Final Report

Bingham Canyon Mine Expansion

Notice of Intent Application

Submitted to:
Utah Division of Air Quality

Submitted by:
Kennecott Utah Copper LLC

Prepared by:
CH2MHILL

August 2010
Revised January 2011

THIS DOCUMENT MAY NOT BE FINAL. THE FINAL DOCUMENT, UPON WHICH THE PERMIT MAY BE ISSUED, MAY DIFFER FROM THIS VERSION IN RESPONSE TO COMMENTS RECEIVED DURING THE PERMITTING PROCESS.

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Acronyms and Abbreviations

AERMOD	American Meteorological Society/EPA Regulatory Model
AO	Approval Order
BACT	best available control technology
BCM	Bingham Canyon Mine
CMB	Chemical Mass Balance
CO	carbon monoxide
dscfm	dry standard cubic foot per minute
EPA	U.S. Environmental Protection Agency
FDCP	Fugitive Dust Control Plan
FEL	front-end loader
gr/dscf	grain per dry standard cubic foot
H_2SO_4	sulfuric acid
HC	hydrocarbon
KUC	Kennecott Utah Copper LLC
LPG	liquefied petroleum gas
$\mu g/m^3$	microgram per cubic meter
NAAQS	National Ambient Air Quality Standards
NOI	Notice of Intent
NO_x	nitrogen oxide
PM	particulate matter
PM_{10}	particulate matter less than 10 micrometers in aerodynamic diameter
$PM_{2.5}$	particulate matter less than 2.5 micrometers in aerodynamic diameter
ppm	part per million
PTE	potential to emit
SIP	State Implementation Plan
SO_2	sulfur dioxide
SX/EW	solvent extraction/electrowinning

tpy	ton per year
TSD	Technical Support Document
UAC	Utah Administrative Code
UAM-AERO	Urban Airshed Model with aerosols
UAQB	Utah Air Quality Board
UDAQ	Utah Division of Air Quality
VOC	volatile organic compound

1.0 Introduction

1.1 Introduction and Purpose of Notice of Intent

Kennecott Utah Copper LLC (KUC) is submitting this Notice of Intent (NOI) to secure an Approval Order (AO) to increase the annual material-moved limit of ore and waste rock material at the Bingham Canyon Mine (BCM) located near Copperton, Utah. The BCM is currently subject to an annual material-moved limitation of 197,000,000 tons per year (tpy)[1] for ore and waste rock combined. This limit is included in both the current AO for the BCM and the Utah State Implementation Plan. To maintain the current level of metal production, KUC proposes to increase the BCM's material-moved limitation to 260,000,000 tpy during peak years.[2]

The current material-moved limitation of 197,000,000 tpy contained in the AO for the BCM was permitted by the *Notice of Intent to Increase Annual Ore and Waste Rock Production at the Kennecott Utah Copper Bingham Canyon Mine* (KUC, 1999), resulting in an AO being issued in 1999. The current AO for the BCM was issued in 2008 by the Utah Division of Air Quality (UDAQ), AO DAQE-IN0105710023-08 (UDAQ, 2008). Condition 21.A of the 2008 AO includes the material-moved limit established in 1999, stating that the "total material moved (ore and waste) shall not exceed 197,000,000 tons per 12-month period" (UDAQ, 2008).

In addition to the AO, the 197,000,000-tpy material-moved limitation is contained in the Utah State Implementation Plan. A material-moved limitation was first included in the 1994 federally approved Utah State Implementation Plan (SIP) for particulate matter (PM) less than 10 micrometers in aerodynamic diameter (PM_{10}) and, like the AO limitation, was increased in 1999 to the currently authorized limitation of 197,000,000 tpy by order of the Utah Air Quality Board (UAQB) as provided for by the 1994 SIP. In 2005, the UAQB approved substantial changes to the PM_{10} SIP. Consistent with the 1999 authorization, the 197,000,000-tpy material-moved limitation for the BCM was carried forward into the 2005 PM_{10} SIP. The 2005 SIP, as approved by the UAQB, was submitted to the U.S. Environmental Protection Agency (EPA); however, the EPA has not taken final action on that submittal. In fact, EPA has largely proposed its disapproval.[3]

Given the inclusion of the material-moved limitation in the AO and the SIP, this NOI requests that UDAQ (1) issue a modified AO authorizing the increase to 260,000,000 tons, and (2) initiate a rulemaking action through the UAQB to increase the material-moved limitation contained in the 2005 state-approved SIP.

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1 Throughout this NOI, the material-moved limitation is expressed on a "tons per year" (tpy) basis; however, it is more accurately expressed on a "tons per 12-month" basis.

2 The actual total amount of material moved is expected to range from current levels to the maximum of 260,000,000 tpy depending on the year. For permitting purposes, including the ambient air quality analyses, the maximum amount of 260,000,000 tpy is assumed.

3 The EPA published its intent to disapprove the 2005 PM_{10} redesignation request and SIP revisions on December 1, 2009 (74 *Federal Register* 62717). In the proposal, the EPA does propose to approve several minor aspects of the 2005 SIP.

This NOI includes an air quality modeling demonstration performed using American Meteorological Society/EPA Regulatory Model (AERMOD) modeling to support the increase in material moved. AERMOD is an EPA-approved model that predicts ground-level concentrations of PM_{10}. The results from AERMOD demonstrate that the changes at the BCM (increasing the material moved limitation to 260,000,000 tpy) will not cause or contribute to an exceedance of the PM_{10} National Ambient Air Quality Standards (NAAQS).

In addition to the AERMOD modeling demonstration, KUC has assessed the implications of the proposed increase on the attainment and maintenance demonstrations, which were relied upon in supporting the 1994 and 2005 PM_{10} SIP actions. The Chemical Mass Balance (CMB) receptor model, in conjunction with emission control and offset requirements, was used in support of the 1994 SIP attainment and maintenance demonstration. The Urban Airshed Model with aerosols (UAM-AERO) was used in support of the 2005 SIP demonstration. Accompanying this NOI is a Technical Support Document (TSD) providing technical demonstrations that the proposed increase in the total material-moved limitation will not adversely affect attainment and maintenance of the PM_{10} NAAQS based on the demonstration methodologies employed for the 1994 PM_{10} SIP and 2005 Maintenance Plan.

1.2 Initiatives to Reduce Emissions

Since 1999, KUC has initiated a number of business improvement projects to proactively reduce PM emissions and reduce emissions of nitrogen oxide (NO_x) and sulfur dioxide (SO_2). These improvement projects are summarized as follows.

1.2.1 Fugitive Dust Control

The reduction of dust is an ongoing part of operations at the BCM and other KUC plants. This is accomplished through various means, including watering roads and revegetating. KUC also uses chemical dust suppressants and water haultrucks to suppress dust at the mine. KUC submits a Fugitive Dust Control Plan (FDCP) report annually to UDAQ that describes dust control measures completed at the BCM every year. The FDCP is an effective mechanism to control emissions in a dynamic industrial environment such as the BCM. The FDCP also includes water applied to the haulroads. To further enhance watering of the haulroads, KUC recently added two new 50,000-gallon water trucks at the cost of approximately $5,500,000. Additionally, KUC plans to add three new 50,000-gallon water trucks at the cost of approximately $6,000,000 in the near future.

Since 2005, KUC has added a crushing and screening unit to crush aggregate material for use as road base on the unpaved haulroads. The application of road base material assists in reducing fugitive dust emissions from haulroads.

KUC has one of the longest and widest conveyors in the world, which transfers ore within the mine. Ore transfer via conveyors reduces fugitive and tailpipe emissions in comparison with the ore transport with haultrucks.

1.2.2 Mine Haultruck Idling Management Project

To help manage fuel costs, reduce emissions, and improve emissions output, KUC is working to reduce idling time for BCM haultrucks while maintaining a safe and productive work environment. This project is ongoing.

1.2.3 Transition to Ultra-low Sulfur Diesel Fuel

KUC has used on-road specification diesel fuel for 20 years in its off-road equipment. In 2007, an EPA ruling required sulfur content in all on-road specification diesel fuels be reduced (from 50 parts per million [ppm] formerly to 15 ppm currently). Because KUC uses only on-road specification diesel fuel in its equipment, KUC also made a transition to ultra-low sulfur diesel fuel. All of KUC's diesel-powered equipment now runs on ultra-low sulfur diesel fuel, which has led to a decrease in the BCM's SO_2 emissions (a precursor to PM_{10}).

1.2.4 Larger Haultrucks

In recent years, KUC has purchased newer haultrucks with higher capacity where possible, which has led to a decrease in the round-trips and vehicle miles traveled, thereby reducing fugitive dust emissions.

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2.0 Description of Emission Sources

The BCM is located in Salt Lake County, Utah, near the town of Copperton. The BCM is currently operating under AO DAQE-AN0105710023-08, issued by UDAQ. With this NOI, KUC proposes to increase the total material-moved limitation to 260,000,000 tpy of ore and waste rock combined on an annual basis to maintain the current levels of metal production. Emissions from the existing mobile and stationary equipment have been recalculated to maintain consistent methodology using the most current emission factors.

Emission sources at the BCM are located either inside or outside the pit influence boundary. When particles, such as fugitive dust, are emitted within the pit influence boundary, only a certain portion of what is originally emitted is modeled to reach the top of the pit and enter the general atmosphere (the so-called escape fraction). *Airflow Patterns and Pit-Retention of Fugitive Dust for the Bingham Canyon Mine* predicts the escape fraction for different conditions at the BCM (Bhaskar and Tandon, 1996). A summary of the study is provided in Appendix D-1, with a copy of the entire study in Appendix D-2.

2.1 Point Sources

This subsection describes the stationary sources of emissions at the BCM.

2.1.1 In-pit Ore Crushers and Transfer Points

The existing in-pit ore crusher is equipped with a baghouse to control emissions. All exhaust air from the crusher is routed through the baghouse before being vented to the atmosphere. The baghouse is designed to handle 12,898 dry standard cubic feet per minute (dscfm) and is permitted to operate 8,760 hours per year (UDAQ, 2008). This source will not change under the proposed modification.

Under the proposed modification, KUC is proposing to add a new in-pit ore crusher within the next 3 to 4 years, also equipped with a baghouse to control emissions. All exhaust air from the new crusher will be routed through the baghouse before being vented to the atmosphere. The baghouse will have a proposed grain loading of 0.007 grains per dry standard cubic foot (gr/dscf) and will be designed to handle 12,898 dscfm airflow. The crusher will be permitted to operate 8,760 hours per year. Both the existing and new in-pit ore crushers are located within the pit influence boundary.

The BCM has two ore conveyor transfer drop points near Copperton that are equipped with baghouses—Point C6/C7 and Point C7/C8. All exhaust air from each transfer drop point is routed through the respective baghouse before being vented to the atmosphere. The C6/C7 drop point baghouse is designed to handle 5,120 dscfm, and the C7/C8 drop point baghouse is designed to handle 3,168 dscfm (UDAQ, 2008). Both baghouses are permitted to operate 8,760 hours per year. KUC is proposing to upgrade both baghouses. The upgrades will include replacing the bags and modifying hopper discharge design to provide a higher PM_{10} capture rate. This will result in reducing grain loading from 0.016 gr/dscf to 0.007 gr/dscf.

2.1.2 Lime Silos at Copperton Concentrator

Each of the two lime silos at the Copperton Concentrator is equipped with fabric bin vent control units. All exhaust air from the lime silos is routed through the control units before being vented to the atmosphere. Both bins are designed to handle 616 dscfm and are permitted to operate 8,760 hours per year (UDAQ, 2008). The PTE of these sources will not change under the proposed modification. These lime silos are associated with the Copperton Concentrator operations, and lime is used for pH adjustment.

2.1.3 Sample Preparation Building

The sample preparation building is equipped with a baghouse. All exhaust air from the sample preparation building is routed through the baghouse before being vented to the atmosphere. The baghouse is designed to handle 4,269 dscfm and is permitted to operate 2,920 hours per year (UDAQ, 2008). This source will not change under the proposed modification. The sample preparation building is located within the pit influence boundary.

2.1.4 Emergency Generators

The BCM has four existing emergency generators fueled with liquefied petroleum gas (LPG) (UDAQ, 2008). The power ratings and location of each emergency generator are listed in Table 2-1. As currently permitted, the use of each of the emergency generators is limited to 500 hours per year for routine maintenance and testing. KUC is also proposing to add a new 71 BHP LPG generator which shall be limited to 100 hours per year for routine maintenance and testing.

TABLE 2-1
Description of Emergency Generators

Location	Power Rating (brake horsepower)
Lark Gate	160
Production Control Building	105
Mine Office	75
Galena Gulch	72
Dinkeyville Hill	71

2.2 Sources of Fugitive Dust Emissions

This subsection describes the sources of fugitive dust emissions at the BCM. All sources of fugitive dust emissions are located on KUC property.

2.2.1 Drilling and Blasting

With the proposed modification, the BCM will drill approximately 90,000 holes each year. The drilling is performed with water injection to help control PM_{10} emissions with an estimated efficiency of 90 percent. The BCM will conduct approximately 1,100 blasts each year with a total area of 57,500 square feet per average blast. Both drilling and blasting operations occur within the pit influence boundary.

2.2.2 Material Movement

The ore and waste rock at the BCM are transferred from the mining areas to other areas of the mine through a series of transfers using haultrucks and conveyor belts. Ore is transferred from the in-pit crushers on conveyors while waste rock is hauled with trucks from the shovel face. From the mining areas, haultrucks are loaded with either ore or waste rock. Because of characteristics of the waste rock/ore material (such as large-diameter material, contained moisture, and minimal drop distance from the shovels to the haultrucks), fugitive dust emissions are minimal. It should be noted that the AO limitation on material moved (ore and waste) is applied to dry tons mined at the shovel face. Ore stockpiled, topsoil movement, road base, and reclamation material should not be counted toward this limit.

Ore Transfers

Ore is hauled and dumped into the in-pit ore crusher(s). The design of the crusher(s) will allow each crusher to process an average of 85,000,000 tpy of ore with the proposed modification. Fugitive dust generated by this activity is controlled with a baghouse. Because of inherent characteristics of the ore, moisture of the material, and physical enclosures, fugitive dust emissions are minimal.

Once the ore is crushed by the in-pit crushers, it is transported from the crusher to the C6 conveyor tunnel. The existing in-pit conveyor system has three enclosed transfer points. Fugitive dust from the transfer points is controlled with an estimated efficiency of 90 percent due to the enclosures.

The proposed modification will include adding a new in-pit conveyor system, interfacing with the new in-pit crusher, and finally transferring to the C6 conveyor tunnel that will include three enclosed transfer points. Consistent with the existing conveyor system, fugitive dust from the new transfer points will be controlled with an estimated efficiency of 90 percent due to the enclosures.

In-pit crushers and associated conveyors are moved approximately once per decade to accommodate changing mine topography. Emissions from the existing crusher are estimated to include two additional transfer points anticipated during the next move.

The previously mentioned transfer points are located within the BCM pit influence boundary.

Ore is conveyed through the C6 conveyor tunnel and transferred to the enclosed conveyor C7 and then C8 through the baghouse-equipped transfer points previously discussed. From the conveyor belt C8, the ore is dropped to the C9 belt and shuttle conveyor (stacker) at the Copperton Concentrator. The inherent characteristics of the material and physical enclosures result in minimal fugitive dust emissions.

The shuttle conveyor (stacker) drops the ore onto the coarse ore storage piles in the A-frame at the Copperton Concentrator. The inherent characteristics of the material and physical enclosures result in minimal fugitive dust emissions.

Finally, the ore is carried from the coarse ore piles to the semiautogenous grinding mills on a conveyor belt in the Reclaim Tunnels. The Reclaim Tunnel conveyors will process an average of 85,000,000 tpy of ore with the proposed modification. The inherent characteristics of the material and physical enclosures result in minimal fugitive dust emissions.

Waste Rock Transfers

Haultrucks place the waste rock onto designated waste rock disposal areas. With the proposed modification, haultrucks will continue to haul and place waste rock in the disposal areas. The waste rock transfers currently occur outside the pit influence boundary.

2.2.3 Low-grade Ore Stockpile

The BCM has low-grade run-of-mine ore stockpiles within the pit operations. With the proposed modification, haultrucks will continue to haul and place ore on the low-grade ore stockpiles. Emissions from the low-grade ore stockpiles are minimized by inherent material characteristics and incidental compaction from mobile equipment. Water application from passing water trucks is used to further reduce emissions. Low-grade ore can be reclaimed by loaders and hauled by trucks to the in-pit crusher as needed.

2.2.4 Disturbed Areas

Areas of land are exposed when mining is performed. While achieving a production rate of 260,000,000 tons of ore and waste rock movement it is estimated, according to proposed mine plan, that approximately 565 total acres of land is disturbed per year.

2.2.5 Haulroads

Unpaved haulroads are used by haultrucks to carry the waste rock and ore from the mining areas to waste rock disposal areas, to and from the low-grade ore stockpile, or to the in-pit crushers. On the haulroads, KUC will apply water frequently or commercial dust suppressants as needed to control fugitive dust emissions. Additionally, application of Application of road base material on haulroads enhances effectiveness of the fugitive dust control measures. Details of this activity will be regulated through the FDCP, which is updated and submitted annually to UDAQ. Each of the dust control measures varies seasonably based on ambient conditions.

2.2.6 Road-base Crushing and Screening Plant

The BCM employs the use of a road-base crushing and screening plant that operates at the 6,190 elevation on the north rim of the pit near the Bingham Truck Shop. The purpose of the plant is to crush non-sulfide-bearing waste rock material for use as road base on the unpaved haulroads. Fugitive emissions from the crushing, screening, and transfer points (10) operation are effectively controlled with water sprays and/or belt enclosures. The crushing and screening unit has a capacity of 700 tons per hour and is currently permitted to operate no more than 4,500 hours per year, resulting in an annual material throughput of 3,150,000 tons (UDAQ, 2008). This source will not be modified as part of this modification. The crushing and screening plant is located within the BCM pit influence boundary.

2.3 Volatile Organic Compound Sources

2.3.1 Maintenance Degreasing

Maintenance degreasing involves the use of a cold solvent to degrease and clean equipment parts. The annual use of solvent from all the degreasers combined is approximately 500 gallons. When not in use, the lids on the degreasers are kept closed at all times to minimize emissions. The solvent is recycled frequently, and no significant loss in volume is observed, implying minimal losses as emissions. For purposes of estimating emissions, a conservative estimate of one solvent change-out lost per year is assumed.

2.3.2 Gasoline and Diesel Fueling Stations

The gasoline and diesel fueling stations are used to fuel the BCM's light-duty trucks, vehicles, and haultrucks. For the proposed modification, the peak year annual throughput at the fueling stations will be approximately 530,000 gallons of gasoline and 55,000,000 gallons of diesel fuel. Volatile organic compounds are emitted as a result of balanced submerged filling, underground tank breathing and emptying, spillage, and uncontrolled displacement losses during vehicle refueling. The gasoline fueling stations are equipped with Stage I Vapor Recovery Systems to minimize volatile organic compound (VOC) emissions.

2.3.3 Solvent Extraction/Electrowinning Plant

The solvent extraction/electrowinning (SX/EW) plant was permitted in 2008. When construction is complete and operation commences, the process will consist of mixers and settlers for the extraction and stripping of copper; organic surge and holding tanks; and raffinate and electrolyte circuits causing agitation of organic solutions. The mixers and settlers will have a combined total surface area of 1,100 square feet and be permitted to operate for 8,760 hours per year. They will be covered at all times except during inspection, sampling, and adjustment to control VOC emissions with an efficiency of 80 percent. A total of four process tanks with a combined total volume of 12,000 gallons will operate. The tanks are also covered at all times to control VOC emissions. The circuits will have a combined average flow rate of 650 gallons per minute (gpm) and be permitted to operate 8,760 hours per year.

The SX/EW plant will also have an electrowinning acid mist eliminator to control process streams from the electrowinning cells. Exhaust air from the electrowinning cells will be routed through the mist eliminator before being vented to the atmosphere. The mist eliminator is designed to handle 8,000 acfm and operate 8,760 hours per year (UDAQ, 2008).

2.4 Mobile Sources

The mine diesel operated support equipment includes front-end loaders (FELs), graders, track dozers, rubber-tire dozers, water trucks, diesel shovels, diesel drills, track excavators, and small haultrucks. The graders primarily operate on the haulroads maintaining surfaces of the roads. The dozers operate in the pit, on the haulroads performing "cleanup" operations, and in dumping operations at the waste rock disposal areas. The smaller FELs operate haulroad construction and cleanup projects. The large FELs are production loaders, which load ore and waste rock into haul trucks from the mining area. Some of this equipment may also be used for snow removal in winter. Tailpipe emissions from the support equipment will meet the required EPA standards for NONROAD equipment.

The haultrucks transfer ore to the in-pit crusher and low-grade ore stockpiles and waste rock to the waste disposal areas 365 days per year.

Tailpipe emissions from the haultrucks will meet the required EPA standards for NONROAD equipment.

3.0 Emissions Summary

This section summarizes emissions resulting from the increase in the annual movement of ore and waste rock material at the BCM.

For emission sources located within the pit influence boundary, PM_{10} emissions are calculated taking into account a pit escape factor of 20 percent. For PM less than 2.5 micrometers in aerodynamic diameter ($PM_{2.5}$), the escape factor was determined to be 21 percent. These factors are based on *Airflow Patterns and Pit-Retention of Fugitive Dust for the Bingham Canyon Mine*, which predicts the escape fraction for different conditions at the BCM (Bhaskar and Tandon, 1996). A figure representing the current pit influence boundary is provided in Appendix B-3.

3.1 Emissions from Point Sources

Detailed emission calculations for the point sources are provided in Appendix B-1.

The existing in-pit ore crusher ventilation system is designed to handle 12,898 dscfm and operate 8,760 hours per year and is equipped with a baghouse for particulate control. The permitted grain loading for this baghouse is 0.016 gr/dscf. EPA's *AP-42, Fifth Edition*, Table B.2.2 Category 3 – Mechanically Generated Aggregate Material and Unprocessed Ores, shows PM_{10} to be 51% of the particle distribution and $PM_{2.5}$ to be 15%. Therefore $PM_{2.5}$ is estimated to be 29% of PM_{10} for operations including material handling and processing of aggregate and unprocessed ore such as milling, grinding, crushing, screening, conveying, cooling and drying. The existing in-pit crusher is located within the pit influence boundary; therefore, emissions are calculated with the pit escape factor. The pit escape factor represents the portion of the particulates not settling in the pit.

As part of this proposed modification, KUC will install a second in-pit ore crusher. The new in-pit ore crusher ventilation system will be designed to handle approximately 12,898 dscfm and operate 8,760 hours per year and will be equipped with a baghouse for particulate control. KUC is proposing a grain loading of 0.007 gr/dscf for the new baghouse. EPA's *AP-42, Fifth Edition*, Table B.2.2 Category 3 – Mechanically Generated Aggregate Material and Unprocessed Ores, shows PM_{10} to be 51% of the particle distribution and $PM_{2.5}$ to be 15%. Therefore $PM_{2.5}$ is estimated to be 29% of PM_{10} for operations including material handling and processing of aggregate and unprocessed ore such as milling, grinding, crushing, screening, conveying, cooling and drying. The second in-pit crusher will be located within the pit influence boundary; therefore, emissions are calculated with the pit escape factor. The pit escape factor represents the portion of the particulates not settling in the pit.

The ventilation system for transfer drop point C6/C7 is designed to handle 5,120 dscfm. The ventilation system for transfer drop point C7/C8 is designed to handle 3,168 dscfm. Both drop points operate 8,760 hours per year and are equipped with baghouses for particulate control. KUC is proposing to reduce the grain loading from 0.016 to

0.007 gr/dscf. Operations of the baghouses will not otherwise be affected by this proposed change in grain loading factor. EPA's *AP-42, Fifth Edition*, Table B.2.2 Category 3 – Mechanically Generated Aggregate Material and Unprocessed Ores, shows PM_{10} to be 51% of the particle distribution and $PM_{2.5}$ to be 15%. Therefore $PM_{2.5}$ is estimated to be 29% of PM_{10} for operations including material handling and processing of aggregate and unprocessed ore such as milling, grinding, crushing, screening, conveying, cooling and drying.

Both lime silos are designed to handle 616 dscfm and operate 8,760 hours per year and are equipped with fabric bin vent control units. The permitted grain loading for the fabric bin vent control units is 0.016 gr/dscf. EPA's *AP-42, Fifth Edition*, Table B.2.2 Category 4 – Mechanically Processed Ores and Nonmetallic Minerals, shows PM_{10} to be 85% of the particle distribution and $PM_{2.5}$ to be 30%. Therefore $PM_{2.5}$ is estimated to be 35% of PM_{10} for operations including material handling and processing of processed ores and nonmetallic minerals such as lime.

The sample preparation building is designed to handle 4,269 dscfm and operate 8 hours per day for a total of 2,920 hours per year and is equipped with a baghouse for particulate control. The permitted grain loading for the baghouse is 0.016 gr/dscf. Material handled during sample preparation is ore and waste rock material and size distribution is the same. EPA's *AP-42, Fifth Edition*, Table B.2.2 Category 3 – Mechanically Generated Aggregate Material and Unprocessed Ores, shows PM_{10} to be 51% of the particle distribution and $PM_{2.5}$ to be 15%. Therefore $PM_{2.5}$ is estimated to be 29% of PM_{10} for operations including material handling and processing of aggregate and unprocessed ore such as milling, grinding, crushing, screening, conveying, cooling and drying. The sample preparation building is located within the pit influence boundary; therefore, emissions are calculated with the pit escape factor. The pit escape factor represents the portion of the particulates not settling in the pit.

Table 3-1 summarizes the emissions after the proposed material-moved increase (future emissions) for point sources.

TABLE 3-1
Proposed Emissions from Point Sources Controlled by Baghouses

Emission Source	Hours of Operation per Year	Design Flow Rate (dscfm)	Future PM_{10} Emissions (tpy)	Future $PM_{2.5}$ Emissions (tpy)
Existing In-pit Crusher	8,760	12,898	1.55	0.48
New In-pit Crusher	8,760	12,898	0.68	0.21
Transfer Point C6/C7	8,760	5,120	1.35	0.40
Transfer Point C7/C8	8,760	3,168	0.83	0.24
Lime Silo (#1)	8,760	616	0.37	0.13
Lime Silo (#2)	8,760	616	0.37	0.13
Sample Preparation Building	2,920	4,269	0.17	0.05

NOTE:
Emissions shown are for a peak year annual material movement of 260,000,000 tpy.

3.2 Emissions from Fugitive Sources

3.2.1 Drilling and Blasting

With the proposed modification, the BCM will drill approximately 90,000 holes each year. The drilling is performed with water injection to control PM_{10} emissions with an efficiency of 90 percent historically. The BCM will conduct approximately 1,100 blasts each year, with an area of 57,500 square feet per average blast. For drilling operations, PM_{10} and $PM_{2.5}$ emissions were derived from the total PM emission factors estimated using methodology from the EPA's *AP-42, Fifth Edition*, Table 11.9-4 (EPA, 1998) and ratio of transfer particle size multipliers in AP-42, *Fifth Edition*, Table 13.2.4, page 4 (EPA, 2006). The ratio of transfer particle size multipliers in AP-42, *Fifth Edition*, Table 13.2.4 (EPA, 2006) are 0.74 for PM, 0.35 for PM_{10} and 0.053 for $PM_{2.5}$. Therefore, PM_{10} is estimated to be 47 percent of PM and $PM_{2.5}$ is estimated to be 15 percent of PM_{10}.. For blasting operations, PM_{10} and $PM_{2.5}$ emissions were estimated using emission factors from EPA's *AP-42, Fifth Edition*, Table 11.9-1 (EPA, 1998). Both drilling and blasting operations occur within the pit influence boundary; therefore, emissions are calculated with the pit escape factor. The pit escape factor represents the portion of the particulates not settling in the pit. Emissions from drilling and blasting are summarized in Table 3-2. Detailed emission calculations are provided in Appendix B-1.

TABLE 3-2
Proposed Emissions from Drilling and Blasting Operations

Source	Future PM_{10} Emissions (tpy)	Future $PM_{2.5}$ Emissions (tpy)
Drilling	0.55	0.09
Blasting	11.0	0.67

NOTE:
Emissions shown are for a peak year annual material movement of 260,000,000 tpy.

3.2.2 Material Movement

With the increase in material moved, 260,000,000 tpy of ore and waste rock combined will be loaded onto haultrucks and later transferred to different locations within the mine. Water and/or commercial dust suppressant is applied to loading and haulage surfaces year-round in accordance with the FDCP. Additionally, the inherent material characteristics, moisture content, and enclosures, where appropriate, minimize fugitive dust emissions. Emissions of PM_{10} and $PM_{2.5}$ resulting from the transfer of material are estimated using methodology from EPA's *AP-42, Fifth Edition*, Section 13.2.4 (EPA, 2006). For emission sources located within the pit influence boundary, emissions are calculated with the pit escape factor. The pit escape factor represents the portion of the particulates not settling in the pit. Emissions for the transfer sources previously discussed are summarized in Table 3-3. Detailed emission calculations are provided in Appendix B-1.

TABLE 3-3
Proposed Emissions from Ore and Waste Rock Transfers

Emission Source	Future PM_{10} Emissions (tpy)	Future $PM_{2.5}$ Emissions (tpy)
Haultruck Loading	1.71	0.27
Truck Dumping to Primary In-pit Crusher	0.56	0.09
Truck Dumping to Secondary In-pit Crusher	0.56	0.09
Truck Dumping at Stockpile	0.56	0.09
Existing In-pit Enclosed Transfer Points	1.68	0.27
Existing In-pit Enclosed Additional Transfer Points (from crusher relocation)	1.12	0.18
New In-pit Enclosed Transfer Points	1.68	0.27
Conveyor Transfer to Stacker	2.79	0.42
Drop to Coarse Ore Storage Pile	2.79	0.42
Coarse Ore to Reclaim Tunnel Vent	2.79	0.42
Truck Dumping of Waste Rock	57.5[a]	8.71

NOTES:
Emissions shown are for a peak year annual material movement of 260,000,000 tpy.
[a] KUC is proposing to use water application and incidental compaction from mobile equipment and dump maintenance practices to minimize emissions. These practices were not in place during the 1999 AO modification.

3.2.3 Low-grade Ore Stockpile

A low-grade ore stockpile is used at the BCM. Emissions of PM_{10} are estimated using methodology from the EPA's *AP-42, Fifth Edition*, Section 11.9.1 (EPA, 1998) and ratio of transfer particle size multipliers in AP-42, *Fifth Edition*, Table 13.2.4, page 4 (EPA, 2006). The ratio of transfer particle size multipliers in AP-42, *Fifth Edition*, Table 13.2.4 (EPA, 2006) are 0.74 for PM, 0.35 for PM_{10} and 0.053 for $PM_{2.5}$. Therefore, PM_{10} is estimated to be 47 percent of PM and $PM_{2.5}$ is estimated to be 15 percent of PM_{10}. Emissions are minimized by inherent material characteristics and mechanical compaction of the pile. Water application from passing trucks is used to further reduce emissions. The stockpile is located within the pit influence boundary; therefore, emissions are calculated with the pit escape factor. The pit escape factor represents the portion of the particulates not settling in the pit. Emissions from the stockpile are summarized in Table 3-4. Detailed emission calculations are provided in Appendix B-1.

TABLE 3-4
Proposed Emissions from Ore Stockpile

Emission Source	Future PM_{10} Emissions (tpy)	Future $PM_{2.5}$ Emissions (tpy)
Ore Stockpile	2.09	0.33

NOTE:
Emissions shown are for a peak year annual material movement of 260,000,000 tpy.

3.2.4 Disturbed Areas

As a result of increased annual material moved to 260,000,000 tons of ore and waste rock it is estimated, according to proposed mine plan, that approximately 565 total acres of land is disturbed per year. Of that total, 310 acres (55%) are within the Pit Influence Boundary.. Emissions of PM_{10} were derived from the total PM emission factors estimated using methodology from the EPA's *AP-42, Fifth Edition*, Table 11.9-4 (EPA, 1998) and ratio of transfer particle size multipliers in AP-42, *Fifth Edition*, Table 13.2.4, page 4 (EPA, 2006). The ratio of transfer particle size multipliers in AP-42, *Fifth Edition*, Table 13.2.4 (EPA, 2006) are 0.74 for PM, 0.35 for PM_{10} and 0.053 for $PM_{2.5}$. Therefore, PM_{10} is estimated to be 47 percent of PM and $PM_{2.5}$ is estimated to be 15 percent of PM_{10}. Since the emission source is partially located within the pit influence boundary, that portion of emissions is calculated with the pit escape factor. The pit escape factor represents the portion of the particulates not settling in the pit. Emissions are summarized in Table 3-5. Detailed emission calculations are provided in Appendix B-1.

TABLE 3-5
Proposed Emissions from Disturbed Areas

Emission Source	Future PM_{10} Emissions (tpy)	Future $PM_{2.5}$ Emissions (tpy)
Disturbed Areas	40.6	8.75

NOTE:
Emissions shown are for a peak year annual material movement of 260,000,000 tpy.

3.2.5 Haulroads and Haultruck Emissions

Unpaved haulroads are used by haultrucks to transport the waste rock and ore from the mining areas to waste rock disposal areas, low-grade ore stockpile, or the in-pit crusher. With the proposed modification, the average unpaved haulroad distance for waste rock and ore will range from 4.5 miles round-trip to 8.3 miles round-trip over time as various areas are mined. The haulroads on which the haultrucks travel will be sprayed with water or commercial dust suppressants to control fugitive dust emissions throughout the year. Emissions of PM_{10} and $PM_{2.5}$ were estimated using methodology from EPA's *AP-42, Fifth Edition*, Section 13.2.2 (EPA, 2006). For the portion of haulroads located within the pit influence boundary, emissions are calculated with the pit escape factor. The pit escape factor represents the portion of the particulates not settling in the pit.

Projected peak year emissions for the haulroads both within and outside the pit influence boundary are summarized in Table 3-6. Per UDAQ policy, for haulroads within the pit influence boundary, a control efficiency of 75 percent is used for watering and road base application. For haulroads outside the pit influence boundary, a control efficiency of 85 percent is used for application of commercial dust suppressants. Detailed emission calculations are provided in Appendix B-1. KUC believes that control efficiency on the haulroads with frequent watering per *AP-42, Fifth Edition*, Section 13.2.2 (EPA, 2006) approaches 95 percent, but emissions summarized herein are based on UDAQ's default control factors, which are conservative.

It should be noted that open pit mine planning occurs in phases where relatively large tonnages of waste rock must be stripped early in a phase so that ore can be accessed in later years. The projections indicated in this NOI represent a high level of activity early in the mine plan phase. As activity reduces with time, the stripping ratio is reduced.

TABLE 3-6
Projected Fugitive Emissions from Haulroads

Emission Source	Future PM_{10} Emissions (tpy)	Future $PM_{2.5}$ Emissions (tpy)
Haulroads	1,054	108

NOTE:
Emissions shown are for a peak year annual material movement of 260,000,000 tpy.

It should be noted, that the daily vehicle miles traveled (VMT) used to calculate the PM_{10} emissions as an input for the AERMOD dispersion modeling analysis were based on the year 2016 material haulage of 260 million tons per year (tpy). Year 2016 is a projected peak year for emissions. The emission inventory in the notice of intent (NOI), submitted August 17, 2010, calculated 9,425,000 annual VMT that would be required by the haul trucks to move the maximum proposed 260 million tpy of ore and waste material. This translates to 25,822 VMT per day if the annual VMT were evenly distributed throughout the year. However, the AERMOD modeling analysis assumed a conservative 20% daily variability factor that was applied to the average daily emissions to account for variability of BCM operations. Therefore, PM_{10} emissions based on 30,986 VMT per day were modeled in AERMOD to demonstrate compliance with the 24-hr PM_{10} National Ambient Air Quality Standard (NAAQS).

It was also assumed for a conservative maximum emissions estimate, that all material was hauled in 240-ton trucks to the farthest destination. In reality, the average truck fleet size is larger than 240-tons and a percentage of material would be on shorter haulage routes. Daily variability in truck traffic is minimal and it isn't anticipated that truck traffic would ever reach the level at which it was modeled (30,986 VMT/day). What small amount of variability that would occur clearly would not lead to emissions that would result in an exceedance of the NAAQS. It is therefore demonstrated that the current daily limit of 30,000 VMT by primary ore and waste haul trucks is sufficient to demonstrate compliance with the 24-hour PM_{10} NAAQS.

Tailpipe emissions from the haultrucks are estimated using the NONROAD program as recommended by UDAQ. Emissions are estimated based on the EPA tier level of haultruck engines and the annual hours of operation for the haultrucks. The emissions estimation methodology using the NONROAD program is provided in Appendix A. Maximum PTE tailpipe emissions from the trucks hauling ore and waste rock are summarized in Table 3-7.

KUC periodically upgrades its haultruck fleet to take advantage of available higher-tier-level, lower-emitting engines. As noted from emissions summarized in Appendix A, tailpipe emissions from haultrucks are expected to decrease as new higher-tier-level trucks are phased into the BCM fleet.

