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FUGITIVE DUST BACKGROUND DOCUMENT AND TECHNICAL INFORMATION DOCUMENT FOR BEST AVAILABLE CONTROL MEASURES

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Disclaimer

This document reflects the latest information that the Environmental Protection Agency (EPA) has obtained on measures for control of fugitive dust. As additional information becomes available, the document will be updated, as appropriate. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use.

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SECTION 1.0
INTRODUCTION

1.1 PURPOSE OF THIS DOCUMENT

The purpose of this document is to provide technical information on control of fugitive dust sources. It provides background information that may be useful in determining reasonably available control measures (RACM) and best available control measures (BACM) for fugitive dust sources. It also provides technical guidance for the development of BACM strategies for fugitive dust in areas that are designated serious nonattainment for PM-10 (particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers). The information is needed by States to develop control strategies for their serious PM-10 nonattainment area State implementation plan (SIP) submittals.

The reader should be aware that the "Control of Open Fugitive Dust Sources" (EPA-450/3-88-008) document has been reformatted for this document. Much of the information contained in that document has been included here. Therefore, in the future, as noted above this document may be consulted for additional information on developing area-specific fugitive dust RACM strategies.

Note also that while the guidance presented herein lists available measures which the Environmental Protection Agency (EPA) is recommending as BACM, and is intended to be comprehensive, it is by no means exhaustive. It also does not establish any binding requirements. Consequently, the State is encouraged to consider other sources of information and is not precluded from selecting other measures and demonstrating to the public and EPA that they constitute BACM.

1.2 STATUTORY BACKGROUND

1.2.1 Designations

Section 107(d) of the Clean Air Act (Act), as amended in 1990, provides generally for the designation of areas of each State as attainment, nonattainment or unclassifiable for each pollutant for which there is a national ambient air quality standard (NAAQS). Certain areas meeting the qualifications of section 107(d)(4)(B) of the amended Act were designated nonattainment for PM-10 by operation of law upon enactment of the 1990 Amendments to the Act (initial PM-10 nonattainment areas). A Federal Register notice announcing all of the areas designated nonattainment for PM-10 at enactment and classified as moderate was published on March 15, 1991 (56 FR 11101). A follow-up notice correcting some of these area designations was published August 8, 1991 (56 FR 37654). The boundaries of the nonattainment areas were formally codified in 40 CFR Part 81, effective January 6, 1992 (56 FR 56694, November 6, 1991). All those areas of the country not designated nonattainment for PM-10 at enactment were designated unclassifiable [see section 107(d)(4)(B)(iii) of the amended Act].

1.2.2 Classifications

Once an area is designated nonattainment, section 188 outlines the process for classification of the area. In accordance with section 188(a), at the time of designation, all PM-10 nonattainment areas are initially classified as moderate by operation of law. A moderate area can subsequently be reclassified as a serious nonattainment area under two general conditions. First, EPA has general discretion under section 188(b)(1) to reclassify a moderate area as a serious area at any time the Administrator of EPA determines the area cannot practicably attain the NAAQS by the statutory attainment date for moderate areas. Second, under section 188(b)(2) a moderate area is reclassified as serious by operation of law after the statutory attainment date has passed if the Administrator finds that the area has not attained the NAAQS. The EPA must publish a Federal Register notice identifying the areas that have failed to attain and were reclassified, within 6 months following the attainment date [see section 188(b)(2)(B)].

Section 188(b)(1)(A) mandates an accelerated schedule by which EPA is to reclassify appropriate initial PM-10 nonattainment areas. The EPA proposed on November 21, 1991 (56 FR 58656) to reclassify 14 of the 70 initial moderate areas as serious. The final decision to reclassify the areas proposed will be based on the criteria utilized in the proposal, comments received in response to the proposal and on information in the moderate area SIP's that were due on November 15, 1991 for each of the areas.

In the future, EPA anticipates that, generally, any proposal to reclassify an initial PM-10 nonattainment area before the attainment date will be based on the State's demonstration that the NAAQS cannot practicably be attained in the area by December 31, 1994 [the statutory attainment date specified in section 188(c)(1) for initial PM-10 nonattainment areas].

In addition to EPA's general authority under section 188(b)(1) to reclassify as serious any area the Administrator determines cannot practicably attain the PM-10 NAAQS by the applicable date, for areas designated nonattainment for PM-10 subsequent to enactment of the 1990 Amendments, subparagraph (B) of section 188(b)(1) mandates that appropriate areas are to be reclassified as serious within 18 months after the required date for the State's submission of a moderate area SIP.[1] Taken together with the statutory requirement that PM-10 SIP's are due within 18 months after an area is designated nonattainment [see

[1]This directive does not restrict EPA's general authority but simply specifies that it must be exercised, as appropriate, in accordance with certain dates.

statutory obligation to issue RACM and BACM technical guidance for urban fugitive dust, residential wood combustion, and prescribed silvicultural and agricultural burning under section 190 of the amended Act. Similar to the manner in which EPA provided guidance on Act requirements applicable to moderate PM-10 nonattainment areas in the General Preamble, including a policy or how to utilize the RACM technical guidance documents, the EPA is planning to provide guidance on Act requirements and provisions applicable to serious PM-10 nonattainment areas, including BACM, in an addendum to the General Preamble. [EPA made a draft of the addendum available for public comment on July 16, 1992 (57 FR 31477).] The portion of the addendum that addresses BACM provides a policy for how to utilize today's fugitive dust BACM technical guidance (and companion technical guidance for control of residential wood combustion and prescribed burning) to develop area-specific BACM strategies.

1.3 DOCUMENT ORGANIZATION

1.3.1 BACM Approach

Since a moderate area with fugitive dust sources may be reclassified to serious, RACM and BACM must be consistent to allow for a new control measure to be mandated or appended without loss of the efficiency of the first measure. The measures described in this document as available for fugitive dust BACM are more stringent than RACM, and therefore should result in greater control efficiencies. When a fugitive dust source has been controlled under a RACM strategy, the implementation of BACM will generally involve additive measures that consist of a more extensive application of fugitive dust control measures imposed under RACM. For example, BACM for unpaved roads may consist of more miles of road to be paved.

Preventive measures for control of fugitive dust, as contrasted with mitigative controls, are preferred and recommended in this document. The reduction of source extent and the incorporation of process modifications or adjusted work practices which reduce the amount of exposed dust-producing material constitute <u>preventive measures</u> for control of fugitive dust emissions. This would include, for example, the elimination of mud/dirt carryout onto paved roads at construction and demolition sites. On the other hand, <u>mitigative measures</u> involve the periodic removal of dust-producing material. Examples of mitigative measures include: cleanup of spillage on travel surface (paved and unpaved) and cleanup of material spillage at conveyor transfer points.

1.3.2 <u>BACM Implementation</u>

The strategy for implementing BACM should begin with an analysis of the required PM-10 emissions reduction to achieve attainment status. The emissions inventory is then used to rank order categories of PM-10 emission sources. Each source category, with its source extent and emission factor is then evaluated for control measures that, cumulatively, will achieve the target level of control. This iterative process continues from the first ranked source down to the source providing the final required emissions reduction increment. Source categories that have been determined to be insignificant contributors to nonattainment (i.e., de minimis) may not need additional control beyond RACM. Examples of fugitive dust sources that may be insignificant (even though the fugitive dust source category as whole may be significant) include:

- Disturbed ground surfaces of less than one (1) acre.
- Construction/demolition activity with a floor plan of less than 10,000 ft^2 or with movement of less than 250 yd^3 of dirt or rock.
- Paved and unpaved driveways, public easements and shared public access roads serving a maximum of 20 single-family residential dwellings.
- Paved and unpaved roads with a road length of less than 1/2 mile or with 20 or less vehicle trips per day.

- Storing and handling of material where total material volume is less than 250 yd^3 or where the total annual throughput is less than 2000 tons.

The site-specific feasibility analysis of candidate BACM includes technical and economic evaluations. These evaluations can be modeled after those described under the model unit/nonattainment area scenarios contained in this document. This feasibility analysis should optimize the overall strategy for achieving the required PM-10 emissions reduction for the lowest cost of control.

Dust control plans should be prepared for each of the identified sources to be controlled, recognizing that BACM strategies described in this document require stringent control application with good assurance of enforceability. These plans may consist of flexible approaches and methods of dealing with special situations. The final stage of implementing BACM involves recordkeeping requirements and inspection schedules for determination of compliance.

1.3.3 Document Contents

This document is structured in a manner similar to an alternative control techniques document for PM-10 emissions from fugitive dust sources. The source categories that are discussed in this document include: paved roads, unpaved roads, storage piles, wind erosion from open areas, construction/demolition, and agriculture. This information is, of necessity, general in nature and does not fully account for unique variations within a source category. Consequently it will be necessary for control agency personnel to conduct their own analysis of BACM for fugitive dust sources based on this guidance and examples contained in this document.

Table 1-1 identifies BACM candidates for each source category based on information presented in this document. The list of control measures offers some flexibility of choice based on site-specific feasibility analysis.

This document is organized as follows:

- Chapter 2 identifies and describes the fugitive sources of PM-10 emissions and presents a model unit for each source category.
- Chapter 3 discusses applicable emission control techniques that are representative of BACM along with estimates of control efficiencies.
- Chapter 4 discusses the environmental impacts that may result from implementing BACM, focusing on the reduction in PM-10 emissions.
- Chapter 5 presents cost analysis procedures and calculates costs for each of the model unit applications.
- Chapter 6 presents example operating permits for each fugitive dust source category.

Table 1-1. AVAILABLE CONTROL MEASURES FOR FUGITIVE DUST BACM

Source category	Control action
Paved roads	Improvements in sanding/salting applications and materials Truck covering Prevention of track-on/wash-on: • Construction site measures • Curb installation • Shoulder stabilization • Storm water drainage
Unpaved roads	Paving Chemical stabilization Surface improvement (graveling) Vehicle speed reduction
Storage piles (transfer operations)	Wet suppression
Construction/demolition	Paving permanent roads early in project Truck covering Access apron construction and cleaning Watering of graveled travel surfaces
Open area wind erosion	Revegetation Limitation of off-road vehicle traffic
Agricultural tilling	Land conservation practices under Food Security Act

SECTION 2

SOURCES AND POLLUTANT EMISSIONS

This section addresses emission factors for fugitive dust sources. In addition, the approach to model units for each source category is presented. The emission factors are drawn primarily from AP-42, EPA's *Compilation of Air Pollutant Emission Factors* (USEPA, 1985).

In AP-42, the reliability of emission factors is indicated by an overall emission factor rating ranging from A (excellent) to E (poor):

A-Excellent. Developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category is specific enough to minimize variability within the source category population.

B-Above average. Developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. As in the A-rating, the source category is specific enough to minimize variability within the source category population.

C-Average. Developed only from A- and B-rated data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. As in the A rating, the source category is specific enough to minimize variability within the source category population.

D-Below average. The emission factor was developed only from A- and B-rated test data from a smaller number of facilities, and there may be reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of unexplained variability within the source category population. Limitations on the use of the emission factor are footnoted in the emission factor table.

<u>E-Poor</u>. The emission factor was developed from C- and D-rated test data, and there may be reason to suspect that the facilities tested do not represent a random sample of the industry. There may be evidence of variability within the source category population. Limitations on the use of these factors are always footnoted.

Because the application of these factors is somewhat subjective, the reasons for each rating are documented in the background files maintained by the Office of Air Quality Planning and Standards (OAQPS).

2.1 PAVED ROADS

Fugitive dust emissions occur whenever a vehicle travels over a paved surface, such as public and industrial roads and parking lots. These emissions originate mostly from material previously deposited on the travel surface, although resuspension of material from tires and undercarriages can be significant when vehicles travel from unpaved to paved areas. In general, emissions correlate with road surface material loading (measured as mass of material per unit area). The dust emitted from the surface is in turn replenished by other sources (e.g., pavement wear, deposition of material from vehicles, deposition from other nearby sources, carryout from surrounding unpaved areas, and litter). Because of the importance of the surface loading, available control techniques either attempt to prevent material from being deposited on the surface or to remove (from the travel lanes) any material that has been deposited.

While the mechanisms of particle deposition and resuspension are largely the same for public and industrial roads, there can be major differences in surface loading characteristics, traffic characteristics, and viable control options. Although public roads generally tend to have lower surface loadings than industrial roads, the fact that public roads have far greater traffic volumes may result in a substantial contribution to the measured air quality in certain areas. For public roads in industrial areas that are heavily loaded and traveled by heavy vehicles, better emission estimates would be obtained by treating these roads as industrial roads. In an extreme case, a road or parking lot may have such a high surface loading that the paved surface is covered completely and is easily mistaken for an unpaved road. In that event, use of a paved road emission factor may actually result in a higher estimate than that obtained from the unpaved road emission factor. If this is the case, the road is better characterized as unpaved in nature for purposes of emission estimation.

Prior to use of the information in this section, the reader should formulate preliminary answers to the following questions:

1. What paved roads are heavily loaded and thus likely to contribute a disproportionate share of emissions?

2. What sources are likely to contribute to these elevated surface loadings? For example, heavy trucks may spill part of their load onto public roads in industrial areas, or large amounts of salt and sand may be applied during winter months.

3. Who is the responsible party for each source identified in 2 above?

4. Can the carryout/deposition from each identified source of surface loading be prevented, or must the affected roadway be cleaned afterward?

As discussed above, the term "public" is used in this document to denote not only ownership of the road but also its surface and traffic characteristics. Roads in this class generally are fairly lightly loaded, are used primarily by light-duty vehicles, and usually have curbs and gutters. Examples are streets in residential and commercial areas and major thoroughfares (including freeways and arterials).

2.1.1 Estimation of Emissions

The current AP-42 PM-10 emission factor for urban paved roads is (USEPA, 1985):

$$e = 2.28\ (sL/0.5)^{0.8}\ (g/VKT) \qquad (2\text{-}1)$$

$$e = 0.0081\ (sL/0.7)^{0.8}\ (lb/VMT)$$

where: e = PM-10 emission factor in grams per vehicle kilometers traveled (VKT) or pounds per vehicle miles traveled (VMT)

s = surface silt content, fraction of material smaller than 75 μm in diameter (as measured by ASTM-C-136)

L = total surface dust loading, g/m^2 ($grains/ft^2$)

The above equation is not rated in AP-42.

The product sL represents the mass of silt-size dust particles per unit area of the road surface and is usually termed the "silt loading." As is the case for all predictive models in AP-42, the use of site-specific values of sL is strongly recommended. In general, roads with a higher traffic volume tend to have lower surface silt loadings. This relationship is expressed in the empirical model presented in Cowherd and Englehart (1984):

$$sL = 21.3\ /\ V^{0.41} \qquad (2\text{-}2)$$

where: sL = surface silt loading (g/m^2)

V = average daily traffic volume (vehicles/d)

Several items should be noted. First, samples used to develop Equation (2-2) are restricted to the eastern and midwestern portions of the country. These can be considered representative of most large urban areas of the United States. Lower silt loadings have been measured in the Southwest. Once again, the use of site-specific data is stressed.

As noted earlier, emission estimation for paved roads depends upon the surface material and traffic characteristics. In this document, the term "industrial" paved roads is used to denote those roads with higher surface loadings and/or that are traveled by heavier vehicles. Consequently, some publicly owned roads are better characterized as industrial in terms of emissions. Examples would include city streets in heavily industrialized areas or areas of construction as well as paved roads in industrial complexes.

The current AP-42 PM-10 emission factor for industrial paved roads is (USEPA, 1985):

$$e = 220\ (sL/12)^{0.3}\ (g/VKT)$$
$$e = 0.77\ (sL/0.35)^{0.3}\ (lb/VMT) \qquad (2-3)$$

where: e = emission factor, in g/VKT or lb/VMT
sL = surface silt loading, g/m^2 (oz/yd^2)

The above equation is rated "A" in AP-42.

Alternatively, AP-42 presents a single-valued emission factor for use in lieu of Equation (2-3) for PM-10 emissions from light-duty vehicles on heavily loaded industrial roads:

$$e = 93 \text{ (g / VKT)}$$
$$e = 0.33 \text{ (lb / VMT)} \quad (2\text{-}4)$$

This single-valued emission factor is rated "C."

Although no hard and fast rules can be provided, Table 2-1 summarizes a recommended decision process for selecting industrial paved road emission factors.

AP-42 presents a summary of silt loading values for industrial paved roads associated with a variety of industries. As is the case with all AP-42 Chapter 11.2 emission models, <u>the use of site-specific data is strongly recommended</u>.

Road sanding results in substantial increases in paved road silt loading above normal levels. After sand is applied to roads to increase traction on snow and ice, vehicle traffic serves to reentrain the particulate, particularly the silt fraction deposited in active lanes. Some additional silt is formed by grinding. Emissions are much greater under dry road conditions.

The mass of emissions reentrained by road traffic is related to sand quantity and size distribution. The entire PM-10 fraction contained in the silt of the applied sand is assumed to become airborne.

The estimated PM-10 emissions from road sanding are calculated as follows (Cowherd et al., 1988):

$$e = 2{,}000 f \text{ } (s/100) \quad \text{(lb/ton of sand applied)} \quad (2\text{-}5)$$

where f is the proportion of PM-10 in the silt fraction of sand (default fraction of 0.0026), and s is the silt content (percent) of the sand (default of 0.35 percent), as measured by ASTM-C-136.

TABLE 2-1. DECISION RULE FOR PAVED ROAD EMISSION ESTIMATES

Silt loading (sL), g/m^2	Average vehicle weight (W), Mg	Use model
sL < 2	W > 4	Equation (2-3)
sL < 2	W < 4	Equation (2-1)
sL > 2[a]	W > 6	Equation (2-3)
2 < sL < 15	W < 6	Equation (2-3)
sL > 15[a]	W < 6	Equation (2-4)

a For heavily loaded surfaces (i.e., sL > ~ 300 to 400 g/m^2, it is recommended that the resulting estimate be compared to that from the unpaved road models (Section 3.0 of this manual), and the smaller of the two values used.

2.1.2 Model Units

For most nonindustrial areas in which the use of BACM is contemplated, paved roads probably will constitute the most spatially extensive source category. Ideally, State and local officials considering BACM for a given area would have at their disposal a complete, spatially resolved paved road emissions inventory. In this context, the term spatially resolved implies an information base that includes:

1. Road segment lengths;
2. "Representative" silt loading values (mass/surface area—g/m^2); and
3. Average daily traffic (ADT)

for essentially all segments in a given paved road network.

From the above information, it is reasonably easy to estimate PM-10 emissions for individual road segments. In turn, one could define model units—high, medium, and low--based on emissions intensity.

One road classification system that can be used in estimating paved road emissions is the Federal Highway Administration (FHWA) Functional Classification. The functional system consists of principal arterials (for main traffic movements), minor arterials (distributors), collectors, and local roads and streets. In urban areas there are further functional subdivisions of the arterial category. In rural areas, there are further functional subdivisions of the collector category. Characteristics of these categories are described by AASHTO (1990). This system is summarized below.

FEDERAL HIGHWAY ADMINISTRATION
FUNCTIONAL CLASSIFICATIONS

Rural:

Interstate
Other principal arterial

Minor arterial
Major collector
Minor collector
Local

Urban:

Interstate
Other freeways and expressways
Other principal arterial
Minor arterial
Collectors
Local

This widely used system treats urban and rural areas separately where urban is defined as an area with boundaries set by the responsible State and local officials and having a population of 5,000 or more; rural areas are those areas outside of urban areas.

In examining this classification scheme, it is important to recognize that road categories are based on the function--character of service--that the roads are intended to provide. For example, in the rural network, arterials (including interstates) generally provide direct service between cities and larger towns, which constitute a large proportion of the relatively longer trips. In contrast, collectors serve small towns directly, connecting them to the arterial network. These collectors take or distribute traffic to the local roads which serve individual farms or other rural land uses.

Other points that should be recognized are:

- The FHWA classification is not directly tied to the physical parameters that are most important to BACM analyses--segment length and ADT. However, one would expect a strong, although certainly not perfect, positive correlation between functional class and ADT.

- The principal advantage of the FHWA system is that it is in widespread use. States routinely compile and report traffic data that are relevant to the determination of BACM, according to this system.

Given the above, the approach to application of BACM may be structured to incorporate the FHWA system. It also is clear that the structure must adopt the principles of preventive control—prevention or at least minimization of mud/dirt source material carried onto roadways. The concept of preventive controls can, in part, be tied to access control.

For example, interstate highways are characterized by strict access control—vehicles can enter or leave the road only at a limited number of locations. In addition, these roads are characterized by relatively wide, improved (asphalt) shoulders and the use of appropriate vegetation for erosion control. The net result is extremely low surface loadings for this type of roadway. For this reason, despite high ADT, it can be argued that interstates/expressways represent a relatively insignificant source category, except in the case of sand/salt applications.

At the other end of the classification scheme--local roads--one also could argue that these roads represent a minor source category. In this case, access is essentially free; however, ADT should generally be quite low. As a result, the dust-emitting potential of these roads is relatively low. It also is important to recognize that actually instituting BACM for the local road network may be impractical given the sheer number of individual road segments contained within an urban area.

Accepting the above arguments—resulting in the classification of interstate highways (and other limited access roadways) and local roads as less important source categories—restricts the application of BACM to arterial and collector street categories. In typical urban functional systems, these categories may constitute 20 percent to 35 percent of total road mileage. In effect, it is for the arterial and collector street categories that the elements of the spatially resolved inventory (segment length, silt loading, ADT), and consideration of adjacent land use, become critical.

2.2 UNPAVED ROADS

As is the case for paved roads, fugitive dust emissions occur whenever a vehicle travels over an unpaved surface. Unlike paved roads, however, the road itself is the source of the emissions rather than any "surface loading." Within the various categories of open dust sources in industrial settings, unpaved travel surfaces have historically accounted for the greatest share of particulate emissions. For example, unpaved travel surfaces were estimated to account for roughly 70 percent of open dust emissions in the iron and steel industry during the 1970's (Cowherd et al., 1988).

Recognition of the importance of unpaved roads led naturally to an interest in their control. During the 1980's, industry paved many previously unpaved roads as part of emission control programs. Nevertheless, the need for continued control of these sources is apparent.

Travel surfaces may be unpaved for a variety of reasons. Possibly the most common type of unpaved road is that found in rural regions throughout the country. These roads may experience only sporadic traffic which, taken with the often considerable road length involved, makes paving impractical.

Some industrial roads are, by their nature, not suitable for paving. These roads may be used by very heavy vehicles or may be subject to considerable spillage from haul trucks. Haul roads typically generate significant unpaved road emissions because of the heavy weight of the haul trucks. Other roads may have poorly constructed bases that make paving impractical. Because of the additional maintenance costs associated with a paved road under these service environments, emissions from these roads are usually controlled by regular applications of water or chemical dust suppressants.

In addition to roadways, many industries often contain important unpaved travel areas. Examples include areas used for truck parking, scraper traffic patterns related to stockpile/reclaim activities in coal yards, compactor traffic proximate to lifts at landfills, and truck travel related to open storage of finished products (such as coil at steel plants). These areas may often account for a substantial fraction of traffic-generated emissions from individual plants. In addition, these areas tend to be much more difficult to control than stretches of roadway. For example, changing traffic patterns make semipermanent controls impractical, and increased shear forces from cornering vehicles may rapidly deteriorate chemically stabilized surfaces.

2.2.1 Estimation of Emissions

As was the case for paved roads, unpaved roads may be divided into the two classes of public and industrial. However, for the purpose of estimating emissions, there is no need to distinguish between the two, because the AP-42 emission factor equation takes source characteristics (such as average vehicle weight and road surface texture) into consideration (USEPA, 1985).

$$e = 0.61\left(\frac{s}{12}\right)\left(\frac{S}{48}\right)\left(\frac{W}{2.7}\right)^{0.7}\left(\frac{w}{4}\right)^{0.5}\frac{(365-p)}{365}\ (\mathrm{kg/VKT})$$

$$e = 2.1\left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.7}\left(\frac{w}{4}\right)^{0.5}\frac{(365-p)}{365}\ (\mathrm{lb/VMT}) \qquad (2\text{-}6)$$

where: e = PM-10 emission factor in units stated

s = silt content of road surface material, percent (ASTM-C-136)

S = mean vehicle speed, km/h (mi/h)

W = mean vehicle weight, Mg (ton)

w = mean number of wheels (dimensionless)

p = number of days with ≥ 0.254 mm (0.01 in) of precipitation per year

Using the scheme given in AP-42, the above equation is rated "A," when used within the tested ranges of correction parameter values. As is the case with all AP-42 emission factors, the use of site-specific data is strongly encouraged.

The number of wet days per year, p, for the geographical area of interest should be determined from local climatic data. Maps giving similar data on a monthly basis are available from the National Climatic Center at Asheville, North Carolina.

It is important to note that for the purpose of estimating annual or seasonal controlled emissions from unpaved roads, average control efficiency values based on worst case uncontrolled emissions levels [i.e., dry roads, p = 0 in Equation (2-6)] are required. This is true simply because the AP-42 predictive emission factor equation for unpaved roads, which is routinely used for inventorying purposes, is based on source tests conducted under dry conditions. Extrapolation to annual average uncontrolled emission estimates is accomplished by assuming that emissions are occurring at the estimated rate on days without measurable precipitation, and conversely are absent on days with measurable precipitation. This assumption has not been verified in a rigorous manner; however, experience with hundreds of field tests indicate that it is a reasonable assumption if the source operates on a fairly "continuous" basis.

2.2.2 Model Units

Many of the comments made concerning the paved road source category are equally applicable to unpaved roads. In particular, BACM for this source category is best considered in light of a spatially resolved inventory that includes:

1. Road segment lengths and geographic locations.
2. Average daily traffic (ADT).
3. Representative silt content values (percent < 75 μmP).
4. Average vehicle characteristics--speed, weight, and wheels.

Segment length and ADT are the most critical data elements as they represent source extent--vehicle miles traveled (VMT). If spatially resolved source extent information is available, one could logically design model units--high, medium, and low--based on this information.

Unlike the paved road case, there is no generally inclusive alternative classification scheme that can be used to structure BACM determinations for the unpaved road source category. However, in a qualitative sense, one can use certain elements of the FHWA system to roughly order road types. For example, based on the presumption that functional arterials and collectors have higher ADT than local roads, high-intensity unpaved roads could be defined in terms of four existing FHWA categories.

1. Urban minor arterials.
2. Urban collectors.
3. Rural major collectors.
4. Rural minor collectors.

Following the same rationale, one could argue that a similar hierarchy of local roads also exists. In other words, there is some systematic (albeit unknown) relationship between the function of local unpaved roads and their corresponding ADT. For example, unpaved private driveways might be considered logically as the lowest intensity or *de minimis* model unit as they see very little ADT. Practically, this type of road would be a difficult, if not impossible, source for which to establish and then enforce BACM.

At the other end of the local system hierarchy might be the relatively short stretches of unpaved roadway that serve as access for subdivision development in unincorporated portions of a given county. One could argue that some farm roads, particularly for situations in which labor-intensive crops are grown, constitute a relatively high-intensity local road source. In a given jurisdiction, if these types of roadways can be identified, then application of BACM probably would be feasible.

2.3 STORAGE PILES

Inherent in operations that use minerals in aggregate form is the maintenance of outdoor storage piles. Storage piles are usually left uncovered, partially because of the need for frequent material transfer into or out of storage.

Dust emissions occur at several points in the storage cycle, during material loading onto the pile, during disturbances by strong wind currents, and during loadout from the pile. The movement of trucks and loading equipment in the storage pile area is also a substantial source of dust.

2.3.1 Estimation of Emissions

The quantity of dust emissions from aggregate storage operations varies with the volume of aggregate passing through the storage cycle. Also, emissions depend on correction parameters that characterize the condition of a particular storage pile: moisture content and proportion of aggregate fines.

When freshly processed aggregate is loaded onto a storage pile, the potential for dust emissions is at a maximum. Fines are easily disaggregated and released to the atmosphere upon exposure to air currents from transfer operations or high winds. As the aggregate weathers, however, potential for dust emissions is greatly reduced. Moisture causes aggregation and cementation of fines to the surfaces of larger particles.

Total dust emissions from aggregate storage piles are contributions of several distinct source activities within the storage cycle:

1. Loading of aggregate onto storage piles (batch or continuous drop operations).
2. Equipment traffic in storage area.
3. Wind erosion of pile surfaces and ground areas around piles.
4. Loadout of aggregate for shipment or for return to the process stream (batch or continuous drop operations).

2.3.1.1 Materials Handling--

Adding aggregate material to a storage pile or removing it usually involves dropping the material onto a receiving surface. Truck dumping on the pile or loading out from the pile to a truck with a front-end loader are examples of batch drop operations. Adding material to the pile by a conveyor stacker is an example of a continuous drop operation.

The following AP-42 equation is recommended for estimating emissions from transfer operations (batch or continuous drop):

$$e = 0.00056 \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \text{ (kg/Mg)}$$

$$e = 0.0011 \frac{\left(\frac{U}{5}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \text{ (lb/ton)} \qquad (2\text{-}7)$$

where: e = PM-10 emission factor, in units stated

U = mean wind speed, m/s (mph)

M = material moisture content, percent

Based on the criteria presented in AP-42, the above equation is rated A, when used within the tested ranges of correction parameter values.

2.3.1.2 Equipment Traffic--

For emissions from equipment traffic (trucks, front-end loaders, dozers, etc.) traveling between or on piles, it is recommended that the equations for vehicle traffic on unpaved surfaces be used (see Section 2.2). For vehicle travel between storage piles, the silt value(s) for the areas between the piles (which may differ from the silt values for the stored materials) should be used.

2.3.1.3 Wind Erosion--

Dust emissions may be generated by wind erosion of open aggregate storage piles and exposed areas within an industrial facility. These sources typically are characterized by nonhomogeneous surfaces impregnated with nonerodible elements (particles larger than approximately 1 cm in diameter). Field testing of coal piles and other exposed materials using a portable wind tunnel has shown that (a) threshold wind speeds exceed 5 m/s (11 mph) at 15 cm above the surface of the pile or 10 m/s (22 mph) at 7 m above the surface of the pile, and (b) particulate emission rates tend to decay rapidly (half life of a few minutes) during an erosion event. In other words, these aggregate material surfaces are characterized by finite availability of erodible material (mass/area) referred to as the erosion potential. Any natural crusting of the surface binds the erodible material, thereby reducing the erosion potential.

2.3.1.3.1 <u>Emissions and Correction Parameters</u>--If typical values for the threshold wind speed at 15 cm are corrected to a typical wind sensor height (6-10 m), the resulting values exceed the upper extremes of hourly mean wind speeds observed in most areas of the country. In other words, mean atmospheric wind speeds usually are not sufficient to sustain wind erosion from aggregate material surfaces. However, wind gusts may quickly deplete a substantial portion of the erosion potential. Because erosion potential has been found to increase rapidly with increasing wind speed (above the threshold value), estimated emissions should be related to the gusts of highest magnitude.

