally performed by passing material through a set of sieves, the smallest of which (#200) has an opening size of 75 microns. In order to test for smaller particle sizes (such as 10 microns), a different and more expensive hydrometer test must be performed on the finer material. If little material smaller than 75 microns is allowed, of course, there will be even less material smaller than 10 microns present, so the hydrometer test is probably unnecessary for dust control purposes.

It should be noted that prior to the winter of 1986/87 contractors for local road maintenance in Eagle River supplied their own sand. The gradation of that material is not known, but it is said to have been a much "dirtier" material than the material now being supplied by the Eagle River Road Service Area. It is relevant in this regard to note that there have been no springtime air quality violations recorded in Eagle River since the Service Area began supplying their own, cleaner sanding material.

Another possible change to sand specifications is to require fractured (sharp-edged) particles. Such particles were found to produce better traction in a previous DOT&PF study (26). The material used last winter by the Service area generally had sharp, angular particles. Some of their reduction in sand use has been attributed to the greater effectiveness of the angular material (25). Standard tests for fractured material, however, apply only to particles larger than 1/4 inch, so a fracture specification would have no effect on two-thirds of the Service

Area material, which is smaller than that. The DOT&PF requires that at least 95% of their material be smaller than 1/4 inch, so a fracture specification would be virtually meaningless in this case. They use then smaller material because larger material is more likely to cause broken windshields on higher speed roads (26). Fracture requirements, then would have little effect unless a new test were devised.

Cost of Cleaner Sanding Material

The size specifications for sanding material used by the Eagle River Road Service Area and the DOT&PF in the Anchorage area are shown in Table 4. The material actually used by the Service Area in the past winter generally had about 6% material retained on the #200 sieve ("fines") and cost $10 per ton, delivered and mixed with enough salt to keep the stockpiles from freezing (8). The DOT&PF contract price last year was $8.79 per ton without delivery and not mixed with salt (23). Some of the material actually received had 3% fines; there was a price penalty for this out-of-spec material. The prices between the two materials are not directly comparable since one was mixed with salt and delivered while the other was not.

The DOT&PF material is a fairly fine sand which probably requires washing in order to reduce fines to the level specified. It would, indeed, be difficult to get such a sand much "cleaner". Coarser material (e.g., pea gravel) can be produced with practically no fines. The DOT&PF has found, however, that such coarser material does not perform as well as a traction aid on their higher-speed roads. It is thus unlikely that the DOT&PF could use much cleaner material without sacrificing traffic safety.

Table 4: Sand Specifications - Eagle River

Sieve Size	Percent Passing: Eagle River Road Service Area	Percent Passing: DOT&PF
1/2"	100	
3/8"	80-90	100
#4		95-100
#16	30-50	
#30	15-30	30-60
#200	0-7	0-2

Note: The openings on #200 sieve are about 75 microns

The Road Service Area, however, could obtain somewhat cleaner material. This would almost certainly require washing the material, a process which has been estimated to cost $0.50 per ton or less assuming the supplier already has the necessary equipment (24). The current supplier, however, is not set up to wash sand; the cost to have that done has been estimated at $0.75 to $1.00 per ton (25). The Road Service Area used about 3,350 tons of sand in Eagle River last winter, which was less severe than normal. If one assumes that 5,000 tons would be used in a "normal" year, the cost to switch to cleaner (washed) sand would thus probably be $5,000 per year, perhaps less.

Dust Reduction from the Use of Cleaner Sand

The sanding material used last winter by the Eagle River Road Service Area contained about 6% "fines", while that used by DOT&PF in the area contained about 2%. Estimated average use of sand by the Service Area is 5,000 tons annually; a reduction in fines content to DOT&PF levels would thus mean 200 tons fewer fines. Assuming, as the inventory does, that

42% of the fines are PM_{10} size, PM_{10} content would be reduced by 84 tons. This is the reduction assumed in this report.

In reality, total available fines would be greater than 2% as some of the sanding material will break down under traffic. Not all of the fines become airborne, however. The magnitude of these two effects is difficult to estimate; it is assumed here that the two counterbalance each other.