TABLE 3-7
Projected Tailpipe Emissions from Haultrucks

Pollutant	Future Tailpipe Emissions (tpy)
PM_{10}	191
$PM_{2.5}$	186
SO_2	5.78
NO_X	5,134
Carbon Monoxide (CO)	1,400
VOC	259

NOTE:
Emissions shown are for a peak year annual material movement of 260,000,000 tpy.

3.2.6 Road-base Crushing and Screening Plant

The BCM has a semiportable plant that crushes and screens waste rock for use as base material on the unpaved haulroads. Application of road base on haulroads improves and enhances effectiveness of the fugitive control measures at the BCM. Fugitive emissions from the crushing, screening, and transfer (10 transfer points) operations are effectively controlled with water sprays and belt enclosures. The crushing/screening plant has a capacity of 700 tons per hour and operates no more than 4,500 hours per year, resulting in a maximum annual material throughput of 3,150,000 tpy. For each of these sources of fugitive dust, PM_{10} and $PM_{2.5}$ emissions were estimated using emission factors from EPA's *AP-42, Fifth Edition*, Table 11.19.2-2 (EPA, 2004) and are summarized in Table 3-8. Detailed emission calculations are provided in Appendix B-1. Since the emission source is located within the pit influence boundary, emissions are calculated with the pit escape factor. The pit escape factor represents the portion of the particulates not settling in the pit.

TABLE 3-8
Proposed Emissions from Road-base Crushing and Screening Plant

Source	Future PM_{10} Emissions (tpy)	Future $PM_{2.5}$ Emissions (tpy)
Crushing	0.17	0.03
Screening	0.23	0.02
Transfers	0.14	0.04

NOTE:
Emissions shown are for a peak year annual material movement of 260,000,000 tpy.

3.3 Sources with VOC Emissions

3.3.1 Maintenance Degreasing

Based on KUC records, approximately 500 gallons of cold solvent are used annually for maintenance degreasing. As a conservative estimate, it is assumed that the cold solvent has a VOC content of 100 percent. The VOC emissions resulting from maintenance degreasing were estimated based on the solvent properties and a material balance. Emissions from degreasers are summarized in Table 3-9. The PTE emission from this source will not change as a result of this permit modification.

TABLE 3-9
Emissions from Maintenance Degreasers

Emission Source	Future VOC Emissions (tpy)
Maintenance Degreasers	1.69

3.3.2 Fueling Stations

Gasoline and diesel use at the fueling stations after the proposed modification will be approximately 530,000 gallons of gasoline and approximately 55,000,000 gallons of diesel fuel during a peak year. The VOC emissions for the gasoline fueling stations are estimated using emission factors from EPA's *AP-42, Fifth Edition*, Table 5.2-7 (EPA, 2008). Volatile organic compound emissions from diesel fueling stations are estimated using emission factors from Colorado Department of Public Health and Environment's guidance on *Gasoline and Diesel Fuel Dispensing Stations*. Volatile organic compound emissions from the fueling stations are summarized in Table 3-10.

TABLE 3-10
Proposed Emissions from Fueling Stations

Emission Source	Future VOC Emissions (tpy)
Gasoline Fueling Stations	3.45
Diesel Fueling Stations	0.80

NOTE:
Emissions shown are for a peak year annual material movement of 260,000,000 tpy.

3.3.3 Solvent Extraction/Electrowinning Plant

The mixers and settlers of the SX/EW plant will have a combined total surface area of 1,100 square feet. Both will operate a maximum of 8,760 hours per year, have a pan rate of 0.00142 foot per 24 hours, and have covers to control VOC emissions with an efficiency of 80 percent. The BCM will have four organic surge and holding tanks with a combined total volume of 12,000 gallons. The tanks will be covered to control VOC emissions. Volatile organic compound emissions from the tanks were estimated using a volume ratio of the pilot plant emissions to the expanded plant emissions; pilot plant emissions were taken from a previous emission inventory. The raffinate and electrolyte circuits will have a combined average flow rate of 650 gpm and operate a maximum of 8,760 hours per year. Volatile organic compound emissions from the circuits were estimated with an assumption that up to 33 percent of the residual organic in the circuits is released to the atmosphere by evaporation or biodegradation. Volatile organic compound emissions from the SX/EW plant are summarized in Table 3-11. The PTE from this source will not change as a result of this modification.

TABLE 3-11
Emissions from the Solvent Extraction/Electrowinning Plant

Plant Operation	Future VOC Emissions (tpy)
Mixer/Settlers	2.92
Aqueous Flows	2.38
Tanks	0.07

The electrowinning acid mist eliminator at the SX/EW plant is designed to handle 6,377 dscfm and operate 8,760 hours per year. The sulfuric acid (H_2SO_4) emissions are estimated with the assumption that the exhaust gas has an H_2SO_4 concentration of 0.004 gr/dscf. Sulfuric acid emissions from the mist eliminator are summarized in Table 3-12.

TABLE 3-12
Emissions from the Electrowinning Acid Mist Eliminator

Emission Source	Future H_2SO_4 Emissions (tpy)
Electrowinning Acid Mist Eliminator	0.96

3.4 Support Equipment

3.4.1 Track Dozers, Rubber Tire Dozers, Graders, and Loaders

To support the proposed modification, the BCM will operate FELs, graders, track dozers, and rubber-tire dozers. Fugitive emissions of PM_{10} and $PM_{2.5}$ were estimated using emission factors from EPA's *AP-42, Fifth Edition*, Table 11.9-1 (EPA, 1998). Emissions from each of these sources are summarized in Table 3-13.

TABLE 3-13
Projected Fugitive Emissions from Support Equipment

Source	Future PM_{10} Emissions (tpy)	Future $PM_{2.5}$ Emissions (tpy)
Track Dozers	5.9	3.6
Rubber-tire Dozers	1.2	0.8
Graders	77.7	9.1
FELs	12.4	2.1

NOTE:
Emissions shown are for a peak year annual material movement of 260,000,000 tpy.

Tailpipe emissions from the support equipment are estimated using the NONROAD program. Emissions are estimated based on the EPA tier level of support equipment engines and the annual hours of operation for the equipment. The emissions estimation methodology using the NONROAD program is provided in Appendix A. Maximum peak year tailpipe PTE emissions from the support equipment are summarized in Table 3-14.

TABLE 3-14
Projected Tailpipe Emissions from Support Equipment

Pollutant	Future Emissions (tpy)
PM_{10}	36
$PM_{2.5}$	35
SO_2	0.78
NO_X	695
CO	272
VOC	43

NOTE:
Emissions shown are for a peak year annual material movement of 260,000,000 tpy.

3.5 Miscellaneous Emissions Sources

3.5.1 Emergency Generators

Four existing emergency generators and one proposed emergency generator, located at the mine, are fueled with LPG and have varying horsepower ratings. Each of the existing emergency generators is permitted to operate no more than 500 hours per year. The proposed emergency generator will operate no more than 100 hours per year. Actual hours of operation are expected to be limited to maintenance and testing activities for the existing (UDAQ, 2008) and proposed generators. Carbon monoxide (CO), NO_x, and total hydrocarbon (HC) emissions are based on manufacturer data. Volatile organic compound emissions are considered a subset of the total HC emissions. Sulfur dioxide and PM_{10} emissions were estimated using emission factors from the EPA's *AP-42, Fifth Edition*, Table 3.2-3 (EPA, 2000) for the existing generators (UDAQ, 2008), assuming a four-stroke, rich-burn, natural-gas–fueled engine. Sulfur dioxide and PM_{10} emissions for the proposed generator were estimated using EPA's NONROAD program. Emissions from the emergency generators are summarized in Table 3-15.

TABLE 3-15
Emissions from Emergency Generators

Generator Location	Emissions (tpy)				
	PM_{10}	**SO_2**	**NO_x**	**CO**	**Total HC**
Production Control Building	0.0006	0.00004	0.347	1.557	0.058
Mine Office	0.0005	0.00003	0.285	1.115	0.042
Lark Gate	0.001	0.00003	0.214	6.476	0.058
Galena Gulch	0.0004	0.00003	0.266	1.246	0.040
Dinkeyville Hill	0.0004	0.0001	0.054	0.212	0.01

3.6 Emissions Summary

Total PTE emissions from the BCM, after the increase in material moved, are summarized in Table 3-16.

TABLE 3-16
Proposed PTE Summary

Pollutant	Point Sources	Fugitives	Mobile Sources	Future BCM PTEs
PM_{10} (tpy)	6.28	1,279	228	1,513
$PM_{2.5}$ (tpy)	2.60	145	221	368
SO_2 (tpy)	0.0002		6.56	6.56
NO_x (tpy)	1.17		5,829	5,830
CO (tpy)	10.6		1,672	1,682
VOC (tpy)	0.20	11.3	302	314
PM_{10} + SO_2 + NO_x (tpy)	**7.44**			

NOTE:
Emissions shown are for a peak year annual material movement of 260,000,000 tpy.

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4.0 Offset Requirements Evaluation

The following section provides an estimate of the point source emissions increase associated with the proposed modification. The BCM is not a major stationary source and is not one of the listed source categories (Utah Administrative Code [UAC] R307-101-2[3] [UDAQ, 2009]). Therefore, fugitive emissions and emissions associated with exempt tailpipe emissions are not included in estimating the emissions increase.

Emissions of point sources after the proposed modification are summarized in Table 4-1.

TABLE 4-1
Post-project Point Source PTE Emissions

Emissions	Point Sources
PM_{10} (tpy)	6.28
SO_2 (tpy)	0.0002
NO_X (tpy)	1.17
PM_{10}+NO_X+SO_2 (tpy)	**7.44**

NOTES:
Post-project emissions include a new in-pit crusher.

Emissions shown are for a peak year annual material movement of 260,000,000 tpy.

Utah Administrative Code R307-403-5(1)(b) states that enforceable offsets of 1.2:1 are required for new sources or modifications that would produce an emission increase greater than or equal to 50 tpy of any combination of PM_{10}, SO_2, and NO_x. Also, UAC R307-403-5(1)(c) states that enforceable offsets of 1.1:1 are required for new sources or modifications that would produce an emission increase greater than or equal to 25 tpy but less than 50 tpy of any combination of PM_{10}, SO_2, and NO_x. The combined total emissions of PM_{10}, SO_2, and NO_x from stationary point sources after the proposed modification, as indicated in Table 4-3, will be less than 25 tpy; therefore, this project will not require any offsets.

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5.0 Best Available Control Technology

This section describes the best available control technology (BACT) analysis for haulroads and ore and waste rock transfer and handling sources.

According to UAC R307-401-8, “The Executive Secretary will issue an approval order if the following conditions have been met: The degree of pollution control for emissions, to include fugitive emissions and fugitive dust, is at least best available control technology.”

KUC is proposing the addition of a new in-pit crusher and a three transfer point conveyor system. The proposed modification will also result in an increase in material moved through existing equipment and emission sources. Specifically, the proposed modification will also result in an increase in fugitive emissions from haulroads and ore and waste rock handling operations. KUC will maintain current or better levels of controls on all emission sources at the BCM as previously specified by UDAQ and as detailed in this NOI. The Utah Division of Air Quality has previously specified the current levels of controls on emission sources as BACT.

5.1 BACT Analysis for New In-pit Crusher and Conveyor System

5.1.1 New In-pit Crusher

Step 1 – Identify All Control Technologies

Potential PM_{10}/$PM_{2.5}$ emission control technologies for the new in-pit crusher include fabric filters, enclosures and water sprays to control dust.

Step 2 – Eliminate Technically Infeasible Options

All three control technologies are technically feasible.

Step 3 – Rank Remaining Control Technologies by Control Effectiveness

Fabric filters are most effective in controlling particulate emissions.

Step 4 – Evaluate Most Effective Controls and Document Results

KUC is proposing to use fabric filters to control emissions from the in-pit crusher. Since the top control technology has been selected, an economic and energy analyses are not required.

Step 5 – Select BACT

Fabric filters with grain loading of 0.007 gr/dscf are identified as BACT for the new in-pit crusher.

5.1.2 New Conveyor System Transfer System

Step 1 – Identify All Control Technologies

Potential PM_{10}/$PM_{2.5}$ emission control technologies for transfer points include enclosures vented to fabric filters, water sprays to control dust and minimizing drop point heights.

Step 2 – Eliminate Technically Infeasible Options

These transfer points cannot be enclosed completely and therefore fabric filters are not technically feasible for such fugitive emission sources. Because of the design of the transfer points and their vulnerability to wind interference, water sprays with fine droplets will not be very effective in minimizing emissions and water sprays with coarse droplets will over-wet the material.

Step 3 and 4 – Rank Remaining Control Technologies by Control Effectiveness

The transfer points will be enclosed and the drop point heights will be minimized to reduce fugitive emissions. This matches current practice at the BCM which has been observed to be effective and has been inspected by the UDAQ on numerous occasions.

Step 5 – Select BACT

Enclosures are therefore identified as BACT. UDAQ has previously specified enclosures as BACT for the transfer points with a control efficiency of 90 percent.

5.2 BACT Analysis for Haulroads

Potential technologies for control of fugitive emissions on unpaved haulroads are paving the unpaved roads, the use of water sprays and the use of dust suppression chemicals. Paving the haulroads is not technically feasible at the BCM because of the weight of the haultrucks and the rapid deterioration that would occur, and the frequently changing road locations.

Watering the unpaved haulroad and applying dust suppressants where appropriate reduces fugitive PM and PM_{10} emissions by binding the soil particles together, reducing free particles available to be picked up by wind or vehicles. Additional watering of an unpaved haulroad also occurs when heavy traffic is expected along the road. Water is applied on a scheduled basis and supplemented as needed based on driver observation of dust conditions. For example, in 2009, 158,485,000 gallons of dust suppression water were applied on haulroads the BCM.

Commercial dust suppressants are not applied on haulroads within the pit influence boundary at the BCM because of the adverse effect the suppressant has on the coefficient of friction of the road surface. Given that the grade of the haulroads exceeds 10 percent in some locations within the pit influence boundary, creating a slippery skin on the road inhibits mobile equipment to brake and steer safely while traveling on the grade. Where dump roads do not have the steep grades of the haulage routes (mainly haulroads outside the pit influence boundary), it is possible to apply commercial dust suppressants in those access areas for dust suppression without significantly increasing the risk of driving on the surface.

KUC also reduces dust through performing regular and routine maintenance of the haulroads and limiting unnecessary traffic on roads. Additionally, newer, larger haultrucks purchased by KUC have increased capacity, which decreases round-trips made and vehicle miles traveled, thereby reducing fugitive emissions.

The BACT is therefore identified as watering and application of crushed road base material within the pit influence boundary and applying commercial dust suppressants outside the pit influence boundary on the unpaved haulroads to reduce fugitive emissions.

5.3 BACT Analysis for Ore and Waste Rock Handling and Transfer

Particulate matter will be emitted from the in-pit crusher, and transfer and handling of ore and waste rock. Emissions from the in-pit crusher will be controlled with a baghouse. Because the material transfer sources are not enclosed in a building, fabric filters are not an effective control option. Potential control technologies for transfer and handling operations are therefore limited to enclosures and water sprays. Application of water is not technically feasible for all the material handling sources. Excessive watering of the material can cause problems with downstream operations. The material characteristics, including size, density, and moisture of the ore and waste rock, also minimize emissions. The design of the transfer points and location of infrastructure also minimize dust generation from these operations.

TABLE 5-1
BACT for Material Handling Sources

Emission Source	Proposed BACT
In-pit Crusher	Baghouse
Haultruck Dumping Ore into Crusher	Inherent material characteristics and physical enclosures
Existing In-pit Enclosed Transfer Points 1, 2, 3	Emissions controlled by enclosures
Conveyor-stacker Transfer Point	Inherent material characteristics and physical enclosures
Coarse Ore Stacker (Drop to Coarse Ore Storage Pile)	Inherent material characteristics and physical enclosures
Reclaim Tunnels (Coarse Ore Reclaim Tunnel Vent)	Inherent material characteristics and physical enclosures
Haultruck Loading	Inherent material characteristics and minimal drop distance
Haultruck Dumping Waste Rock	Inherent material characteristics and mechanical compaction to minimize emissions; water application from passing water trucks is used to further reduce emissions
Drilling with Water Injection	Water injection at 90 percent control efficiency

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6.0 Regulatory Review

This section provides a regulatory review of the applicability of state and federal air quality permitting requirements for the BCM.

6.1 State of Utah Air Permitting Requirements

The State of Utah has been granted authority to implement and enforce the permitting requirements specified by the federal Clean Air Act. The general requirements for permits and permit revisions are codified under the state environmental protection regulations, UAC R307-401.

6.1.1 Major Sources and Major Modifications (UAC R307-101-2)

Utah Administrative Code R307-101-2 defines a major stationary source, in pertinent part, as follows, with some parts underlined for emphasis:

> To the extent provided by the federal Clean Air Act as applicable to R307:
>
> (1) any stationary source of air pollutants which emits, or has the potential to emit, one hundred tons per year or more of any pollutant subject to regulation under the Clean Air Act;
>
> (2) any physical change that would occur at a source not qualifying under subpart 1 as a major source, if the change would constitute a major source by itself;
>
> (3) the fugitive emissions and fugitive dust of a stationary source shall not be included in determining for any of the purposes of these R307 rules whether it is a major stationary source, unless the source belongs to one of the following categories of stationary sources:
>
> (a) Coal cleaning plants (with thermal dryers);
> (b) Kraft pulp mills;
> (c) Portland cement plants;
> (d) Primary zinc smelters;
> (e) Iron and steel mills;
> (f) Primary aluminum or reduction plants;
> (g) Primary copper smelters;
> (h) Municipal incinerators capable of charging more than 250 tons of refuse per day;
> (i) Hydrofluoric, sulfuric, or nitric acid plants;
> (j) Petroleum refineries;
> (k) Lime plants;
> (l) Phosphate rock processing plants;
> (m) Coke oven batteries;
> (n) Sulfur recovery plants;
> (o) Carbon black plants (furnace process);
> (p) Primary lead smelters;

(q) Fuel conversion plants;
(r) Sintering plants;
(s) Secondary metal production plants;
(t) Chemical process plants;
(u) Fossil-fuel boilers (or combination thereof) totaling more than 250 million British Thermal Units per hour heat input;
(v) Petroleum storage and transfer units with a total storage capacity exceeding 300,000 barrels;
(w) Taconite ore processing plants;
(x) Glass fiber processing plants;
(y) Charcoal production plants;
(z) Fossil fuel-fired steam electric plants of more than 250 million British Thermal Units per hour heat input;
(aa) Any other stationary source category which, as of August 7, 1980, is being regulated under section 111 or 112 of the federal Clean Air Act.

The BCM source is not a major stationary source.[5] The majority of emissions associated with this source are specifically exempt fugitive emissions (this source category is not among those listed under Subparagraph 3 of this definition) or emissions associated with exempt tailpipe emissions.

Similarly, most of the emissions increases associated with the proposed modification are also exempt fugitive and tailpipe emissions. Therefore, the production increase will not constitute a major source under Subparagraph 2 of the definition.

6.1.2 Notice of Intent and Approval Order (UAC R307-401)

KUC is required by UAC R307-401-5 to submit this NOI application to UDAQ and obtain an AO issued by UDAQ before exceeding any limitations listed in the current AO (UDAQ, 2008). Utah Administrative Code R307-401-5 requires the NOI to include the following:

- A description of the project (provided in Section 1.0 of the NOI)
- Description and characteristics of emissions (provided in Sections 2.0 and 3.0 of the NOI)
- An analysis of BACT for the proposed source or modification (provided in Section 5.0 of the NOI)
- Location map (provided in Section 2.0 of the NOI)

6.1.3 Enforceable Offsets (UAC R307-403-5, UAC R307-420, and UAC R307-421)

Utah Administrative Code R307-403-5(1)(b) states that enforceable offsets of 1.2:1 are required for new sources or modifications that would produce an emission increase greater than or equal to 50 tpy of any combination of PM_{10}, SO_2, and NO_x.

5 UDAQ (2008) Engineering Review for AO (DAQE-AN0105710023-08) authorizing relocation/expansion of SX/EW plant.

Utah Administrative Code R307-403-5(1)(c) states that enforceable offsets of 1.1:1 are required for new sources or modifications that would produce an emissions increase greater than or equal to 25 tpy but less than 50 tpy of any combination of PM_{10}, SO_2, and NO_x.

Utah Administrative Code R307-403-5(2) specifically states that for offset determinations, PM_{10}, SO_2, and NO_x will be considered on an equal basis.

The net change in the combined total emissions of PM_{10}, SO_2, and NO_x from stationary point source from the proposed modification, as indicated in Table 4-3, is less than 25 tpy. Therefore, this project will not require any offsets.

6.1.4 Emissions Impact Analysis (UAC R307-410)

The BCM is not subject to UAC R307-410, which describes the emissions impact analysis requirements, since the emissions from point and fugitive sources are expected to be the same or decrease for pollutants that are in attainment for Salt Lake County. As a result, dispersion modeling is not required for the requested increase in material-moved limitation.

KUC has nonetheless performed AERMOD modeling to support the increase in material moved. The AERMOD model predicts ground-level concentrations of PM_{10} and demonstrates that the changes at the BCM will not cause or contribute to an exceedance of the PM_{10} NAAQS. The modeling report with this analysis and the results are included in Appendix C of this NOI.

As discussed in Appendix C, the results from the AERMOD analysis indicate that the total impacts from the emissions associated with peak year material movement of 260,000,000 tpy and background is 144.2 micrograms per cubic meter ($\mu g/m^3$). This is less than the NAAQS of 150 $\mu g/m^3$.

6.1.5 Monitoring and Reporting

After an AO is issued by UDAQ, KUC will be required to submit emission reports and conduct other activities as UDAQ requests. Some of these requirements include the following:

- Meet the reporting requirements specified in UAC R307-107-2 in the event of an unavoidable breakdown
- Submit and retain an air emission inventory as required in UAC R307-150-6, based on its applicability under UAC R307-150-3(3)

6.2 Federal Air Quality Permitting Requirements

The BCM is currently operating under the conditions of the 2008 AO and meets all applicable federal air quality permitting requirements. The BCM is not subject to any additional federal air quality permitting requirements as a result of the requested increase in material moved.

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7.0 Requested AO Conditions

KUC is requesting the following modification to the AO conditions:

- New condition: “Total emissions of PM_{10}, SO_2, and NO_x combined for the BCM shall not exceed 7,350 tons per calendar year per current calculations methodology.”
- Revise Condition 21.A: “Total material moved (ore and waste) shall not exceed 260,000,000 tons per 12-month period.”
- Conditions for Haulroads: “Fugitive dust shall be minimized in accordance with the fugitive dust control plan. Unpaved haulroads that are used by primary ore and waste haultrucks shall be water sprayed and/or chemically treated to control fugitive dust. Frequency will vary seasonally based on ambient conditions. Dust suppressants need not be applied if weather conditions would create a dangerous driving condition.
- Chemical treatment shall be applied to the active haulroads outside the pit influence boundary no less than two (2) times per year. More frequent applications shall be applied as necessary or as required by the fugitive dust control plan.”
- New Condition: KUC shall operate an ambient monitoring station as described in this Approval Order. The monitoring plan will be periodically reviewed by UDAQ and revised as necessary. [R307-401]

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8.0 References

Bhaskar, Ragula, and Navin Tandon. 1996. *Airflow Patterns and Pit-Retention of Fugitive Dust for the Bingham Canyon Mine*. Department of Mining Engineering, University of Utah.

Kennecott Utah Copper, LLC (KUC). 1999. *Notice of Intent to Increase Annual Ore and Waste Rock Production at the Kennecott Utah Copper Bingham Canyon Mine*. February.

United States Environmental Protection Agency (EPA). 1985, as updated through 2008. *AP-42, Fifth Edition: Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources*. Available at http://www.epa.gov/ttn/chief/ap42/#drafts. Accessed August 10, 2010.

Utah Division of Air Quality (UDAQ). 2008. *Approval Order DAQE-IN0105710023-08*.

Utah Division of Air Quality (UDAQ). 2009. "R307" *Utah Administrative Code*. http://www.airquality.utah.gov/Planning/Rules/index.htm

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APPENDIX A

Methodology of Estimating Tailpipe Emissions

APPENDIX A

Tailpipe Emissions Estimation from Haultrucks and Support Equipment using NONROAD

To support the Notice of Intent (NOI) application and per Utah Division of Air Quality (UDAQ) guidance, tailpipe emissions from haultrucks and support equipment were estimated using the U.S. Environmental Protection Agency's (EPA's) NONROAD emission factors and methodology. This appendix outlines this analysis.

Annual tailpipe emissions were estimated for each year from 2010 through 2029 to determine the emissions associated with the proposed increase of annual material moved of ore and waste rock to 260,000,000 tons per year.

Description of Mobile Emission Sources

Based on current mine plans, Kennecott Utah Copper LLC (KUC) estimated fleet distribution for the haultrucks and other support equipment.

KUC may purchase new haultrucks almost every year, and older trucks are either phased out or are rebuilt. KUC also uses front-end loaders, track dozers, rubber-tire dozers, graders, trackhoes, water trucks, construction trucks, diesel shovels, and diesel drills to support operations at the Bingham Canyon Mine (BCM). The types of haultruck engines and support equipment engines representing the present and future fleet at the BCM are listed in Table A-1.

TABLE A-1
Projected List of BCM Nonroad Engines

Equipment Type	Model	Tier	Horsepower
Haultrucks	CAT 793C	0	2,337
	CAT 793D	1	2,415
	CAT 795F	2	3,440
	KOM 930	1,2,4F	3,500
Track Dozers	CAT D10	0	580
	CAT D10	1	613
	CAT D10	2	661
	CAT D10	3, 4F	646
	CAT D11	0	850
	CAT D11	1, 4T, 4F	936

TABLE A-1
Projected List of BCM Nonroad Engines

Equipment Type	Model	Tier	Horsepower
Graders	CAT 16	1	289
	CAT 16	2	299
	CAT 16	3, 4T, 4F	297
	CAT 24H	0	500
	CAT 24	0	540
	CAT 24	2, 4F	533
Rubber-tired Dozers	CAT 834	0	487
	CAT 834	3, 4T, 4F	525
	CAT 854	1	880
Front-end Loaders	KOM WA500	1	235
	KOM WA600	3, 4F	396
	KOM WA700	1	502
	CAT 992	2	800
	CAT 992	4T, 4F	801
	KOM WA1200	0	1,560
	KOM WA1200	1, 4F	1,782
Trackhoes	CAT 330	2	264
	CAT 330	4F	268
	CAT 385	3, 4T, 4F	523
	KOM PC800	1, 4F	323
	KOM PC400	1	246
Water Trucks	CAT 789	0	1,900
	CAT 793C	1	2,300
	CAT 793D	2	2,415
Hydraulic Shovels	O&K RH 200	0	2,100
	O&K RH 200	1	2,520
Construction Trucks	KOM 785-7	1	1,200
Diesel Drills	P&H	1, 2	1,100
	ATLAS COPCO	2, 4F	750

KUC has estimated the hours of operation of each engine type based on estimated production activity for each year of analysis. The estimated haultruck hours are listed in Table A-2. A complete listing of the projected hours of operation per year for each support equipment type is included in the detailed calculations (Appendix B-1).

TABLE A-2
Projected KUC Haultruck Fleet Operational Hours by EPA Engine Tier Level (in thousands of hours)

Truck Type	Engine	2011	2012	2013	2014	2015	2016	2017	2018	2019
CAT 793C Fleet (2,337 hp)	Tier 0	46	-	-	-	-	-	-	-	-
CAT 793D Fleet (2,415 hp)	Tier 1	203	203	203	203	203	161	203	161	84
CAT 795F Fleet (3,440 hp)	Tier 2	12	-	-	-	-	-	-	-	-
KOM Fleet (3,500 hp)	Tier 1	179	215	215	186	207	193	157	193	143
	Tier 2	81	301	336	336	336	336	336	336	336
	Tier 4f	-	-	-	-	213	213	207	207	207
Total Hours		**475**	**719**	**754**	**725**	**960**	**903**	**904**	**897**	**770**

TABLE A-2, CONTINUED
Projected KUC Haultruck Fleet Operational Hours by EPA Engine Tier Level (in thousands of hours)

Truck Type	Engine	2020	2021	2022	2023	2024	2025	2026	2027	2028
CAT 793C Fleet (2,337 hp)	Tier 0	-	-	-	-	-	-	-	-	-
CAT 793D Fleet (2,415 hp)	Tier 1	-	-	-	-	-	-	-	-	-
CAT 795F Fleet (3,440 hp)	Tier 2	-	-	-	-	-	-	-	-	-
KOM Fleet (3,500 hp)	Tier 1	-	-	-	-	-	-	-	-	-
	Tier 2	315	86	64	136	215	200	29	50	36
	Tier 4f	207	207	114	100	107	107	207	193	207
Total Hours		**522**	**293**	**179**	**236**	**322**	**307**	**236**	**243**	**243**

NOTES:
hp = horsepower

Emission Standards

The emissions calculations are driven by the EPA-assigned tier designation of the engine. The tier values refer to federal nonroad diesel emissions standards. The first federal standards (Tier 1) for new nonroad diesel engines were adopted in 1994 for engines over 37 kilowatts (kW) (50 horsepower [hp]), to be phased in from 1996 to 2000. In 1996, a Statement of Principles (SOP) pertaining to nonroad diesel engines was signed between the EPA, California Air Resources Board, and engine manufacturers. On August 27, 1998, the EPA signed the final rule reflecting the provisions of the SOP.

The 1998 nonroad engine regulations are structured as a three-tiered progression. Each tier involves a phase-in (by horsepower rating) over several years. Tier 1 standards were phased in from 1996 to 2000. The more stringent Tier 2 standards take effect from 2001 to 2006, and the yet more stringent Tier 3 standards phase in from 2006 to 2008 (Tier 3 standards apply only for engines from 37–560 kW). On May 11, 2004, the EPA signed the final rule introducing Tier 4 emission standards, which are to be phased in over the period of 2008–2015. Any diesel engine manufactured prior to the adoption of the tier standards is labeled as a Tier 0 engine.

The regulations for the horsepower classes included in this analysis are summarized in Table A-3. The full table of nonroad engine emission standards can be found in the U.S. *Code of Federal Regulations*, Title 40, Part 89.

TABLE A-3
Nonroad Engine Emissions Standards (g/hp-hr)

Engine Power (hp)	Model Years	Regulation	HC	CO	NO_X	PM
≥175 to ≤300	1996–2005	Tier 1	1.0	8.5	6.9	0.4
	2003–2005	Tier 2		2.6		0.15
	2006–2010	Tier 3		2.6		
	2011–2013	Tier 4 transitional [a]	0.14 (50%)		0.30 (50%)	0.01
	2014	Tier 4 final	0.14		0.30	0.01
≥300 to ≤600	1996–2000	Tier 1	1.0	8.5	6.9	0.4
	2001–2005	Tier 2		2.6		0.15
	2006–2010	Tier 3		2.6		
	2011–2013	Tier 4 transitional [a]	0.14 (50%)		0.30 (50%)	0.01
	2014	Tier 4 final	0.14		0.30	0.01
≥600 to ≤750	1996–2001	Tier 1	1.0	8.5	6.9	0.4
	2002–2005	Tier 2		2.6		0.15
	2006–2010	Tier 3		2.6		
	2011–2013	Tier 4 transitional [a]	0.14 (50%)		0.30 (50%)	0.01
	2014	Tier 4 final	0.14		0.30	0.01
≥750 except generator sets	2000–2005	Tier 1	1.0	8.5	6.9	0.4
	2006–2010	Tier 2		2.6		0.15
	2011–2014	Tier 4 transitional [a]	0.30		2.6	0.075
	2015+	Tier 4 final	0.14		2.6	0.03

NOTES:
CO = carbon monoxide
g/hp-hr = gram per horsepower-hour
HC = hydrocarbon
NO_x = nitrogen oxide
PM = particulate matter

EPA emission standards for nonroad diesel engines are published in the U.S. Code of Federal Regulations, Title 40, Part 89 [40 CFR Part 89].

[a] Percentages are model year sales fractions required to comply with the indicated NO_X standard, for model years where less than 100 percent is required.

Potential to emit (PTE) estimates were calculated based on tier availability communicated to KUC from the equipment and engine manufacturers.

NONROAD Methodology

Emission factors were calculated using the methodology described in the NONROAD modeling guidance. Emission factors were applied to the annual activity for each type of engine and vehicle to estimate annual emissions. NONROAD 2005 is an EPA model designed to predict emissions from various nonroad equipment categories. The model predicts emissions of hydrocarbon (HC), nitrogen oxides (NO_x), carbon monoxide (CO), sulfur oxides (SO_x), and particulate matter (PM) based on regional listings of specific equipment and further stratifies the engine by horsepower rating and federal engine tier standards.

In order to calculate the emissions of a known fleet of vehicles, NONROAD population and activity files can be customized with the specific fleet data. Alternatively, emission factor equations used by the model are available within the technical documentation.

Because of the large number of project years and variations in the vehicle fleet population in each project year, vehicle emission factors were calculated using the methodology described in the EPA NONROAD technical document *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition* (EPA, 2004a). The following equation was used to estimate emissions:

Annual emissions = emission factor (g/hp-hr) * engine horsepower (hp) * hours of operation (hr) * load factor

Load factors represent the average load on an engine that operates at a variety of speeds or load conditions. KUC and the haultruck engine manufacturers developed a site-specific load factor of 0.34 for the haultrucks at the mine. Load factors for support equipment, shovels, and drills were selected based on Tables 9 and 10 of the document *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling* (EPA, 2004b). An average load factor of 0.43 was applied to the diesel drills, and a loader-specific load factor of 0.48 was used for the front-end loaders. The remaining equipment types used a load factor of 0.58 designated for the “crawler cycle class.” This is a representative load factor as it represents slow moving, high powered construction vehicles.

Emission Factor Calculations

Steady-state emission factors for each engine type were calculated and then adjusted based on transient adjustment factors and deterioration factors according to the following equation from *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition* (EPA, 2004a):

$$EF_{adj} = EF_{SS} \times TAF \times DF - S_{PMadj}$$

Steady-state emission factors (EF_{SS}) are determined based on model year and horsepower category. Transient adjustment factors (TAF) vary by engine type to account for how engine speed and load variations in the field effect emissions. Deterioration factors (DFs) adjust for age-related deterioration and are a function of technology type and the age of the engine. DF is not used for sulfur dioxide (SO_2) emissions. S_{PMadj} is an additional adjustment to the

PM less than 10 micrometers in aerodynamic diameter (PM_{10}) emission factor to account for variations in fuel sulfur content.

Further details about the emission factor equation are laid out in *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition* (EPA, 2004a). All input values are based on model year and horsepower, using the values suggested in the document. The specific inputs used for this analysis are documented in the calculation worksheets.

Calculated emission factors are presented in Table A-4, grouped by horsepower class and federal engine tier standards. These emission factors were applicable to all haultrucks and support equipment considered in this analysis.

TABLE A-4
Emission Factors by Horsepower Class (g/hp-hr)

	Pollutant	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4t	Tier 4f
175- to 300-hp class	HC	1.05	0.34	0.33	0.20	0.13	0.13
	CO	4.90	1.26	1.26	1.32	0.09	0.09
	NO_x	8.15	5.43	3.83	2.39	2.52	0.28
	SO_2	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049
	PM_{10}	0.64	0.37	0.15	0.15	0.01	0.01
300- to 600-hp class	HC	1.05	0.22	0.18	0.18	0.13	0.13
	CO	4.90	2.20	1.42	1.48	0.10	0.10
	NO_x	8.15	5.85	4.16	2.39	2.52	0.28
	SO_2	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049
	PM_{10}	0.64	0.28	0.15	0.15	0.01	0.01
600- to 750-hp class	HC	1.05	0.16	0.18	0.18	0.13	0.13
	CO	4.90	2.24	2.24	2.34	0.15	0.15
	NO_x	8.15	5.66	3.93	2.39	2.52	0.28
	SO_2	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049
	PM_{10}	0.64	0.31	0.15	0.15	0.01	0.01
>750-hp class	HC	1.05	0.31	0.18	NA	0.29	0.13
	CO	4.90	1.29	1.29	NA	0.09	0.09
	NO_x	8.15	5.99	3.93	NA	2.41	2.41
	SO_2	0.0049	0.0049	0.0049	NA	0.0049	0.0049
	PM_{10}	0.64	0.26	0.15	NA	0.02	0.02

NOTES:
g/hp-hr = grams per horsepower-hour

All emission factors represent the lesser of EPA emission limits and factors calculated using EPA NONROAD methodology.

Analysis Results

Annual emissions from each vehicle type were estimated based on the calculated emission factors, engine horsepower, and hours of operation for each year 2010 through 2029. Tables A-5 and A-6 summarize the annual haultruck and support equipment tailpipe emissions, respectively, between 2010 and 2029. The detailed calculation files are included in Appendix B-1.

