An Improved Model for Prediction of PM_{10} from Surface Mining Operations

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(ABSTRACT)

Air quality permits are required for the construction of all new surface mining operations. An air quality permit requires a surface mining operation to estimate the type and amount of pollutants the facility will produce. During surface mining the most common pollutant is particulate matter having an aerodynamic diameter less than 10 microns (PM_{10}).

The Industrial Source Complex (ISC3) model, created by the United States Environmental Protection Agency (U.S. EPA), is a model used for predicting dispersion of pollutants from industrial facilities, including surface mines and quarries. The use of this model is required when applying for a surface mining permit. However, the U.S. EPA and mining companies have repeatedly demonstrated that this model over-predicts the amount of PM_{10} dispersed by surface mining facilities, resulting in denied air quality permits.

Past research has shown that haul trucks create the majority (80-90%) of PM_{10} emissions from surface mining operations. Therefore, this research concentrated on improving the ISC3 model by focusing on modeling PM_{10} emissions from mobile sources, specifically haul trucks at surface mining operations.

Research into the ISC3 model showed that its original intended use was for facilities that emit pollutants via smoke stacks. The method used to improve the ISC3 model consisted of applying the dispersion equation used by the ISC3 model in a manner more representative of a moving haul truck. A new model called the Dynamic Component Program was developed to allow modeling of dust dispersion from haul trucks.

To validate the Dynamic Component Program, field experiments were designed and conducted. These experiments measured PM_{10} from haul trucks at two different surface mining operations. The resulting analysis of the Dynamic Component Program, ISC3 model, and the actual field study results showed that the Dynamic Component Program was a 77% improvement over the ISC3 model overall.

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Chapter 1 Introduction

1.0 Statement of the Problem

Mining operations acquire air quality permits prior to completing any new construction, modifications, or expansions (VA DEQ, Air Permitting Guidelines, 1996). This can involve estimating pollutant emissions from the existing surface mining operations, which can be a complex and lengthy process. Modeling of emissions may be required depending upon the amount of pollutants emitted. Many existing operations may not have air quality permits because they were in operation before the regulations were enacted. But any new construction that results in an expansion will require the facility to obtain an air quality permit. Contingent upon the location of the surface mine, the undertaking of a modification or new construction project may result in stricter air pollution controls having to be installed in order to obtain approval from the permitting agency. The result may be that the entire facility, with the new pollution controls, does not have the ability to meet the new air pollution requirements thus resulting in a denial of approval from the permitting agency. Another possible impact of the expansion is that the new pollution controls may be so costly to install and operate that they may change the economics of the entire operation possibly causing the facility to lose economic viability resulting in shutdown.

When issued, air quality permits require a facility to be built to operate below the PM_{10} levels calculated by the dispersion model. One might think that over-prediction by the model would result in a benefit to the mining industry. However, it does not; over-prediction hinders mining because many facilities can be denied air quality permits on the basis of modeling results (Cole and Zapert, 1995). Therefore, the mining industry needs a model that can accurately predict PM_{10} levels.

1.1 Background

The United States Environmental Protection Agency (U. S. EPA) has created a list of approved equations that attempt to quantify the amount of pollutants, including dust, that emanate from specific operations throughout the entire industrial spectrum. These equations are based upon observations and testing of specific industrial operations, and they attempt to predict the amount of pollutants that form from these operations. The dust specific equations quantify dust in the size ranges of 30 microns (μm) and below. A listing of the equations, called emissions factors, can be found in the U. S. EPA's AP-42 (U. S. EPA, AP-42, 1995). These emissions factors are used to determine the amount of pollutant produced by an operation and are then input into a model for dispersion modeling.

Numerous models have been created that attempt to predict the dispersion of pollutants as they are released into the atmosphere. Most address pollutants such as Oxides of Nitrogen (NO_x), Sulfur Oxides (SO_x), Carbon Monoxide (CO), and Volatile Organic Compounds (VOC). These models do not generally apply to mining operations because mining operations do not have significant emissions of these pollutants. The major pollutant emitted by mining facilities is particulate matter less than 10 μm (PM_{10}). Therefore, only the models that predict the dispersion of PM_{10} are of interest to mining operations.

The ISC3 is the model that state and federal regulating agencies accept for use by mining operations to estimate pollutant dispersion from mining facilities. It is used for estimating concentrations of various pollutants such as CO, NO_x, SO_x, VOC, and lead (Pb); and it can be used for predicting concentrations of Particulate Matter, specifically PM_{10} (U. S. GPO, Code of Federal Regulations, Title 40, Part 51, 2002). The ISC3 model has routines for short-term and long-term applications, and it has a routine for estimating concentrations of pollutants from open pits (Schnelle and Dey, 2000). This model can also calculate deposition of particulate matter but it requires more inputs such as particle size distribution and particle density (U. S. EPA, User's Guide Vol II, 1995).

Personnel representing the stone quarrying industry who have used the ISC3 dispersion model state, "The ISC3 model over-predicts the concentrations of PM_{10} generated from surface mining facilities."[1] This over-prediction of PM_{10} has also been documented in an U. S. EPA study on surface coalmines in the western United States (U. S. EPA, Modeling Fugitive Dust Phase III, 1995). Recently, the Texas Natural Resource Conservation Commission has

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[1] Cole, Clifford F., and Zapert, James G.; Air Quality Dispersion Model Validation at Three Stone Quarries. (Washington D.C.: National Stone Association, January 1995) 2.

acknowledged that the ISC3 model over-predicts pollutant concentrations for near-ground fugitive emissions (Ruggeri, 2002).

1.2 Proposed Solution

The overall goal of this research is to create a model that can more accurately predict the dispersion of PM10 from surface mining operations than the existing ISC3 model. This goal will be accomplished by meeting the following objectives:

In order to predict dust propagation more accurately than the ISC3 model, a mining-based model must be created. Hauling at surface mines creates the greatest amount of PM_{10} emissions for the facility. Therefore, this mining-based model will focus on modeling the dispersion of PM_{10} from hauling operations. This model will be based upon the dispersion algorithm of the ISC3 model, but it will estimate the dispersion of PM_{10} from haul trucks at surface mining operations.

A field study will be conducted to validate the results of the new model. Since the new model focuses on haul trucks at a surface mining operation, the field study will be conducted on the same. The field study will sample dust from haul trucks at a surface mining operation in order to test the new model. It will be designed to obtain information required so that comparisons can be made between the old ISC3 model and the new model. In addition, the field study will be conducted on haul trucks at actual mining operations to represent "real-life" situations in order to make the new model as accurate as possible.

1.3 Methodology

This dissertation is separated into seven chapters, each presenting a necessary step required to accomplish the overall project goal. Chapter Two presents a literature review on modeling the dispersion of pollutants. Chapter Three covers the creation of the new model that attempts to correct the over-prediction of the ISC3 model. Chapter Four discusses the methodology behind the field study that is completed in order to validate the new model. Chapter Five discusses the analysis of the gravimetric dust concentration results from the field study. Topics covered are time-weighted-average dust concentration analysis, particle size distribution of airborne dust, and instantaneous dust concentration analysis. Chapter Six discusses the comparison of the results of the field study to the results of the ISC3 model and the new model. Finally, Chapter Seven summarizes and states the conclusions from the completed research. Opportunities for future research are also discussed in this chapter.

Chapter 2 Literature Review

2.0 Mining

A review of mining practice is necessary to understand where dust originates in mining operations, and the environmental factors affecting dust emissions. Since the focus of this research is being conducted on surface mining operations, the review will be concentrated on the topic of surface mining practice.

2.1 Current Surface Mining

Surface mining operations can be categorized into three different types of mining methods. They are placer, open-pit, and strip mining. Placer mining is generally associated with alluvial deposits, and mining can be accomplished through dredging techniques. Placer mining is used to mine out streambeds and is used to mine metals such as gold and tin. It can also be used to mine sand and gravel.

Open-pit mines are associated with pipes or tabular deposits that consist of a pit that expands as it goes deeper into the earth's surface. Open-pit mining is used to mine metals, such as copper and gold. Quarries are a type of open-pit mine, but the material mined is rock which is used to make crushed rock.

Strip mining is usually associated with laminar deposits. It is a type of open-pit mining that starts at one end of a property and mining advances through to the other side of the property. Strip mining mines the entire property, whereas open-pit mining generally mines out one portion of the property. An open-pit or cut that extends across the width of the property is created. This cut generally starts at one side of the property and a new cut is made adjacent to the initial cut after the mineral is mined out. The material from the new cut is placed in the mined out area of the old cut. Thus mining proceeds along the length of the property cut by cut with the mined out areas being backfilled. The only open-pit is the cut. Strip mining is used to mine coal, lignite, gypsum, etc.

In addition to the differences in the surface mining types, there are significant differences from one mine to another. Differences from mine to mine can be in the geology of the mine, the type of material extracted, the locations of the mines, and the type of equipment used in conducting the surface mining operation. Although these differences can be significant, the environmental and health and safety impacts from the mining operations are very similar.

Dust from surface mining operations affects the workers at the operations, and since there is no ability to contain the dust from surface mining operations, it can also expand to neighboring properties. Effects on neighboring properties can include health and safety effects on people and animals, damage to property through the deposition of dust, visibility issues, and the nuisance of the deposition of dust.

2.1.1 Surface Mining Practice

The surface mining operation is conducted in stages through separate operations. These stages or operations can be classified as

1 removal of topsoil,
2 drilling and blasting of overburden,
3 removal of overburden,
4 removal of material containing the mineral,
5 processing of material containing the mineral, and
6 reclamation of the mined out area.

A brief description of each operation is given in the following subsections. Figure 2.1 shows some of the equipment that is used in these mining operations.

2.1.2 Removal of Topsoil

The first step at a mining operation is to remove the topsoil from the area that is to be mined. The topsoil is removed and stored in a location away from the mine area to be used for later reclamation of the mine area. Federal law requires the removal and storing of topsoil for coal mining operations, and state law may require the removal and storage of topsoil at metal/nonmetal mining operations. Topsoil generally consists of a clayey and/or silty material and can be dug without the use of explosives to loosen the material. In some cases, bulldozers with rippers may have to rip the soil to loosen it. The removal of topsoil is usually completed through the use of scrapers or loader and trucks. A loader removes the topsoil by loading it into trucks that haul it to a different location for storage. The topsoil is then dumped and shaped into a large storage pile by bulldozers. The truck then returns to the loader after

a. Drilling

b. Blasting

c. Loading

d. Hauling

e. Dumping

Figure 2.1 Typical equipment used in various mining stages in a mining operation.

dumping and the cycle repeats itself. Scrapers are generally preferable to loader and trucks, because they have the ability to load-haul-dump. Sometimes dozers are used with scrapers at the loading and dumping end in order to push, load, and shape the storage pile. However, these actions are normally not required.

2.1.3 Drilling and Blasting of Overburden

Once the topsoil is removed the overburden, which is generally a waste material overlying the mineral deposit, is exposed. The overburden normally consists of rock and must be loosened or broken by drilling and blasting the material. This is done by creating a pattern of blastholes. The blastholes are usually laid out in a square pattern. When a small number of blastholes is used, the blastholes are laid out in a line. Blastholes are created in the overburden using a drill. These holes are drilled to a depth from 1.5 – 30.5 meters (m). The number of blastholes in a blast pattern can vary from as little as four to as many as several hundred. The number and depth of blastholes is dependent upon the type of surface mining method used and the location of the mine.

Once all the blastholes are drilled, they are loaded with explosive. The explosive used is generally an ammonium nitrate and fuel oil mix because it is less expensive to use in comparison with other methods of breaking rock. If water is encountered during mining, then a more powerful type of explosive may be used. After the blast pattern is loaded with explosives, the area is cleared and the explosives are set off. A chemical reaction in the explosive occurs, releasing a tremendous amount of energy, which in turn breaks the rock. Once the explosives are set off, removal of the overburden can begin.

2.1.4 Removal of Overburden

Removal of overburden is usually completed with a loader and a fleet of trucks. A loader removes the overburden by loading it into trucks that haul it to a waste dump for storage. The overburden is then dumped and the material is spread out over the waste dump by bulldozers. The truck then returns to the loader after dumping and the cycle is repeated.

In coal strip mines, the overburden is moved differently. Since the overburden from the new cut is moved to the adjacent old cut, the material is required to be moved only a short distance. Sometimes this move can be completed using a loader and a fleet of trucks, at other times bulldozers or draglines are used.

Bulldozers are used to push the overburden from the new cut into the adjacent old cut, thus exposing the coal deposit. A dragline is a machine that looks like a crane with a large bucket connected to the end of its wire cables. The wire cables control the operation of the bucket. The dragline sits on the broken overburden of the new cut, which has been smoothed using bulldozers. The bucket is swung out into the overburden and is dragged through the overburden material to fill the bucket using the cables. Then the bucket is lifted and the dragline turns ninety degrees so the bucket is over the adjacent old cut. The bucket is then dumped, the dragline turns back ninety degrees, the bucket is swung out into the overburden, and the cycle is repeated.

2.1.5 Removal of Material Containing the Mineral

The material containing the mineral is called ore. Removal of the ore sometimes may require drilling and blasting. If so, then the steps in the drilling and blasting section are repeated. The ore is removed using a loader and a fleet of trucks. A loader removes the ore by loading it into trucks that haul it to a processing plant where the ore is processed to its final stage and ultimately sold to the public.

2.1.6 Processing of Material Containing the Mineral

Processing of the ore consists of extracting the final product from the rock. In most cases, crushing and grinding of the ore is completed. Generally, the extent of the surface mining operation is the removal of the material from the ground and the crushing and grinding of the ore. Further processing may be required depending upon the type of material to be extracted, but this would be considered part of the processing phase and not part of the mining phase.

2.1.7 Reclamation of the Mined Out Area

Once mining is completed and the mine site is mined out, reclamation begins. Reclamation consists of making the mined out areas usable again. It differs for each of the different surface mining methods. For open-pit mines, reclamation may or may not consist of backfilling the pit. However, the surrounding areas, waste dumps, haul roads, etc. must be cleaned up and revegetated. This process may require moving or reshaping the overburden piles and any other disturbed areas. Normally loaders, trucks, scrapers, and bulldozers are used in the reclamation operation.

For strip mining, reclamation generally occurs concurrently with mining, and the mined out area must be put back to the approximate original contours. As mining advances, the adjacent old cuts are mined out and made ready for reclamation. The old cuts are backfilled, covered with topsoil, and revegetated. Again, loaders, trucks, scrapers, and bulldozers are used in the reclamation operation.

2.2 Surface Mining Locations

Surface mining occurs in every state of the United States. The Office of Surface Mining (OSM), which regulates surface coal mining in the United States, maintains that there are 2,526 surface coal permits as of December 17, 2001; this translates to the number of mining locations in the U.S. (OSM, U. S. Coal Production, 2002). Figure 2.2 shows where most of the surface coal mining occurs by state. The Mine Safety and Health Administration (MSHA) maintains records for the number of metal, non-metal, stone, and sand & gravel mines in the United States. According to the MSHA database, updated in 2000, there are 229 surface metal mining operations, 747 surface non-metal mining operations, 4,395 surface stone mining operations, and 8,394 sand & gravel operations in the United States (NIOSH, MSHA Data, 2002). Figures 2.3, 2.4, 2.5, and 2.6 show, in their respective order, the state-by-state concentration of the metal, non-metal, stone, and sand & gravel mining operations in the United States. This data may include operations that have been recently shutdown or temporarily closed. As can be seen from the figures, surface coal mining is concentrated in the Appalachian and Western regions of the United States with some surface coal mining occurring in the Midwest. The surface metal mining is predominantly located in the western part of the United States. Surface non-metal operations occur in every state with a few exceptions. Sand & gravel operations are all surface operations, and they occur in every state. Surface stone mining also occurs in every state except Delaware.

As of 1997 the U. S. Census Bureau states that there were 188,988 employees in mining production, development, and exploration; 105,403 of these employees were associated with surface mining operations (U. S. Census Bureau, Mining Subject Series, 2001). The MSHA database for the year 2000 states that there were a total of 181,184 employees working at all types of surface mining operations (NIOSH, MSHA Data, 2002). Both the U. S. Census Bureau

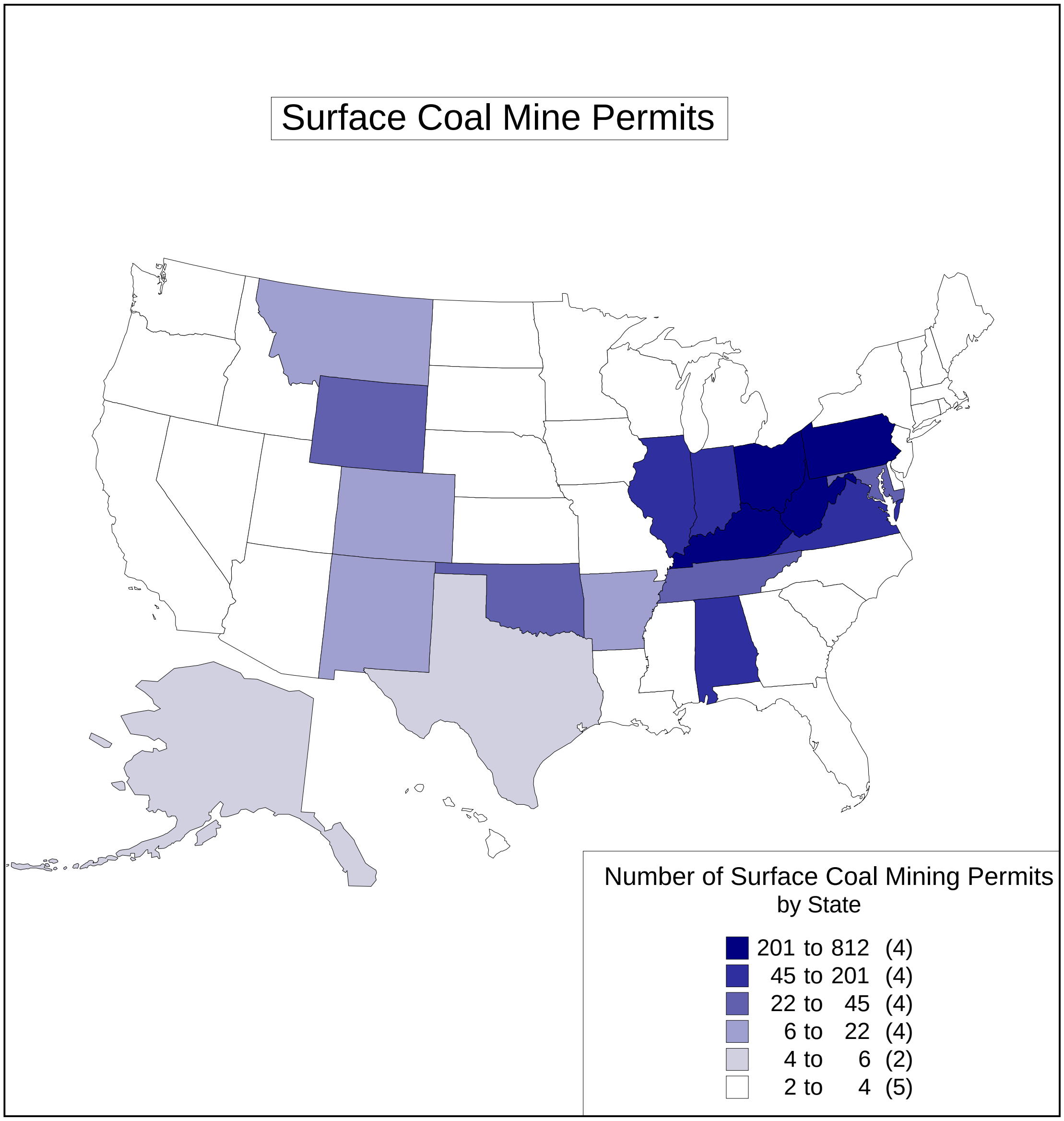

Figure 2.2 The locations of surface coal mining operations by state. Numbers in parentheses are the number of states in the quantity of mining operations category (OSM, U. S. Coal Production, 2002).

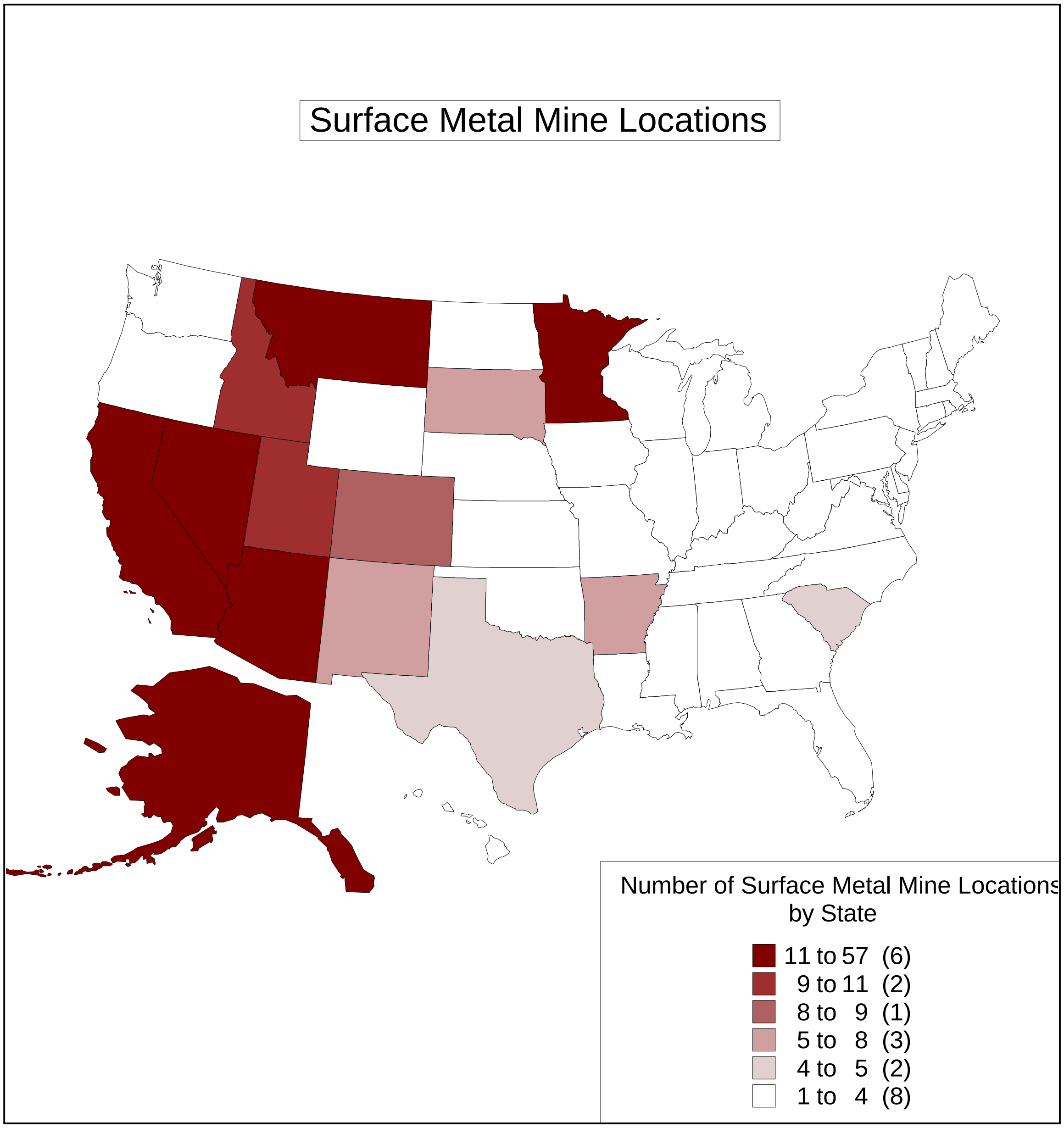

Figure 2.3 Locations of surface metal mining operations by state. Numbers in parentheses are the number of states in the quantity of mining operations category (NIOSH, MSHA Data, 2002).

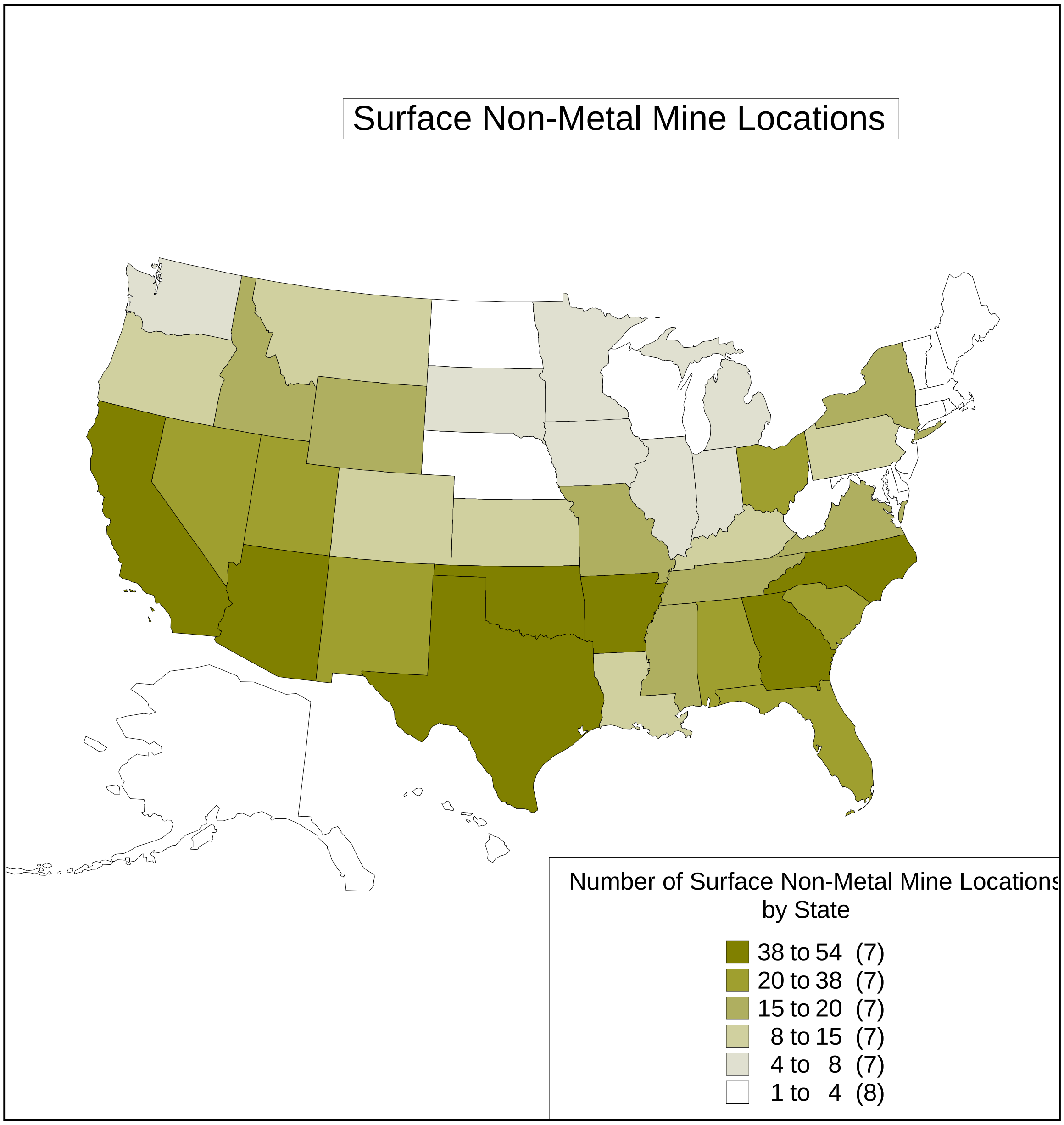

Figure 2.4 Locations of surface non-metal mining operations by state. Numbers in parentheses are the number of states in the quantity of mining operations category (NIOSH, MSHA Data, 2002).

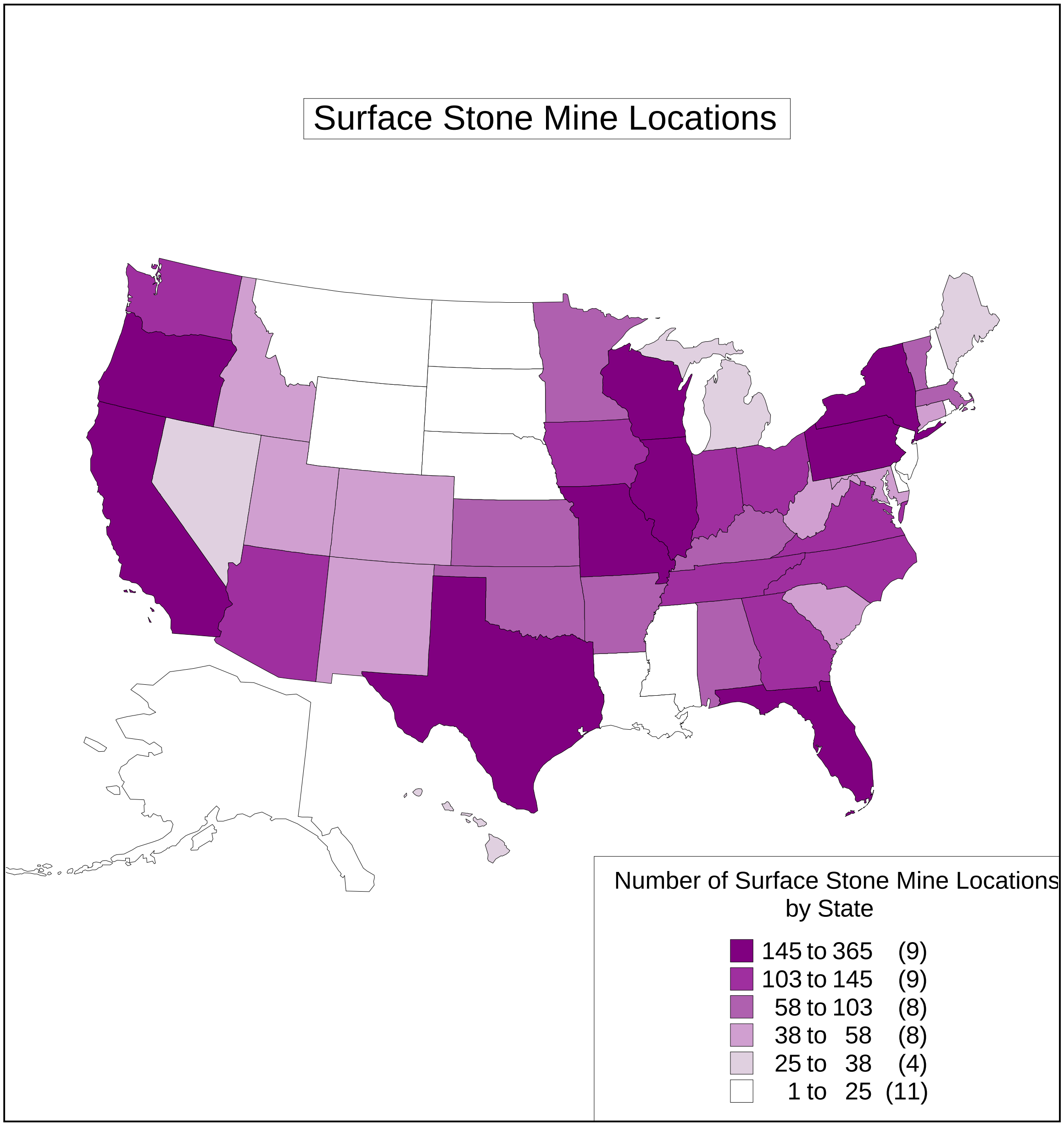

Figure 2.5 Locations of stone mining operations by state. Numbers in parentheses are the number of states in the quantity of mining operations category (NIOSH, MSHA Data, 2002).

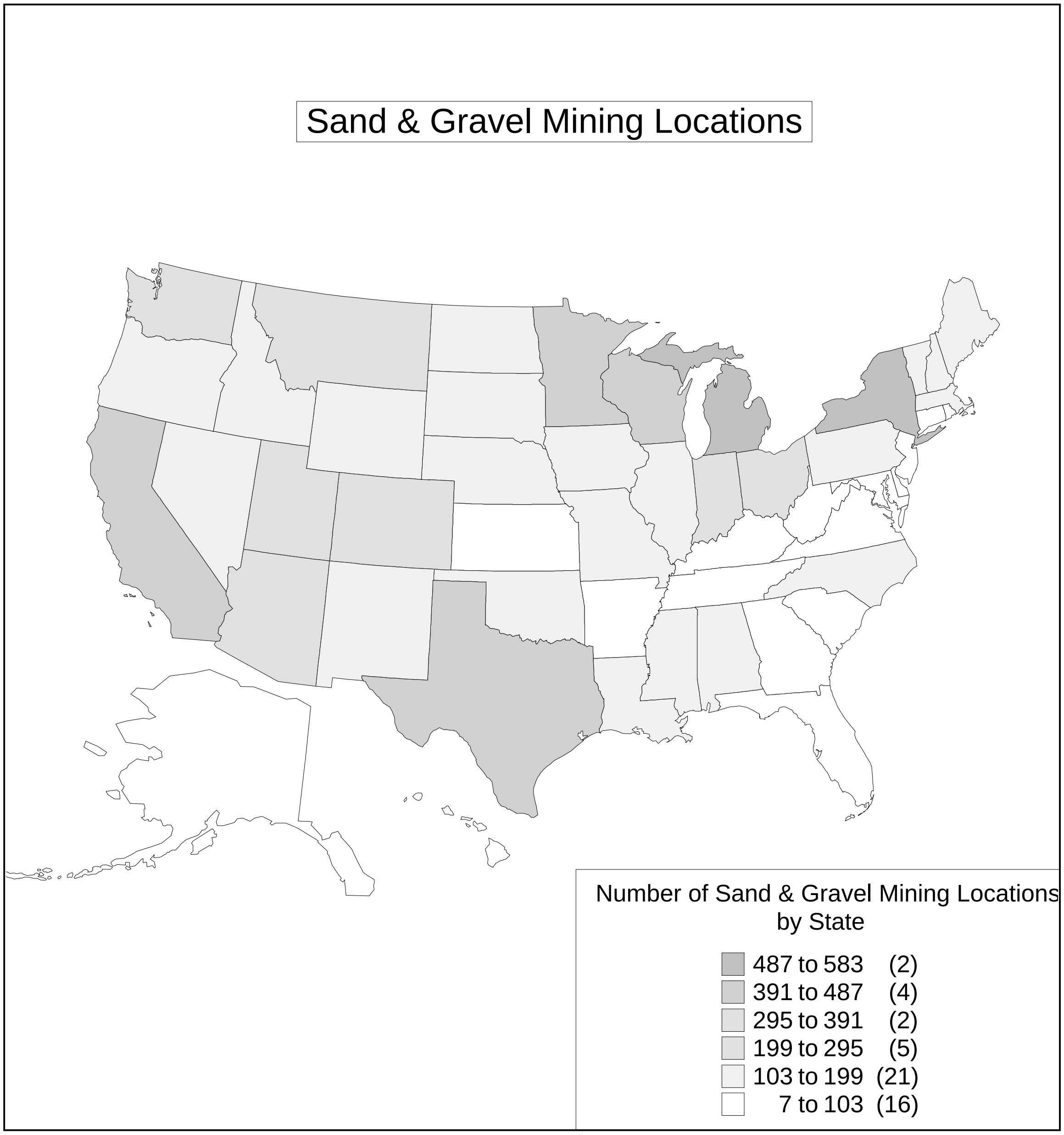

Figure 2.6 Locations of sand & gravel mining operations by state. Numbers in parentheses are the number of states in the quantity of mining operations category (NIOSH, MSHA Data, 2002).

and the MSHA data exclude personnel categorized as office workers, but they include workers categorized as mill or prep plant workers.

The common factor in surface mining is the use of mobile equipment to conduct the mining operation. This mobile equipment can generate considerable amounts of dust, the effects of which can be wide reaching. This dust has the potential to directly affect between 105,000 - 182,000 miners each year. However, in reviewing the extent of surface mining throughout the United States, there is also the potential for dust to affect the general population outside of mining operations, as most surface stone mining and sand & gravel operations are located in relatively urban areas. The dust emissions from surface mine operations can have a negative impact on the health and safety of the general public.

2.3 Dust

Dust can be found in sizes ranging from the sub-microns to more than 100 μm. Fog or mists generally range in sizes between sub-micronic to 200 μm (Hinds, 2000). Dust tends to create health problems in the respirable size ranges; 10 μm or less. For comparison purposes, the human hair is approximately 60 μm in diameter (California Air Resources Board, 2001).

Small dust particles are capable of being transported over long distances. As a result modeling of facility emissions has been used to estimate the effects of the facility on the surrounding area. Figure 2.7 shows the residence times of different size fractions of airborne particles. The long residence times for the smaller size particles mean that these particles have the potential to travel long distances, spreading their effects over a larger area. By contrast, the larger size particles drop out quickly.

2.3.1 Definitions

There are two classifications of particulate matter (PM): primary PM and secondary PM. Primary PM consists of material that is directly emitted into the air. Secondary PM is created by chemical reactions occurring in the atmosphere to create particles (Seigneur, et. al., 1999). Examples of primary PM are clay, soil, and silica. Examples of secondary PM are sulfate compounds and nitrate compounds. PM_{10} consists mostly of primary PM. Secondary PM is more of a concern when dealing with particulate matter less than 2.5 μm ($PM_{2.5}$) (Seigneur, et. al., 1999). This research will focus on respirable, thoracic or PM_{10}, and inhalable

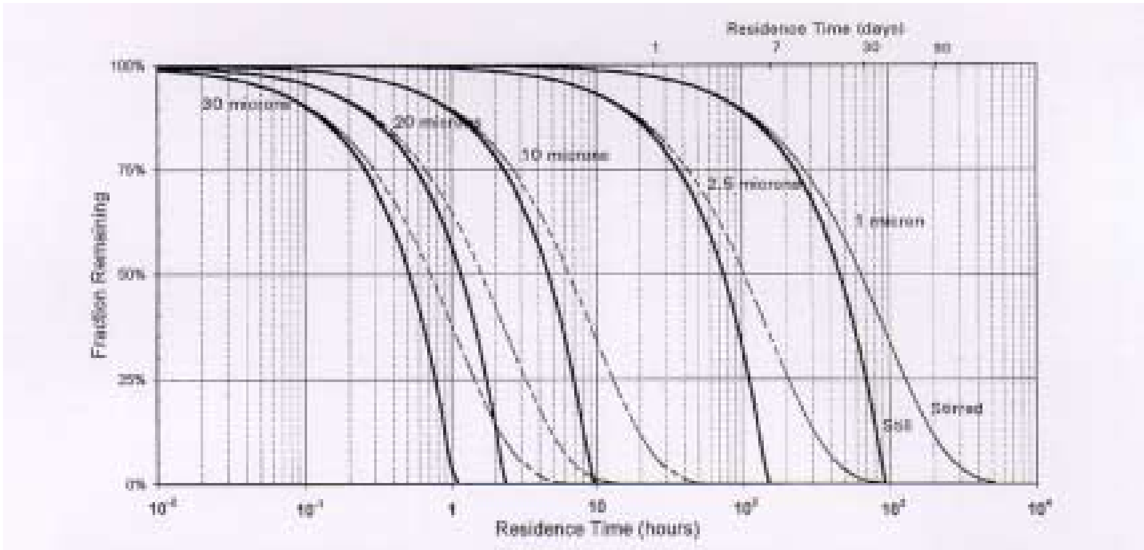

Figure 2.7 Residence times for homogeneously distributed particles of different aerodynamic diameters. Gravitational settling is assumed (taken from Watson, et. al., 1997).

categories consisting of primary PM. Secondary PM will not be considered as it is beyond the scope of this research.

The American Conference of Governmental Industrial Hygienists (ACGIH) has recommended standards for these categories of dust. However, these are not the only dust categories with standards. In addition, the U. S. EPA has created standards for their own dust categories: PM_{10} and $PM_{2.5}$. Table 2.1 shows the standards for the respirable, thoracic, and inhalable dust categories recommended by ACGIH (Lippman, Chapter 5 Size-Selective Health, 1995). Also shown in Table 2.2 is the standard for PM_{10} as defined by the U. S. EPA (U. S. GPO, Code of Federal Regulations, Title 40, Part 53, 2002). These standards show the percent particulate mass for each aerodynamic diameter.

The particle sizes of 4.0 μm for respirable, 10 μm for thoracic, 100 μm for inhalable and 10 μm for PM_{10} are median sizes (D_{50}). When comparing the thoracic and PM_{10} categories, both categories are essentially the same because they have the same median size of 10 μm, but the thoracic category contains some larger sized particles that the PM_{10} category does not (Lippmann, Chapter 5 Size-Selective Health, 1995). Figure 2.8 shows that the ACGIH thoracic standard may contain some particle sizes up to 25 μm, whereas the U. S. EPA's PM_{10} standard will only contain particle sizes up to 15 μm.

The U. S. Atomic Energy Commission first created a respirable dust standard with a median size of 3.5 μm. ACGIH adopted a modified version of this standard that also had a median size of 3.5 μm. This standard was changed in 1993 in order to create an international standard with a median size of 4.0 μm. This international standard is shown in Table 2.1 (Lippmann, Chapter 5 Size-Selective Health, 1995). However, the U. S. Department of Labor adopted the earlier ACGIH modified version of the U. S. Atomic Energy's respirable dust standard, and it currently applies to mining operations. Table 2.3 shows the respirable dust standard that is applied to the mining industry (Lippman, Chapter 5 Size-Selective Health, 1995). The dust standards used in this research will be the ACGIH's recommended respirable and thoracic standard, and the U. S. EPA's PM_{10} standard.

Table 2.1 ACGIH's recommended standards for respirable, thoracic, and inhalable dust.

Respirable Dust		Thoracic Dust		Inhalable Dust	
Particle Aerodynamic Diameter (μm)	Respirable Particulate Mass (RPM) %	Particle Aerodynamic Diameter (μm)	Thoracic Particulate Mass (TPM) %	Particle Aerodynamic Diameter (μm)	Inhalable Particulate Mass (IPM) %
0.0	100.0	0.0	100.0	0.0	100.0
1.0	97.0	2.0	94.0	1.0	97.0
2.0	91.0	4.0	89.0	2.0	94.0
3.0	74.0	6.0	80.5	5.0	87.0
4.0	**50.0**	8.0	67.0	10.0	77.0
5.0	30.0	**10.0**	**50.0**	20.0	65.0
6.0	17.0	12.0	35.0	30.0	58.0
7.0	9.0	14.0	23.0	40.0	54.5
8.0	5.0	16.0	15.0	50.0	52.5
10.0	1.0	18.0	9.5	**100.0**	**50.0**
		20.0	6.0		
		25.0	2.0		

Table 2.2 EPA's standard for PM_{10}.

Particle Aerodynamic Diameter (μm)	EPA's PM_{10} Particulate Mass (%)
1.0	100.0
1.5	94.9
2.0	94.2
2.5	93.3
3.0	92.2
3.5	90.9
4.0	89.3
4.5	87.6
5.0	85.7
5.5	83.5
6.0	81.2
6.5	78.6
7.0	75.9
7.5	72.9
8.0	69.7
8.5	66.4
9.0	62.8
9.5	59.0
10.0	55.1
10.5	**50.9**
11.0	46.5
12.0	37.1
13.0	26.9
14.0	15.9
15.0	4.1

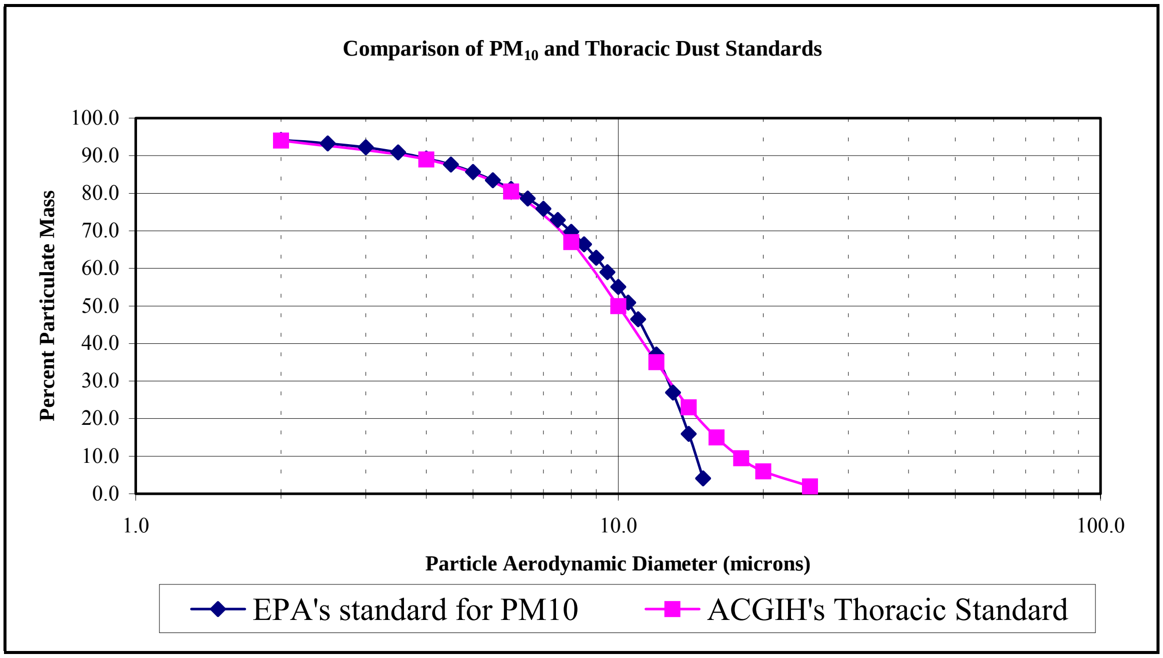

Figure 2.8 Comparison of EPA's PM_{10} standard with ACGIH's thoracic standard.

Table 2.3 Respirable dust standard as applied to the mining industry by the U. S. Department of Labor.

Particle Aerodynamic Diameter (μm)	Respirable Particulate Mass (%)
2.0	90.0
2.5	75.0
3.5	50.0
5.0	25.0
10.0	0.0

2.3.2 Effects of PM_{10}

PM_{10} has adverse effects on humans and animals. In order to understand the effects of dust, particularly silica and coal dust, on the human respiratory system, a review of the respiratory system is given. To better understand the impact of dust on humans the three regions of the respiratory system will be examined: the extrathoracic region, which consists of the nose, mouth, pharynx, and larynx; the tracheobronchial region, which extends from the trachea to the terminal bronchioles; and the alveolar region, which contains the lungs (Hinds, 1999). This third region, the alveolar region, is where most of the impact from respiratory dust occurs. The extrathoracic and the tracheobronchial regions contain layers of mucus that help expel respiratory dust, but the alveolar region, where oxygen exchange takes place, does not have this mucus layer (Hinds, 1999). Instead, the alveolar region contains scavenging cells called microphages, which migrate to the respirable dust particles and surround and digest them, particularly if the particles are organic. However, mineral dusts are insoluble; therefore, the microphages cannot digest these particles. Instead they attempt to move these particles to the tracheobronchial region for expulsion. This action may take from months to years for the particles to be expelled. Silica and coal dusts interfere with the microphages removal attempts and are not expelled but instead cause scarring of the lung tissue, also known as fibrosis (Wagner, 1980). This scarring of the lung tissue from silica or coal dust is also known as silicosis or pneumoconiosis.

If silica or coal dust is a component of PM_{10}, then the effects of exposure pose a very serious heath concern. In the U.S., silicosis, caused by crystalline silica, causes more than 250 deaths annually (MSHA, Labor Department Renews Push, 1997). There are three levels of silicosis: chronic silicosis, which occurs after ten years of exposure; accelerated silicosis, which occurs between 5-10 years of exposure; and acute silicosis which occurs within a few weeks to five years of high exposure to silica (U. S. Department of Labor, Preventing Silicosis, 1996). Silicosis has no cure and is generally fatal. Miners are susceptible to silicosis, both when working underground and when working on the surface.

A simplified definition of black lung is a chronic disease occurring in miners that develops over a long time period and is generally fatal (NIOSH, Criteria for a Recommended Standard, 1995). Black lung is caused when coal dust is the major component in the air that is breathed and occurs primarily in miners who work underground. Employees who work coal stockpiles are also susceptible to black lung. Approximately 2000 workers die each year from black lung (NIOSH, NIOSH Facts Mine Safety and Health, 1996).

Many epidemiologic studies have been completed that show that PM_{10}, by itself, causes harm to humans. It has been shown that a 50 microgram/cubic meter ($\mu g/m^3$) increase in the 24-hour average PM_{10} concentration was statistically significant in increasing mortality rates by 2.5 - 8.5 % (U. S. EPA, Air Quality Criteria for Particulate Matter, 1996). For hospitalization due to chronic obstructive pulmonary disease, PM_{10} caused a statistically significant increase by 6 - 25 % with an increase of the 24-hour average PM_{10} concentration by 50 $\mu g/m^3$ (U. S. EPA, Air Quality Criteria for Particulate Matter, 1996). Other studies show that children are affected by short-term PM_{10} exposure, and that increased chronic cough, chest illness, and bronchitis were associated with a 50 $\mu g/m^3$ increase in the 24-hour average PM_{10} concentrations (U. S. EPA, Air Quality Criteria for Particulate Matter, 1996). Long-term effects from PM_{10} are dependent upon the exposure to PM_{10} over the life of the worker.

There are other adverse results from PM_{10} exposure in addition to the health effects. PM_{10} affects visibility in the air and has also been thought to contribute to climate change. It is known that small particles in the air hinder visibility, as the small particles scatter and absorb light as it travels to the observer from an object. This action results in extraneous light from sources other than the observed object being detected by the observer, thus impairing visibility (U. S. EPA, Air Quality Criteria for Particulate Matter, 1996). Climate change may also occur, because the small particles in the atmosphere absorb and reflect the radiation from the sun, affecting the cloud physics in the atmosphere (U. S. EPA, Air Quality Criteria for Particulate Matter, 1996). PM_{10} may also have an effect on materials such as paint, wood, metals, etc. The effects are dependent upon the amount of PM_{10} in the atmosphere, the deposition of the PM_{10} on the material, and the elemental composition of the PM_{10} (U. S. EPA, Air Quality Criteria for Particulate Matter, 1996).

2.3.3 Regulations Pertaining to PM_{10}

There are two legislative acts which regulate the air quality from mining operations. They are the Federal Coal Mine Health and Safety Act of 1969 which was amended by the Federal Mine Safety and Health Act of 1977 (NIOSH, Criteria for a Recommended Standard, 1995), and the Clean Air Act of 1970 which was amended in 1977 and 1990 (Schnelle and Dey, 2000). The Federal Mine Safety and Health Act of 1977 regulates the amount of dust allowable in air for health and safety purposes. The Clean Air Amendment of 1990 (CAA) regulates air quality from facilities from an environmental perspective.

2.3.3.1 Health and Safety Regulations

The Federal Mine Safety and Health Act of 1977 was responsible for creating MSHA, the agency which enforces safety regulations for mining operations. At that time a limit of 2.0 milligrams per cubic meter (mg/m^3) for respirable dust for coal mining operations was enacted (NIOSH, Criteria for a Recommended Standard, 1995). If more than 5% quartz or silica is found in the respirable dust then the limit is determined by using the following formula (U. S. GPO, Code of Federal Regulations, Title 30, Part 71, 2002):

$$\Phi = \frac{10}{\%Quartz} \qquad (2.1)$$

where

Φ = Respirable dust limit in mg/m^3, where $0 \le \Phi \le 2.0$

$\%Quartz$ = Percent Quartz or Silica found in dust as a fraction.

The American Conference of Governmental Industrial Hygenists also recommends this limit for respirable dust. There are also recommended limits set for dusts containing other toxic substances, such as lead, mercury, and arsenic. (Hartman, et. al., 1982).

2.3.3.2 Environmental Regulations

The CAA regulates emissions from any facility into the air and is addresses toxic substances. It also creates the national ambient air quality standards (NAAQS) for the criteria pollutants, CO, NO_x, SO_x, VOC, Pb, and PM_{10} (Schnelle and Dey, 2000). NAAQS has been in effect for PM_{10} since before 1987 (Watson, et. al., 1997). Facilities are not allowed to emit levels of PM_{10} pollutants above the following standards:

> "Twenty-four hour average PM_{10} not to exceed 150 μg/m^3 for a three year average of annual 99th percentiles at any monitoring site in a monitoring area.

Three year average PM_{10} not to exceed 50 μg/m^3 for three annual average concentrations at any monitoring site in a monitoring area."[2]

The NAAQS regulations for PM_{10} are the maximum emission levels allowable in outdoor air, however, states have the right to create stricter regulations. In California the twenty-four hour average for PM_{10} is 50 μg/m^3 and its annual average is 30 μg/m^3 (California Air Resources Board, 2001).

The NAAQS are also used to determine if an area is a non-attainment area. In determining non-attainment areas, each state is required to have in place an air monitoring network for different regions (Watson, et. al., 1997). This air monitoring network measures the air for a particular pollutant. If the NAAQS cannot be met for one or more pollutants, then the region is designated as "non-attainment" for that pollutant. Non-attainment areas can have stricter standards applied for that region and permitees may have to institute better pollution control technology at their facilities in order to obtain approvals for air quality permits (VA DEQ, Business and Industry Guide, 1996).

Regulations have been enacted by the state of Virginia for emissions of PM_{10} that are essentially similar to the NAAQS for PM_{10} and are listed as follows:

"A. 1. The primary and secondary 24-hour ambient air quality standard is 150 μg/m^3 -24- hour average concentration.

2. The standard is attained when the expected number of days per calendar year with a 24-hour average concentration above 150 μg/m^3, as determined in accordance with Appendix K of 40 CFR 50, is equal to or less than one.

B. 1. The primary and secondary annual air quality standard is 50 μg/m^3 - annual arithmetic mean.

2. The standard is attained when the expected annual arithmetic mean concentration, as determined in accordance with Appendix K of 40 CFR 50, is less than or equal to 50 μg/m^3

[2] Watson, John G., Chow, Judith C., Dubois, D., Green, M., Frank, N., Pitchford, M.; Guidance for Network Design and Optimum Site Exposure for $PM_{2.5}$ and PM_{10}. (Research Triangle Park: U. S. EPA, Office of Air Quality Planning and Standards, December 1997).

C. For the purpose of determining attainment of the primary and secondary standards, particulate matter shall be measured in the ambient air as PM_{10} (particles with an aerodynamic diameter less than or equal to a nominal 10 μm) by the reference method described in Appendix J of 40 CFR 50, or other method designated as such, or by an equivalent method."[3]

Virginia also has additional regulations that pertain to total suspended solids emissions. They are as follows:

"A. The primary ambient air quality standards are as follows:

1. 75 $\mu g/m^3$ - annual arithmetic mean.
2. 260 $\mu g/m^3$ - maximum 24-hour concentration not to be exceeded more than once per year.

B. The secondary ambient air quality standards are as follows:

1. 60 $\mu g/m^3$ - annual geometric mean, as a guide to be used in assessing achievement of the 24-hour standared in subsection B 2 of this section.
2. 150 $\mu g/m^3$ - maximum 24-hour concentration not to be exceeded more than once per year.

C. Particulate matter shall be measured by the reference method described in Appendix B of 40 SFR 50, or other method designated as such, or by an equivalent method."[4]

The secondary ambient air quality standards become effective if the facility is located in a region that is designated "non-attainment." Overall the NAAQS regulations for PM_{10} are much stricter than the 2.0 mg/m^3 respirable dust limit imposed by the health and safety regulations promulgated by the MSHA.

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[3] Commonwealth of Virginia, State Air Pollution Control Board; Regulations for the Control and Abatement of Air Pollution; 9 VAC 5 Chapter 30, Ambient Air Quality Standards, Section 60. (Commonwealth of Virginia, November 1999) 3.

[4] Commonwealth of Virginia, State Air Pollution Control Board; Regulations for the Control and Abatement of Air Pollution; 9 VAC 5 Chapter 30, Ambient Air Quality Standards, Section 20. (Commonwealth of Virginia, November 1999) 2.

In Virginia, if a facility emits more than 227 metric tons of PM_{10} per year, then the facility is considered to adversely affect the region and must meet more stringent ambient permitting requirements (VA DEQ, Business and Industry Guide, 1996). Modeling of the emissions from the facility will be required in order to obtain a permit (VA DEQ, Air Permitting Guidelines, 1996). The requirements for modeling emissions vary from state to state. For example, the state of Georgia has requirements that any facility that emits more than 91 metric tons per year of a pollutant becomes a Title V facility. Title V pertains to regulations of emissions of toxic pollutants from a facility. Once a facility is designated as Title V, it is regulated under the strictest regulations, which include modeling of emissions (GA DNR, 1994). Therefore, modeling may be an important part of obtaining an air quality permit, depending upon the amount of PM_{10} emitted by the facility.

2.4 Dust Propagation Models

The results from modeling the emissions of a facility are used to ensure that the regional air quality does not exceed the NAAQS or deteriorate the air quality further (Schnelle and Dey, 2000). If the modeling results show the facility will not cause the regional air quality to exceed the NAAQS nor deteriorate the air quality, then the air quality permit will be granted. Otherwise the air quality permit application will be denied. Therefore, it is important that the modeling method accurately estimates the amount of pollutant a facility will emit and accurately estimates the pollutant's dispersion. The use of a modeling method that over-estimates the amount of pollutant emitted from the facility may result in denial of air quality permits.

2.4.1 Mathematical Algorithms

Modeling of pollutants is completed using mathematical algorithms. There are several basic mathematical algorithms in use. They are the box model, the Gaussian model, the Eulerian model, and the Lagrangian model (Collett and Oduyemi, 1997). The box model is the simplest of the modeling algorithms. It assumes the airshed is in the shape of a box. The air inside the box is assumed to have a homogeneous concentration. The box model is represented using the following equation:

$$\frac{dCV}{dt} = QA + uC_{in}WH - uCWH \tag{2.2}$$

where

Q = pollutant emission rate per unit area.

C = homogeneous species concentration within the airshed.

V = volume described by box.

C_{in} = species concentration entering the airshed.

A = horizontal area of the box (L*W).

L = length the box.

W = width of the box.

u = wind speed normal to the box.

H = mixing height.

This model has limitations. It assumes the pollutant is homogeneous across the airshed and it is used to estimate average pollutant concentrations over a very large area. This mathematical model is very limited in its ability to predict dispersion of the pollutant over an airshed because of its inability to use spatial information (Collett and Oduyemi, 1997).

The Gaussian models are the most common mathematical models used for air dispersion. They are based upon the assumption that the pollutant will disperse according to a "normal" distribution. The Gaussian Equation generally used for point source emissions is given as follows:

$$\chi = \frac{Q}{2\pi u_s \sigma_y \sigma_z}\left[\exp\left\{-0.5\left(\frac{y}{\sigma_y}\right)^2\right\}\right]\left[\exp\left\{-0.5\left(\frac{H}{\sigma_z}\right)^2\right\}\right] \qquad (2.3)$$

where

χ = hourly concentration at downwind distance x.

Q = pollutant emission rate.

u_s = Mean wind speed at release height.

σ_y, σ_z = Standard deviation of lateral and vertical concentration distribution.

y = crosswind distance from source to receptor.

H = Stack height or emission source height.

The terms σ_y and σ_z are the standard deviations of the horizontal and vertical Gaussian distributions that are used to represent the plume of the pollutant. These coefficients are based upon the atmospheric stability coefficients created by Pasquil and Gifford, and they generally become larger as the distance downwind from the source becomes greater. Larger standard deviations mean the Gaussian curve or plume has a low peak and has a wide spread; smaller standard deviations mean the Gaussian curve or plume has a high peak and has a narrow spread (Oduyemi, 1994).

When using this equation for calculation of pollutant dispersion, there are some assumptions that must be made in order for the equation to be valid. They are 1) the emissions must be constant and uniform, 2) the wind direction and speed are constant, 3) downwind diffusion is negligible compared to vertical and crosswind diffusion, 4) the terrain is relatively flat, i.e., no crosswind barriers, 5) there is no deposition or absorption of the pollutant, 6) the vertical and crosswind diffusion of the pollutant follow a Gaussian distribution, 7) the shape of the plume can be represented by an expanding cone, and 8) the use of the vertical and horizontal standard deviations, σ_y, and σ_z require that the turbulence of the plume to be homogeneous throughout the entire plume (Beychok, 1994). It can be seen that several of the assumptions are not met when applying this equation for PM_{10} to surface mining operations, especially to haul trucks. The emissions are not constant and uniform and there is deposition of the pollutant. Downwind diffusion is not negligible compared to vertical and crosswind diffusion, because downwind diffusion may occur due to the deposition of the dust.

The accuracy of this model to predict pollutant concentrations has been documented to be within 20% for ground level emissions at distances less than one kilometer. For elevated emissions the accuracy is within 40%. At distances greater than a kilometer the equation is estimated to be accurate within a factor of two. The Gaussian model also has the limitation that it cannot be used for sub-hourly prediction of concentrations (Collett and Oduyemi, 1997).

Eulerian models solve a conservation of mass equation for a given pollutant. The equation generally follows the form (Collett and Oduyemi, 1997):

$$\frac{\partial\langle c_i\rangle}{\partial t} = -\overline{U}\cdot\nabla\langle c_i\rangle - \nabla\cdot\langle c_i' U'\rangle + D\nabla^2\langle c_i\rangle + \langle S_i\rangle \qquad (2.4)$$

where

$U = \overline{U} + U'$

U = wind field vector $U(x,y,z)$.

$\overline{U}$ = average wind field vector.

U' = fluctuating wind field vector.

$c = \langle c \rangle + c'$

c = pollutant concentration.

$\langle c \rangle$ = average pollutant concentration, $\langle \ \rangle$ denotes average.

c' = fluctuating pollutant concentration.

D = molecular diffusivity.

S_i = source term.

The term with molecular diffusivity is neglected as the magnitude of this term is significantly small. The turbulent diffusion term $\nabla \cdot \langle c_i^{'} U^{'} \rangle$ is modeled where the rate of diffusion is assumed to be constant. It is modeled as $\langle c_i^{'} U^{'} \rangle = -K\nabla\langle c_i \rangle$, where K is an eddy diffusivity tensor. This tensor is simplified so that diffusivity transport is along the turbulent eddy vector making the eddy diffusivity tensor diagonal and the cross vector diffusivities negligible, i.e.,

$K = \begin{bmatrix} K_{xx} & 0 & 0 \\ 0 & K_{yy} & 0 \\ 0 & 0 & K_{zz} \end{bmatrix}$ where $K_{xx} = K_{yy} = K_H$ with K_H being horizontal diffusivity (Collett and Oduyemi, 1997).

Equation (2.4) can be difficult to solve because the advection term $-\overline{U} \cdot \nabla\langle c_i \rangle$ is hyperbolic, the turbulent diffusion term is parabolic, and the source term is generally defined by a set of differential equations. This type of equation can be computationally expensive to solve and requires some form of optimization in order to reduce the solution time required. Solutions have been achieved by reducing the problem to one and two dimensions rather than using three dimensions. However, no statement of the accuracy of the solutions of this model is made (Collett and Oduyemi, 1997).

Lagrangian models predict pollutant dispersion based upon a shifting reference grid. This shifting reference grid is generally based upon the prevailing wind direction, or vector, or the general direction of the dust plume movement. The Lagrangian model has the following form:

$$\langle c(r,t)\rangle = \int_{-\infty}^{t}\int p(r,t|r',t')S(r',t')dr'dt' \tag{2.5}$$

where

$\langle c(r,t)\rangle$ = average pollutant concentration at location *r* at time *t*

$S(r',t')$ = source emission term

$p(r,t|r',t')$ = the probability function that an air parcel is moving from *r'* at *t'* (source) to location *r* at time *t*

The probability function works as it is shown for sources consisting of gases; if the source of emissions consists of particles, then more information must be incorporated into the function such as the particle size distribution and the particle density (Collett and Oduyemi, 1997).

This mathematical model has difficulties in comparing its results with actual measurements. This is due to the dynamic nature of the model. Measurements are generally made at stationary points, while the model predicts pollutant concentration based upon a moving reference grid. This makes it difficult to validate the model during initial use. To compensate for this problem, the Lagrangian models are typically modified by adding an Eulerian reference grid. This allows for better comparision to actual measurements, because it incorporates a static reference grid into the model (Collett and Oduyemi, 1997).

These four mathematical models are the basic models used for air dispersion modeling. There are many variations based upon these equations. Some variations add statistical functions to represent the randomness of wind direction, wind speed, and turbulence. Other variations include the introduction of site specific source terms. Because of the increased speed of computational ability via personal computers, the model variations have become more complex. This has resulted in the creation of a vast number of computer models for air dispersion.

2.4.2 Existing Industrial Computer Models

There have been many computer models created to predict pollutant dispersion from industrial facilities. The following is a list of models that are accepted for use by the U. S. EPA and a short summary of the purpose of each model is given (U. S. GPO, Code of Federal Regulations, Title 40, Part 51, 2002):

The BLP model is used to estimate pollutant concentrations specifically for aluminum reduction plants.

The Caline3 model will estimate pollutant concentrations from highways.

The CDM 2.0 model calculates pollutant concentrations for long-term averaging times in urban areas.

The RAM model calculates pollutant concentrations for short-term averaging times.

The UAM model is specifically used for estimating concentrations of ozone (O_3), CO, NO_x, and VOC for short term conditions.

The OCD model estimates pollutant dispersion from offshore or coastal sources.

The EDMS calculates pollutant concentrations from military or civilian airports.

The CTDMPLUS model estimates pollutant concentrations from sources in stable and unstable weather conditions.

These models have specific applications and most are not applicable for mining facilities. In addition, there are a myriad of other models available for use that do not have the acceptance of the U. S. EPA.

One such model is TRACK, which is a long-range transport model used to study atmospheric acid deposition. It uses a Lagrangian dispersion model. A study by Lee, Kingdon, Pacyna, Bouwman, and Tegen used it to study the transport and deposition of Calcium in the United Kingdom. The main conclusion of the study was that large sources such as cement plants, iron and steel production and power generation contributed only a small amount of calcium into the atmosphere. Most emissions of calcium occurred from small power generation sources that did not have emissions controls. However, one source, agricultural soil emissions, was not quantified and may produce up to 66% of the Calcium emissions. The study stated that there are uncertainties in the deposition of calcium due to the many parameters involved in calculating deposition, and that the deposition of Calcium offsets approximately 7% of the acid deposition resulting from Sulfur in the atmosphere (Lee, et. al., 1999).

APEX is a model that calculates dispersion of pollutants from explosions. It uses an Eulerian model to calculate the pollutant concentrations. The model analyzes the effect of the upward convective flow, after the explosion, on the dispersion of the pollutant. A paper by

Makhviladze, Roberts, and Yakush presents the results of modeling a large scale (nuclear) explosion and the results of a small-scale explosion. The modeling results of both explosions demonstrated that the larger particles are more likely to settle out and less likely to be injected into the upper reaches of the atmosphere than are the smaller particles (Makhviladze, et. al., 1995).

The three dimensional GISS tracer transport model is a global dust model created by the Goddard Institute for Space Studies. Tegen and Fung present a paper that describes the use of this model to simulate seasonal variations of dust over the entire world. The inputs of this model are dust sources from undisturbed areas, such as deserts and grasslands. Disturbed areas or manmade sources were not included. The model uses deposition or gravitational velocities of the particle sizes to predict the concentrations around the world. Many areas where actual measurements were taken were found to be in agreement with the model results. There were many areas, such as the Sahara Desert and the Australian Desert, where the model failed to reproduce the seasonal variations of the dust plume. It was thought that these areas had more manmade disturbance than was estimated which caused the failure of the model. The concentrations of mineral dust in the atmosphere predicted by this model ranged from 1 to 25 $\mu g/m^3$ with some areas reaching 60 $\mu g/m^3$. Many of these concentrations correlated well with actual measured concentrations. The higher concentrations generally occurred during the summer months. The particle sizes were then divided into two categories, one being 1 - 10 μm and the other being 10 - 25 μm. Again, as in all cases the smaller particles were able to stay in the atmosphere longer than the larger particles (Tegen and Fung, 1994). Since this model only uses sources from undisturbed areas, it shows that there is a significant amount of dust in the atmosphere, before any contributions from manmade emissions sources. The size range of the concentrations of this dust in the atmosphere is 1 - 25 μm and no statistics of the quantity of PM_{10} was provided.

There are many traffic models created to predict pollutant concentrations from vehicles. Many predict concentrations of chemical pollutants from the vehicle’s exhaust. One such model is the SLAQ, Street Level Air Quality. This model was presented in a paper by Micallef and Colls and can be used for city streets. While this model can predict the amount of PM_{10} from both the vehicle’s emission and the road surface, the main emphasis is on tailpipe emissions. It uses a Gaussian plume model. Since traffic does not produce constant emissions due to varying operation of vehicles (acceleration, deceleration, idle, uniform speed), a traffic model was used to estimate the time a vehicle was in different operation modes. The paper did not include how the frequency of vehicles was managed, but a frequency of 600 vehicles per hour was used. The model was tested and performed well, having a correlation coefficient of 0.8 for the conditions the modeled. It was observed during the study that the tailpipe emissions mass median diameter was in the range of 0.14 - 0.25 μm and did not dominate the mass distribution of vehicle-derived airborne particulate matter. It was the other emissions, such as road dust and brake dust, that dominated the mass distribution. (Micallef and Colls, 1999).

There are many other studies that have evaluated the Gaussian dispersion equation. Goyal, Singh and Gulati conducted a study using two different Gaussian dispersion equations to predict total dust concentrations from cement facilities in India. The dispersion was calculated from the industrial stacks located at these facilities. Two models were evaluated: the ISI model and the IITST model. This study modified the equations in order to use the meteorological data in a manner that is specific to the climate of India. The study stated that the results showed satisfactory comparison to actual observed values at the cement facilities, with the IITST model being the better predictor of the two models. When reviewing the data presented in the study, the IITST model comparison results generally over-predicted the actual results by a factor of 1.6 (Goyal, et. al., 1996).

In Canada, the Gaussian dispersion equation was used to predict the dispersion of radioactive uranium from a Canadian uranium processing facility. This model also predicted dispersion from the facility's industrial stacks. The study, completed by Ahier and Tracy, found that the model's predicted concentrations were within a factor of 2 - 3 of the actual concentrations. Overall, the study stated the Gaussian dispersion model provided reasonable results compared to actual observations for Uranium concentrations. In reviewing the predicted versus observed data presented in the study, the model would over-predict more often than it would under-predict. However, it was difficult to pick out the trend because the over-prediction and the under-prediction occurred almost equally (Ahier and Tracy, 1997).

These are just a few of the computer models available for predicting pollutant concentrations. Many more models could be discussed, but only a small sample was chosen for review in this section. A review of all the models listed show that they all have one thing in common: they use one of the four mathematical models previously presented. In addition, the review of the Gaussian models show that they consistently over-predict actual dust concentrations.

2.4.3 Mine Specific Models

Air dispersion modeling has not bypassed the mining industry. There have been some mine specific models created, most having been created specifically for underground mines. The surface mines have generally adapted an existing industrial model for their use.

A report by Hwang, Singer, and Hartz discussed several models for predicting dust dispersion in an underground entry by a turbulent gas stream, in other words "the prediction of dust dispersion after an explosion." The basic diffusion equation used, was defined:

$$\frac{\partial c}{\partial t} + U\frac{\partial c}{\partial z} = k\left(\frac{\partial^2 c}{\partial x^2} + \frac{\partial^2 c}{\partial y^2} + \frac{\partial^2 c}{\partial z^2}\right) \qquad (2.6)$$

where

c	=	dust concentration.
U	=	convection velocity.
k	=	diffusion coefficient.
x,y,z	=	directions of coordinate grid.
t	=	time.

This report derived from Equation (2.6) mathematical interpretations of the modeling process for four different types of sources: point source, line source, moving line source, and flat plane. The resulting modeling equations for each type of source are rather lengthy and not fully explained. For example, the equation for an instantaneous point source in the plane $z = z_1$ at the point (x_1, y_1) emitted at time $t = t_1$ is given as

$$c = \frac{Qe^{\frac{-\{(z-z_1)-U(t-t_1)\}}{4k(t-t_1)}}}{2ab\{\pi k(t-t_1)\}^{1/2}}\left\{1+2\sum_{m=1}^{\infty} e^{\frac{-km^2\pi^2(t-t_1)}{a^2}} \cdot \cos\frac{m\pi x}{a}\cos\frac{m\pi x_1}{a}\right\}\cdot \left\{1+2\sum_{n=1}^{\infty} e^{\frac{-kn^2\pi^2(t-t_1)}{b^2}} \cdot \cos\frac{n\pi y}{a}\cos\frac{n\pi y_1}{a}\right\} \qquad (2.7)$$

where

c	=	dust concentration.
U	=	convection velocity.
k	=	diffusion coefficient.
x,y,z	=	directions of coordinate grid.
t	=	time.
a	=	entry opening height.
b	=	entry opening width.
n	=	distance in a direction normal to the boundary or walls of the opening (assumed to be for the y direction).
m	=	undefined, but assumed to be similar to n except for the x direction.
Q	=	point source emission strength.

The uncertainty is in the variables n and m. Explanations for these variables were insufficient to fully understand what the authors meant by these variables. Results of calculations were completed, but no comparisons of calculated results to actual results were given as it was stated that there were no measured observations available (Hwang, et. al., 1974).

Courtney, Kost, and Colinet completed a study that defined dust deposition in underground coal mine airways. The main emphasis of this study was to determine an optimum schedule for rock dusting entries in an underground coal mine by using an airborne particle deposition model. Testing was completed at eight locations in five U. S. underground coal mines. The deposition model in this study was based upon a model created by Dawes and Slack in 1954. Their model was based upon the deposition of coal dust in a small laboratory wind tunnel. The resulting model is defined:

$$\frac{\partial m}{\partial t} = Kc = Kc_0 \exp\left(\frac{-Kx}{vH}\right) \qquad (2.8)$$

where

$\frac{\partial m}{\partial t}$	=	dust deposition rate.
K	=	rate constant, taken as Stoke's sedimentation velocity.

$$K = kD^2 \qquad (2.9)$$

where

D = particle diameter.

k = Stoke's sedimentation constant.

$$k = \frac{(\rho - \sigma)g}{18\eta} \qquad (2.10)$$

where

ρ = particle density.

g = acceleration of gravity.

σ = density of air.

η = viscosity of air.

x = distance of deposit from the dust source.

c_0, c = airborne dust concentration of particles of diameter D at the dust source and at x, respectively.

v = air velocity.

H = height of airway.

This model was found to have satisfactory results for particles with diameters less than 40 µm, and the exponential decay with distance agreed with their experimental results (Courtney, Kost, and Colinet, 1982). Courtney, Kost, and Colinet's study also stated that Bradshaw and Godbert completed a study of the deposition rate of dust in the return airway of underground coal mines. The results of this study showed an exponential decay rate, but the first 23 m from the source was found to have 2 to 4 times more dust deposition than was calculated (Courtney, Kost, and Colinet, 1982). Ontin was stated to have completed studies on dust deposition in underground coal mines. Ontin found that the deposition rate also decayed exponentially, and that 50% of the airborne dust settled out within 1.8 m of the source (Courtney, Kost, and Colinet, 1982). Therefore, experimental testing was demonstrating that Equation (2.8) may be under-predicting the deposition rate of dust at distances close to sources. Through testing, Courtney, Kost, and Colinet found that the deposition rate in pounds per square foot per hour was independent of the airborne particle size, but increased with increasing total airborne dust concentration. Their recommended deposition model was presented:

$$\frac{\partial m}{\partial t} = \left[\left(\frac{K_1 V}{S} \right) c_0 \right] \exp\{-Ax\} \tag{2.11}$$

where

$\frac{\partial m}{\partial t}$ = dust deposition rate.

K_1 = a proportionality constant, found to be 15.6 in this study.

A = K_1 / v

x = distance along the airway.

c_0 = initial dust concentration.

v = air velocity.

V/S = volume/surface area of the airway.

This equation was stated to be correct if the airflow is turbulent in the airway and not laminar, and if the rate of deposition is exponential with distance (Courtney, Kost, and Colinet, 1982). The result of the study found that this model could be used for determining an optimum rock dusting schedule for an underground coal mine, but that further testing should be completed at many other mine sites because of the variability from one mine location to another (Courtney, Kost, and Colinet, 1982).

Courtney, Cheng, and Divers completed a study for underground coal mines in 1986 titled "Deposition of Respirable Coal Dust in an Airway." The study stated that the "rate of decrease of the airborne concentration must be equal to the deposition of the airborne particles onto the surfaces of the airway."[5] This was represented by the following equation:

$$-vA\frac{\partial c}{\partial x} = L\frac{\partial m}{\partial t} \tag{2.12}$$

where

v = air velocity

A = cross-sectional area of airway.

c = local dust concentration.

x = distance along airway.

[5] Courtney, Welby G.; Cheng, Lung; and Divers, Edward F.; "Deposition of Respirable Coal Dust in an Airway." U. S. Bureau of Mines Report of Investigation 9041. (U. S. Department of the Interior, 1986) 3.

$\frac{\partial m}{\partial t}$ = rate of dust deposition per unit area along airway.

L = deposition surface across airway.

L = perimeter if dust deposits on roof, walls and floor.

L = width of airway if dust deposits only on floor.

If the rate of dust deposition was dependent upon local dust concentration as stated in the study completed by Courtney, Kost, and Colinet, then Equation (2.12) could then be represented as

$$-Av\frac{\partial c}{\partial x} = Lkc \tag{2.13}$$

where

The terms are the same as given in equation (2.12).

k = dust deposition rate constant.

$$\frac{c}{c_0} = \exp\left\{\left(\frac{-L}{AV}\right)kx\right\} \tag{2.14}$$

where

c_0 = dust concentration at the source.

c = dust concentration at a distance x from the source.

Experiments to test the deposition of dust with varying air velocities and relative humidities were conducted at an underground limestone mine. It was thought that deposition might depend upon Stokes' sedimentation velocity. But it was found that the deposition was dependent upon air velocity and that large and small particles deposited at similar rates along the first 91 meters distance from the source in the airway. The larger particles had fully deposited by 152 meters distance from the source. The rough surface of the walls of the limestone mine were thought to effect the deposition of smaller particles by trapping the larger particles. The dependence of particle deposition on air velocity in the airway implied a change in the airborne particle size distribution, which remained to be explained (Courtney, Cheng, and Divers, 1986).

The results of the study demonstrated that the median particle sizes were higher at the floor of the airway (6.5 µm) than at the roof of the airway (4.7 µm) at 30.5 meters away from the source. At distances 152 - 213 meters away from the source, the median diameters were closer together (4.9 – 4.5 µm). Respirable dust deposition rate was shown to decrease as a function of distance from the source. At low air velocities, the deposition rates were linear. At higher air velocities, the deposition rates decreased as the distance from the source became greater. Relative humidity was found to have a negligible effect on the dust deposition rate (Courtney, Cheng, and Divers, 1986).

Ratios of deposition rates of dust onto the floor, walls, and roof of the airways were also presented. These deposition rates were dependent upon particle size, and the floor deposition rate was greater than the roof and wall deposition rate. The ratios were established by studies conducted by Pereles and Owen (Courtney, Cheng, and Divers, 1986).

Bhaskar and Ramani wrote a series of papers that describe a modeling method for the deposition of respirable dust in an underground coal mine. This series of papers is related to Ragula Bhaskar's doctor of philosophy dissertation titled "Spatial and Temporal Behavior of Dust in Mines –Theoretical and Experimental Studies," completed at Penn State University in 1987. The mathematical model presented was defined:

$$\frac{\partial c}{\partial t} = E_x\left(\frac{\partial^2 c}{\partial x^2}\right) - U\frac{\partial c}{\partial x} + \text{sources} - \text{sinks} \qquad (2.15)$$

where

c	=	concentration of airborne dust.
t	=	time.
E_x	=	dispersion coefficient.
x	=	distance from source.
U	=	velocity of airflow.

The source term represents dust generated by cutting mechanisms in the underground mine and the sink term refers to the deposition of the dust on the floor, walls, and roof of the airway (Bhaskar, Dust Flows in Mine Airways, 1989). This mathematical model is applied to all the particle size intervals that are represented in a dust cloud generated from a mining operation.

Results of comparison of the model to experiments conducted in an underground airway showed that the model predicted deposition of the dust in airways satisfactorily. The model tended to predict better at lower airway air velocities than with higher air velocities. Also, total dust size was better predicted than the respirable dust size (Bhaskar, 1987).

Detailed explanations for the processes used in creating this model are given in Ramani and Bhaskar's "Dust Transport in Mine Airways." The processes considered are particle deposition, deposition by convective diffusion, deposition due to gravity, coagulation, collision mechanisms, and re-entrainment (Ramani, Dust Transport in Mine Airways, 1984). Particle deposition is related to mass transfer of a particle to the immediate adjacent surface; this represents deposition onto the roof and walls of the airway, and is represented by Brownian diffusion, eddy diffusion, or sedimentation. Deposition by convective diffusion refers to deposition caused by eddies in turbulent flow and represents deposition onto the walls. Deposition due to gravity uses the particle's gravitational velocity to determine the deposition of the particle onto the floor of the airway. Coagulation and collision mechanisms are related and are based upon the interaction of the particles with one another. These two processes are important in determining the airborne particle size distribution, and therefore, important in determining the amount of dust deposited onto the airway surfaces. They take into account forces such as electrostatic charge, Van der Waals forces, and the nature of the colliding particle's surfaces. Re-entrainment evaluates the amount of dust that is generated from dust that has already been deposited. Dust may be re-entrained due to the shear forces from the velocity of air in the airway exceeding the cohesive force of the particle on the surface. This process is dependent upon the air velocity in the airway (Ramani, Dust Transport in Mine Airways, 1984).

Xu and Bhaskar wrote a paper in 1989 which determined the turbulent deposition velocities for coal dust in an underground mine airway. This study showed that the turbulent deposition was independent of particle size but dependent upon particle density as air velocity increased. It was stated that particle properties and air velocities may influence gravitational velocities more than turbulent deposition velocities (Xu and Bhaskar, 1995).

Very few models have been created for surface mining operations. Cole and Fabrick discuss pit retention of dust from surface mining operations. They discuss a study completed by Shearer that states that approximately one third of the emissions from mining activities escapes the open-pit. Further discussions are completed on a proprietary model by Winges, which calculates the mass fraction of dust that escapes an open-pit. This mathematical model is given (Cole and Fabrick, 1984):

$$\varepsilon = \frac{1}{1+\left(\frac{V_d}{K_z}\right)H} \qquad (2.16)$$

where

ε = mass fraction of dust that escapes an open-pit.

V_d = particle deposition velocity.

K_z = vertical diffusivity.

H = pit depth.

Fabrick also created an open-pit retention model based upon wind velocity at the top of the pit. This model is given (Cole and Fabrick, 1984):

$$\varepsilon = 1 - V_d\left[\frac{C}{u}\left(\frac{1}{2} + \ln\frac{w}{4}\right)\right] \tag{2.17}$$

where

ε = mass fraction of dust that escapes an open-pit.

V_d = particle deposition velocity.

u = wind velocity at the top of the pit.

C = empirical dimensionless constant equal to 7.

w = pit width.

The deposition velocity in both models was based on a gravitational settling velocity determined by Stoke's law. A comparison was completed using both models and the results agreed well with each other and the study by Shearer that stated one third of the emissions from mining activities escape the open-pit.

Several open-pit dust models are discussed in a study on "Dispersion of Airborne Particulates in Surface Coal Mines," completed for the U. S. EPA by TRC Environmental Consultants. These include the models previously discussed by Cole and Fabrick. Another model created by Herwehe in 1984 is described. This model is a computer simulation using finite-element analysis. It takes into account many factors such as wind conditions, surface roughness, complex terrain, atmospheric stability, pollutant sources, particulate terminal settling and deposition velocities, and surface particulate accumulation (TRC Environmental, 1985). However, it was stated that this model may not give good results for open-pits with pit angles greater than 35 degrees from the horizontal or in stable atmospheres. This model also has not been tested with field results (TRC Environmental, 1985). Another model, the FEM (3 Dimensional Galerkin Finite Element Model), which was not created specifically for the mining industry, was mentioned as one that could be modified for use in predicting dispersion of dust from open-pits. Its drawback was that it required a very large computer to run the model. This model has also not been tested with field data.

Modeling of dust dispersion for specific mining operations has been completed for the blasting phase. At the Kalgoorlie Consolidated Gold Mines Pty Ltd, a computer program was created to determine dust dispersion from blasting operations. This program uses meteorology, bench height, blast design information, and rock density to predict the behavior of dust from blasting. It accounts for some absorption of the dust on the pitwalls and for some reflection of the dust off the pitwalls. The dust concentrations are calculated using settling velocities for different particle sizes and densities. The program is used to determine if blasting will have an impact on a nearby town (Wei, et. al., 1999). Another model for predicting dust dispersion from blasting operations has been created by Kumar and Bhandari. This model uses a gradient transport theory or an Eulerian approach. This model considers atmospheric stability and wind velocity and direction for computing dust concentrations at different distances from the blast (Kumar and Bhandari, 2002). No mention of any field validation has been presented in either of these two articles.

Pereira, Soares, and Branquinho used a Gaussian dispersion equation to predict dust concentrations from the stockpiles of an operating surface mine in Portugal. This equation was used to create risk maps of air quality for locations surrounding the mine site. It was mentioned that these risk maps should be viewed as extreme risk maps. No experimental validation was performed to determine the accuracy of these maps to actual conditions (Pereira, et. al., 1997).

Very few mine specific models have been created for surface mining operations, but it can be seen that a great deal of research has been conducted on modeling dust deposition for underground mining operations. While this research is not directly applicable to surface mining operations, it is a good basis for characterizing the prediction of dust concentrations and the deposition of dust, as underground mining openings are a controlled environment. This controlled environment facilitates prediction of concentration and deposition, because the variability due to wind speed and wind direction can be controlled. Dust dispersion modeling for surface mining operations is generally completed using an established model. The model used for surface mining operations is generally the ISC3 model created by the U. S. EPA.

2.4.4 ISC3 Model

The ISC3 model is particularly important to mining operations, because this model is the required model for modeling dust dispersion from mining operations. The ISC3 model is based upon the Gaussian Equation for point source emissions, which is given as the following for the ISC3 model (U. S. EPA, User's Guide Vol. II, 1995):

$$\chi = \frac{QKVD}{2\pi u_s \sigma_y \sigma_z} \exp\left[-0.5\left(\frac{y}{\sigma_y} \right)^2 \right] \tag{2.18}$$

where

Q	=	pollutant emission rate.
K	=	scaling coefficient to convert calculated concentrations to desired units (default value of 1).
V	=	vertical term.
D	=	Decay term.
u_s	=	Mean wind speed at release height.
σ_y, σ_z	=	Standard deviation of lateral and vertical concentration distribution.
χ	=	hourly concentration at downwind distance x.
y	=	crosswind distance from source to receptor.

There are a series of supporting equations that must be used with this equation. These equations are listed in Appendix A.

The PM_{10} concentrations are calculated for receptor locations. These locations are based upon a Cartesian coordinate system where each source and receptor have an "X" and a "Y" coordinate. These "X" and "Y" coordinates are input into the downwind and crosswind distance equations shown in appendix A, equations (A.2) and (A.3) respectively. These equations calculate the downwind distance x and crosswind distance y which are input into Equation (2.18).

Hourly meteorological data are distributed from the U. S. EPA website. The data are processed through another program called RAMMET, which is distributed by the U. S. EPA along with the ISC3 model. This program uses the meteorological data to calculate the mixing height z_i. The mixing height is used in equations (A.9) or (A.10). It then organizes the data into a format readable by the ISC3 program. The data are then read into the ISC3 model for use in Equation (2.18).

Once all the data are entered, Equation (2.18) calculates the PM_{10} concentration χ at the coordinates of the receptor. Generally, there is more than one receptor and they are aligned in a grid format. PM_{10} concentrations χ are calculated for each receptor point in the grid, with the emission source being stationary. These calculations are completed for all the hourly meteorological data. The hourly results are then averaged, either for a 24-hour period or a yearly period, and input into the receptor grid. This resulting grid of PM_{10} concentrations allows for the creation of contour maps of the dispersion modeling results, where the contours represent the concentrations of PM_{10}. The User's guide, Volume I and Volume II written by the U. S. EPA, explain in greater detail the procedure for the operation of the program.

There have been very few studies completed to determine the accuracy of the ability of the ISC3 model to predict PM_{10} dispersion from surface mining operations. The U. S. EPA completed a large-scale study at a surface coal mine in Wyoming in 1994 - 1995. This study, issued in three volumes, reviewed the entire mining operation for dust dispersion. The emissions factors from the U. S. EPA's AP-42 were used to determine the amount of emissions from the operation. These emissions were then input into the ISC3 model and to complete dispersion modeling. Field testing, to validate the ISC3 model, was completed by placing six PM_{10} sampling stations throughout the surface mining operation. The sampling equipment used at each station was the Wedding PM_{10} Reference Sampler. These six stations were used in addition to three existing PM_{10} sampling stations that were located at the mine site to fulfill air quality permitting requirements (U. S. EPA, Modeling Fugitive Dust Phase I, 1994). The sampling stations were placed on both the upwind and downwind side of major excavating operations. Weather data were recorded throughout the duration of the test, and time studies of equipment operation were completed. The testing occurred over a time interval of two months, with air sampling occurring every other day (U. S. EPA, Modeling Fugitive Dust Phase I, 1994). The modeling results of the operations were compared to the actual measurements from the sampling network.

The study documents that there is a significant over-prediction of PM_{10} emissions from the surface coal mining operation by the ISC3 model (U. S. EPA, Modeling Fugitive Dust Phase

III, 1995). This report has a statistical protocol that defines significant over-prediction as an over-prediction of more than a factor of two at a single site where modeled vs. measured results are compared (U. S. EPA, Modeling Fugitive Dust Phase II, 1994). No attempt to determine the source of the over-prediction of PM_{10} was made in this study.

Cole and Zapert completed a study, submitted to the National Stone, Sand, & Gravel Association (NSSGA), to test the ISC3 model at three Georgia stone quarries. It was stated that the ISC3 model had a history of over-predicting particulate concentrations based upon data obtained by the Department of Energy's Hanford, Washington site (Cole and Zapert, 1995). This study calculated emission rates for operations, modeled the dispersion of the emitted particulates, and completed a comparison of modeled versus measured particulate concentrations for each of the three stone quarries. The model testing methodology was similar to that employed in the previously mentioned U. S. EPA's report titled "Modeling Fugitive Dust Impacts from Surface Coal Mines, Phase I - III." The number and type of PM_{10} sampling stations is unknown. However, it can be determined that there were at least two sampling stations at each site because there was a primary downwind site and a site located upwind of the prevailing winds to allow for subtraction of ambient PM_{10} concentrations. Once the comparison of modeled versus measured results was completed, it was determined that the model over-predicted the actual PM_{10} concentrations by a range of a factor of less than one (87% over-prediction) to a factor of five (Cole and Zapert, 1995).

This study concluded that there could be two reasons for the over-prediction of the PM_{10} concentrations by the ISC3 model. One was that the model failed at that time to account for any deposition of the particulates. The other reason was that the emissions factor for unpaved roads over-predicts the amount of emissions from haul trucks. The emissions factor was cited as a possible cause of over-prediction because during the study, it was noted that the hauling operations contributed 79-96% of the PM_{10} emissions from the entire quarrying operation (Cole and Zapert, 1995). The U. S. EPA has been modifying a deposition routine for the ISC3 model, but no literature has been found where testing has been completed using the deposition routine in the ISC3 model. Cole and Zapert used an initial deposition routine created by the U.S. EPA, and found that it reduced the modeled results by 5%. Even with this reduction in modeled PM_{10}

concentrations, there is still a significant over-prediction. This has led the NSSGA to embark on a series of studies that attempt to better quantify the PM_{10} emissions from haul trucks.

The blasting operation at surface mines as a possible cause of the over-prediction by the ISC3 model was eliminated. One reason is that there are no reliable emissions factors in the U.S. EPA's AP-42 to calculate the amount of PM_{10} that could be emitted from blasting (Cole and Zapert, 1995). Another reason is that the U.S. EPA considers the contribution of PM_{10} from blasting operations to the emissions of PM_{10} from the entire mining facility to be small because blasting is conducted infrequently not continuously (U. S. EPA, AP-42, Western Surface Coal Mining, 1998). Therefore, the U.S. EPA has not pursued an accurate emissions factor in AP-42 nor has it emphasized modeling blasting emissions from surface mining operations.

Recently, Reed, Westman, and Haycocks completed a study on the ISC3 model using a theoretical rock quarry. This study also concluded that hauling operations contributed the majority of PM_{10} concentrations and that the haul truck emissions factors may be part of the cause of the over-prediction of PM_{10} concentrations by the ISC3 model (Reed, et. al., An Improved Model, 2001). However, further analysis of the data provided by the Cole and Zapert study presented another hypothesis explaining the cause of the ISC3's over-prediction of PM_{10} concentrations. This hypothesis stated that the ISC3 model was predicting concentrations from stationary sources; however, in mining, the majority of the sources producing PM_{10} are moving or mobile sources. Therefore, further investigation of the dispersion of PM_{10} from haul trucks at surface mining operations was recommended. It was recommended that this investigation include revising the ISC3 model to accommodate these moving sources.

2.5 Prior Field Studies of Dust Propagation at Surface Mine Operations

Field studies measuring dust concentrations have been completed at surface mining operations. Two studies, already mentioned, "Modeling Fugitive Dust Impacts from Surface Coal Mining Operations - Phase I, II, & III" by the U. S. EPA and "Air Quality Dispersion Model Validation at Three Stone Quarries" by Cole and Zapert, form the basis for completing the research for improving the modeling method for surface mining operations.

2.5.1 Olson and Vieth Haul Road Field Study

In 1987 Olson and Vieth completed a study titled "Fugitive Dust Control for Haulage Roads and Tailings Basins," which tested haul roads at a sand and gravel operation for dust concentrations from haul trucks. This test was conducted to determine the effectiveness of the use of dust suppressants on a haul road. Dust measurements were taken with the GCA RAM-1 dust monitors. This monitor was used without the cyclones; therefore, dust particles up to 20 μm in size were measured. The stations were set up on berms along the downwind side of the haul roads at a distance of 5 meters from the edge of the road. The trucks then passed the measurement stations as the measurements were taken. One dust monitor was used for each section of haul road; therefore three dust monitors were used.

The haul roads were tested both untreated and with treatments of AMS-2200 (a petroleum derivative), Dustgard (a magnesium chloride ($MgCl_2$) salt), Dust-Set (a resin), and Haulage Road Dust Control (a wetting agent). The AMS-220 and the Dustgard were tested simultaneously. The Haulage Road Dust Control testing was compared with water, since the wetting agent, like water, is only a temporary dust control. The petroleum derivative and the $MgCl_2$ salt are more long-term dust control methods.

The Dust-Set (resin) was tested and cancelled after the average dust measurements after application were 10.5 mg/m^3 as compared to an average dust measurement of 5.1 mg/m^3 for the untreated area (Olson and Vieth, 1987). It was not stated why the treated section of haul road had higher dust measurement readings than the untreated areas. An explanation was given that the resin may work under different soil types and less severe traffic conditions.

For the petroleum derivative and the $MgCl_2$ salt, three sections of haul road were used. One was treated with the petroleum derivative, one was treated with the $MgCl_2$ salt, and one was left untreated as a control for comparison.

Three tests for the untreated, $MgCl_2$, and petroleum derivative were conducted at different times. Table 2.4 shows the results of the tests and their average. It is assumed that each measurement recorded for each test represents a haul truck passing the measuring device. The control efficiency shown in Table 2.4 was calculated using the following equation (Olson and Vieth, 1987):

$$\%eff = \left[1 - \frac{T - B}{U - B}\right] \times 100 \tag{2.19}$$

where

B	=	Background measurements.
U	=	Untreated test section measurements.
T	=	Treated test section measurements.

Test 1 and Test 2 seem to be very consistent. However, Test 3, the untreated section, had an unusually high dust measurement level. It was mentioned that the humidity levels were lower during Test 3 at 30% compared to 43% for Test 1 and 54% for Test 2 (Olson and Vieth, 1987).

Table 2.4 Results of haul road test conducted by Olson and Veith.

Treatment and site	Test 1	Test 2	Test 3	Avg. of 3 Tests
Average Background, mg/m^3	<0.02	<0.02	0.03	0.02
Average Dust Level, mg/m^3				
Untreated	1.52	1.29	12.5	5.10
$MgCl_2$	0.21	0.03	0.20	0.15
Petroleum Derivative	0.79	0.31	2.04	1.05
Control efficiency, %				
$MgCl_2$	87.3	99.2	98.6	95.0
Petroleum Derivative	48.7	77.2	83.9	69.9

No mention was made of any differing traffic conditions, such as amount of traffic, types of traffic vehicles, etc. The overall results show that the $MgCl_2$ is a better dust control reagent.

The testing of the haul roads treated with Haul Road Dust Control (wetting agent) and water was completed separately. The setup was similar to the petroleum derivative and $MgCl_2$ test. In this case, the wetting agent and the water were applied to their corresponding sections of haul road. Dust measurements were taken with the same type of equipment as before. The time measurements were taken at timed intervals from the application of the wetting agent and the water. This resulted in average dust levels from the haul road. In reviewing the results, there is no trend that shows the wetting agent is better than water or vice versa (Olson and Vieth, 1987).

These results show the amount of dust that is generated from the haul roads by the haul trucks. The measurements show the total dust concentrations from the entire dust plume of the haul truck. No particle size distributions were able to be determined, and the amount of respirable or PM_{10} could not be determined. This study is not able to provide information on how the concentrations degrade away from the haul road because the sampling locations were located at the edge of the haul road.

2.5.2 Page and Miksimovic Drilling Operation Field Study

Another study completed by Page and Maksimovic, titled "Transport of Respirable Dust from Overburden Drilling at Surface Coal Mines" contains results that are significant to the propagation of dust. It sampled respirable dust as it dispersed from a rock drill at a surface coal mine. There were two sampling setups. One was to set a sampling station at the drill on the downwind side, with another sampling station located on the upwind side. Then five other sampling stations were arranged in an arc on the downwind side of the drill with the radius ranging from 16 to 71 meters. The center of the arc was oriented with the predominant wind direction. The other setup was to set a sampling station at the drill on the downwind side, with another sampling station located on the upwind side. Then five other sampling stations were arranged in a line going away from the drill in the predominant wind direction. The distance between the sampling stations was 10 to 15 meters depending on the space available on the bench.

Personal gravimetric samplers with a 10 millimeter (mm) cyclone operating at a flow rate of 2.0 liters/minute (L/min) were used along with integrated gas bag samplers using constant flow pumps. The gravimetric samplers with the 10mm cyclones sampled the respirable dust while the gas bag samplers measured the amount of sulfur hexaflouride (SF_6), a tracer gas, that was released from the drill. The SF_6 was released in an attempt to determine or isolate the specific dust source since it was thought that dust from other sources in the area might contaminate the dust sampler. A total of three gravimetric samplers and one gas bag sampler were operated at each sampling station location. The samplers were placed at heights of 1.2 to 1.5 meters above the ground.

The results reported in this study were the relative contribution of the total downwind worker exposure attributable to the drilling operation. These results were calculated using the defined equation (Page and Maksimovic):

$$R = \frac{Q_d C_t}{Q_t C_d} \times 100 \tag{2.20}$$

where

R	=	Relative contribution of the total downwind worker exposure attributable to the drilling operation in percent.
Q_d	=	Mass emission rate of respirable dust from the drill in milligrams/minute (mg/min).
Q_t	=	SF_6 tracer gas release rate in mg/min.
C_t	=	SF_6 tracer gas concentration at downwind location in mg/m^3.
C_d	=	Respirable dust concentration at downwind location in mg/m^3.

The results were reported in this manner because MSHA data show that the highwall driller and driller helper are the number one and two positions, respectively, with the greatest exposure to respirable dust (Page and Maksimovic, 1987). This format should allow one to determine the amount of respirable dust attributable to the drilling operation that a person downwind of the drill would receive.

The conclusions were that the highwall driller and driller helper may be exposed to high concentrations of respirable dust, but personnel downwind of the drilling operation will be exposed to minimal amounts of respirable dust. The sphere of influence of the drilling operation was determined to be approximately 76 meters. Beyond this distance, the drilling operations had no effect on respirable dust concentrations (Page and Maksimovic, 1987). The highest contribution of dust from drilling was 42%, occurring at a distance of 29 meters downwind with the average contribution being 13.6% (Page and Maksimovic, 1987). Respirable dust from drilling operations tends to decay rapidly with distance, within 32 meters, but no explanations were attempted to determine the cause of this rapid decay (Page and Maksimovic, 1987).

2.5.3 Singh and Sharma Surface Coal Mine Field Study

Singh and Sharma completed a yearlong study titled “A Study of Spatial Distribution of Air Pollutants in Some Coal Mining Areas of Raniganj Coalfield, India.” It measured ambient pollutant dispersion from surface mining operations in India to determine seasonal variation. Suspended particulate matter was measured along with sulfur dioxide and nitrogen oxides; only the suspended particulate matter information is pertinent. It is assumed that only total dust was measured in this study, as no particle sizes were mentioned.

The dust was measured using high volume samplers stationed at various locations surrounding the mining areas. No separate measurements of the individual mining operations, such as drilling, loading, and hauling were made. The results showed that the dust concentration levels differed between day and night. At areas surrounding underground operations the difference was less than 50 $\mu g/m^3$ and for surface operations the difference was more than 50 $\mu g/m^3$ (Singh and Sharma, 1992). The seasonal variations in the minimum background levels of dust concentrations had a range of 100 $\mu g/m^3$ for monsoon season, 150 $\mu g/m^3$ for summer season, and 200 $\mu g/m^3$ for the winter and spring seasons (Singh and Sharma, 1992). It was stated that the highest levels of dust concentration occurred around the mining areas, suggesting that they are significant contributors to the dust background levels. From the data presented, it was shown that the highest average dust concentrations were approximately 500 $\mu g/m^3$ for summer, 400 $\mu g/m^3$ for spring, 400 $\mu g/m^3$ for winter, and 300 $\mu g/m^3$ for monsoon season (Singh and Sharma, 1992). No further analysis of the data were presented.

2.5.4 Merefield, Stone, Roberts, Dean, and Jones Surface Coal Mine Field Study

Merefield, Stone, Roberts, Dean, and Jones completed a study titled "Monitoring airborne dust from quarrying and surface mining operations," where dust deposition samples were taken from the surrounding area of an open pit coal mining operation in South Wales in England. These samples were taken using the improved British Standard Dust gage. These samples were then analyzed to determine the components in the dust, such as feldspar, gypsum, halite, dolomite, calcite, kaolinite illite, and chlorite. The components were then used to determine the origins of the dust whether it was from the surface coal mining operation or from some other source. This method of analyzing the dust components is called dust "fingerprinting." The objective of dust "fingerprinting" is to eliminate dust nuisance in the planning stages of a mining operation by determining if the dust actually comes from that operation (Merefield, et. al., 1995). This study analyzed the chemical composition of the dust deposition samples, and did not present any results for dispersion or deposition of the dust.

2.5.5 Jamal and Ratan Surface Coal Mine Field Study

A study completed by Jamal and Ratan sampled dust from different operations at a surface coal mine in India and analyzed it for several characteristics. The operations sampled included drilling, blasting, hauling and dumping, and loading of material. Dust deposition was measured at each of the operations, both upwind and downwind, using double-sided tape attached to a stub to collect the sample. Characteristics of dust analyzed from each operation included particle shape, particle size, and particle composition.

Particle shape was divided into several categories: angular, sub-angular, and sub-rounded. Particle shapes were determined from the samples taken, and placed into these categories, resulting in a particle size distribution. Drilling was found to have the most angular particles (Jamal and Ratan, 1997).

Particle size distribution was determined for each sample. The size categories were based on the following categories (Jamal and Ratan, 1997):

Superfine	< 0.5 μm.
Fine	0.5 to 2.5 μm.
Medium	2.5 to 5.0 μm.
Coarse	5.0 to 15.0 μm.
Very coarse	15.0 μm and above.

It was found that the respirable fraction of dust (up to 5.0 μm) varied according to what activity was occurring during the sampling. Respirable dust at mining operations was found to be in the range of 20% to 43% of total particulate matter, while residential areas were higher, above 45% (Jamal and Ratan, 1997).

Composition of the dust was broken into categories of free silica, silicate, iron oxides, and coal particles. The percentage of coal particles was higher in coal handling situations, while the percentage of silica was higher in overburden drilling operations. The percentage of iron oxides and silicates was found to be small, though it may be significant (Jamal and Ratan, 1997). This study recommended that air quality regulations based upon mass alone may not be enough to control air pollution and prescribe control measures.

2.5.6 Organiscak and Page Cab Filtration Field Study

Organiscak and Page measured respirable dust to determine cab filtration efficiencies for drills and bulldozers separately. In sampling the drills, four dust samplers were placed under the drill shroud, and four dust samplers were placed inside the cab. The bulldozer had four dust samplers located on each side of the dozer above the tracks, and four dust samplers were placed inside the cab. Each sampler had a 10 mm cyclone operating at 2.0 L/min. The respirable dust from the sampler was captured on a 37 mm coal dust filter cassette. These samplers were placed on several types of drills and dozers at several different sites.

Testing was conducted to determine the amount of respirable dust that was generated outside the cabs and the amount of respirable dust inside the cabs. The samples captured on the 37 mm filters were analyzed for silica to determine the amount of silica in the respirable dust. The silica contents of the respirable dust both inside and outside the cab were examined. Cab efficiencies were given in the results of this study. No information concerning dust dispersion was presented in this study. It did present a methodology for measuring respirable dust at a surface mining operation (Organiscak and Page, 1999).

2.5.7 Organiscak and Page Drilling Operation Field Study

Organiscak and Page completed another study titled “Assessment of Airborne Dust Generated from Small Truck-Mounted Rock Drills.” This study tested the propagation of respirable dust from surface truck-mounted rock drills and the orientation of the sampler inlets to wind direction. Three dust samplers were used; one located at the drill deck and two located 12.2 to 30.5 meters downwind of the drill. Each sampler contained a real-time aerosol monitor, a RAM-1 with data logger, and two personal respirable dust gravimetric samplers. The results showed that high respirable dust concentrations ranging from 8.68 to 95.15 mg/m^3 were found next to the drill shroud, while the respirable dust concentrations were significantly reduced (1.37 to 2.69 mg/m^3) at distances of 12.2 to 30.5 meters downwind of the drill (Organiscak and Page, 1995). Results for inlet orientation confirmed prior U.S. Bureau of Mines research that inlets oriented parallel to wind direction tend to over-sample respirable dust concentrations, while inlets oriented perpendicular to the wind tend to under-sample the respirable dust concentration (Organiscak and Page, 1995).

2.5.8 California Environmental Protection Agency Road Field Study

Another study that was recently published by the California Environmental Protection Agency's Air Resources Board is a pre-certification program that evaluates the results of a dust suppressant chemical. This program evaluated results from a study that measured PM_{10} from vehicles as they traveled a section of treated and untreated dirt road. The type of equipment used is not listed but is stated to be consistent with test methods used by the U.S. EPA (California Air Resources Board, 2002). One sampler was placed 100 meters upwind and a set of samplers was placed at a distance of 2 meters on both sides of the road at heights of 1.3, 2.0, 2.5, 5.0, and 10.0 meters. Another set of samplers was placed 30 meters from the road on both sides of the road, at a height of 2 meters. This set up was used for the untreated section and another similar setup was used for the treated section of road (California Air Resources Board, 2002). Measurements were taken for 17 vehicle passes. Table 2.5 shows the summary of the results from the upwind sampler and the average of all the results of the adjacent road samplers. The results presented are used to determine that the chemical dust suppressant has a control efficiency of approximately 84% (California Air Resources Board, 2002). No analysis of the results was conducted to examine the PM_{10} propagation or dispersion.

2.5.9 NSSGA Field Studies

The NSSGA embarked upon a series of studies to better define the emissions factor from the U. S. EPA's AP-42 for hauling operations at surface mines. The series of tests, completed in North Carolina, to test the AP-42 emissions factor used a complex sampling system that consisted of large hoods with ductwork and fans to collect the dust emissions from haul trucks. The emissions collected by this system were then sampled using the U.S. EPA reference method 201A. This reference method consists of a sampling nozzle, a PM_{10} cyclone, and a flow control system (Richards and Brozell, 2001). The flow control system controls the flow rate of air through the nozzle and PM_{10} cyclone. The dust sample enters the nozzle and flows through the cyclone; the PM_{10} fraction is collected on a filter to obtain a gravimetric sample. Four of these complex sampling systems, two on each side of the haul road, were used in the haul truck testing. In addition, ambient PM_{10} Hi-Vol monitors were placed upwind. Additional samplers such as PM_{10} Hi-Vol samplers, nephelometers, and cascade impactors were used as needed.

During testing, road surface moisture level, road silt content, stone production, number of truck passes, wind speed, wind direction, and truck speed were all monitored (Richards and Brozell, 2001). The results of the monitoring and sampling were used to determine the accuracy of the emissions factors in AP-42 and in the development of new emissions factors that were stated to be more accurate. The results of these tests were not used to analyze the dispersion or propagation of PM_{10} from the haul trucks. The NSSGA also conducted similar tests on different mineral processing equipment, such as crushers and screens, to better define the emissions factor equations for these operations.

The NSSGA continued sponsoring testing at stone quarries, evaluating the air quality impact of stone quarrying operations. Studies were conducted at three mine-site locations to measure the amount of $PM_{2.5}$ emitted from stone quarries and their associated plants. Monitoring sites were placed within the quarry property boundary with one monitoring site upwind from the plant and quarry and two monitoring sites located downwind. The sampling equipment used in this series of studies was the model FRM-2000 $PM_{2.5}$ monitors that are manufactured by Rupprecht & Patashnick Co. (Richards and Brozell, 2001). These samplers were operated 24 hours per day for thirty days. The results of the study demonstrated that there was only a small amount of difference between the upwind and downwind sample results when the wind direction was from the upwind monitor to the downwind monitor and traveling across the mining site. One study in North Carolina showed the difference in $PM_{2.5}$ to be only 0.7 $\mu g/m^3$ (Richards and Brozell, 2001). When the wind blew from directions across other sources rather than across the mine site, the differences in the upwind and downwind sampling results were greater. The results of this study were stated to establish the fact that other off-site sources had greater emissions of $PM_{2.5}$ and that mining operations are not a significant contributor of $PM_{2.5}$ (Richards and Brozell, 2001).

Another study completed by the NSSGA analyzed the deposition of PM_{10} in addition to $PM_{2.5}$ and TSP. Monitoring sites were placed within the quarry property boundary with one monitoring site upwind from the plant and quarry at a distance of approximately 518 meters and three monitoring sites located downwind at distances of 350, 670, and 975 meters from the plant and quarry (Richards and Brozell, 2001). The model FRM-2000 monitors that are manufactured

Table 2.5 Summary of Results from California Air Resources Board Pre-certification Program Study (California Air Resources Board, 2002).

		Untreated				Treated			
Run	Date	Upwind $\mu g/m^3$	Downwind $\mu g/m^3$	Max $\mu g/m^3$	Min $\mu g/m^3$	Upwind $\mu g/m^3$	Downwind $\mu g/m^3$	Max $\mu g/m^3$	Min $\mu g/m^3$
1	7/22/95	24.2	71.0	193.7	21.4	45.3	32.6	41.1	27.2
2	7/23/95	32.1	277.1	456.2	55.6	24.3	31.8	43.8	24.3
3	7/24/95	27.8	150.9	264.0	38.0	17.2	36.1	54.1	23.7
4	7/25/95	35.5	319.4	610.4	91.7	49.6	24.4	33.6	15.7
5	7/26/95	25.4	285.7	615.0	66.8	18.7	40.0	94.1	18.4
6	7/27/95	41.2	133.3	267.8	44.2	35.0	29.4	32.2	24.3
7	10/17/95	30.2	138.4	280.5	53.4	41.5	45.1	55.6	32.7
8	10/18/95	86.7	373.5	675.0	24.4	56.2	56.9	71.3	45.7
9	10/20/95	198.2	166.8	291.3	87.9	44.6	56.4	58.9	54.0
10	10/21/95	24.5	229.4	539.2	34.6	29.5	27.1	32.6	20.4
11	10/22/95	133.1	239.3	335.6	119.1	69.6	77.6	80.7	79.6
12	6/13/96	11.8	147.2	263.9	26.5	26.8	43.9	51.4	10.9
13	6/14/96	31.3	242.7	477.6	80.9	26.3	49.6	84.2	24.0
14	6/15/96	37.4	183.1	364.1	59.6	31.8	52.1	80.3	33.3
15	6/16/96	54.7	287.0	580.0	73.2	24.1	72.1	118.7	45.0
16	6/17/96	26.8	151.9	325.1	29.0	25.2	45.2	70.5	25.1
17	6/18/96	16.8	209.5	399.1	35.6	35.2	69.6	103.6	43.7

by Rupprecht & Patashnick Co. were used for measuring $PM_{2.5}$, Andersen and General Metal Works High-Volume samplers were used for measuring PM_{10}, and General Metal Works High Volume samplers were used for measuring TSP (Richards and Brozell, 2001). These samplers were operated 24 hours per day for fourteen days.

The upwind results for $PM_{2.5}$ averaged 10.3 $\mu g/m^3$ and the downwind results averaged 9.3 $\mu g/m^3$ (Richards and Brozell, 2001). These results were similar to the results from previous studies conducted by NSSGA for $PM_{2.5}$ and reinforced the previously established fact that mining operations are not significant contributors of $PM_{2.5}$. The results for PM_{10} and TSP showed that both fractions had high dust concentrations for the first sampling point at 350 meters away from the plant. No mention was made of the actual recorded results, but these concentrations were said to be lower than NAAQS for 24-hour periods (Richards and Brozell, 2001). These dust concentrations quickly dropped to background levels, as defined by the upwind sampling point, at the next or second downwind sampling point that was 975 meters away from the plant (Richards and Brozell, 2001).

This review shows that thirteen field studies conducting dust measurements at surface mine-sites have been completed with seven being conducted to measure dust concentrations from the entire mining operations. One study examined cab filtration efficiencies of drills and dozers while two studies evaluated dust dispersion from drilling operations. Drilling operations differ significantly from hauling operations, but these evaluations are of significant importance as they present possible procedures for use in conducting similar studies on haul trucks. The other three studies measured dust from haul trucks, but the emphasis was placed on the amount of dust that a truck creates. An evaluation of the dispersion of dust from haul trucks was not completed. This lack of information for haul trucks warrants further investigation to characterize the dust emissions of haul trucks.