The routinely measured meteorological variable which best reflects the magnitude of wind gusts is the fastest mile. This quantity represents the wind speed corresponding to the whole mile of wind movement that has passed by the 1-mi contact anemometer in the least amount of time. Daily measurements of the fastest mile are presented in the monthly Local Climatological Data (LCD) summaries available from the National Climatic Center, Asheville, North Carolina. The duration of the fastest mile, typically about 2 min (for a fastest mile of 30 mph), matches well with the half life of the erosion process, which ranges between 1 and 4 min. It should be noted, however, that instantaneous peak winds can significantly exceed the daily fastest mile.

The wind speed profile in the surface boundary layer is found to follow a logarithmic distribution:

$$u(z) = \frac{u^*}{0.4} \ln\left(\frac{z}{z_o}\right) \quad (z > z_o) \qquad (2-8)$$

where:
- u = wind speed, cm/s
- u^* = friction velocity, cm/s
- z = height above test surface, cm
- z_o = roughness height, cm

0.4 = von Karman's constant, dimensionless

The friction velocity (u^*) is a measure of wind shear stress on the erodible surface, as determined from the slope of the logarithmic velocity profile. The roughness height (z_o) is a measure of the roughness of the exposed surface as determined from the y-intercept of the logarithmic velocity profile, i.e., the height at which the wind speed is zero. A typical roughness height for open terrain is 0.5 cm.

Emissions generated by wind erosion are also dependent on the frequency of disturbance of the erodible surface because each time that a surface is disturbed, its erosion potential is restored. A disturbance is defined as an action which results in the exposure of fresh surface material. On a storage pile, this would occur whenever aggregate material is either added to or removed from the old surface. A disturbance of an exposed area may also result from the turning of surface material to a depth exceeding the size of the largest pieces of material present.

2.3.1.3.2 Predictive Emission Factor Equation (USEPA, 1985)--The AP-42 emission factor for wind-generated particulate emissions from mixtures of erodible and nonerodible surface material subject to disturbance may be expressed in units of g/m^2-yr as follows:

$$e = 0.5 \sum_{i=1}^{N} P_i \qquad (2-9)$$

where: e = PM-10 emission factor, g/m^2

N = number of disturbances per year

P_i = erosion potential corresponding to the observed (or probable) fastest mile of wind for the ith period between disturbances, g/m^2

In calculating emission factors, each area of an erodible surface that is subject to a different frequency of disturbance should be treated separately. For a surface disturbed daily, $N = 365/yr$, and for a surface disturbance once every 6 mo, $N = 2/yr$.

The erosion potential function for a dry, exposed surface has the following form:

$$P = 58 \left(u^* - u_t^*\right)^2 + 25 \left(u^* - u_t^*\right) \qquad (2\text{-}10)$$

$$P = 0 \text{ for } u^* \le u_t^*$$

where: u^* = friction velocity (m/s)

u_t^* = threshold friction velocity (m/s)

Because of the nonlinear form of the erosion potential function, each erosion event must be treated separately.

Equations 2-9 and 2-10 apply only to dry, exposed materials with limited erosion potential. The resulting calculation is valid only for a time period as long or longer than the period between disturbances. Calculated emissions represent intermittent events and should not be input directly into dispersion models that assume steady state emission rates.

For uncrusted surfaces, the threshold friction velocity is best estimated from the dry aggregate structure of the soil. A simple hand sieving test of surface soil (adapted from a laboratory procedure published by W. S. Chepil, 1952) can be used to determine the mode of the surface aggregate size distribution by inspection of relative sieve catch amounts (Figure 2-1). The threshold friction velocity for erosion can be determined from the mode of the aggregate size distribution, as described by Gillette (1980) (Figure 2-2). Threshold friction velocities for

1. Prepare a nest of sieves with the following openings: 4 mm, 2 mm, 1 mm, 0.5 mm, 0.25 mm. Place a collector pan below the bottom sieve (0.25-mm opening).

2. Collect a sample representing the surface layer of loose particles (approximately 1 cm in depth for an uncrusted surface), removing any rocks larger than about 1 cm in average physical diameter. The area to be sampled should not be less than 30 cm x 30 cm.

3. Pour the sample into the top sieve (4-mm opening), and place a lid on the top.

4. Rotate the covered sieve/pan unit by hand using broad sweeping arm motions in the horizontal plane. Complete 20 rotations at a speed just necessary to achieve some relative horizontal motion between the sieve and the particles.

5. Inspect the relative quantities of catch within each sieve and determine where the mode in the aggregate size distribution lies, i.e., between the opening size of the sieve with the largest catch and the opening size of the next largest sieve.

Source: Adapted from a laboratory procedure published by W. S. Chepil (1952).

Figure 2-1. Field Procedure for the Determination of Surface Aggregate Size Distribution Mode.

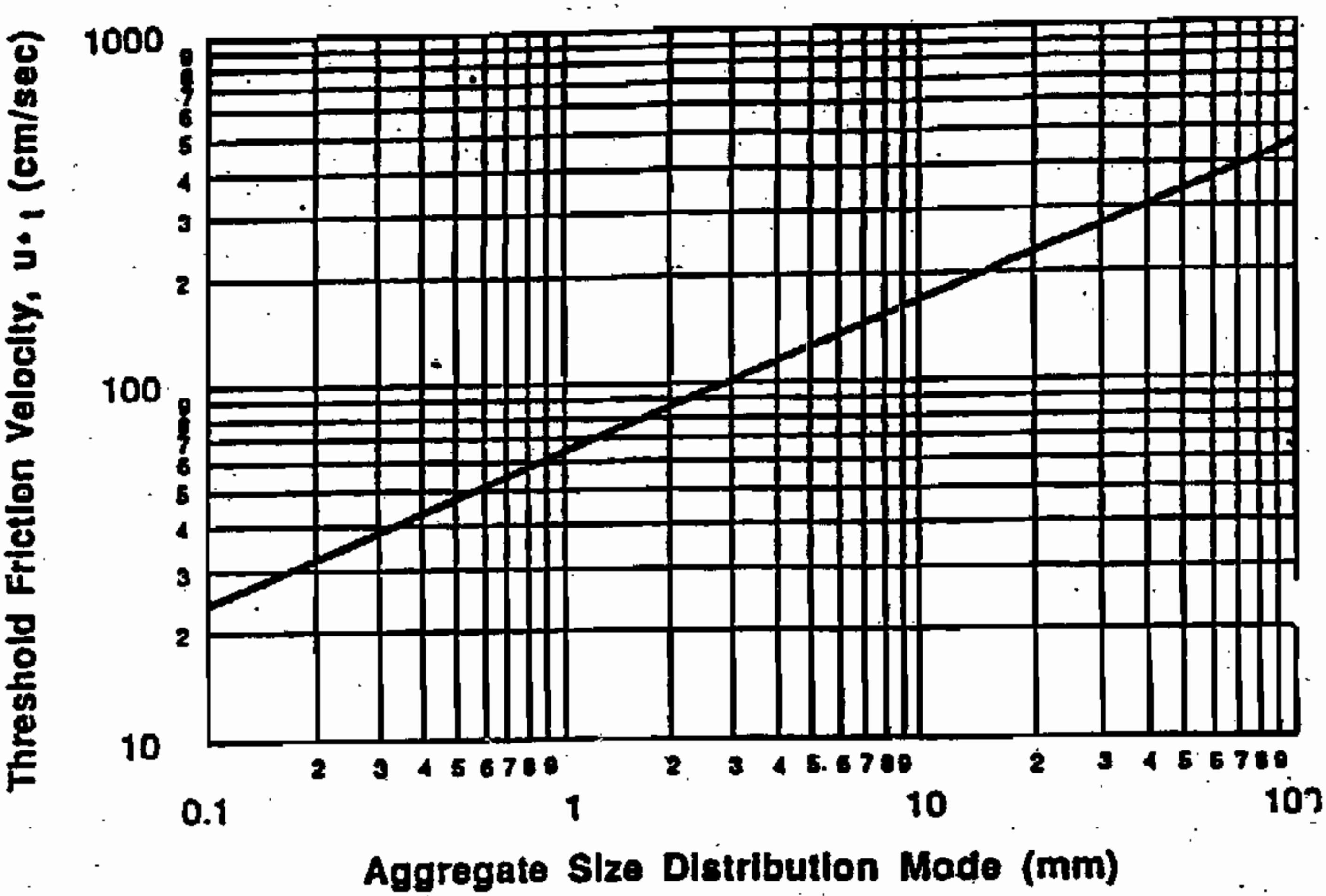

Figure 2-2. Relationship of Threshold Friction Velocity to Size Distribution Mode.

several surface types have been determined by field measurements with a portable wind tunnel (Gillette, 1980; Muleski, 1985; Nickling and Gillies, 1986).

The friction velocity (u*) is best related to the fastest mile of wind in the area for the periods between pile disturbances. As discussed above, the fastest mile may be obtained from the monthly LCD summaries for the nearest reporting weather station that is representative of the site in question, available from the National Climatic Center. These summaries report actual fastest mile values for each day of a given month. Because the erosion potential is a highly nonlinear function of the fastest mile, mean values of the fastest mile are inappropriate. The anemometer heights of reporting weather stations are found in Changery (1978), and should be corrected to a 10-m reference height using Equation 2-8.

To convert the fastest mile of wind (u^+) from a reference anemometer height of 10 m to the equivalent friction velocity (u^*), the logarithmic wind speed profile may be used to yield the following equation:

$$u^* = 0.053\, u_{10}^+ \qquad (2\text{-}11)$$

where: u^* = friction velocity (m/s)

u_{10}^+ = fastest mile of reference anemometer for period between disturbances (m/s)

This assumes a typical roughness height of 0.5 cm for open terrain. Equation 2-11 is restricted to large relatively flat piles or exposed areas with little penetration into the surface wind layer.

If the pile significantly penetrates the surface wind layer (i.e., with a height-to-base ratio exceeding 0.2), it is necessary to divide the pile area into subareas representing different degrees of exposure to wind. The results of physical modeling as described below show that the frontal face of an elevated pile is exposed to wind speeds of the same order as the approaching wind speed at the top of the pile.

For two representative pile shapes (conical pile and oval pile with flat-top, 37 degree side slope), the ratios of surface wind speed (u_s) to approach wind speed (u_r) have been derived from physical modeling in a laboratory wind tunnel (Studer and Arya, 1988). The results are shown in AP-42, Section 11.2.7, corresponding to an actual pile height of 11 m, a reference (upwind) anemometer height of 10 m, and a pile surface roughness height (z_o) of 0.5 cm. The measured surface winds correspond to a height of 25 cm above the surface. The profiles of u_s/u_r can be used to estimate the surface friction velocity distribution around similarly shaped piles, using the procedure described in AP-42.

The recommended emission factor equation presented above assumes that all of the erosion potential corresponding to the fastest mile of wind is lost during the period between disturbances. Because the fastest mile event typically lasts only about 2 min, which corresponds roughly to the half-life for the decay of actual erosion potential, it could be argued that the emission factor overestimates particulate emissions. However, there are other aspects of the wind erosion process which offset this apparent conservatism:

1. The fastest mile event contains instantaneous peak winds which substantially exceed the mean value for that event.

2. Whenever the fastest mile event occurs, there are usually a number of periods of slightly lower mean wind speed which contain peak gusts of the same order as the fastest mile wind speed.

Of greater concern is the likelihood of overprediction of wind erosion emissions in the case of surfaces disturbed infrequently in comparison to the rate of crust formation.

2.3.1.3.3 Wind Emissions From Continuously Active Piles--For emissions from wind erosion of active (frequently disturbed) storage piles, the following AP-42 emission factor equation is recommended for estimating total suspended particulate (TSP) emissions:

$$e_{TSP} = 1.9\left(\frac{s}{1.5}\right)\left(\frac{365-p}{235}\right)\left(\frac{f}{15}\right) \text{ (kg/d/hectare)}$$

$$e_{TSP} = 1.7\left(\frac{s}{1.5}\right)\left(\frac{365-p}{235}\right)\left(\frac{f}{15}\right) \text{ (lb/d/acre)} \qquad (2\text{-}12)$$

where: e_{TSP} = total suspended particulate emission factor, units stated above

s = silt content of aggregate, percent (ASTM-C-136)

p = number of days with ≥ 0.25 mm (0.01 in.) of precipitation per year

f = percentage of time that the unobstructed wind speed exceeds 5.4 m/s (12 mph) at the mean pile height

The fraction of TSP which is PM-10 is estimated at 0.5 and is consistent with the PM-10/TSP ratios for materials handling.

The coefficient in Equation (2-12) is taken from Cowherd et al. (1974), based on sampling of emissions from a sand and gravel storage pile area during periods when transfer and maintenance equipment was not operating. The factor from Cowherd et al. (1974), expressed in mass per unit area per day, is more reliable than the factor expressed in mass per unit mass of material placed in storage, for reasons stated in that report. Note that the coefficient has been halved to adjust for the estimate that the wind speed through the emission layer at the test site was one half of the value measured above the top of the piles. The other terms in this equation were added to correct for silt, precipitation, and frequency of high winds, as discussed in Bohn et al. (1978).

Worst case emissions from storage pile areas occur under dry windy conditions. Worst case emissions from materials handling (batch and continuous drop) operations may be calculated by substituting into Equation (2-7) appropriate values for aggregate material moisture content and for anticipated wind speeds during the worst case averaging period, usually 24 h. The treatment of dry conditions for vehicle traffic (Equation 2-6) and for wind erosion (Equation 2-12), centering around parameter p = 0, follows the methodology described for unpaved roads (Section 2.2). Also, a separate set of nonclimatic correction parameters and source extent values corresponding to higher than normal storage pile activity may be justified for the worst case averaging period.

2.3.2 Model Units

In general, it is expected that most storage piles in urban areas would either be part of a permitted industrial operation (such as a quarry) or be associated with other sources discussed in this report (antiskid material stockpiles, earthen material piles at construction sites, etc.). It is anticipated that virtually all other storage piles (such as might be found at landscaping contractors) would be below the *de minimis* threshold.

2.4 CONSTRUCTION/DEMOLITION

2.4.1 Estimation of Emissions

At present, the only emission factor available in AP-42 is 1.2 tons/acre/month (related to particles < ~ 30-μm Stokes' diameter) for an entire construction site. No factor has been published for demolition in AP-42. However, PM-10 emission factors have been developed for construction site preparation using test data from a study conducted in Minnesota for topsoil removal, earthmoving (cut-and-fill), and truck haulage operations (Kinsey et al., 1983). For these operations, the PM-10 emission factors based on the level of vehicle activity (i.e., vehicle kilometers traveled or VKT) occurring on-site are (Grelinger et al., 1988):

- Topsoil removal: 5.7 kg/VKT for pan scrapers
- Earthmoving: 1.2 kg/VKT for pan scrapers
- Truck haulage: 2.8 kg/VKT for haul trucks

PM-10 emissions due to materials handling and wind erosion of exposed areas can be calculated using the emission factors for storage piles (section 2.3) and agricultural wind erosion (section 2.5), respectively.

2.4.1.1 Demolition Emissions--

For demolition sites, the operations involved in demolishing and removing structures from a site are:

- Mechanical or explosive dismemberment
- Debris loading
- Onsite truck traffic
- Pushing (dozing) operations

2.4.1.2 Dismemberment--

Since no emission factor data are available for blasting or wrecking a building, the operation is addressed through the use of the revised AP-42 materials handling equation:

$$e_D = 0.00056 \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \quad (kg/Mg) \qquad (2\text{-}13)$$

where: e_D = PM-10 emission factor in kg/Mg of material

u = mean wind speed in m/s (default = 2.2 m/s)

M = material moisture content in percent (default = 2 percent)

E_D = 0.00056 kg/Mg (with default parameters)

The above factor can be modified for waste tonnage related to structural floor space where 1 m^2 of floor space represents 0.45 Mg of waste material (0.046 ton/ft^2) (Grelinger et al., 1988). The revised emission factor related to structural floor space (using default parameters) can be obtained by:

$$e_D = 0.00056 \; kg/Mg \cdot 0.45 \; \frac{Mg}{m^2} \qquad (2\text{-}14)$$
$$= 0.00025 \; kg/m^2 \textit{ of structural floor space}$$

2.4.1.3 Debris Loading--

The emission factor for debris loading is based on two tests of the filling of trucks with crushed limestone using a front-end loader which is part of the test basis for the batch drop equation in AP-42, Section 11.2.3. The resulting PM-10 emission factor for debris loading is (Grelinger et al., 1988):

$$e_L = k\,(0.029)\ \text{kg/Mg} \cdot 0.45\ \frac{\text{Mg}}{\text{m}^2} = 0.0046\ \text{kg/m}^2 \qquad (2\text{-}15)$$

where 0.029 kg/Mg is the average measured TSP emission factor and k is the particle size multiplier (0.35 for PM-10).

2.4.1.4 Onsite Truck Traffic--

Emissions from onsite truck traffic is estimated from the existing AP-42 unpaved road equation:

$$e_T = 0.61\left(\frac{s}{12}\right)\left(\frac{S}{48}\right)\left(\frac{W}{2.7}\right)^{0.7}\left(\frac{w}{4}\right)^{0.5}\left(\frac{365-p}{365}\right) \qquad (2\text{-}16)$$

where:
- e_T = PM-10 emission factor in kg/VKT
- s = silt content in percent (default = 12 percent)
- S = truck speed in km/h (default = 16 km/h)
- W = truck weight in Mg (default = 20 Mg)
- w = number of truck wheels (default = 10 wheels)
- p = number of days with measurable precipitation (default = 0 days)

and e_T = 1.3 kg/VKT (with default values)

The above factor is converted from kg/VKT to kg/m² of structural floor space by:

$$E_T = \frac{0.40\ \text{km}}{23\ \text{m}^3\ \text{waste}} \cdot \frac{1\ \text{m}^3\ \text{waste}}{4\ \text{m}^3\ \text{volume}} \cdot \frac{7.65\ \text{m}^3\ \text{volume}}{0.836\ \text{m}^2\ \text{floor space}} \cdot \frac{1.3\ \text{kg}}{\text{VKT}} = 0.052\ \text{kg/m}^2 \qquad (2\text{-}17)$$

2.4.1.5 Pushing Operations--

For pushing (bulldozer) operations, the AP-42 emission factor equation for overburden removal at Western surface coal mines can be used. Although the AP-42 equation actually relates to particulate 15 µm, it can be converted to 10 µm by a correction factor. The AP-42 dozer equation is:

$$e_p = (0.75)\ \frac{0.45\ (s)^{1.5}}{(M)^{1.4}} \tag{2-18}$$

where: e_p = PM-10 emission rate in kg/hr

s = silt content of surface material in percent (default = 6.9 percent) (ASTM-C-136)

M = moisture content of surface material in percent (default = 7.9 percent)

0.75 = PM-10/PM-15 conversion factor

and E_p = 0.34 kg/hr (with default parameters)

2.4.1.6 Mud/Dirt Carryout Emissions--

Mud and dirt carryout from construction and demolition sites often accounts for a temporary but substantial increase in paved road emissions. The increase in emissions on paved roads due to mud/dirt carryout has been developed based on surface loading measurements at eight sites (Englehart and Kinsey, 1983). Tables 2-2 and 2-3 provide these emission factors in terms of g/vehicle pass which represent PM-10 generated over and above the "background" for the paved road sampled. Table 2-2 expresses the emission factors according to the volume of traffic entering and leaving the site, whereas Table 2-3 expresses the same data according to type of construction. Either table may be used by the analyst.

2.4.2 Model Units

Construction represents a fugitive dust source category for which permitting and inspection systems are clearly in place. Furthermore, each site is associated with a party who could be held responsible for dust control. Finally, even though the area may be large, the spatial extent of a construction site is well defined. Because of these factors, an effective emission

TABLE 2-2. EMISSIONS INCREASE (ΔE) BY SITE TRAFFIC VOLUME[a]

Particle size fraction	Sites with > 25 vehicles/day Mean, $\bar{x}$	Std. deviation, σ	Range	Sites with < 25 vehicles/day Mean, $\bar{x}$	Std. deviation, σ	Range
< ~ 30 μm	52	28	15-80	19	7.8	14-28
< 10 μm	13	6.7	4.4-20	5.5	2.3	4.2-8.1
< 2.5 μm	5.1	2.6	1.7-7.8	2.2	0.88	1.6-3.2

[a] ΔE expressed in g/vehicle pass.

[b] Aerodynamic diameter.

TABLE 2-3. EMISSIONS INCREASE (ΔE) BY CONSTRUCTION TYPE[a]

Particle size fraction[b]	Commercial Mean, $\bar{x}$	Std. deviation, σ	Range	Residential Mean, $\bar{x}$	Std. deviation, σ	Range
< ~ 30 μm	65	39	15-110	39	22	10-72
< 10 μm	16	9.3	4.2-25	10	5.4	2.8-19
< 2.5 μm	6.3	3.6	1.6-9.7	3.9	2.1	1.1-7.3

[a] ΔE expressed in g/vehicle pass.

[b] Aerodynamic diameter.

inventory can be more readily developed for construction dust than for the other source categories. In addition, these factors make permit requirements involving dust control more tractable than for the other source categories.

The following discussion uses three sequential "phases" to provide a model unit framework in which emissions from construction activities are conveniently identified and estimated. Each phase considers "unit" dust emitting activities involving similar equipment and, hence, relatively similar emission estimation procedures. The three phases are:

Phase I. Debris Removal, during which debris from any man-made structures or natural obstructions is removed from the site. Thus, this phase includes the removal of demolition debris from implosion or mechanical dismemberment (e.g., "headache" ball) of buildings as well as from the blasting of rock formations and from excavation. Principal emission categories are: material loadout, vehicle travel on paved or unpaved surfaces, and trackout of mud/dirt onto adjacent public streets.

Phase II. Site Preparation, during which the ground surface of the site is brought to final or near-final grade. Thus, this phase includes on-site cut/fill operations (e.g., scrapers, dozers) as well as the transport of cut material off-site and the receipt of "imported" fill materials. Principal emission categories are: scraping and bulldozing, material loadout, vehicle travel on paved or unpaved surfaces, and trackout of mud/dirt onto adjacent public streets.

Phase III. Construction, which includes the other major construction activities, including flatwork, structural and reinforcing steel, exterior operations, interior finishing, and landscaping. Although major source categories can be identified, it is generally difficult to accurately estimate daily source extents, etc. That is, in contrast to Phase I and Phase II activities which can be relatively accurately scheduled and estimated, Phase III is highly dependent on the receipt of materials and there are many simultaneous operations.

Three points should be noted. First, this division of the overall construction process into three phases is certainly arbitrary in that other phases could have been defined or certain operations could be moved from one phase to another. For example, another scheme might classify removal of blasted rock as "site preparation" rather than "debris removal." The scheme presented here merely provides a series of sequential phases involving similar equipment and emission estimation procedures. Second, all three phases need not be present at an individual construction site. Finally, only emissions due to debris removal operations, rather than the demolition process itself, will be considered in the following discussion.

Compared to continuously emitting (point) emission sources, it is more difficult to envision model units for construction-related dust sources. Because construction dust is inherently short-term at one location, cost-effective control depends more upon available materials, environmental setting, and phasing than upon available control technology. In other words, because dust needs to be controlled for only a short period of time at one location, the installation of long-term controls is usually not warranted unless that control is already planned as part of the construction project. Rather, the selection of appropriate control measures depends upon issues such as:

<u>What materials (e.g., water, salts) are available to use in controlling dust?</u> As an example, consider vehicular traffic on unpaved surfaces. For most roads, chemical stabilization is far more cost-effective than regular road watering. However, it is often difficult to justify the more expensive chemical treatment of construction site travel routes which have very short lives.

<u>What constraints does surrounding land use place on the types of controls that could be used?</u> Control techniques available for use in heavily developed areas with traffic

congestion can be expected to differ substantially from those used in largely undeveloped areas.

What changes to the construction schedule could be made to reduce dust emissions? Construction projects, such as industrial parks and residential development, usually involve permanent roads that will eventually be paved. In those instances, early paving represents an effective and economical (because the roads have already been budgeted) control measure.

2.5 OPEN AREA WIND EROSION

Dust emissions may be generated by wind erosion of open agricultural land or exposed ground areas on public property or within an industrial facility. With regard to estimating particulate emissions from wind erosion of exposed surface material, site inspection can be used to determine the potential for continuous wind erosion. The two basic requirements for wind erosion are that the surface be dry and exposed to the wind. For example, if the site lies in a swampy area or is covered by grass, the potential for wind erosion is virtually nil. If, on the other hand, the vegetative cover is not continuous over the exposed surface, then the plants are considered to be nonerodible elements which absorb a fraction of the wind stress that otherwise acts to suspend the intervening soil.

For estimating emissions from wind erosion, either of two emission factor equations are recommended depending on the erodibility of the surface material. Based on the site survey, the exposed surface must be placed in one of two erodibility classes described below. The division between these classes is best defined in terms of the threshold wind speed for the onset of wind erosion.

Nonhomogeneous surfaces impregnated with nonerodible elements (stones, clumps of vegetation, etc.) are characterized by the finite availability ("limited reservoir") of erodible material. Such surfaces have high threshold wind speeds for wind erosion, and particulate emission rates tend to decay rapidly during an erosion event. On the other hand, bare surfaces of finely divided material such as sandy agricultural soil are characterized by an "unlimited reservoir" of erodible surface particles.

Based on analysis of wind erosion research, the dividing line for the two erodibility classes is a threshold friction velocity of about 50 cm/s. This division is based on the observation that highly erodible surfaces, usually corresponding to sandy surface soils that are fairly deep, have threshold friction velocities below 50 cm/s. Surfaces with friction velocities larger than 50 cm/s tend to be composed of aggregates too large to be eroded mixed in with a small amount of erodible material or having crusts that are resistant to erosion. The cutoff friction velocity of 50 cm/s corresponds to an ambient wind speed of about 7 m/s (15 mph), measured at a height of about 7 m.

Crusted surfaces are regarded as having a "limited reservoir" of erodible particles. Crust thickness and strength should be examined during the site inspection by testing with a pocket knife. If the crust is more than 0.6 cm thick and not easily crumbled between the fingers (modulus of rupture 1 bar), then the soil may be considered nonerodible. If the crust thickness is less than 0.6 cm or is easily crumbled, then the surface should be treated as having a limited reservoir of erodible particles. If a crust is found beneath a loose deposit, the amount of this loose deposit, which constitutes the limited erosion reservoir, should be carefully estimated.

For uncrusted surfaces, the threshold friction velocity is best estimated from the dry aggregate structure of the soil. A simple hand-sieving test of surface soil is highly desirable to determine the mode of the surface aggregate size distribution by inspection of relative sieve catch amounts, following the procedure specified in Figure 2-1. The threshold friction velocity for erosion can be determined from the mode of the aggregate size distribution, as shown in Figure 2-2.

A more approximate basis for determining threshold friction velocity would be based on hand sieving with just one sieve, but otherwise follows the procedure specified in Figure 2-1. Based on the relationship developed by Bisal and Ferguson (1970), if more than 60 percent of the soil passes a 1-mm sieve, the "unlimited reservoir" model will apply; if not, the "limited reservoir" model will apply. This relationship has been verified by Gillette (1980) on desert soils.

If the soil contains nonerodible elements which are too large to include in the sieving (i.e., greater than about 1 cm in diameter), the effect of these elements must be taken into account by increasing the threshold friction velocity (U_t^*). Marshall (1971) has employed wind tunnel studies to quantify the increase in the threshold velocity for differing kinds of nonerodible elements. His results are depicted in terms of a graph of the rate of corrected to uncorrected friction velocity versus L_c (Figure 2-3), where L_c is the ratio of the silhouette area of the roughness elements to the total area of the bare loose soil. The silhouette area of a nonerodible element is the projected frontal area normal to the wind direction. A value for L_c is obtained by marking off a 1-m x 1-m surface area and determining the fraction of area, as viewed from directly overhead, that is occupied by nonerodible elements. Then the overhead area should be corrected to the equivalent frontal area; for example, if a spherical nonerodible element is half-embedded in the surface, the frontal area is one-half of the overhead area. Although it is difficult to estimate L_c for values below 0.05, the correction to friction velocity becomes less sensitive to the estimated value of L_c.

The difficulty in estimating L_c also increases for small nonerodible elements. However, because small nonerodible

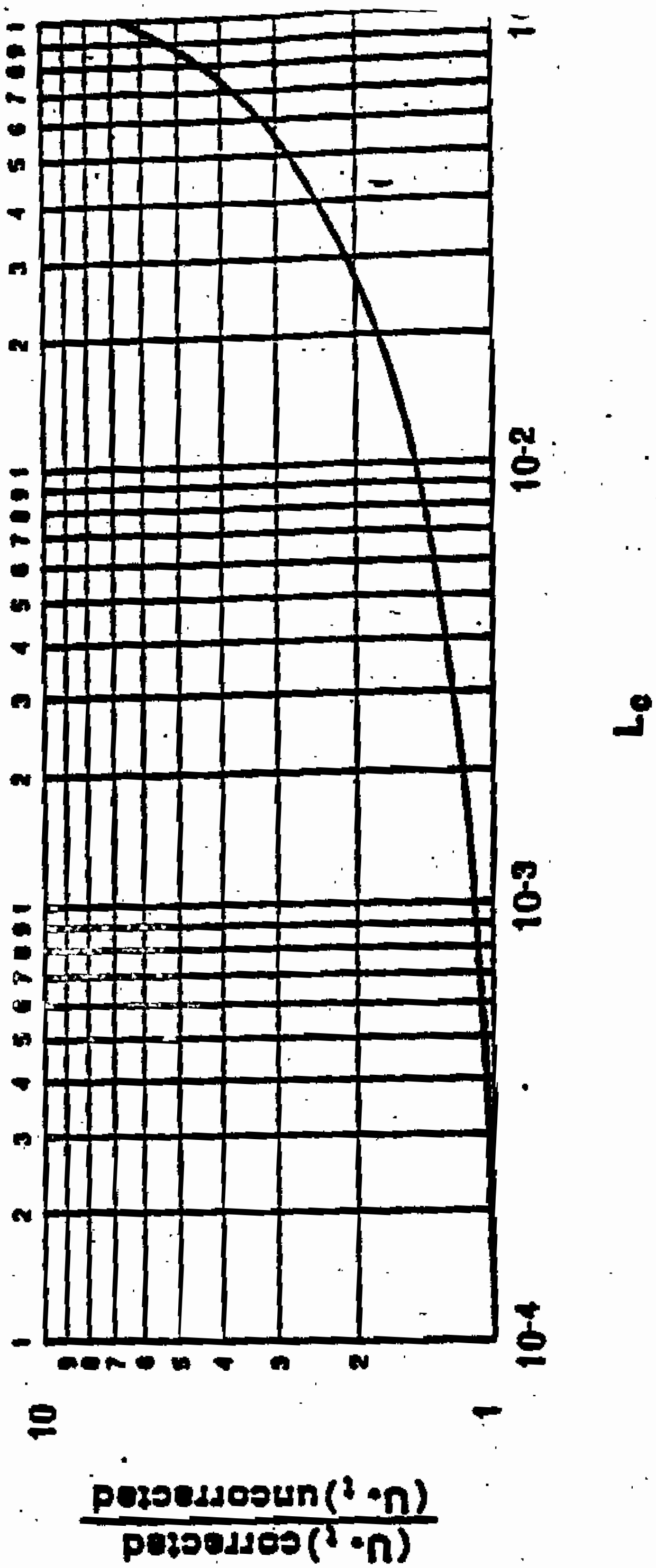

Figure 2-3. Increase in Threshold Friction Velocity with L_c.

elements are more likely to be evenly distributed over the surface, it is usually acceptable to examine a smaller surface area, e.g., 30 cm x 30 cm.