5.6 REDUCED SANDING AND BETTER CLEANUP

The less sand that is used as a winter traction aid, and the sooner it is cleaned up in the springtime, the smaller the dust emissions from this source will be.

Prior to the last winter, road sanding material for local streets in Eagle River was provided by the maintenance contractor, who was paid both for the material and its application according to the amount that was used. Furthermore, the material used at that time was of poor quality, and a lot of material was required to provide effective traction (25).

The Eagle River Road Service Area now provides the contractor with sanding material, and has obtained a better quality material for this purpose. They also have increased snow plowing efforts to clear roads down to a bare surface. The result has been a large reduction in the amount of traction sand needed. In the winter of 1986/87, about 12,500

tons of sand was used on the local streets in Eagle River. Only about 3,350 tons were used in the past winter (8). Part of this reduction, however, is attributed to the past winter's weather, which had less freezing rain and other icy conditions than normal. Had more "normal" conditions prevailed, perhaps 5,000 tons would have been used.

Another change made by the Service Area is the introduction of a spring street sweeping program, which began two years ago. These changes have undoubtedly reduced dust emissions and may be partly responsible for the absence of spring air quality violations during the past two breakup seasons.

Both the Service Area and the DOT&PF now feel they cannot make further substantial reductions in sanding without reducing traffic safety and incurring liability for negligence.

Both also claim that they are starting street sweeping as early as they can. The sweepers use water to reduce the dust they generate (and protect the fans on vacuum units), so they cannot be used in freezing temperatures. Some roads in Anchorage which were swept too early the past spring "became an ice rink" and had to be resanded to reduce the skidding hazard (23). It would be possible to operate tractor or loader mounted brooms (which do not use water) before thawing temperatures prevailed to remove some sand and debris not frozen in place. Since dust is generally not a problem this early in the year, however, this procedure was not considered for this report.

It has been noted that driveways are generally not swept in the spring street sweeping operations, and suggested that road crews might sweep off an apron area of driveways. This might result in a modest reduction in the amount of material tracked out onto roadways for a relatively modest cost. This possibility was not examined in detail for this report.

Cost of Reduced Sanding and Better Cleanup

The reduction in sand use by the Eagle River Road Service Area has undoubtedly resulted in a cost savings, but the exact amount of this is not entirely clear. The program introduced in the past year may reduce sand use by 6,000 to 7,000 tons annually in a year with a "normal" winter. Part of the reason for this, however, is that they are now using a better quality, more expensive material. The price of the previously used material included its application as part of the maintenance contract, so the cost of the material itself is not known with certainty. The net savings in materials costs, however, may exceed $25,000.

The Service Area's labor and equipment cost for applying sand was considerably less last winter (about $65,000) than had been budgeted based on prior years' experience (about $110,000) (25). Much of this reduction, however, may have been due to last winter's weather rather than to changes in the sanding program. In a "normal" winter the labor and equipment requirements might not be much less than that in years prior to the changes in the sanding program. The Service Area, in other words, is sanding as often and may be using nearly as much labor and equipment time as previously, even though the volume of sand used has been reduced.

The past spring was only the second in which the Eagle River Road Service Area has performed spring street sweeping. The cost of this was about $8,000 this year. The cost of more intensive plowing efforts is not clear, but was relatively modest (25). The net change in costs due to the changes in plowing, sanding and sweeping by the Service Area in the past two years is thus probably quite small; a net savings may, in fact, have occurred. Further changes in the Service Area's procedures were not considered for this report.

DOT&PF maintains that they have not used excessive amounts of sand in the past, and that to reduce their sanding program would create a safety hazard. They also state that in the past year Eagle River was made a top priority in their spring street sweeping program (23). This, of course, would have little to no effect on the cost of the sweeping. No additional changes in the DOT&PF's sanding and sweeping procedures were considered for this report.

Dust Reduction from Reduced Sanding and Better Cleanup

Sand use by the Eagle River Road Service Area and the DOT&PF used to be perhaps 17,000 tons in an average year, most of it the "dirty" material used by the Service Area contractor. Assuming the weighted average fines content was 8%, that 42% of the fines were of PM_{10} size (as the inventory assumed), and that all of the PM_{10} material became airborne, road sanding material generated about 571 tons of PM_{10} particulates. This is about a third of the 1716.9 tons of particulate emissions for paved roads estimated in the inventory. This is only an estimate; in reality further fines would be generated by breakdown of sanding material under traffic, but not all of the fines would become airborne. The tradeoff between these two factors is unclear.