2.6 Summary

A number of studies relevant to the research have been found on both modeling techniques and mine specific models. Mathematical modeling techniques, dust propagation models for underground mining, dust propagation models for surface mining, and the completion of field testing for the measurement of dust from mining operations are all topics that have been previously discussed. A review of the creation of dust dispersion models for surface mining shows that eight different models have been created. Of these only three have been tested at actual mining operations. The tested models are the Shearer model, which states that 1/3 of the mining emissions escapes the open-pit; the blasting model created by Kalgoorlie Consolidated Gold Mines, Ltd.; and the ISC3 model. The ISC3 model is the only model that is accepted by the U.S. EPA for conducting dispersion modeling on surface mining facilities.

The U.S. EPA, which maintains the guidelines for air quality modeling, created the ISC3 model from past modeling algorithms in the ISC2 models (U.S. EPA, Users Guide Vol. I, 1995). This model has become the basis for predicting PM_{10} concentrations from mining operations. A study was first conducted by the U.S. EPA to determine its validity for surface mining operations. This study titled "Modeling Fugitive Dust Impacts from Surface Coal Mining Operations - Phase I, II, & III" was conducted at a western surface coal mine and compared modeled results with actual field measurements. The results of the study stated that the ISC3 model over-predicted the amount of PM_{10} from the mining operation by more than a factor of two (U.S. EPA, Modeling Fugitive Dust Phase I, 1994).

Cole and Zapert studied three stone quarries in Georgia testing the ISC3 modeling results with actual field measurements. This study titled "Air Quality Dispersion Model Validation at Three Stone Quarries" stated that the ISC3 model over-predicted PM_{10} concentrations from mining operations by a factor of 2 - 5 over actual surface mine emissions (Cole and Zapert, 1995). Cole and Zapert also state that haul trucks contribute to most of the PM_{10} emissions from surface mining operations.

The fact that the ISC3 model over-predicts PM_{10} concentrations from surface mining operations and that haul trucks generate the majority of PM_{10} that is emitted by the surface mining facility are the reasons for conducting further research to improve the accuracy of the ISC3 model. Analyzing the dust generation and dispersion from haul trucks at surface mining operations will allow for this improvement. The field studies reviewed show previous research has been conducted on PM_{10} emissions and dispersion from the entire mine site. While this is meaningful research, analyzing the specific operations conducted at a mine site will yield results that can be used to improve PM_{10} modeling. Evaluating PM_{10} dispersion from entire sites has not yielded any improvements to the modeling process, but it does show that individual operations need to be reviewed.

Individual studies have been conducted on drilling operations and haul trucks. The studies involving drilling are pertinent and yield useful results for PM_{10} dispersion. But these results are not applicable to haul trucks, as haul trucks are mobile. The haul truck studies that have been conducted were completed to define the amount of PM_{10} generated from the haul trucks. This allowed for improving the accuracy of the emissions factor equation given in the U.S. EPA's AP-42. As there have been no studies found that review or evaluate the dispersion of PM_{10} from hauling operations, there is a need for research in this area.

Chapter 3 Dynamic Component Program Development

3.0 Introduction

The goal of the research is to create a model that can more accurately predict the dispersion of PM_{10} from surface mining operations, and the literature review has shown that no models currently exist that can accomplish this task. Currently, the ISC3 is the best available model for estimating PM_{10} dispersion but it over-predicts by a factor of 2 - 5. The lack of accurate models has led to the need for a new mining-based model that attempts to correct the over-prediction of the ISC3 model. Chapter Three outlines the development of the Dynamic Component Program completed through this research to meet the needs of the mining industry. The chapter reviews the issues affecting the modeling process and the emissions factors input into the model. A study, completed by Cole and Zapert, hypothesized that the emissions factors used to calculate emissions from each sub-operation at mine sites or from the mining equipment are inaccurate and cause the over-prediction by the ISC3 model (Cole and Zapert, 1995). This hypothesis is examined and found not to be the only cause of the model over-prediction. The real cause of model inaccuracy is reviewed in this chapter and steps to correct this inaccuracy are developed and implemented in the new Dynamic Component Program. Finally, Chapter Three reviews the operation of the new model and compares its results with the ISC3.

3.1 Factors Affecting the Modeling Process.

Modeling of dust at surface operations is a complex process, and there are many factors influencing the dispersion of dust. Some of these factors are meteorological conditions, such as wind speed and direction; temperature; relative humidity; rainfall amounts and frequency; topographical conditions of the surface mine; topographical conditions of the surrounding areas; vegetation types of the surrounding area; and physical properties of the dust, such as shape, density, and size distribution. Because a number of these factors involve inputs into the modeling routine, they will be reviewed in the following sections.

3.1.1 Meteorological effects

Meteorological factors, including temperature, wind, and rainfall, have an impact on PM_{10} transport, deposition, and dispersion. Temperature controls the production of wind that causes turbulence over the surface of the earth, which in turn affects the dispersion of PM_{10}

(Schnelle and Dey, 2000). Temperature may also create inversions, which limit the altitude PM_{10} can reach in certain areas (Schnelle and Dey, 2000).

The wind direction will determine the direction that dust will travel, as wind is the primary transport mechanism. Wind speed causes PM_{10} to disperse. This dispersion can be seen by the fact that the concentration of PM_{10} at its source will be higher than the concentration of PM_{10} at a distance away from the source if the wind speed is high (Schnelle and Dey, 2000). High wind speed can also inhibit PM_{10} deposition. In addition, wind speeds of 5.4 meters/second (m/s) or greater have the ability to acquire, transport, and disperse dust without any mechanical disturbances (Hesketh and Cross, 1983).

Meteorological data, especially wind data, can vary tremendously from site-to-site. The modeling routines that handle meteorological data are used consistently throughout various industries, and mining operations are not unique enough to warrant a change in these routines at this time. It will be assumed that the routines using the meteorological data are inherently correct.

A third weather factor, rainfall, has an affect on the concentration of PM_{10} in the atmosphere. Water causes dust to coagulate and become heavier particles that cannot be transported by wind. Like rainfall, humidity can also lead to the coagulation of dust, though not as great as the direct application of water (Hesketh and Cross, 1983). As a result, areas of the United States that have a large number of days with rainfall will have less wind erosion rates than areas with low rainfall amounts (Hesketh and Cross, 1983). Rainfall will not be addressed in this research in order to simplify the dispersion modeling process.

3.1.2 Terrain Effects

Topographic conditions have a great impact on the modeling of the dispersion of PM_{10} because topography helps create wind patterns that transport PM_{10}. Topographical effects, such as mountain passes and valleys, can amplify the wind. Studies have been completed which have shown the effects of topography on particulate deposition. One such study by Goossens and Offer demonstrated that dust tends to deposit on the windward side of slopes or hillsides rather than the leeward side as previously thought (Goossens and Offer, 1990). Various factors can affect the deposition of dust on the windward slopes and these factors are based upon the condition of the slopes. For example, if the leeward side of the slope has more vegetation, a higher soil moisture content, or higher moisture [dew on vegatation] than the windward side, then the leeward side might collect more dust than the windward slope (Goossens and Offer, 1990).

In urban areas, buildings are considered part of the local topography. Studies completed on the aerodynamics of buildings demonstrate that dust can become trapped in low-pressure cavities on the lee side of buildings (Schnelle and Dey, 2000). This trapping effect will have a significant impact on the long-range dispersion of pollutants because the portion of the pollutant trapped on the leeward side of a building will not be available for dispersion or deposition further downwind.

The terrain data will also vary tremendously from site-to-site, causing differences in results from the ISC3 model. There are modeling routines that handle the topographical and vegetation effects. These modeling routines are used consistently throughout various industries in a manner similar to the meteorological data. Therefore, any possible errors from the terrain modeling routines will be neglected at this time in order to simplify the dispersion modeling process.

Vegetation would also have an effect on dust dispersion. Studies have been conducted on the effects of dust on vegetation, but few of them have been completed on the effects of vegetation on dust transport. It has been shown that vegetation creates a greater surface area on which PM can deposit (Farmer, 1993). However, it is not known whether the vegetation attracts the dust or if the dust is simply depositing in the surrounding area that contains vegetation.

3.1.3 Material Properties

The physical properties of size, density, and shape of the particulates have a great impact on their transport. Particles in the size range of 100 µm - 30 µm can be windblown and create a nuisance. Particles <30 µm can be suspended and cause nuisance problems. Particles <15 µm are inhalable and, with densities <2.5 grams/cubic centimeters (g/cm^3), can be transported long distances. Particles <2.5 µm are respirable and can be transported long distances (Hesketh and Cross, 1983). Smaller particles remain airborne longer and deposit more slowly than larger particle sizes. This is due to the higher terminal settling velocities of larger particles. For example, a 10 µm particle has a terminal settling velocity of 0.305 cm/s while a 1 µm particle has a terminal settling velocity of 0.0035 cm/sec (Lippman, Chapter 13 Filters and Filter

Holders, 1995). Therefore, the smaller the particle, the further it can be transported in the atmosphere.

The shape of individual particles can also affect their transport properties because of its effect on drag force. The drag force helps determine the settling rate of the particle, affecting the deposition of the particle. Particles with irregular shapes can have different settling rates than spherically shaped particles because the drag force on the irregular shaped particle is different from the force on a spherical particle (Licht, 1988). The shape of the particles becomes less important in a turbulent environment like the atmosphere, unless the particle is a fiber (Hinds, 2000).

The final effect on the transport properties of particles is density. Particles with higher densities will have higher settling velocities than those that are less dense (Hesketh and Cross, 1983). Road material may have small variations in material density but these variations are not significant enough to impact the deposition or dispersion of dust from haul trucks.

As stated, particle shape and density are expected to have minimal effects on the type of dust emissions being evaluated in this study. Therefore, these factors will be neglected. Particle size, however, is an important factor and will be examined by evaluating specific size ranges, rather than the entire spectrum of dust.

3.1.4 Emissions Factors

The U. S. EPA's AP-42 lists emission factors for PM that are applicable to the mining industry. These emission factors have been created from studies conducted at various mining operations (U. S. EPA, AP-42, Western Surface Coal Mining, 1998). Emission factors that pertain to the surface mining industry are shown in Appendix B. It should be noted that the emission factors listed for the western surface coal mining operations are the only emission factors available that address PM emissions for the individual mining operations in surface mining. Since surface mining operations are similar among different mining activities, these emission factors should be applicable to similar metal/non-metal surface mining operations. Engineering judgment should be used when estimating emissions using these factors because the U. S. EPA states that these western surface coal mining emission factors may be too conservative for use with eastern surface coal mines; that is, they may over-predict PM emissions for eastern surface coal mines (U. S. EPA, AP-42, Western Surface Coal Mining, 1998). In addition, the

U.S. EPA states that these published factors are neither standards nor recommended values (U. S. EPA, AP-42, Western Surface Coal Mining, 1998). If there are better methods available for estimating emissions, then these methods can be used over the emission factors. However, these methods must be proven to be more accurate which can be costly and time consuming. Therefore, the emission factors are more readily accepted than other methods of estimating emissions from facilities.

The emission factors, which determine the amount of emissions from a source, are input into the model. A study by Cole and Zapert states that the over-estimation of emissions from a source can cause the modeling process to over-estimate its results (Cole and Zapert, 1995). Since the emissions factors generally provide the basis for all modeling exercises. a review of the emissions factors is conducted.

3.2 Review of Surface Mining Emission Factors

Cole and Zapert's study demonstrated that the major activities contributing to PM_{10} emissions were truck hauling on unpaved roads and loading of stockpiles and trucks. Table 3.1 shows the distribution of PM_{10} emissions from three actual quarry operations used in Cole and Zapert's study (Cole and Zapert, 1995). These emissions were calculated using the emission factors from the U. S. EPA's AP-42.

Calculating PM_{10} emissions on a theoretical quarry by using the emission factors from U.S. EPA's AP-42 gave the results shown in Table 3.2. These results agree well with the results from the Cole and Zapert study. The assumptions made for the calculated results in Table 3.2 are

1. The theoretical quarry had a production rate of approximately 900,000 metric tons per year. This production rate was sustained by operating the quarry eight hours per day, 250 days per year.
2. The material was assumed to have a silt content of 10%, a moisture content of 1.0%, and a specific weight of 2.37 metric tons per cubic meter.
3. The theoretical quarry contained a crushing operation with eight final product stockpiles located nearby. These stockpiles are also the load out areas for loading over-the-road trucks, which are used to transport the product to its final destination.

Table 3.1 Distribution of Annual PM_{10} Emissions.

Quarry #1		
Source	**Emissions (metric tons/year)**	**Emissions (%)**
Road Dust Emissions	233.05	96.7
Loading/Unloading	2.90	1.2
Drilling	0.09	0.0
Crushing	4.89	2.0

Quarry #2		
Source	**Emissions (metric tons/year)**	**Emissions (%)**
Road Dust Emissions	185.25	79.1
Loading/Unloading	26.80	11.4
Drilling	0.13	0.1
Crushing	22.11	9.4

Quarry #3		
Source	**Emissions (metric tons/year)**	**Emissions (%)**
Road Dust Emissions	172.32	96.2
Loading/Unloading	3.62	2.0
Drilling	0.04	0.00
Crushing	3.20	1.8

Table 3.2 Distribution of Annual PM_{10} Emissions from a Theoretical Quarry.

Source	Emissions (metric tons/year)	Emissions (%)
Road Dust Emissions	1483.36	95.6
Loading/Unloading	7.18	0.5
Drilling	0.04	0.0
Crushing	60.72	3.9

4. The theoretical quarry used 1 drill, 2 in-pit loaders, 4 haul trucks, 1 grader, 1 bulldozer 2 pickups, and 200 over-the-road trucks hauling final product from the site per day.
5. The processing plant used 1 primary crusher, 1 secondary crusher, 1 terteriary crusher, 2 main screens, and 1 fines screen. The processing plant also contained 18 conveyor transfer points and 8 final product stockpiles.
6. The haul trucks, over-the-road trucks, and the grader required the number of miles traveled per year on the site. A total number of 12,767 kilometers (km) per year was used for each haul truck, 826 km per year was used for each over-the-road truck, and 6,439 km per year was used for the grader. No adjustment was made for watering of any haulroads or using any dust suppression chemicals.
7. The bulldozer emissions factor was based upon 2,000 hours of operation per year.
8. The average wind speed was assumed at 3.5 m/s. This wind speed was used in the emission factor equation for loading trucks and loading stockpiles.
9. No results were calculated for blasting since the emissions factor concerns coal operations only and the emissions factor is not to be used for quarrying operations (United States Environmental Protection Agency, AP-42, 1995).
10. Stockpile wind erosion calculations were completed and found to be negligible in this particular case.
11. In all emission factor calculations, no corrections or adjustments were made for any occurrences of precipitation during the year.

Since the majority of the PM_{10} emissions come from the hauling operations at a quarry, it follows that the haul truck emissions should be evaluated. If the emissions from the haul trucks are being over-predicted, then lowering the estimate of the amount of emissions from haul trucks should cause the model to become more accurate.

3.3 Testing the ISC3 Model with Varying Emissions

A study was completed to review the ISC3 model by varying the emissions of a theoretical quarry (Reed, et. al., An Improved Model, 2000). In this study a theoretical quarry layout was used. Source emissions were calculated for this quarry layout using the assumptions from the previous section. All this information was entered into the ISC3 program. The program was run and the results recorded. Four runs were completed, with changes made only to the emissions from the quarry as follows: 50% of total emissions, 100% of total emissions, 150% of total emissions, and 200% of total emissions. Figure 3.1 shows the quarry layout, and Table 3.3 lists the program input sources and their corresponding emissions. All sources were input as area sources except the haul truck road and the over-the road (OTR) truck road; these two were input as line sources. Open pit sources were input as area sources on the ground surface. The weather data used in the study was 1991 Roanoke weather data. The ISC-AEROMOD View created by Lakes Environmental Software was used to facilitate the use of the ISC3 model. This program uses the ISC3 model in its original form for dispersion modeling, but it creates a Windows interface to the model, which facilitates inputting data and running the model (Thé, et. al., Vol. I, 2000).

The results of the ISC-AEROMOD View program produced a contour plot of the PM_{10} concentrations surrounding the quarry, with the contours representing the concentration of PM_{10} in grams/cubic meter (g/m^3). Two sample plots for 100% emissions data, one for the fourth highest 24-hour concentration and one for the annual average concentration, are shown in Figures 3.2 and 3.3, respectively. The first plot shown in Figure 3.2 produces contours of the fourth highest 24-hour concentration that was calculated during the year. The second plot shown in Figure 3.3 produces contours of the annual average of the daily concentrations. The annual average concentration results were used because the purpose was to compare average annual results, not the 4^{th} highest results.

Both Figures 3.2 and 3.3 contain cross-section lines, where the contour results are graphed as PM_{10} concentration versus the "X" coordinates for the east-west cross-section or "Y" coordinates for the north-south cross-section. The graphs for the annual average PM_{10} concentrations along the east-west and north-south cross-section lines are shown in Figures 3.4 and 3.5, respectively. These graphs are intended to show the calculated concentration of PM_{10} as a function of distance. The sources of these modeled emissions results that intersect the cross-section line are located at the highest points of the graphs.

Figures 3.4 and 3.5 also show that as the emissions were increased or decreased by a constant amount, the dispersion modeling results also increased or decreased by a similar

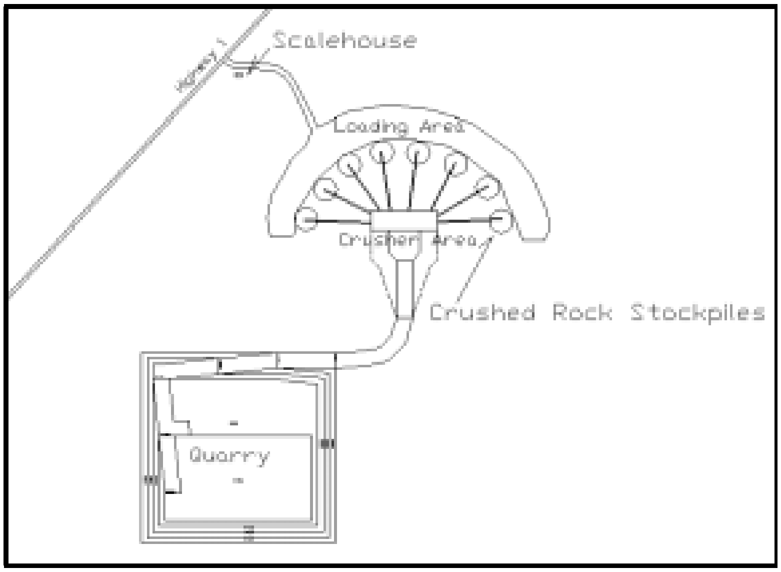


Figure 3.1 Layout of theoretical quarry.

Table 3.3 PM_{10} Emission Rates of Sources in grams/second.

Source	50% Emissions	100% Emissions	150% Emissions	200% Emissions
Crusher	4.06	8.11	12.16	16.22
Haul Truck Road	81.02	162.03	243.04	324.06
OTR Truck Road	175.34	350.67	526.00	701.34
Open Pit	104.84	209.69	314.54	419.38
Stockpile	26.14	52.29	78.44	104.58

amount. For example, when the 100% emission was doubled to 200% emissions, then the dispersion modeling results also doubled. However, a review of the results from the study conducted by Cole and Zapert, showed that the differences between modeled and measured concentrations were not consistent (Cole and Zapert, 1995). This is shown by calculating the average and standard deviation of the difference between the modeled and measured concentrations, as shown in Table 3.4. The standard deviations calculated were almost as great as the calculated average, which demonstrates a lack of consistency in the difference between modeled and measured concentrations.

Further calculations were completed on the Cole and Zapert data by reducing the modeled concentrations by 50% and calculating the average and standard deviation on the difference between the modeled and measured concentrations for these reduced concentrations. These results are shown in Table 3.5. These calculations resulted in the averages being closer to zero, demonstrating improved accuracy of the model. But the standard deviations, although smaller than previously calculated, were still very large compared to the averages. This comparison demonstrates that this improved accuracy was achieved by the model over-predicting and under-predicting in an inconsistent manner. Therefore, while the accuracy may be improved, the precision of the ISC3 model will not be improved by decreasing the emissions input into the model or by revising the emissions factors for unpaved roads, loading trucks, and loading stockpiles. The ISC3 model, itself, needs to be modified to improve its correctness.

3.4 The Cause of the Inconsistency in Modeled Vs. Measured Results

Assumptions of the ISC3 model are that the emission source is stationary with a constant emission rate and that the model calculates the concentration of a pollutant at a stationary receptor. The ISC3 model is generally used for point sources such as stacks (U.S. EPA, User’s Guide Vol. II, 1995). However, a mining facility has a different scenario. All measurements for PM_{10} emissions from a mining facility are completed at stationary points, but the majority of the PM_{10} emissions sources at mining facilities are moving sources (haul trucks and loading). This has been demonstrated through emissions calculations completed for actual and theoretical facilities.

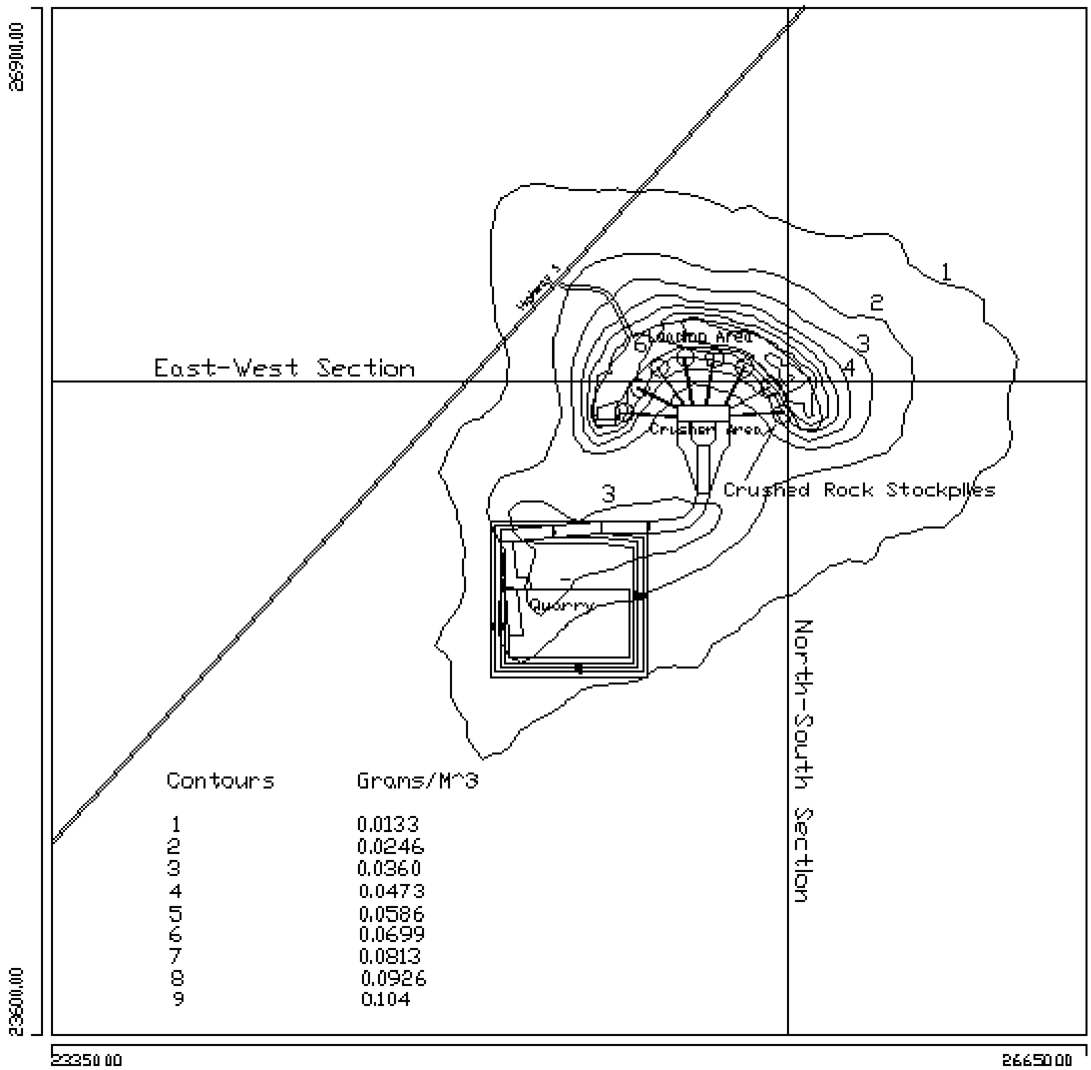


Figure 3.2 Fourth highest 24-hour PM_{10} concentration plot for theoretical quarry.

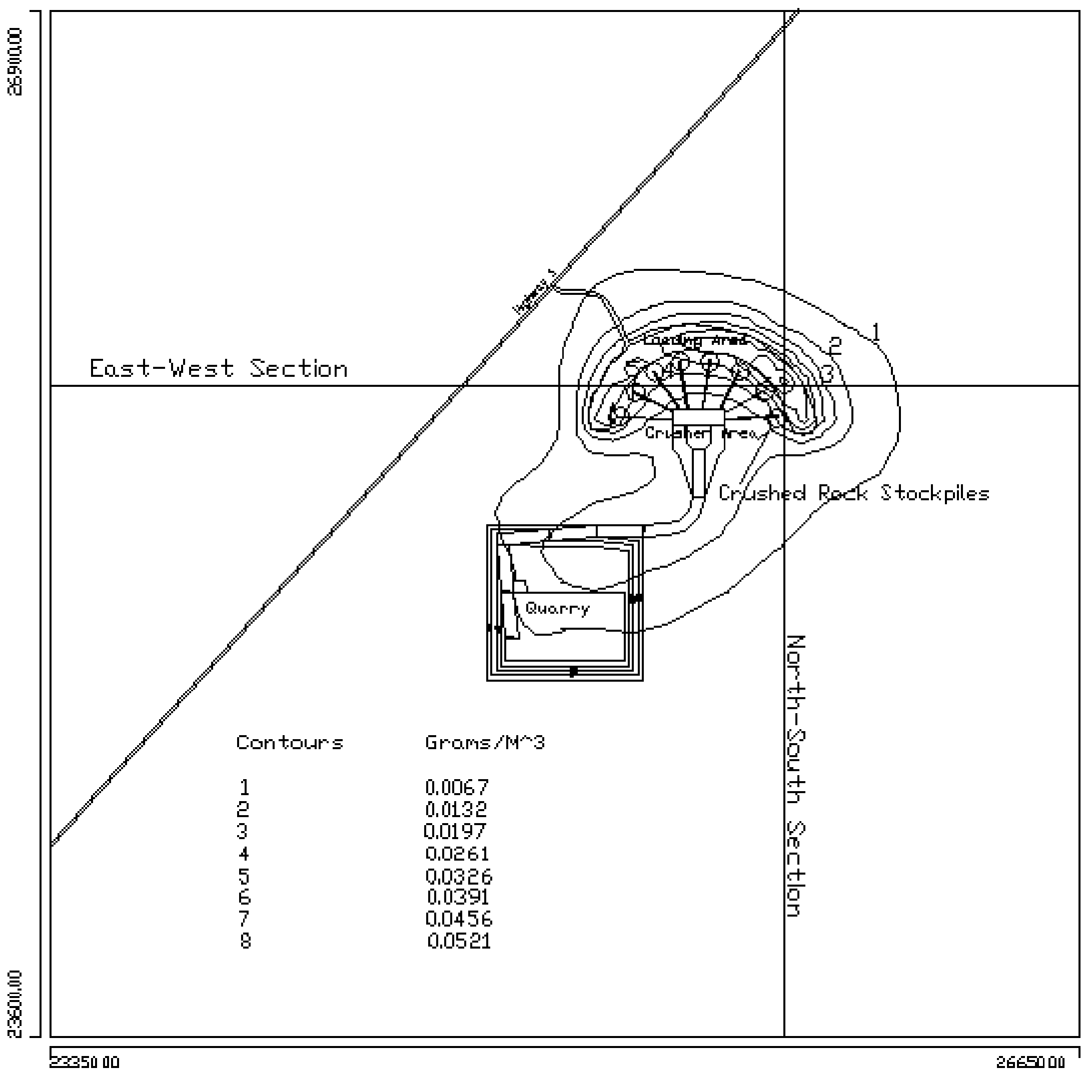


Figure 3.3 Annual average PM_{10} concentration plot for theoretical quarry.

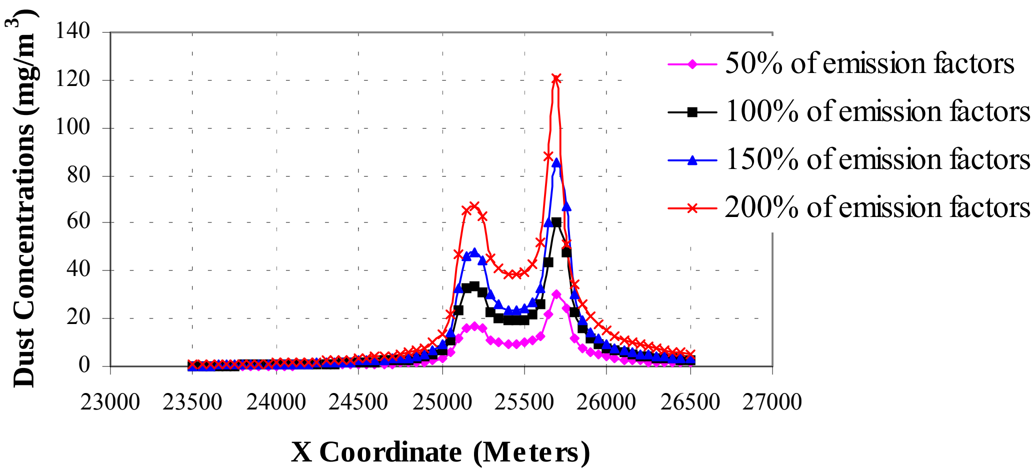


Figure 3.4 Annual average PM_{10} concentrations along East-West cross-section line of theoretical quarry.

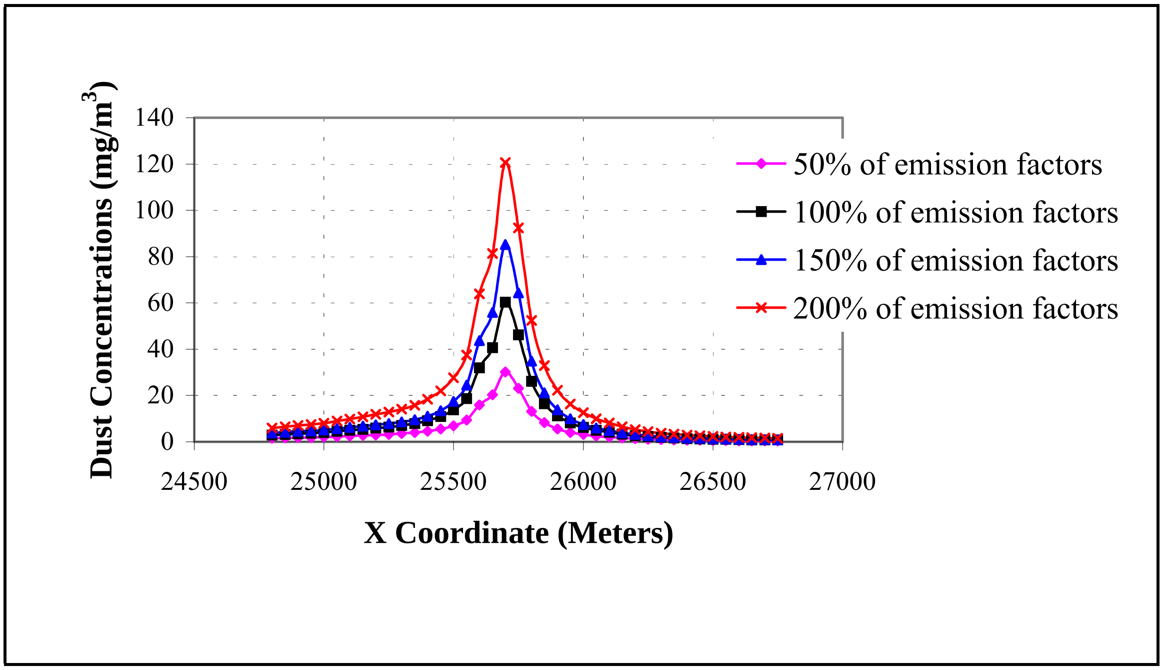


Figure 3.5 Annual average PM_{10} concentration along North-South cross-section line of theoretical quarry.

Table 3.4 Average and standard deviations of the difference between modeled concentrations and measured concentrations from study completed by Cole and Zapert, 1995.

	Quarry 1 ($\mu g/m^3$)	Quarry 2 ($\mu g/m^3$)	Quarry 3 ($\mu g/m^3$)
Average	43.56	37.00	59.51
Standard Deviation	40.77	78.54	41.76

Table 3.5 Average and standard deviations of the difference between 50% of modeled concentrations and measured concentrations from study completed by Cole and Zapert, 1995.

	Quarry 1 ($\mu g/m^3$)	Quarry 2 ($\mu g/m^3$)	Quarry 3 ($\mu g/m^3$)
Average	3.64	-2.56	22.80
Standard Deviation	23.92	45.29	21.99

The over-prediction of PM_{10} concentrations by the ISC3 model may occur because the model applies the total emissions of the mobile sources to a specific area source. This application creates a constant uniform distribution of emissions over this specified area, as shown in Figure 3.6. In real-life, the emissions from traffic or a mobile source are not uniform (Micallef and Colls, 1999). Figure 3.7 shows how the emissions from a moving haul truck actually occur. They act more like a moving point source rather than the continuous uniform emission distribution that the ISC3 model uses. A moving point source is more representative because the emissions occur abruptly as the emissions source approaches a point and then slowly dissipate as the emissions source moves away from the point. At a mining facility, this moving point source will move along a predictable path from the pit to the processing operations.

There have been studies of pollutant dispersion modeling along highways, and modeling the emissions of haul trucks is similar to modeling emissions of highways. However, these studies generally focus on pollutants other than PM_{10}, and they use other models besides the ISC3 model. The emissions from traffic flow are also generally treated as line or volume sources, which are basically modified area sources, and are modified depending upon the traffic volumes and the scale of the modeling (Owen, et. al., 1999). Line or volume sources are used because dispersion modeling systems, coupled with traffic flow models, do not currently exist (Schmidt and Schafer, 1998). Mining facilities generally do not have a high traffic volume; therefore, the line or volume sources are not adequate for representing the haul truck flow at mining facilities.

In order to more accurately represent this moving point source in dispersion modeling, a dynamic component representing haul truck emission sources shall be introduced into the ISC3 model to reduce the over-prediction of PM_{10} emissions for surface mining operations.

3.5 Proposed Correction of the ISC3 Model

The Dynamic Component is based upon the Gaussian dispersion equation for point source emissions since this is the approach of the current ISC3 model. There are other modeling equations available for estimating dispersion such as the Box dispersion model, the Eularian dispersion model, and the Lagrangian dispersion model. The Box model is the simplest modeling method, but it applies the emissions to an area creating a uniform distribution of

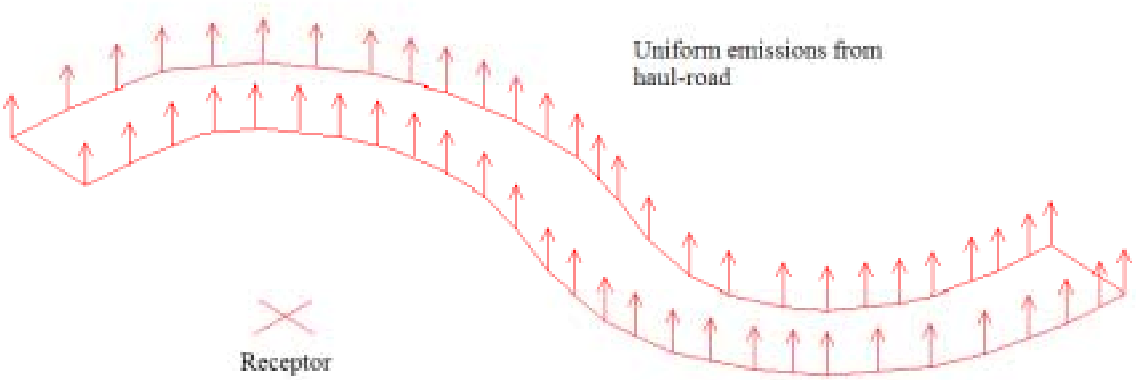
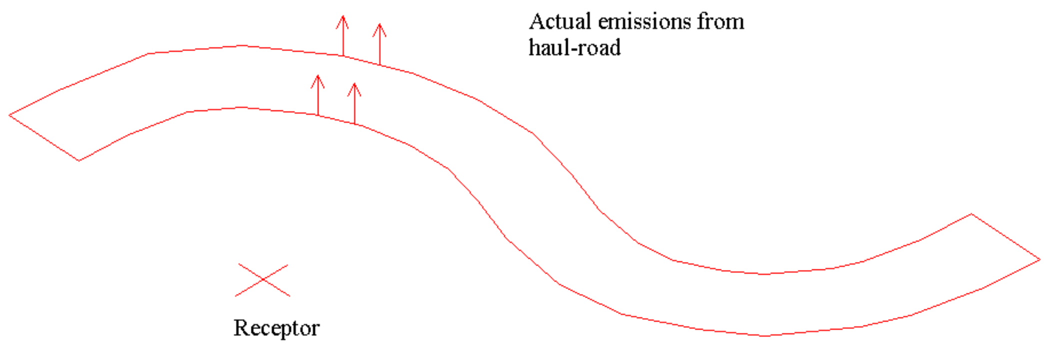


Figure 3.6 Emissions from haul-road as handled by the ISC3 model.



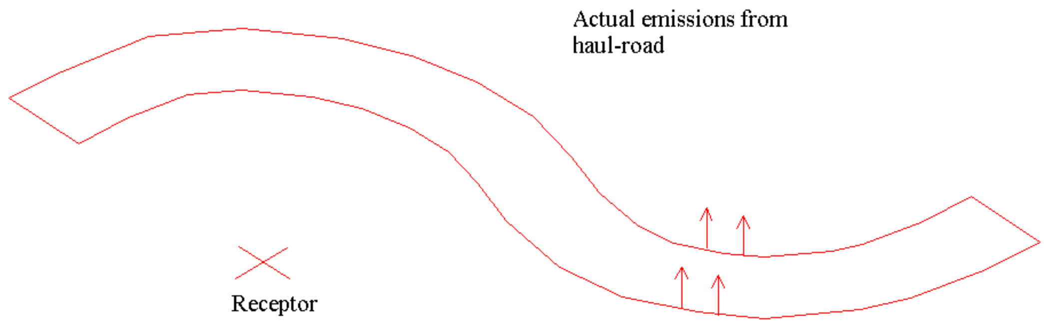


Figure 3.7 Representation of actual emissions from a haul truck.

emissions over that area (Collett and Oduyemi, 1997). This is not representative of the mobile sources; therefore, the Box modeling method will not be used. The Eularian and Lagrangian dispersion models use detailed information of dispersion parameters, such as rate of advection, rate of turbulent diffusion, and rate of molecular diffusion of pollutants, to predict dispersion (Collett and Oduyemi, 1997). These modeling methods are more detailed than required at this time therefore, they will not be used at this time but they may represent areas of future research.

3.5.1 Dynamic Component Equations

The main dispersion equation for the Dynamic Component model is the Gaussian dispersion equation, which is represented by the following equation:

$$\chi = \frac{QKVD}{2\pi u_s \sigma_y \sigma_z} \exp\left[-0.5\left(\frac{y}{\sigma_y}\right)^2\right] \qquad (3.1)$$

where

χ	=	hourly concentration at downwind distance x in μg/m^3.
Q	=	pollutant emission rate in grams/second (g/s).
K	=	conversion factor $1x10^6$ for χ in μg/m^3 and Q in g/s.
V	=	vertical term.
D	=	decay factor, a default value of 1 if decay of pollutant is unknown.
u_s	=	mean wind speed at emissions release height in m/s.
σ_y	=	standard deviation of lateral concentration distribution in m.
σ_z	=	standard deviation of vertical concentration distribution in m.

The decay term D is assumed to be one. The vertical term V is calculated using the mechanical mixing height, the stack height or emission height, and the receptor height. However, because the emission height and the receptor height for haul trucks are nearly equal, and the emissions of the haul truck will never be above the mechanical mixing height, V can be eliminated from Equation (3.1).

The u_s term is an adjustment of the wind speed using the measurement height and the emission height. Since the emission height will never be above the measurement height, the actual wind speed was used. These changes resulted in the following new dynamic component equation:

$$\chi = \frac{QK}{2\pi w_s \sigma_y \sigma_z} \exp\left[-0.5\left(\frac{y}{\sigma_y}\right)^2\right] \qquad (3.2)$$

where

χ	=	hourly concentration at downwind distance x in μg/m^3.
Q	=	pollutant emission rate in g/s.
K	=	conversion factor 1x10^6 for χ in μg/m^3 and Q in g/s.
w_s	=	wind speed in m/s.
σ_y	=	standard deviation of lateral concentration distribution in m.
σ_z	=	standard deviation of vertical concentration distribution in m.

3.5.2 Other Terms Defined

The terms σ_y and σ_z are both calculated using the downwind distance and the Pasquil-Gifford stability categories (U.S. EPA, User's GuideVol. II, 1995). The equation for σ_y is represented by the equation:

$$\sigma_y = 465.11628(x)\tan(TH) \qquad (3.3)$$

where

σ_y	=	standard deviation of lateral concentration distribution in m.
x	=	downwind distance in km.
TH	=	function of Pasquil-Gifford stability categories, units are in degrees.

The variable TH is defined by the following equation:

$$TH = [c - d\ln(x)] \qquad (3.4)$$

where

c,d	=	constants defined by the Paquil-Gifford stability categories which are determined by wind speed.
x	=	downwind distance in km.

The downwind distance is defined by the following equation:

$$x = -(X(R) - X(S))\sin(WD) - (Y(R) - Y(S))\cos(WD) \qquad (3.5)$$

where

x	=	downwind distance in m.
$X(R)$	=	x coordinate of the receptor in m.
$X(S)$	=	x coordinate of the source in m.
$Y(R)$	=	y coordinate of the receptor in m.
$Y(S)$	=	y coordinate of the source in m.
WD	=	north azimuth of wind direction in degrees.

The other term σ_z has the following equation:

$$\sigma_z = ax^b \tag{3.6}$$

where

σ_z	=	standard deviation of vertical concentration distribution in m.
x	=	downwind distance in km.
a,b	=	constants defined by Pasquil-Gifford stability categories and the downwind distance.

The y term used in Equation (3.2) is given by the following equation:

$$y = (X(R) - X(S))\cos(WD) - (Y(R) - Y(S))\sin(WD) \tag{3.7}$$

where

y	=	crosswind distance in m.
$X(R)$	=	x coordinate of the receptor in m.
$X(S)$	=	x coordinate of the source in m.
$Y(R)$	=	y coordinate of the receptor in m.
$Y(S)$	=	y coordinate of the source in m.
WD	=	north azimuth of wind direction in degrees.

All of the previous terms and equations are the same equations used by the USEPA in the ISC3 model (U.S. EPA, User's Guide Vol. II, 1995). The only equation that differs is Equation (3.2) where V has been removed and where u_s becomes the actual wind speed instead of an adjusted wind speed.

The emission rate Q for PM_{10} is calculated for the haul trucks using the emissions factor for haul trucks published in U. S. EPA's AP-42 (U.S. EPA, AP-42, Unpaved Road, 1998). This emission factor equation is represented by the following equation:

$$Q = \frac{2.6\left(\frac{s}{12}\right)^{0.8}\left(\frac{W}{3}\right)^{0.4}}{\left(\frac{M}{0.2}\right)^{0.3}} \tag{3.8}$$

where

Q	=	emissions from haul truck in pounds/vehicle mile traveled (lb/vmt).
s	=	surface material silt content in %.
W	=	mean vehicle weight in tons.
M	=	surface material moisture content in %.

Equation (3.8) uses English units instead of SI units. In order to use Q, calculated from equation (3.8), Q had to be converted from lb/vmt to g/s. This was accomplished by converting lb/vmt to grams per vehicle meters traveled, then multiplying it by the speed of the haul truck in m/s.

3.5.3 Dynamic Component Algorithm

The procedure for calculating dispersion of PM_{10} for mobile sources by the new model is described as follows: The processed hourly meteorological data will be read into the program and used in the ISC3 model for use in the Equation (3.2). Each hourly meteorological data point will be used at each "X" and "Y" coordinate of the source and receptor as described later.

Haul road information will be input into the program representing the possible locations of the source (haul truck). Receptor coordinates will be input representing the desired locations for results of the modeling exercise. Each source and receptor will have an "X" and a "Y" coordinate. These "X" and "Y" coordinates will be input into the downwind and crosswind distance Equations (3.5) and (3.7), respectively, to calculate the downwind distance x and crosswind distance y, which are then input into Equation (3.2), the Gaussian equation.

Receptor array variables will be created which are representative of the locations of PM_{10} monitors at a mine site. These variables will contain the PM_{10} concentrations calculated by Equation (3.2).

The Dynamic Component will calculate the PM_{10} concentrations from the mobile emissions source for the receptor variables. The sources will be mobilized by changing the "X" and "Y" coordinates of the source. At the starting point of the mobile emissions source, the PM_{10} concentrations for the receptors will be calculated using the starting "X" and "Y" coordinates of the source, the "X" and "Y" coordinates of the receptor, and the meteorological data for the current hour.

The coordinates of the mobile source will be changed by a predetermined amount (N) representing the movement of the source and resulting in a new "X_{X+N}" and "Y_{Y+N}" coordinate. This change in coordinates, (N), will be determined by the path and the speed of the source. The PM_{10} concentrations for the receptors will be calculated resulting in new receptor variables. These calculations will continue until the mobile source has reached the end of its travel. When the mobile source has finished its run, the meteorological data will proceed to the next hour of data, and the process will repeat. The end-result will be a list of receptor array variables sequenced by receptor, source location, and meteorological data hour. Figure 3.8 shows a simplified flow chart for the Dynamic Component Program algorithm that was previously described.

The receptor array variables will then be averaged to obtain a final total concentration for each receptor for the time-period that the model is run. This will be accomplished through a separate program dedicated to the manipulation of the receptor array variables. Figure 3.9 shows the simplified flow chart of the algorithm for this program.

3.6 Description of Dynamic Component Program Operation

The Dynamic Component Program was created using Microsoft Visual Basic 6.0. The program name is "*Dynamic Component ISC3*

DYNAMIC COMPONENT ISC3.EXE

." The complete Visual Basic code for this program can be found in Appendix C. This program is designed to calculate the concentration of PM_{10} at a receptor from a haul truck traveling along a predetermined path using Equation (3.2). Only straight paths are allowed in the initial release of the program. The program emulates the calculations used in the ISC3 Program, but the program introduces the dynamic component previously described in the Dynamic Component Algorithm section. A complete set of operating instructions can be found in Appendix D.

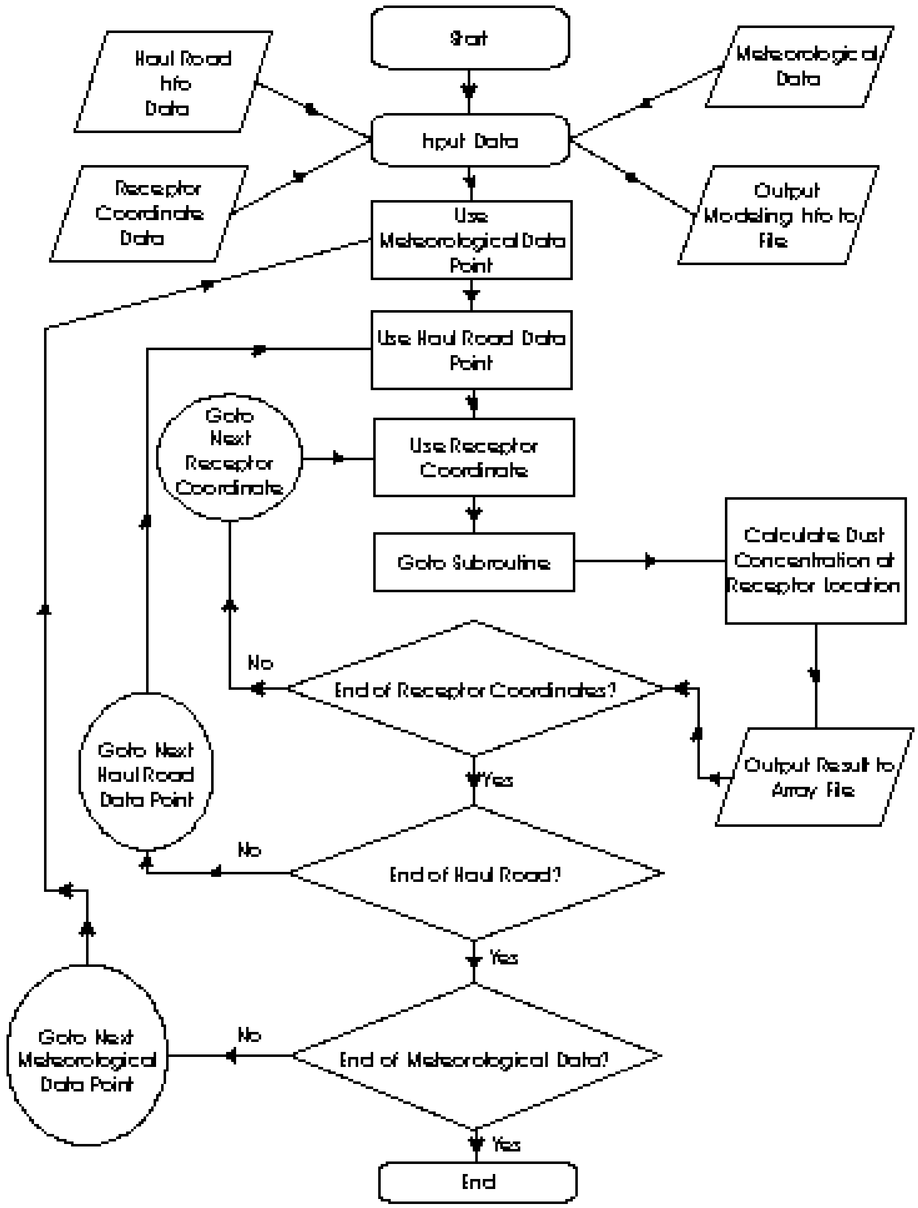


Figure 3.8 Flow chart of simplified algorithm for Dynamic Component Program.

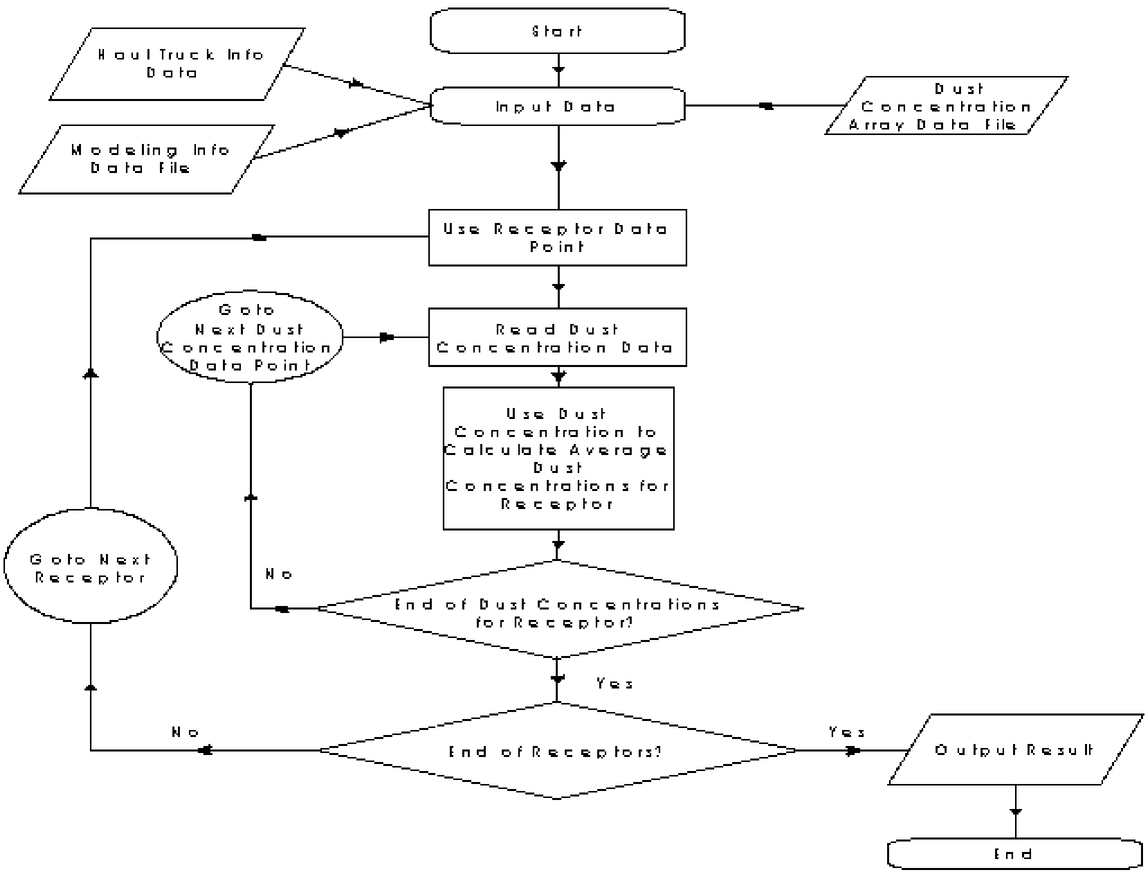


Figure 3.9 Flow chart of simplified algorithm for program that manipulates the receptor array variables from the Dynamic Component Program.

The first step of the program is to input all the data required for the calculations. The data include receptor coordinates, haul truck pathway coordinates, weather data for the entire year, and all other information required by the emission factor equation.

Figure 3.10 shows the window displayed when the program is started. Once the program is started, information is requested via interactive menus. The first input is the haul road information. Figure 3.11 shows the series of window displays for inputting the haul road information. An equation characterizing the haul road in Cartesian coordinates must be known. The equation is in the form:

$$y = mx + b \tag{3.9}$$

where

y	=	Y coordinate of the line representing the haul road.
x	=	X coordinate of the line representing the haul road.
m	=	slope of the line representing the haul road.
b	=	Y-intercept of the line representing the haul road.

Once entered, the haul truck pathway coordinates are calculated from the straight line between the starting and ending coordinates that are input into the program.

The receptor coordinates are read in from an ASCII file. The program will automatically ask for the location of the file, which contains the receptor coordinates. Figure 3.12 shows the window displays for the receptor information.

Once the receptor information is read-in by the program, it will display a series of interactive menus to obtain information concerning the haul road material and the haul trucks using the road. Figure 3.13 presents the window displays for obtaining this information. The program will then calculate the PM_{10} emissions for the haul truck using the information obtained and the U.S. EPA's emission factor equation for unpaved roads from AP-42. The results are displayed as shown in Figure 3.14. The program will then ask for the height of the receptor to complete the first stage of inputs.

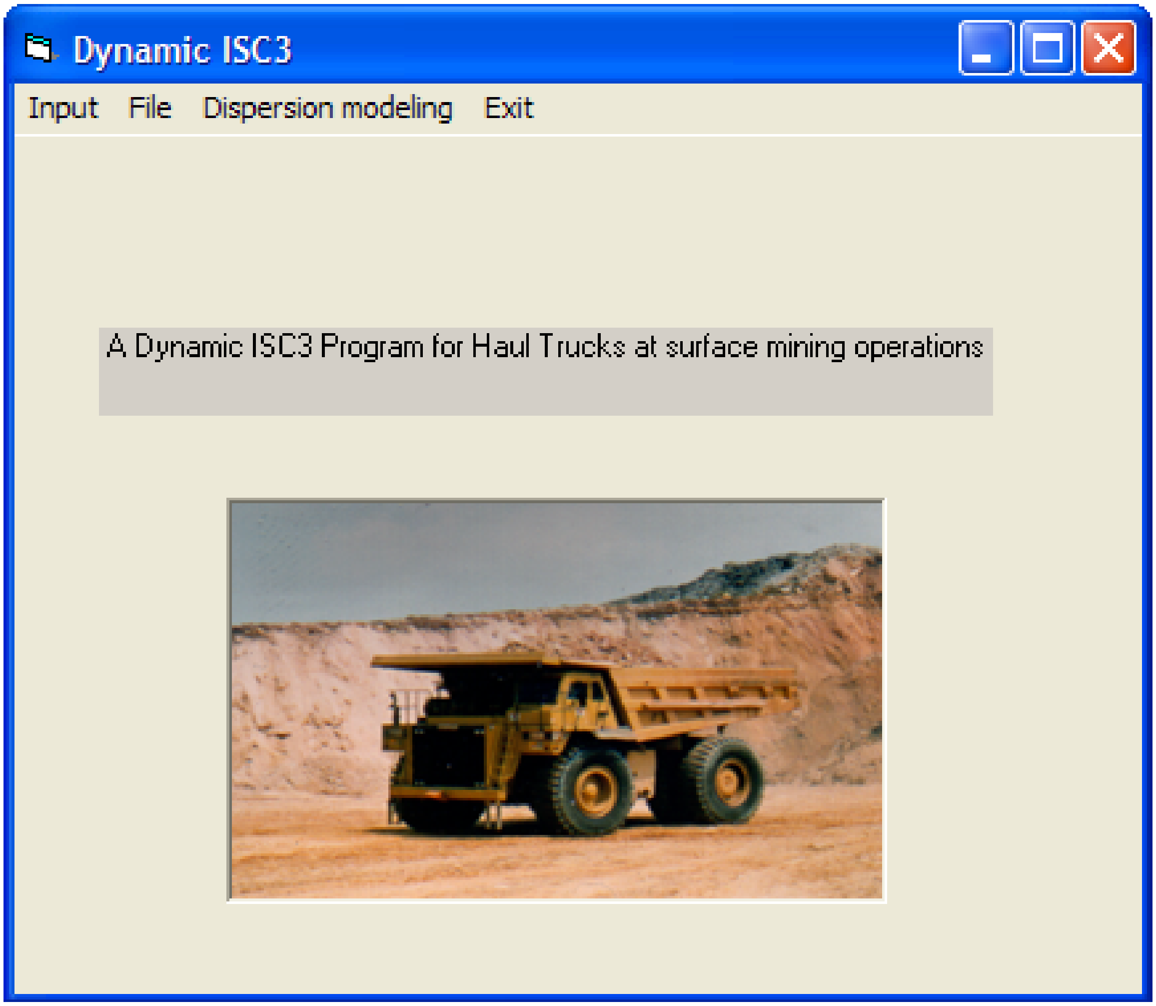


Figure 3.10 Startup window display of *Dynamic Component ISC3*.

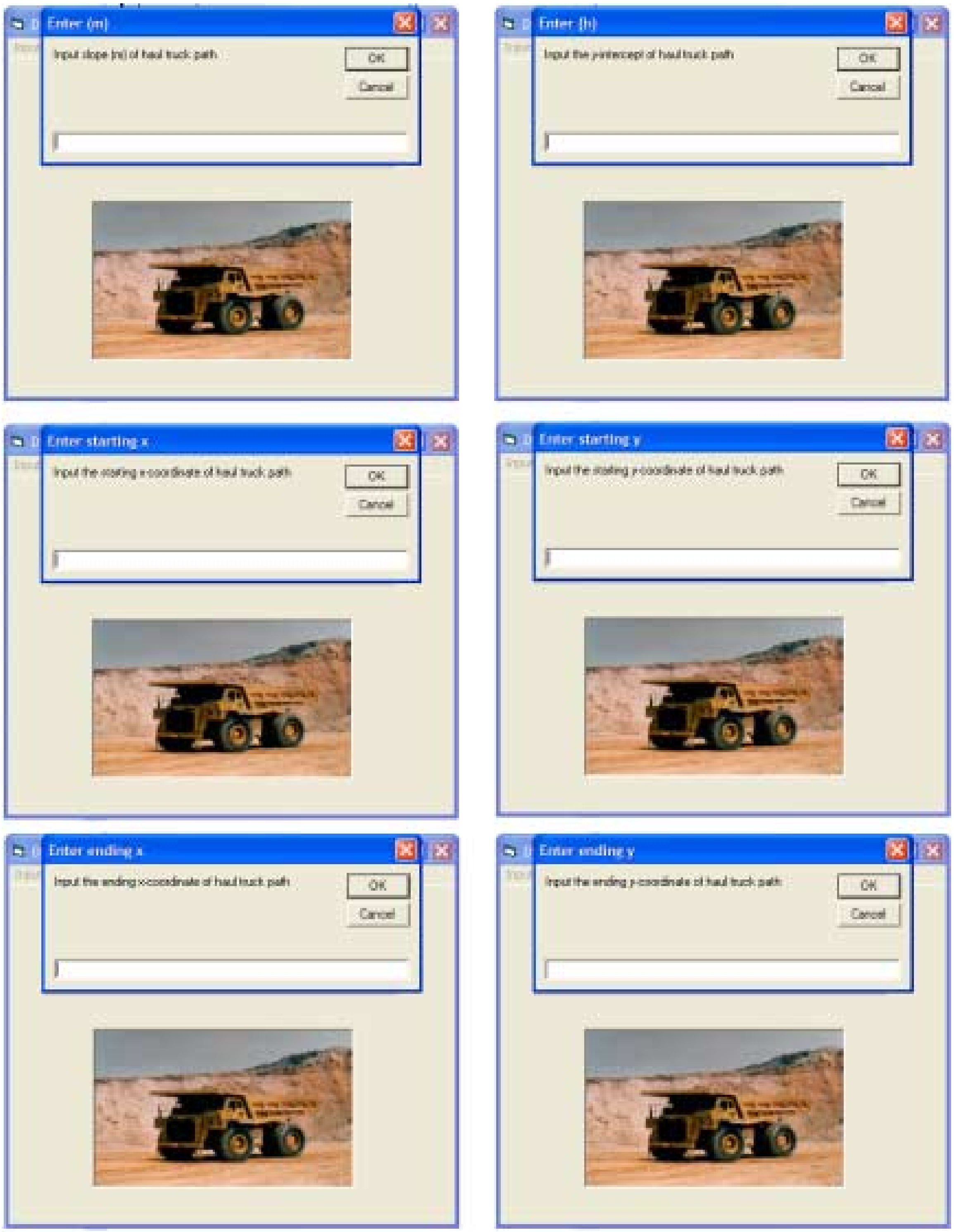


Figure 3.11 Windows requesting information about the haul road (the sequence follows left to right then from top to bottom).

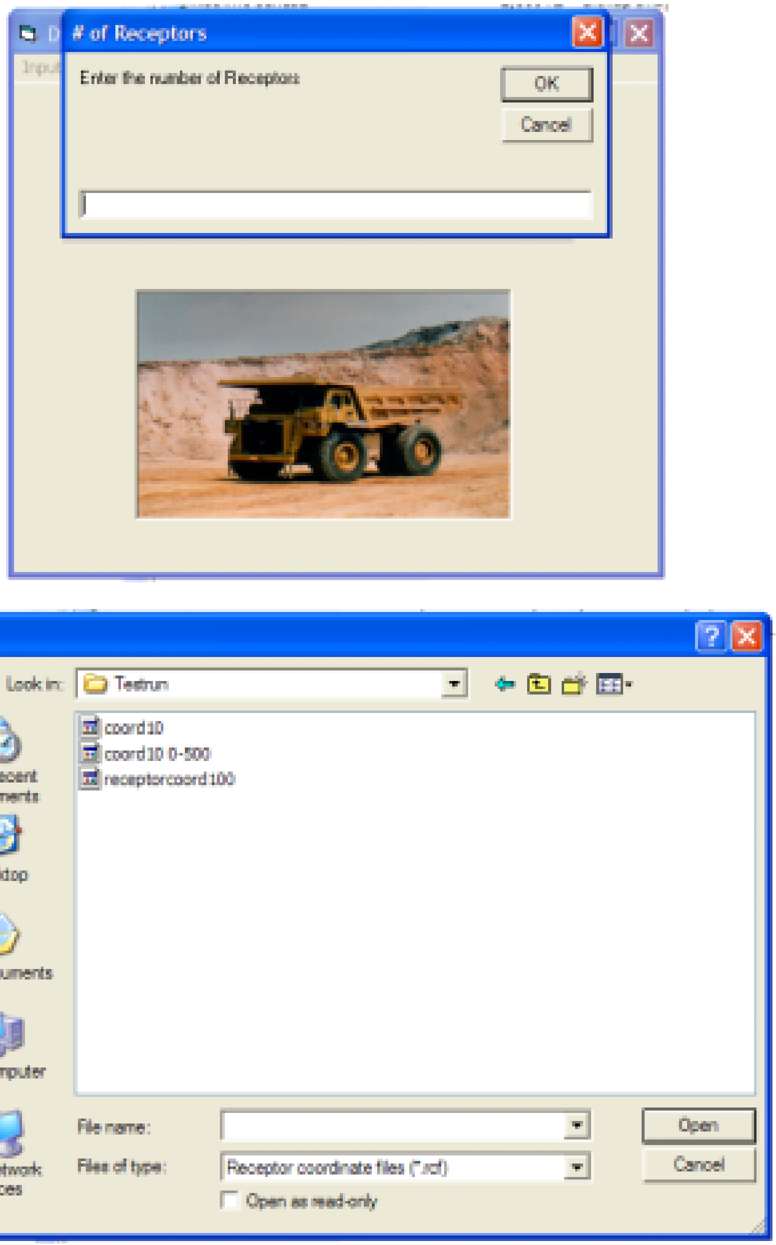
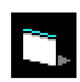


Figure 3.12 Window displays for inputting receptor coordinate data from file.

The "*File*" menu can be activated next and the weather data can be input. Figure 3.15 shows the window displays for entering the weather data into the program. The weather data are read in from an ASCII file. This file contains the following information: year, month, day, hour of day, wind speed, wind direction, and temperature. The "hour of day" variable is used by *Dynamic Component ISC3* only as a sorting mechanism for the weather data. This variable could have other units of time such as minutes or seconds. However, the ISC3 model requires this variable to be the actual hour of the day, since it cannot calculate sub-hourly concentrations. In addition to the above listed variables, there are dummy variables and reference heights for the wind data and temperature that are read into the program but are not used.

The weather information can be obtained from the U.S. EPA's website that contains weather information from airports around the country. The information from this website requires some minor manipulating in order to be used in *Dynamic Component ISC3*. The format for the file to be input into *Dynamic Component ISC3* can be found in Appendix D. The Pasquil-Gifford stability categories, listed in Appendix A, are used in this program for calculating PM_{10} concentrations at receptors. These stability categories are built into the Dynamic Component Program and therefore, do not require input.

Figure 3.16 displays the windows that are presented to create a data file that will contain all the information input up to this point, except the weather data. This file is required in the next program, named "*Dynamic Manipulation*



DYNAMIC MANIPULATION.EXE

," which completes the manipulation of the array variables to calculate the final concentrations for each receptor.

The next step is to calculate the PM_{10} concentrations once all the information is input. These calculations are completed using Equation (3.2) in the algorithm presented in Figure 3.8. The concentrations are calculated at each receptor coordinate using all the haul truck coordinates of the haul road for all hourly weather data. This creates a list of concentrations broken down into haul truck coordinate, weather hour data, and receptor number. Figure 3.17 shows window that contains the menu for calculating the PM_{10} concentrations.

Once the calculations have been completed, the results need to be saved as a data file for use in *Dynamic Manipulation*. This file can be quite large depending upon the length of the

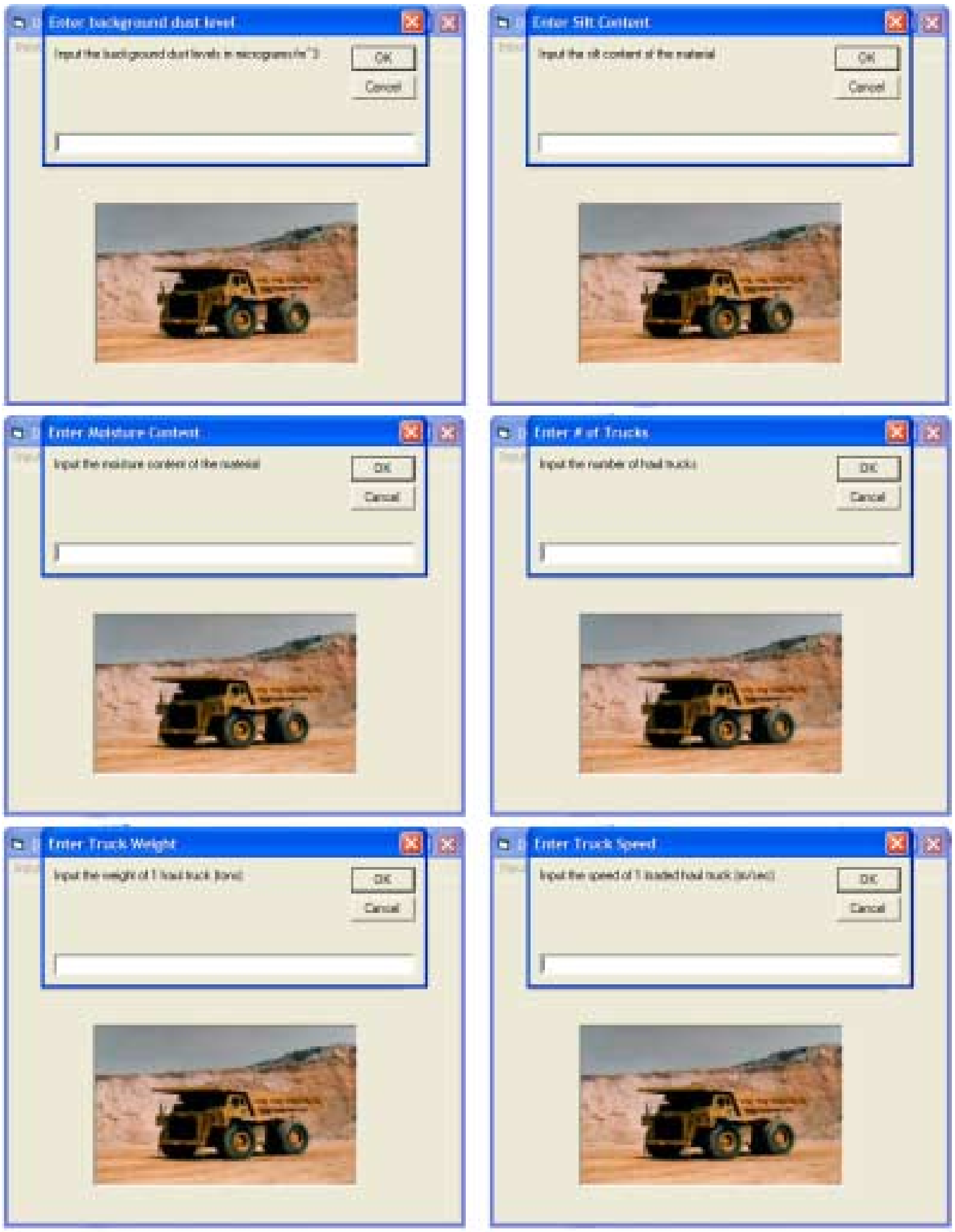


Figure 3.13 Window displays for obtaining information about the haul road material and the haul trucks (the sequence follows left to right then from top to bottom).

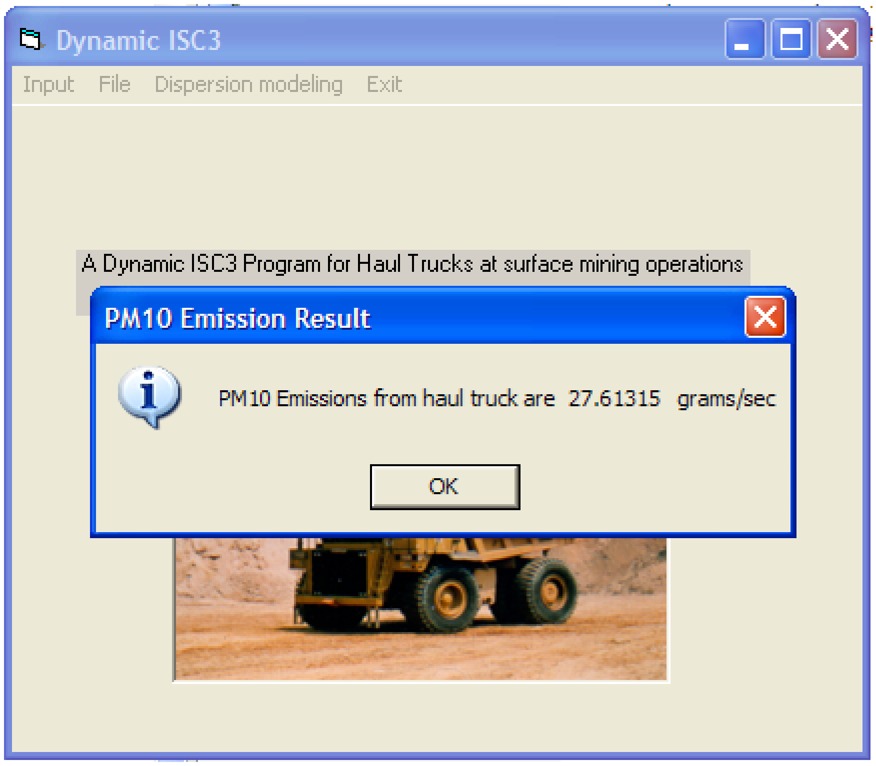


Figure 3.14 Window displaying the results of the calculation for the amount of PM_{10} emitted from the haul truck.

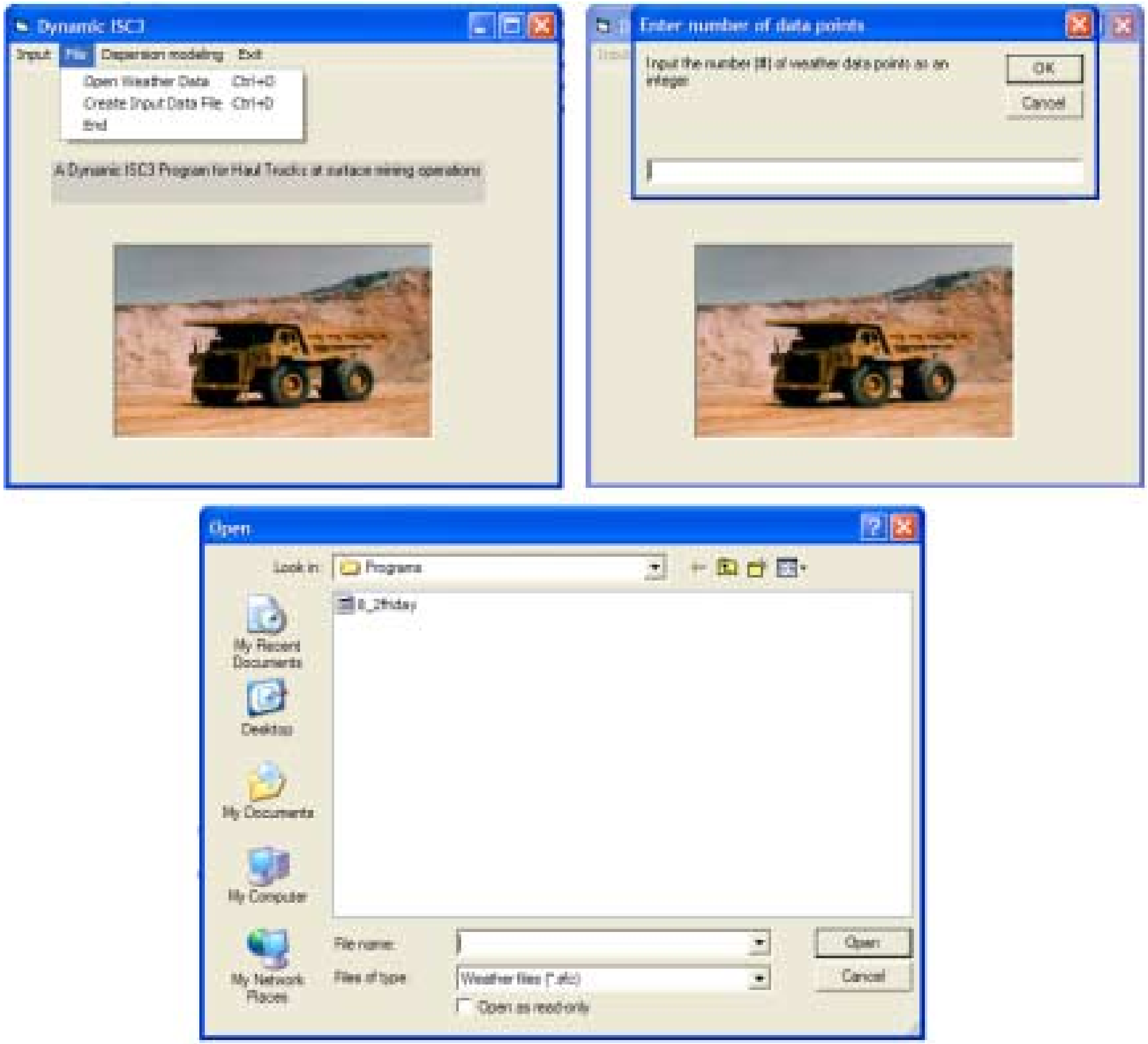


Figure 3.15 Window displays for entering weather information (the sequence follows left to right then from top to bottom).

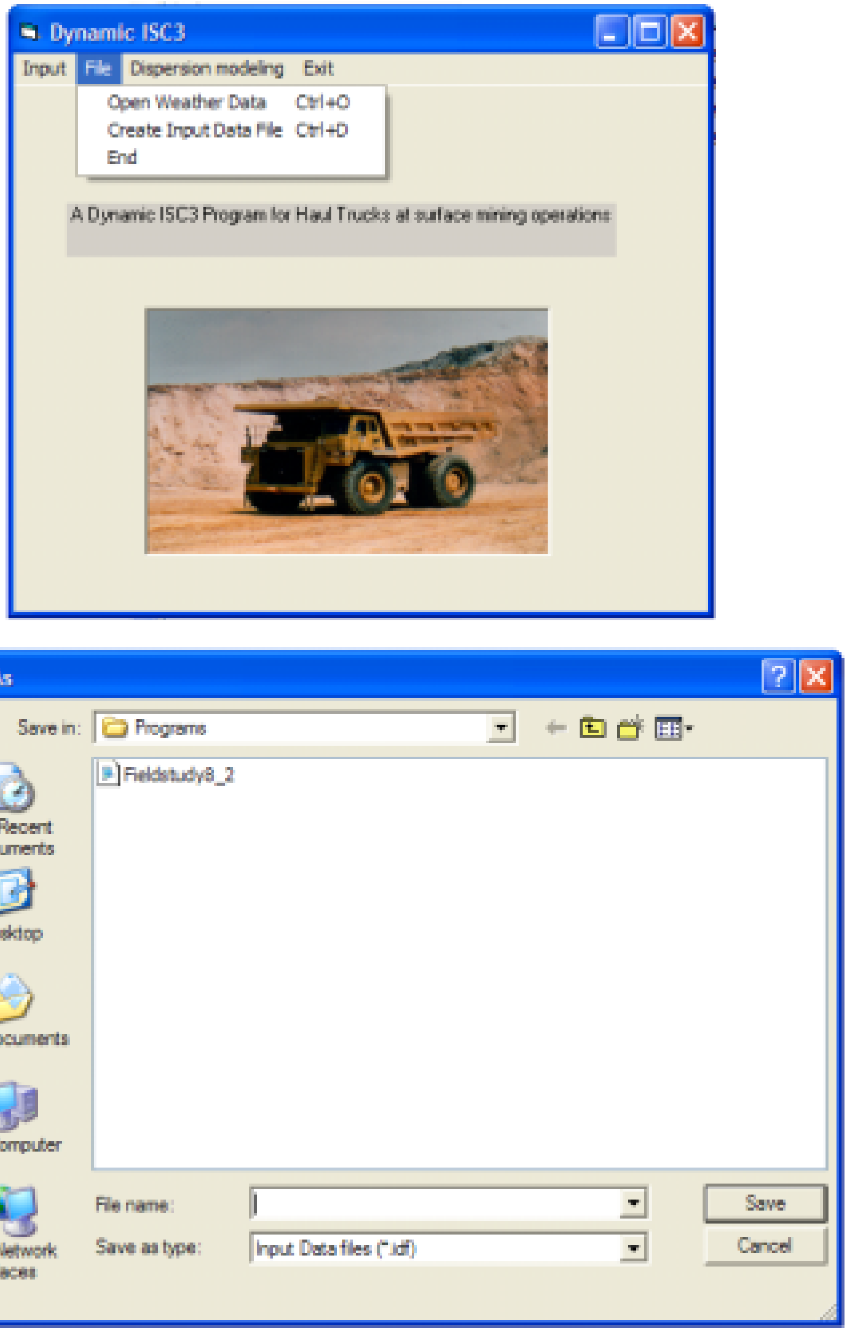


Figure 3.16 Window displays for the creation of "input data" file.

haul road, amount of weather data, and the number of receptors. Files with sizes up to 29 Megabytes are common. Figure 3.18 presents the windows that are displayed to create the array data file.

To calculate the final PM_{10} concentration for each receptor, the program "*Dynamic Manipulation*" must be used. Memory constraints on the PC required that the process of calculating these final concentrations be split into two programs: *Dynamic Component ISC3*, previously described, that creates the array file, and *Dynamic Manipulation* that calculates the final PM_{10} concentrations.

Dynamic Manipulation requires input of the two data files created by the *Dynamic Component ISC3* program. These two data files are the input data file and the array variable file. At this point in the modeling exercise, the frequency of the haul trucks traveling the haul road must be known. Figure 3.19 shows the window displays for entering the input data file. Figure 3.20 shows the window displays for entering the array variable file.

The next step is to calculate the final PM_{10} concentrations for each receptor. This is completed using the following equation:

$$X = \frac{\left(\left(y\left(\frac{cD}{\left(S/60\right)}\right)\right) + \left(BE\left(t - \left(\frac{cD}{\left(S/60\right)}\right)\right)\right)\right)}{t} \tag{3.10}$$

where

X	=	final PM_{10} concentration for receptor after correction for background emission level in μg/m^3.
y	=	PM_{10} concentration for receptor before correction for background emission level in μg/m^3.
c	=	frequency of trucks traveling the haul road (number of truck passes).
D	=	distance of haul road segment in meters.
S	=	speed of haul truck in m/sec.
BE	=	PM_{10} concentration background emission level for site in μg/m^3.

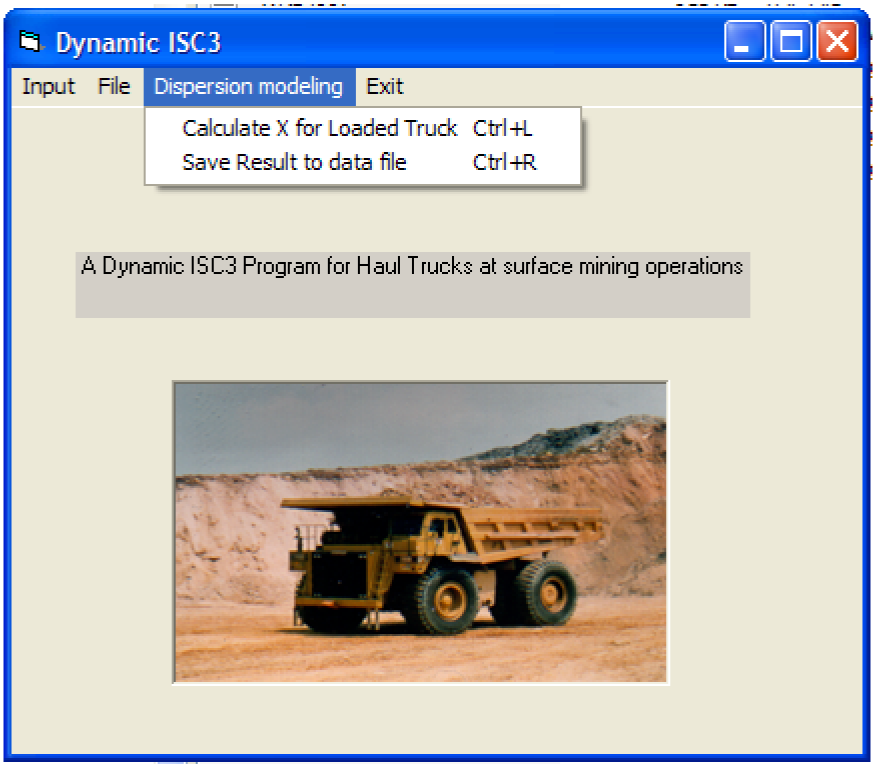


Figure 3.17 Display of menu to calculate the PM_{10} concentrations for the array file.

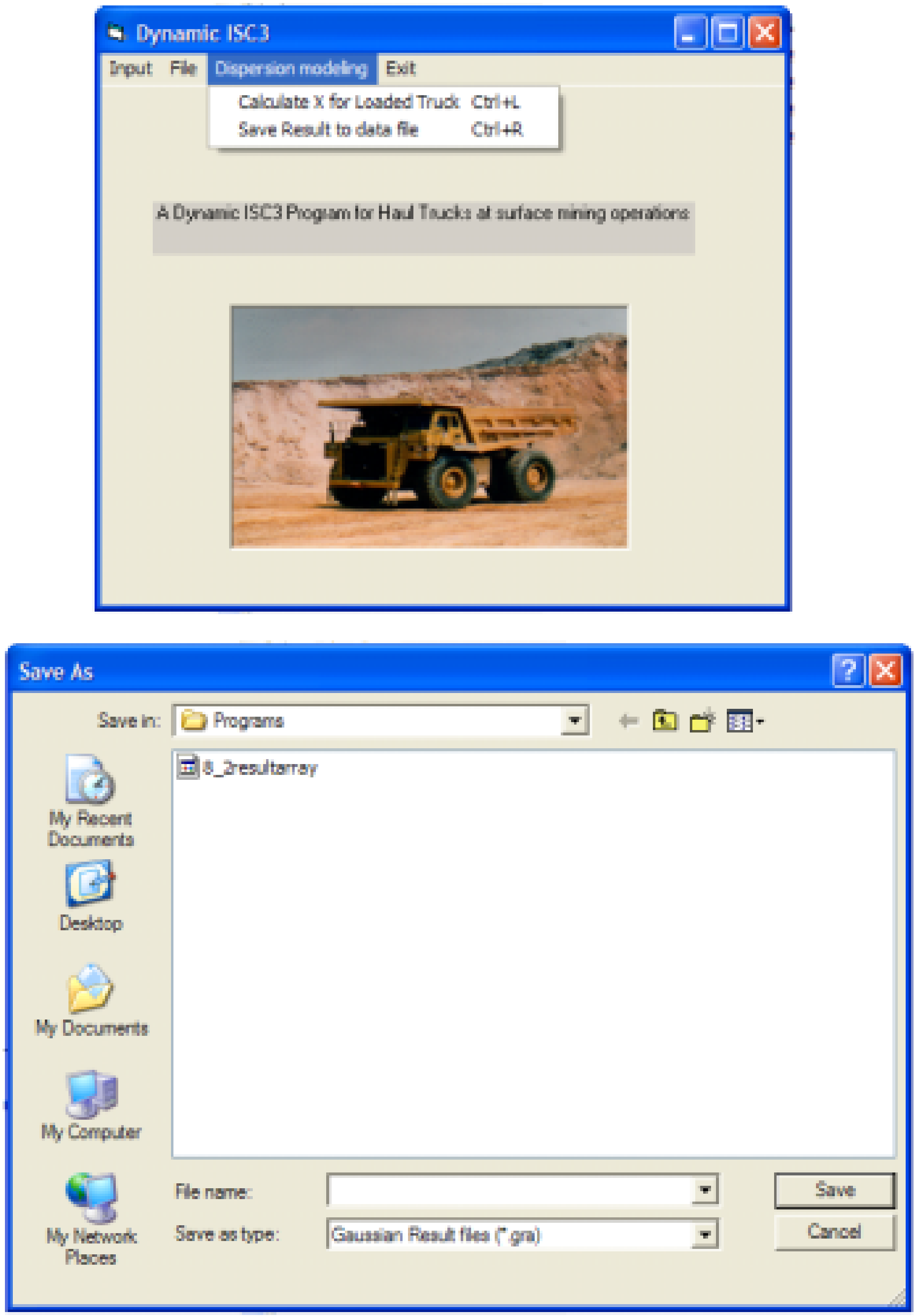


Figure 3.18 Display of menus to create the PM_{10} concentration array file.

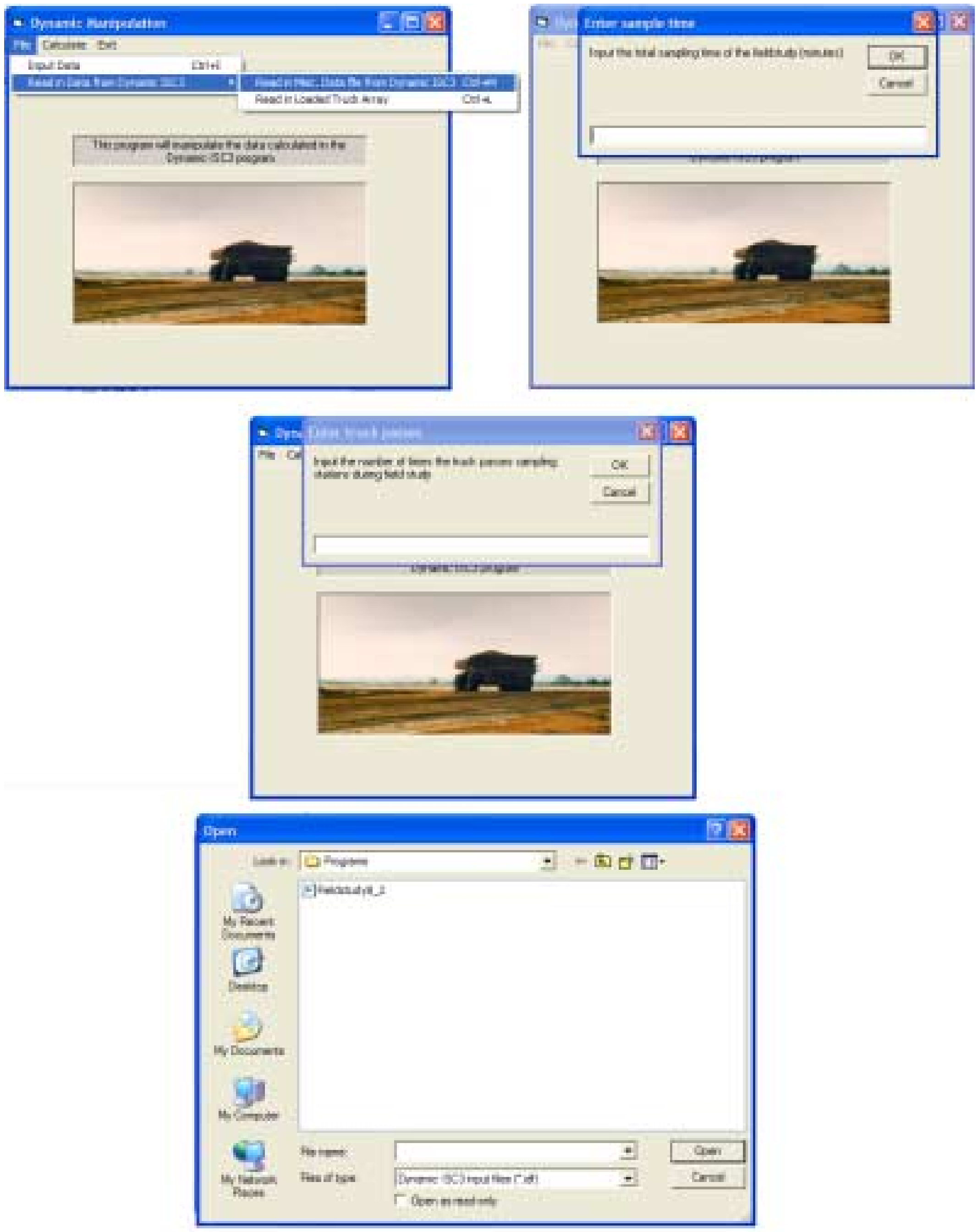


Figure 3.19 Window displays for entering the input data file created by *Dynamic Component ISC3* (the sequence follows left to right then from top to bottom).

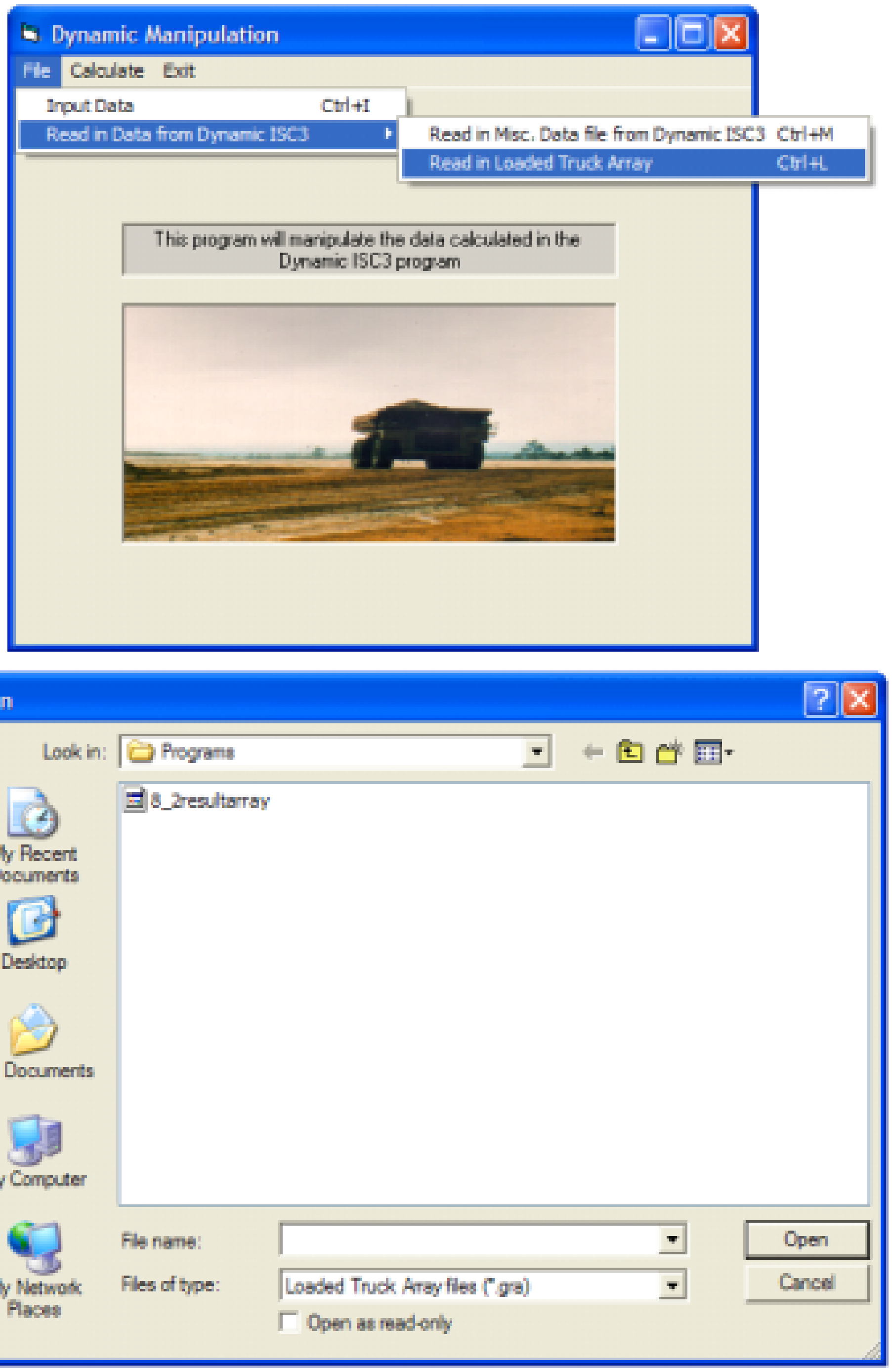


Figure 3.20 Window displays for entering array variable file, created by Dynamic *Component ISC3*, that contains the calculated PM_{10} concentrations.

The list of corrected PM_{10} concentrations are averaged for each receptor. These averages are then corrected using the PM_{10} concentration background emissions level for the site. This practice results in a more conservative result because the correction has the effect of raising the receptor concentrations. Figure 3.21 shows the window display for calculating the final PM_{10} concentrations.

Once the final PM_{10} concentrations are calculated, the results are output to the default printer. There is no method to display the results to the video screen unless Adobe Acrobat is set as the default printer. Figure 3.22 shows the window for printing out the results. Figure 3.23 shows the printout of results using the data from the August 2, 2002 field study. The printout presents the input data along with the results for the modeling exercise. On the first page the PM_{10} concentration results for each receptor are uncorrected for PM_{10} concentration background emission levels. The time-weighted-average PM_{10} concentration results, shown under page two of the printout, are corrected using the PM_{10} concentration background emission levels for the site.

3.7 Comparison of Dynamic Component Program and the ISC3 Program

To test the Dynamic Component Program, a test situation was created and run in both the Dynamic Component Program and the ISC3 Program. The results were then compared to determine whether the Dynamic Component Program was an improvement over the ISC3 Program. If the results of the Dynamic Component Program predict dust concentrations that are lower than the ISC3 model, it will be considered an improvement over the ISC3 model.

The test situation consisted of a haul road and receptor layout, as shown in Figure 3.24. The haul road shown in this figure represents the possible locations of the point source (haul truck). Other information used in the test situation is listed in Table 3.6. The receptors were located perpendicular to the haul road, with approximately 15 meters between the receptors. Receptor coordinates were input by data file. The weather data used in the test situation was downloaded from the U. S. EPA’s website and converted using RAMMET View, a program created by Lakes Environmental that emulates the U.S. EPA’s PCRAMMET program (Thé, et. al., Vol II, 2000). The data were from the Pittsburgh Greater International Airport for 1990. These data were also input by data file.

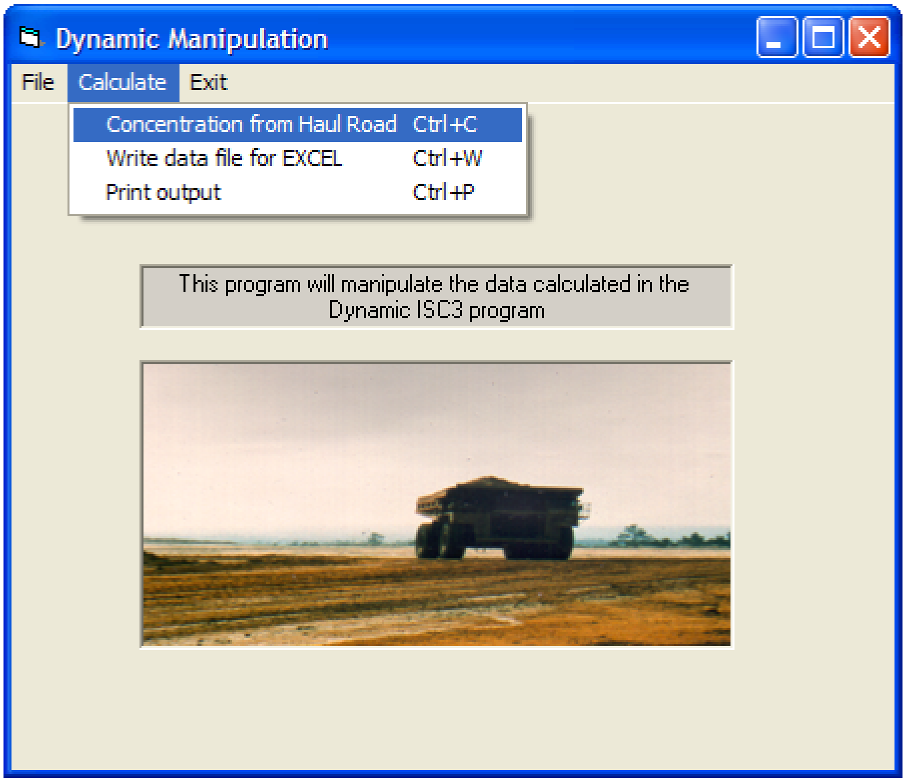


Figure 3.21 Display of menu to calculate the PM_{10} concentrations from the array file.

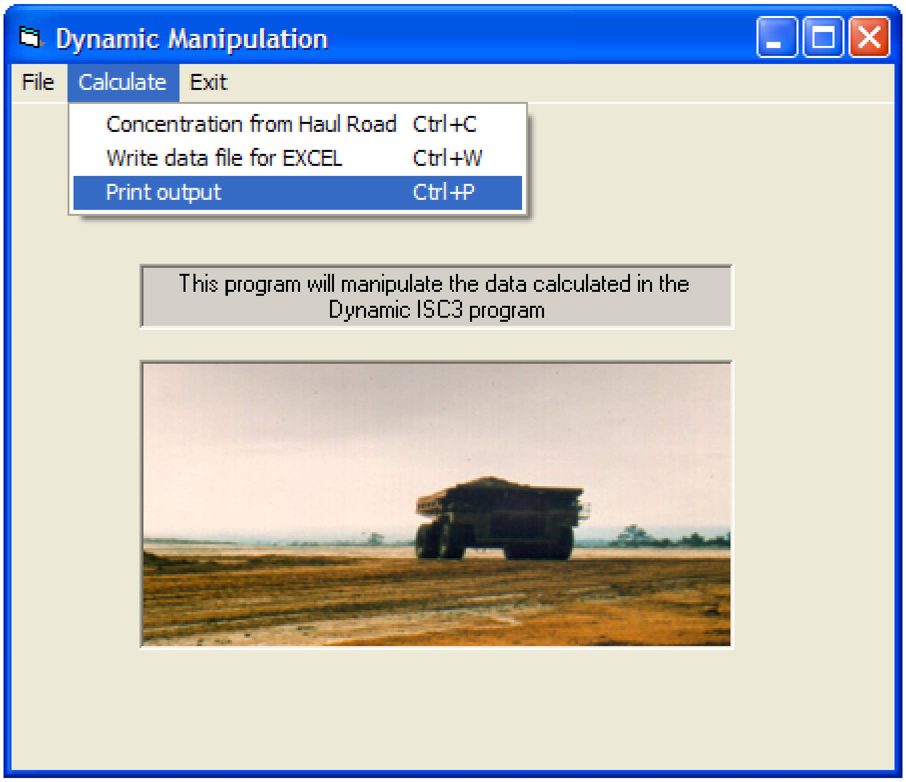


Figure 3.22 Display of menu to print out the final PM_{10} concentrations for the receptors.

Dynamic ISC3 Manipulations Complete

Input Parameters

Number of receptors = 7
X-Y Coordinates of receptors:
Receptor # 1 X Coordinate = 950.76 Y Coordinate = 1008.68
Receptor # 2 X Coordinate = 1000 Y Coordinate = 1000
Receptor # 3 X Coordinate = 1049.24 Y Coordinate = 991.32
Receptor # 4 X Coordinate = 1098.48 Y Coordinate = 982.64
Receptor # 5 X Coordinate = 1017.36 Y Coordinate = 1098.48
Receptor # 6 X Coordinate = 1066.6 Y Coordinate = 1089.8
Receptor # 7 X Coordinate = 1115.84 Y Coordinate = 1081.12

Number of trucks = 1 Weight of trucks (tons)= 50
Speed of loaded truck (m/sec) = 6.92
Speed of empty truck (m/sec) = 6.92

Background Dust Level (micrograms/m^3) = 137.5
Silt Content (%) = 21.18
Moisture Content (%) = 0.65

Calculation Results

Emissions from loaded truck (grams/sec) = 17.29413

Uncorrected Instantaneous Average Concentration of PM10 at receptors:

Results for Receptor 1 = 172.7923 micrograms/m^3

Results for Receptor 2 = 715.8829 micrograms/m^3

Results for Receptor 3 = 252.4471 micrograms/m^3

Results for Receptor 4 = 150.353 micrograms/m^3

Results for Receptor 5 = 716.985 micrograms/m^3

Results for Receptor 6 = 254.0709 micrograms/m^3

Results for Receptor 7 = 152.3236 micrograms/m^3

Dynamic ISC3 Manipulations Complete (continued)

Page 2

Calculation Results

Time Weighted Average Concentration of PM10 at receptors:

Results for Receptor 1 = 270.251687364724120567472412 micrograms/m^3

Results for Receptor 2 = 813.3422535220358396565948502 micrograms/m^3

Results for Receptor 3 = 349.90653785720629661003021545 micrograms/m^3

Results for Receptor 4 = 247.81241016773059780546505518 micrograms/m^3

Results for Receptor 5 = 814.44446207716167519160536 micrograms/m^3

Results for Receptor 6 = 351.53032256638388486016815555 micrograms/m^3

Results for Receptor 7 = 249.78299016575874286898318445 micrograms/m^3

Figure 3.23 Printout of results from modeling exercise completed on August 2, 2002 field study data.

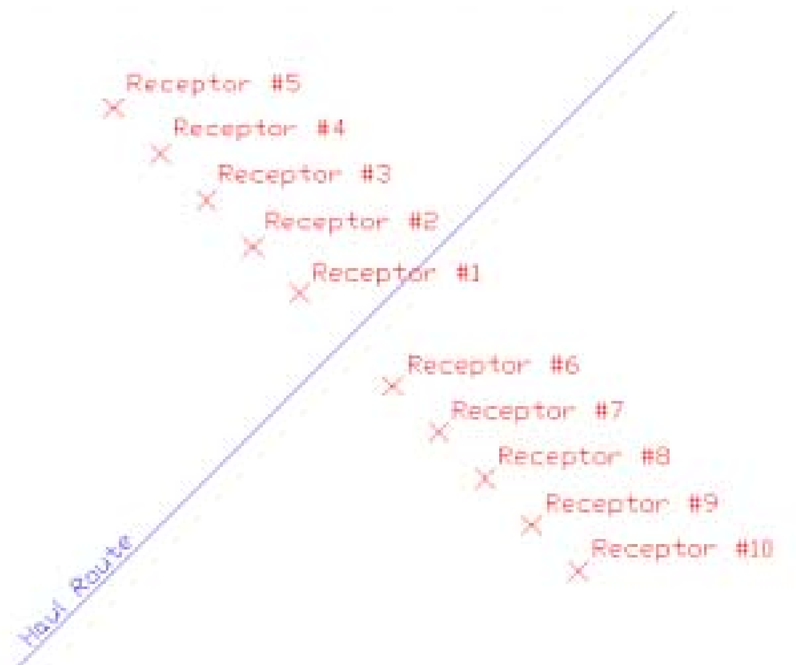


Figure 3.24 Haul road and receptor layout used in testing of ISC3 and Dynamic Component Models.

Once all data were input, *Dynamic Component ISC3* and *Dynamic Manipulation* would normally be used to calculate the average PM_{10} concentration for each of the receptor locations. However, an additional program listed in Appendix D named "*Autodynamic Comp ISC3 Year*" was used in place of *Dynamic Component ISC3*. *Dynamic Component ISC3* and *Autodynamic Comp ISC3 Year* are essentially the same programs and are used to create an array of PM_{10} concentration results from the source at each receptor. The difference is that *Autodynamic Comp ISC3 Year* allows for calculation of monthly time-weighted-average PM_{10} concentration at receptors. This program allows for the calculation of an annual average PM_{10} concentration at each receptor, which can be directly compared to the ISC3 model.

The ISC3 Program used for comparison, was the ISC-AEROMOD View program created by Lakes Environmental Software. This program is the same as the ISC3 program except it has a MicroSoft Windows interface that makes it easier to input the required data. This program's results were then compared with the results of the Dynamic Component Program.

Table 3.7 shows the PM_{10} concentrations produced at each receptor location for both the Dynamic Component Program and the ISC3 Program. A graph of these results, displayed in Figure 3.25, shows that the results from the Dynamic Component Program are approximately 74-79% lower than the ISC3 results. These results agree well with field measurements reported by prior research completed by Cole and Zapert suggesting that the ISC3 Program over-predicts emissions of mobile sources.

The averaging of all PM_{10} concentration results for each receptor is more representative of the actual conditions produced by a haul truck. The reasons for this are clear. The haul truck creates PM_{10} emissions at a point on the haul road. Once the haul truck moves from that point, the emissions stop. The PM_{10} emissions continue at the next point. Again, once the haul truck moves on, the emissions at the second point stop. The process repeats itself until the haul truck reaches its destination. The haul road does not produce constant emissions; rather, the haul truck produces constant emissions. The receptors receive concentrations from the emissions of a moving haul truck. This situation is modeled by the Dynamic Component Program but not the ISC3 Program.

Table 3.6 Input data for the ISC3 program and the Dynamic Component ISC3 program.

Starting Coordinates of Haul Road (x,y)	500 m , 500 m	Ending Coordinates of Haul Road (x,y)	1000 m , 1000 m
Material Silt Content	11.0%	Weight of Trucks	45 metric tons
Material Moisture Content	0.1%	Speed of Empty Haul Truck	13.41 m/s
Number of Trucks	1	Speed of Loaded Haul Truck	2.23 m/s

Table 3.7 PM_{10} results for the ISC3 program and the Dynamic Component ISC3 program.

Receptors	PM_{10} Concentration from ISC3 Program ($\mu g/m^3$)	PM_{10} Concentration from Dynamic Component ISC3 Program ($\mu g/m^3$)
1	2433.83	604.06
2	1208.79	292.06
3	782.98	183.74
4	559.13	126.39
5	426.88	90.51
6	1938.90	484.27
7	938.98	241.98
8	596.65	149.14
9	420.36	106.48
10	308.88	74.85

It should also be noted that PM_{10} concentrations are highly dependent upon wind direction. A wind rose diagram of the Pittsburgh weather data, used in this situation and produced by RAMMET View, is shown in Figure 3.26. The wind rose diagram shows the wind directions coming predominantly from the southwest. However, the wind also came from the northwest and the southeast at approximately equal frequencies, resulting in PM_{10} concentrations on both sides of the haul truck road.

The results of the Dynamic Component Program show a promising improvement over the ISC3 Program. This improvement has been achieved through a different method of modeling emissions from a haul truck: modeling mobile sources as incrementally moving sources, rather than modeling mobile sources as stationary sources. This methodology, while a promising improvement, requires further testing in order to verify the results as realistic.

In order to determine the accuracy of the Dynamic Component Program, a comparison will be made to actual data (presented in Chapter 5). Data were collected on haul trucks operating at actual surface mining operations to validate this model. The field studies consisted of sampling airborne PM_{10} from a haul truck on an unpaved surface.

3.8 Summary

The Dynamic Component Program uses the same equations as the ISC3 Program to calculate PM_{10} concentrations. However, the methodology of calculating these concentrations for mobile sources has been changed. Instead of dividing the emissions of the source over the area of the mobile source path, the entire emissions from the haul truck are applied at points along the path of the source. This results in an array of PM_{10} concentrations that are then averaged for each receptor. This methodology has produced promising results. In the test situation, the dynamic component results were 74-79% lower than the ISC3 results, agreeing with prior research completed by Cole and Zapert in 1995.

In order to test the accuracy of the new Dynamic Component Program, field studies were completed. These field studies test the dynamic component's accuracy and should support the results of the new Dynamic Component Program. In addition, the field studies help enhance the understanding of PM_{10} propagation from mobile sources.

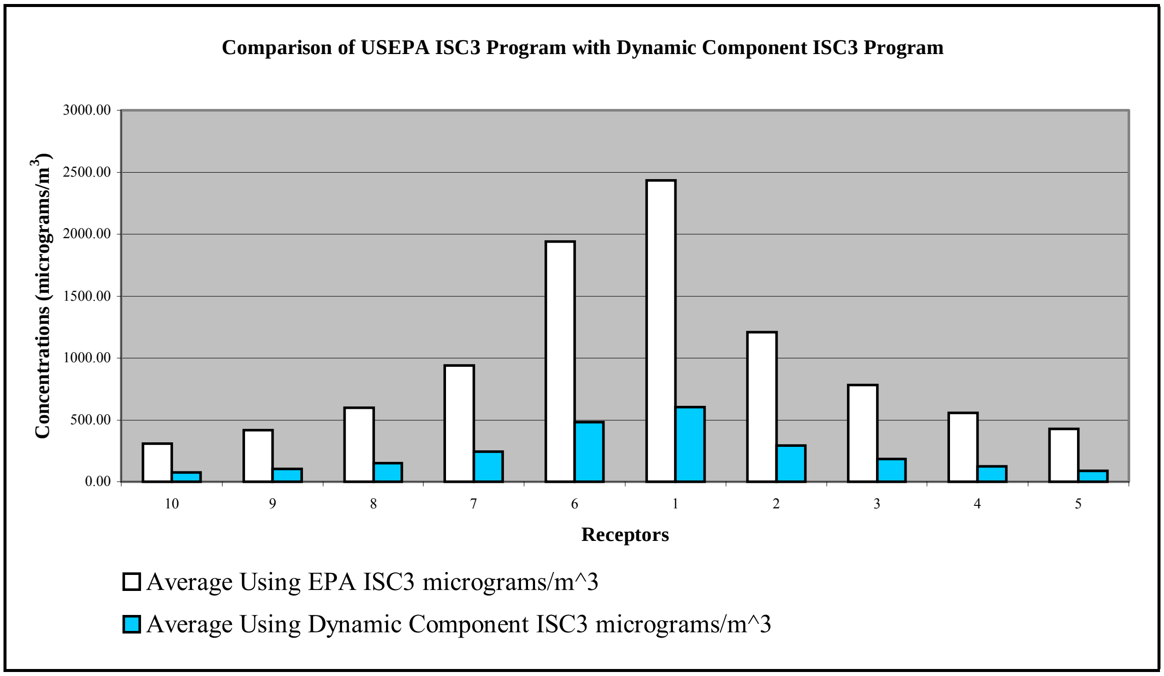


Figure 3.25 PM_{10} concentration comparison from ISC3 program and Dynamic Component ISC3 Program.