Once again, loose sandy soils fall into the high erodibility ("unlimited reservoir") classification. These soils do not promote crust formation, and show only a brief effect of moisture addition by rainfall. On the other hand, compacted soils with a tendency for crust formation fall into the low ("limited reservoir") erodibility group. Clay content in soil, which tends to promote crust formation, is evident from crack formation upon drying.

The roughness height, z_o, which is related to the size and spacing of surface roughness elements, is needed to convert the friction velocity to the equivalent wind speed at the typical weather station sensor height of 7 m above the surface. Figure 2-4 depicts the roughness height scale for various conditions of ground cover (Cowherd and Guenther, 1976).

2.5.1 Estimation of Emissions

2.5.1.1 "Limited" Erosion Potential--

In the case of surfaces characterized by a "limited reservoir" of erodible particles, the emission estimation procedure is identical to that presented in Section 2.2.1.3.2 for a "flat" pile.

2.5.1.2 "Unlimited" Erosion Potential--

For a surface characterized by an "unlimited reservoir" of erodible particles, particulate emission rates are relatively time independent at a given wind speed. The technology currently used for predicting agricultural wind erosion in the United States is based on variations of the Wind Erosion Equation (Skidmore and Woodruff, 1968; Woodruff and Siddoway, 1965). This prediction system uses erosion loss estimates that are integrated

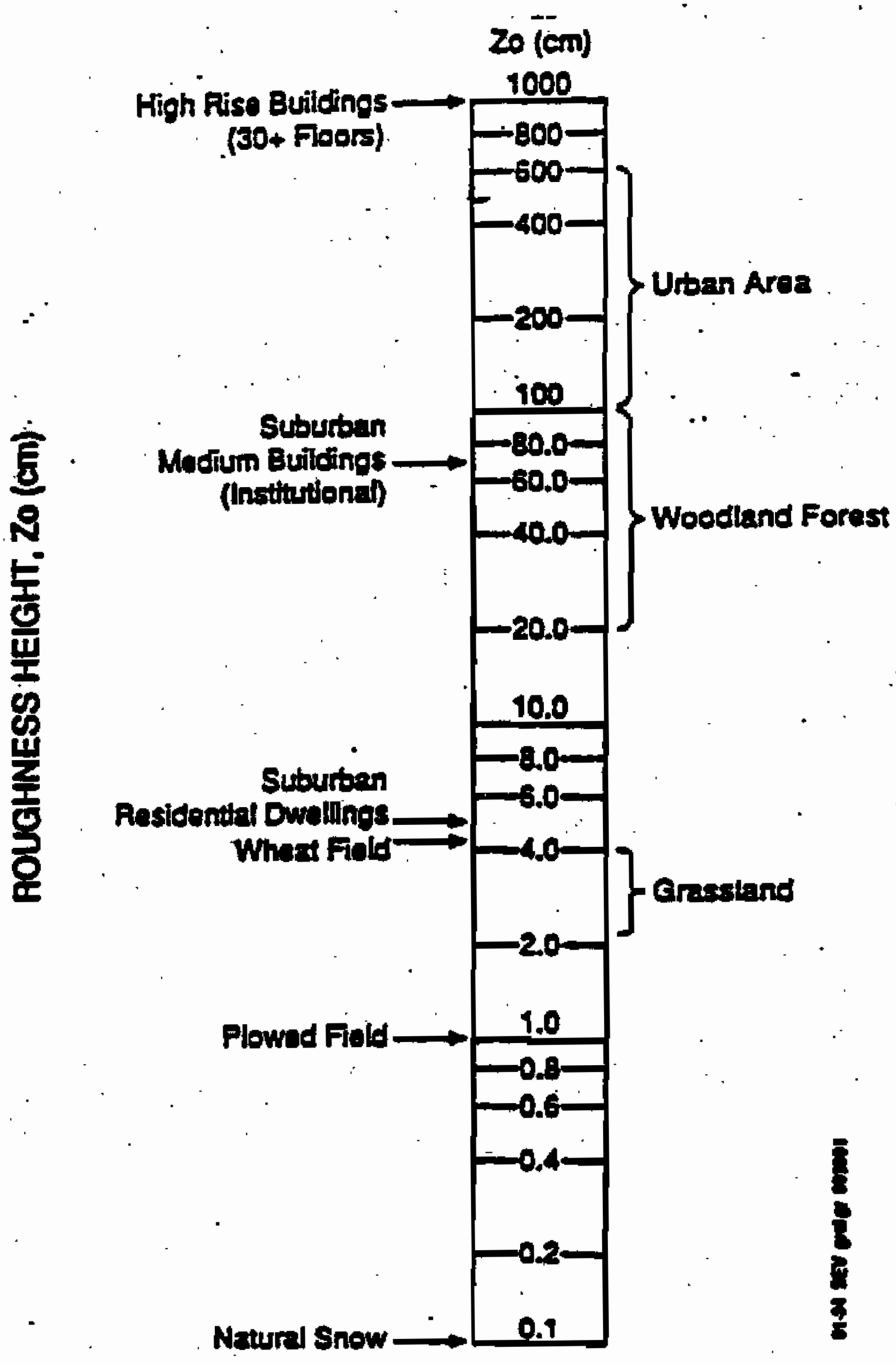

Figure 2-4. Roughness Heights for Various Surfaces.

over large fields and long-time scales to produce average annual values.

2.5.2 Model Units

Compared to mechanical disturbances (e.g., vehicular traffic), emissions from open area wind erosion may be a relatively minor contributor to the total PM-10 emissions in most urban areas. As such, this entire source category could be considered as *de minimis* except for areas with dry climate and high wind speeds. The proposed model unit for open areas can be based on the total acres exposed and the number of disturbances per year. Wind erosion calculations would then be performed to determine the overall contribution to the total PM-10 emissions inventory.

2.6 AGRICULTURAL TILLING

Fugitive dust from agricultural operations occasionally contributes to the ambient PM-10 levels in many rural counties and in some urban areas. Such agricultural operations include (a) plowing, (b) disking, (c) fertilizing, (d) applying herbicides and insecticides, (e) bedding, (f) flattening and firming beds, (g) planting, (h) cultivating, and (i) harvesting. These operations can be generically classified as soil preparation, soil maintenance, and crop harvesting operations. This section will focus on emissions from agricultural tilling operations that are designed to (a) create the desired soil structure for the crop seed bed and (b) to eradicate weeds.

2.6.1 Estimation of Emissions

2.6.1.1 Tilling--

The mechanical tilling of agricultural land injects dust particles into the atmosphere as the soil is loosened or turned under by plowing, disking, harrowing, etc. AP-42 presents a predictive emission factor equation for the estimation of dust emissions from agricultural tilling.

$$e = 1.1\,(s)^{0.6}\ \text{kg/ha}$$
$$e = 1.0\,(s)^{0.6}\ \text{lb/acre} \qquad (2\text{-}19)$$

where: e = PM-10 emission factor, in kilograms per hectare

s = silt content (percent) of surface soil (default value of 18 percent) (ASTM-C-136)

The above equations are based solely on field testing information cited in AP-42. Silt content of tested soils ranged from 1.7 percent to 88 percent.

2.6.1.2 Wind Erosion--

The technology currently used for predicting agricultural wind erosion in the United States is based on variations of the Wind Erosion Equation (Skidmore and Woodruff, 1968; Woodruff and Siddoway, 1965). This prediction system uses erosion loss estimates that are integrated over large fields and long time scales to produce average annual values. The modified Wind Erosion Equation is:

$$e = kaIKCL'V' \qquad (2\text{-}20)$$

where:

- e = PM-10 wind erosion losses of tilled fields, tons/acre/yr
- k = 0.5, the estimated fraction of TSP which is PM-10
- a = portion of total wind erosion losses that would be measured as total suspended particulate, estimated to be 0.025
- I = soil erodibility, tons/acre/yr
- K = surface roughness factor, dimensionless
- C = climatic factor, dimensionless
- L' = unsheltered field width factor, dimensionless
- V' = vegetative cover factor, dimensionless

As an aid in understanding the mechanics of this equation, "I" may be thought of as the basic erodibility of a flat, very large, bare field in a climate highly conducive to wind erosion (i.e., high wind speeds and temperature with little precipitation) and K, C, L', and V' as reduction factors for a ridged surface, a climate less conducive to wind erosion, smaller-sized fields, and vegetative cover, respectively.

2.6.2 Model Unit

The PM-10 emissions from agricultural tilling are both crop-specific and directly related to the total acreage in production. For example, the quantity of emissions from the production of nuts is quite different than that associated with row crops on a per acre basis. Therefore, a classification scheme based on type of crop and acreage in production is proposed.

A suitable model unit for tilling operations can be based on acreage of a field tilled five times a year and classified as "highly erodible" under the Food Security Act (FSA) of 1985.

This model unit will be used in section 4 to demonstrate PM-10 control effectiveness of placing agricultural land into the Conservation Reserve program of the FSA.

SECTION 3

EMISSION CONTROL TECHNIQUES

3.1 PAVED ROADS

Available control methods are largely designed either to prevent deposition of material on the roadway surface or to remove material which has been deposited in the driving lanes. Measurement-based efficiency values for control methods are presented in Table 3-1. Note that all values in this table are for mitigative measures applied to industrial paved roads.

In terms of public paved road dust control, only very limited field measurement data are available. Estimated PM-10 control efficiencies of approximately 35 percent were developed by applying Equation (2-1) to measurements before and immediately after road cleaning (Duncan et al., 1984). Note that these estimates should be considered upper bounds on efficiencies obtained in practice because no redeposition after cleaning is considered. Note also that these estimated emission control efficiencies for urban roads compare fairly well with measurements at industrial roads. No airborne mass emission measurements quantifying control efficiency of public paved road dust control were found in the published literature.

In general terms, one would expect that demonstrated control techniques applied to industrial paved roads could also be applied to public roads. One important point to note, however, is that the effectiveness of mitigative measures generally

TABLE 3-1. MEASURED EFFICIENCY VALUES FOR PAVED ROAD CONTROLS[a]

Method	Cited efficiency	Comments
Vacuum sweeping	0-58%	Field emission measurement (PM-15) 12,000-cfm blower[b]
	46%	Reference 7, based on field measurement of 30 μm particulate emissions
Water flushing	69-0.231 V[c,d]	Field measurement of PM-15 emissions[b]
Water flushing followed by sweeping	96-0.263 V[c,d]	Field measurement of PM-15 emissions[b]

[a] All results based on measurements of air emissions from industrial paved roads. Broom sweeping measurements presented in Section 2.3.2.1 (Cowherd and Kinsey, 1986).
[b] PM-10 control efficiency can be assumed to be the same as that tested.
[c] Water applied at 0.48 gal/yd^2.
[d] Equation yields efficiency in percent, V = number of vehicle passes since application.

decreases as the surface loadings decrease (i.e., it would be less effective to clean the interstate highway surfaces rather than collector street surfaces).

Because mitigative measures are less effective for public paved roads, an EPA urban dust policy stresses the importance of long-term preventive measures as BACM candidates, especially in instances where no dominant or localized source of paved road surface loading can be identified. Examples of nonlocalized sources of paved road surface loading would include: (a) unpaved shoulders adjacent to paved roads, (b) erosion due to storm water runoff, and (c) spillage from passing trucks. Corresponding examples of preventive measures include: (1) installing curbs, paving shoulders, or painting lines near the edge of the pavement; (2) channeling storm water runoff or using vegetation to stabilize surrounding areas; and (3) requiring trucks to be covered and to maintain freeboard (i.e., distance between top of the load and top of truck bed sides).

In instances where the source of loading can be easily identified (e.g., salt or sand spread during snow or ice storms) or the effects are localized (e.g., near the entrance to construction sites or unpaved parking lots), either preventive or mitigative measures could be prescribed. Table 3-2 summarizes Agency guidance on nonindustrial paved road preventive controls. There are few measured efficiency values for any of the preventive measures presented in Table 3-2.

Almost all measured control efficiency values for paved roads are based on data from industrial roads. Consequently, the information presented earlier in Table 3-1 is more applicable to this class of road. Mitigative measures may be more practical for industrial plant roads because: (1) the responsible party is known; (2) the roads may be subject to considerable spillage and carryout from unpaved areas; and (3) all affected roads are relatively close proximity, thus allowing a more efficient use of cleaning equipment. Preventive measures, of course, can be used

TABLE 3-2. NONINDUSTRIAL PAVED ROAD DUST SOURCES AND PREVENTIVE CONTROLS

Source of deposit on road	Recommended controls
-- Sanding/salt	-- Make more effective use of abrasives through planning, uniform spreading, etc. -- Improve the abrasive material through specifications limiting the amount of fines and material hardness, etc. -- Rapid cleanup after streets become clear and dry
-- Spills from haul trucks	-- Require trucks to be covered -- Require freeboard between load and top of hopper -- Wet material being hauled
-- Construction carryout and entrainment	-- Clean vehicles before entering road -- Pave access road near site exit -- Semicontinuous cleanup of exit
-- Vehicle entrainment from unpaved adjacent areas	-- Pave/stabilize portion of unpaved areas nearest to paved road
-- Erosion from stormwater washing onto streets	-- Storm water control -- Vegetative stabilization -- Rapid cleanup after event
-- Wind erosion from adjacent areas	-- Wind breaks -- Vegetative stabilization or chemical sealing of ground -- Pave/treat parking ares, driveways, shoulders -- Limit traffic or other use that disturbs soil surface
-- Other	-- Case-by-case determination

in conjunction with plant street cleaning programs and prevention is the preferred approach for reducing emissions from city streets in industrialized areas with many potential sources of paved road dust. As before, the lack of efficiency values for preventive measures remains an important gap and requires further investigation.

3.1.1 Preventive Measures

These types of control measures prevent the deposition of additional materials on a paved surface area. As a result, it is difficult to estimate their control effectiveness. Instead of assigning control effectiveness values for preventive measures, regulatory personnel may choose to require all responsible parties (e.g., general contractors, street departments spreading salt and sand, businesses/homeowners with unpaved parking lots and driveways) to either submit control plans or agree to agency-supplied programs. Note that frequent watering of unpaved access areas should be discouraged (if possible) because that practice may compound mud/dirt carryout problems.

As early as 1971, EPA recommended reasonable mud/dirt carryout precautions including:

- Watering or use of suppressants at construction/demolition, road grading, and land clearing sites.
- Prompt removal of materials deposited upon paved roadways.
- Covering of open trucks transporting material likely to become airborne.

While most States have adapted many of EPA's recommendations to their own regulations, the vast number and spatial distribution of potential mud/dirt carryout points, as well as the large number of potentially responsible parties, make enforcement very difficult to plan and administer. Consequently, smaller jurisdictive areas (such as cities and counties) should be used in monitoring carryout enforcement. Note that these local agencies include several besides those involved in air pollution per se. For example, building permits may be used to require carryout controls with building inspectors enforcing the regulations. Finally, it is clear that some agreement with the local public works department would be necessary to implement modifications in street salting and sanding procedures or to ensure prompt cleanup.

3.1.1.1 Sanding for Snow and Ice--

After winter snow and ice control programs, the heavy springtime street loadings found in certain areas of the country are known to adversely affect ambient PM-10 concentrations. For example, data collected in Montana indicate that road sanding may produce early silt loadings 5 to 6 times higher than the baseline loading (MRI, 1983). Because that increase corresponds to roughly a fourfold increase in the emission level, it is clear that residual surface loadings represent an important source potentially requiring control. As determined by Kinsey (1991):

1. Antiskid materials are frequently applied at loadings well above recommended levels because of public perception that effectiveness is proportional to the visible amount of surface loading.

2. Excess silt loadings (and thus PM-10 emissions) associated with antiskid materials result primarily from overapplication and noncompliance with recommended fines and durability specifications for antiskid abrasives.

As indicated in Table 3-2, appropriate controls may include: (a) cleanup as soon as practical (vacuum sweeping or flushing followed by broom sweeping), (b) the use of improved materials, and (c) improvements in planning or application methods.

3.1.1.1.1 Improved Antiskid Materials--Some municipalities have experimented by supplementing or replacing their usual snow/ice control materials with other harder and/or coarser materials. Because the choice of usual materials is based upon local availability (salt, sand, cinders) and price, it is clear that changes in materials applied will generally result in higher costs. However, the use of antiskid materials with either a lower initial silt content or greater resistance to forming silt-size particles will result in lower road surface silt loadings. Only limited field measurements comparing resultant silt contents and no measurements of silt loading values have been identified; consequently, it is not possible at this time to accurately estimate the control efficiency afforded by use of improved materials. Kinsey (1991) has formulated selection criteria for antiskid materials that will result in lower silt generation, as shown in Table 3-3.

3.1.1.1.2 Application of Sand--Improvements in planning and application techniques limit the amount of antiskid material applied to roads in an area. AASHTO guidelines for application are shown in Table 3-4. As was the case with improved materials, no field data are known to exist. However, an adequate estimate of areawide control efficiency can be obtained by: (a) comparing the amounts of material applied; (b) assuming that both applications are equally subject to formation of fines, removal, etc.; (c) assuming that both resultant silt loadings are substantially greater than the "baseline" (i.e., prewinter) value; and (d) using Equation (2-1). For example, if a community, through better planning, uses 30 percent less antiskid material, then the resultant silt loadings may be expected to be 30 percent lower. Use of Equation (2-1) would then indicate an effective PM-10 control efficiency of 24.8 percent. Note that if assumption (c) above does not hold, the estimated control efficiency should be viewed only as an upper bound. The

TABLE 3-3. SELECTION CRITERIA FOR ANTISKID ABRASIVES

Measurement parameter	Units	Acceptable materials[a] Range of values	Acceptable materials[a] Mean	Unacceptable materials[b] Range of values	Unacceptable materials[b] Mean
Modified Los Angeles abrasion loss	Weight %	0.9 - 4	3	7 - 17	11
Initial silt content[c]	Weight %	0.02 - 0.03	0.1	4 - 9	6
Vickers hardness	kg/mm^2	500 - 1,200	1,000	400 - 1,000	800
Particle shape index	Dimensionless	6.3 - 15	10	6.5 - 13	9

[a] Based on data for cluster C4.

[b] Based on data for cluster C5.

[c] This parameter is coupled to LA abrasion loss and thus included in the material selection criteria.

TABLE 3-4. GUIDELINES FOR CHEMICAL APPLICATION RATES (AASHTO, 1976)

Weather conditions			Application rate (pounds of material per mile of two-lane road or two lanes divided)				
Temperature	Pavement conditions	Precipitation	Low- and high-speed multilane divided	Two- and three-lane primary	Two-lane secondary		Instructions
30°F and above	Wet	Snow	300 salt	300 salt	300 salt	•	Wait at least 0.5 h before plowing
		Sleet or freezing rain	200 salt	200 salt	200 salt	•	Reapply as necessary
25°-30°F	Wet	Snow or sleet	Initial at 400 salt; repeat at 200 salt	Initial at 400 salt; repeat at 200 salt	Initial at 400 salt; repeat at 200 salt	•	Wait at least 0.5 h before plowing; repeat
		Freezing rain	Initial at 300 salt; repeat at 200 salt	Initial at 300 salt; repeat at 200 salt	Initial at 300 salt; repeat at 200 salt	•	Repeat as necessary
20°-25°F	Wet	Snow or sleet	Initial at 500 salt; repeat at 250 salt	Initial at 500 salt; repeat at 250 salt	1,200 of 5:1 sand/ salt; repeat same	•	Wait about 0.75 h before plowing; repeat
		Freezing rain	Initial at 400 salt; repeat at 300 salt	Initial at 400 salt; repeat at 300 salt		•	Repeat as necessary
15°-20°F	Dry	Dry snow	Plow	Plow	Plow	•	Treat hazardous areas with 1,200 of 20:1 sand/salt
	Wet	Wet snow or sleet	500 of 3:1 salt/ calcium chloride	500 of 3:1 salt/ calcium chloride	1,200 of 5:1 sand/ salt	•	Wait about 1 h before plowing; continue plowing until storm ends; then repeat application
Below 15°F	Dry	Dry snow	Plow	Plow	Plow	•	Treat hazardous are with 1,200 of 20:1 sand/salt

application of less material may be achieved by applying sand only to intersections, hills, and curves on roads with low ADT, as safety permits. Another method to reduce emissions is the use of plowing instead of sanding.

3.1.1.2 Carryout from Unpaved Areas and Construction Sites--

Mud and dirt carryout from unpaved areas such as parking lots and construction sites often accounts for a substantial fraction of paved road silt loadings in many areas. The elimination of this carryout can significantly reduce paved road emissions.

As noted earlier, quantification of control efficiencies for preventive measures is essentially impossible using the standard before/after measurement approach. The methodology described below results in <u>upper bounds of emission reductions</u>. That is, the control afforded cannot be easily described in terms of percent but rather is discussed in terms of mass emissions prevented.

Furthermore, tracking of material onto a paved road results in substantial spatial variation in loading about the access point. This variation may complicate the modeling of emission reductions as well as their estimation, although these difficulties become less important, as the number of unpaved areas in an area and their access points become larger.

For an individual access point from an unpaved area to a paved road, let N represent the daily number of vehicles entering or leaving the area. Let E be given by:

$$E = \begin{cases} 5.5 \text{ g/vehicle for } N \leq 25 \\ 13 \text{ g/vehicle for } N > 25 \end{cases} \qquad (3\text{-}1)$$

where E is the unit PM-10 emission increase in g/vehicle. Finally, if M represents the daily number of vehicle passes <u>on</u>

the paved road, then the net daily emission reduction (g/d) is given by E x M, assuming complete prevention.

The emission reduction calculated above assumes that essentially all carryout from the unpaved area is controlled and, as such, is viewed as an upper limit. In use, a regulatory agency may choose to assign an effective level of carryout control by using some fraction of the E values given above to calculate an emission reduction. Also, the regulatory agency could choose a percent control efficiency and substantiate compliance with testing data.

3.1.1.2.1 Curbing--In arid climates, the major sources of street dust are the exposed soil areas near the streets (e.g., unpaved road shoulders). Dust from the exposed road shoulders is transported to the street surface by turbulence from passing vehicles, wind erosion, tracking by vehicles, and water runoff. Mud carryout by motor vehicles is a significant cause of street surface dust, particularly in areas with abundant rainfall.

In many areas, roadway improvements such as curbing will result in significant impacts on street dust loadings. These improvements are important because dust loadings for streets with uncurbed shoulders are estimated to be four times greater than that observed for curbed streets (APWA, 1969). Since the major portion of vehicle miles traveled in any area is concentrated within the cities, the urban street improvements will have far greater impact on PM-10 levels than would similar improvements implemented in county road networks. Accordingly, intensification of the street improvement plans should be considered as a potential control for street dust emissions.

Continuous curbs usually require gutters and storm sewers for street water runoff. The cost of gutters and sewers is greater than the cost of curbing alone.

To increase the effectiveness of street curbing as a dust control measure, the adjacent soil should be stabilized or covered to prevent wind erosion or tracking of this soil onto the street. Clearly, the most effective means of soil protection at the curb is a sidewalk. A typical and desirable city policy is to include sidewalks whenever curbs are constructed on major streets. The effectiveness of this measure has not been quantified, but it is expected that transfer of exposed soil to adjacent road surfaces will be decreased significantly.

Curbs are effective in keeping vehicles on the pavement, thereby eliminating tracking from the edge of the pavement. However, other techniques such as painting the road 1 to 2 ft from the edge with a stripe and installing parking caution signs may accomplish this objective at far less expense.

3.1.1.3 Other Preventive Control Measures--

As shown in Table 3-2, numerous other preventive controls have been proposed for certain sources of paved road silt loadings. These controls range from wind fences in desert regions to keep sand off highways and other roads to measures designed to prevent losses of materials transported in trucks. These measures are known to control PM-10 emissions effectively, but have not been quantified.

It is recommended that, if the use of one or more of these controls is contemplated in an area, the local control agency design small-scale field tests of the surface loadings before and after implementation to determine a reasonable estimate of the efficiency. Note that, in the design of any program of that type, particular attention must be paid to spatial variations in both sources and controls applied. For example, while a program for wind fences in desert areas would present few complications in assessing control, a program to assess the impact of storm water control or haul truck restrictions must include provisions for the localized (and possibly, random) nature of the source and its effects on surrounding roads.

3.1.2 Mitigative Measures

While preventive measures are preferred under the EPA urban dust policy, some sources of road dust loadings may not be easily controlled by prevention. Consequently, some mitigative measures may be necessary to achieve desired goals. This section discusses demonstrated mitigative measures.

3.1.2.1 Sweeping of Roads--

Mechanical street cleaners employ rotary brooms to remove surface materials from roads and parking lots. Much of their effect is cosmetic, in the sense that, while the roadway appears much cleaner, a substantial fraction of the original dust loading is emitted during the process. Thus, there is some credence to claims that mechanical cleaning is as much a source as a control of particulate emissions.

Measurement-based control efficiency for industrial roads (Table 3-1) and estimated efficiencies for urban roads both indicate a maximum (initial) instantaneous control of roughly 25 to 30 percent. Efficiency, of course, can be expected to decrease prior to the next cleanup. Because of the poor amount of control broom sweeping provides, it will not be considered as a viable candidate for BACM.

Vacuum sweepers remove material from paved surfaces by entraining particles in a moving air stream. A hopper is used to contain collected material and air exhausts through a filter system in an open loop. A regenerative sweeper functions in much the same way, although the air is continuously recycled. In addition to the vacuum pickup heads, a sweeper may also be equipped with gutter and other brooms to enhance collection.

Instantaneous control efficiency values were given earlier in Table 3-1. An average of field measurements indicates an efficiency of 34 percent for vacuum sweeping.

3.1.2.2 Water Flushing of Roads--

Street flushers remove surface materials from roads and parking lots using high pressure water sprays. Some systems supplement the cleaning with broom sweeping after flushing. Unlike the two sweeping methods, flushing faces some obvious drawbacks in terms of water usage, potential water pollution, and the frequent need to return to the water source. However, flushing generally tends to be more effective in controlling particulate emissions.

Equations to estimate instantaneous control efficiency values are given in Table 3-1. Note that water flushing and flushing followed by broom sweeping represent the two most effective control methods (on the basis of field emission measurements) given in that table.

In the case of winter sanding, dust generation potential can be reduced if the fine materials left on roadways after pavement drying are cleaned up promptly and without further spreading and resuspension. Prompt cleaning also keeps abrasives from being ground into small particles by road traffic or freeze/thawing. Quick cleanup may not be mandated, however, if a new snowstorm is likely. Cleanup using combination water flushing/broom sweeping is recommended as soon as possible after a storm when above-freezing temperatures keep the flushing water from freezing on the roadway. If the road is already wet, flushing may not be required.

3.2 UNPAVED ROADS

There are numerous control options for unpaved travel surfaces, as shown in Table 3-5. Note that the controls fall into the three general categories of source extent reductions, surface improvements, and surface treatment. Each of these is discussed in greater detail in the following sections.

TABLE 3-5. CONTROL TECHNIQUES FOR UNPAVED TRAVEL SURFACES[a]

Source extent reduction:	Speed reduction
	Traffic reduction
Source improvement:	Paving
	Gravel surface
Surface treatment:	Watering
	Chemical stabilization

[a] Table entries reflect EPA draft guidance on urban fugitive dust control.

3.2.1 Source Extent Reductions

These controls either limit the amount of traffic on a road to reduce the PM-10 emission rate or lower speeds to reduce the emission factor value given by Equation (2-6). Examples could include ride share programs, restriction of roads to certain vehicle types, or strict enforcement of speed limits. In any instance, the control afforded by these measures is readily obtained by the application of the equation.

3.2.2 Surface Improvements

These controls alter the road surface. Unlike surface treatments (discussed below), these improvements are largely "one-shot" control methods; that is, periodic retreatments are not normally required.

The most obvious surface improvement is, of course, paving an unpaved road. This option is expensive and is probably most applicable to high volume (more than a few hundred passes per day) public roads and industrial plant roads that are not subject to very heavy vehicles (e.g., slag pot carriers, haul trucks, etc.) or spillage of material in transport. Control efficiency estimates can be obtained by applying the information of Section 3-1.

Other improvement methods cover the road surface material with another material of lower silt content (e.g., covering a dirt road with gravel or slag, or using a "road carpet" under ballast). Because Equation (2-6) shows a linear relationship between the emission factor and the silt content of the road surface, any reduction in the silt value is accompanied by an equivalent reduction in emissions. This type of improvement is initially much less expensive than paving; however, maintenance (such as grading and spot reapplication of the cover material) may be required.

Finally, vegetative cover has been proposed as a surface improvement for very low traffic volume roads (i.e., access roads to agricultural fields). Even though vehicle related emissions from such a road would be quite low, this method will also reduce wind erosion of the road surface.

3.2.3 Surface Treatments

Surface treatment refers to those control techniques which require periodic reapplications. Treatments fall into the two main categories of (1) wet suppression (i.e., watering, possibly with surfactants or other additives), which keeps the surface wet to control emissions, and (2) chemical stabilization, which attempts to change the physical (and, hence, the emissions) characteristics of the roadway. Necessary reapplication frequencies may range from several minutes for plain water under hot, summertime conditions to several weeks (or months) for chemicals.

Water is usually applied to unpaved roads using a truck with a gravity or pressure feed. This is only a temporary measure, and periodic reapplications are necessary to achieve any substantial level of control efficiency. Some increase in overall control efficiency is afforded by wetting agents which reduce surface tension.

Chemical dust suppressants, on the other hand, have much less frequent reapplication requirements. These suppressants are designed to alter the roadway, such as cementing loose material into a fairly impervious surface (thus simulating a paved surface) or forming a surface which attracts and retains moisture (thus simulating wet suppression).

Chemical dust suppressants are generally applied to the road surface as a water solution of the agent. The degree of control achieved is a direct function of the application intensity (volume of solution per area), dilution ratio, and frequency (number of applications per unit time) of the chemical applied to the surface and also depends on the type and number of vehicles using the road.