TABLE A-5
Projected Estimated Haultruck Emissions by Truck Type (tons/year)

		2011	2012	2013	2014	2015	2016	2017	2018	2019
CAT 793C	HC	30	-	-	-	-	-	-	-	-
	CO	197	-	-	-	-	-	-	-	-
	NO_x	328	-	-	-	-	-	-	-	-
	SO_2	0.2	-	-	-	-	-	-	-	-
	PM_{10}	26	-	-	-	-	-	-	-	-
CAT 793D	HC	57	57	57	57	57	45	57	45	24
	CO	237	237	237	237	237	188	237	188	98
	NO_x	1,100	1,100	1,100	1,100	1,100	872	1,100	872	455
	SO_2	0.9	0.9	0.9	0.9	0.9	0.7	0.9	0.7	0.4
	PM_{10}	48	48	48	48	48	38	48	38	20
CAT 795F	HC	3	-	-	-	-	-	-	-	-
	CO	20	-	-	-	-	-	-	-	-
	NO_x	61	-	-	-	-	-	-	-	-
	SO_2	0.1	-	-	-	-	-	-	-	-
	PM_{10}	2	-	-	-	-	-	-	-	-
KOM 930	HC	92.2	159.2	167.4	155.8	202.3	196.4	180.8	195.4	175.0
	CO	438	871	930	881	1,164	1,139	1,072	1,133	1,048
	NO_x	1,820	3,238	3,416	3,192	4,034	3,922	3,623	3,904	3,511
	SO_2	1.68	3.33	3.56	3.37	4.87	4.78	4.51	4.74	4.42
	PM_{10}	77.9	134.1	141.0	131.1	142.8	137.9	125.4	137.8	120.5
Total	HC	194	216	225	213	259	242	238	241	199
	CO	892	1,108	1,166	1,118	1,400	1,327	1,309	1,320	1,146
	NO_x	3,309	4,337	4,516	4,292	5,134	4,794	4,723	4,776	3,966
	SO_2	2.9	4.2	4.5	4.3	5.8	5.5	5.4	5.5	4.8
	PM_{10}	154	182	189	179	191	176	174	176	141

TABLE A-5 (CONTINUED)
Projected Estimated Haultruck Emissions by Truck Type (tons/year)

		2020	2021	2022	2023	2024	2025	2026	2027	2028
CAT 793C	HC	-	-	-	-	-	-	-	-	-
	CO	-	-	-	-	-	-	-	-	-
	NO_x	-	-	-	-	-	-	-	-	-
	SO_2	-	-	-	-	-	-	-	-	-
	PM_{10}	-	-	-	-	-	-	-	-	-
CAT 793D	HC	-	-	-	-	-	-	-	-	-
	CO	-	-	-	-	-	-	-	-	-
	NO_x	-	-	-	-	-	-	-	-	-
	SO_2	-	-	-	-	-	-	-	-	-
	PM_{10}	-	-	-	-	-	-	-	-	-
CAT 795F	HC	-	-	-	-	-	-	-	-	-
	CO	-	-	-	-	-	-	-	-	-
	NO_x	-	-	-	-	-	-	-	-	-
	SO_2	-	-	-	-	-	-	-	-	-
	PM_{10}	-	-	-	-	-	-	-	-	-
KOM 930	HC	111.5	57.1	35.5	50.0	70.0	66.6	43.5	46.1	45.2
	CO	770	384	241	345	486	462	288	307	300
	NO_x	2,278	1,098	694	1,017	1,445	1,371	803	869	840
	SO_2	3.36	1.88	1.15	1.52	2.07	1.98	1.51	1.56	1.56
	PM_{10}	66.8	21.3	15.1	29.1	44.8	42.0	9.9	13.9	11.4
Total	HC	111	57	36	50	70	67	44	46	45
	CO	770	384	241	345	486	462	288	307	300
	NO_x	2,278	1,098	694	1,017	1,445	1,371	803	869	840
	SO_2	3.4	1.9	1.1	1.5	2.1	2.0	1.5	1.6	1.6
	PM_{10}	67	21	15	29	45	42	10	14	11

TABLE A-6
Estimated Support Equipment Emissions (tons/year)

	2011	2012	2013	2014	2015	2016	2017	2018	2019
HC	43.0	39.3	38.3	38.0	38.0	34.8	33.8	32.9	31.7
CO	272	242	231	229	228	204	191	176	168
NO_x	695	665	644	641	638	588	561	539	517
SO_2	0.70	0.75	0.77	0.78	0.78	0.78	0.76	0.75	0.72
PM_{10}	36.3	31.3	28.7	28.3	28.1	24.6	23.2	21.9	20.8
	2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
HC	25.5	23.5	22.0	21.6	21.5	20.8	20.8	19.5	19.5
CO	131	107	93.4	82.5	79.0	67.6	67.4	67.0	66.9
NO_x	405	363	327	312	309	297	296	286	285
SO_2	0.60	0.55	0.51	0.51	0.52	0.51	0.51	0.49	0.49
PM_{10}	15.6	13.9	12.6	11.9	11.7	10.9	10.9	10.8	10.8

References

United States Environmental Protection Agency (EPA). 2004a. *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling – Compression-Ignition*. Assessment and Standards Division, Office of Transportation and Air Quality. EPA420-P-04-009, NR-009c. April.

United States Environmental Protection Agency (EPA). 2004b. *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling*. Assessment and Standards Division, Office of Transportation and Air Quality. EPA420-P-04-005, NR-005c. April.

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APPENDIX B

Emissions Calculations

APPENDIX B-1

Post-modification Emissions Calculations

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Units	Definitions
°C	degree Celsius
acfm	actual cubic feet per minute
bhp	brake horsepower
dcf	dry cubic feet
dscf	dry standard cubic feet
dscf	dry standard cubic feet
dscfm	dry standard cubic feet per minute
ft^2	square feet
g	gram
gal	gallon
gpm	gallon per minute
gr	grain
hp	horsepower
hp-hr	horsepower-hour
hr	hour
kW	kilowatt
lb	pound
mg	milligram
mg/kg	milligram per kilogram
mg/L	milligram per liter
min	minute
mmBtu	million British thermal units
mph	miles per hour
Mtpy	million tons per year
ppm	part per million
tpy	ton per year
yr	year
Acronyms	**Definitions**
AEI	Air Emissions Inventory
AO	Approval Order
BCM	Bingham Canyon Mine
BSFC	brake-specific fuel consumption
CDPHE	Colorado Department of Public Health and Environment
CMB	Chemical Mass Balance
CO	carbon monoxide
EPA	U.S. Environmental Protection Agency
H_2SO_4	sulfuric acid
HAP	hazardous air pollutant
HC	hydrocarbon
ID	identification
KUC	Kennecott Utah Copper LLC
LPG	liquefied petroleum gas
MSDS	material safety data sheet
MSL	mean sea level
NH_3	ammonia
NOI	Notice of Intent
NO_x	nitrogen oxides
PM	particulate matter
PM_{10}	particulate matter less than 10 micrometers in aerodynamic diameter
$PM_{2.5}$	particulate matter less than 2.5 micrometers in aerodynamic diameter
PTE	potential to emit
SIP	State Implementation Plan
SO_2	sulfur dioxide
SO_x	sulfur oxides
SX/EW	solvent extraction/electrowinning
UDAQ	Utah Division of Air Quality
VMT	vehicle miles traveled
VOC	volatile organic compound

TABLE B1-1
Emissions Summary (260 MM case)
KUC—Bingham Canyon Mine

	Point Sources	Other Fugitive Sources	Haulroad Fugitives (within pit influence boundary)	Haulroad Fugitives (outside pit influence boundary)	Mobile Sources	Post Project BCM PTEs
PM_{10} Emissions (tpy)	6.28	226	573	480	228	1,513
$PM_{2.5}$ Emissions (tpy)	2.60	37	60	48	221	368
SO_2 Emissions (tpy)	0.0002				6.56	6.56
NO_X Emissions (tpy)	1.17				5,829	5,830
CO Emissions (tpy)	10.6				1,672	1,682
VOC Emissions (tpy)	0.20	11.30			302	314
HAP Emissions (tpy)		1.37				1.37
$PM_{10}+SO_2+NO_X$ Emissions (tpy)	7.44					7,350

NOTES:
(1) Calculations assume 85,000,000 tons per year ore production.
(2) Mobile Source emissions shown above are the maximum emissions between 2011 through 2028.
(3) Haulroad emissions shown above are the maximum emissions between 2011 through 2028.
(4) Calculations incorporate 75% control efficiency for the haulroads within the pit influence boundary and 85% outside the pit influence boundary.
Calcs for C6/C7 transfer point baghouse and C7/C8 transfer point baghouse are based on 0.007 gr/dscf grain loading.
(5) Haulroad emissions inside the pit influence boundary include a 0.20 escape factor in the calculations.

TABLE B1-2
In-pit Crusher
KUC—Bingham Canyon Mine

Source Name	PM_{10} Emission Factor (gr/dscf)	Hours of Operation (hrs/yr)	Design Flow Rate (dcf/min)	PM_{10} Emissions with Primary Control (lbs/hr)	PM_{10} Emissions with Primary Control (tpy)	$PM_{2.5}$ Emissions with Primary Control (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
In Pit Crusher	0.016	8,760	12,898	1.77	7.75	2.28	20	21	1.55	0.48	Emissions controlled with a baghouse. Source Located in the pit.

NOTES:

Emissions based on AO limits.

Emissions for $PM_{2.5}$ based on factors from AP-42, Table B.2.2, Category 3 - Mechanically Generated Aggregate and Unprocessed Ores.

PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).

TABLE B1-3
New In-pit Crusher
KUC—Bingham Canyon Mine

Source Name	PM_{10} Emission Factor (gr/dscf)	Hours of Operation (hrs/yr)	Design Flow Rate (dcf/min)	PM_{10} Emissions with Primary Control (lbs/hr)	PM_{10} Emissions with Primary Control (tpy)	$PM_{2.5}$ Emissions with Primary Control (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
New In Pit Crusher	0.007	8,760	12,898	0.77	3.39	1.00	20	21	0.68	0.21	Emissions controlled with a baghouse. Source Located in the pit.

NOTES:

The new crusher is expected to be similar to the existing crusher.

Emissions for $PM_{2.5}$ based on factors from AP-42, Table B.2.2, Category 3 - Mechanically Generated Aggregate and Unprocessed Ores.

PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).

TABLE B1-4
C6/C7 Conveyor Transfer Point
KUC—Bingham Canyon Mine

Source Name	PM_{10} Emission Factor (gr/dscf)	Hours of Operation (hrs/yr)	Design Flow Rate (dcf/min)	Controlled PM_{10} Emissions (lbs/hr)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
C6/C7 Conveyor Transfer Point	0.007	8,760	5,120	0.31	1.35	0.40	Emissions controlled with a baghouse.

NOTES:
Emissions based on AO limits.
Emissions for $PM_{2.5}$ based on factors from AP-42, Table B.2.2, Category 3 - Mechanically Generated Aggregate and Unprocessed Ores.
KUC is proposing a lower grain loading for the baghouse.

TABLE B1-5
C7/C8 Conveyor Transfer Point
KUC—Bingham Canyon Mine

Source Name	PM_{10} Emission Factor (gr/dscf)	Hours of Operation (hrs/yr)	Design Flow Rate (dcf/min)	Controlled PM_{10} Emissions (lbs/hr)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
C7/C8 Conveyor Transfer Point	0.007	8,760	3,168	0.19	0.83	0.24	Emissions controlled with a baghouse.

NOTES:
Emissions based on AO limits.
Emissions for $PM_{2.5}$ based on factors from AP-42, Table B.2.2, Category 3 - Mechanically Generated Aggregate and Unprocessed Ores.
KUC is proposing a lower grain loading for the baghouse.

TABLE B1-6

Lime Bin

KUC—Bingham Canyon Mine

Source Name	PM_{10} Emission Factor (gr/dscf)	Hours of Operation (hrs/yr)	Design Flow Rate (dcf/min)	Controlled PM_{10} Emissions (lbs/hr)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Lime Bin	0.016	8,760	616	0.08	0.37	0.13	Emissions controlled with a baghouse.

NOTES:

Emissions based on AO limits.

Lime is an industrial nonmetalic mineral.

Emissions for PM2.5 based on factors from AP-42, Table B.2.2, Category 4 - Mechanically Generated Processed Ores and Nonmetallic Minerals.

TABLE B1-7
Lime Bin
KUC—Bingham Canyon Mine

Source Name	PM_{10} Emission Factor (gr/dscf)	Hours of Operation (hrs/yr)	Design Flow Rate (dcf/min)	Controlled PM_{10} Emissions (lbs/hr)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Lime Bin	0.016	8,760	616	0.08	0.37	0.13	Emissions controlled with a baghouse.

NOTES:
Emissions based on AO limits.
Lime is an industrial nonmetalic mineral.
Emissions for $PM_{2.5}$ based on factors from AP-42, Table B.2.2, Category 4 - Mechanically Generated Processed Ores and Nonmetallic Minerals.

TABLE B1-8
Sample Preparation
KUC—Bingham Canyon Mine

Source Name	PM_{10} Emission Factor (gr/dscf)	Hours of Operation (hrs/yr)	Design Flow Rate (dcf/min)	PM_{10} Emissions with Primary Control (lbs/hr)	PM_{10} Emissions with Primary Control (tpy)	$PM_{2.5}$ Emissions with Primary Control (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
Sample Preparation	0.016	2,920	4,269	0.59	0.85	0.25	20	21	0.17	0.05	Emissions controlled with a baghouse. Source Located in the pit.

NOTES:
Hours of operation will continue to be 8 hours per day. No change in hours of operation due to the proposed project.
Emissions for $PM_{2.5}$ based on factors from AP-42, Table B.2.2, Category 3 - Mechanically Generated Aggregate and Unprocessed Ores.
Material handled during sample preparation is ore and waste rock material.
PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).

TABLE B1-9
Gasoline and Diesel Fueling
KUC—Bingham Canyon Mine

Source Name	Total VOC Emissions (tpy)	Total HAP Emissions (tpy)
Gasoline and Diesel Fueling	4.24	1.29

Gasoline Fueling

Source Name	Annual Throughput (1,000 gal/yr)	VOC Emissions (tpy)	Primary Control System and Comments
Gasoline Fueling	530	3.45	Stage I Vapor Recovery

NOTES:
VOC Emission Factor (lb/10^3 gal) 13
Emission Factor obtained from AP-42, Table 5.2-7.
Station used to fuel light trucks and vehicles.

VOC Emission Factors (lb/10^3 gal) from AP-42, Table 5.2.7

Balanced Submerged Filling	0.3
Underground Tank Breathing & Emptying	1
Vehicle refueling Displacement Losses (uncontrolled)	11
Spillage	0.7

HAP Calculations

HAP	Concentration	Emissions (tpy)
Xylenes	6.5%	0.22
Toluene	10.0%	0.34
Naphthalene	0.2%	0.01
Benzene	3.0%	0.10
1,2,4-Trimethyl Benzene	7.0%	0.24
Ethyl Alcohol	10.0%	0.34
Cyclohexane	0.5%	0.02
Total HAP Emissions		1.28

NOTES:
(1) HAP Concentration data obtained from the MSDS for Gasoline.

Diesel Fueling

Source Name	Annual Throughput (1,000 gal/yr)	VOC Emissions (tpy)	Primary Control System and Comments
Diesel Fueling	55,000	0.80	Submerged Pipe

NOTES:
VOC Emission Factor (lb/10^3 gal) 0.029
In the absence of an applicable AP-42 emission factor, the Colorado Department of Public Health and Environment guidance on emissions from service stations was used for estimating diesel dispensing emissions.
Stations are used to fuel light trucks, vehicles and haul trucks.

HAP Calculations

HAP	Concentration	Emissions (tpy)
Toluene	0.5%	0.00399
Naphthalene	0.5%	0.00399
Total HAP Emissions		0.00798

NOTES:
(1) HAP Concentration data obtained from the MSDS for Diesel.

TABLE B1-10
Truck Offloading Ore at In-pit Crusher
KUC—Bingham Canyon Mine

Source Name	PM_{10} Aerodynamic Particle Size Multiplier (k)	$PM_{2.5}$ Aerodynamic Particle Size Multiplier (k)	Moisture Content (%)	Wind Speed (mph)	PM_{10} Emission Factor (lbs/ton)	$PM_{2.5}$ Emission Factor (lbs/ton)	Annual Process Rate (tpy)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Primary Control Efficiency (%)	PM_{10} Emissions with Primary Controls (tpy)	$PM_{2.5}$ Emissions with Primary Controls (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
Truck Offloading Ore	0.35	0.053	4	7	0.00066	0.00010	85,000,000	27.9	4.2	90	2.79	0.42	20	21	0.56	0.09	Inherent material characteristics and physical enclosures. Source Located in the pit.

NOTES:
Emission factors estimated using methodology in AP-42, Section 13.2.4.
Wind speed and moisture content data based on historical data.
PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).
Characteristics of the ore material, such as large diameter material, and inherent material moisture content of 4 percent, limit dust being generated during the transfer operations.
The control efficiency listed is based on previous determinations of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling.

TABLE B1-11
In-pit Enclosed Transfer Points 1, 2, and 3
KUC—Bingham Canyon Mine

Source Name	Number of Transfer Points	PM_{10} Aerodynamic Particle Size Multiplier (k)	$PM_{2.5}$ Aerodynamic Particle Size Multiplier (k)	Moisture Content (%)	Wind Speed (mph)	PM_{10} Emission Factor (lbs/ton)	$PM_{2.5}$ Emission Factor (lbs/ton)	Annual Process Rate (tpy)	Uncontrolled PM_{10} Emissions per Transfer Point (tpy)	Uncontrolled $PM_{2.5}$ Emissions per Transfer Point (tpy)	Primary Control Efficiency (%)	PM_{10} Emissions with primary controls per Transfer Point (tpy)	$PM_{2.5}$ Emissions with primary controls per Transfer Point (tpy)	PM_{10} Emissions with Primary Controls (tpy)	$PM_{2.5}$ Emissions with Primary Controls (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
In-Pit Enclosed Transfer Point 1, 2, 3	3	0.35	0.053	4	7	0.00066	0.00010	85,000,000	27.9	4.2	90	2.79	0.42	8.38	1.27	20	21	1.68	0.27	Emissions controlled by enclosures. Source located in the pit.

NOTES:
Emission factors estimated using methodology in AP-42, Section 13.2.4.
Wind speed and moisture content data based on historical data.
PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).
The control efficiency listed is based on previous determinations of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling.

TABLE B1-12

New In-pit Enclosed Transfer Point 1, 2, and 3

KUC—Bingham Canyon Mine

Source Name	Number of Transfer Points	PM_{10} Aerodynamic Particle Size Multiplier (k)	$PM_{2.5}$ Aerodynamic Particle Size Multiplier (k)	Moisture Content (%)	Wind Speed (mph)	PM_{10} Emission Factor (lbs/ton)	$PM_{2.5}$ Emission Factor (lbs/ton)	Annual Process Rate (tpy)	Uncontrolled PM_{10} Emissions per Transfer Point (tpy)	Uncontrolled $PM_{2.5}$ Emissions per Transfer Point (tpy)	Primary Control Efficiency (%)	PM_{10} Emissions with primary controls per Transfer Point (tpy)	$PM_{2.5}$ Emissions with primary controls per Transfer Point (tpy)	PM_{10} Emissions with Primary Controls (tpy)	$PM_{2.5}$ Emissions with Primary Controls (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
New In-Pit Enclosed Transfer Point 1, 2, 3	3	0.35	0.053	4	7	0.00066	0.00010	85,000,000	27.9	4.2	90	2.79	0.42	8.38	1.27	20	21	1.68	0.27	Emissions controlled by enclosures. Source located in the pit.

NOTES:

Emission factors estimated using methodology in AP-42, Section 13.2.4.

Wind speed and moisture content data based on historical data.

PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).

The control efficiency listed is based on previous determinations of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling.

TABLE B1-13

In-pit Enclosed Transfer Point 4 and 5 (proposed new transfer point with the relocation of the existing in-pit crusher)

KUC—Bingham Canyon Mine

Source Name	Number of Transfer Points	PM_{10} Aerodynamic Particle Size Multiplier (k)	$PM_{2.5}$ Aerodynamic Particle Size Multiplier (k)	Moisture Content (%)	Wind Speed (mph)	PM_{10} Emission Factor (lbs/ton)	$PM_{2.5}$ Emission Factor (lbs/ton)	Annual Process Rate (tpy)	Uncontrolled PM_{10} Emissions per Transfer Point (tpy)	Uncontrolled $PM_{2.5}$ Emissions per Transfer Point (tpy)	Primary Control Efficiency (%)	PM_{10} Emissions with Primary Controls per Transfer Point (tpy)	$PM_{2.5}$ Emissions with Primary Controls per Transfer Point (tpy)	PM_{10} Emissions with Primary Controls (tpy)	$PM_{2.5}$ Emissions with Primary Controls (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the Pit (tpy)	Controlled $PM_{2.5}$ Emissions from the Pit (tpy)	Control System and Comments
In-Pit Enclosed Transfer Point 4,5	2	0.35	0.053	4	7	0.00066	0.00010	85,000,000	27.9	4.2	90	2.79	0.42	5.59	0.85	20	21	1.12	0.18	Emissions controlled by enclosures. Source located in the pit.

NOTES:

Emission factors estimated using methodology in AP-42, Section 13.2.4.

Wind speed and moisture content data based on historical data.

PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).

The control efficiency listed is based on previous determinations of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling.

TABLE B1-14
Conveyor-Stacker Transfer Point
KUC—Bingham Canyon Mine

Source Name	PM_{10} Aerodynamic Particle Size Multiplier (k)	$PM_{2.5}$ Aerodynamic Particle Size Multiplier (k)	Moisture Content (%)	Wind Speed (mph)	PM_{10} Emission Factor (lbs/ton)	$PM_{2.5}$ Emission Factor (lbs/ton)	Annual Process Rate (tpy)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Conveyor-Stacker Transfer Point	0.35	0.053	4	7	0.00066	0.00010	85,000,000	27.9	4.2	90	2.79	0.42	Inherent material characteristics and physical enclosures.

NOTES:
Emission factors estimated using methodology in AP-42, Section 13.2.4.
Wind speed and moisture content data based on historical data.
Characteristics of the ore material, such as large diameter material, and inherent material moisture content of 4 percent, limit dust being generated during the transfer operations.
The control efficiency listed is based on previous determinations of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling.

TABLE B1-15

Coarse Ore Stacker

KUC—Bingham Canyon Mine

Source Name	PM_{10} Aerodynamic Particle Size Multiplier (k)	$PM_{2.5}$ Aerodynamic Particle Size Multiplier (k)	Moisture Content (%)	Wind Speed (mph)	PM_{10} Emission Factor (lbs/ton)	$PM_{2.5}$ Emission Factor (lbs/ton)	Annual Process Rate (tpy)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Coarse Ore Stacker (Drop to Coarse Ore Storage Pile)	0.35	0.053	4	7	0.00066	0.00010	85,000,000	27.9	4.2	90	2.79	0.42	Inherent material characteristics and physical enclosures.

NOTES:

Emission factors estimated using methodology in AP-42, Section 13.2.4.

Wind speed and moisture content data based on historical data.

Characteristics of the ore material, such as large diameter material, and inherent material moisture content of 4 percent, limit dust being generated during the transfer operations.

The control efficiency listed is based on previous determinations of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling.

TABLE B1-16
Reclaim Tunnels
KUC—Bingham Canyon Mine

Source Name	PM_{10} Aerodynamic Particle Size Multiplier (k)	$PM_{2.5}$ Aerodynamic Particle Size Multiplier (k)	Moisture Content (%)	Wind Speed (mph)	PM_{10} Emission Factor (lbs/ton)	$PM_{2.5}$ Emission Factor (lbs/ton)	Annual Process Rate (tpy)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Reclaim Tunnels (Coarse Ore Reclaim Tunnel Vent)	0.35	0.053	4	7	0.00066	0.00010	85,000,000	27.9	4.2	90	2.79	0.42	Inherent material characteristics and physical enclosures.

NOTES:
Emission factors estimated using methodology in AP-42, Section 13.2.4.
Wind speed and moisture content data based on historical data.
Characteristics of the ore material, such as large diameter material, and inherent material moisture content of 4 percent, limit dust being generated during the transfer operations.
The control efficiency listed is based on previous determinations of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling.

TABLE B1-17

Disturbed Areas

KUC—Bingham Canyon Mine

Source Name	Number of Days per Year	Number of Days of precipitation	PM Emission Factor (tons/acre-yr)	PM_{10} Emission Factor (tons/acre-yr)	$PM_{2.5}$ Emission Factor (tons/acre-yr)	Total Disturbed Area (acres)	Uncontrolled PM_{10} Emissions (tpy)	Primary Control Efficiency (%)	PM_{10} Emissions with Primary Controls (tpy)	$PM_{2.5}$ Emissions with Primary Controls (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
Disturbed Areas (Unstabilized Areas) - areas Outside the Pit	365	106	0.38	0.18	0.03	256	32.7	0	32.7	7.0	100	100	32.67	6.97	Inherent material characteristics and water application from passing water trucks is used to further reduce emissions.
Disturbed Areas (Unstabilized Areas) - areas Inside the Pit	365	106	0.38	0.18	0.03	310	39.6	0	39.6	8.4	20	21	7.92	1.77	Inherent material characteristics and source located in the pit.

NOTES:

PM Emission factor estimated using methodology in AP-42, Section 11.9-4 (Wind Erosion of Exposed Areas).

PM_{10} and $PM_{2.5}$ emission factor derived from ratio of transfer particle size multipliers in AP 42, Fifth Edition, Table 13.2.4 (EPA, 2006), (Wind Erosion of Pile Surfaces and Ground Areas around Piles).

Characteristics of the ore material, such as large diameter material, and inherent material moisture content of 4 percent, limit dust being generated.

PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).

Days of precipitation data obtained from the East Butte Meterological Station. Number of days with at least 0.01 inches of precipitation per year.

Distribution of acres in and out of pit are based on expected mine operations provided by the KUC Mine group.

TABLE B1-18
Cold Solvent Degreasing Parts
KUC—Bingham Canyon Mine

Source Name	Throughput (gal/yr)	Specific Gravity	Density (lbs/gal)	Percent VOCs	Uncontrolled VOC Emissions (tpy)	Control Efficiency (%)	Controlled VOC Emissions (tpy)	Control System and Comments
Cold Solvent Degreasing Parts	500	0.81	6.76	100	1.69	0	1.69	Degreasers are enclosed.

NOTES:
Emissions estimated based on material balance.
Throughput based on one solvent change per year for 8 degreasers.

TABLE B1-19
Haul Roads
KUC—Bingham Canyon Mine

Max Hauled: **260,000,000 tons per year**

Emissions for 2011

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	214,000,000	3.9	891,667	3,477,500	5,411	541	75	1,353	135	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	214,000,000	0.8	891,667	713,333	1,110	111	85	167	17	Chemical Suppressants and Water Sprays
								4,190,833				1,519	152	

Emissions for 2012

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	235,000,000	4.4	979,167	4,308,333	6,704	670	75	1,676	168	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	235,000,000	0.7	979,167	685,417	1,067	107	85	160	16	Chemical Suppressants and Water Sprays
								4,993,750				1,836	184	

Emissions for 2013

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	255,000,000	5.5	1,062,500	5,843,750	9,094	909	75	2,273	227	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	255,000,000	2.1	1,062,500	2,231,250	3,472	347	85	521	52	Chemical Suppressants and Water Sprays
								8,075,000				2,794	279	

Emissions for 2014

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	259,000,000	6.2	1,079,167	6,690,833	10,412	1,041	75	2,603	260	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	259,000,000	1.3	1,079,167	1,402,917	2,183	218	85	327	33	Chemical Suppressants and Water Sprays
								8,093,750				2,930	293	

Emissions for 2015

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	259,000,000	5.8	1,079,167	6,259,167	9,740	974	75	2,435	244	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	259,000,000	2.7	1,079,167	2,913,750	4,534	453	85	680	68	Chemical Suppressants and Water Sprays
								9,172,917				3,115	312	

TABLE B1-19
Haul Roads
KUC—Bingham Canyon Mine

Emissions for 2016

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	260,000,000	6.8	1,083,333	7,366,667	11,463	1,146	75	2,866	287	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	260,000,000	1.9	1,083,333	2,058,333	3,203	320	85	480	48	Chemical Suppressants and Water Sprays
								9,425,000				3,346	335	

Emissions for 2017

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	242,000,000	6.2	1,008,333	6,251,667	9,728	973	75	2,432	243	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	242,000,000	3.0	1,008,333	3,025,000	4,707	471	85	706	71	Chemical Suppressants and Water Sprays
								9,276,667				3,138	314	

Emissions for 2018

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	217,000,000	3.4	904,167	3,074,167	4,784	478	75	1,196	120	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	217,000,000	6.4	904,167	5,786,667	9,005	900	85	1,351	135	Chemical Suppressants and Water Sprays
								8,860,833				2,547	255	

Emissions for 2019

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	204,000,000	4.8	850,000	4,080,000	6,349	635	75	1,587	159	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	204,000,000	5.3	850,000	4,505,000	7,010	701	85	1,052	105	Chemical Suppressants and Water Sprays
								8,585,000				2,639	264	

Emissions for 2020

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	154,000,000	5.8	641,667	3,721,667	5,791	579	75	1,448	145	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	154,000,000	3.5	641,667	2,245,833	3,495	349	85	524	52	Chemical Suppressants and Water Sprays
								5,967,500				1,972	197	

TABLE B1-19
Haul Roads
KUC—Bingham Canyon Mine

Emissions for 2021

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	101,000,000	3.1	420,833	1,304,583	2,030	203	75	508	51	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	101,000,000	7.2	420,833	3,030,000	4,715	472	85	707	71	Chemical Suppressants and Water Sprays
								4,334,583				1,215	121	

Emissions for 2022

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	71,000,000	4.2	295,833	1,242,500	1,933	193	75	483	48	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	71,000,000	7.7	295,833	2,277,917	3,545	354	85	532	53	Chemical Suppressants and Water Sprays
								3,520,417				1,015	102	

Emissions for 2023

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	77,000,000	5.5	320,833	1,764,583	2,746	275	75	686	69	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	77,000,000	10.3	320,833	3,304,583	5,142	514	85	771	77	Chemical Suppressants and Water Sprays
								5,069,167				1,458	146	

Emissions for 2024

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	90,000,000	6.9	375,000	2,587,500	4,026	403	75	1,007	101	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	90,000,000	6.7	375,000	2,512,500	3,910	391	85	586	59	Chemical Suppressants and Water Sprays
								5,100,000				1,593	159	

Emissions for 2025

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	84,000,000	7.5	350,000	2,625,000	4,085	408	75	1,021	102	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	84,000,000	8.1	350,000	2,835,000	4,412	441	85	662	66	Chemical Suppressants and Water Sprays
								5,460,000				1,683	168	

TABLE B1-19
Haul Roads
KUC—Bingham Canyon Mine

Emissions for 2026

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	80,000,000	4.7	333,333	1,566,667	2,438	244	75	609	61	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	80,000,000	10.9	333,333	3,633,333	5,654	565	85	848	85	Chemical Suppressants and Water Sprays
								5,200,000				1,458	146	

Emissions for 2027

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	84,000,000	4.2	350,000	1,470,000	2,288	229	75	572	57	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	84,000,000		350,000	0	0	0	85	0	0	Chemical Suppressants and Water Sprays
								1,470,000				572	57	

Emissions for 2028

Activity & Road Description	Number of days of precipitation	PM Emission Factor (lbs/VMT)	PM_{10} Emission Factor (lbs/VMT)	$PM_{2.5}$ Emission Factor (lbs/VMT)	Annual Material Hauled (tons)	Round Trip Haul Distance (miles)	Number of Round Trips	Vehicle Miles Traveled (VMT)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Haul Roads Inside the Pit	106	12.66	3.11	0.31	85,000,000	4.2	354,167	1,487,500	2,315	231	75	579	58	Water Sprays and Road Base.
Haul Roads Outside the Pit	106	12.66	3.11	0.31	85,000,000		354,167	0	0	0	85	0	0	Chemical Suppressants and Water Sprays
								1,487,500				579	58	

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Fugitive PM_{10} Emissions	1,519	1,836	2,794	2,930	3,115	3,346	3,138	2,547	2,639	1,972	1,215	1,015	1,458	1,593	1,683	1,458	572	579
$PM_{2.5}$ Emissions	152	184	279	293	312	335	314	255	264	197	121	102	146	159	168	146	57	58

Average Vehicle Weight - Full (tons)	413
Average Vehicle Weight - Empty (tons)	173
S = Silt Content (%)	4
Vehicle Capacity (tons)	240
W = Average Vehicle Weight (tons)	293

NOTES:
Days of precipitation data obtained from the East Butte Meterological Station.
Haul Road Distances and Maximum Material Hauled based on data provided by KUC Mine Group.
240-Ton Truck capacity used in the calculation.
Average Vehicle Weight is used in the calculation.

TABLE B1-19
Haul Roads
KUC—Bingham Canyon Mine
AP-42 emission calculations for <u>unpaved</u> roads. Chapter 13.2.2 (11/06)

$$E = k \times \left(\frac{s}{12}\right)^{a} \times \left(\frac{W}{3}\right)^{b} \times \left(\frac{365-p}{365}\right)$$

Equation (1a):

$$E = k \times \left(\frac{s}{12}\right)^{a} \times \left(\frac{W}{3}\right)^{b} \times \left(\frac{365-p}{365}\right)$$

	Unpaved		
	PM	PM_{10}	$PM_{2.5}$
k =	4.9	1.5	0.150
a =	0.7	0.9	0.9
b =	0.45	0.45	0.45

E: emission factor (lb/VMT)   VMT = vehicle miles traveled
k, a, b: dimensionless constants from Table 13.2.2-2
S: silt content (%) of road surface
W: mean vehicle weight (tons); = (wt.loaded + wt.unloaded / 2)
p: number of days with at least 0.01 inches of precipitation per year; not used for calculating hourly emissions (default = 90)

TABLE B1-20
Low-grade Coarse Ore Storage Piles
KUC—Bingham Canyon Mine

Source Name	Size of Storage Pile (acres)	Mean Wind Speed (mph)	PM Emission Factor (lb/acre-hr)	PM_{10} Emission Factor (lb/acre-hr)	$PM_{2.5}$ Emission Factor (lb/acre-hr)	Hours of Operation (hrs/yr)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Primary Control Efficiency (%)	PM_{10} Emissions with Primary Controls (tpy)	$PM_{2.5}$ Emissions with Primary Controls (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
Low-grade Coarse Ore Storage Piles	10	7	5.04	2.38	0.36	8,760	104.4	15.8	90	10.44	1.58	20	21	2.09	0.33	Inherent material characteristics and mechanical compaction to minimize emissions. Water application from passing water trucks is used to further reduce emissions. Source is located in the pit.

NOTES:
Emission factors estimated using methodology in AP-42, Table 11.9-1.
Based on ratio of transfer particle size multipliers in AP 42, Fifth Edition, Table 13.2.4 (EPA, 2006), assume PM_{10} to be 47% of PM and $PM_{2.5}$ to be 15% of PM_{10}.
PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).
Characteristics of the ore material, such as large diameter material, and inherent material moisture content of 4 percent, limit dust being generated during the transfer operations.
Wind speed and moisture content data based on historical data.
The control efficiency listed is based on previous determinations of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling.

TABLE B1-21
Front-end Loaders
KUC—Bingham Canyon Mine

Source Name	Moisture Content (%)	PM_{10} Emission Factor (lbs/ton)	$PM_{2.5}$ Emission Factor (lbs/ton)	Annual Process Rate (tpy)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Primary Control Efficiency (%)	PM_{10} Emissions with Primary Controls (tpy)	$PM_{2.5}$ Emissions with Primary Controls (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
Front-end Loaders (Operation in Pit)	4	0.0256	0.0042	10,350,000	132.6	21.61	70	39.8	6.5	20	21	7.96	1.36	Water application from passing water trucks is used to further reduce emissions. Source located in the pit.
Front-end Loaders (Operation out of Pit)	4	0.0256	0.0042	1,150,000	14.7	2.40	70	4.4	0.7	100	100	4.42	0.72	Water application from passing water trucks is used to further reduce emissions.

NOTES:
Emission factors estimated using methodology outlined in AP-42, Table 11.9-1.
PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).
Moisture content data based on historical data.
Front end loaders operate primarily in vehicular traveled areas. These areas are subject to road watering.
Front end loaders are not utilized for loading primary ore and waste haulage trucks.
70 percent Control Efficiency for water application in the areas where loaders are operated, per UDAQ policy.
Process rates in and out of pit are based on expected mine operations provided by the KUC Mine group.

TABLE B1-22
Truck Loading
KUC—Bingham Canyon Mine

Source Name	PM_{10} Aerodynamic Particle Size Multiplier (k)	$PM_{2.5}$ Aerodynamic Particle Size Multiplier (k)	Moisture Content (%)	Wind Speed (mph)	PM_{10} Emission Factor (lbs/ton)	$PM_{2.5}$ Emission Factor (lbs/ton)	Annual Process Rate (tpy)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Primary Control Efficiency (%)	PM_{10} Emissions with Primary Controls (tpy)	$PM_{2.5}$ Emissions with Primary Controls (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
Truck Loading	0.35	0.053	4	7	0.00066	0.00010	260,000,000	85.4	12.9	90	8.5	1.3	20	21	1.71	0.27	Inherent material characteristics and minimal drop distance. Source is located in the pit.