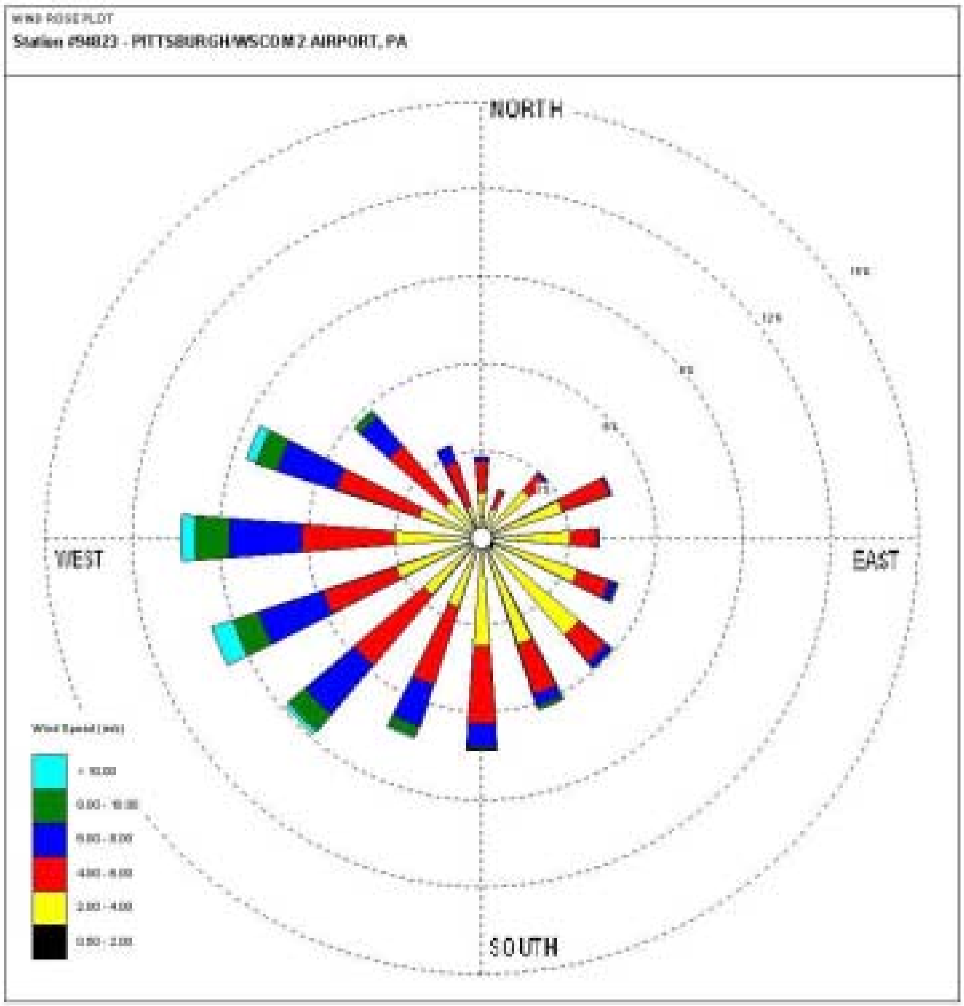


Figure 3.26 Windrose diagram for Greater Pittsburgh International Airport wind directions (diagram created using RAMMET view created by Lakes Environmental Software)

Chapter 4 Field Studies

4.0 Field Study Design

A field study was designed to collect dust concentration information from haul trucks as they traveled a haul road. Dust sampling was performed for the respirable, thoracic (or PM_{10}), and total fractions of dust. This information was used to determine the effects of haul trucks on the surrounding areas and the resulting data were then compared to results from the ISC3 and the Dynamic Component ISC3 programs.

4.1 Site Selection

The dust study was conducted at two surface mine sites. One is a stone quarry located in Virginia that sells crushed limestone to the surrounding community. The other site is a coal mine in Pennsylvania. This site is an underground coal mine with a coal preparation plant located on site. Haul trucks are used to remove waste or reject material from the coal prep plant to a waste pile.

Criteria for the selection of the testing location within the site include:

1. The haul road must be long, straight, and isolated from other operations of the mine site.
2. The topography along this length of haul road should not have any major or significant topographical features. Flat topography is preferable to rolling topography, as it is easier to model because of fewer turbulent wind disturbances (Schnelle and Dey, 2000).
3. The vegetation along the haul road should also not be significant. Grassland would be acceptable. However, a haul road that is heavily forested on both sides would not be acceptable.
4. The haul road should be constructed of material that originates from the mine site. Roads constructed with aggregates brought in from other locations would be acceptable.
5. The length of haul road should be untreated. No treatments of CaCl or MgCl should have been completed for dust control (Wolf, 2001).

The majority of the criteria were met when site observations were completed; however, no site is perfect. The stone quarry has the possibility of being cross-contaminated by dust from other operations, as there is a stone processing plant and several stockpiles located near the section of haul road used in the study. During an initial site visit, observations of the stone processing plant were made. There were no noticeable dust plumes emanating from the plant. During the actual study, however, the stone processing plant and surrounding stockpiles did create visible dust plumes. The wind direction was also favorable, as it negated the effects of the small uphill grade. The height of the surrounding stockpiles helped to keep the majority of other fugitive dust sources, other than the stone processing plant, from contaminating the measurements of the study. The stone quarry had a mix of haul trucks, ranging from 50 ton trucks to OTR trucks, which were the majority of the traffic using this road. There were also measurements made of other equipment using the road. This site had a high volume of traffic with trucks arriving every 3 - 10 minutes.

The coal mine site had a better layout. All of the conditions were met, except that the topography of the study area included a slight uphill grade. A processing plant was located on the site, but it was several miles from the testing location. Therefore, the effects from the processing plant would be less than at this location than the stone quarry location. This study measured dust from 50-ton Caterpillar haul trucks, 40-ton Payhauler trucks, and 60-ton Euclid trucks. The volume of traffic at the site was much lower than that of the stone quarry study with trucks arriving every 10 - 20 minutes.

4.2 Selection of PM_{10} Sampling Layout

The goal of this study was to record measurements of dust concentrations generated from haul trucks at several locations along the haul road. This data would be used to determine the particle size distribution of airborne dust generated by the haul trucks, determine the decay of the airborne dust concentrations generated by the haul trucks, and to determine the accuracy of the new Dynamic Component Program to actual conditions. The desired results influenced the determination of the locations of the sampling points. Site-specific factors also influenced the locations of the sampling points, as the area available for sampling was limited in both cases. There were several options available as shown in the following figures.

Figure 4.1 shows the original proposed sampling layout. This layout was proposed because it was the layout used to conduct the preliminary Dynamic Component ISC3 model test calculations. Because wind is the mechanism that moves dust particles, wind direction is a dominant factor in dust propagation. Therefore, dust concentrations will be higher at the downwind sampling stations than at the upwind sampling stations. This meant that the majority of the sampling stations were placed down wind of the haul road, and that not all of the upwind stations were needed. Therefore, a sampling layout shown in Figure 4.2 was proposed. It was assumed that only one sampling station would be required upwind of the haul road to determine the ambient PM_{10} concentrations in the air, since the majority of the PM_{10} concentrations from the haul truck would travel downwind of the haul road following the wind direction.

It was thought that the sampling layouts should be placed parallel to the haul road in order to characterize the highs and lows of the PM_{10} concentrations along the haul road as being representative of the emissions from the haul trucks. However, the Dynamic Component Program only minimally changed the equation used to determine the decay of the airborne PM_{10}. The program's major change was the methodology of applying the equation to the source. This led to a sampling layout, shown in Figure 4.3, as being a possible layout to be used during the field study.

A preliminary field trip was made to the stone quarry to inspect the layout of the site and to test some of the dust sampling equipment to determine the magnitude of respirable dust concentrations that could be expected from the haul trucks. A preliminary layout with two sampling stations, shown in Figure 4.4, was used to test an MIE personal data RAM connected to a 10 mm Dorr-Oliver cyclone to measure instantaneous respirable dust, and a Cascade Impactor at each receptor location. The data from this preliminary study revealed that the instantaneous data display the high and low spikes in the respirable dust concentration from the haul road as the haul truck travels through the area. Figure 4.5 shows the spikes of the instantaneous respirable dust data. The results from the preliminary study basically eliminated the need for the sampling layout parallel to the haul road, as shown in Figure 4.3, since one sampling location can show that haul road emissions from haul trucks are not constant but vary over time.

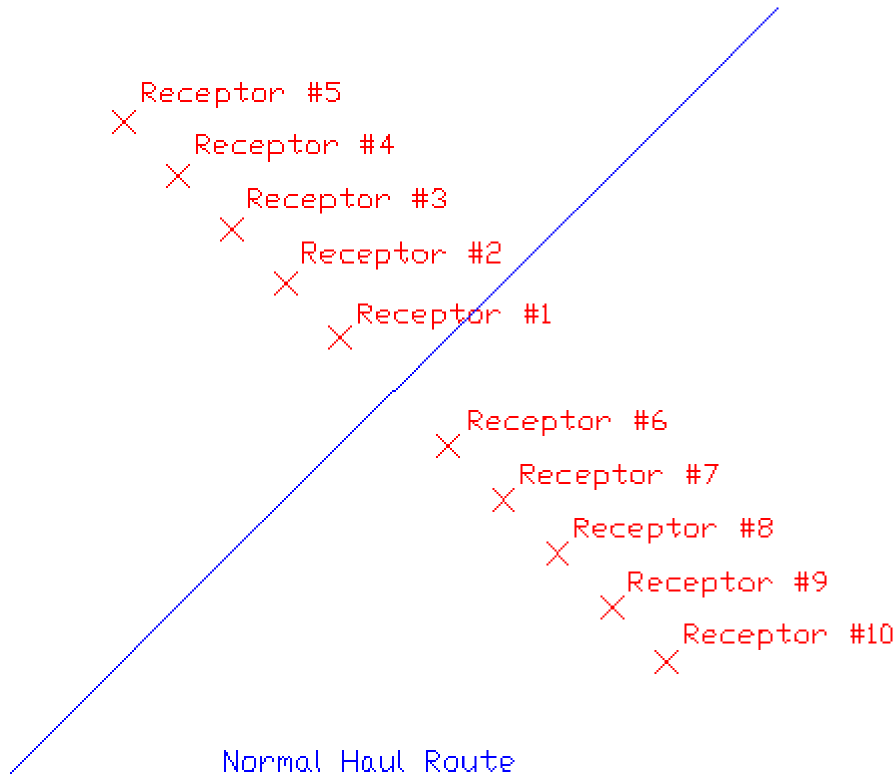


Figure 4.1 Original sampling layout.

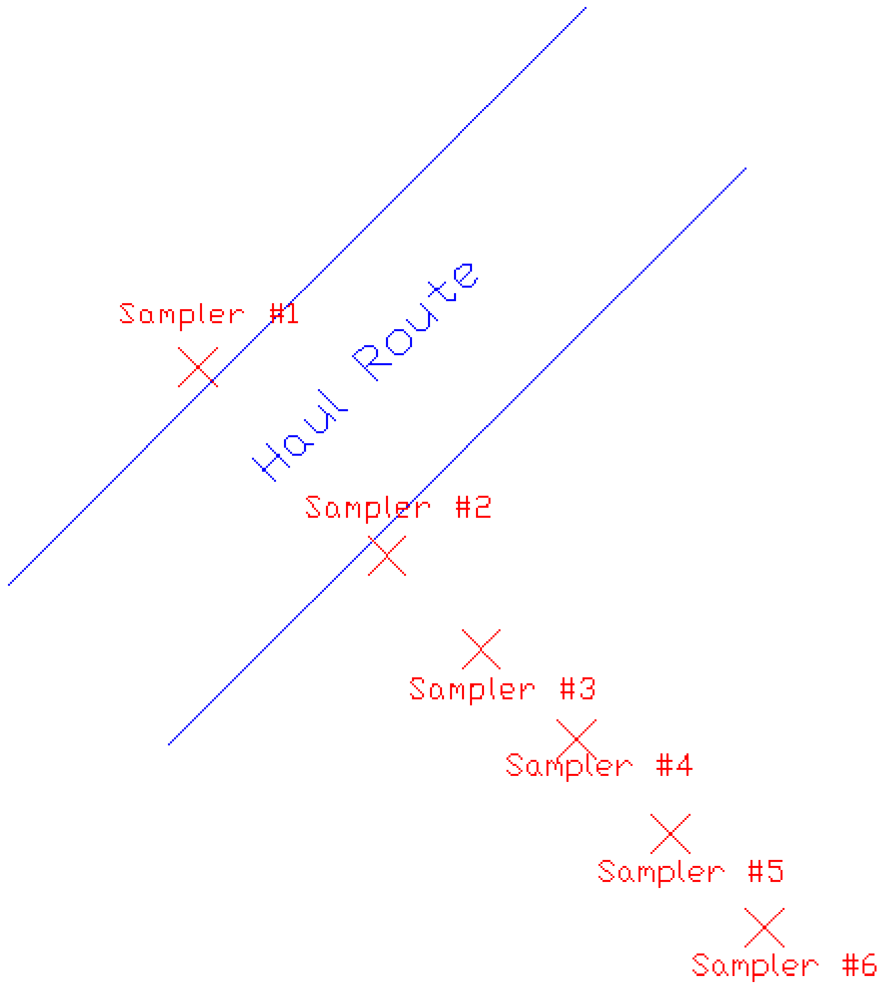


Figure 4.2 Modified sampling layout assuming all sampling locations are downwind of the haul road.

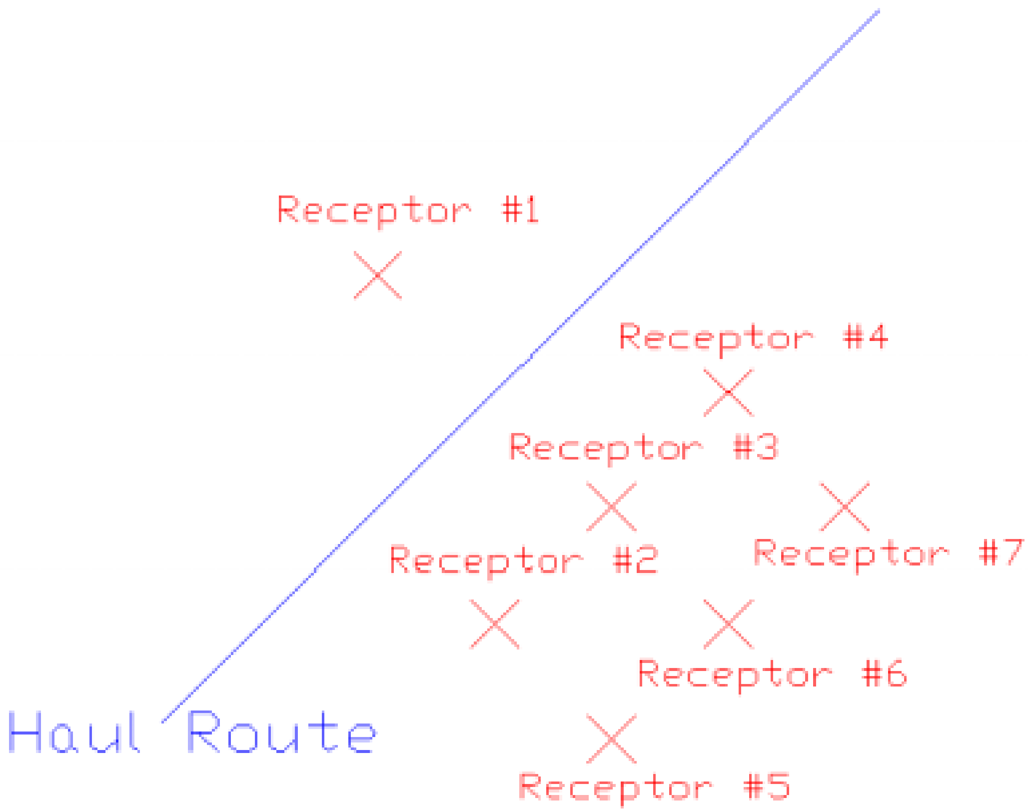


Figure 4.3 Sampling layout to characterize PM_{10} concentration spikes along haul road due to haul truck travel.

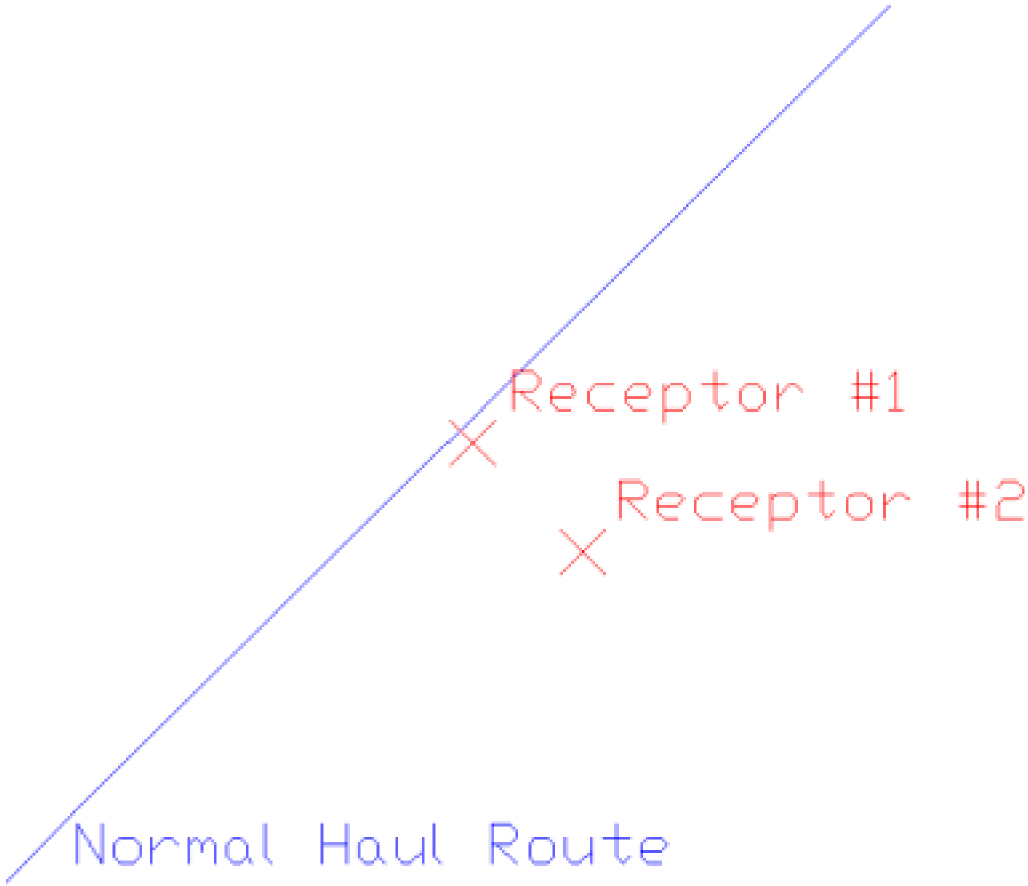


Figure 4.4 Preliminary field study at the stone quarry in Virginia.

The selected layout, shown in Figure 4.6, was a compromise between the layouts shown in Figures 4.2 and Figure 4.3. Prior research conducted on overburden drilling operations at surface coal mines, showed that at distances of 30 meters or more the amount of respirable dust in the air was minimal. Most of the decay of the concentrations of airborne respirable dust occurred within the range of 10 - 30 meters (Page and Maksimovic, 1987). If the respirable dust decays rapidly, as in the drilling study, then the PM_{10} fraction of dust should decay as rapidly. Prior research has shown that the material density not particle size affects deposition of dust therefore, the sampling locations that are further away from the haul road as shown in Figure 4.2 should be unnecessary.

Two parallel lines perpendicular to the haul road and 30 meters apart from each other were selected. The three sampling stations in each line perpendicular to the haul road are set 15 meters away from the next sampling station, resulting in a total distance of 30 meters away from the haul road. This distance was chosen because of the previously mentioned study, and the parallel lines were chosen because it was thought that this layout would allow for better determination of the decay of dust from the haul truck in differing wind directions. A particular example would be when the wind direction was close to being parallel to the haul road direction. In this case only the first sampling stations that are parallel along the haul road may collect data, but the second station in the second perpendicular sampling line may collect data missed by the second sampling station in the first perpendicular sampling line. Therefore, if the wind direction was such that the airborne dust bypassed the first perpendicular line, resulting in no data, it was thought that the second perpendicular line would be located in a position to be able to collect some data.

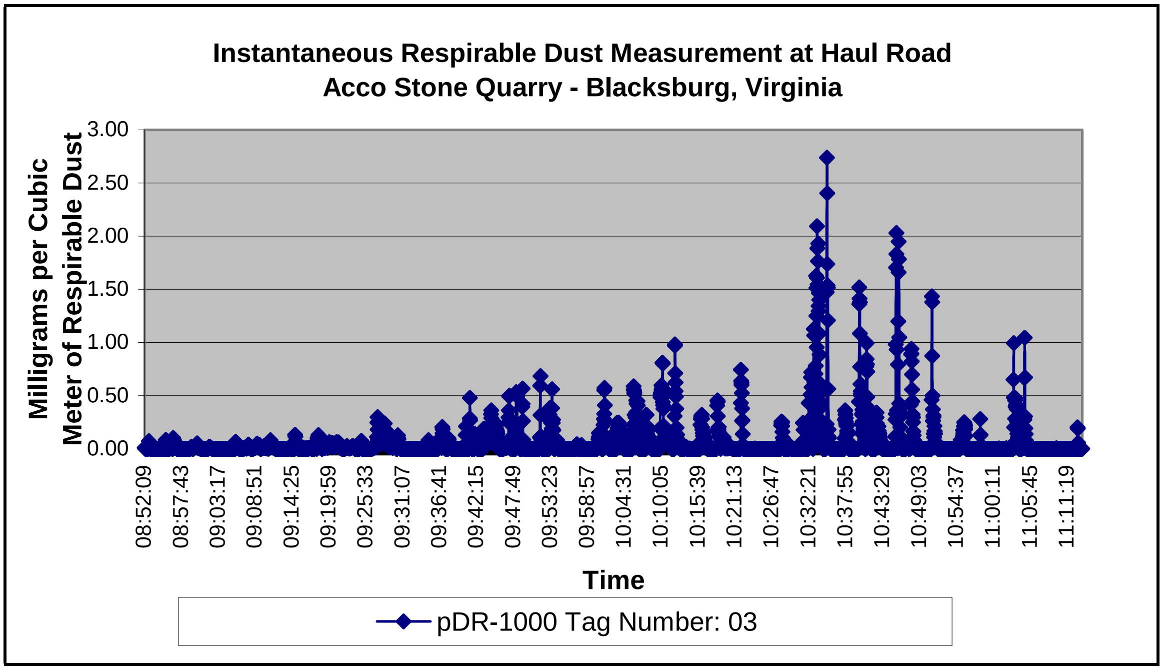


Figure 4.5 Instantaneous respirable dust data from preliminary field study at the stone quarry in Virginia.

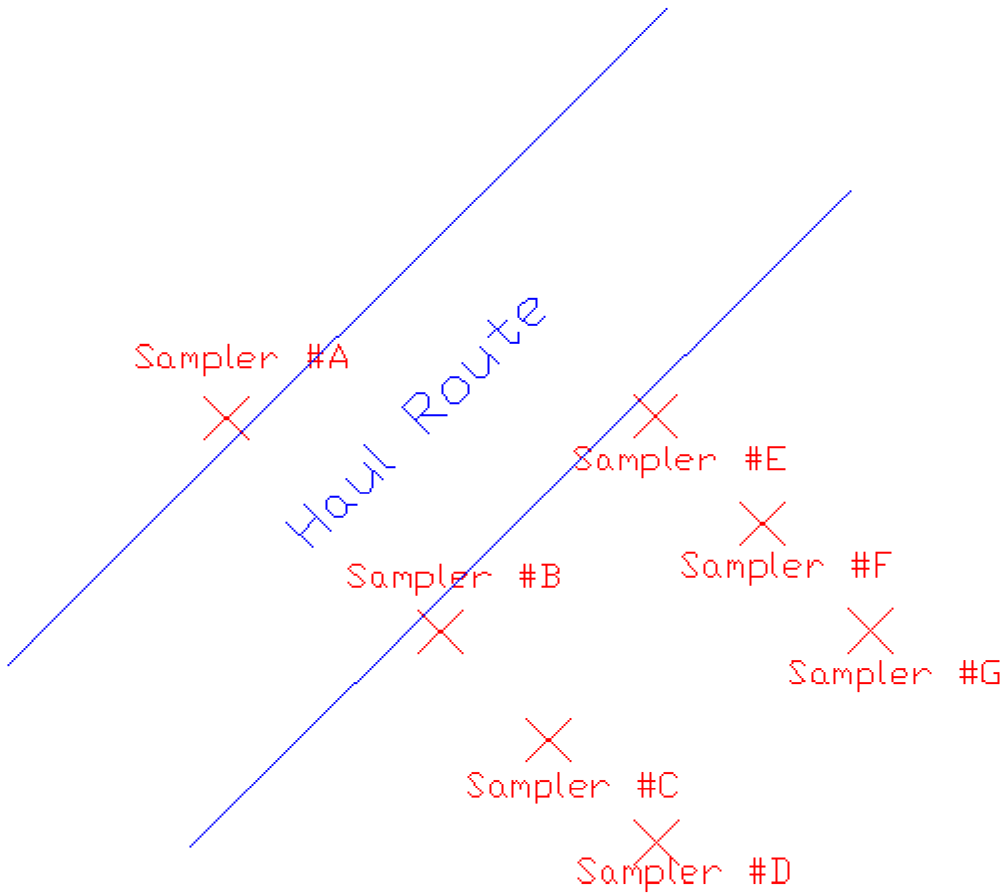


Figure 4.6 The selected sampling layout for field study.

4.3 Selection of Sampling Equipment

The ability to obtain instantaneous dust concentration data to validate the dynamic model was important. The instantaneous dust concentration data can be used to characterize the dust emissions from the haul trucks. This will be important in any future considerations of modeling dust dispersion from these sources. Normally time-weighted-average concentrations are obtained when dust concentration measurements are conducted. Time-weighted-averages smooth the concentrations over a specific time period. During this time period, the instantaneous dust concentrations may vary a significant amount, as can be seen in Figure 4.5. The variance of dust concentrations may contain a pattern that may be specific to a particular source. Identifying these patterns is important in the characterization of the dust emissions from the source because modeling attempts to reproduce these patterns. When measuring or recording time-weighted-average dust concentrations, this variance is eliminated. It is impossible for time-weighted-average dust concentrations to derive the instantaneous dust concentrations. However, the instantaneous dust concentrations can be used to derive the time-weighted-average dust concentrations (Boubel, et. al., 1994).

The equipment normally used to measure PM_{10} from facilities is the high-volume sampler. Examples of such samplers are the GMW PM_{10} High Volume Sampler built by Andersen Instruments, Inc.; the Model HVP-2000 and HVP-3000 built by Hi-Q Environmental Products Co.; and the PM_{10} Critical Flow High-Volume sampler built by Wedding and Associates, Inc. These samplers use a high flow rate of approximately 1.1 m^3/minute to conduct ambient air sampling of PM, and they generally meet the requirements of the U. S. EPA reference method for sampling ambient PM_{10} in the atmosphere (Rubow, 1995). The disadvantage to this equipment is that it is very expensive, costing approximately $5,000 - $10,000.00 per sampler, and the equipment does not have the ability to record instantaneous PM_{10} concentrations.

The Mini-Vol built by Airmetrics, Inc. is a more affordable PM_{10} sampler costing approximately $2,000.00 per sampler, but it does not meet the U. S. EPA reference method for sampling ambient PM_{10} in the atmosphere, and it also is not able to record instantaneous PM_{10} concentrations. MIE, Inc. makes a personal data RAM that has the ability to record

Figure 4.7 Wind speed and direction weather station.

instantaneous dust concentrations. This equipment has a particle size range of 0.1 – 10 μm. However, it is best suited for measuring respirable dust (MIE, 2000). The method for determining thoracic and total instantaneous concentrations was to calculate ratios from the gravimetric time-weighted-average measurements. These ratios were applied to each respirable instantaneous data point. An assumption must be made in order to project the thoracic and total instantaneous concentrations. This assumption is that the total and thoracic instantaneous concentrations will be consistent with the instantaneous respirable concentrations and that the total and thoracic instantaneous concentrations will follow the general trend of the buildup and decay of these respirable concentrations.

4.3.1 Dust Sampling Equipment Required

The equipment used in this study consisted of weather monitoring equipment, and dust sampling equipment. The weather monitoring equipment consisted of a barometer for determining atmospheric pressure, a sling pyschrometer for determining relative humidity, and a data-recording weather station, shown in Figure 4.7 that records wind speed and wind direction at 30-second time intervals. This equipment will be used to gather the weather data that are vital for conducting the modeling process. The dust sampling equipment will consist of personal data RAM's and MSA Escort ELF personal sampling pumps. Both gravimetric and instantaneous data will be measured in order to obtain a particle size distribution from the haul trucks. The following is a list of the equipment quantities that were used in recording the respirable, thoracic, and total dust concentrations:

- 7 MIE Personal data RAM model pDR-1000 samplers with 10mm Dorr-Oliver cyclones, (PDR).
- 7 MSA Escort ELF personal dust sampling pumps with 10mm Dorr-Oliver cyclones, (respirable sampler).
- 7 MSA Escort ELF personal dust sampling pumps with BGI GK2.69 cyclones, (thoracic sampler).
- 7 MSA Escort ELF personal dust sampling pumps without any cyclones, (total sampler).
- 3 Cascade Impactors, for obtaining particle size distribution of dust at certain locations.

Figure 4.8 The MIE Personal Data Ram Model pDR-1000 with 10 mm Dorr-Oliver cyclone and 37 mm filter.

Figure 4.9 Escort ELF pump (in background) connected to 10 mm Dorr-Oliver cyclone and 37 mm filter for measuring respirable dust.

Figure 4.10 BGI Model GK2.69 cyclone and 37 mm filter connected to Escort ELF pump for measuring thoracic dust.

Figure 4.11 37 mm filter connected to Escort ELF pump (shown in circle) for measuring total dust along with the typical dust sampling setup for each sampling station.

The MSA Escort ELF personal dust sampling pumps were used to collect dust samples on 37 mm filters. This would allow for the calculation of time-weighted-average dust concentrations in mg/m^3. Since the sampling layout in Figure 4.6 contained seven sampling stations, seven of each type of dust sampler was used. One type of sampler was placed at each station in the layout.

4.3.2 Description of Dust Sampling Equipment

The MIE Personal Data RAM model pDR-1000 sampler (PDR), fitted with the 10mm Dorr-Oliver cyclone shown in Figure 4.8, was used with a personal dust sampling pump to obtain the instantaneous respirable dust measurements in mg/m^3. The sampling airflow rate for the 10mm Dorr-Oliver cyclone was set for 1.7 liters/minute to allow for measuring respirable dust according to ACGIH's respirable dust standard (Bartley, et. al., 1994). This sampler collected respirable dust on a 37 mm filter attached to the cyclone, which allowed calibration of the instantaneous data. The PDR contains an auto-logger; therefore, the dust concentration readings were recorded continuously. The auto-logger was set to record measurements every 2 seconds. This allowed for the proper presentation of instantaneous respirable dust concentration data. Any longer time interval might have missed the dust concentration peaks caused by the haul trucks.

Seven Escort ELF sampling pumps were fitted with the 10mm Dorr-Oliver cyclones in order to measure the respirable dust and to double check the respirable fraction measured by the PDRs. An example of the respirable sampler is shown in Figure 4.9. The sampling airflow rates for the respirable sampler were also set for 1.7 liters/minute.

In order to obtain data for the PM_{10} size fraction, an MSA personal dust sampling pump connected to BGI GK2.69 cyclone with an attached 37 mm filter, shown in Figure 4.10, was used to obtain the time-weighted average for the thoracic size fraction. The thoracic size fraction is not exactly the same as the PM_{10} size fraction as explained in Chapter 2. The thoracic size fraction will contain some larger particles because the curve showing the mass fraction of material versus particle size is not as steep for the thoracic as it is for the PM_{10} curve (refer to Figure 2.8). As a result, the sampled thoracic concentrations should represent a more conservative measurement for PM_{10}. Again, seven thoracic samplers were used in the study, one located at each sampling station. The sampling airflow rates for the thoracic samplers were set for 1.6 liters/minute in order to collect the thoracic fraction of dust (Maynard, 1999).

Figure 4.12 Cascade Impactor for measuring particle size distribution of airborne dust.

To measure the total dust fraction, the MSA Escort ELF personal dust sampling pumps were attached directly to 37 mm filters without the use of cyclones. The sampling airflow rates were set for 1.7 L/min. in order to collect total dust. This sampler is shown in Figure 4.11, circled in red. Figure 4.11 also shows the entire dust sampling setup with the exception of the Cascade Impactors that are typical of each sampling station.

All filters collected dust samples for a time period of approximately 6 - 7 hours. This gave a time weighted average (TWA) concentration for the corresponding measurements that were used to calibrate the Personal Data Rams and obtain ratios that allowed calculation of the thoracic and total instantaneous dust fraction from the respirable instantaneous dust fraction. All samplers were placed on tripods and set at a height of approximately 1.2 - 1.5 m. (Organiscak, and Page, 1995). This height allowed the samplers to obtain samples that would be representative of what miners are exposed to.

A total of twenty-one MSA Escort ELF personal dust sampling pumps with differing cyclone attachments and seven MIE Personal Data RAM model pDR-1000 samplers were used for the field study. The differing cyclone attachments were seven BGI GK2.69 cyclones and fourteen 10mm Dorr-Oliver cyclones. At least twenty-eight 37mm filters were used per day.

A total of three Cascade Impactors were used during each day of testing. These samplers gave particle size fractions ranging from 21 μm to 0.5 μm (Andersen Instruments, Inc. 2002). Figure 4.12 shows this type of sampler. Only three Cascade Impactors were used because they are difficult to setup and operate. The setup is complex as there are eight stages for each Cascade Impactor, thus requiring nine filters for each impactor. The filters must be placed and positioned correctly on each stage, which can be a time consuming process. During operation, the Cascade Impactors can become easily overloaded resulting in invalid data results. The use of three Cascade Impactors requires 27 filters for each day of testing. A list of equipment required for three sampling periods is listed in Appendix E.

4.4 Other Field Study Parameters

During the field study, observations were made to identify the typical operational patterns of each site. During this observational period, a time study was completed recording the number and type of trucks and miscellaneous equipment using the road (U.S. EPA, Phase I, December

1995). This information was then used to calculate the average speed of each piece of equipment passing the dust sampling equipment.

Sampling of loose material on the haul road was completed to obtain material density, silt content, and moisture content (U.S. EPA, Phase I, December 1995). One sample was taken per day and the procedure for sampling the loose material from the haul road followed the methods listed in appendix C of the U.S. EPA's AP-42 (U.S. EPA, AP-42).

The haul road sample taken during the field study was analyzed for moisture content, silt content, and density. The samples were sent to a laboratory where the analysis according to ASTM (American Society for Testing and Materials) standards was conducted. The moisture content was determined using the D-2216 ASTM standard titled "Standard Test for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass" (ASTM, Vol. 04.08, Moisture, 2001).

Silt is defined as the amount of material < 75 μm (ASTM, Vol. 04.08, Classification, 2001). The method of determining the silt content followed the C-117 ASTM standard titled "Standard Test Method for Materials Finer than 75 μm (No. 200) Sieve in Mineral Aggregates by Washing" (ASTM, Vol. 04.02, Sieve, 2001).

Density of an in-place material can be determined rather easily using ASTM standard D-1556 titled "Standard Test Method for Density and Unit Weight of Soil in Place by the Sand Cone Method." The samples obtained were not "in-place" samples and required the determination of material density using a different method. The density of this material was determined using ASTM standard D-854 titled "Standard Test Method for Specific Gravity of Soil Solids by Water Pycnometer" (ASTM, Vol. 04.08, Specific Gravity, 2001).

4.5 Field Study Procedure

The dust sampling at a site lasted three days during each field study. The sampling period for each day was approximately 6 - 7 hours. The field study was conducted according to the following methodology:

1. Prior to conducting the field study, all filters used in the study for the MSA respirable, MSA thoracic, MSA total, MIE Personal Data RAM, and the Cascade Impactors were prepared and weighed.

2. The MSA sampling pumps were tested and calibrated prior to each series of testing. This testing was performed using a Solomat Model PDM-205 pressure meter and a Bios Dry Cal DC-Lite Model DCL-M Rev 1.08 flow calibration meter. The testing procedure was as follows:

   a. An MSA sampling pump was connected to the Bios Dry Cal DC-Lite flow calibration meter.
   b. The Solomat pressure meter was connected in-line with the MSA pump and the flow calibration meter.
   c. The pressure on the MSA sampling pump was at least 10 inches water gage as shown by the Solomat pressure meter.
   d. The flow from the MSA sampling pump was tested to make sure it was within ± 5% of the desired reading, 1.7 L/min. for respirable and total dust, 1.6 L/min. for thoracic dust, and 2.0 L/min for the Cascade Impactors.
   e. Three readings were recorded and averaged for each sampling pump, making sure the flow rates were within the desired ± 5% range of flow rates.

3. The field study was conducted at the most isolated area available in order to avoid contamination from other emissions sources.
4. The manufacturers' names and model numbers of the haul trucks were recorded. This information gave the size and weight of the trucks. The haul trucks were also timed during the study to determine their average speeds loaded and unloaded.
5. Weather measurements were completed. They consisted of temperature, wind direction, wind speed, humidity, etc. These measurements were taken at hourly intervals.
6. A straight stretch of unpaved road, about 90 meters in length, was marked for the test. There was no watering of haul roads within this area.
7. Seven sampling stations were placed in a grid formation parallel to the haul road, as shown in Figure 4.6. Six stations were placed on the downwind side and one sampling station was placed on the upwind side, across from one of the sampling lines perpendicular to the haul road.

8. Sampling stations B and E were located parallel and as close as safely possible to the haul road, as was sampling station A. Sampling station line E - F - G was located parallel and 30 meters away from sampling stations B - C - D in a line perpendicular to the haul road. The distance between stations B - C - D was 15 meters. The same applied for stations E - F - G.
9. The field study layout with respect to the surrounding mine site was mapped. Any pertinent information concerning the field study layout was noted on the map. A form used for completing this map is shown in Appendix E, Section 2.1.
10. Material from the road was gathered so material density, moisture content, and silt content could be determined. The procedure for collecting material for density, moisture content and silt content was as follows:
    a. The loose material was collected at random locations between sampling locations B and E using brooms and dustpans. None of the material that made up the hard surface was collected.
    b. A minimum of a 0.5 kg sample was collected for laboratory analysis for density, moisture content, and silt content.

    One set of samples was taken per day as the haul road conditions remained relatively constant. If the conditions of the haul road had changed, several samples would have been taken to represent the different conditions of the haul road.
11. The MSA personal dust samplers and the MIE personal data RAM's were placed at the sampling stations and collected samples of the airborne dust created by the haul truck. There were four samplers at each station, including
    a. One PDR for measuring the respirable fraction.
    b. One respirable sampler for measuring the respirable fraction.
    c. One thoracic sampler for measuring the thoracic fraction.
    d. One total sampler for measuring total fraction.
    e. Three Cascade Impactors, for obtaining particle size distribution of dust were located at sampling stations A, B, and C.

12. The intakes of the all dust samplers were placed at approximately 1.2 - 1.5 m. above ground level to represent the exposure of mining personnel to dust. The intakes of the samplers were also oriented in the direction toward the haul road. It would be desired that the inlets be oriented parallel to the direction of the wind in order to minimize any sampling error, but fluctuations in wind direction made this almost impossible (Hinds, 1999). Keeping all the inlets oriented towards the haul road ensured that sampling errors due to inlet orientation were consistent throughout the test.
13. Once the samplers were started, a time study of the operation was completed throughout the duration of the sampling period. The time that any equipment left the sampling area was recorded. This was done for all types of equipment. Notes were taken as to what type of equipment entered the area at the recorded time periods. Watering of roads was also recorded. A form used for recording information on the time study is shown in Appendix E, Section 2.2.
14. Filters from the dust samplers were changed and collected at the end of the sampling period.
15. Data from the PDRs were downloaded into a computer for further analysis. The weather data from the weather station were also downloaded into a computer.
16. All equipment was cleaned each day after testing was completed, so that it would be ready for the next day of testing.

This procedure was repeated for each sampling period of the field study. The data sheets recorded during the field studies are listed in Appendix E, Section 3.

4.6 Field Study Completion

The field study for the stone quarry was completed on July 16, 17, and 18 of 2002. The field study for the coal mine was completed on August 2, 5, and 6 of 2002. Both studies followed the protocol presented in "Section 4.5 Field Study Procedure."

4.6.1 Site-Specific Layout and Sampling Set-up Procedure

The layout for the sampling stations followed the sampling setup presented in Figure 4.6. Each station had a PDR, a respirable, a thoracic, and a total sampler. Stations A, B, and C, also each contained a Cascade Impactor. Figure 4.13 shows a plan view schematic of the field study layout within the facility for the stone quarry study. Figure 4.14 shows the same type of schematic for the coal mine study.

The layout for the stone quarry in Figure 4.13 shows the location of the haul road and sampling stations. It also shows the nearby processing plant and several stockpiles associated with the quarry. Figure 4.15 shows a picture of the sampling layout with the processing plant in the background. These operational areas probably had an effect on the amount of dust measured during testing, but it can be seen from the instantaneous data that these sources only influence background emissions. The dust emissions from the trucks can be easily distinguished by reviewing the dust measurement data.

The layout for the coal mine in Figure 4.14 also shows the location of the haul road and sampling stations. This figure shows the approximate location of the prep plant (approximately 1.6 - 3.2 km distance), the waste dump (0.5 km distance), and a nearby construction site (approximately 3.2 - 4.8 km distance). The large distances of the layout from these sources suggest that the dust emission effects from these sources should be smaller than in the stone quarry study. Again, it can be seen from the data that these sources only influence background emissions, and the dust emissions from the trucks can be easily distinguished, as determined by reviewing the dust measurement data.

4.6.2 Sampling Set-up Procedure

The set-up of the samplers and the weather station for the study was started between 8:00 and 9:00 AM each morning and took about 1 hour to complete. Once the setup of all samplers was complete, the sampling pumps were started. Testing continued for approximately 6 - 7 hours. During this period the time study was completed. Wet and dry bulb temperature and barometer measurements were recorded hourly until the study was completed. At 3:00 - 3:30 pm testing was stopped and the sampling pumps shutdown. After all the samplers were shutdown, the equipment was gathered, taken-down, cleaned, and put away. Filters were collected from the samplers and capped, and the data were downloaded from the wind weather station and the PDRs. This procedure was followed for each day of testing for field studies at both the stone quarry and the coal mine. The photographs in Figures 4.16 through 4.31 show the sampling layout, and the trucks passing the sampling stations during these studies.

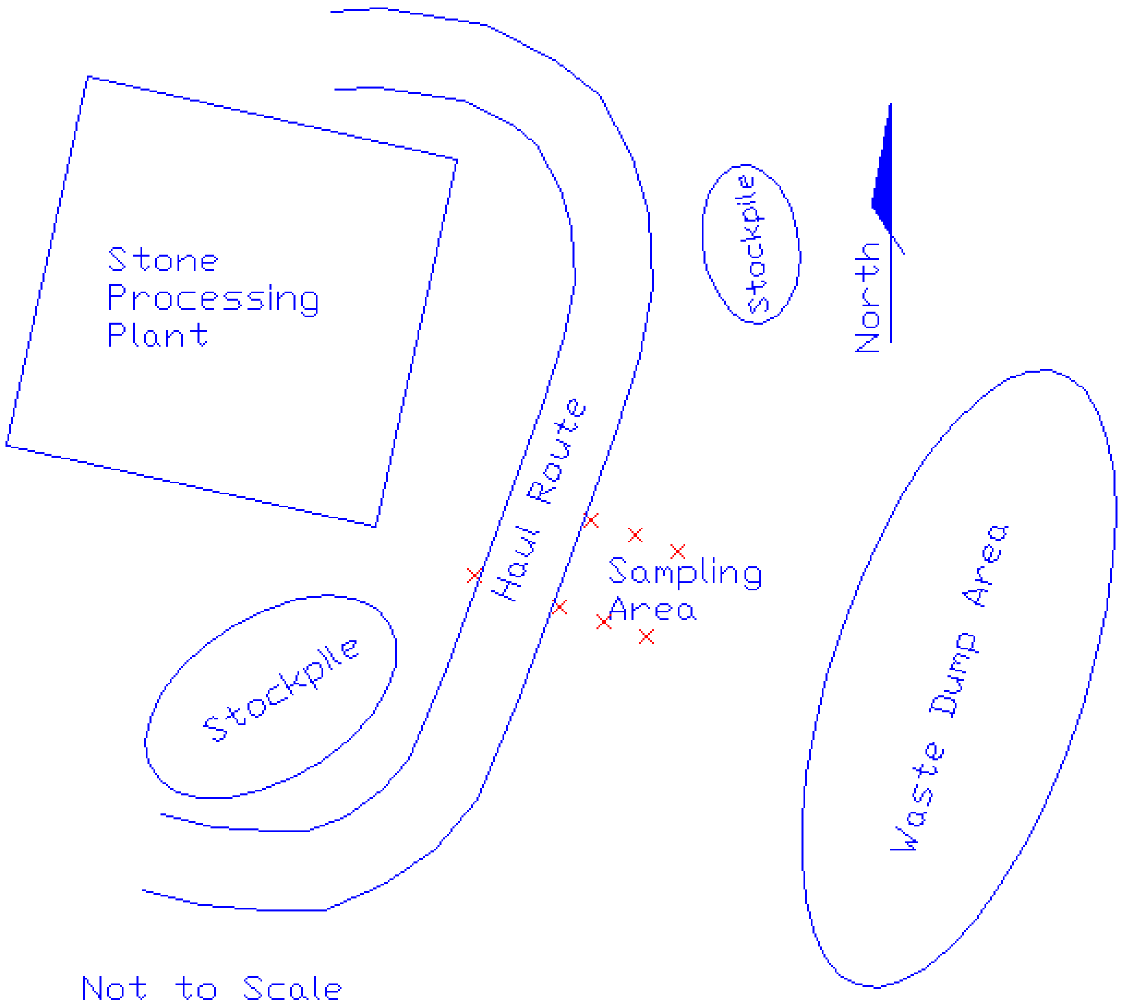


Figure 4.13 Site layout of the stone quarry in Virginia.

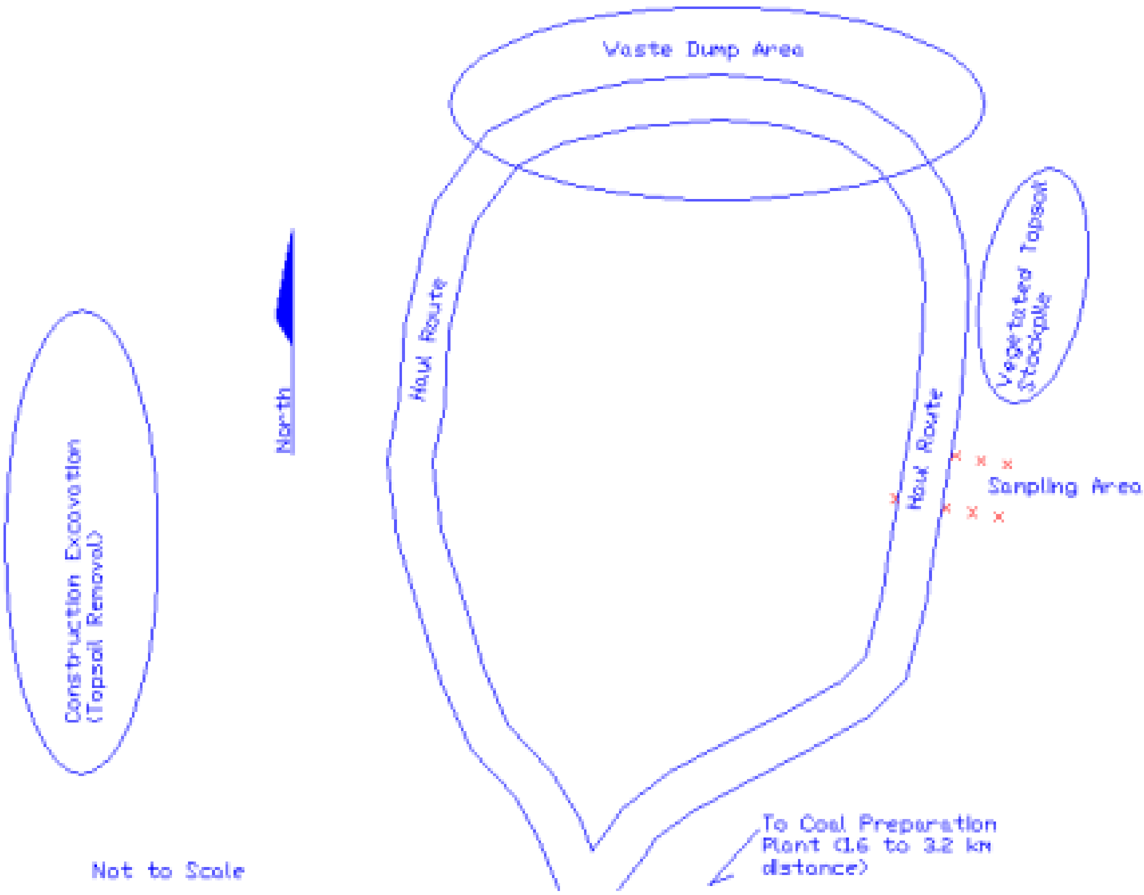


Figure 4.14 Site layout of the coal mine in Pennsylvania.

Figure 4.15 View of several sampling station locations (locations shown in red circle) at the stone quarry in Virginia with the crushing operations located in the background.

4.6.3 Weather conditions

The weather cooperated during both studies by being hot and dry. However, it did rain on the afternoon of August 5 at the end of the coal mine study. On August 5th the study was completed but some of the equipment had not been stored properly before it started raining. Many of the samplers got wet and the result was the loss of data from one PDR. It also rained on the afternoon of July 18 at the end of the stone quarry study after the study was completed and all the equipment was put away. This rain event had no effect on the study completed at the stone quarry.

4.7 Laboratory Analysis of Dust Samples

The sampling equipment gave results for three size categories, respirable, thoracic, and total dust. The PDRs provided instantaneous dust concentration data for the entire sampling period. The 37 mm filter from this sampler was used for calibration of the instantaneous results. The 37 mm filter from the respirable sampler was used to double-check the results from the PDR. The other 37 mm filters from the thoracic and the total samplers were used to create a ratio to create or project the instantaneous results for the thoracic and the total dust size fractions.

All filters were weighed prior to use. After the sampling period was completed, the filters were weighed again to obtain a time-weighted-average concentration. This procedure was completed in an environmentally controlled room located at the National Institute for Occupational Safety and Health's Pittsburgh Research Laboratory in order prevent contamination of the samples (Chow and Watson, August 1998).

The filters from the Cascade Impactors gave results of the airborne particle size distribution in the range of 0.5 μm to 21 μm. These data presented a more detailed particle size distribution curve than the other samplers had given, and can be used to check the data from the respirable and thoracic data. These data can also be used to compare total dust concentrations, but the highest cut size the Cascade Impactor can segregate is 21 μm. Therefore, the Cascade Impactor data may not be compatible for comparison with the total suspended particulate, which is considered to have a cut size of ≤30 μm as defined by the U. S. EPA (U.S. EPA, AP-42, Unpaved Roads, 1998).

Figure 4.16 An over-the-road haul truck passing a sampling station at the stone quarry in Virginia.

Figure 4.17 An off-road haul truck passing a sampling station [series 1 of 7] at the stone quarry in Virginia.

Figure 4.18 An off-road haul truck passing a sampling station [series 2 of 7] at the stone quarry in Virginia.

Figure 4.19 An off-road haul truck passing a sampling station [series 3 of 7] at the stone quarry in Virginia.

Figure 4.20 An off-road haul truck passing a sampling station [series 4 of 7] at the stone quarry in Virginia.

Figure 4.21 An off-road haul truck passing a sampling station [series 5 of 7] at the stone quarry in Virginia.

Figure 4.22 An off-road haul truck passing a sampling station [series 6 of 7] at the stone quarry in Virginia.

Figure 4.23 An off-road haul truck passing a sampling station [series 7 of 7] at the stone quarry in Virginia.

Figure 4.24 View of sampling stations along side the haul road at the coal mine in Pennsylvania.

Figure 4.25 View of sampling station line perpendicular to haul road at coal mine in Pennsylvania.

Figure 4.26 View of sampling layout (sampling stations are circled in red, weather station is circled in blue) at the coal mine in Pennsylvania.

Figure 4.27 View of sampling layout with haul truck [series 1 of 3] (sampling stations pointed in red, weather station is pointed in blue) at the coal mine in Pennsylvania.

Figure 4.28 View of sampling layout with haul truck [series 2 of 3] (sampling stations pointed in red, weather station is pointed in blue) at the coal mine in Pennsylvania.

Figure 4.29 View of sampling layout with haul truck [series 3 of 3] (sampling stations pointed in red, weather station is pointed in blue) at the coal mine in Pennsylvania.

Figure 4.30 View of haul truck passing sampling station at the roadside at the coal mine in Pennsylvania [series 1 of 2].

Figure 4.31 View of haul truck passing sampling station at the roadside at the coal mine in Pennsylvania [series 2 of 2].

The filters from the Cascade Impactors were also pre-weighed prior to use and weighed after sampling concluded. Extra care had to be taken in handling these filters as they contained localized areas covered with impaction grease, which was used to collect the dust particles. The parts of the filter that were greased were not to be touched in any way, as this was where the sample is located on the filter. These filters were also weighed in the environmentally controlled room to obtain a time-weighted-average concentration for the different particle size ranges that the Cascade Impactor sampled.

Chapter 5 Analysis of Field Study Results

5.0 Introduction

The field study data were used to validate the Dynamic Component dust dispersion model (described in Chapter Three). The study measured respirable, PM_{10} or thoracic, and total dust from haul trucks traveling haul roads as described in Chapter Four. The data included both instantaneous and gravimetric dust concentration measurements. The following presents the results of the analysis of the gravimetric and instantaneous measurements from the field study.

5.1 Coal Mine Gravimetric Analysis

The gravimetric results from the coal mine field study for each of the stations are shown in Table 5.1. These results are measurements of dust concentrations from Cat 773B, Payhauler 350, and Euclid R60 haul trucks, with the majority of the trucks being Cat 773B's. The dust concentrations are time-weighted-average concentrations for a time frame of approximately 6 ½ - 7 hours.

Figures 5.1, 5.2, and 5.3 illustrate the decay of the respirable, thoracic, and total gravimetric time-weighted-average dust concentrations as the distance from the source increases. The dust concentrations from these figures are based on the gravimetric results shown in Table 5.1. For reference, the haul road is located between Stations A and B, and the distance between station B-C and C-D is 15 meters. As shown, the dust concentrations decrease rapidly within 30 meters from the source. Once at 30 meters distance from the source, the dust concentration levels get very close to the background dust concentration levels. The total and thoracic dust concentrations seem to decrease much more rapidly from the source than the respirable dust.

Dust propagation and the dust concentration decrease from the haul trucks is highly dependent upon wind directions. Figures F.1, F.2, and F.3 in Appendix F, Section F.1 show the general wind directions for each day. The gravimetric results shown in Figures 5.1, 5.2, and 5.3 display an association with the wind data.

Table 5.1 Gravimetric time weighted average dust concentrations in mg/m^3.

August 2, 2002

	Station A	Station B	Station C	Station D	Station E	Station F	Station G
Respirable PDR	0.266	0.320	0.112	0.066	0.218	0.030	0.046
Respirable	0.274	0.248	0.054	0.063	0.304	0.077	0.073
Thoracic	1.026	1.132	0.302	0.177	0.966	0.355	0.187
Total	2.519	2.820	0.680	0.411	2.504	0.785	0.640

August 5, 2002

	Station A	Station B	Station C	Station D	Station E	Station F	Station G
Respirable PDR	0.126	0.103	0.030	0.009	0.122	0.035	0.009
Respirable	0.128	0.073	0.004	0.000	0.132	0.030	0.051
Thoracic	0.602	0.320	0.096	0.076	0.472	0.123	0.095
Total	1.079	0.542	0.364	0.170	0.887	0.403	0.122

August 6, 2002

	Station A	Station B	Station C	Station D	Station E	Station F	Station G
Respirable PDR	0.252	0.189	0.058	0.011	0.179	0.081	0.000
Respirable	0.305	0.278	0.114	0.000	0.206	0.015	0.035
Thoracic	0.999	0.735	0.188	0.153	0.969	0.147	0.108
Total	2.422	2.159	0.414	0.457	2.015	0.519	0.406

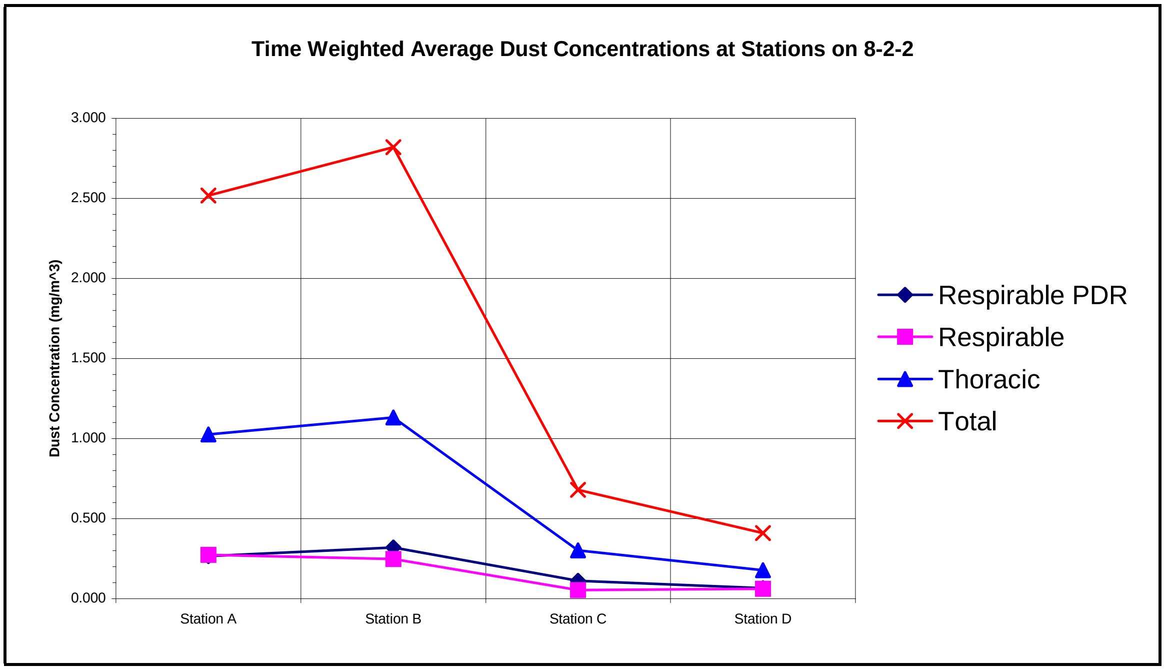


Figure 5.1 Time weighted average gravimetric dust concentrations in mg/m^3 for the coal mine field study.

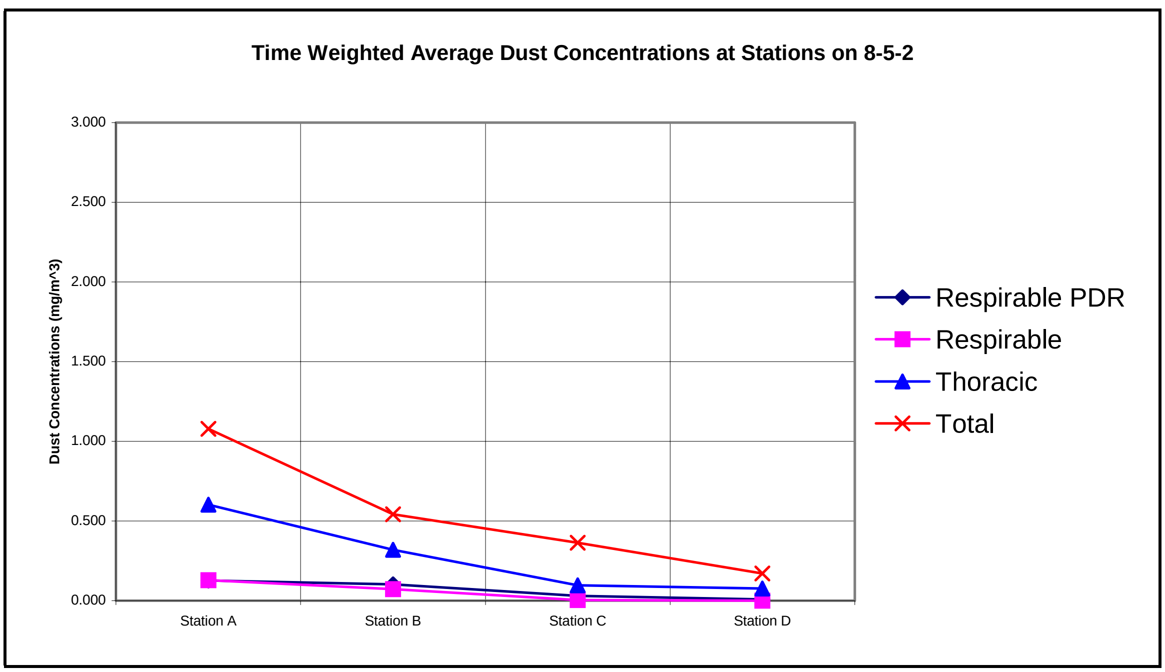


Figure 5.2 Time weighted average gravimetric dust concentrations in mg/m^3 for the coal mine field study.

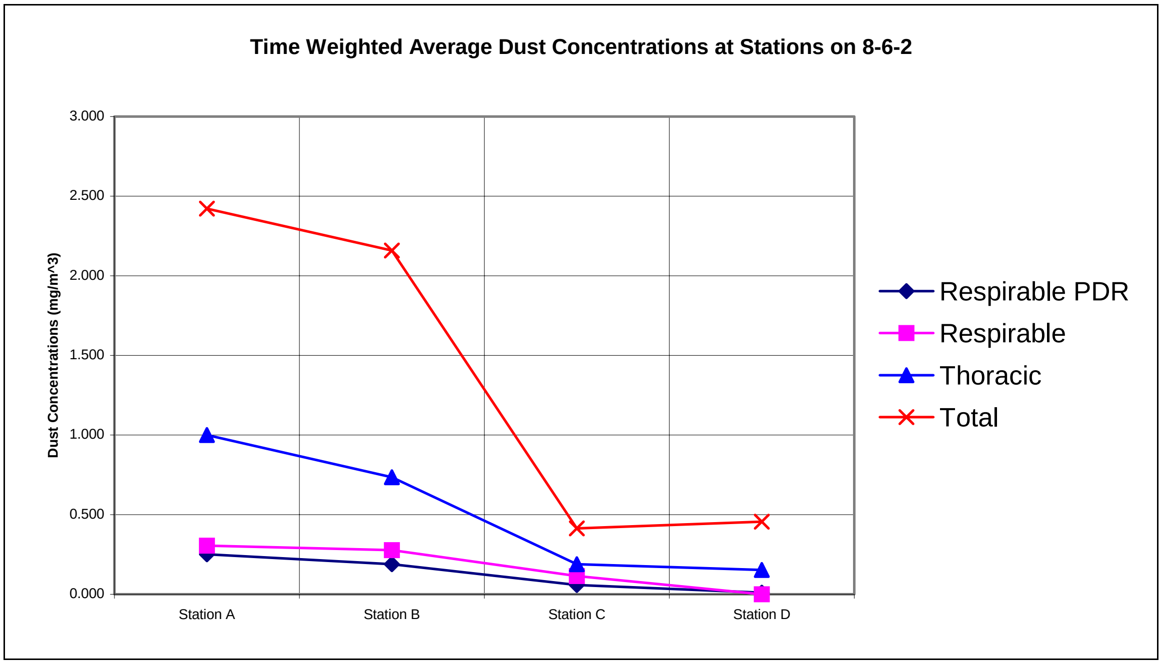


Figure 5.3 Time weighted average gravimetric dust concentrations in mg/m^3 for the coal mine field study.

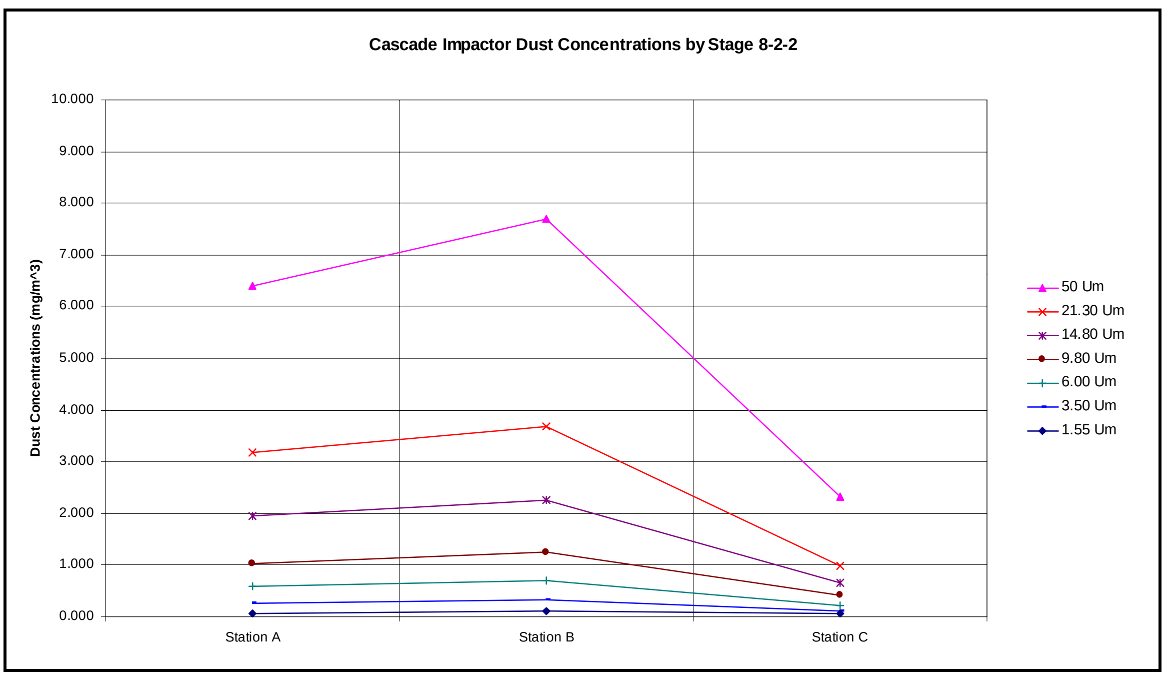


Figure 5.4 Time weighted average dust concentration from Cascade Impactors in mg/m^3 for the coal mine field study.

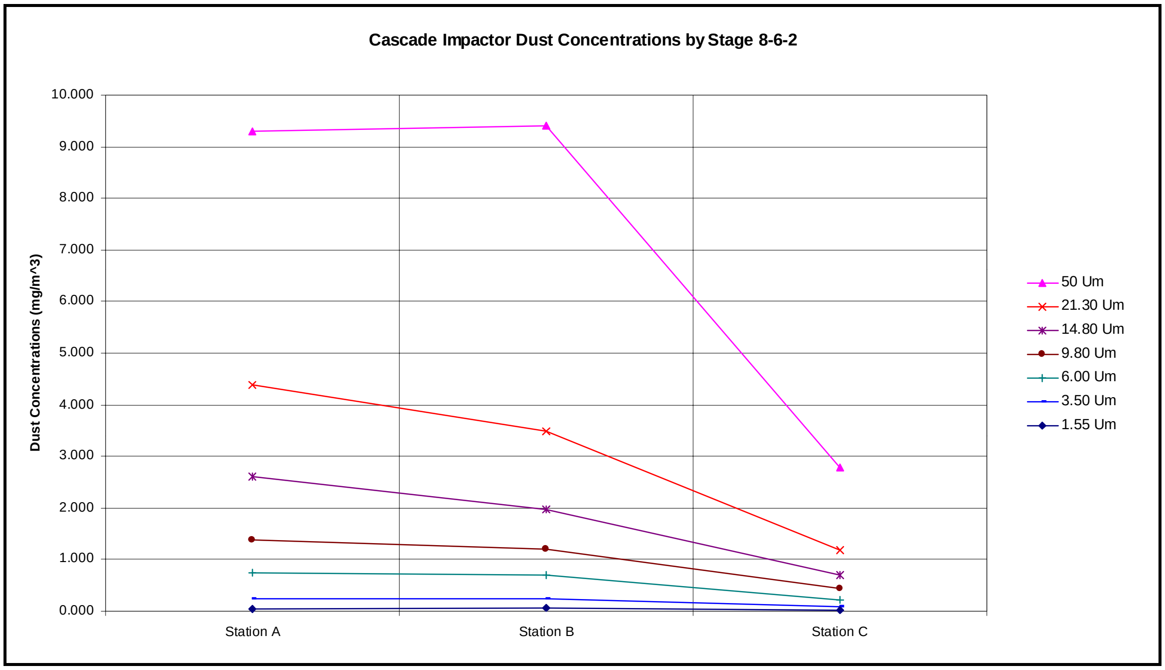


Figure 5.5 Time weighted average dust concentration from Cascade Impactors in mg/m^3 for the coal mine field study.

On August 2, 2002 the wind came from the west - southwest and the sampling stations were generally downwind and parallel to the haul road. Figure 5.1 shows that stations A and B have basically the same dust concentrations, which is indicative of a parallel wind direction. On August 5, 2002 the wind came from the southeast and the sampling stations tended to be upwind in this case. Figure 5.2 shows that the dust concentration decay is rather rapid, with stations B, C, and D having lower concentration values than station A. Also, the overall concentrations are lower than the other days. On August 6, 2002, the wind came from the Northeast, generally parallel to the haul road. Figure 5.3 shows that stations A and B have generally the same dust concentrations. Again, this is indicative of wind directions parallel to the haul road. The dust concentration decay from station B to C and its leveling off at stations C and D is also shown.

The results from the Cascade Impactors also support the dramatic reduction in dust concentrations as one proceeds 50 feet away from the edge of the haul road. This is illustrated in Figures 5.4 and 5.5. The results from the Cascade Impactor at station C for August 5, 2002 were discarded, as problems were encountered with the operation of the Cascade Impactor at station C. Therefore, the graph of the Cascade Impactor dust concentrations for August 5, 2002 was not shown because the mass concentrations for A and B are similar.

5.2 Coal Mine Airborne Particle Size Distribution

The Cascade Impactors allow a review of the particle size distribution of the airborne dust from the haul trucks. They have six stages, which allow for the examination of seven particle size ranges. These ranges and their corresponding geometric mean diameters are shown in Table 5.2. Table 5.3 shows the mass concentrations for each size range and the total mass concentration at each sampling station for each day of the field study. Table 5.4 presents the particle size distribution of airborne dust from haul trucks at each sampling location for each day of the field study by showing the mass fraction of dust for each particle size range. Notice that the mass fractions are relatively constant for each particle size range at all sampling stations for each day of testing. The consistency of the mass fractions can also be seen in the cumulative particle size distribution plots shown in Figures 5.6, 5.7, and 5.8. The mass fractions for each particle size range and the cumulative particle size distributions for sampling stations A and B located adjacent to the haul road are comparable to

Table 5.2 Particle Size Ranges Measured by Cascade Impactor.

Particle Size Range µm	Stage Mid-point
50 - 21.30	35.65
21.30 - 14.80	18.05
14.80 - 9.80	12.30
9.80 - 6.00	7.90
6.00 - 3.50	4.75
3.50 - 1.55	2.53
1.55 - 0.00	0.78

Table 5.3 Mass Concentrations in µg/m^3 of Dust Created by Haul Trucks.

	August 2, 2002			August 5, 2002		August 6, 2002		
Particle Size Range µm	**Station A**	**Station B**	**Station C**	**Station A**	**Station B**	**Station A**	**Station B**	**Station C**
50 - 21.3	3.23	3.99	1.33	1.55	1.65	4.92	5.93	1.61
21.3 - 14.80	1.21	1.43	0.33	0.78	0.42	1.77	1.50	0.47
14.80 - 9.80	0.92	1.02	0.23	0.47	0.28	1.25	0.79	0.26
9.80 - 6.00	0.45	0.54	0.20	0.26	0.16	0.63	0.51	0.22
6.00 - 3.50	0.33	0.38	0.11	0.21	0.14	0.49	0.46	0.13
3.50 - 1.55	0.18	0.21	0.06	0.07	0.07	0.20	0.17	0.06
1.55 - 0.00	0.07	0.11	0.06	0.09	0.08	0.04	0.06	0.03
Total Mass Concentration	6.40	7.69	2.32	3.44	2.79	9.31	9.41	2.78

Table 5.4 Particle Size Distribution Showing Mass Fraction (%) of Airborne Dust Created by Haul Trucks.

	August 2, 2002			August 5, 2002		August 6, 2002		
Particle Size Range µm	**Station A**	**Station B**	**Station C**	**Station A**	**Station B**	**Station A**	**Station B**	**Station C**
50 - 21.3	50.44%	51.97%	57.31%	45.23%	59.05%	52.88%	62.99%	57.74%
21.3 - 14.80	18.93%	18.61%	14.32%	22.68%	14.90%	18.98%	15.94%	16.89%
14.80 - 9.80	14.44%	13.27%	9.95%	13.81%	9.88%	13.40%	8.35%	9.31%
9.80 - 6.00	7.05%	7.02%	8.57%	7.49%	5.79%	6.81%	5.38%	8.05%
6.00 - 3.50	5.18%	4.98%	4.67%	6.12%	5.13%	5.30%	4.86%	4.78%
3.50 - 1.55	2.80%	2.75%	2.45%	2.02%	2.37%	2.20%	1.84%	2.20%
1.55 - 0.00	1.16%	1.40%	2.74%	2.66%	2.88%	0.44%	0.64%	1.03%

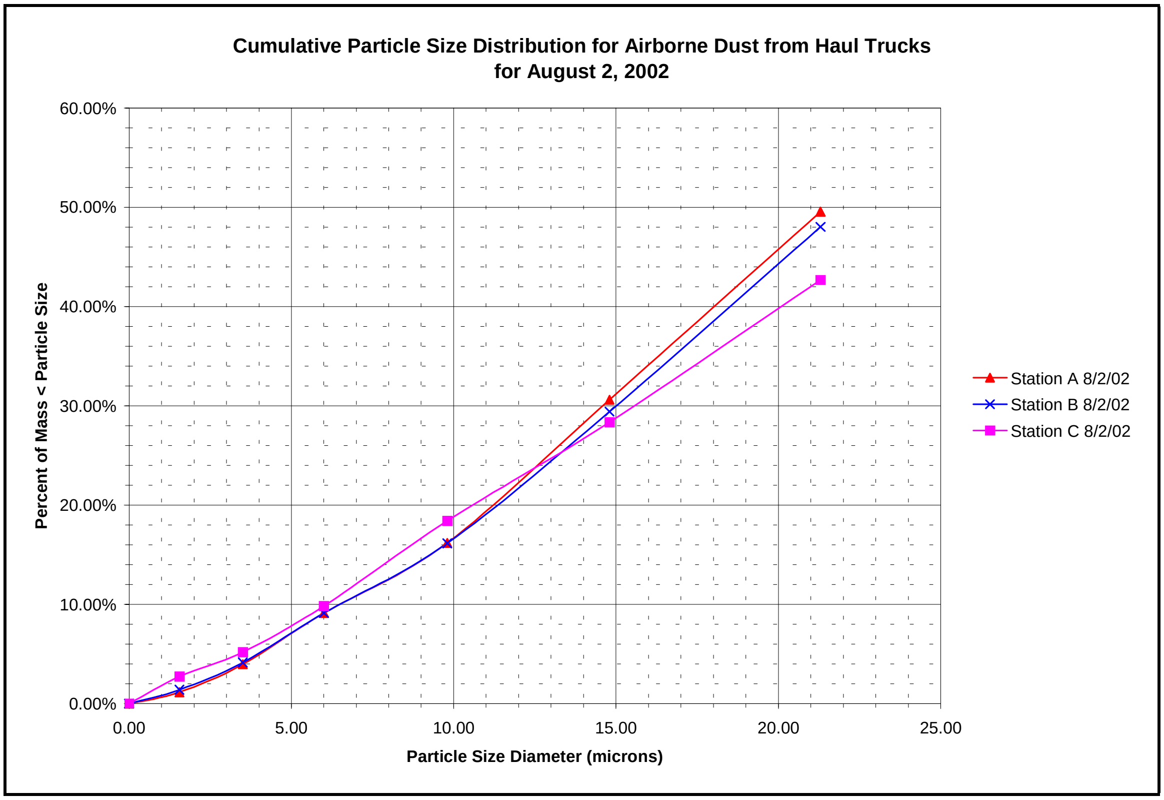


Figure 5.6 Cumulative particle size distribution for airborne dust from haul trucks at the coal mine in Pennsylvania.

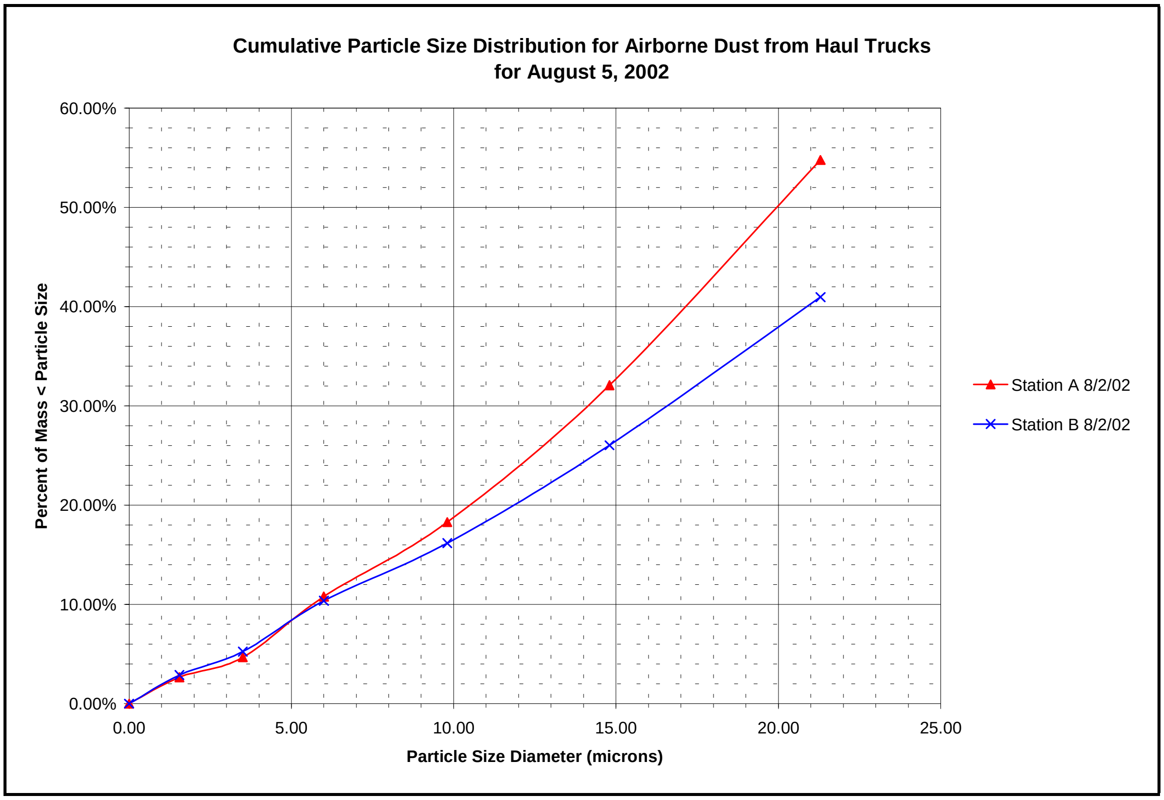


Figure 5.7 Cumulative particle size distribution for airborne dust from haul trucks at the coal mine in Pennsylvania.

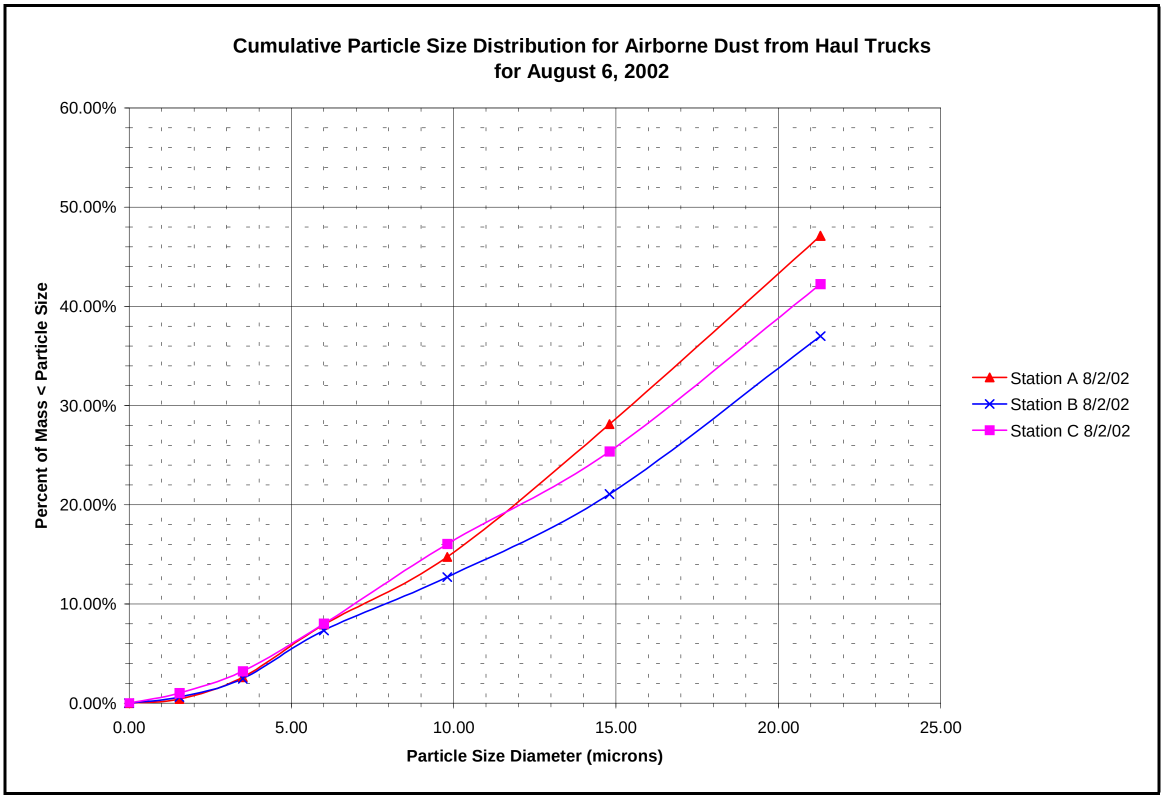


Figure 5.8 Cumulative particle size distribution for airborne dust from haul trucks at the coal mine in Pennsylvania.

those of sampling station C, which is 15.2 m. away from the haul road. The equivalent mass fractions of the Cascade Impactor stage intervals, and the equivalent cumulative particle size distributions for stations A, B, and C show that the deposition rate of the dust is not dependent upon particle size. Therefore, the deposition rate or rate of decrease in concentrations is the same for all particle size ranges. This finding agrees with prior research that stated that particle size is dependent upon particle density, not particle size (Courtney, Kost, and Colinet, 1982).

The cumulative percent finer than 10 μm ranges from 12.72% - 18.42%. Therefore, PM_{10} consists of only a small percentage of the dust, whose particle size generally ranges from 50 μm or less. The percent of dust in the range of 10 - 50 μm can vary from 81.58% - 87.28%. The fact that airborne dust contains more mass in the larger particle diameters explains the higher decrease in dust concentration for the larger particle sizes. Since there is more mass in the larger particle sizes, a constant deposition rate will give the illusion that the larger particles' dust concentrations will decrease faster than those of the smaller particles. This can be seen from Figures 5.1 through 5.5. However, examining Table 5.3 shows that the dust concentrations for all size ranges decrease at approximately the same rate, approximately a 70% decrease from stations B to C for all particle size ranges. The fact that most of the mass of the airborne dust is concentrated in the larger particle sizes creates the false impression that the larger particles are settling out first. The exception to the consistent 70 % decrease in mass concentrations is the size range of 1.55 - 0.00 μm. This phenomenon can be explained by the fact that particles of approximately < 1 μm tend to behave more like gases (Hinds, 2000). Therefore, the deposition of this particle size range may behave differently than the other size ranges.

Figures 5.8, 5.9, and 5.10 show particle size distribution graphs of the dust from haul trucks. The data for these graphs were obtained from Table 5.4. The graphs make it easier to see that most of the dust mass is in the larger particle size ranges. The fact that the particle size distributions from day to day are fairly consistent means that this particle size distribution will be typical of haul trucks operating at this surface mining operation.

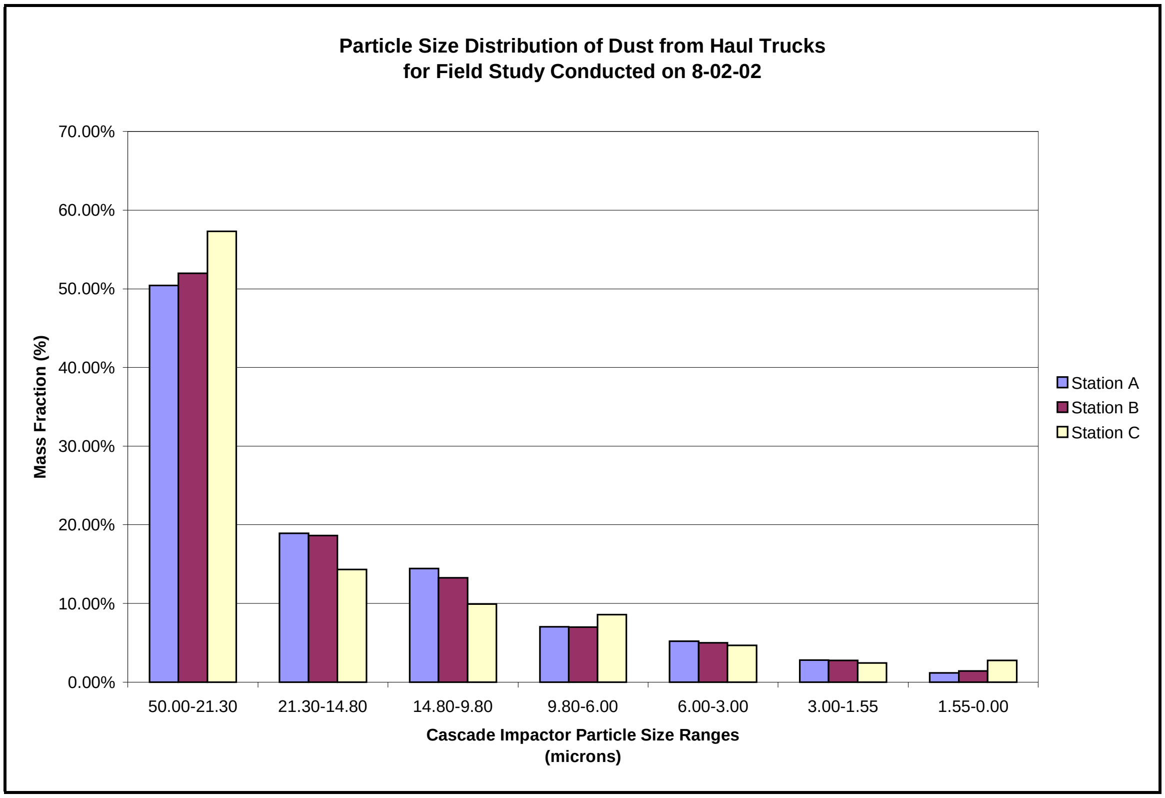


Figure 5.9 Particle size distribution of airborne dust from haul trucks at the coal mine.

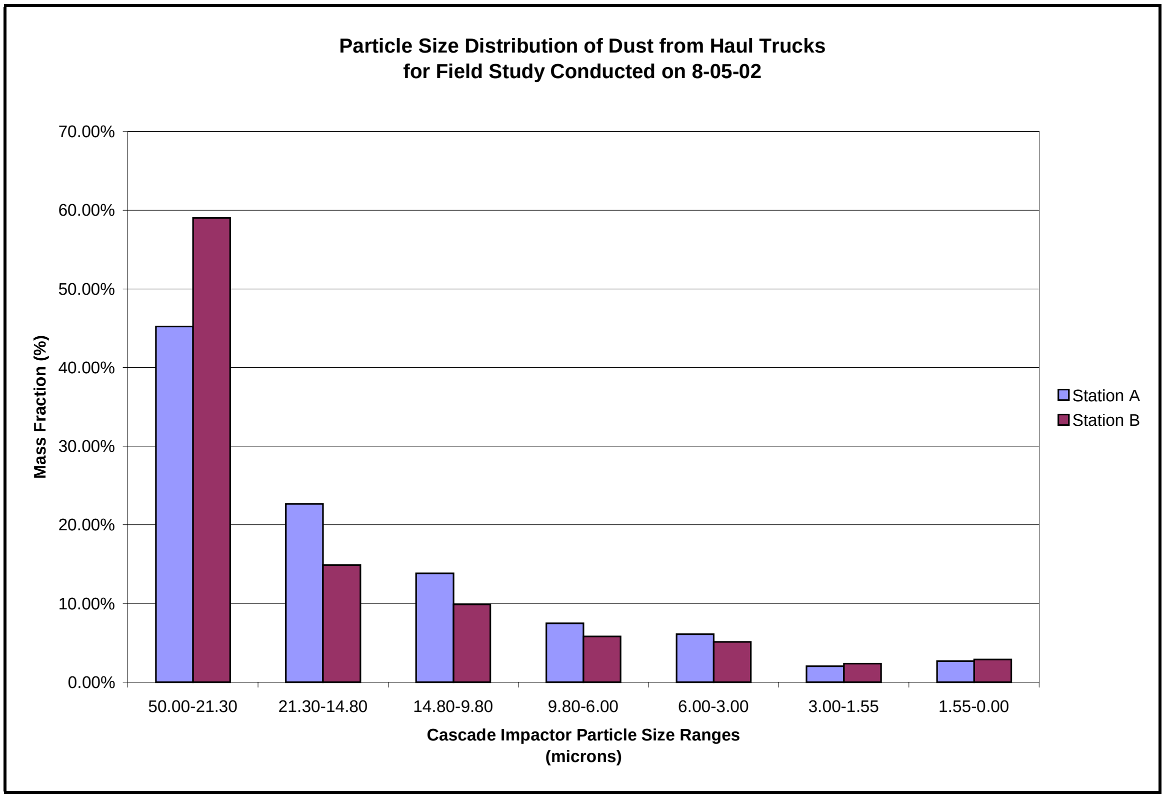


Figure 5.10 Particle size distribution of airborne dust from haul trucks at the coal mine.

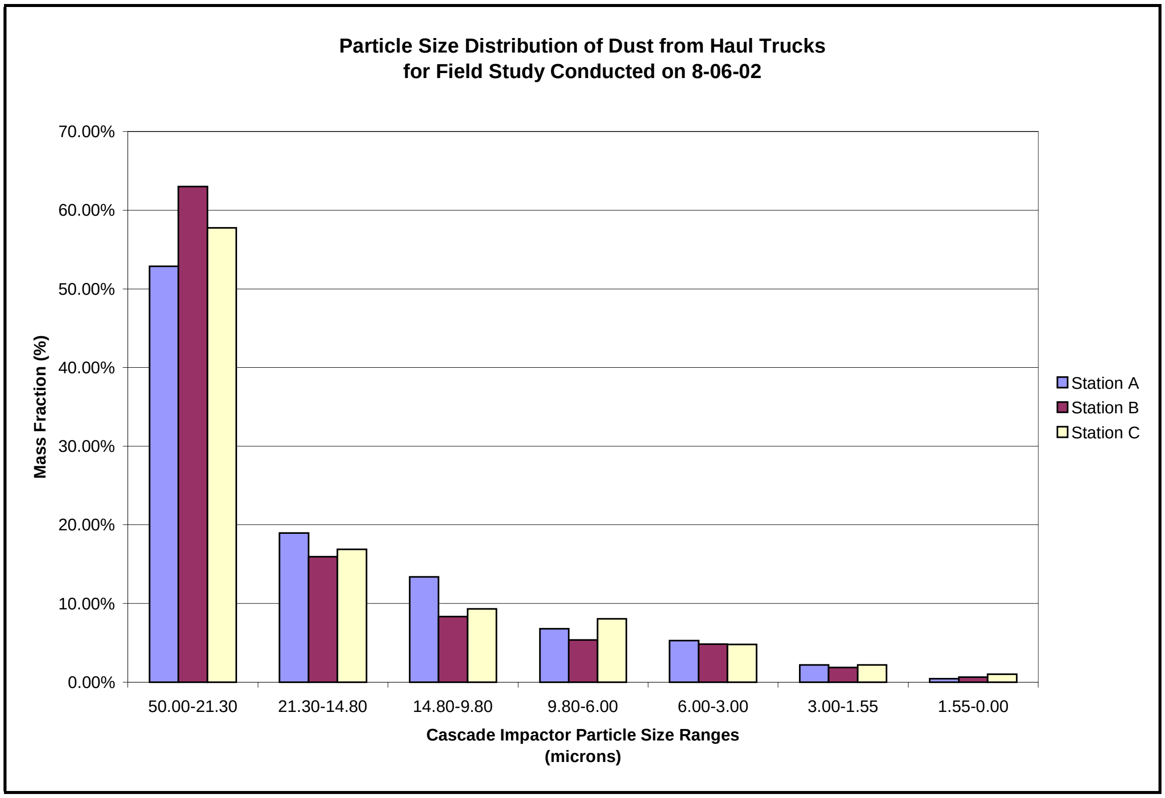


Figure 5.11 Particle size distribution of airborne dust from haul trucks at the coal mine.

5.3 Coal Mine Gravimetric Ratio Analysis

Along with gravimetric measurements, instantaneous measurements of respirable dust were made at two-second intervals throughout the duration of the field study. The instantaneous respirable dust concentration data were used to project instantaneous thoracic and total dust concentration data. This was completed through the use of ratios calculated from the gravimetric dust concentration results. Calibration or corrections to the instantaneous respirable dust measurements were also completed using these ratios. All instantaneous respirable dust measurements presented are the corrected respirable dust measurements, and the instantaneous thoracic and total dust concentrations are calculated from these corrected respirable dust measurements.

In using these ratios to project the thoracic and total dust concentrations, an assumption is made that the total and thoracic instantaneous concentrations will be consistent with the instantaneous respirable concentrations and will follow the general trend of the buildup and decay of the instantaneous respirable concentrations. It has been shown that most of the mass of the dust is in the larger particle size ranges and that the dust deposition rate is the same across all particle size ranges. However, the magnitude of the amount of dust deposition in the larger particle sizes may be greater than that of the smaller particle size ranges. Therefore, the total and thoracic instantaneous dust concentrations may actually peak higher and drop off faster than the instantaneous respirable dust concentrations. The lack of dust measuring equipment with the ability to measure the instantaneous total and thoracic concentrations requires the use of this assumption in order to analyze the instantaneous thoracic and total dust fractions.

The individual gravimetric ratios for each station calculated from the study are shown in Table 5.5. These ratios all use the PDR gravimetric sample concentrations as the standard. The instantaneous respirable dust concentrations were corrected using the respirable dust ratio, which is calculated as the PDR respirable gravimetric sample concentration divided by the PDR respirable electronically measured time-weighted-average concentration. Thoracic and total instantaneous dust concentrations were calculated by dividing the PDR respirable gravimetric sample into the gravimetric thoracic and total dust concentration measurements, respectively.

Table 5.5 Gravimetric dust ratios.

Respirable dust ratios

	Station A	**Station B**	**Station C**	**Station D**	**Station E**	**Station F**	**Station G**
August 2, 2002	1.4794	1.4615	1.3531	1.2460	1.0998	0.3316	1.1188
August 5, 2002	0.8179	0.8048	0.3200	0.1083	0.9184	0.3921	No data
August 6, 2002	1.2217	1.2783	3.8513	0.3026	1.1267	1.3524	Invalid

Thoracic dust ratios

	Station A	**Station B**	**Station C**	**Station D**	**Station E**	**Station F**	**Station G**
August 2, 2002	3.8523	3.5380	2.6871	2.6863	4.4370	12.0397	4.0746
August 5, 2002	4.7767	3.1021	3.1747	8.4216	3.8656	3.4745	No data
August 6, 2002	3.9713	3.8846	3.2624	14.4243	5.4114	1.8116	Invalid

Total dust ratios

	Station A	**Station B**	**Station C**	**Station D**	**Station E**	**Station F**	**Station G**
August 2, 2002	9.4592	8.8094	6.0524	6.2214	11.4984	26.6030	13.9623
August 5, 2002	8.5628	5.2567	12.1019	18.9552	7.2646	11.4126	No data
August 6, 2002	9.6246	11.4119	7.1600	43.1031	11.2477	6.3914	Invalid

Table 5.6 Correlations of respirable dust ratios.

	Station A	Station B	Station C	Station D	Station E	Station F
Station A	1					
Station B	0.9925	1				
Station C	0.4035	0.5126	1			
Station D	0.8823	0.8179	-0.0747	1		
Station E	0.8700	0.9239	0.8022	0.5355	1	
Station F	0.0740	0.1957	0.9423	-0.4041	0.5561	1

Table 5.7 Correlations of thoracic dust ratios.

	Station A	Station B	Station C	Station D	Station E	Station F
Station A	1					
Station B	-0.8384	1				
Station C	0.4797	0.0761	1			
Station D	0.1053	0.4538	0.9231	1		
Station E	-0.7027	0.9769	0.2873	0.6336	1	
Station F	-0.4708	-0.0862	-0.9999	-0.9269	-0.2969	1

Table 5.8 Correlations of total dust ratios.

	Station A	Station B	Station C	Station D	Station E	Station F
Station A	1					
Station B	0.9584	1				
Station C	-0.9498	-0.8211	1			
Station D	0.3165	0.5741	-0.0040	1		
Station E	0.9805	0.8835	-0.9928	0.1237	1	
Station F	0.1370	-0.1514	-0.4399	-0.8963	0.3292	1

Correlations were completed on the respirable, thoracic, and total dust gravimetric concentration ratios to determine if the data sets exhibited any strong relationships to each other. The results of the correlations can be seen in Tables 5.3, 5.4, and 5.5.

In order to understand the correlation results, the correlation rules are provided (Devore, 1982). A correlation equal to one represents positive correlation. In this case the large values of one data set correspond to large values of the other. Zero represents no correlation. A correlation equal to negative one represents negative correlation. In this situation the large values of one data set correspond to small values of the other. Strong relationships are defined as > 0.8, moderate relationships as > 0.5 and weak relationships as ≤ 0.5. No correlation, however, does not mean the data exhibit no relationship; it just shows that the relationship of the data is not linear (Devore, 1982).

The respirable ratio correlations showed 10 strong to moderate relationships and five weak relationships. Thoracic ratio correlations showed seven strong to moderate relationships and eight weak relationships. Total ratio correlations showed eight strong to moderate relationships, and seven weak relationships. There were no correlations equal to zero in any category. These results show that there is a moderate to weak linear relationship among the ratios by station.

These ratios are too variable to be used in projecting instantaneous thoracic and total concentrations and to be used in correcting the respirable concentrations. Some of this variability may be the result of measurement errors inherent in weighing the gravimetric filters. These measurement errors are more noticeable when dealing with filters containing smaller masses of dust (Chow and Watson, August 1998). Since there is some linear relationship of the ratios, a better method to determine the ratios for respirable, thoracic and total dust concentration categories may be to plot the data for each category and use linear regression techniques to calculate one ratio for each category. This will also minimize the effect of the measurement weighing error upon a single ratio by distributing the measurement weighing error over the entire category.

The procedure for determining the ratio to correct the respirable instantaneous dust concentrations was to plot all the electronically measured PDR time-weighted-average dust concentrations against the gravimetric PDR time-weighted-average dust concentrations for all three days of the field study. The linear regression was used to calculate the best-fit line through the data points with the y-intercept being held to zero. Figure 5.13 presents the resulting graph, showing the data points with the best-fit line and its corresponding equation:

$$y = 0.8188x \tag{5.1}$$

where

x = PDR gravimetric respirable dust concentration in mg/m^3

y = electronic measured PDR respirable dust concentration in mg/m^3

This equation has an $R^2 = 0.5989$. To correct the instantaneous dust concentrations, which were electronically measured, the electronically measured instantaneous dust concentrations were entered as y and solved for x. Therefore, the equation must be simplified to solve for x resulting in the following equation:

$$x = 1.2213y \tag{5.2}$$

where

x = PDR gravimetric respirable dust concentration in mg/m^3

y = electronic measured PDR respirable dust concentration in mg/m^3

Equation 5.2 was used to correct all the electronically measured instantaneous respirable dust concentrations.

The procedure for determining the ratio to project the thoracic and the total instantaneous dust concentrations was to plot all the thoracic and the total gravimetric time-weighted-average dust concentrations against the gravimetric PDR time-weighted-average dust concentrations for all three days of the field study. Then linear regression was used to calculate the best-fit line through the data points with the y-intercept being held to zero. Figures 5.14 and 5.15 display the resulting graphs of the thoracic and total data points, respectively, with their best-fit line and corresponding equations. The resulting equation for the thoracic instantaneous dust concentrations is

$$y = 3.9335x \tag{5.3}$$

where

x = PDR gravimetric respirable dust concentration in mg/m^3

y = thoracic dust concentration in mg/m^3

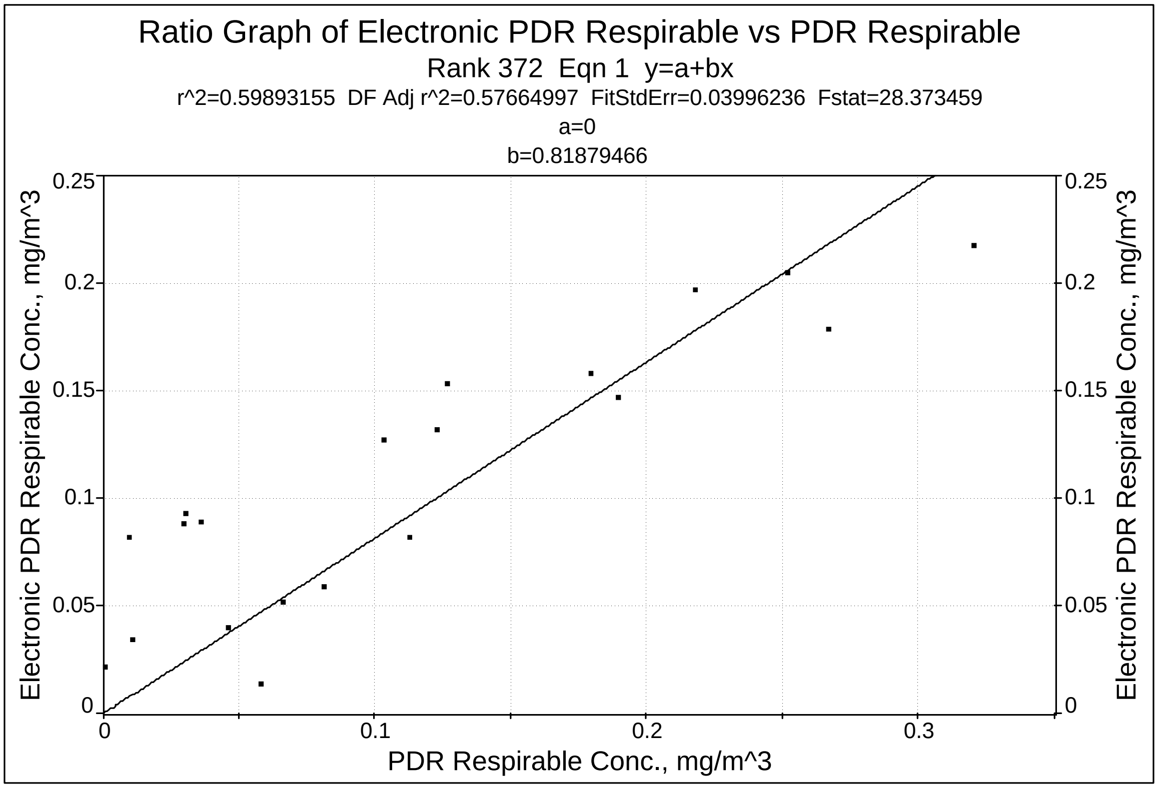


Figure 5.12 Linear regression solution to determine ratio to correct the instantaneous respirable dust concentrations.

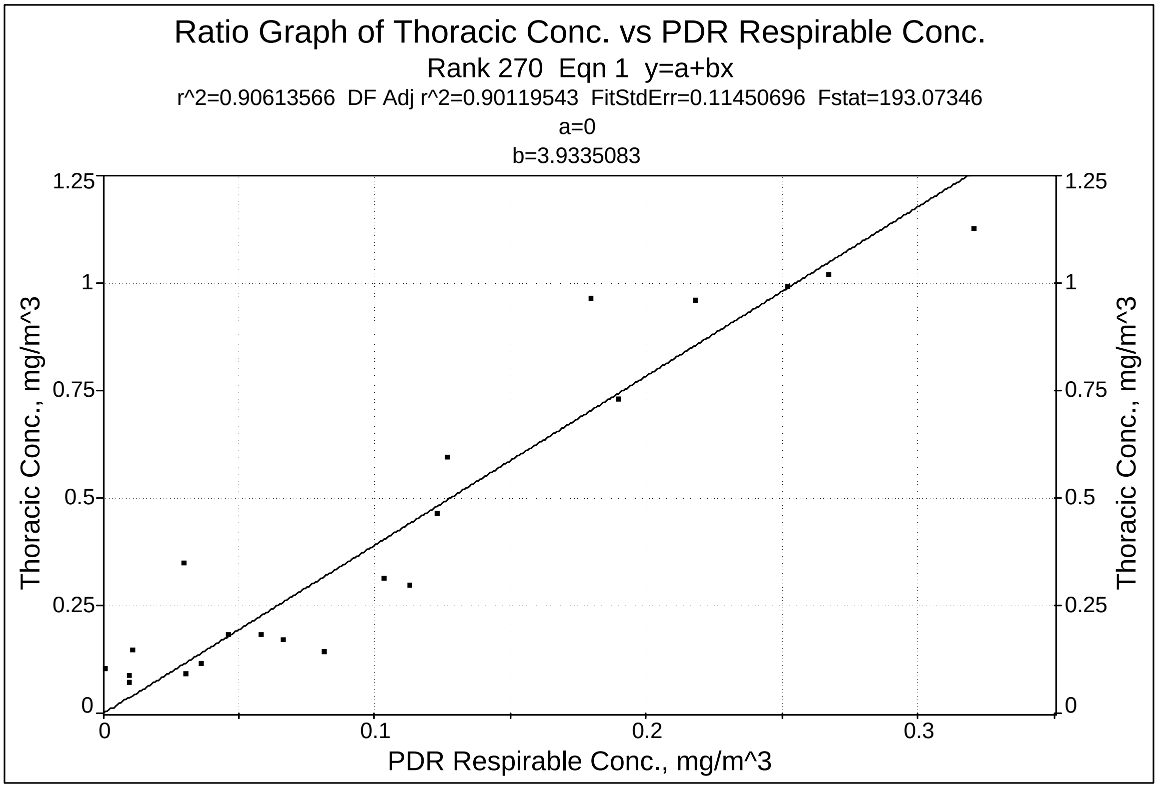


Figure 5.13 Linear regression determination of ratio to project instantaneous thoracic dust concentrations from instantaneous respirable dust concentrations.

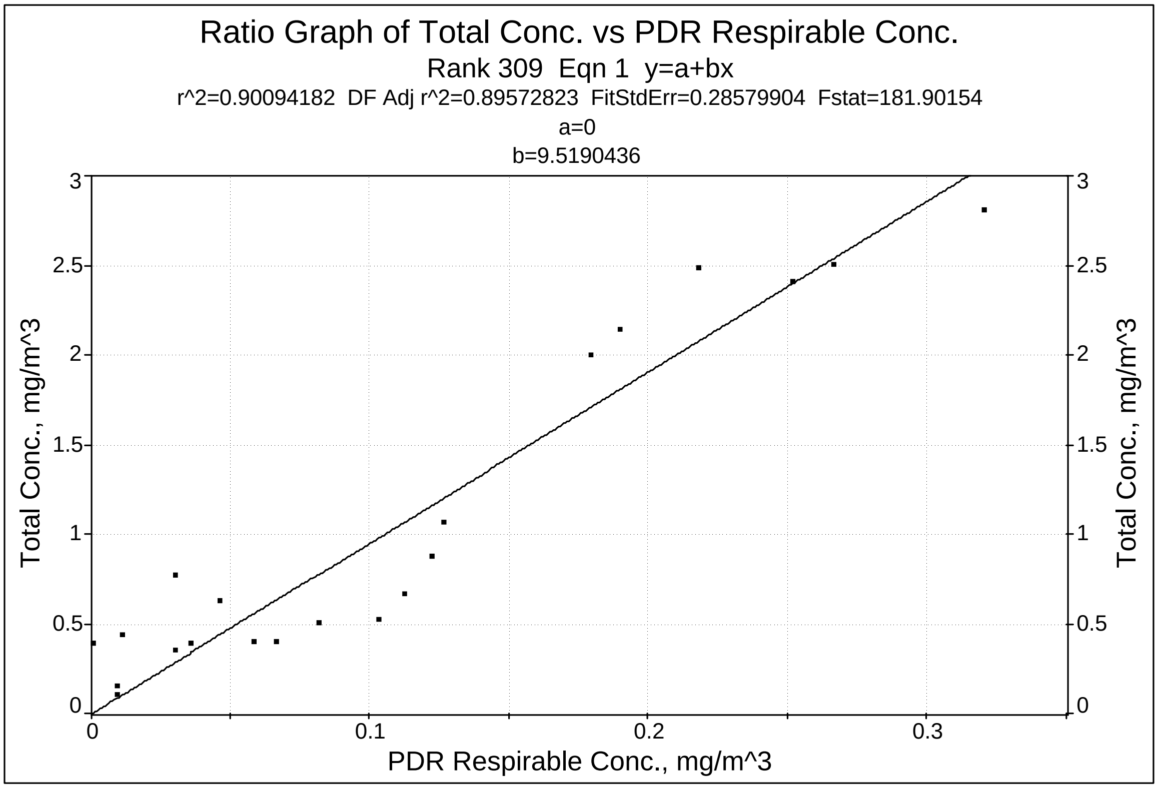


Figure 5.14 Linear regression determination of ratio to project instantaneous total dust concentrations from instantaneous respirable dust concentrations.

This equation has an $R^2 = 0.9061$. To project the instantaneous thoracic dust concentrations, the corrected instantaneous respirable dust concentrations were entered as x and solved for y. The resulting equation for the total instantaneous dust concentrations is

$$y = 9.5190x \tag{5.4}$$

where

x = PDR gravimetric respirable dust concentration in mg/m^3

y = total dust concentration in mg/m^3

This equation has an $R^2 = 0.9009$. To project the instantaneous total dust concentrations, the corrected instantaneous respirable dust concentrations were entered as x and solved for y.

Equations 5.3 and 5.4 were used in calculating the instantaneous thoracic and instantaneous total dust concentration data, respectively. Comparing the ratios from the equations to the corresponding ratios in Table 5.5 shows that the equation ratios are close to the individual calculated ratios, but there are some differences. These differences can be attributed to those gravimetric data points having high measurement weighing errors, with a few being anomalous values. The linear regression technique for calculating the ratios is a better technique because it distributes the measurement weighing errors across the entire data range and smoothes any anomalous values.

5.4 Stone Quarry Gravimetric Analysis

The gravimetric results from the stone quarry field study for each of the stations are shown in Table 5.9. These results are measurements of dust concentrations predominately from over-the-road highway haul trucks, with some Cat 773B haul trucks. The dust concentrations are time weighted average concentrations for a time frame of approximately 7 - 7 ½ hours.

Figures 5.16, 5.17, and 5.18 illustrate the decay of the respirable, thoracic, and total gravimetric time weighted average dust concentrations as the distance from the source increases. The dust concentrations from these figures are based on the gravimetric results of the field study shown in Table 5.9. Again for reference, the haul road is located between Stations A and B, and the distance between station B-C and C-D is 15 meters. As shown, the dust concentrations decrease rapidly within 30 meters from the source. Once at 30 meters distance from the source, the dust levels get very close to the background dust concentration levels. As in the coal mine field study, the total and thoracic dust concentrations decay much more rapidly from the source than the respirable dust.

Figures F.4, F.5, and F.6 in Appendix F, Section F.2 show the general wind directions for each day. The gravimetric results shown in Figures 5.16, 5.17, and 5.18 display results expected with the wind data. The wind came predominately from the West on all three days of the field study, and the sampling stations were on the downwind side of the haul road. Station A always had a lower dust concentration than Station B, as was to be expected. However, Station A dust concentrations were still quite high for being on the upwind side of the haul road. These high concentrations occurred because the major source of the resulting dust concentrations was the haul trucks. The haul trucks imparted a momentum to the dust enabling it to overcome the wind. Some dust from the crushing plant may also have contributed to the high dust concentrations on the upwind side of the haul road, but it would have also affected the downwind sampling stations. The dust concentrations at stations C and D stabilized to a point that is close to the background dust concentration levels that are calculated in Section 5.8. The close proximity of the crushing plant may have had an effect on the dust measurement results, but its effect would have been on the background dust concentration levels. Reviewing the instantaneous data from this field study shows that the dust concentration spikes from the haul truck are plainly evident as the haul truck passes the measurement stations.

The results from the Cascade Impactors, again, support the reduction in dust concentrations as one proceeds 50 feet away from the edge of the haul road. This is illustrated in Figures 5.15, 5.16 and 5.17. The results from the Cascade Impactor from July 18, 2002 showed a dramatic drop in dust concentrations from station A to station B and then an increase from station B to station C. This result is atypical compared to the results from the other Cascade Impactors. After the field study was completed, it was questioned whether the mylar filter sets for stations A and B on July 18, 2002 were accidentally mislabeled and switched (i.e., the mylar filter set recorded as station A was really the mylar filter set for station B and vice versa). This could easily have happened, as there were a multitude of filter cassettes and mylar filter sets to track. The Cascade Impactor results as shown are expected to be correct, but due to the fact that there is still some lingering doubt about the mislabeled mylar filter sets, it is recommended to discard the Cascade Impactor results on July, 18 2002.

Table 5.9 Gravimetric time weighted average dust concentrations in mg/m^3.