Sand use has been reduced to about 10,000 tons per year, and fines content has been reduced to an average of perhaps 4%. With other assumptions unchanged, this implies PM_{10} emissions of 168 tons annually, a reduction of about 403 tons annually. It further implies that only about 1/8 of the remaining emissions from paved roads are due to the sanding material.

The sweeping initiated by the Service Area affects about half of the paved roads in the area, but these roads have less traffic than the DOT&PF maintained roads. The inventory estimates that of the vehicle miles travelled on paved roads, about 30% are on the "local" paved roads. The inventory assumed that "dirty" road conditions prevailed for 45 days annually. Assuming that the new sweeping program reduces this number by half on the local paved roads, this implies a reduction in PM_{10} emissions (already reduced by changed sanding practices) of 219 tons annually.

Total annual PM_{10} reduction from the procedural changes already made (less sanding, cleaner material, and local road sweeping) is thus estimated at 622 tons annually.

6. Short term (24 hour) Emissions Reductions

Short-term particulate levels, especially in the fall, are of primary interest in Eagle River (see Section 2). An attempt is therefore given here to evaluate the effects of the selected treatments on "worst-case" 24-hour PM_{10} emissions.

These "worst-case" emissions as determined by the inventory are shown in Table 5. As the table shows, the inventory found that the worst season by far for emissions is spring. Dust monitoring records, however, clearly indicate that the worst problems at the Parkgate site occur in late fall. The inventory, then, does not appear to adequately explain short term emissions in Eagle River. A possible explanation of the high levels of particulates in the fall is discussed in Section 2.

Given that there is no accurate quantitative understanding of short-term emissions, quantitative estimates of reductions in these emissions will be rough at best.

It is also worth noting that the inventory's estimate of "worst-case" fall emissions indicates that only one-third of these are due to fugitive dust from roads. If this is indeed the case, then air quality standards violations might not be drastically reduced even if roadway emissions were entirely eliminated.

TABLE 5

WORST-CASE 24-HOUR EMISSIONS BY SEASON
EAGLE RIVER

(tons/day)

Source Category	Spring		Summer		Fall		Winter	
	PM_{10}	TSP	PM_{10}	TSP	PM_{10}	TSP	PM_{10}	TSP
Paved Streets - Fugitive Dust	34.42	82.39	1.02	2.73	1.02	2.73	1.02	2.73
Unpaved Streets - Fugitive Dust	18.96	42.13	18.96	42.13	18.96	42.13	0.26	0.75
Windblown Dust*	39.70	79.41	N	N	39.70	79.41	N	N
Woodstoves and Fireplaces	0.06	0.06	N	N	0.06	0.06	0.24	0.24
Others	0.87	1.13	0.77	1.03	0.87	1.13	0.77	1.03
TOTAL	94.01	205.12	20.75	45.89	60.61	125.46	2.29	4.75

N = Negligible
* These estimated emissions do not include the emissions generated in the Matanuska and Knik river valleys.

Note: This table is reproduced from the inventory report (Reference 1).

Given these caveats, estimates of emissions reductions under "worst-case" spring and fall conditions were made. These are summarized in Table 6 and are based on the following:

6.1 Paving Gravel Roads

The inventory's estimate of fugitive dust PM_{10} emissions on unpaved local roads is 1.367 lbs. per vehicle mile travelled. The estimate for paved local roads in clean condition is 0.433×10^{-3} lb/VMT. The implied reduction of 99.97% was used for fall conditions.

The inventory's emissions estimate for local paved roads when covered with sanding material and other debris is 0.330 lb/VMT. Reductions already made in Eagle River in the type and quantity of sanding material used result in a revised figure of 0.253 lb/VMT (see Section 5.6). This is 81.5% less than the figure for gravel roads; this reduction was used for spring conditions. Note that emissions reduction due to Eagle River's improved spring cleanup procedures have not been accounted for here, as it is assumed that the "worst case" will occur before street sweeping is accomplished.