NOTES:
Emission factors estimated using methodology in AP-42, Section 13.2.4.
Wind speed and moisture content data based on historical data.
PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).
Characteristics of the ore/waste rock material, such as large diameter material, and inherent material moisture content of 4 percent, limit dust being generated during the transfer operations.
The control efficiency listed is based on previous determinations of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling.
Ore and waste rock is loaded into the haultrucks with shovels.

TABLE B1-23
Truck Offloading of Waste Rock
KUC—Bingham Canyon Mine

Source Name	PM_{10} Aerodynamic Particle Size Multiplier (k)	$PM_{2.5}$ Aerodynamic Particle Size Multiplier (k)	Moisture Content (%)	Wind Speed (mph)	PM_{10} Emission Factor (lbs/ton)	$PM_{2.5}$ Emission Factor (lbs/ton)	Annual Process Rate (tpy)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Primary Control Efficiency (%)	Controlled PM_{10} Emissions (tpy)	Controlled $PM_{2.5}$ Emissions (tpy)	Control System and Comments
Truck Offloading of Waste Rock	0.35	0.053	4	7	0.00066	0.00010	175,000,000	57.5	8.7	0	57.5	8.7	Inherent material characteristics and mechanical compaction to minimize emissions. Water application from passing water trucks is used to further reduce emissions.

NOTES:
Emission factors estimated using methodology in AP-42, Section 13.2.4.
Wind speed and moisture content data based on historical data.
Characteristics of the waste rock material, such as large diameter material, and inherent material moisture content of 4 percent, limit dust being generated during the transfer operations.
Mechanical compaction is achieived with dozers operating in the waste rock disposal areas.

TABLE B1-24
Graders
KUC—Bingham Canyon Mine

Source Name	Mean Vehicle Speed (mph)	Number of Graders	Hours of Operation (hrs/yr)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Primary Control Efficiency (%)	PM_{10} Emissions with Primary Controls (tpy)	$PM_{2.5}$ Emissions with Primary Controls (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
Graders (Operation in Pit)	8	18	3,140	443	51	61	173	20	20	21	34.5	4.16	Water application from passing water trucks is used to further reduce emissions. Source is located in the pit.
Graders (Operation out of Pit)	8	18	785	111	13	61	43	5	100	100	43.2	4.95	Water application from passing water trucks is used to further reduce emissions.

NOTES:
Emissions calculated using methodology outlined in AP-42, Table 11.9-1.
61 percent Control Efficiency for water application in the areas where graders are operated (construction type activities), per Table 3-7 - WRAP Fugitive Dust Handbook.
PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).
Graders primarily operate on the haulroads maintaining surfaces of the roads.
Operation hours in and out of pit and vehicle speed are based on expected mine operations provided by the KUC Mine group.

Hours per year:	8,760
Availability (%):	80
Effective Use of Utilization (%):	56
Hours of operation:	3,924

TABLE B1-25
Bulldozers (Track Dozers)
KUC—Bingham Canyon Mine

Source Name	Silt Content (%)	Moisture Content (%)	Number of Track Dozers	Hours of Operation (hrs/yr)	PM_{10} Emission Factor (lbs/hr)	$PM_{2.5}$ Emission Factor (lbs/hr)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Primary Control Efficiency (%)	PM_{10} Emissions with Primary Controls (tpy)	$PM_{2.5}$ Emissions with Primary Controls (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
Track dozers (Operation in Pit)	4	4	26	2,137	0.86	0.52	24	14	61	9.33	5.65	20	21	1.9	1.19	Water application from passing water trucks is used to further reduce emissions. Source is located in the pit.
Track dozers (Operation out of Pit)	4	4	26	916	0.86	0.52	10	6	61	4.00	2.42	100	100	4.0	2.42	Water application from passing water trucks is used to further reduce emissions. Source is located in the pit.

NOTES:
Emission factors estimated using methodology outlined in AP-42, Table 11.9-1.
61 percent Control Efficiency for water application in the areas where dozers are operated (construction type activities), per Table 3-7 - WRAP Fugitive Dust Handbook.
PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).
Wind speed and moisture content data based on historical data.
Dozers operate in the pit, on the haulroads and in waste rock disposal areas performing “cleanup” operations.
Operations in and out of pit are based on expected mine operations provided by the KUC Mine group.
EPA default silt content for Utah was applied.

Hours per year:	8,760
Availability (%):	85
Effective Use of Utilization (%):	41
Hours of Operation:	3,053

TABLE B1-26
Wheeled Dozers
KUC—Bingham Canyon Mine

Source Name	Silt Content (%)	Moisture Content (%)	Number of Wheeled Dozers	Hours of Operation (hrs/yr)	PM_{10} Emission Factor (lbs/hr)	$PM_{2.5}$ Emission Factor (lbs/hr)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Primary Control Efficiency (%)	PM_{10} Emissions with Primary Controls (tpy)	$PM_{2.5}$ Emissions with Primary Controls (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
Rubber Tire Dozers	4	4	11	3,193	0.86	0.52	15.1	9.2	61	5.9	3.6	20	21	1.2	0.75	Water application from passing water trucks is used to further reduce emissions. Source is located in the pit.

NOTES:
Emission factors estimated using methodology outlined in AP-42, Table 11.9-1.
61 percent Control Efficiency for water application in the areas where dozers are operated (construction type activities), per Table 3-7 - WRAP Fugitive Dust Handbook.
PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).
Wind speed and moisture content data based on historical data.
Dozers operate in the pit, on the haulroads and in waste rock disposal areas performing “cleanup” operations.
EPA default silt content for Utah was applied.

Hours per year:	8,760
Availability (%):	81
Effective Use of Utilization (%):	45
Hours of Operation:	3,193

TABLE B1-27
Drilling with Water Injection
KUC—Bingham Canyon Mine

Source Name	PM Emission Factor (lbs/hole)	PM_{10} Emission Factor (lbs/hole)	$PM_{2.5}$ Emission Factor (lbs/hole)	Number of Holes (holes/yr)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Primary Control Efficiency (%)	PM_{10} Emissions with Primary Controls (tpy)	$PM_{2.5}$ Emissions with Primary Controls (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
Drilling with Water Injection	1.3	0.615	0.093	90,000	27.7	4.2	90	2.77	0.42	20	21	0.6	0.09	Water injection at 90% efficiency. Source is located in the pit.

NOTES:
PM Emission factor obtained from AP-42, Table 11.9-4. Ratio of transfer particle size multipliers in AP 42, Fifth Edition, Table 13.2.4 (EPA, 2006), assume PM_{10} to be 47% of PM and $PM_{2.5}$ to be 15% of PM_{10}.
PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).
The control efficiency listed is based on previous determinations of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling.
Number of holes drilled per year proved by the KUC mine group.

TABLE B1-28
Blasting with Minimized Area
KUC—Bingham Canyon Mine

Source Name	Blasting Area (ft^2)	PM_{10} Emission Factor (lbs/blast)	$PM_{2.5}$ Emission Factor (lbs/blast)	Blasts per Year	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Primary Control Efficiency (%)	PM_{10} Emissions with Primary Controls (tpy)	$PM_{2.5}$ Emissions with Primary Controls (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments	NH_3 Emission Factor (lbs/blast)	Uncontrolled NH_3 Emissions (tpy)	Control Efficiency (%)	Controlled NH_3 Emissions (toy)	Control System and Comments
Blasting with Minimized Area	57,500	100.4	5.8	1,100	55.2	3.2	0	55.2	3.2	20	21	11.0	0.67	Source is located in the pit.	4.6	2.5	0	2.5	No controls.

NOTES:
Emission factors for PM_{10} and $PM_{2.5}$ obtained from AP-42, Table 11.9-1.
Emission factor for Ammonia based on a historical Industrial Hygiene assessment completed onsite.
PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).
Blasting Area and Blasts per Year are provided by the KUC mine group.

TABLE B1-29
Tertiary Crushing
KUC—Bingham Canyon Mine

Source Name	Transient Process Rate (tpy)	Uncontrolled PM_{10} Emissions (tpy)	PM_{10} Emissions (tpy)	$PM_{2.5}$ Emissions (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
Tertiary Crushing	3,150,000	3.78	0.85	0.16	20	21	0.17	0.03	Source is located in the pit.

Emission Factors:

Emission Factor (lbs/ton)	0.0024	For tertiary crushing - uncontrolled (lbs of PM_{10} per ton of material handled)
Emission Factor (lbs/ton)	0.00054	For tertiary crushing - controlled (lbs of PM_{10} per ton of material handled)
Emission Factor (lbs/ton)	0.00010	For tertiary crushing - controlled (lbs of $PM_{2.5}$ per ton of material handled)

NOTES:
Emission factors for PM_{10} and $PM_{2.5}$ obtained from AP-42, Table 11.19-2-2.
Transient Process Rate information obtained from the 2005 NOI submitted to UDAQ.
PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).

TABLE B1-30
Screening
KUC—Bingham Canyon Mine

Source Name	Transient Process Rate (tpy)	Uncontrolled PM_{10} Emissions (tpy)	PM_{10} Emissions (tpy)	$PM_{2.5}$ Emissions (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
Screening	3,150,000	13.70	1.17	0.08	20	21	0.23	0.02	Source is located in the pit.

Emission Factors:

Emission Factor (lbs/ton)	0.0087	For screening - uncontrolled (lbs of PM_{10} per ton of material handled)
Emission Factor (lbs/ton)	0.00074	For screening - controlled (lbs of PM_{10} per ton of material handled)
Emission Factor (lbs/ton)	0.00005	For screening - controlled (lbs of $PM_{2.5}$ per ton of material handled)

NOTES:
Emission factors for PM_{10} and $PM_{2.5}$ obtained from AP-42, Table 11.19-2-2.
Transient Process Rate information obtained from the 2005 NOI submitted to UDAQ.
PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).

TABLE B1-31
Transfer Points
KUC—Bingham Canyon Mine

Source Name	Transient Process Rate (tpy)	Number of Transfer Points	PM_{10} Emissions (tpy)	$PM_{2.5}$ Emissions (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
Transfer Points	3,150,000	10	0.72	0.20	20	21	0.14	0.04	Source is located in the pit.

Emission Factors:

Emission Factor (lbs/ton)	0.000046	For controlled transfer points (lbs of PM_{10} per ton of material handled)
Emission Factor (lbs/ton)	0.000013	For controlled transfer points (lbs of $PM_{2.5}$ per ton of material handled)

NOTES:
Emission factors for PM_{10} and $PM_{2.5}$ obtained from AP-42, Table 11.19-2-2 for controlled transfer points.
Transient Process Rate information obtained from the 2005 NOI submitted to UDAQ.
PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).

TABLE B1-32
SX/EW Copper Extraction
KUC—Bingham Canyon Mine

Source Name	VOC Emissions (tpy)
SX/EW Copper Extraction	5.37

Summary of Allowable VOC Emissions (tpy)

	Mixer/Settlers	Aqueous Flows	Tanks	Total
Proposed	2.92	2.38	0.07	5.37

Organic Solution Used

	Diluent				Extractant		
	Constituent	**Concentration**	**Spec. Gravity**	**Boiling Range**	**Constituent**	**Concentration**	**Spec. Gravity**
Proposed	SX-12 Diluent	96%	0.81 - 0.83	187–274°C	LIX 984N	4%	0.915

Specific gravity for of the diluent was obtained from the MSDS of the diluent.

Mixers/Settlers

	surface area (ft^2)	pan rate (ft/24-hr day)		density (lb/gal)	time (hrs)	Control (%)		VOC (tpy)
Proposed Plant								
Extraction	550	0.00142	(a)	6.84	8,760	80%	(b)	1.46
Strip	550	0.00142	(a)	6.84	8,760	80%		1.46
Total	**1100**							**2.92**

VOC (tpy) = ((surface area(ft^2))*(evap rate(ft/day))*(7.48 gal/ft^3)*(density(lb/gal))*(operating hrs/yr))(1 - control eff)/((24 hrs)*(2000 lb/ton))

(a) From Emission Inventory
(b) Control eff of 80% for proposed plant, to be achieved by covers in place except during inspection, sampling, and adjustment.
(c) Existing Pilot Plant mixer/settlers were not covered.

Volatilization from Aqueous Flows

	avg flow (gpm)	TPH Conc (mg/L)		operating (hrs)	throughput gal/yr		Est Evap		VOC (tpy)	
Proposed Plant (a)										
Raffinate	650.00	5.00	(b)	8,760	341,640,000	<	33%	(c)	2.38	
Electrolyte Circuit									0.00	(d)
Total									**2.38**	

TABLE B1-32
SX/EW Copper Extraction
KUC—Bingham Canyon Mine

VOC (tpy) = (flow (gpm))*(TPH Conc (mg/L))*(3.79 L/gal)*(60 min/hr)*(operating hrs/yr))/((453597 mg/lb)*(2000 lb/ton))

(a) The proposed plant will take Cu-bearing meteoric drainage from waste rock once through. Tailwater (raffinate) from the extraction settler in SX will go to the Large Bingham Reservoir, then to Copperton Concentrator as makeup water, and then to the tailings impoundment.
(b) Because the solutions are mixed in agitation tanks for 3 minutes, organic concentration averaged 5 ppm in raffinate leaving the extractor settler in the pilot plant, although the solubility is less ("negligible" according to the MSDS).
5 ppm is the detection limit using centrifugal methods that are standard in the industry.
(c) It is estimated that less than a third of the residual organic in the raffinate from the proposed plant will evaporate, some will biodegrade, & some will stay in the tailings impoundment. Note the high boiling range of the diluent.
(d) No emission from the electrolyte circuit because it is contained in tanks and pipes.
(e) The existing pilot plant took PLS from heap leaching, and recirculated the raffinate back to the heaps for further leaching.
(f) A small percentage of the residual organic in the raffinate from the Pilot Plant evaporated when it was sprayed on the heaps, some biodegraded, but the large majority returned to the process in PLS. Note the high boiling range of the diluent.
(g) Emission from volatilization in aqueous flows was apparently not included when the Pilot Plant was permitted, so current allowable for this source is 0.

Organic Surge Tanks and Organic Holding Tanks

	No. Tanks	Tank Volume (gal)	Total Volume (gal)	VOC Emission (tpy)	
Pilot (calc)	2	3300	6,600	0.04	from Emission Inventory
Proposed	4	3000	12,000	0.07	Estimated by volume ratio

TABLE B1-33
Electrowinning
KUC—Bingham Canyon Mine
(From 2008 Mine AO Modification NOI)

	Exhaust Gas H_2SO_4 Concentration (grains/dscf)	**Volume Flow Rate (acfm)**	**(dscfm)**		**Control**	**Operating Hours**	**H_2SO_4 Emission (tpy)**	**(lb/hr)**
Proposed	0.004	8,000	6,377		Surfactant, covers, and	8,760	0.96	0.22
			52.1	T(act)	Mist Eliminator			
			10%	ø				
			12.58	P(act)				
			14.7	P(std)				
			70	T(std)				

Existing Pilot Plant — Acid Mist emissions were not included in the AO at the time of permitting. — 0

Net change in permitted emissions — 0.96

There were two Pilot Plant electrowinning cells, each the same size as one of the four in the proposed plant, but their acid mist emissions were controlled only by use of chemical mist suppression (surfactant). Therefore, acid mist emissions are estimated to have been greater than those of the proposed plant.

Net change in actual emissions: Unquantified, but < 0

H_2SO_4 Emission (tpy)
= (H_2SO_4 concentration(grains/dscf) x (volume flow(dscfm)) x 60 min/hr x annual operating time (hours)/(7000 grains/lb x 2000 lb/ton)

Notes:

TABLE B1-34

LPG Generators

KUC—Bingham Canyon Mine

Location	Model	Max Power Rating (bhp)	(kW)	(mmBtu/hr)	Usage (hr/yr)		Emission (tpy)
Production Control Building	Kohler 60RZG	105	78	0.27	500		
						$PM_{10} = PM_{2.5}$	0.0006
						SO_2	0.00004
						NO_x	0.347
						CO	1.557
						Total HC	0.058
Communication 6190	Kohler 45RZG	75	56	0.19	500		
						$PM_{10} = PM_{2.5}$	0.0005
						SO_2	0.00003
						NO_x	0.285
						CO	1.115
						Total HC	0.042
Lark Gate	Olympian G100	160	119	0.41	500	$PM_{10} = PM_{2.5}$	0.0010
						SO_2	0.00003
						NO_x	0.214
						CO	6.476
						Total HC	0.058
Galena Gulch	Kohler 35RZG	72	54	0.18	500		
						$PM_{10} = PM_{2.5}$	0.0004
						SO_2	0.00003
						NO_x	0.266
						CO	1.246
						Total HC	0.040
Total						$PM_{10} = PM_{2.5}$	0.0025
						SO_2	0.0001
						NO_x	1.1117
						CO	10.3935
						Total HC	0.1966

NOTES:

Emissions data obtained from previously submitted NOIs (2005-12-21 and 2008-05-12).

TABLE B1-35
Metal HAP Emissions (from dust)
KUC—Bingham Canyon Mine

PM_{10} Emissions (tpy) 230 [Includes PM_{10} emissions from point and fugitive sources - excludes lime bins]

Metal HAP	Concentration (mg/kg)	HAP Emissions (tpy)
Sb	3	0.001
As	37	0.009
Be	1	0.000
Cd	1	0.000
Cr	15	0.003
Co	8	0.002
Pb	76	0.018
Mn	190	0.044
Ni	21	0.005
Se	15	0.003

Notes:
Metal HAP concentration based on ore and waste rock sampling at BCM

TABLE B1-36

2011–2029 Haul Truck Emissions—260 Mtpy

KUC—Bingham Canyon Mine

Emissions Summary (tpy)	Maximum Annual
HC	259
CO	1400
NO_x	5134
SO_2	5.78
PM_{10}	191
$PM_{2.5}$	186

$PM_{2.5}$ calculated as 97% of PM_{10} emissions, per NONROAD guidance

Estimated Number of Trucks in Operation

Tier Information	Engine		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
CAT 793C Fleet (2337 hp)	Tier 0		8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAT 793D Fleet (2415 hp)	Tier 1		29	29	29	29	29	23	29	23	12	0	0	0	0	0	0	0	0	0
	Tier 2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tier 4t		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tier 4f		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAT 795F Fleet (3440 hp)	Tier 1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tier 2		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tier 4t		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tier 4f		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KOM Fleet (3500 hp)	Tier 1		25	30	30	26	29	27	22	27	20	0	0	0	0	0	0	0	0	0
	Tier 2		11	41	47	47	47	47	47	47	47	44	12	9	19	30	28	4	7	5
	Tier 4t		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tier 4f		0	0	0	0	29	29	29	29	29	29	29	16	14	15	15	29	27	29
Total Truck s			67	100	106	102	134	126	127	126	108	73	41	25	33	45	43	33	34	34

It is assumed that all trucks will be repowered in kind every 3 years (~20,000 hours of operation).

Estimated Number of Operational Hours (in thousands)

Tier Information	Engine		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
CAT 793C Fleet (2337 hp)	Tier 0		46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAT 793D Fleet (2415 hp)	Tier 1		203	203	203	203	203	161	203	161	84	0	0	0	0	0	0	0	0	0
	Tier 2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tier 4t		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tier 4f		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAT 795F Fleet (3440 hp)	Tier 1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tier 2		12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tier 4t		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tier 4f		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KOM Fleet (3500 hp)	Tier 1		179	215	215	186	207	193	157	193	143	0	0	0	0	0	0	0	0	0
	Tier 2		81	301	336	336	336	336	336	336	336	315	86	64	136	215	200	29	50	36
	Tier 4t		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tier 4f		0	0	0	0	213	213	207	207	207	207	207	114	100	107	107	207	193	207
Total Hours			475	719	754	725	960	903	904	897	770	522	293	179	236	322	307	236	243	243

Emission Factors by Tier (g/hp-hr)	Tier 0	Tier 1	Tier 2	Tier 4t	Tier 4f
HC	0.75	0.31	0.18	0.29	0.13
CO	4.90	1.29	1.29	0.88	0.88
NOx	8.15	5.99	3.93	2.41	2.41
SO2	0.0049	0.0049	0.0049	0.0049	0.0049
PM10	0.64	0.26	0.15	0.02	0.02

All Age Factors assumed to be equal to 1.

Hydrocarbon emission factors for tier 4f represent the EPA proposed emission limits, and were not calculated using NONROAD guidance.

All emission factors represent the lesser of EPA emission limits and factors calculated using EPA NONROAD methodology.

TABLE B1-36
2011–2029 Haul Truck Emissions—260 Mtpy
KUC—Bingham Canyon Mine

Emissions by Truck Type (tpy)			2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
CAT 793C Fleet (2337 hp)	HC		30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	CO		197	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	NO_x		328	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SO_2		0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	PM_{10}		26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CAT 793D Fleet (2415 hp)	HC		57	57	57	57	57	45	57	45	24	-	-	-	-	-	-	-	-	-
	CO		237	237	237	237	237	188	237	188	98	-	-	-	-	-	-	-	-	-
	NO_x		1100	1100	1100	1100	1100	872	1100	872	455	-	-	-	-	-	-	-	-	-
	SO_2		0.9	0.9	0.9	0.9	0.9	0.7	0.9	0.7	0.4	-	-	-	-	-	-	-	-	-
	PM_{10}		48	48	48	48	48	38	48	38	20	-	-	-	-	-	-	-	-	-
CAT 795F Fleet (3440 hp)	HC		3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	CO		20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	NO_x		61	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SO_2		0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	PM_{10}		2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KOM Fleet (3500 hp)	HC		92.2	159.2	167.4	155.8	202.3	196.4	180.8	195.4	175.0	111.5	57.1	35.5	50.0	70.0	66.6	43.5	46.1	45.2
	CO		438	871	930	881	1164	1139	1072	1133	1048	770	384	241	345	486	462	288	307	300
	NO_x		1820	3238	3416	3192	4034	3922	3623	3904	3511	2278	1098	694	1017	1445	1371	803	869	840
	SO_2		1.68	3.33	3.56	3.37	4.87	4.78	4.51	4.74	4.42	3.36	1.88	1.15	1.52	2.07	1.98	1.51	1.56	1.56
	PM_{10}		77.9	134.1	141.0	131.1	142.8	137.9	125.4	137.8	120.5	66.8	21.3	15.1	29.1	44.8	42.0	9.9	13.9	11.4
Total	HC		182	216	225	213	259	242	238	241	199	111	57	36	50	70	67	44	46	45
	CO		892	1108	1166	1118	1400	1327	1309	1320	1146	770	384	241	345	486	462	288	307	300
	NO_x		3309	4337	4516	4292	5134	4794	4723	4776	3966	2278	1098	694	1017	1445	1371	803	869	840
	SO_2		2.9	4.2	4.5	4.3	5.8	5.5	5.4	5.5	4.8	3.4	1.9	1.1	1.5	2.1	2.0	1.5	1.6	1.6
	PM_{10}		154	182	189	179	191	176	174	176	141	67	21	15	29	45	42	10	14	11

Calculation Data

	NONROAD Equipment SCC
Haul Truck	2270002051

All tables and factors are from "Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling--Compression-Ignition", EPA, 2004, unless otherwise noted.

Table A2 Zero-Hour, Steady-State Emission Factors for Nonroad CI Engines (>750 hp)

	BSFC	HC	CO	NO_x	PM_{10}
T0	0.367	0.68	2.7	8.38	0.402
T1	0.367	0.2861	0.7642	6.1525	0.1934
T2	0.367	0.1669	0.7642	4.1	0.1316
T4t	0.367	0.2815	0.7642	2.392	0.069
T4f	0.0367	0.1314	0.7642	2.392	0.069

Table A3 Transient Adjustment Factors by Equipment Type for Nonroad CI Equipment

SCC	Cycle	TAF Assign.	HC	CO	NO_x	PM_{10}	BSFC
2270002051	Crawler	Hi LF	1.05	1.53	0.95	1.23	1.01

TAFs are not applied to the emission factors for Tier 4 engines

Table A4 Deterioration Factors for Nonroad Diesel Engines (A)

Pollutant	T0	T1	T2	T3+
HC	0.047	0.036	0.034	0.027
CO	0.185	0.101	0.101	0.151
NO_x	0.024	0.024	0.009	0.008
PM_{10}	0.473	0.473	0.473	0.473

Sulfur Content of Diesel Fuel

sulfur conversion	7.0	grams PM sulfate/gram Sulfur		
soxcnv	0.02247	grams PM sulfur/gram fuel consumed		
default (soxbas)	3300	ppm	0.33	wt %
Diesel Sulfur Conc. (soxdsl)	15	ppm	0.0015	wt %

TABLE B1-36
2011–2029 Haul Truck Emissions—260 Mtpy
KUC—Bingham Canyon Mine

Engine Life at Full Load

7000 hrs

Engine life from Table 1 of "Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling", EPA, 2004.

Load Factor

0.34

Load factor estimated by KUC using BCM haul truck data.

TABLE B1-37
2011–2029 Mobile Support Equipment Emissions—260 Mtpy
KUC—Bingham Canyon Mine

Emissions Summary (tpy)	Maximum Annual
HC	43
CO	272
NO_x	695
SO_2	0.78
PM_{10}	36
$PM_{2.5}$	35

Hydrocarbon Emissions (tpy)				2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
TRACK DOZERS - CAT D10																					
NOT TIER RATED (Existing)	580	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 1 (Existing)	613	1		0.75	0.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	661	2		0.92	0.92	0.92	0.92	0.92	0.92	0.61	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing, New and Replacements)	646	3		3.93	4.84	5.75	5.75	5.75	5.75	5.75	5.75	5.45	4.54	3.03	2.42	1.51	1.21	0.30	0.30	0.30	0.30
TIER 4F (New and Replacements)	646	4F		-	-	-	-	-	-	-	-	-	-	-	-	0.67	1.11	1.78	1.78	1.78	1.78
TRACK DOZERS - CAT D11																					
NOT TIER RATED (Existing)	850	0		4.27	2.84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 1 (Existing)	936	1		0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	936	4T		0.61	1.21	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	2.42	1.82	1.21	1.21	-	-
TIER 4F (New and Replacements)	936	4F		-	-	-	-	-	-	-	-	-	-	-	-	-	0.28	0.57	0.57	0.57	0.57
GRADERS - CAT 16																					
TIER 1 (Existing)	289	1		0.62	0.31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	299	2		0.96	0.96	0.96	0.64	0.64	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing)	297	3		0.94	0.94	0.94	0.94	0.94	0.94	0.19	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	297	4T		0.13	0.38	0.51	0.64	0.64	0.64	0.64	0.64	0.64	0.51	0.26	-	-	-	-	-	-	-
TIER 4F (New and Replacements)	297	4F		-	-	-	-	0.13	0.38	0.90	1.02	1.02	1.02	1.28	1.41	1.41	1.41	1.41	1.41	1.41	1.41
GRADERS - CAT 24																					
NOT TIER RATED (Existing)	540	0		2.32	2.32	2.32	2.32	2.32	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	533	2		0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	533	4F		-	-	-	-	-	0.41	0.41	0.41	0.41	0.41	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
RTDS - CAT 834																					
834B - NOT TIER RATED (Existing)	487	0		2.09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
834G - NOT TIER RATED (Existing)	487	0		1.05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing)	525	3		0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.54	0.54	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	525	4T		0.20	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.41	-	-	-	-	-	-	-
TIER 4F (Replacements)	525	4F		-	-	-	-	-	-	-	0.20	0.20	0.20	0.41	0.82	0.82	0.82	0.82	0.82	0.82	0.82
RTDS - CAT 854																					
TIER 1 (Existing)	880	1		0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	-	-	-	-	-	-	-	-	-	-
FEL - KOMATSU																					
WA500 - TIER 1 (Existing)	235	1		0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	-	-	-	-	-	-	-	-	-
WA600 - TIER 3 (Existing)	396	3		0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.14	-	-	-	-	-	-	-
WA600 - TIER 4F (Replacements)	396	4F		-	-	-	-	-	-	-	-	-	-	0.10	0.21	0.21	0.21	0.21	0.21	0.21	0.21
WA700 - TIER 1 (Existing)	502	1		0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	-	-	-	-	-	-	-
FEL - CAT 992																					
TIER 2 (Existing)	800	2		0.57	0.57	0.57	0.57	0.57	0.57	0.28	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	801	4T		-	-	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
TIER 4F (Replacements)	801	4F		-	-	-	-	-	-	0.21	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
PRODUCTION FEL - KOM WA1200																					
TIER 1 (Existing)	1,782	1		1.47	1.47	1.47	1.47	1.47	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	1,782	4F		-	-	-	-	-	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
TRACKHOES - CAT 330																					
TIER 2 (Existing)	264	2		0.12	0.12	0.12	0.12	0.12	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	268	4F		-	-	-	-	-	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
TRACKHOES - CAT 385																					
TIER 3 (Existing)	523	3		0.26	0.26	0.26	0.13	0.13	0.13	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (Replacements)	523	4T		-	-	-	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	-	-	-	-	-	-
TIER 4F (Replacements)	523	4F		-	-	-	-	-	-	0.10	0.10	0.10	0.10	0.10	0.10	0.20	0.20	0.20	0.20	0.20	0.20
TRACKHOES - KOMATSU																					
PC800 - TIER 1 (Existing)	323	1		0.20	0.20	0.20	0.20	0.10	0.10	0.10	0.10	0.10	-	-	-	-	-	-	-	-	-
PC800 - TIER 4F (Replacements)	323	4F		-	-	-	-	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	-	-
PC400 - TIER 1 (Existing)	246	1		0.12	0.12	0.12	0.12	0.12	0.12	-	-	-	-	-	-	-	-	-	-	-	-

TABLE B1-37
2011–2029 Mobile Support Equipment Emissions—260 Mtpy
KUC—Bingham Canyon Mine

WATER TRUCKS																					
CAT 789 (Existing)	1,900	0		2.27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CAT 793C - TIER 1 (Existing)	2,300	1		2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29
CAT 793D - TIER 2 (New and Replaceme	2,415	2		1.40	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
HYDRAULIC SHOVELS																					
O&K RH 200, (NOT CERT)	2,100	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O&K RH 200, (TIER 1)	2,520	1		7.32	7.25	7.17	7.14	7.10	7.06	7.03	6.99	6.95	3.66	3.66	3.59	3.59	3.55	3.55	3.51	3.51	3.48
CONSTRUCTION TRUCKS																					
KOM 785-7 TIER 1 (Existing)	1,200	1		3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01	3.01
DIESEL DRILLS - P&H																					
TIER 1 (Existing)	1,100	1		0.86	0.86	0.43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (during T4I) (Replacements)	1,100	2		-	-	0.26	0.52	0.52	0.52	0.51	0.51	0.51	0.51	0.50	0.25	0.25	0.25	0.17	0.16	0.16	0.16
DIESEL DRILLS - ATLAS COPCO																					
TIER 2 (Existing)	750	2		0.90	0.90	0.90	0.89	0.89	0.89	0.66	0.44	0.33	-	-	-	-	-	-	-	-	-
TIER 2 (during T4I) (New)	750	2		0.23	0.46	0.46	0.45	0.45	0.45	0.45	0.45	0.37	0.26	0.12	-	-	-	-	-	-	-
TIER 4F (Replacements)	750	4F		-	-	-	-	-	-	-	0.20	0.34	0.34	0.34	0.25	0.22	0.28	0.29	0.28	0.28	0.28
TOTAL				**43.0**	**39.3**	**38.3**	**38.0**	**38.0**	**34.8**	**33.8**	**32.9**	**31.7**	**25.5**	**23.5**	**22.0**	**21.6**	**21.5**	**20.8**	**20.8**	**19.5**	**19.5**
Carbon Monoxide Emissions (tpy)				**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**

TRACK DOZERS - CAT D10	**HP**	**Tier**																			
NOT TIER RATED (Existing)	580	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 1 (Existing)	613	1		10.51	3.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	661	2		11.34	11.34	11.34	11.34	11.34	11.34	7.56	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing, New and Replacements)	646	3		50.20	61.78	73.36	73.36	73.36	73.36	73.36	73.36	69.50	57.92	38.61	30.89	19.31	15.44	3.86	3.86	3.86	3.86
TIER 4F (New and Replacements)	646	4F		-	-	-	-	-	-	-	-	-	-	-	-	0.76	1.26	2.02	2.02	2.02	2.02
TRACK DOZERS - CAT D11																					
NOT TIER RATED (Existing)	850	0		27.93	18.62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 1 (Existing)	936	1		2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	2.70	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	936	4T		0.18	0.37	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.55	0.37	0.37	-	-
TIER 4F (New and Replacements)	936	4F		-	-	-	-	-	-	-	-	-	-	-	-	-	0.18	0.37	0.37	0.37	0.37
GRADERS - CAT 16																					
TIER 1 (Existing)	289	1		2.33	1.16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	299	2		3.61	3.61	3.61	2.41	2.41	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing)	297	3		6.25	6.25	6.25	6.25	6.25	6.25	1.25	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	297	4T		0.08	0.25	0.33	0.41	0.41	0.41	0.41	0.41	0.41	0.33	0.16	-	-	-	-	-	-	-
TIER 4F (New and Replacements)	297	4F		-	-	-	-	0.08	0.25	0.57	0.66	0.66	0.66	0.82	0.90	0.90	0.90	0.90	0.90	0.90	0.90
GRADERS - CAT 24																					
NOT TIER RATED (Existing)	540	0		15.21	15.21	15.21	15.21	15.21	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	533	2		2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	533	4F		-	-	-	-	-	0.30	0.30	0.30	0.30	0.30	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
RTDS - CAT 834																					
834B - NOT TIER RATED (Existing)	487	0		13.72	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
834G - NOT TIER RATED (Existing)	487	0		6.86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing)	525	3		6.72	6.72	6.72	6.72	6.72	6.72	6.72	4.48	4.48	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	525	4T		0.15	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.29	-	-	-	-	-	-	-
TIER 4F (Replacements)	525	4F		-	-	-	-	-	-	-	0.15	0.15	0.15	0.29	0.58	0.58	0.58	0.58	0.58	0.58	0.58
RTDS - CAT 854																					
TIER 1 (Existing)	880	1		3.26	3.26	3.26	3.26	3.26	3.26	3.26	3.26	-	-	-	-	-	-	-	-	-	-
FEL - KOMATSU																					
WA500 - TIER 1 (Existing)	235	1		0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	-	-	-	-	-	-	-	-	-
WA600 - TIER 3 (Existing)	396	3		2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	1.15	-	-	-	-	-	-	-
WA600 - TIER 4F (Replacements)	502	4F		-	-	-	-	-	-	-	-	-	-	0.10	0.19	0.19	0.19	0.19	0.19	0.19	0.19
WA700 - TIER 1 (Existing)	396	1		1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	-	-	-	-	-	-	-
FEL - CAT 992																					
TIER 2 (Existing)	800	2		4.03	4.03	4.03	4.03	4.03	4.03	2.02	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	801	4T		-	-	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
TIER 4F (Replacements)	801	4F		-	-	-	-	-	-	0.14	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
PRODUCTION FEL - KOM WA1200																					
TIER 1 (Existing)	1,782	1		6.07	6.07	6.07	6.07	6.07	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	1,782	4F		-	-	-	-	-	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
TRACKHOES - CAT 330																					
TIER 2 (Existing)	264	2		0.47	0.47	0.47	0.47	0.47	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	268	4F		-	-	-	-	-	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

TABLE B1-37
2011–2029 Mobile Support Equipment Emissions—260 Mtpy
KUC—Bingham Canyon Mine

TRACKHOES - CAT 385																					
TIER 3 (Existing)	523	3		2.18	2.18	2.18	1.09	1.09	1.09	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (Replacements)	523	4T		-	-	-	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	-	-	-	-	-	-
TIER 4F (Replacements)	523	4F		-	-	-	-	-	-	0.07	0.07	0.07	0.07	0.07	0.07	0.14	0.14	0.14	0.14	0.14	0.14
TRACKHOES - KOMATSU																					
PC800 - TIER 1 (Existing)	323	1		2.00	2.00	2.00	2.00	1.00	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-
PC800 - TIER 4F (Replacements)	323	4F		-	-	-	-	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	-	-
PC400 - TIER 1 (Existing)	246	1		0.44	0.44	0.44	0.44	0.44	0.44	-	-	-	-	-	-	-	-	-	-	-	-
WATER TRUCKS																					
CAT 789 (Existing)	1,900	0		14.87	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CAT 793C - TIER 1 (Existing)	2,300	1		9.46	9.46	9.46	9.46	9.46	9.46	9.46	9.46	9.46	9.46	9.46	9.46	9.46	9.46	9.46	9.46	9.46	9.46
CAT 793D - TIER 2 (New and Replaceme	2,415	2		9.94	19.88	19.88	19.88	19.88	19.88	19.88	19.88	19.88	19.88	19.88	19.88	19.88	19.88	19.88	19.88	19.88	19.88
HYDRAULIC SHOVELS																					
O&K RH 200, (NOT CERT)	2,100	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O&K RH 200, (TIER 1)	2,520	1		30.28	29.98	29.67	29.52	29.37	29.22	29.07	28.92	28.77	15.14	15.14	14.84	14.84	14.69	14.69	14.53	14.53	14.38
CONSTRUCTION TRUCKS																					
KOM 785-7 TIER 1 (Existing)	1,200	1		12.44	12.44	12.44	12.44	12.44	12.44	12.44	12.44	12.44	12.44	12.44	12.44	12.44	12.44	12.44	12.44	12.44	12.44
DIESEL DRILLS - P&H																					
TIER 1 (Existing)	1,100	1		3.56	3.56	1.78	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (during T4I) (Replacements)	1,100	2		-	-	1.85	3.69	3.69	3.69	3.62	3.62	3.62	3.62	3.56	1.78	1.78	1.78	1.19	1.16	1.16	1.16
DIESEL DRILLS - ATLAS COPCO																					
TIER 2 (Existing)	750	2		6.42	6.42	6.42	6.36	6.30	6.30	4.72	3.15	2.31	-	-	-	-	-	-	-	-	-
TIER 2 (during T4I) (New)	750	2		1.64	3.27	3.27	3.21	3.21	3.21	3.21	3.21	2.62	1.84	0.82	-	-	-	-	-	-	-
TIER 4F (Replacements)	750	4F		-	-	-	-	-	-	-	0.13	0.22	0.22	0.22	0.16	0.15	0.18	0.19	0.18	0.18	0.18
TOTAL				**272**	**242**	**231**	**229**	**228**	**204**	**191**	**176**	**168**	**131**	**107**	**93.4**	**82.5**	**79.0**	**67.6**	**67.4**	**67.0**	**66.9**