16-Jul-02

	Station A	Station B	Station C	Station D	Station E	Station F	Station G
Respirable PDR	0.188	0.178	0.060	0.049	0.156	0.090	0.066
Respirable	0.103	0.157	0.078	0.053	0.127	0.070	0.062
Thoracic	0.459	0.688	0.247	0.122	0.540	0.253	0.153
Total	1.136	2.103	1.017	0.365	2.110	0.624	0.620

17-Jul-02

	Station A	Station B	Station C	Station D	Station E	Station F	Station G
Respirable PDR	0.132	0.394	0.080	0.066	0.272	0.115	0.065
Respirable	0.116	0.467	0.081	0.075	0.358	0.115	0.064
Thoracic	0.756	1.587	0.327	0.226	1.629	0.337	0.154
Total	1.741	5.118	1.042	0.601	4.216	0.602	0.661

18-Jul-02

	Station A	Station B	Station C	Station D	Station E	Station F	Station G
Respirable PDR	0.038	0.153	0.050	0.034	0.142	0.060	0.032
Respirable	0.041	0.150	0.050	0.038	0.245	0.075	0.055
Thoracic	0.176	0.675	0.216	0.102	1.054	0.252	0.154
Total	0.376	2.550	1.004	0.526	1.744	1.149	0.663

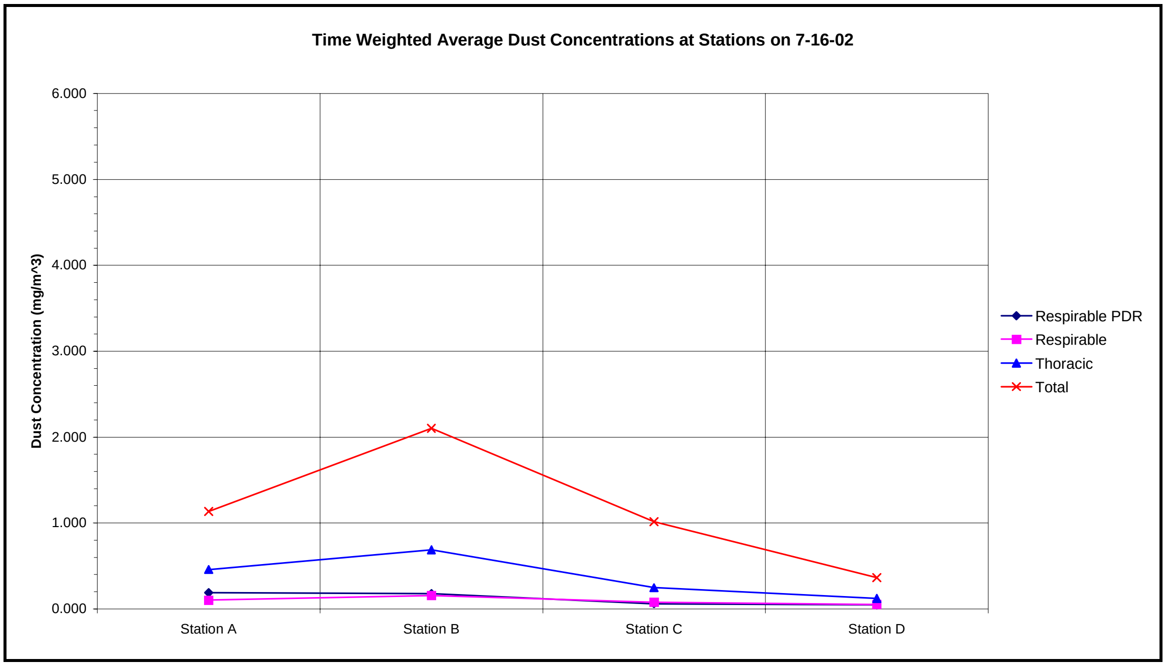


Figure 5.15 Time weighted average gravimetric dust concentrations in mg/m^3 for the stone quarry field study.

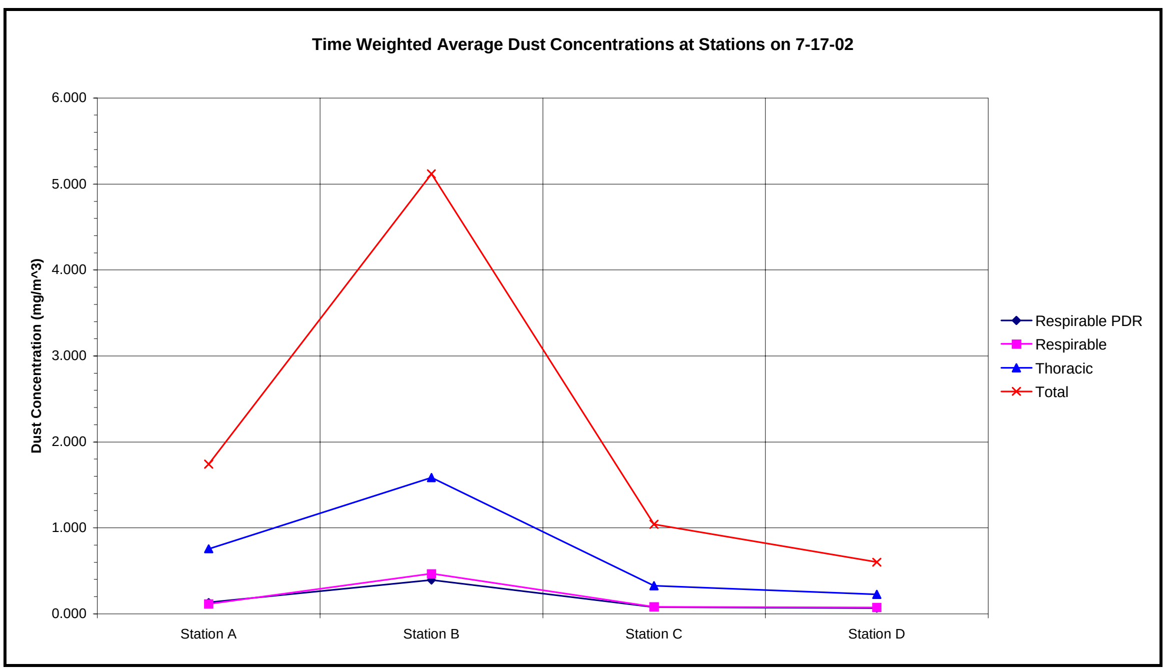


Figure 5.16 Time weighted average gravimetric dust concentrations in mg/m^3 for the stone quarry field study.

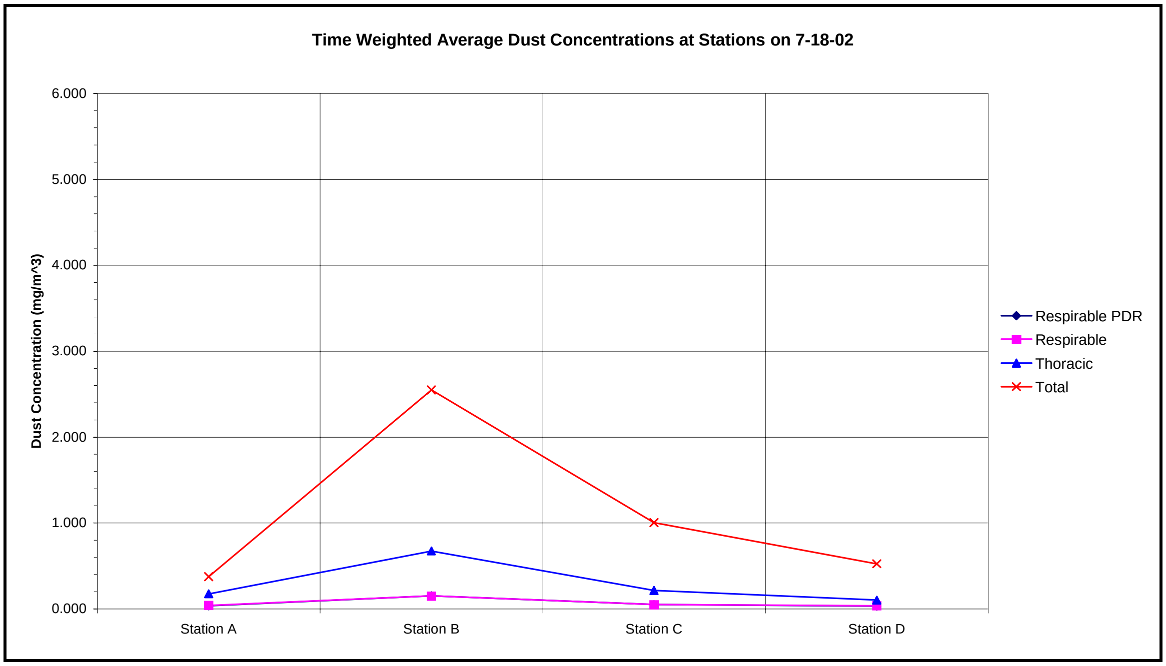


Figure 5.17 Time weighted average gravimetric dust concentrations in mg/m^3 for the stone quarry field study.

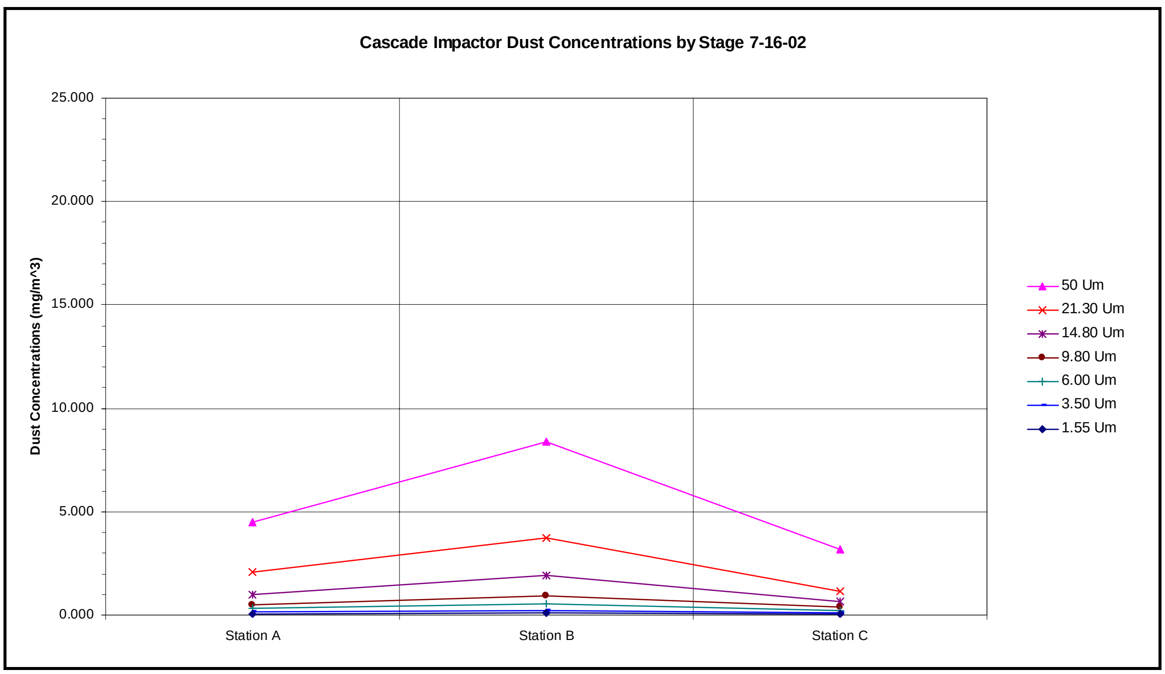


Figure 5.18 Time weighted average dust concentration from Cascade Impactors in mg/m^3 for the stone quarry field study.

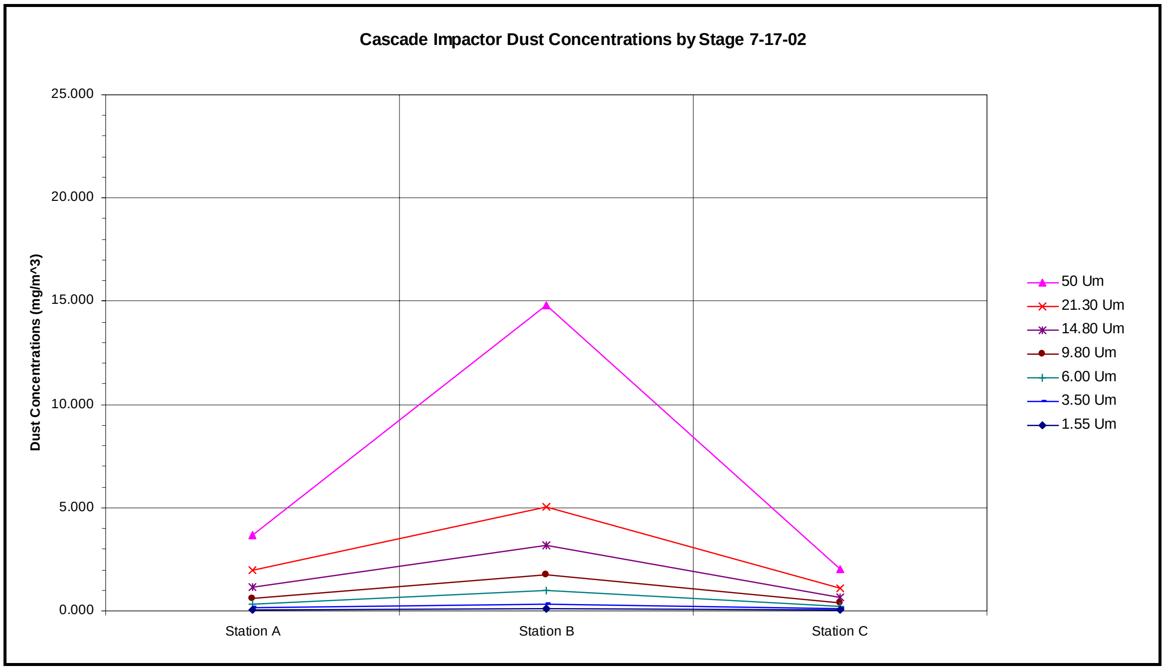


Figure 5.19 Time weighted average dust concentration from Cascade Impactors in mg/m^3 for the stone quarry field study.

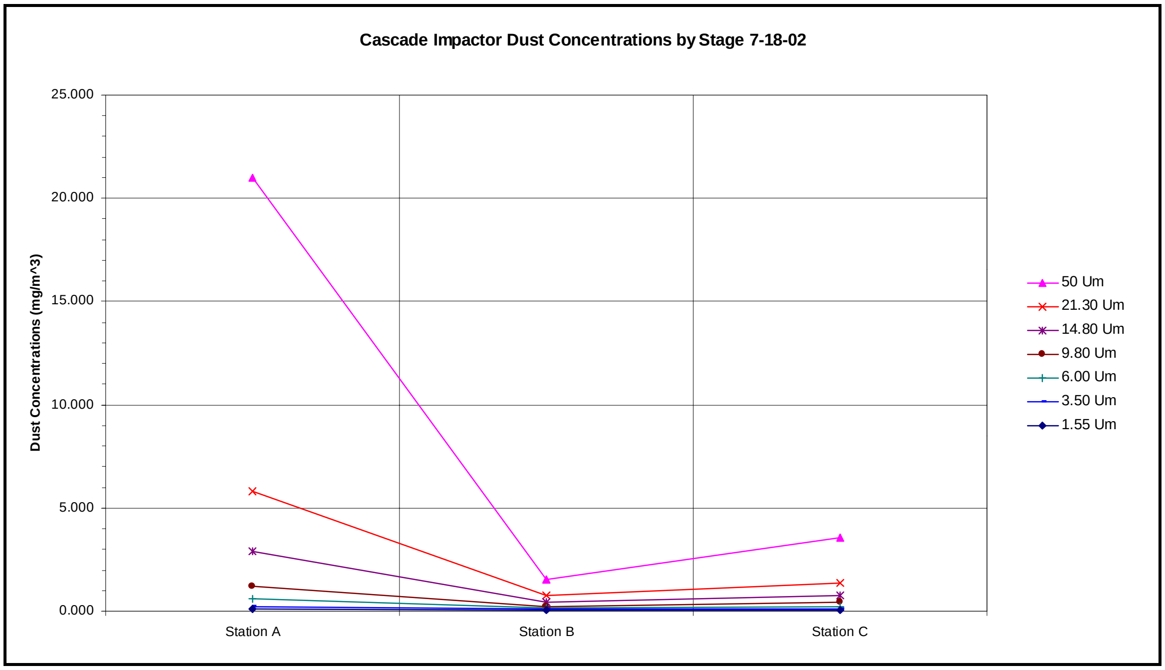


Figure 5.20 Time weighted average dust concentration from Cascade Impactors in mg/m^3 for the stone quarry field study.

5.5 Stone Quarry Airborne Particle Size Distribution

An examination of the airborne particle size distribution can be made from the Cascade Impactor sampling results. Table 5.10 presents the mass concentrations for each size range and the total mass concentration at each sampling station for each day of the field study. Table 5.11 shows the particle size distribution of airborne dust from haul trucks at each sampling location for each day of the field study by showing the mass fraction of dust for each particle size range. The mass fractions seem to be fairly consistent for the particle size ranges at all sampling stations for July 16, 2002. The other days contain some anomalous values and the mass fractions do not exhibit the same consistency as in the coal mine field study. The cumulative particle size distribution plots shown in Figures 5.21, 5.22, and 5.23 display the inconsistencies in the mass fractions better than the values in Table 5.10.

The cumulative particle size distribution plot for July 17, 2002, shown in Figure 5.22, shows that the Cascade Impactor results for station B deviate substantially from the results of stations A and C -as much as a difference of 20 percentage points at the largest particle size fraction. Reviewing Table 5.10 shows that the Cascade Impactor at station B had a large mass concentration, with the majority of this mass concentration being contributed by the 50 - 21.30 μm particle size range. This large mass concentration may be the result of the Cascade Impactor being overloaded. Therefore, this impactor's results are not reliable and should be discarded. Once station B is discarded, the particle size distributions of stations A and C demonstrate the consistency in the mass fractions that has been seen in other results of the field studies.

The Cascade Impactor results for July 18, 2002 will be discarded for the previously mentioned reason that there is some confusion with the labeling of the mylar filter sets. In addition, further investigation shows that the results from the Cascade Impactor at station A should be discarded because of possible overloading. Table 5.10 shows that the Cascade Impactor at station A had a large mass concentration, with the majority of this mass concentration being contributed by the 50 - 21.30 μm particle size range similar to the Cascade Impactor for station B on July 17, 2002. A review of the Cascade Impactor data for stations B and C for July 18, 2002 shows a variance that cannot be explained. This Cascade Impactor results for this day will be discarded for the two reasons given previously.

Using the Cascade Impactor results for July 16, 2002 and the Cascade Impactor result of station A and C for July 17, 2002, the cumulative percent finer than the 10 μm particle size

Table 5.10 Mass Concentrations in μg/m^3 of Dust Created by Haul Trucks.									
	July 16, 2002			**July 17, 2002**			**July 18, 2002**		
Particle Size Range μm	**Station A**	**Station B**	**Station C**	**Station A**	**Station B**	**Station C**	**Station A**	**Station B**	**Station C**
50 - 21.3	2.43	4.66	2.08	2.03	11.78	1.16	15.22	0.78	2.19
21.3 - 14.80	1.04	1.81	0.50	1.00	2.20	0.49	2.89	0.32	0.57
14.80 - 9.80	0.50	0.96	0.26	0.64	1.76	0.32	1.69	0.17	0.34
9.80 - 6.00	0.21	0.41	0.16	0.33	0.93	0.23	0.60	0.08	0.21
6.00 - 3.50	0.17	0.31	0.09	0.23	0.78	0.13	0.40	0.06	0.11
3.50 - 1.55	0.07	0.12	0.05	0.11	0.29	0.07	0.12	0.03	0.06
1.55 - 0.00	0.07	0.11	0.07	0.07	0.11	0.07	0.09	0.07	0.06
Total Mass Conc.	4.49	8.38	3.21	4.42	17.84	2.47	21.00	1.52	3.54

Table 5.11 Particle Size Distribution Showing Mass Fraction (%) of Airborne Dust Created by Haul Trucks.

	July 16, 2002			July 17, 2002			July 18, 2002		
Particle Size Range µm	**Station A**	**Station B**	**Station C**	**Station A**	**Station B**	**Station C**	**Station A**	**Station B**	**Station C**
50 - 21.3	54.49	55.55	64.73	46.08	66.02	47.03	72.72	51.18	61.85
21.3 - 14.80	23.35	21.63	15.53	22.76	12.32	19.95	13.81	21.10	16.22
14.80 - 9.80	11.16	11.49	8.22	14.56	9.85	13.10	7.73	11.51	9.63
9.80 - 6.00	4.61	4.88	4.98	7.49	5.22	9.16	2.87	5.53	5.92
6.00 - 3.50	3.26	3.72	2.78	5.22	4.39	5.28	1.91	3.93	3.08
3.50 - 1.55	1.47	1.40	1.50	2.39	1.60	2.71	0.55	1.99	1.59
1.55 - 0.00	1.66	1.34	2.25	1.51	0.60	2.78	0.41	4.77	1.70

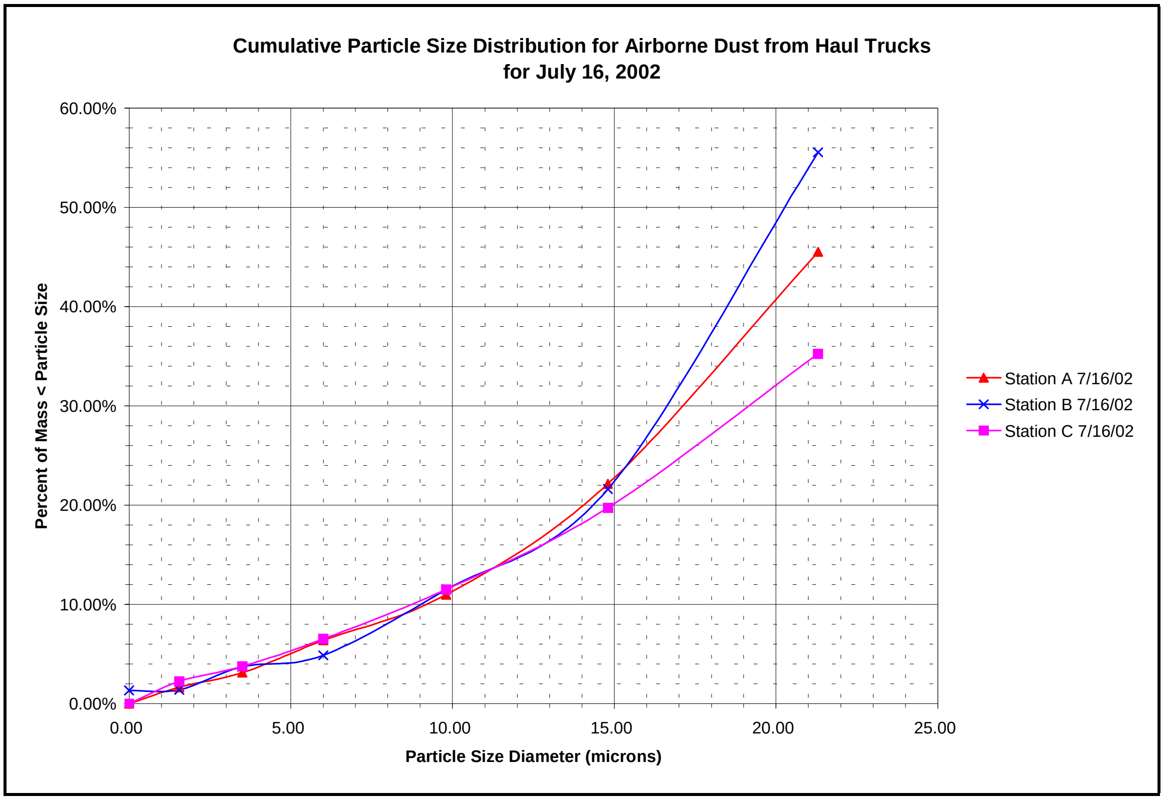


Figure 5.21 Cumulative particle size distribution for airborne dust from haul trucks at the stone quarry in Virginia.

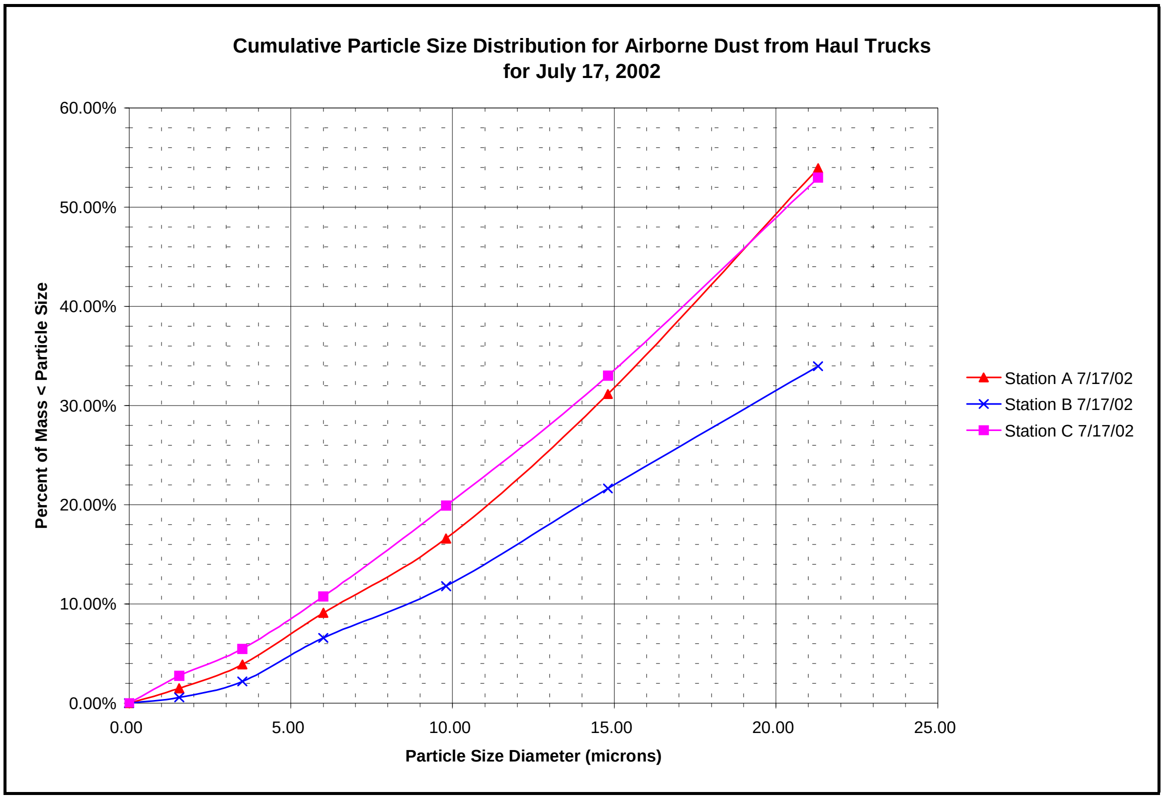


Figure 5.22 Cumulative particle size distribution for airborne dust from haul trucks at the stone quarry in Virginia.

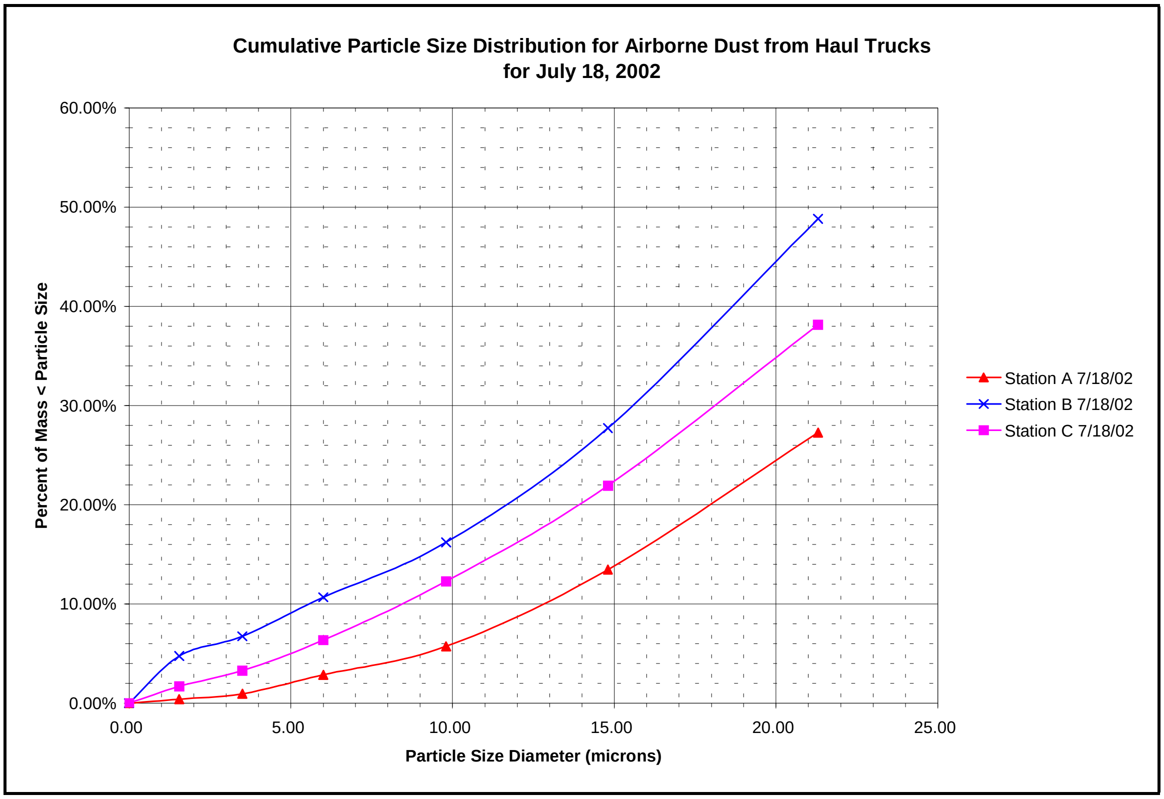


Figure 5.23 Cumulative particle size distribution for airborne dust from haul trucks at the stone quarry in Virginia.

ranges from 6.39% - 10.77%. Therefore, PM_{10} consists of only a small percentage of the dust, whose particle size generally ranges from 50 μm or less. The percent of dust in the range of 10 - 50 μm can range from 89.23% - 93.61%. These results demonstrate consistency with the results from the Cascade Impactor results of the coal mine field study.

Figures 5.24 and 5.25 show particle size distribution graphs of the dust from haul trucks. The data for these graphs were obtained from Table 5.11 using only the acceptable Cascade Impactor results. The graphs make it easier to see that most of the mass of the dust is in the larger particle size ranges. The particle size distributions shown in Figures 5.24 and 5.25 are remarkably similar to the particle size distributions from the coal mine field study shown in Figures 5.9, 5.10, and 5.11. The fact that the particle size distributions from day to day are fairly consistent means that this particle size distribution may be typical of haul trucks operating at surface mining operations.

5.6 Stone Quarry Gravimetric Ratio Analysis

The instantaneous respirable dust concentration data were used to project instantaneous thoracic and total dust concentration data. Again, this was completed through the use of ratios calculated from the gravimetric dust concentration results. Calibration or corrections to the instantaneous respirable dust measurements were also completed using these ratios, and all instantaneous respirable dust measurements presented are the corrected respirable dust measurements.

The same assumption made in Section 5.3 was made in projecting the instantaneous thoracic and total dust concentrations. This assumption is that the total and thoracic instantaneous concentrations will be consistent with the instantaneous respirable concentrations and will follow the general trend of the buildup and decay of the instantaneous respirable concentrations.

The procedure for determining the ratio to correct the respirable instantaneous dust concentrations was to plot all the electronically measured PDR time-weighted-average dust concentrations against the gravimetric PDR time-weighted-average dust concentrations for all three days of the field study. Then linear regression was used to calculate the best-fit line through the data points with the y-intercept being held to zero. Figure 5.26 displays the resulting graph presenting the data points with the best-fit line and its corresponding equation:

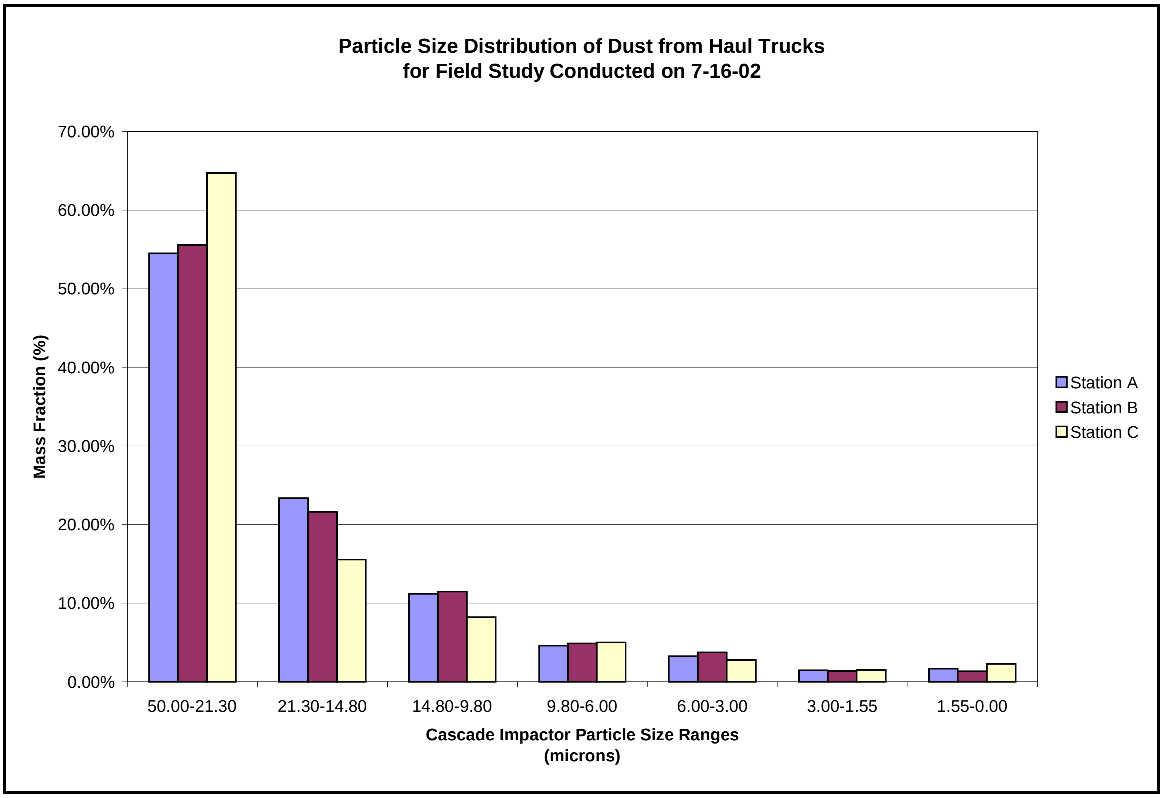


Figure 5.24 Particle size distribution of airborne dust from haul trucks at the stone quarry.

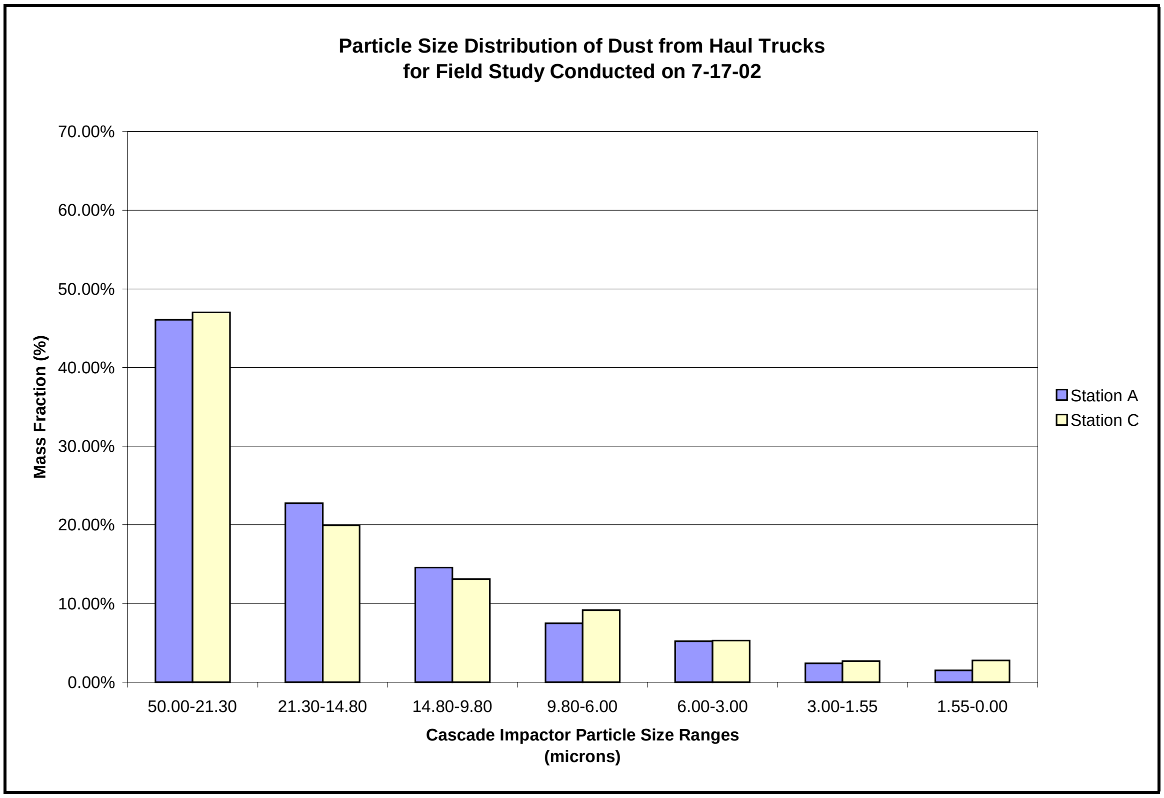


Figure 5.25 Particle size distribution of airborne dust from haul trucks at the stone quarry.

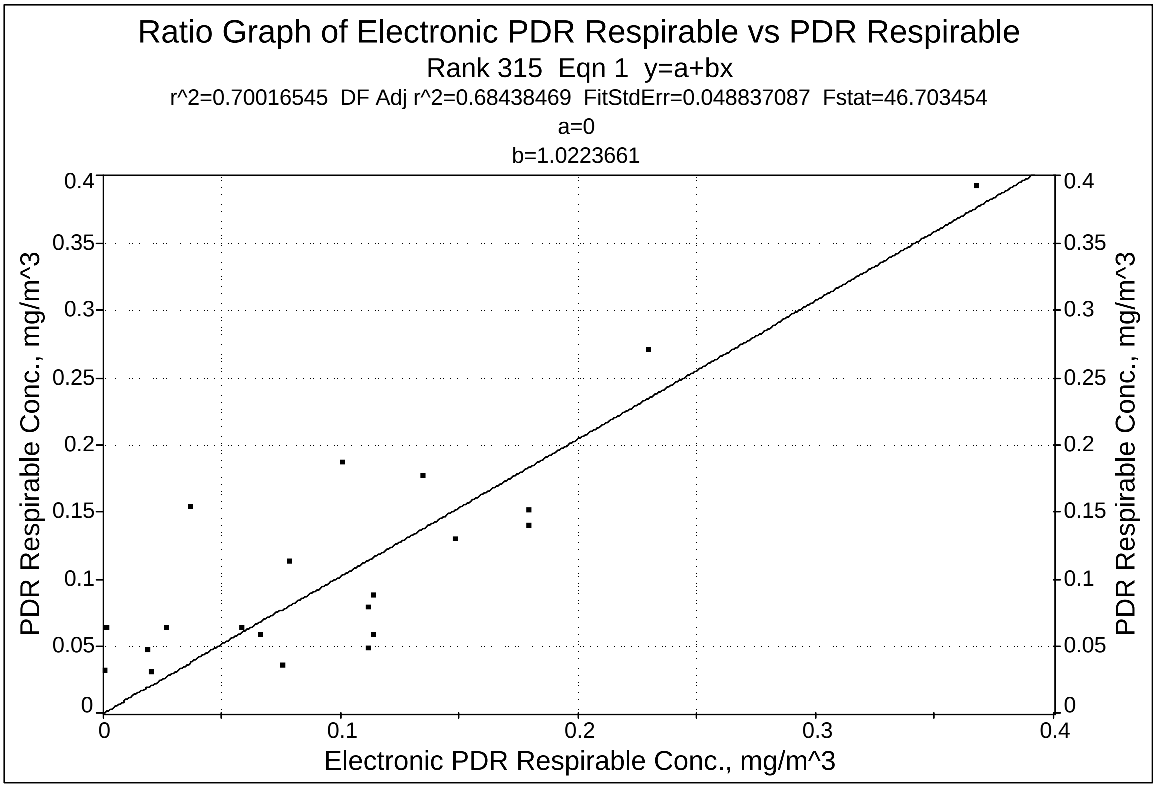


Figure 5.26 Linear regression solution to determine ratio to correct the instantaneous respirable dust concentrations.

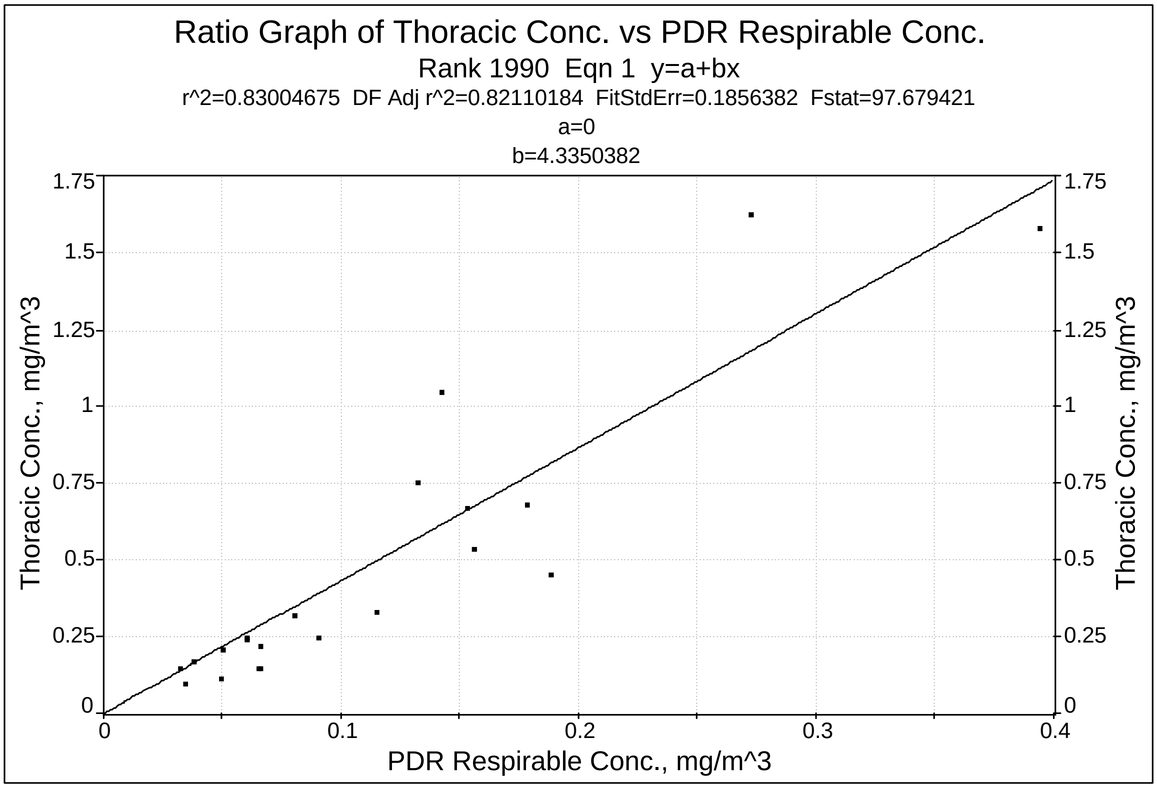


Figure 5.27 Linear regression determination of ratio to project instantaneous thoracic dust concentrations from instantaneous respirable dust concentrations.

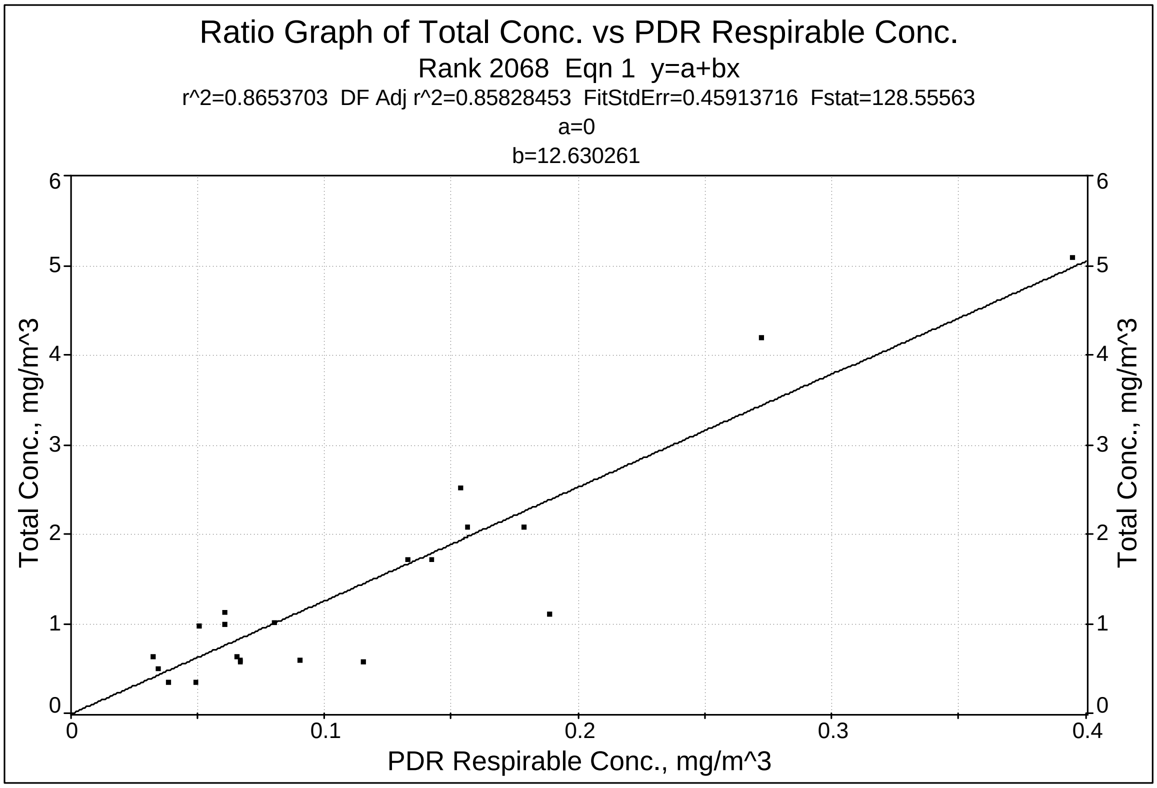


Figure 5.28 Linear regression determination of ratio to project instantaneous total dust concentrations from instantaneous respirable dust concentrations.

$$y = 1.0224x \qquad (5.5)$$

where

x	=	electronic measured PDR respirable dust concentration in mg/m^3
y	=	PDR gravimetric respirable dust concentration in mg/m^3

This equation has an $R^2 = 0.7002$. To correct the instantaneous dust concentrations, which are electronically measured, the electronically measured instantaneous dust concentrations were entered as x and solved for y. Equation 5.5 was used to correct all the electronically measured instantaneous respirable dust concentrations.

The procedure for determining the ratio to project the instantaneous thoracic and the total dust concentrations was the same used on the coal mine field study results. All the thoracic and total gravimetric time-weighted-average dust concentrations are plotted against the gravimetric PDR time-weighted-average dust concentrations for all three days of the field study. Then linear regression was used to calculate the best-fit line through the data points with the y-intercept being held to zero. Figures 5.27 and 5.28 display the resulting graphs of the thoracic and total data points, respectively, with their best-fit line and corresponding equations. The resulting equation for the thoracic instantaneous dust concentrations is

$$y = 4.3350x \qquad (5.7)$$

where

x	=	PDR gravimetric respirable dust concentration in mg/m^3
y	=	thoracic dust concentration in mg/m^3

This equation has an $R^2 = 0.8300$. To project the instantaneous thoracic dust concentrations, the corrected instantaneous respirable dust concentrations were entered as x and solved for y. The resulting equation for the total instantaneous dust concentrations is

$$y = 12.6303x \qquad (5.8)$$

where

x	=	PDR gravimetric respirable dust concentration in mg/m^3
y	=	total dust concentration in mg/m^3

This equation has an $R^2 = 0.8654$. To project the instantaneous total dust concentrations, the corrected instantaneous respirable dust concentrations were entered as x and solved for y.

Equations 5.7 and 5.8 were used in calculating the instantaneous thoracic and instantaneous total dust concentration data, respectively. The ratios in these equations for the stone quarry are similar to the ratios in the equations used for the coal mine field study. The ratios for the coal mine study were 1.2213, the correction ratio; 3.9335, the thoracic ratio; and 9.5190 the total ratio. Whereas the ratios for the stone quarry field study were 1.0224, 4.3350, and 12.6303, respectively. The differences in the ratios are due to the varying dust concentrations from the two sites. The dust concentrations will always vary from site-to-site; therefore, the ratios will never be exactly the same.

5.7 Coal Mine Instantaneous Analysis

The instantaneous dust concentrations for the coal mine field study were analyzed in order to characterize the dust emitted from haul trucks. The coal mine field study was chosen because the haul trucks were off-road trucks typically used in mining operations, and the frequency of the trucks was such that a good representation of dust emissions from a haul truck could be obtained. The frequency of trucks at the coal mine was approximately one truck every ten to twenty minutes rather than one truck every three to five minutes as at the stone quarry.

The trucks in the stone quarry study were over-the-road haul trucks, not the off road trucks desired. Characterization of the dust emissions from an individual truck was not feasible in the stone quarry study with the selected time interval of three minutes because the frequency of truck arrival was so high that there was interference from one truck to another within the selected time interval. Therefore, the instantaneous data from the stone quarry study were not analyzed at this time.

Figures 5.29 through 5.35 show the average instantaneous thoracic dust concentration in mg/m^3 at each station before and after the truck passes on August 2, 2002. Each individual graph shows the growth and decay of the dust concentrations as the truck passes the measurement stations. The series of graphs shows the decay of the dust concentrations away from the haul truck source on the haul road. Similar graphs were produced for August 5 and 6, 2002, and graphs for the corrected respirable and total dust concentrations were also produced. These other graphs are displayed in Appendix F, Section F.3 as figures F.7 through F.52.

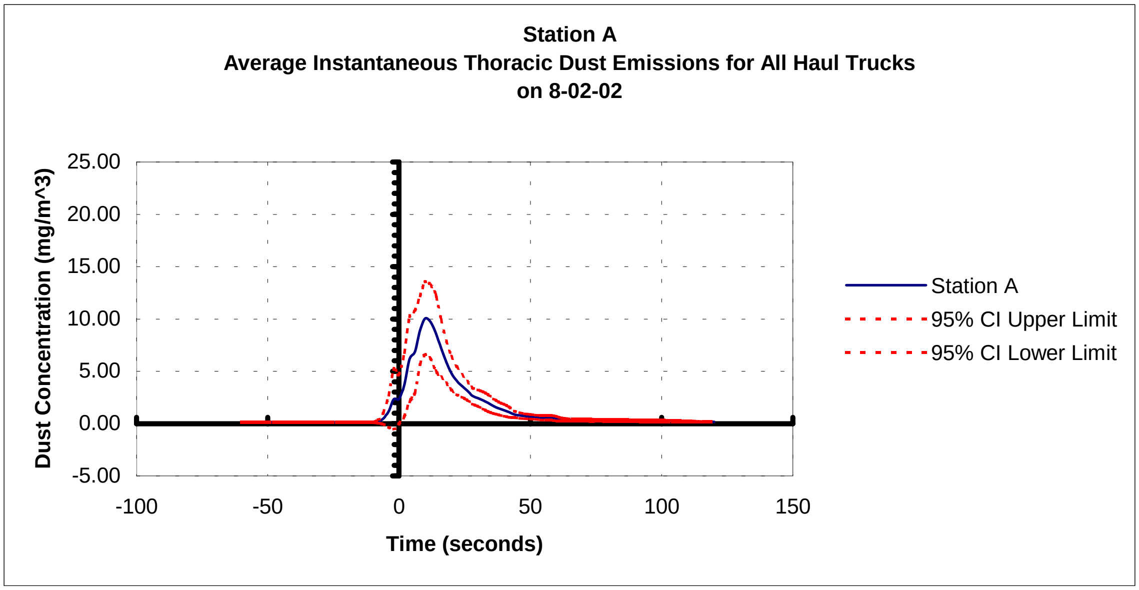


Figure 5.29 Average instantaneous thoracic dust concentrations with 95% confidence interval for Station A for the 8-02-02 coal mine field study.

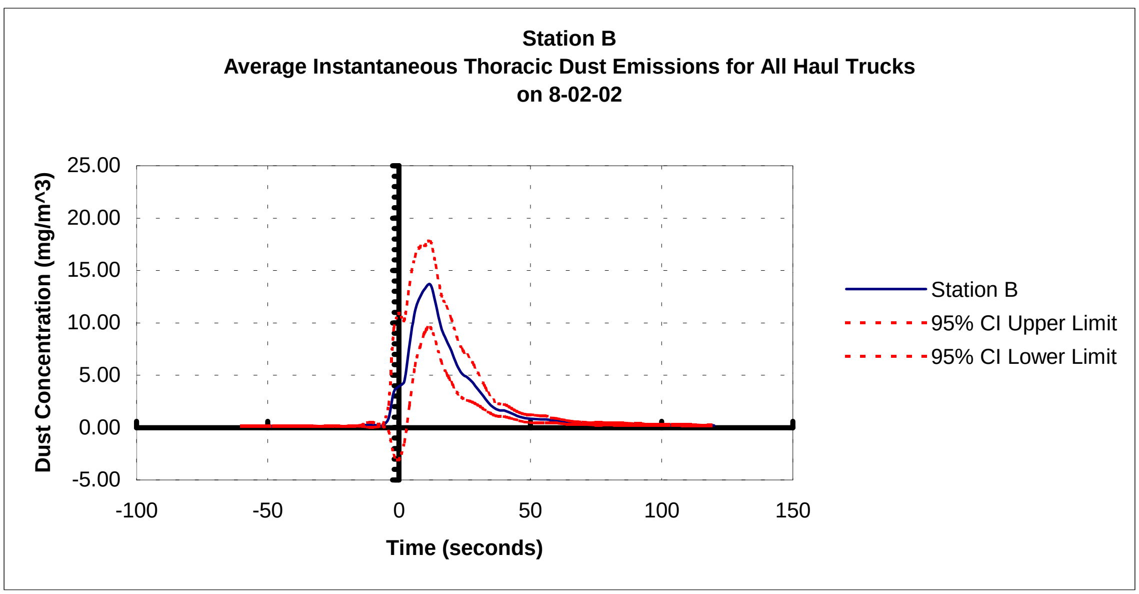


Figure 5.30 Average instantaneous thoracic dust concentrations with 95% confidence interval for Station B for the 8-02-02 coal mine field study.

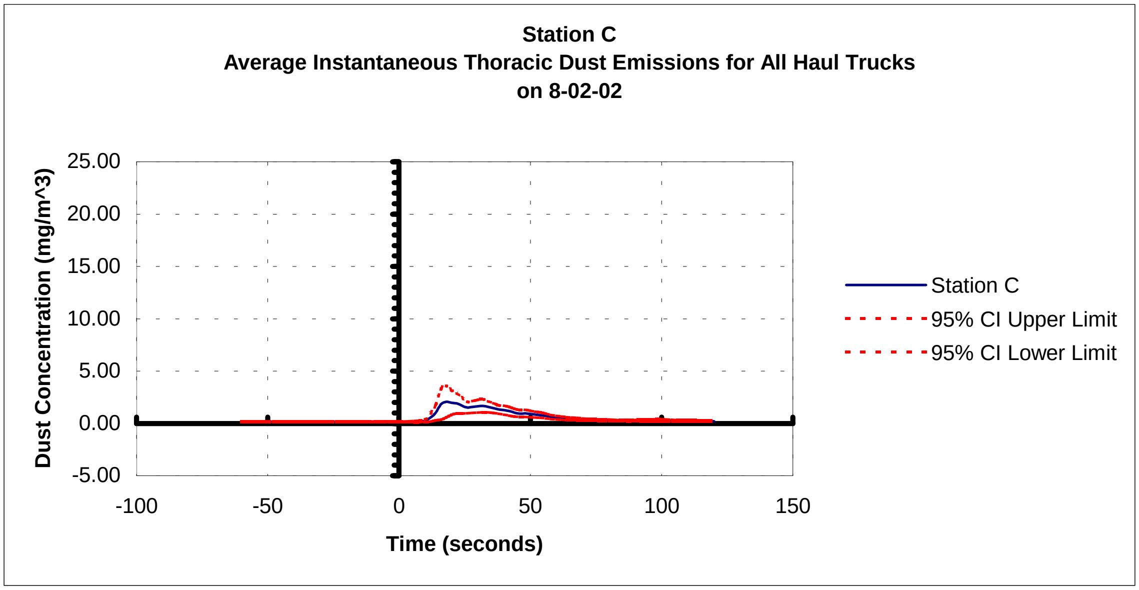


Figure 5.31 Average instantaneous thoracic dust concentrations with 95% confidence interval for Station C for the 8-02-02 coal mine field study.

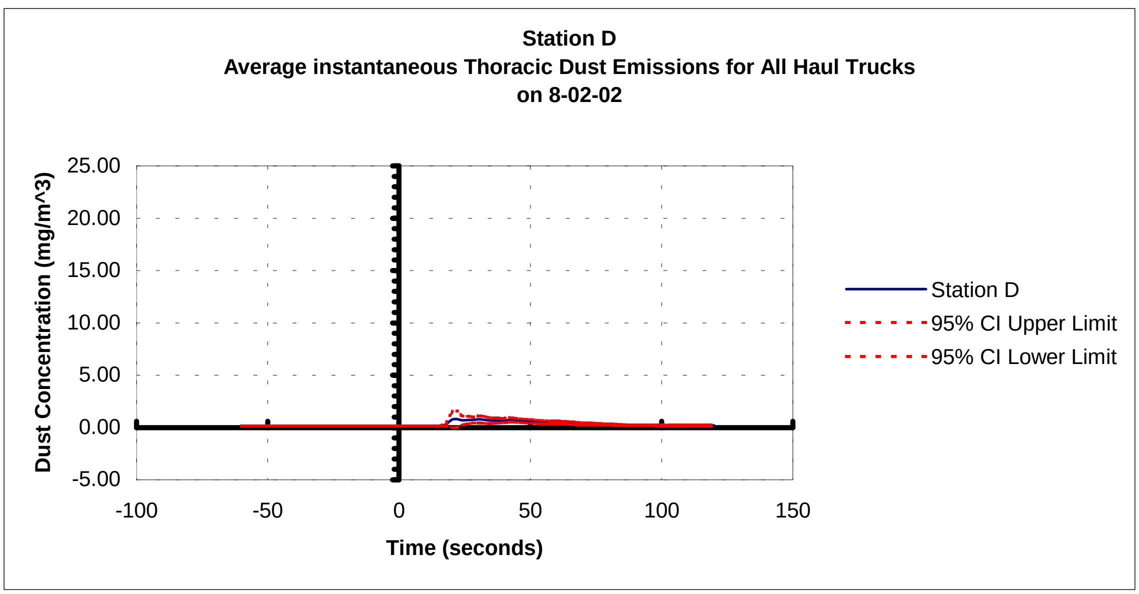


Figure 5.32 Average instantaneous thoracic dust concentrations with 95% confidence interval for Station D for the 8-02-02 coal mine field study.

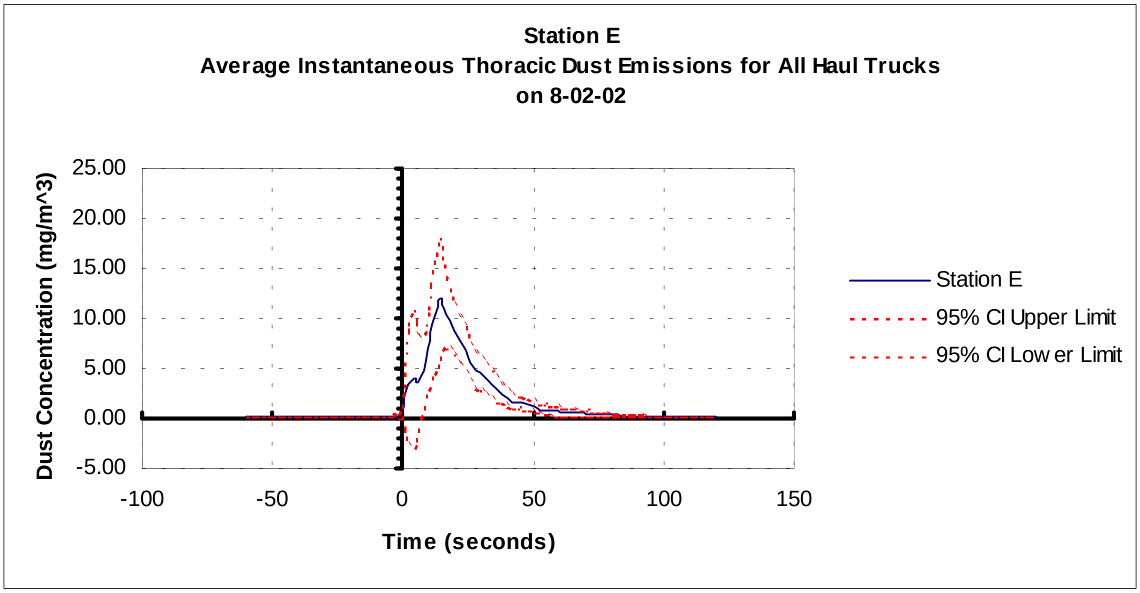


Figure 5.33 Average instantaneous thoracic dust concentrations with 95% confidence interval for Station E for the 8-02-02 coal mine field study.

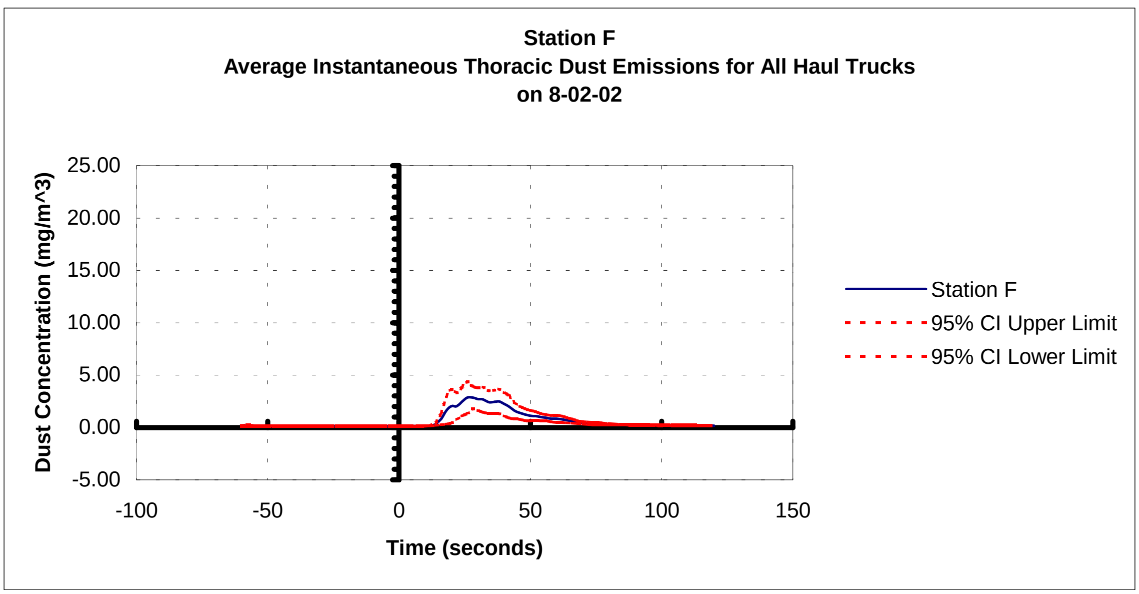


Figure 5.34 Average instantaneous thoracic dust concentrations with 95% confidence interval for Station F for the 8-02-02 coal mine field study.

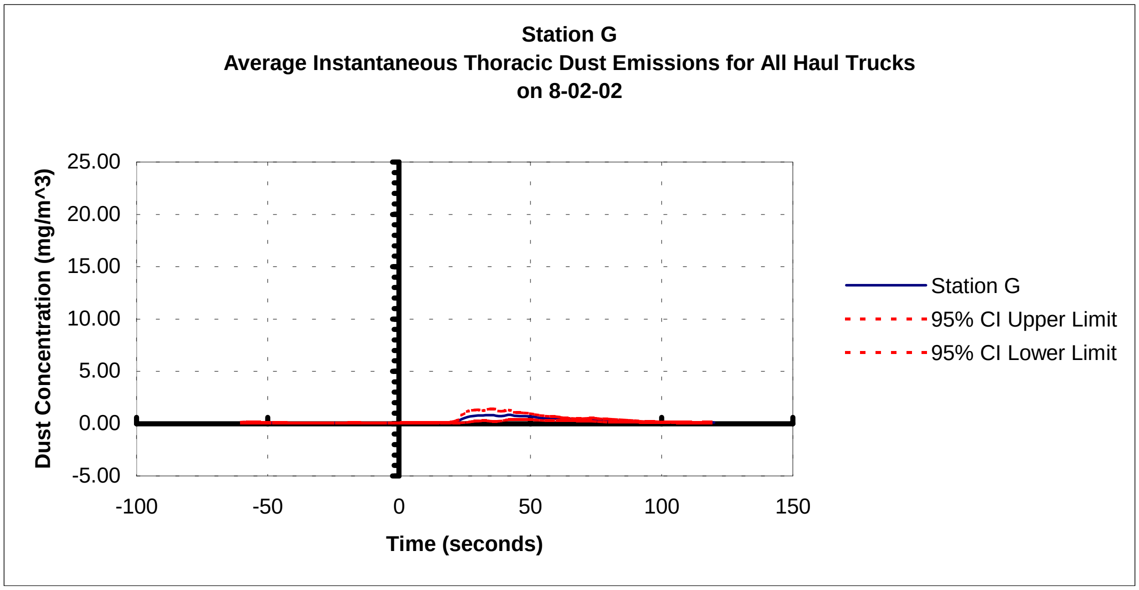


Figure 5.35 Average instantaneous thoracic dust concentrations with 95% confidence interval for Station G for the 8-02-02 coal mine field study.

The haul truck interval spans from one minute before the truck arrives to two minutes after the truck passes. The negative numbers on the time line represent the haul truck location prior to reaching the dust measurement stations. Point zero represents the moment the haul truck passes at the line of stations E, F, and G. Therefore, dust concentrations may arrive at stations A, B, C, and D approximately 5 seconds before the zero point. The positive numbers represent the haul truck location after it has passed the dust measurement stations. The three-minute interval was determined to be an adequate time frame to show the dust concentrations at background levels, increasing to the peak level, and returning to background levels. In all individual truck cases, the dust concentrations went from background levels, peaked, and returned to background levels well within this defined three-minute time interval.

The 95% confidence intervals for the average instantaneous thoracic dust concentrations are also included on these figures. As seen from the 95% confidence intervals, the instantaneous respirable dust measurements span a wide range, especially at the peaks. The wide range of the 95% confidence interval, which is often equal to or greater than the maximum average dust concentration of the three-minute interval, is due to the high variability of the instantaneous dust concentrations. Table 5.12 shows the maximum of the average instantaneous dust concentration measurements for respirable, thoracic, and total dust fractions for the three-minute time interval surrounding the truck pass along with the corresponding 95% confidence interval. In other words, this table shows the peak dust concentrations displayed in Tables 5.29 through 5.35 and F.7 through F.52. The series of graphs in Figures 5.29 to 5.35 also show the time lag of the arrival of the average instantaneous thoracic dust concentrations at the stations and also display the decay of the average instantaneous dust concentration as the source is moved away from the measurement point.

5.8 Background Dust Concentration Levels

The atmosphere normally contains some amount of PM_{10}. This concentration is the ambient or background dust concentration level and it represents the level of PM_{10} already existing in the atmosphere. It can be created by sources both on and off the site. If measured correctly, by placing measurement stations in the proper locations, it can represent the amount of dust in the air contributed from off-site sources. Therefore it can be an important measure of what other sources are contributing to the mining operation's emissions.

Table 5.12 Maximum of average instantaneous dust concentrations in mg/m^3 with 95% confidence intervals.

Respirable

	Station A	Station B	Station C	Station D
Aug. 2, 2002	2.5528 ± 0.8890	3.2612 ± 1.0330	0.5288 ± 0.3817	0.2028 ± 0.1990
Aug. 5, 2002	4.2207 ± 1.6205	1.1002 ± 1.1219	0.3954 ± 0.5790	0.1970 ± 0.2140
Aug. 6, 2002	3.1200 ± 0.8530	2.2166 ± 0.5610	0.4326 ± 0.4407	0.2028 ± 0.0793
		Station E	**Station F**	**Station G**
Aug. 2, 2002		3.0332 ± 1.5130	0.7273 ± 0.2820	0.2107 ± 0.1167
Aug. 5, 2002		1.0509 ± 0.9195	0.3875 ± 0.5944	No Data
Aug. 6, 2002		2.4797 ± 0.6969	0.4460 ± 0.1446	0.2149 ± 0.0938

Thoracic

	Station A	Station B	Station C	Station D
Aug. 2, 2002	10.0416 ± 3.4968	13.6324 ± 4.1086	2.0782 ± 1.5019	0.7962 ± 0.7829
Aug. 5, 2002	16.6040 ± 6.3731	4.3275 ± 4.4132	1.5554 ± 2.2776	0.7749 ± 0.8417
Aug. 6, 2002	10.0488 ± 2.6472	7.1390 ± 1.8070	1.3934 ± 0.4530	0.6530 ± 0.2557
		Station E	**Station F**	**Station G**
Aug. 2, 2002		11.9701 ± 5.9437	2.8573 ± 1.1100	0.8299 ± 0.4589
Aug. 5, 2002		4.1337 ± 3.6170	1.5243 ± 2.3381	No Data
Aug. 6, 2002		7.9865 ± 2.2447	1.4365 ± 0.4658	0.8453 ± 0.3690

Total

	Station A	Station B	Station C	Station D
Aug. 2, 2002	24.3006 ± 8.4620	32.9902 ± 9.9426	5.0292 ± 3.6345	1.9267 ± 1.8947
Aug. 5, 2002	40.1813 ± 15.4230	10.4726 ± 10.6798	3.7639 ± 5.5118	1.8751 ± 2.0370
Aug. 6, 2002	24.3179 ± 6.6481	17.2762 ± 4.3730	3.3719 ± 1.0964	1.5803 ± 0.6186
		Station E	**Station F**	**Station G**
Aug. 2, 2002		28.9674 ± 14.3838	6.9147 ± 2.6861	2.0084 ± 1.1105
Aug. 5, 2002		10.0034 ± 8.7533	3.6887 ± 5.6582	No Data
Aug. 6, 2002		19.3271 ± 5.4322	3.4763 ± 1.1272	2.0455 ± 0.8931

Table 5.13 Background dust concentration levels for the coal mine field study.

	Respirable Dust (mg/m^3)	Thoracic Dust (mg/m^3)	Total Dust (mg/m^3)
August 2, 2002	0.0374	0.1470	0.3557
August 5, 2002	0.0953	0.3747	0.9068
August 6, 2002	0.0083	0.0328	0.0794

Table 5.14 Background dust concentration levels for the stone quarry field study.

	Respirable Dust (mg/m^3)	Thoracic Dust (mg/m^3)	Total Dust (mg/m^3)
July 16, 2002	0.0375	0.1628	0.4742
July 17, 2002	0.0396	0.1715	0.4996
July 18, 2002	0.0871	0.3774	1.0997

Prior to the execution of the field studies, Station A was planned to measure background dust concentrations. Explanations given previously about the parallel wind directions in Section 5.2 and the observation of the dust plume of the haul truck in Section 5.4 make clear that station A was not able to measure the background dust concentrations as planned. Therefore, the background dust concentration levels were calculated from the instantaneous dust data for respirable, thoracic and total dust. These background dust concentration levels are not ambient background levels. However, the background dust concentration levels calculated from the instantaneous data were calculated during times that no haul trucks were operating in the vicinity of the field study. It is also expected that effects from residual concentrations from the haul trucks were minimal and that contamination from other operations located nearby would have had the same impact on a properly located upwind ambient dust sampler. Therefore, these levels are used as background dust concentrations for each site because they are the best data available.

The background dust concentration levels were calculated from the instantaneous data by removing the three-minute intervals for each truck that passed. The background dust levels during the coal mine study for each day are shown in Table 5.13. The background levels seem surprisingly high considering this was an isolated location with no other apparent sources generating dust. The drop in background levels from August 5 to August 6 are most likely due to the rain event that occurred the afternoon of August 5. Background levels were also calculated for the stone quarry field study using the same methodology that was used to calculate the coal mine field study background levels. The background dust concentration levels for the stone quarry are shown in Table 5.9. These background levels also seemed high, but these high levels were anticipated because of the proximity of the crushing plant to the field study area. However, comparing the background dust concentration levels from both studies show that the background dust concentration levels for the stone quarry study were not significantly higher than the coal mine field study.

5.9 Three-Dimensional graphs of Instantaneous Dust Concentrations

The graphs presented of the instantaneous dust concentrations, thus far, are the two-dimensional graphs of dust concentrations compared to distance. Dust disperses in three-dimensions. Therefore, a better method to portray the decay of the average instantaneous thoracic dust concentrations is to present three-dimensional graphs of the data. Figures 5.35, 5.36, and 5.37 present these graphs. These figures are three-dimensional surface graphs of the average instantaneous respirable dust concentrations at stations A, B, C, and D. Stations E, F, and G were not plotted because of Microsoft Excel's lack of capacity to plot three-dimensional graphs. A review was conducted of parallel stations, such as A and E, and the dust concentrations from the first station (B) generally overwhelmed the second parallel station (E). Graphing the instantaneous dust concentrations from the second parallel station, station E, generally fit inside the graph of the instantaneous dust concentrations from the first parallel station, station B. This was also true for the parallel stations C-F and D-G.

In all figures, stations A and B are on opposite edges of the haul road. Station lines BC and CD are 50 feet in length. As shown in the figures, the average instantaneous thoracic dust concentrations decay rapidly from station B to C. The average instantaneous thoracic dust concentrations almost reach background levels at station D. These graphs present a good characterization of the dust plume from a moving haul truck as viewed from the dust measurement station. The three-dimensional surface graphs of the average instantaneous respirable and average instantaneous total dust concentrations are shown in Appendix F, Section F.4 as Figures F.53 through F.58.

Several measurements of the instantaneous respirable dust concentrations from the haul trucks were taken after the haul road was watered on August 5, 2002, and projected to the thoracic concentrations. Figure 5.39 shows the decay of the average instantaneous thoracic dust concentrations after three truck runs on the watered haul road. It is obvious that watering the roads will reduce the amount of dust. However, this graph shows that there is still a spike in dust emissions at the haul road when the truck passes by the measurement stations, and that the average instantaneous thoracic dust concentrations quickly return to the background levels. The comparison of Figure 5.29 with Figures 5.36, 5.37, and 5.38 also shows that dust from the watered haul road does not propagate as far as the dust generated from the haul road that has not been watered. However, further studies should be completed comparing dry haul roads with watered haul roads before any further conclusions can be made.

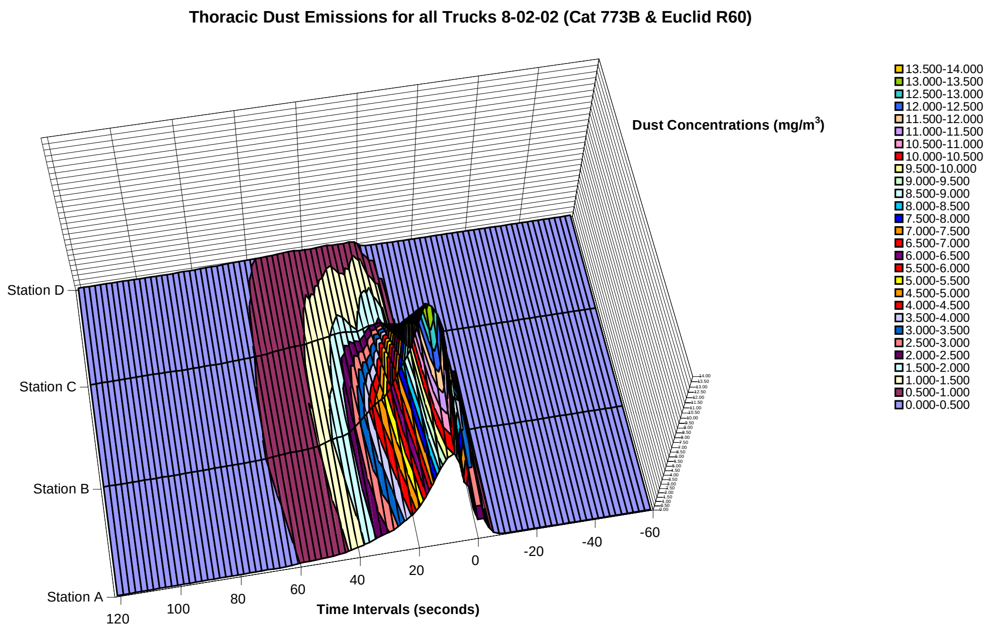


Figure 5.36 Three-dimensional graph of thoracic dust emissions for stations A, B, C, and D for the 8-02-02 coal mine field study.

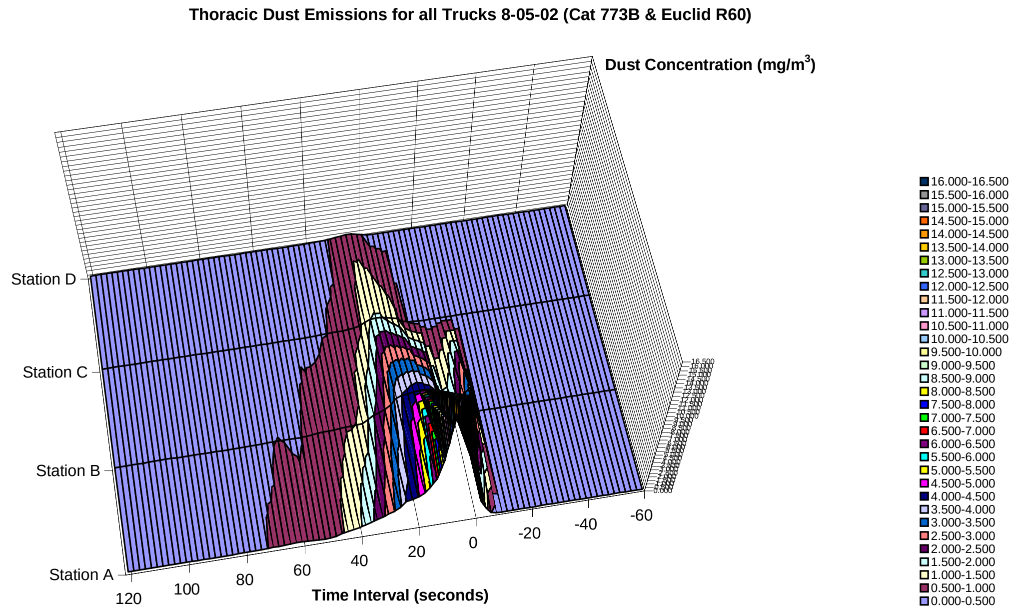


Figure 5.37 Three-dimensional graph of thoracic dust emissions for stations A, B, C, and D for the 8-05-02 coal mine field study.

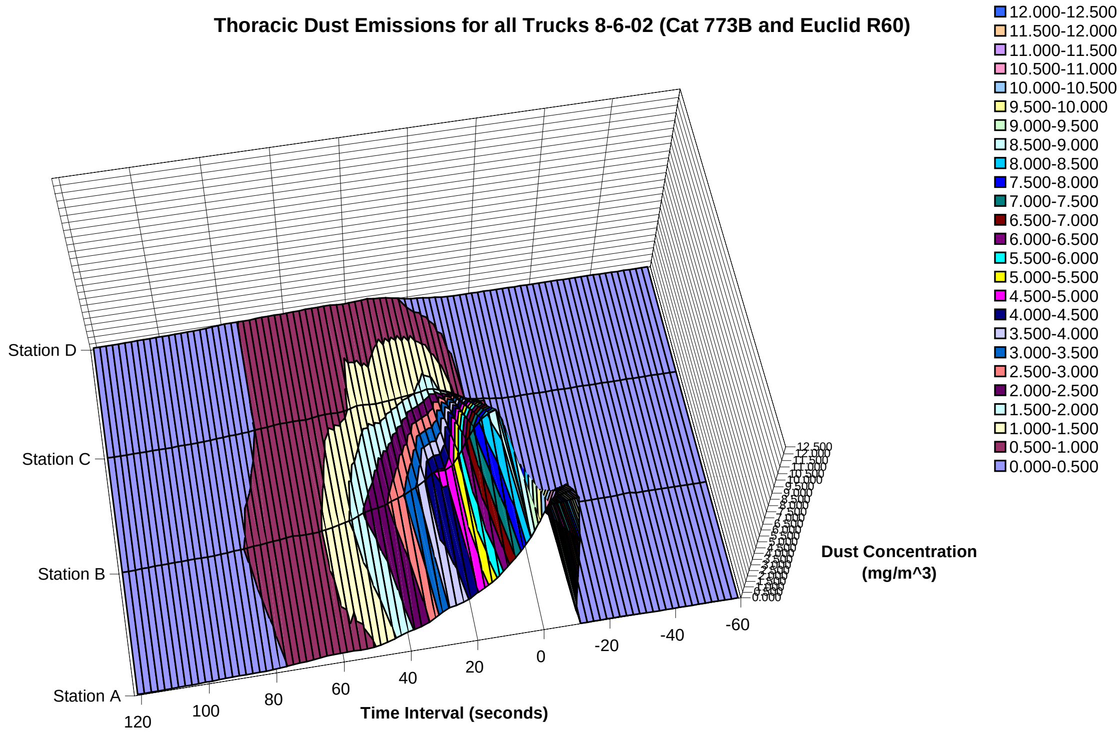


Figure 5.38 Three-dimensional graph of thoracic dust emissions for stations A, B, C, and D for the 8-05-02 coal mine field study.

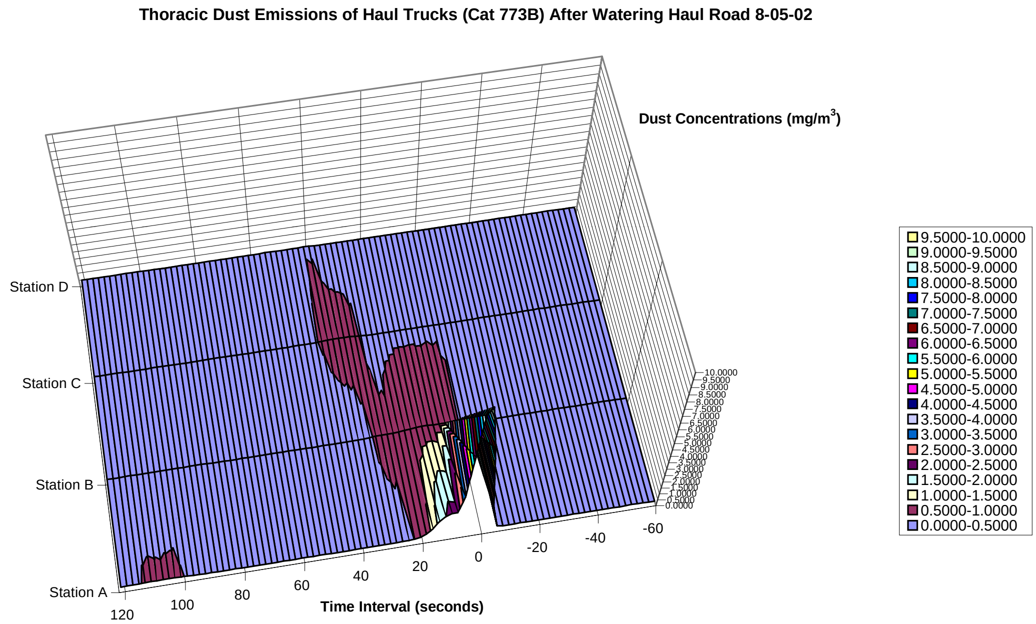


Figure 5.39 Three-dimensional graph of thoracic dust emissions for stations A, B, C, and D for the 8-05-02 coal mine field study after watering haul road.

Chapter 6 Analysis of Model Comparison

6.0 Introduction

After completing the field studies, a comparison was made between the results obtained and the modeling results. The comparison was completed in the following manner:

1. The background information of the field studies was input into the Dynamic Component model and the ISC3 model. This background information included information on truck size, truck speed, truck emissions, wind direction, wind speed, and receptor (sample) locations.
2. The Dynamic Component model and the ISC3 model were run.
3. The results of the Dynamic Component model and the ISC3 model were compared with the results of the field studies. A comparison was also made between the two models.
4. An analysis of the comparison of the results was completed.

The data used in the comparison were the gravimetric time-weighted-average dust concentrations for the thoracic fraction for each day of each study. The Dynamic Component Program accepted data from the field study to calculate time-weighted-average concentrations of dust dispersion from the haul trucks. The Dynamic Component Program has the ability to calculate these results for any length of time period. This is important because time-weighted-average dust concentrations are only comparable to concentrations with similar lengths of time (Rock, 1995). The ISC3 model also accepted the same data, used in the Dynamic Component program, to calculate the dust dispersion results of the haul trucks. The 6 hour time period for the time-weighted-average dust concentration was chosen because it was equal to the duration of the field study (6 hours).

6.1 Model Input Data

The data used as input from each field study are shown in Appendix G. The data include information concerning the layout of the haul road, shown in Table G.1. These data were input to the Dynamic Component Program through a series of menu displays, shown in Figure 6.1. The coordinates for the locations of the receptors, based upon a local coordinate system, were calculated and are shown in Table G.4. This information was input via ASCII file,

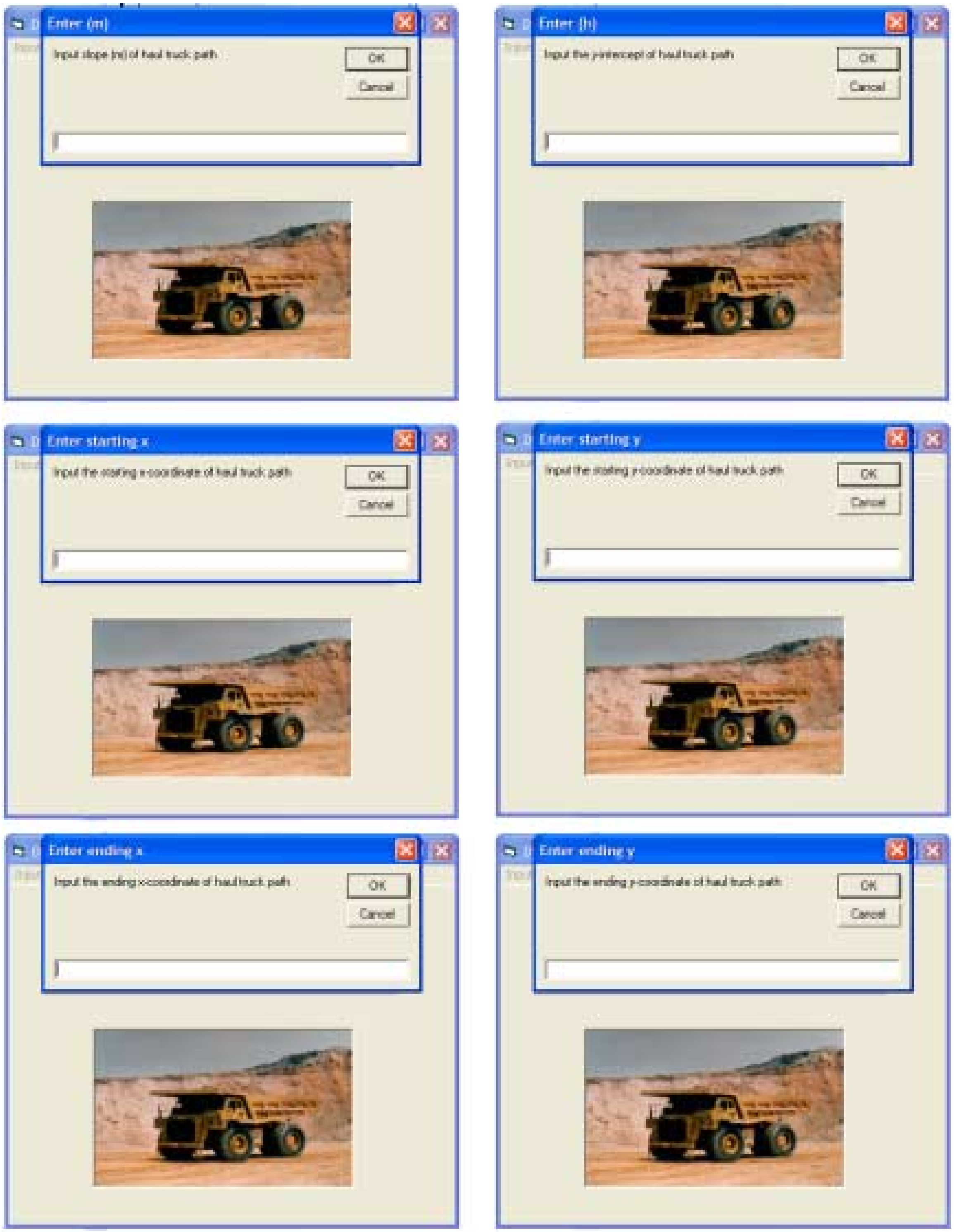


Figure 6.1 Menu displays in *Dynamic ISC3* requesting haul road layout information.

and the menu displays presented in Table 6.2 illustrate the input process for the receptor information. The background dust concentration level; haul road material specifications, such as silt content and moisture content; and haul truck speed and weight are shown in Tables G.2, G.3, and G.5. The requested data were input via the menu displays, shown in Figure 6.3. The wind speed and direction data used in the modeling process was the same as that measured during the field study. Each field study day's weather data were input into the Dynamic Component Program for their corresponding modeling comparison (i.e., August 5th weather data were used for the August 5th model comparison). The weather data were input via ASCII file through the menu displays, shown in Figure 6.4. Once the information was input, the PM_{10} concentrations were calculated and placed in the array file. Then *Dynamic Manipulation* was used to calculate the final PM_{10} concentration results for each receptor. Figure 6.5 displays a sample printout of the results for the model comparison with the August 2, 2002 field study. This process was completed for each day of the field study. The data in Tables G.1 through G.5 were used for the coal mine model comparison, and the data in Tables G.6 through G.11 were used for the stone quarry model comparison.

These same data were input into the ISC3 model so that all conditions were identical in order to achieve comparable results. Figure 6.6 displays the menu of *ISC3 Aeromod View* used to input source data. The amount of haul truck emissions calculated from the Dynamic Component Program, using the U.S. EPA's emissions factor, was input into the ISC3 program. Figures 6.7 and 6.8 show the menus used to input the receptors and the meteorological data, respectively. Once the information was entered, the calculations were completed and the results were used in the model comparison.

6.2 Comparison of the Stone Quarry Study Results to Modeling Results.

The comparison of the stone quarry study data is presented in Tables 6.1, 6.2, and 6.3 and in Figures 6.9, 6.10, and 6.11. Tables 6.4, 6.5, and 6.6 show the percent differences of the Dynamic Component Program model and the ISC3 model from the field study results. The Dynamic Component Program model performs better than the ISC3 model. The Dynamic Component Program model has average percent differences of 248% on July 16th, 154% on July 17th, and 365% on July 18th, compared to 796%, 889%, and 1172% respectively, for the ISC3 model. In all cases for this field study, both models over-predicted the actual results. These

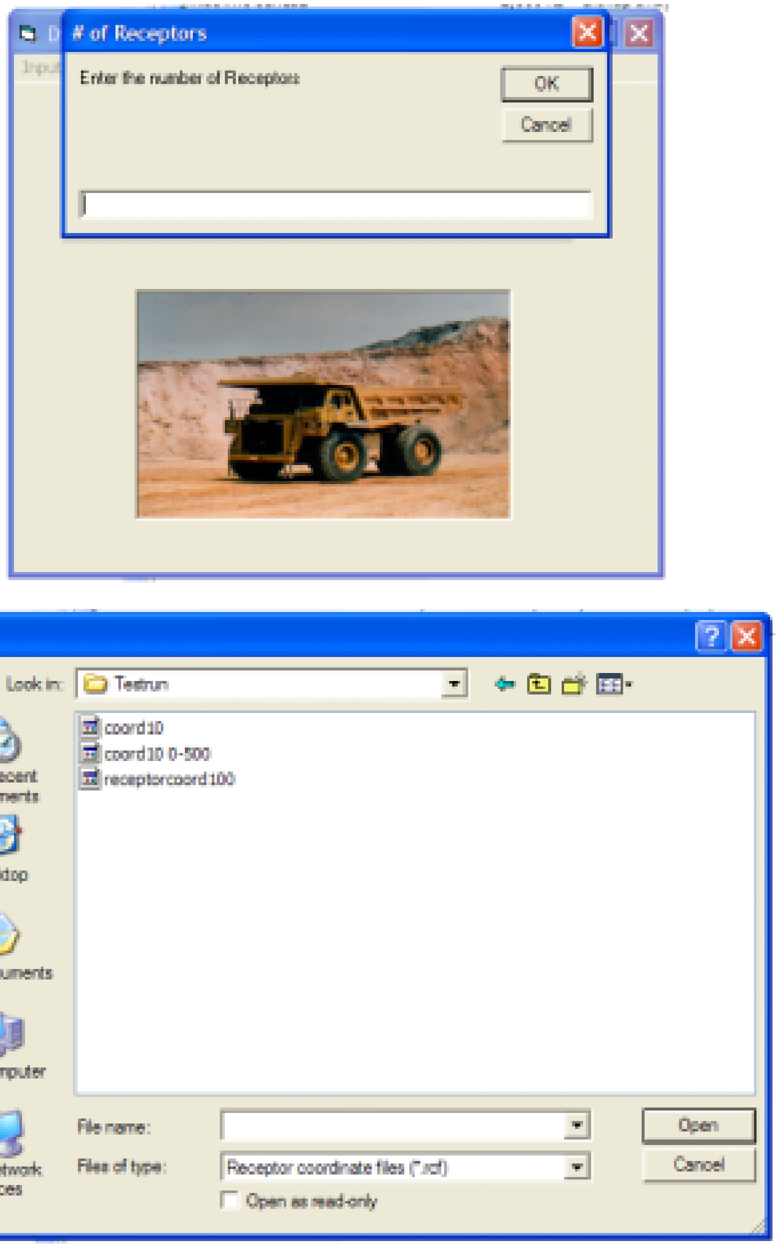


Figure 6.2 Menu displays in *Dynamic ISC3* requesting receptor location information.

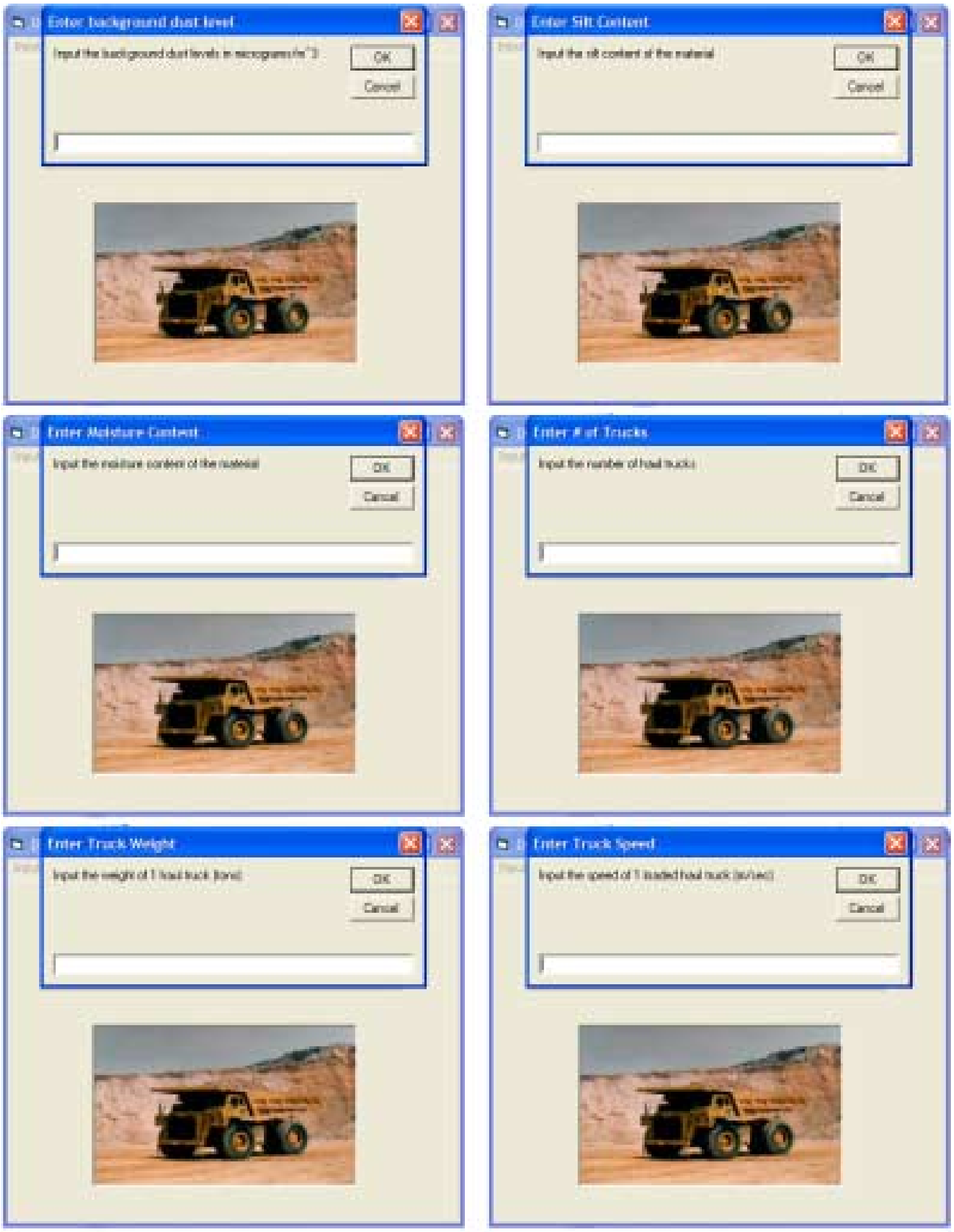


Figure 6.3 Menu displays in *Dynamic ISC3* requesting information about the background dust concentration level, haul road material specifications and haul truck speed and weight.

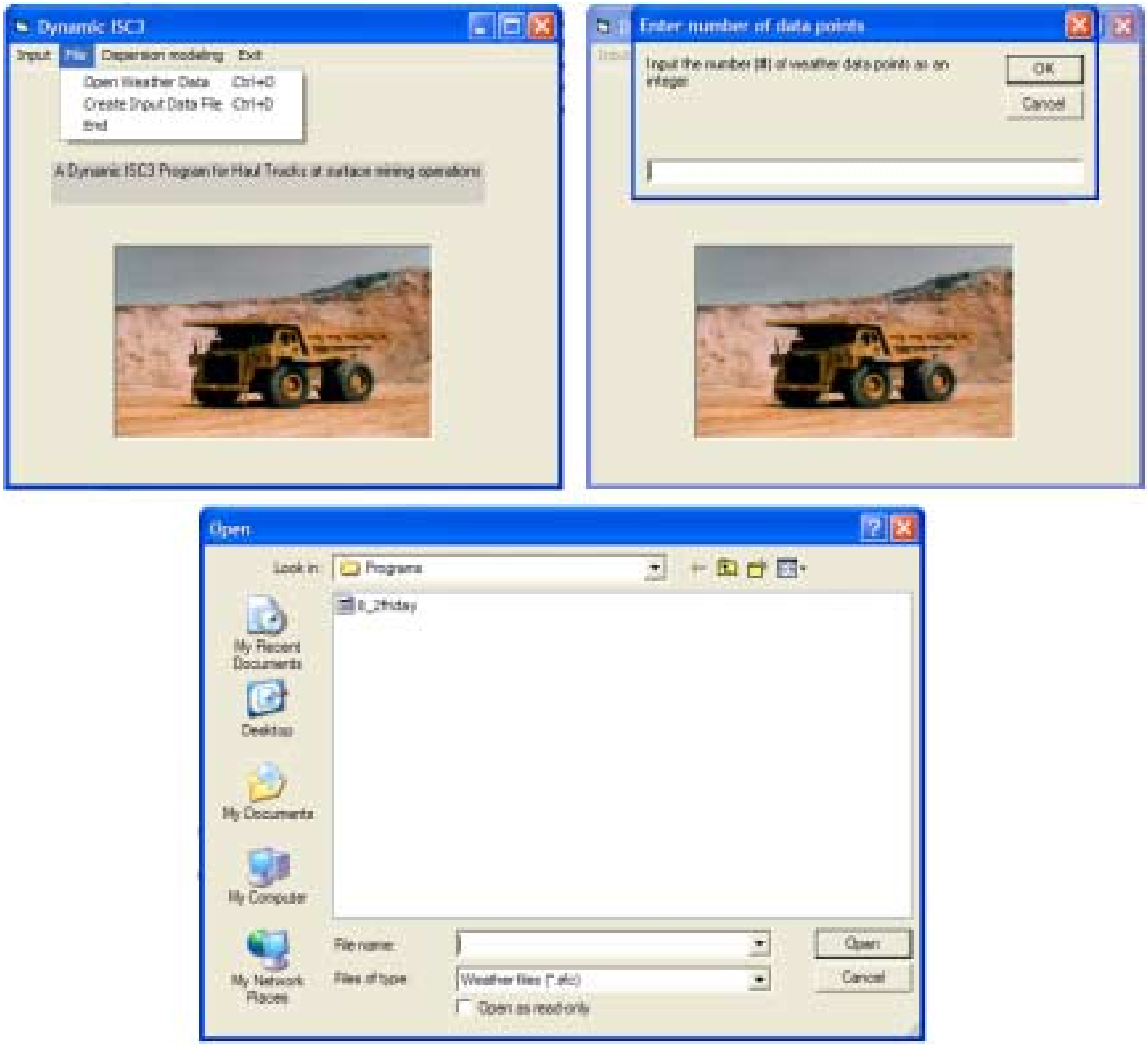


Figure 6.4 Menu displays in *Dynamic ISC3* requesting weather information.

Dynamic ISC3 Manipulations Complete

Input Parameters

Number of receptors = 7
X-Y Coordinates of receptors:
Receptor # 1 X Coordinate = 950.76 Y Coordinate = 1008.68
Receptor # 2 X Coordinate = 1000 Y Coordinate = 1000
Receptor # 3 X Coordinate = 1049.24 Y Coordinate = 991.32
Receptor # 4 X Coordinate = 1098.48 Y Coordinate = 982.64
Receptor # 5 X Coordinate = 1017.36 Y Coordinate = 1098.48
Receptor # 6 X Coordinate = 1066.6 Y Coordinate = 1089.8
Receptor # 7 X Coordinate = 1115.84 Y Coordinate = 1081.12

Number of trucks = 1 Weight of trucks (tons)= 50
Speed of loaded truck (m/sec) = 6.92
Speed of empty truck (m/sec) = 6.92

Background Dust Level (micrograms/m^3) = 137.5
Silt Content (%) = 21.18
Moisture Content (%) = 0.65

Calculation Results

Emissions from loaded truck (grams/sec) = 17.29413

Uncorrected Instantaneous Average Concentration of PM10 at receptors:

Results for Receptor 1 = 172.7923 micrograms/m^3

Results for Receptor 2 = 715.8829 micrograms/m^3

Results for Receptor 3 = 252.4471 micrograms/m^3

Results for Receptor 4 = 150.353 micrograms/m^3

Results for Receptor 5 = 716.985 micrograms/m^3

Results for Receptor 6 = 254.0709 micrograms/m^3

Results for Receptor 7 = 152.3236 micrograms/m^3

Dynamic ISC3 Manipulations Complete (continued)

Page 2

Calculation Results

Time Weighted Average Concentration of PM10 at receptors:

Results for Receptor 1 = 270.251687364724120567472412 micrograms/m^3

Results for Receptor 2 = 813.3422535220358396565948502 micrograms/m^3

Results for Receptor 3 = 349.90653785720629661003021545 micrograms/m^3

Results for Receptor 4 = 247.81241016773059780546505518 micrograms/m^3

Results for Receptor 5 = 814.44446207716167519160536 micrograms/m^3

Results for Receptor 6 = 351.53032256638388486016815555 micrograms/m^3

Results for Receptor 7 = 249.78299016575874286898318445 micrograms/m^3

Figure 6.5 Printout of the Dynamic Component Program modeling results for August 2, 2002.

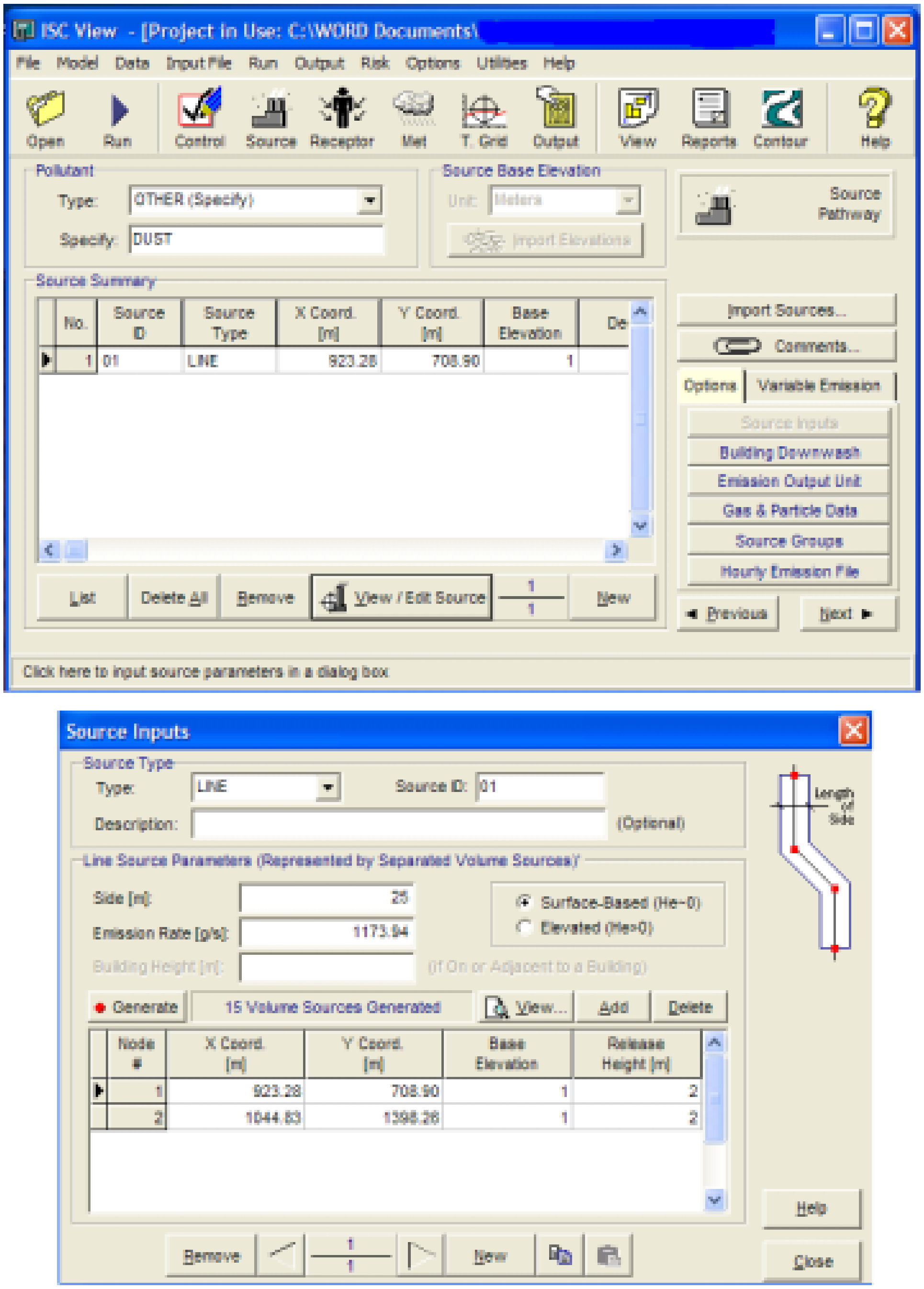


Figure 6.6 ***ISC3 Aeromod View*** **menus used to input source data from the coal mine field study (to obtain the bottom menu -click on the “View/Edit Source” button).**

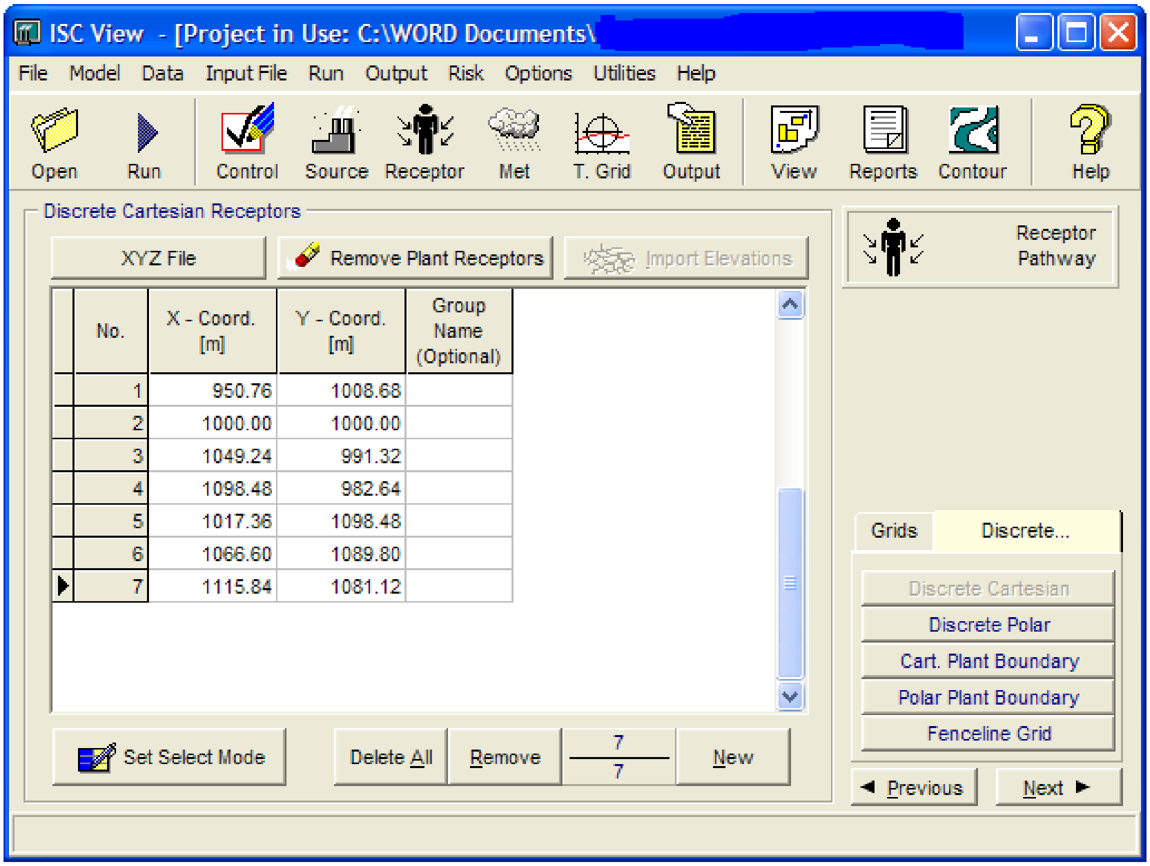


Figure 6.7 ***ISC3 Aeromod View*** **menu used to input receptor data from the coal mine field study**

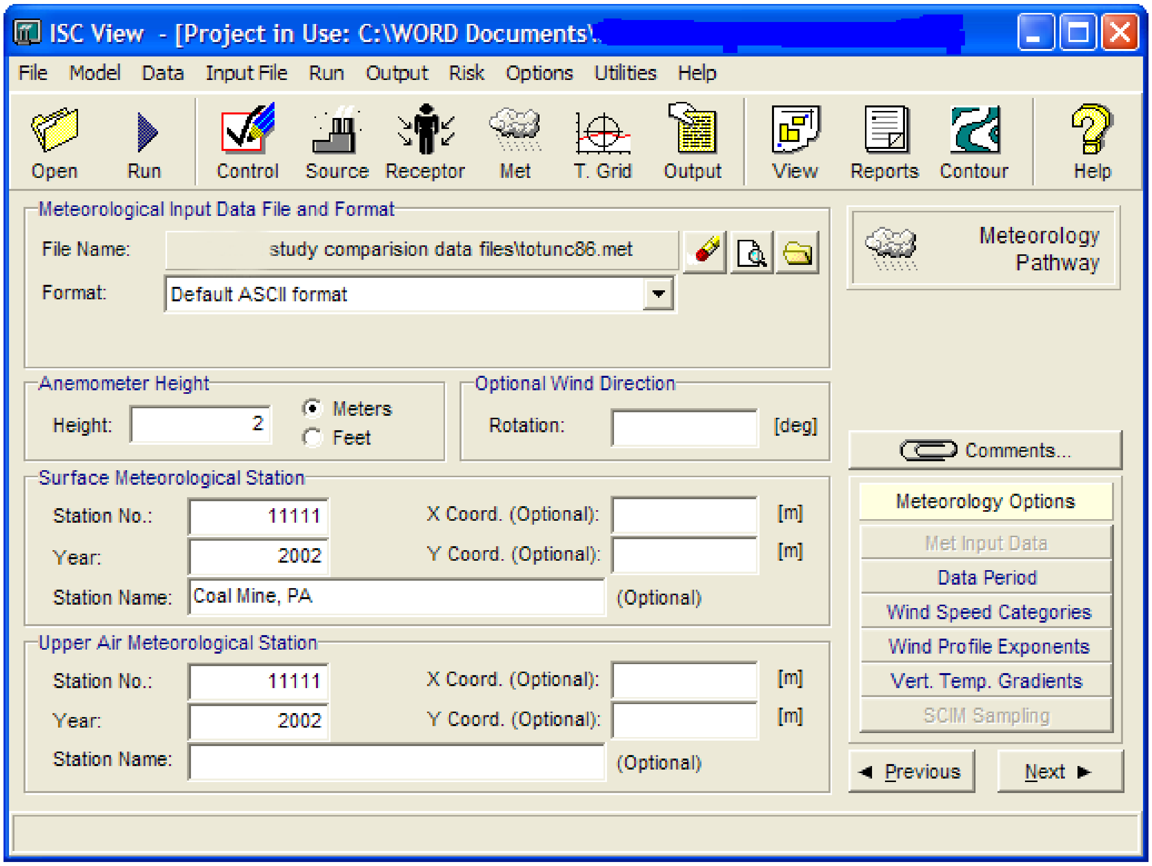


Figure 6.8 *ISC3 Aeromod View* menu used to input meteorological data from the coal mine field study

Table 6.1 Summary of Thoracic time weighted averages for July 16, 2002 (micrograms/m^3).