3.2.3.1 Watering--

The control efficiency of unpaved road watering depends upon: (a) the amount of water applied per unit area of road surface, (b) the time between reapplications, (c) traffic volume during that period, and (d) prevailing meteorological conditions during the period. All of these factors affect the road surface moisture content. The control efficiency relationship shown in Figure 3-1 is buried in field tests conducted at a coal-fired power plant. Surface moisture grab samples over the daily watering cycle along with the daily traffic flow cycle are needed to determine an average control efficiency using this figure. The low control efficiency for watering of unpaved roads and the need for frequent (almost daily) reapplication preclude the use of watering as possible BACM.

3.2.3.2 Chemical Treatments--

As noted, some chemicals (most notably salts) simulate wet suppression by attracting and retaining moisture on the road surface. These methods are often supplemented by some watering. It is recommended that control efficiency estimates be obtained using Figure 3-1 and enforcement be based on grab sample moisture contents.

The more common chemical dust suppressants form a hard cemented surface. It is this type of suppressant that is considered below.

Besides water, petroleum resins (such as Coherex®) have historically been the products most widely used in industry. However, considerable interest has been shown at both the plant and corporate level in alternative chemical dust suppressants. As a result of this continued interest, several new dust

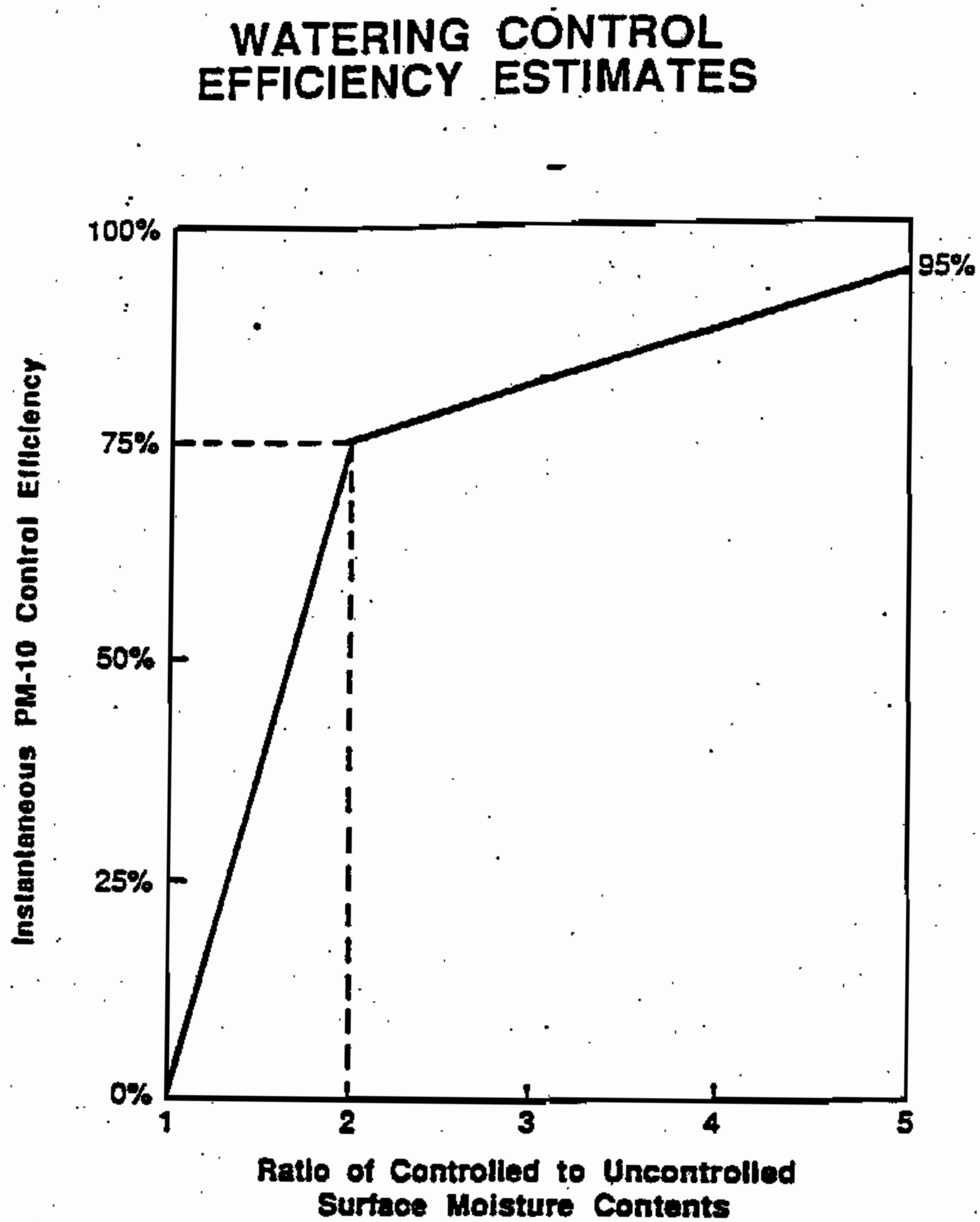

Figure 3-1. Watering Control Effectiveness for Unpaved Travel Surfaces.

suppressants have been introduced. These have included asphalt emulsions, acrylics, and adhesives. In addition, the generic petroleum resin formulations developed at the Mellon Institute with funding from the American Iron and Steel Institute (AISI) have gained considerable attention. These generic suppressants were designed to be produced on-site at iron and steel plants. On-site production of this type of suppressant in quantities commonly used in iron and steel plants has been estimated to reduce chemical costs by approximately 50 percent (Russell and Caruso, 1984).

In an earlier test report, average performance curves were generated for four chemical dust suppressants: (a) a commercially available petroleum resin, (b) a generic petroleum resin for on-site production at an industrial facility, (c) an acrylic cement, and (d) an asphalt emulsion (Muleski and Cowherd, 1987). (Note that at the time of the testing program, these suppressant types accounted for the majority of the market share in the iron and steel industry.) The results of this program were combined with other test results to develop a model to estimate time-averaged PM-10 control performance. This model is illustrated in Figure 3-2. Several items are to be noted:

- The term "ground inventory" is a measure of residual effects from previous applications. Ground inventory is found by adding together the total volume (per unit area) of concentrate (not solution) since the start of the dust control season. An example is provided below.
- Note that no credit for control is assigned until the ground inventory exceeds 0.05 gal/yd^2.
- Because suppressants must be periodically reapplied to unpaved roads, use of the time-average values given in the figure are appropriate. Recommended minimum reapplication frequencies (as well as alternatives) are discussed later in this section.

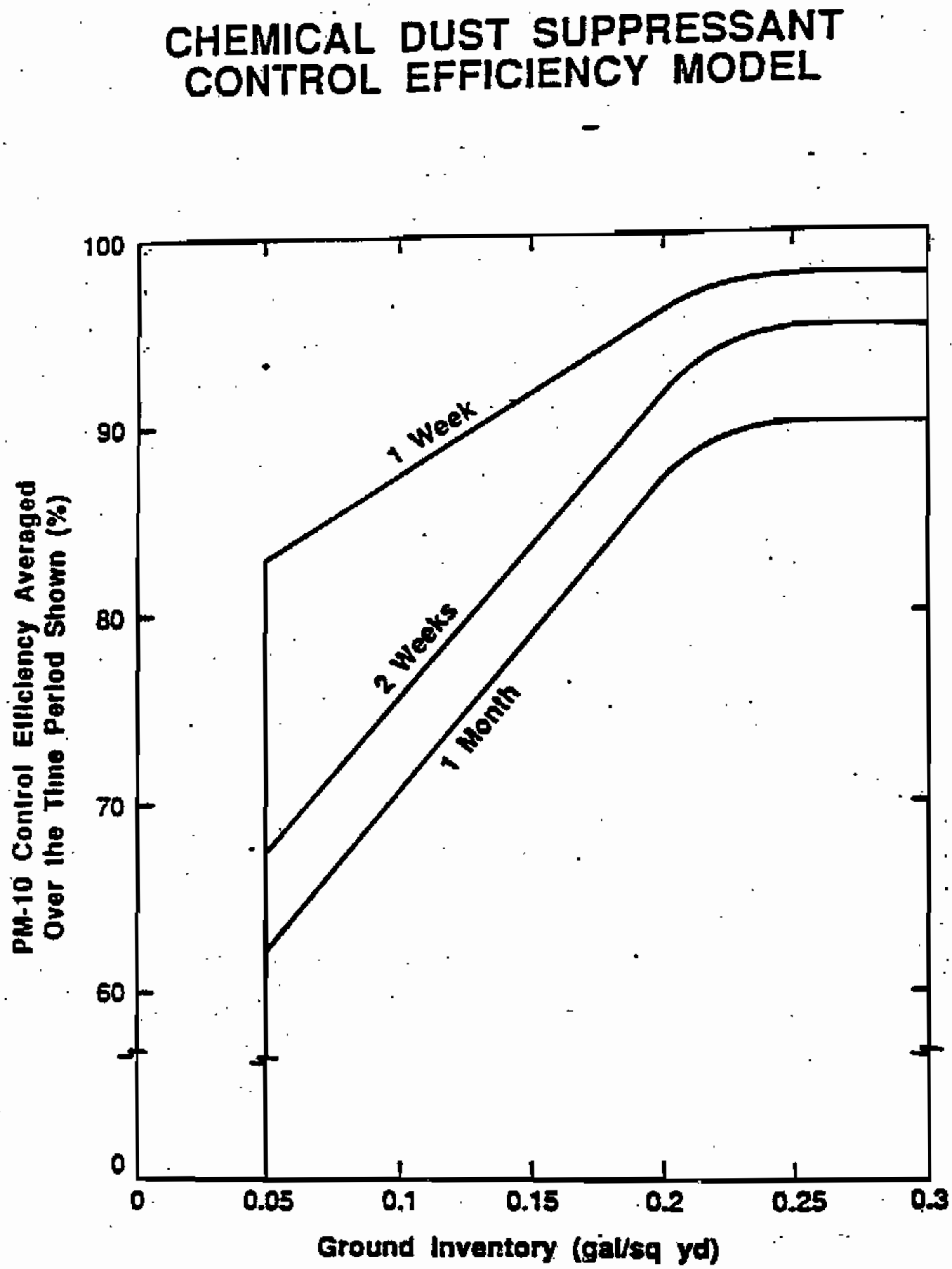

Figure 3-2. Average PM10 control efficiency for chemical suppressants.

- Figure 3-2 represents an <u>average</u> of the four suppressants given above. The basis of the methodology lies in a similar model for petroleum resins only (Muleski and Cowherd, 1987). However, agreement between the control efficiency estimates given by Figure 3-2 and available field measurements is reasonably good.

As an example of the use of Figure 3-2, suppose the Equation (2-6) has been used to estimate a PM-10 emission factor of 2.0 kg/VKT. Further, suppose that starting on May 1, the road is treated with 0.25 gal/yd^2 of a (1 part chemical to 5 parts water) solution on the first of each month until October. In this instance, the following average controlled emission factors are found:

Period	Ground inventory, gal/yd^2	Average control efficiency, percent[a]	Average controlled emission factor, kg/VKT
May	0.042	0	2.0
June	0.083	68	0.64
July	0.12	75	0.50
August	0.17	82	0.36
September	0.21	88	0.24

[a] From Figure 3-1; zero efficiency assigned if ground inventory is less than 0.05 gal/yd^2.

In formulating dust control plans for chemical dust suppressants, additional topics must be considered. These are briefly discussed below.

3.2.3.2.1 <u>Use of Paved Road Controls on Chemically Treated Unpaved Roads</u>--Repeated use of chemical dust suppressants tend, over time, to form fairly impervious surfaces on unpaved roads. The resulting surface may permit the use of paved road cleaning techniques to reduce aggregate loading due to spillage and track-on. A field program conducted tests on surfaces that had been flushed and vacuumed 3 days earlier (Muleski and Cowherd, 1987). (The surfaces themselves had last been chemically treated 70 days before.) Control efficiency values of 90 percent or more (based on the uncontrolled emission factor of the unpaved roads) were found for each particulate size fraction considered.

The use of paved road techniques for "housekeeping" purposes would appear to have the benefits of both high control (referenced to an uncontrolled unpaved road) and potentially relatively low cost (compared to follow-up chemical applications). Generally, it is recommended that these methods not be employed until the ground inventory exceeds approximately 0.2 gal/yd^2 (0.9 L/m^2). Plant personnel should, of course, first examine the use of paved road techniques on chemically-treated surfaces in limited areas prior to implementing a full-scale program.

3.2.3.2.2 <u>Minimum Reapplication Frequency</u>--Because unpaved roads in industry are often used for the movement of materials and are often surrounded by additional unpaved travel areas, spillage and carryout onto the chemically treated road required periodic "housekeeping" activities. In addition, gradual abrasion of the treated surface by traffic will result in loose material on the surface which should be controlled.

It is recommended that at least dilute reapplications be employed every month to control loose surface material unless paved road control techniques are used (as described above). More frequent reapplications would be required if spillage and track-on pose particular problems for a road.

3.2.3.2.3 <u>Weather Considerations</u>--Roads generally have higher moisture contents during cooler periods due to decreased evaporation. Small increases in surface moisture may result in large increases in control efficiency (as referenced to the dry summertime conditions inherent in the AP-42 unpaved road predictive equation). In addition, application of chemical dust suppressants during cooler periods of the year may be inadvisable for traffic safety reasons.

Weather-related application schedules should be considered prior to implementing any control program. Responsible parties and regulatory agency personnel should work closely in making this joint determination.

Compared to the other open dust sources discussed in this manual, there is a wealth of cost information available for chemical dust suppressants on unpaved roads. Note that many salt products are delivered and applied by the same truck. For those products, costs are easily obtained by contacting a local distributor.

3.3 STORAGE PILES

The control techniques applicable to storage piles fall into distinct categories as related to materials handling operations (including traffic around piles) and wind erosion. In both cases, the control can be achieved by: (a) source extent reduction, (b) source improvement related to work practices and transfer equipment (load-in and load-out operations), and (c) surface treatment. These control options are summarized in Table 3-6. The efficiency of these controls ties back to the emission factor relationships presented earlier in this section.

In most cases, good work practices which confine freshly exposed material provide substantial opportunities for emission reduction without the need for investment in a control application program. For example, pile activity, loading and unloading, can be confined to leeward (downwind) side of the pile. This statement also applies to areas around the pile as well as the pile itself. In particular, spillage of material caused by pile load-out and maintenance equipment can add a large

TABLE 3-6. CONTROL TECHNIQUES FOR STORAGE PILES

Material handling	
Source extent reduction	Mass transfer reduction
Source improvement	Drop height reduction Wind sheltering Moisture retention
Surface treatment	Wet suppression
Wind erosion	
Source extent reduction	Disturbed area reduction Disturbance frequency reduction Spillage cleanup
Source improvement	Spillage reduction Disturbed area wind exposure reduction
Surface treatment	Wet suppression Chemical stabilization

source component associated with traffic-entrained dust. Emission inventory calculations show, in fact, that the traffic dust component may easily dominate over emissions from transfer of material and wind erosion. The prevention of spillage and subsequent spreading of material by vehicle tracking is essential to cost-effective emission control. If spillage cannot be prevented because of the need for intense use of mobile equipment in the storage pile area, then regular cleanup should be employed as a necessary mitigative measure.

Preventive methods for control of windblown emissions from raw material storage piles include chemical stabilization, enclosures, and wetting. Physical stabilization by covering the exposed surface with less erodible aggregate material and/or vegetative stabilization are seldom practical control methods for raw material storage piles.

To test the effectiveness of chemical stabilization controls for wind erosion of storage piles and tailings piles, wind tunnel measurements have been performed. Although most of this work has been carried out in laboratory wind tunnels, portable wind tunnels have been used in the field on storage piles and tailings piles (Cuscino, Muleski, and Cowherd, 1983; Bohn and Johnson, 1983). Laboratory wind tunnels have also been used with physical models to measure the effectiveness of wind screens in reducing surface wind velocity (Studer and Arya, 1988).

3.3.1 Chemical Stabilization

A portable wind tunnel has been used to measure the control of coal pile wind erosion emissions by a 17 percent solution of Coherex® in water applied at an intensity of 3.4 L/m^2 (0.74 gal/yard^2), and a 2.8 percent solution of Dow Chemical M-167 Latex Binder in water applied at an average intensity of 6.8 L/m^2 (1.5 gal/yard^2) (Cuscino, Muleski, and Cowherd, 1983). The control efficiency of Coherex® applied at the above intensity to an undisturbed steam coal surface approximately 60 days before the test, under a wind of 15.0 m/s (33.8 mph) at 15.2 cm (6 in.) above the ground, was 89.6 percent for TP and approximately 62 percent for IP and FP. The control efficiency of the latex binder on a low volatility coking coal is shown in Figure 3-3.

3.3.2 Enclosures

Enclosures are an effective means by which to control fugitive particulate emissions from open dust sources. Enclosures can either fully or partially enclose the source. Included in the category of partial enclosures are porous wind screens or barriers. This particular type of enclosure is discussed in detail below.

With the exception of wind fences/barriers, a review of available literature reveals no quantitative information on the effectiveness of enclosures to control fugitive dust emissions from open sources. Types of passive enclosures traditionally used for open dust control include three-sided bunkers for the storage of bulk materials, storage silos for various types of aggregate material (in lieu of open piles), open-ended buildings, and similar structures. Practically any means that reduces wind entrainment of particles produced either through erosion of a dust-producing surface (e.g., storage silos) or by a source (e.g., front-end loader) is generally effective in controlling fugitive particulate emissions. However, available data are not sufficient to quantify emission reductions.

Partial enclosures used for reducing windblown dust from large exposed areas and storage piles include porous wind fences and similar types of physical barriers (e.g., trees). The principle of the wind fence/barrier is to provide an area of reduced wind velocity which allows settling of the large particles (which cause saltation) and reduces the particle flux from the exposed surface on the leeward side of the

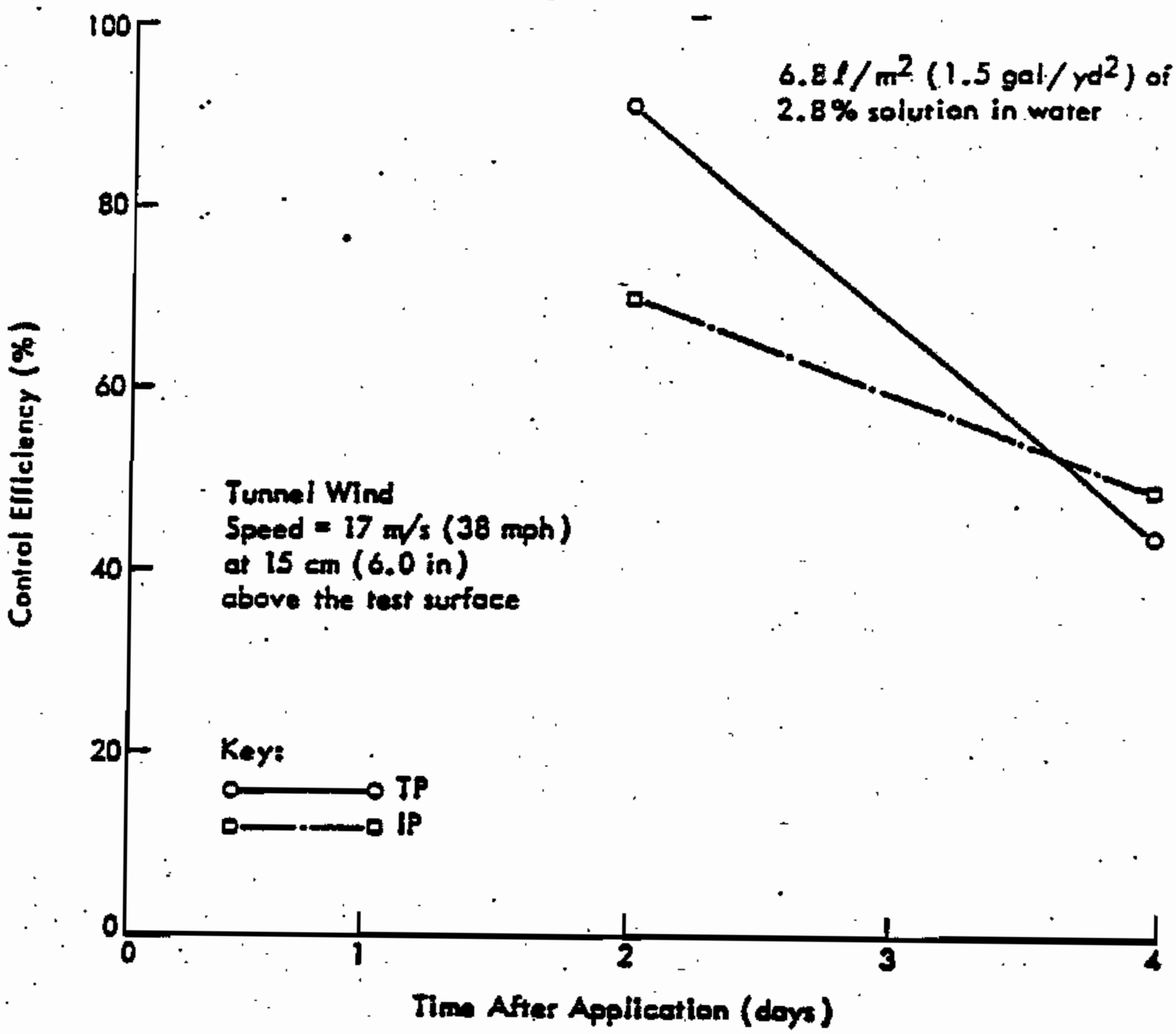

Figure 3-3. Decay in Control Efficiency of Latex Binder Applied to Coal Storage Piles

fence/barrier. The control efficiency of wind fences is dependent on the physical dimensions of the fence relative to the source being controlled. In general, a porosity (i.e., percent open area) of 50 percent seems to be optimum for most applications. Wind fences/barriers can either be man-made structures or vegetative in nature.

A number of studies have attempted to determine the effectiveness of wind fences/barriers for the control of windblown dust under field conditions. Several of these studies have shown both a significant decrease in wind velocity as well as an increase in sand dune growth on the lee side of the fence (Chepil and Woodruff, 1963; Carnes and Drehmel, 1982; Larson, 1982; Westec Services, 1984).

Various problems have been noted with the sampling methodology used in each of the field studies conducted to date. These problems tend to limit an accurate assessment of the overall degree of control achievable by wind fences/barriers for large open sources. Most of this work has either not thoroughly characterized the velocity profile behind the fence/barrier or adequately assessed the particle flux from the exposed surface.

A 1988 laboratory wind tunnel study of windbreak effectiveness for coal storage piles showed area-averaged wind speed reductions of 50 percent to 70 percent for a 50 percent porosity windbreak with height equal to the pile height and length equal to the pile base. The windbreak was located three pile heights upwind from the base of the pile. This study also suggested "that fugitive dust emissions on the top of the pile may be controlled locally through the use of a windbreak at the top of the pile" (Studer and Arya, 1988).

Based on the 1.3 power given in Equation (2-7), reductions of ~ 50 percent to 70 percent would correspond to ~ 60 percent to 80 percent control requires source-specific evaluation because of the interrelation of u_t and u^* (for both controlled and uncontrolled conditions) in Equation (2-7).

This same laboratory study showed that a storage pile may itself serve as a wind break by reducing wind speed on the leeward face (Figure 2-4). The degree of wind sheltering and associated wind erosion emission reduction is dependent on the shape of the pile and on the approach angle of the wind to an elongated pile.

3.3.3 Wet Suppression Systems

Fugitive emissions from aggregate materials handling systems are frequently controlled by wet suppression systems. These systems use liquid sprays or foam to suppress the formation of airborne dust. The primary control mechanisms are those that prevent emissions through agglomerate formation by combining small dust particles with larger aggregate or with liquid droplets. The key factors that affect the degree of agglomeration and, hence, the performance of the system are the coverage of the material by the liquid and the ability of the liquid to "wet" small particles. This section addresses two types of wet suppression systems--liquid sprays which use water or water/surfactant mixtures as the wetting agent and systems which supply foams as the wetting agent.

Liquid spray wet suppression systems can be used to control dust emissions from materials handling at conveyor transfer points. The wetting agent can be water or a combination of water and a chemical surfactant. This surfactant, or surface active agent, reduces the surface tension of the water. As a result, the quantity of liquid needed to achieve good control is reduced. For systems using water only, addition of surfactant can reduce the quantity of water necessary to achieve a good control by a ratio of 4:1 or more (USEPA, 1983; JACA Corp., 1979).

The design specifications for wet suppression systems are generally based on the experience of the design engineer rather than on established design equations or handbook calculations.

Some general design guidelines that have been reported in the literature as successful are listed below:

1. A variety of nozzle types have been used on wet suppression systems, but recent data suggest that hollow cone nozzles produce the greatest control while minimizing clogging (U.S. Bureau of Mines, 1982).

2. Optimal droplet size for surface impaction and fine particle agglomeration is about 500 µm; finer droplets are affected by drift and surface tension and appear to be less effective (Courtney and Cheng, 1978).

3. Application of water sprays to the underside of a conveyor belt improves the performance of wet suppression systems at belt-to-belt transfer points (Seibel, 1976). Micron-sized foam application is an alternative to water spray systems. The primary advantage of foam systems is that they provide equivalent control at lower moisture addition rates than spray systems. However, the foam system is more costly and requires the use of extra materials and equipment. The foam system also achieves control primarily through the wetting and agglomeration of fine particles (Seibel, 1976). The following guidelines to achieve good particle agglomeration have been suggested.

1. The foam can be made to contact the aggregate material by any means. High velocity impact or other brute force means are not required.

2. The foam should be distributed throughout the product material. Inject the foam into free-falling material rather than cover the product with foam.

3. The amount applied should allow all of the foam to dissipate. The presence of foam with the product indicates that either too much foam has been used or it has not been adequately dispersed within the material.

Available data for both water spray and foam wet suppression systems are presented in AP-42. The data primarily included estimates of control efficiency based on concentrations of total particulate or respirable dust in the workplace atmosphere. Some data on mass emissions reduction are also presented. The data should be viewed with caution in that test data ratings are generally low and only minimal data on process or control system parameters are presented.

The data in AP-42 do indicate that a wide range of efficiencies can be obtained from wet suppression systems. For conveyor transfer stations, liquid spray systems had efficiencies ranging from 42 percent to 75 percent, while foam systems had efficiencies ranging from 0 percent to 92 percent. The data are not sufficient to develop relationships between control or process parameters and control efficiencies. However, the following observations relative to the data are noteworthy:

1. The quantity of foam applied to a system does have an impact on system performance. On grizzly transfer points, foam rates of 7.5 ft^3 to 10.5 ft^3 of foam per ton of sand produced increasing control efficiencies ranging from 68 percent to 98 percent (Volkwein et al., 1983). Foam rates below 5 ft^3 per ton produced no measurable control.

2. Material temperature has an impact on foam performance. At one plant where sand was being transferred, control efficiencies ranged from 20 percent to 65 percent when 120 F sand was handled. When sand temperature was increased to 190 F, all control efficiencies were below 10 percent (Volkwein et al., 1983).

3. Data at one plant suggest that undesirable belt sprays increase control efficiencies for respirable dust (56 percent to 81 percent) (Seibel, 1976).

4. When spray systems and foam systems are used to apply equivalent moisture concentrations, foam systems appear to provide greater control (Volkwein et al., 1983). On a grizzly feed to a crusher, equivalent foam and spray applications provided 68 percent and 46 percent control efficiency, respectively.

3.4 CONSTRUCTION/DEMOLITION

Work practice controls refer to those measures which reduce either emissions potential and/or source extent. These will be discussed below for both construction and demolition activities.

For construction activities, a number of work practice controls can be applied to reduce PM-10 emissions from the site. These include paving of roads and access points early in the project, compaction or stabilization (chemical or vegetative) of disturbed soil, phasing of earthmoving activities to reduce source extent, and reduction of mud/dirt carryout onto paved streets. Each of these techniques is site-specific. However, subdivisions, for example, can be constructed in phases (or plats) whereby the amount of land disturbed is limited to only a selected number of home sites. Also, subdivision streets can be constructed and paved when the utilities are installed, thus reducing the duration of land disturbance.

Finally, increased surface loading on paved city streets due to mud/dirt carryout can be reduced to mitigate secondary site impacts. This may involve the installation of a truck wash at access points to remove mud/dirt from the vehicles prior to exiting the site or periodic cleaning of the street near site entrances. All of these techniques require preplanning for implementation without substantially interfering with the conduct of the project.

In the case of demolition sites, the work practice controls which can be employed are far more limited than is the case for construction. Normally, demolition is an intense activity conducted over a relatively short timeframe; therefore, measures to limit source extent are not usually possible. The most significant technique to limit emissions potential is to control mud/dirt carryout onto paved city streets. This could be conducted by installing a truck wash and grizzly to remove mud and debris from the vehicles as they leave the site. Also, controlling dust generated by vehicle traffic on the site can be significant.

Control efficiency values can be obtained by a site-specific analysis of alternative site preparation schemes based on the planned level of activity for the entire project using the emission factors provided above. For mud/dirt carryout, a quantitative value for control efficiency could be obtained if street surface loading data for uncontrolled (i.e., those which do not employ any measures to reduce carryout) and controlled sites were collected.

3.4.1 Traditional Control Technology

In addition to work practices, a number of open source controls are also available for reducing PM-10 emissions from construction and demolition sites. These traditional controls are: watering of unpaved surfaces; wet suppression for materials storage, handling, and transfer operations; and wind fences for control of windblown dust.

The use of water is probably the most widely used method to control open source emissions. However, very little quantitative data are available on the efficacy of wet suppression for the control of fugitive PM-10. This is especially true for materials storage and handling operations. Some limited data are available for watering of unpaved surfaces, but estimation of control efficiency (and thus a watering control plan) is difficult. Those data which are available are presented below.

It should be noted that treatment of unpaved surfaces using chemical dust suppressants has not been included in the list of available controls for construction/demolition. This is due to the fact that the temporary nature of these operations may not warrant their use. The same travel surfaces may not be used for sufficient time to allow reapplications of the chemicals and achieve cost-effective use of the chemical suppressants. An exception might be the use of hydroscopic salts which require only one application at the beginning of the project.

With regard to wind fences, only three studies have been identified for this particular control technique which attempt to quantify the degree of control achieved. Wind fences (and other types of barriers) are extremely cost effective in that they incur little or no operating and maintenance costs. For this reason wind fences are an attractive control alternative for windblown PM-10 emissions.

3.4.2 Watering of Unpaved Surfaces

Watering of unpaved roads is one form of wet dust suppression. This technique prevents (or suppresses) the fine particulate from leaving the surface and becoming airborne through the action of mechanical disturbance or wind. The water acts to bind the smaller particles to the larger material thus reducing emissions potential.