Oxides of Nitrogen Emissions (tpy)				**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
TRACK DOZERS - CAT D10	**HP**	**Tier**																			
NOT TIER RATED (Existing)	580	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 1 (Existing)	613	1		26.6	8.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	661	2		19.9	19.9	19.9	19.9	19.9	19.9	13.3	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing, New and Replacements)	646	3		51.4	63.3	75.1	75.1	75.1	75.1	75.1	75.1	71.2	59.3	39.5	31.6	19.8	15.8	4.0	4.0	4.0	4.0
TIER 4F (New and Replacements)	646	4F		-	-	-	-	-	-	-	-	-	-	-	-	1.4	2.3	3.7	3.7	3.7	3.7
TRACK DOZERS - CAT D11																					
NOT TIER RATED (Existing)	850	0		46.5	31.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 1 (Existing)	936	1		12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	936	4T		5.0	10.1	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	15.1	10.1	10.1	-	-
TIER 4F (New and Replacements)	936	4F		-	-	-	-	-	-	-	-	-	-	-	-	-	5.0	10.1	10.1	10.1	10.1
GRADERS - CAT 16																					
TIER 1 (Existing)	289	1		10.0	5.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	299	2		11.0	11.0	11.0	7.3	7.3	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing)	297	3		11.4	11.4	11.4	11.4	11.4	11.4	2.3	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	297	4T		2.4	7.2	9.6	12.0	12.0	12.0	12.0	12.0	12.0	9.6	4.8	-	-	-	-	-	-	-
TIER 4F (New and Replacements)	297	4F		-	-	-	-	0.3	0.8	1.8	2.1	2.1	2.1	2.6	2.9	2.9	2.9	2.9	2.9	2.9	2.9
GRADERS - CAT 24																					
NOT TIER RATED (Existing)	540	0		25.3	25.3	25.3	25.3	25.3	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	533	2		6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	533	4F		-	-	-	-	-	0.9	0.9	0.9	0.9	0.9	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
RTDS - CAT 834																					
834B - NOT TIER RATED (Existing)	487	0		22.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
834G - NOT TIER RATED (Existing)	487	0		11.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing)	525	3		10.8	10.8	10.8	10.8	10.8	10.8	10.8	7.2	7.2	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	525	4T		3.8	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	7.6	-	-	-	-	-	-	-
TIER 4F (Replacements)	525	4F		-	-	-	-	-	-	-	0.4	0.4	0.4	0.8	1.7	1.7	1.7	1.7	1.7	1.7	1.7
RTDS - CAT 854																					
TIER 1 (Existing)	880	1		15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	-	-	-	-	-	-	-	-	-	-
FEL - KOMATSU																					
WA500 - TIER 1 (Existing)	235	1		2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	-	-	-	-	-	-	-	-	-
WA600 - TIER 3 (Existing)	396	3		3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	1.9	-	-	-	-	-	-	-
WA600 - TIER 4F (Replacements)	502	4F		-	-	-	-	-	-	-	-	-	-	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5
WA700 - TIER 1 (Existing)	396	1		4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	-	-	-	-	-	-	-
FEL - CAT 992																					
TIER 2 (Existing)	800	2		12.3	12.3	12.3	12.3	12.3	12.3	6.2	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	801	4T		-	-	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
TIER 4F (Replacements)	801	4F		-	-	-	-	-	-	3.8	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6

TABLE B1-37
2011–2029 Mobile Support Equipment Emissions—260 Mtpy
KUC—Bingham Canyon Mine

PRODUCTION FEL - KOM WA1200																					
TIER 1 (Existing)	1,782	1		28.2	28.2	28.2	28.2	28.2	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	1,782	4F		-	-	-	-	-	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4	11.4
TRACKHOES - CAT 330																					
TIER 2 (Existing)	264	2		1.4	1.4	1.4	1.4	1.4	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	268	4F		-	-	-	-	-	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
TRACKHOES - CAT 385																					
TIER 3 (Existing)	523	3		3.5	3.5	3.5	1.8	1.8	1.8	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (Replacements)	523	4T		-	-	-	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	-	-	-	-	-	-
TIER 4F (Replacements)	523	4F		-	-	-	-	-	-	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.4	0.4	0.4	0.4	0.4
TRACKHOES - KOMATSU																					
PC800 - TIER 1 (Existing)	323	1		5.3	5.3	5.3	5.3	2.7	2.7	2.7	2.7	2.7	-	-	-	-	-	-	-	-	-
PC800 - TIER 4F (Replacements)	323	4F		-	-	-	-	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	-	-
PC400 - TIER 1 (Existing)	246	1		1.9	1.9	1.9	1.9	1.9	1.9	-	-	-	-	-	-	-	-	-	-	-	-
WATER TRUCKS																					
CAT 789 (Existing)	1,900	0		24.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CAT 793C - TIER 1 (Existing)	2,300	1		44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0
CAT 793D - TIER 2 (New and Replaceme	2,415	2		30.3	60.7	60.7	60.7	60.7	60.7	60.7	60.7	60.7	60.7	60.7	60.7	60.7	60.7	60.7	60.7	60.7	60.7
HYDRAULIC SHOVELS																					
O&K RH 200, (NOT CERT)	2,100	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O&K RH 200, (TIER 1)	2,520	1		140.8	139.4	138.0	137.3	136.6	135.9	135.2	134.4	133.7	70.4	70.4	69.0	69.0	68.3	68.3	67.6	67.6	66.9
CONSTRUCTION TRUCKS																					
KOM 785-7 TIER 1 (Existing)	1,200	1		57.9	57.9	57.9	57.9	57.9	57.9	57.9	57.9	57.9	57.9	57.9	57.9	57.9	57.9	57.9	57.9	57.9	57.9
DIESEL DRILLS - P&H																					
TIER 1 (Existing)	1,100	1		16.5	16.5	8.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (during T4I) (Replacements)	1,100	2		-	-	5.6	11.3	11.3	11.3	11.1	11.1	11.1	11.1	10.9	5.4	5.4	5.4	3.6	3.6	3.6	3.6
DIESEL DRILLS - ATLAS COPCO																					
TIER 2 (Existing)	750	2		19.6	19.6	19.6	19.4	19.2	19.2	14.4	9.6	7.1	-	-	-	-	-	-	-	-	-
TIER 2 (during T4I) (New)	750	2		5.0	10.0	10.0	9.8	9.8	9.8	9.8	9.8	8.0	5.6	2.5	-	-	-	-	-	-	-
TIER 4F (Replacements)	750	4F		-	-	-	-	-	-	-	3.6	6.1	6.1	6.0	4.5	4.0	5.0	5.3	4.9	4.9	4.9
TOTAL				**695**	**665**	**644**	**641**	**638**	**588**	**561**	**539**	**517**	**405**	**363**	**327**	**312**	**309**	**297**	**296**	**286**	**285**
Sulfur Dioxide Emissions (tpy)				**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
TRACK DOZERS - CAT D10	**HP**	**Tier**																			
NOT TIER RATED (Existing)	580	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 1 (Existing)	613	1		0.0232	0.0077	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	661	2		0.0250	0.0250	0.0250	0.0250	0.0250	0.0250	0.0167	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing, New and Replacements)	646	3		0.1058	0.1302	0.1546	0.1546	0.1546	0.1546	0.1546	0.1546	0.1465	0.1220	0.0814	0.0651	0.0407	0.0325	0.0081	0.0081	0.0081	0.0081
TIER 4F (New and Replacements)	646	4F		-	-	-	-	-	-	-	-	-	-	-	-	0.0242	0.0403	0.0645	0.0645	0.0645	0.0645
TRACK DOZERS - CAT D11																					
NOT TIER RATED (Existing)	850	0		0.0280	0.0187	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 1 (Existing)	936	1		0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	0.0103	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	936	4T		0.0102	0.0204	0.0408	0.0408	0.0408	0.0408	0.0408	0.0408	0.0408	0.0408	0.0408	0.0408	0.0408	0.0306	0.0204	0.0204	-	-
TIER 4F (New and Replacements)	936	4F		-	-	-	-	-	-	-	-	-	-	-	-	-	0.0102	0.0204	0.0204	0.0204	0.0204
GRADERS - CAT 16																					
TIER 1 (Existing)	289	1		0.0091	0.0045	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	299	2		0.0141	0.0141	0.0141	0.0094	0.0094	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing)	297	3		0.0234	0.0234	0.0234	0.0234	0.0234	0.0234	0.0047	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	297	4T		0.0046	0.0139	0.0185	0.0232	0.0232	0.0232	0.0232	0.0232	0.0232	0.0185	0.0093	-	-	-	-	-	-	-
TIER 4F (New and Replacements)	297	4F		-	-	-	-	0.0046	0.0139	0.0324	0.0370	0.0370	0.0370	0.0463	0.0509	0.0509	0.0509	0.0509	0.0509	0.0509	0.0509
GRADERS - CAT 24																					
NOT TIER RATED (Existing)	540	0		0.0153	0.0153	0.0153	0.0153	0.0153	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	533	2		0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	533	4F		-	-	-	-	-	0.0150	0.0150	0.0150	0.0150	0.0150	0.0224	0.0224	0.0224	0.0224	0.0224	0.0224	0.0224	0.0224
RTDS - CAT 834																					
834B - NOT TIER RATED (Existing)	487	0		0.0138	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
834G - NOT TIER RATED (Existing)	487	0		0.0069	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing)	525	3		0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0149	0.0149	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	525	4T		0.0074	0.0295	0.0295	0.0295	0.0295	0.0295	0.0295	0.0295	0.0295	0.0295	0.0147	-	-	-	-	-	-	-
TIER 4F (Replacements)	525	4F		-	-	-	-	-	-	-	0.0074	0.0074	0.0074	0.0147	0.0295	0.0295	0.0295	0.0295	0.0295	0.0295	0.0295
RTDS - CAT 854																					
TIER 1 (Existing)	880	1		0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	-	-	-	-	-	-	-	-	-	-

TABLE B1-37
2011–2029 Mobile Support Equipment Emissions—260 Mtpy
KUC—Bingham Canyon Mine

FEL - KOMATSU																					
WA500 - TIER 1 (Existing)	235	1		0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	0.0023	-	-	-	-	-	-	-	-	-
WA600 - TIER 3 (Existing)	396	3		0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0038	-	-	-	-	-	-	-
WA600 - TIER 4F (Replacements)	502	4F		-	-	-	-	-	-	-	-	-	-	0.0048	0.0096	0.0096	0.0096	0.0096	0.0096	0.0096	0.0096
WA700 - TIER 1 (Existing)	396	1		0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	-	-	-	-	-	-	-
FEL - CAT 992																					
TIER 2 (Existing)	800	2		0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0077	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	801	4T		-	-	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076	0.0076
TIER 4F (Replacements)	801	4F		-	-	-	-	-	-	0.0076	0.0153	0.0153	0.0153	0.0153	0.0153	0.0153	0.0153	0.0153	0.0153	0.0153	0.0153
PRODUCTION FEL - KOM WA1200																					
TIER 1 (Existing)	1,782	1		0.0232	0.0232	0.0232	0.0232	0.0232	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	1,782	4F		-	-	-	-	-	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230	0.0230
TRACKHOES - CAT 330																					
TIER 2 (Existing)	264	2		0.0018	0.0018	0.0018	0.0018	0.0018	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	268	4F		-	-	-	-	-	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018
TRACKHOES - CAT 385																					
TIER 3 (Existing)	523	3		0.0072	0.0072	0.0072	0.0036	0.0036	0.0036	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (Replacements)	523	4T		-	-	-	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072	-	-	-	-	-	-
TIER 4F (Replacements)	523	4F		-	-	-	-	-	-	0.0036	0.0036	0.0036	0.0036	0.0036	0.0036	0.0072	0.0072	0.0072	0.0072	0.0072	0.0072
TRACKHOES - KOMATSU																					
PC800 - TIER 1 (Existing)	323	1		0.0045	0.0045	0.0045	0.0045	0.0022	0.0022	0.0022	0.0022	0.0022	-	-	-	-	-	-	-	-	-
PC800 - TIER 4F (Replacements)	323	4F		-	-	-	-	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	-	-
PC400 - TIER 1 (Existing)	246	1		0.0017	0.0017	0.0017	0.0017	0.0017	0.0017	-	-	-	-	-	-	-	-	-	-	-	-
WATER TRUCKS																					
CAT 789 (Existing)	1,900	0		0.0149	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CAT 793C - TIER 1 (Existing)	2,300	1		0.0362	0.0362	0.0362	0.0362	0.0362	0.0362	0.0362	0.0362	0.0362	0.0362	0.0362	0.0362	0.0362	0.0362	0.0362	0.0362	0.0362	0.0362
CAT 793D - TIER 2 (New and Replaceme	2,415	2		0.0380	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760	0.0760
HYDRAULIC SHOVELS																					
O&K RH 200, (NOT CERT)	2,100	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O&K RH 200, (TIER 1)	2,520	1		0.1158	0.1146	0.1134	0.1129	0.1123	0.1117	0.1111	0.1106	0.1100	0.0579	0.0579	0.0567	0.0567	0.0561	0.0561	0.0556	0.0556	0.0550
CONSTRUCTION TRUCKS																					
KOM 785-7 TIER 1 (Existing)	1,200	1		0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476	0.0476
DIESEL DRILLS - P&H																					
TIER 1 (Existing)	1,100	1		0.0136	0.0136	0.0068	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (during T4I) (Replacements)	1,100	2		-	-	0.0071	0.0141	0.0141	0.0141	0.0139	0.0139	0.0139	0.0139	0.0136	0.0068	0.0068	0.0068	0.0045	0.0045	0.0045	0.0045
DIESEL DRILLS - ATLAS COPCO																					
TIER 2 (Existing)	750	2		0.0246	0.0246	0.0246	0.0243	0.0241	0.0241	0.0181	0.0120	0.0089	-	-	-	-	-	-	-	-	-
TIER 2 (during T4I) (New)	750	2		0.0063	0.0125	0.0125	0.0123	0.0123	0.0123	0.0123	0.0123	0.0100	0.0070	0.0031	-	-	-	-	-	-	-
TIER 4F (Replacements)	750	4F		-	-	-	-	-	-	-	0.0072	0.0124	0.0124	0.0122	0.0091	0.0081	0.0101	0.0106	0.0099	0.0099	0.0099
TOTAL				**0.70**	**0.75**	**0.77**	**0.78**	**0.78**	**0.78**	**0.76**	**0.75**	**0.72**	**0.60**	**0.55**	**0.51**	**0.51**	**0.52**	**0.51**	**0.51**	**0.49**	**0.49**

Particulate Matter (PM_{10}) Emissions (tpy)				**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
TRACK DOZERS - CAT D10	**HP**	**Tier**																			
NOT TIER RATED (Existing)	580	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 1 (Existing)	613	1		1.4668	0.4889	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	661	2		0.7686	0.7686	0.7686	0.7686	0.7686	0.7686	0.5124	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing, New and Replacements)	646	3		3.2549	4.0060	4.7571	4.7571	4.7571	4.7571	4.7571	4.7571	4.5068	3.7556	2.5038	2.0030	1.2519	1.0015	0.2504	0.2504	0.2504	0.2504
TIER 4F (New and Replacements)	646	4F		-	-	-	-	-	-	-	-	-	-	-	-	0.0496	0.0826	0.1322	0.1322	0.1322	0.1322
TRACK DOZERS - CAT D11																					
NOT TIER RATED (Existing)	850	0		3.6602	2.4401	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 1 (Existing)	936	1		0.5519	0.5519	0.5519	0.5519	0.5519	0.5519	0.5519	0.5519	0.5519	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	936	4T		0.0327	0.0654	0.1309	0.1309	0.1309	0.1309	0.1309	0.1309	0.1309	0.1309	0.1309	0.1309	0.1309	0.0982	0.0654	0.0654	-	-
TIER 4F (New and Replacements)	936	4F		-	-	-	-	-	-	-	-	-	-	-	-	-	0.0327	0.0654	0.0654	0.0654	0.0654
GRADERS - CAT 16																					
TIER 1 (Existing)	289	1		0.6834	0.3417	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	299	2		0.4346	0.4346	0.4346	0.2897	0.2897	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing)	297	3		0.7194	0.7194	0.7194	0.7194	0.7194	0.7194	0.1439	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	297	4T		0.0095	0.0285	0.0380	0.0475	0.0475	0.0475	0.0475	0.0475	0.0475	0.0380	0.0190	-	-	-	-	-	-	-
TIER 4F (New and Replacements)	297	4F		-	-	-	-	0.0095	0.0285	0.0665	0.0760	0.0760	0.0760	0.0949	0.1044	0.1044	0.1044	0.1044	0.1044	0.1044	0.1044
GRADERS - CAT 24																					
NOT TIER RATED (Existing)	540	0		1.9931	1.9931	1.9931	1.9931	1.9931	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	533	2		0.2324	0.2324	0.2324	0.2324	0.2324	0.2324	0.2324	0.2324	0.2324	0.2324	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	533	4F		-	-	-	-	-	0.0307	0.0307	0.0307	0.0307	0.0307	0.0460	0.0460	0.0460	0.0460	0.0460	0.0460	0.0460	0.0460

TABLE B1-37
2011–2029 Mobile Support Equipment Emissions—260 Mtpy
KUC—Bingham Canyon Mine

RTDS - CAT 834																					
834B - NOT TIER RATED (Existing)	487	0		1.7975	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
834G - NOT TIER RATED (Existing)	487	0		0.8987	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing)	525	3		0.6867	0.6867	0.6867	0.6867	0.6867	0.6867	0.6867	0.4578	0.4578	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	525	4T		0.0151	0.0604	0.0604	0.0604	0.0604	0.0604	0.0604	0.0604	0.0604	0.0604	0.0302	-	-	-	-	-	-	-
TIER 4F (Replacements)	525	4F		-	-	-	-	-	-	-	0.0151	0.0151	0.0151	0.0302	0.0604	0.0604	0.0604	0.0604	0.0604	0.0604	0.0604
RTDS - CAT 854																					
TIER 1 (Existing)	880	1		0.6672	0.6672	0.6672	0.6672	0.6672	0.6672	0.6672	0.6672	-	-	-	-	-	-	-	-	-	-
FEL - KOMATSU																					
WA500 - TIER 1 (Existing)	235	1		0.1702	0.1702	0.1702	0.1702	0.1702	0.1702	0.1702	0.1702	0.1702	-	-	-	-	-	-	-	-	-
WA600 - TIER 3 (Existing)	396	3		0.2350	0.2350	0.2350	0.2350	0.2350	0.2350	0.2350	0.2350	0.2350	0.2350	0.1175	-	-	-	-	-	-	-
WA600 - TIER 4F (Replacements)	502	4F		-	-	-	-	-	-	-	-	-	-	0.0098	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197	0.0197
WA700 - TIER 1 (Existing)	396	1		0.2147	0.2147	0.2147	0.2147	0.2147	0.2147	0.2147	0.2147	0.2147	0.2147	0.2147	-	-	-	-	-	-	-
FEL - CAT 992																					
TIER 2 (Existing)	800	2		0.4747	0.4747	0.4747	0.4747	0.4747	0.4747	0.2374	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	801	4T		-	-	0.0245	0.0245	0.0245	0.0245	0.0245	0.0245	0.0245	0.0245	0.0245	0.0245	0.0245	0.0245	0.0245	0.0245	0.0245	0.0245
TIER 4F (Replacements)	801	4F		-	-	-	-	-	-	0.0245	0.0490	0.0490	0.0490	0.0490	0.0490	0.0490	0.0490	0.0490	0.0490	0.0490	0.0490
PRODUCTION FEL - KOM WA1200																					
TIER 1 (Existing)	1,782	1		1.2423	1.2423	1.2423	1.2423	1.2423	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	1,782	4F		-	-	-	-	-	0.0736	0.0736	0.0736	0.0736	0.0736	0.0736	0.0736	0.0736	0.0736	0.0736	0.0736	0.0736	0.0736
TRACKHOES - CAT 330																					
TIER 2 (Existing)	264	2		0.0563	0.0563	0.0563	0.0563	0.0563	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	268	4F		-	-	-	-	-	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038	0.0038
TRACKHOES - CAT 385																					
TIER 3 (Existing)	523	3		0.2230	0.2230	0.2230	0.1115	0.1115	0.1115	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (Replacements)	523	4T		-	-	-	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147	-	-	-	-	-	-
TIER 4F (Replacements)	523	4F		-	-	-	-	-	-	0.0074	0.0074	0.0074	0.0074	0.0074	0.0074	0.0147	0.0147	0.0147	0.0147	0.0147	0.0147
TRACKHOES - KOMATSU																					
PC800 - TIER 1 (Existing)	323	1		0.2516	0.2516	0.2516	0.2516	0.1258	0.1258	0.1258	0.1258	0.1258	-	-	-	-	-	-	-	-	-
PC800 - TIER 4F (Replacements)	323	4F		-	-	-	-	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	0.0045	-	-
PC400 - TIER 1 (Existing)	246	1		0.1280	0.1280	0.1280	0.1280	0.1280	0.1280	-	-	-	-	-	-	-	-	-	-	-	-
WATER TRUCKS																					
CAT 789 (Existing)	1,900	0		1.9480	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CAT 793C - TIER 1 (Existing)	2,300	1		1.9375	1.9375	1.9375	1.9375	1.9375	1.9375	1.9375	1.9375	1.9375	1.9375	1.9375	1.9375	1.9375	1.9375	1.9375	1.9375	1.9375	1.9375
CAT 793D - TIER 2 (New and Replaceme	2,415	2		1.1700	2.3400	2.3400	2.3400	2.3400	2.3400	2.3400	2.3400	2.3400	2.3400	2.3400	2.3400	2.3400	2.3400	2.3400	2.3400	2.3400	2.3400
HYDRAULIC SHOVELS																					
O&K RH 200, (NOT CERT)	2,100	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O&K RH 200, (TIER 1)	2,520	1		6.1987	6.1367	6.0747	6.0437	6.0127	5.9817	5.9507	5.9197	5.8888	3.0993	3.0993	3.0374	3.0374	3.0064	3.0064	2.9754	2.9754	2.9444
CONSTRUCTION TRUCKS																					
KOM 785-7 TIER 1 (Existing)	1,200	1		2.5474	2.5474	2.5474	2.5474	2.5474	2.5474	2.5474	2.5474	2.5474	2.5474	2.5474	2.5474	2.5474	2.5474	2.5474	2.5474	2.5474	2.5474
DIESEL DRILLS - P&H																					
TIER 1 (Existing)	1,100	1		0.7282	0.7282	0.3641	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (during T4I) (Replacements)	1,100	2		-	-	0.2173	0.4346	0.4346	0.4346	0.4267	0.4267	0.4267	0.4267	0.4188	0.2094	0.2094	0.2094	0.1396	0.1370	0.1370	0.1370
DIESEL DRILLS - ATLAS COPCO																					
TIER 2 (Existing)	750	2		0.7558	0.7558	0.7558	0.7485	0.7412	0.7412	0.5559	0.3706	0.2725	-	-	-	-	-	-	-	-	-
TIER 2 (during T4I) (New)	750	2		0.1926	0.3852	0.3852	0.3779	0.3779	0.3779	0.3779	0.3779	0.3089	0.2162	0.0963	-	-	-	-	-	-	-
TIER 4F (Replacements)	750	4F		-	-	-	-	-	-	-	0.0232	0.0397	0.0397	0.0390	0.0292	0.0260	0.0325	0.0341	0.0318	0.0318	0.0318
TOTAL				**36.3**	**31.3**	**28.7**	**28.3**	**28.1**	**24.6**	**23.2**	**21.9**	**20.8**	**15.6**	**13.9**	**12.6**	**11.9**	**11.7**	**10.9**	**10.9**	**10.8**	**10.8**
Operation Hours				**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**

TRACK DOZERS - CAT D10	**HP**	**Tier**																			
NOT TIER RATED (Existing)	580	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 1 (Existing)	613	1		12,000	4,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	661	2		12,000	12,000	12,000	12,000	12,000	12,000	8,000	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing, New and Replacements)	646	3		52,000	64,000	76,000	76,000	76,000	76,000	76,000	76,000	72,000	60,000	40,000	32,000	20,000	16,000	4,000	4,000	4,000	4,000
TIER 4F (New and Replacements)	646	4F		-	-	-	-	-	-	-	-	-	-	-	-	12,000	20,000	32,000	32,000	32,000	32,000
TRACK DOZERS - CAT D11																					
NOT TIER RATED (Existing)	850	0		10,500	7,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 1 (Existing)	936	1		3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	936	4T		3,500	7,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000	10,500	7,000	7,000	-	-
TIER 4F (New and Replacements)	936	4F		-	-	-	-	-	-	-	-	-	-	-	-	-	3,500	7,000	7,000	7,000	7,000

TABLE B1-37

2011–2029 Mobile Support Equipment Emissions—260 Mtpy

KUC—Bingham Canyon Mine

GRADERS - CAT 16																					
TIER 1 (Existing)	289	1		10,000	5,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	299	2		15,000	15,000	15,000	10,000	10,000	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing)	297	3		25,000	25,000	25,000	25,000	25,000	25,000	5,000	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	297	4T		5,000	15,000	20,000	25,000	25,000	25,000	25,000	25,000	25,000	20,000	10,000	-	-	-	-	-	-	-
TIER 4F (New and Replacements)	297	4F		-	-	-	-	5,000	15,000	35,000	40,000	40,000	40,000	50,000	55,000	55,000	55,000	55,000	55,000	55,000	55,000
GRADERS - CAT 24																					
NOT TIER RATED (Existing)	540	0		9,000	9,000	9,000	9,000	9,000	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (Existing)	533	2		4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	533	4F		-	-	-	-	-	9,000	9,000	9,000	9,000	9,000	13,500	13,500	13,500	13,500	13,500	13,500	13,500	13,500
RTDS - CAT 834																					
834B - NOT TIER RATED (Existing)	487	0		9,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
834G - NOT TIER RATED (Existing)	487	0		4,500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 3 (Existing)	525	3		13,500	13,500	13,500	13,500	13,500	13,500	13,500	9,000	9,000	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	525	4T		4,500	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	9,000	-	-	-	-	-	-	-
TIER 4F (Replacements)	525	4F		-	-	-	-	-	-	-	4,500	4,500	4,500	9,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
RTDS - CAT 854																					
TIER 1 (Existing)	880	1		4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	-	-	-	-	-	-	-	-	-	-
FEL - KOMATSU																					
WA500 - TIER 1 (Existing)	235	1		3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700	-	-	-	-	-	-	-	-	-
WA600 - TIER 3 (Existing)	396	3		7,400	7,400	7,400	7,400	7,400	7,400	7,400	7,400	7,400	7,400	3,700	-	-	-	-	-	-	-
WA600 - TIER 4F (Replacements)	502	4F		-	-	-	-	-	-	-	-	-	-	3,700	7,400	7,400	7,400	7,400	7,400	7,400	7,400
WA700 - TIER 1 (Existing)	396	1		3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700	-	-	-	-	-	-	-
FEL - CAT 992																					
TIER 2 (Existing)	800	2		7,400	7,400	7,400	7,400	7,400	7,400	3,700	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (New and Replacements)	801	4T		-	-	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700	3,700
TIER 4F (Replacements)	801	4F		-	-	-	-	-	-	3,700	7,400	7,400	7,400	7,400	7,400	7,400	7,400	7,400	7,400	7,400	7,400
PRODUCTION FEL - KOM WA1200																					
TIER 1 (Existing)	1,782	1		5,000	5,000	5,000	5,000	5,000	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	1,782	4F		-	-	-	-	-	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
TRACKHOES - CAT 330																					
TIER 2 (Existing)	264	2		2,200	2,200	2,200	2,200	2,200	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4F (Replacements)	268	4F		-	-	-	-	-	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200
TRACKHOES - CAT 385																					
TIER 3 (Existing)	523	3		4,400	4,400	4,400	2,200	2,200	2,200	-	-	-	-	-	-	-	-	-	-	-	-
TIER 4A (Replacements)	523	4T		-	-	-	4,400	4,400	4,400	4,400	4,400	4,400	4,400	4,400	4,400	-	-	-	-	-	-
TIER 4F (Replacements)	523	4F		-	-	-	-	-	-	2,200	2,200	2,200	2,200	2,200	2,200	4,400	4,400	4,400	4,400	4,400	4,400
TRACKHOES - KOMATSU																					
PC800 - TIER 1 (Existing)	323	1		4,400	4,400	4,400	4,400	2,200	2,200	2,200	2,200	2,200	-	-	-	-	-	-	-	-	-
PC800 - TIER 4F (Replacements)	323	4F		-	-	-	-	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	2,200	-	-
PC400 - TIER 1 (Existing)	246	1		2,200	2,200	2,200	2,200	2,200	2,200	-	-	-	-	-	-	-	-	-	-	-	-
WATER TRUCKS																					
CAT 789 (Existing)	1,900	0		2,500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CAT 793C - TIER 1 (Existing)	2,300	1		5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
CAT 793D - TIER 2 (New and Replaceme	2,415	2		5,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
HYDRAULIC SHOVELS																					
O&K RH 200, (NOT CERT)	2,100	0		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O&K RH 200, (TIER 1)	2,520	1		14,600	14,454	14,308	14,235	14,162	14,089	14,016	13,943	13,870	7,300	7,300	7,154	7,154	7,081	7,081	7,008	7,008	6,935
CONSTRUCTION TRUCKS																					
KOM 785-7 TIER 1 (Existing)	1,200	1		12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600	12,600
DIESEL DRILLS - P&H																					
TIER 1 (Existing)	1,100	1		5,300	5,300	2,650	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TIER 2 (during T4I) (Replacements)	1,100	2		-	-	2,750	5,500	5,500	5,500	5,400	5,400	5,400	5,400	5,300	2,650	2,650	2,650	1,767	1,733	1,733	1,733
DIESEL DRILLS - ATLAS COPCO																					
TIER 2 (Existing)	750	2		10,400	10,400	10,400	10,300	10,200	10,200	7,650	5,100	3,750	-	-	-	-	-	-	-	-	-
TIER 2 (during T4I) (New)	750	2		2,650	5,300	5,300	5,200	5,200	5,200	5,200	5,200	4,250	2,975	1,325	-	-	-	-	-	-	-
TIER 4F (Replacements)	750	4F		-	-	-	-	-	-	-	3,092	5,300	5,300	5,200	3,900	3,467	4,333	4,550	4,250	4,250	4,250

Material is loaded into haul trucks by shovels. KUC primarily operates electric shovels in addition to the hydraulic shovels included in the emissions calculations.

TABLE B1-37
2011–2029 Mobile Support Equipment Emissions—260 Mtpy
KUC—Bingham Canyon Mine

Emission Factors (g/hp-hr)	Pollutant	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4t	Tier 4f
175–300-hp class	HC	0.75	0.34	0.33	0.20	0.13	0.13
	CO	4.90	1.26	1.26	1.32	0.09	0.09
	NO_x	8.15	5.43	3.83	2.39	2.52	0.28
	SO_2	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049
	PM_{10}	0.64	0.37	0.15	0.15	0.01	0.01
300–600-hp class	HC	0.75	0.22	0.18	0.18	0.13	0.13
	CO	4.90	2.20	1.42	1.48	0.10	0.10
	NO_x	8.15	5.85	4.16	2.39	2.52	0.28
	SO_2	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049
	PM_{10}	0.64	0.28	0.15	0.15	0.01	0.01
600–750-hp class	HC	0.75	0.16	0.18	0.18	0.13	0.13
	CO	4.90	2.24	2.24	2.34	0.15	0.15
	NO_x	8.15	5.66	3.93	2.39	2.52	0.28
	SO_2	0.0049	0.0049	0.0049	0.0049	0.0049	0.0049
	PM_{10}	0.64	0.31	0.15	0.15	0.01	0.01
>750-hp class	HC	0.75	0.31	0.18	NA	0.29	0.13
	CO	4.90	1.29	1.29	NA	0.09	0.09
	NO_x	8.15	5.99	3.93	NA	2.41	2.41
	SO_2	0.0049	0.0049	0.0049	NA	0.0049	0.0049
	PM_{10}	0.64	0.26	0.15	NA	0.02	0.02
All emission factors represent the lesser of EPA emission limits and factors calculated using EPA NONROAD methodology.							

All Age Factors assumed to be equal to 1.

Calculation Data

	NONROAD Equipment SCC
Front-end Loaders	2270002060
Graders	2270002048
Truck Dozers	2270002069
Wheeled Dozers	2270002063

All tables and factors are from "Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling--Compression-Ignition", EPA, 2004, unless otherwise noted.

Table A2 Zero-Hour, Steady-State Emission Factors for Nonroad CI Engines (>175 to 300 hp)

	BSFC	HC	CO	NO_x	PM_{10}
T0	0.367	0.68	2.7	8.38	0.402
T1	0.367	0.3085	0.7475	5.5772	0.2521
T2	0.367	0.3085	0.7475	4	0.1316
T3	0.367	0.1836	0.7475	2.5	0.15
T4t	0.367	0.1314	0.075	2.5	0.0092
T4	0.367	0.1314	0.075	0.276	0.0092

Table A2 Zero-Hour, Steady-State Emission Factors for Nonroad CI Engines (>300 to 600 hp)

	BSFC	HC	CO	NO_x	PM_{10}
T0	0.367	0.68	2.7	8.38	0.402
T1	0.367	0.2025	1.306	6.0153	0.2008
T2	0.367	0.1669	0.8425	4.3351	0.1316
T3	0.367	0.1669	0.8425	2.5	0.15
T4t	0.367	0.1314	0.084	2.5	0.0092
T4	0.367	0.1314	0.084	0.276	0.0092

Table A2 Zero-Hour, Steady-State Emission Factors for Nonroad CI Engines (>600 to 750 hp)

	BSFC	HC	CO	NO_x	PM_{10}
T0	0.367	0.68	2.7	8.38	0.402
T1	0.367	0.1473	1.3272	5.8215	0.2201
T2	0.367	0.1669	1.3272	4.1	0.1316
T3	0.367	0.1699	1.3272	2.5	0.15
T4t	0.367	0.1314	0.133	2.5	0.0092
T4	0.367	0.1314	0.133	0.276	0.0092

Table A2 Zero-Hour, Steady-State Emission Factors for Nonroad CI Engines (>750 hp)

	BSFC	HC	CO	NO_x	PM_{10}
T0	0.367	0.68	2.7	8.38	0.402
T1	0.367	0.2861	0.7642	6.1525	0.1934
T2	0.367	0.1669	0.7642	4.1	0.1316
T4t	0.367	0.2815	0.076	2.392	0.069
T4f	0.367	0.1314	0.076	2.392	0.0276

Table A3 Transient Adjustment Factors by Equipment Type for Nonroad CI Equipment

HC	CO	NO_x	PM_{10}	BSFC
1.05	1.53	0.95	1.23	1.01

TABLE B1-37
2011–2029 Mobile Support Equipment Emissions—260 Mtpy
KUC—Bingham Canyon Mine

TAFs are not applied to the emission factors for Tier 4 engines

Table A4 Deterioration Factors for Nonroad Diesel Engines (A)

Pollutant	T0	T1	T2	T3+
HC	0.047	0.036	0.034	0.027
CO	0.185	0.101	0.101	0.151
NO_x	0.024	0.024	0.009	0.008
PM_{10}	0.473	0.473	0.473	0.473

Sulfur Content of Diesel Fuel

sulfur conversion	7.0	grams PM sulfate/gram Sulfur		
soxcnv	0.02247	grams PM sulfur/gram fuel consumed		
default (soxbas)	3300	ppm	0.33	wt %
2010+ (soxdsl)	15	ppm	0.0015	wt %

Load Factor

0.48 RTLoader Cycle Class
0.58 Crawler Cycle Class
0.43 7-cycle average

Load factors from Tables 9 and 10 of "Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling", EPA, 2004.