	Station A	Station B	Station C	Station D	Station E	Station F	Station G
Field Study Gravimetric	459.00	688.00	247.00	122.00	540.00	253.00	153.00
Dynamic Component Program Model	798.97	2353.11	862.49	535.42	2358.85	867.69	540.38
ISC3 Model	5605.33	3248.41	2551.46	1379.67	3125.16	2469.43	1219.04

Table 6.2 Summary of Thoracic time weighted averages for July 17, 2002 (micrograms/m^3).

	Station A	Station B	Station C	Station D	Station E	Station F	Station G
Field Study Gravimetric	756.00	1587.00	327.00	226.00	1329.00	337.00	154.00
Dynamic Component Program Model	1140.89	2951.21	1005.42	589.19	2965.91	1019.27	601.35
ISC3 Model	12925.27	7425.93	3932.88	1878.07	6844.05	3827.68	1786.79

Table 6.3 Summary of Thoracic time weighted averages for July 18, 2002 (micrograms/m^3).

	Station A	Station B	Station C	Station D	Station E	Station F	Station G
Field Study Gravimetric	176.00	675.00	216.00	102.00	1054.00	252.00	154.00
Dynamic Component Program Model	587.31	2928.69	1149.13	749.01	2931.90	1152.46	753.7
ISC3 Model	11629.50	2914.03	1081.92	475.89	2439.59	1001.24	422.25

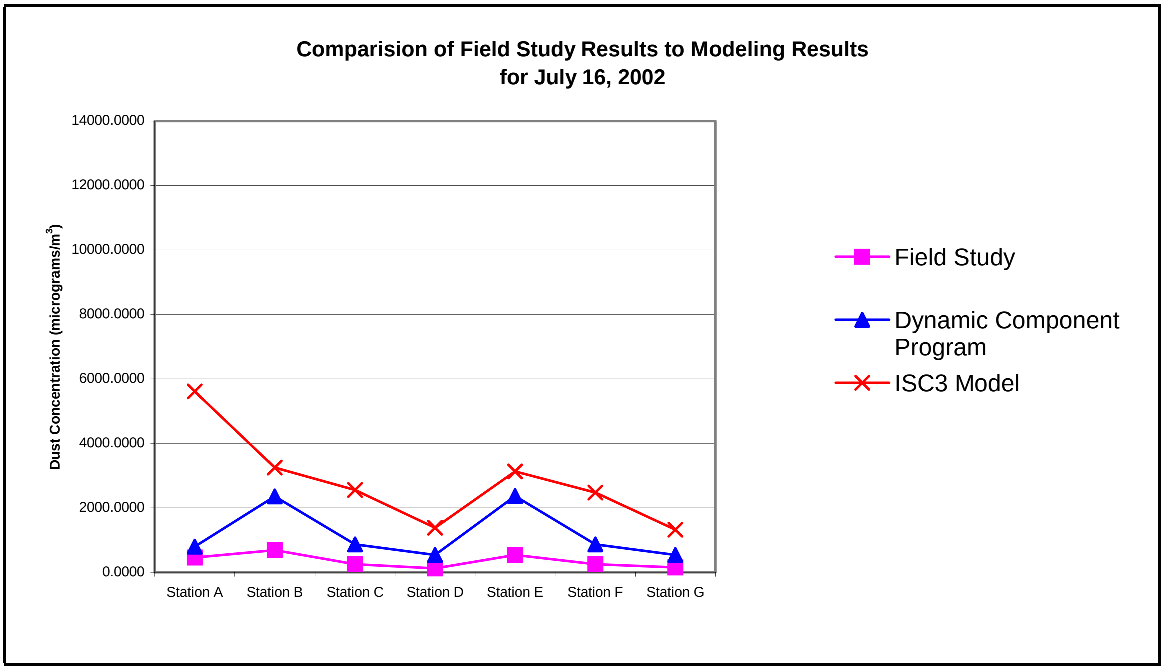


Figure 6.9 Comparison of modeling results with the stone quarry field study results for July 16, 2002.

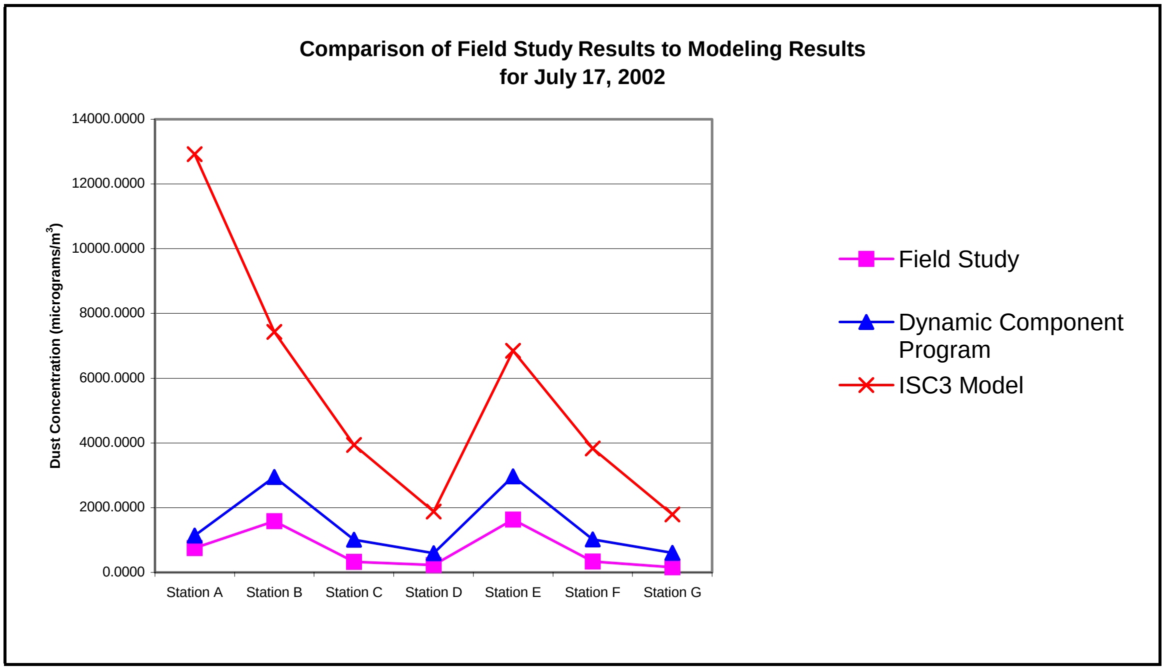


Figure 6.10 Comparison of modeling results with the stone quarry field study results for July 17, 2002.

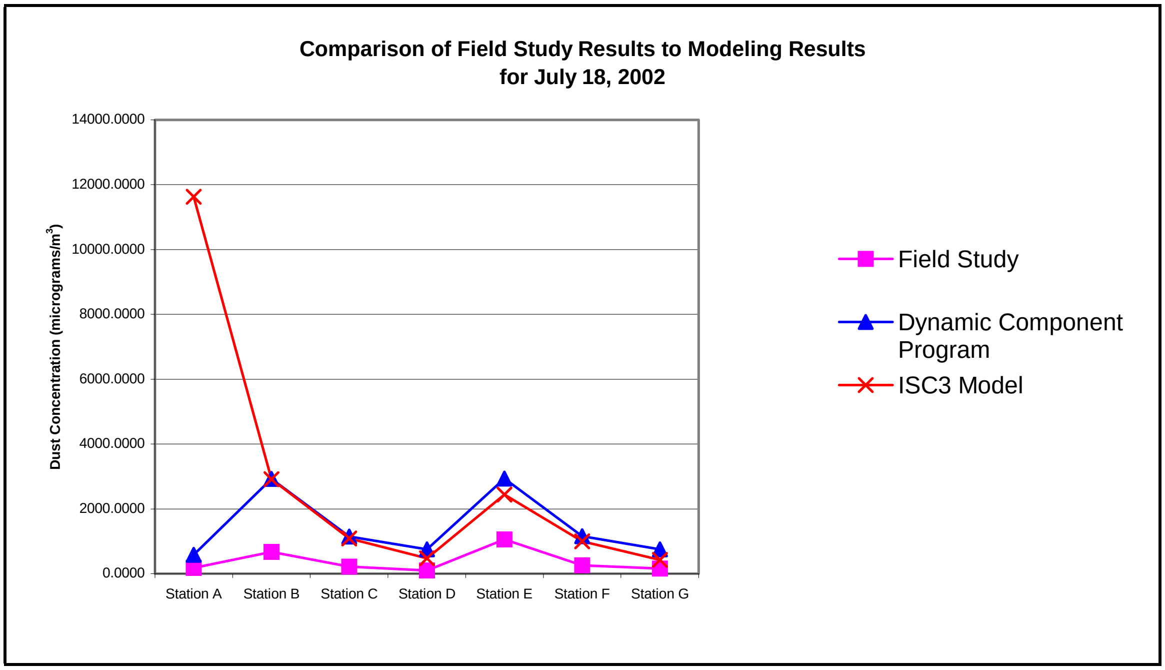


Figure 6.11 Comparison of modeling results with the stone quarry field study results for July 18, 2002.

Table 6.4 Percent difference over(+)/under(-) from field study results for July 16, 2002.

	Station A	Station B	Station C	Station D	Station E	Station F	Station G	Average % Difference
Dynamic Component Program	74.07%	242.02%	249.19%	338.87%	336.82%	242.96%	253.19%	248.16%
ISC3 Model	1121.20%	372.15%	932.98%	1030.88%	478.73%	876.06%	762.12%	796.30%

Table 6.5 Percent difference over(+)/under(-) from field study results for July 17, 2002.

	Station A	Station B	Station C	Station D	Station E	Station F	Station G	Average % Difference
Dynamic Component Program	50.91%	85.96%	207.47%	160.70%	82.07%	202.45%	290.49%	154.29%
ISC3 Model	1609.69%	367.92%	1102.72%	731.00%	320.14%	1035.81%	1060.25%	889.65%

Table 6.6 Percent difference over(+)/under(-) from field study results for July 18, 2002.

	Station A	Station B	Station C	Station D	Station E	Station F	Station G	Average % Difference
Dynamic Component Program	233.70%	333.88%	432.00%	634.32%	178.17%	357.33%	389.42%	365.55%
ISC3 Model	6507.67%	331.71%	400.89%	366.56%	131.46%	297.32%	174.19%	1172.83%

results show that the ISC3 model results are 8 to 12 times the actual results, whereas the Dynamic Component Program model results are generally within 2 to 4 times the actual results.

6.3 Comparison of Coal Mine Field Study Results to Modeling Results

The comparison of the coal mine study data is presented in Tables 6.7, 6.8, and 6.9 and in Figures 6.12, 6.13, and 6.14. The methodology outlined in Sections 6.0 and 6.1were followed. Tables 6.10, 6.11, and 6.12 show the percent differences of the Dynamic Component Program model and the ISC3 model from the field study results. Again, the Dynamic Component Program model results match the field measurements more closely than the ISC3 model. The Dynamic Component Program model has average percent differences of -1.64% on August 2nd, 249.42% on August 5th, and -72.28% on August 6th, compared to -42.18%, 721.68%, and 335.44% respectively, for the ISC3 model. The negative percent difference represents under prediction. These results show that the ISC3 model results are 4 to 8 times the actual results whereas the Dynamic Component Program model results are generally within 2 times the actual results, except for August 5th. August 2, 2002 was an exception where the ISC3 model predicted relatively close to the actual field study results, -42.18% difference. However, the Dynamic Component Program model still outperformed the ISC3 model with a percent difference of -1.64%.

6.4 Discussion of the Comparison of Modeling and Field Study Results

In reviewing all the modeling results compared to the field study results, the Dynamic Component Program generally outperforms the ISC3 model. Results from the stone quarry and the coal mine will be discussed individually.

6.4.1 Stone Quarry

In the comparison of the stone quarry modeling versus field study results, both models over-predict the thoracic dust concentrations for each day. The wind directions in the stone quarry study were favorable, with the wind directions predominately blowing across the haul road and the dust sampling stations being on the downwind side of the road. Figures F.4, F.5, and F.6 in Appendix F show the wind directions during the field study with respect to the haul road. The results of the comparison for the stone quarry were expected because the ISC3 model has been stated to over-predict actual conditions.

Table 6.7 Summary of Thoracic time weighted averages for Aug. 2, 2002 (micrograms/m^3).

	Station A	Station B	Station C	Station D	Station E	Station F	Station G
Field Study Gravimetric	1026.00	1132.00	302.00	177.00	966.00	355.00	187.00
Dynamic Component Program Model	279.68	821.36	358.79	256.68	822.42	360.32	258.53
ISC3 Model	1712.82	403.29	157.87	67.06	371.68	144.19	61.53

Table 6.8 Summary of Thoracic time weighted averages for Aug. 5, 2002 (micrograms/m^3).

	Station A	Station B	Station C	Station D	Station E	Station F	Station G
Field Study Gravimetric	602.00	320.00	96.00	76.00	472.00	123.00	95.00
Dynamic Component Program Model	852.03	765.55	482.90	424.12	767.05	484.26	425.52
ISC3 Model	1466.82	1580.56	1516.51	831.42	1477.10	1469.16	791.45

Table 6.9 Summary of Thoracic time weighted averages for Aug. 6, 2002 (micrograms/m^3).

	Station A	Station B	Station C	Station D	Station E	Station F	Station G
Field Study Gravimetric	999.00	735.00	188.00	153.00	969.00	147.00	108.00
Dynamic Component Program Model	251.90	115.34	57.28	45.44	115.04	57.20	45.54
ISC3 Model	593.00	1507.24	1256.82	666.12	1452.35	1288.04	705.98

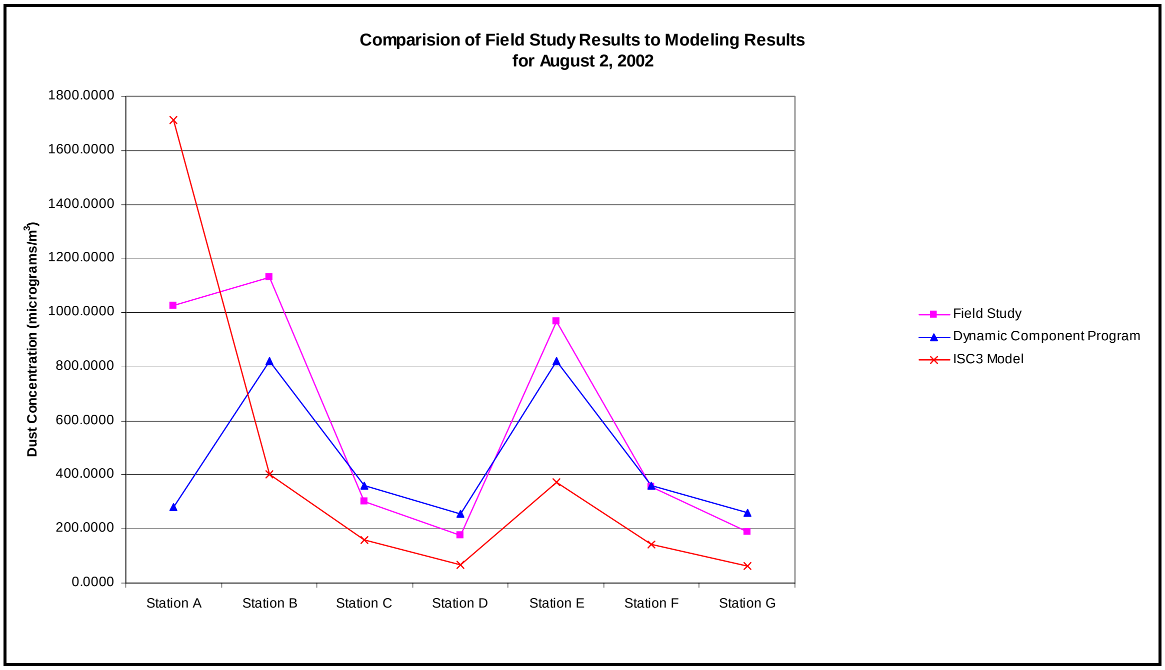


Figure 6.12 Comparison of modeling results with the coal mine field study results for August 2, 2002.

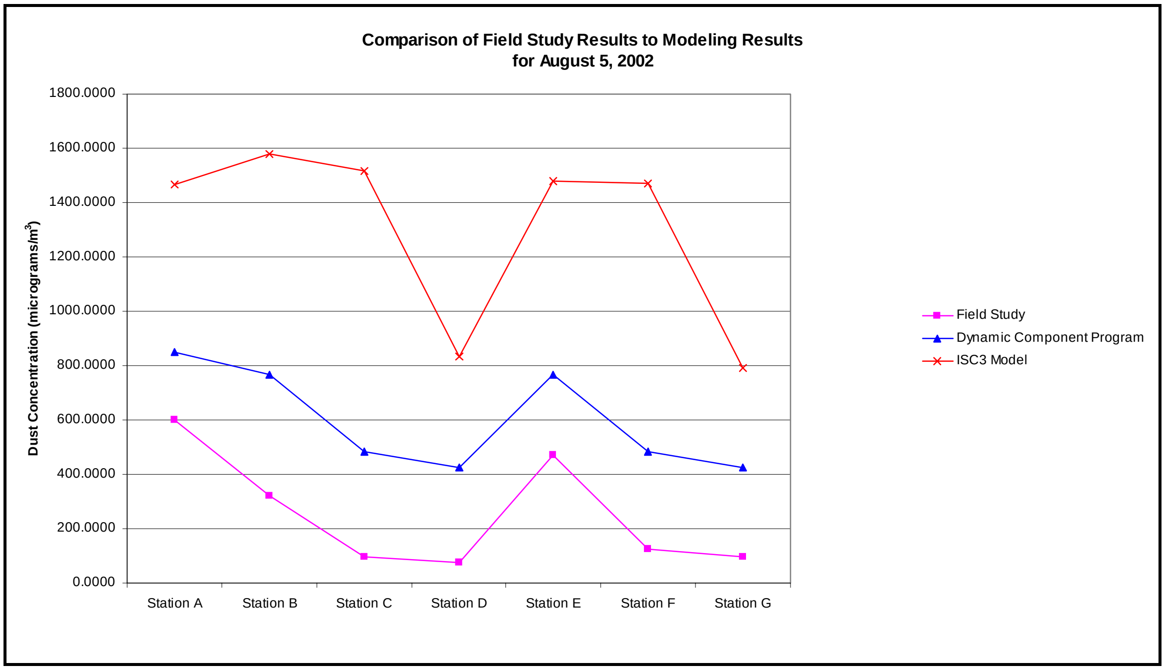


Figure 6.13 Comparison of modeling results with the coal mine field study results for August 5, 2002.

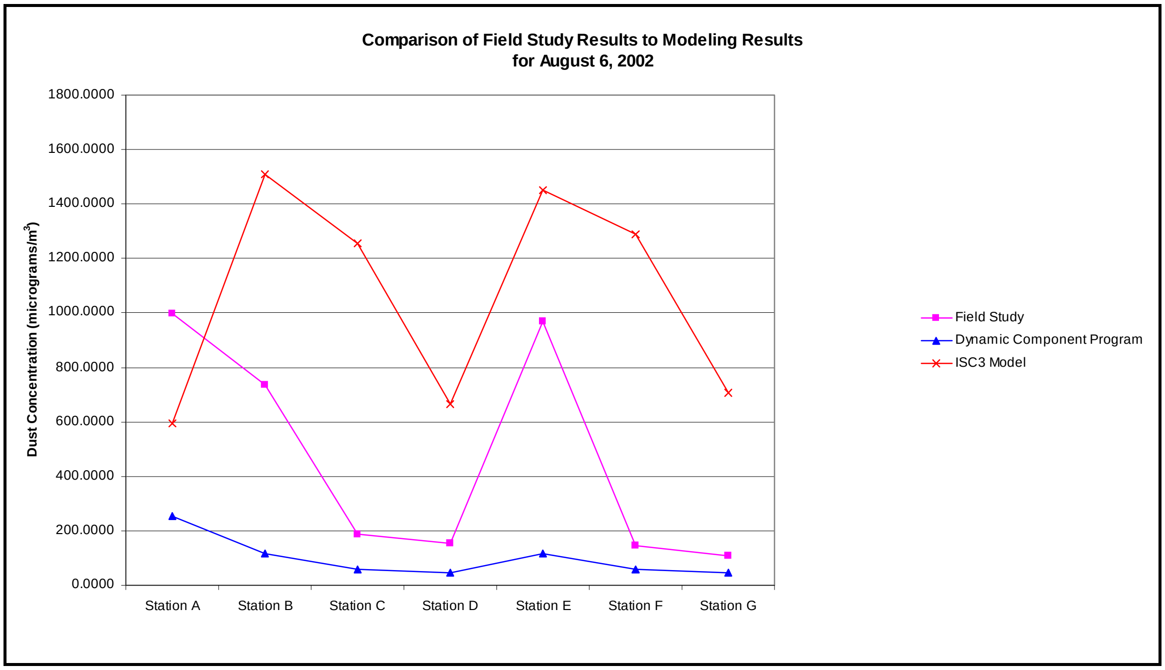


Figure 6.14 Comparison of modeling results with the coal mine field study results for August 6, 2002.

Table 6.10 Percent difference over(+)/under(-) from field study results for August 2, 2002.

	Station A	Station B	Station C	Station D	Station E	Station F	Station G	Average % Difference
Dynamic Component Program	-72.74%	-27.44%	18.80%	45.02%	-14.86%	1.50%	38.25%	-1.64%
ISC3 Model	66.94%	-64.37%	-47.73%	-62.11%	-61.52%	-59.38%	-67.10%	-42.18%

Table 6.11 Percent difference over(+)/under(-) from field study results for August 5, 2002.

	Station A	Station B	Station C	Station D	Station E	Station F	Station G	Average % Difference
Dynamic Component Program	41.53%	139.23%	403.02%	458.05%	62.51%	293.71%	347.92%	249.42%
ISC3 Model	143.66%	393.93%	1479.70%	993.97	212.94%	1094.44%	733.11%	721.68%

Table 6.12 Percent difference over(+)/under(-) from field study results for August 6, 2002.

	Station A	Station B	Station C	Station D	Station E	Station F	Station G	Average % Difference
Dynamic Component Program	-74.78%	-84.31%	-69.53%	-70.30%	-88.13%	-61.09%	-57.83%	-72.28%
ISC3 Model	-40.64%	105.07%	568.52%	335.37%	49.88%	776.22%	553.69%	347.06%

The only unusual aspect to the stone quarry study is the magnitude of the over-prediction by both models. As stated earlier in Section 6.1, the ISC3 model over-prediction is 8 to 12 times the actual results. This is much greater than the over-prediction of 2 to 5 times the actual results shown in past research. Causes of the large over-prediction can be related to the assumptions of the Gaussian equation: there is no deposition of PM_{10} and downwind dispersion is negligible (Beychok, 1994). This is clearly not the case in real life, as layers of dust could be seen on the dust measurement equipment being used in the study, and dispersion clearly occurred as the dust plume thinned out as it traveled away from the haul truck. But this explanation would not have a large effect on the modeling results. The reason being that the rate of decay shown in the comparison of the modeling versus field study graphs can sometimes be seen to be equal to or greater than the rate of decay of the actual field data results. This rate of decay can be attributed to dust dispersion or deposition. Therefore, the higher the rate of decay, the higher the dispersion or deposition, meaning that the models in some cases predict higher dispersion or deposition rates than what actually occurred. If the model is predicting higher rates of dispersion or deposition than what actually occurred in the field study, then the assumptions for the Gaussian equation cannot have an effect on the modeling results. The model that has higher dispersion or deposition rates than the actual dispersion or deposition rates should predict lower concentrations for locations further away from the source than what actually occurs.

Another explanation for the model over-prediction is the fact that the emissions factor equation, used in calculating the amount of PM_{10} that a haul truck generates, over-predicts the amount of PM_{10} generated by the haul truck. Past research by the NSSGA has pursued this aspect of the over-prediction problem and proposed an equation that lowers the amount of emissions created by haul trucks that can be used in place of the emissions factor equation recommended by the U. S. EPA (Richards and Brozell, 2001). Reducing the amount of input emissions into the model will ultimately lower the amount of the dust concentrations predicted by modeling. But it is not known if it will produce more accurate results. To illustrate this point, a test was conducted to demonstrate that a source emissions reduction would reduce the over-prediction by the models and produce accurate results.

Initially the emissions factor equation recommended by the NSSGA was to be used in this test. But this new equation can only be used for haul roads that are watered. The haul roads in the field study were not watered. Therefore, this equation could not be used. The test was still conducted to determine if a source emissions reduction might reduce the over-prediction and produce accurate results by the models. This test consisted of running the models using the haul truck emissions reduced by an arbitrary amount of 50%. Since past research has shown that the reduction of source emissions by 50% results in the modeled dust concentrations being reduced by 50%, actual re-modeling did not need to be performed (Reed, et. al., An Improved Model, 2000). The modeling results from the field study comparisons were reduced by 50% in order to complete the test. The results from reducing the modeling results 50% show a great improvement in the field study and modeling comparison results. This is shown in Tables 6.13, 6.14, and 6.15 which show the percent difference of the modeling results reduced by 50% from the actual field study results. This improvement is also displayed in Figures 6.15, 6.16, and 6.17.

With the 50% reduction in the modeling results, the Dynamic Component Program modeling results improve to within 27% to 74% over the actual results. But on July 18, 2002 the Dynamic Component program is still off by approximately 2 times the actual results. The ISC3 model results improve to within 4 to 6 times the actual results, showing that the Dynamic Component Program model still performs better than the ISC3 model. The reduction of the input emissions by 50% improved the performance of the ISC3 model, but it did not improve its accuracy. However, the Dynamic Component Program's results improved and became more accurate with the reduced emissions. These results strengthened the premise that the Dynamic Component Program is a better modeling method than the ISC3 in estimating PM_{10} dispersion.

6.4.2 Coal Mine

The comparison of the coal mine modeling and field study results offers different results from the stone quarry comparison. The Dynamic Component Program model still performs better than the ISC3 model. The ISC3 model results were 4 to 8 times the actual results, whereas the Dynamic Component Program model results were generally within 2 times the actual results. These results demonstrate that the Dynamic Component Program's modeling methodology for estimating PM_{10} dispersion is an improvement over the ISC3 model. The difference between the coal mine and the stone quarry comparisons are that the stone quarry comparison shows both the Dynamic Component Program and the ISC3 model over-predicting actual field study results.

Table 6.13 Percent difference (over(+)/under(-)) of 50% of the modeling results from the field study results for July 16, 2002.

	Station A	Station B	Station C	Station D	Station E	Station F	Station G	Average % Difference
Dynamic Component Program	-12.97%	71.01%	74.59%	119.43%	118.41%	71.48%	76.59%	74.08%
ISC3 Model	510.60%	136.08%	416.49%	465.44%	189.37%	388.03%	331.06%	348.15%

Table 6.14 Percent difference (over(+)/under(-)) of 50% of the modeling results from the field study results for July 17, 2002.

	Station A	Station B	Station C	Station D	Station E	Station F	Station G	Average % Difference
Dynamic Component Program	-24.54%	-7.02%	53.73%	30.35%	-8.97%	51.23%	95.24%	27.15%
ISC3 Model	754.85%	133.96%	501.36%	315.50%	110.07%	467.91%	480.13%	394.82%

Table 6.15 Percent difference (over(+)/under(-)) of 50% of the modeling results from the field study results for July 18, 2002.

	Station A	Station B	Station C	Station D	Station E	Station F	Station G	Average % Difference
Dynamic Component Program	66.85%	116.94%	166.00%	267.16%	39.08%	128.66%	144.71%	132.77%
ISC3 Model	3203.84%	115.85%	150.44%	133.28%	15.73%	98.66%	37.09%	536.41%

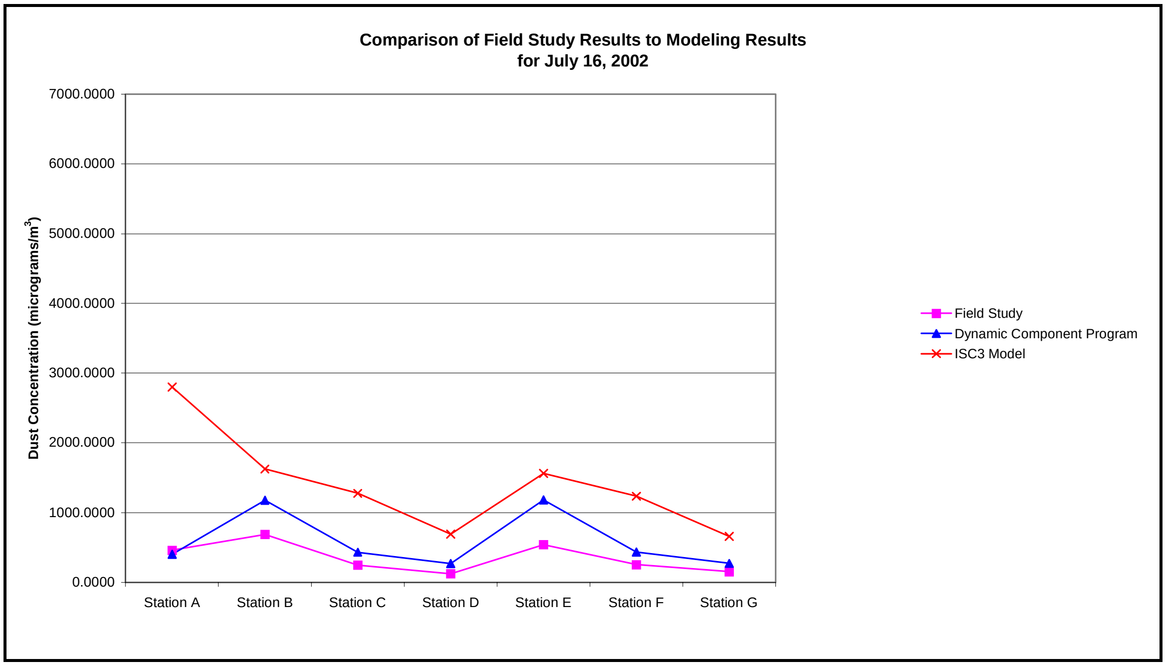


Figure 6.15 Comparison of 50% of the modeling results with the stone quarry field study results for July 16, 2002.

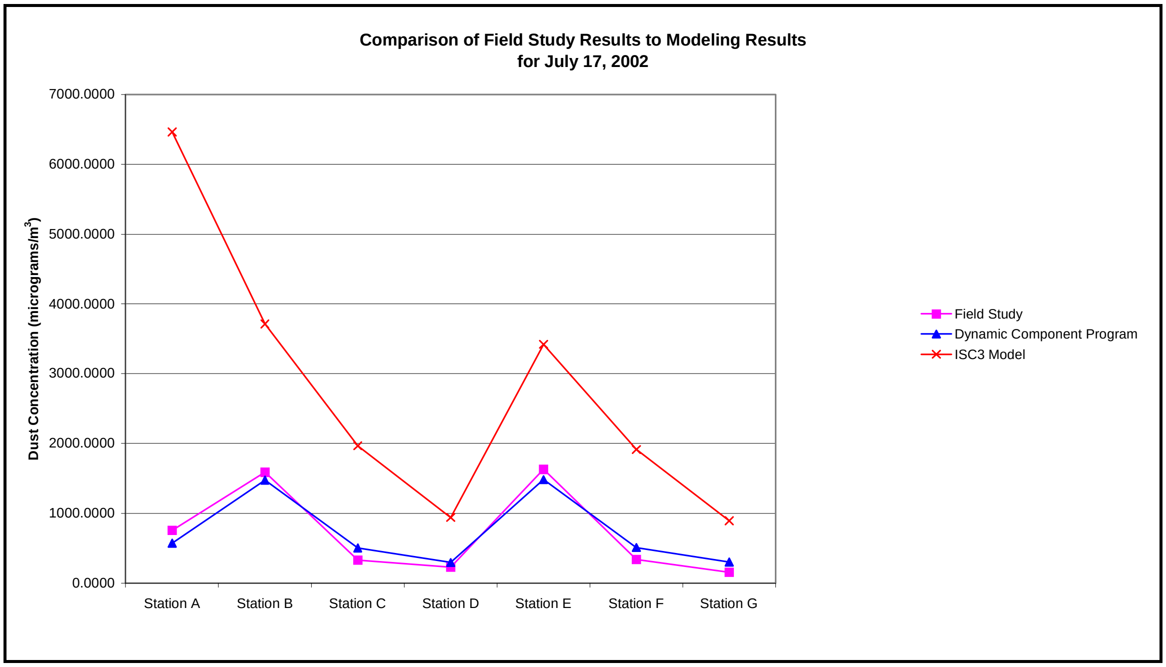


Figure 6.16 Comparison of 50% of the modeling results with the stone quarry field study results for July 16, 2002.

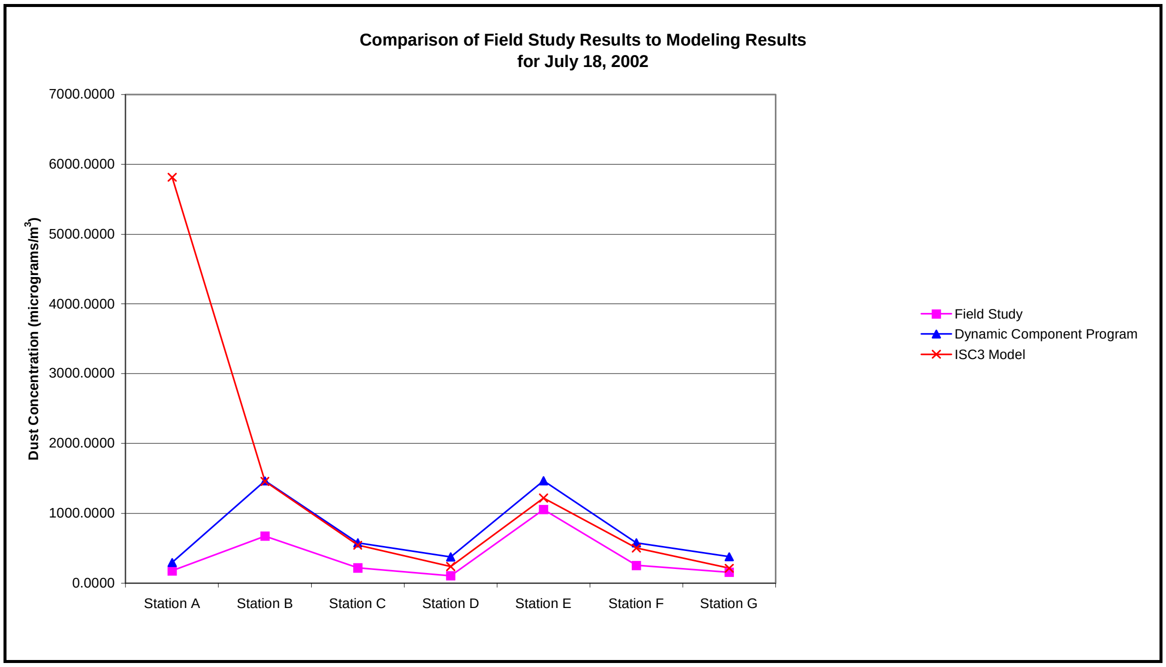


Figure 6.17 Comparison of 50% of the modeling results with the stone quarry field study results for July 18, 2002.

The coal mine comparison shows that both models over-predict actual field study results for only one day: August 5, 2002, and they alternately under-predict the field study results for the other two days of the field study: August 2 and August 6, 2002.

Possible explanations for these results were reviewed. The assumptions of the Gaussian equation that there is no deposition of PM_{10} or that downwind dispersion is negligible, as stated previously, would not have a large effect on the modeling results as the rate of decay shown in the comparison of the modeling versus field study graphs can sometimes be seen to be equal to or greater than the rate of decay of the actual field data results.

The over-prediction caused by the source emissions factor equation used in calculating the amount of PM_{10} that a haul truck generates is a possible issue in model over-prediction. However, it should not be an issue in model under-prediction, as lowering the source emissions would increase the under-prediction of the model, as shown in Tables 6.16, 6.17, and 6.18. Another issue concerning the emissions factor equation is that the studies measured dust dispersion from two significantly different types of haul trucks. The stone quarry study measured dust dispersion from over-the-road haul trucks, while the coal mine study measured dust dispersion from off-road haul trucks. However, the emissions factor equation is supposed to correct for this disparity through the use of the weight factor [weight of the haul truck] in the equation.

It was also thought that a possible cause for the model under-prediction might be the fact that the background dust concentration levels at the coal mine field study were higher than those at the stone quarry field study. This would result in the actual field study results being higher than what the models could predict. But, reviewing Tables 5.13 and 5.14 from Chapter 5 showed that during the days the models under-predicted PM_{10} dispersion; the background dust concentration levels at the coal mine field study were lower than those at during the stone quarry field study.

Another possible explanation for the models over-predicting and under-predicting might be due to the wind direction. In the stone quarry field study, the wind directions were predominately blowing across the haul road, with the dust sampling stations on the downwind side of the haul road. This was not the case in the coal mine field study. Figures F.1, F.2, and F.3 in Appendix F show the wind directions during the coal mine field study in relation to the haul road for each day of the field study. Each day the majority of the wind directions were nearly parallel to the haul road. This is expected to cause the dust concentrations for the actual field study results to be higher than if the wind was perpendicular to the haul road. When the wind is in a direction perpendicular to the haul road, the dust sampling stations would collect PM_{10} from only a small segment of the haul road directly adjacent to the measuring stations as the haul truck went by. This segment's size increases as the wind direction goes from perpendicular to parallel to the haul road. When the wind direction is parallel to the haul road, the dust sampling equipment would collect PM_{10} from the haul truck dust plume that travels an entire length of the haul road, parallel and upwind of the equipment. This action causes the airborne dust to compound upon itself, thus, possibly causing higher recorded dust concentrations.

At the coal mine field study site on August 2, 2002, the wind directions were mostly parallel to the haul road and the sampling stations were slightly downwind. The dust sampling equipment could have received PM_{10} from an entire length of haul road. The dust plume of a haul truck passing along this length of road could have had an impact on the sampling stations. The haul truck dust plume would move continuously along the length of the haul road toward the sampling stations. This could have resulted in the dust samplers measuring dust for the entire time the plume traveled along the haul road, resulting in higher actual dust concentrations.

On August 5, 2002 the wind direction was parallel to the haul road, but all stations with the exception of Station A were slightly upwind of the haul road. Again, as the haul truck passed the sampling stations, the haul truck dust plume would move continuously along the haul road toward the sampling stations. However, since all the sampling stations with the exception of Station A, were now upwind of the haul road, the dust plume bypassed the upwind sampling stations. Therefore, the effect of the wind direction parallel to the haul road would not have the adverse effect on the dust concentrations measured at these stations as it did on the dust concentration measurements for the downwind sampling stations during the August 2nd field study.

On August 6, 2002 the wind direction was parallel to the haul road and the sampling stations were slightly upwind. The dust sampling equipment could have received PM_{10} from a 0.56 km length of haul road. The length of this segment was measured from the straightaway of the haul road, and to the beginning of the next curve in the road. The dust plume of a haul truck passing through this straightaway could have had an impact on the sampling stations by moving continuously along the haul road toward the sampling stations. This could have resulted in the dust samplers measuring dust for the entire time the plume traveled along the haul road, resulting in higher actual dust concentrations. However, on August 6, 2002 the sampling locations were slightly upwind of the haul road. Therefore, this explanation does not seem to be viable for this situation.

However, there is another factor to consider. On August 6, 2002 the average wind speed was approximately double that of the wind speeds measured during all the other field studies. The differing results from the model comparison for this day could be due to a combination of wind direction and wind speed. Higher turbulence from the higher wind speed could have caused the disparity of results in the modeling comparison for August 6, 2002.

The results clearly show that the Dynamic Component Program model is an improvement over the ISC3 model. Performing the same test that was completed on the stone quarry study, where a combination of reducing the source emissions by 50% and modeling were used, would only make the model predictions worse for the days that the models under-predicted actual results; causing larger under-predictions. While the day (August 5, 2002) that both models over-predict the dispersion of PM_{10} would gain an improvement. These results can be seen in Tables 6.16, 6.17, and 6.18 and in Figures 6.10, 6.11, and 6.12. Even though reducing the modeling results, as in the stone quarry comparison, deteriorate the Dynamic Component Program model results compared to the actual field results, the Dynamic Component Program model still performs better than the ISC3 model. But, it is demonstrated that both models lack the capacity to accurately predict PM_{10} dispersion when the wind direction is parallel to the haul road.

6.5 Conclusion.

The results from the modeling comparison demonstrate that the Dynamic Component Program model is clearly an improvement over the ISC3 model. The Dynamic Component Program model generally better predicts PM_{10} dispersion from haul trucks by a factor of 3 to 6. This has been demonstrated for two different mine sites that each have different characteristics, one being a rock quarry and the other being a coal mining site.

Table 6.16 Percent difference (over(+)/under(-)) of 50% of the modeling results from the field study results for August 2, 2002.

	Station A	Station B	Station C	Station D	Station E	Station F	Station G	Average % Difference
Dynamic Component Program	-86.37%	-63.72%	-40.60%	-27.49%	-57.43%	-49.25%	-30.87%	-50.82%
ISC3 Model	-16.53%	-82.19%	-73.86%	-81.06%	-80.76%	-79.69%	-83.55%	-71.09%

Table 6.17 Percent difference (over(+)/under(-)) of 50% of the modeling results from the field study results for August 5, 2002.

	Station A	Station B	Station C	Station D	Station E	Station F	Station G	Average % Difference
Dynamic Component Program	-29.23%	-19.42%	151.51%	179.03%	-18.74%	96.85%	123.96%	74.71%
ISC3 Model	21.83%	146.96%	689.85%	446.99%	56.47%	497.22%	316.55%	310.84%

Table 6.18 Percent difference (over(+)/under(-)) of 50% of the modeling results from the field study results for August 6, 2002.

	Station A	Station B	Station C	Station D	Station E	Station F	Station G	Average % Difference
Dynamic Component Program	-87.39%	-92.15%	-84.77%	-85.15%	-94.06%	-80.54%	-78.92%	-86.14%
ISC3 Model	-70.32%	2.53%	234.26%	117.69%	-25.06%	338.11%	226.84%	117.72%

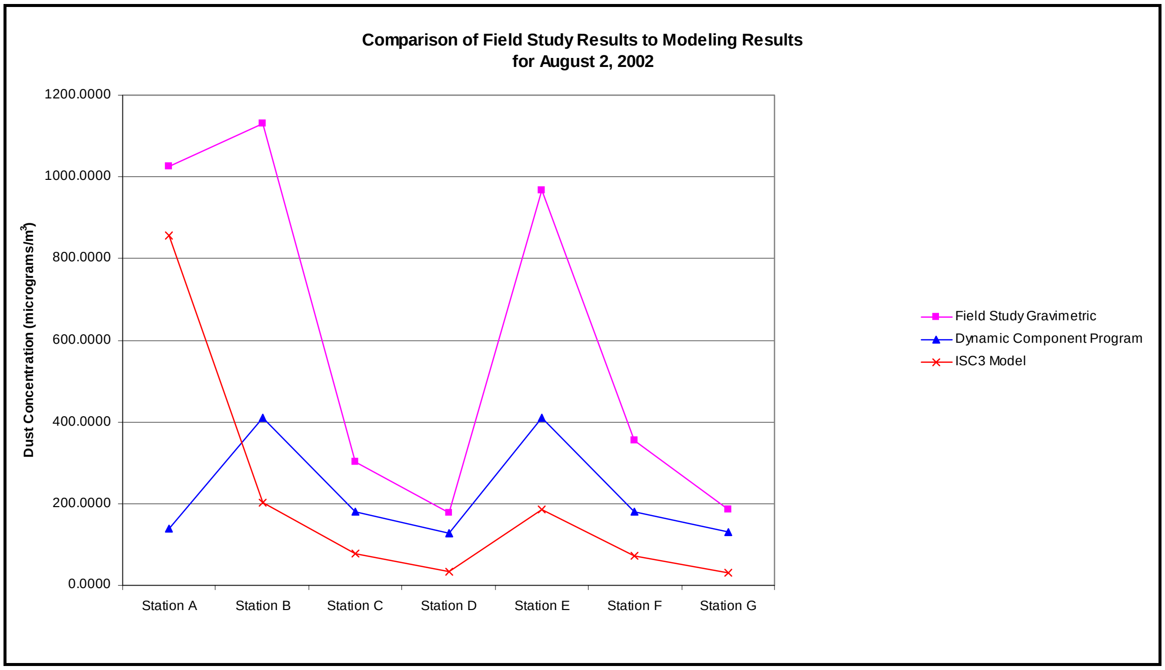


Figure 6.18 Comparison of 50% of the modeling results with the coal mine field study results for August 2, 2002.

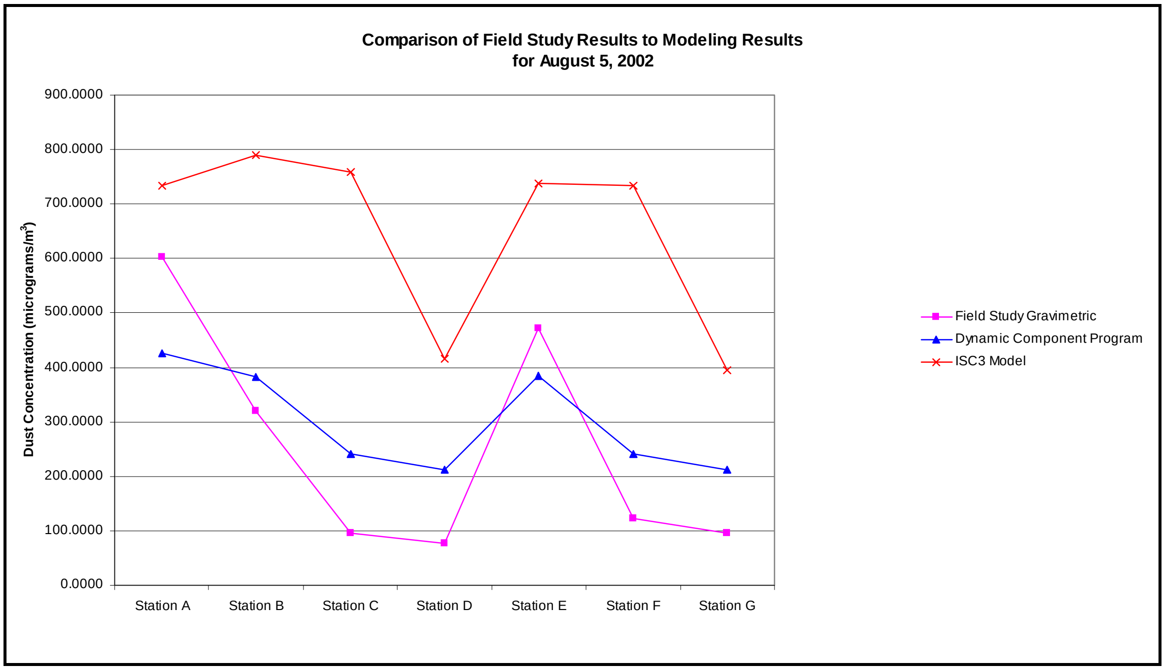


Figure 6.19 Comparison of 50% of the modeling results with the coal mine field study results for August 5, 2002.

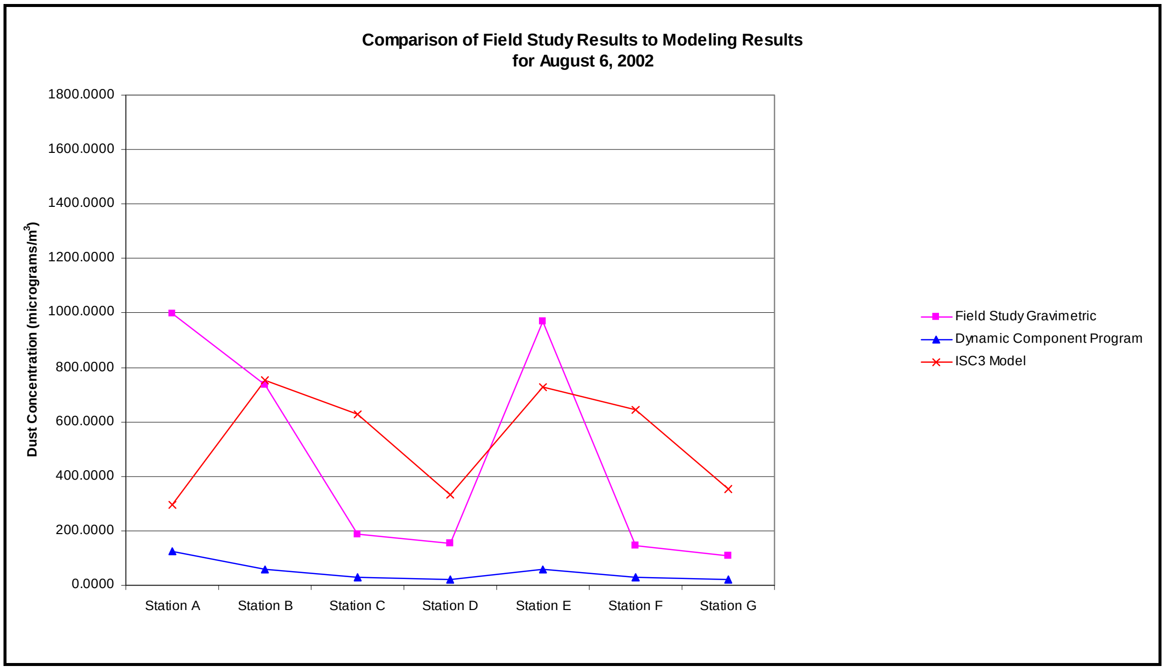


Figure 6.20 Comparison of 50% of the modeling results with the coal mine field study results for August 6, 2002.

The Dynamic Component Program model can still over-predict actual results two times. Various explanations have been given for this over-prediction ranging from basic assumptions of the Gaussian equation used in the model to the inability of the model to accurately predict results for certain wind directions. The best explanation that corrects this large amount of over-prediction is the combination of the use of the Dynamic Component Program model and the reduction of the emissions of the haul trucks.

The combination of the use of the Dynamic Component Program and the reduction of the emissions of the haul trucks has presented an improvement, with model results being within 27 - 74% over the actual field study results. In comparison, the ISC3 model improved to within 4 to 6 times the actual results. When the Dynamic Component Program model under-predicted actual results, the combination of the model and reduced emissions resulted in poorer performance. But these results were still a 26 to 28% improvement over using the ISC3 model and reduced emissions.

The ultimate result of this testing is that the over-prediction from emissions factor equations must be considered as a possible factor in causing over-prediction of the modeling results. To quantify the effect of this factor requires further testing, which is beyond the scope of this study. However, it is expected to have a significant effect. Previous testing has shown that the Dynamic Component Program model is an improvement in modeling PM_{10} dispersion. In addition, it has been presented that a combination of 1) reducing the amount of the source emissions by recommending a better emissions factor equation and 2) the use of the Dynamic Component Program model result in improved and accurate modeling performance.

Chapter 7 Conclusions and Recommendations

7.0 Summary and Conclusions

The Dynamic Component Program model was created to improve the ISC3 model's ability to predict PM_{10} dispersion from surface mining operations. The focus of the Dynamic Component Program model was the mobile sources (haul trucks) since the majority of emissions from surface mining operations emanate from these sources (Cole and Zapert, 1995). The new model, created in Visual Basic 6.0, uses a different methodology for processing the emissions of haul trucks and calculating PM_{10} dispersion and was shown to improve upon the prediction of PM_{10} from the ISC3 model. In order to determine if this improvement was accurate, measurements were completed on actual hauling operations at surface mine sites.

Field studies were conducted at two sites to validate the output of the Dynamic Component Program model. Both a stone quarry located in Virginia and a coal mine in Pennsylvania were surveyed. While the sites had differing characteristics, the basic prerequisites of each field study were the same. Haul road characteristics, dust sampling equipment, and sampling locations were selected to be comparable from one field study to the other. A field study sampling procedure was created and used to ensure that the proper data were collected and that the field studies' results would be comparable to each other. Once the field studies were completed, the data were processed and analyzed.

7.1 Conclusions from Field Study Data

The comparison of the modeling estimates with the actual field study results demonstrated that results from the Dynamic Component Program model performed more closely matched field data than those from ISC3 model. The Dynamic Component Program model had percent differences from the actual field study results of -1.64%, 249.42%, and -72.28% for the August 2nd, 5th, and 6th coal mine field study comparisons, while the percent difference of the ISC3 model from the actual field study results were -42.18%, 721.68%, and 335.44%, respectively. The percent differences of the Dynamic Component Program from the actual field study results were 248.16%, 154.29%, and 365.55% for the July 16th, 17th, and 18th stone quarry field study comparisons, respectively, while the percent differences of the ISC3 model from the actual field study results were 796.30%, 889.65%, and 1172.83%, respectively. Overall, the

Dynamic Component Program model was, on average, a 76.8% improvement over the ISC3 model, with the range of performance varying from a 65.4 - 96.1% improvement over the ISC3 model.

The following is a synopsis of the items that were observed from conducting the field studies and analyzing the data that were collected:

1. From gravimetric measurements, the dust concentrations decay rapidly within the first 15 meters from the source. At 30 meters distance, the dust concentrations are close to background concentrations.
2. Average instantaneous dust concentrations measured at the site support the fact that the dust concentrations decay rapidly within the first 15 meters and that the dust concentrations are close to background concentrations at 30 meters distance from the haul road.
3. Dust propagation is highly dependent upon wind direction, but along the haul road, the haul trucks impart momentum to the dust particles such that they are able to overcome the wind velocity at the edges of the haul road. Therefore, this action causes high dust concentrations on both sides of the haul road.
4. Particle size analysis shows that the amount of PM_{10} contained in the total airborne dust from haul trucks ranges from 6.39 - 18.42%, with the average amount being 15.31%.
5. Particle size analysis of the field study data of airborne dust showed that the deposition of dust was dependent upon density of material, not particle size.
6. The average time for the dust concentrations to spike and return to background is around 1 ½ minutes. Therefore, a haul truck traveling 6.70 m/s will have an influence on a location which lasts until 1 ½ minutes have elapsed.
7. The background dust concentration levels calculated from the instantaneous data are not ambient background levels. The reason these levels cannot be considered ambient background dust concentration levels is due to the dust from the haul truck overpowering the upwind station located adjacent to the haul road.

Overall, the dispersion of PM_{10} from haul trucks has been shown to be a short-range problem. The effects of PM_{10} from haul trucks will be limited to a small area of influence of approximately 30 meters distance on each side of the truck and approximately 600 meters distance behind it. The fact that a haul truck's PM_{10} emissions are located at ground surface and have a relatively small area of influence, preclude the use of the ISC3 model for use on mobile equipment, as the ISC3 model is designed to be more of a long-range model. The Dynamic Component Program model is the recommended model for estimating PM_{10} dispersion because it is, on average, a 77% improvement over the ISC3 model. The observations from this study give a characterization of the haul truck dust plume that has been unknown until now. Prior research only characterized the amount of dust emissions the haul truck would generate under different conditions. No research had been completed to characterize the propagation of the dust from the haul trucks. This information, along with prior research, will be essential in performing future research on the effects of dust from mobile equipment.

7.2 Recommendations for Future Research

The Dynamic Component Program developed in this research can only be applied to a straight stretch of haul road. Actual haul roads may contain curves, both horizontal and vertical. The next step in this research would be to expand the model to accommodate the entire length of the haul road. This would require more programming to accommodate curves. Once the program was operating, field measurements would be required to validate this model. The field study testing would be designed to test the model at the curves of the haul road to find out if the model accurately estimates PM_{10} dispersion at these locations.

The Dynamic Component Program still sometimes over-predicts actual dust concentrations by a significant amount (a factor of 2 or more). A possible method to improve upon this over-prediction is to determine another equation that may be more accurate than the Gaussian equation on which the model is based. The use of regression analysis on the existing data may provide a basis for this new equation. The use of regression analysis will not be a simple procedure because the data are non-linear, and a review of three-dimensional graphs created in this research show the complex shape of the dust concentration for the affected area. However, the shapes of these curves have a similarity that may allow the development of a new equation for dust dispersion at surface mining operations. Once this equation has been determined, testing would be required for validation.

Additional testing, similar to the field studies just completed, should also be completed along the straightaways of the haul road. These field studies should use the original dust sampling layout proposed in Chapter Four. This recommended layout, shown in Figure 7.1, adds sampling stations to the upwind side of the haul road and adds two more stations to the downwind side of the haul road. In addition, another sampling station should be located at an isolated location away from the study area and away from any possible dust sources. This layout will augment existing data from the previous research by evaluating PM_{10} dispersion upwind of the haul road and by completing the profile of the PM_{10} dispersion beyond the 30 meters that has already been completed. The isolated sampling station will allow for better measurement of ambient background dust concentration levels. The second parallel line of sampling stations has been removed, as it was not as critical to the field study as originally thought.

Additional considerations for additional testing include that the testing should be completed at surface mining sites that have varying characteristics. The frequency of haul truck travel should be no less than 10 to 15 minutes per haul truck pass, as this will allow maximum usage of the data collected. This testing should expand upon the existing collection of data concerning dust dispersion from haul trucks, and it should allow for the creation of a PM_{10} dispersion database that contains varying conditions. To enhance the prediction of the PM_{10} dispersion from haul trucks, the model could refer to this database. Having a diverse set of actual conditions for PM_{10} dispersion testing would allow for improvements to the model, making the modeling process more accurate.

Continued testing of PM_{10} dispersion can be completed in other areas beyond the mining industry. Field studies of this research can be conducted on many different types of construction and agricultural equipment. Incorporating this data into a database will allow the Dynamic Component Program dust model to be applied to a wide range of projects and industries. For example, it can be expanded to allow its use in predicting PM_{10} emissions from traffic traveling rural dirt roads, emissions from small local construction sites, emissions from major construction sites at interstate highways, airports, etc., and emissions from agricultural activities such as tilling and harvesting operations.

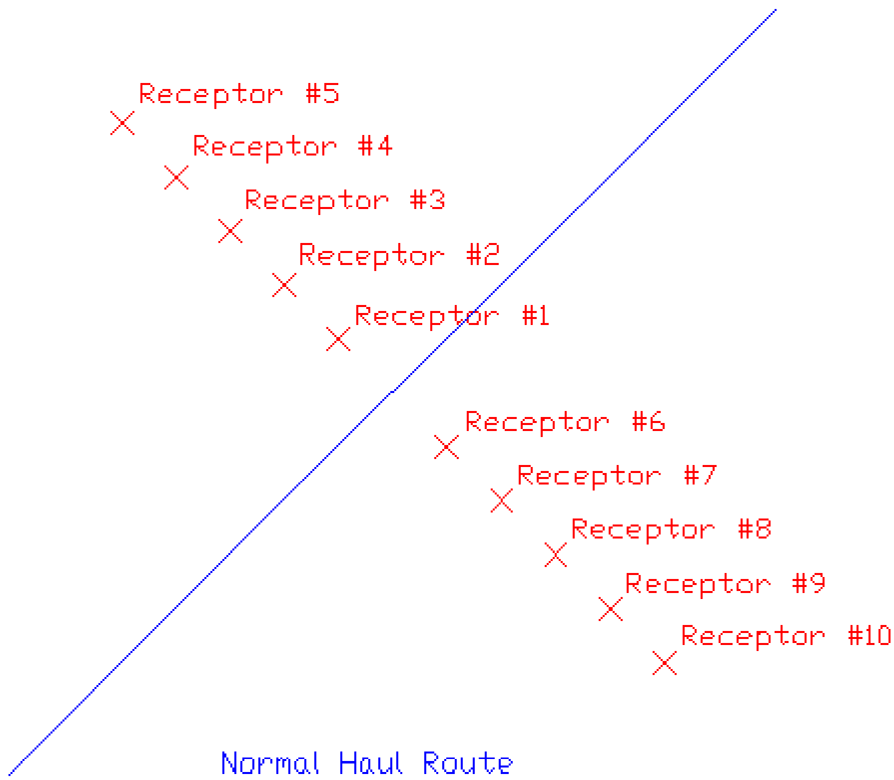


Figure 7.1 Recommended sampling station line-up for further testing of PM_{10} dispersion from haul trucks.

There is always the need to conduct research on existing dust measurement equipment. This research would consist of performing experiments that make comparisons of dust measurement results among different types of measurement instruments. Other research could be performed to test the measurement limits of existing equipment such as the 10-mm Dorr-Oliver cyclone. For example, an equation has been developed that calculates different particle size cut-points from different flow-rates for the 10-mm Dorr-Oliver cyclone (Chan and Lippmann, 1977). This equation has not been tested for measuring particle sizes above 7 - 8 μm. Testing could be conducted to determine if this equation is valid for particle size ranges above 7 - 8 μm. The goal of this research would be to determine the accuracy and reliability among different instruments and their dust measurement results. Further research could be performed testing the dust measurement equipment to expand the uses of existing dust measurement equipment and to create new methods of dust measurement. All of this would be completed to ensure the accuracy of the permitting process and ultimately the health and safety of personnel in the workforce and at home.

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Appendix A

The following equations are all required in order to use the Gaussian equation for pollutant dispersion. This information is taken directly from the User's guide for the Industrial Source Complex (ISC3) Dispersion Models, Volume II - Description of Model Algorithms, written by the United States Environmental Protection Agency (U. S. EPA, User's Guide Vol. II, 1995).

A.1 The Gaussian Equation for point source emissions

$$\chi = \frac{QKVD}{2\pi u_s \sigma_y \sigma_z} \exp\left[-0.5\left(\frac{y}{\sigma_y}\right)^2\right] \qquad \text{(A.1)}$$

where

Q	=	pollutant emission rate
K	=	scaling coefficient to convert calculated concentrations to desired units (default value of 1)
V	=	vertical term
D	=	Decay term
u_s	=	Mean wind speed at release height
σ_y, σ_z	=	Standard deviation of lateral and vertical concentration distribution
χ	=	hourly concentration at downwind distance x
y	=	crosswind distance from source to receptor

A.2 Downwind and Crosswind distances

$$x = -(X(R) - X(S))\sin(WD) - (Y(R) - Y(S)\cos(WD)) \qquad \text{(A.2)}$$

where

x	=	downwind distance
$X(R)$	=	x coordinate of receptor
$Y(R)$	=	y coordinate of receptor
$X(S)$	=	x coordinate of source
$Y(S)$	=	y coordinate of source
WD	=	direction from which wind is blowing (angle measured clockwise from north)

$$y = -(X(R) - X(S))\cos(WD) - (Y(R) - Y(S))\sin(WD) \qquad \text{(A.3)}$$

where

y	=	crosswind distance
$X(R)$	=	x coordinate of receptor
$Y(R)$	=	y coordinate of receptor
$X(S)$	=	x coordinate of source
$Y(S)$	=	y coordinate of source
WD	=	direction from which wind is blowing (angle measured clockwise from north)

A.3 Wind speed profile

$$u_s = u_{ref}\left(\frac{h_s}{z_{ref}}\right)^p \qquad \text{(A.4)}$$

where

u_{ref}	=	observed wind speed from a measured reference height (z_{ref}) (m/s)
h_s	=	stack height (m)
p	=	wind profile exponent (dimensionless)
z_{ref}	=	measured reference height for wind speed (m)

Default values:

Stability Category	Rural Exponent	Urban exponent
A	0.07	0.15
B	0.07	0.15
C	0.10	0.20
D	0.15	0.25
E	0.35	0.30
F	0.55	0.30

A.4 Plume Rise due to momentum

$$h_e = h_s^{'} + 3d_s\left(\frac{v_s}{u_s}\right) \qquad \text{(A.5)}$$

where

h_e	=	plume rise (m)
h_s'	=	stack height (m)
d_s	=	inside diameter of stack (m)
v_s	=	exit velocity of stack gas (m/s)
u_s	=	mean wind speed (m/s)

A.5 Dispersion Parameters (σ_y, σ_x)

$$\sigma_y = 465.11628(x)\tan(TH) \qquad \text{(A.6)}$$

where

$$TH = 0.017453293[c - d\ln(x)] \qquad \text{(A.7)}$$

where

x	=	downwind distance (km)
c,d	=	coefficients
		Coefficient default values:

Pasquill Stability Category	c	d
A	24.167	2.5334
B	18.333	1.8096
C	12.500	1.0857
D	8.333	0.72382
E	6.250	0.054287
F	4.1667	0.36191

The Pasquill stability category refers to the stability of air layers near the ground. It is based upon wind speed and insolation (incoming solar radiation) (Schnelle and Dey, 2000). The following table defines the six categories.

Table A.1 Pasquill-Gifford Stability Categories.

Surface Wind	Day-Time Insolation			Night-Time Cloudiness	
(Measured at 10 m) (mph)	Strong	Moderate	Slight	Thinly overcast or ≥4/8 Cloudiness	≤3/8 Cloudiness
4.5	A	A – B	B	-	-
4.5 - 6.7	A - B	B	C	E	F
6.7 - 11.2	B	B – C	C	D	E
11.2 – 13.4	C	C – D	D	D	D
>13.4	C	D	D	D	D

Notes:

1. Insolation is the rate of radiation from the sun received per unit of earth's surface.
2. Strong insolation corresponds to sunny mid-day in summer. Slight insolation corresponds to similar conditions in winter.
3. For A-B, B-C, etc. take the average of A and B values.
4. Night refers to 1 hour before sunset to 1 hour after dawn.
5. Regardless of wind speed, the neutral category D should be assumed for overcast conditions during day or night and for any sky conditions during the hour preceding or following night.

A = Extremely unstable   C = Slightly unstable   E = Slightly stable
B = Moderately unstable   D = Neutral   F = moderately stable

The previous information on the Pasquill stability categories are taken directly from Schnelle, K.B. and Partha, R.D.

$$\sigma_z = ax^b \qquad \text{(A.8)}$$

here

x	=	downwind distance (km)
a,b	=	coefficients

Default values: (taken from U. S. EPA, User's Guide Vol. II, 1995)

Pasquill Stability Category	x (km)	a	b
A	<0.10	122.800	0.94470
	0.10-0.15	158.080	1.05420
	0.16-0.20	170.220	1.09320
	0.21-0.25	179.520	1.12620
	0.26-0.30	217.410	1.26440
	0.31-0.40	258.890	1.40940
	0.41-0.50	346.750	1.72830
	0.51-3.11	453.850	2.11660
	>3.11	**	**
B	<0.20	90.673	0.93198
	0.21-0.40	98.483	0.98332
	>0.40	109.300	1.09710
C	All	61.141	0.91465
D	<0.30	34.459	0.86974
	0.31-1.00	32.093	0.81066
	1.01-3.00	32.093	0.64403
	3.01-10.00	33.504	0.60486
	10.01-30.00	36.650	0.56589
	>30.00	44.053	0.51179
E	<0.10	24.260	0.83660
	0.10-0.30	23.331	0.81956
	0.31-1.00	21.628	0.75660
	1.01-2.00	21.628	0.63077
	2.01-4.00	22.534	0.57154
	4.01-10.00	24.703	0.50527
	10.01-20.00	26.970	0.46713
	20.01-40.00	35.420	0.37615
	>40.00	47.618	0.29592

F	<0.20	15.209	0.81558
	0.21-0.70	14.457	0.78407
	0.71-1.00	13.953	0.68465
	1.01-2.00	13.953	0.63227
	2.01-3.00	14.823	0.54503
	3.01-7.00	16.187	0.46490
	7.01-15.00	17.836	0.41507
	15.01-30.00	22.651	0.32681
	30.01-60.00	27.074	0.27436
	>60.00	34.219	0.21716

A.6 Vertical Term

$$V = \exp\left[-0.5\left(\frac{z_r - h_e}{\sigma_z}\right)^2\right] + \exp\left[-0.5\left(\frac{z_r + h_e}{\sigma_z}\right)^2\right]$$
$$+\sum_{i=1}^{\infty}\left\{\exp\left[-0.5\left(\frac{H_1}{\sigma_z}\right)^2\right] + \exp\left[-0.5\left(\frac{H_2}{\sigma_z}\right)^2\right] + \exp\left[-0.5\left(\frac{H_3}{\sigma_z}\right)^2\right] + \exp\left[-0.5\left(\frac{H_4}{\sigma_z}\right)^2\right]\right\}$$

(A.9)

where

$h_e = h_s + \Delta h$
h_e = plume height (m)
h_s = stack height (m)
Δh = plume rise (m)
$H_1 = z_r - (2iz_i - h_e)$
$H_2 = z_r + (2iz_i - h_e)$
$H_3 = z_r - (2iz_i + h_e)$
$H_4 = z_r + (2iz_i + h_e)$

z_r = receptor height above ground (m)
z_i = mixing height (m)

$$V = \frac{\sqrt{2\pi}\sigma_z}{z_i} \qquad \text{(A.10)}$$

This form is used to save on computational time without sacrificing accuracy

There are variations of the vertical term depending upon the routine used in calculating dispersion.

A.7 Decay term

$$D = \exp\left(-\psi \frac{x}{u_s}\right) \qquad \text{For } \psi > 0 \qquad \text{(A.11)}$$

D=1 For ψ=0

where

ψ = decay coefficient

$$\psi = \frac{0.693}{T_{1/2}} \qquad \text{(A.12)}$$

$T_{1/2}$ = pollutant half life (seconds)
x = downwind distance (m)

Default value of ψ = 0 unless specified

Appendix B

B.1 Emissions Factor for Western Surface Coal Mines (Current 1998)

Table B.1 U. S. EPA Emission Factors for Western Surface Coal Mines (U. S. EPA,Western Surface Coal Mines, 1998).

Operation	Total Suspended Particulate <30μm (lb/ton unless otherwise noted)	PM_{10} (lb/ton unless otherwise noted)	$PM_{2.5}$ (lb/ton unless otherwise noted)
Blasting	$0.000014(A)^{1.5}$ (lb/blast)	$7.28\times10^{-6}(A)^{1.5}$ (lb/blast)	$4.2\times10^{-7}(A)^{1.5}$ (lb/blast)
Truck Loading Activities (coal only)	$\frac{1.16}{M^{1.2}}$	$\frac{0.08925}{M^{0.9}}$	$\frac{0.02204}{M^{1.2}}$
Bulldozing Activities (coal only)	$\frac{78.4(s)^{1.2}}{M^{1.3}}$ (lb/hour)	$\frac{13.95(s)^{1.5}}{M^{1.4}}$ (lb/hour)	$\frac{1.7248(s)^{1.2}}{M^{1.3}}$ (lb/hour)
Bulldozing Activities (overburden only)	$\frac{5.7(s)^{1.2}}{M^{1.3}}$ (lb/hour)	$\frac{0.75(s)^{1.5}}{M^{1.4}}$ (lb/hour)	$\frac{0.5985(s)^{1.2}}{M^{1.3}}$ (lb/hour)
Dragline Activities	$\frac{0.0021(d)^{1.1}}{M^{0.3}}$ (lb/yd^3)	$\frac{1.575\times10^{-3}(d)^{0.7}}{M^{0.3}}$ (lb/yd^3)	$\frac{3.57\times10^{-5}(d)^{1.1}}{M^{0.3}}$ (lb/yd^3)
Road Grading Activities	$0.040(S)^{2.5}$ (lb/VMT)	$0.0306(S)^{2}$ (lb/VMT)	$1.24\times10^{-3}(S)^{2.5}$ (lb/VMT)
Active Storage Pile Activities	$0.72(u)$ (lb/acre-hour)	None	None

A = horizontal area, ft^2 (not vertical face of the bench) blasting depth $\leq$ 70 ft. for both coal and overburden operations.
M = moisture content, percent.
s = silt content, percent.
d = drop height, ft.
S = mean vehicle speed, mph.
u = wind speed, mph.

All units are English units.

B.2 Emission Factors for Crushed Stone Processing (current 1995)

Table B-2 U. S. EPA Emission Factors for Screening and Crushing Operations (U. S. EPA, AP-42, Crushed Stone Processing, 1995).

Source	TSP (Total Suspended Particulate Matter) lb/ton	PM_{10} (Particulate Matter $\leq 10\mu m$) lb/ton
Screening		0.015
Screening (controlled)		0.00084
Primary Crushing	0.00070	No Data
Secondary Crushing	No Data	No Data
Tertiary Crushing		0.0024
Primary Crushing (controlled)	No Data	No Data
Secondary Crushing (controlled)	No Data	No Data
Tertiary Crushing (controlled)		0.00059
Fines Crushing		0.015
Fines Crushing (controlled)		0.0020
Fines Screening		0.071
Fines Screening (controlled)		0.0021
Conveyor Transfer Point		0.0014
Conveyor Transfer Point (controlled)		0.000048
Wet Drilling (unfragmented stone)	No Data	0.00008
Truck Unloading (unfragmented stone)	No Data	0.000016
Truck/Conveyor Loading (crushed stone)	No Data	0.00010

All units are English units.

B.3 Emission Factor for Unpaved Roads (current 1998) (U. S. EPA, AP-42, Unpaved Roads, 1998)

$$E = \frac{k\left(\frac{s}{12}\right)^{a}\left(\frac{W}{3}\right)^{b}}{\left(\frac{M}{0.2}\right)^{c}} \qquad \text{(B.1)}$$

where

E	=	size-specific emission factor (lb/vehicle mile traveled)
s	=	surface material silt content (%)
W	=	mean vehicle weight (tons)
M	=	surface moisture content (%)
		All units are english units.

Empirical Constant	$PM_{2.5}$	PM_{10}	PM_{30}
k	0.38	2.6	10
a	0.8	0.8	0.8
b	0.4	0.4	0.5
c	0.3	0.3	0.4

B.4 Emission Factors for Loading (drop) Operations (current 1995) (U. S. EPA, AP-42, Aggregate Handling, 1995)

$$E = k(0.0032)\frac{\left(\frac{U}{5}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \qquad \text{(B.2)}$$

where

E	=	size-specific emission factor (lb/ton of material)
k	=	particle size multiplier (dimensionless)
U	=	mean wind speed (miles per hour)
M	=	material moisture content (%)
		All units are english units.

Aerodynamic Particle Size Multiplier (*k*) for Equation B-2				
<30 µm	<15 µm	<10 µm	<5 µm	<2.5 µm
0.74	0.48	0.35	0.20	0.11

Appendix C

C.1 Visual Basic Code for Dynamic Component ISC3

The Dynamic Component ISC3 Program which uses the Gaussian dispersion equation as stated in the "User's guide for the ISC3 Dispersion model –Volume II, Description of Model Algorithms." This program calculates PM_{10} concentrations for each receptor location from a moving haul truck. It creates an array of concentrations from each haul road point for each receptor point for the duration of the meteorological data. This program was used when testing the data from the field study. The following is the Visual Basic code for the program.

```
Option Base 1
Public Xreceptor() As Single
Public Yreceptor() As Single
Public Qpm10truckloaded, Qpm10truckempty As Single
Public Xsource() As Single
Public Ysource() As Single
Public Year, Month(730), Day(730), Julianday(730), Hour(730), Senhf(730), Surfricvel(730),
        Dummyh1, Dummyi2, Dummyj3, Mechboundlayer(730), Moninobukhov(730),
        Surroughness(730), Bowenratio(730), Albedo(730), Windspeed(730),
        Winddirection(730), Referenceheight(730), Temp(730), Refhgttemp(730) As Single
Public ConcentrationX() As Single
Public Weathernumber
Public Background
Public MSlope, Byintercept, Xstart, Ystart, Xend, Yend, Numreceptor, Silt, Moisture,
        Trucknumber, Truckweight, Totalxdist, Truckspeedloaded, Truckspeedempty As Single
Public Distance, PM10emissionsgramssec As Single
Public c, d, p, a, b1 As Single
Public Us, TH, Sigmay, Decay, Kconversion, Verticalterm, Sigmaz, Ygaussian, Xgaussian,
        XgaussianKM As Single
Public he, zr, infiniteseries1, infiniteseries2, infiniteseries3 As Single
Public Const Pi = 3.14159265


Private Sub Image1_Click()
```

```
End Sub

Private Sub mnuCalculateitem_Click()
ReDim ConcentrationX(Totalxdist, Weathernumber, Numreceptor)
'Calculate the pm10 concentrations using the gaussian equation for a loaded truck
Decay = 1
Kconversion = 1 * 10 ^ 6
Form1.MousePointer = 11
For k = 1 To Numreceptor
  For j = 1 To Weathernumber
    For i = 1 To Totalxdist
    Directionradian = 0: Ygaussian = 0: Xgaussian = 0: Windspeednotzero = 0: Us = 0: TH = 0:
      Sigmay = 0: XgaussianKM = 0: Sigmaz = 0: Verticalterm = 0
    he = 0
    'he = 0: infiniteseries1 = 0: infiniteseries2 = 0: infiniteseries3 = 0: FQ = 0:
      Depositionvertterm = 0

'CALCULATE gaussian y coordinate
    Directionradian = (Pi / 180) * Winddirection(j)
    Ygaussian = (Xreceptor(k) - Xsource(i)) * Cos(Directionradian) - (Yreceptor(k) -
      Ysource(i)) * Sin(Directionradian)

'CALCULATE gaussian x coordinate
    Xgaussian = -(Xreceptor(k) - Xsource(i)) * Sin(Directionradian) - (Yreceptor(k) -
      Ysource(i)) * Cos(Directionradian)
      If Xgaussian = 0 Then
        Xgaussian = 1
      End If
```

```
‘CALCULATE Us
        If Windspeed(j) = 0 Then
           Windspeednotzero = 1
        Else
           Windspeednotzero = Windspeed(j)
        End If

'CALCULATE Sigma Y
        If Month(j) = 6 Or Month(j) = 7 Or Month(j) = 8 Or Month(j) = 9 Then
           If Windspeed(j) <= 2 Then
              c = 24.167
              d = 2.5334
           ElseIf Windspeed(j) > 2 And Windspeed(j) <= 3 Then
              c = 21.25
              d = 2.1715
           ElseIf Windspeed(j) > 3 And Windspeed(j) <= 5 Then
              c = 18.333
              d = 1.8096
           Else
              c = 12.5
              d = 1.0857
           End If
        ElseIf Month(j) = 1 Or Month(j) = 2 Or Month(j) = 3 Or Month(j) = 11 Or Month(j) = 12
             Then
             If Windspeed(j) <= 2 Then
              c = 18.333
              d = 1.8096
           ElseIf Windspeed(j) > 2 And Windspeed(j) <= 5 Then
              c = 12.5
              d = 1.0857
```

```
            Else
                c = 8.333
                d = 0.72382
            End If
        Else
            If Windspeed(j) <= 2 Then
                c = 21.25
                d = 2.1715
            ElseIf Windspeed(j) > 2 And Windspeed(j) <= 3 Then
                c = 18.333
                d = 1.8096
            ElseIf Windspeed(j) > 3 And Windspeed(j) <= 5 Then
                c = 15.4165
                d = 1.44765
            ElseIf Windspeed(j) > 5 And Windspeed(j) <= 6 Then
                c = 10.4165
                d = 0.633345
            Else
                c = 8.333
                d = 0.72382
            End If
        End If
        TH = 0.017453293 * (c - (d * (Log(Abs(Xgaussian / 1000)))))
        Sigmay = 465.11628 * (Xgaussian / 1000) * Tan(TH)

'CALCULATE Sigma Z
    XgaussianKM = Abs(Xgaussian) / 1000
    If Month(j) = 6 Or Month(j) = 7 Or Month(j) = 8 Or Month(j) = 9 Then
        If Windspeed(j) <= 2 Then     'category A
            If XgaussianKM <= 0.1 Then
```

```
    a = 122.8
    b1 = 0.9447
    Sigmaz = a * XgaussianKM ^ b1
ElseIf XgaussianKM > 0.1 And XgaussianKM <= 0.15 Then
    a = 158.08
    b1 = 1.0542
    Sigmaz = a * XgaussianKM ^ b1
ElseIf XgaussianKM > 0.15 And XgaussianKM <= 0.2 Then
    a = 170.22
    b1 = 1.0932
    Sigmaz = a * XgaussianKM ^ b1
ElseIf XgaussianKM > 0.2 And XgaussianKM <= 0.25 Then
    a = 179.52
    b1 = 1.1262
    Sigmaz = a * XgaussianKM ^ b1
ElseIf XgaussianKM > 0.25 And XgaussianKM <= 0.3 Then
    a = 217.41
    b1 = 1.2644
    Sigmaz = a * XgaussianKM ^ b1
ElseIf XgaussianKM > 0.3 And XgaussianKM <= 0.4 Then
    a = 258.89
    b1 = 1.4094
    Sigmaz = a * XgaussianKM ^ b1
ElseIf XgaussianKM > 0.4 And XgaussianKM <= 0.5 Then
    a = 346.75
    b1 = 1.7283
    Sigmaz = a * XgaussianKM ^ b1
ElseIf XgaussianKM > 0.5 And XgaussianKM <= 3.11 Then
    a = 453.85
    b1 = 2.1166
```

```
      Sigmaz = a * XgaussianKM ^ b1
    Else
      Sigmaz = 5000
    End If
  ElseIf Windspeed(j) > 2 And Windspeed(j) <= 3 Then     'Category A-B
    If XgaussianKM <= 0.1 Then
      a = 106.7365
      b1 = 0.93834
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.1 And XgaussianKM <= 0.15 Then
      a = 124.3765
      b1 = 0.99309
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.15 And XgaussianKM <= 0.2 Then
      a = 130.4465
      b1 = 1.01259
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.2 And XgaussianKM <= 0.25 Then
      a = 139.0015
      b1 = 1.05476
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.25 And XgaussianKM <= 0.3 Then
      a = 157.9465
      b1 = 1.12386
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.3 And XgaussianKM <= 0.4 Then
      a = 178.6865
      b1 = 1.19636
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.4 And XgaussianKM <= 0.5 Then
```

```
        a = 228.025
        b1 = 1.4127
        Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.5 And XgaussianKM <= 3.11 Then
        a = 281.575
        b1 = 1.60685
        Sigmaz = a * XgaussianKM ^ b1
    Else
        Sigmaz = 5000
    End If
ElseIf Windspeed(j) > 3 And Windspeed(j) <= 5 Then     'Category B
    If XgaussianKM <= 0.2 Then
        a = 90.673
        b1 = 0.93198
        Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.2 And XgaussianKM <= 0.4 Then
        a = 98.483
        b1 = 0.98332
        Sigmaz = a * XgaussianKM ^ b1
    Else
        a = 109.3
        b1 = 1.0971
        Sigmaz = a * XgaussianKM ^ b1
        If Sigmaz >= 5000 Then
            Sigmaz = 5000
        End If
    End If
Else              ' Category C
    a = 61.141
    b1 = 0.91465
```

```
        Sigmaz = a * XgaussianKM ^ b1
        If Sigmaz >= 5000 Then
          Sigmaz = 5000
        End If
      End If
ElseIf Month(j) = 1 Or Month(j) = 2 Or Month(j) = 3 Or Month(j) = 11 Or Month(j) = 12
    Then
      If Windspeed(j) <= 2 Then     'Category B
        If XgaussianKM <= 0.2 Then
          a = 90.673
          b1 = 0.93198
          Sigmaz = a * XgaussianKM ^ b1
        ElseIf XgaussianKM > 0.2 And XgaussianKM <= 0.4 Then
          a = 98.483
          b1 = 0.98332
          Sigmaz = a * XgaussianKM ^ b1
        Else
          a = 109.3
          b1 = 1.0971
          Sigmaz = a * XgaussianKM ^ b1
            If Sigmaz >= 5000 Then
              Sigmaz = 5000
            End If
        End If
      ElseIf Windspeed(j) > 2 And Windspeed(j) <= 5 Then      'Category C
          a = 61.141
          b1 = 0.91465
          Sigmaz = a * XgaussianKM ^ b1
          If Sigmaz >= 5000 Then
            Sigmaz = 5000
```

```
            End If
        Else                                'Category D
            If XgaussianKM <= 0.3 Then
                a = 34.459
                b1 = 0.86974
                Sigmaz = a * XgaussianKM ^ b1
            ElseIf XgaussianKM > 0.3 And XgaussianKM <= 1 Then
                a = 32.093
                b1 = 0.81066
                Sigmaz = a * XgaussianKM ^ b1
            ElseIf XgaussianKM > 1 And XgaussianKM <= 3 Then
                a = 32.093
                b1 = 0.64403
                Sigmaz = a * XgaussianKM ^ b1
            ElseIf XgaussianKM > 3 And XgaussianKM <= 10 Then
                a = 33.504
                b1 = 0.60486
                Sigmaz = a * XgaussianKM ^ b1
            ElseIf XgaussianKM > 10 And XgaussianKM <= 30 Then
                a = 36.65
                b1 = 0.56589
                Sigmaz = a * XgaussianKM ^ b1
            Else
                a = 44.053
                b1 = 0.51179
                Sigmaz = a * XgaussianKM ^ b1
            End If
        End If
    ElseIf Month(j) = 4 Or Month(j) = 5 Or Month(j) = 10 Then          'month 4,5, or 10
        If Windspeed(j) <= 2 Then           'category A-B
```

```
If XgaussianKM <= 0.1 Then
    a = 106.7365
    b1 = 0.93834
    Sigmaz = a * XgaussianKM ^ b1
ElseIf XgaussianKM > 0.1 And XgaussianKM <= 0.15 Then
    a = 124.3765
    b1 = 0.99309
    Sigmaz = a * XgaussianKM ^ b1
ElseIf XgaussianKM > 0.15 And XgaussianKM <= 0.2 Then
    a = 130.4465
    b1 = 1.01259
    Sigmaz = a * XgaussianKM ^ b1
ElseIf XgaussianKM > 0.2 And XgaussianKM <= 0.25 Then
    a = 139.0015
    b1 = 1.05476
    Sigmaz = a * XgaussianKM ^ b1
ElseIf XgaussianKM > 0.25 And XgaussianKM <= 0.3 Then
    a = 157.9465
    b1 = 1.12386
    Sigmaz = a * XgaussianKM ^ b1
ElseIf XgaussianKM > 0.3 And XgaussianKM <= 0.4 Then
    a = 178.6865
    b1 = 1.19636
    Sigmaz = a * XgaussianKM ^ b1
ElseIf XgaussianKM > 0.4 And XgaussianKM <= 0.5 Then
    a = 228.025
    b1 = 1.4127
    Sigmaz = a * XgaussianKM ^ b1
ElseIf XgaussianKM > 0.5 And XgaussianKM <= 3.11 Then
    a = 281.575
```

```
      b1 = 1.60685
      Sigmaz = a * XgaussianKM ^ b1
    Else
      Sigmaz = 5000
    End If
  ElseIf Windspeed(j) > 2 And Windspeed(j) <= 3 Then          'Category B
    If XgaussianKM <= 0.2 Then
      a = 90.673
      b1 = 0.93198
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.2 And XgaussianKM <= 0.4 Then
      a = 98.483
      b1 = 0.98332
      Sigmaz = a * XgaussianKM ^ b1
    Else
      a = 109.3
      b1 = 1.0971
      Sigmaz = a * XgaussianKM ^ b1
      If Sigmaz >= 5000 Then
        Sigmaz = 5000
      End If
    End If
  ElseIf Windspeed(j) > 3 And Windspeed(j) <= 5 Then       'Category B-C
    If XgaussianKM <= 0.2 Then
      a = 75.907
      b1 = 0.923315
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.2 And XgaussianKM <= 0.4 Then
      a = 79.812
      b1 = 0.948985
```

```
      Sigmaz = a * XgaussianKM ^ b1
    Else
      a = 85.2205
      b1 = 1.005875
      Sigmaz = a * XgaussianKM ^ b1
      If Sigmaz >= 5000 Then
        Sigmaz = 5000
      End If
    End If
  ElseIf Windspeed(j) > 5 And Windspeed(j) <= 6 Then      'Category C-D
    If XgaussianKM <= 0.3 Then
      a = 47.8
      b1 = 0.892195
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.3 And XgaussianKM <= 1 Then
      a = 46.617
      b1 = 0.862655
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 1 And XgaussianKM <= 3 Then
      a = 46.617
      b1 = 0.77934
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 3 And XgaussianKM <= 10 Then
      a = 47.3225
      b1 = 0.759755
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 10 And XgaussianKM <= 30 Then
      a = 48.8955
      b1 = 0.74027
      Sigmaz = a * XgaussianKM ^ b1
```

```
    Else
      a = 52.597
      b1 = 0.71322
      Sigmaz = a * XgaussianKM ^ b1
    End If
Else                          'Category D
    If XgaussianKM <= 0.3 Then
      a = 34.459
      b1 = 0.86974
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.3 And XgaussianKM <= 1 Then
      a = 32.093
      b1 = 0.81066
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 1 And XgaussianKM <= 3 Then
      a = 32.093
      b1 = 0.64403
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 3 And XgaussianKM <= 10 Then
      a = 33.504
      b1 = 0.60486
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 10 And XgaussianKM <= 30 Then
      a = 36.65
      b1 = 0.56589
      Sigmaz = a * XgaussianKM ^ b1
    Else
      a = 44.053
      b1 = 0.51179
      Sigmaz = a * XgaussianKM ^ b1
```

```
            End If
          End If
      Else
      End If

'CALCULATE gaussian dispersion
      If Xgaussian < 0 Then
         ConcentrationX(i, j, k) = 0
      Else
        ' Following equation is Gaussian Equation w/o vertical term:
      ConcentrationX(i, j, k) = ((PM10emissionsgramssec * Decay * Kconversion) / (2 * Pi *
           Windspeednotzero * Sigmay * Sigmaz)) * Exp(-0.5 * ((Ygaussian / Sigmay) ^ 2))
      End If
         If ConcentrationX(i, j, k) < Background Then
            ConcentrationX(i, j, k) = Background
         End If
      Next i
   Next j
Next k
Form1.MousePointer = 0
MsgBox "Finished calculating ConcentrationX(i,j,k)in micrograms/m^3 -goto Save Result
    menu"
End Sub

Private Sub mnudatafileitem_Click()
'Save Input Data to data file
CommonDialog3.Filter = "Input Data files (*.idf)|*.idf"
   CommonDialog3.ShowSave         'display Save dialog box
   If CommonDialog3.FileName <> "" Then
        Form1.MousePointer = 11
```

```
     Open CommonDialog3.FileName For Output As #3
'Input data into file
          i = 1
          Print #3, Silt, Moisture, Numreceptor, Trucknumber, Truckweight,
            Truckspeedloaded, Truckspeedempty, PM10emissionsgramssec
          Print #3, Totalxdist, Weathernumber, Numreceptor, Background, Distance
          For i = 1 To Numreceptor
            Print #3, Xreceptor(i), Yreceptor(i)
          Next i
    Close #3
    End If
'Tell user program has finished creating gaussian Results Array file
    MsgBox "Program has completed creating Input Data file .idf file", vbExclamation
    Form1.MousePointer = 0    'reset mouse
End Sub

Private Sub mnuEnditem_Click()
'End program using Ok and Cancel buttons
  If MsgBox("This will end the program", vbOKCancel, "End Program") = vbOK Then
    End
  Else
    Exit Sub
  End If
End Sub

Private Sub mnuopenitem_Click()
' Read-in weather data and place data into arrays
  Weathernumber = InputBox("Input the number (#) of weather data points as an integer",
      "Enter number of data points")
  CommonDialog1.Filter = "Weather files (*.sfc)|*.sfc"
```

```
   CommonDialog1.ShowOpen          'display open dialog box
   If CommonDialog1.FileName <> "" Then
        Form1.MousePointer = 11
        Open CommonDialog1.FileName For Input As #1
        i = 1
'Input data into arrays
         Do Until EOF(1)
            Input #1, Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf(i), Surfricvel(i),
                  Dummyh1, Dummyi2, Dummyj3, Mechboundlayer(i), Moninobukhov(i),
                  Surroughness(i), Bowenratio(i), Albedo(i), Windspeed(i), Winddirection(i),
                  Referenceheight(i), Temp(i), Refhgttemp(i)
            'Printer.Print Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf(i), Surfricvel(i),
                  Dummyh1, Dummyi2, Dummyj3, Mechboundlayer(i), Moninobukhov(i),
                  Surroughness(i), Bowenratio(i), Albedo(i), Windspeed(i), Winddirection(i),
                  Referenceheight(i), Temp(i), Refhgttemp(i)
            i = i + 1
         Loop
'Tell user program has read in weather data
      MsgBox "Program has completed reading in weather data file -goto Calculate Menu",
                  vbExclamation
      Form1.MousePointer = 0    'reset mouse
      Close #1
    End If
End Sub

Private Sub mnuExititem_Click()
'Exit program using Ok and cancel buttons
If MsgBox("This will end the program", vbOKCancel, "End Program") = vbOK Then
   End
Else
```

```
   Exit Sub
End If
End Sub

Private Sub mnusaveresultitem_Click()
'Save Gaussian Calculation results ConcentrationX(i,j,k) to data file
CommonDialog2.Filter = "Gaussian Result files (*.gra)|*.gra"
   CommonDialog2.ShowSave          'display Save dialog box
   If CommonDialog2.FileName <> "" Then
        Form1.MousePointer = 11
        Open CommonDialog2.FileName For Output As #2
'Input data from array into file
        i = 1: j = 1: k = 1
        For k = 1 To Numreceptor
            For j = 1 To Weathernumber
               For i = 1 To Totalxdist
               Print #2, i, j, k, ConcentrationX(i, j, k)
               Next i
            Next j
         Next k
      Close #2
      End If
'Tell user program has finished creating gaussian Results Array file
      MsgBox "Program has completed creating Gaussian Results Array .gra file",
         vbExclamation
      Form1.MousePointer = 0    'reset mouse
End Sub

Private Sub mnuStartProgramItem_Click()
'Input source locations information for source location equation
```

```
   MSlope = InputBox("Input slope (m) of haul truck path", "Enter (m)")
   Byintercept = InputBox("Input the y-intercept of haul truck path", "Enter (b)")
   Xstart = InputBox("Input the starting x-coordinate of haul truck path", "Enter starting x")
   Ystart = InputBox("Input the starting y-coordinate of haul truck path", "Enter starting y")
   Xend = InputBox("Input the ending x-coordinate of haul truck path", "Enter ending x")
   Yend = InputBox("Input the ending y-coordinate of haul truck path", "Enter ending y")
   Background = InputBox("Input the background dust levels in micrograms/m^3", "Enter
         background dust level")
'Input receptor location information
   Numreceptor = InputBox("Enter the number of Receptors", "# of Receptors")
   Dim i As Integer
   ReDim Xreceptor(Numreceptor), Yreceptor(Numreceptor)
   If Numreceptor < 2 Then
      For i = 1 To Numreceptor
         Xreceptor(i) = InputBox("Enter the x-coordinate of receptor", "Enter x-coordinate")
         Yreceptor(i) = InputBox("Enter the y-coordinate of receptor", "Enter y-coordinate")
      Next i
   Else
      MsgBox "Input receptor coordinate file "
'Open receptor coordinate file *.RCF
      CommonDialog4.Filter = "Receptor coordinate files (*.rcf)|*.rcf"
      CommonDialog4.ShowOpen         'display Open dialog box
      If CommonDialog4.FileName <> "" Then
           Form1.MousePointer = 11
           Open CommonDialog4.FileName For Input As #4
'Input data from array into file
           k = 1
           For k = 1 To Numreceptor
               Input #4, Xreceptor(k), Yreceptor(k)
           Next k
```

```
        Close #4
        End If
        Form1.MousePointer = 0    'reset mouse
    End If
'Compute emissions from haul trucks
Silt = InputBox("Input the silt content of the material", "Enter Silt Content")
Moisture = InputBox("Input the moisture content of the material", "Enter Moisture Content")
Trucknumber = InputBox("Input the number of haul trucks", "Enter # of Trucks")
Truckweight = InputBox("Input the weight of 1 haul truck (tons)", "Enter Truck Weight")
Truckspeedloaded = InputBox("Input the speed of 1 loaded haul truck (m/sec)", "Enter Truck
        Speed")
Truckspeedempty = InputBox("Input the speed of 1 empty haul truck (m/sec)", "Enter Truck
        Speed")
Totalxdist = Xend - Xstart
Distance = Sqr(((Xend - Xstart) ^ 2) + ((Yend - Ystart) ^ 2))
'Compute truck emissions in grams/meter traveled
    Qpm10truckloaded = ((2.6 * ((Silt / 12) ^ 0.8) * ((Truckweight / 3) ^ 0.4)) / ((Moisture / 0.2) ^
        0.3)) * 0.282
'Compute number of meters truck travels per year
    PM10emissionsgramssec = Qpm10truckloaded * Truckspeedloaded
    MsgBox "PM10 Emissions from haul truck are  " & PM10emissionsgramssec & "
        grams/sec", vbInformation, "PM10 Emission Result"
'Calculate all possible source locations
    'and create an array for these locations
ReDim Xsource(Totalxdist), Ysource(Totalxdist)
Xsource(1) = Xstart
For i = 1 To (Totalxdist - 1)
    Xsource(i + 1) = Xsource(i) + 1
Next i
For i = 1 To Totalxdist
```

```
    Ysource(i) = MSlope * Xsource(i) + Byintercept
Next i
'Input receptor height
zr = InputBox("Input the height of the receptor (m)", "Enter Receptor Height")
MsgBox "Program has completed all inputs -goto File Menu", vbExclamation
End Sub

Private Sub Picture2_Click()

End Sub
```

C.2 Visual Basic Code for Dynamic Manipulation

The Dynamic Manipulation program takes the information (arrays) from the Dynamic Component ISC3 program and manipulates it to get a final average PM_{10} concentration at each receptor for the time frame specified month of the year. The following is the Visual Basic code for the program.

```
Option Base 1
Public g, i, j, k As Single
Public Totalxdist, Weathernumber, Numreceptor, Silt, Moisture, Trucknumber, Truckweight,
Truckspeedloaded, Truckspeedempty, PM10emissionsgramssec As Single
Public Xreceptor(), Yreceptor() As Single
Public Loadedadded(), Aveloadedadded() As Single
Public Locationaverage(), Weatheradded(), ConcentrationX() As Single
Public Arrayvariable1 As Single
Public Timeweightedaverage() As Single
Public Truckpasses, Distance, Background, Totalsampletime As Single

Private Sub mnuconcentrationitem_Click()
    Form1.MousePointer = 11
    Arrayvariable1 = Totalxdist * Weathernumber
```

```
ReDim Loadedadded(Numreceptor), Aveloadedadded(Numreceptor),
        Timeweightedaverage(Numreceptor)
'Calculate average of all concentrations
  i = 1: j = 1: k = 1
  For k = 1 To Numreceptor
    For j = 1 To Weathernumber
      For i = 1 To Totalxdist
      Loadedadded(k) = Loadedadded(k) + (ConcentrationX(i, j, k))
      Next i
    Next j
  Next k
  k = 1
  For k = 1 To Numreceptor
    Aveloadedadded(k) = Loadedadded(k) / Arrayvariable1
  Next k
'Calculate Time weighted average for each receptor
  For k = 1 To Numreceptor
    Timeweightedaverage(k) = ((Aveloadedadded(k) * ((Truckpasses * Distance /
          Truckspeedloaded) / 60)) + (Background * (Totalsampletime - ((Truckpasses *
          Distance / Truckspeedloaded) / 60)))) / Totalsampletime
  Next k
'Calculate an array of concentrations for each distance location at each receptor
  ReDim Weatheradded(Numreceptor, Totalxdist), Locationaverage(Numreceptor, Totalxdist)
  k = 1: j = 1: i = 1
  For k = 1 To Numreceptor
    For i = 1 To Totalxdist
      For j = 1 To Weathernumber
        Weatheradded(k, i) = Weatheradded(k, i) + ConcentrationX(i, j, k)
      Next j
    Next i
```

```
    Next k
    k = 1: i = 1
    For k = 1 To Numreceptor
       For i = 1 To Totalxdist
          Locationaverage(k, i) = Weatheradded(k, i) / Weathernumber
       Next i
    Next k
    Form1.MousePointer = 0
    MsgBox "Program has completed calculations -goto Print output Menu", vbExclamation
End Sub
Private Sub mnuexititem_Click()
'exit program using Ok and cancel buttons
If MsgBox("This will end the program", vbOKCancel, "End Program") = vbOK Then
    End
Else
    Exit Sub
End If
End Sub

Private Sub mnuinputitem_Click()
'Input speed of haultrucks
    Truckspeedloaded = InputBox("Input speed of loaded haul truck (m/s)", "Enter truck speed")
    Truckspeedempty = InputBox("Input speed of empty haul truck (m/s)", "Enter truck speed")
    Distancetraveled = InputBox("Input distance truck travels (m)", "Enter distance")
    numberofhours = InputBox("Input the number of hours for this month to be evaluated (hrs)",
          "Enter hours")
    Trucknumber = InputBox("Input the number of trucks running (#)", "Enter # of trucks")
   MsgBox "Program has completed input data -goto Read in Loaded Truck Array Menu",
          vbExclamation
End Sub
```

```
Private Sub mnuloadedreadinitem_Click()
'Notify user this will read in Loaded Truck data
If MsgBox("This will require data from the Loaded Truck Array", vbOKCancel, "End Program")
        = vbOK Then
'Read in array data
  CommonDialog1.Filter = "Loaded Truck Array files (*.gra)|*.gra"
  CommonDialog1.ShowOpen        'display open dialog box
  If CommonDialog1.FileName <> "" Then
       Open CommonDialog1.FileName For Input As #1
       ReDim ConcentrationX(Totalxdist, Weathernumber, Numreceptor)
       Form1.MousePointer = 11
'Input data into array
       i = 1: j = 1: k = 1
       For k = 1 To Numreceptor
         For j = 1 To Weathernumber
           For i = 1 To Totalxdist
           Input #1, m, n, o, ConcentrationX(i, j, k)
           Next i
         Next j
        Next k
     Close #1
  End If
End If
'tell user program has read in loaded truck array data
     Form1.MousePointer = 0   'reset mouse
     MsgBox "Program has completed reading in array data file -goto Calculate Menu",
        vbExclamation
End Sub
```

```
Private Sub mnumiscdataitem_Click()
'Notify user this will read in input data from Dynamic ISC3 program
If MsgBox("This will acquire input data from the Dynamic ISC3 program", vbOKCancel, "End
        Program") = vbOK Then
'Input the total sampling time of the field study and the number of times the truck passes
   Totalsampletime = InputBox("Input the total sampling time of the fieldstudy (minutes)",
        "Enter sample time")
   Truckpasses = InputBox("Input the number of times the truck passes sampling stations during
        field study", "Enter truck passes")
'Read in input data
   CommonDialog3.Filter = "Dynamic ISC3 input files (*.idf)|*.idf"
   CommonDialog3.ShowOpen          'display open dialog box
   If CommonDialog3.FileName <> "" Then
       Form1.MousePointer = 11
       Open CommonDialog3.FileName For Input As #3
       z = 1
       Input #3, Silt, Moisture, Numreceptor, Trucknumber, Truckweight, Truckspeedloaded,
             Truckspeedempty, PM10emissionsgramssec
       Input #3, Totalxdist, Weathernumber, Numreceptor, Background, Distance
       ReDim Xreceptor(Numreceptor), Yreceptor(Numreceptor)
 'Input data into arrays
        Do Until EOF(3)
           Input #3, Xreceptor(z), Yreceptor(z)
           z = z + 1
        Loop
'tell user program has read in loaded truck array data
     Form1.MousePointer = 0    'reset mouse
     MsgBox "Program has completed reading in Dynamic ISC3 input data file -goto Read in
           Loaded Truck Array", vbExclamation
     Close #3
```

```
  End If
 End If
End Sub

Private Sub mnuprintoutitem_Click()
   Printer.FontSize = 18
   Printer.FontBold = True
   Printer.Print "Dynamic ISC3 Manipulations Complete"
   Printer.Print ""
   Printer.FontSize = 12
   Printer.Print "Input Parameters"
   Printer.Print ""
   Printer.FontBold = False
   Printer.Print "Number of receptors ="; Numreceptor
   Printer.Print "X-Y Coordinates of receptors:"
      For w = 1 To Numreceptor
      Printer.Print "     Receptor # "; w; "  X Coordinate = "; Xreceptor(w); "    Y Coordinate = ";
Yreceptor(w)
   Next w
   Printer.Print ""
   Printer.Print "Number of trucks = "; Trucknumber; "     Weight of trucks (tons)= ";
Truckweight
   Printer.Print "Speed of loaded truck (m/sec) = "; Truckspeedloaded
   Printer.Print "Speed of empty truck (m/sec)  = "; Truckspeedempty
   Printer.Print ""
   Printer.Print "Background Dust Level (micrograms/m^3) = "; Background
   Printer.Print "Silt Content (%)     = "; Silt
   Printer.Print "Moisture Content (%) = "; Moisture
   Printer.Print ""
   Printer.Print ""
```

```
Printer.FontBold = True
Printer.Print "Calculation Results"
Printer.FontBold = False
Printer.Print ""
Printer.Print "Emissions from loaded truck (grams/sec) = "; PM10emissionsgramssec
Printer.Print ""
Printer.Print "Total Instantaneous Average Concentration of PM10 at receptors:"
Printer.Print ""
For x = 1 To Numreceptor
   Printer.Print "     Results for Receptor "; x; " = "; Aveloadedadded(x); " micrograms/m^3"
Printer.Print ""
Next x
Printer.NewPage
Printer.FontSize = 18
Printer.FontBold = True
Printer.Print "Dynamic ISC3 Manipulations Complete (continued)"
Printer.FontBold = False
Printer.FontSize = 12
Printer.Print "Page 2"
Printer.Print
Printer.Print
Printer.FontBold = True
Printer.Print "Calculation Results"
Printer.FontBold = False
Printer.Print ""
Printer.Print "Time Weighted Average Concentration of PM10 at receptors:"
Printer.Print ""
For x = 1 To Numreceptor
   Printer.Print "     Results for Receptor "; x; " = "; Timeweightedaverage(x); "
         micrograms/m^3"
```

```
   Printer.Print ""
   Next x
  MsgBox "Program has completed printing output --it is ok to quit now", vbExclamation
End Sub

Private Sub mnuwriteexceldata_Click()
'Save Concentration by Receptor & Location array to data file
CommonDialog4.Filter = "Receptor & Location Array files (*.prn)|*.prn"
   CommonDialog4.ShowSave         'display Save dialog box
   If CommonDialog4.FileName <> "" Then
        Form1.MousePointer = 11
        Open CommonDialog4.FileName For Output As #4
'Input data from array into file
        i = 1: j = 1: k = 1
        For k = 1 To Numreceptor
           For i = 1 To Totalxdist
               Print #4, k, i, Locationaverage(k, i)
               Next i
           Next k
      Close #4
      End If
'Tell user program has finished creating gaussian Results Array file
      MsgBox "Program has completed creating Receptor & Location Array .prn file",
         vbExclamation
      Form1.MousePointer = 0    'reset mouse
End Sub
```