The control efficiency of watering of unpaved surfaces is a direct function of the amount of water applied per unit surface area (liters per square meter); the frequency of application (time between reapplication); the volume of traffic traveling over the surface between applications; and prevailing meteorological conditions (e.g., wind speed, temperature, etc.). As stated previously, a number of studies have been conducted with regard to the efficiency of watering to control dust, but few have quantified all parameters listed above.

The only specific control efficiency data which are available for construction and demolition involve the use of watering to control truck haulage emissions for a road construction project in Minnesota (Kinsey et al., 1983). Using the geometric means of the important source characteristics (i.e., silt content, traffic volume, and surface moisture) and the regression equation developed from the downwind concentration data, a PM-10 control efficiency of approximately 50 percent was obtained for a water application intensity of approximately 0.2 $gal/yd^2/hour$.

It should be noted that truck travel at road construction sites is only somewhat similar to travel on unpaved roads. The road bed surface is generally not as compacted as a well-constructed unpaved road. There are also subtle differences in surface composition. Care should be taken, therefore, in estimating control efficiency for noncompacted surfaces.

For more compacted, unpaved surfaces found in construction and demolition sites, an empirical model for the performance of watering as a control technique has been developed (Cowherd and Kinsey, 1986). The supporting data base consists of 14 tests performed in four States during five different summer and fall months. The model is:

$$C = 100 - \frac{0.8\, p\, d\, t}{i} \qquad (3\text{-}2)$$

where:
- C = average control efficiency, in percent
- p = potential average hourly daytime evaporation rate in mm/h
- d = average hourly daytime traffic rate in vehicles per hour
- i = application intensity in L/m^2
- t = time between applications in h

The term p in the above equation is determined using Figure 3-4 and the relationship:

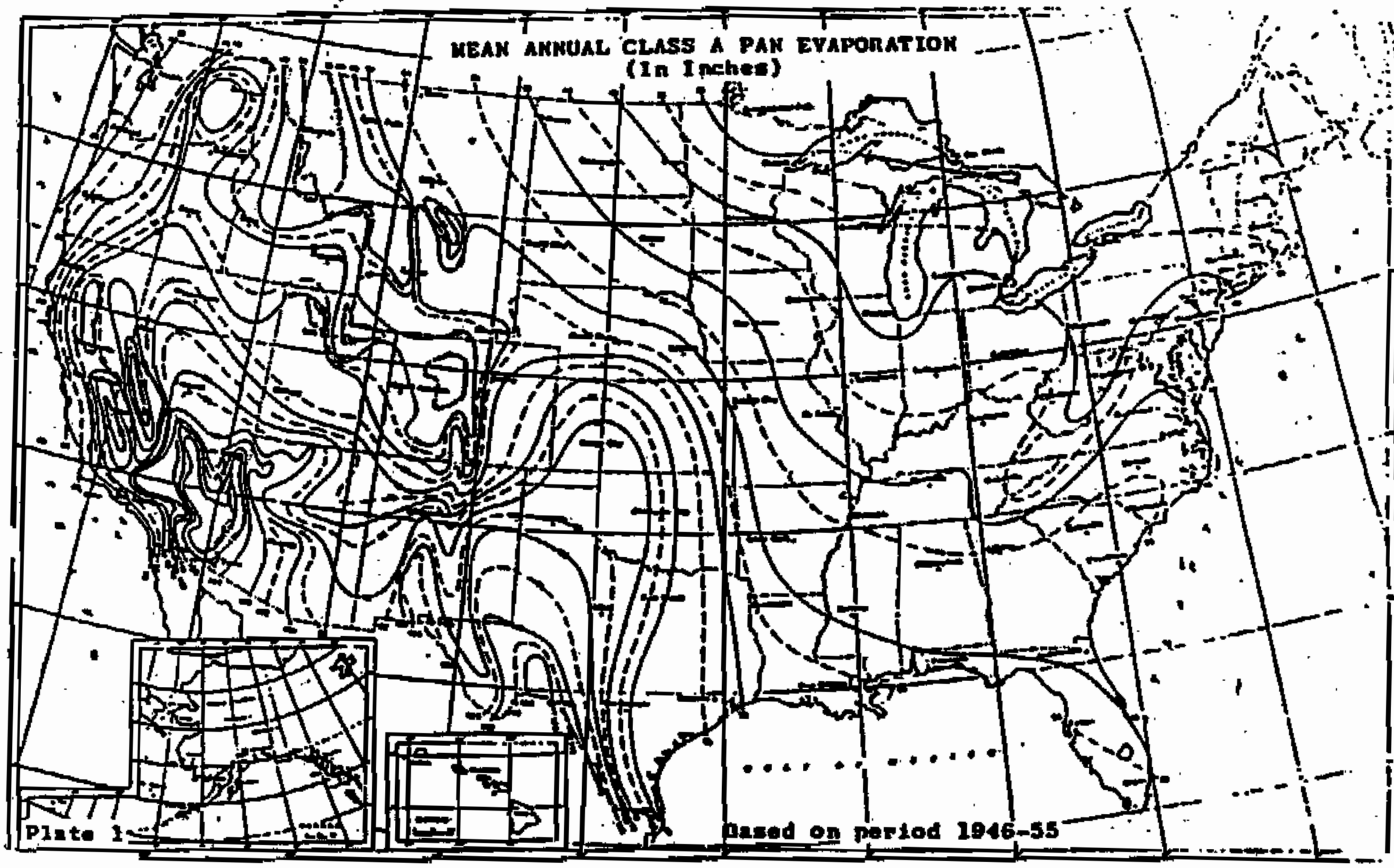

Figure 3-4. Annual Evaporation Data. (Climatic Atlas, 1968)

$$p = \begin{cases} 0.0049\, e \text{ (annual average)} \\ 0.0065\, e \text{ (worst case)} \end{cases} \quad (3\text{-}3)$$

where: p = potential average hourly daytime evaporation rate (mm/h)

e = mean annual pan evaporation (inches) from Figure 3-4

An alternative approach (which is potentially suitable for a regulatory format) is shown as Figure 3-1.

Figure 3-1 shows that, between the average uncontrolled moisture content and a value of twice that, a small increase in moisture content results in a large increase in control efficiency. Beyond this point, control efficiency grows slowly with increased moisture content.

3.4.3 Wet Suppression for Materials Storage and Handling

Wet suppression of materials storage and handling operations is similar to that used for unpaved surfaces. However, in addition to plain water, this technique can also use water plus a chemical surfactant or micronized foam to control fugitive PM-10

Surfactants added to the water supply allow particles to more easily penetrate the water droplet and increase the total number of droplets, thus increasing total surface area and contact potential. Foam is generated by adding a chemical (i.e., detergent-like substance) to a relatively small quantity of water which is then vigorously mixed to produce small bubble, high energy foam in the 100 to 200 µm size range. The foam uses very little liquid volume and, when applied to the surface of the bulk material, wets the fines more effectively than untreated water.

As with watering of unpaved surfaces, the control efficiency of wet suppression for materials storage and handling is dependent on the same basic application parameters. These include: the amount of water, water plus surfactant, or foam applied per unit mass or surface area of material handled (i.e., liters per metric ton or square meter); if not continuous, the time between reapplications; the amount of surfactant added to the water (i.e., dilution ratio), if any; the method of application including the number and types of spray nozzles used; and applicable meteorological conditions occurring on-site.

For suppression using plain water, the most applicable efficiency information available is for feeder to belt transfer of coal in mining operations. Control efficiencies of 56 percent to 81 percent are reported for respirable particulate (particles $< \sim 3.5$ µmA) at application intensities of 6.7 to 7.1 L/Mg (1.6 to 1.7 gal/ton), respectively. Assuming that respirable particulate is essentially equivalent to PM-10, the above control efficiencies would be representative of similar controls for construction/demolition. (The above application intensities were estimated assuming 5 min to discharge 7 Mg of coal and 1.4 L/min/spray nozzle.)

In the case of foam suppression, the most appropriate data available are for the transfer of sand from a grizzly. Using the respirable particulate control efficiencies at various foam application intensities (and assuming respirable particulate is equivalent to PM-10), the following equation was developed by simple linear regression of the data compiled by Cowherd and Kinsey (1986):

$$C = 8.51 + 7.96\,(A) \tag{3-4}$$

where: C = PM-10 control efficiency in percent

A = application intensity in ft^3 foam/ton of material

A coefficient of determination (r^2) of 99.97 percent was obtained for the above equation based on the three data sets used in its derivation.

An alternate approach (which is potentially suitable for regulatory formats) involves the use of the recently developed materials handling equations soon to be published in AP-42, by determining the "uncontrolled" moisture content of the material and again after wet suppression.

The above calculations would necessitate the determination of the amount of water added to the material by laboratory analysis. This could be accomplished by taking grab samples of the material before and after application of the wet suppression technique being employed.

3.4.4 Portable Wind Screens or Fences

The principle of wind screens or fences is to provide a sheltered region behind the fenceline to allow gravitational settling of larger particles as well as a reduction in wind erosion potential. Wind screens or fences reduce the mechanical turbulence generated by ambient winds in an area the length of which is many times the physical height of the fence.

As stated previously, wind fences and screens are applicable to a wide variety of fugitive dust sources. They can be used to control wind erosion emissions from storage piles or exposed areas as well as providing a sheltered area for materials handling operations to reduce entrainment during load-in/load-out, etc. Fences and screens can be portable and thus capable of being moved around the site, as needed.

The control efficiency of wind fences is dependent on the physical dimensions of the fence relative to the source being controlled. In general, a porosity (i.e., percent open area) of 50 percent seems to be optimum for most applications. Note that no data directly applicable to construction/demolition activities were found. According to a recent field study of small soil storage piles, a screen length of five times the pile diameter, a screen-to-pile distance of twice the pile height, and a screen height equal to the pile height was found best (Zimmer et al., 1986). Various problems were noted with the sampling methodology used, however, and it is doubtful that the study adequately assessed the particle flux from the exposed surface. These problems tend to limit an accurate assessment of the overall degree of control achievable by wind fences/barriers for large open sources.

While not entirely applicable to construction/demolition activities, results of a laboratory wind tunnel study were used to estimate 60 percent to 80 percent control efficiencies for materials handling emissions.

3.4.5 Control of Mud/Dirt Carryout

Mud and dirt carryout from construction and demolition sites often accounts for a temporary but substantial increase in paved road emissions in many areas. Elimination of carryout can thus significantly reduce increases in paved road emissions.

At present, the efficacy of various methods to prevent or reduce mud/dirt carryout have not been quantified. These techniques include both methods to remove material from truck underbodies and tires prior to leaving the site (e.g., a temporary grizzly with high pressure water sprays) as well as techniques to periodically remove mud/dirt carryout from paved streets at the access point(s). The following method has been developed, however, to conservatively estimate the reduction in mass emissions due to carryout.

For an individual access point from a paved road to a typical construction or demolition site, let N represent the number of vehicles entering or leaving the area on a daily basis. Let E be given by:

$$E = \begin{cases} 5.5 \text{ g/vehicle for } N \le 25 \\ 13 \text{ g/vehicle for } N > 25 \end{cases} \quad (3\text{-}5)$$

where E is the unit PM-10 emission increase in g/vehicle pass. Finally, if M represents the daily number of vehicle passes on the paved road, then the net daily emission reduction (g/day) is given by E x M, assuming complete prevention.

The emission reduction calculated above assumes that essentially all carryout from the unpaved area is either prevented or removed periodically from the paved surface and, as such, is viewed as an upper limit. In use, a regulatory agency may choose to assign an effective level of carryout control by using some fraction of the E values given above to calculate an emission reduction.

Alternatively, field measurements of the silt loadings on paved surfaces at the construction site access point after control has been implemented, compared with adjacent paved areas, may also be used to gauge the effectiveness of control programs.

3.5 WIND EROSION OF OPEN AREAS

Wind erosion control of soil surfaces is accomplished by stabilizing erodible soil particles. The stabilization process is accomplished in three major successive stages: (a) trapping of moving soil particles, (b) consolidation and aggregation of trapped soil particles, and (c) revegetation of the surface (Chepil and Woodruff, 1963).

The trapping of eroding soil is termed "stilling" of erosion. This may be effected by roughening the surface, by placing barriers in the path of the wind, or by burying the erodible particles during tillage. Trapping is accomplished naturally by soil crusting resulting from rain followed by a slow process of revegetation. It should be stressed that the stilling of erosion is only temporary; to effect a permanent control, plant cover must be established or plant residues must be maintained.

In bare soils containing a mixture of erodible and nonerodible fractions, the quantity of soil eroded by the wind is limited by the height and number of nonerodible particles that become exposed on the surface. The removal of erodible particles continues until the height of the nonerodible particles that serve as barriers to the wind is increased to a degree that affords complete shelter to the erodible fractions. If the nonerodible barriers are low, such as fine gravel, a relatively large number of pieces are needed for protection of soil from wind erosion. The gravel in such a case would protect the erodible portion more by covering than by sheltering from the wind. Thus, all nonerodible materials on the ground that control erosion have an element of cover in addition to the barrier principle which protects the soil. The principles of surface barriers and cover are, therefore, inseparable.

The above principles extend to almost all elements used in wind erosion control. All of these control methods are designed to (a) take up some or all of the wind force so that only the residual force, if any, is taken up by the erodible soil fractions; and (b) trap the eroded soil, if any, on the lee side or among surface roughness elements or barriers, thereby reducing soil avalanching and intensity of erosion.

In the sections that follow, various control methods are discussed with respect to their characteristics and effectiveness in controlling open area wind erosion. Methods include vegetative cover, soil ridges, windbreaks, crop stirps, chemical stabilizers, and irrigation.

3.5.1 Chemical Stabilization

A portable wind tunnel has been used to measure the control of coal surface wind erosion emissions by a 17 percent solution of Coherex® in water applied at an intensity of 3.4 L/m^2 (0.74 gal/yd^2), and a 2.8 percent solution of Dow Chemical M-167 Latex Binder in water applied at an average intensity of 6.8 L/m^2 (1.5 gal/yd^2) (Cuscino et al., 1983). The control efficiency of Coherex® applied at the above intensity to an undisturbed coal surface approximately 60 days before the test, under a wind of 15.0 m/s (33.8 mph) at 15.2 cm (6 in) above the ground, was 89.6 percent for TP and approximately 62 percent for IP and FP. The control efficiency of the latex binder on a low volatility coking coal is shown in Figure 3-3.

3.5.2 Wind Fences/Barriers

Wind fences/barriers are an effective means by which to control fugitive particulate emissions from open dust sources. The principle of the wind fence/barrier is to provide an area of reduced wind velocity which allows settling of the large particles (which cause saltation) and reduces the particle flux from the exposed surface on the leeward side of the fence/barrier. Wind fence/barriers can either be man-made structures or vegetative in nature.

Windbreaks consist of trees or shrubs in 1 to 10 rows, wind and snow fences, solid wooden or rock walls, and earthen banks. The effectiveness of any barrier depends on the wind velocity and direction, shape, width, height, and porosity of the barrier.

Nearly all barriers provide maximum reduction in wind velocity at leeward locations near the barrier, gradually decreasing downwind. Percentage reductions in wind velocities for rigid barriers remain constant no matter what the wind velocity (Chepil and Woodruff, 1963).

Direction of wind influences the size and location of the protected areas. The area of protection is greatest for winds perpendicular to the barrier length and least for winds parallel with the barrier.

The shape of the windbreak indicates that a vertically-abrupt barrier will provide large reductions in velocity for relatively short leeward distances, whereas porous barriers provide smaller reductions in velocity but for more extended distances.

Height of the barrier is, perhaps, the most important factor influencing effectiveness. Expressed in multipliers of barrier height, the zone of wind velocity reduction on the leeward side may extend to 40 to 50 times the height of the barrier; however, reductions at those distances are insignificant for wind erosion control. If complete control is desired, then barriers must be placed at frequent intervals.

3.5.2.1 Tree Windbreaks--

One-, two-, three-, and five-row barriers of trees are found to be the most effective arrangement for planting to control wind erosion. The type of tree species planted also has considerable influence on the effectiveness of a windbreak. The rate of growth governs the extent of protection that can be realized in later years.

3.5.2.2 Artificial Barriers--

Snow fences, fences constructed of board or lath, bamboo and willow fences, earthen banks, hand-inserted straw rows, and rock walls have been used for wind erosion control on a rather limited scale. Because of the high cost of both material and labor required for construction, their use has been limited to where high value crops are grown or where overpopulation requires intensive agriculture.

In the United States, the application of artificial barriers for wind erosion control has been limited. Snow fences constructed from strips of lath held together with wire have been used for protecting vegetable crops. Such fences provide only a relatively short zone of protection against erosion, approximately 10 times the height of the barrier.

3.5.2.3 Effectiveness--

A number of studies have attempted to determine the effectiveness of wind fences/barriers for the control of windblown dust under field conditions. Several of these studies have shown both a significant decrease in wind velocity as well as an increase in sand dune growth on the lee side of the fence (Chepil and Woodruff, 1963; Carnes and Drehnel, 1982; Larson, 1982; Westec, 1984). The degree of emissions reduction varied from study to study ranging from 0 to a maximum of about 90 percent depending on test conditions (Larson, 1982; Radkey and MacCready, 1980). A summary of available test data contained in the literature on the control achieved by wind fences/barriers is provided in Table 3-7.

Various problems have been noted with the sampling methodology used in each of the studies conducted to date. These problems tend to limit an accurate assessment of the overall degree of control achievable by wind fences/barriers for large, open sources. Most of this work has either not thoroughly characterized the velocity profile behind the fence/barrier or adequately assessed the particle flux from the exposed surface.

3.5.3 Vegetative Cover

Natural vegetative cover is the most effective, easiest, and most economical way to maintain an effective control of wind erosion. In addition to the crops such as grasses, wheat, sorghum, corn, legumes, and cotton, crop residues are often

TABLE 3-7. SUMMARY OF AVAILABLE CONTROL EFFICIENCY DATA FOR WIND FENCES/BARRIERS

Material or control parameter	(Larson, 1982)	(Radkey and MacCready, 1980)
/Type of fence/barrier	Textile fabric	Wood cyclone fence
Porosity of fence/barrier	50%	50%
Height/length of fence/barrier	1.8 m/50 m	3 m/12 m
Type of erodible material	Fly ash	Mixture of topsoil and coal
Material characteristics	Percent H_2O = 1.6 Percent <50 pm = 14.7 Percent <45 pm = 4.6	Unknown
Incident wind speed	Average (no screen) = 4.3 m/s (9.7 mph) Average (upwind) = 5.32 m/s (11.9 mph)	Maximum 27 m/s (60 mph)
Lee-side wind speed	Average = 2 m/s (4.0 mph) or 64% reduction	Unknown
Particulate measurement technique[a]	U/D = hi-vol and hi-vol w/SSI (11 tests)	U/D - Bagnold catchers (one test)
Test data rating[b]	C	C
Measured particulate control efficiency[c]	TP = 64% (average) TSP = 0% (average)	TP = 88% (average)

[a] Hi-vol = high volume air sampler; hi-vol w/SSI = high volume air sampler with 15 μmA size-selective inlet, SSI.

[b] Data rated using criteria specified in Section 4.4.

[c] TP = total particulate matter, TSP = total suspended particulate matter (particles < ~ 30 μmA).

placed on fallow fields until a permanent crop is started. All of these methods can remove 5 to 99 percent of the direct wind force from the soil surface (Zingg, 1954).

3.5.3.1 Effectiveness--

Grasses and legumes are most effective because they provide a dense, complete cover. Wheat and other small grains are effective beyond the crucial 2 or 3 months after planting. Corn, sorghum, and cotton are only of intermediate effectiveness because they are planted in rows too far apart to protect the soil.

After harvesting, vegetative residue should be anchored to the surface (Chepil et al., 1960). Duley (1958) found that legume residues decay rapidly, while corn and sorghum stalks are durable. He found wheat and rye straw more resistant to decay than oat straw.

3.5.3.2 Maintenance--

Excessive tillage, tillage with improper implements, and overgrazing are the major causes of crop cover destruction. Effective land management practices must be instituted if wind erosion is to be controlled.

For grazing, the number of animals per acre should be controlled to maximize the use of grass and still maintain sufficient vegetative cover.

Stubble mulching and minimum tillage or plow-plant systems of farming tend to maintain vegetative residues on the surface when the land is fallow. Stubble mulching is a year-round system in which all tilling, planting, cultivating, and harvesting operations are performed to provide protection from erosion. This practice requires the use of tillage implements which undercut the residue without soil inversion.

3.5.4 Limited Irrigation of Barren Field

The periodic irrigation of a barren field controls blowing soil by adding moisture which consolidates all particles and creates a crust upon the soil surface when drying occurs. The amount of water and frequency of each irrigation during fallow to maintain a desired level of control would be a function of the season and of the crusting ability of the soil.

3.6 AGRICULTURE

3.6.1 Tilling

Operational modifications to tilling of the soil include the use of novel implements or the alteration of cultural techniques to eliminate some operations altogether. All operational modifications will affect soil preparation or seed planting operations. Furthermore, the suggested operational modifications are crop specific. Estimated PM-10 efficiencies for agricultural controls are presented in Table 3-8.

The punch planter is a novel implement which might have applications for emissions reduction from planting cotton, corn, and lettuce. The punch planter is already being used in sugar beet production. The punch planter punches a hole and places the seed into it, as opposed to conventional planters which make a trough and drop the seeds in at a specified spacing. The advantage is that punch planters can leave much of the surface soil and surface crop residues undisturbed. Large-scale use of the punch planters would require initial capital investments by the farming industry for new equipment.

Herbicides for weed control is a cultural practice which could reduce emissions from cultivation for most new crops with wide enough spacing for cultivation and for some close-grown crops like wheat. The use of herbicides, however, must be

TABLE 3-8. ESTIMATED PM-10 EFFICIENCIES FOR AGRICULTURAL CONTROLS[a]

Control technique	Operation affected	Estimated control efficiency (percent) crop for applicable techniques							
		Cotton	Barley	Alfalfa	Rice	Corn	Wheat	Process tomatoes	Lettuce
Punch planter	Planting	50				50			50
Herbicides	Cultivation or soil preparation	100	25[a]	25[a]	b	100	25[a]	100	100
Sprinkler irrigation	Land planing	90	90	90	c	90	90	90	90
Laser-directed land plane	Land planing or floating	30	30	30	30	30	30	30	30
Develop high quality alfalfa	All soil preparation operations			75					
Double crop corn with wheat	Disking or plowing					50[d]			
Aerial seeding	Planting			50	3[e]		50		

[a] Eliminates only some soil preparation operations, whereas in other cases, all cultivation operations are eliminated.

[b] Herbicides already applied by airplane for majority of acreage.

[c] Flood irrigation necessary.

[d] Fifty percent control only for double-cropped acreage.

[e] Seeding already performed by airplane for majority of acreage.

balanced against potential increased herbicide emissions caused by wind and by water runoffs.

Sprinkler irrigation is an existing cultural technique which could produce fugitive emission control for any crop which is currently irrigated by surface watering systems. Sprinkler irrigation eliminates the need for extensive land planting operations which surface irrigation requires. However, the capital investment for sprinkler irrigation equipment and the increased costs of pumping the water are major deterrents.

The laser-directed land plane is a novel implement which might yield some emissions controls for surface-irrigated crops. Laser-guided grading equipment has been used in construction for years and can be expected to reduce the amount of land planing required due to its more precise leveling blade. This device might be retrofitted to existing land planes, but capital investment funds are required.

The developing of long lasting varieties of alfalfa with high leaf protein content would help to reduce emissions, because present practices require replanting every 3 to 5 years. New varieties already exist which can last up to 20 years, but the protein content is low. If longevity and quality could be combined, the soil would not have to be prepared so often, thus yielding a subsequent reduction in emissions.

Double-cropping corn with wheat or other grain instead of corn with corn might reduce fugitive emissions. Since corn provides so much stubble, it must be plowed or disked under. The beds must then be formed and shaped for the next corn seed planting. If wheat or another grain were grown on a bedded field, then corn could be planted on the beds after the wheat harvest and stubble removal. The beds would require only reshaping. This would eliminate a plowing or disking operation and a bed-forming operation while adding a less dusty wheat stubble removal operation.

Finally, aerial seeding, which is already used in rice production, would probably reduce emissions somewhat from alfalfa and wheat production. However, at least in the case of wheat, the aerially applied seed must be covered. This covering operation will produce dust, but it may be less dust than a ground-planting operation would produce.

SECTION 4

ENVIRONMENTAL ANALYSIS OF BACM

This section discusses the positive environmental effects of controlling PM-10 from fugitive dust sources. The unfavorable cross-media impacts of control measures available for BACM application, such as water pollution, solid waste production, and energy consumption are also addressed.

The PM-10 emissions are known to adversely affect human health (especially for sensitive persons), soil and water, manmade materials, visibility, weather, and possibly climate. Fine particles that disperse from sources and remain suspended over relatively long periods of time also create hazards to transportation, deterioration of economic values, and personal discomfort.

Human beings at special risk from acute exposures to PM-10 include the elderly and those with preexisting cardiorespiratory disease conditions. Chronic exposure to PM-10 has been reported to decrease lung function and increase respiratory disease in children. These and other studies are examined in the three-volume document, "Air Quality Criteria for Particulate Matter and Sulfur Oxides," EPA 600/8-82--029 (1982).

The cited EPA document also examines affects of particulate emissions on terrestrial ecosystems, visibility, and materials. Nontoxic fugitive particulate matter from natural and anthropogenic sources has little impact on terrestrial ecosystems, unless rates of deposition are very high. However, suspended particulate matter often soils materials and infiltrates into sensitive electrical and mechanical equipment.

The PM-10 substantially affects visibility, especially as a relatively homogenous haze layer that reduces target image clarity and range of viewing. Visual range is inversely related to the total extinction value which is in itself closely proportional to the fine particle mass concentration. Reductions in visibility can adversely affect both air and ground transportation, property values and aesthetics.

Climate may also be affected by high concentrations of PM-10. If the amount of solar energy directed to the earth's surface is reduced by reflection from a PM-10 haze, the temperature balance and precipitation patterns may be altered with consequent effects upon agricultural production, sea levels and energy usage.

4.1 COMPARISON OF BASELINE TO POST-BACM PM-10 EMISSIONS

The measures available for BACM application focus on preventive measures to ensure that potentially emitting surfaces are kept clean or are stabilized. In the following sections, baseline emissions in the absence of controls are compared to emissions after application of BACM. Emissions are quantitatively assessed for each of the major fugitive dust sources. The model units discussed in section 2 are used to estimate the reduction in PM-10 emissions that can be expected from application of BACM.

4.1.1 Paved Roads

As shown in Table 4-1, major and collector streets under normal silt loading conditions present the best options for control based on high emission density. Mitigative control operations are presented in Table 4-2 for industrial roads and Table 4-3 for urban roads, together with estimated control efficiencies. Mitigative control of paved road emissions is usually not safe for those roads that have traffic intensities exceeding about 15,000 ADT (Cowherd et al., 1988), which would

TABLE 4-1. PAVED ROAD EMISSIONS POTENTIAL

Roadway category	Lanes	Average daily traffic (vehicles)	Silt loading[a] ($\bar{X}_g$, g/m²)	N	Road emission potential (veh-g/m²)
Freeways/expressways	≥ 4	> 50,000	0.022	1	> 1,100
Major streets/highways	≥ 4	> 10,000	0.36	26	> 3,600
Collection streets	2[b]	500-10,000	0.92	10	460-9,200
Local streets	2[c]	< 500	1.41	7	< 705

[a] $\bar{X}_g$ = Geometric mean based on corresponding n sample size; silt loading data presented by city (Cowherd et al., 1988).

[b] Road width ≥ 32 ft.

[c] Road width < 32 ft.

TABLE 4-2. MEASURED EFFICIENCY VALUES FOR PAVED ROAD CONTROLS[a]

Method	Cited efficiency	Comments
Vacuum sweeping	0-58%	Field emission measurement (PM-15) 12,000-cfm blower[b]
	46%	Reference 7, based on field measurement of 30 μm particulate emissions
Water flushing	69-0.231 V[c,d]	Field measurement of PM-15 emissions[b]
Water flushing followed by sweeping	96-0.263 V[c,d]	Field measurement of PM-15 emissions[b]

a All results based on measurements of air emissions from industrial paved roads. Broom sweeping measurements presented in section 2.3.2.1 (Cowherd and Kinsey, 1986).

b PM-10 control efficiency can be assumed to be the same as that tested.

c Water applied at 0.48 gal/yd^2.

d Equation yields efficiency in percent, V = number of vehicle passes since application.

TABLE 4-3. ESTIMATED PM-10 EMISSION CONTROL EFFICIENCIES[a]

Method	Estimated PM-10 efficiency, %
Vacuum sweeping	34
Improved vacuum sweeping[b]	37

a Estimated based on measured initial and residual $\leq$ 63-μm loadings on urban paved roads and Equation (2-1). Value reported represents the mean of 13 tests for each method. Broom sweeping mean (18 tests) given in section 2.3.2.1.

b Sweeping improvements described in Duncan et al. (1984).

exclude freeways/expressways. Because broom sweepers are observed to cause, rather than mitigate, dust emissions from dry roads, they are generally not recommended. Control measures that aim to prevent, rather than clean up silt loadings on paved roads, are preferable, with no restriction as to road classification.

Candidate BACM for paved roads include those preventive measures designed to keep the silt loading on the road surface as low as possible. Mud/dirt track-on is the major cause of elevated silt loadings that intensify particulate emissions from paved roadways.

Available measures to prevent track-on include curbing to prevent vehicle traffic on dirt surfaces adjacent to paved roads, and construction and daily cleaning of paved or graveled access aprons at construction sites. These aprons enable construction-related vehicles to "clean" their tires on the apron before movement to a more heavily travelled paved public roadway.

Candidate BACM also include mitigative measures applied under specialized conditions. Regular road surface cleanup operations must follow winter sanding of roads. Road cleaning cannot be advised under dry conditions. Street cleaners should operate only when water can be applied (or the road is otherwise wet) and there is no possibility of refreezing on the roadway.

The model unit proposed in Figure 4-1 is a collector road segment of 0.8 km (0.5 mi) length (1/4 mi in each direction from a construction site). The collector road is assumed to have an average daily traffic (ADT) of 5,000 vehicles, including the traffic due to the construction site. The construction site is estimated to be active for 90 days with about 40 truck accesses each day. Application of the paved road equation with a default silt loading for collector roads (Table 4-1) produces an emission factor of 14.0 kg/day for baseline conditions. Emissions due to carryout onto the portion of the collector road adjacent to the construction site are estimated to be 65 kg/day.

The addition of a 100-foot long, paved asphalt apron at the entrance to the construction site with daily cleaning is estimated to control 86 percent of the track-on to the collector road. In other words, truck traffic using this apron is expected to deposit 95 percent of mud and dirt on this apron (to be cleaned daily), rather than on the 5,000 ADT collector road.