TABLE B1-38
Emissions Summary
KUC—Bingham Canyon Mine

Source ID	Source Description	PM_{10} Emissions (tpy)	$PM_{2.5}$ Emissions (tpy)	Location of Source within Pit Influence Boundary
BCM01	In Pit Crusher	1.55	0.48	Yes
BCM201	New In Pit Crusher	0.68	0.21	Yes
BCM02	C6/C7 Conveyor Transfer Point	1.35	0.40	
BCM03	C7/C8 Conveyor Transfer Point	0.83	0.24	
BCM04	Lime Bin	0.37	0.13	
BCM05	Lime Bin	0.37	0.13	
BCM07	Sample Preparation	0.17	0.05	Yes
SX/EW	Electrowinning (as H_2SO_4)	0.96	0.96	
Total Point Sources:		**6.27**	**2.60**	
BCM1.1	Truck Dump Ore	0.56	0.09	Yes
BCM204	Truck Dump Ore at Crusher	0.56	0.09	Yes
BCM205	Truck Dump Ore at Stockpile	0.56	0.09	Yes
BCM1.2	In-pit enclosed transfer point 1, 2,3	1.68	0.27	Yes
BCM202	New In-pit enclosed transfer point 1, 2,3	1.68	0.27	Yes
BCM203	In-pit enclosed transfer point 4,5	1.12	0.18	Yes
BCM1.3	Conveyor Stacker Transfer Point	2.79	0.42	
BCM1.4	Coarse Ore Stacker (drop to coarse ore storage pile)	2.79	0.42	
BCM1.5	Reclaim Tunnels (Coarse ore reclaim tunnel vent)	2.79	0.42	
BCM1.9	Disturbed Areas	40.6	8.7	Yes
BCM1.13	Coarse Ore Storage Pile	2.09	0.33	Yes
BCM1.16	Front End Loaders	12.38	2.08	Yes
BCM1.17	Truck Loading	1.71	0.27	Yes
BCM1.19	End Dump Trucks (truck dumping of waste)	57.5	8.71	
BCM1.20	Graders	77.7	9.1	Yes
BCM1.21	Track Dozers	5.9	3.6	Yes
BCM1.22	Wheeled Dozers	1.2	0.7	Yes
BCM1.23	Drilling w/Water Injection	0.55	0.09	Yes
BCM1.24	Blasting w/Minimized Area	11.0	0.7	Yes
BCM100	Tertiary Crushing	0.17	0.03	Yes
BCM101	Screening	0.23	0.02	Yes
BCM102	Transfer Points	0.14	0.04	Yes
Total Fugitive Sources:		**225.69**	**36.69**	
Total		**231.00**	**38**	

TABLE B1-39

Truck Offloading Ore at In-pit Crusher (Additional drop point at the new crusher

KUC—Bingham Canyon Mine

Source Name	PM_{10} Aerodynamic Particle Size Multiplier (k)	$PM_{2.5}$ Aerodynamic Particle Size Multiplier (k)	Moisture Content (%)	Wind Speed (mph)	PM_{10} Emission Factor (lbs/ton)	$PM_{2.5}$ Emission Factor (lbs/ton)	Annual Process Rate (tpy)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Primary Control Efficiency (%)	PM_{10} Emissions with Primary Controls (tpy)	$PM_{2.5}$ Emissions with Primary Controls (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
Truck Offloading Ore	0.35	0.053	4	7	0.00066	0.00010	85,000,000	27.9	4.2	90	2.79	0.42	20	21	0.56	0.09	Inherent material characteristics and physical enclosures. Source Located in the pit.

NOTES:

Emission factors estimated using methodology in AP-42, Section 13.2.4.

Wind speed and moisture content data based on historical data.

PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).

Characteristics of the ore material, such as large diameter material, and inherent material moisture content of 4 percent, limit dust being generated during the transfer operations.

The control efficiency listed is based on previous determinations of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling.

TABLE B1-40
Truck Offloading Ore at Stockpile
KUC—Bingham Canyon Mine

Source Name	PM_{10} Aerodynamic Particle Size Multiplier (k)	$PM_{2.5}$ Aerodynamic Particle Size Multiplier (k)	Moisture Content (%)	Wind Speed (mph)	PM_{10} Emission Factor (lbs/ton)	$PM_{2.5}$ Emission Factor (lbs/ton)	Annual Process Rate (tpy)	Uncontrolled PM_{10} Emissions (tpy)	Uncontrolled $PM_{2.5}$ Emissions (tpy)	Primary Control Efficiency (%)	PM_{10} Emissions with Primary Controls (tpy)	$PM_{2.5}$ Emissions with Primary Controls (tpy)	PM_{10} Pit Escape Factor (%)	$PM_{2.5}$ Pit Escape Factor (%)	Controlled PM_{10} Emissions from the pit (tpy)	Controlled $PM_{2.5}$ Emissions from the pit (tpy)	Control System and Comments
Truck Offloading Ore	0.35	0.053	4	7	0.00066	0.00010	85,000,000	27.9	4.2	90	2.79	0.42	20	21	0.56	0.09	Inherent material characteristics and source located in the pit.

NOTES:
Emission factors estimated using methodology in AP-42, Section 13.2.4.
Wind speed and moisture content data based on historical data.
PM_{10} and $PM_{2.5}$ Pit Escape Factor applied to the calculations and is based on University of Utah study (1996).
Characteristics of the ore material, such as large diameter material, and inherent material moisture content of 4 percent, limit dust being generated during the transfer operations.
The control efficiency listed is based on previous determinations of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling.

TABLE B1-41
New LPG Generator (Dinkeyville Hill)
KUC—Bingham Canyon Mine

NO_X Emission Factor (g/HP-hr)	6.9	[Vendor Data]
CO Emission Factor (g/HP-hr)	27	[Vendor Data]
THC Emission Factor (g/HP-hr)	1	[Vendor Data]
SO_2 Emission Factor (g/HP-hr)	0.0121	[EPA NONROAD Program]
PM_{10} Emission Factor (g/HP-hr)	0.0557	[EPA NONROAD Program]
$PM_{2.5}$ Emission Factor (g/HP-hr)	0.0557	[EPA NONROAD Program]

	Generator
Engine Rating (HP)	71
Annual Hours of Operations (hrs/yr)	100
NO_X Emissions (lb/hr)	1.1
CO Emissions (lb/hr)	4.24
VOC Emissions (lb/hr)	0.16
SO_2 Emissions (lb/hr)	0.002
PM_{10} Emissions (lb/hr)	0.01
$PM_{2.5}$ Emissions (lb/hr)	0.01
NO_X Emissions (tpy)	0.0542
CO Emissions (tpy)	0.212
VOC Emissions (tpy)	0.01
SO_2 Emissions (tpy)	0.0001
PM_{10} Emissions (tpy)	0.0004
$PM_{2.5}$ Emissions (tpy)	0.0004

Notes:
(1) Emissions of NO_X, CO, and VOC estimated using vendor provided data.
(2) Emissions of SO_2, PM_{10}, and $PM_{2.5}$ estimated using EPA's NONROAD Program

APPENDIX B-2

Emissions Calculations References

Small Business Assistance Program

Colorado Department of Public Health and Environment
http://www.cdphe.state.co.us/ap/sbap.asp

A Guide to Air Regulations for:

Gasoline and Diesel Fuel Dispensing Stations

Fuel dispensing stations emit substances that are regulated as air pollutants by the Colorado Department of Public Health and Environment, Air Pollution Control Division (Division). This document provides an overview of the air pollution reporting and permitting requirements for gasoline and diesel fuel dispensing stations with underground storage tanks.

➢ AREAS OF CONCERN

Air emission reporting and permitting requirements vary depending on where a source is located. To determine your air requirements, first identify your business area:

- **Denver 1-Hour Ozone Attainment/Maintenance Area:** Includes all of Denver, Broomfield, Jefferson, Douglas, and Boulder County (excluding Rocky Mountain National Park) and the western portions of Adams and Arapahoe Counties.
- **All Other Areas of Colorado**

➢ ENVIRONMENTAL CONCERNS

Volatile Organic Compounds (VOCs)

Volatile Organic Compounds contained in gasoline vapor, with sunlight acting as a catalyst, readily combine with oxides of nitrogen to form ozone. Ozone is a regulated pollutant in Colorado. At ground level, ozone is a major ingredient of smog, aggravates heart and respiratory illnesses, and may contribute to the development of various diseases including bronchitis and emphysema.

Hazardous Air Pollutants (HAPs)

Some of the chemicals contained in fuel are classified as HAPs. These chemicals can have detrimental effects on humans and the environment. HAPs in gasoline vapor include, but are not limited to, benzene, methyl tert butyl ether (MTBE[1]), hexane, toluene, 2,2,4-trimethyl pentane, and xylene. These substances have been known to cause headaches, dizziness, difficulty breathing, and an increased risk of cancer and birth defects. Highly concentrated vapor can be emitted when fuel is transferred from tank trucks to underground storage tanks at service stations. It can also be emitted directly into your breathing zone when you refuel your vehicle. The most immediate concern has been benzene because it is a known human carcinogen and is persistent in the atmosphere.

At one time lead was added to gasoline as an anti-knock agent to increase the octane of the fuel. Lead was then found to be a developmental toxicant in humans and regulations were adopted to restrict its use. Most fuels now consist of more highly branched and aromatic compounds that may include a higher benzene content.

[1]*Note: The blending MTBE is prohibited in Colorado after April 30, 2002 (Colorado Revised Statutes 25-7-139).*

➢ REPORTING REQUIREMENTS:

Air Pollutant Emission Notice (APEN) and Emission Permits (or Construction Permits)

Most operators of gasoline and diesel fuel dispensing stations in Colorado are required to submit an APEN to the Air Pollution Control Division. An APEN is a form used to report a facility's air emissions. The APEN form, titled *Fuel Dispensing Stations-, Air Pollutant Emission Notice (APEN) – and –Application for Construction Permit*, is downloadable at www.cdphe.state.co.us/ap/downloadforms.asp.

✓ **An APEN must be filed under the following conditions:**

- ❖ **In the Denver 1-Hour Ozone Attainment/Maintenance Area:** Gasoline and diesel service stations located in the Denver 1-Hour Ozone Attainment/Maintenance Area (described above) must file an APEN if uncontrolled actual VOC emissions equals or exceeds two tons per year. In addition, these stations must obtain an air permit if VOC emissions equals or exceeds five tons per year.

  The air permit will include requirements that approved fittings for a vapor recovery system to be installed on all gasoline storage tanks. The operator must ensure that the tanks are only filled with fuel from a certified delivery truck equipped with an approved vapor recovery system and that the system is properly connected during the entire filling operation. The air permit defines the type of air pollution control measures that will be used, the kinds and amounts of materials used by the facility and any other operating limits that may apply. Fuel dispensing facilities are normally required to maintain records of gasoline dispensed from each tank and maintain vapor recovery equipment/fittings to minimize air emissions.

  Exemption: Diesel storage tanks with an annual throughput of less than four hundred thousand gallons are exempt from APEN requirements unless other federal standards (such as 40 CFR 60, Subpart Kb for storage tanks with design capacities above 75 m^3 or approximately 20,000 gallons) apply. (Regulation 3, Section II.E.3.fff.(i)).

❖ **All Other Areas of Colorado:** Gasoline and diesel fuel dispensing stations located in all other areas of Colorado must file an APEN if uncontrolled actual VOCs emissions equal or exceed two tons per year. However, these stations are exempt from air permit requirements (Regulation No. 3, Part III.D).

Exemption: Diesel storage tanks with an annual throughput of less than four hundred thousand gallons are exempt from APEN requirements unless other federal standards (such as 40 CFR 60, Subpart Kb for storage tanks with design capacities above 75 m^3 or approximately 20,000 gallons) apply. (Regulation 3, Section II.E.3.fff.(i)).

✓ **APEN Calculations**

Operators of gasoline and diesel fuel dispensing stations may calculate annual emissions on the APEN form (see Attachment A) or the Division can calculate this information based on fuel throughput (gallons/year) provided by the source on the APEN. Please contact the Small Business Assistance Program or someone in the Air Pollution Control Division if you have questions.

Hazardous Air Pollutant **(HAP)** emissions must be reported on a **Non-Criteria Reportable Air Pollutant Emission Notice Addendum Form** if they exceed any of the reporting levels specified in Regulation No. 3. Contact the Division at (303) 692-3150 for a list of HAPs and reporting thresholds.

✓ **When to File a Revised APEN**

A Revised APEN must be filed with the Division anytime there is a **significant change** in emissions or a modification in equipment or controls.

- A significant change for **VOC** is an increase of one ton per year over the amount previously reported on an APEN or five percent, whichever is greater (Regulation No. 3, Part A.II.C.2 and .3).
- A significant change for **HAPs** is five tons per year over the amount previously reported, or 50 percent, whichever is less.

A Revised APEN must be filed whenever a permit emission limit is exceeded.

An APEN must be filed (renewed) every five years (or sooner if any of the above situations trigger an APEN revision).

✓ **APEN and Permit Fees**

APEN Filing Fee: A $119.96 filing fee is required for each APEN submitted, including APENs submitted for administrative changes (e.g., changes in ownership, change in location).

Annual Emission Fee: State law requires all sources which are required to file Air Pollutant Emission Notice to pay an annual fee. The fee is based on the total annual emissions as reported on the most current Air Pollutant Emission Notice the Division has on file. Invoices for these fees will be mailed in May or June of each year. Current annual fees are $13.54 for each ton of criteria pollutants emitted and $90.34 for each ton of hazardous air pollutants emitted. These fees are subject to change by the legislature on a yearly basis. The Inventory and Support Unit at the Air Pollution Control Division administers annual emission.

Permit Processing Fee: In addition to the APEN filing fee and annual fee, the Division is required by law to recover the costs of operating the permitting program by charging applicants a processing fee. This fee is based on the amount of time it takes the Division to process the application according to an hourly rate and including costs such as publication of public notice. Effective July 1, 2001, processing fees are $59.98 per hour.

Please contact the Station Sources Program at (303) 692-3150 or visit the APCD website at: www.cdphe.state.co.us/ap/aphom.asp for current information or questions.

➢ POLLUTION CONTROLS

Stage I Vapor Recovery refers to the process of reclaiming vapor that, in the past, was released into the air when loading fuel into transport vehicles (tankers) at terminals and the unloading of the fuel at the service station. The cargo tank retrieves the vapors displaced during product unloading and transports the vapors through a vapor recovery system (equipment installed to control the release of vapors) or back to the loading terminal (closed loop vapor balance system). A vapor balance system is approved in Colorado if its design and operation are in accordance with provisions in Colorado Regulation No. 7 Section VI.B.

Stage I control applies gasoline stations in the Denver Metro Attainment Maintenance Area. Stage I controls are normally not required in Attainment areas in Colorado outside of the Denver Metro area; however, terminals, bulk stations, and service stations equipped to use Stage I controls are encouraged to use them state-wide to control emissions of volatile organic compounds and hazardous air pollutants. **In areas where vapor recovery equipment is required, the equipment must be utilized at all times**. Failure to properly operate the equipment can result in violations being issued to both the transporter and the owner of the service station or gasoline terminal.

The responsibility for complying with Stage I requirements falls on both the transporter and the recipient of the gasoline. Transporters of gasoline must have their equipment pressure and vacuum tested annually (Regulation No. 7, Section VI.D) to ensure that there are no leaks in the lines or other parts of the tank. This includes hoses, piping, and connections. In addition, the deliverer must ensure that the equipment is properly connected when transferring gasoline from the transport tank to the storage tank. The recipient of the gasoline (usually a service station) must also ensure that the proper equipment has been installed and is in working order. Regularly scheduled inspections and maintenance will help you to stay in compliance with the control requirements and avoid costly and time-consuming enforcement actions.

➢ HOUSEKEEPING

Gasoline must not be intentionally spilled, discarded in sewers, stored in open containers, or disposed of in any other manner that would result in evaporation (Regulation No. 7, Section V.B.). If a spill does occur, it should be cleaned up immediately. Spill reporting and clean up procedures must be conducted in accordance with applicable Colorado Regulations.

➢ RECORD KEEPING

Annual records of gasoline and diesel throughput (gallons per year) must be maintained by the owner/operator and made available to the Division for inspection upon request. A copy of the most recent Air Pollutant Emission Notice (APEN) and Permit (if required) should be maintained by the owner/operator. Records must be maintained by the owner/operator for at least two years.

➢ SMALL BUSINESS ASSISTANCE PROGRAM

The Small Business Assistance Program (SBAP) is available to answer questions you may have regarding environmental issues at your facility. The SBAP can help you understand the regulations, help you determine what your company has to do to be in compliance, help you file required forms, help you complete the APEN process (if required), help you calculate your emissions, or provide information by presenting a workshop for your company or for your industry. Our services are always free and confidential.

Small Business Assistance Program
Colorado Department of Public Health and Environment

Home Page: www.cdphe.state.co.us/ap/sbap.asp

Program Contacts:
Joni Canterbury – (303) 692-3175
Margo Griffin – (303) 692-3148

Colorado Department
of Public Health
and Environment

ATTACHMENT A
Calculating Emissions from Underground Storage Tanks

Operators of gasoline and diesel fuel dispensing stations with underground storage tanks may calculate and list emissions of volatile organic compounds (VOCs) on the APEN form or they may request the Division to perform these calculations while processing the permit. To calculate your own emissions, use the following steps:

1. Determine the *actual* throughput (in gallons of fuel per year) for each tank. The actual throughput is the quantity of fuel actually dispensed for the previous calendar year.

2. Determine the *requested* throughput (in gallons of fuel per year) for each tank. The requested throughput will become your permit limit. This number should allow room for your business to grow over the next five years.

3. Determine the type of vapor or emission control at your facility. Examples of emission controls include Stage I Vapor Recovery, Stage II Vapor Recovery, Submerged Pipe Fill, and Splash Fill. Emission factors for various types of fuel and emission controls are provided in Table 1.

Calculate your actual and requested annual VOC emissions by selecting the appropriate emission factor(s) from Table 1 and using the equation in Table 2.

Table 1
Emission Factors

Fuel Type and Emission Control	Emission Factor[1] (pounds of VOC per gallon throughput)
Gasoline with Stage I Vapor Recovery	0.013
Gasoline with Stage II Vapor Recovery	0.0031
Gasoline without Stage I - With Submerged Pipe Fill - With Splash Fill	 0.02 0.0242
Diesel - With Stage I, Stage II, or Submerged Pipe - With Splash Fill	 0.000029 0.000045

1 These emission factors are commonly used to calculate VOC emissions for fuel dispensing stations. The Division reserves the right to use alternate emission factors or methodologies to calculate VOC emissions as warranted by site-specific conditions or other available data.

Table 2
Equation for Calculating VOC Emissions

$$VOC\ Emissions \left(\frac{pounds}{year}\right) = Throughput \left(\frac{gallons}{year}\right) X\ Emission\ Factor\ From\ Table\ 1$$

To convert "pounds per year" to "tons per year," simply divide "pounds per year" by 2000.

Example Calculation: A service station in Denver has two underground storage tanks with Stage I Vapor Recovery. The first tank, containing gasoline, has an actual throughput of 374,400 gallons per year and a requested throughput of 395,000 gallons per year. The second tank, containing diesel[2], has an actual throughput of 12,000 gallons per year and a requested throughput of 15,000 gallons per year. Calculate the facility's total VOC emissions in *tons per year* based on the actual and requested throughputs.

VOC Emissions Based on Actual Throughput:

Tank 1 - Gasoline

VOC Emissions = 374,400 (gallons/year) X 0.013 (pounds/gallon) = 4,867 pounds/year

Convert to tons VOC per year: 4,867 (pounds/year) / 2000 (pounds/ton) = 2.43 tons/year

Tank 2 - Diesel

VOC Emissions = 12,000 (gallons/year) X 0.000029 (pounds/gallon) = 0.348 pounds/year

Convert to tons VOC per year: 0.348 (pounds/year) / 2000 (pounds/ton) = 0.00017 tons/year

Total VOC Emissions

2.43 tons/year + 0.00017 tons/year = 2.43 tons/year

VOC Emissions Based on Requested Throughput:

Tank 1 - Gasoline

VOC Emissions = 395,000 (gallons/year) X 0.013 (pounds/gallon) = 5,135 pounds/year

Convert to tons VOC per year: 5,135 (pounds/year) / 2000 (pounds/ton) = 2.57 tons/year

Tank 2 - Diesel

VOC Emissions = 15,000 (gallons/year) X 0.000029 (pounds/gallon) = 0.43 pounds/year

Convert to tons VOC per year: 0.43 (pounds/year) / 2000 (pounds/ton) = 0.00022 tons/year

Total VOC Emissions

2.57 tons/year + 0.00022 tons/year = 2.57 tons/year

[2] Regulation Number 3 provides some exemptions from air emission reporting and permitting requirements for tanks containing diesel and other fuels. Contact the Division or the Small Business Assistance Program to determine if any exemptions apply to your business.

View Section : 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

SECTION 1: CHEMICAL PRODUCT and COMPANY IDENTIFICATION F2

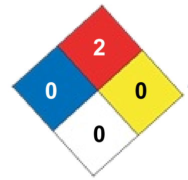
Product Name: **Sinclair Diesel**

Synonyms: No. 2 Diesel Fuel, Ultra Low Sulfur Diesel - Dyed and Undyed, Oil Distillate, Cycle Oil, Fuel Oil, Diesels Cycle Oil, Furnace Oil

CAS Number: ##1 Diesel 8008-20-6; ##2 Diesel 68476-34-6

Chemical Family: Liquid Hydrocarbons

NFPA



Manufacturer MSDS.: F2

Manufacturer Name: Sinclair Oil Corporation

Address: P.O. Box 30825
Salt Lake City, Utah 84130

EMERGENCY PHONE: CHEMTREC - (703) 527-3887 (collect)

Product Description: APPLICATIONS: Diesel - Dyed Fuel

HMIS

HEALTH	0
FIRE	2
REACTIVITY	0
PPE	

Business Phone: (888) 340-3466

Business Fax: (801) 524-2740

CHEMTREC Numbers:

For emergencies in the US, call CHEMTREC: 800-424-9300

Revision Date: January 2007.

Trade Names: Diesel

NFPA 704/HMIS:
(0=insignificant, 1=slight, 2=moderate, 3=high, 4=extreme)

Product Codes:

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SECTION 2 : COMPOSITION, INFORMATION ON INGREDIENTS F2

Ingredient Name	CAS#	Ingredient Percent
##1 Diesel: Toluene EC Index Number: 1	108-88-3	Typical: 0-0.5% by Weight
##1 Diesel: Naphthalene EC Index Number: 1	91-20-3	Typical: 0-0.5% by Weight
##2 Diesel: Toluene EC Index Number: 1	108-88-3	Typical: 0-0.5% by Weight
##2 Diesel: Naphthalene EC Index Number: 1	91-20-3	Typical: 0-0.5% by Weight
##1 Diesel EC Index Number: 1	8008-20-6	Typical: 100% by Weight
##2 Diesel EC Index Number: 1	68476-34-6	Typical: 100% by Weight

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SECTION 3 : HAZARDS IDENTIFICATION F2

Emergency Overview:	May cause eye, skin and respiratory tract irritation. Combustible liquid and vapor. Harmful or fatal if swallowed. Toxic to aquatic organisms.
Physical State:	Liquid
Color:	Colorless, red, blue, amber
Odor:	Kerosene odor

Applies to All Ingredients :

Potential Health Effects:	Trauma and burns secondary to explosions and fires can result. In enclosed spaces, oxygen may be displaced by vapors or consumed by combustion. Incomplete combustion will produce carbon monoxide and other toxic gases.
Eye Contact:	Contact may cause eye irritation. Naphthalene vapor causes eye irritation.
Skin Contact:	Contact may irritate or burn skin. Absorption through the skin may cause symptoms of intoxication, followed by kidney damage.
Inhalation:	Overexposure may cause weakness, headache, nausea, confusion, blurred vision, drowsiness and other central nervous system effects.
Ingestion:	Contact may irritate or burn skin. Absorption through the skin may cause symptoms of intoxication, followed by kidney damage.

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SECTION 4 : FIRST AID MEASURES F2

Eye Contact:	Flush immediately with water for at least 15 minutes. Seek medical attention promptly.
Skin Contact:	Discard contaminated leather articles. Wash contact areas with soap and water. Launder contaminated clothing before reuse.
Inhalation:	Remove from further exposure. If unconsciousness occurs, seek immediate medical assistance. If breathing stops, use mouth-to-mouth resuscitation.
Ingestion:	DO NOT INDUCE VOMITING. Get medical assistance promptly. (Note to Physician: Material, if aspirated into lungs, may cause chemical pneumonitis. Treat appropriately.)
Other First Aid:	GENERAL: Remove all clothing impregnated with material immediately. Consult a physician for major exposures of inhalation or skin contact.

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SECTION 5 : FIRE FIGHTING MEASURES F2

Flash Point:	100 deg F Minimum
Upper Flammable or Explosive Limit:	6.0
Lower Flammable or Explosive Limit:	1.3
Auto Ignition Temperature:	490 deg F - 545 deg F
Flammability Class:	Combustible Liquid
Hazardous Combustion Byproducts:	May produce carbon monoxide.
Fire Fighting Instructions:	Use foam, dry chemical, CO_2, water fog or vaporizing liquid (Halon). Keep personnel removed from and up-wind of fire. Cool adjacent structures and storage drums with water spray. Evacuate area. Prevent runoff from fire control dilution from entering streams or drinking water supply.
Fire Fighting Equipment:	Use of SCBA in enclosed or confined spaces, or as otherwise needed. Bunker gear.
GENERAL HAZARD:	Incomplete burning can produce carbon monoxide. Vapors will be released above flash point and when mixed with air, can burn or explode in confined space if exposed to sources of ignition.

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SECTION 6 : ACCIDENTAL RELEASE MEASURES F2

Land Spill:	Shut off and eliminate all ignition sources. Keep people away. Remove leaking containers to a safe area. Contain and remove by mechanical means. Add sand, earth or other suitable absorbent to spill area than scrape off the ground. Guard against contamination of water supplies. Report spills to appropriate authorities. Dispose of in accordance with Federal, State and Local regulations.
Water Spill:	Spill may be removed from water with mechanical dredges or lifts. Report spills to appropriate authorities. Dispose of in accordance with Federal, State and Local regulations.

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SECTION 7 : HANDLING and STORAGE F2

Handling:	When handling use non-sparking tools and equipment. Do not use as a cleaner or solvent, use only as fuel. Do not siphon by mouth.
Storage:	Ground and bond all transfer and storage equipment. Drums must be grounded/bonded/equipped with self-closing valves, pressure vacuum bungs and flame arrestors. Store away from ignition sources in a cool area. Outside or detached storage is preferred.

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SECTION 8 : EXPOSURE CONTROLS, PERSONAL PROTECTION F2

Engineering Controls:	Provide ventilation sufficient to prevent exceeding recommended exposure limit or build-up of explosive concentrations of vapor in air. Use explosion-proof equipment.
Personal Protective Equipment Routine Handling:	If contact is likely the following protective clothing and equipment is recommended.
Protective Clothing/Body Protection:	Use full-face shield, chemical goggles, impervious gloves, boots and whole body protection.
Respiratory Protection:	Approved respiratory protection must be used when vapors or mist concentrations are unknown or exceed the TLV. Avoid prolonged or repeated breathing of vapor or mists.
Exposure Limits:	COMPONENT: Diesel ACGIH_TLV: 100 mg/M3 NOTATION: A3 OTHER: Skin, Irritation COMPONENT: Toluene OSHA_PEL: 200 ppm CEILING: 300 ppm COMPONENT: Toluene ACGIH_TLV: 50 ppm NOTATION: A4 OTHER: Skin, CNS COMPONENT: Naphthalene OSHA_PEL: 10 ppm COMPONENT: Naphthalene ACGIH_TLV: 10 ppm STEL: 15 ppm NOTATION: A4 OTHER: Skin COMPONENT: Petroleum Distillates (Naphtha) OSHA_PEL: 500 ppm
Comments:	A3 = Confirmed Animal Carcinogen with Unknown Relevance to Humans A4 = Not Classified as a Human Carcinogen CNS = Central Nervous System Skin = Absorption through the skin may contribute to overall exposure

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SECTION 9 : PHYSICAL and CHEMICAL PROPERTIES F2

Physical State/Appearance:	Liquid
Color:	Colorless, red, blue, or amber
Odor:	Kerosene odor
pH:	Not Applicable
Vapor Pressure:	< 1 PSIA
Vapor Density:	(Air = 1): > 1
Boiling Point:	550 deg F
Freezing Point:	0 deg F
Solubility:	In Water: No
Specific Gravity:	(g/ml): 0.75 - 0.90
Density:	(g/ml): 0.75 - 0.90
Viscosity:	Not Applicable Found

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SECTION 10 : STABILITY and REACTIVITY F2

Chemical Stability:	General: This product is stable.
Conditions to Avoid:	Strong acids, alkalies and oxidizers. Avoid heat, sparks, flame and static electricity.
Incompatibilities with Other Materials:	MATERIALS TO AVOID: Strong acids, alkalies and oxidizers. Avoid heat, sparks, flame and static electricity.

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SECTION 11 : TOXICOLOGICAL INFORMATION F2

Applies to All Ingredients :

Eye Effect:	ACUTE: Conjunctivitis and burning, watery eyes have been reported in acute exposures to various hydrocarbon fuels and oils.
Skin Effects:	ACUTE: Mild erythema to full thickness chemical burns have occurred after prolonged exposure to various hydrocarbon fuels and oils.
Ingestion Effects:	ACUTE: Central nervous system, cardiovascular, and respiratory effects have been reported with acute exposures to various hydrocarbon fuels and oils similar to those reported with inhalation. Nausea, vomiting, cramping and diarrhea may occur.
Inhalation Effects:	ACUTE: Headaches, confusion, disorientation, blurred vision occur with inhalation. Higher exposures may cause hallucinations, CNS excitation, drowsiness, CNS depression. Seizure and coma occur from very high exposures and death may result from respiratory depression. ECG changes, cardiac arrhythmias, tachycardia, shock and cardiovascular collapse can occur. Pneumonia, pulmonary edema and hemorrhages can occur.

	Inhalation of 8000-16000 mg/m3 for 2 to 4 hours was lethal to rats.
Chronic Effects:	Chronic dermatitis with acanthosis, inflammation, parakeratosis and hyperkeratosis have occurred with chronic exposures to various hydrocarbon fuels and oils.
Carcinogenicity:	Occupational exposures in petroleum refining are considered Group 2A (probably carcinogenic) by IARC.
Other Toxicological Information:	Systemic: Petroleum-derived fuels and fuel oils are complex and variable mixtures of hydrocarbons. In general, the more viscous the mixture, the less toxic it will be. At high level exposures, humans experience multiple organ failures, some of which may be due to hypoxia and secondary to the failure of other organ systems. In humans kidney failure has been noted only at high, acute levels of exposures, and appears reversible. Liver enzymes may be transiently elevated. At lower level exposures, most acute health effects are reversible. People can be exposed by inhalation, ingestion and dermal contact. Frequently, people are exposed by combined dermal and inhalation exposure.

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SECTION 12 : ECOLOGICAL INFORMATION F2

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SECTION 13 : DISPOSAL CONSIDERATIONS F2

Waste Disposal:	Dispose of in accordance with Federal, State, and Local regulations.
RCRA Hazard Class:	Disposal of this product or material contaminated with this product may be regulated by RCRA due to the characteristic of ignitability.
EPA Waste Number:	EPA Hazard Class: Acute Hazard/Chronic Hazard/Fire Hazard

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SECTION 14 : TRANSPORT INFORMATION F2

DOT Shipping Information:	DOT (Department of Transportation):
DOT Shipping Name:	Combustible Liquid nos (Diesel ##1, Diesel ##2)
DOT Hazard Class:	Combustible Liquid
DOT Identification Number:	UN 1993
DOT Packing Group:	PG III
NAERG Number:	NAERG96 NUMBER: 128

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SECTION 15 : REGULATORY INFORMATION F2

Applies to all ingredients:

Section 304:	CERCLA (Comprehensive Environmental Response Compensation and Liability Act): Naphthalene and Toluene are hazardous substances under CERCLA and therefore are subject to emergency notification requirements.
Section 312 Hazard Category:	SARA TITLE III (Superfund Amendments and Reauthorization Act): Naphthalene and Toluene are subject to SARA Title III, Sections 311 and 312, which require MSDS reporting and hazardous chemical inventory reporting.
Section 313 Toxic Release Form:	Naphthalene and Toluene are also subject to SARA Title III, Section 313, which requires chemical release reporting.
OSHA 29 CFR 1200:	MEETS THE REQUIREMENTS OF THE HAZARDOUS COMMUNICATION PROVISIONS OF SARA TITLE III AND 29CFR1910.1200(g) OF THE OSHA REGULATIONS.

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SECTION 16 : ADDITIONAL INFORMATION F2

HMIS:	
Health Hazard:	0
Fire Hazard:	2
Reactivity:	0
NFPA:	
Health:	0
Fire Hazard:	2
Reactivity:	0
MSDS Revision Date:	January 2007.
	REVISION SUMMARY: Complete review of MSDS, January 2007.

Disclaimer:

THIS PRODUCT MATERIAL SAFETY DATA SHEET PROVIDES HEALTH AND SAFETY INFORMATION. THE PRODUCT SHOULD BE USED IN APPLICATIONS CONSISTENT WITH THIS PRODUCT LITERATURE. FOR ANY OTHER USES, EXPOSURES SHOULD BE EVALUATED SO THAT APPROPRIATE HADLING PRACTICES AND TRAINING PROGRAMS CAN BE ESTABLISHED TO ENSURE SAFE WORKPLACE OPERATIONS.

THIS MATERIAL SAFETY DATA SHEET IS PROVIDED IN GOOD FAITH AND MEETS THE REQUIREMENTS OF THE HAZARDOUS COMMUNICATION PROVISIONS OF SARA TITLE III AND 29CFR1910.1200(g) OF THE OSHA REGULATIONS. THE ABOVE INFORMATION IS BASED ON REVIEW OF AVAILABLE INFORMATION SINCLAIR BELIEVES IS RELIABLE AND IS SUPPLIED FOR INFORMATIONAL PURPOSES ONLY. SINCLAIR DOES NOT GUARANTEE ITS COMPLETENESS OR ACCURACY. SINCE CONDITIONS OF USE ARE OUTSIDE THE CONTROL OF SINCLAIR, SINCLAIR DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, AND ANY LIABILITY FOR DAMAGE OR INJURY WHICH RESULTS FROM THE USE OF THE ABOVE DATA. NOTHING HEREIN IS INTENDED TO PERMIT INFRINGEMENT OF VALID PATENTS AND LICENSES.

NFPA 704/HMIS: (0=insignificant, 1=slight, 2=moderate, 3=high, 4=extreme)

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SECTION 1: CHEMICAL PRODUCT and COMPANY IDENTIFICATION F1

Product Name: **Gasoline**
Synonyms: Regular, Premium, Subgrade, Motor Fuel, Gasohol

CAS Number: 8006-61-9

Chemical Family: Liquid Hydrocarbon

Manufacturer MSDS.: F1
Distributor Name: Sinclair Oil Corporation
Distributor Address: P.O. Box 30825
Salt Lake City, Utah 84130

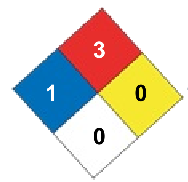
EMERGENCY PHONE: CHEMTREC – (800) 424-9300 or (703) 527-3887 (collect)

FAX: (801) 524-2740

Distributor Telephone: (888) 340-3466
Revision Date: December 2005
Supersedes: December 2002
Trade Names: Gasoline

Manufacturer Name: Sinclair Oil Corporation
General Use: APPLICATIONS: Automotive Gasoline
NFPA 704/HMIS:
(0 = insignificant, 1 = slight, 2 = moderate, 3 = high, 4 = extreme)

NFPA



HMIS

HEALTH	1
FIRE	3
REACTIVITY	0
PPE	

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SECTION 2 : COMPOSITION, INFORMATION ON INGREDIENTS F1

Ingredient Name	CAS#	Ingredient Percent
Regular Unleaded Gasoline including: EC Index Number: 1	8006-61-9	Typical: 100.0% by Weight
Cyclohexane EC Index Number: 1	110-82-7	Typical: 0.5% by Weight
Benzene EC Index Number: 1	71-43-2	Typical: 3.0% by Weight
Toluene EC Index Number: 1	108-88-3	Typical: 10.0% by Weight
Xylene EC Index Number: 1	1330-20-7	Typical: 6.5% by Weight
Trimethyl Benzene EC Index Number: 1	25551-13-7	Typical: 7.0% by Weight
Napthalene EC Index Number: 1	91-20-3	Typical: 0.2% by Weight
Ethyl Alcohol EC Index Number: 1	64-17-5	Typical: 10.0% by Weight

Premium Unleaded Gasoline including: EC Index Number: 1	8006-61-9	Typical: 100.0% by Weight
Cyclohexane EC Index Number: 1	110-82-7	Typical: 0.2% by Weight
Benzene EC Index Number: 1	71-43-2	Typical: 4.0% by Weight
Toluene EC Index Number: 1	108-88-3	Typical: 13.7% by Weight
Xylene EC Index Number: 1	1330-20-7	Typical: 12.7% by Weight
Trimethyl Benzene EC Index Number: 1	25551-13-7	Typical: 11.9% by Weight
Napthalene EC Index Number: 1	91-20-3	Typical: 0.3% by Weight
Ethyl Alcohol EC Index Number: 1	64-17-5	Typical: 10.0% by Weight

Gasoline consists of a complex blend of paraffinic, olefinic, napthenic, and aromatic hydrocarbons which may contain up to 5% benzene and dosages of multi-functional additives. May contain 0-10% ethanol.