C.3 Visual Basic Code for Autodynamic Comp ISC3 Year

The Autodynamic Comp ISC3 Year program uses the Gaussian dispersion equation to calculate PM_{10} concentrations at receptor locations from a moving haul truck. This program is the same as the Dynamic Component ISC3 program. The only difference is the input data used is entered monthly and the results are output monthly. It calculates the PM_{10} concentrations from each haul road point for each receptor for every month of the year. The results are placed into an array and stored in a file.

```
Private Sub Image1_Click()
End Sub


Private Sub mnucalculateemptyitem_Click()
End Sub


Private Sub mnuCalculateitem_Click()
'This program uses the Actual windspeed.  It does not adjust the windspeed to Us and the
'windspeed cannot be less than 1 m/s.  This program does not use the vertical term nor the
    infinite series term.
Form1.MousePointer = 11
For monthcount = 1 To 12
ReDim Month(730), Day(730), Julianday(730), Hour(730), Windspeed(730),
        Winddirection(730), Referenceheight(730), Temp(730), Refhgttemp(730) As Single
'Read-in weather data and place data into arrays
If monthcount = 1 Then
        Open "c:\dynamic component\VB dynamic ISC3 program\testrun\weatherjan1.sfc" For
                Input As #1
        i = 1
 'Input data into arrays
          Do Until EOF(1)
            Input #1, Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf, Surfricvel, Dummyh1,
                    Dummyi2, Dummyj3, Mechboundlayer, Moninobukhov, Surroughness,
                    Bowenratio, Albedo, Windspeed(i), Winddirection(i), Referenceheight(i),
                    Temp(i), Refhgttemp(i)
            'Printer.Print Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf(i), Surfricvel(i),
                    Dummyh1, Dummyi2, Dummyj3, Mechboundlayer(i), Moninobukhov(i),
```

```
                    Surroughness(i), Bowenratio(i), Albedo(i), Windspeed(i), Winddirection(i),
                    Referenceheight(i), Temp(i), Refhgttemp(i)
        i = i + 1
      Loop
    Close #1
ElseIf monthcount = 2 Then
      Open "c:\dynamic component\VB dynamic ISC3 program\testrun\weatherfeb2.sfc" For
              Input As #1
      i = 1
'Input data into arrays
      Do Until EOF(1)
        Input #1, Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf, Surfricvel, Dummyh1,
                    Dummyi2, Dummyj3, Mechboundlayer, Moninobukhov, Surroughness,
                    Bowenratio, Albedo, Windspeed(i), Winddirection(i), Referenceheight(i),
                    Temp(i), Refhgttemp(i)
        'Printer.Print Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf(i), Surfricvel(i),
                    Dummyh1, Dummyi2, Dummyj3, Mechboundlayer(i), Moninobukhov(i),
                    Surroughness(i), Bowenratio(i), Albedo(i), Windspeed(i), Winddirection(i),
                    Referenceheight(i), Temp(i), Refhgttemp(i)
        i = i + 1
      Loop
      Close #1
ElseIf monthcount = 3 Then
      Open "c:\dynamic component\VB dynamic ISC3 program\testrun\weathermar3.sfc" For
             Input As #1
      i = 1
'Input data into arrays
      Do Until EOF(1)
        Input #1, Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf, Surfricvel, Dummyh1,
                    Dummyi2, Dummyj3, Mechboundlayer, Moninobukhov, Surroughness,
```

```
                Bowenratio, Albedo, Windspeed(i), Winddirection(i), Referenceheight(i),
                Temp(i), Refhgttemp(i)

            'Printer.Print Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf(i), Surfricvel(i),
                Dummyh1, Dummyi2, Dummyj3, Mechboundlayer(i), Moninobukhov(i),
                Surroughness(i), Bowenratio(i), Albedo(i), Windspeed(i), Winddirection(i),
                Referenceheight(i), Temp(i), Refhgttemp(i)
            i = i + 1
        Loop
        Close #1
ElseIf monthcount = 4 Then
        Open "c:\dynamic component\VB dynamic ISC3 program\testrun\weatherapr4.sfc" For
            Input As #1
        i = 1
'Input data into arrays
        Do Until EOF(1)
            Input #1, Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf, Surfricvel, Dummyh1,
                Dummyi2, Dummyj3, Mechboundlayer, Moninobukhov, Surroughness,
                Bowenratio, Albedo, Windspeed(i), Winddirection(i), Referenceheight(i),
                Temp(i), Refhgttemp(i)
            'Printer.Print Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf(i), Surfricvel(i),
                Dummyh1, Dummyi2, Dummyj3, Mechboundlayer(i), Moninobukhov(i),
                Surroughness(i), Bowenratio(i), Albedo(i), Windspeed(i), Winddirection(i),
                Referenceheight(i), Temp(i), Refhgttemp(i)
            i = i + 1
        Loop
        Close #1
ElseIf monthcount = 5 Then
        Open "c:\dynamic component\VB dynamic ISC3 program\testrun\weathermay5.sfc" For
          Input As #1
```

```
        i = 1
'Input data into arrays
         Do Until EOF(1)
            Input #1, Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf, Surfricvel, Dummyh1,
                      Dummyi2, Dummyj3, Mechboundlayer, Moninobukhov, Surroughness,
                      Bowenratio, Albedo, Windspeed(i), Winddirection(i), Referenceheight(i),
                      Temp(i), Refhgttemp(i)
           'Printer.Print Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf(i), Surfricvel(i),
                      Dummyh1, Dummyi2, Dummyj3, Mechboundlayer(i), Moninobukhov(i),
                      Surroughness(i), Bowenratio(i), Albedo(i), Windspeed(i), Winddirection(i),
                      Referenceheight(i), Temp(i), Refhgttemp(i)
           i = i + 1
         Loop
         Close #1
ElseIf monthcount = 6 Then
        Open "c:\dynamic component\VB dynamic ISC3 program\testrun\weatherjun6.sfc" For
             Input As #1
        i = 1
'Input data into arrays
         Do Until EOF(1)
            Input #1, Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf, Surfricvel, Dummyh1,
                      Dummyi2, Dummyj3, Mechboundlayer, Moninobukhov, Surroughness,
                      Bowenratio, Albedo, Windspeed(i), Winddirection(i), Referenceheight(i),
                      Temp(i), Refhgttemp(i)
           'Printer.Print Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf(i), Surfricvel(i),
                      Dummyh1, Dummyi2, Dummyj3, Mechboundlayer(i), Moninobukhov(i),
                      Surroughness(i), Bowenratio(i), Albedo(i), Windspeed(i), Winddirection(i),
                      Referenceheight(i), Temp(i), Refhgttemp(i)
           i = i + 1
         Loop
```

```
        Close #1
ElseIf monthcount = 7 Then
        Open "c:\dynamic component\VB dynamic ISC3 program\testrun\weatherjuly7.sfc" For
            Input As #1
        i = 1
'Input data into arrays
        Do Until EOF(1)
           Input #1, Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf, Surfricvel, Dummyh1,
                    Dummyi2, Dummyj3, Mechboundlayer, Moninobukhov, Surroughness,
                    Bowenratio, Albedo, Windspeed(i), Winddirection(i), Referenceheight(i),
                    Temp(i), Refhgttemp(i)

           'Printer.Print Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf(i), Surfricvel(i),
                    Dummyh1, Dummyi2, Dummyj3, Mechboundlayer(i), Moninobukhov(i),
                    Surroughness(i), Bowenratio(i), Albedo(i), Windspeed(i), Winddirection(i),
                    Referenceheight(i), Temp(i), Refhgttemp(i)
          i = i + 1
        Loop
        Close #1
ElseIf monthcount = 8 Then
        Open "c:\dynamic component\VB dynamic ISC3 program\testrun\weatheraug8.sfc" For
            Input As #1
        i = 1
'Input data into arrays
        Do Until EOF(1)
           Input #1, Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf, Surfricvel, Dummyh1,
                    Dummyi2, Dummyj3, Mechboundlayer, Moninobukhov, Surroughness,
                    Bowenratio, Albedo, Windspeed(i), Winddirection(i), Referenceheight(i),
                    Temp(i), Refhgttemp(i)
```

```
    'Printer.Print Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf(i), Surfricvel(i),
            Dummyh1, Dummyi2, Dummyj3, Mechboundlayer(i), Moninobukhov(i),
            Surroughness(i), Bowenratio(i), Albedo(i), Windspeed(i), Winddirection(i),
            Referenceheight(i), Temp(i), Refhgttemp(i)
   i = i + 1
  Loop
  Close #1
ElseIf monthcount = 9 Then
  Open "c:\dynamic component\VB dynamic ISC3 program\testrun\weathersept9.sfc" For
    Input As #1
  i = 1
'Input data into arrays
  Do Until EOF(1)
    Input #1, Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf, Surfricvel, Dummyh1,
            Dummyi2, Dummyj3, Mechboundlayer, Moninobukhov, Surroughness,
            Bowenratio, Albedo, Windspeed(i), Winddirection(i), Referenceheight(i),
            Temp(i), Refhgttemp(i)
   'Printer.Print Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf(i), Surfricvel(i),
            Dummyh1, Dummyi2, Dummyj3, Mechboundlayer(i), Moninobukhov(i),
            Surroughness(i), Bowenratio(i), Albedo(i), Windspeed(i), Winddirection(i),
            Referenceheight(i), Temp(i), Refhgttemp(i)
   i = i + 1
  Loop
  Close #1
ElseIf monthcount = 10 Then
  Open "c:\dynamic component\VB dynamic ISC3 program\testrun\weatheroct10.sfc" For
    Input As #1
  i = 1
'Input data into arrays
  Do Until EOF(1)
```

```
            Input #1, Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf, Surfricvel, Dummyh1,
                    Dummyi2, Dummyj3, Mechboundlayer, Moninobukhov, Surroughness,
                    Bowenratio, Albedo, Windspeed(i), Winddirection(i), Referenceheight(i),
                    Temp(i), Refhgttemp(i)
           'Printer.Print Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf(i), Surfricvel(i),
                    Dummyh1, Dummyi2, Dummyj3, Mechboundlayer(i), Moninobukhov(i),
                    Surroughness(i), Bowenratio(i), Albedo(i), Windspeed(i), Winddirection(i),
                    Referenceheight(i), Temp(i), Refhgttemp(i)
           i = i + 1
        Loop
        Close #1
ElseIf monthcount = 11 Then
        Open "c:\dynamic component\VB dynamic ISC3 program\testrun\weathernov11.sfc" For
             Input As #1
        i = 1
'Input data into arrays
        Do Until EOF(1)
            Input #1, Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf, Surfricvel, Dummyh1,
                    Dummyi2, Dummyj3, Mechboundlayer, Moninobukhov, Surroughness,
                    Bowenratio, Albedo, Windspeed(i), Winddirection(i), Referenceheight(i),
                    Temp(i), Refhgttemp(i)
            'Printer.Print Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf(i), Surfricvel(i),
                    Dummyh1, Dummyi2, Dummyj3, Mechboundlayer(i), Moninobukhov(i),
                    Surroughness(i), Bowenratio(i), Albedo(i), Windspeed(i), Winddirection(i),
                    Referenceheight(i), Temp(i), Refhgttemp(i)
           i = i + 1
        Loop
        Close #1
ElseIf monthcount = 12 Then
```

```
        Open "c:\dynamic component\VB dynamic ISC3 program\testrun\weatherdec12.sfc" For
            Input As #1
        i = 1
'Input data into arrays
        Do Until EOF(1)
            Input #1, Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf, Surfricvel, Dummyh1,
                    Dummyi2, Dummyj3, Mechboundlayer, Moninobukhov, Surroughness,
                    Bowenratio, Albedo, Windspeed(i), Winddirection(i), Referenceheight(i),
                    Temp(i), Refhgttemp(i)
          'Printer.Print Year, Month(i), Day(i), Julianday(i), Hour(i), Senhf(i), Surfricvel(i),
                    Dummyh1, Dummyi2, Dummyj3, Mechboundlayer(i), Moninobukhov(i),
                    Surroughness(i), Bowenratio(i), Albedo(i), Windspeed(i), Winddirection(i),
                    Referenceheight(i), Temp(i), Refhgttemp(i)
          i = i + 1
        Loop
        Close #1
End If

'CALCULATE the pm10 concentrations using the gaussian equation for a loaded truck
ReDim ConcentrationX(Totalxdist, 730, Numreceptor)
Decay = 1
Kconversion = 1 * 10 ^ 6
For k = 1 To Numreceptor
   For j = 1 To 730
      For i = 1 To Totalxdist
      Directionradian = 0: Ygaussian = 0: Xgaussian = 0: Windspeednotzero = 0: Us = 0: TH = 0:
            Sigmay = 0: XgaussianKM = 0: Sigmaz = 0: Verticalterm = 0
      he = 0: infiniteseries1 = 0: infiniteseries2 = 0: infiniteseries3 = 0: FQ = 0:
            Depositionvertterm = 0
```

```
'CALCULATE gaussian y coordinate
    Directionradian = (Pi / 180) * Winddirection(j)
    Ygaussian = (Xreceptor(k) - Xsource(i)) * Cos(Directionradian) - (Yreceptor(k) -
        Ysource(i)) * Sin(Directionradian)

'CALCULATE gaussian x coordinate
    Xgaussian = -(Xreceptor(k) - Xsource(i)) * Sin(Directionradian) - (Yreceptor(k) -
        Ysource(i)) * Cos(Directionradian)
      If Xgaussian = 0 Then
        Xgaussian = 1
      End If

'CALCULATE Us
      If Windspeed(j) = 0 Then
        Windspeednotzero = 1
      Else
        Windspeednotzero = Windspeed(j)
      End If

'CALCULATE Sigma Y
      If Month(j) = 6 Or Month(j) = 7 Or Month(j) = 8 Or Month(j) = 9 Then
        If Windspeed(j) <= 2 Then
          c = 24.167
          d = 2.5334
        ElseIf Windspeed(j) > 2 And Windspeed(j) <= 3 Then
          c = 21.25
          d = 2.1715
        ElseIf Windspeed(j) > 3 And Windspeed(j) <= 5 Then
          c = 18.333
          d = 1.8096
```

```
    Else
        c = 12.5
        d = 1.0857
    End If
ElseIf Month(j) = 1 Or Month(j) = 2 Or Month(j) = 3 Or Month(j) = 11 Or Month(j) = 12
        Then
    If Windspeed(j) <= 2 Then
        c = 18.333
        d = 1.8096
    ElseIf Windspeed(j) > 2 And Windspeed(j) <= 5 Then
        c = 12.5
        d = 1.0857
    Else
        c = 8.333
        d = 0.72382
    End If
Else
    If Windspeed(j) <= 2 Then
        c = 21.25
        d = 2.1715
    ElseIf Windspeed(j) > 2 And Windspeed(j) <= 3 Then
        c = 18.333
        d = 1.8096
    ElseIf Windspeed(j) > 3 And Windspeed(j) <= 5 Then
        c = 15.4165
        d = 1.44765
    ElseIf Windspeed(j) > 5 And Windspeed(j) <= 6 Then
        c = 10.4165
        d = 0.633345
    Else
```

```
            c = 8.333
            d = 0.72382
         End If
      End If
      TH = 0.017453293 * (c - (d * (Log(Abs(Xgaussian / 1000)))))
      Sigmay = 465.11628 * (Xgaussian / 1000) * Tan(TH)

'CALCULATE Sigma Z
   XgaussianKM = Abs(Xgaussian) / 1000
      If Month(j) = 6 Or Month(j) = 7 Or Month(j) = 8 Or Month(j) = 9 Then
         If Windspeed(j) <= 2 Then     'category A
            If XgaussianKM <= 0.1 Then
               a = 122.8
               b1 = 0.9447
               Sigmaz = a * XgaussianKM ^ b1
            ElseIf XgaussianKM > 0.1 And XgaussianKM <= 0.15 Then
               a = 158.08
               b1 = 1.0542
               Sigmaz = a * XgaussianKM ^ b1
            ElseIf XgaussianKM > 0.15 And XgaussianKM <= 0.2 Then
               a = 170.22
               b1 = 1.0932
               Sigmaz = a * XgaussianKM ^ b1
            ElseIf XgaussianKM > 0.2 And XgaussianKM <= 0.25 Then
               a = 179.52
               b1 = 1.1262
               Sigmaz = a * XgaussianKM ^ b1
            ElseIf XgaussianKM > 0.25 And XgaussianKM <= 0.3 Then
               a = 217.41
               b1 = 1.2644
```

```
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.3 And XgaussianKM <= 0.4 Then
      a = 258.89
      b1 = 1.4094
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.4 And XgaussianKM <= 0.5 Then
      a = 346.75
      b1 = 1.7283
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.5 And XgaussianKM <= 3.11 Then
      a = 453.85
      b1 = 2.1166
      Sigmaz = a * XgaussianKM ^ b1
    Else
      Sigmaz = 5000
    End If
  ElseIf Windspeed(j) > 2 And Windspeed(j) <= 3 Then     'Category A-B
    If XgaussianKM <= 0.1 Then
      a = 106.7365
      b1 = 0.93834
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.1 And XgaussianKM <= 0.15 Then
      a = 124.3765
      b1 = 0.99309
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.15 And XgaussianKM <= 0.2 Then
      a = 130.4465
      b1 = 1.01259
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.2 And XgaussianKM <= 0.25 Then
```

```
      a = 139.0015
      b1 = 1.05476
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.25 And XgaussianKM <= 0.3 Then
      a = 157.9465
      b1 = 1.12386
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.3 And XgaussianKM <= 0.4 Then
      a = 178.6865
      b1 = 1.19636
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.4 And XgaussianKM <= 0.5 Then
      a = 228.025
      b1 = 1.4127
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.5 And XgaussianKM <= 3.11 Then
      a = 281.575
      b1 = 1.60685
      Sigmaz = a * XgaussianKM ^ b1
    Else
      Sigmaz = 5000
    End If
  ElseIf Windspeed(j) > 3 And Windspeed(j) <= 5 Then     'Category B
    If XgaussianKM <= 0.2 Then
      a = 90.673
      b1 = 0.93198
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.2 And XgaussianKM <= 0.4 Then
      a = 98.483
      b1 = 0.98332
```

```
        Sigmaz = a * XgaussianKM ^ b1
      Else
        a = 109.3
        b1 = 1.0971
        Sigmaz = a * XgaussianKM ^ b1
        If Sigmaz >= 5000 Then
          Sigmaz = 5000
        End If
      End If
    Else              ' Category C
      a = 61.141
      b1 = 0.91465
      Sigmaz = a * XgaussianKM ^ b1
      If Sigmaz >= 5000 Then
        Sigmaz = 5000
      End If
    End If
  ElseIf Month(j) = 1 Or Month(j) = 2 Or Month(j) = 3 Or Month(j) = 11 Or Month(j) = 12
        Then
    If Windspeed(j) <= 2 Then     'Category B
      If XgaussianKM <= 0.2 Then
        a = 90.673
        b1 = 0.93198
        Sigmaz = a * XgaussianKM ^ b1
      ElseIf XgaussianKM > 0.2 And XgaussianKM <= 0.4 Then
        a = 98.483
        b1 = 0.98332
        Sigmaz = a * XgaussianKM ^ b1
      Else
        a = 109.3
```

```
      b1 = 1.0971
      Sigmaz = a * XgaussianKM ^ b1
      If Sigmaz >= 5000 Then
        Sigmaz = 5000
      End If
    End If
  ElseIf Windspeed(j) > 2 And Windspeed(j) <= 5 Then      'Category C
      a = 61.141
      b1 = 0.91465
      Sigmaz = a * XgaussianKM ^ b1
      If Sigmaz >= 5000 Then
        Sigmaz = 5000
      End If
  Else                              'Category D
    If XgaussianKM <= 0.3 Then
      a = 34.459
      b1 = 0.86974
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.3 And XgaussianKM <= 1 Then
      a = 32.093
      b1 = 0.81066
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 1 And XgaussianKM <= 3 Then
      a = 32.093
      b1 = 0.64403
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 3 And XgaussianKM <= 10 Then
      a = 33.504
      b1 = 0.60486
      Sigmaz = a * XgaussianKM ^ b1
```

```
      ElseIf XgaussianKM > 10 And XgaussianKM <= 30 Then
        a = 36.65
        b1 = 0.56589
        Sigmaz = a * XgaussianKM ^ b1
      Else
        a = 44.053
        b1 = 0.51179
        Sigmaz = a * XgaussianKM ^ b1
      End If
    End If
  ElseIf Month(j) = 4 Or Month(j) = 5 Or Month(j) = 10 Then              'month 4,5, or 10
                  (also not completed, needs to be finished)
    If Windspeed(j) <= 2 Then           'category A-B
      If XgaussianKM <= 0.1 Then
        a = 106.7365
        b1 = 0.93834
        Sigmaz = a * XgaussianKM ^ b1
      ElseIf XgaussianKM > 0.1 And XgaussianKM <= 0.15 Then
        a = 124.3765
        b1 = 0.99309
        Sigmaz = a * XgaussianKM ^ b1
      ElseIf XgaussianKM > 0.15 And XgaussianKM <= 0.2 Then
        a = 130.4465
        b1 = 1.01259
        Sigmaz = a * XgaussianKM ^ b1
      ElseIf XgaussianKM > 0.2 And XgaussianKM <= 0.25 Then
        a = 139.0015
        b1 = 1.05476
        Sigmaz = a * XgaussianKM ^ b1
      ElseIf XgaussianKM > 0.25 And XgaussianKM <= 0.3 Then
```

```
      a = 157.9465
      b1 = 1.12386
      Sigmaz = a * XgaussianKM ^ b1

    ElseIf XgaussianKM > 0.3 And XgaussianKM <= 0.4 Then
      a = 178.6865
      b1 = 1.19636
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.4 And XgaussianKM <= 0.5 Then
      a = 228.025
      b1 = 1.4127
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.5 And XgaussianKM <= 3.11 Then
      a = 281.575
      b1 = 1.60685
      Sigmaz = a * XgaussianKM ^ b1
    Else
      Sigmaz = 5000
    End If
  ElseIf Windspeed(j) > 2 And Windspeed(j) <= 3 Then          'Category B
    If XgaussianKM <= 0.2 Then
      a = 90.673
      b1 = 0.93198
      Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.2 And XgaussianKM <= 0.4 Then
      a = 98.483
      b1 = 0.98332
      Sigmaz = a * XgaussianKM ^ b1
    Else
      a = 109.3
```

```
            b1 = 1.0971
            Sigmaz = a * XgaussianKM ^ b1
            If Sigmaz >= 5000 Then
               Sigmaz = 5000
            End If
         End If
      ElseIf Windspeed(j) > 3 And Windspeed(j) <= 5 Then      'Category B-C
         If XgaussianKM <= 0.2 Then
            a = 75.907
            b1 = 0.923315
            Sigmaz = a * XgaussianKM ^ b1
         ElseIf XgaussianKM > 0.2 And XgaussianKM <= 0.4 Then
            a = 79.812
            b1 = 0.948985
            Sigmaz = a * XgaussianKM ^ b1
         Else
            a = 85.2205
            b1 = 1.005875
            Sigmaz = a * XgaussianKM ^ b1
            If Sigmaz >= 5000 Then
               Sigmaz = 5000
            End If
         End If
      ElseIf Windspeed(j) > 5 And Windspeed(j) <= 6 Then      'Category C-D
         If XgaussianKM <= 0.3 Then
            a = 47.8
            b1 = 0.892195
            Sigmaz = a * XgaussianKM ^ b1
         ElseIf XgaussianKM > 0.3 And XgaussianKM <= 1 Then
            a = 46.617
```

```
        b1 = 0.862655
        Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 1 And XgaussianKM <= 3 Then
        a = 46.617
        b1 = 0.77934
        Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 3 And XgaussianKM <= 10 Then
        a = 47.3225
        b1 = 0.759755
        Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 10 And XgaussianKM <= 30 Then
        a = 48.8955
        b1 = 0.74027
        Sigmaz = a * XgaussianKM ^ b1
    Else
        a = 52.597
        b1 = 0.71322
        Sigmaz = a * XgaussianKM ^ b1
    End If
Else                        'Category D
    If XgaussianKM <= 0.3 Then
        a = 34.459
        b1 = 0.86974
        Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 0.3 And XgaussianKM <= 1 Then
        a = 32.093
        b1 = 0.81066
        Sigmaz = a * XgaussianKM ^ b1
    ElseIf XgaussianKM > 1 And XgaussianKM <= 3 Then
        a = 32.093
```

```
                b1 = 0.64403
                Sigmaz = a * XgaussianKM ^ b1
            ElseIf XgaussianKM > 3 And XgaussianKM <= 10 Then
                a = 33.504
                b1 = 0.60486
                Sigmaz = a * XgaussianKM ^ b1
            ElseIf XgaussianKM > 10 And XgaussianKM <= 30 Then
                a = 36.65
                b1 = 0.56589
                Sigmaz = a * XgaussianKM ^ b1
            Else
                a = 44.053
                b1 = 0.51179
                Sigmaz = a * XgaussianKM ^ b1
            End If
          End If
        Else
        End If
'No Verticalterm used in this version of the Gaussian dispersion equation
'Calculate gaussian dispersion
      If Xgaussian < 0 Then
        ConcentrationX(i, j, k) = 0
      Else
        ConcentrationX(i, j, k) = ((PM10emissionsgramssec * Decay * Kconversion) / (2 * Pi *
                Windspeednotzero * Sigmay * Sigmaz)) * Exp(-0.5 * ((Ygaussian / Sigmay) ^ 2))
      End If
      Next i
   Next j
Next k
```

```
'Save Gaussian Calculation results ConcentrationX(i,j,k) to data file
    If monthcount = 1 Then
        Open "c:\dynamic component\VB dynamic ISC3 program\testrun\loadedJan1.gra" For
                Output As #2
'Input data from array into file
            i = 1: j = 1: k = 1
            For k = 1 To Numreceptor
                For j = 1 To 730
                    For i = 1 To Totalxdist
                    Print #2, i, j, k, ConcentrationX(i, j, k)
                    Next i
                Next j
            Next k
        Close #2
    ElseIf monthcount = 2 Then
        Open "c:\dynamic component\VB dynamic ISC3 program\testrun\loadedFeb2.gra" For
                Output As #2
'Input data from array into file
            i = 1: j = 1: k = 1
            For k = 1 To Numreceptor
                For j = 1 To 730
                    For i = 1 To Totalxdist
                    Print #2, i, j, k, ConcentrationX(i, j, k)
                    Next i
                Next j
            Next k
        Close #2
     ElseIf monthcount = 3 Then
        Open "c:\dynamic component\VB dynamic ISC3 program\testrun\loadedMar3.gra" For
                Output As #2
```

```
'Input data from array into file
         i = 1: j = 1: k = 1
         For k = 1 To Numreceptor
            For j = 1 To 730
               For i = 1 To Totalxdist
               Print #2, i, j, k, ConcentrationX(i, j, k)
               Next i
            Next j
         Next k
      Close #2
   ElseIf monthcount = 4 Then
      Open "c:\dynamic component\VB dynamic ISC3 program\testrun\loadedApr4.gra" For
                  Output As #2
'Input data from array into file
         i = 1: j = 1: k = 1
         For k = 1 To Numreceptor
            For j = 1 To 730
               For i = 1 To Totalxdist
               Print #2, i, j, k, ConcentrationX(i, j, k)
               Next i
            Next j
         Next k
      Close #2
   ElseIf monthcount = 5 Then
      Open "c:\dynamic component\VB dynamic ISC3 program\testrun\loadedMay5.gra" For
                  Output As #2
'Input data from array into file
         i = 1: j = 1: k = 1
         For k = 1 To Numreceptor
            For j = 1 To 730
```

```
            For i = 1 To Totalxdist
            Print #2, i, j, k, ConcentrationX(i, j, k)
            Next i
         Next j
      Next k
   Close #2
ElseIf monthcount = 6 Then
   Open "c:\dynamic component\VB dynamic ISC3 program\testrun\loadedJune6.gra" For
            Output As #2
'Input data from array into file
      i = 1: j = 1: k = 1
      For k = 1 To Numreceptor
         For j = 1 To 730
            For i = 1 To Totalxdist
            Print #2, i, j, k, ConcentrationX(i, j, k)
            Next i
         Next j
      Next k
   Close #2
ElseIf monthcount = 7 Then
   Open "c:\dynamic component\VB dynamic ISC3 program\testrun\loadedJuly7.gra" For
            Output As #2
'Input data from array into file
      i = 1: j = 1: k = 1
      For k = 1 To Numreceptor
         For j = 1 To 730
            For i = 1 To Totalxdist
            Print #2, i, j, k, ConcentrationX(i, j, k)
            Next i
         Next j
```

```
      Next k
    Close #2
  ElseIf monthcount = 8 Then
    Open "c:\dynamic component\VB dynamic ISC3 program\testrun\loadedAug8.gra" For
            Output As #2
'Input data from array into file
      i = 1: j = 1: k = 1
      For k = 1 To Numreceptor
        For j = 1 To 730
          For i = 1 To Totalxdist
          Print #2, i, j, k, ConcentrationX(i, j, k)
          Next i
        Next j
      Next k
    Close #2
  ElseIf monthcount = 9 Then
    Open "c:\dynamic component\VB dynamic ISC3 program\testrun\loadedSept9.gra" For
            Output As #2
'Input data from array into file
      i = 1: j = 1: k = 1
      For k = 1 To Numreceptor
        For j = 1 To 730
          For i = 1 To Totalxdist
          Print #2, i, j, k, ConcentrationX(i, j, k)
          Next i
        Next j
      Next k
    Close #2
  ElseIf monthcount = 10 Then
```

```
        Open "c:\dynamic component\VB dynamic ISC3 program\testrun\loadedOct10.gra"
            For Output As #2
'Input data from array into file
      i = 1: j = 1: k = 1
      For k = 1 To Numreceptor
        For j = 1 To 730
          For i = 1 To Totalxdist
          Print #2, i, j, k, ConcentrationX(i, j, k)
          Next i
        Next j
      Next k
    Close #2
  ElseIf monthcount = 11 Then
    Open "c:\dynamic component\VB dynamic ISC3 program\testrun\loadedNov11.gra" For
            Output As #2
'Input data from array into file
      i = 1: j = 1: k = 1
      For k = 1 To Numreceptor
        For j = 1 To 730
          For i = 1 To Totalxdist
          Print #2, i, j, k, ConcentrationX(i, j, k)
          Next i
        Next j
      Next k
    Close #2
  ElseIf monthcount = 12 Then
    Open "c:\dynamic component\VB dynamic ISC3 program\testrun\loadedDec12.gra" For
            Output As #2
'Input data from array into file
      i = 1: j = 1: k = 1
```

```
        For k = 1 To Numreceptor
          For j = 1 To 730
            For i = 1 To Totalxdist
            Print #2, i, j, k, ConcentrationX(i, j, k)
            Next i
          Next j
        Next k
      Close #2
    End If
Next monthcount

'Tell user program has finished creating gaussian Results Array file
      MsgBox "Program has completed creating Gaussian Results Array .gra files",
                  vbExclamation
      Form1.MousePointer = 0    'reset mouse
End Sub

Private Sub mnudatafileitem_Click()
'Save Input Data to data file
CommonDialog3.Filter = "Input Data files (*.idf)|*.idf"
    CommonDialog3.ShowSave          'display Save dialog box
    If CommonDialog3.FileName <> "" Then
         Form1.MousePointer = 11
         Open CommonDialog3.FileName For Output As #3
'Input data into file
            i = 1
            Print #3, Silt, Moisture, Numreceptor, Trucknumber, Truckweight,
                  Truckspeedloaded, Truckspeedempty, PM10emissionsgramssec
            Print #3, Totalxdist, 730, Numreceptor
            For i = 1 To Numreceptor
```

```
                Print #3, Xreceptor(i), Yreceptor(i)
            Next i
    Close #3
    End If

'Tell user program has finished creating gaussian Results Array file
    MsgBox "Program has completed creating Input Data file .idf file", vbExclamation
    Form1.MousePointer = 0    'reset mouse
End Sub

Private Sub mnuEnditem_Click()
'End program using Ok and Cancel buttons
  If MsgBox("This will end the program", vbOKCancel, "End Program") = vbOK Then
    End
  Else
    Exit Sub
  End If
End Sub

Private Sub mnuExititem_Click()
'exit program using Ok and cancel buttons
If MsgBox("This will end the program", vbOKCancel, "End Program") = vbOK Then
  End
Else
  Exit Sub
End If
End Sub

Private Sub mnusaveresultitem_Click()
End Sub
```

```
Private Sub mnuStartProgramItem_Click()
'Input source locations information for source location equation
   MSlope = InputBox("Input slope (m) of haul truck path", "Enter (m)")
   Byintercept = InputBox("Input the y-intercept of haul truck path", "Enter (b)")
   Xstart = InputBox("Input the starting x-coordinate of haul truck path", "Enter starting x")
   Ystart = InputBox("Input the starting y-coordinate of haul truck path", "Enter starting y")
   Xend = InputBox("Input the ending x-coordinate of haul truck path", "Enter ending x")
   Yend = InputBox("Input the ending y-coordinate of haul truck path", "Enter ending y")
'Input receptor location information
   Numreceptor = InputBox("Enter the number of Receptors", "# of Receptors")
   Dim i As Integer
   ReDim Xreceptor(Numreceptor), Yreceptor(Numreceptor)
   If Numreceptor < 2 Then
      For i = 1 To Numreceptor
         Xreceptor(i) = InputBox("Enter the x-coordinate of receptor", "Enter x-coordinate")
         Yreceptor(i) = InputBox("Enter the y-coordinate of receptor", "Enter y-coordinate")
      Next i
   Else
      MsgBox "Input receptor coordinate file "
'open receptor coordinate file *.RCF
      CommonDialog4.Filter = "Receptor coordinate files (*.rcf)|*.rcf"
      CommonDialog4.ShowOpen       'display Open dialog box
      If CommonDialog4.FileName <> "" Then
           Form1.MousePointer = 11
           Open CommonDialog4.FileName For Input As #4
'Input data from array into file
           k = 1
           For k = 1 To Numreceptor
               Input #4, Xreceptor(k), Yreceptor(k)
```

```
      Next k
    Close #4
    End If
    Form1.MousePointer = 0    'reset mouse
  End If

'Compute emissions from haul trucks
Silt = InputBox("Input the silt content of the material", "Enter Silt Content")
Moisture = InputBox("Input the moisture content of the material", "Enter Moisture Content")
Trucknumber = InputBox("Input the number of haul trucks", "Enter # of Trucks")
Truckweight = InputBox("Input the weight of 1 haul truck (tons)", "Enter Truck Weight")
Truckspeedloaded = InputBox("Input the speed of 1 loaded haul truck (m/sec)", "Enter Truck
          Speed")
Truckspeedempty = InputBox("Input the speed of 1 empty haul truck (m/sec)", "Enter Truck
          Speed")
Totalxdist = Xend - Xstart
Distance = Sqr(((Xend - Xstart) ^ 2) + ((Yend - Ystart) ^ 2))

'Compute truck emissions in grams/meter traveled
  Qpm10truckloaded = ((2.6 * ((Silt / 12) ^ 0.8) * ((Truckweight / 3) ^ 0.4)) / (Moisture / (0.2 ^
          0.3))) * 0.282

'Compute number of meters truck travels per year
Traveltimeempty = (Distance / Truckspeedempty) / 60
Traveltimeloaded = (Distance / Truckspeedloaded) / 60
Totaltraveltime = Traveltimeempty + Traveltimeloaded + 4
Trips = 525600 / Totaltraveltime
Metersperyear = (Trips * 2 * Distance) / 31536000
PM10emissionsgramssec = Qpm10truckloaded * Metersperyear
```

```
MsgBox "PM10 Emissions from haul truck are  " & PM10emissionsgramssec & "   grams/sec",
        vbInformation, "PM10 Emission Result"

'Calculate all possible source locations
   'and create an array for these locations
ReDim Xsource(Totalxdist), Ysource(Totalxdist)
Xsource(1) = Xstart
For i = 1 To (Totalxdist - 1)
   Xsource(i + 1) = Xsource(i) + 1
Next i
For i = 1 To Totalxdist
   Ysource(i) = MSlope * Xsource(i) + Byintercept
Next i

'Input receptor height
zr = InputBox("Input the height of the receptor (m)", "Enter Receptor Height")
MsgBox "Program has completed all inputs -goto File Menu", vbExclamation
End Sub

Private Sub Picture2_Click()
End Sub
```

Appendix D

D.1 Introduction

There are two programs that are used in the Dynamic Component program. These programs have been created in Visual Basic 6.0 and converted to executable files. The primary program is *"Dynamic Component ISC3"* and the secondary program is *"Dynamic Manipulation."* The primary program completes the calculations for dust concentrations and places them into array files. The secondary program reads in the array files and completes calculations to present the final dust concentration results at each desired location.

There is one other program that was used to compare the Dynamic Component program to the ISC3 program. This program is *"Autodynamic Comp ISC3 Year*  AUTODYNAMIC COMP ISC3 YEAR.EXE *"* and is the primary program. This program also required the use of a secondary program to complete the final dust concentration calculations. The secondary program *Dynamic Manipulation Year* was also used for this program. The main difference between *Dynamic Component ISC3* and *Autodynamic Comp ISC3 Year* is that *Autodynamic Comp ISC3 Year* completes dust concentration calculations for each month of the year and places the results into array files. The result is one array file per month of the year (12 array files). The *Dynamic Manipulation* program can then complete the final dust concentration calculations on each array file, which can then be used to calculate the average annual dust concentration. The instructions for the use of these programs are provided in the following documentation.

D.2 Instructions for the use of *Dynamic Component ISC3*

The program name is Dynamic Component ISC3.exe start the program by double-clicking on the program name with the mouse or by typing the name at the "run" menu item on the start menu. Figure D.1 shows the menu that is displayed when the program runs. It can be seen that there are four menu items on the display. They are *Input, File, Dispersion modeling,* and *Exit*. The program is run by choosing the menu items in the following order; from left to right and from uppermost to lowermost. The commands *End* or *Exit* always end the program without saving any information. The following instructions show how to operate the program by stepping through the program's operation.

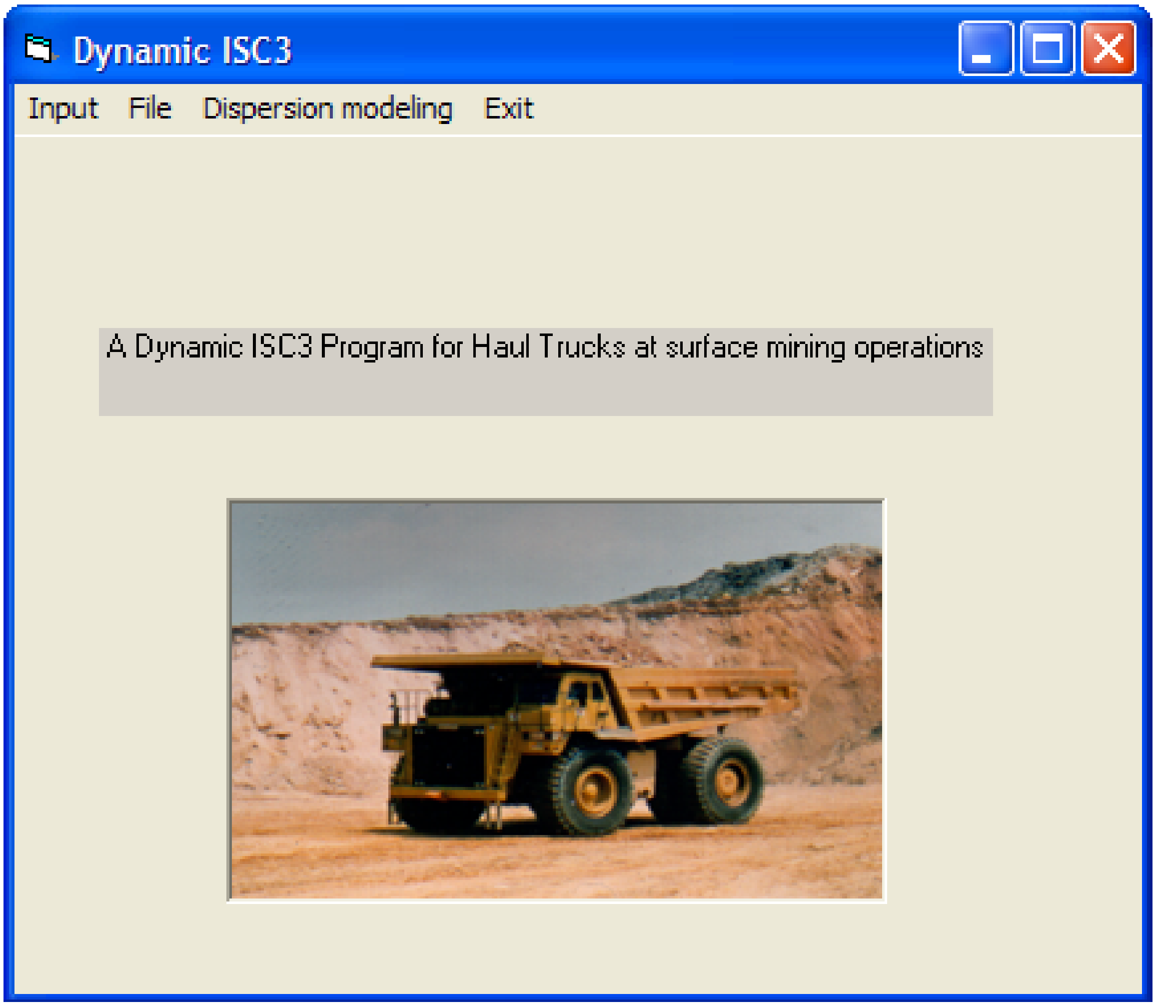


Figure D.1 Display of *Dynamic Component ISC3* program menu.

Step 1 Click on *Input - Start Program.*

The program will automatically start asking for the information required to run the program.

Step 2 Input data

A. The first part of the input data is data concerning the predetermined path of the haul truck, or the haul truck route. The program assumes the pathway of the truck is a straight-line. In order to input the data the equation of the haul truck pathway or line must be known. The format for the pathway equation is in the format of $y = mx + b$ where m is the slope and b is the y-intercept. The slope, y-intercept, starting x and y coordinates, and ending x and y coordinates must be known.

1. The first dialog box asks for the slope (m) of the pathway. Enter the slope and click *"Ok."* Note: clicking *"Cancel"* will result in no value being entered and the program may not work correctly in later program calculations when the data is required.
2. This dialog box asks for the y-intercept or b of the pathway. Enter the y-intercept and click *"Ok."*
3. Enter the starting x coordinate of the haul truck path and click *"Ok."*
4. Enter the starting y coordinate of the haul truck path and click *"Ok."*
5 Enter the ending x coordinate of the haul truck path and click *"Ok."*
6. Enter the ending y coordinate of the haul truck path and click *"Ok."*

B. This part of the program inputs required information for completing the calculations for the array files.

1. Enter the background dust levels in micrograms per cubic meter and click *"Ok."*
2. Enter the number of receptor locations where it is desired to have the concentration calculations completed and click *"Ok."*
3. The next dialog box states *"Input receptor coordinate file - Ok."* Click *"Ok"* this will bring up an open file dialog box. The receptor coordinates should be in a text file with the extension *".rcf"* The format of the receptor coordinates in the *.rcf* file should be:

x y
x y
x y

The receptor coordinates can be put into the text file by using notepad or wordpad. Only a space is placed between the x value and the y value, no commas are used.

4. The next dialog box asks for the silt content of the road material. Enter the silt content as a percent and click *"Ok."*
5. Enter the moisture content of the road material as a percent and click *"Ok."*
6. Enter the number of haul trucks. Use 1 haul truck at this point. Enter 1 and click *"Ok."*
7. Enter the weight of the haul truck in tons. The weight of a haul truck is generally equal to the capacity of the haul truck. The weight must be entered in units of short tons (english units), not metric units. Enter the weight and click *"Ok."*
8. Enter the speed of the loaded haul truck in meters per second and click *"Ok."*
9. Enter the speed of the empty haul truck in meters per second and click *"Ok."*
10. The next dialog box will display the PM_{10} emissions from the haul truck in grams per second. Click *"Ok."*
11. Enter the height of the receptor in meters. Generally input 1 meter in this dialog box. Enter the height in meters and click *"Ok."*
12. The next dialog box displays *"Program has completed all inputs -goto File Menu."* Click *"Ok."*

Step 3 Click on *File -Open weather data file*

The weather data file is also a text file. It should have the *.sfc* extension. This file is generally weather data provided by the U. S. EPA website and is used in the RAMMET program. The data in this file is formatted as follows: year, month, day, day, hour, dummy1, dummy2, dummy3, dummy4, dummy5, dummy6, dummy7, dummy8, dummy9, dummy10, windspeed (m/s), wind direction (north azimuth), wind data reference height (m), temperature (^{o}K), temperature reference height. This data list is contained in a single line, with the file containing a series of single lines. A typical format is as follows:

2 8 2 2 1 9 9 9 9 9 9 9 9 9 9 2.0563 261 6 302 1
2 8 2 2 2 9 9 9 9 9 9 9 9 9 9 1.6093 259 6 302 1
2 8 2 2 3 9 9 9 9 9 9 9 9 9 9 1.2517 259 6 302 1
etc.

The list continues until the end of the file. Normally the dummy variables have the value of 9. The wind data reference height is not used in the program as is the temperature reference height. This file can also be created in notepad or wordpad.

A. The next dialog box asks for the number of weather data points as an integer. This is the number of lines in the weather data file. For one month the number of lines is generally 730. This question was put into the program because the number of lines in the weather data file can vary when using this program to calculate dust concentrations for comparison with a field study with a different sampling period. Enter the number of weather data points and click *"Ok."*

B. Then the open file dialog box appears. Enter the file name of the weather data file being used and click *"Ok."*

C. The next dialog box displays *"Program has completed reading in weather data file -goto Calculate menu."* Click *"Ok."*

Step 4 Click on *File - Create Input Data File*

This step creates a data file for use in the secondary program *Dynamic Manipulation.* These data files have the extension *.idf*. Enter the location and file name desired and click *"Ok."* Once this is done a dialog box displays *"Program has completed creating Input Data File .idf file."* Click *"Ok."*

Step 5 Click on *Dispersion modeling - Calculate X for Loaded Truck*

Once this command is clicked, the program calculates the dust concentrations at each receptor location from each haul road point and each weather data point. Dust concentrations are calculated using the starting x coordinate value. The program then increases the starting x coordinate value by 1 and calculates another concentration for the same receptor and weather data point. Once the x coordinate value reaches the ending x coordinate value, the program goes to the next weather data point and completes concentration calculation for each of the previous x coordinate values. This process continues for each weather data point. Once the program completes the concentration calculations for all the weather data points, the program then calculates the concentrations for the next receptor. This process is followed until all receptors have been calculated. This part of the program can be time consuming depending upon the length of the haul road pathway, number of receptors, and the number of weather data points.

Step 6 Click on *Dispersion modeling -Save result to data file*

This step saves all the results calculated in Step 5 to an array file. The array files have the extension *.gra*. If this step is not completed there will be no data saved for use in the secondary program *Dynamic Manipulation,* which gives the final concentration results for each receptor. The array file can be large depending upon the length of the haul road pathway, number of receptors, and the number of weather data points.

Step 7 Click on *Exit*

The primary program has completed once the array file is saved. Click on *"Ok"* in the end program dialog box.

D.3 Instructions on the use of *Dynamic Manipulation*

The *Dynamic Manipulation* program uses the array files created in the *Dynamic Component ISC3* program to calculate the final dust concentrations at the receptor locations. To start the program, double-click on the program name *Dynamic Manipulation.exe* with the mouse or by typing the name at the "run" menu item on the start menu. Figure D.2 shows the menu that is displayed when the program runs. It can be seen that there are three menu items on the display. They are *File, Calculate,* and *Exit*. The program is run by choosing the menu items in the following order; from left to right and from uppermost to lowermost. The command *Exit* always ends the program without saving any information. The following instructions show how to operate the program by stepping through the program's operation.

Step 1 Click on *File - Read in Data from Dynamic ISC3 - Read in Misc. Data file from Dynamic ISC3.*

The program will display a dialog box *"This will acquire input data from the Dynamic ISC3 program."* Click *"Ok."* An open file box will appear. Enter the name of the file that saved the input information from the *Dynamic Component ISC3* program. The file will have the extension *.idf*. Note: you can use the *Input Data* command to manually

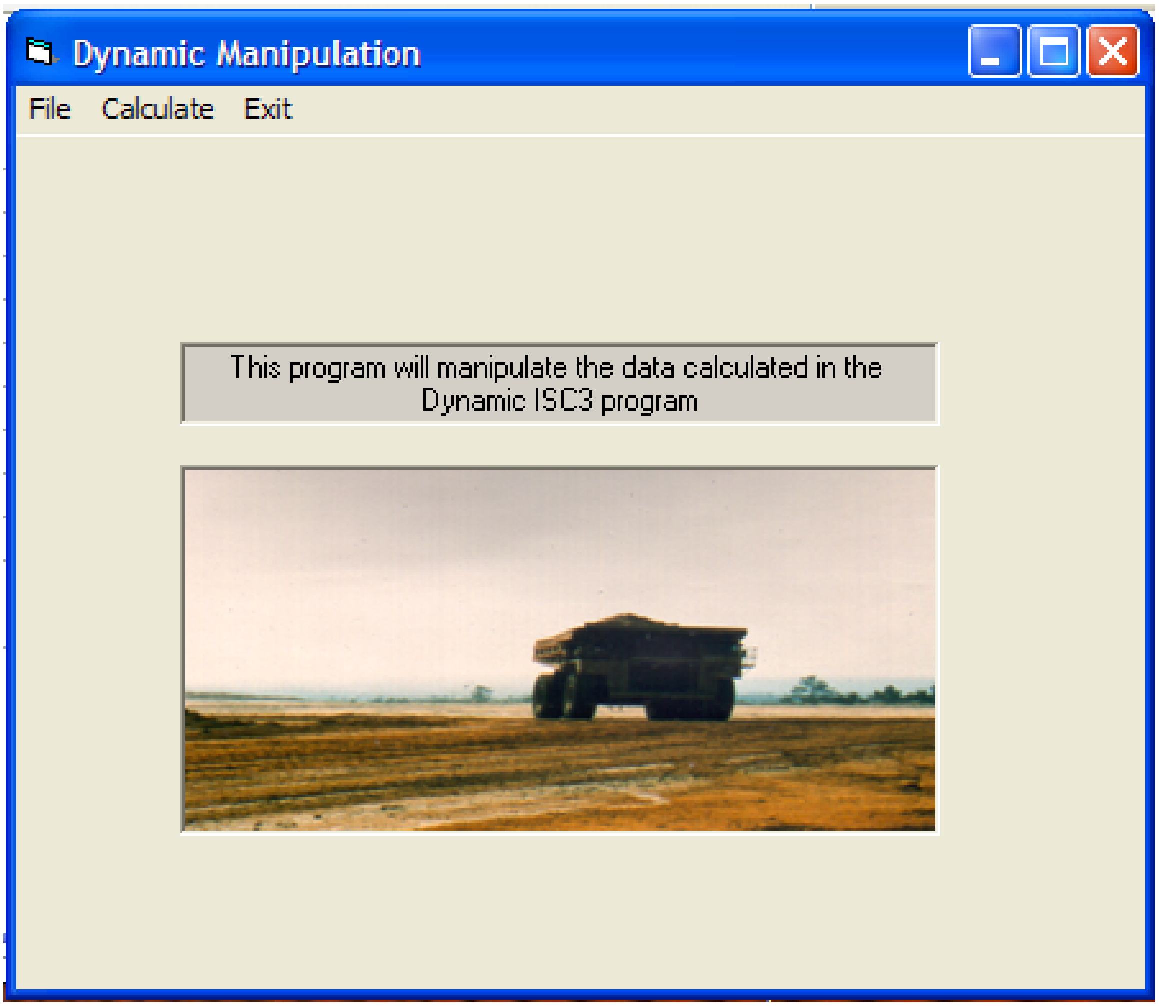


Figure D.2 Display of *Dynamic Manipulation* program menu.

enter data into this program, but it is not recommended since the input data file was already created in the previous program run.

Step 2 Click on *File - Read in Data from Dynamic ISC3 - Read in Loaded Truck Array.* This will display a dialog box *"This will require data from the Loaded Truck Array."* Click *"Ok."* An open file box will appear. Enter the name of the file that saved the array data results from the *Dynamic Component ISC3* program. The file will have the extension *.gra*.

Step 3 Click on *Calculate - Concentration from Haul Road.* This will start the program to calculate the final dust concentrations at the predetermined receptor locations.

Step 4 Click on *Calculate - Print output.* This command will print the results to the printer. Note: The only method to view the final results is to use this command to print the results to the printer. There is no method to view the results on the computer screen or in a text file. Exiting the program before printing the results will result in the loss of the results.

Step 5 Click on *Exit*

The secondary program has completed. Click on *"Ok"* in the end program dialog box.

D.4 Instructions for the use of *Autodynamic Comp ISC3 Year*

The *Autodynamic Comp ISC3 Year* program accomplishes the same task as the *Dynamic Component ISC3* program. The difference is that in *Autodynamic Comp ISC3 Year* the weather data file must contain weather data for the entire month, and there must be twelve weather data files; one for each month of the year. The *Autodynamic Comp ISC3 Year* program uses the same input data as *Dynamic Component ISC3* to create the same type of dust concentration array files for each month of the year. These array files can be read by *Dynamic Manipulation* to calculate final monthly average dust concentrations for each receptor.

The program name is *Autodynamic Comp ISC3 Year.exe* start the program by double-clicking on the program name with the mouse or by typing the name at the "run" menu item on the start menu. The menu displayed by this program is similar to Figure D.1; the menu display for the *Dynamic Component ISC3* program. It can be seen that there are four menu items on the display. They are *Input, File, Dispersion modeling,* and *Exit*. The program is run by choosing the menu items in the following order; from left to right and from uppermost to lowermost. The commands *End* or *Exit* always end the program without saving any information. The following instructions show how to operate the program by stepping through the program's operation.

An important note about Weather Data Files used in this program. Before the program is started, there must be twelve weather data files. The weather data files are text files. They must have the following names or else the program will not read in the weather data: *weatherjan1.sfc, weatherfeb2.sfc, weathermar3.sfc, weatherapr4.sfc, weathermay5.sfc, weatherjun6.sfc, weatherjuly7.sfc, weatheraug8.sfc, weathersept9.sfc, weatheroct10.sfc, weathernov11.sfc,* and *weatherdec12.sfc*. The *Autodynamic Comp ISC3* program automatically searches for these filenames to read in the weather data. The weather data files should be located in *C:\Dynamic Component\VB Dynamic ISC3 program\Testrun* directory and all weather files should have the *.sfc* extension. These files generally contain weather data provided by the U. S. EPA website that can be used in the RAMMET program.

The data in this file is formatted as follows: year, month, day, day, hour, dummy1, dummy2, dummy3, dummy4, dummy5, dummy6, dummy7, dummy8, dummy9, dummy10, windspeed (m/s), wind direction (north azimuth), wind data reference height (m), temperature (^oK), temperature reference height. This data list is contained in a single line, with the file containing a series of single lines. A typical format is as follows:

```
2 8 2 2 1 9 9 9 9 9 9 9 9 9 9 2.0563 261 6 302 1
2 8 2 2 2 9 9 9 9 9 9 9 9 9 9 1.6093 259 6 302 1
2 8 2 2 3 9 9 9 9 9 9 9 9 9 9 1.2517 259 6 302 1
etc.
```

The weather file can have no more than 730 lines of weather data. Normally the dummy variables have the value of 9. The wind data reference heights are not used in the program, as is the temperature reference height. These files can be created in notepad or wordpad.

Step 1 Click on *Input - Start Program.*

The program will automatically start asking for the information required to run the program.

Step 2 Input data

A. The first part of the input data is data concerning the predetermined path of the haul truck, or the haul truck route. The program assumes the pathway of the truck is a straight-line. In order to input the data the equation of the haul truck pathway or line must be known. The format for the pathway equation is in the format of $y = mx + b$ where m is the slope and b is the y-intercept. The slope, y-intercept, starting x and y coordinates, and ending x and y coordinates must be known.

1. The first dialog box asks for the slope (m) of the pathway. Enter the slope and click *"Ok."* Note: clicking *"Cancel"* will result in no value being entered and the program may not work correctly in later program calculations when the data is required.
2. This dialog box asks for the y-intercept or b of the pathway. Enter the y-intercept and click *"Ok."*
3. Enter the starting x coordinate of the haul truck path and click *"Ok."*
4. Enter the starting y coordinate of the haul truck path and click *"Ok."*
5 Enter the ending x coordinate of the haul truck path and click *"Ok."*
6. Enter the ending y coordinate of the haul truck path and click *"Ok."*

B. This part of the program inputs required information for completing the calculations for the array files.

1. Enter the number of receptor locations where it is desired to have the concentration calculations completed and click *"Ok."*
2. The next dialog box states *"Input receptor coordinate file - Ok."* Click *"Ok"* this will bring up an open file dialog box. The receptor coordinates should be in a text file with the extension *".rcf"* The format of the receptor coordinates in the *.rcf* file should be:

```
x    y
x    y
x    y
```

The receptor coordinates can be put into the text file by using notepad or wordpad. Only a space is placed between the x value and the y value, no commas are used.

3. The next dialog box asks for the silt content of the road material. Enter the silt content as a percent and click *"Ok."*
4. Enter the moisture content of the road material as a percent and click *"Ok."*

5. Enter the number of haul trucks. Use 1 haul truck at this point. Enter 1 and click *"Ok."*
6. Enter the weight of the haul truck in tons. The weight of a haul truck is generally equal to the capacity of the haul truck. The weight must be entered in units of short tons (english units), not metric units. Enter the weight and click *"Ok."*
7. Enter the speed of the loaded haul truck in meters per second and click *"Ok."*
8. Enter the speed of the empty haul truck in meters per second and click *"Ok."*
10. The next dialog box will display the PM_{10} emissions from the haul truck in grams per second. Click *"Ok."*
11. Enter the height of the receptor in meters. Generally input 1 meter in this dialog box. Enter the height in meters and click *"Ok."*
12. The next dialog box displays *"Program has completed all inputs -goto File Menu."* Click *"Ok."*

Step 3 Click on *File - Create Input Data File*

This step creates a data file for use in the secondary program *Dynamic Manipulation.* These data files have the extension *.idf*. Enter the location and file name desired and click *"Ok."* Once this is done a dialog box displays *"Program has completed creating Input Data File .idf file."* Click *"Ok."*

Step 4 Click on *Dispersion modeling - Calculate X and create data files*

Once this command is clicked, the program calculates the dust concentrations at each receptor location from each haul road point and each weather data point. Dust concentrations are calculated using the starting x coordinate value. The program then increases the starting x coordinate value by 1 and calculates another concentration for the same receptor and weather data point. Once the x coordinate value reaches the ending x coordinate value, the program goes to the next weather data point and completes concentration calculation for each of the previous x coordinate values. This process continues for each weather data point. Once the program completes the concentration calculations for all the weather data points, the program then calculates the concentrations for the next receptor. This process is followed until all receptors have been calculated. This part of the program can be time consuming depending upon the length of the haul road pathway, number of receptors, and the number of weather data points.

This step also saves all the results calculated in Step 4 to an array file. The array files have the extension *.gra*. The program will create twelve array files; one for each month of the year. The names of the array files are as follows: *loadedjan1.gra, loadedfeb2.gra, loadedmar3.gra, loadedapr4.gra, loadedmay5.gra, loadedjun6.gra, loadedjuly7.gra, loadedaug8.gra, loadedsept9.gra, loadedoct10.gra, loadednov11.gra,* and *loadeddec12.gra*. These files contain the data required by *Dynamic Manipulation*. If these files are deleted, then the calculation results from *Autodynamic Comp ISC3* are gone and the program must be re-run to recreate these files. The array files can be large depending upon the length of the haul road pathway and the number of receptors. It is not unusual to see *gra* files that are 29 megabytes in size.

Step 7 Click on *Exit*

The primary program has completed once the array file is saved. Click on *"Ok"* in the end program dialog box.

Appendix E

E.1 List of Equipment used in Field Study

The following list is the required equipment needed to conduct the field study for three sampling periods. If the filters must be changed out during the sampling period, then the number of 37mm filters will be more than listed here. It is anticipated that one filter will last for the duration of the sampling period.

Number Required	Equipment Type/ Description
1	100 foot tape
1	Brunton compass (or similar device)
1	Sling psychrometer
1	Barometer
1	Weather station
1	Laptop computer for downloading information from weather station and MIE personal data RAMs
7	MIE Personal data RAM model pDR-1200 samplers
31	MSA Escort ELF personal dust samplers
3	Cascade Impactors,
14	10mm Dorr-Oliver cyclones
7	BGI GK2.69 cyclones
7	Tripods
84	37mm filters
81	Filters for Cascade Impactors
1	Broom
1	Dust pan
4	5 gal. Buckets with lids
50	gallon size Ziploc bags
1	Lawn chair
1	Watch
1	Stopwatch
1	Notebook
1	Clipboard
20-30	Wooden stakes1
	Can of fluorescent orange paint for marking dust sampling area on haul road and sampling locations
1	roll of flagging

E.2 Data Forms Used in Field Study
Location Data Form

Location:
Dates of Sampling:
Mining Operation Type:
Material Types:
Sketch of sampling setup:
Possible Interferences/Sources of Contamination:

Time Study Form

Date:		Location:				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
Miscellaneous:						

E.3 Field Study Data Record Sheets for the Stone Quarry

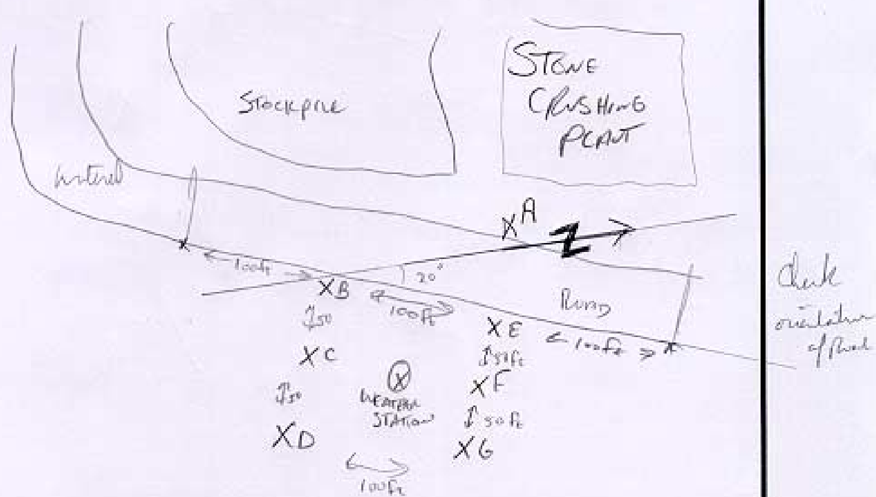
Location: BLACKSBURG, VA [redacted]

Dates of Sampling: 7/16/02

Mining Operation Type: STONE QUARRY

Material Types: LIMESTONE
CRUSHED ROCK

Sketch of sampling setup:



Possible Interferences/Sources of Contamination: wind blowing from the North direction will bring contamination from crushing plant

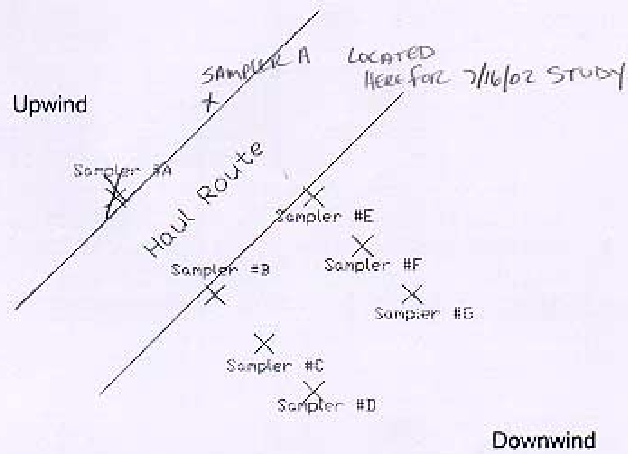


Figure 1 Sampling locations for field study.

CORRECTED + CHECKED 7/22/02

Date: 7/16/02		Location: BLACKSBURG VA [redacted] QUARRY						min Pump Runtime (From pump)
Station # A		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S8	58	JD PDR1		9:17:45	4:37:39	445
	Respirable	S14	~~25~~ 53			9:17:45	4:37:39	444
	Thoracic	J06	11			9:17:45	9:37:39	444
	Total	S4	89			9:17:45	4:37:38	445
	Impactor	J010			A	9:17:45	4:37:39	445
Station # B		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S16	48	JD PDR2		9:21:20	4:41:10	443
	Respirable	S17	37			9:21:20	4:41:10	444
	Thoracic	J03	~~01~~ 10			9:21:20	4:41:10	444
	Total	S15	~~04~~ 40			9:21:20	4:41:10	444
	Impactor	J07		B				444
Station # C		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S5	25	JD PDR3		9:22:45	4:41:58	444
	Respirable	S9	62			9:22:45	4:41:58	443
	Thoracic	J05	~~12~~ 15			9:22:45	4:41:58	443
	Total	S23	57			9:22:45	4:41:58	443
	Impactor	J09		11		9:22:45	4:41:58	443
Station # D		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S20	52	JR1		9:27:40	4:44:23	442
	Respirable	S10	69			9:27:40	4:44:23	441
	Thoracic	S25	18			9:27:40	4:44:23	441
	Total	S21	35			9:27:40	4:44:23	440
	Impactor							
Station # E		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S2	46	JR2		9:19:56	4:38:39	444
	Respirable	S22	59			9:19:56	4:38:39	443
	Thoracic	S01	16			9:19:56	4:38:39	444
	Total	S1	47			9:19:56	4:38:39	443
	Impactor					~~9:19:56~~		
Station # F		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S13	79	JR3		9:24:01	4:43:15	441
	Respirable	S7	50			9:24:01	4:43:15	442
	Thoracic	J04	13			9:24:01	4:43:15	443
	Total	S18	34			9:24:01	4:43:15	443
	Impactor							
Station # G		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S6	86	GG PDR1		9:25:36	4:45:25	443
	Respirable	S12	51			9:25:36	4:45:25	443
	Thoracic	S24	19			9:25:36	4:45:25	444
	Total	S11	82			9:25:36	4:45:25	445
	Impactor							

Misc: Changed out PDR JR3 to PDR 4802 12:07:10 Shut off

Date: 7/16/02	Location: BLACKSBURG VA			
Time	Barometer Reading	Dry Bulb Temperature	Wet Bulb Temperature	
9:30	28.18"Hg	72°F	70°F	61%
10:33	28.18	81°F	72°F	64%
11:34	28.17	84°F	71°F	52%
12:32	28.16	86°F	72°F	50%
1:27	28.15	87	69°F	39%
2:32	28.14	90°F	71°F	38
3:30	28.13	89°F	70°F	37%
4:23	28.12	88	71	42

Misc:
WEATHER STATION STARTED @ 9:13 AM

ENTERED 7/22/02

Date: 2/16/02	Location: BLACKSBURG VA						
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??	
	9:52:51	9:52:57	5:56	6 wheel OTR ~~Tractor~~ Truck	up	yes	
		9:53:04		6 wheel OTR Truck	up	yes	
	9:55:25	9:55:29	3:55	6 wheel OTR Truck	up	yes	
		9:55:51		6 wheel OTR Truck	up	yes	
	9:59:07	9:59:12	4:46	6 wheel OTR Truck	Down	yes	Drying out
	9:59:24	9:59:29	4:16	6 wheel OTR Truck	Down	yes	
		9:59:40		6 wheel OTR Truck	Down	yes	Drying out
		9:59:53		6 wheel OTR Truck	Down	yes	
	10:00:13	10:00:18	4:57	6 wheel OTR Truck	up	yes	
	10:02:34	10:02:40	5:14	6 wheel OTR Truck Stopped 100 ft up road	up	yes	
		10:04:33	4:56	"	up		
	10:04:49	10:04:54	4:88	"	up		
	10:06:20	10:06:24	4:11	6 wheel OTR Truck	Down		
	10:06:53	10:06:58	4:41	4 wheel OTR Truck	up		
	10:08:14	10:08:18	3:31	6 wheel OTR Truck	up		
	10:10:35	10:10:39	3:42	6 wheel OTR Truck	Down	yes	
	10:11:43	10:11:49	5:03	6 wheel OTR Truck	Down		
	10:12:44	10:12:50	5:41	6 wheel OTR	Down		
	10:15:32	10:15:37	5:01	6 wheel OTR	up		
		10:16:22	4:50	6 wheel OTR	Down		

Miscellaneous:

Graded 1-[illegible]

Date: 7/16/02	Location: BLACKSBURG VA					
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
	9:29:16	9:29:22		6 wheel OTR	up	yes
	9:30:30	9:30:35		6 wheel OTR		yes
	9:31:28	9:31:33		6 wheel OTR		yes
	9:32:31	9:32:40		6 wheel OTR		yes
	9:33:32	9:33:36		6 wheel OTR		yes
	9:34:09	9:34:12		6 wheel OTR		yes
	9:37:17	9:37:21		6 wheel OTR	up	yes
	9:38:03	9:38:08	4:51	6 wheel OTR	Down	yes
	9:41:25	9:41:30	4:57	6 wheel OTR	Down	yes
	9:41:32	9:41:37	[illegible]	6 wheel OTR	Down	yes
	9:41:48	9:41:54	5:14	6 wheel OTR	up	yes
	9:44:07	9:44:11	4:00	6 wheel OTR	Down	yes
	9:44:35	9:44:40	4:46	6 wheel OTR	Down	yes
	9:44:45	9:45:53		6 wheel OTR Stopped to talk	Down	yes
	9:46:32	9:46:37	4:21	6 wheel OTR	Down	
	9:47:00	9:47:04	4:12	6 wheel OTR	Down	
	9:47:30	9:47:33		6 wheel OTR	up	yes
	9:48:46	9:48:41	4:50	6 wheel OTR	Down	yes
	9:49:09	9:49:14	4:58	6 wheel OTR	Down	yes
		9:49:23		6 wheel OTR	up	yes

Miscellaneous:

Date: 7/16/02	Location: BLACKSBURG QUARRY VA					
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
	10:17:22	10:17:26	4:00	6 wheel OTR	up	No
	10:18:02	10:18:07	4:49	6 wheel OTR	up	
		10:18:12		6 wheel OTR	Down	
	10:20:53	10:20:57	3.52	6 wheel OTR	up	
		10:21:30	3:54	6 wheel OTR	Down	
		10:22:01	4:59	Tractor Truck 10 whe	Down	
		10:22:17	4:80	6 wheel OTR	Down	
		10:22:22		6 wheel OTR	Down	
		10:22:40		4 wheel OTR	Down	
		10:24:01	4:22	6 wheel OTR	Down	
		10:24:34	5:65	6 wheel OTR	Down	
		10:25:57	4:22	6 wheel OTR	Down	
		10:26:14		6 wheel OTR	up	
		10:26:15		6 wheel OTR	Down	
		10:26:30		6 wheel OTR	up	
		10:27:40	4.00	6 wheel OTR	up	
		10:28:350	4:44	6 wheel OTR	up	
		10:29:15	5.35	6 wheel OTR	up	
		10:29:41	4:05	6 wheel OTR	Down	
		10:31:00		4 wheel OTR	up	

still wet

Miscellaneous:

Entered
[illegible]/02

Date: 7/16/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		10:32:11		6 wheel OTR	up	
		10:34:38		6 wheel OTR	up	
		10:34:50		6 wheel OTR	Down	
		10:35:25	3:20	6 wheel	Down	
		10:35:56	3.83	6 wheel OTR	Down	
		10:37:57		6 wheel OTR	up	
		10:40:15		6 wheel OTR	up	
		10:40:20		6 wheel OTR	up	
		10:40:43	3:25	6 wheel OTR	Down	
		10:41:48	4:56	6 wheel OTR	up	
		10:43:27		6 wheel OTR	Down	
		44:19		6 wheel OTR	Down	
		10:44:34		6 wheel OTR	Down	
		10:44:43		"	Down	
		10:45:0[illegible]	3:44	"	up	
		10:47:31	5:42	6 wheel OTR	Down	
		10:47:36		6 wheel OTR	Down	
		10:49:14		4 wheel OTR	up	
		—		6 wheel OTR	up	
		10:53:46	4:23	6 wheel OTR	Down	

Miscellaneous:

[illegible]

Date: 7/16/02

Location: BLACKSBURG VA QUARRY

Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		10:54:58	4:52	6 wheel OTR	Down	
		10:57:33	5:46	6 wheel OTR	Down	
		10:59:08	4:13	6 wheel OTR	Down	
		11:00:10	4:26	10 wheel trailer Truck	Down	
		11:01:06	16:48	Bobcat Loader	up	
		11:02:56	5:36	10 wheel truck OTR	up	
		11:04:36	3,05	10 wheel Trailer Truck ~~OTR~~	Down	
		11:05:35	4:47	6 wheel OTR	Down	
		11:06:04	5.75	6 wheel OTR	up	
		11:06:48		771 cat Truck	Down	
		11:08:40	7:51	6 wheel OTR	up	
		11:09:30	5:09	6 wheel OTR	up	
		11:10:45	3:83	6 wheel OTR	up	
		11:12:25		10 wheel Trailer truck	up	
		11:12:39	5:76	" 10 wheel Trailer Truck	up	
		11:12:45		" 10 wheel Trailer Truck	up	
		11:18:22	6:38	6 wheel OTR Truck	Down	
		11:19:04	5.74	6 wheel OTR Truck	Down	
		11:22:20	5:49	6 wheel OTR Truck	up	
		11:24:52	3:72	6 wheel OTR Truck	up	

11:12:12 Plant Stopped

Miscellaneous:

ENTERED 7/23/02

Date: 7/16/02

Location: BLACKSBURG VA QUARRY

Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		11:25:39	3:55	6 wheel OTR Truck	Down	
		11:27:31	4:92	6 wheel OTR Truck	up	
		11:31:04	4:38	6 wheel OTR Truck	up	
		11:31:45	3:40	4 wheel OTR Truck	Down	
		11:33:13	4:14	6 wheel OTR truck	Down	
		11:34:03	4:04	6 wheel OTR Truck	up	
		11:34:19	4:51	6 wheel OTR Truck	Down	
		11:38:30	5:16	6 wheel OTR Truck	up	
		11:38:41		4 wheel OTR Truck	up	
		11:38:46		6 wheel OTR Truck	up	
		11:40:58	5:67	6 wheel OTR Truck	Down	
		11:42:04	4:46	6 wheel OTR Truck	up	
		11:43:53	3:88	6 wheel OTR Truck	Down	
		11:47:28	7:27	6 wheel OTR Truck	Down	
		11:48:30	4:34	6 wheel OTR Truck	up	
		11:49:02	3,35	6 wheel OTR Truck	Down	
		11:50:05	4:03	6 wheel OTR Truck	Down	
		11:50:49	4:00	6 wheel OTR Truck	Down	
		11:51:19	3:81	6 wheel Truck OTR	up	
		11:53:31	6:15	6 wheel Truck OTR	up	

11:29:00 plant Started

Miscellaneous:

ENTERED 1-8/02

Date: 7/16/02		Location: Bradshaw VA Quarry				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		11:53:38		6 wheel OTR	up	
		11:53:58	4:74	6 wheel OTR	Down	
		11:56:33	5:16	6 wheel OTR Truck	Down	
		11:57:54	5:66	6 wheel OTR Truck	up	
		12:00:57		6 wheel OTR Truck	up	
		12:02:05	5:02	6 wheel OTR Truck	up	
		12:05:38		6 wheel OTR Truck	up	
		12:09:50		6 wheel OTR Truck	up	NO
		12:10:0[illegible]		6 wheel Truck	Down	
		12:12:31	4:47	6 wheel Truck	Down	
		12:14:08		6 wheel Truck	Down	
		12:17:04	3,97	6 wheel Truck	Down	
		12:17:53	4,75	6 wheel Truck	up	
		12:20:42	4:91	10 wheel Trailer Truck OTR	Down	
		12:20:11	5:40	6 wheel Truck OTR	up	
		12:21:50	6:24	6 wheel Truck OTR	up	
		12:22:36	5:65	6 wheel Truck OTR	up	
		12:23:58	4:23	6 wheel Truck OTR	up	
		12:24:50	4:67	6 wheel Truck OTR	up	
		12:25:36	4:42	6 wheel Truck OTR	Down	

Miscellaneous:

ENTERED 7/23/02

Date: 7/16/02		Location: Blacksburg VA Quarry				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		12:28:11	4:88	6 wheel Truck OTR	up	
		12:30:16		6 wheel Truck OTR	up	
		12:30:16		6 wheel truck OTR	Down	
		12:31:59	4:37	6 wheel Truck	Down	
		12:32:35	3.92	6 wheel Truck	up	
		12:33:46	3:14	6 wheel Truck	Down	
		12:34:10	3.82	6 wheel Truck	Down	
		12:34:15		6 wheel Truck	Down	
		12:35:20	5:09	6 wheel Truck	up	
		12:37:28		6 wheel Truck OTR	up	
		12:38:18		6 wheel Truck	up	
		12:38:46		6 wheel truck	Down	
		12:38:57		6 wheel truck	up	
		12:39:43	5:04	6 wheel Truck	up	
		12:41:56		6 wheel Truck	Down	
		12:41:59		6 wheel Truck	Down	
		12:43:47		6 wheel Truck	Down	
		12:45:59	4.85	6 wheel Truck OTR	Down	
		12:49:28		4 wheel truck OTR	Down	
		12:49:37		6 wheel truck OTR	up	

Miscellaneous:

ENTERED 9/23/02

Date: 7/16/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		12:49:41		6 wheel Truck OTR	Down	
		12:50:22		6 wheel Truck OTR	up	
		12:53:02		6 wheel Truck OTR	Down	
		12:54:03		6 wheel truck OTR	up	
		12:55:24	5:05	6 wheel truck OTR	Down	
		12:56:33	3:65	6 wheel Truck OTR	Down	
		12:57:06	4:59	6 wheel Truck	Down	
		12:59:44	5:51	6 wheel Truck	Down	
		1:01:35	4,53	6 wheel truck	Down	
		1:02:30	4,31	6 wheel truck	Down	
		1:04:29	4,12	6 wheel Truck	up	
		1:04:49	3:44	6 wheel truck	Down	
		1:05:02	4:09	6 wheel Truck	up	
		1:06:36		6 wheel truck	Down	
		1:06:59	3,62	6 wheel Truck	Down	
		1:07:03		6 wheel Truck	Down	
		1:08:15		Trailer Trucks 10 wheel Trucks	Down	
		1:08:17		6 wheel Truck	up	
		1:08:20		Trailer Trucks 10 wheel Trucks	Down	
		1:09:48	5:53	6 wheel Truck	up	

Miscellaneous:

ENTERED 7/23/02

Date: 7/16/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		1:11:41	4:30	6 wheel Truck	up	
		1:12:35		Water Truck	Down	
		1:12:45		6 wheel truck	up	
		1:12:51		10 wheel Truck	Down	
		1:12:56		6 wheel truck	Down	
		1:14:37	3.68	4 wheel truck	Down	
		1:15:01	3:08	6 wheel truck	up	
		1:17:16	4.91	6 wheel Truck	up	
		1:18:32	4:06	4 wheel truck	up	
		1:19:16	3:12	6 wheel truck	Down	
		1:20:16	7:58	10-wheel Truck Trailer Truck	up	
		1:20:43	4:86	10 wheel trailer Truck	up	
		1:20:43		6 wheel OTR Truck	Down	
		1:20:51		10 wheel Trailer Truck	up	
		1:23:23	3.24	6 wheel OTR Truck	up	
		1:25:34		Water Truck	up	
		1:25:46	5.93	6 wheel Truck	up	
		1:25:54		6 wheel Truck	up	
		1:31:59		6 wheel Truck	up	
		1:32:36	4:77	6 wheel Truck	Down	

Miscellaneous:

ENTERED 10/3/02

Date: 7/16/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
	1:35:00	1:35:00	3:34	6 wheel Truck OTR	Down	
		1:41:35	4:27	4 wheel Truck	Down	
		1:44:16	4:09	6 wheel Truck	Down	
		1:46:28	5:02	6 wheel Truck	up	
		1:46:30		6 wheel Truck	up	
		1:49:32		6 wheel Truck OTR	up	
		1:50:29	4:55	6 wheel Truck OTR	Down	
		1:53:04		4 wheel truck	up	
		1:59:12	4:20	6 wheel Truck	Down	
		2:02:54	3:95	6 wheel truck	up	
		2:05:23	4:41	6 wheel truck	up	
		2:08:07	4:73	6 wheel truck	up	
		2:09:06	3:66	6 wheel truck	Down	
		2:11:16		6 wheel truck	up	
		2:11:23		6 wheel truck	up	
		2:13:49		6 wheel truck	up	
		2:14:31		6 wheel Truck	up	
		2:16:49		6 wheel Truck	up	
		2:17:28		6 wheel truck	Down	
	2:20:39	2:20:39		6 wheel Truck	up	

Miscellaneous:

ENTERED 10/3/02

Date: 7/16/02

Location: Blacksburg VA Quarry

Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		2:22:47		Tractor Truck 10 wheel	up	
		2:23:14	5.95	6 wheel Truck	up	
		2:23:15		6 wheel Truck	up	
		2:24:35	4.59	4 wheel Truck	Down	
		2:26:52	6.85	6 wheel Truck	up	
		2:33:09		4 wheel Truck	up	
		2:34:20		6 wheel Truck	Down	
		2:38:55		6 wheel truck	up	
		2:39:10		6 wheel Truck	Down	
		2:44:15	3.99	Water Truck	Down	
		2:45:08	4:46	6 wheel OTR Truck	Down	
		2:50:03	5:45	6 wheel truck	Down	
		2:51:16	3:77	6 wheel Truck	Down	
		2:51:40	3:80	6 wheel Truck	Down	
		2:56:18	6:19	6 wheel truck	up	
		2:56:27		6 wheel Truck	up	
		2:56:58	4:45	6 wheel Truck	Down	
		2:58:14	4:39	6 wheel truck	Down	
		2:58:35	3:34	6 wheel truck	Down	
		2:59:30	4:77	6 wheel Truck	Down	

Miscellaneous:

ENTERED 6/3/02

Date: 7/16/02		Location: Blacksburg VA Quarry				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		3:01:25	3.78	6 wheel Truck	Down	
		3:04:12	4:06	4 wheel Truck	Down	
		3:04:16	3:31	6 wheel Truck	Down	
		3:05:28	6:47	6 wheel truck	up	
		3:06:02	3:69	6 wheel Truck	up	
		3:10:43	7:95	4 wheel truck	up	
		3:10:51		6 wheel Truck	up	
		3:12:48	5:82	6 wheel truck	Down	
		3:16:20	4:14	6 wheel truck	Down	
		3:19:44	4:28	6 wheel Truck	Down	
		3:20:37	5:13	6 wheel Truck	up	
		3:23:11	4:46	6 wheel Truck	Down	
		3:24:23	4.63	6 wheel truck	up	
		3:25:02	4:24	4 wheel Truck	Down	
		3:26:45	3.29	6 wheel truck	Down	
		3:28:10		water Truck	up	
		3:29:35	3:17	6 wheel Truck	Down	
		3:29:35		4 wheel truck	up	
		3:34:37		6 wheel Truck	up	
		3:41:46	4.88	6 wheel Truck	up	

3:19 Rust cloud from Road Blown up by wind

Miscellaneous:

ENTERED 8/23/02

Date: 7/16/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		3:42:02	4:68	6 wheel truck	up	
		3:42:36	4:93	6 wheel truck	up	
		3:44:30	5:09	6 wheel Truck	up	
		3:45:55	4:11	4 wheel truck	Down	
		3:46:46	4:19	6 wheel truck	up	
		3:47:35	4:01	10 wheel Trailer Trucks	Down	
		3:47:47		10 wheel Trailer Truck	Down	
		3:48:15	3:61	6 wheel Truck	Down	
		3:50 42	5:23	6 wheel truck	up	
		3:50:47		6 wheel truck	Down	
		3:54.20	4:15	6 wheel truck	Down	
		3:58:31	7:70	4 wheel truck	up	
		3:59:29	477	6 wheel truck	up	
		4:01:12	5:31	10 wheel Trailer Truck	up	
		4:01:20		10 wheel trailer Truck	up	
		4:03:45	4:66	6 wheel Truck	Down	
		4:04:09	5:26	6 wheel Truck	up	
		4:07:01	3:68	6 wheel Truck	up	
		09:14	4:46	6 wheel Truck	up	
		9:39	5:69	6 wheel truck	up	

4:08 plant shut Down

Miscellaneous:

ENTERED 7/23/02

Date: 7/16/02

Location: BLACKSBURG QUARRY VA

Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		4:10:12		Cat 771 Loaded	up	
		4:10:12		6 wheel Truck	Down	
		4:10:12		771 Cat Loaded	up.	
		4:10:12		6 wheel Truck	up	
		4:10:30		771 Cat unloaded	Down	
		4:14:14	5:00	771 Cat unloaded	Down	
		4:16:31	4:00	6 wheel truck	Down	
		4:17:35		771 Cat Loaded	up	
		4:18:24		6 wheel truck	Down	
		4:19:30		771 cat unloaded	Down	
		4:19:30		771 cat loaded	up	
		4:21:23	4:14	771 cat unloaded	Down	
		4:24:22	5:04	771 cat Loaded	up	
		4:26:37		771 cat unloaded	Down	
		4:26:53	4:60	771 Cat Loaded	up	
		4:28:44		6 wheel truck	Down	
		4:28:51		771 cat unloaded	Down	
		4:32:15		6 wheel	Down	
		4:32:17	5:41	771 loaded	up	
		4:32:22		6 wheel	Down	

Miscellaneous:

ENTERED 7/22/02

Date: 7/16/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		4:33:02		6 wheel truck	up	
		4:34:51	4:12	771 cat empty	Down	
		4:34:57		6 wheel truck	Down	
		4:35:56		6 wheel truck	up	
		4:40:40		Cat 771 Loaded	up	
				~~Cat 771 unloaded~~	~~Down~~	

Miscellaneous:

305

ENTERED 7/23/02

7/16/02 BLACKSBURG VA QUARRY STUDY

Miscellaneous Notes:

Road was Saturated from Repeated watering of the Road with the water truck

Loader was dumping fines on Stockpiles which could effect Sampling

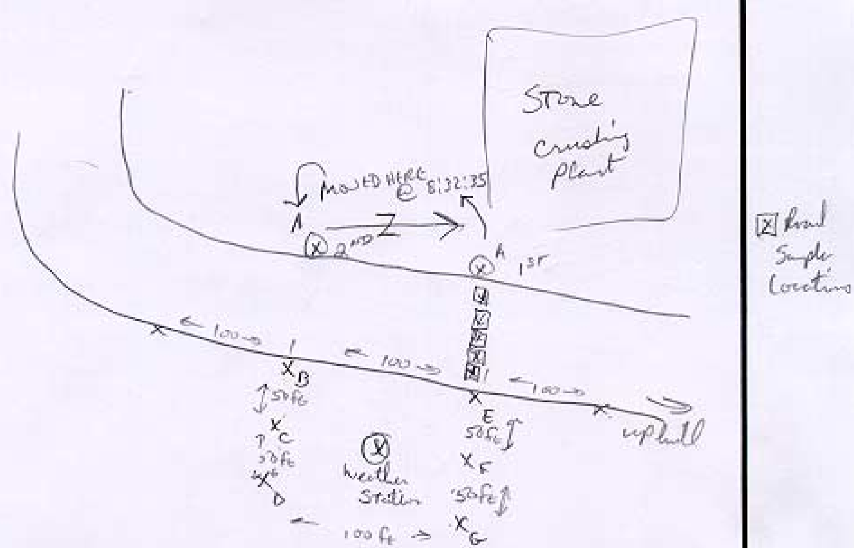
Location: BLACKSBURG VA [redacted] STONE QUARRY

Dates of Sampling: 7/17/02

Mining Operation Type: STONE QUARRY

Material Types: LIMESTONE
CRUSHED ROCK

Sketch of sampling setup:



Possible Interferences/Sources of Contamination:

Stone Crushing Plant
although wind seemed to direct most of
Dust from plant away wind from S.–SW

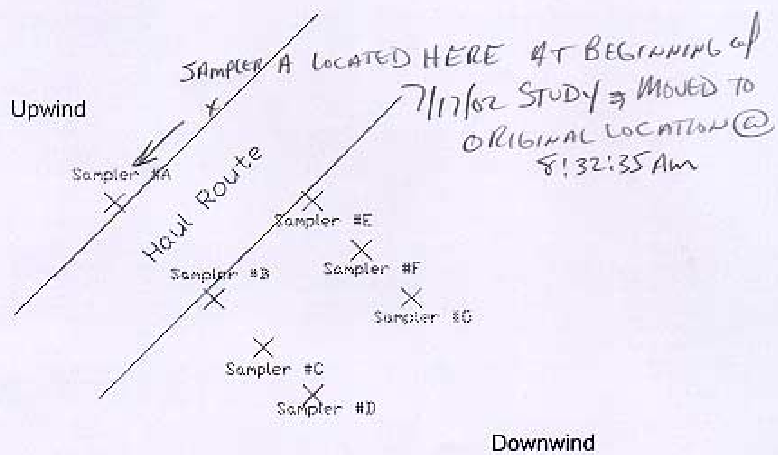


Figure 1 Sampling locations for field study.

6

CORRECTED & CHECKED 7/22/02

Date: 7/17/02

Location: BLACKSBURG VA QUARRY

Station # A	Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	MINUTES Pump Run Time (From pump)
Respirable PDR	S7	43	JR3		8:11:48	3:03:20	414
Respirable	S21	74			8:11:48	3:03:20	415
Thoracic	S24	02			8:11:48	3:03:20	415
Total	S16	31			8:11:48	3:03:20	415
Impactor	J010			A	8:11:48	1:52	345

Station # B	Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
Respirable PDR	S17	36	JO PDR2		8:13:50	3:04:20	414
Respirable	S5	68			8:13:50	3:04:20	415
Thoracic	J06	14			8:13:50	3:04:20	414
Total	S4	90			8:13:50	3:04:20	415
Impactor	J07			B	8:13:50	1:54	343

Station # C	Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
Respirable PDR	S12	66	JO PDR3		8:14:43	3:10:21	419
Respirable	S23	~~32~~ 45			8:14:43	3:10:21	419
Thoracic	J05	12			8:14:43	3:10:21	420
Total	S20	28			8:14:43	3:10:21	420
Impactor	J09			11	8:14:43	1:55	343

Station # D	Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
Respirable PDR	S18	39	JR1		8:18:15	3:11:29	412
Respirable	S13	78			8:18:15	3:11:29	417
Thoracic	J02	23			8:18:15	3:11:29	417
Total	S8	24			8:18:15	3:11:29	418
Impactor							

Station # E	Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
Respirable PDR	S2	81	JR2		8:12:45	3:06:47	419
Respirable	S14	61			8:12:45	3:06:47	417
Thoracic	J04	17			8:12:45	3:06:47	418
Total	S1	54			8:12:45	3:06:47	419
Impactor							

Station # F	Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
Respirable PDR	S6	67	4802		8:15:50	3:08:20	416
Respirable	S10	32			8:15:50	3:08:20	416
Thoracic	S25	21			8:15:50	3:08:20	417
Total	S11	76			8:15:50	3:08:20	417
Impactor							

Station # G	Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
Respirable PDR	S15	85	GGPDR1		8:17:12	3:12:57	419
Respirable	S9	64			8:17:12	3:12:57	419
Thoracic	J03	08			8:17:12	3:12:57	419
Total	S22	88			8:17:12	3:12:57	420
Impactor							

Misc: STATION D PDR NOT READING

D SHUTDOWN 8:21:68 8:24 STARTED working

ENTERED [illegible]/02

Date: 7/17/02		Location: BLACKSBURG VA		
Time	Barometer Reading	Dry Bulb Temperature	Wet Bulb Temperature	
8:28	28.20 "Hg	74 °F	69 °F	77%
9:29	28.19 "Hg	78 °F	70 °F	66%
10:26	28.18	81 °F	70 °F	57%
11:29	28.19 "Hg	86	73	53%
12:26	28.18	90	74	41%
1:28	28.19	92 °F	73 °F	39%
2:32	28.16	88 °F	72 °F	45%

Misc:
weather Station Started @ 8:10 Am

ENTERED

Date: 7/17/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		8:22:00		water Truck	Down	NO
		8:26:20		6 wheel OTR	Down	NO
		8:30:10		4 wheel Septic Tank Truck	Down	NO
		8:32:35		Moved Station A Across from B	Outside of E	
		8:33:44	6.74	6 wheel Truck	up	NO
		8:38:45	3.64	6 wheel Truck	up	NO
		8:38:56		6 wheel truck	Down	NO
		8:45:51	4:20	6 wheel Truck	up	NO
		8:47:14		Septic Tank Truck	up	
		8:47:26	3:44	6 wheel Truck	Down	
		8:48:16	5:22	4 wheel Truck	Down	
		8:50:49	4:71	4 wheel truck	up	
		9:00:11	5:37	6 wheel truck	up	
		9:02:03	2.91	6 wheel truck	up	
		9:04:12	2.95	6 wheel truck	up	
		9:07:31	3.74	6 wheel truck	up	
		9:10:05	2.95	6 wheel truck	up	
		9:10:45	3:56	6 wheel Truck	Down	
		9:11:32	3.98	Garbage truck (6 wheel)	Down	
		9:13:45	4.70	6 wheel truck	up	

Miscellaneous:

ENTERED 7/23/02

Date: 7/17/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		9:14:41	5:11	GARBAGE Truck (6 wheel)	up	
		9:16:08	3:59	6 wheel (8 wheels Down)	up	
		9:18:51	3:49	6 wheel Truck	up	
		9:23:34	3.56	6 wheel truck	Down	
		9:28:31	5:10	6 wheel Truck	Down	
		9:28:52	5:66	water Truck	up	
		9:31:22	5:56	6 wheel Truck	up	
		9:32:02	3:22	6 wheel Truck	Down	
		9:34:26	4:09	6 wheel Truck	Down	
		9:36:49	3:56	6 wheel Truck	up	
		9:37:20	3:66	6 wheel Truck	Down	
		9:37:27		6 wheel Truck	Down	
		9:40:35	3:31	water Truck	Down	
		9:41:50	4:03	6 wheel truck	up	
		9:51:57	4:87	4 wheel Truck	Down	
		9:55:30	3:32	6 wheel Truck	Down	
		9:56:11	5:76	4 wheel Truck	up	
		10:01:56	3.97	6 wheel truck	Down	
		10:04:10	3.94	6 wheel Truck	Down	
		10:04:16	3.95	Trailer Truck 10 wheel	Down	

Miscellaneous:

ENTERED 1-3/02

Date: 7/17/02 | Location: BLACKSBURG VA QUARRY

Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		10:08:30	4.25	6 wheel Truck	up	
		10:13:40	4:01	Cat 771 unloaded	Down	
		10:15:59	5:38	Trailer Truck 10 wheel	up	
		10:17:10	3:77	6 wheel Truck	Down	
		10:19:12	4.74	water Truck	Down	
		10:21:41	3:39	6 wheel Truck	Down	
		10:22:00	4:64	6 wheel truck	up	
		10:24:46	4.66	Cat 771 unloaded	Down	
		10:24:46		6 wheel truck	up	
		10:27:18	4.59	6 wheel truck	up	
		10:29:51	4.70	6 wheel Truck	up	
		10:32:03	4.39	6 wheel Truck	Down	
		10:32:07		6 wheel truck	Down	
		10:32:39	4:06	6 wheel Truck	up	
		10:33:47	5:36	water Truck	up	
		10:34:16	2.88	6 wheel Truck	up	
		10:36:17	4:24	Cat 771 unloaded	Down	
		10:37:10	4:53	6 wheel Truck	up	
		10:37:58	4:85	6 wheel truck	up	
		10:39:33	3.38	6 wheel Truck	up	

Stone plant 10:18:57 Down

Stone plant 10:37:44 Start

Miscellaneous:

ENTERED 7/23/02

Date: 7/17/02

Location: BLACKSBURG VA QUARRY

Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		10:41:35	2.94	6 wheel Truck	up	
		10:42:01	4.12	6 wheel truck	Down	
		10:43:57	4.84	Cat 771 loaded	up	
		10:46:47	4.18	6 wheel truck	up	
		10:47:12	3.64	6 wheel truck	Down	
		10:49:02	3.95	Cat 771 unloaded	Down	
		10:49:34	3.78	6 wheel truck	up	
		10:52:04	4.31	6 wheel truck	Down	
		10:54:59	5.43	6 wheel Truck	Down	
		10:56:22	3.61	6 wheel Truck	up	
		10:56:30		6 wheel truck	Down	
		10:55:06	4.82	6 wheel Truck	up	
		10:59:27	4.08	6 wheel Truck	Down	
		11:02:52	4.70	6 wheel truck	up	
		11:04:04	3.09	6 wheel truck	Down	
		11:05:18	4.34	6 wheel Truck	up	
		11:07:48	3.61	6 wheel Truck	up	
		11:10:23	3.07	6 wheel Truck	up	
		11:13:43	4.71	6 wheel Truck	Down	
		11:18:35	4.77	6 wheel truck	Down	

Miscellaneous:

ENTERED 7/23/02

Date: 7/16/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		11:19:40	4.83	6 wheel Truck	Down	NO
		11:21:19	4.78	6 wheel Truck	up	
		11:22:06	3.70	6 wheel Truck	Down	
		11:25:06	3.57	6 wheel Truck	Down	
		11:25:34	4.43	6 wheel Truck	Down	
		11:26:16	4:57	Cat 771 unloaded	Down	
		11:26:48	3.63	6 wheel Truck	Down	
		11:28:00	4.26	6 wheel truck	up	
		11:30:27	3.83	6 wheel truck	Down	
		11:30:55	3.74	6 wheel truck	up	
		11:31:13	4.52	6 wheel Truck	Down	
		11:31:39	3.44	6 wheel Truck	Down	
		11:32:38	4.56	6 wheel truck	Down	
		11:32:48		6 wheel Truck	up	
	11'	11:33:12	3.79	6 wheel Truck	up	
		11:33:36	3.06	6 wheel Truck	Down	
		11:37:25	5.73	6 wheel Truck	up	
		11:37:38	4.84	6 wheel truck	up	
		11:41:00	5:03	6 wheel Truck	up	
		11:42:40	2.74	6 wheel Truck	Down	

Miscellaneous:

ENTERED 8/24/02

Date: 7/17/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		12:46:51	3,14	6 wheel truck	Down	
		12:47:17		4 wheel truck	Down	
		12:51:12	5,08	6 wheel Truck	up	
		12:51:31	5,11	4 wheel truck	up	
		12:52:20	3,27	6 wheel Truck	Down	
		12:52:41	3,34	6 wheel truck	Down	
		12:54:41	3.10	6 wheel Truck	Down	
		12:56:00	3,59	6 wheel truck	Down	
		12:56:16	[illegible]	6 wheel truck	up	
		12:59:09	3,60	6 wheel Truck	up	
		12:59:15		6 wheel Truck	Down	
		12:59:58	3,34	6 wheel Truck	up	
		1:01:02	4,27	6 wheel Truck	Down	
		1:01:10		6 wheel truck	Down	
		1:01:46	4.44	6 wheel truck	up	
		1:03:06	5,00	6 wheel Truck	Down	
		1:03:29	3:10	4 wheel Truck	Down	
		1:04:37	4,81	6 wheel truck	Down	
		1:05:04	3,83	6 wheel truck	Down	
		1:06:13		6 wheel truck	up	

Miscellaneous:

ENTERED
/02

Date: 7/17/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		12:19:52		4 wheel truck	Down	
		12:22:03	5.09	6 wheel truck	Down	
		12:23:16	6.83	Trailer truck 10 wheel	up	
		12:25:03	3.95	6 wheel Truck	Down	
		12:27:56	6.98	Trailer Truck 10 wheel Tanker	Down	
		12:29:05	4.49	6 wheel truck	up	
		12:31:06	4.88	6 wheel Truck	up	
		12:31:19		6 wheel truck	Down	
	12:33:02				up	
		12:34:23		6 wheel Truck	Down	
		12:37:06	3.51	6 wheel truck	Down	
		12:35:00	4.77	6 wheel Truck	up	
		12:41:40	4.41	6 wheel truck	Down	
		12:41:56	3.56	6 wheel truck	Down	
		12:43:50	4.98	water Truck	Down	
		12:43:56		6 wheel truck	Down	
		12:44:31	4.53	6 wheel truck	Down	
		12:44:37		6 wheel Truck	up	
		12:44:50	3.52	6 wheel Truck	Down	
		12:45:53		6 wheel Truck	up	

Miscellaneous:

ENTERED 7/1/02

Date: 7/17/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		11:43:54	3.75	6 wheel Truck	Down	
		11:44:15	3.99	6 wheel truck	Down	
		11:44:23		6 wheel truck	up	
		11:47:04	3.57	6 wheel truck	up	
		11:47:11		6 wheel Truck	Down	
		11:47:55	4.31	6 wheel truck	up	
		11:49:17	2.57	6 wheel truck	Down	
		11:51:25	3.95	6 wheel truck	up	
		11:52:03	3.61	6 wheel truck	Down	
		11:53:06	4.14	6 wheel truck	up	
		11:53:24	3.52	6 wheel truck	up	
		11:56:52	4:14	6 wheel truck	up	
		11:59:24	5:06	6 wheel Truck	Down	
		11:59:46	3.59	6 wheel Truck	up	
		12:08:56	4.72	6 wheel truck	up	
		12:09:49	3.60	6 wheel truck	Down	
		12:11:04	6.11	water Truck	up	
		12:14:40	4.99	Trailer truck 10 wheel	Down	
		12:15:12	3.96	6 wheel Truck	up	
		12:17:28	4.99	6 wheel Truck	Down	

Miscellaneous:

ENTERED 7/24/02

Date: 7/17/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		1:07:17	5.45	6 wheel truck	up	
		1:10:12	5.23	6 wheel Truck	up	
		1:12:25	4.59	4 wheel truck	up	
		1:14:22	4.84	6 wheel truck	up	
		1:14:34		6 wheel truck	Down	
		1:15:58		Water Truck	up	
		1:15:58		6 wheel Truck	Down	
		1:16:20	3.05	6 wheel Truck	Down	
		1:17:07		6 wheel truck	up	
		1:18:45	7.07	Trailer Truck 10 wheel tanker	up	
		1:19:26	3.84	6 wheel truck	Down	
		1:19:55	4.45	6 wheel truck	up	
		1:20:03		6 wheel truck	Down	
		1:22:20	5.52	6 wheel truck	up	
		1:23:06	4.31	6 wheel truck	up	
		1:24:33	5.74	6 wheel truck	Down	
		1:25:19	5.76	6 wheel truck	up	
		1:27:07	3.88	6 wheel truck	up	
		1:27:43		water truck	Down	
		1:27:52		6 wheel truck	Down	

Miscellaneous:

ENTERED 7/24/02

Date: 7/17/02

Location: Blacksburg VA Quarry

Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		1:29:24	3.22	6 wheel truck	up	
		1:32:02	3.97	6 wheel Truck	Down	
		1:32:22	4.13	6 wheel Truck	up	
		1:34:27	3.53	6 wheel truck	Down	
		1:35:40	4:04	6 wheel truck	up	
		1:37:57	3.08	6 wheel truck	Down	
		1:38:50	4.66	6 wheel truck	up	
		1:38:59		6 wheel truck	up	
		1:39:07		6 wheel truck	up	
		1:41:08	3.21	6 wheel truck	Down	
		1:41:13		6 wheel truck	up	
		1:41:58	3.72	6 wheel Truck	Down	
		1:44:29	5.46	6 wheel Truck	up	
		1:44:32		6 wheel Truck	up	
		1:44:49	4.84	6 wheel Truck	Down	
		1:45:08		4 wheel truck	Down	
		1:46:48	3:15	6 wheel Truck	up	
		1:47:23	4.71	6 wheel Truck	Down	
		1:47:50	4:13	Trailer Truck 10 wheel	Down	
		1:52:10	5:00	6 wheel Truck	Down	

Miscellaneous:

ENTERED
/18/02

12

Date: 7/17/02		Location: Blacksburg VA				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		1:52:22		water truck	Down	
		1:53:36	5:32	6 wheel truck	up	
		1:56:29	4.64	6 wheel Truck	up	
		1:57:00	4.88	6 wheel Truck	Down	
		1:58:30	5:38	4 wheel truck	up	
		1:59:10	4:52	Trailer Truck 10 wheel	up	
		1:59:11		6 wheel Truck	Down	
		2:01:08		6 wheel	up	
		2:01:09		6 wheel	Down	
		2:01:38		"	Down	
		2:01:43		"	Down	
		2:02:19		"	Down	
		2:04:15	3.50	6 wheel truck	Down	
		2:05:40		6 wheel truck	up	
		2:06:00		6 wheel truck	up	
		2:07:19		6 wheel truck	Down	
		2:07:58		6 wheel truck	up	
		2:08:26		"	up	
		2:08:31		"	up	
		2:09:20		"	up	

Miscellaneous:

ENTERED 7/28/02

Date: 7/17/02		Location: Blacksburg VA Quarry				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		2:11:43	3.98	6 wheel truck	Down	
		2:16:33		6 wheel truck	Down	
		2:17:36	4.47	6 wheel Truck	up	
		2:20:19	4.92	Trailer Truck 10 wheel	Down	
		2:21:14	3.77	6 wheel Truck	up	
		2:22:16	4.43	6 wheel truck	Down	
		2:22:45	3.85	6 wheel Truck	Down	
		2:24:44	3.17	6 wheel truck	up	
		2:25:08	3.45	6 wheel truck	Down	
		2:26:06	4:04	6 wheel truck	Down	
		2:26:48	3.58	6 wheel Truck	Down	
		2:27:27	6.24	Trailer Truck 10 wheels	up	
		2:28:47	4.64	6 wheel truck	up	
		2:29:56		6 wheel truck	Down	
		2:32:46	4.20	6 wheel truck	up	
		2:33:06	3.54	6 wheel truck	up	
		2:35:38		6 wheel truck	Down	
		2:36:36	4.20	6 wheel truck	up	
		2:37:52	4.81	6 wheel truck	Down	
		2:39:35	4.08	6 wheel Truck	Down	

Miscellaneous:

Entered ... /02

Date: 7/17/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		2:38:48		6 wheel truck	up	
		2:40:45	4.89	6 wheel truck	Down	
		2:43:31	5.98	6 wheel truck	up	
		2:44:21	4:44	Drill Truck mounted	Down	
		2:45:51	3.88	6 wheel Truck	Down	
		2:47:30	5.03	6 wheel Truck	up	
		2:47:33		6 wheel Truck	Down	
		2:49:08	3.81	6 wheel Truck	Down	
		2:50:33		6 wheel Truck	Down	
		2:50:45	4.59	Cat 771 unloaded	Down	
		2:50:57		6 wheel truck	up	
		2:53:31	3.80	6 wheel truck	up	
		2:56:31	4.26	6 wheel truck	up	
		2:57:16	3.81	6 wheel truck	Down	
		2:59:52	5:59	6 wheel truck	Down	
		2:59:54		6 wheel Truck	Down	
		3:00:34	3.86	6 wheel truck	Down	
		3:01:03	5.40	6 wheel truck	up	
		3:02:44		6 wheel Truck	up	
		3:05:57		6 wheel truck	Down	

Plant Shut Down 2:51:31

Miscellaneous:

ENTERED 7/25/02

Date: 7/17/02

Location: BLACKSBURG VA QUARRY

Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		3:06:47		6 wheel truck	up	
		3:07:28		6 wheel truck	up	
		3:08:18		6 wheel truck	Down	

Miscellaneous:

Entered 7/25/02

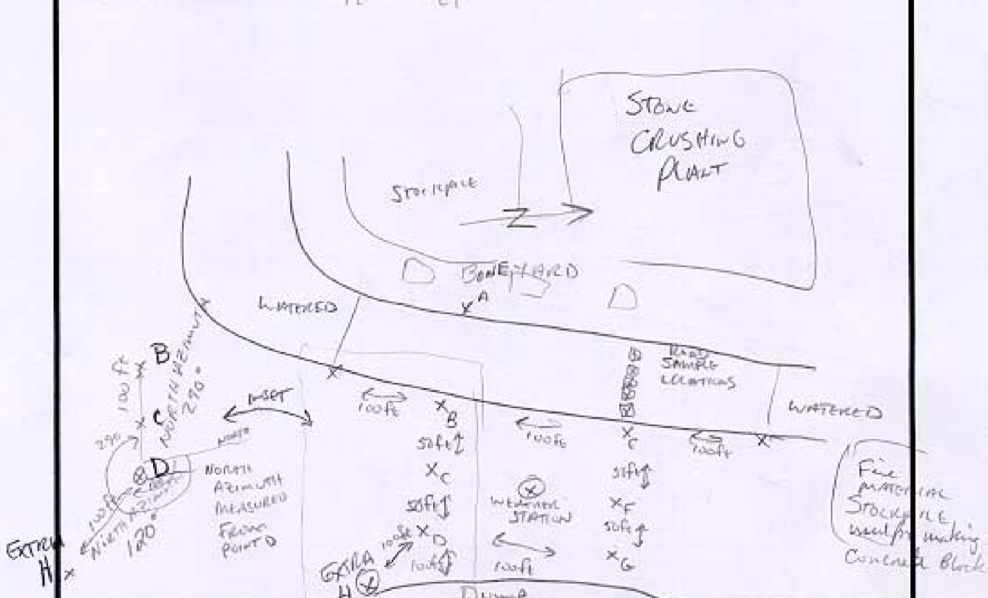
Location: BLACKSBURG VA

Dates of Sampling: 7/18/02

Mining Operation Type: STONE QUARRY

Material Types: LIMESTONE CRUSHED ROCK

Sketch of sampling setup: 120 290



Possible Interferences/Sources of Contamination:
STONE CRUSHING PLANT
LOCAL STOCKPILES
TRUCKS DRIVING AROUND BACKSIDE of STUDY AREA

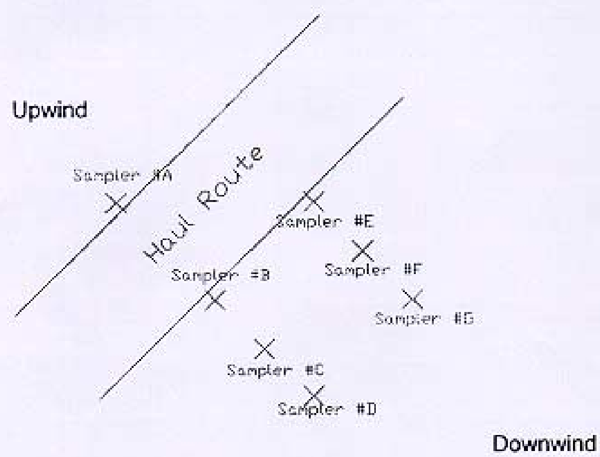


Figure 1 Sampling locations for field study.