Assuming 86 percent control of track-on to the collector road, total uncontrolled emissions of 79.0 kg/day can be reduced to 23.1 kg/day, with an estimated control efficiency of 71 percent for the half-mile length of collector road adjacent to the construction site. The cost items presented in Figure 4-1 are analyzed more fully in section 5. These include capital costs, operation and maintenance costs, and enforcement costs. By dividing the emission reduction by the annualized cost (from section 5), a calculated cost effectiveness for this control scenario is 0.61/kg of PM-10 emission reduction.

4.1.2 Unpaved Roads

Significant PM-10 emissions can be expected from unpaved roads, especially those with traffic greater than 100 ADT and travelling at speeds above 25 mph. The model unit proposed in this section is a 1-km segment of unpaved road with 225 ADT, and an average vehicle with weight of 9 Mg and with 6 wheels. As shown in Figure 4-2, uncontrolled emissions from this road segment are estimated as 217 kg/day.

For the model unit, a chemical suppression program has been designed to control PM-10 emissions. From Table 4-4, it can be calculated that seven applications of a latex binder are required to be applied over a period of a year to this particular road to achieve an estimated PM-10 control efficiency of 75 percent. The application intensity will be 3.8 L/m^2 of 20 percent solution for the first application. A subsequent application of 4.5 L/m^2 (12 percent solution) will occur every 2 weeks after the initial one and will then be required every 52 days. This chemical suppression program is estimated to produce a PM-10 emission reduction of 195 kg/day.

MODEL UNIT

Source classification: Paved Road

Source description: Dirt carryout from construction site onto 0.8 km of paved road adjacent to site. Resuspension of carryout by vehicles on paved road.

Source specifications: Collector road (5000 ADT) adjacent to construction site. 40 truck accesses/day.

Regulation: No person shall allow any visible accumulation of mud, dirt, dust, or other material onto paved roads, including paved shoulders adjacent to the site where construction/demolition activity occurs.

BACM: Pave 30 m of access apron. Flush and sweep paved access apron daily.

Variable Controlled: Surface loading on paved road.

Capital cost items: Paving equipment, material and labor, restoration costs

O&M cost items: Labor and water associated with cleanup (2 hours/day)

Enforcement: Permitting. Visual confirmation of apron cleaning. Silt loading samples from paved road.

Environmental effects: Energy and fuel use; minor VOC emissions; disposal of emulsified asphalt/base rock (expected to be very low due to short apron length)

Calculation of PM_{10} emission reduction:

Uncontrolled: (USEPA, 1988)
- Background: 14 kg/day
- Construction dirt carryout: 5000 ADT · 13 g/vehicle (if > 25 accesses/day) = 65 kg/day

Controlled:
- 1 - 0.95 · (1-0.855) = 86% control efficiency from road emissions due to construction site carryout [30m of paved apron contains 95% of the carryout; from Table 4-2, water flushing and sweeping yield a control efficiency of 85.5%]
- Construction dirt carryout: 65 · (1-0.86) = 9.1 kg/day

Reduction:
- R = 55.9 kg/day

Control efficiency: 71%

Figure 4-1. Proposed model unit—paved roads.

MODEL UNIT

Source classification: Unpaved Road

Source description: 1 km of unpaved road. Vehicle entrainment of surface dirt.

Source specifications: 1 km of road (225 ADT) with silt content 10%. No significant annual rainfall. Vehicle characteristics: average speed of 32 km/h, vehicle weight of 9 Mg, 6 wheels.

Regulation: Unless otherwise exempted, no active unpaved road surfaces shall remain in an unstabilized state.

BACM: Stabilize unpaved road surface with the chemical suppressant Coherex or equivalent.

Variable Controlled: Silt content.

Capital cost items: Truck, storage tanks or areas, pumps, piping

O&M cost items: Truck maintenance and repair, labor, fuel, chemicals

Enforcement: Permitting. Reviews of chemical application records. Site inspection including silt loading.

Environmental effects: Leaching of chemical suppressants; possible VOCs from petroleum-based resins

Calculation of PM_{10} emission reduction:

Uncontrolled: Equation (2-6)

$$E = 0.61 \cdot \left(\frac{10}{12}\right)\left(\frac{32}{48}\right)\left(\frac{9}{2.7}\right)^{0.7}\left(\frac{6}{4}\right)^{0.5}\left(\frac{365-0}{365}\right) \text{kg/VKT} \cdot 225 \text{vehicles/day} \cdot 1 \text{km}$$
$$= 217 \text{kg/day}$$

Controlled:

From Figure 3-4, 75% control is achieved with 3.8 L/m^2 of 20% solution initially. Applications of 4.5 L/m^2 of 12% solution begin two weeks after the initial application and continued every 52 days following (from Table 4-4).

$E = 217 \cdot (1-0.75) = 54.3$ kg/day

Reduction:

$R = 195$ kg/day

Control efficiency: 75%

Figure 4-2. Proposed model unit—unpaved roads.

TABLE 4-4. EXAMPLE CONTROL PROGRAM DESIGN FOR COHEREX® APPLIED TO TRAVEL SURFACES[a,b]

Average percent control desired	Vehicle passes between applications	Days between applications as a function of ADT		
		100	300	500
50	23,300	233	78	47
75	11,600	16	39	23
90	4,650	47	16	9

[a] Calculated time and vehicle passes between application are based on the following conditions:

Suppressant application:
- 3.8 L of 20 percent solution/m^2 (0.83 gallon of 20 percent solution/yd^2) initial application
- 4.5 L of 12 percent solution/m^2 (1.0 gallon of 12 percent solution/yd^2); reapplications

Vehicular traffic:
- Average weight—9 Mg (8 tons)
- Average wheels—6
- Average speed—29 km/h (20 mph)

Road structure: bearing strength—low to moderate

[b] PM-10 = Particles ≤ 10 μmA.

[c] For reapplications that span time periods greater than 365 d, the effects of the freeze-thaw cycle are not incorporated in the reported values.

The calculated cost effectiveness for chemical suppression of PM-10 emissions from an unpaved road is estimated as $0.92/kg, based on the presentation of annualized costs in section 6. These costs include capital cost items, O&M cost items, and estimated enforcement costs.

4.1.3 Construction/Demolition Activities

The model unit for construction/demolition activities consists of a building demolition operation. It will include control of emissions from loading of debris into trucks, unpaved road traffic, and carry-out of mud and dirt onto surrounding roads.

It has not been shown feasible to effectively control dust emissions from building dismemberment. Explosive demolition will produce a large cloud of dust emissions that disappears over a period of several minutes. It is desirable for the settling out of large particles near the demolition site that wind speeds be light during explosive dismemberment, but this restriction is not likely to be a candidate BACM because of low control efficiency stemming from the fact that the settling velocity of PM-10 is so small.

Additional control of PM-10 can be achieved by wet suppression of the debris loadout process, but the following calculations will demonstrate that this control measure produces only a small increase in control efficiency. Also, trucks should be covered as they deliver the building debris to a burial site.

Figure 4-3 presents the model unit for building demolition. A building with 18,500 m^2 (200,000 ft^2) floorspace is to be explosively demolished, and the resulting debris will be loaded onto trucks for transport to a burial site. For a period of a month, 30 trucks will be loaded each day and will remove debris from the site. The control measures to be applied include wet suppression of debris handling and transfer, watering of the on-site area to be travelled by the trucks, and the creation of an access apron to be cleaned daily by broom sweeping/flushing to

MODEL UNIT

Source classification: Construction/Demolition Activities

Source description: Dismemberment of previous building, debris loading and carryout.

Source specifications: One acre site with 18,500 m^2 single floor space. One access point to a paved street (2000 ADT). Thirty vehicles/day removing debris. Thirty days of work. Mean annual pan evaporation of 60 inches.

Regulations: The city and its contractors shall not engage in the loading, unloading, conveying or transporting of bulk materials unless a dust control plan is approved by the APCO which demonstrates that an overall (80%) efficiency reduction of PM_{10} emissions from storage piles and related activities will be achieved.

No person shall allow any visible accumulation of mud, dirt, dust, or other material on the paved roads, including paves shoulders adjacent to the site where construction/demolition activity occurs.

BACM: Apply wet suppression to debris handling & transfer (6700 L/kg). Water unpaved travel surfaces (2 L/m^2/hr) daily. Pave 30 m of access apron. Flush and sweep access apron daily.

Variables controlled: Moisture content of traveled surface areas and debris transferred. Surface loading on adjacent paved road.

Capital cost items: Paving equipment, material and labor, restoration costs, pumps, piping, and application equipment

O&M cost items: Labor and water associated with cleanup (2 hours/day)

Enforcement: Permitting. Visual confirmation of water suppression program and apron cleaning. Moisture content of samples from travel areas and debris. Silt loading samples from paved road.

Environmental effects: Energy and fuel use; minor VOC emissions; disposal of emulsified asphalt/base rock (expected to be very low due to short apron length); energy costs; leaching of storage material into ground and surface water.

Calculation of PM_{10} emission reduction:

- Uncontrolled: Figure 4-4
  - Dismemberment: 4.6 kg (will remain uncontrolled)
  - Debris loading: 85.1 kg
  - On-site traffic: 962 kg
  - Dirt carryout: 780 kg
- Controlled:
  - Dismemberment: 4.6 kg (0% control efficiency)
  - Debris loading: 37.4 kg (56% control efficiency)
  - On-site traffic: 163.5 kg (83% control efficiency)
  - Dirt carryout: 109.2 kg (86% control efficiency)
- Reduction: R = 1513 kg

Control efficiency: 83%

Figure 4-3. Proposed model unit—building demolition.

prevent mud/dirt trackout. With these BACM in place, the PM-10 emission reduction is estimated to be 1,517 kg of a total uncontrolled total of 1,832 kg. Figure 4-4 gives additional details on the calculation methodology. Cost effectiveness is estimated at $8.69/kg to achieve an 83 percent control efficiency for PM-10. Eliminating wet suppression of the truck loading operation will only slightly reduce this control efficiency to 80 percent, and the cost effectiveness will decrease to a more favorable value of $6.64/kg.

4.1.4 Storage Piles

Wind erosion from storage piles is not believed to produce significant PM-10 emissions for most nonattainment areas. Control of wind erosion from most storage piles is not cost effective.

Material transfer operations associated with storage pile formation or loadout can be controlled by water sprays. The model storage pile shown in Figure 4-5 is a conically-shaped coal pile with daily reclaiming. About two-thirds of the pile is replenished every 3 days. The fully-formed coal pile has dimensions of 11 m height and 29.2 m base, and contains 11,797 Mg coal. The amount of coal transferred by conveyor in and out of the pile every 3 days is estimated at:

$$2 \times 2/3 \times 11,797 = 15,729 \text{ Mg/3 days}$$

$$E = 0.35\,(0.0016)\,\frac{\left(\frac{2.2}{2.2}\right)^{1.3}}{\left(\frac{1.5}{2}\right)^{1.4}}\ \text{kg/Mg} \cdot 1913736\ \text{Mg/yr} = 1603\ \text{kg/yr}$$

Uncontrolled PM-10 emissions from these transfer operations over the course of a year are estimated at 1,603 kg/yr. The water spray system is estimated to control 60 percent of the emissions, reducing PM-10 emissions by 962 kg/yr. This number, when

- Source Description:

  18,500 m^2 (200,000 ft^2) floor space of a building on a 1-acre site
  1 access point to a paved city street (2,000 ADT)
  30 vehicles/day removing building debris
  30 days project duration

- Assumptions:

  No detailed data are available for debris removal activities
  No dozing will be performed on site
  Negligible exposed areas
  8 h/day operation

- Calculation of Uncontrolled Emissions:

From Section 5.1.2 of USEPA, 1988, the uncontrolled PM_{10} emissions from dismemberment (E_D), debris loading (E_L), and on site traffic (E_{Tr}) are calculated as:

$$E_{DLTr} = (E_D + E_L + E_{Tr}) \text{ kg/m}^2 \cdot \text{m}^2 \text{ floor space}$$

$$= (0.00025 + 0.0046 + 0.052) \text{ kg/m}^2 \cdot 18{,}500 \text{ m}^2$$

$$= 1.05 \text{ Mg } PM_{10} \text{ emissions}$$

For mud/dirt carryout (E_{MD}) from haul trucks entering and leaving the site, the mean increase in paved road emissions is calculated using Table 5-2 (USEPA, 1988) for sites with greater than 25 vehicles/day:

$$E_{MD} = 13 \text{ g/vehicle pass} \cdot 2{,}000 \text{ vehicles/day} \cdot 30 \text{ days}$$

$$= 0.78 \text{ Mg } PM_{10} \text{ emissions}$$

Therefore, the total emissions (E_T) over the duration of the project are:

$$E_T = E_{DLTr} + E_{MD} = 1.05 \text{ Mg} + 0.78 \text{Mg}$$

$$= 1.83 \text{ Mg total } PM_{10} \text{ emissions}$$

Figure 4-4. Example PM_{10} control plan for building demolition.

- Methods of Control:

  -Wet suppression of debris handling and transfer (6.7 L/Mg application intensity)
  -Watering of unpaved travel surfaces (0.1 L/m²/h application intensity)
  -Broom sweeping/flushing for removal of mud/dirt carryout

- Demonstration of Control Program Adequacy:

As stated in Section 5.3.2.1 of USEPA, 1988, an efficiency of 56% is typical for wet suppression of debris loading. Thus, the controlled emissions for debris loading (E_{CL}) would be:

$$E_{CL} = 0.0046 \text{ kg } PM_{10}/m^2 \cdot 18{,}500 \text{ m}^2 \cdot (1 - 0.56) = 0.037 \text{ Mg } PM_{10}$$

Using water for dust control for unpaved surfaces, Equations 3-2 and 3-3 as well as Figure 3-4 will allow calculation of controlled emissions (assuming the site is located in Los Angeles, California):

$$\begin{aligned} p &= 0.0049 \cdot e \\ &= 0.0049 \cdot 60 \text{ inches} \\ &= 0.29 \text{ mm/h} \end{aligned}$$

and

$$\begin{aligned} C &= 100 - \frac{0.8\, pdt}{i} \\ &= 100 - \frac{0.8 \cdot 0.29 \cdot (60/8) \cdot 1}{0.1} \\ &= 82.6\% \end{aligned}$$

Therefore, the controlled PM_{10} emissions for haul truck traffic (E_{CTr}) would be:

$$\begin{aligned} E_{CTr} &= 0.052 \text{ kg/m}^2 \cdot 18{,}500 \text{ m}^2 \cdot (1 - 0.826) \cdot \text{Mg}/1000 \text{ kg} \\ &= 0.1674 \text{ Mg } PM_{10} \text{ emissions} \end{aligned}$$

Finally, for removal of mud/dirt carryout using a combination of broom sweeping and flushing, no prevention efficiency data are available. However, if it is assumed that the emissions increase on the paved road for this source is reduced by 86%. Consequently, the controlled emissions of mud/dirt carryout (E_{CMD}) = 0.109 Mg PM_{10} (see Section 5.3.5.1 of USEPA, 1985).

Figure 4-4. (continued)

The total emissions controlled (E_C) are:

$$E_C = E_{CL} + E_{CTr} + E_{CMD}$$

$$= (0.037 + 0.1674 + 0.109)\ Mg$$

$$= 0.3134\ Mg\ PM_{10}\ \text{after control}$$

Thus, the control efficiency (CE) with wet suppression of debris loading:

$$CE = \frac{E_T - E_C}{E_T} \cdot 100\%$$

$$= \frac{(1.83 - 0.3134)}{1.83} \cdot 100$$

$$= 82.9\%$$

Without wet suppression of debris loading:

$$CE = \frac{(1.83 - 0.3615)}{1.83} \cdot 100$$

$$= 80.2\%$$

As demonstrated, wet suppression will not be required as BACM because of its very small influence in controlling PM_{10} emissions from construction/demolition activities.

Figure 4-4. (concluded)

MODEL UNIT

Source classification: Storage Piles

Source description: Conically shaped coal storage pile with conveyor transfer operations. Wind erosion of pile. Entrainment of dust from transfer operations.

Source specifications: Storage pile characteristics: 11 m high pile, 29.2 m diameter, 2455 m^3 volume, 11,797 Mg capacity. 2/3 of pile transferred by conveyor in/out of storage every three days. Uncontrolled moisture content of 1.5%. Mean wind speed of 2.2m/s.

Regulation: The city and its contractors shall not engage in the loading, unloading, conveying or transporting of bulk materials unless a dust control plan is approve by the APCO which demonstrates that an overall (60%) percent reduction of PM_{10} emissions from storage piles and related activities will be achieved.

BACM: Operate water spray system to achieve 60% control efficiency

Variable controlled: Moisture content.

Capital cost items: Pumps, piping, nozzles and control system

O&M cost items: Fuel (electricity), water, repair parts, labor

Enforcement: Permitting and inspection of the site. Moisture content of samples from the storage pile.

Environmental effects: Energy costs; leaching of storage material into ground and surface water

Calculation of PM_{10} emission reduction:

Uncontrolled: Equation (2-6)

$$E = 0.35 \cdot 0.0016 \cdot \frac{\left(\frac{2.2}{2.2}\right)^{1.3}}{\left(\frac{1.5}{2}\right)^{1.4}} kg/Mg \cdot 1{,}913{,}736 Mg/yr$$

$$= 1{,}603 kg/yr$$

Controlled:

E = 1603 · (1-0.60) = 641 kg/yr

Reduction:

R = 962 kg/yr

Control efficiency: 60%

Figure 4-5. Proposed model unit—storage pile associated with the analytical costs presented in section 5, show the calculated cost effectiveness to be $9.07/kg.

4.1.5 Open Areas

A good example of a potential BACM applied to open areas is an unpaved parking lot that is subsequently covered with a nonerodible surface material. By paving or graveling an unpaved parking lot with traffic access of greater than 100 vehicles/day, three sources of emissions are substantially eliminated. These include the traffic emissions (substantially the same as on an unpaved road), track-out of mud onto surrounding paved roadways for subsequent resuspension, and wind erosion of the exposed surface.

Figure 4-6 presents a model open area to which BACM is applied for control of wind erosion. The PM-10 control cost effectiveness is estimated at $12.17/kg for graveling the parking lot to a depth of 2 inches.

4.1.6 Agricultural Tilling

Agricultural tilling is only partially amenable to effective dust control practices, because land must be cultivated when the ground is relatively dry. However, taking land out of production and planting with permanent grasses or trees are control alternatives for land classified as "highly erodible" under the Food Securities Act of 1985. Figure 4-7 examines a model farm unit of 320 acres, with 25 percent of the field classified as "highly erodible." The PM-10 control cost effectiveness of taking land out of agricultural production is calculated as $7.45/kg, assuming a 100 percent control efficiency and, $60/acre/yr in farmer payments.

4.2 CROSS MEDIA IMPACTS

Soil stabilization is a major bulwark of a PM-10 control strategy. This has the added desirable effect of reducing soil

MODEL UNIT

Source classification: Wind Erosion of Open Areas

Source description: Wind erosion from an unpaved parking lot

Source specifications: Dirt lot 100 x 100 m. Uniform daily disturbance. Average particle size 0.56 mm. Local Climatological Data as shown in Figure 6-8 in USEPA (1988).

Regulation: Effective ___, the City of ____ shall not cause, permit, suffer, or allow the operation or use, of an unpaved motor vehicle parking area.

BACM: Cover with a less erodible material, such as gravel, to 2" of depth (70% control).

Variable controlled: Erodibility of exposed surface

Capital cost items: Material, application equipment, labor

O&M cost items: Periodic grading equipment and labor

Enforcement: Permitting. Visual confirmation of graveling. Silt loading samples from parking area

Environmental effects: Energy costs

Calculation of PM_{10} emission reduction:

Uncontrolled: Equation (2-9)

$$E = 0.5 \cdot 32.8 \text{ g/m}^2\text{/month} \cdot 10{,}000 \text{ m}^2 \cdot 1 \text{ kg/1000 g} = 164 \text{ kg/month}$$

Controlled:

Using a material of threshold friction velocity $u_t^* > 0.64$ m/s

$E = 164 \cdot (1\text{-}0.70) = 49.2$ kg/month

Reduction:

R = 115 kg/month

Control efficiency: 70%

Figure 4-6. Proposed model unit—wind erosion of open areas.

MODEL UNIT

Source classification: Agricultural Tilling

Source description: Suspension of dust by plowing, disking, harrowing, etc.

Source specifications: A 320-acre field tilled/cultivated 5x a year; 18% soil silt content. 25% of land is classified as "highly erodible" under the Food Securities Act (FSA)

Regulation: Food Securities Act provides for revegetation of highly erodible land.

BACM: Place 80 acres of the 320-acre field into the Conservation Reserve Program of the FSA

Variable Controlled: Source extent

Capital cost items: Seed, fertilizer, fencing, gasoline, labor, transfer and implements.

O&M cost items: Labor, gasoline, fertilizer for grass maintenance; USDA annual payments

Enforcement cost items: Soil Conservation Service inspection under Conservation Reserve Program.

Environmental effects: No adverse environmental effects; soil loss by water and wind reduced to minimal levels

Calculation of PM_{10} emission reduction:

Uncontrolled: Equation (2-19)

$$E = 0.21 \cdot 4.80 \cdot 18^{0.6} \text{ lb/acre} \cdot 320 \text{ acres} \cdot 5/\text{yr} = 9136 \text{ lb/yr} = 4153 \text{ kg/yr}$$

Controlled:

$$E = \frac{(320-80)}{320} \cdot 4153 \text{ kg} = 3115 \text{ kg/yr (after grass is planted)}$$

Reduction:

$$R = 1038 \text{ kg/yr}$$

Control efficiency: 25%

Figure 4-7. Proposed model unit—agricultural tilling.

erosion by rainwater and eliminating tracking and washing of soil-onto-paved traffic areas where it can be resuspended when dried.

Street dirt contributes a significant amount of pollutants to urban runoff. As discussed by Lorant (1986), samples collected from street surfaces identified the smaller particles as the major carriers of contaminants. Studies by Sartor and Boyd (1972) indicated that up to 85 percent of pesticides, 95 percent of lead and 60 percent of other heavy metals are found in sediment particles smaller than 850 microns. For example, Pitt (1983) showed that concentrations measured in paved parking runoff or street gutter flow were ten times higher than concentrations observed from other urban sources. This suggests that improved control of the silt loading on paved and unpaved roads will result in a decrease in runoff pollution.

The application of BACM will have some minor influence on increased water pollution, solid waste production, and energy consumption. The primary environmental concerns are the leaching of chemical dust suppressants and storage pile soluble material into surrounding soils and waters, the disposal of temporary paving material, and VOC emissions from petroleum-based dust suppressants.

Chemical dust suppressant are likely to leach out over an extended period of time. The Arizona DOT (1975) found that the percentage reduction in extractable residues from areas treated with chemical dust suppressants ranged between 16 percent and 70 percent and averaged 42 percent. This figure relates to a 56 percent leachout over the 14-month monitoring period.

Calcium chloride produces the same types of environmental problems when used as a dust suppressant as when used for road deicing, but when used as a dust suppressant is considerably less because of the smaller amounts used. Little internal hazard is connected with the use of calcium chloride due to its low systemic toxicity. Calcium chloride, under conditions of high duration or intensity rainfall, can move considerable distances either as surface runoff or as soil leachate. However, calcium added by way of dust suppressant is insignificant in comparison to the amount already present in the environment. Chloride itself is also present in all natural waters.

There is a potential for mobilizing mercury associated with the use of calcium chloride. Since calcium and sodium ions compete with mercury for exchange sites and the chloride ion reacts with mercury to convert it to a soluble form, the runoff of calcium chloride could result in the release of mercury from soils or bottom sediments to lakes or streams.

Lignin sulfonates have very low mobility through soils and pose little, if any, threat to groundwater when applied to the surface. Except for trout, this dust suppressant seems to pose little direct systemic toxicity problems in aquatic organisms, animals and humans, or vegetation.

Temporary paving material used to create "cleaning aprons" near construction sites must be disposed of. It is likely to be both environmentally and cost beneficial to recycle this gravel/asphalt mixture for construction of new roads in the vicinity of the construction site.

Volatile organic compounds (VOC's) escape from paving materials made with petroleum based solvents. The VOC emissions from cutback asphalt are estimated in AP-42, section 4.5. Only minor amounts of VOC's are emitted from emulsified asphalts and asphaltic cement. Emulsified asphalts rely on water evaporation to cure or on ionic bonding of the emulsion and the aggregate surface, and can substitute for cutback in almost any application.

SECTION 5

CONTROL COST ANALYSIS METHODOLOGY

The costs of implementing BACM for PM-10 emissions from fugitive dust are presented in this section. These costs have been developed for the model units presented in Section 4. All costs presented in this chapter have been updated to second quarter 1991 dollars.

The following discussion describes the process for calculating the cost of an available control measure for BACM application. Examples are given for selected model units for paved roads, unpaved roads, construction/demolition activities, and wind erosion from open areas.

5.1 ESTIMATING ANNUALIZED COST

Annualized cost is comprised of capital, operating, overhead, and enforcement/compliance costs. Annualized cost, C_a, is determined using the following equation:

$$C_a = (CRF \cdot C_e) + C_o + 0.5C_o + C_i \qquad (5\text{-}1)$$

where: CRF = capital recovery factor (defined in Equation 5-3).
C_e = direct capital costs.
C_o = annual direct operating costs.
0.5 = overhead cost rate.
C_i = direct annual enforcement and inspection costs.

Annualized cost for an individual control measure is likely to vary because of economic and environmental conditions. Costs will vary geographically due to differences in wage rates and equipment/material costs by region. Costs will also vary because of differences in availability of existing equipment and personnel. For example, local governments that need to chemically stabilize unpaved roads to meet PM-10 standards and that already own tank trucks capable of distributing chemical dust suppressants will have smaller initial costs than other governments without tank trucks.

The individual elements for Equation 5-1 are described in the following sections.

5.1.1 Capital Costs, Ce

The capital investment in a fugitive dust control system consists of those costs incurred in purchase and installation of equipment, development of support facilities (such as utilities), and associated labor. In general, capital costs are divided into direct and indirect costs. Direct capital costs are the costs of control equipment, support facilities, and labor and materials needed for installation of utilities. For example, implementation of chemical dust suppression measures will require tanks for storage and mixing, spray trucks, pumps, piping, etc.

Direct costs cover the cost of purchase of equipment, support facilities and auxiliaries, and the cost of installation. Structures may require certain restrictions which add to the direct costs. General types of direct capital costs associated with fugitive dust control systems include:

1. Equipment costs for items such as trucks, sweepers or vacuums; chemical application equipment; storage tanks; and facilities.

2. Installation, including adaption into current system (or replacement of old system), and testing and adjustment of control apparatus and procedures.

3. Support facility upgrading costs for items such as newly paved roads or gravel placement over dirt roads.

4. Associated direct costs, such as utility lines and connections, site development, and materials related to the acquisition and installation of the capital items.

Indirect capital costs cover the expenses not attributable to specific equipment or structures. General types of indirect capital costs associated with fugitive dust emissions control systems include:

1. Engineering and administrative costs such as specifications and design work, overhead costs, training of personnel, safety engineering, and modeling.

2. Construction and field expenses, including buildings and equipment, warehouses, repair-work areas, temporary facilities, and tools.

3. Contractor's fee and contingency costs.

The capital cost to be incurred is dependent on the maximum amount of control desired. For instance, chemical suppressants may be applied to unpaved roads a maximum of once every month. In that case, sufficient capital equipment should be obtained to apply chemical suppressants to the unpaved roads in about a month's time. If, however, the maximum number of applications is later increased to twice per month, the current capital investment may not be able to accommodate the increased application intensity, and additional capital equipment will have to be purchased. On the other hand, if enough equipment is purchased to allow a maximum of one application per week (on the assumption that at some time it may be needed), and subsequently only two applications are made per month, then excess capital equipment is wasted. Therefore, the issue in determining capital costs is one of optimization: minimizing the capital cost subject to a minimum equipment utilization rate and minimum emissions reduction percentage, or alternatively, maximizing the emissions reduction percentage subject to a maximum equipment utilization rate and maximum capital cost.

The annualized cost of capital equipment, support facilities, and related capital expenses is calculated by using a Capital Recovery Factor (CRF). The CRF provides an average level of annualized cost associated with one dollar of initial capital investment. The CRF takes into account the real interest rate of borrowed funds (a pretax marginal rate of return on private investment, annual percent as a fraction) and the economic life of the control system (number of years):

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \quad (5-2)$$

where: i = annual interest rate.

n = economic life of the control system in years.

For instance, given an annual interest rate of 10 percent on borrowed funds, and an economic life of 15 years on capital equipment, the CRF will be approximately 0.13. This factor, multiplied by the total capital costs, provides annualized capital recovery cost, the annualized capital cost over the life of the equipment.

5.1.2 Operating Cost, C_o

Operating cost will be a major component of many control measures. First, those control measures that are mechanical in nature or require repeated applications or maintenance will likely have operating costs exceeding capital costs over time. An example is chemical stabilization of unpaved road surfaces where the costs of labor, fuel, and materials (chemical stabilizers) will, over time, exceed the cost of capital equipment (storage tanks, tank truck, spray equipment). Second, operating costs for many control measures will continue for as long as control is required. Operating costs typically include:

- Utilities: electricity, water, natural gas, telephone, etc.
- Raw materials/process inputs.
- Operating labor.
- Maintenance and repairs: labor and materials.
- By-product costs: material collected during application, or as a result of operations, that must be disposed.
- Fuel costs.

Generally, operating costs will increase linearly with increases in application intensity or expansion of source extent to be controlled (i.e., increase the number of miles of roadway subject to BACM). However, there are many exceptions to this. As an example, increasing application rates may result in an increasing rate of maintenance and repair costs. Estimates of operating costs need to reflect the impact of the varying intensities of BACM application.

Operating costs are calculated for a particular year using the following equation.

$$C_o = C_u + C_r + C_l + C_m + C_b + C_f \qquad (5\text{-}3)$$

where: C_o = annual direct operating costs.
C_u = annual direct utility costs.
C_r = annual direct raw materials/process inputs.
C_l = annual operating labor.
C_m = annual direct maintenance/repair costs.
C_b = annual direct by-product costs.
C_f = annual direct fuel costs.

All of these costs may not apply to a particular control measure.

5.1.2.1 Utilities, C_u—

Utility costs for the current year are calculated directly based upon utility rates and estimated utility usage. Utility usage can often be determined from the owner's manual or other manufacturer product data.

5.1.2.2 Raw Materials/Process Inputs, C_r--

Some control measures, such as chemical stabilization or paving roads, have raw material and/or process inputs. Determination of these costs are accomplished by contacting area vendors and determining unit costs for these materials.