6.2 Road Oiling

PM_{10} emissions reduction from road oiling was assumed to be 80% for the long term estimate. The "worst case", however, is assumed to occur after fall road grading, which destroys most of oiling's beneficial effects. Emissions reduction of only 20% was therefore used for the fall "worst case" 24-hour period.

The same figure was used for "worst case" spring conditions, as it was assumed to occur before the roads were re-oiled.

6.3 Calcium Chloride

The fall 24 hour "worst case" conditions were assumed to occur just after road grading, as was the case for road oiling. As with road oiling, PM_{10} emissions reduction is assumed to be only 20% immediately after grading.

Calcium chloride regains some effectiveness over time, however. Some such recovery was assumed to occur by spring; a 33% PM_{10} emissions reduction was therefore assumed for spring 24 hour "worst case" conditions.

Table 6: Costs and Benefits of Selected Roadway PM_{10} Emission Control Techniques ("worst-case" 24 hour period)

Technique	PM_{10} Emissions Reduction (tons/24 hr) Spring	Fall	Cost ($/year)	Cost per ton ($) Spring	Fall
Unpaved Streets					
1. Paving - 2" hot asphalt pavement (per mile) (Note 1)	0.422	0.518	17,850	42,300	34,460
2. Paving - Bituminous surface treatment (per mile) (Note 1)	0.422	0.518	13,650	32,350	26,350
3. Oiling Streets (per mile) (Note 2)	0.104	0.104	3,675	35,340	35,340
4. Calcium Chloride Application (per mile)	0.172	0.104	2,580	15,000	24,810
Paved Streets					
1. Paving Driveways, Lots, and Street Approaches (Note 3)	8.97	-0-	33,700	3,760	N/A
2. Use of Cleaner Sand	1.68	-0-	5,000	2,980	N/A
3. Reduced Sanding/Better Cleanup (Note 4)	8.09	-0-	-0-	-0-	N/A

Notes:

1. Figures are based on paving about 20% of unpaved roads in the inventory area (see text). Cost effectiveness would be reduced for paving of additional, less travelled roads.
2. Figures are based on the use of CSS-1 emulsified asphalt. If waste oils were available, costs would be reduced.
3. Figures are for paving areas adjacent to the Old Glenn Highway, Eagle River Loop and Eagle River Road only (see text).
4. Figures are for actions already taken in the past two years (see text).

6.4 Paving Driveways, Lots, and Gravel Street Approaches

The inventory assumed that paved streets were clean in the fall. If this assumption is accepted, no emissions reduction in the fall can be credited to paving driveways, etc.

Mud carryout from paved areas was estimated to account for 66% of the PM_{10} emissions listed in the inventory for dirty paved roads (see Section 5.4). It was estimated that the mud carryout could be reduced by 75% by paving driveways, etc. The reduction in emissions listed in the inventory for spring "worst case" conditions would therefore by (75%) (66%) = 50%. This would imply an emissions reduction of 17.21 tons of PM_{10} emissions under spring 24-hour "worst case" conditions.

As noted in Section 5.4 of this report, however, the inventory may have overestimated this emissions source. Making the same adjustment for this as was made in Section 5.4 results in a revised emissions reduction quantity of 8.97 tons PM_{10} for spring 24-hour "worst case" conditions. This is the figure listed in Table 6.

6.5 Changing Sanding Material Specifications

The inventory assumed that paved roads were free of sanding material in the fall, so no fall emissions reductions can be attributed to changes in sanding material specifications.

The annual PM_{10} emissions reduction from such changes was estimated in Section 5.5 to be 84 tons, or 4.89% of the inventory total for paved road fugitive dust. For the spring 24-hour "worst case", this percentage is equivalent to 1.68 tons, the figure shown in Table 6.

6.6 Reduced Sanding and Better Cleanup

No fall emissions reductions can be attributed to this procedure, as was the case for the two previous procedures.

The spring 24-hour "worst case" is assumed to occur before street sweeping has been done, so only the effects of improved sanding material and reduced use of sand apply. These were estimated in Section 5.6 to result in an annual reduction of 403 tons PM_{10} in the 1717 ton total (which includes windblown dust from paved streets as well as fugitive dust).