Date: 7/18/02		Location: BLACKSBURG VA						
Station # A		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	Pump Run Time (from pump)
	Respirable PDR	S7	56	JR3		8:15:11	3:04:49	412
	Respirable	S4	38			8:15:11	3:04:49	414
	Thoracic	J06	04			8:15:11	3:04:49	413
	Total	S17	49			8:15:11	3:04:49	413
	Impactor	J07			A	8:15:11	3:04:49	413
Station # B		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S11	26	JOPDR2		8:16:31	3:06:08	414
	Respirable	S12	42			8:16:31	3:06:08	412
	Thoracic	J05	01			8:16:31	3:06:08	414
	Total	S20	70			8:16:31	3:06:08	414
	Impactor	J010			B	8:16:31	3:06:08	414
Station # C		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S1	29	JOPDR3		8:19:29	3:10:29	415
	Respirable	S2	55			8:19:29	3:10:29	416
	Thoracic	S24	20			8:19:29	3:10:29	414
	Total	S22	30			8:19:29	3:10:29	415
	Impactor	J09			11	8:19:29	3:10:29	415
Station # D PDR SHOWED MALFUNCTION DURING CALIBRATION		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S8	77	JR1		8:20:30	3:11:30	415
	Respirable	S14	65			8:20:30	3:11:30	414
	Thoracic	S25	06			8:20:30	3:11:30	416
	Total	S13	84			8:20:30	3:11:30	415
	Impactor							
Station # E		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S10	44	JR2		8:17:38	3:07:54	414
	Respirable	S6	73			8:17:38	3:07:54	413
	Thoracic	J03	07			8:17:38	3:07:54	413
	Total	S5	71			8:17:38	3:07:54	414
	Impactor							
Station # F		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S15	60	4802		8:18:33	3:09:17	414
	Respirable	S21	83			8:18:33	3:09:17	414
	Thoracic	J04	22			8:18:33	3:09:17	415
	Total	S16	87			8:18:33	3:09:17	414
	Impactor							
Station # G		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S23	72	GGPDR1		8:21:45	3:13:12	415
	Respirable	S9	27			8:21:45	3:13:12	415
	Thoracic	J02	09			8:21:45	3:13:12	415
	Total	S18	75			8:21:45	3:13:12	415
	Impactor							
Misc:								

ENTERED 7/22/02

Date: 7/18/02

Location: BLACKSBURG VA

Time	Barometer Reading	Dry Bulb Temperature	Wet Bulb Temperature	
8:40	28.12"Hg	72 °F	67 °F	77%
9:39	28.12"Hg	75 °F	69 °F	73%
10:39	28.11"Hg	79	71	66%
11:41	28.10	79	70	63%
12:46	28.09"Hg	80	71	64%
1:41	28.07"Hg	80	71	64%
2:40	28.06"Hg	84	72	55%

Misc: weather Station Started @ 7:46 AM

CLOUDY / OVERCAST

ENTERED 7/22/02

EXTRA SAMPLERS

STATION 4

RESPIRABLE

FILTER	PUMP	START	STOP	MINUTES
33	S3	8:31:23	3:14:50	408

THORACIC

FILTER	PUMP	START	STOP	
05	J01	8:31:23	3:14:50	408

Date: 7/18/02

Location: BLACKSBURG VA QUARRY

Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		8:25:27		6 wheel Truck	up	yes
		8:36:03		6 wheel Truck	Down	
		8:37:12		6 wheel Truck	Down	
		8:38:29		6 wheel Truck	Down	
		8:41:22	4.56	6 wheel truck	up	
		8:42:17	4.51	6 wheel Truck	Down	
		8:42:25		6 wheel Truck	Down	
		8:43:46	5.80	6 wheel Truck	up	
		8:44:54	4.34	6 wheel Truck	Down	yes
		8:57:46	5.40	6 wheel truck	Down	
		9:11:34	3.13	6 wheel truck	Down	
		9:12:52	3.28	6 wheel truck	up	
		9:15:34	3.46	6 wheel truck	up	
		9:18:50	3.04	6 wheel truck	Down	
		9:19:26	3.41	6 wheel Truck	Down	
		9:20:50	5.33	6 wheel truck	Down	
		9:21:37		6 wheel Truck	Down	
		9:22:02	3.75	6 wheel Truck	Down	
		9:22:08		6 wheel truck	Down	
		9:23:10	4.39	6 wheel Truck	up	

Plant Down at Start of Shift

Miscellaneous:

ENTERED 7/25/02

Date: 7/18/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		9:24:21	4.31	6 wheel truck	up	
		9:24:33	3.21	6 wheel Truck	up	
		9:25:39	4.15	6 wheel truck	up	
		9:26:34	4.99	6 wheel truck	Down	
		9:27:56	4.72	6 wheel truck	up	
		9:29:13	5.99	6 wheel truck	Down	
		9:29:46	5.81	6 Wheel Truck	up	
		9:35:28	4.04	6 wheel truck	Down	
		9:35:44	3.73	6 wheel truck	Down	
		9:36:30	4.84	6 wheel truck	Down	
		9:36:58		4 wheel Truck	Down	
		9:40:53	5.95	6 wheel truck	up	
		9:41:15	5.71	6 wheel truck	up	
		9:41:54	4.64	4 wheel Truck	up	
		9:44:40	4.20	6 wheel truck	Down	
		9:46:34	4.97	Trailer Truck 10 wheel	Down	
		9:46:39		Trailer Truck 10 wheel	Down	
		9:49:55	4.93	6 wheel Truck	up	
		9:59:36	4.48	6 wheel truck	Down	
		10:01:49	4.50	6 wheel truck	Down	

Miscellaneous:

2

ENTERED 9/25/02

Date: 7/18/02 Location: Blacksburg VA Quarry

Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??	
		10:02:14	4.34	4 wheel truck	Down		
		10:03:44	3.84	6 wheel truck	Down		
		10:04:15	4.97	Trailer Truck 10 wheel	up		
		10:04:23		Trailer Truck 10 wheel	up		
		10:04:32		6 wheel Truck	up	No	Dry Road Surface
		10:07:49	5.08	6 wheel truck	Down		
		10:08:43	4.32	4 wheel truck	up		
		10:13:08	4.34	6 wheel truck	Down		plant started 10:13:20
		10:16:16	3.76	6 wheel truck	up		
		10:21:45	3.41	6 wheel truck	Down		
		10:25:21	5.15	6 wheel truck	Down		
		10:34:25	2.93	6 wheel truck	up		
		10:38:29	5.08	6 wheel truck	up		
		10:41:43	3.87	6 wheel truck	Down		
		10:42:13	3.61	6 wheel truck	up		
		10:42:21		Trailer truck 10 wheel	up		
		10:44:13	4.28	6 wheel truck	Down		
		10:46:59	3.31	6 wheel Truck	up		
		10:48:10	5.32	6 wheel truck	up		
		10:48:24	5.58	6 wheel truck	up		

Miscellaneous:

ENTERED 7/25/02

Date: 7/18/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		10:49:07	5.25	Trailer truck 10 wheel	up	NO
		10:54:18	3.88	6 wheel truck	Down	
		10:54:51	4.20	4 wheel truck	Down	
		10:59:56	4.36	6 wheel truck	Down	
		11:00:02		6 wheel truck	Down	
		11:00:59	4.37	6 wheel truck	up	
		11:02:19	3.71	6 wheel Truck	Down	
		11:03:07	3.61	6 wheel truck	Down	
		11:04:36	6.05	4 wheel truck	up	
		11:05:08	4.06	6 wheel truck	up	
		11:06:26	4.90	6 wheel Truck	Down	
		11:06:57	4.06	6 wheel Truck	Down	
		11:07:17	4.84	6 wheel truck	up	
		11:09:27	4.39	6 wheel truck	Down	
		11:11:34		6 wheel truck	up	
		11:21:45	2.98	6 wheel truck	Down	
		11:35:11		6 wheel truck	Down	
		11:36:04	3.24	6 wheel truck	Down	
		11:40:10	5.79	6 wheel truck	up	
		11:41:56	4.74	6 wheel Truck	up	

Miscellaneous:

10:52 Stone plant stopped

Stone Plant Started 11:01

ENTERED 7/25/02

Date: 7/18/02		Location: BLACKSBURG, VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		11:42:02		6 wheel truck	up	
		11:43:02	5.62	6 wheel truck	up	
		11:47:54	4.41	6 wheel truck	up	
		11:49:48		6 wheel truck	up	
		11:53:40	3.70	6 wheel truck	up	
		11:54:34	4.04	4 wheel truck	Down	
		11:56:37		6 wheel truck	up	
		11:57:40	6.13	6 wheel truck	up	
		11:59:51	5.35	4 wheel truck	up	
		12:00:16	3.99	6 wheel truck	up	
		12:01:48	5.96	6 wheel truck	Down	
		12:03:54	6.09	6 wheel truck	Down	
		12:04:08	5.52	6 wheel truck	Down	
		12:05:30	5.62	6 wheel truck	up	
		12:06:36	3.80	6 wheel truck	Down	
		12:07:57	5.52	6 wheel truck	up	
		12:08:58	4.51	6 wheel truck	Down	
		12:12:45	5.30	6 wheel truck	Down	
		12:13:39		water truck	Down	
		12:15:43	5.60	6 wheel truck	up	

Miscellaneous:

Very very light drizzle

Very very very light drizzle stopped

ENTERED 7/25/02

Date: 7/18/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		12:19:39	4.03	Trailer Truck 10 wheel	Down	
		12:19:51	3.93	Trailer truck 10 wheel	Down	
		12:20:43	4.91	6 wheel truck	up	
		12:22:18	4.06	6 wheel truck	Down	
		12:23:01	3.13	6 wheel truck	up	
		12:24:30	4.37	6 wheel truck	up	
		12:26:09	4.34	6 wheel truck	up	
		12:27:07	5.37	6 wheel truck	Down	
		12:28:49	3.57	6 wheel truck	up	
		12:29:50	4.33	6 wheel truck	Down	
		12:32:14	4.62	Trailer Trucks 10 wheel	up	
		12:32:24		Trailer Trucks 10 wheel	up	
		12:33:01		Trailer truck 10 wheel tanker	Down	
		12:34:26	4.20	6 wheel truck	up	
		12:36:15	3.66	6 wheel truck	Down	
		12:36:45	5.42	6 wheel truck	Down	
		12:38:39	3.55	6 wheel truck	up	
		12:42:40	4.75	Trailer truck 10 wheel	Down	
		12:42:50		6 wheel truck	Down	
		12:43:26	4.51	4 wheel Truck	Down	

Miscellaneous:

ENTERED 7/25/02

Date: 7/16/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		12:43:36		4 wheel truck	Down	
		12:45:02	5.21	4 wheel Truck	Down	
		12:45:50	5.01	6 wheel truck	Down	
		12:47:34	5.82	6 wheel truck	up	
		12:48:36		Trailer Truck 10 wheel	up	
		12:48:44		6 wheel truck	up	
		12:48:48		4 wheel truck	up	
		12:50:03	2.96	6 wheel truck	Down	
		12:50:20	4.76	4 wheel truck	up	
		12:52:38	5.12	4 wheel truck	up	
		12:53:50	4.93	Euclid R50	up	
		12:55:13	3.87	6 wheel truck	Down	
		12:58:21	5.63	6 wheel truck	Down	
		1:00:41	5.34	6 wheel truck	Down	
		1:01:16	5.23	6 wheel truck	up	
		1:01:21	4.38	6 wheel truck	Down	
		1:03:38	4.56	6 wheel truck	up	
		1:04:04		6 wheel truck	Down	
		1:04:20	3.76	6 wheel truck	Down	
		1:05:12	4.20	6 wheel truck	Down	

light Drizzle

stopped Drizzle

Miscellaneous:

ENTERED 7/25/02

Date: 7/18/02		Location: BLACKSBURG VA QUARRY					
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??	
		1:05:36	4.52	6 wheel truck	up		
		1:10:50	4.74	6 wheel truck	up		
		1:11:25	4.08	6 wheel truck	up		
		1:14:19	5.62	6 wheel truck	up		Stone plant Down @ 1:20
		1:19:25	4.53	6 wheel truck	up		
		1:20:36	4.85	6 wheel truck	Down		
		1:22:03	3.06	6 wheel truck	up		
		1:22:13		6 wheel truck	Down		
		1:22:50	3.95	6 wheel truck	Down		
		1:25:05	3.92	6 wheel truck	Down		
		1:27:22	5.75	6 wheel truck	up		
		1:27:55	7.29	Trailer truck tanker	up		
		1:29:52	7.45	loader 970 F	up		
		1:30:22	5.74	6 wheel truck	up		
		1:35:23	5.73	6 wheel truck	Down		
		1:36:11	6.22	6 wheel truck	Down		
		1:39:11	5.85	water truck	Down		
		1:39:16		6 wheel truck	Down		
		1:39:50		6 wheel truck	Down		Stone plant START 1:42
		1:40:15	3.78	6 wheel truck	up		

Miscellaneous:

8

ENTERED 7/25/02

Date: 7/18/02

Location: BLACKSBURG VA QUARRY

Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		1:42:25	5.19	6 wheel truck	Down	
		1:43:40	3.93	Euclid R50	Down	
		1:47:15	3.79	6 wheel truck	Down	
		1:47:39	5.09	Trailer Truck 10wheel tanker	Down	
		1:51:30	4:19	4 wheel truck	Down	
		1:51:38		6 wheel truck	up	
		1:54:09	3.56	6 wheel truck	up	
		1:57:22	5.53	6 wheel truck	up	
		1:57:40	5.24	4 wheel truck	up	
		1:59:40	4.06	6 wheel truck	up	
		1:59:52		6 wheel truck	Down	
		2:01:54	3.44	6 wheel truck	up	
		2:03:40	4:51	Cat 771D Loaded	up	
		2:03:55		6 wheel truck	up	
		2:06:02	4.94	6 wheel truck	up	
		2:07:31	4:05	Cat 771D unloaded	Down	
		2:08:36	4:88	6 wheel Truck	up	
		2:10:35	3.58	6 wheel truck	up	
		2:14:14	3.35	6 wheel truck	Down	
		2:14:14		6 wheel truck	up	

Miscellaneous:

ENTERED 7/25/02

Date: 7/18/02

Location: BLACKSBURG VA QUARRY

Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		2:15:06	4,45	Cat 771 D loaded	up	
		2:16:45	4,65	6 wheel truck	Down	
		2:19:27		water truck	Down	
		2:19:36	4,09	Cat 771D unloaded	Down	
		2:22:36		6 wheel truck	Down	
		2:22:45		6 wheel truck	up	
		2:24:38	5,13	6 wheel truck	up	
		2:28:29	4,94	6 wheel truck	Down	
		2:29:26	3,81	6 wheel truck	up	
		2:29:54	3,88	6 wheel truck	Down	
		2:32:14	4,09	Cat 771D unloaded	Down	
		2:34:20	5.57	6 wheel truck	Down	
		2:35:35		6 wheel truck	Down	
		2:35:40	5.52	water truck	up	
		2:36:10		6 wheel truck	Down	
		2:36:59	5,47	6 wheel truck	up	
		2:37:29	4.33	6 wheel truck	Down	
		2:38:13	6.49	6 wheel Truck	up	
		2:38:34	3,75	6 wheel Truck	up	
		2:41:30	5.59	6 wheel Truck	Down	

Miscellaneous:

ENTERED
?/25/02

10

Date: 7/18/02		Location: BLACKSBurg VA Quarry				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		2:41:42		6 wheel Truck	Down	
		2:41:51		Trailer Truck 10 wheel Tanker	up	
		2:42:10		6 wheel truck	up	
		2:42:20		trailer Truck 10 wheel	Down	
		2:42:28	5:13	Cat 771D unloaded	Down	
		2:43:45	5.88	6 wheel truck	up	
		2:44:48	6.40	6 wheeled truck	Down	
		2:46:23		6 wheel truck	Down	
		2:47:51		6 wheel truck	up	
		2:47:59		6 wheel truck	Down	
		2:49:19	5.80	Trailer truck 10 wheel	up	
		2:49:29		6 wheel truck	up	
		2:49:56	4.20	6 wheel truck	Down	
		2:53:13	4.70	6 wheel truck	up	
		2:53:28	4.90	6 wheel truck	up	
		2:53:48	5.62	6 wheel truck	Down	
		2:56:06	3.93	6 wheel truck	Down	
		3:00:07	3.91	6 wheel truck	up	
		3:00:29	4:03	6 wheel truck	up	
		3:00:37		4 wheel truck	Down	

Miscellaneous:

11

ENTERED 7/23/02

Date: 7/18/02		Location: BLACKSBURG VA QUARRY				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		3:03:13	4.76	6 wheel truck	Down	
		3:03:43	4.47	6 wheel truck	up	
		3:06:08		6 wheel truck	up	
		3:06:22		6 wheel truck	up	
		3:06:45		6 wheel truck	Down	
		3:08:59		6 wheel truck	up	
		3:10:59		"	Down	
		3:12:22		"	up	
		3:13:40		"	Down	
		3:13:46		"	Down	

Miscellaneous:

ENTERED

E.4 Field Study Filter Results and Pump Test Data Record Sheets for the Stone Quarry

		PRE-WEIGHTS	POST-WEIGHTS
A	1	25.579	26.535
	2	25.635	25.904
	3	25.470	25.652
	4	25.245	25.371
	5	25.686	25.761
	6	25.575	25.616
	F	14.178	14.242
B	1	25.488	27.638
	2	25.259	26.241
	3	25.541	26.208
	4	25.360	25.683
	5	25.482	25.745
	6	25.847	25.947
	F	14.698	14.798
C	1	25.271	26.397
	2	25.613	26.179
	3	25.642	25.988
	4	25.772	25.935
	5	25.653	25.776
	6	25.312	25.368
	F	15.225	15.291
D	1	25.771	26.185
	2	25.572	25.778
	3	25.426	25.599
	4	25.317	25.455
	5	25.490	25.575
	6	25.318	25.342
	F	14.228	14.275
E	1	25.736	29.937 ✓
	2	25.339	26.259
	3	25.513	26.453
	4	25.655	26.224
	5	25.441	25.951
	6	25.664	25.852
	F	15.040	15.113
F	1	25.337	26.067
	2	25.298	25.721
	3	25.288	25.634
	4	25.636	25.839
	5	25.737	25.888
	6	25.740	25.810
	F	16.052	16.098
G	1	25.798	26.744
	2	25.615	25.906
	3	25.445	25.666
	4	25.543	25.698
	5	25.306	25.392
	6	24.891	24.936
	F	13.490	13.540
H	1	25.457	31.993
	2	25.397	26.853
	3	25.944	27.036 ✓
	4	25.399	25.840
	5	25.578	25.892
	6	25.403	25.495
	F	17.945	18.016
I	1	25.480	25.815
	2	25.389	25.551
	3	25.870	25.983
	4	25.555	25.617
	5	25.413	25.460
	6	25.230	25.254
	F	14.574	14.634

← MYLAR SET

A-11 ← IMPACTOR # D-11 - G-11 ←

B-B E-B - H-A

C-A F-A - I-B

these are Correct Tom thought he had Measured the mylars and associated them with the wrong site. But everything is Correct as of 9/5/02

T. MAL / JOHN O. / RANDY 02 JULY 02 (2 OF 2)

75	10.376	10.830
76	10.406	11.452
77	10.139	10.163
78	11.789	11.842
79	10.947	11.015
80	10.761	10.761
81	11.286	11.482
82	10.607	11.073
83	11.120	11.173
84	10.036	10.408
85	10.221	10.268
86	11.021	11.070
87	11.900	12.714
88	11.058	11.532
89	10.713	11.575
90	12.311	15.934

PRESSURE METER

SOLOMAT
MODEL#: PDM 205
SERIAL#: 004114

FLOW CALIBRATION METER

BIOS DRYCAL DC-LITE

MODEL#: DCL-M REV 1.08

SERIAL#: 3616

pumps

PITTSBURGH RESEARCH LABORATORY

1.7 LITER/MIN

PRE

PUMP #	DATE	CALIBRATION w/ cyclone FLOWRATE, l/min Test 1	Test 2	Test 3	AVERAGE
S1	7/8/02	1.696	1.693	1.690	1.693
S2	7/8/02	1.742	1.746	1.744	1.744
S3	7/8/02	1.712	1.713	1.714	1.713
S4	7/8/02	1.705	1.706	1.714	1.708
S5	7/8/02	1.724	1.718	1.726	1.723
S6	7/8/02	1.673	1.677	1.676	1.675
S7	7/8/02	1.721	1.718	1.716	1.718
S8	7/8/02	1.668	1.663	1.667	1.666
S9	7/8/02	1.688	1.687	1.689	1.688
S10	7/8/02	1.692	1.692	1.694	1.693
S11	7/8/02	1.685	1.680	1.677	1.681
S12	7/8/02	1.717	1.718	1.717	1.717
S13	7/8/02	1.709	1.711	1.710	1.710
S14	7/8/02	1.682	1.673	1.681	1.679
S15	7/8/02	1.723	1.723	1.723	1.723
S16	7/8/02	1.715	1.715	1.716	1.715
S17	7/8/02	1.666	1.662	1.669	1.666
S18	7/8/02	1.728	1.730	1.736	1.731
S19	7/8/02				
S20	7/8/02	1.686	1.687	1.690	1.688
S21	7/8/02	1.683	1.687	1.689	1.686
S22	7/8/02	1.703	1.700	1.703	1.702
S23	7/8/02	1.660	1.665	1.671	1.665

POST

PUMP #	DATE	CALIBRATION w/ cyclone FLOWRATE, l/min Test 1	Test 2	Test 3	AVERAGE
S1	7/24/02	1.678	1.679	1.678	1.678
S2	7/24/02	1.695	1.695	1.697	1.696
S3	7/24/02	1.742	1.740	1.741	1.741
S4	7/24/02	1.706	1.700	1.710	1.705
S5	7/24/02	1.717	1.712	1.712	1.714
S6	7/24/02	1.662	1.663	1.657	1.661
S7	7/24/02	1.742	1.747	1.753	1.749
S8	7/24/02	1.685	1.693	1.687	1.688
S9	7/24/02	1.672	1.669	1.670	1.670
S10	7/24/02	1.746	1.751	1.747	1.748
S11	7/24/02	1.697	1.695	1.697	1.696
S12	7/24/02	1.706	1.703	1.700	1.703
S13	7/24/02	1.703	1.700	1.701	1.701
S14	7/24/02	1.660	1.651	1.656	1.656
S15	7/24/02	1.739	1.741	1.743	1.741
S16	7/24/02	1.709	1.709	1.707	1.708
S17	7/24/02	1.669	1.667	1.673	1.670
S18	7/24/02	1.734	1.725	1.727	1.729
S19	7/24/02	[illegible]	[illegible]	[illegible]	[illegible]
S20	7/24/02	1.695	1.697	1.692	1.695
S21	7/24/02	1.729	1.724	1.733	1.729
S22	7/24/02	1.714	1.711	1.720	1.715
S23	7/24/02	1.693	1.697	1.697	1.696

ENTERED

PITTSBURGH RESEARCH LAB

pumps

PRE 1,6 LITERS/MIN POST

PUMP #	DATE	CALIBRATION w/ cyclone FLOWRATE, l/min Test 1	Test 2	Test 3	AVERAGE		PUMP #	DATE	CALIBRATION w/ cyclone FLOWRATE, l/min Test 1	Test 2	Test 3	AVERAGE
S24	7/8/02	1,570	1,571	1,573	1,571		S24	7/24/02	1,587	1,583	1,583	1,584
S25	7/8/02	1.587	1,587	1,587	1,587		S25	7/24/02	1,612	1,615	1,620	1,616
J01	7/8/02	1,587	1.603	1,604	1.598		J01	7/24/02	1,596	1,596	1,594	1,595
J02	7/8/02	1,645	1,645	1,643	1,644		J02	7/24/02	1,597	1,598	1,599	1,598
J03	7/8/02	1,581	1,586	1,587	1,585		J03	7/24/02	1,600	1,598	1,597	1,598
J04	7/8/02	1,611	1,612	1,613	1,612		J04	7/24/02	1,603	1,604	1,603	1,603
J05	7/8/02	1,643	1,644	1,645	1,644		J05	7/24/02	1,634	1,635	1,634	1,634
J06	7/8/02	1,610	1,606	1,603	1,606		J06	7/24/02	1,581	1,584	1,589	1,585

Entered 7/23/02

PITTSBURGH RESEARCH LAB

pumps

PRE　　　　2.0 LITERS/MIN　　　　POST

		CALIBRATION w/ cyclone							CALIBRATION w/ cyclone			
PUMP	DATE	FLOWRATE, l/min					PUMP	DATE	FLOWRATE, l/min			
#		Test 1	Test 2	Test 3	AVERAGE		#		Test 1	Test 2	Test 3	AVERAGE
J07	7/8/02	2,006	2,007	2,008	2,007		J07	7/24/02	1,993	2,005	1,995	1,998
J08	7/8/02	1,985	1,980	1,984	1,983		J08	7/24/02	1,989	1,998	1,989	1,992
J09	7/8/02	1,969	1,975	1,972	1,972		J09	7/24/02	1,956	1,967	1,962	1,962
J010	7/8/02	2,007	2,009	2,009	2,008		J010	7/24/02	2,011	2,014	2,011	2,012

E.5 Field Study Data Record Sheets for the Coal Mine

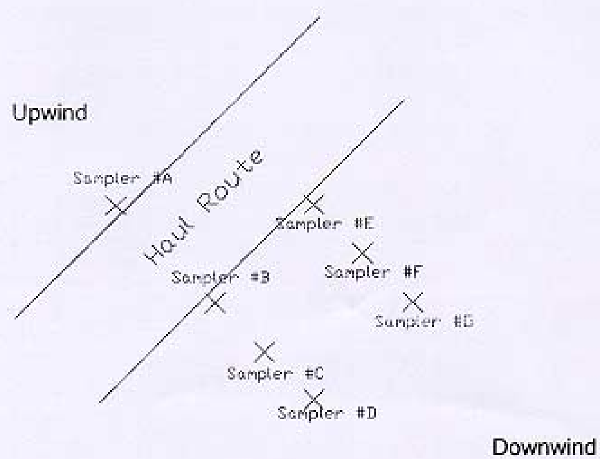


Figure 1 Sampling locations for field study.

6

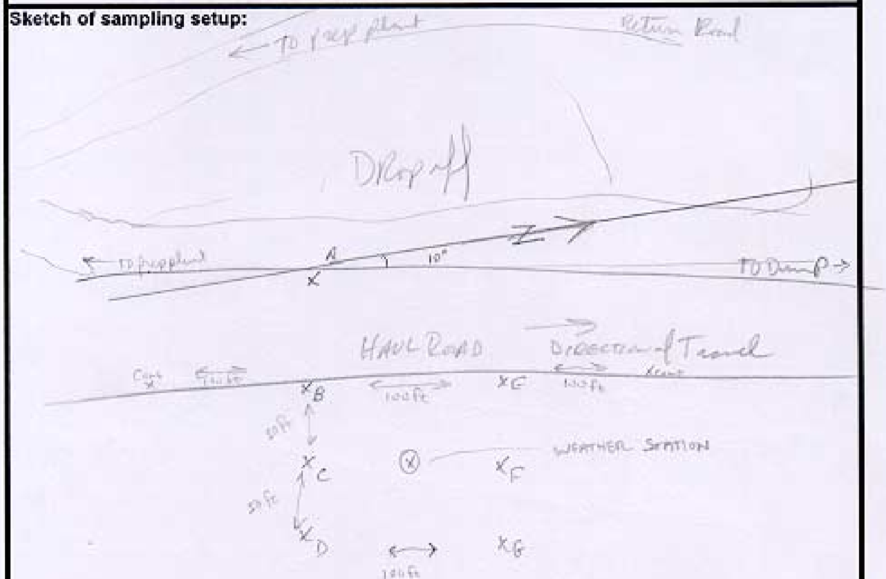
Location: [redacted] PREP PLANT [redacted]

Dates of Sampling:
8/2/02

Mining Operation Type: U/G COAL MINE /PREPPLANT
HAULING REJECT MATERIAL FOR COAL PREP PLANT

Material Types:
REJECT MATERIAL FROM COAL PREP PLANT

Sketch of sampling setup:



Possible Interferences/Sources of Contamination:
POSSIBLE from Return Haul Road

Entered 8/8/02

Date: 8/2/02		Location: [redacted] PREP PLANT						
Station # A		**Pump #**	**Cassette Filter #**	**PDR #**	**Impactor #**	**Start**	**Stop**	MINUTES USED pump run time (from pump)
	Respirable PDR	S13	140	SR3		9:19:50	2:46:18	329
	Respirable	S5	130			9:19:50	2:46:18	330
	Thoracic	J01	112			9:19:50	2:46:18	330
	Total	S3	170			9:19:50	2:46:18	DOWN HITTWICE
	Impactor	J07			A	9:19:50	2:46:18	329
Station # B		**Pump #**	**Cassette Filter #**	**PDR #**	**Impactor #**	**Start**	**Stop**	
	Respirable PDR	S11	129	JOPDR2		9:20:56	2:48:20	331
	Respirable	S20	123			9:20:56	2:48:20	331
	Thoracic	J06	104			9:20:56	2:48:20	330
	Total	S10	178			9:20:57	2:48:20	330
	Impactor	J09			B	9:20:56	2:48:26	330
Station # C		**Pump #**	**Cassette Filter #**	**PDR #**	**Impactor #**	**Start**	**Stop**	
	Respirable PDR	S1	148	JO PDR3		9:22:34	2:50:08	331
	Respirable	S4	151			9:22:34	2:50:08	331
	Thoracic	J04	107			9:22:34	2:50:08	331
	Total	S2	114			9:22:34	2:50:08	332
	Impactor	J010			C	9:22:34	2:50:08	331
Station # D		**Pump #**	**Cassette Filter #**	**PDR #**	**Impactor #**	**Start**	**Stop**	
	Respirable PDR	S7	118	JR1		9:23:54	2:51:10	329
	Respirable	S8	128			9:23:54	2:51:10	331
	Thoracic	J05	111			9:23:54	2:51:10	330
	Total	S18	172			9:23:54	2:51:10	330
	Impactor							
Station # E		**Pump #**	**Cassette Filter #**	**PDR #**	**Impactor #**	**Start**	**Stop**	
	Respirable PDR	S22	171	JR2		9:26:57	2:56:03	332
	Respirable	S14	147			9:26:57	2:56:03	332
	Thoracic	S24	92			9:26:57	2:56:03	332
	Total	S21	153			9:26:57	2:56:03	332
	Impactor							
Station # F		**Pump #**	**Cassette Filter #**	**PDR #**	**Impactor #**	**Start**	**Stop**	
	Respirable PDR	S23	175	4802		9:32:48	2:53:35	324
	Respirable	S15	173			9:32:48	2:53:55	324
	Thoracic	J02	108			9:32:48	2:53:55	324
	Total	S16	150			9:32:48	2:53:55	323
	Impactor							
Station # G		**Pump #**	**Cassette Filter #**	**PDR #**	**Impactor #**	**Start**	**Stop**	
	Respirable PDR	S9	155	GGPDR1		9:25:22	2:52:40	330
	Respirable	S12	137			9:25:22	2:52:40	330
	Thoracic	S25	109			9:25:22	2:52:40	331
	Total	S17	154			9:25:22	2:52:40	330
	Impactor							
Misc:								

ENTERED 10/8/2

Date: 8/02/02		Location: [redacted]		
Time	Barometer Reading	Dry Bulb Temperature	Wet Bulb Temperature	
9:39 Am	28.76	84	74	62%
10:41 Am	28.75	82	74	68%
11:41 Am	28.76	85	75	63%
12:40 pm	28.77	89	76	55%
1:40 pm	28.77	95	75	38%
2:42 pm	28.76	95	75	38%

Misc: Weather Station Started @ 9:18 Am

Overcast Partly Cloudy

Entered 8/7/02 RR

Date: 8/02/02		Location: [redacted] PREP PLANT				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		9:21:38	4:49	Cat 773B Loaded 50 TON	up	No
		9:25:46	4:57	PAYHAULER 350C LOADED 35-40 TON	up	"
		9:34:27	5:13	Cat 773B LOADED 50 TON	up	
		9:40:35	4.70	Cat 773B LOADED	up	
		9:47:25	4.76	PAYHAULER 350C LOADED 35-40 TON	up	
		9:58:00		Cat 773B Loaded	up	NO
		10:01:01		Cat 773B LOADED	up	No
		10:09:56		Pay Hauler 350C LOADED	up	NO
		10:14:06	4:44	Cat 773B Loaded	up	
		10:18:58	4.81	Cat 773B LOADED	up	No
		10:25:33	4.25	Pay Hauler 350C LOADED	up	NO
		10:31:29	4.43	Cat 773B LOADED	up	NO
		10:36:15	5:27	Cat 773B LOADED	up	NO
		10:44:30	3.82	PayHauler 350C LOADED	up	NO
		10:53:06	4.26	Cat 773B Loaded	up	No
		11:02:16	4.42	Cat 773B	up	NO
		11:04:38	4.32	Pay Hauler 350 C	up	NO
		11:09:37	4.28	Cat 773B	up	NO
		11:14:27	4.83	Cat 773B	up	NO
		11:20:51	4.81	Pay Hauler 350 C	up	No

Miscellaneous:

Entered 8/8/02

Date: 8/02/02

Location: [redacted] Prep plant

Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		11:27:58	4:42	Cat 773B ALL Loaded	up	NO
		11:31:55	4.96	Cat 773B	up	NO
		11:36:48	4.41	Pay Hauler 350C	up	No
		11:58:47	5,10	Cat 773B	up	NO
		11:59:57	3,87	Cat 773B	up	No
		12:02:57	4:22	Pay Hauler 350C	up	NO
		12:08:38	4:28	Cat 773	up	NO
		12:12:04	5,13	Cat 773	up	NO
		12:17:56	3.83	Pay Hauler	up	NO
		12:18:36	4.88	Cat 773B	up	NO
		12:25:06	4.59	Cat 773B	up	NO
		12:31:06	4,13	Cat 773B	up	NO
		12:50:59	4.42	Pay Hauler 350C	up	NO
		12:52:37	4.91	Cat 773B	up	NO
		12:54:42	4.75	Cat 773B	up	NO
		1:06:00		Pay Loader 350C	up	No
		1:07:50	4.64	Cat 773B	up	NO
		1:13:08	4.06	Cat 773B	up	NO
		1:18:52	5:01	Cat 773B	up	NO
		1:28:57	3,84	Pay Hauler 350C	up	No

Cleared up weather wise

Miscellaneous:

Entered 8/6/02

Date: 8/2/02

Location: [redacted] Prep Plant

Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		1:36:26	4.78	Cat 773B Loaded	up	No
		1:44:24	4.64	Cat 773B	up	No
		1:48:51	5.13	Cat 773B	up	NO
		1:50:26	4.10	PAY HAULER 350 C	up	NO
		1:55:56	2.18	Euclid R60 Empty	up	NO
		1:58:36	4.82	Cat 773B Loaded	up	NO
		2:00:34	4.63	Cat 773B Loaded	up	NO
		2:06:27	3.81	Pay Hauler 350c "	up	No
		2:08:31	4.55	Cat 773B	up	No
		2:12:08	4.99	Cat 773 D	up	NO
		2:18:30	4.45	Cat 773B	up	No
		2:30:09	3.65	Pay Hauler 350 C	up	NO
		2:31:41	5.12	Cat 773B	up	NO
		2:44:28	4.89	Cat 773B	up	No
		2:45:06	3.81	Euclid R60	up	No
		2:47:27	4.77	Cat 773	up	No
		2:49:43	6.14	water truck	up	yes

Miscellaneous:

2

Entered 8/8/02

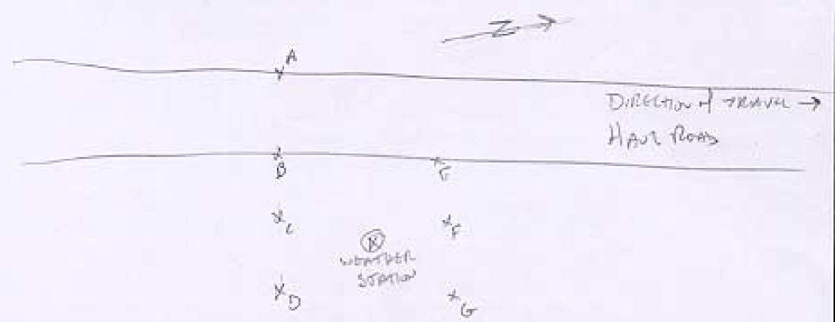
Location: [redacted] COAL PREP PLANT

Dates of Sampling: 8/05/02

Mining Operation Type:
UNDERGROUND COAL MINE PREPARATION PLANT
HAUL ROAD

Material Types:
U/G COAL REJECT TO WASTE DUMP

Sketch of sampling setup:



Possible Interferences/Sources of Contamination:

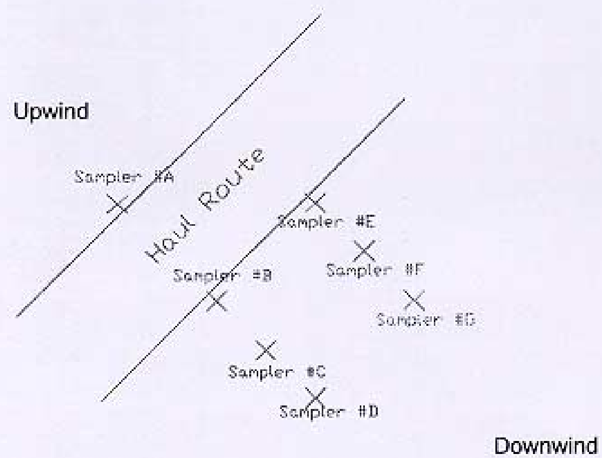


Figure 1 Sampling locations for field study.

Date: 8/5/02 | Location: [redacted] PREP PLANT

Station # A		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	Pump [illegible] (from pump)
	Respirable PDR	S22	124	JR3		8:56:23	2:15:52	322
	Respirable	S2	156			8:56:23	2:15:52	323
	Thoracic	J04	94			8:56:23	2:15:52	322
	Total	S1	138			8:56:23	2:15:52	323
	Impactor	J010			A	8:56:23	2:15:52	323

Station # B		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S21	179	JO PDR2		8:57:26	2:18:05	323
	Respirable	S16	144			8:57:26	2:18:05	323
	Thoracic	J06	105			8:57:26	2:18:05	324
	Total	S17	119			8:57:26	2:18:05	323
	Impactor	J09			B	8:57:26	2:18:05	323

Station # C		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S15	115	JO PDR3		8:58:48	2:21:54	326
	Respirable	S23	162			8:58:48	2:21:54	326
	Thoracic	S25	103			8:58:48	2:21:54	327
	Total	S9	164			8:58:48	2:21:54	326
	Impactor	J08			C	8:58:48	2:21:54	86

Station # D		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S12	166	JR1		8:59:45	2:23:23	326
	Respirable	S3	141			8:59:45	2:23:23	327
	Thoracic	J05	91			8:59:45	2:23:23	327
	Total	S7	120			8:59:45	2:23:23	326
	Impactor							

Station # E		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S10	167			9:03:05	2:19:38	319
	Respirable	S14	121			9:03:05	2:19:38	319
	Thoracic	J01	102			9:03:05	2:19:38	320
	Total	S4	152			9:03:05	2:19:38	320
	Impactor							

Station # F		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S18	134	4802		9:01:49	2:25:24	327
	Respirable	S5	116			9:01:49	2:25:24	327
	Thoracic	S24	93			9:01:49	2:25:24	326
	Total	S11	149			9:01:49	2:25:24	327
	Impactor							

Station # G		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S13	143	GG PDR1		9:00:55	2:25:54	328
	Respirable	S8	169			9:00:55	2:25:55	329
	Thoracic	J02	104			9:00:55	2:25:55	328
	Total	S20	161			9:00:55	2:25:54	328
	Impactor							

Misc:

Date: 8/5/02

Location: [redacted] COAL PREP PLANT [redacted] TWNSHIP

Time	Barometer Reading	Dry Bulb Temperature	Wet Bulb Temperature	
9:10	28.78	81	74	72%
10:19	28.79	87	75	57%
11:15	28.77	89	77	58%
12:14	28.77	88	76	58%
1:14	28.75	90	76	52%
1:52	28.74	79	—	NONE TAKEN INTERMEDIATE
2:08	28.73	79	73	74%

Misc: Weather Station Started 8:55 AM

Clear / partly overcast

Rained @ end of the Day

ENTERED 8/8/02

Date: 8/5/02		Location: [redacted] PREP PLANT				
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		8:58:00		Cat 773B LOADED	up	No
		9:11:17	4.90	Cat 773B	up	No
		9:24:43	4.99	Cat 773B	up	No
		9:38:33	4.92	Cat 773 B	up	No
		9:51:22	4.10	Cat 773B	up	No
		9:54:00	4.70	Cat 773B	up	No
		10:06:19	5.02	Cat 773B	up	No
		10:07:24	—	Cat 773 B	up	No
		10:21:15	4.84	Cat 773B	up	No
		10:23:53	4.55	Cat 773 B	up	No
		10:37:44	4.28	Cat 773B	up	No
		10:40:22	4.74	Cat 773B	up	No
		10:54:04	4:40	Cat 773B	up	No
		10:55:32	4.71	Cat 773B	up	No
		11:03:15	3.51	Euclid R60	up	No
		11:09:44	4.38	Cat 773B	up	No
		11:12:20	4.84	Cat 773B	up	No
		11:24:40	~~4.53~~	Cat 773B	up	No
		11:25:49	5.00	Cat 773B	up	No
		11:39:44	4.73	Cat 773B	up	No

Miscellaneous:

[illegible]

ENTERED 8/8/02

[redacted]

Date: 8/05/02	Location: [redacted] Coal Prep plant					
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
	11:40:54	5:15		Cat 773B	up	NO
	11:41:34	15,88		16G Grader Cat	up	NO
	11:56:07	4.66		Cat 773B	up	NO
	11:58:36	—		Cat 773B	up	NO
	12:11:46	4,56		Cat 773B	up	NO
	12:12:56	4,62		Cat 773B	up	NO
	12:23:05	15,56		Euclid water Truck	up	water Truck yes
	12:24:45	13:46		Euclid water Truck	Down	water Truck yes
	12:27:11	4,72		Cat 773 B	up	
	12:28:15	9,59		Euclid water Truck	up	yes
	12:28:31	5.08		Cat 773B	up	
	12:29:53	10:11		Euclid water Truck	Down	yes
	12:34:19	5.87		Payhauler 350C	up	
	12:42:03	4.06		Cat 773B	up	
	12:44:10	4,56		Cat 773B	up	
	12:56:42	4,29		Cat 773B	up	
	12:59:11	4,64		Cat 773B	up	
	1:12:48	4.92		Cat 773B	up	
	1:13:50	4,80		Cat 773B	up	
	1:27:17	4,50		Cat 773 B	up	

Miscellaneous:

ENTERED 8/8/02

Date: 8/05/02	Location: [redacted] Coal prep plant					
Equip. ID#	~~Time Entered~~	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
	1:28:34	4.72		Cat 773B	up	
	1:42:33	—		Cat 773B	up	
	1:43:38	4.66		Cat 773B	up	
	1:57:55	—		Cat 773B	up	
	2:10:10	—		Cat 773B	up	
	2:16:49	4.99	~~4~~	Cat 773B	up	
	2:21:02	—		Cat 773B	up	

Miscellaneous:

3

ENTERED 8/8/2

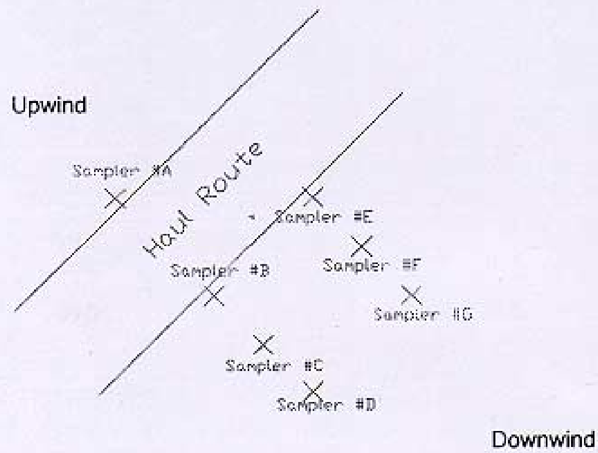


Figure 1 Sampling locations for field study.

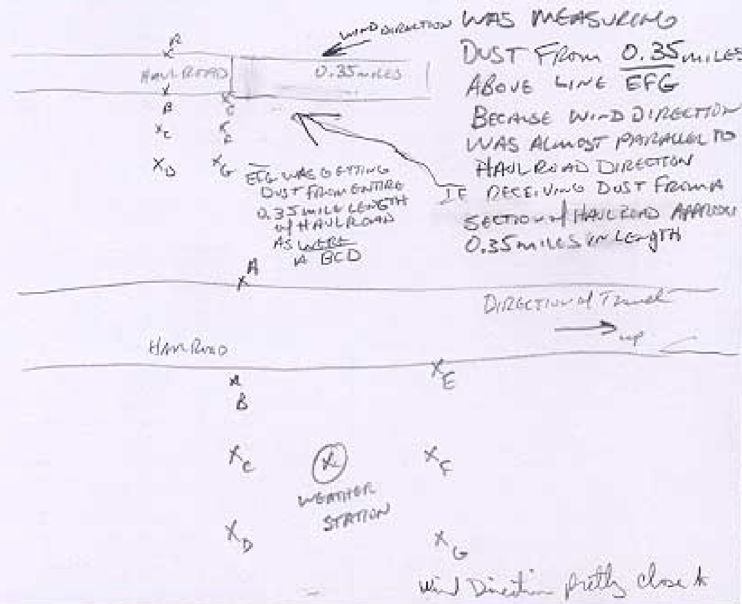
Location: [redacted] Coal Prep Plant

Dates of Sampling: 8/06/02

Mining Operation Type: U/G Coal mine Coal preparation plant

Material Types: U/G Coal Reject From Prep Plant Waste Rock

Sketch of sampling setup:



For north See previous Sketches

Possible Interferences/Sources of Contamination: Parallel to Haul Road

Date: 8/6/02 | Location: [redacted] Coal Prep Plant

Station # A		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	Pump RunTime (From Pump)
	Respirable PDR	S4	126	JR3		8:44:47	3:04:00	384
	Respirable	S12	157			8:44:47	3:04:00	382
	Thoracic	J03	101			8:44:47	3:04:00	382
	Total	S18	174			8:44:47	3:04:00	383
	Impactor	J07			A	8:44:47	3:04:00	382

Station # B		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S3	176	JOPDR 2		8:45:50	3:05:04	383
	Respirable	S15	139			8:45:50	3:05:04	382
	Thoracic	J06	110			8:45:50	3:05:04	383
	Total	S2	135			8:45:50	3:05:04	384
	Impactor	J09			B	8:45:50	3:05:04	382

Station # C		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S5	117	JOPDR3		8:46:49	3:06:33	384
	Respirable	S9	177			8:46:49	3:06:33	383
	Thoracic	J02	113			8:46:49	3:06:33	383
	Total	S6	168			8:46:49	3:06:33	382
	Impactor	J010			C	8:46:49	3:06:33	384

Station # D		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S13	122	JR1		8:48:51	3:11:36	386
	Respirable	S22	146			8:48:51	3:11:36	386
	Thoracic	J01	99			8:48:51	3:11:36	387
	Total	S7	158			8:48:51	3:11:36	386
	Impactor							

Station # E		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S8	131	JR4		8:51:57	3:09:23	382
	Respirable	S1	125			8:51:57	3:09:23	381
	Thoracic	S24	98			8:51:57	3:09:23	381
	Total	S17	145			8:51:57	3:09:23	381
	Impactor							

Station # F		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S23	127	4802		8:50:45	3:10:22	383
	Respirable	S20	142			8:50:45	3:10:22	383
	Thoracic	J04	96			8:50:45	3:10:22	383
	Total	S14	163			8:50:45	3:10:22	382
	Impactor							

Station # G		Pump #	Cassette Filter #	PDR #	Impactor #	Start	Stop	
	Respirable PDR	S16	165	JOPDR1		8:49:55	3:12:53	386
	Respirable	S21	159			8:49:55	3:12:53	386
	Thoracic	J05	97			8:49:55	3:12:53	387
	Total	S10	160			8:49:55	3:12:53	387
	Impactor							

Misc:

Entered

Date: 8/06/02	Loc [redacted]			
Time	Barometer Reading	Dry Bulb Temperature	Wet Bulb Temperature	
8:57	28.81	65	59	70%
10:02	28.81	68	59	58%
11:02	28.83	70	59	52%
12:02	28.83	71	60	52%
1:02	28.82	74	60	43%
2:02	28.81	77	61	38%
3:00	28.81	81	65	41%

Misc:

Weather Station Started @
8:43AM

ENTERED
8/8/02

Date: 8/6/02

Location: [redacted] Coal Prep plant

Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		8:48:01	—	Cat 773B Loaded	up	No
		8:53:09	—	Cat 773B	up	
		8:59:50	3.66	Euclid R60	up	No
		9:05:15	4.71	Cat 773B	up	No
		9:14:08	4.46	Cat 773B	up	No
		9:18:00	3.47	Euclid R60	up	No
		9:23:15	4.41	Cat 773 B	up	No
		9:31:07	3.34	Euclid R60	up	No
		9:34:36	4.33	Cat 773 B	up	No
		9:39:29	4.46	Cat 773 B	up	No
		9:46:18	3.22	Euclid R60	up	No
		9:51:15	4.08	Cat 773B	up	No
		9:56:46	4.43	Cat 773B	up	No
		10:02:05	3.29	Euclid R60	up	No
		10:07:58	4.53	Cat 773B	up	No
		10:12:34	4.30	Cat 773B	up	
		10:19:27	3.31	Euclid R60	up	
		10:24:57	4.06	Cat 773B	up	
		10:29:10	4.27	Cat 773B	up	
		10:37:03	3.65	Euclid R60	up	

Rained the night before

Miscellaneous:

ENTERED 8/8/02

1

Date: 8/6/02		Lo[redacted] Coal prep plant				
Equip. ID#	**Time Entered**	**Time Exited**	**Stop-watch Time**	**Equipment Description**	**Direction Equipment Traveled**	**Roads Watered ??**
		10:42:19	4.10	Cat 773B	up	No
		10:47:44	4.44	Cat 773B	up	↓
		10:53:56	4.24	Euclid R60	up	
		11:00:20	4.32	Cat 773B	up	No
		11:07:07	3.10	Euclid R60	up	No
		11:13:31	4.52	Cat 773B	up	
		11:28:56	3.33	Euclid R60	up	
		11:27:10	4.49	Cat 773B	up	
		11:35:06	3.27	Euclid R60	up	
		11:~~34~~ 39:49	4.29	Cat 773B	up	
		11:46:54	4.36	Cat 773B	up	
		11:53:59	3.31	Euclid R60	up	
		12:00:18	4.48	Cat 773B	up	
		12:05:22	4.41	Cat 773B	up	
		12:12:21	3.30	Euclid R60	up	
		12:18:02	3.95	Cat 773B	up	
		12:23:20	4.02	Cat 773B	up	
		12:30:22	3.19	Euclid R60	up	
		12:34:58	4.31	Cat 773B	up	
		12:40:41	4.22	Cat 773B	up	

Miscellaneous:

7

Entered 8/9/02

Date: 8/6/02	Location: [redacted] Coal prep plant					
Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		12:47:36	3.59	Euclid R60	up	No
		12:52:24	4.38	Cat 773B	up	
		12:58:03	4.34	Cat 773B	up	
		1:05:57	3.58	Euclid R60	up	
		1:11:27	4.09	Cat 773B	up	
		1:17:23	4.36	Cat 773B	up	
		1:24:02	3.19	Euclid R60	up	
		1:29:38	4.01	Cat 773B	up	
		1:35:38	4.59	Cat 773B	up	
		1:43:15	3.54	Euclid R60	up	
		1:48:47	4.09	Cat 773B	up	
		1:54:47	4.52	Cat 773	up	
		2:02:07	3.95	Euclid R60	up	
		2:08:43	4.14	Cat 773B	up	
		2:14:25	4.49	Cat 773B	up	
		2:21:46	3.36	Euclid R60	up	
		2:28:08	3.85	Cat 773B	up	
		2:33:50	3.50	Cat 773B	up	
		2:41:13	3.45	Euclid R60	up	
		2:46:34	3.55	Cat 773B	up	

Miscellaneous:

2

ENTERED 8/6/02

Date: 8/6/02 | Location: [redacted] Coal Prep plant

Equip. ID#	Time Entered	Time Exited	Stop-watch Time	Equipment Description	Direction Equipment Traveled	Roads Watered ??
		2:52:56	4.29	Cat 773B	up	No
		3:00:17	3.39	Euclid R60	up	
		3:06:05		Cat 773B	up	
		3:11:45		Cat 773B	up	

Miscellaneous:

11

Entered 8/18/08

E.6 Field Study Filter Results and Pump Test Data Record Sheets for the Coal Mine

TOTAL / JOHN O / RANDY R. 30 JULY 02 (1 OF 2)

391	14.089	14.130
392	13,039	13,574
393	12.725	12,792
394	11,738	12.058
395	13,557	13,550
396	14,512	14.605
397	12.683	12.752
398	13,394	14,010
399	13,354	13.456
400	12,849	12,841
401	13,554	14,208
402	14,385	14,637
403	13.938	13,991
404	13.825	13,878
405	13,491	13,665
406	13,492	14,120
407	13.375	13,540
408	14,662	14,855
409	13,975	14,080
410	12.176	12,649
411	13.168	13,265
412	12.920	13,504
413	13,949	14.070
414	14,135	14,578
415	9.486	9.503
416	10.773	10.790
417	14.531	14.569
418	14.365	14.401
419	14.454	14.742
420	13,471	13.563
421	9.915	9.985
422	10.493	10,500
423	11.261	11,400
424	11.180	11,249
425	11.185	11,316
426	10,825	10.987
427	13,612	13,664

428	12,936	12,971
429	13,079	13,256
430	15.011	15.166
431	10-574	10,689
432	11,170	13,867 *
433	11.320	11,290
434	9.860	9.880
435	10,454	11,861
436	11.036	11,015
437	13,312	13,353
438	13,841	14.422
439	13,683	13,867
440	12,840	12,990
441	12,581	12.578
442	12.205	12.215
443	11.378	11,378
444	11.514	11.554
445	11,567	12.831
446	10.978	10.975
447	13.130	13,298
448	12,901	12.963
449	13,403	13.623
450	13,602	14.035
451	12,145	12,175
452	12,114	12,590
453	11,735	13,159 * TOTAL
454	11.394	11,742
455	11.931	11,956
456	11,499	11.569
457	13.662	13.861
458	13,626	13,918
459	12,747	12,770
460	13.695	13.965
461	11.247	11,315
462	10,766	10,768
463	11,136	11.466
464	11.686	11.882
465	11.572	11.563

* HEAVY? WET? TOTAL?

T.MAL (2 OF 2) 30 JULY 02

466	10,992	10,997
467	13,008	13,075
468	14,016	14,277
469	13,743	13,771
470	10,607	12,041
471	11,031	11,154
472	11,499	11,734
473	10,497	10,540
474	11,000	12,608
475	10,619	10,635
476	11,373	11,498
477	11,907	11,979
478	13,076	14,656
479	14,219	14,276
180	10,246	10,232

T. MAL / JOHN O. / R. REED 30 JUL 02

J	1	25.426	26.530
(A)	2	25.067	25.533
	3	25.249	25.723
	4	25.094	25.358
	5	26.001	26.203
	6	25.115	25.228
	F	16.035	16.084
K	1	25.380	26.751
(B)	2	25.045	25.621
	3	24.873	25.396
	4	24.966	25.283
	5	25.055	25.295
	6	25.091	25.225
	F	14.859	14.930
L	1	25.329	25.786
(C)	2	25.662	25.796
	3	25.099	25.218
	4	25.452	25.569
	5	24.784	24.852
	6	25.102	25.138
	F	14.332	14.374

8/2/02

M	1	25.461	25.983
(A)	2	25.665	25.972
	3	25.646	25.885
	4	25.057	25.205
	5	24.998	25.127
	6	25.743	25.786
	F	13.167	13.226
N	1	25.272	25.926
(B)	2	25.168	25.332
	3	25.189	25.328
	4	24.939	25.032
	5	25.262	25.350
	6	25.248	25.289
	F	13.339	13.391

8/5/02

8/5/02

O	1	24.926	25.032
(C)	2	24.413	25.424
	3	25.544	25.544
	4	25.453	25.455
	5	24.894	24.892
	6	25.586	25.583
	F	12.836	12.848

? May not use in Data Consider Quadrant only ran 86 min

P	1	25.190	27.145
(A)	2	24.593	25.46
	3	25.128	25.871
	4	24.164	24.595
	5	24.800	25.158
	6	24.923	25.073
	F	15.924	15.955
Q	1	25.103	27.457 ✓✓
(B)	2	25.538	~~25.237~~ 26.237 per John O 10/8/02
	3	25.254	25.722
	4	25.403	25.747
	5	25.429	25.761
	6	25.367	25.494
	F	15.200	15.246
R	1	25.301	25.942
(C)	2	25.418	25.638
	3	25.208	25.363
	4	25.363	25.516
	5	25.712	25.809
	6	25.020	25.065
	F	14.478	14.500

8/6/02

✓✓ - DOUBLE CHECKED

pumps

1.7 LITER/MIN

PUMP #	DATE	CALIBRATION w/ cyclone FLOWRATE, l/min Test 1	Test 2	Test 3	AVERAGE
S1	7/8/02	1.696	1.693	1.690	1.693
S2	7/8/02	1.742	1.746	1.744	1.744
S3	7/8/02	1.712	1.713	1.714	1.713
S4	7/8/02	1.705	1.706	1.714	1.708
S5	7/8/02	1.724	1.718	1.726	1.723
S6	7/8/02	1.673	1.677	1.676	1.675
S7	7/8/02	1.721	1.718	1.716	1.718
S8	7/8/02	1.668	1.663	1.667	1.666
S9	7/8/02	1.688	1.687	1.689	1.688
S10	7/8/02	1.692	1.692	1.694	1.693
S11	7/8/02	1.685	1.680	1.677	1.681
S12	7/8/02	1.717	1.718	1.717	1.717
S13	7/8/02	1.709	1.711	1.710	1.710
S14	7/8/02	1.682	1.673	1.681	1.679
S15	7/8/02	1.723	1.723	1.723	1.723
S16	7/8/02	1.715	1.715	1.716	1.715
S17	7/8/02	1.666	1.662	1.669	1.666
S18	7/8/02	1.728	1.730	1.736	1.731
S19	7/8/02				
S20	7/8/02	1.686	1.687	1.690	1.688
S21	7/8/02	1.683	1.687	1.689	1.686
S22	7/8/02	1.703	1.700	1.703	1.702
S23	7/8/02	1.660	1.665	1.671	1.665

PUMP #	DATE	CALIBRATION w/ cyclone FLOWRATE, l/min Test 1	Test 2	Test 3	AVERAGE
S1	[illegible]				
S2	[illegible]				
S3					
S4					
S5					
S6					
S7					
S8					
S9					
S10					
S11					
S12					
S13					
S14					
S15					
S16					
S17					
S18					
S19					
S20					
S21					
S22					
S23					

pumps

1,6 LITERS/min

PUMP #	DATE	CALIBRATION w/ cyclone FLOWRATE, l/min Test 1	Test 2	Test 3	AVERAGE		PUMP #	DATE	CALIBRATION w/ cyclone FLOWRATE, l/min Test 1	Test 2	Test 3	AVERAGE
S24	7/8/02	1,570	1.571	1.573	1,571							
S25	7/8/02	1.587	1,587	1.587	1,587							
J01	7/8/02	1,587	1.603	1.604	1.598							
J02	7/8/02	1,645	1.645	1.643	1.644							
J03	7/8/02	1.581	1.586	1,587	1.585							
J04	7/8/02	1.611	1.612	1,613	1,612							
J05	7/8/02	1,643	1,644	1,645	1,644							
J06	7/8/02	1,610	1,606	1,603	1,606							

7/24/02
PITTSBURGH RESEARCH LAB

pumps

PRG 1,7 LITERS/min

PUMP #	DATE	CALIBRATION w/ cyclone FLOWRATE, l/min Test 1	Test 2	Test 3	AVERAGE
S1	7/24/02	1.678	1.679	1.678	1.678
S2	7/24/02	1.695	1.695	1.697	1.696
S3	7/24/02	1.742	1.740	1.741	1.741
S4	7/24/02	1.706	1.700	1.710	1.705
S5	7/24/02	1.717	1.712	1.712	1.714
S6	7/24/02	1.662	1.663	1.657	1.661
S7	7/24/02	1.668	1.664	1.669	1.667
S8	7/24/02	1.685	1.693	1.687	1.688
S9	7/24/02	1.672	1.669	1.670	1.670
S10	7/24/02	1.720	1.717	1.718	1.718
S11	7/24/02	1.697	1.695	1.697	1.696
S12	7/24/02	1.706	1.703	1.700	1.703
S13	7/24/02	1.703	1.700	1.701	1.701
S14	7/24/02	1.660	1.657	1.656	1.656
S15	7/24/02	1.739	1.741	1.743	1.741
S16	7/24/02	1.709	1.709	1.707	1.708
S17	7/24/02	1.669	1.667	1.673	1.670
S18	7/24/02	1.734	1.725	1.727	1.729
S19	7/24/02				
S20	7/24/02	1.695	1.697	1.692	1.695
S21	7/24/02	1.729	1.724	1.733	1.729
S22	7/24/02	1.714	1.711	1.720	1.715
S23	7/24/02	1.653	1.657	1.657	1.696

PUMP #	DATE	CALIBRATION w/ cyclone FLOWRATE, l/min Test 1	Test 2	Test 3	AVERAGE
S1	8/7/02	1.659	1.656	1.657	1.657
S2	8/7/02	1.698	1.700	1.698	1.699
S3	8/7/02	1.712	1.705	1.711	1.709
S4	8/7/02	1.652	1.645	1.645	1.647
S5	8/7/02	1.711	1.716	1.710	1.712
S6	8/7/02	1.645	1.640	1.644	1.643
S7	8/7/02	1.646	1.650	1.645	1.647
S8	8/7/02	1.674	1.669	1.675	1.673
S9	8/7/02	1.634	1.633	1.631	1.633
S10	8/7/02	1.722	1.720	1.720	1.721
S11	8/7/02	1.647	1.644	1.644	1.645
S12	8/7/02	1.711	1.711	1.711	1.711
S13	8/7/02	1.723	1.720	1.726	1.723
S14	8/7/02	1.678	1.676	1.673	1.676
S15	8/7/02	1.726	1.726	1.726	1.726
S16	8/7/02	1.705	1.704	1.710	1.706
S17	8/7/02	1.628	1.620	1.622	1.623
S18	8/7/02	1.736	1.737	1.741	1.738
S19	8/7/02				
S20	8/7/02	1.700	1.698	1.697	1.698
S21	8/7/02	1.692	1.697	1.703	1.697
S22	8/7/02	1.685	1.688	1.690	1.688
S23	8/7/02	1.643	1.652	1.657	1.651

Page 1

ENTERED 8/8/02

pumps

2.0 LITERS/min

		CALIBRATION w/ cyclone			
PUMP	DATE	FLOWRATE, l/min			
#		Test 1	Test 2	Test 3	AVERAGE
J07	7/8/02	2,006	2,007	2,008	2,007
J08	7/8/02	1,985	1.980	1,984	1,983
J09	7/8/02	1,969	1,975	1,972	1,972
J010	7/8/02	2,007	2,009	2,009	2,008

		CALIBRATION w/ cyclone			
PUMP	DATE	FLOWRATE, l/min			
#		Test 1	Test 2	Test 3	AVERAGE

Page 1

E.7 Road Sample Analysis Results of Total Moisture, Silt Content, and Specific Gravity

GEOCHEMICAL TESTING
Environmental and Energy Analysis

2005 N Center Ave
Somerset PA 15501

814/443-1671
814/445-6666
FAX: 814/445-6729

ANALYSIS REPORT

Client: NIOSH

Sampled by: Randy Reed

Sampling Date: 07/16/2002

Use this one for 7/17/03

Analyzed on: 08/26/2002

Description: [redacted] Road Sample
PO #0000258586

LAB NO. 02-C070956

As Received

Total Moisture....D2961.... 0.17

SCREEN DATA:

Size Fraction	wt %	cum wt %
+200M....................................	79.74	79.74
200M X 0..................................	20.26	100.00

True Specific Gravity 2.85

[redacted]

MEMBER ACIL

GEOCHEMICAL TESTING
Environmental and Energy Analysis

2005 N Center Ave
Somerset PA 15501

814/443-1671
814/445-6666
FAX: 814/445-6729

ANALYSIS REPORT

Client: NIOSH

Sampled by: Randy Reed

Sampling Date: 07/16/2002

Analyzed on: 08/26/2002

Description: [redacted] Road Surface Bulk Material Across Road
PO #0000258586

LAB NO. 02-C070955

As Received

Total Moisture....D2961.... 0.26

SCREEN DATA:

Size Fraction	wt %	cum wt %
+200M......................................	73.04	73.04
200M X 0...................................	26.96	100.00

True Specific Gravity 2.85

[redacted]

MEMBER ACIL

GEOCHEMICAL TESTING
Environmental and Energy Analysis

2005 N Center Ave
Somerset PA 15501

814/443-1671
814/445-6666
FAX: 814/445-6729

ANALYSIS REPORT

Client: NIOSH

Sampled by: Randy Reed

Sampling Date: 08/02/2002

Analyzed on: 08/26/2002

Description: [redacted] Road Sample
PO #0000258586

LAB NO. 02-C070958

As Received

Total Moisture....D2961.... 0.65

SCREEN DATA:

Size Fraction	wt %	cum wt %
+200M.....................................	78.82	78.82
200M X 0..................................	21.18	100.00

True Specific Gravity 2.44

[redacted]

GEOCHEMICAL TESTING
Environmental and Energy Analysis

2005 N Center Ave
Somerset PA 15501

814/443-1671
814/445-6666
FAX: 814/445-6729

ANALYSIS REPORT

Client: NIOSH

Sampled by: Randy Reed

Sampling Date: 08/05/2002

Analyzed on: 08/26/2002

Description: [redacted] Bulk Road Sample
PO #0000258586

LAB NO. 02-C070959

As Received

Total Moisture....D2961.... 0.68

SCREEN DATA:

Size Fraction	wt %	cum wt %
+200M......................................	73.80	73.80
200M X 0...................................	26.20	100.00

True Specific Gravity 2.49

[redacted]

MEMBER ACIL

GEOCHEMICAL TESTING
Environmental and Energy Analysis

2005 N Center Ave
Somerset PA 15501

814/443-1671
814/445-6666
FAX: 814/445-6729

ANALYSIS REPORT

Client: NIOSH

Sampled by: Randy Reed

Sampling Date: 08/06/2002

Analyzed on: 08/26/2002

Description: [redacted] Bulk Road Material
PO #0000258586

LAB NO. 02-C070960

As Received

Total Moisture....D2961....   0.54

SCREEN DATA:

Size Fraction	wt %	cum wt %
+200M......................................	81.66	81.66
200M X 0...................................	18.34	100.00

True Specific Gravity 2.52

[redacted]

MEMBER ACIL

E.8 Dynamic Component Program Model and ISC3 Model Output for the Stone Quarry and Coal Mine

Dynamic ISC3 Manipulations Complete

7/16/02 Field Study

Input Parameters

Number of receptors = 7
X-Y Coordinates of receptors:
Receptor # 1 X Coordinate = 987.22 Y Coordinate = 1111.07
Receptor # 2 X Coordinate = 1000 Y Coordinate = 1000
Receptor # 3 X Coordinate = 1046.98 Y Coordinate = 982.9
Receptor # 4 X Coordinate = 1093.97 Y Coordinate = 965.8
Receptor # 5 X Coordinate = 1034.2 Y Coordinate = 1093.97
Receptor # 6 X Coordinate = 1081.18 Y Coordinate = 1076.87
Receptor # 7 X Coordinate = 1128.17 Y Coordinate = 1059.77

Number of trucks = 1 Weight of trucks (tons)= 20
Speed of loaded truck (m/sec) = 6.84
Speed of empty truck (m/sec) = 6.84

Background Dust Level (micrograms/m^3) = 162.8
Silt Content (%) = 26.96
Moisture Content (%) = 0.26

Calculation Results

Emissions from loaded truck (grams/sec) = 18.91864

Total Instantaneous Average Concentration of PM10 at receptors:

Results for Receptor 1 = 704.5278 micrograms/m^3

Results for Receptor 2 = 2027.95 micrograms/m^3

Results for Receptor 3 = 758.6167 micrograms/m^3

Results for Receptor 4 = 480.1035 micrograms/m^3

Results for Receptor 5 = 2032.838 micrograms/m^3

Results for Receptor 6 = 763.0479 micrograms/m^3

Results for Receptor 7 = 484.3288 micrograms/m^3

Dynamic ISC3 Manipulations Complete (continued)

Page 2

Calculation Results

Time Weighted Average Concentration of PM10 at receptors:

Results for Receptor 1 = 798.9686 micrograms/m^3

Results for Receptor 2 = 2353.106 micrograms/m^3

Results for Receptor 3 = 862.4869 micrograms/m^3

Results for Receptor 4 = 535.4198 micrograms/m^3

Results for Receptor 5 = 2358.846 micrograms/m^3

Results for Receptor 6 = 867.6906 micrograms/m^3

Results for Receptor 7 = 540.3817 micrograms/m^3

```
 *** ISCST3 - VERSION 00101 ***     *** Acco ISC3 Modeling Routines for 7-16-02                       ***
01/27/03
                                     ***                                                              ***
12:34:54
**MODELOPTs:
PAGE  11
CONC                         RURAL  FLAT          DFAULT

                              *** THE PERIOD (   897 HRS) AVERAGE CONCENTRATION   VALUES FOR SOURCE GROUP: ALL       ***
                                  INCLUDING SOURCE(S):       L1       , L2       , L3       , L4       , L5       , L6       ,
L7        ,
         L8       , L9       , L10      , L11      , L12      , L13      , L14      , L15      ,

                                             *** DISCRETE CARTESIAN RECEPTOR POINTS ***

                                        ** CONC OF DUST      IN MICROGRAMS/M**3                          **

      X-COORD (M)  Y-COORD (M)        CONC                    X-COORD (M)  Y-COORD (M)      CONC
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - -
          987.22      1111.07      5605.33105                      1000.00      1000.00     3248.41089
□□□□□□□□□□□□
         1046.98       982.90      2551.45728                      1093.97       965.80     1379.66956
         1034.20      1093.97      3125.16260                      1081.18      1076.87     2469.42822
         1128.17      1059.77      1319.03906
```

Dynamic ISC3 Manipulations Complete

7/17/02 Field Study

Input Parameters

Number of receptors = 7
X-Y Coordinates of receptors:
Receptor # 1 X Coordinate = 953.02 Y Coordinate = 1017.1
Receptor # 2 X Coordinate = 1000 Y Coordinate = 1000
Receptor # 3 X Coordinate = 1046.98 Y Coordinate = 982.9
Receptor # 4 X Coordinate = 1093.97 Y Coordinate = 965.8
Receptor # 5 X Coordinate = 1034.2 Y Coordinate = 1093.97
Receptor # 6 X Coordinate = 1081.18 Y Coordinate = 1076.87
Receptor # 7 X Coordinate = 1128.17 Y Coordinate = 1059.77

Number of trucks = 1 Weight of trucks (tons)= 20
Speed of loaded truck (m/sec) = 7.39
Speed of empty truck (m/sec) = 7.39

Background Dust Level (micrograms/m^3) = 171.5
Silt Content (%) = 20.26
Moisture Content (%) = 0.17

Calculation Results

Emissions from loaded truck (grams/sec) = 18.47444

Total Instantaneous Average Concentration of PM10 at receptors:

Results for Receptor 1 = 1148.795 micrograms/m^3

Results for Receptor 2 = 2973.888 micrograms/m^3

Results for Receptor 3 = 1012.218 micrograms/m^3

Results for Receptor 4 = 592.5993 micrograms/m^3

Results for Receptor 5 = 2988.706 micrograms/m^3

Results for Receptor 6 = 1026.186 micrograms/m^3

Results for Receptor 7 = 604.8571 micrograms/m^3

Dynamic ISC3 Manipulations Complete (continued)

Page 2

Calculation Results

Time Weighted Average Concentration of PM10 at receptors:

Results for Receptor 1 = 1140.888 micrograms/m^3

Results for Receptor 2 = 2951.214 micrograms/m^3

Results for Receptor 3 = 1005.416 micrograms/m^3

Results for Receptor 4 = 589.1922 micrograms/m^3

Results for Receptor 5 = 2965.912 micrograms/m^3

Results for Receptor 6 = 1019.271 micrograms/m^3

Results for Receptor 7 = 601.3508 micrograms/m^3

*** ISCST3 - VERSION 00101 ***   *** Acco ISC3 Modeling Routines for 7-17-02   ***
01/27/03
***   ***
12:50:57
**MODELOPTs:
PAGE 11
CONC   RURAL FLAT   DFAULT

*** THE PERIOD (845 HRS) AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): L1 , L2 , L3 , L4 , L5 , L6 ,
L7 ,
L8 , L9 , L10 , L11 , L12 , L13 , L14 , L15 ,

*** DISCRETE CARTESIAN RECEPTOR POINTS ***

** CONC OF DUST IN MICROGRAMS/M**3 **

X-COORD (M)	Y-COORD (M)	CONC	X-COORD (M)	Y-COORD (M)	CONC
953.02	1017.10	12925.27051	1000.00	1000.00	7425.93066
□□□□□□□□□□□□					
1046.98	982.90	3932.87915	1093.97	965.80	1878.07166
1034.20	1093.97	6844.04785	1081.18	1076.87	3827.68262
1128.17	1059.77	1786.77808			

Dynamic ISC3 Manipulations Complete

7/18/02 Field Study

Input Parameters

Number of receptors = 7
X-Y Coordinates of receptors:

Receptor #	1	X Coordinate = 953.02	Y Coordinate = 1017.1
Receptor #	2	X Coordinate = 1000	Y Coordinate = 1000
Receptor #	3	X Coordinate = 1046.98	Y Coordinate = 982.9
Receptor #	4	X Coordinate = 1093.97	Y Coordinate = 965.8
Receptor #	5	X Coordinate = 1034.2	Y Coordinate = 1093.97
Receptor #	6	X Coordinate = 1081.18	Y Coordinate = 1076.87
Receptor #	7	X Coordinate = 1128.17	Y Coordinate = 1059.77

Number of trucks = 1 Weight of trucks (tons)= 20
Speed of loaded truck (m/sec) = 6.84
Speed of empty truck (m/sec) = 6.84

Background Dust Level (micrograms/m^3) = 377.4
Silt Content (%) = 19.5
Moisture Content (%) = 0.06

Calculation Results

Emissions from loaded truck (grams/sec) = 22.6667

Total Instantaneous Average Concentration of PM10 at receptors:

Results for Receptor 1 = 598.9218 micrograms/m^3

Results for Receptor 2 = 3069.788 micrograms/m^3

Results for Receptor 3 = 1191.81 micrograms/m^3

Results for Receptor 4 = 769.5626 micrograms/m^3

Results for Receptor 5 = 3073.177 micrograms/m^3

Results for Receptor 6 = 1195.322 micrograms/m^3

Results for Receptor 7 = 774.5161 micrograms/m^3

Dynamic ISC3 Manipulations Complete (continued)

Page 2

Calculation Results

Time Weighted Average Concentration of PM10 at receptors:

Results for Receptor 1 = 587.3128 micrograms/m^3

Results for Receptor 2 = 2928.692 micrograms/m^3

Results for Receptor 3 = 1149.13 micrograms/m^3

Results for Receptor 4 = 749.011 micrograms/m^3

Results for Receptor 5 = 2931.903 micrograms/m^3

Results for Receptor 6 = 1152.458 micrograms/m^3

Results for Receptor 7 = 753.705 micrograms/m^3

*** ISCST3 - VERSION 00101 ***   *** Acco ISC3 Modeling Routines for 7-17-02   ***
01/27/03
***   ***
12:57:19
**MODELOPTs:
PAGE 11
CONC   RURAL FLAT   DFAULT

*** THE PERIOD (838 HRS) AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): L1 , L2 , L3 , L4 , L5 , L6 ,
L7 , L8 , L9 , L10 , L11 , L12 , L13 , L14 , L15 ,

*** DISCRETE CARTESIAN RECEPTOR POINTS ***

** CONC OF DUST IN MICROGRAMS/M**3 **

X-COORD (M)	Y-COORD (M)	CONC	X-COORD (M)	Y-COORD (M)	CONC
953.02	1017.10	11629.49902	1000.00	1000.00	2914.02612
1046.98	982.90	1081.92493	1093.97	965.80	475.88672
1034.20	1093.97	2439.58740	1081.18	1076.87	1001.24384
1128.17	1059.77	422.24939			

Dynamic ISC3 Manipulations Complete

5/22/02 Field Study

Input Parameters

Number of receptors = 7
X-Y Coordinates of receptors:
Receptor # 1 X Coordinate = 950.76 Y Coordinate = 1008.68
Receptor # 2 X Coordinate = 1000 Y Coordinate = 1000
Receptor # 3 X Coordinate = 1049.24 Y Coordinate = 991.32
Receptor # 4 X Coordinate = 1098.48 Y Coordinate = 982.64
Receptor # 5 X Coordinate = 1017.36 Y Coordinate = 1098.48
Receptor # 6 X Coordinate = 1066.6 Y Coordinate = 1089.8
Receptor # 7 X Coordinate = 1115.84 Y Coordinate = 1081.12

Number of trucks = 1 Weight of trucks (tons)= 50
Speed of loaded truck (m/sec) = 6.92
Speed of empty truck (m/sec) = 6.92

Background Dust Level (micrograms/m^3) = 147
Silt Content (%) = 21.18
Moisture Content (%) = 0.65

Calculation Results

Emissions from loaded truck (grams/sec) = 17.29413

Total Instantaneous Average Concentration of PM10 at receptors:

Results for Receptor 1 = 602.6116 micrograms/m^3

Results for Receptor 2 = 2462.757 micrograms/m^3

Results for Receptor 3 = 874.2804 micrograms/m^3

Results for Receptor 4 = 523.6428 micrograms/m^3

Results for Receptor 5 = 2466.415 micrograms/m^3

Results for Receptor 6 = 879.5397 micrograms/m^3

Results for Receptor 7 = 530.0082 micrograms/m^3

Dynamic ISC3 Manipulations Complete (continued)

Page 2

Calculation Results

Time Weighted Average Concentration of PM10 at receptors:

Results for Receptor 1 = 279.6761 micrograms/m^3

Results for Receptor 2 = 821.3586 micrograms/m^3

Results for Receptor 3 = 358.7872 micrograms/m^3

Results for Receptor 4 = 256.68 micrograms/m^3

Results for Receptor 5 = 822.4238 micrograms/m^3

Results for Receptor 6 = 360.3188 micrograms/m^3

Results for Receptor 7 = 258.5337 micrograms/m^3

*** ISCST3 - VERSION 00101 ***   *** ISC3 Run of Consol Energy Mine Eighty-Four Prep Plant   ***
01/27/03
***   ***
14:39:02
**MODELOPTs:
PAGE 11
CONC   RURAL FLAT   DFAULT

*** THE PERIOD (719 HRS) AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): L1 , L2 , L3 , L4 , L5 , L6 ,
L7 ,
L8 , L9 , L10 , L11 , L12 , L13 , L14 , L15 ,

*** DISCRETE CARTESIAN RECEPTOR POINTS ***

** CONC OF DUST IN MICROGRAMS/M**3 **

X-COORD (M)	Y-COORD (M)	CONC	X-COORD (M)	Y-COORD (M)	CONC
950.76	1008.68	1712.81860	1000.00	1000.00	403.28955
1049.24	991.32	157.86923	1098.48	982.64	67.05721
1017.36	1098.48	371.68549	1066.60	1089.80	144.18857
1115.84	1081.12	61.52816			

Dynamic ISC3 Manipulations Complete

8/5/02 Field Study

Input Parameters

Number of receptors = 7
X-Y Coordinates of receptors:

Receptor # 1	X Coordinate = 950.76	Y Coordinate = 1008.68
Receptor # 2	X Coordinate = 1000	Y Coordinate = 1000
Receptor # 3	X Coordinate = 1049.24	Y Coordinate = 991.32
Receptor # 4	X Coordinate = 1098.48	Y Coordinate = 982.64
Receptor # 5	X Coordinate = 1017.36	Y Coordinate = 1098.48
Receptor # 6	X Coordinate = 1066.6	Y Coordinate = 1089.8
Receptor # 7	X Coordinate = 1115.84	Y Coordinate = 1081.12

Number of trucks = 1 Weight of trucks (tons)= 50
Speed of loaded truck (m/sec) = 6.62
Speed of empty truck (m/sec) = 6.62

Background Dust Level (micrograms/m^3) = 374.7
Silt Content (%) = 26.2
Moisture Content (%) = 0.68

Calculation Results

Emissions from loaded truck (grams/sec) = 19.34961

Total Instantaneous Average Concentration of PM10 at receptors:

Results for Receptor 1 = 2247.624 micrograms/m^3

Results for Receptor 2 = 1908.309 micrograms/m^3

Results for Receptor 3 = 799.235 micrograms/m^3

Results for Receptor 4 = 568.6034 micrograms/m^3

Results for Receptor 5 = 1914.199 micrograms/m^3

Results for Receptor 6 = 804.5904 micrograms/m^3

Results for Receptor 7 = 574.0913 micrograms/m^3

Dynamic ISC3 Manipulations Complete (continued)

Page 2

Calculation Results

Time Weighted Average Concentration of PM10 at receptors:

Results for Receptor 1 = 852.0311 micrograms/m^3

Results for Receptor 2 = 765.5537 micrograms/m^3

Results for Receptor 3 = 482.8965 micrograms/m^3

Results for Receptor 4 = 424.118 micrograms/m^3

Results for Receptor 5 = 767.0548 micrograms/m^3

Results for Receptor 6 = 484.2614 micrograms/m^3

Results for Receptor 7 = 425.5166 micrograms/m^3

```
*** ISCST3 - VERSION 00101 ***    *** ISC3 Run of Consol Energy Mine Eighty-Four Prep Plant            ***
01/27/03
                                  ***                                                                  ***
14:42:31
**MODELOPTs:
PAGE  11
CONC                      RURAL  FLAT         DFAULT

                         *** THE PERIOD (   713 HRS) AVERAGE CONCENTRATION   VALUES FOR SOURCE GROUP: ALL      ***
                             INCLUDING SOURCE(S):     L1      , L2      , L3      , L4      , L5      , L6      ,
L7      ,
    L8      , L9      , L10     , L11     , L12     , L13     , L14     , L15     ,

                                  *** DISCRETE CARTESIAN RECEPTOR POINTS ***

                             ** CONC OF DUST     IN MICROGRAMS/M**3                       **

   X-COORD (M)  Y-COORD (M)     CONC                   X-COORD (M)  Y-COORD (M)      CONC
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - -
       950.76      1008.68    1466.81665                  1000.00      1000.00    1580.55566
□□□□□□□□□□□□
      1049.24       991.32    1516.51062                  1098.48       982.64     831.42499
      1017.36      1098.48    1477.09534                  1066.60      1089.80    1469.16138
      1115.84      1081.12     791.44684
```

Dynamic ISC3 Manipulations Complete

8/6/02 Field study

Input Parameters

Number of receptors = 7
X-Y Coordinates of receptors:

Receptor # 1	X Coordinate = 950.76	Y Coordinate = 1008.68
Receptor # 2	X Coordinate = 1000	Y Coordinate = 1000
Receptor # 3	X Coordinate = 1049.24	Y Coordinate = 991.32
Receptor # 4	X Coordinate = 1098.48	Y Coordinate = 982.64
Receptor # 5	X Coordinate = 1017.36	Y Coordinate = 1098.48
Receptor # 6	X Coordinate = 1066.6	Y Coordinate = 1089.8
Receptor # 7	X Coordinate = 1115.84	Y Coordinate = 1081.12

Number of trucks = 1 Weight of trucks (tons)= 50
Speed of loaded truck (m/sec) = 7.79
Speed of empty truck (m/sec) = 7.79

Background Dust Level (micrograms/m^3) = 32.8
Silt Content (%) = 18.34
Moisture Content (%) = 0.54

Calculation Results

Emissions from loaded truck (grams/sec) = 18.34276

Total Instantaneous Average Concentration of PM10 at receptors:

Results for Receptor 1 = 910.5806 micrograms/m^3

Results for Receptor 2 = 363.503 micrograms/m^3

Results for Receptor 3 = 130.8965 micrograms/m^3

Results for Receptor 4 = 83.46014 micrograms/m^3

Results for Receptor 5 = 362.2804 micrograms/m^3

Results for Receptor 6 = 130.5351 micrograms/m^3

Results for Receptor 7 = 83.85419 micrograms/m^3

Dynamic ISC3 Manipulations Complete (continued)

Page 2

Calculation Results

Time Weighted Average Concentration of PM10 at receptors:

Results for Receptor 1 = 251.899 micrograms/m^3

Results for Receptor 2 = 115.3453 micrograms/m^3

Results for Receptor 3 = 57.28544 micrograms/m^3

Results for Receptor 4 = 45.44506 micrograms/m^3

Results for Receptor 5 = 115.0402 micrograms/m^3

Results for Receptor 6 = 57.19523 micrograms/m^3

Results for Receptor 7 = 45.54341 micrograms/m^3

```
*** ISCST3 - VERSION 00101 ***    *** ISC3 Run of Consol Energy Mine Eighty-Four Prep Plant             ***
*/27/03
                                  ***                                                                   ***
1:45:48
**MODELOPTs:
PAGE  11
CONC                      RURAL  FLAT          DFAULT

                          *** THE PERIOD (  815 HRS) AVERAGE CONCENTRATION   VALUES FOR SOURCE GROUP: ALL      ***
                              INCLUDING SOURCE(S):      L1       , L2       , L3       , L4       , L5       , L6      ,
L7      ,
       L8       , L9       , L10      , L11      , L12      , L13      , L14      , L15      ,

                                        *** DISCRETE CARTESIAN RECEPTOR POINTS ***

                                   ** CONC OF DUST      IN MICROGRAMS/M**3                              **

     X-COORD (M)  Y-COORD (M)        CONC                    X-COORD (M)  Y-COORD (M)        CONC
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - -
        950.76      1008.68      592.99603                     1000.00      1000.00     1507.23840
□□□□□□□□□□□
       1049.24       991.32     1256.81982                     1098.48       982.64      666.12134
       1017.36      1098.48     1452.35059                     1066.60      1089.80     1288.04285
       1115.84      1081.12      705.98297
```

Appendix F

F.1 Windrose Plots for Coal Mine Field Studies

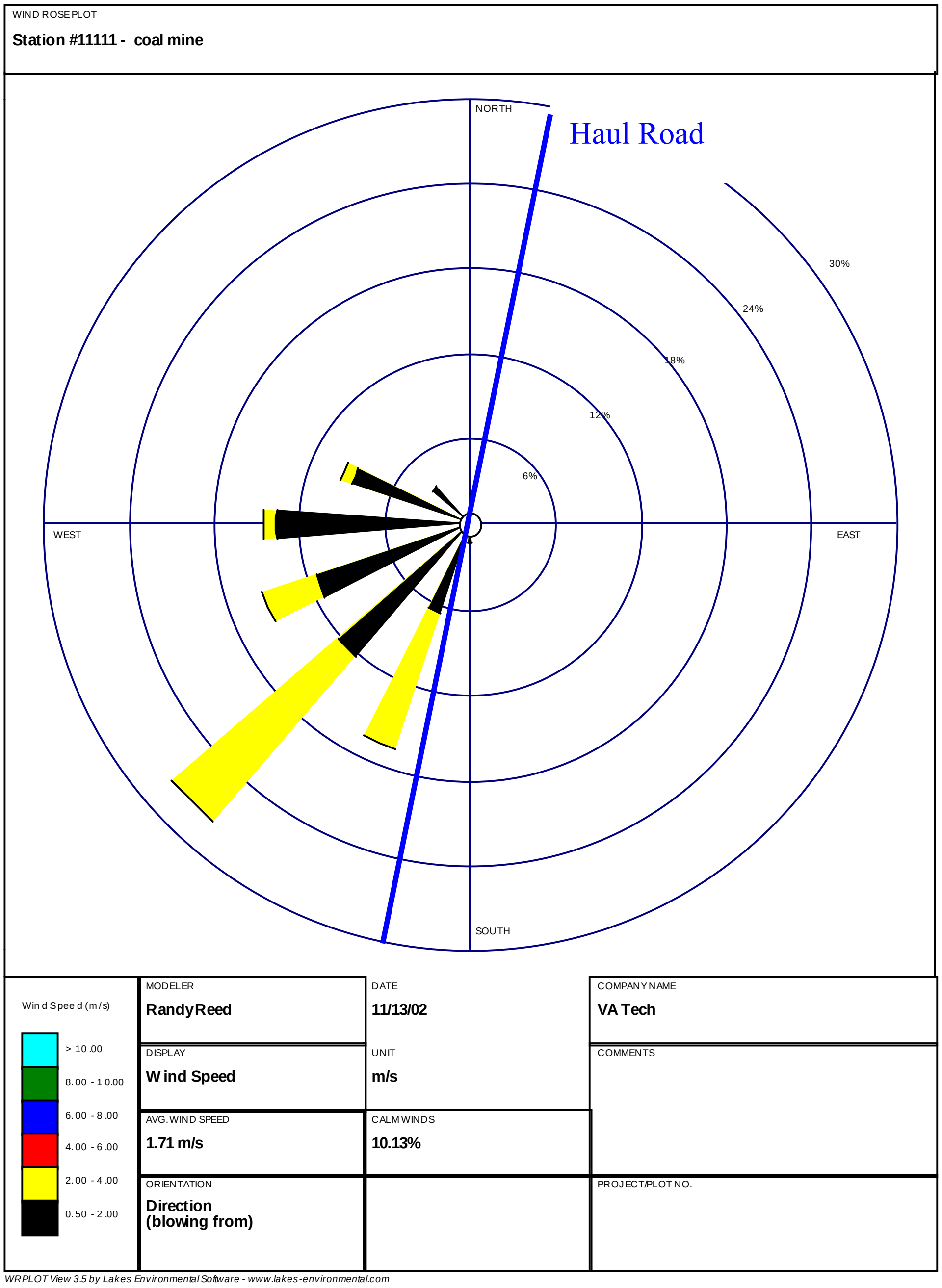


Figure F.1 Windrose plot for coal mine on 8-02-02.

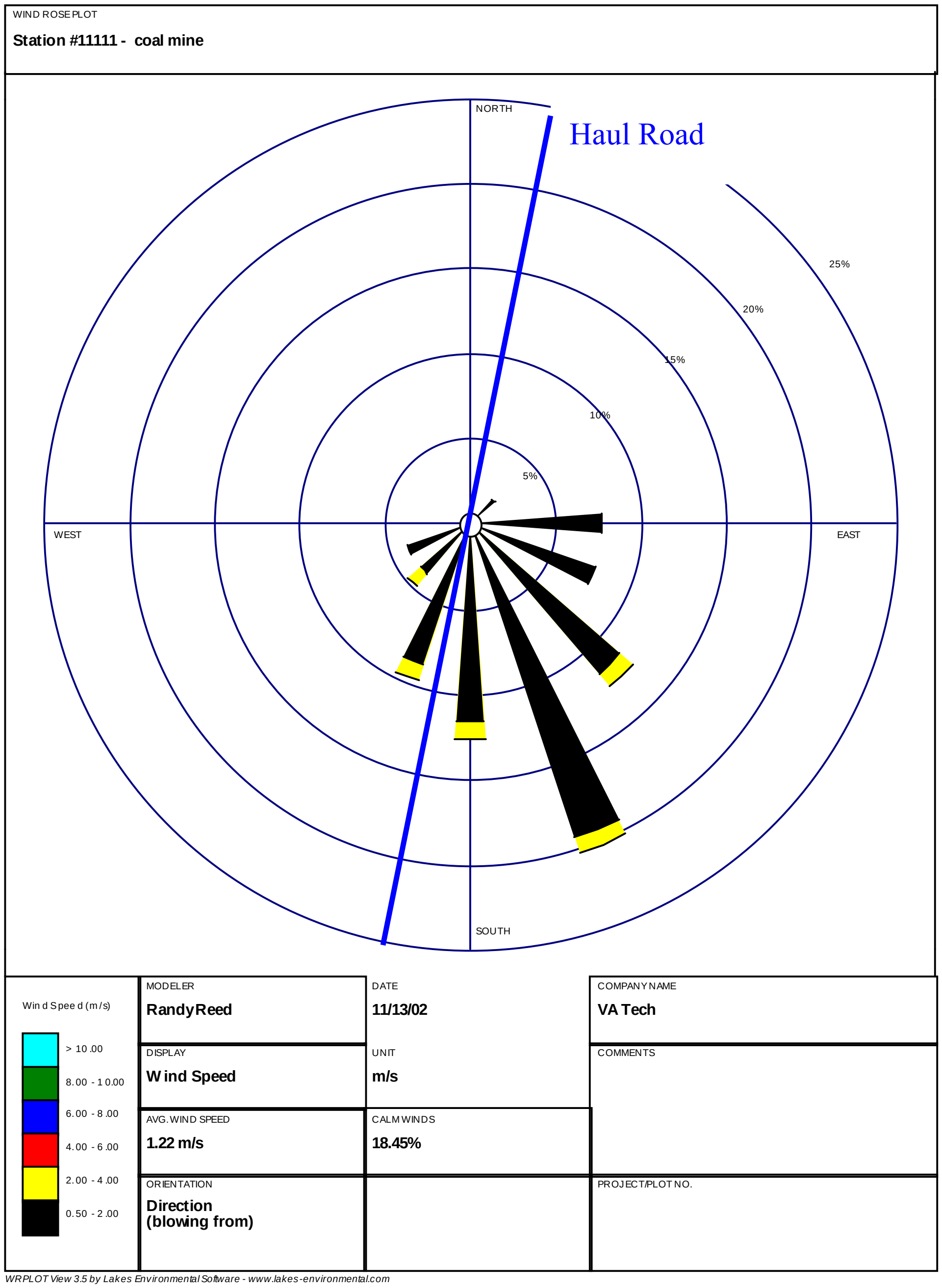


Figure F.2 Windrose plot for coal mine on 8-05-02.

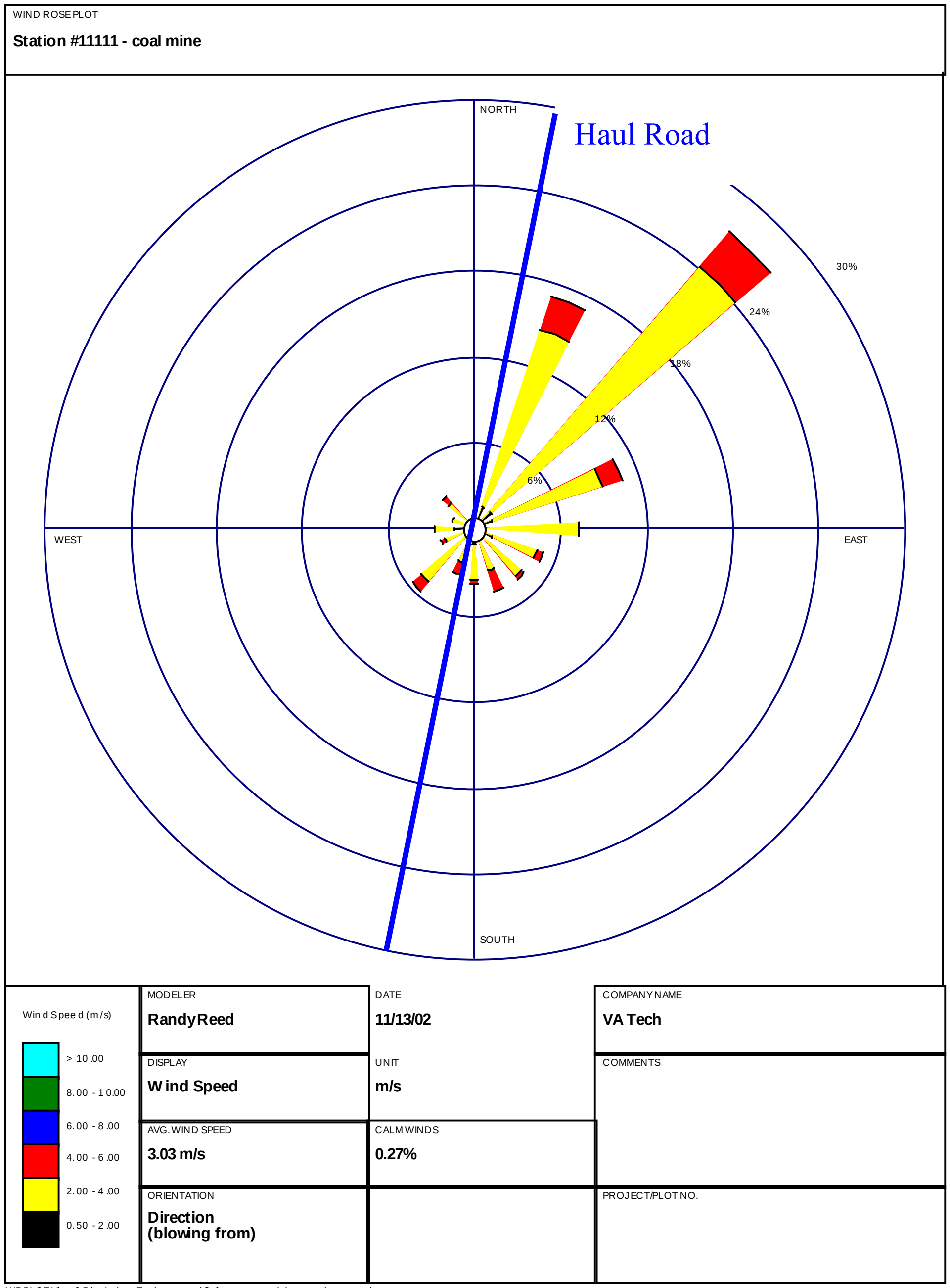


Figure F.3 Windrose plot for coal mine on 8-06-02.

F.2 Windrose Plots for Stone Quarry Field Studies

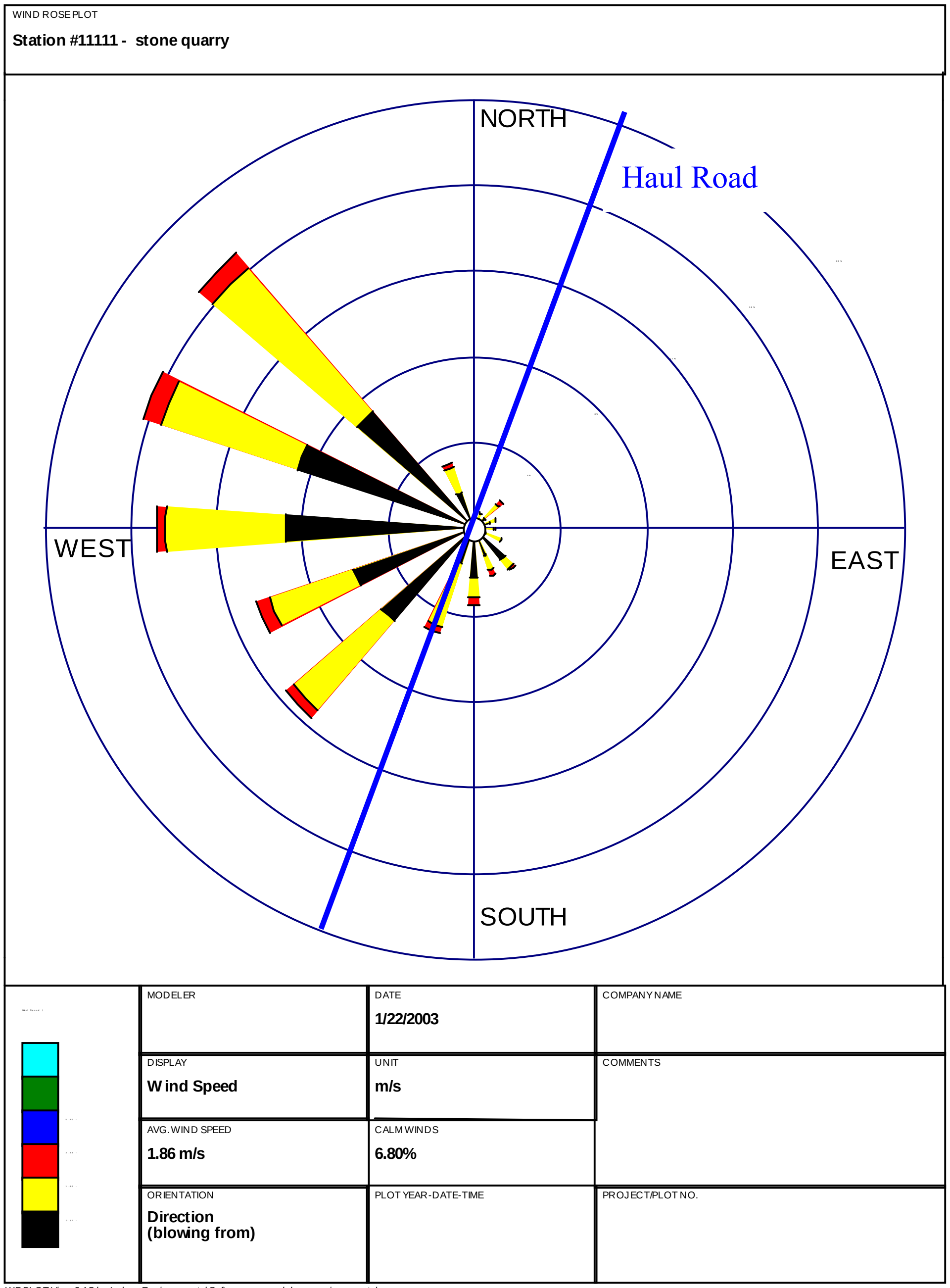


Figure F.4 Windrose plot for stone quarry on 7-16-02.

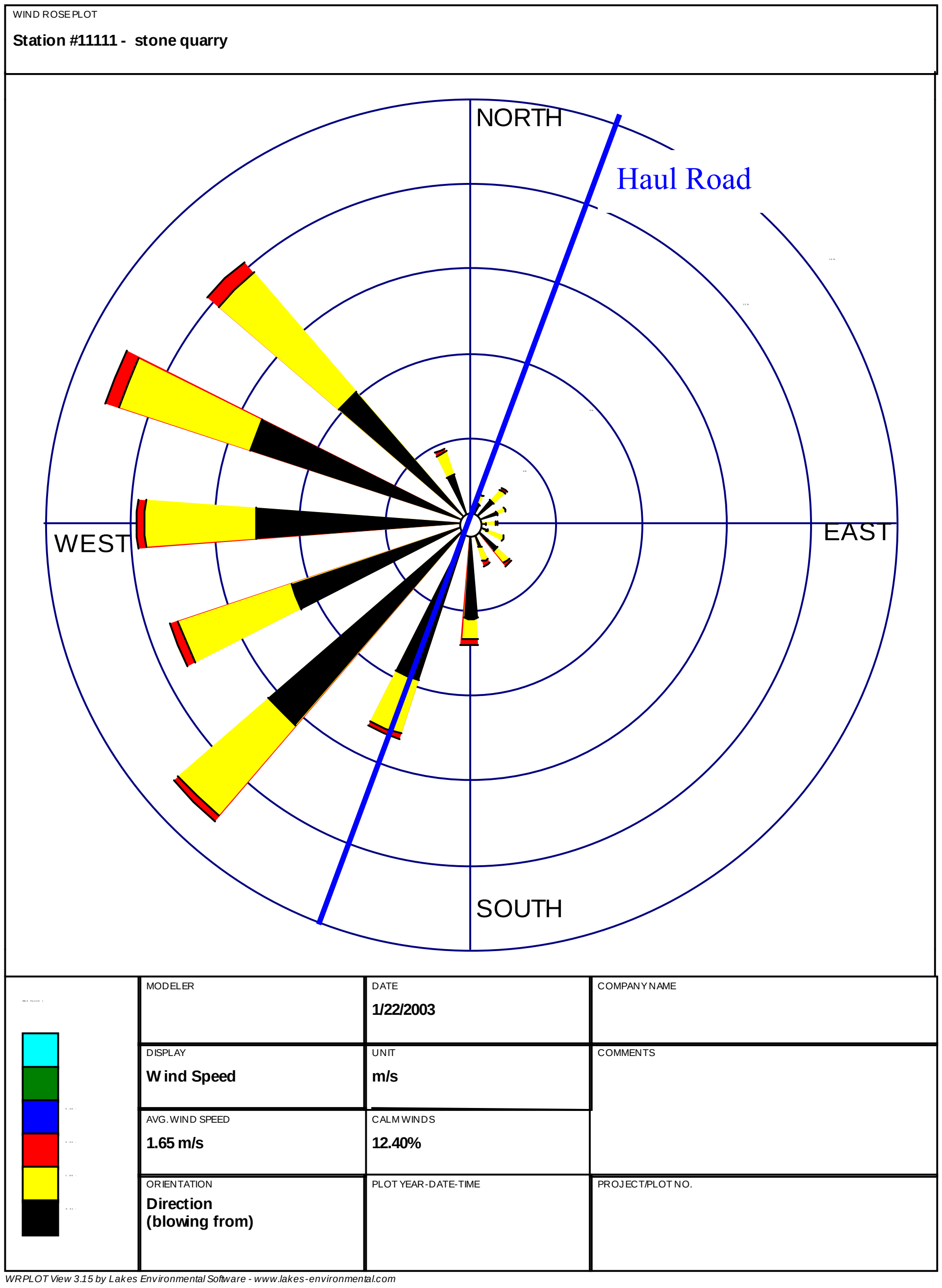


Figure F.5 Windrose plot for stone quarry on 7-17-02.

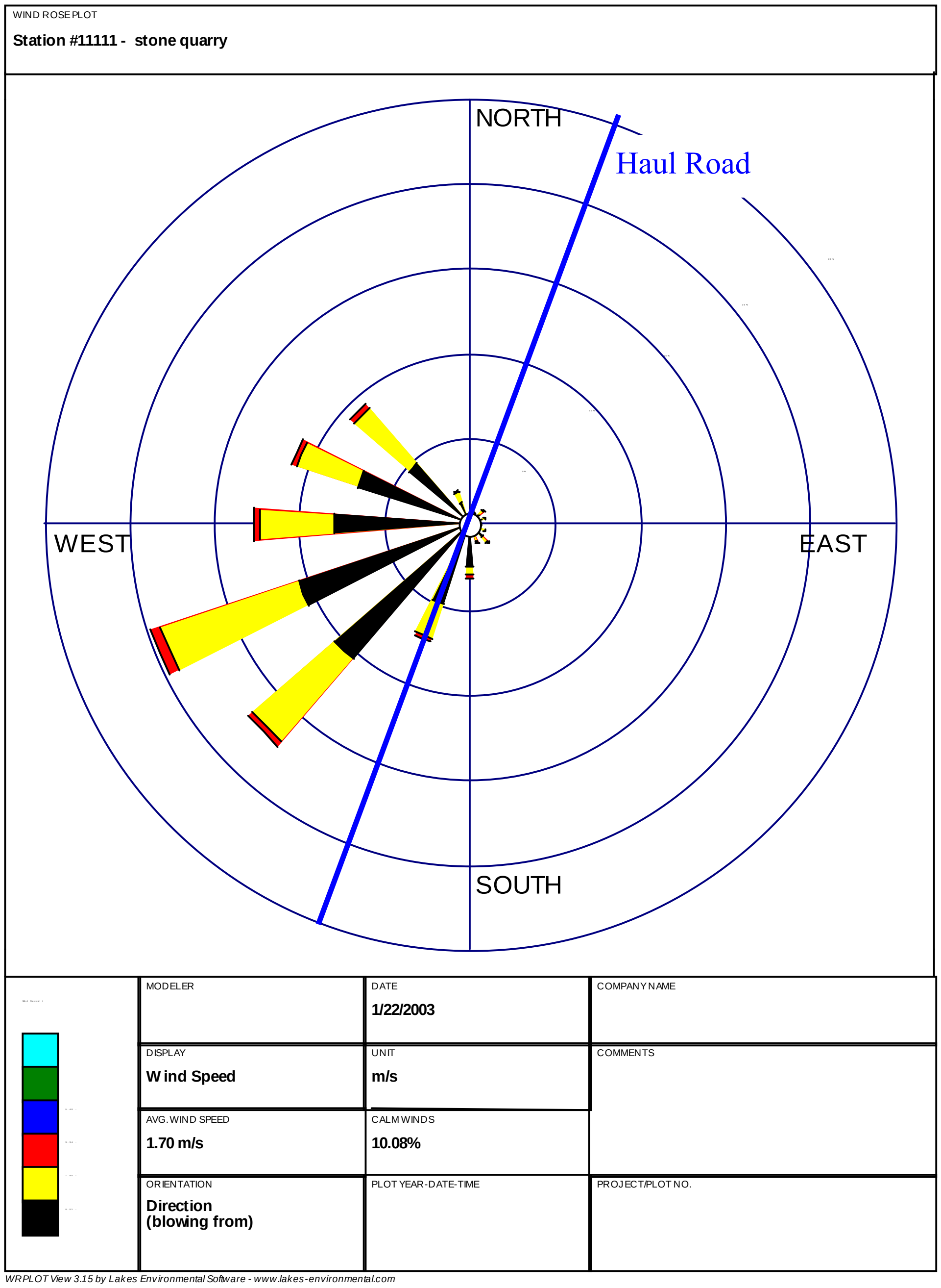


Figure F.6 Windrose plot for stone quarry on 7-17-02.

F.3 Average Instantaneous Dust Concentrations of Truck Passes from Coal Mine Field Studies

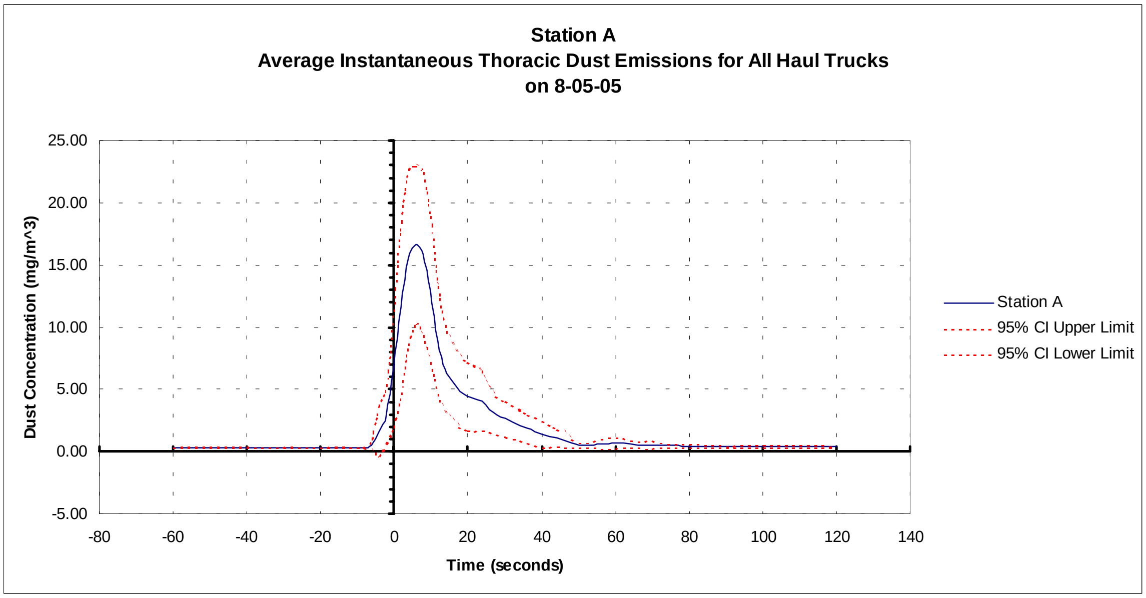


Figure F.7 Average instantaneous thoracic dust concentrations with 95% confidence interval for Station A on 8-05-02.

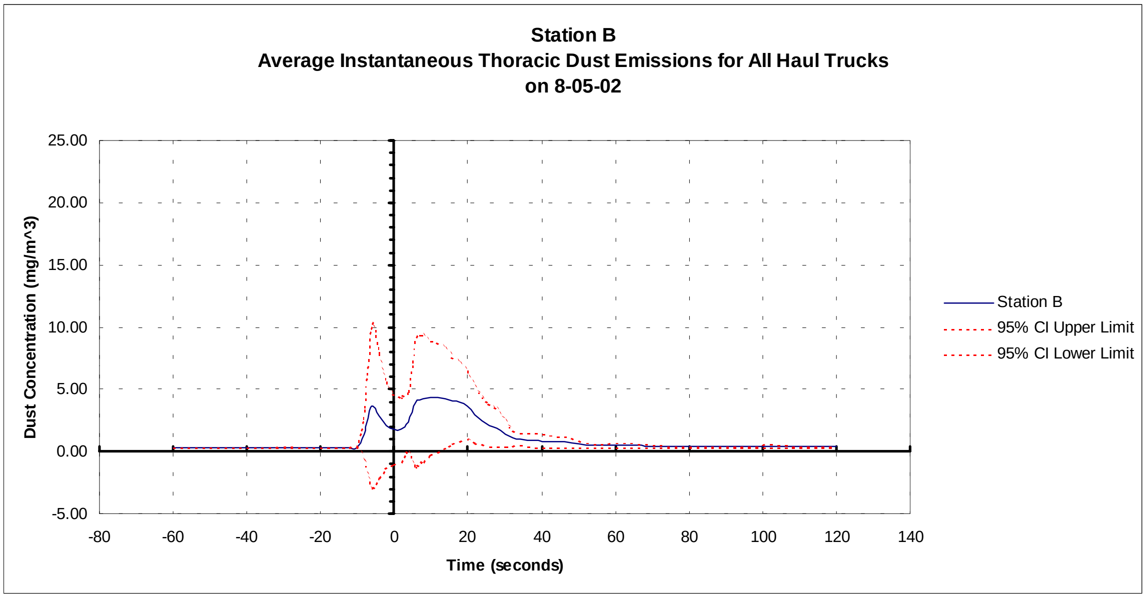


Figure F.8 Average instantaneous thoracic dust concentrations with 95% confidence interval for Station B on 8-05-02.

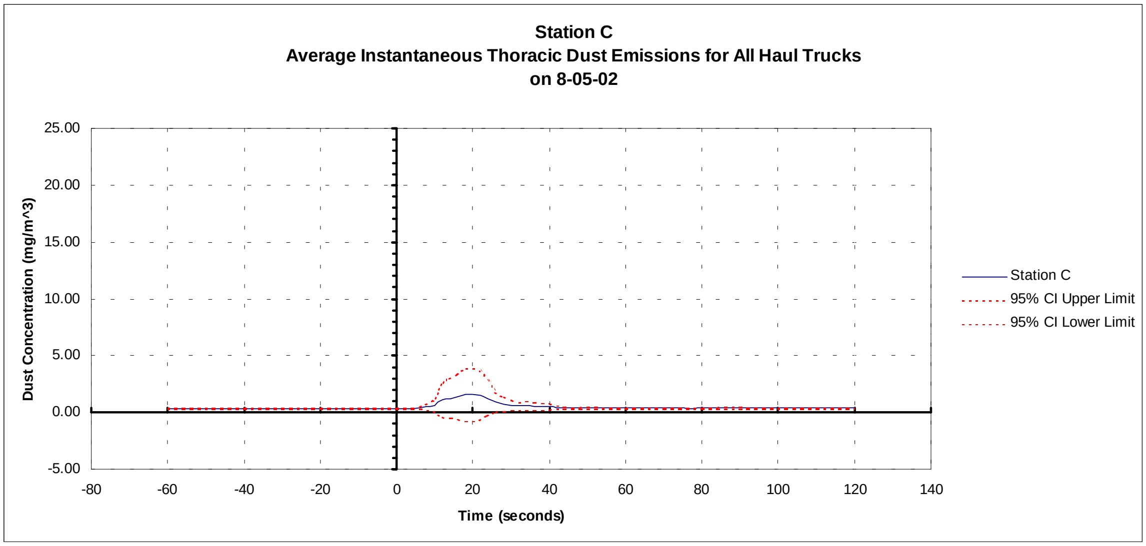


Figure F.9 Average instantaneous thoracic dust concentrations with 95% confidence interval for Station C on 8-05-02.

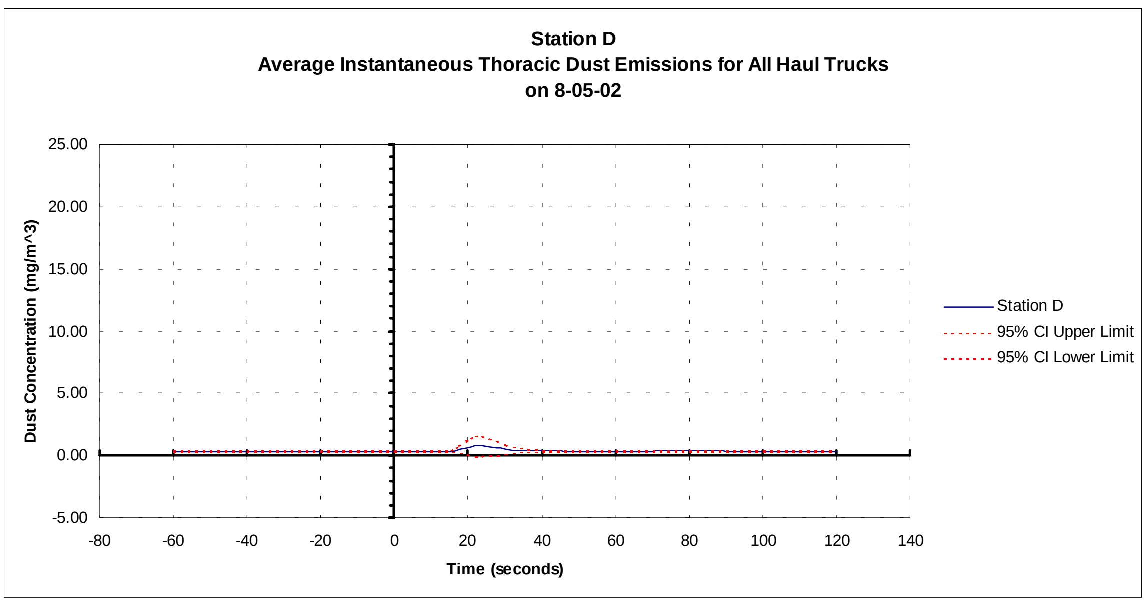


Figure F.10 Average instantaneous thoracic dust concentrations with 95% confidence interval for Station D on 8-05-02.

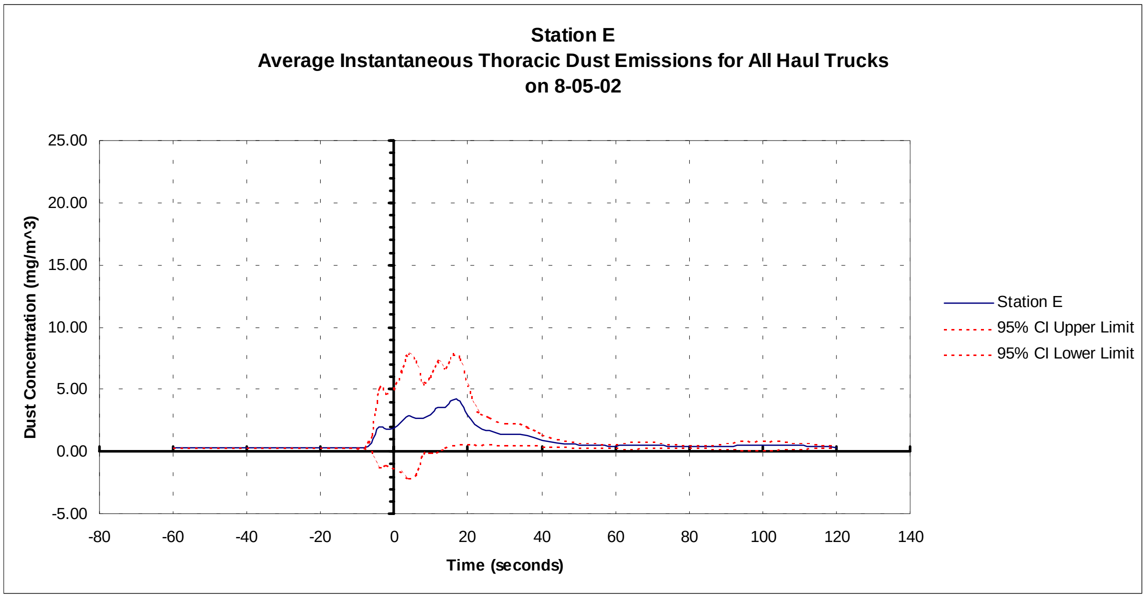


Figure F.11 Average instantaneous thoracic dust concentrations with 95% confidence interval for Station E on 8-05-02.

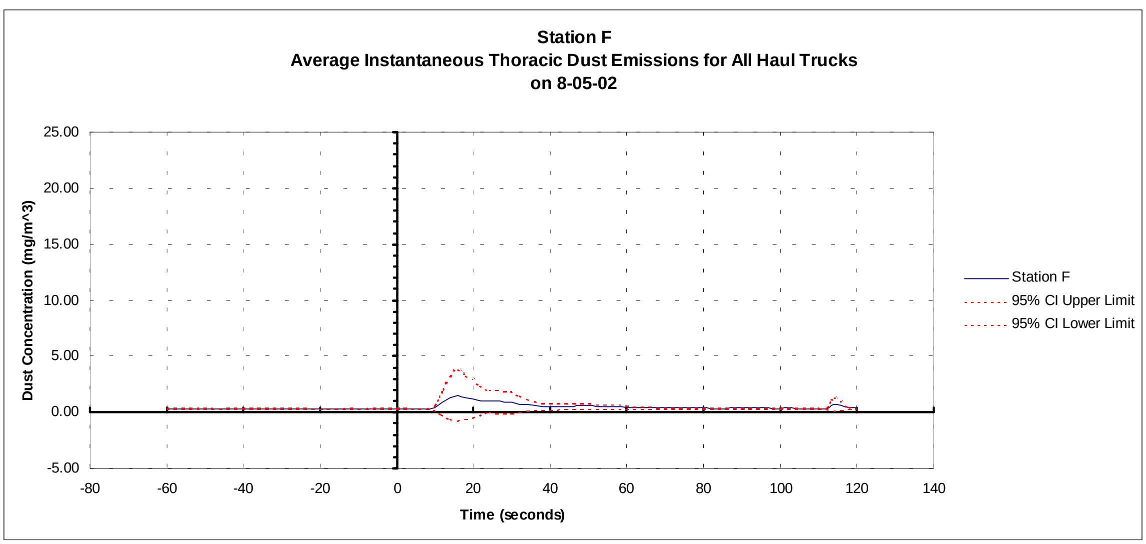


Figure F.12 Average instantaneous thoracic dust concentrations with 95% confidence interval for Station F on 8-05-02.

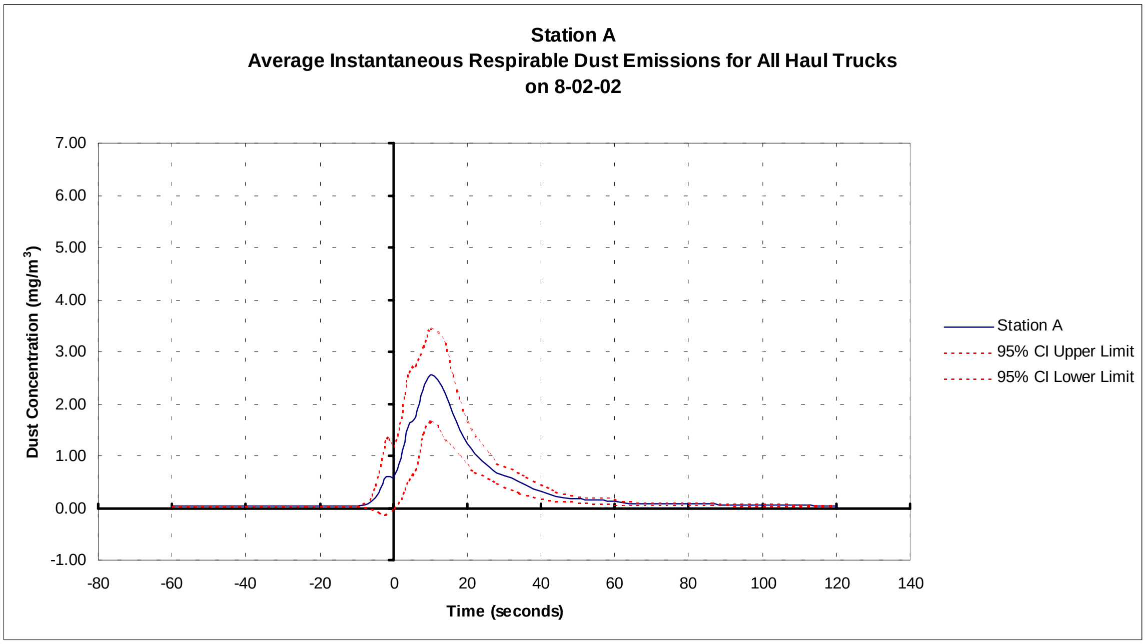


Figure F.13 Average instantaneous respirable dust concentrations with 95% confidence interval for Station A on 8-02-02.