Listed below are popular publications that provide current cost data:

- *Hydrocarbon* (petroleum-based products)
- *Oil and Gas Journal* (petroleum-based products)
- *Chemical Marketing Reporter* (chemicals)
- *Purchasing World* (major commodities and industrial equipment)
- *Engineering News Research* (construction costs, heavy equipment costs, materials costs—gravel, cement, etc.)
- *McGraw Plant and Equipment Survey* (buildings and equipment)
- *Means Building Construction Cost Data* (construction and materials)

It is important in the planning effort to allow for price swings, because many raw materials and process inputs may be subject to wide changes in price over narrow time frames. It is not unusual to allow for a ±15 percent range in price for basic raw materials like petroleum-based feedstocks. Moreover, an estimate of miscellaneous losses should be added to the costs of raw materials. Estimates for price variation allowance and loss allowance should be determined by local conditions and the specific nature of the raw material. For example, if very little loss is expected either due to the nature of the raw material or the quality of the specific handling and storage equipment, then an appropriately low percent loss should be used in estimating loss allowance.

The amount of raw materials used during the year will depend upon the application intensity which is dependent on the control efficiency sought. (See Section 3 for discussion of emission control effectiveness.) Annual costs for raw materials are estimated using Equation 5-4.

$$C_r = (C_r' * N) * (1 + F_V + F_L) \qquad (5\text{-}4)$$

where: C_r = Raw materials cost.

C_r' = Cost per raw material unit ($/unit).

N = Total units required.

F_V = Price variation factor.

F_L = Loss factor.

It is important that C_r' is estimated carefully. Many materials are subject to seasonal price swings, and an estimate based on a yearly low price may not reflect real costs. If the material can be stored in sufficient quantities to last through seasonal usage (i.e., it can be stored and storage facilities are available), then the use of a yearly average price would be appropriate. However, if the material is likely to be purchased during a season of historically high prices, then the yearly high price should be used for C_r. Moreover, it is important to observe historic price fluctuations over at least a 5-year period. Those raw materials that experience large changes in price may require the use of a multiyear average or weighted average to accurately reflect C_r.

5.1.2.3 Operating Labor, C_l--

Operating labor costs depend on the control measure size and frequency of application. Costs are calculated by determining the types of labor (by *Dictionary of Occupational Titles* job description) and hours needed for the annual utilization of the control measure. Data on wage rates can be obtained from the U.S. Department of Labor's *Employment and Earnings* (a quarterly publication). Local wage rates can be estimated from data from the State Job Service (Employment Security) agency or from the State Occupational Information Coordinating Council. To cover the costs of supervision, an additional 15 percent of estimated labor costs is added.[R] Equation 5-5 illustrates the method for calculating labor costs:

$$C_l = F_s \sum_{i=1}^{n} W_i H_i \tag{5-5}$$

where: C_l = Labor costs ($).
W_i = Hourly wage rate for labor category i ($/hour).
H_i = Total annual hours for labor category i.
F_S = Supervision allowance; factor of 1.15.

5.1.2.4 Cost of Maintenance/Repairs, C_m--

Maintenance labor hours in practice are determined by the maintenance recommendations (as specified by the manufacturer/builder) of the equipment and property to be used. If maintenance/repair labor is at a premium over operating labor, a 10 percent premium should be added to the operating labor wage rates for each operating labor category.

Unfortunately, the Department of Labor's data limitations do not allow for distinguishing between operating labor for a particular operation and the maintenance labor for the operation. Therefore, maintenance labor costs are determined from operating labor costs. There are a few common business service maintenance categories that are recorded, such as heating and air conditioning maintenance workers; however, for most industrial machinery, there is no direct maintenance labor estimate.

In addition to labor, maintenance typically requires materials such as lubricants, solvents, cooling fluids, and replacement parts. Regularly used lubricant, cleaning, cooling, etc. materials costs are usually estimated as 100 percent of total maintenance labor costs. However, when manufacturers' specifications can allow direct cost estimates, these should be used instead.

Equation 5-6 shows the method for estimating maintenance/repair cost.

$$C_m = \sum_{i=1}^{n} W_i H_i + (C_p * CRF) + C_s \qquad (5\text{-}6)$$

where: W_i = Hourly wage rate for category i.

H_i = Total annual hours for labor category i.

C_s = Cost of supplies ($).

C_p = initial cost of replacement parts, including taxes and freight ($).

C_l = cost of labor ($).

CRF = capital recovery factor for replacement parts; life span should be defined by manufacturers' specifications (See Equation 5-4 for CRF formula).

5.1.2.5 By-Product Costs, C_b--

Some BACM may result in by-product costs (or possibly by-product revenues which would be a negative value in the direct operating costs equation) because of possible costs for disposal, reuse, etc. For example, street vacuuming produces waste material (dirt, trash, organic material, etc.) that must be disposed. These costs will have to be estimated directly based upon local price quotes from local waste disposal firms.

5.1.2.6 Fuel Costs, C_f--

BACM that require machine vehicles, such as street sweepers, will have fuel costs. These costs are calculated by multiplying equipment hourly or mileage fuel consumption estimates by estimated annual operation hours or miles. Due to volatility of petroleum fuel prices, fuel costs should be estimated based on anticipated prices. One method for estimating future prices is to use predicted prices reported by the American Petroleum Institute or other forecasting organization.

5.1.3 Overhead Costs

Overhead represents the costs associated with the control measure activity, but not directly tied to the activity. Payroll overhead costs include worker's compensation, Social Security, pension contributions, vacations, and other fringe benefits. System or operational overhead include security costs (like outfitting vehicles with alarms or storing them in fenced parking lots), facility lighting and heating, parking areas for employees, etc. Overhead is typically calculated as 50 percent of total annualized operating costs (USEPA, 1989).

5.1.4 Enforcement/Compliance Costs

A real cost of implementing control measures will be enforcement/compliance costs. Government agencies or their designees with responsibility for air quality programs will need to insure BACM is being implemented. Industry will need to document and demonstrate to agencies that they are complying with the requirements of operating permits. Moreover, many control measures will be implemented by local or State Government bodies that will require the air pollution control agency to implement monitoring programs with these government bodies. Likely costs to be incurred by enforcement agency and/or industry and government bodies in compliance and enforcement activities include:

- Additional labor to issue permits and conduct inspections;

- Other operating expenses such as recordkeeping materials (such as forms, data bases, etc.), fuel, overhead; etc.
- Capital costs such as inspection vehicles, computer equipment; etc.

Many local governments will be able to add much of the enforcement/compliance functions to existing personnel and equipment. For example, BACM permitting activity at construction sites may be easily handled by current inspection staff within their normal duties. However, costs may vary tremendously from agency to agency.

Likewise, industry operating under air quality permits that cover BACM will have varying compliance costs. For example, firms that currently staff an environmental regulation office may easily be able to handle additional record-keeping activity, but firms without such staffing may be forced to hire additional staff.

Due to such variability, estimating compliance/enforcement costs is very difficult. However, hours per compliance/enforcement activity can be estimated. Typical management/supervisory wage rates for the agency or industry should be used to determine hourly cost. Generally, Government time and resources will be spent on:

- Permit issuance.
- Site inspection/testing.
- Permit review/renewal.
- Enforcement action; issuance of warnings, fines, administrative/legal proceedings.

For industry and Government bodies, time and resources will be spent on:

- Permit application preparation.
- Additional planning necessary to fulfill permit requirements.
- Recordkeeping associated with control measures.

Total annual compliance/enforcement costs are the sum of both government and industry annual compliance/enforcement costs.

5.2 ESTIMATING EMISSION REDUCTION

The annual unit emission reduction, ΔR, is calculated by:

$$\Delta R = M \bullet e \bullet c \qquad (5\text{-}7)$$

where:
- ΔR = Annual unit emission reduction.
- M = annual source extent.
- e = uncontrolled emission factor.
- c = average control efficiency expressed as a fraction (see Section 3 for estimates of control efficiencies and uncontrolled emission factors).

For comparison purposes, the source extent should be defined as a model unit that typifies the sources to be controlled. By using the same model unit (quantified source extent) for each source, different control measures for each type of source can be compared.

5.3 MODEL UNIT EXAMPLES

Example costs have been estimated for the model units of paved collector roads, unpaved roads, construction/demolition site, storage pile, and open areas. The calculations follow the general format presented in the above sections and are shown in a stepwise method.

5.3.1 Paved Collector Road Model Unit

The model unit is a paved collector road with 5,000 average daily traffic passes. The collector road is adjacent to a construction site with daily traffic volume of 40 trucks (entering and exiting). The construction site operates for 250 days per year.

BACM for the road will be preventive in nature and will consist of a 30 meter paved access apron to the construction site. The operating permit for the construction site will require sufficient flush and sweep cleaning of the apron (at least once daily) to prevent trackout onto the collector road. A 71 percent control efficiency (control of trackout onto the collector road) will be achieved.

5.3.1.1 Costs--

Capital costs will primarily consist of the equipment and materials needed to construct the apron. Other equipment would include hoses and sweeping equipment needed to clean the apron. Given the temporary nature of the construction access apron, asphaltic material will be most likely used. In addition, unless the construction firm currently owns paving equipment, it will be unlikely that any paving equipment will be purchased; rather the firm will contract a paving firm to construct the apron. For this model unit the construction site is assumed to only be operational for a 1-year period, therefore, there will be no application of the CFR since all capital costs will be incurred during the first year.

Operating costs will be limited to the labor and supervision needed to clean the apron and ensure that it is in good condition. Most likely 2 h of unskilled labor can handle the cleaning demands. Overhead costs will be minimal due to the small operation costs.

Compliance/enforcement costs will include permitting and inspection costs. Inspection costs should be small since only visual confirmation that the apron was put into place and is being cleaned is all that is required. The air pollution control agency may want to require the construction firm to keep a record of when and how often the apron is cleaned. The compliance/ enforcement costs presented here are illustrative and may not reflect actual costs.

Estimates for each of these costs are provided in Table 5-1.

5.3.1.2 Total Annual Reduction, ΔR--

Total annual reduction of PM-10 emissions is calculated using Equation 5-7. Given a 5,000 ADT with an emission rate of 13 g/vehicle and a control efficiency of 71 percent, the total daily emission reduction is 55.9 kg. Assuming the construction site operates 250 days per year (5 day work week with 10 holidays) then total annual emission reduction is 13,975 kg (250 days x 55.9 kg/day). (See Figure 4-1.)

5.3.2 Unpaved Road Model Unit

The model unit is a 1-km unpaved public road with 225 ADT and a 10 percent silt content. Average vehicle speed is 32 km/h, average weight is 9 Mg, and average number of wheels is 6. BACM is a chemical suppressant program using Coherex®. A 75 percent control efficiency should be achievable with 7 applications per year.

5.3.2.1 Costs--

Capital costs will consist of the chemical truck(s) and applicator(s), storage tanks or storage area, and pumps and piping. The trucks and storage tanks may be purchased, or the job may be contracted out. For this model unit, the items will be purchased with intent to use for 5 years. For purposes of annualizing the costs, the capital costs will be annualized using the CRF with a 10 percent annual interest rate.

Operating costs will include labor costs for operation of the truck and storage areas as well as maintenance and repair of the equipment, fuel for the trucks and pumps, and the application chemicals.

TABLE 5-1. MODEL PAVED ROAD

Model unit	
Source:	Paved collector roads
Source extent:	Carryout from unpaved area onto a paved road adjacent to site; collector road (5000 ADT) adjacent to construction site; 40 truck access/day for 25 days
BACM:	Pave 30 m of access apron; daily flush and sweep paved access apron

Cost categories	Annualized cost
Capital costs:	
Apron construction	$1,500
Post-construction restoration costs	1,500
(Apron pavement reclamation revenues)	0
Sweep materials and hoses	50
Operations and maintenance costs:	
Labor for sweep and flush (2 hours/day)	750
Supervision--15% of labor	113
Water for flush	500
Overhead costs:	3,988
Enforcement compliance costs:	
Permitting	100
Total	$8,501

Cost sources: MRI and *Means Building Construction Cost Data.*

Enforcement compliance costs include permitting for use of the chemical, on-site inspection of the application process and emissions reduction, and record keeping and review. The on-site inspection will include sample analysis, and record keeping will include documenting amount of chemical applied, emissions reduction, and sample analysis results. Once again, these estimates are illustrative and may not reflect actual costs. Estimates for each of these costs is provided in Table 5-2.

5.3.2.2 Total Annual Reduction, ΔR--

Given a 225 ADT with emission rate of 0.964 kg/vehicle/km and a control efficiency of 75 percent the total daily emission reduction is 195 kg, or 71,175 kg/yr. (See Figure 4-2.)

5.3.3 Wind Erosion of Open Areas

The model unit is an unpaved parking lot, 100 m x 100 m, with uniform daily disturbance. Average particle size of the lot surface is 0.56 mm. BACM for the parking lot will consist of using larger particle sizes for the surface cover. A 70 percent control efficiency will be achieved using a less erodible material, such as gravel.

5.3.3.1 Costs--

A gravel surface material with larger particle size is estimated to have a life span of 10 yr, with 1,000 m2 of material of 2 in depth being replaced yearly. Capital costs are annualized using the CRF. The interest rate is set at 10 percent for this model unit. Operating costs include periodical grading of the surface, and operations costs associated with material replacement in erosion areas. Enforcement compliance costs include permitting for the lot, on-site inspection of material to determine particle size and emission reduction, and record keeping of material addition and grading. Table 5-3 lists component cost categories and annualized costs.

TABLE 5-2. MODEL UNPAVED ROAD

Model unit	
Source:	Unpaved road
Source extent:	1 km of road (225 ADT) with silt content of 10%, average speed of 32 km/h, average vehicle weight 9 Mg, with six wheels
BACM:	Chemical suppressant program aimed at 75% control from Table 4-4, seven applications of Coherex® a year

Cost categories	Annualized cost
Capital costs:	
Chemical truck(s) with applicator	$12,390
Storage tanks or area	5,310
Pumps	885
Piping	
Operations and maintenance costs:	
Labor for truck and storage area	10,000
Supervision—15% of labor	1,500
Fuel	4,512
Chemicals	5,000
Truck maintenance and repair	10,000
Overhead costs:	15,506
Enforcement compliance costs:	
Permitting	100
On-site inspection (sample analysis)	200
Record reviews	50
Total	$65,453

Cost sources: MRI, *Means Building Construction Cost Data*, and *Chemical Marketing Reporter*.

TABLE 5-3. MODEL OPEN AREA

Model unit	
Source:	Wind erosion
Source extent:	Wind erosion from an unpaved parking lot; dirt lot 100 m x 100 m; uniform daily disturbance; average particle size 0.56 mm
BACM:	Cover with a less erodable material (70% efficiency)

Cost categories	Annualized cost
Capital costs:	
Surface material and installation	$4,069
Operations and maintenance costs:	
Periodical grading	5,750
Material replacement in erosion areas	2,500
Overhead costs:	4,125
Enforcement compliance costs:	
Permitting	100
On-site inspection	200
Recordkeeping	50
Total	$16,794

Cost sources: MRI and *Means Building Construction Cost Data*.

5.3.3.2 Total Annual Reduction, ΔR--

Total annual emission reduction from Equation 5-8, given a 10,000 sq m lot with 70 percent control efficiency is 1,380 kg/yr (see Figure 4-6).

5.3.4 Storage Piles

The model unit is a conically-shaped coal storage pile with conveyor transfer operations. The pile stands 11 m high, 29.2 m in diameter and has a volume of 2,455 cu m and capacity of 11,797 Mg. Two-thirds of the pile is transferred by conveyor into and out of storage daily. The uncontrolled moisture content is 1.5 percent.

BACM for the storage pile will consist of a water spray system during conveyor transfer to achieve 60 percent control efficiency.

5.3.4.1 Costs--

Table 5-4 list annualized costs of $8,721. Capital costs include a submersible pump, 1200 ft of piping, and a control system for the water. For each conveyor belt, three (3) spray bars will each provide 10 cc/s, using fanjet sprays.

Operating costs include fuel (electricity) for the pumps, water, repair parts, and labor. Enforcement compliance costs include on-site inspection (sampling), record keeping, and permitting.

5.3.4.2 Total Annual Reduction, ΔR--

Total annual emission reduction to achieve 60 percent control efficiency is 962 kg/yr (see Figure 4-5).

TABLE 5-4. MODEL STORAGE PILE

Model unit	
Source:	Storage piles
Source extent:	Conically shaped storage pile; 11 m high; 29.2-m diameter; 838-m^2 surface area; pile disturbed every 3 days; moisture content 1.5%, LCD as shown in Figure 11.2.7-4 of AP-42.
BACM:	Watering to achieve 60% efficiency

Cost categories	Annualized cost
Capital costs:	
Pump system	$90
Pipe/hose system	$1,698
Control system	$81
Operations and maintenance costs:	
Labor for watering (1 hour/day)	$3,163
Supervision—15% of labor	$475
Water	$56
Electricity	$9
Repair parts/labor	$633
Overhead costs:	$2,167
Enforcement compliance costs:	
Permitting	$100
On-site inspection	$200
Recordkeeping	$50
Total	$8,721

Cost sources: MRI and *Means Building Construction Cost Data*.

5.3.5 Agricultural Tilling

Conventional agricultural farming operations include plowing, disking, harrowing, etc. This model unit is a 320-acre field tilled/cultivated five times per year. The soil has an 18 percent silt content. Twenty-five percent of farmland is typically classified as "highly erodible" under the Food Securities Act (FSA).

BACM for the field will consist of placing 80 acres of the 320 acres into the Conservation Resource Program of the FSA.

5.3.5.1 Costs--

Table 5-5 lists annualized costs of $7,730. The Conservation Resource Program requires specific grasses or trees be planted and fertilized for a 10-yr period. Capital costs include initial seed and fertilizer, fencing, gasoline, labor, and use of tractor and implements. For this model unit, tractor and implement costs are assumed zero.

Operating costs include periodical fuel, labor, and fertilizer for grass maintenance. In addition, operating costs include the payments made by USDA annually. Enforcement compliance costs include on-site inspection by Soil Conservation Service and record keeping.

5.3.5.2 Total Annual Reduction, ΔR--

Total annual emission reduction to achieve 25 percent control efficiency is 1,038 kg/yr (see Figure 4-7).

5.3.6 Construction/Demolition Activities

The model unit is demolition of a building in an urban area. The building is 18,500 sq ft located on a 1-acre site. There is one access point to a paved road carrying 2,000 ADT. The demolition will take 30 days, during which 30 vehicles per day will be removing debris.

TABLE 5-5. MODEL AGRICULTURAL TILLING OPERATION

Model unit	
Source:	Agricultural tilling
Source extent:	Wind erosion from agricultural activities; 320-acre field tilled/cultivated five times per year; 18% silt content; 25% classified "highly erodable" under Food Service Act
BACM:	Place 80 acres into the Conservation Resource Program

Cost categories	Annualized cost
Capital costs:	
Seed, fertilizer	$1,630
Tractor and implements	$0
Fuel	$41
Fencing	$103
Labor	$130
Operations and maintenance costs:	
Periodical fertilizing	$5,000
Fuel	$250
Labor	$800
USDA annual payments	($4,800)
Overhead costs:	$6,050
Enforcement compliance costs:	
On-site inspection (sampling)	$200
Record keeping	$100
Total	$7,730

Cost source: MRI.

BACM for the site will consist of wet suppression of debris loading and watering of unpaved travel surfaces on the 1-acre site. A 30 m access apron will be constructed and then swept and flushed daily.

5.3.6.1 Costs--

Table 5-6 lists annualized costs of $13,190 for BACM which includes wet suppression of debris transfer operations. Capital costs include a submersible pump, piping (and/or hoses), and control systems. Capital costs remain the same whether debris and handling are subject to wet suppression or not.

Operating costs include water and labor for sweeping and flushing of the access apron, for watering of unpaved travel surfaces, and for wet suppression of debris. Without wet suppression of debris, labor costs are cut in half, and water costs reduced by $20. Enforcement compliance costs include permitting, on-site inspection (sampling), and record keeping.

5.3.6.2 Total Annual Reduction, ΔR--

Total emission reduction to achieve 83 percent control efficiency is 1,517 kg over the 30-day period. Eliminating the wet suppression of debris from the BACM results in total emission reduction of 1,465 kg, a 80 percent control efficiency (see Figures 4-3 and 4-4).

TABLE 5-6. MODEL CONSTRUCTION/DEMOLITION ACTIVITY

Model unit	
Source:	Construction/demolition activities
Source extent:	Demolition of a building in an urban area; 18,500-m^2 building on 1-acre site; one access point to a paved road (2,000 ADT); 30 days of work; 30 vehicles/day removing debris
BACM:	Wet suppression of debris handling and transfer (6.7 L/Mg); watering of unpaved travel surfaces (0.1 L/m^2; sweep and flush access points

Cost categories	Annualized cost
Capital costs:	
Apron construction	$ 1,500
Post-construction restoration costs	1,500
Sweep material and hoses	50
Pump system	548
Piping system	774
Control system	50
Operations and maintenance costs:	
Labor for wet suppression and watering unpaved surfaces (8 hours/day)	3,600
Labor for sweeping and flushing access apron (2 hours/day)	900
Supervision—15% of labor	675
Water for flush	550
Overhead costs:	2,851
Enforcement compliance costs:	
Permitting	200
Inspection (included in permitting cost)	
Record keeping (included in supervision cost)	
Total	$13,198

Cost sources: MRI and *Means Building Construction Cost Data*.

SECTION 6

OPERATING PERMITS

This section outlines a framework of example dust control regulations, plans, and operating permits for publicly-owned or controlled PM-10 sources. Examples are presented to instruct regulatory personnel who need to implement BACM for PM-10 nonattainment areas.

6.1 PAVED ROADS

Clear and specific enforceable plan provisions are needed to gain credit for claimed emission reductions in State implementation plans (SIP's), which for paved road dust sources will likely rely on record keeping, reporting, and surrogate factors rather than short-term mass emissions or opacity limits. Surrogate factors will include control program regulations, permits, or intergovernmental agreements to institute programs such as vacuum sweeping, mud/dirt carryout precautions, spill cleanup, erosion control, and/or measures to prevent or mitigate entrainment from unpaved adjacent areas. Record review of control programs (e.g., vacuum sweeping, road sand/salt application, etc.) and field checks (i.e., road silt loading sampling) will provide the likely means of compliance determination for these sources. Because paved road emissions are directly related to the surface silt loading, the most reliable regulatory formats are based on loading. Formats viable for other open dust sources, including opacity measurements, visible emissions at the property line are generally not applicable for paved roads because of the lower unit emission levels involved (e.g., there are usually no visible plumes from a vehicle pass).

Many States currently have regulations related to the control of paved roads. Colorado, for example, may require a control plan from any party that repeatedly deposits materials which might create fugitive emissions from a public or private roadway. Note, however, that no quantitative determination of loading levels is specified.

An alternative format is presented below to suggest how a quantitative method could be incorporated in a regulation. Figure 6-1 presents a possible format for use with public paved road sources. In this example, if the silt loading on a road with an average traffic volume of 2,000 vehicles per day ever exceeds 2.9 g/m^2 (the "action level"), the regulatory agency may require the city or its contractor and subcontractors (e.g., a construction site with mud/dirt carryout) to reduce the silt loading to a level less than the action level. The action level is an agency-supplied multiple of baseline measurements of the surface silt loading and should correspond to a minimum control efficiency level.

The maximum allowed silt loading requirement could be made part of a construction permit or an enforceable intergovernmental agreement. Note that additional traffic due to the construction activity should be included in the daily traffic volume used to determine the action level for the affected roadways. In addition, a request for permit should be accompanied with a description of the control technique(s) that will be employed. Similarly, intergovernmental agreements should clearly and specifically describe control techniques and associated record keeping and reporting requirements.

The field measurement of silt loading could either be made a requirement of the responsible party or be assigned to agency inspection personnel, or a combination of the two could be used.

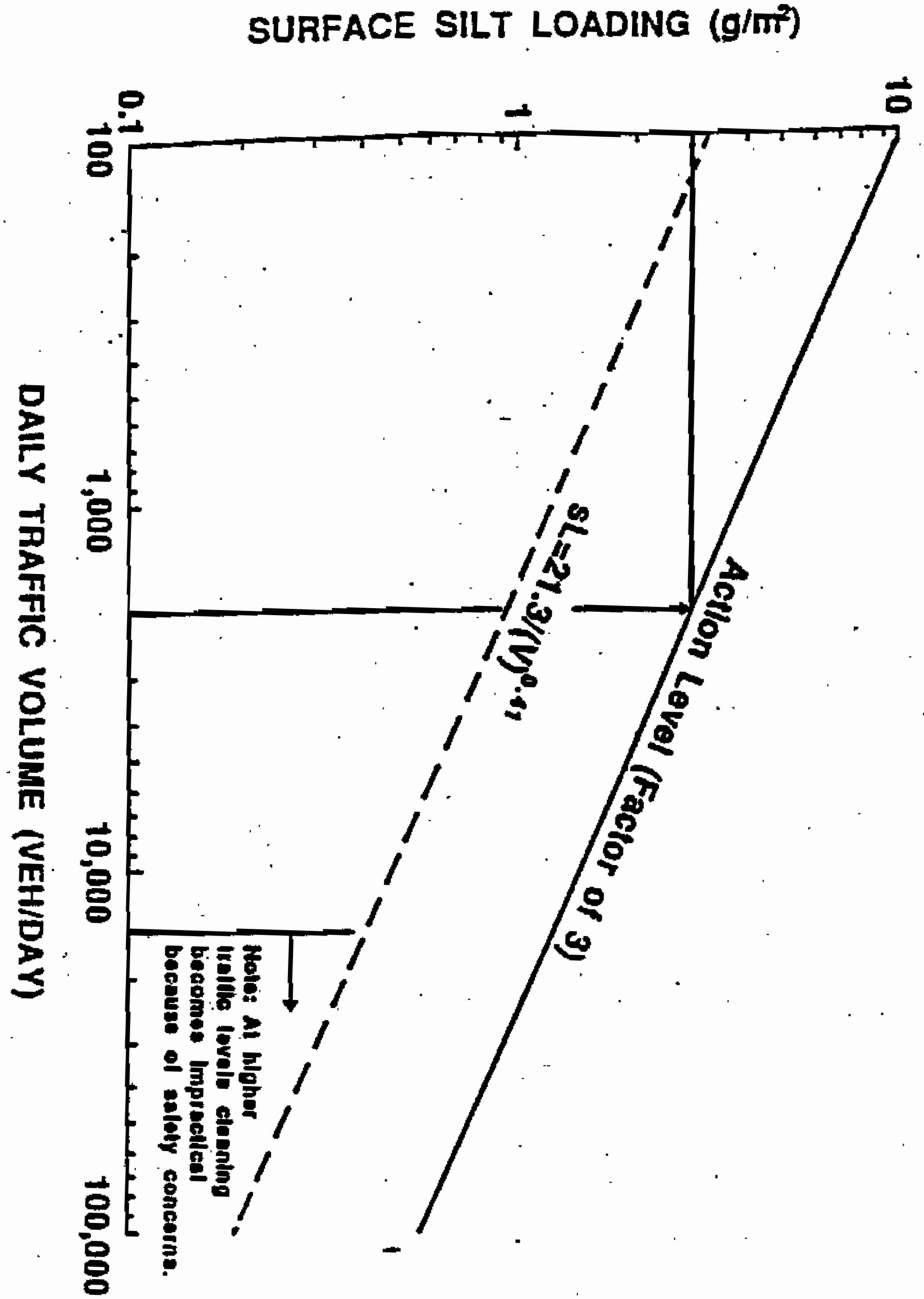

Figure 6-1. Possible quantitative format for public paved road sources.

In either event, certain features of the measurement technique must be specified.

1. The sampling and analysis methods used to determine silt loading for compliance inspection should conform to the techniques used to develop the AP-42 urban paved road equation. These methods are described in Appendices D and E of the AP-42 document.

2. Arrangements must be made to account for spatial variation of surface silt loading. Possible suggestions include (a) visually determining the heaviest loading on the road and selecting that spot for sampling, (b) sampling the midpoint of the road length segment of interest, and (c) sampling preselected strips on the road surface.

3. Provision should be made to grant a "grace period" following a spill or other accidental increase in loading. An 8-h period is suggested to allow time for the responsible party to clean the affected area. This allowance should be made part of a construction or other permit.

The control efficiency equations presented in Table 3-1 provide a potential regulatory format for paved road sources. This approach involves inspection of both road cleaning records and traffic counts. By combining the two sets of information, regulatory personnel would be able to determine average efficiency values for the controlled paved roads. Provision must be made to collect traffic information. Obtaining traffic data may require more frequent inspections than for surface loading samples; however, analysis of traffic data is more easily accomplished. Surface loading sampling provides an additional means for checking the success of achieving the estimated control efficiency.

6.1.1 Example SIP Language

Public paved roads are important PM-10 sources in areas across the country. Unlike the industrial sources described in this manual, control of municipal paved roads generally requires a close working agreement between various Government bodies and the general public.

6.1.1.1 General Description--

The purpose of this rule is to reduce the amount of particulate matter, especially the amount of fine particulate matter (PM-10), reentrained in the ambient air as a result of motor vehicle traffic on paved roadways and to control sources that are contributing to particulate matter loadings on the roadways.

6.1.1.2 Material Transport--

- No person shall cause or permit the handling or transporting of any material in a manner which allows or may allow controllable particulate matter to become airborne. Visible dust emissions from the transportation of materials must be eliminated by covering stock loads in open-bodied trucks or other equivalently effective controls.
- Earth or other material that is deposited by trucking and earth-moving equipment on paved streets shall be reported to the (local Department of Sanitation at ____________) and removed within 8 h subject to safety considerations by the party or person responsible for such deposits.

6.1.1.3 Motor Vehicle Parking Areas--

- Effective ________________, the City of ________________ shall not cause, permit, suffer, or allow the operation or use, of an unpaved motor vehicle parking area.

Low-use parking area exemption: Motor vehicle parking area requirements shall not apply to any parking area from which less than ____ (e.g., 10) vehicles exit on each day. Any person seeking such an exemption shall: (1) submit a petition to the Control Officer in writing identifying the location, ownership, and person(s) responsible for control of the parking area, and indicating the nature and extent of daily vehicle use; and (2) receive written approval from the regulating agency that a low-use exemption has been granted.

6.1.1.4 Erosion and Entrainment From Nearby Areas--

- The City of ______________ will pave or treat by using chemical binders, calcium chloride, or acceptable equivalent materials the following: paved road shoulders and approach aprons for unpaved roads and parking areas that connect to paved roads, which are within the City's right-of-ways or under the City's control and within X feet (e.g., 25) of roadways [specify location], in amounts and frequencies as is necessary to effectively control PM-10 emissions to a level of X percent control efficiency (e.g., paving--90 percent; chemical treatment per specified requirements--70 percent). [Include list of roads in memorandum of understanding and specify whether those areas will be paved or treated.]
- If loose sand, dust, or dust particles are found to contribute to excessive silt loadings on nearby paved roads, the Control Officer shall notify the contractor or user of said public land that said situation is to be corrected within a specified period of time, dependent upon the scope and extent of the problem, but in no case may such a period of time exceed X (e.g., 2) days.