This 23.5% reduction applied to the spring 24-hour "worst case" conditions in the inventory, is equal to a reduction of 8.09 tons.

7. REFERENCES

1. Pazera, K., 1988, "PM_{10} Emission Inventories for the Mendenhall Valley and Eagle River Areas", Engineering-Science, Inc., Berkeley, CA.

2. Reckard, M., 1988, "Analysis of Cost Effectiveness for Alternative Roadway Dust Control Methods, Interim Progress Report", Alaska DOT&PF Research Section, Fairbanks, AK.

3. Chapple, Tom, Alaska Department of Environmental Conversation, Juneau, AK, personal communication.

4. Hoover, J.M., 1981, "Mission-Oriented Dust Control and Surface Improvement Processes for Unpaved Roads", Engineering Research Institute, Iowa State University, Ames, IA.

5. Turpin, Frank, Morrison-Knudsen Engineers, Inc., Anchorage, AK, personal communication.

6. "Estimated Paving Prices per L.F.", obtained from Bill Wilcox, ARDSA Supt., Municipality of Anchorage, Department of Public Works.

7. Connor, Billy, 1987, "Use of High Float Emulsion Asphalt in Alaska", Alaska DOT&PF Research Report No. FHWA-AK-RD-87-03, Fairbanks, AK.

8. Pierce, Dick, Areawide Street Maintenance Supt., Municipality of Anchorage, AK.

9. Anchorage Public Works Department, Maintenance Work Program and Budget, Fiscal Year, 1988.

10. Stiles, Gary, Chevron USA Inc., Anchorage, AK, personal communication.

11. Center for Environmental Research Information, 1987, "User's Guide - Emission Control Technologies and Emission Factors for Unpaved Road Fugitive Emissions", U.S. Environmental Protection Agency, Research Triangle Park, NC.

12. Sultan, H., 1975, "Soil Erosion and Dust Control on Arizona Highways", Part IV Final Report, Field Testing Program, Arizona Department of Transportation, Phoenix, AZ.

13. Hoover, J.M. et al, 1975, "Evaluation of Chemically Stabilized Secondary Roads-Linn County, Iowa", Progress Report No.2, Engineering Research Institute, Project 1049-S. (cited in ref. 4).

14. Reckard, M., 1983, "Economics Aspects of High Speed Gravel Roads", State of Alaska DOT&PF Research Report No. FHWA-AK-RD-83-20, Fairbanks, AK.

15. Stuller, Dwight, Alaska DOT&PF Northern Region, Maintenance Section, personal communication.

16. Lapham, Pete, Alaska DOT&PF Haines Maintenance Station foreman, personal communication.

17. Parsons, John, Alaska DOT&PF Headquarters, Supply Section, Juneau, AK, personal communication.

18. Dataquest, 1988, "Rental Rate Blue Book for Construction Equipment", June 1988 update, January 1988 Update, Dataquest, San Jose, CA.

19. PEDCo-Environmental, Inc., Kansas City, MO, 1977, "Control of Reentrained Dust from Paved Streets", U.S. Department of Commerce, National Technical Information Service, PB-280 325.

20. Paving products, Fairbanks, AK, personal communication with "Cal".

21. Hamilton, Dick, Alaska DOT&PF Southeast Region maintenance manager, Juneau, AK, personal communication.

22. Alaska DOT&PF, 1985, "Alaska Highways Annual Traffic Volume Report" Alaska DOT&PF Headquarters Plans, Programs, and Budget, Juneau, AK.

23. Coatney, Alaska DOT&PF Central Region maintenance manager, Anchorage, AK, personal communication.

24. Engles, John, Fairbanks Sand and Gravel Inc., Fairbanks, AK, personal communication.

25. Schnell, Scott, Eagle River Road Service Area general foreman, Eagle River, AK, personal communication.

26. Connor, Billy and Gaffi, D., 1982 "Optimum Sand Specifications For Roadway Ice Control", Alaska DOT&PF Research Report No. AK-RD-82-26, Fairbanks, AK.