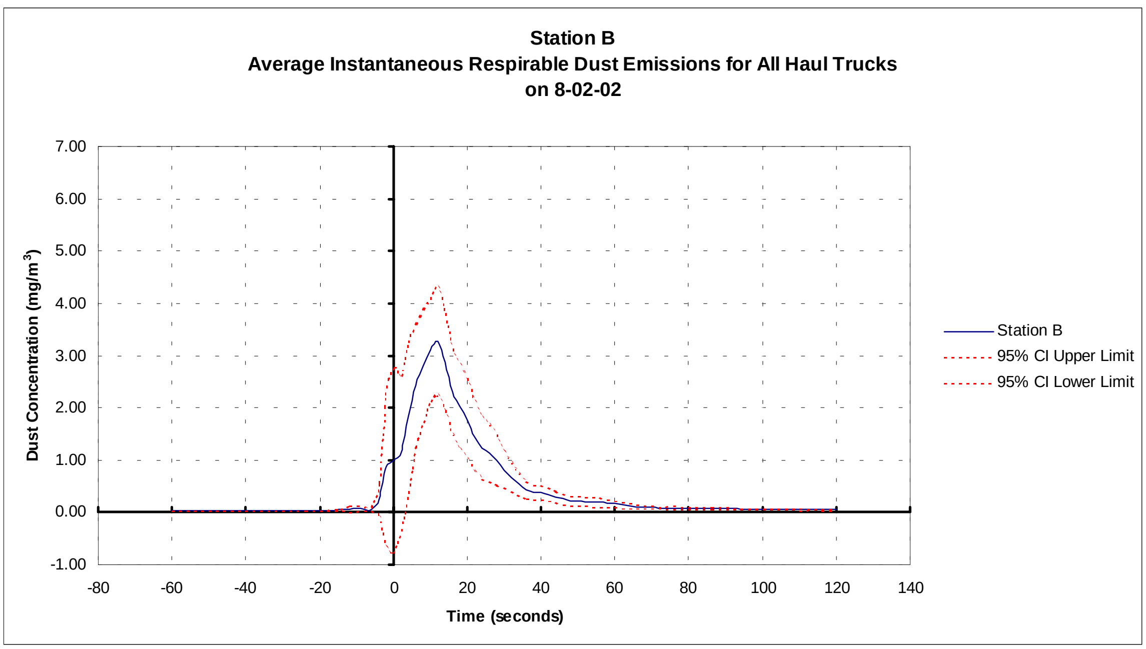


Figure F.14 Average instantaneous respirable dust concentrations with 95% confidence interval for Station B on 8-02-02.

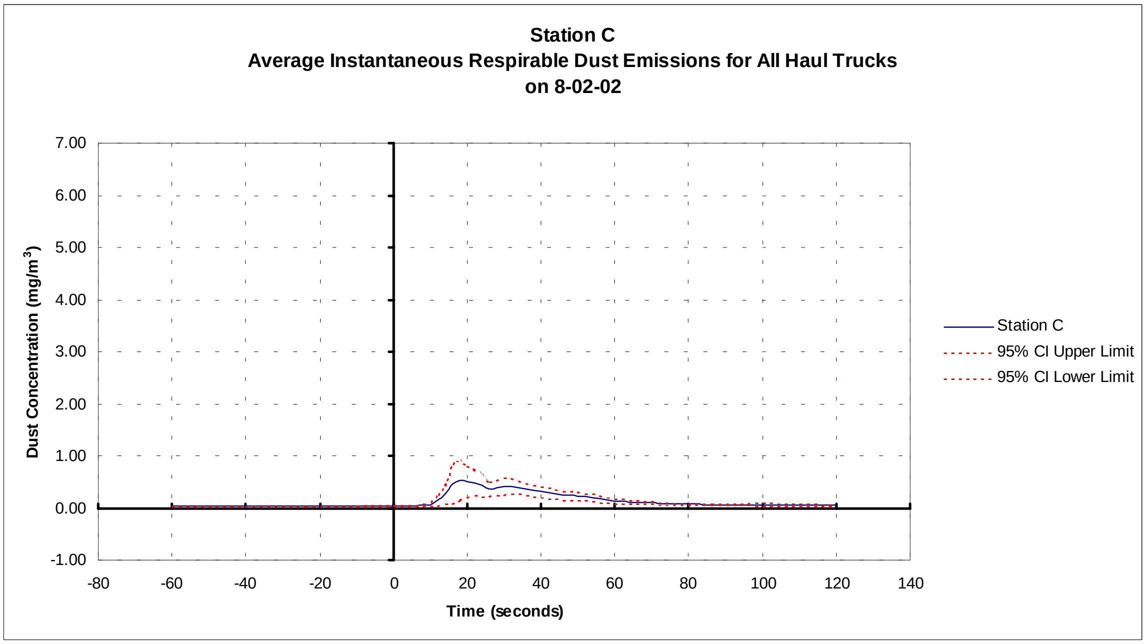


Figure F.15 Average instantaneous respirable dust concentrations with 95% confidence interval for Station C on 8-02-02.

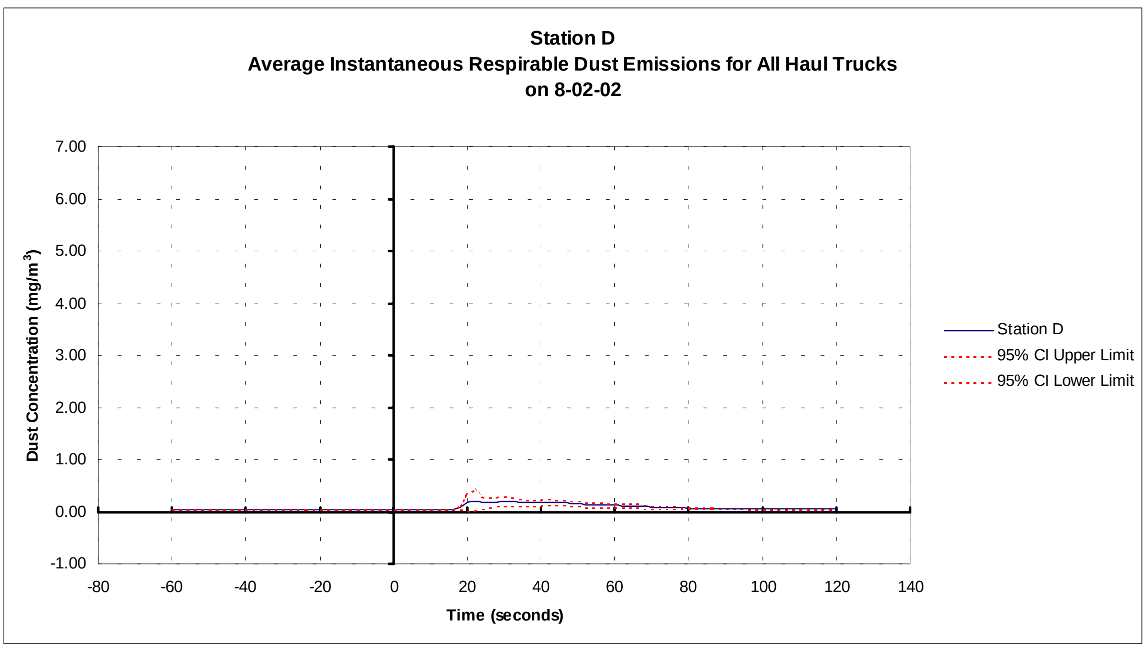


Figure F.16 Average instantaneous respirable dust concentrations with 95% confidence interval for Station D on 8-02-02 .

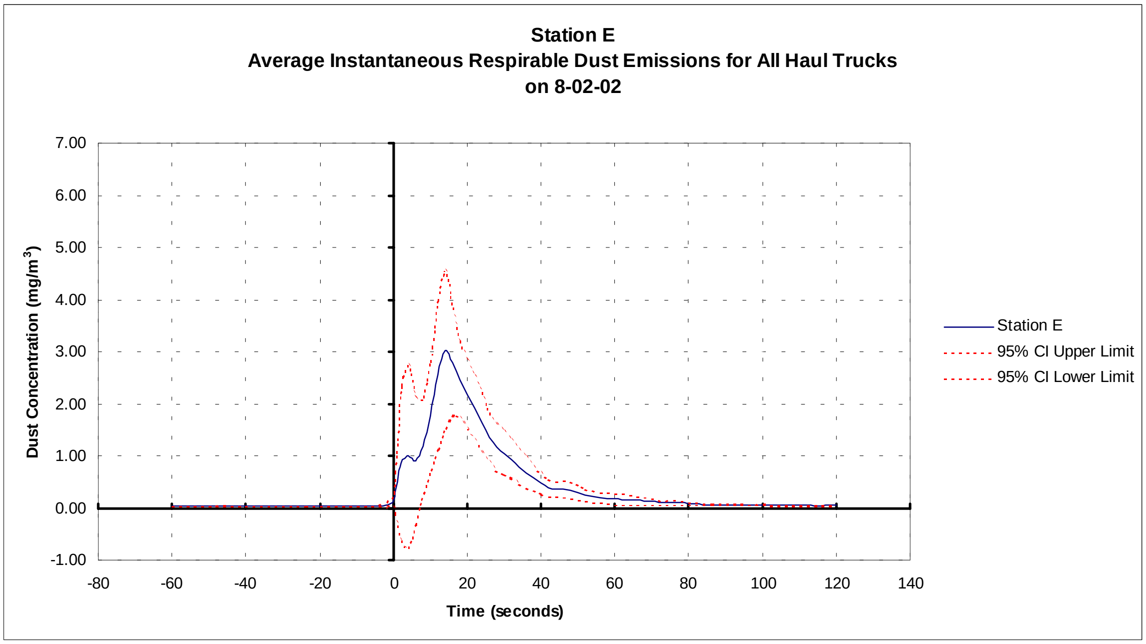


Figure F.17 Average instantaneous respirable dust concentrations with 95% confidence interval for Station E on 8-02-02.

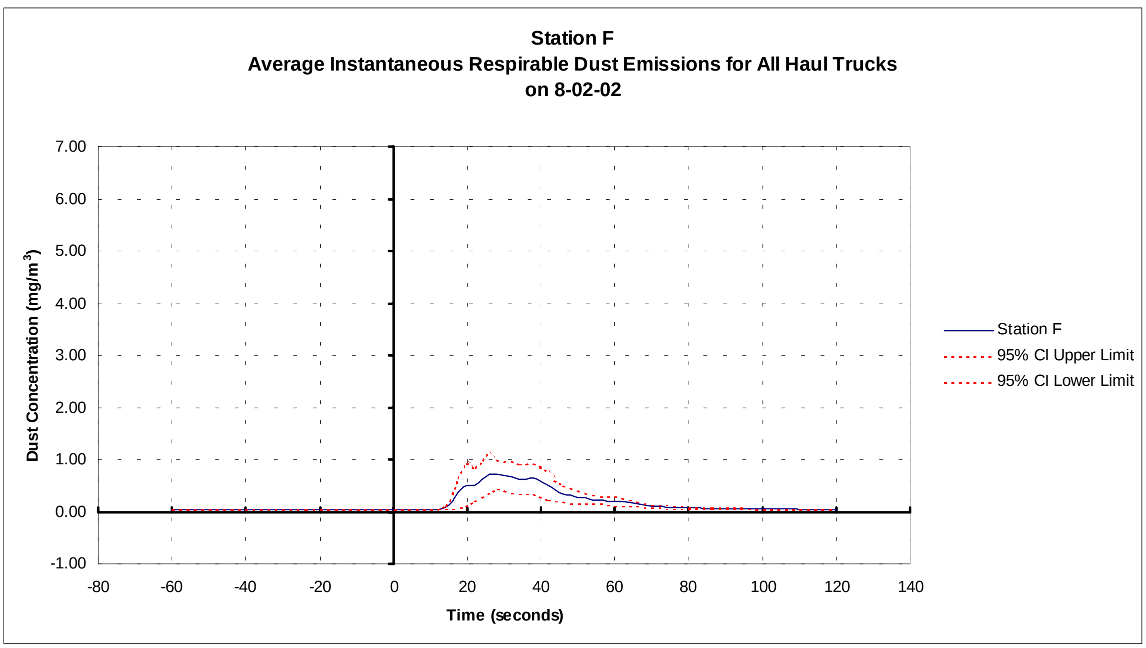


Figure F.18 Average instantaneous respirable dust concentrations with 95% confidence interval for Station F on 8-02-02.

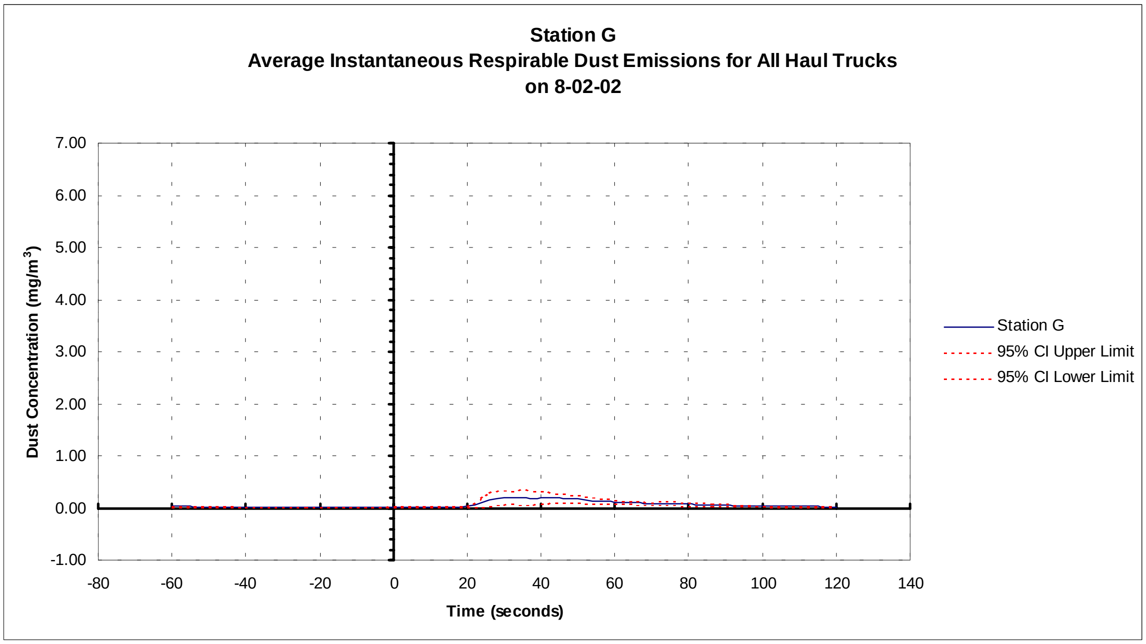


Figure F.19 Average instantaneous respirable dust concentrations with 95% confidence interval for Station G on 8-02-02.

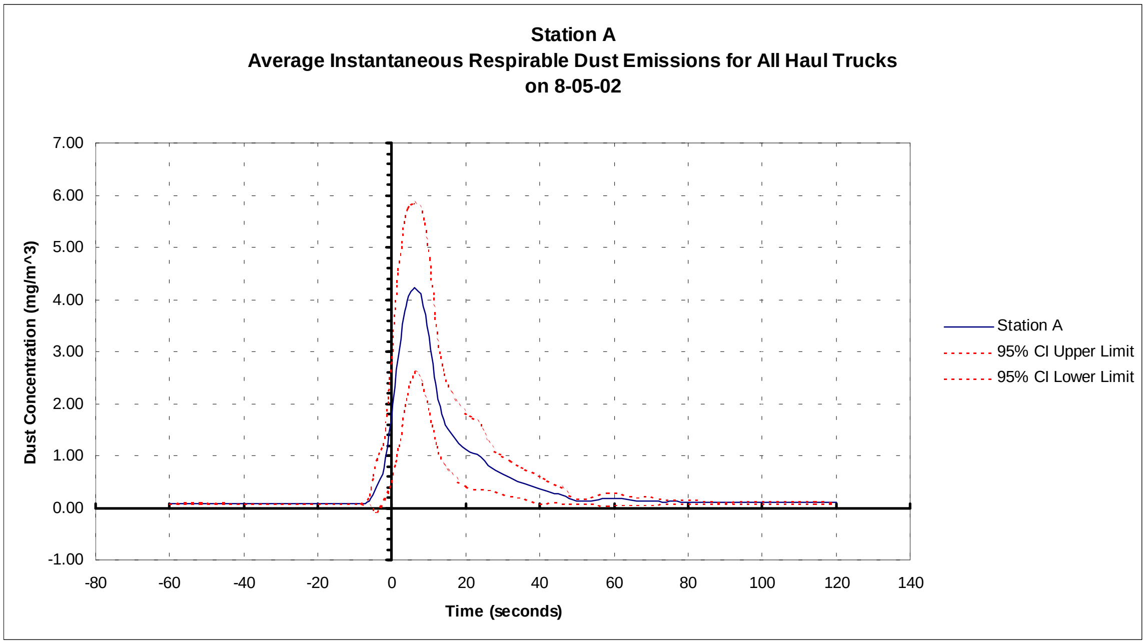


Figure F.20 Average instantaneous respirable dust concentrations with 95% confidence interval for Station A on 8-05-02.

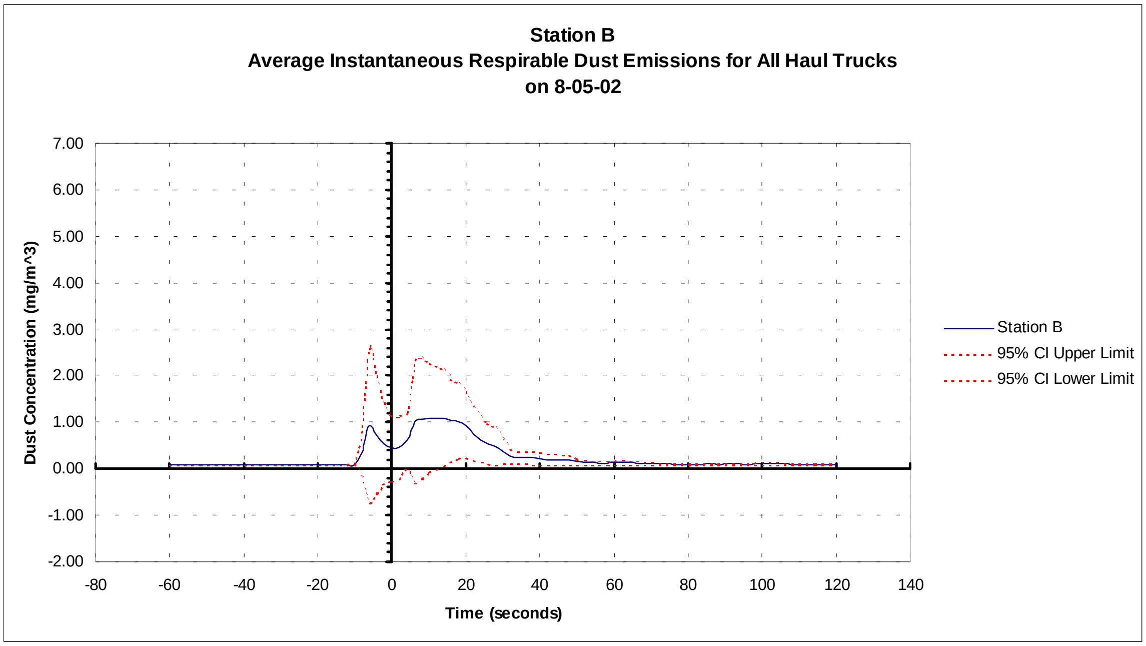


Figure F.21 Average instantaneous respirable dust concentrations with 95% confidence interval for Station B on 8-05-02.

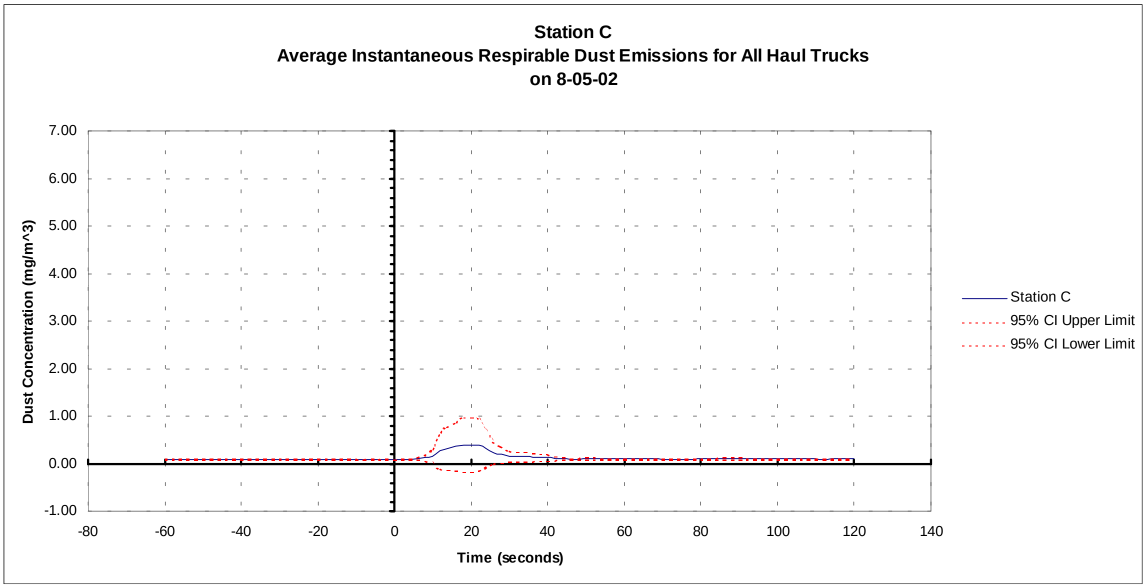


Figure F.22 Average instantaneous respirable dust concentrations with 95% confidence interval on Station C on 8-05-02.

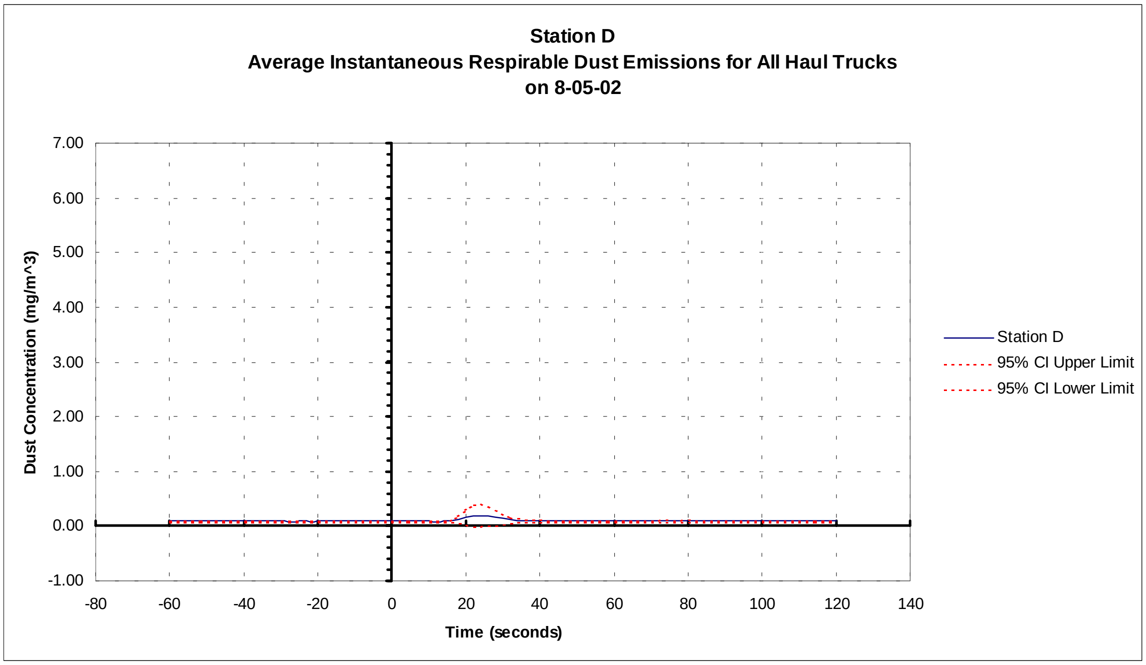


Figure F.23 Average instantaneous respirable dust concentrations with 95% confidence interval for Station D on 8-05-02.

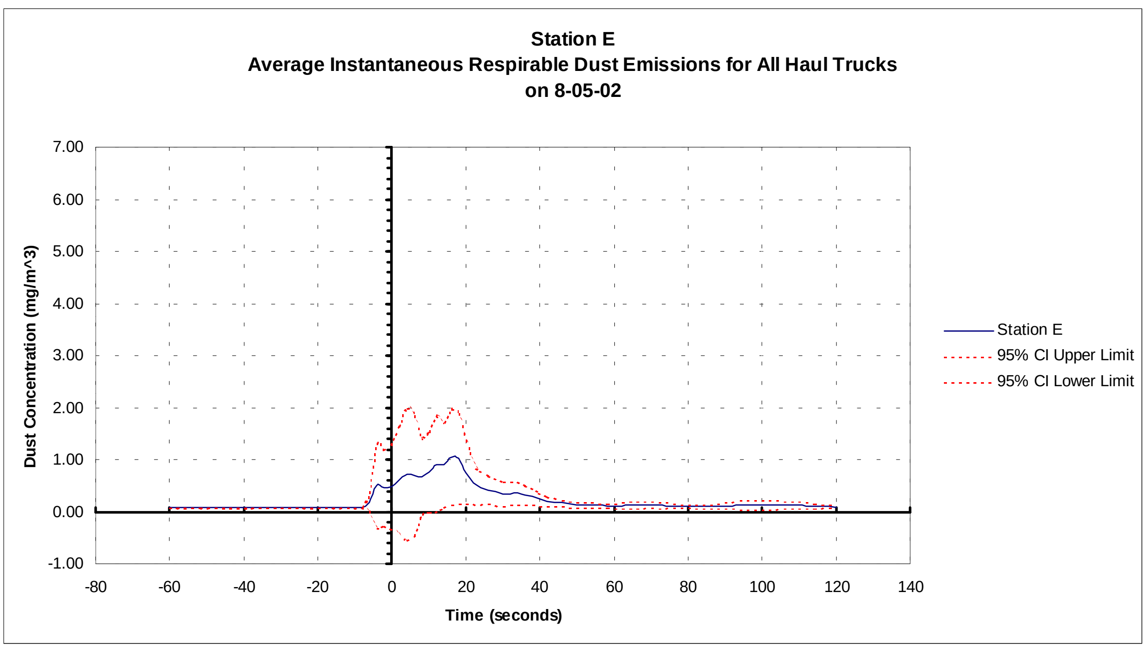


Figure F.24 Average instantaneous respirable dust concentrations with 95% confidence interval for Station E on 8-05-02.

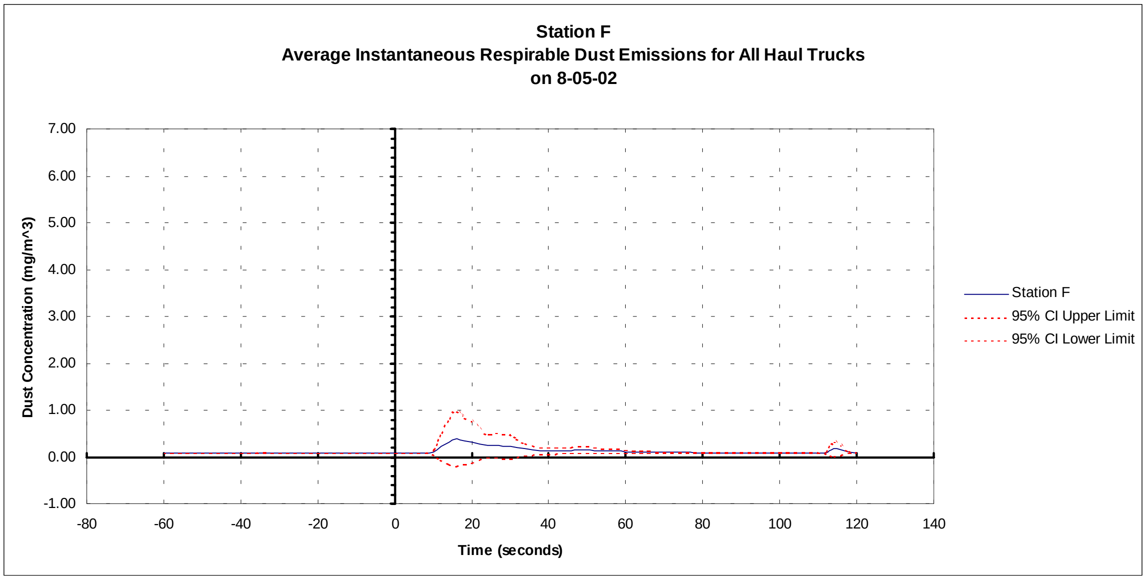


Figure F.25 Average instantaneous respirable dust concentrations with 95% confidence interval for Station F on 8-05-02.

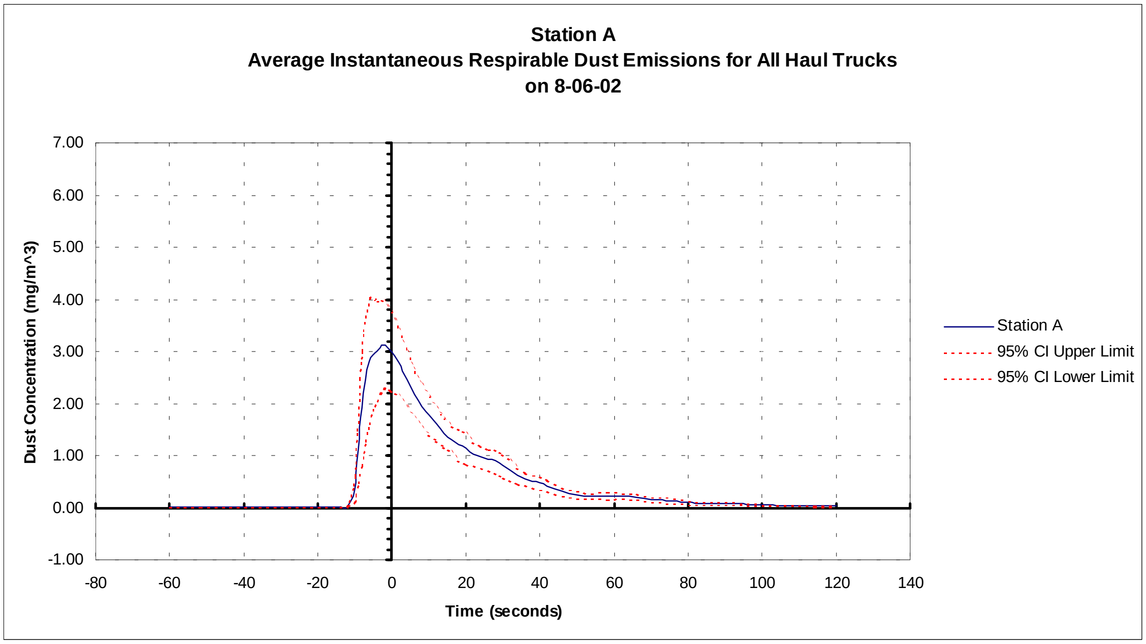


Figure F.26 Average instantaneous respirable dust concentrations with 95% confidence interval for Station A on 8-06-02.

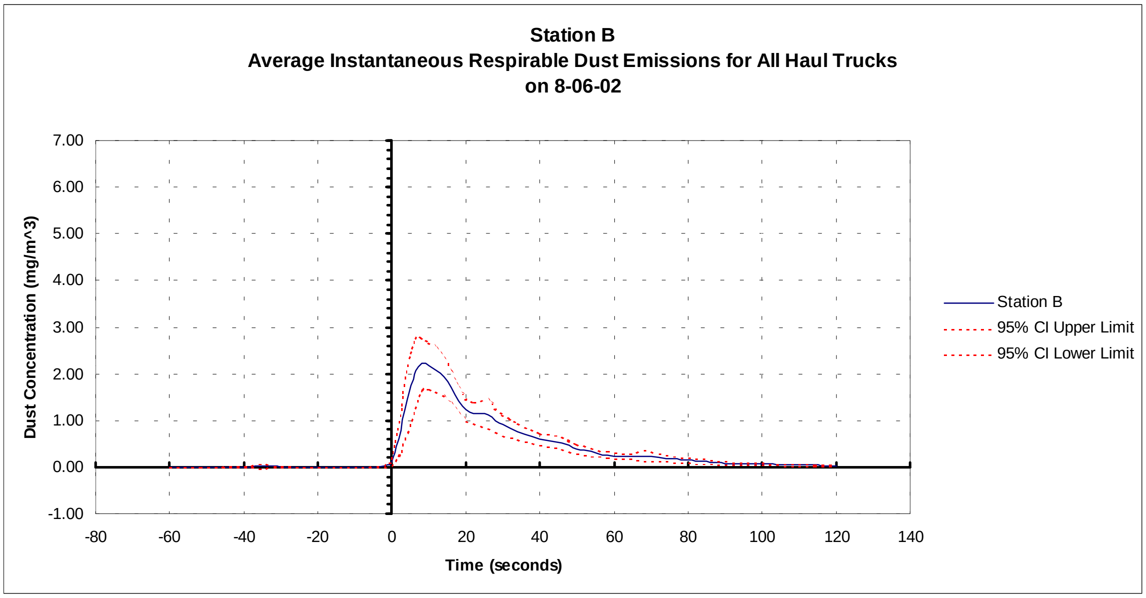


Figure F.27 Average instantaneous respirable dust concentrations with 95% confidence interval for Station B on 8-06-02.

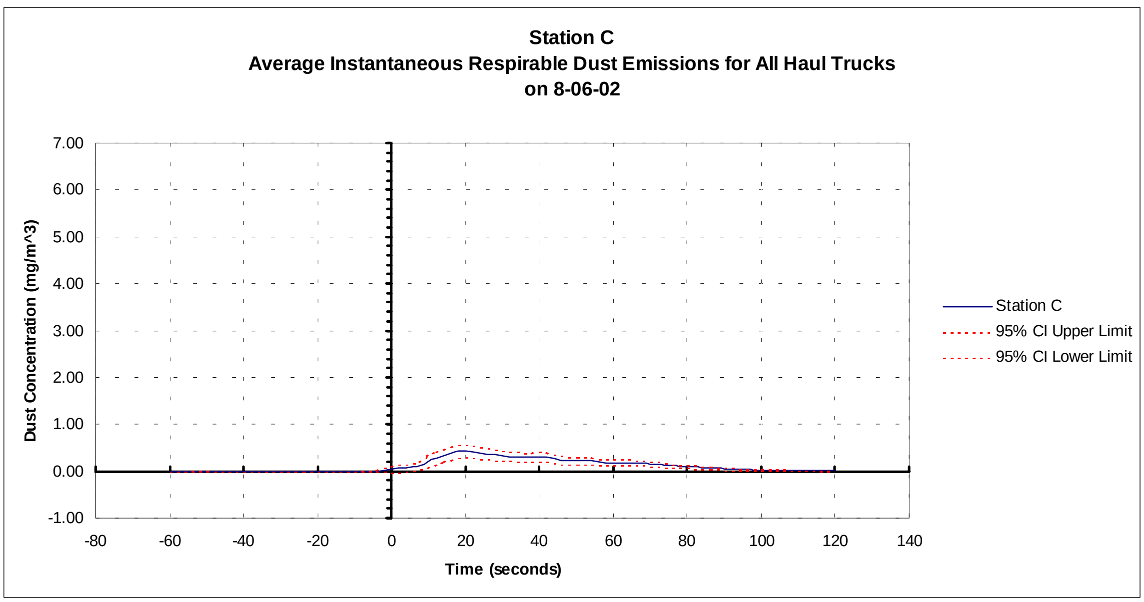


Figure F.28 Average instantaneous dust concentrations with 95% confidence interval for Station C on 8-06-02.

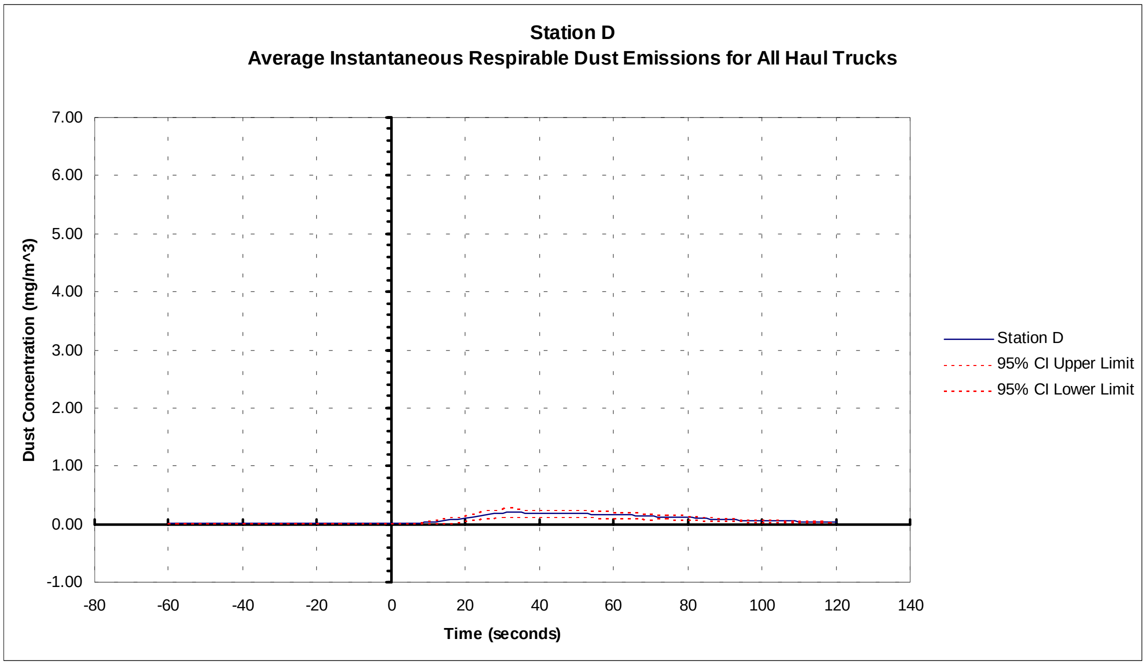


Figure F.29 Average instantaneous respirable dust concentrations with 95% confidence interval for Station D on 8-06-02.

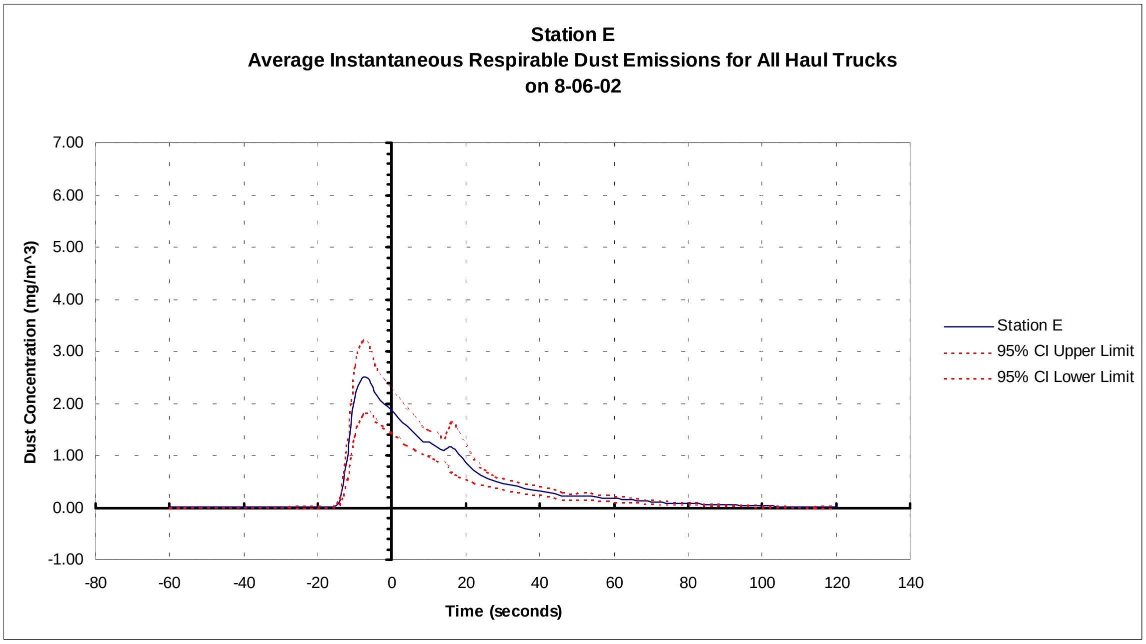


Figure F.30 Average instantaneous respirable dust concentrations with 95% confidence interval for Station E on 8-06-02.

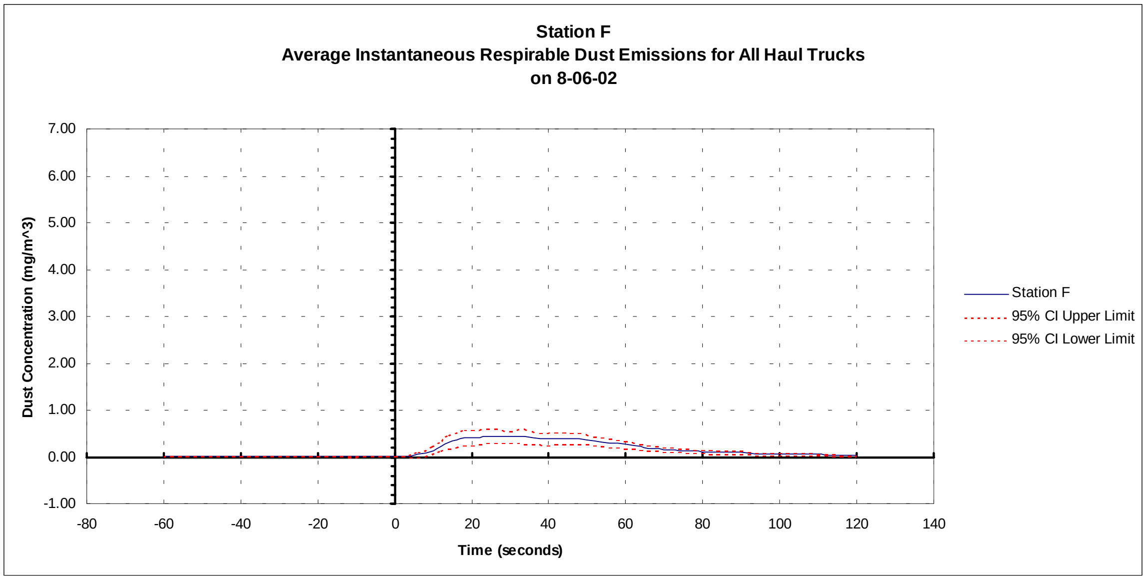


Figure F.31 Average instantaneous respirable dust concentrations with 95% confidence interval for Station F on 8-06-02.

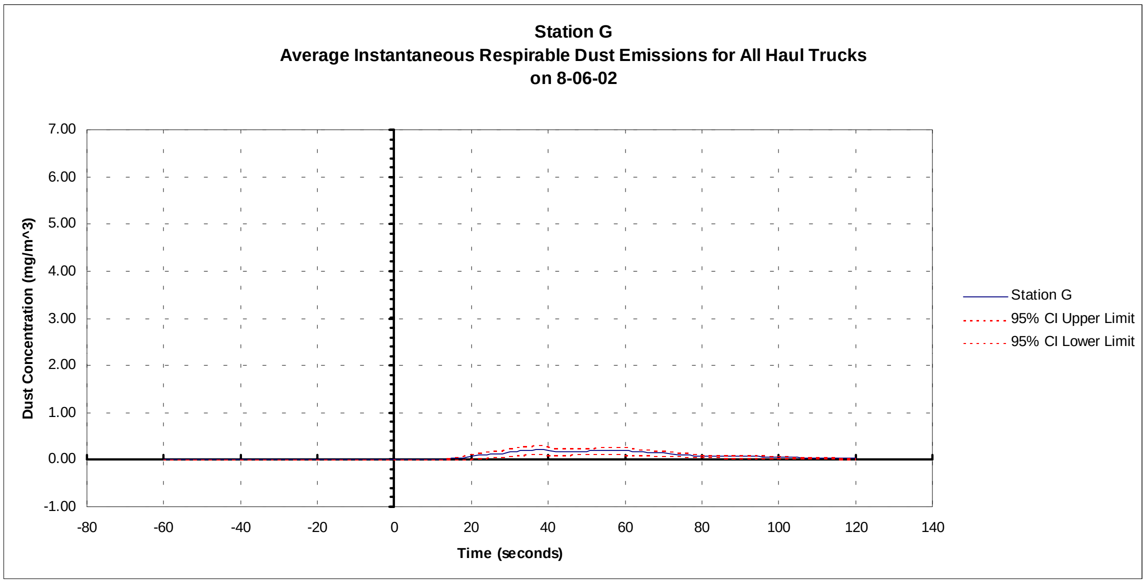


Figure F.32 Average instantaneous respirable dust concentrations with 95% confidence interval for Station G on 8-06-02.

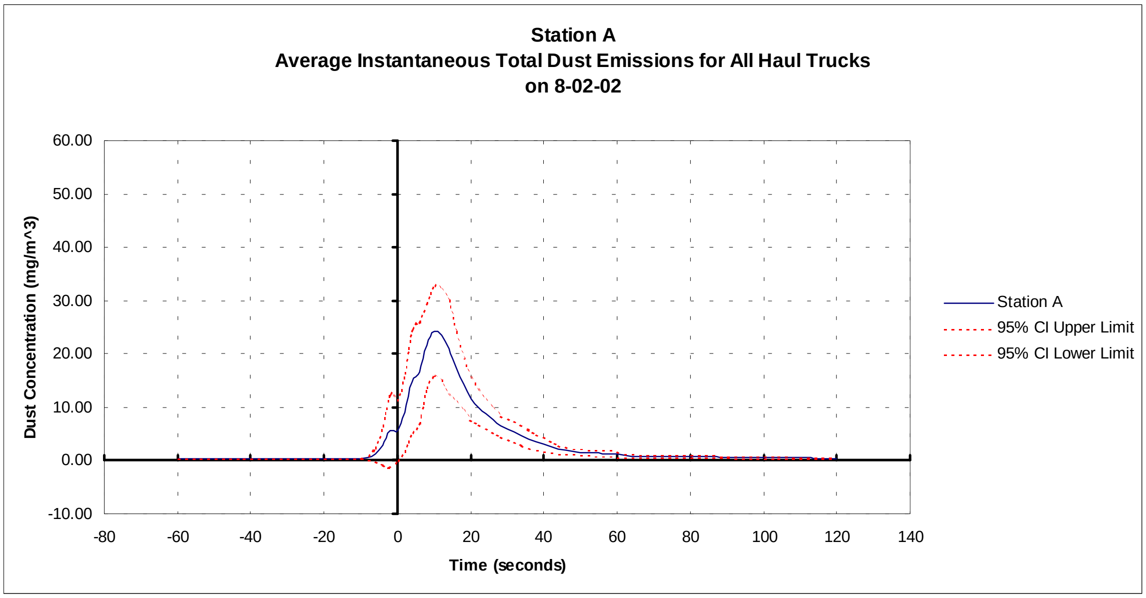


Figure F.33 Average instantaneous total dust concentrations with 95% confidence interval for Station A on 8-02-02.

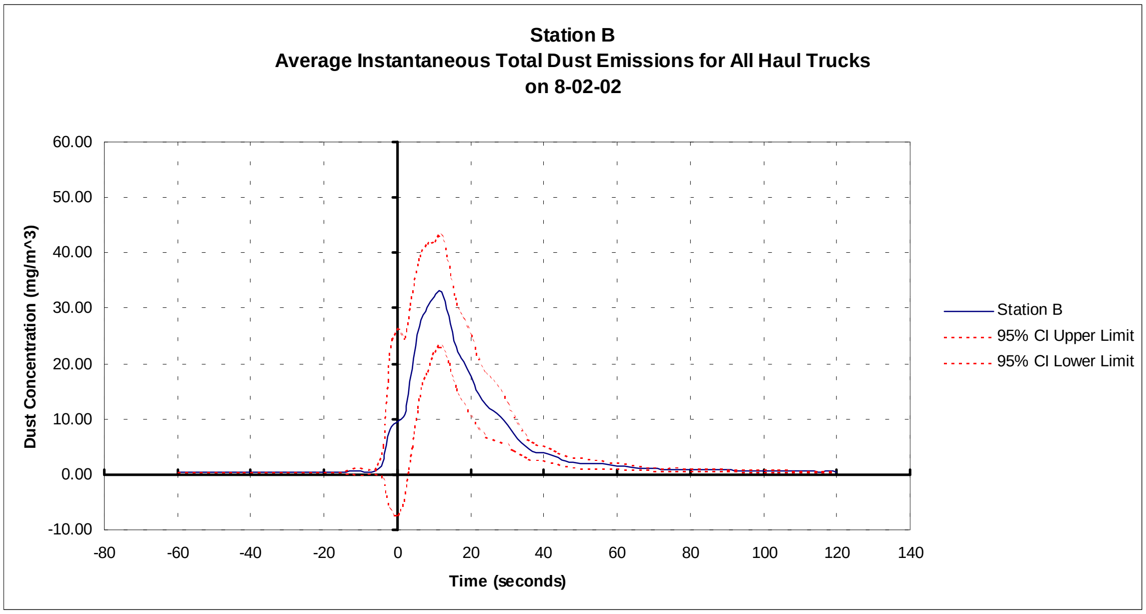


Figure F.34 Average instantaneous total dust concentrations with 95% confidence interval for Station B on 8-02-02.

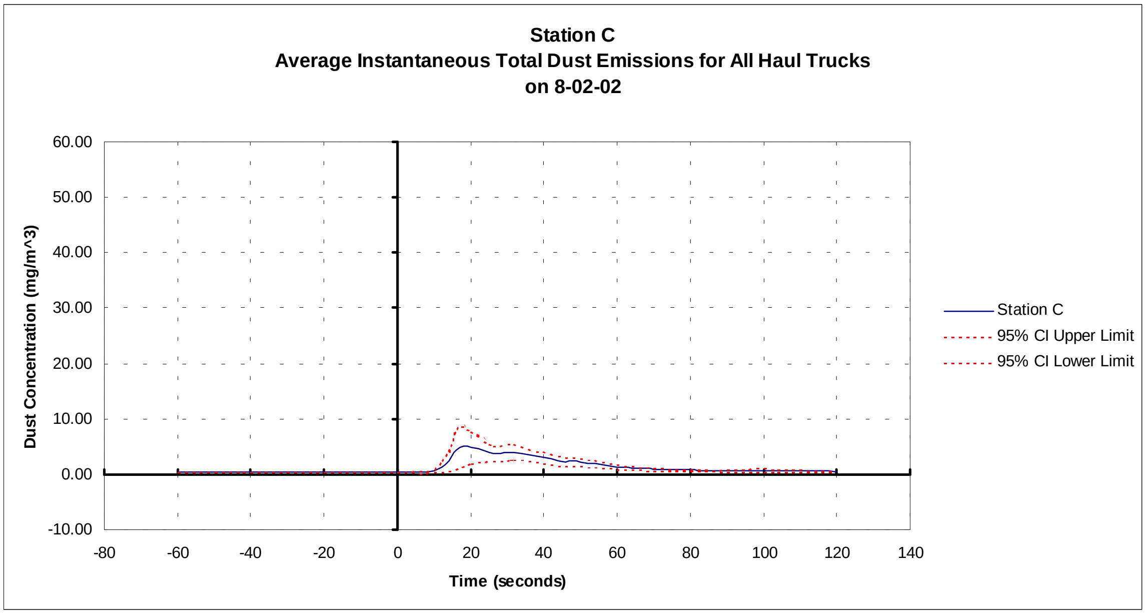


Figure F.35 Average instantaneous total dust concentrations with 95% confidence interval for Station C on 8-02-02.

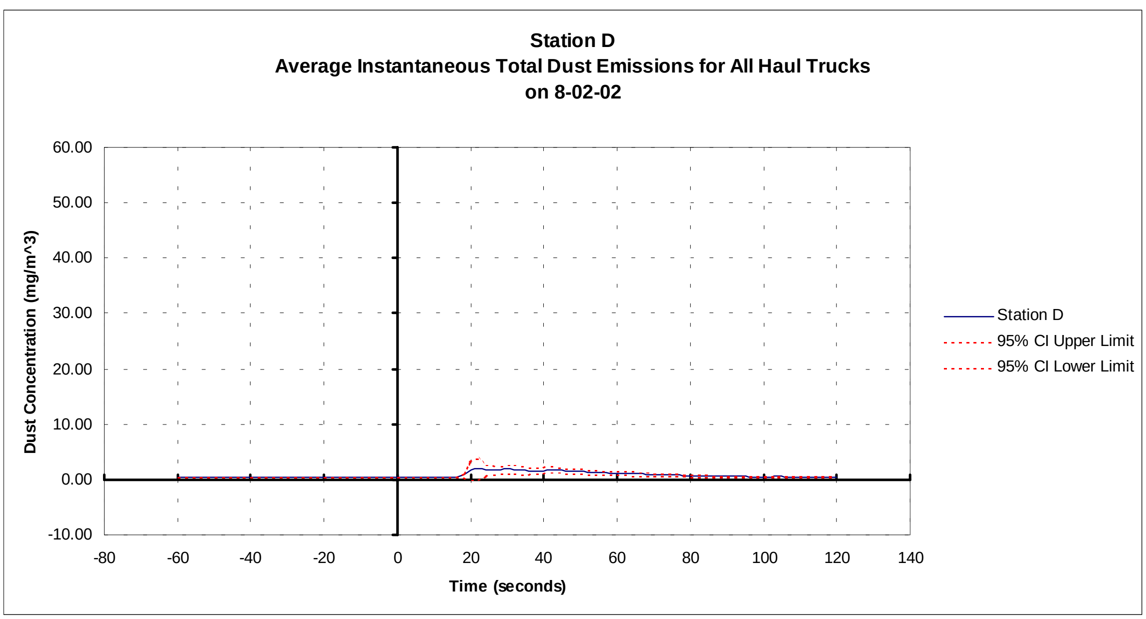


Figure F.36 Average instantaneous total dust concentrations with 95% confidence interval for Station D on 8-02-02.

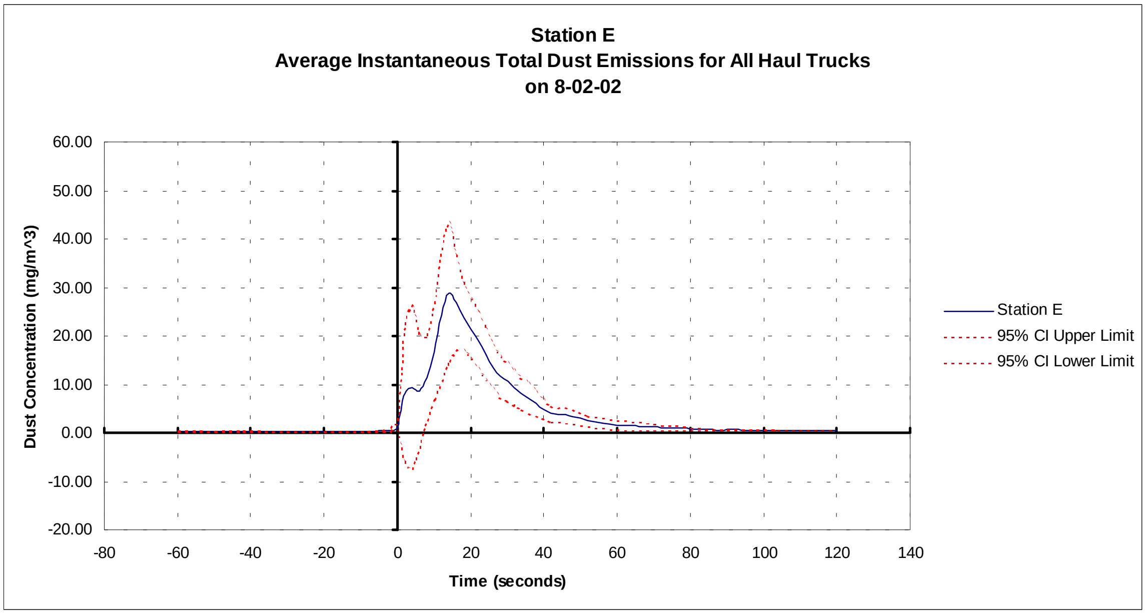


Figure F.37 Average instantaneous total dust concentrations with 95% confidence interval for Station E on 8-02-02.

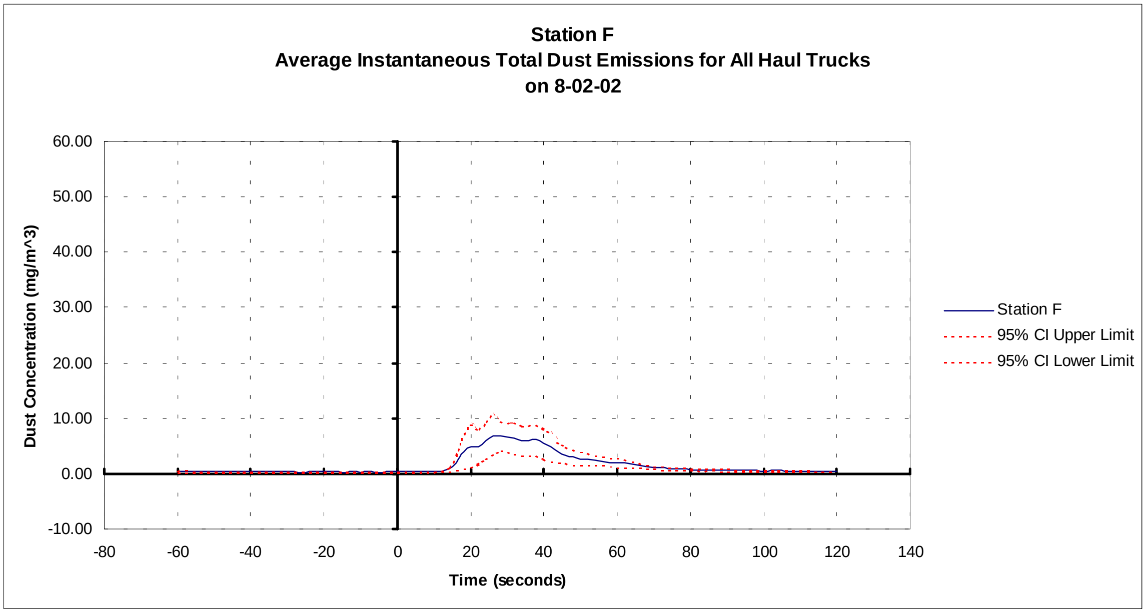


Figure F.38 Average instantaneous total dust concentrations with 95% confidence interval for Station F on 8-02-02.

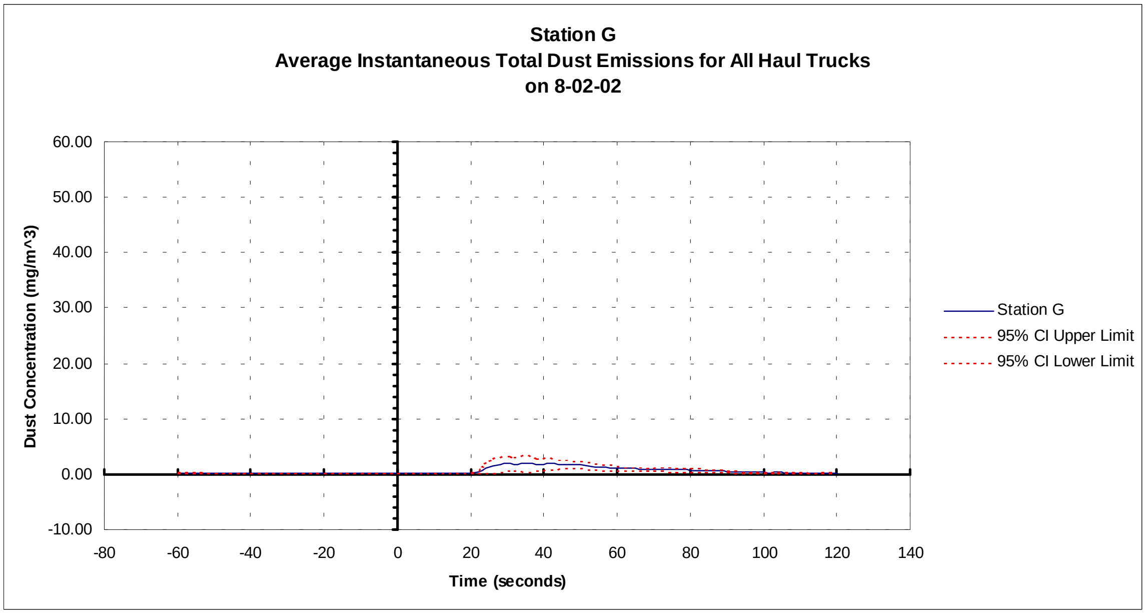


Figure F.39 Average instantaneous total dust concentrations with 95% confidence interval for Station G on 8-02-02.

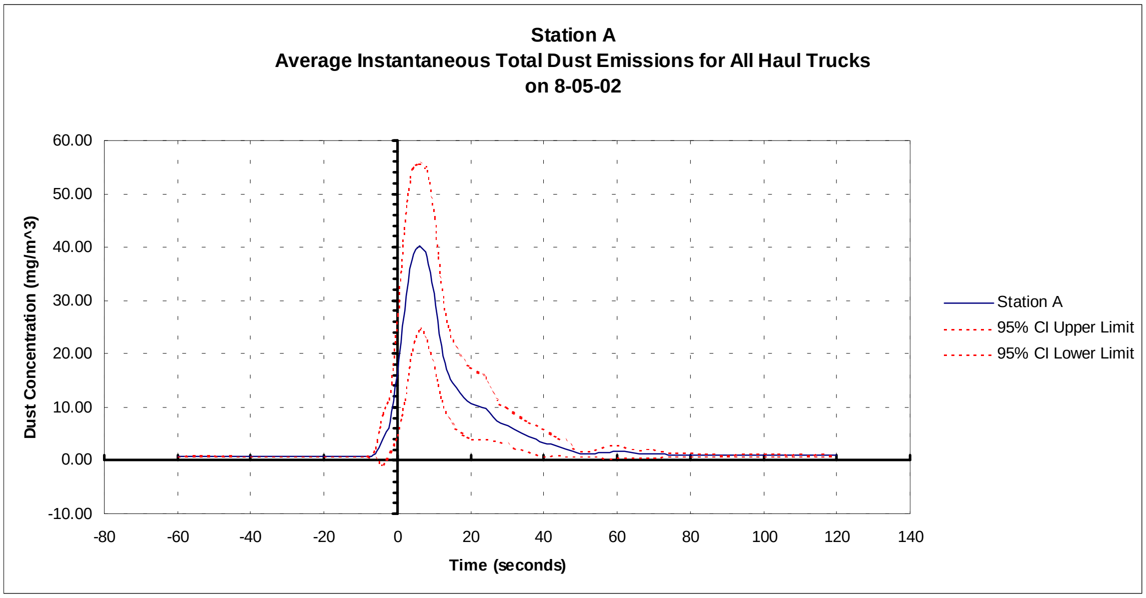


Figure F.40 Average instantaneous total dust concentration with 95% confidence interval for Station A on 8-05-02.

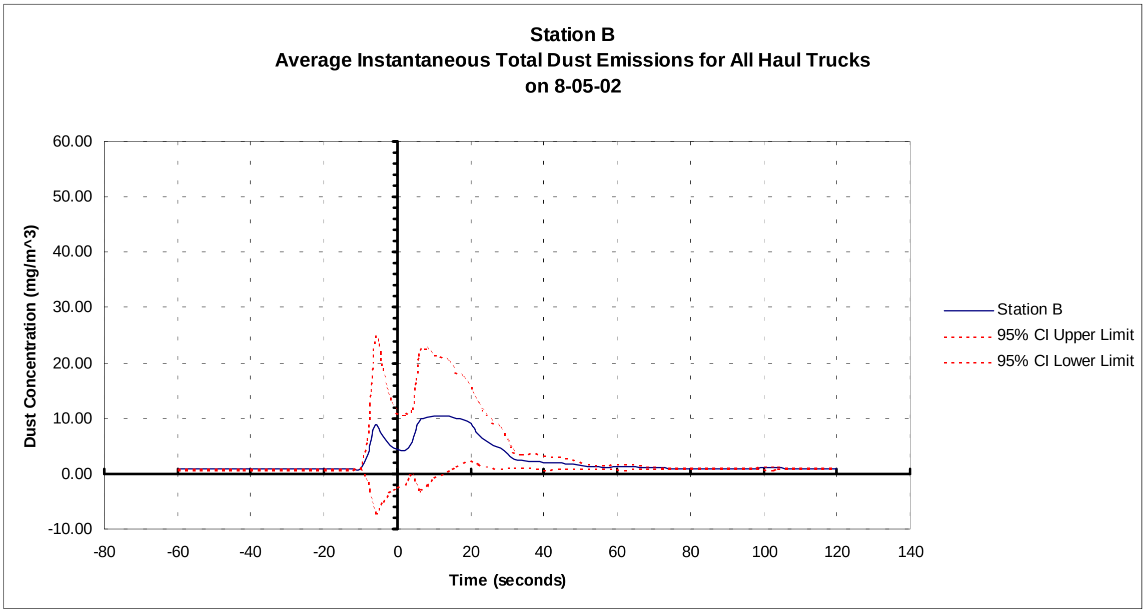


Figure F.41 Average instantaneous total dust concentrations with 95% confidence interval for Station B on 8-05-02.

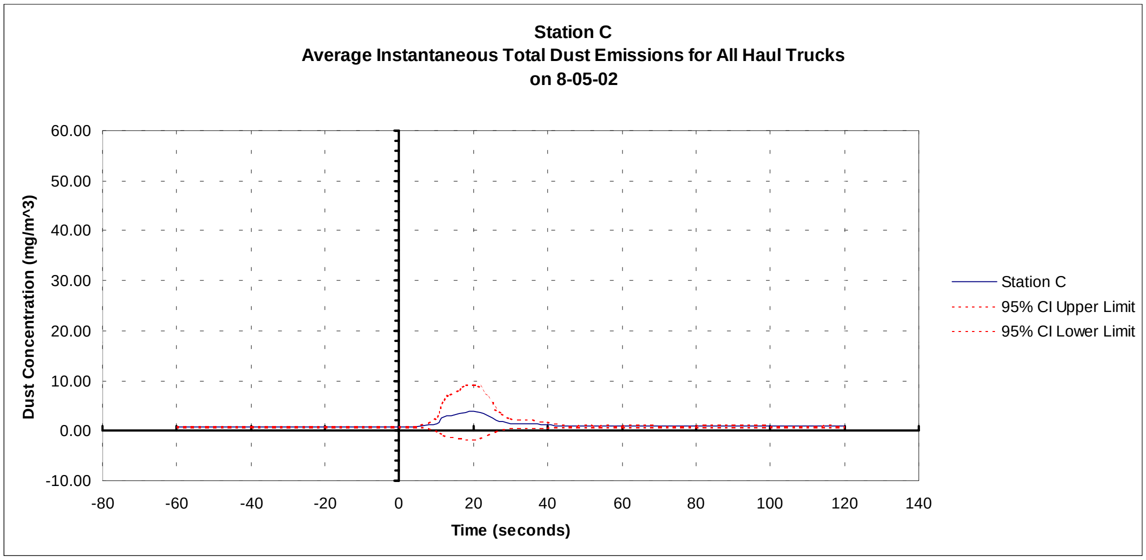


Figure F.42 Average instantaneous total dust concentrations with 95% confidence interval for Station C on 8-05-02.

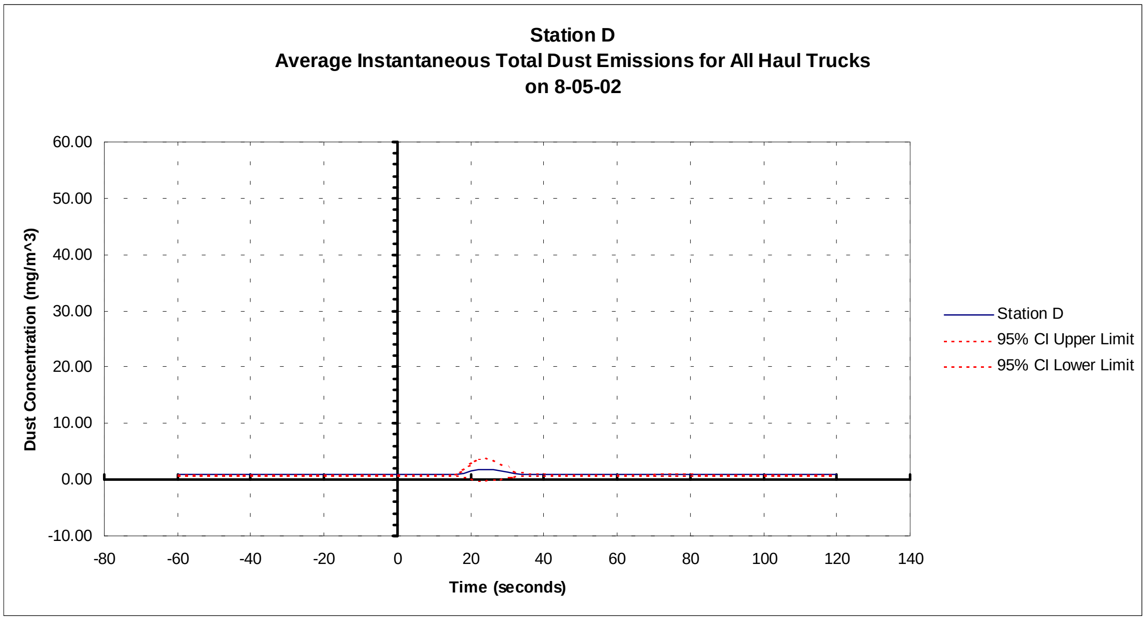


Figure F.43 Average instantaneous total dust concentrations with 95% confidence interval for Station D on 8-05-02.

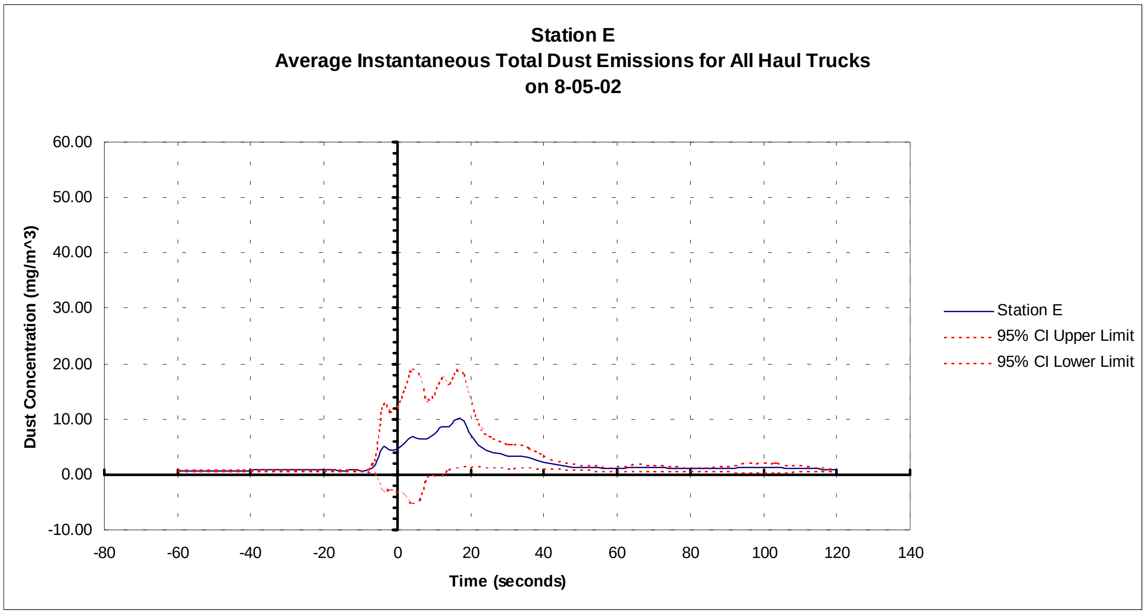


Figure F.44 Average instantaneous total dust concentrations with 95% confidence interval for Station E on 8-05-02.

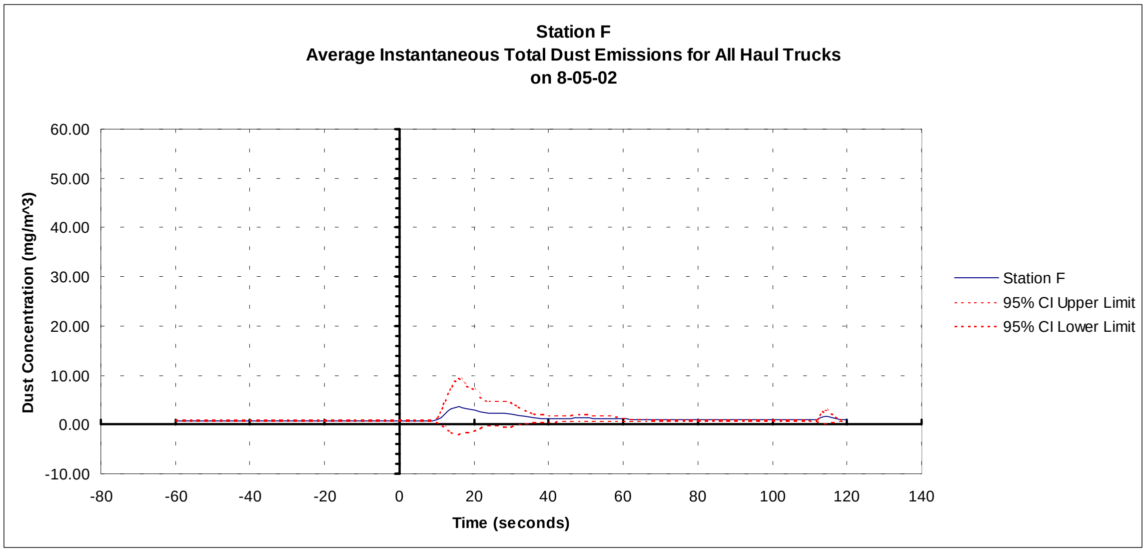


Figure F.45 Average instantaneous total dust concentrations with 95% confidence interval for Station F on 8-05-02.

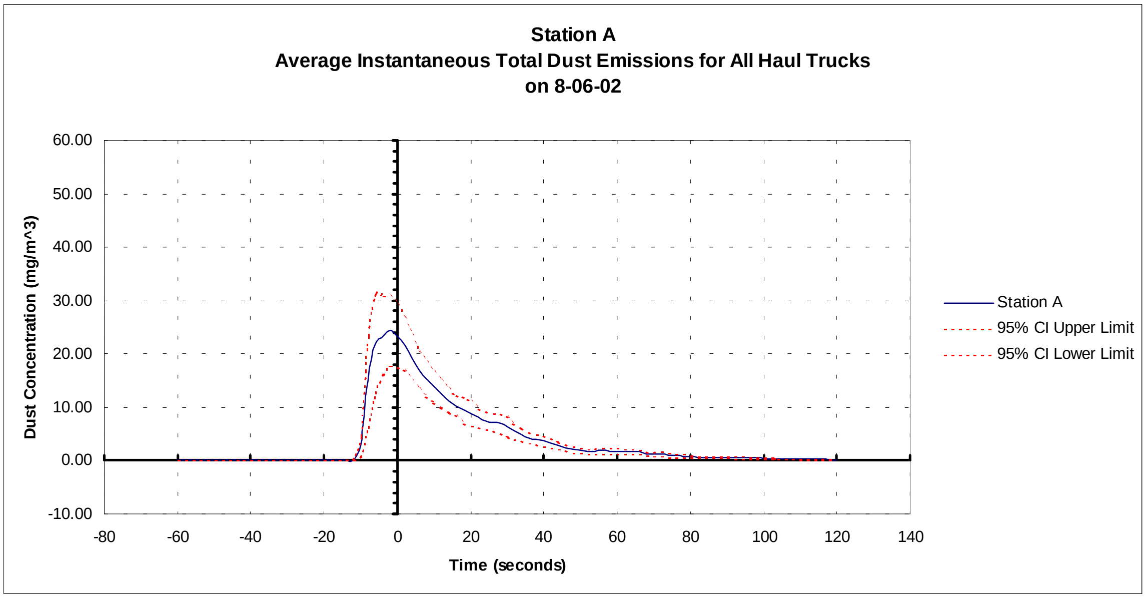


Figure F.46 Average instantaneous total dust concentrations with 95% confidence interval for Station A on 8-06-02.

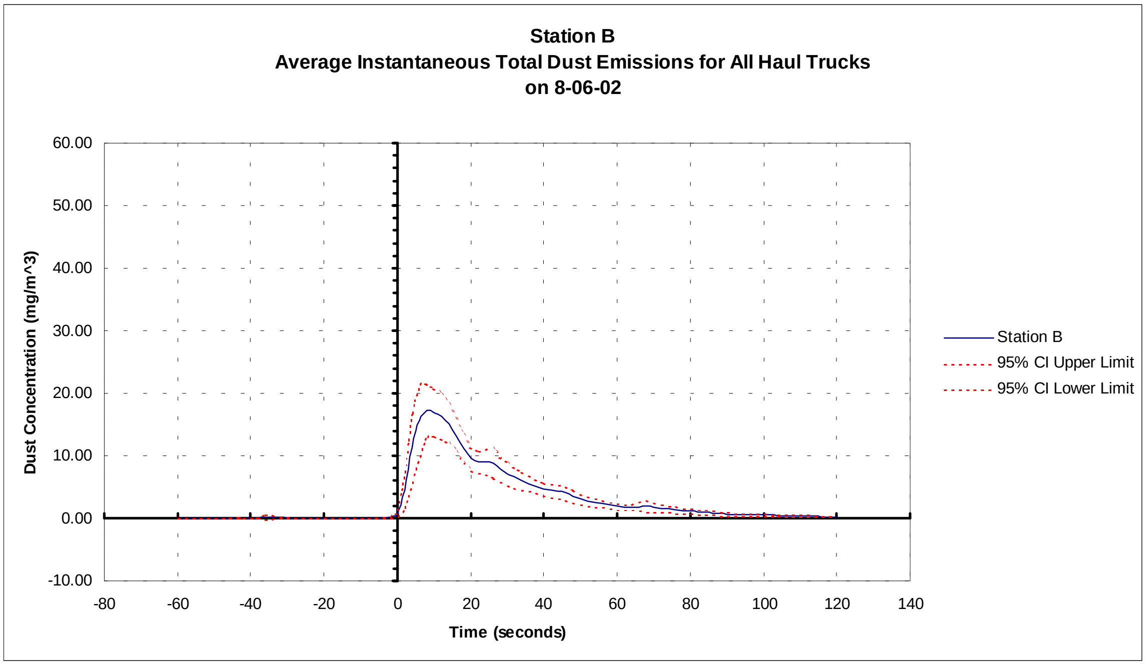


Figure F.47 Average instantaneous total dust concentrations with 95% confidence interval for Station B on 8-06-02.

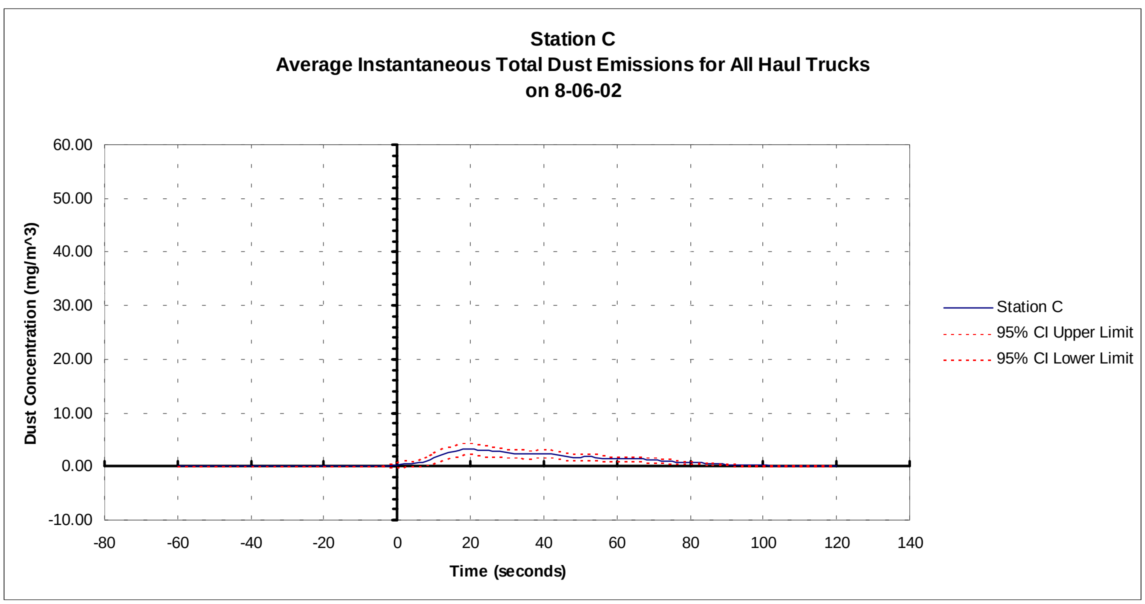


Figure F.48 Average instantaneous total dust concentrations with 95% confidence interval for Station C on 8-06-02.

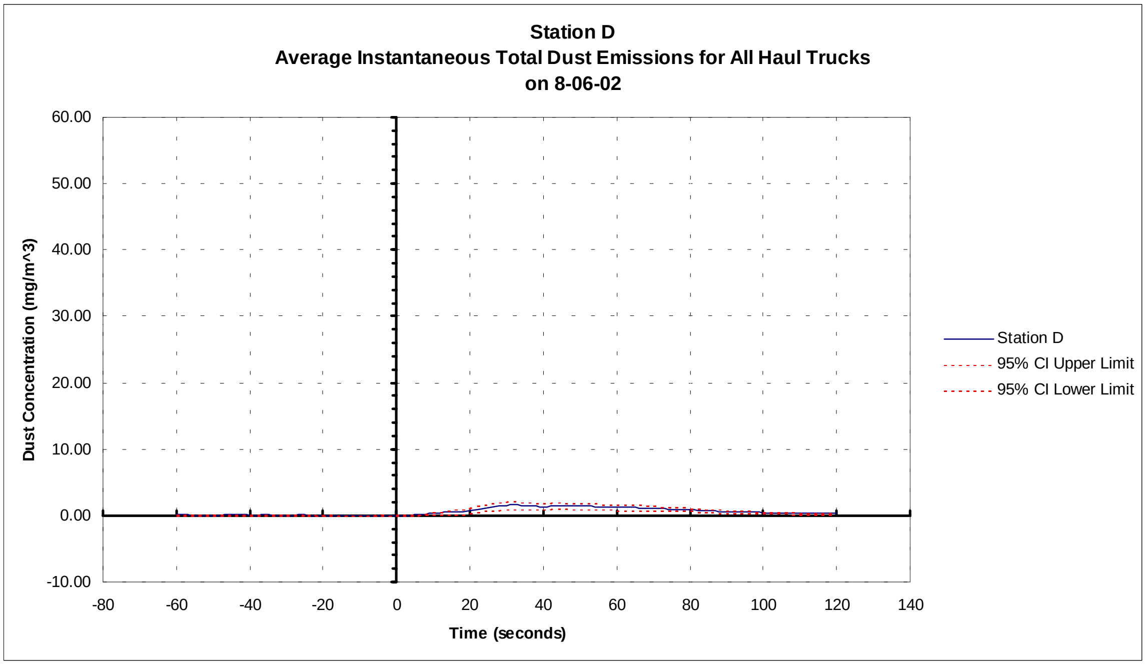


Figure F.49 Average instantaneous total dust concentrations with 95% confidence interval for Station D on 8-06-02.

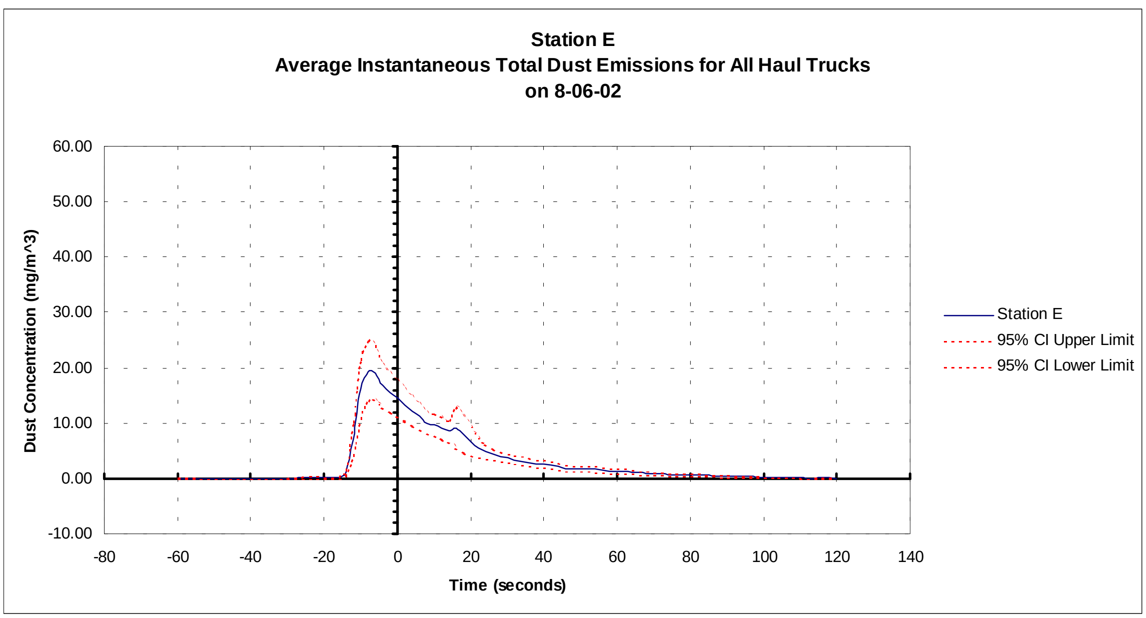


Figure F.50 Average instantaneous total dust concentration with 95% confidence interval for Station E on 8-06-02.

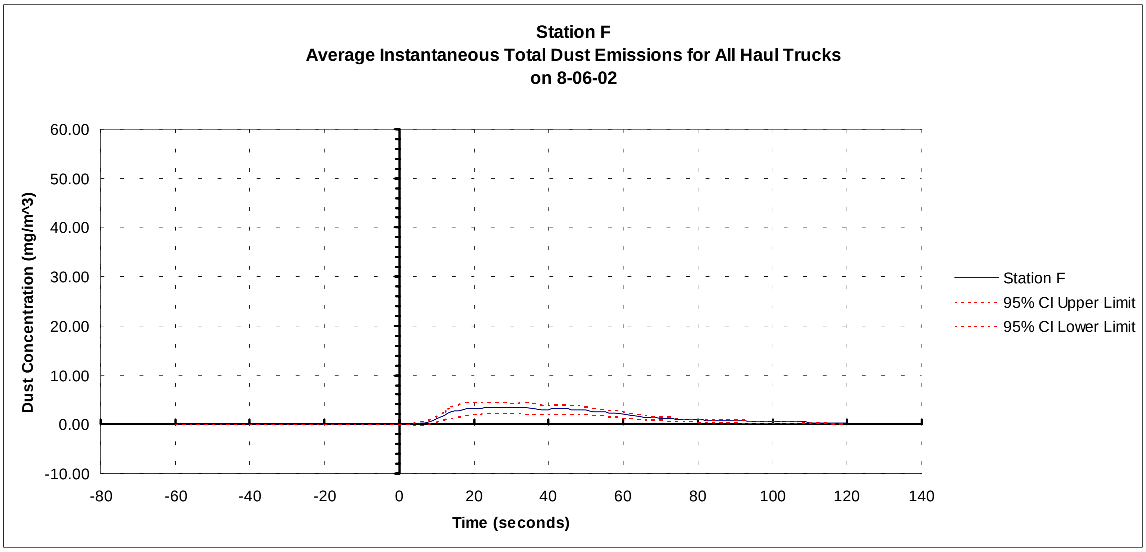


Figure F.51 Average instantaneous total dust concentrations with 95% confidence interval for Station F on 8-06-02.

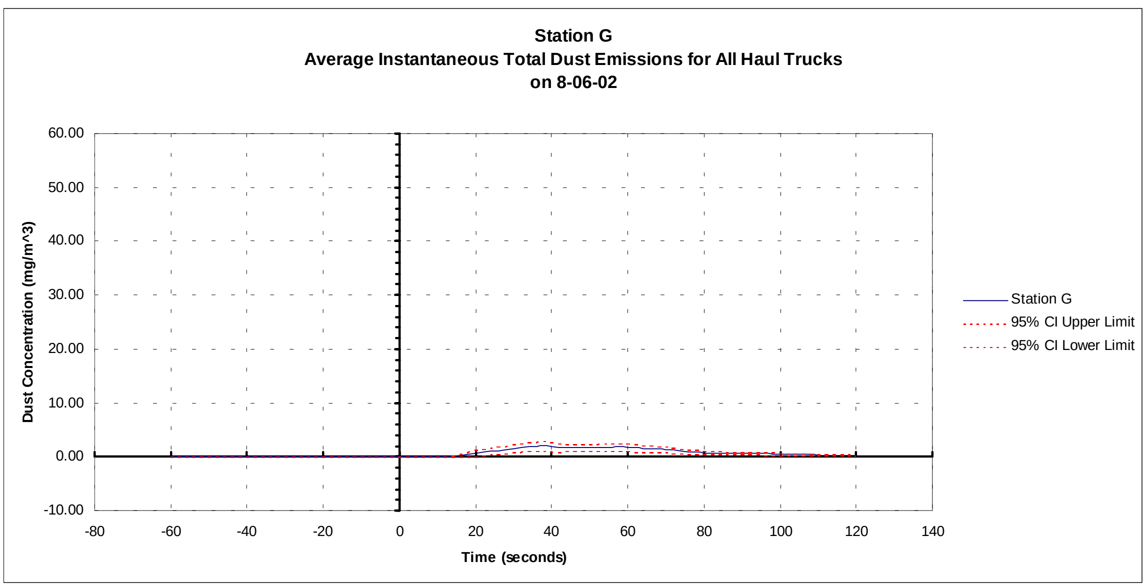


Figure F.52 Average instantaneous total dust concentrations with 95% confidence interval for Station G on 8-06-02.

F.4 Three-Dimensional Graphs of Average Instantaneous Respirable and Total Dust Concentrations for Stations A, B, C, and D.

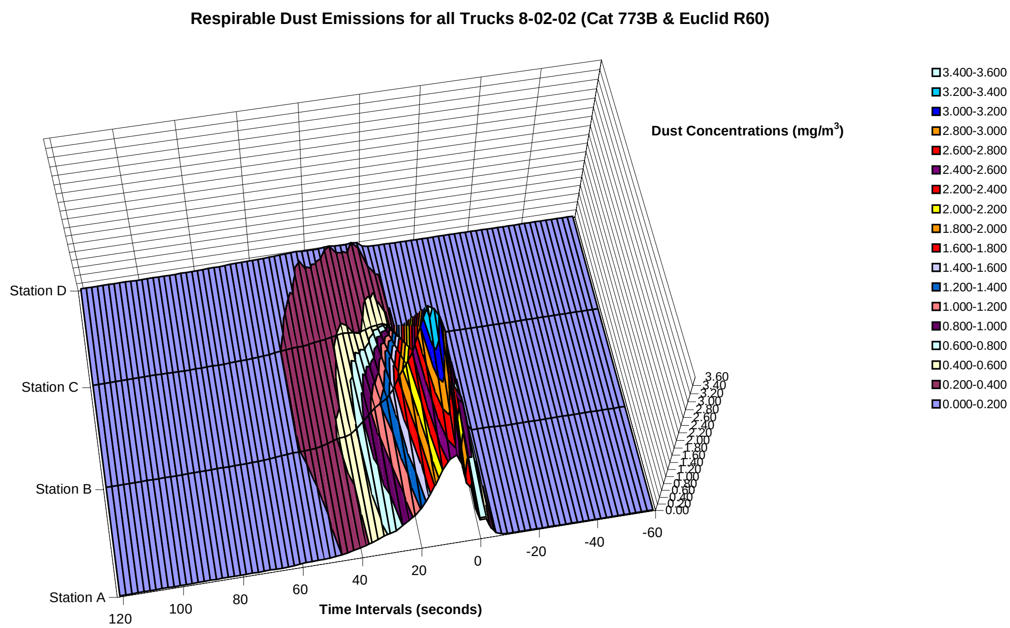


Figure F.53 Three-Dimensional graph of average instantaneous respirable dust concentrations for stations A, B, C, and D on 8-02-02.

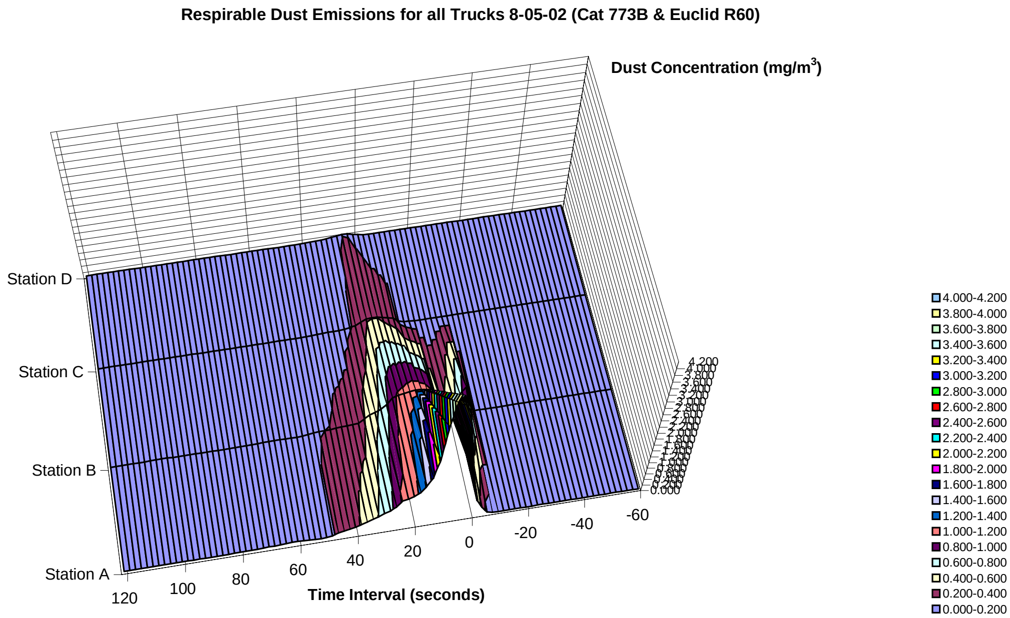


Figure F.54 Three-Dimensional graph of average instantaneous respirable dust concentrations for stations A, B, C, and D on 8-05-02.

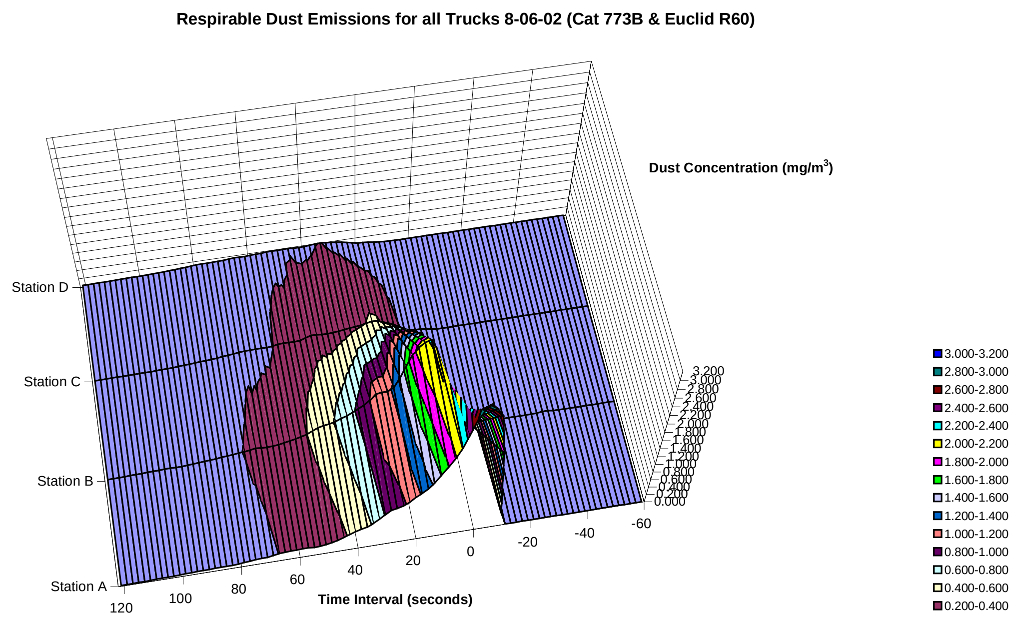


Figure F.55 Three-Dimensional graph of average instantaneous respirable dust concentrations for stations A, B, C, and D on 8-06-02.

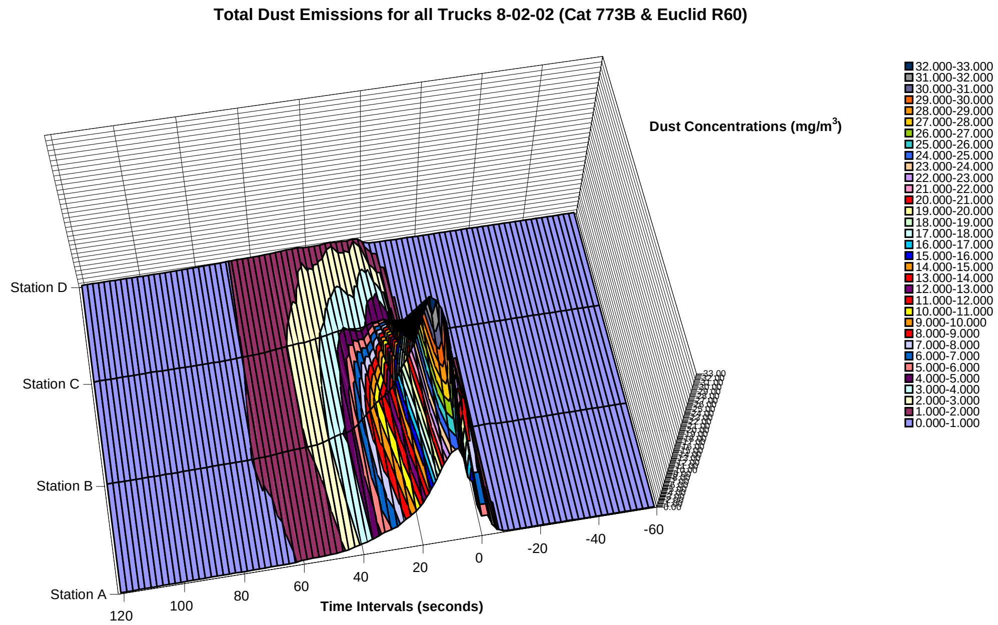


Figure F.56 Three-Dimensional graph of average instantaneous total dust concentrations for stations A, B, C, and D on 8-02-02.

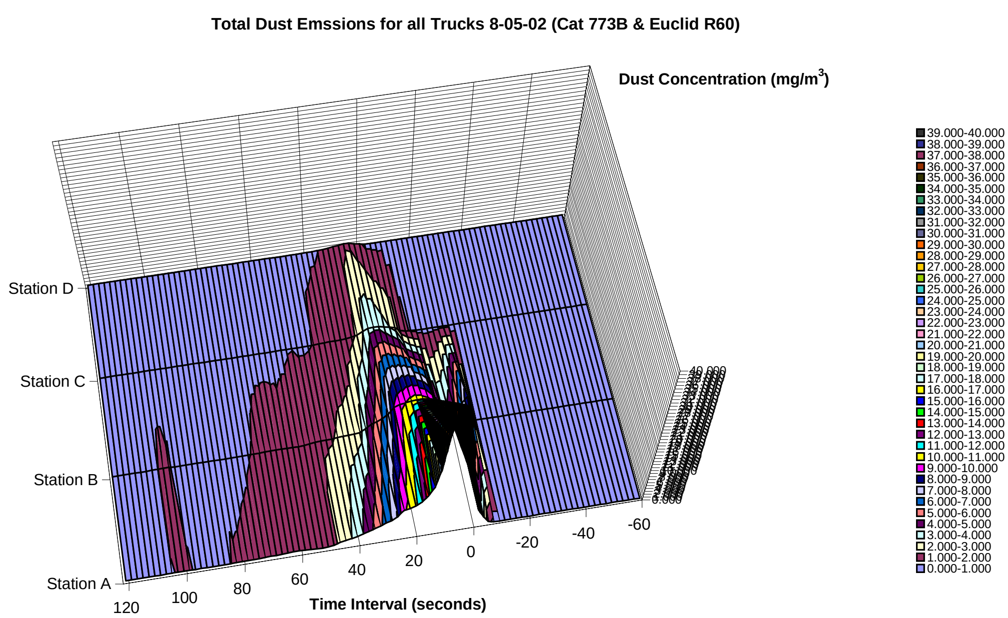


Figure F.57 Three-Dimensional graph of average instantaneous total dust concentrations for stations A, B, C, and D on 8-05-02.

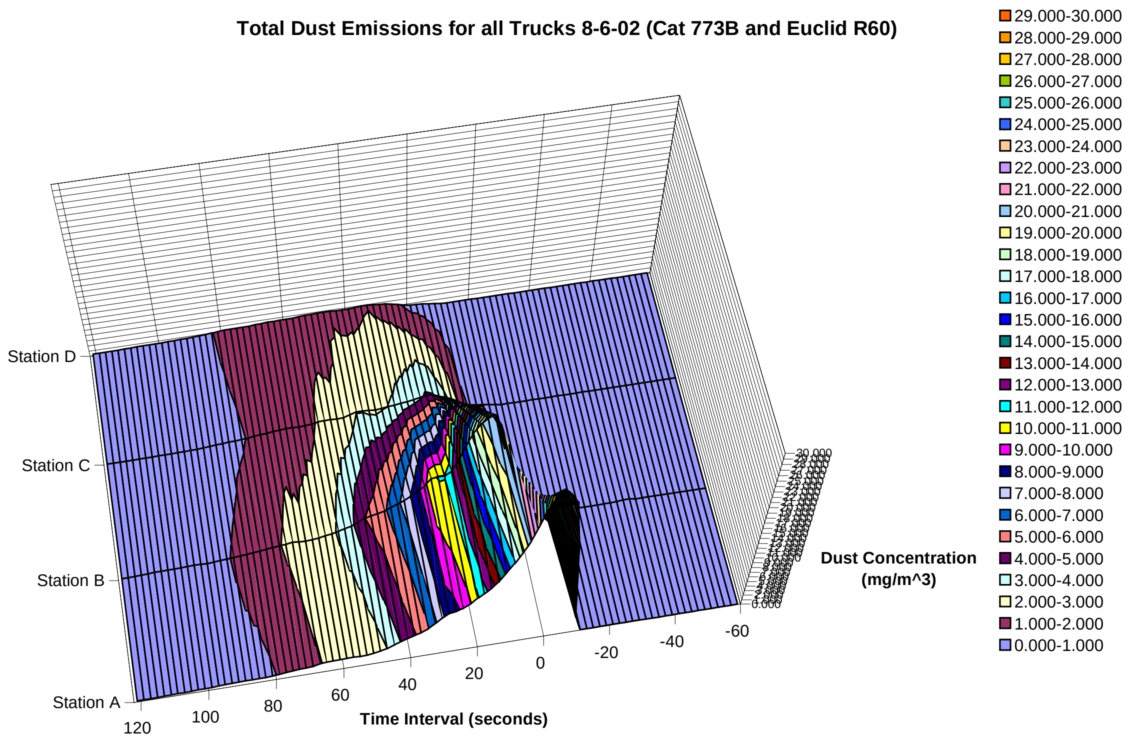


Figure F.58 Three-Dimensional graph of average instantaneous total dust concentrations for stations A, B, C, and D on 8-05-02.

Appendix G

G.1 Input Data for the Coal Mine Field Study/Model Comparison

The following is the data input into the Dynamic Component Program and the ISC3 model to produce model results for comparison with the coal mine field study results. Table G.1 shows input data concerning the haul road based upon a Cartesian coordinate system. Table G.2 shows the haul road material properties as measured from the haul road material samples taken during the field study. Table G.3 shows information concerning the haul trucks. Table G.4 shows the receptor locations in the same Cartesian coordinate system as the haul road is defined. Table G.5 shows other miscellaneous information that was required for the modeling exercises.

Table G.1 Haul road layout information.

Starting point	923.28	708.90
Ending point	1044.83	1398.26
Slope of haul road line		5.672
Y-intercept of haul road line		-4527.94

Table G.2 Haul road material specifications.

Field Study Date	Moisture Content	Silt Content	Specific Gravity
August 2, 2002	0.65%	21.18%	2.44
August 5, 2002	0.68%	26.20%	2.49
August 6, 2002	0.54%	18.34%	2.52

Table G.3 Haul truck information.

	Aug. 2, 2002	Aug. 5, 2002	Aug. 6, 2002
Average speed of haul truck as calculated from field study.	6.92 m/s	6.62 m/s	7.79 m/s
Number of haul trucks passing sampling stations during field study	57	47	64
Haul truck weight	50 tons (short)	50 tons (short)	50 tons (short)

Table G.4 Field study receptor coordinate locations.

	X-Coordinate	Y-Coordinate
Station A	950.76	1008.68
Station B	1000.00	1000.00
Station C	1049.24	991.32
Station D	1098.48	982.64
Station E	1017.36	1098.48
Station F	1066.6	1089.80
Station G	1115.84	1081.12

Table G.5 Miscellaneous information used in Dynamic Component Program and ISC3 modeling exercises.

	Aug. 2, 2002	Aug. 5, 2002	Aug. 6, 2002
PM_{10} background dust concentration level (as measured from field study instantaneous data)	0.1470 mg/m^3	0.3747 mg/m^3	0.0328 mg/m^3
Number of wind speed and direction data points recorded	719	713	815
Sampling time of field study	330 min.	325 min.	384 min.

G.2 Input data for the Stone Quarry Field Study/Model Comparison

The following is the data input into the Dynamic Component Program and the ISC3 model to produce model results for comparison with the stone quarry field study results. Table G.6 shows input data concerning the haul road based upon a Cartesian coordinate system. Table G.7 shows the haul road material properties as measured from the haul road material samples taken during the field study. Table G.8 shows information concerning the haul trucks. Table G.9 shows the receptor locations in the same Cartesian coordinate system as the haul road is defined used for July 16, 2002. Table G10 shows the receptor locations in the same Cartesian coordinate system as the haul road is defined used for July 17 and July 18, 2002. The coordinates used are different from for July 16, 2002 because Station A was in a different location on July 16, 2002. Table G.11 shows other miscellaneous information that was required for the modeling exercises.

Table G.6 Haul road layout information.

Starting point	873.90	726.34
Ending point	1113.32	1384.13
Slope of haul road line		2.747
Y-intercept of haul road line		-1674.26

Table G.7 Haul road material specifications.

Field Study Date	Moisture Content	Silt Content	Specific Gravity
July 16, 2002	0.26%	26.96%	2.85
July 17, 2002	0.17%	20.26%	2.85
July 18, 2002	0.06%	19.50%	2.87

Table G.8 Haul truck information.

	July 16, 2002	July 17, 2002	July 18, 2002
Average speed of haul truck as calculated from field study.	6.84 m/s	7.39 m/s	6.84 m/s
Number of haul trucks passing sampling stations during field study	305	262	230
Haul truck weight	20 tons (short)	20 tons (short)	20 tons (short)

Table G.9 Field study receptor coordinate locations for July 16, 2002.

	X-Coordinate	Y-Coordinate
Station A	987.22	1111.07
Station B	1000.00	1000.00
Station C	1046.98	982.90
Station D	1093.97	965.8
Station E	1034.20	1093.97
Station F	1081.18	1076.87
Station G	1128.17	1059.77

Table G.10 Field study receptor coordinate locations for July 17 and July 18, 2002.

	X-Coordinate	Y-Coordinate
Station A	953.02	1017.10
Station B	1000.00	1000.00
Station C	1046.98	982.90
Station D	1093.97	965.8
Station E	1034.20	1093.97
Station F	1081.18	1076.87
Station G	1128.17	1059.77

Table G.11 Miscellaneous information used in Dynamic Component Program and ISC3 modeling exercises.

	July 16, 2002	July 17, 2002	July 18, 2002
PM_{10} background dust concentration level (as measured from field study instantaneous data)	0.1628 mg/m^3	0.1715 mg/m^3	0.3774 mg/m^3
Number of wind speed and direction data points recorded	897	845	838
Sampling time of field study	443 min.	417 min.	414 min.

Vita

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Advisor: Erik C. Westman

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RESEARCH EXPERIENCE:

Research

Student Trainee, Engineer, National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory / Health Branch, Pittsburgh, Pennsylvania, May 2002 - August 2002

- Researched particulate matter (PM) measurement equipment.
- Finalized field study protocol to validate computer model.
- Obtained sites to conduct field study.
- Conducted field studies at two surface mine locations to measure respirable, thoracic, and total dust generation and propagation from haul trucks.
- Reviewed and analyzed data from field study.

Research Assistant, Department of Mining and Minerals Engineering, Virginia Polytechnic Institute & State University, Blacksburg, Virginia, January 1999 - May 2003

- Researched possible proposals for noise in the mining industry.
- Examined current PM dispersion models used by mining industry.
- Reviewed causes of ISC3 model over-prediction of PM dispersion from surface mining operations.
- Created a computer model that predicts PM dispersion from mobile equipment to improve the accuracy of the existing ISC3 dispersion model.

- Created field study protocol to validate the new computer model.
- Obtained funding from NIOSH through a student intern program to conduct the field study on PM dispersion from haul trucks at surface mining operations.
- Reviewed and analyzed data from field study.

Teaching

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MINE 3545, Ventilation Engineering, Spring 2001 & 2002
MINE 4524, Project Engineering and Mine Management, Fall 2000 & 2001

HONORS:

Outstanding Graduate Student, Department of Mining and Minerals Engineering, Virginia Polytechnic Institute and State University, 2002.

Eleanor Davenport Leadership Fellowship, 2001 - 2002

PEER REVIEWED PUBLICATIONS:

Reed, Wm. R.; Westman, E.C.; and Haycocks, C.; "The Introduction of a Dynamic Component to the ISC3 Model in Predicting Dust Emissions from Surface Mining Operations." Application of Computers and Operations Research in the Mineral Industry, Proceedings of the 30th International Symposium. Ed. Bandopadhyay, S.; (Littleton, CO: Society for Mining, Metallurgy, and Exploration, Inc. 2002) 659-667.

Reed, Wm. R.; Westman, E.C.; and Haycocks, C.; "An Improved Model for Estimating Particulate Emissions from Surface Mining Operations in the Eastern United States." Securing the Future; International Conference on Mining and the Environment, 2001. (Skellefteå, Sweden: Swedish Mining Association, 2001) 693-702.

OTHER PUBLICATIONS:

Reed, Wm. R.; Westman, E.C.; and Haycocks, C.; "Environmental effects of increased blasting density in Appalachian limestone operations." Environmental Issues and Management of Waste in Energy and Mineral Production. Ed. Singhal, R. K.; Mehrotra A. K.; (Rotterdam, Netherlands: A. A. Balkema, 2000) 231-235.

PRESENTATIONS:

The 30th International Symposium on Application of Computers and Operations Research in the Mineral Industry, Phoenix, AZ, February 23-25, 2002. "The Introduction of a Dynamic Component to the ISC3 Model in Predicting Dust Emissions from Surface Mining Operations."

Securing the Future; International Conference on Mining and the Environment, Skellefteå, Sweden, June 25 -July 1, 2001. "An Improved Model for Estimating Particulate Emissions from Surface Mining Operations in the Eastern United States."

West Virginia Coal Mining Institute - Central Appalachian Section SME 2000 Annual Joint Fall Meeting, White Sulphur Springs, West Virginia, October 26-28, 2000. "Environmental effects of increased blasting density in Appalachian limestone operations."

The 6th International Conference on Environmental Issues and Management of Waste in Energy and Mineral Production (SWEMP 2000), Calgary, Alberta, Canada, May 30 - June 2, 2000. "Environmental effects of increased blasting density in Appalachian limestone operations."

INDUSTRIAL EXPERIENCE:

Project Manager, Concord Engineering & Surveying, Inc., Concord, North Carolina, 1998

- Created site plans for construction sites requiring design of sanitary sewer-lines, water-lines, grading plans, facility placement, and sediment erosion control plans. Typical sites were apartment complexes, hotels, hospitals, and industrial facilities.
- Obtained all environmental and zoning permits for construction sites.
- Used computers in all aspects of design (Word, Excel, WordPerfect, AutoCad, SoftDesk, & Eaglepoint).

Sr. Project Engineer, Brewer Gold Company, Jefferson, South Carolina, 1994 - 1997

- Developed and obtained wastewater construction permits.
- Participated in the design of the final closure plans for the reclamation of the Brewer Gold Mine.
- Participated in negotiations with the South Carolina Department of Health and Environmental Control (SCDHEC) in obtaining permits.
- Reviewed NPDES permit renewal.
- Designed and supervised the construction of pumping and treatment facilities used for removing water at a rate of 2,500 GPM from the Brewer Pit.
- Designed and supervised the construction of stormwater removal pumping system.
- Designed and supervised the construction of a collection system for pit seepage.
- Managed the operation and maintenance of the water treatment facilities.
- Developed and implemented a maintenance recordkeeping system for equipment.
- Participated in decisions of oversite engineering and budgeting.
- Coordinated reclamation activities with contractors and on-site personnel.
- Directed methods of sludge removal from the different ponds on site.
- Directed final grading and revegetation of miscellaneous disturbed areas.
- Updated surveying capabilities for the mine site.

Mine Engineer, Montana Talc Company, Ennis, Montana, 1993 - 1994

- Developed applications for all permits, MPDES permit, final operation permit, etc.
- Maintained and monitored environmental requirements for site.
- Participated in negotiations with the Montana Department of State Lands and the U.S. Forest Service in obtaining permits.
- Completed major redesign of long-term plans to resolve a serious ore-shortage.
    - Completed ore reserve estimates using three-dimensional computer modeling.
    - Redesigned pit and waste dump using computer model and drafting techniques.
    - Evaluated different equipment types for accomplishing long-term plans.
- Involved in budgeting for the implementation of the new long-term plans.
- Formulated short-term plans for production operations.
- Modernized planning operations to use modern mapping and surveying techniques.
- Maintained and stream-lined production records.

Mine Engineer, Brewer Gold Company, Jefferson, South Carolina, 1990 - 1993

- Developed applications for NPDES, wastewater construction, and mine site permits.
- Developed preliminary reclamation plans for gold mining operation.
- Participated in negotiations with SCDHEC in obtaining permits.
- Designed ponds, pumps, and pipelines for stormwater runoff and effluent discharge.
- Supervised construction of chemical addition stations for water treatment.
- Developed long-term plans.
    - Completed ore reserve estimates using three-dimensional computer modeling.
    - Redesigned pit and waste dump using computer model and drafting techniques.
- Formulated short-term plans for production operations.
- Planned and scheduled blasting operations.
- Supervised a team of surveyors.
- Worked as drilling and blasting foreman, relief production foreman, and temporary superintendent.

Mining Engineer, Rand Mining Company, Randsburg, California, 1988 - 1990

- Developed short-term plans involving surveying, ore grade control, and coordination with production.
- Maintained mine production records.
- Monitored contractor's construction of a heap leach pad.
- Maintained gold adsorption records.
- Developed layout of cyanide solution lines on heap leach pads.
- Assisted with smelting gold.

AFFILIATIONS:

American Society of Civil Engineers
Society of Mining Engineers