The Control Officer, or a designated agent, must take such remedial and corrective action as may be deemed appropriate to relieve, reduce, or remedy the existent dust condition, where the contractor or user of the subject land, fails to do so.

Any cost incurred in connection with any such remedial or corrective action by the Control Officer shall be assessed against the contractor or user of the involved property, and failure to pay the full amount of such costs shall result in a lien against contractor or user of real property, which lien shall remain in full force and effect until any and all such costs shall have been fully paid, which shall include, but not be limited to, costs of collection and reasonable attorney's fee therefore.

[A preferable option is to include provisions in applicable city contracts that require specified dust control measures and establish penalties for not meeting contract objectives.]

6.1.1.5 Road Sanding/Salting and Traffic Reduction--

- The City of ________________ will, beginning with the (year) winter season, restrict the use of sand used for antiskid operations to a material with greater than X percent (e.g., 95) grit retained by a number 100 mesh sieve screen and a degradation factor of X.
- The City of ________________ will conduct its street cleaning once per year at the end of the winter season. The street cleaning program shall be designed to provide for maximum effort throughout spring months and shall provide for adequate personnel and equipment to ensure thorough cleanup within safety constraints. The City will begin cleaning the roads sand/salt loadings from streets per the following priority schedule: [include schedule in memo of understanding].

6.2 UNPAVED ROADS

There are numerous regulatory formats possible for unpaved roads. For example, some States rules have been developed using opacity readings to determine compliance. Michigan and Illinois formulated rules based on opacity and both resulted in considerable debates of merit.

It is important to note that opacity has yet to be related to emission levels from roads. One often-raised question deals with prevailing wind speeds during opacity readings; ambient air concentrations (and hence, opacity levels) tend to be greater under lower wind speeds. Consequently, for a road with even a constant emission rate, opacity readings would vary indirectly with wind speed.

Record keeping offers another compliance tool for unpaved road dust controls. The level of detail needed varies with the control option employed. Record keeping, together with traffic records as required, will allow the regulator to estimate control performance for a variety of control programs, such as for estimation of chemical suppressant efficiency between applications. While record keeping affords a convenient method of assessing long-term control performance, it is important that regulatory personnel have "spot-check" compliance tools at their disposal.

For chemically controlled surfaces, it has been found that the control efficiency equation tends to <u>overestimate</u> the controlled emission factor (and thus, <u>underestimate</u> instantaneous control efficiency) (Muleski and Cowherd, 1987). Thus, an inspector could collect an unpaved sample with a whisk broom and dustpan and, after laboratory analysis for silt content, calculate a conservatively low estimate of control efficiency resulting from the chemical treatment. If a rule is written to maintain a certain higher level of efficiency, the inspector could then instruct the responsible party to reapply the chemical or use paved road controls (if feasible).

6.3 STORAGE PILES

There are several possible regulatory formats for control of dust emissions from formation and loadout of storage piles. Opacity standards are suitable for observations at the point of emissions, such as continuous drop from a stacker; however, in some States they may not be legally applied at the property line.

For wet suppression and chemical stabilization, suitable record keeping forms would provide evidence of control plan implementation. In addition, simple measurements of moisture level in transferred material or of the crust strength of the chemically treated surface could be used to verify compliance. In addition, the surface loading as well as the texture of material deposited around the pile could be used to check whether good work practices are being employed relative to pile reclamation and maintenance operations. The suitability of these measurements of surrogate parameters for source emissions stems from the emission factor models which relate the parameters directly to emission rate.

6.3.1 Example SIP Language

The purpose of this rule is to reduce the amount of particulate matter, especially the amount of fine particulate matter (PM-10), entrained in the ambient air related to the loading or unloading of open storage piles of bulk materials.

6.3.2 Requirements

1. The city and its contractors shall not engage in the loading, unloading, conveying or transporting of bulk materials unless a dust control plan is approved by the APCO which demonstrates that an overall X percent (e.g., 75 percent) reduction of PM-10 emissions from storage piles and related activities will be achieved. Control measures may include, but are not limited to, the following: application of water or chemical suppressants, application of wind breaks or wind fences, enclosure of the storage piles, enclosure of conveyor belts,

minimizing material drop at transfer point, securing loads and cleaning vehicles leaving worksite, and other means as specified by the APCO.

2. The contractor/operator is in possession of a currently-valid permit which has been issued by the APCO.

6.3.3 Control of Mud/Dirt Carryout

1. Street cleaning: No person shall engage in any dust-producing storage pile related activity at any work site unless the paved streets (including shoulders) adjacent to the site where the storage pile-related activity occurs are cleaned at a frequency of not less than X (e.g., once) a day unless:

a. vehicles do not pass from the work site onto adjacent paved streets, or
b. vehicles that do pass from the work site onto adjacent paved streets are cleaned and have loads secured to effectively prevent the carryout or dirt or mud onto paved street surfaces.

6.4 CONSTRUCTION/DEMOLITION

This section discusses record keeping, measures of control performance, and enforcement issues as well as an example rule which implements a permit system for construction and demolition sites. Example regulatory formats are provided for the following sources associated with construction/demolition: unpaved roads, haul roads, disturbed soil, and mud carryout. These example formats provide a starting point for development of construction rules in a specific area.

The reader is especially encouraged to review a separate EPA document issued September 25, 1990, *Survey of Construction/ Demolition Open Source Regulations and Dust Control Plans*. This 64-page final report issued under EPA Contract 68-02-4395, WA.48, gives a detailed assessment of existing regulations, presents an example regulation (reproduced in Table 6-1), and also offers example dust control plans for four scenarios.

The example regulation presented in Table 6-1 was largely based on features found during the review of existing and draft regulations.

Several points should be noted about the example:

1. First, the example presents only a skeleton of a regulation which must be "fleshed out" for use. For example, agencies will need to decide if dust control plans are to be attached to building permits or if a separate air regulatory permit is to be issued.

TABLE 6-1. EXAMPLE REGULATION

Section 100—General

101 Purpose—To reasonably regulate construction and demolition activities that release particulate matter emissions to the ambient atmosphere

102 Applicability—This regulation applies to all construction and demolition activities within the ______________'s jurisdiction unless specifically exempted below.

Section 200—Definitions

For the purpose of this regulation, the following definitions apply

201 APCO (Air Pollution Control Officer)—The person heading the (agency) or any of his/her designees.

202 Applicant—The individual, public and/or private corporation, or any other legal entity preparing the dust control plan described in Section 301.

203 Chemical Stabilization/Suppression—A means of dust control implemented by any person to mitigate PM-10 emissions by applying petroleum resins, asphaltic emulsion, acrylics, adhesives, or any other APCO-approved materials.

204 Construction/Demolition Related Activities—Any on-site mechanical activities preparatory to or related to the building, alteration, rehabilitation, or demolition of an improvement on real property, including but not limited to: grading, excavation, loading, crushing, cutting, planing, shaping, or breaking.

205 Disturbed Surface Area—A portion of earth's surface, or materials placed thereon, which has been physically moved, uncovered, destabilized, or otherwise modified, thereby increasing the potential for emission of fugitive dust.

206 Dust Suppressants—Water, hygroscopic materials, chemical stabilization/ suppression materials (see definition 203), and other materials not prohibited for use by the Environmental Protection Agency or any other applicable law, rule, or regulation, as a treatment material to reduce PM-10 emissions.

207 Fugitive Dust—The particulate matter entrained in the ambient air which is caused from man-made and natural activities such as, but not limited to, movement of soil, vehicles, equipment, blasting, and wind. This excludes particulate matter emitted directly in the exhaust of motor vehicles, other fuel combustion devices, from portable brazing, soldering, or welding equipment, and from pile drivers.

208 Lot—A designated parcel, tract, or areas of land established by plat, subdivision, or as otherwise permitted by law, to be used, developed, or built upon a unit.

209 Open Area—An unsealed or unpaved motor vehicle parking area, truck stop, vacant lot, or any other disturbed surface area located on public or private property which is subject to wind erosion, and is a source of PM-10 emissions.

210 Paved Surface—An improved street, highway, alley, public way, easement, or other area that is covered by concrete, asphaltic concrete, asphalt, or other materials specified by the APCO.

211 PM-10—Particulate matter with an aerodynamic diameter smaller than or equal to a nominal 10 μ as measured by the applicable Federal reference method.

212 (PM-10 Dust Prevention and) Control Plan—A written document that describes dust emission sources present at the site and identifies the means and strategies used to reduce the emissions.

213 Site—The real property upon which construction/demolition activities occur.

214 (Surface, Soil) Stabilization—The process used to mitigate PM-10 emissions for an extended period of time by applying petroleum resins, asphaltic emulsion, acrylics, adhesives, or any other APCO-approved material or physical stabilization by vegetation or the addition of aggregate material to the surface.

215 Traffic Volume (ADT)—The average daily traffic (ADT) is the number of vehicle trips on a paved or unpaved surface during a 24-h period. The ADT value for a publicly owned road shall be determined according to the regulations of the public agency responsible for that road.

216 Unpaved Surface—Any surface not defined as paved in definition 210 above.

Section 300—Prohibitions/Requirements

301 No person shall engage in any construction/demolition related activity (as defined above) without having an APCO-approved PM-10 dust prevention and control plan, unless exempted below. This control plan will be in writing and, at a minimum, will

1. briefly describe construction/demolition activities to be performed at the site that will produce PM-10 dust emissions. These dust-generating activities shall include, but not be limited to:
   - I. Removal of Obstructions (Natural/Man-made)
     - a. Transfer of the debris into vehicles for haulage
     - b. Transportation of the debris on-site
     - c. Additional transfers of the debris (if on-site, as for fill material)
   - II. Preparation of the Site
     - a. Bulldozing and scraping operations
     - b. Truck transportation of materials (such as "imported" fill) on-site
     - c. Transfers of materials
   - III. Construction Operations
     - a. Traffic on paved surfaces and staging areas
     - b. Traffic on unpaved surfaces and staging areas

2. present estimated uncontrolled PM-10 emission rates for each activity and summarize the total uncontrolled PM-10 emissions expected.

3. describe the control measures (if any) to be applied to each activity and estimate the corresponding controlled emission rate for each activity.

4. estimate the overall efficiency of the control plan by comparing the total controlled emissions to total uncontrolled emissions. (Note that the APCO may choose to prescribe a minimum target overall efficiency for the control plan.)

The applicant is responsible for ensuring that each contractor or subcontractor working at the site adhere to the provisions of the dust control plan.

The APCO shall make available for inspection examples of approved dust control plans at the offices of ______________.

301 Unless specifically exempted below, no person shall allow any visible accumulation of mud, dirt, dust, or other material on the paved roads, including paved shoulders adjacent to the site where construction/demolition activity occurs. The methods used to prevent accumulation as well as the scheduled frequency of cleaning must be addressed in the dust control plan.

302 Unless specifically exempted below, disturbed surfaces may not be allowed to remain in an unstabilized state. Disturbed surfaces must be stabilized against wind and water erosion within ___ calendar days after the disturbing activity ceases. In no event shall a disturbed area be allowed to remain unstabilized for a period greater than ___ calendar days. The method(s) used to stabilize the surface shall be described in the dust control plan.

303 As evidence of control application, the applicant shall keep dust control records on agency-supplied forms. These forms will be included with the APCO's written approval of the applicant's dust control plan. Records are to be kept current, be submitted upon the request of the APCO, and be open for inspection during unscheduled inspections.

304 For construction projects with a duration of at least ___ calendar days, the APCO shall perform at least one on-site inspection. Prior to this scheduled inspection, the APCO may require the applicant to furnish information or other records.

305 For construction projects with a duration of at least ___ calendar days, the APCO will formally review the dust control plan within ___ calendar days of the on-site inspection.

Section 400—Exemptions

The following sources are specifically exempted from the provision of this regulation:

401 Construction/demolition activity involving a floor plan of less than _____ sq feet

402 Any construction/demolition meeting the following activity levels or requirements

1. occurring entirely within an enclosed structure from which no visible airborne particulate matter escapes;

2. modifications to the residential dwellings by the owner/occupant that do not require building permits;

3. movement of less than _____ cubic yards of dirt.

403 Disturbed surface areas of less than _____ acre.

404 The implosion or mechanical dismemberment of any structure. (Note, however, that this activity may be subject to regulation _______, which requires a permit or variance to be granted.

405 Blasting of rock or other earthen materials in conjunction with construction/ demolition activities. (Note, however, that this activity may be subject to regulation _______, which requires a permit or variance to be granted.)

Similarly, it is important that regulators have legal counsel rephrase the example for consistency with State and local laws. Table 6-1, for example, only prohibits persons from "allowing" certain situations; many agencies will need to supplement this with verbs such as "cause" or "permit." Also, no specific mention of fees or penalties is made.

2. The example regulation contains several blank fields for items such as the minimum size of areas to be considered or time periods within which control must be applied. Agencies need to determine an appropriate value for each blank.

3. As noted in the example, dust emissions resulting from mechanical dismemberment or implosion of an existing structure or from blasting of rock are not covered by the regulation. However, it is recommended that agencies provide additional phrasing referring to a separate permit or variance to cover this type of emission source.

4. Readers are reminded that the regulation given in Table 6-1 is meant solely as an example and is intended only to provide a general framework around which regulations may be developed. Agencies should freely add or delete material as appropriate for their jurisdictions.

6.4.1 Permit System

The regulatory approach involves the implementation and enforcement of a permit program for construction and demolition sites. A permit system would require the site operator to file an application with the appropriate regulatory agency having jurisdiction. This permit application would include the specific dust control plan to be implemented at the site which would involve the individual elements discussed in Section 3.4.

The air permit for construction and demolition sites would be coupled to the standard building or demolition permitting process whereby no permit to conduct such activity would be issued by the county or city until such time that the air permit is approved. To reduce the burden of processing large numbers of such permits, a *de minimis* level would be established whereby construction and demolition projects below a certain cut-off size would not require an air permit. This *de minimis* level would depend on local factors such as the amount of emission reduction required to meet the applicable PM-10 NAAQS.

As part of the permit application, record keeping should be one of the main conditions for approval. Records of site activity and control should be submitted to the regulatory agency on a monthly basis as indicated above. These records must be certified by a responsible party as to their completeness and accuracy. All site records should be maintained by the local agency for the duration of the project.

To enforce the dust control plan submitted as part of the permit application, field audits of key control parameters should be made by regulatory personnel. The results of these audits would then be compared to site records for that period to determine compliance with permit conditions. An example form to be used by regulatory personnel during inspection of the site is shown in Figure 6-2. An example permit for a contractor operating a construction site is shown in Figure 6-3.

No quantitative data are required for enforcement of the dust control plan. This eliminates the need for a set performance standard (e.g., opacity limits) against which the site operator is evaluated. This approach is, however, predicated on the fact that strict implementation of the dust control plan will achieve certain reductions in PM-10 emissions associated with site operation.

6.4.2 Other Indirect Measures of Control Performance

The most obvious approach to indirectly measuring control performance involves the collection and analysis of material samples from various sources operating on-site. For mud/dirt carryout, collection of surface samples at site access points and

1. Type of construction activity (check one)

a. Residential ____
b. Commercial ____
c. Industrial ____

Additional description (i.e., multiunit, residential, or suburban commercial, etc.)

2. How long have you worked at this location?

Note: In the case of a multiyear project, we are only interested in the current season.

3. How long is the job projected to last?

4. What percentage of the work is completed?

5. What construction activities are you currently performing?

6. What construction activities have you been performing over the past week to 10 days?

7. What is the construction activity's source extent which is currently being performed (e.g., tons of earth moved/day or yards of concrete poured/day)?

8. Estimate the number of daily vehicle passes through the site entrance.

9. What types of vehicles enter the site daily and what percentage of the traffic is of each type?

	Vehicle type	Percent
a.	Cars	____
b.	Pickups/vans	____
c.	Medium-duty trucks	____
d.	Other	____

10. Do you employ control measures to keep dust down? If yes, what type?

11. What is the usual frequency and intensity of application? When was the most recent application?

Figure 6-2. Questionnaire for construction site personnel.

THIS PERMIT WILL BE PROMINENTLY DISPLAYED IN THE ON-SITE CONSTRUCTION OFFICE

Location: ______________________ No. of Acres: __________

Name of Project: ______________________

PERMITTEE: ______________________ Telephone No.: __________

Address: ______________________

Prime Contractor: ______________________ Telephone No.: __________

Subcontractor: ______________________ Telephone No.: __________

Issue Date of Permit: __________ Expiration Date of Permit: __________

PERMIT NO.: __________ FEE: $__________ RECEIPT NO.: __________

THE PERMITTEE SHALL COMPLY WITH THE FOLLOWING CONDITIONS:

1. (Reference to local APCD regulation for construction/demolition-related activities.)

2. The PERMITTEE is responsible for dust control from commencement of project to final completion. Areas which will require particular ATTENTION:

   a. Unimproved access roads used for entrance to or exit from construction site.
   b. Areas in and around building(s) being constructed.
   c. Dirt and mud deposited on adjacent improved streets and roads.

3. If wind conditions are such that PERMITTEE cannot control dust, PERMITTEE shall shut down operations (except for equipment used for dust control).

4. The PERMITTEE is responsible for ensuring his contractor(s) and/or subcontractor(s) and all other persons abide by the conditions of the permit from commencement of project to final completion.

5. The PERMITTEE also is subject to compliance with all applicable state, county, and local ordinances and regulations. Issuance of this permit shall not be a defense to violation of above-referenced statutes, ordinances, and regulations.

6. On-site permit conditions (attached)

____

Air Pollution Control Division (date)

Figure 6-3. Example dust permit.

analysis of these samples for silt content would indicate the efficacy of control for this particular source. The silt loadings obtained could be compared with "typical" surface loading values for similar uncontrolled sites to determine the degree of loading (and thus emissions) reductions achieved. This would, of course, necessitate the availability of a data base of "uncontrolled" silt loadings due to mud/dirt carryout for a wide variety of construction and demolition sites for comparison with site-specific data.

Another indirect measure of control efficiency can be determined from the collection and analysis of material samples from unpaved surfaces and materials handling and storage operations. In this case, analysis of the moisture content of these samples would indicate the amount of water applied and thus the degree of control achieved by wet suppression. Appropriate equations presented in Section 3.4 would be used to determine control efficiency based on the sample data.

6.5 WIND EROSION

Potential regulatory formats for control of open area wind erosion are listed in Table 6-2. These focus on appropriate measures for compliance determination. An example regulation for water mining activities is presented in Figure 6-4.

6.5.1 Example SIP Language

The purpose of this rule is to reduce the amount of particulate matter, especially the amount of fine particulate matter (PM-10), entrained in the ambient air as a result of emissions from open areas.

TABLE 6-2. METHODS FOR COMPLIANCE DETERMINATION

Source types	Permits	Field audits	Work practices (recordkeeping)	Emission measurement
Construction areas	Yes	Threshold friction velocity Moisture content Visible erosion (scouring)	Wet stabilization Chemical stabilization Wind fences	% V.E. at property line/source; PM_{10}/TSP concentration at property line
Vacant lots	Yes-cond. on area disturbed	Threshold friction velocity Moisture content Visible erosion (scouring)	Chemical stabilization Vegetative cover (%)	% V.E. at property line/source; PM_{10}/TSP concentration at property line
Unpaved parking lots	Yes	Threshold friction velocity Moisture content	Graveling Chemical stabilization	% V.E. at property line/source; PM_{10}/TSP concentration at property line
Feed lots	Yes-cond. on size-where allowed	Moisture content	Wet suppression (sprinklers) Wind fences	% V.E. at property line/source; PM_{10}/TSP concentration at property line
Staging area	Yes	Threshold friction velocity Moisture content Visible erosion (scouring)	Wet stabilization Chemical stabilization Wind fences	% V.E. at property line/source; PM_{10}/TSP concentration at property line
Off-road recreation area	Yes	-	Limit area disturbed Limit vehicles (emission activity)	-
Landfills	Yes	-	Limit working face Wet suppression of access and working area Vegetative cover (%)	% V.E. at property line/source; PM_{10}/TSP concentration at property line
Land disposal (spreading)	Yes	Threshold friction velocity Moisture content Visible erosion	Chemical stabilization Vegetative cover (%) Wind fences	% V.E. at property line/source; PM_{10}/TSP concentration at property line
Retired farm land	No	-	Vegetative cover (%)	-
H_2O mining	Yes	-	Vegetative cover (%)	-
Dry washes & river beds	No	-	Prohibit motor vehicles	-
Unpaved air strip	Yes	Threshold friction velocity Moisture content Visible erosion	Chemical stabilization	-

(continued)

REGULATION—PARTICULATE MATTER
RULE—WATER MINING ACTIVITIES

General

a. The purpose of this Rule is to reduce the amount of particulate matter, especially fine particulate matter (PM-10) entrained in the ambient air related to water mining activities.

Definitions

a. For the purpose of this Rule, water mining activities are defined as those activities related to the production, diversion, storage, or conveyance of water which has been developed for export purposes.
b. Dust: Particulate matter, excluding any materials emitted directly in the exhaust of motor vehicles and other internal combustion engines, from portable brazing, soldering, or welding equipment, and from piledrivers.
c. Particulate matter: Any material emitted or entrained into the air as liquid or solid particles.
d. PM-10: Particulate matter with an aerodynamic diameter of a nominal 10 μm or less as measured by reference or equivalent methods that meet the requirements specified for PM-10 in 40 *CFR* Part 50, Appendix J.
e. Reasonably available dust control measures: Techniques used to prevent the emission and/or airborne transport of dust and dirt from water mining activities including: application of water or other liquids, covering, paving, enclosing, shrouding, compacting, stabilizing, planting, cleaning, or such other measures the Air Pollution Control Officer (APCO) may specify to accomplish equal or greater control.

Requirements

No person shall engage in any water mining activity unless all of the following conditions are satisfied:

a. A dust control plan is approved by the APCO which demonstrates that an overall x (e.g., 75) percent reduction from water mining activities will be achieved by applying reasonably available control measures. Such measures may include, but are not limited to, revegetation, chemical stabilization, application of wind fences, and other means as specified by the APCO.
b. The owner/operator is in possession of a currently valid permit which has been issued by the APCO.

Record Control Application

The owner and/or operator shall record the evidence of the application of the control measures. Records shall be submitted upon request from APCO, and shall be open for inspection during unscheduled audits.

Figure 6-4. Example regulation for water mining activities.

6.5.2 Requirements

6.5.2.1 Parking Lots, Truck Stops, Driving, etc.--

The City of ____________ shall not operate, maintain, use, or permit the use of any area larger than x (e.g., 5,000) square feet for the parking, storage, or servicing of more than x (e.g., 6) vehicles in any one day, unless a dust control plan is approved by the APCO which demonstrates an overall x (e.g., 75 percent) reduction of PM-10.

6.5.2.2 Industrial, Manufacturing and Commercial Staging Areas--

The City of ____________ shall not allow the operation, use or maintenance of a staging area larger than x (e.g., 5,000) square feet, unless a dust control plan is approved by the APCO which demonstrates an overall x (e.g., 75 percent) reduction of PM-10 emissions from the staging area will be achieved by reasonably available measures. Such measures may include, but are not limited to, adequate use of chemical suppressants, paving, and other means, as specified by the APCO.

6.5.2.3 Record Control Application--

The owner and/or operator shall record the evidence of the application of the control measures. Records shall be submitted upon request from APCO and shall be open for inspection during unscheduled audits.

6.6 AGRICULTURAL TILLING

Land classified as "highly erodible" (HEL) is already controlled for water and wind erosion through the Food Security Act (FSA) of 1985. Another provision of the FSA has paid farmers to take HEL out of production under the Conservation Reserve Program. This program commits a minimum of 40 million acres to permanent ground cover.

The Conservation Compliance provision of the FSA requires that tillage practices be modified to leave more crop residue on the surface. For example, V-blade implements undercut the roots of surface vegetation, rather than plowing plants under the soil.

Other modified tillage practices may also have the potential to reduce PM-10 emissions. Currently, the agricultural industry is working with the EPA and California air quality organizations to conduct a multiyear research study to identify and quantify PM-10 emissions from agricultural operations and to develop effective control measures.

Currently available data indicate that replacement of tilling operations, where feasible, with plug and punch planting and aerial seeding will reduce dust emissions.

6.7 OPACITY MEASUREMENT

Once a specific PM-10 control strategy has been developed and implemented, it becomes necessary for either the control agency or industrial concern to assure that it is achieving the desired level of control. As stated previously, the control efficiency actually attained by a particular technique depends on its proper implementation. This section will discuss opacity measurement as a means for determining compliance with various regulatory requirements relating to PM-10 control strategies.

6.7.1 Method for Determining Visible Emissions

Visible emission measurement methods have been adopted by a number of States as a tool for compliance. Although opacity observations at the property line have commonly been employed in earlier fugitive dust control regulations, recent court decisions in Colorado and Alabama have found that rules of that type are unconstitutional (failing to provide equal protection). It is strongly recommended that property-line opacity observations serve only as an indicator of a potential problem, thus "triggering" further investigation. Source-specific opacity determinations, on the other hand, have long been a court-tested approach to regulation. The following section describes two States' approach to fugitive dust regulation using visible emission methods.

6.7.1.1 Tennessee Visible Emission Method--

The State of Tennessee has developed a method (TVEE Method 1) for evaluating visible emissions (VE) from roads and parking lots (Telecon, 1984). The following discussion focuses on TVEE Method 1 (M1) in the technical areas: (1) reader position/techniques, and (2) data reduction/evaluation procedures. Table 6-3 summarizes the relevant features of TVEE M1.

As indicated in Table 6-3, TVEE Method 1 specifies an observer location of 15 feet from the source. In most cases, this distance should allow an unobstructed view and, at the same time, meet observer safety requirements.

M1 also specifies that the plume be read at approximately 4 feet directly above the emitting surface. This specification presumably results from field experiments conducted to support the method. It is probably intended to represent the point (i.e., location) of maximum opacity. While there is no quantitative supporting evidence, it seems likely that the height and location of maximum opacity relative to a passing vehicle will vary depending upon ambient factors (wind speed and direction) as well as vehicle type and speed.

Implied in the M1 specification that the plume be read approximately 4 feet above the emitting surface is the fact that observations will be made against a terrestrial (vegetation) background. The results of one study using a conventional smoke generator, modified to emit horizontal plumes, indicated that under these conditions observers are likely to underestimate opacity levels. More specifically, the study found that as opacity levels increased, opacity readings showed an increasing negative bias. For example, at 15 percent opacity, the observers

TABLE 6-3. SUMMARY OF TVEE METHOD 1 REQUIREMENTS (M1)

Reader position/techniques

- Sun in 140° sector behind the reader.
- Observer position ~ 15 ft from the source.
- Observer line of sight should be as perpendicular as possible to both plume and wind direction.
- Only one plume thickness read.
- Plume read at ~ 4 ft directly above emitting surface.
- Individual opacity readings taken each 15 s, recorded to nearest 5% opacity.
- Readings terminated if vehicles passing in opposite directions create intermixed plume.

Data reduction

- 2-min time-averages consisting of eight consecutive 15-s readings.

Certification

- Per Tennessee requirements

underestimated opacity by about 5 percent, and at 40 percent opacity, observations averaged about 11 percent low (Rose, 1984). Black plumes were underestimated at all opacity levels.

M1 specifies that only one plume thickness be read. It includes qualifying provisions that: (1) readings terminate if vehicles passing in opposite directions create an intermixed plume, but (2) readings continue if intermixing occurs as a result of vehicles moving in the same direction. Unlike (1), the latter condition is considered representative of the surface. The intent here is probably to minimize the influence of increasing plume density which results from "overlaying" multiple plumes.

There are two basic approaches that can be used to reduce opacity readings for comparison with VE regulations. One approach involves the time-averaging of consecutive 15-s observations over a specified time period to produce an average opacity value.

In the development of M1, the State of Tennessee concluded that a short averaging period--2 min (i.e., eight consecutive 15-s readings)--was appropriate for roads and parking lots, because these sources typically produce brief, intermittent opacity peaks.

Although not specified in M1, discrete 15-s VE readings from open sources could be evaluated in a time-aggregating framework. In this case, the individual observations are compiled into a histogram from which the number of observations (or equivalent percent of observation time) in excess of an opacity limit may then be ascertained. The principal advantage of using the time-aggregate technique as a method to reduce VE readings is that the resultant indicator of opacity conditions is then compatible with regulations that include a time exemption clause. Under time exemption standards, a source is permitted opacity in excess of the standard for a specified fraction of the time (e.g., 3 min/h). The concept of time exemption was originally developed to accommodate stationary source combustion processes.

Without more detailed supporting information, it is difficult to determine which of the two approaches is most appropriate for evaluating VE from open sources. With respect to time-averaging, statistics of observer bias in reading plumes from a smoke generator do indicate at least a slight decrease in the "accuracy" of the mean observed opacity value as averaging time decreases. In M1 (2-min average), this is reflected in the inclusion of an 8.8 percent buffer for observational error. This buffer is taken into account before issuing a Notice of Violation (Telecon, 1984).

One potential problem with applying time-averaging to opacity from roads and parking lots is that the resulting average will be sensitive to variations in source activity. For example, interpreting one conclusion offered in support of Method 1, it is likely that under moderate wind conditions a single vehicle pass will produce only two opacity readings ≥ 5 percent. Averaging these with six zero (0) readings yields a 2-min value below any reasonable opacity standard. Yet, under the same conditions with two or more vehicle passes, the average value will suggest elevated opacity levels. While there is no information available on the use of time aggregation for open source opacity, it appears that this approach would more easily accommodate variations in level of source activity. For this reason alone, it may be the evaluation approach better suited to roads and parking lots.

6.7.1.2 Ohio Draft Rule 3745-17-(03)(B)--

The State of Ohio submitted a fugitive dust visible emission measurement technique which the EPA proposed to approve in the *Federal Register* on January 2, 1987. Unlike the Tennessee method, the Ohio draft rule contains provisions for sources other than roads and parking lots. Average opacity values are based on 12 consecutive readings. Table 6-4 summarizes the Ohio method;

as can be seen from the table, many features of the Ohio draft rule are similar to TVEE Method 1. Consequently, the remarks made earlier in this section are equally applicable here.

TABLE 6-4. SUMMARY OF OHIO DRAFT RULE 3745-17-(03)(B)

Reader position/techniques
Roadways and parking lots:
• Line of vision approximately perpendicular to plume direction.
• Plume read at ~ 4 ft above surface.
• Readings suspended if vehicle obstructs line of sight; subsequent readings considered consecutive to that taken before the obstruction.
• Readings suspended if vehicles passing in opposite direction create an intermixed plume; subsequent readings considered consecutive to that taken before intermixing.
• If unusual condition (e.g., spill) occurs, another set of readings must be conducted.
All other sources:
• Sun behind observer.
• Minimum of 15 ft from source.
• Line of sight approximately perpendicular to flow of fugitive dust and to longer axis of the emissions.
• Opacity observed for point of highest opacity.

SECTION 7

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