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SECTION 3 : HAZARDS IDENTIFICATION F1

Emergency Overview: Extremely flammable liquid and vapor. Vapors may cause flash fire. Harmful or fatal if swallowed and may cause lung damage if aspirated. Causes skin and eye irritation. Long term exposure may have caused cancer in laboratory animals. Keep away from children. Toxic to aquatic organisms.

Physical State: Liquid/Vapor

Color: Clear, bronze, Red, yellow, or purple color

Odor: Strong hydrocarbon odor

Applies to All Ingredients :

Potential Health Effects: Trauma and burns secondary to explosions and fires can result. In enclosed spaces, oxygen may be displaced by vapors or consumed by combustion. Incomplete combustion will produce carbon monoxide and other toxic gases.

Eye Contact: May cause eye irritation.

Skin Contact: Contact may irritate or burn skin. Repeated contact may cause skin to become dry & scaly.

Inhalation: High vapor concentrations are possible and can be hazardous on single exposure. Overexposure may cause weakness, headache, nausea, confusion, blurred vision, drowsiness and other central nervous system effects. Extremely high-level exposure may result in dizziness, irregular heartbeat, coma, collapse and death.

Ingestion: If aspirated (liquid enters lung) following ingestion, severe lung irritation and pulmonary edema (swelling of lung tissue) may occur. Aspiration may also result in central nervous system depression or excitement. Serious, permanent lung damage may result. Nausea, vomiting, diarrhea, or abdominal pain may occur following ingestion.

Carcinogenicity: Gasoline mixtures are not listed as carcinogenic by NTP, OSHA and, ACGIH. Gasoline mixtures are listed as a possible carcinogen by IARC (2B) and NIOSH. Benzene is listed as a confirmed human carcinogen by IARC, NTP, OSHA, NIOSH and, ACGIH.

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SECTION 4 : FIRST AID MEASURES F1

Eye Contact:	Flush immediately with water for at least 15 minutes. Seek medical attention promptly.
Skin Contact:	Discard contaminated leather articles. Wash contact areas with soap and water. Launder contaminated clothing before reuse.
Inhalation:	Remove from further exposure. If unconsciousness occurs, seek immediate medical assistance. If breathing stops, use mouth-to-mouth resuscitation.
Ingestion:	DO NOT INDUCE VOMITING. Get medical assistance promptly. (Note to Physician: Material, if aspirated into lungs, may cause chemical pneumonitis. Treat appropriately.)

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SECTION 5 : FIRE FIGHTING MEASURES F1

Flash Point:	-45 deg F
Upper Flammable or Explosive Limit:	7.6%
Lower Flammable or Explosive Limit:	1.4%
Auto Ignition Temperature:	530 deg F+
Flammability Class:	Flammable Liquid
Hazardous Combustion Byproducts:	May produce carbon monoxide.
Fire Fighting Instructions:	Use CO2, foam, dry chemical, Halon, or water fog. Keep personnel removed from and up-wind of fire. Cool adjacent structures and storage drums with water spray. Evacuate area. Prevent runoff from fire control dilution from entering streams or drinking water supply. A vapor suppressing foam may be used to reduce vapors.
Fire Fighting Equipment:	Fire fighters should use SCBA and full protective equipment (Bunker gear).
	GENERAL HAZARD: Incomplete burning can produce carbon monoxide. This is an extremely flammable liquid; vapor accumulation could flash and/or explode if it comes into contact with open flame.

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SECTION 6 : ACCIDENTAL RELEASE MEASURES F1

Land Spill:	Treat spill as an oil spill. Eliminate all sources of ignition. Remove leaking containers to a safe area. Contain and remove by mechanical means. Guard against contamination of water supplies. Report spills to appropriate authorities. Dispose of in accordance with Federal, State, and Local regulations.
Water Spill:	Treat spill as an oil spill. Report spills to appropriate authorities. Dispose of in accordance with Federal, State, and Local regulations.

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SECTION 7 : HANDLING and STORAGE F1

Handling:	When handling, use non-sparking tools and equipment. Do not use as a cleaner or solvent. Use only as motor fuel. DO NOT SIPHON BY MOUTH.
Storage:	Ground and bond all transfer and storage equipment. Drums must be grounded/bonded/equipped with self-closing valves, pressure vacuum bungs and flame arrestors. Store away from ignition sources in a cool area. Outside or detached storage is preferred. Containers should be labeled: FLAMMABLE. VAPOR HARMFUL. Improper filling of portable gasoline containers creates a danger of fire. Only dispense gasoline into approved and properly labeled gasoline containers. Always place portable containers on the ground while filling. Ensure pump nozzle is in contact with the container while filling. Do not use the nozzle's lock open device. Do not fill portable containers that are inside a vehicle or trailer/truck bed.

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SECTION 8 : EXPOSURE CONTROLS, PERSONAL PROTECTION F1

Engineering Controls:	Assure adequate natural or mechanical ventilation. Eliminate all sources of ignition.
Personal Protective Equipment Routine Handling:	If contact is likely, the following protective clothing and equipment is recommended.
Protective Clothing/Body Protection:	Use full-face shield, chemical goggles, impervious gloves, boots, and whole-body protection.
Respiratory Protection:	Approved respiratory protection must be used when vapors or mist concentrations are unknown or exceed the TLV. Avoid prolonged or repeated breathing of vapor or mists.
Exposure Limits:	COMPONENT: Gasoline LIMIT: ACGIH_TLV TWA: 300ppm STEL: 500ppm NOTATION: A3 COMPONENT: Gasoline

LIMIT: OSHA_PEL
TWA: 300ppm

COMPONENT: Gasoline
LIMIT: ACGIH_TLV
TWA: 100ppm
OTHER: CNS

COMPONENT: Benzene
LIMIT: OSHA_PEL
TWA: 1ppm
STEL: 5ppm

COMPONENT: Benzene
LIMIT: OSHA_Z2
TWA: 10ppm
CEILING: 25ppm

COMPONENT: Benzene
LIMIT: ACGIH_TLV
TWA: 0.5ppm
STEL: 2.5ppm
NOTATION: A1
OTHER: Skin

COMPONENT: Toluene
LIMIT: OSHA_PEL
TWA: 200ppm
CEILING: 300ppm

COMPONENT: Toluene
LIMIT: ACGIH_TLV
TWA: 50ppm
NOTATION: A4
OTHER: Skin, CNS

COMPONENT: Xylene
LIMIT: OSHA_PEL
TWA: 100ppm

COMPONENT: Xylene
LIMIT: ACGIH_TLV
TWA: 100ppm
STEL: 150ppm
NOTATION: A4
OTHER: Irritation

COMPONENT: Trimethyl Benzene
LIMIT: ACGIH_TLV
TWA: 25ppm
OTHER: Irritation, CNS

COMPONENT: Naphthalene
LIMIT: OSHA_PEL
TWA: 10ppm

COMPONENT: Naphthalene
LIMIT: ACGIH_TLV
TWA: 10ppm
STEL: 15ppm
NOTATION: A4
OHTER: Skin

COMPONENT: Ethyl Alcohol
LIMIT: OSHA_PEL
TWA: 1000ppm

COMPONENT: Ethyl Alcohol
LIMIT: ACGIH_PEL
TWA: 1000ppm
NOTATION: A4
OTHER: Irritation

A1=Confirmed Human Carcinogen
A3=Confirmed Animal Carcinogen with Unknown Relevance to Humans
A4=Not Classified as a Human Carcinogen
CNS=Central Nervous System
Skin=Absorption through the skin may contribute to overall exposure

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SECTION 9 : PHYSICAL and CHEMICAL PROPERTIES F1

Color:	Clear/bronze/red/yellow/purple
Physical State:	Liquid
pH:	Not Applicable
Vapor Pressure:	7-15 PSIA
Vapor Density:	(Air=1): > 1
Boiling Point:	230 deg F
Freezing Point:	-76 deg F
Solubility:	IN WATER: Negligible
Specific Gravity:	(g/ml): 0.65 – 0.75
Density:	(g/ml): 0.65 – 0.75

Viscosity:	No Applicable found

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SECTION 10 : STABILITY and REACTIVITY F1

Chemical Stability:	This product is stable
Conditions to Avoid:	Avoid Halogens, strong acids, alkalies, and oxidizers. Also keep away from heat, sparks, flame and static electricity.
Incompatibilities with Other Materials:	MATERIALS TO AVOID: Avoid Halogens, strong acids, alkalies, and oxidizers. Also keep away from heat, sparks, flame and static electricity.
Hazardous Decomposition Products:	Incomplete burning can produce carbon monoxide

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SECTION 11 : TOXICOLOGICAL INFORMATION F1

Applies to All Ingredients :

Eye Effect:	ACUTE: Eye irritation to atomized gasoline has been noted at 200, 500 and 1000 mg/m for 30 minutes and after an 8-hour exposure to 140 ppm. Atomized gasoline has the same composition as liquefied gasoline while gasoline vapors are different. Conjunctivitis has been reported after 1 hour of exposure to 900 ppm.
Skin Effects:	ACUTE: Mild erythema to full thickness chemical burns have occurred after prolonged exposure to arious hydrocarbon fuels and oils.
Ingestion Effects:	ACUTE: Central nervous system, cardiovascular, and respiratory effects have been reported with acute exposures to various hydrocarbon fuels and oils similar to those reported with inhalation. Nausea, vomiting, cramping and diarrhea may occur.
Inhalation Effects:	ACUTE: Headaches, confusion, disorientation, blurred vision occur with inhalation. Higher exposures may cause hallucinations, CNS excitation, drowsiness, CNS depression. Seizure and coma occur from very high exposures and death may result from respiratory depression. ECG changes, cardiac arrhythmias, tachycardia, shock and cardiovascular collapse can occur. Pneumonia, pulmonary edema and hemorrhages can occur.
Chronic Effects:	Chronic exposure results in kidney damage in male rats. However, this damage appears to be related to a protein produced in large amounts in male rats, but not in humans or female rats. Occupational exposures in petroleum refining are considered Group 2A (probably carcinogenic) by IARC. Liver and kidney tumors have been noted in animals. Data is less clear in humans because of confounding factors in epidemiological studies. Some components (e.g. benzene) are known carcinogens. Contains benzene, a known human carcinogen, which can be toxic to the blood and blood-forming organs.
Other Toxicological Information:	SYSTEMIC: Petroleum-derived fuels and fuel oils are complex and variable mixtures of hydrocarbons. In general, the more viscous the mixture, the less toxic it will be. At high-level exposures, humans experience multiple organ failures, some of which may be due to hypoxia and secondary to the failure of other organ systems. In humans, kidney failure has been noted only at high, acute levels of exposures and appears reversible. Liver enzymes may be transiently elevated. At lower level exposures, most acute health effects are reversible. People can be exposed by inhalation, ingestion and dermal contact. Frequently, people are exposed by combined and inhalation exposure.

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SECTION 12 : ECOLOGICAL INFORMATION F1

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SECTION 13 : DISPOSAL CONSIDERATIONS F1

Waste Disposal:	Dispose of in accordance with Federal, State, and Local regulations.
RCRA Hazard Class:	Disposal of this product or material contaminated with this product may be regulated by RCRA due to the characteristic of ignitability or due to the toxicity characteristic of benzene (D018). EPA Hazard Class: Acute Hazard/Chronic Hazard/Fire Hazard

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SECTION 14 : TRANSPORT INFORMATION F1

DOT Shipping Name:	Gasoline
DOT Hazard Class:	3 Flammable Liquid
DOT Identification Number:	UN 1203
DOT Packing Group:	II
NAERG Number:	128

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SECTION 15 : REGULATORY INFORMATION F1

Applies to all ingredients:

Section 304: CERCLA (Comprehensive Environmental Response Compensation and Liability Act):): The following components are hazardous substances in CERCLA and therefore are subject to emergency notification requirements:
Benzene
Cyclohexane
Naphthalene
Toluene
Xylene

Section 312 Hazard Category: SARA TITLE III (Superfund Amendments and Reauthorization Act): The following components are subject to SARA Title III, Sections 311 and 312, which require MSDS reporting and hazardous chemical inventory reporting:
Benzene
Cyclohexane
Ethyl Alcohol
Naphthalene
Toluene
Trimethyl Benzene
Xylene

Section 313 Toxic Release Form: The following components are subject to SARA Title III, Section 313, which requires chemical release reporting:
Benzene
Cyclohexane
Methy-tert-butyl ether
Naphthalene
Toluene
Trimethyl Benzene
Xylene

OSHA 29 CFR 1200: The following components are subject to OSHA 29CFR1910.1200 Hazard Communication Standard:
Benzene* 1
Cyclohexane 2
Ethyl Alcohol 2
Naphthalene 2
Toluene 2
Trimethyl Benzene 2
Xylene 2

(1)* Benzene has been identified by NIOSH, IARC, NTP as a human carcinogen. Refer to 29CFR1910.1000 Table Z-2 and 29CFR1910.1028 for information.

(2) Consult MSDS or NIOSH Occupational Guidelines for more information.

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SECTION 16 : ADDITIONAL INFORMATION F1

HMIS:

Health Hazard:	1 = Slight
Fire Hazard:	3 = High
Reactivity:	0 = Insignificant

NFPA:

Health:	1 = Slight
Fire Hazard:	3 = High
Reactivity:	0 = Insignificant

MSDS Revision Date: December 2005
Supersedes: December 2002

REVISION SUMMARY:
Complete review of MSDS, December 2002.

Disclaimer:

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NFPA 704/HMIS:
(0 = insignificant, 1 = slight, 2 = moderate, 3 = high, 4 = extreme)

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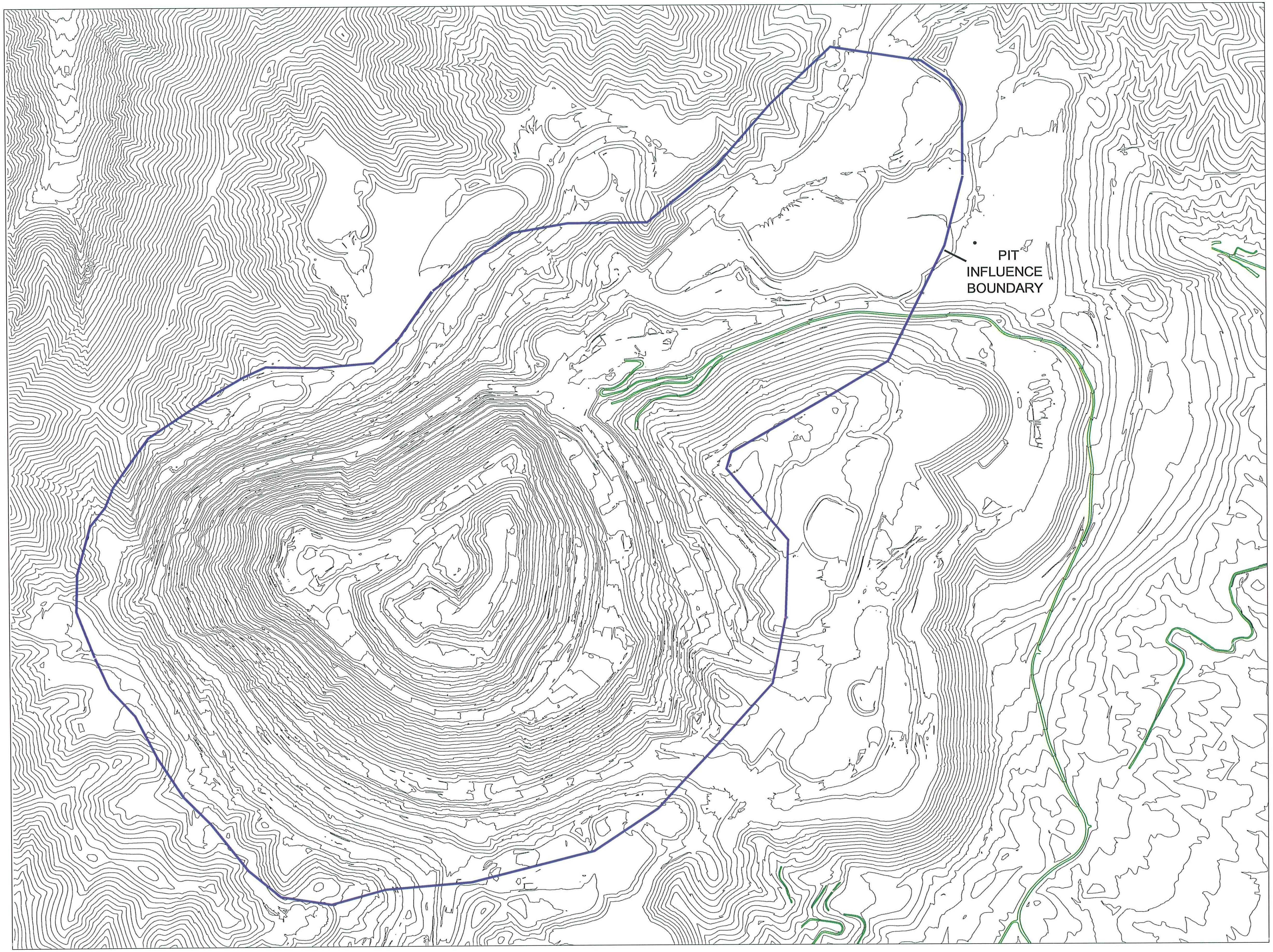
APPENDIX B-3

Pit Influence Boundary



KENNECOTT UTAH
COPPER
BINGHAM CANYON
COPPER MINE

PIT AREA

AUG 12, 2010

APPENDIX C

AERMOD Report

Report

Bingham Canyon Mine Expansion

AERMOD Modeling Analysis

Submitted to

Utah Division of Air Quality

Prepared for

Kennecott Utah Copper Corporation

PO Box 6001
Magna, Utah 84044-6001

CH2MHILL

215 S. State Street, Suite 1000
Salt Lake City, Utah 84111

1.0 Introduction

The Bingham Canyon Mine (BCM) is currently limited to an annual material throughput of 197,000,000 tons per year (tpy) for ore and waste rock combined. This limit was established by the *Notice of Intent to Increase Annual Ore and Waste Rock Production at the Kennecott Utah Copper Bingham Canyon Mine*, issued in 1999. In 2008, the Utah Division of Air Quality (UDAQ) issued Approval Order (AO) DAQE-IN0105710023-08. Condition 21.A of the 2008 AO includes the material throughput limit established in the 1999 Notice of Intent (NOI), stating that the "total material moved (ore and waste) shall not exceed 197,000,000 tons per 12-month period." To maintain the current level of metal production, Kennecott Utah Copper LLC (KUC) proposes to increase the BCM's annual throughput of ore and waste rock material to 260,000,000 tpy.

The BCM is not subject to Utah Administrative Code R307-410, which describes the emissions impact analysis requirements, since the emissions of point and fugitive sources are expected to be the same or decrease for pollutants that are in attainment for Salt Lake County. As a result, dispersion modeling is not required for the requested increase in material throughput to maintain the current level of metal production. However, KUC is submitting this near-field modeling analysis demonstrating that particulate matter less than 10 micrometers in aerodynamic diameter (PM_{10}) impacts from the proposed project will not violate the near-field National Ambient Air Quality Standards (NAAQS) near the mine.

The BCM's potential to emit (PTE) emissions after the increase in material throughput to 260,000,000 tpy of ore and waste rock are also summarized in Table 3-16 of the NOI. Appendix B-1 summarizes the emission rates used in the modeling analysis.

1.1 Regulatory Status

The BCM is located in an area that is classified as a nonattainment area for sulfur dioxide (SO_2) and for particulate matter (PM) less than 10 micrometers in aerodynamic diameter (PM_{10}); it is classified as a maintenance area for 8-hour ozone. The PM_{10} NAAQS are listed in Table C-1.

TABLE C-1
National Ambient Air Quality Standards

Averaging Period/ Pollutant	NAAQS ($\mu g/m^3$)	Significant Monitoring Concentrations ($\mu g/m^3$)
24-hour PM_{10}	150[a]	10
Annual PM_{10}	NS	NS

NOTES:
$\mu g/m^3$ = microgram per cubic meter
NS = no standard
[a] Not to be exceeded more than once per year on average over 3 years

1.2 Monitor Data

There are a number of PM_{10} ambient air quality monitors in the vicinity of Salt Lake City and Provo, Utah. Since the BCM is located outside of each city, KUC operates a PM_{10} ambient monitor near the city of Copperton.

Selecting a representative background PM_{10} concentration for the proposed KUC mine life extension project is critical because existing operations at the mine would be included in the modeling and need to be excluded from a representative background value. The criteria outlined in the *Federal Register* Section 40, Part 51 Appendix W, were used to determine a monitored value near the BCM site, which would include PM_{10} concentrations from (a) natural sources, (b) nearby sources other than the ones currently under consideration, and (c) unidentified sources.[1]

The Copperton, Utah, PM_{10} monitor is maintained by KUC and has records over the last 5 years. The monitor is located within the city of Copperton, Utah, and is approximately 2 kilometers east of the main mining pit. The monitoring equipment is operated and maintained by KUC staff consistent with EPA ambient monitoring requirements. Third-party audits are conducted quarterly as required by EPA monitoring requirements. The data are reported regularly to the town of Copperton. The eight highest recorded concentrations over the past 5 years are summarized in Table C-2.

TABLE C-2
Copperton, Utah PM_{10} Monitoring Data, 2003 through 2007

Rank	24-hour Monitor Value ($\mu g/m^3$)	Date
1	139.3	May 18, 2007
2	93.9	September 10, 2005
3	81.5	July 21, 2005
4	77.8	December 30, 2003
5	67.1	July 15, 2005
6	66.9	July 6, 2005
7	65.1	October 27, 2007
8	59.1[a]	February 4, 2004

NOTES:
$\mu g/m^3$ = Microgram per Cubic Meter
[a] Used as natural background

The Copperton, Utah, data demonstrate there have not been any recorded exceedances of the PM_{10} 24-hour NAAQS over this time period. The PM_{10} NAAQS allows for one exceedance of the standard per year averaged over 3 years.

For modeling purposes, an appropriate background value for an existing facility should not allow for any overlap of existing operations in the background value. Therefore, a further analysis of the data, following 40 *Code of Federal Regulations* (CFR) 51, Appendix W, guidelines, concluded a number of the maximum recorded impacts could be discounted in

1 40 CFR 51 Appendix W Section 8.2.1(a)

regards to modeling due to natural dust events (UDAQ, 2002). Other values were eliminated from consideration for background values because they occurred during periods when the existing operations would impact the monitored value. Using these procedures, the maximum background PM_{10} value selected was 59.1 micrograms per cubic meter (µg/m^3). Appendix C-1 contains a technical memorandum for selecting the 24-hour PM_{10} concentration at Copperton for modeling and the determination of valid or invalid data based on meteorological conditions and dust events.

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2.0 Near-field Modeling

2.1 Model Selection

The U.S. Environmental Protection Agency (EPA)-approved American Meteorological Society/EPA Regulatory Model (AERMOD) Improvement Committee Model dispersion modeling system was used to evaluate near-field air quality impacts. The latest generation of the EPA's dispersion model is AERMOD Version 09292, which is recommended for predicting impacts in the near-field (within 50 kilometers) of industrial point sources as well as area and volume sources. Preprocessors associated with the AERMOD modeling system are summarized in Section 2.2.

Terrain surrounding the BCM is classified as complex terrain. Complex terrain is defined as terrain above final plume height. AERMOD is able to accurately calculate complex terrain impacts by determining the horizontal plume state and terrain following plume state impacts. The total complex terrain impact is a weighted sum of the two extreme plume states. This is an enhanced calculation algorithm embedded in AERMOD that allows the model to calculate complex terrain impacts in the same modeling framework instead of specifying the use of complex terrain algorithms in the model.

An air quality modeling analysis was conducted for the project following guidance and procedures outlined in 40 CFR 51, Appendix W (EPA, 2005), the *AERMOD Implementation Guide* (EPA, 2008), and the *Utah Division of Air Quality Modeling Guidelines* (UDAQ, 2008).

2.2 Modeling Options and Assumptions

AERMOD was used with regulatory default options as recommended in the EPA Guideline on Air Quality Models (EPA, 2005). The following supporting preprocessors for AERMOD were also used:

- AERMET (Version 06341), for processing meteorological data by UDAQ
- AERMAP (Version 09040), for extracting receptor elevations and controlling hill heights

Post-project PTE emissions were calculated on an annual throughput of 260,000,000 tons per year. Therefore, annual average daily emissions were increased by 20 percent to account for daily variability in the mine operations and to capture a worst-case day scenario for comparison to the NAAQS.

2.3 Emission Source Characterization

Emissions of PM_{10} come from a variety of different sources at the BCM. Fugitive dust is emitted from roads, haultruck loading and dumping, and ore and waste rock transfer and handling sources. Particulate PM_{10} from haultruck exhaust (tailpipe emissions) are also included.

The BCM is a very large open pit mine. Therefore, the sources located within the pit influence boundary were modeled as area sources in the AERMOD model for all emissions within the pit. The area source emissions were estimated by applying a 20 percent escape factor as discussed in Section 3 of the NOI. This escape factor was derived based on a computational fluid dynamics modeling study conducted by the University of Utah in 1996 (Appendix D). Sources outside of the mine pit influence boundary were modeled with the applicable source type. Sources outside and inside the pit influence boundary are described in Table C-3.

TABLE C-3
AERMOD Emission Sources

Source Name	Description	Source Type
Main1	Main mine pit area and haulroads inside the mine pit influence boundary.	Area source
Haulroads	Haulroads outside the mine pit influence boundary	String of volume sources
Haultruck Dumping	Haultruck dumping locations outside the mine pit influence boundary	Volume source
C6/C7 Transfer	Conveyor transfer point, baghouse. Outside pit.	Point source
C7/C8 Transfer	Conveyor transfer point, baghouse. Outside pit.	Point source
Limebin1	Lime storage. Outside pit.	Point source
Limebin2	Lime storage. Outside pit.	Point source

Particle size distributions were assigned to each source in order to account for particle deposition between the emission location and the ambient receptors. A majority of the emissions are from fugitive sources (roads, loading, dumping, hauling, and crushing) and exhaust emissions from haultrucks. Therefore, the emissions from the pit area used a particle size distribution that was proportioned based on the percentage of representative source types for each source. The representative source types at the BCM for particle size distributions were aggregate rock mining and vehicle exhaust. The EPA's *AP-42, Fifth Edition* publishes emissions factors and particle size distribution for these sources. The EPA's *AP-42*, Appendix B, Table B.2-2, Categories 1 and 2 were used to determine the particle size distributions for diesel exhaust and aggregate dust source types. Table C-4 summarizes the particle size distribution breakdown from the open pit area source.

TABLE C-4
Particle Size Distribution

Particle Size Bin[a]	Main1[b]
0 to 1	0.183
1 to 2	0.127
2 to 2.5	0.071
2.5 to 3	0.051
3 to 4	0.122
4 to 5	0.086
5 to 6	0.068
6 to 10	0.293

NOTES:
[a]Micrometers
[b]Mass fraction

Appendix B-1 summarizes the emission rate for each source included in the AERMOD modeling analysis.

The haulroads were modeled as a string of volume sources outside the main pit influence boundary. At the end of each haulroad, a single volume source was used for the truck dumping operations. Truck traffic and dumping operations were apportioned across the mine site based on communications with mine operations staff. Table C-5 summarizes the volume source parameters used for the haulroads and dump sites.

TABLE C-5
Haulroad and Dump Site AERMOD Modeling Source Parameters

Source	Number of sources	Elevation	Width (feet)	Height (feet)	Initial Horizontal Dimension (feet)	Initial Vertical Dimension (feet)
Haulroads	576	AERMAP[a]	100	40	23.256	9.302
Truck Dumping	6	AERMAP[a]	100	40	23.256	9.302

[a] The AERMAP pre-processor was used to determine base elevations for haulroads and truck dumping sources.

The PM_{10} emissions from sources outside the main pit also require a particle size distribution to account for dry deposition as well. Depending on the emissions from the source type, a particle size distribution was proportioned based on the percentage of representative source types for each group as either exhaust emissions or fugitive emissions. Table C-6 summarizes the particle size bin fractions for exhaust and fugitive aggregate emission types.

TABLE C-6
Particle Size Distributions (mass fraction of PM_{10})

Particle Bin Size (µg)	Exhaust Emissions	Fugitive Aggregate
1	0.854	0.078
2	0.063	0.137
2.5	0.021	0.078
3	0.000	0.059
4	0.021	0.137
5	0.010	0.098
6	0.000	0.078
10	0.031	0.333

Source: AP-42, Table B.2.2, Categories 1 and 3.

2.4 Receptors

The base modeling receptor grid for AERMOD modeling consisted of receptors that were placed at the ambient air boundary and Cartesian-grid receptors that were placed beyond the boundary at spacing that increases with distance from the origin. The property boundary was used as the ambient air boundary, except for along the eastern and southern property boundaries.

Because the KUC permit boundary extends into Copperton the receptor boundary was moved slightly inside of the KUC permit boundary. There are two conveyor baghouse point sources directly to the west of Copperton; therefore, the baghouse transfer points just to the west of Copperton were used to establish this eastern most ambient air boundary.

A year-round public access road crosses through the southern portion of the KUC property boundary (Butterfield Canyon Road). Therefore, receptors were placed along the road and were used as the south and southeast receptor boundary.

Additionally two discrete receptors were placed inside of the permit boundary at a small housing community just west of the baghouses and at the Ore House Saloon along West State Highway. These locations are accessible to the general public; therefore, they are considered ambient air.

Figure C-1 shows the base AERMOD receptor grid for the project. Property boundary receptors were placed at 50-meter intervals. Beyond the property boundary, receptor spacing was at 100-meter spacing from property boundary to 2 kilometers. Receptors were not placed beyond 2 kilometers for this analysis since as expected for primarily fugitive sources; previous modeling exercises for this project indicated the maximum concentrations are at or near the ambient boundary and downwind concentrations are reduced significantly beyond 2 kilometers from the facility boundary using AERMOD.

All receptors and source locations are in Universal Transverse Mercator North American Datum 1927 (NAD27), Zone 12 coordinate system.

Terrain in the vicinity of the project was accounted for by assigning base elevations and controlling hill heights to each receptor. These values are used in AERMOD to determine the horizontal plume state and terrain following plume state impacts used to determine the modeled pollutant concentrations. Digital Elevation Model (DEM) data from the U.S. Geological Survey (USGS) in 7.5-minute format (30-meter resolution or better) were used to determine receptor elevations.

AERMAP (Version 09040) was used to calculate the receptor elevations and the controlling hill heights. A sufficient AERMAP domain and DEM file selection were identified to encompass the 10 percent slope calculation recommended by the EPA to calculate the controlling hill heights in AERMAP.

2.4.1 AERMET

The AERMET preprocessor (Version 06341) was used to prepare the Herriman surface meteorological dataset provided by UDAQ. Upper air sounding data from the Salt Lake City Airport were used in conjunction with the surface data. Years 2004 through 2006 were used for this analysis and a wind rose is attached in Figure C-2.

The Herriman dataset was modified to reflect invalid data between October 1, 2004, and October 12, 2004. The wind direction sensor was inoperable during this period and UDAQ agreed to this change on May 18, 2009 (e-mail from UDAQ to CH2M HILL presented in Appendix C-3). No other changes to the data set were made.

FIGURE C-1
KUC Receptor Grid

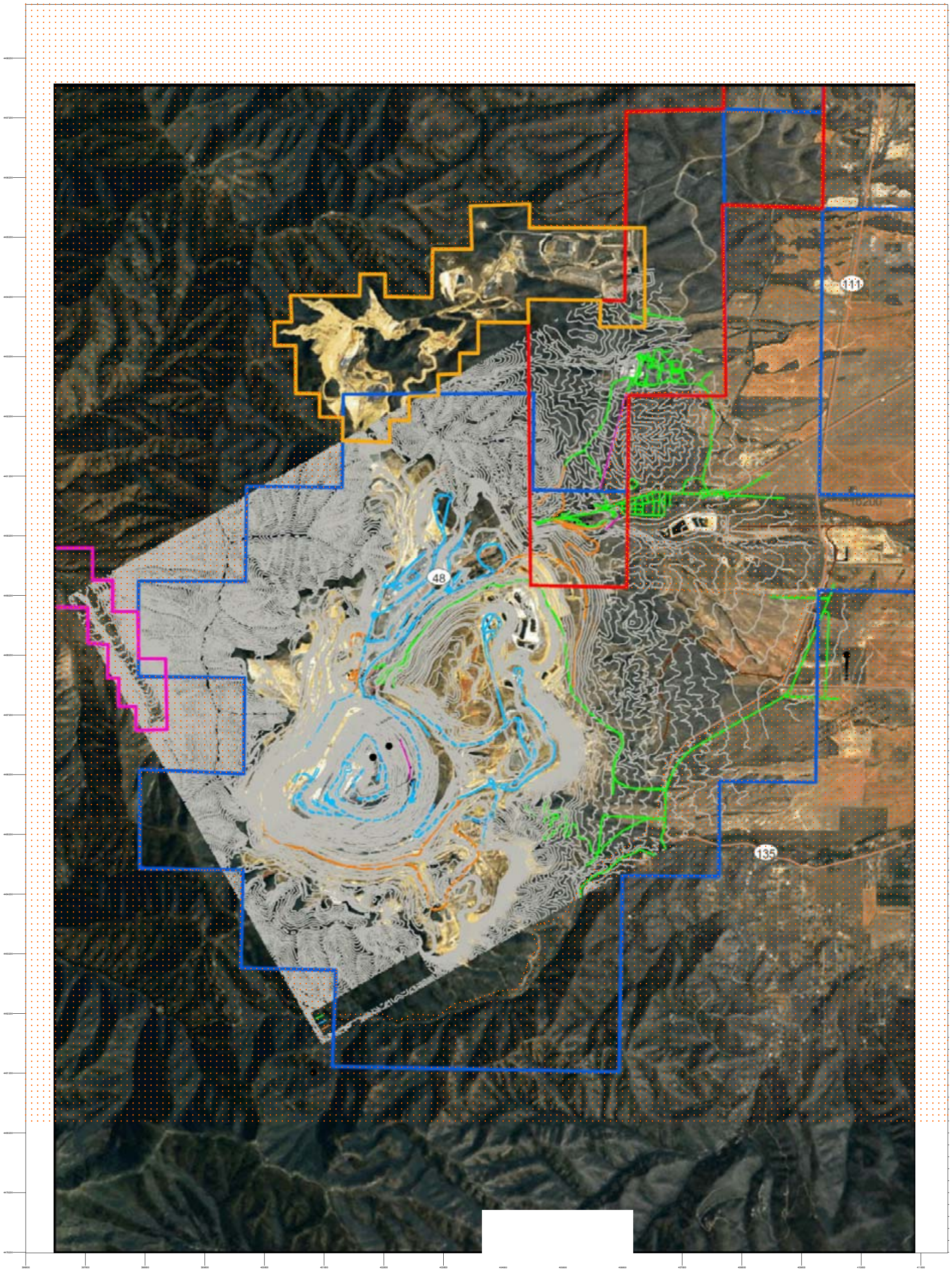
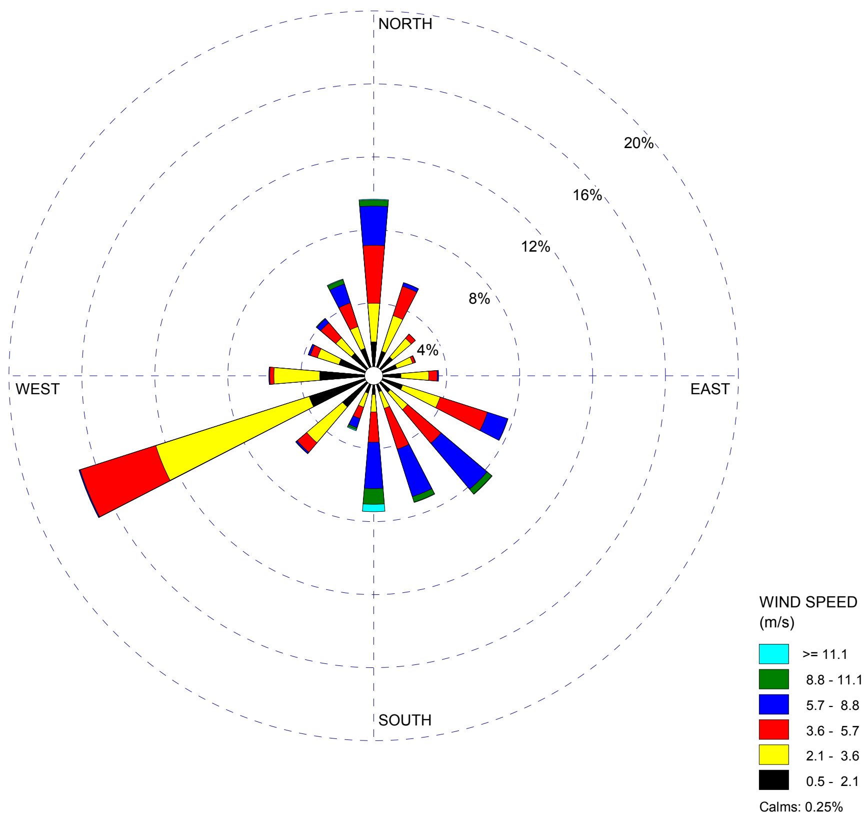


FIGURE C-2
Herriman, Utah, 4-year Wind Rose

WIND ROSE PLOT:
Herriman Meteorological Data Set
AERMET Processed Data 2004 through 2007

DISPLAY:
Wind Speed
Direction (blowing from)



COMMENTS:
10-m AGL
Processed by UDAQ

COMPANY NAME:
CH2M HILL

AVG. WIND SPEED:
3.69 m/s

PROJECT NO.:
KUC

WRPLOT View - Lakes Environmental Software

3.0 Results

As discussed previously, the PM_{10} NAAQS allows for one exceedance of the standard per year averaged over 3 years. Therefore, conservatively, the highest of the highest-second-high from each modeled year were used in conjunction with the applicable background value for comparison to the NAAQS.

The AERMOD modeling results are summarized in Table C-7. The modeling results indicate the predicted post project 24-hour PM_{10} impact from the KUC facility would be 85.1 μg/m^3.

TABLE C-7
KUC 24-hour PM_{10} AERMOD Modeling Results

2004	2005	2006
61.8	69.2	**85.1**

NOTE:
Results in μg/m^3
Bold values indicate modeled concentration used for comparison to the NAAQS.

This analysis includes some conservative assumptions in that the modeled emissions represent the total potential PM_{10} emissions from the BCM, including those from current operations. Also, a background PM_{10} concentration from the data measured at the Copperton, Utah, monitor site is added to the modeled value. It is likely that the measured data include emissions from current operations under some meteorological conditions. Therefore, addition of the modeled concentration and the background measured concentrations may be double counting some contribution from current operations.

TABLE C-8
Post-project Total 24-hour PM_{10} Impact[a]

Scenario	Modeled Concentration (μg/m^3)	Copperton, Utah, Background Concentration[a]	Total Concentration	Above 150 μg/m^3 NAAQS?
Post-project	85.1	59.1	144.2	No

NOTES:
[a]Background concentration from the Copperton, Utah, monitoring station

The results indicate that the total impact from the emissions associated with post-project maximum throughput of 260,000,000 tpy and background would result in post-project impacts of 144.2 μg/m^3. This is less than the NAAQS of 150 μg/m^3. As indicated in the Section 2.2 of the AERMOD report, these results include a 20 percent increase in the annual average daily emissions to account for variability in the daily operations.

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4.0 References

U.S. Environmental Protection Agency (EPA). 2004. AERMET User's Guide.

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APPENDIX C-1

PM_{10} Ambient Monitor Data

KUC Bingham Canyon Mine Life Extension Project PM_{10} Background Value

Kennecott Utah Copper LLC (KUC) is proposing to increase the annual rate of ore and waste rock production at the Bingham Canyon Mine (BCM) located near Copperton, Utah. This increase in production may result in an increase of particulate matter (PM) emissions, specifically emissions of PM less than 10 micrometers in aerodynamic diameter (PM_{10}), which is a criteria pollutant regulated by the state and U.S. Environmental Protection Agency (EPA). KUC will submit a modeling analysis using the EPA approved American Meteorological Society/EPA Regulatory Model (AERMOD) modeling system to demonstrate compliance with the PM_{10} National Ambient Air Quality Standards (NAAQS) standard after the proposed modification.

The modeling analysis will include total operations and the results compared to the NAAQS for PM_{10} of 150 micrograms per cubic meter (μg/m^3) for a 24-hour period[2]. This comparison will include both the modeled concentration from BCM emissions and the background PM_{10} concentrations to account for other sources of PM_{10} in the area. The proposed background value for this project is 59.1 μg/m^3.

This memorandum summarizes the top 15 monitored days for PM_{10} near the BCM site and the justification for selection of the proposed background value.

Monitored Concentrations

The Copperton, Utah, PM_{10} monitor is maintained by KUC, and data collected during the period of 2003 and 2007 were used for this analysis. The monitor is located within the City of Copperton and is approximately 2 kilometers northeast of the main mining pit. Table 1 summarizes the maximum 15 monitored 24-hour PM_{10} concentrations from the KUC PM_{10} monitor between 2003 and 2007. The data demonstrates there have not been any recorded exceedances of the PM_{10} 24-hr NAAQS over this time period. The meteorological conditions for each of the 15 days were studied in order to assess the probability that emissions from BCM sources were contributing to the monitored concentration on a given day. The prevailing meteorological conditions for each day based on data collected at both the Herriman and Salt Lake City monitoring sites are summarized in Table 1 also. Figure 1 shows the location of the Copperton PM_{10} monitor in relation to the KUC active mine site.

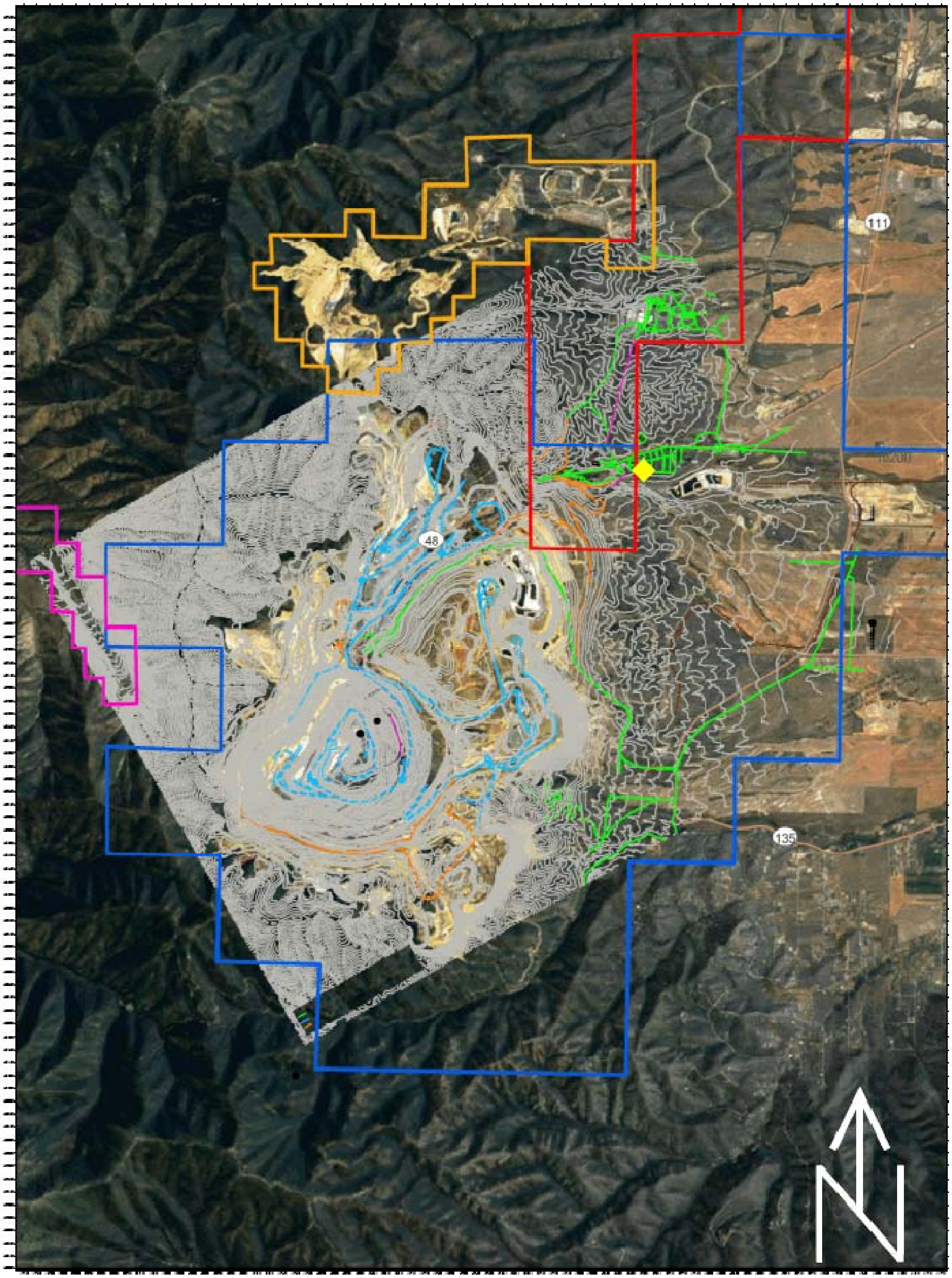
[2] The 150 μg/m^3 24-hour standard is allowed to be exceeded once per year on average over 3 years.

TABLE 1
KUC 24-Hour PM_{10} Monitored Concentrations
Top 15 Concentrations

Rank	Date	Monitored Concentration [a]	Meteorological Conditions
1	05/18/2007	139.291	Suspect: Missed Collection Period [b]
2	09/10/2005	93.941	Gusts greater than 33 mph [c], Average speed 13.1 mph, Average direction from NN [d]
3	07/21/2005	81.5	Stronger Winds from NNW, Average Speed 7.7 mph, Gust 31 mph
4	12/30/2003	77.768	Average Speed 11.4 mph, average direction from SSE
5	07/15/2005	67.1	Gusts greater than 17 mph, average speed 5.5 mph, average direction from NNW
6	07/06/2005	66.9	Gusts greater than 18 mph, average speed 7.3 mph, average direction from SE
7	10/27/2007	65.053	Gust greater than 18 mph, average speed 4.1 mph, average direction (everywhere, mostly low wind speed)
8	02/04/2004	59.136	Average Speed 7.5 mph, average direction from NW
9	03/03/2006	58.1	Gusts greater than 39 mph, average speed 15.0 mph, average direction from SSE
10	07/27/2005	57.4	Gusts greater than 17 mph, average speed 7.0 mph, average direction SSE
11	08/05/2005	57	Gusts greater than 20 mph, average speed 8.1 mph, average direction SSE
12	12/03/2004	56.797	Gust greater than 14 mph, average speed 6.0 mph, average direction from SE
13	01/27/2007	56.64	Gust greater than 10 mph, average speed 2.7 mph, average direction NNW
14	07/18/2005	56.5	Gusts greater than 22 mph, average speed 7.2 mph, average direction from SE
15	11/18/2004	55.029	Gusts greater than 14 mph, average speed 4.1 mph, average direction from SSE

NOTES:
[a] $\mu g/m^3$= Micrograms per Cubic Meter
[b] The data collected on May 18, 2007, has been invalidated since the collection period was missed. The data recovery from the site is very good (>90 percent). Therefore, invalidating this monitor value would not jeopardize the completeness of the monitored data.
[c] mph = Miles per Hour
[d] Compass rose directions. i.e. NW = northwest

FIGURE 1
KUC PM_{10} Monitor Location



PM10 Monitor Location

Representative Background Concentration for KUC Modeling

Selecting a representative background PM_{10} concentration for the proposed KUC mine expansion extension project is critical because existing operations at the mine are included in the modeling and need to be excluded from a representative background value. The criteria outlined in the Federal Register Section 40, Part 51 Appendix W, was used to determine a monitored value near the BCM site, which would include PM_{10} concentrations from (a) natural sources, (b) nearby sources other than the ones currently under consideration, and (c) unidentified sources.[3]

In addition, monitored concentration values were discarded due to nonmanmade natural dust events that occur during days with high wind gusts. The landfills and dry sand beaches along the Great Salt Lake, north of Magna, Utah, are the predominant sources of fugitive dust events.[4] Therefore, data on days with strong gusts from the north were also disregarded as a representative background value since the landfills and dry sand beaches along the Great Salt Lake would be a major contributor to the monitored background value. The identified value that fits all criteria would then be used as the representative PM_{10} background with the KUC mine life extension AERMOD modeling analysis.

The modeling would include emissions calculated for the proposed operations at the mine including haultruck traffic, conveyor transfer of ore, and dumping operations. Since many of these operations are currently conducted at the mine, the background value must not include current impacts from the mine in order to avoid double accounting for their contribution to ambient concentrations. Therefore, monitored values that include corresponding winds from the 90 degree sector upwind of the monitor location will be excluded from consideration as a representative background[5] value on the basis of condition (b) from the previous paragraph. Winds from this sector are defined as those between 180 degrees and 270 degrees, where zero degrees is defined as true north.

Wind roses for the top 10 highest PM_{10} monitored days are included in Appendix A-2. Table 2 summarizes the top 10 monitored PM_{10} concentrations and the percentage of hourly winds that blew southwest from the excluded sector during each monitored day.

Table 1 indicates the first ranked value was disregarded because of a missed collection period. Table 1 also indicates the second and third ranked values had high wind gusts (greater than 30 miles per hour) from the north. Table 2 demonstrates that the fourth through seventh highest values occurred on days with a significant percentage of winds from the southwest sector. Therefore, the top seven ranked values have been determined not representative of background for the KUC modeling analysis.

February 4, 2004, was the only day in the top 10 monitored values that did not have winds blowing from the southwest sector and/or did not have any major wind gusts from the north. Therefore, February 4, 2004, is most representative and 59.1 $\mu g/m^3$ is proposed as the 24-hour PM_{10} background concentration for the KUC modeling analysis. The proposed background concentration meets the criteria from 40 *Code of Federal Regulations* (CFR) 50 Appendix W and the Utah State Implementation Plan.

---

[3] 40 CFR 51 Appendix W Section 8.2.1(a)

[4] *Utah State Implementation Plan. Section IX, Part A.* UDAQ, Air Quality Board, 2002

[5] 40 CFR 51 Appendix W Section 8.2.2(b)

TABLE 2
Kennecott Utah Copper Corporation Wind Conditions
Top 10 Concentrations

Rank	Date	Monitored Concentration [a]	Percentage of Winds From SW Sector [b]
1	05/18/2007	139.291	Suspect [c]
2	09/10/2005	93.941	16.7% from SW sector
3	07/21/2005	81.5	4.7% from SW sector
4	12/30/2003	77.768	29.2% from SW sector
5	07/15/2005	67.1	18.2% from SW sector
6	07/06/2005	66.9	21.7% from SW sector
7	10/27/2007	65.053	8.3% from SW sector
8	02/04/2004	59.136	0.0% from SW sector
9	03/03/2006	58.1	21.6% from SW sector
10	07/27/2005	57.4	10.0% from SW sector

NOTES:
SW= Southwest
[a] $\mu g/m^3$= Micrograms per Cubic Meter
[b] Defined as the sector between 180 degrees and 270 degrees from true north
[c] The maximum monitored value was labeled suspect since a collection period was missed. No wind data were required.

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APPENDIX C-2

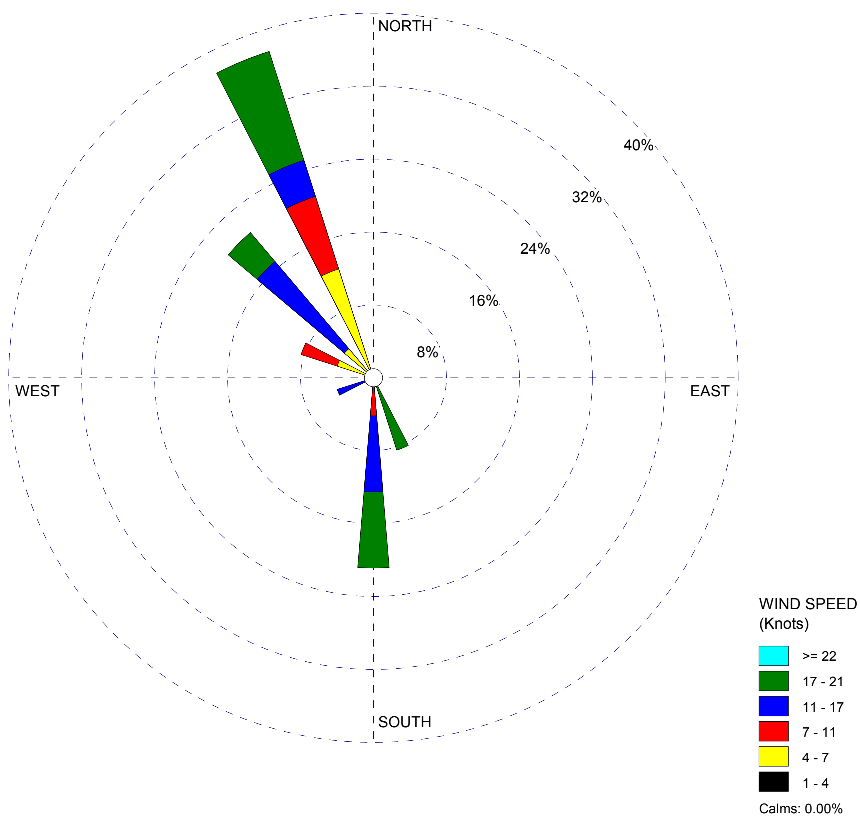
Max Day Wind Roses

WIND ROSE PLOT:

KUC
09/10/2005

DISPLAY:

Wind Speed
Direction (blowing from)



COMMENTS:

KUC Background Determination

COMPANY NAME:

CH2M HILL

AVG. WIND SPEED:

12.75 Knots

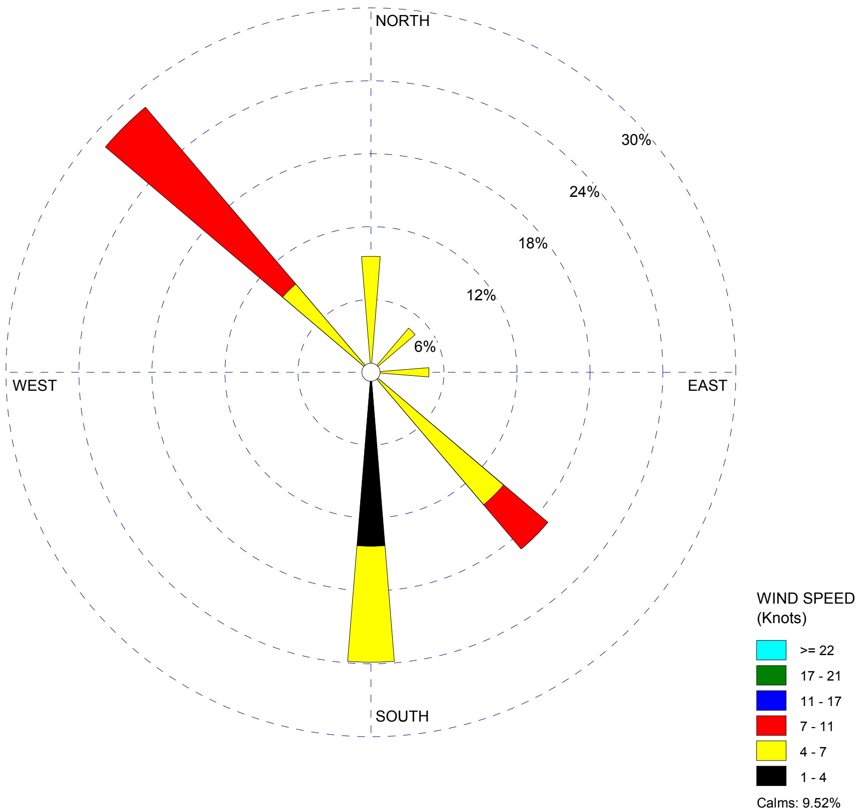
PROJECT NO.:

KUCC

WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:
KUC
07/21/2005

DISPLAY:
Wind Speed
Direction (blowing from)



COMMENTS:
KUC Background Determination

COMPANY NAME:
CH2M HILL

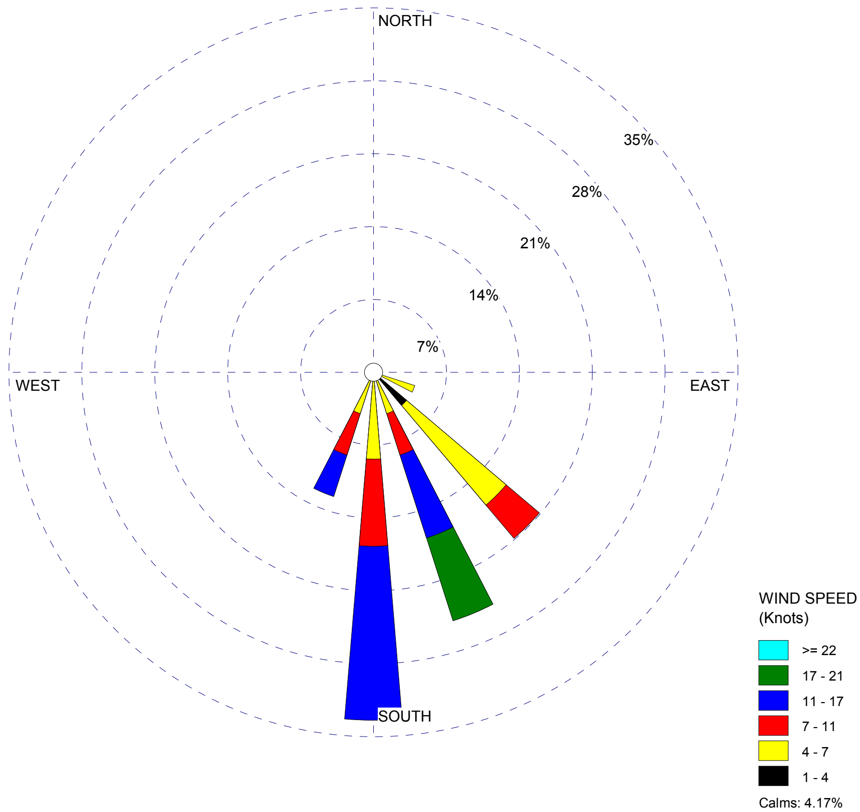
AVG. WIND SPEED:
6.30 Knots

PROJECT NO.:
KUCC

WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:
KUC
12/30/2003

DISPLAY:
Wind Speed
Direction (blowing from)



COMMENTS:
KUC Background Determination

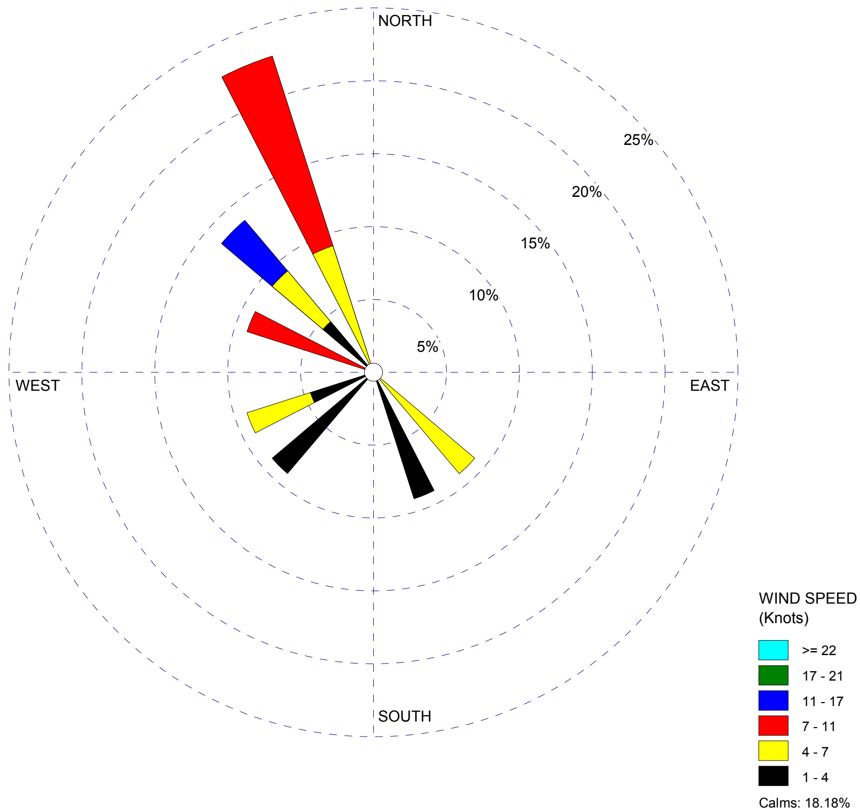
COMPANY NAME:
CH2M HILL

AVG. WIND SPEED:
9.88 Knots

PROJECT NO.:
KUCC

WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:	DISPLAY:
KUC **07/15/2005**	**Wind Speed** **Direction (blowing from)**



COMMENTS:

KUC Background Determination

COMPANY NAME:

CH2M HILL

AVG. WIND SPEED:

4.96 Knots

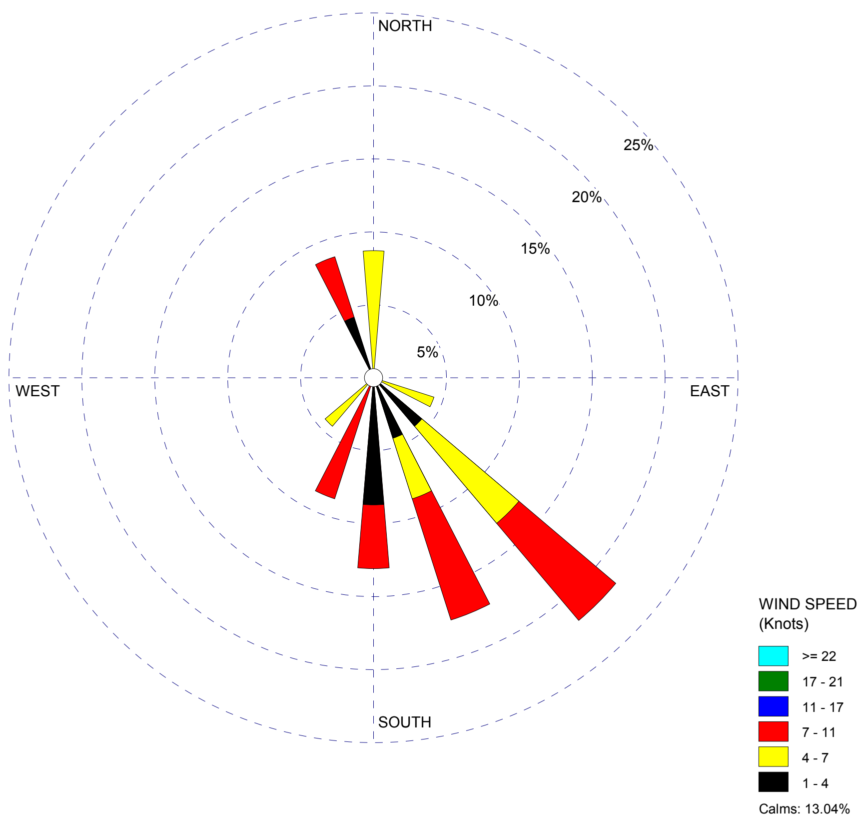
PROJECT NO.:

KUCC

WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:
KUC
07/06/2005

DISPLAY:
Wind Speed
Direction (blowing from)



COMMENTS:
KUC Background Determination

COMPANY NAME:
CH2M HILL

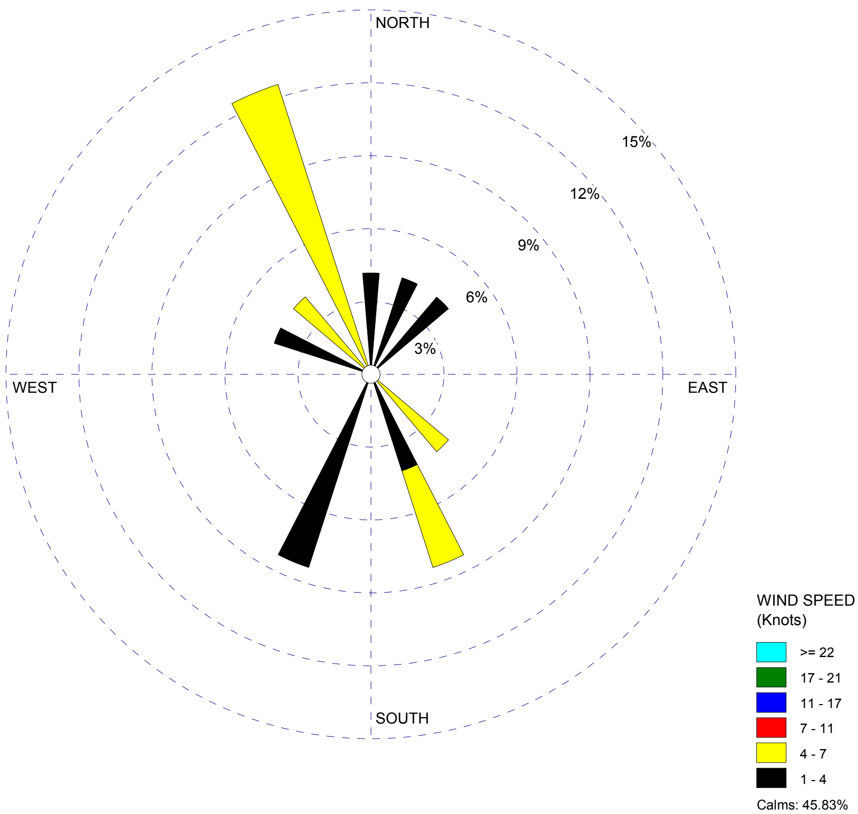
AVG. WIND SPEED:
5.76 Knots

PROJECT NO.:
KUCC

WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT:
KUC
10/27/2007

DISPLAY:
Wind Speed
Direction (blowing from)



COMMENTS:
KUC Background Determination

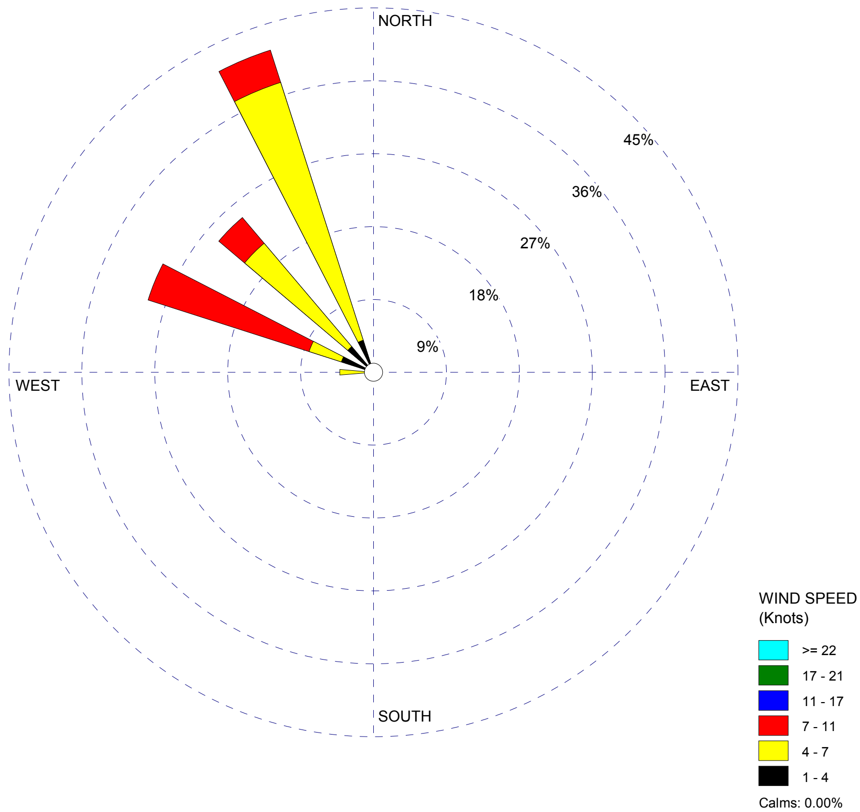
COMPANY NAME:
CH2M HILL

AVG. WIND SPEED:
2.65 Knots

PROJECT NO.:
KUCC

WRPLOT View - Lakes Environmental Software

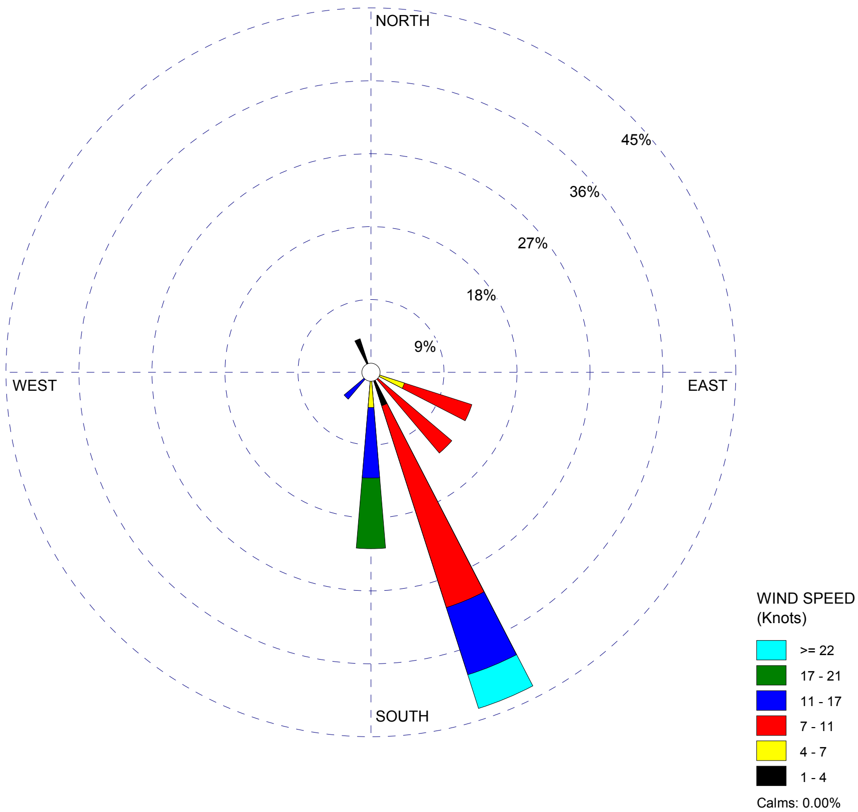
WIND ROSE PLOT: **KUC** **02/04/2004**	DISPLAY: **Wind Speed** **Direction (blowing from)**



COMMENTS: KUC Background Determination		COMPANY NAME: **CH2M HILL**	
	AVG. WIND SPEED: **6.49 Knots**		PROJECT NO.: **KUCC**

WRPLOT View - Lakes Environmental Software

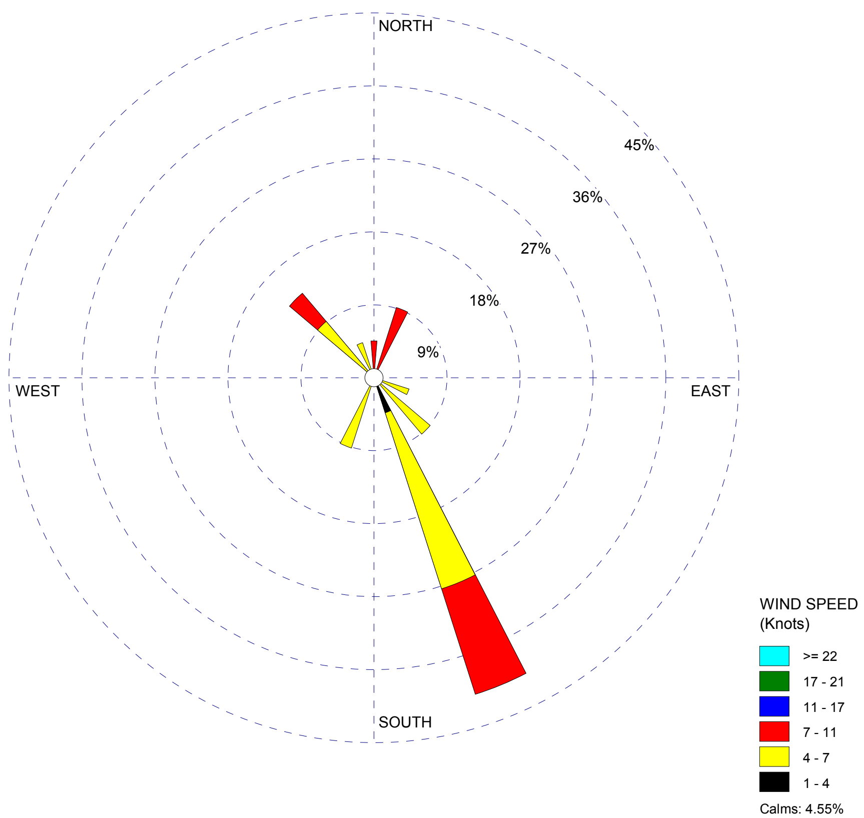
WIND ROSE PLOT:	DISPLAY:
KUC **03/03/2006**	**Wind Speed** **Direction (blowing from)**



COMMENTS:		COMPANY NAME:	
KUC Background Determination		**CH2M HILL**	
	AVG. WIND SPEED: **11.33 Knots**		PROJECT NO.: **KUCC**

WRPLOT View - Lakes Environmental Software

WIND ROSE PLOT: **KUC** **07/27/2005**	DISPLAY: **Wind Speed** **Direction (blowing from)**



COMMENTS:		COMPANY NAME:
KUC Background Determination		**CH2M HILL**
	AVG. WIND SPEED: **6.60 Knots**	PROJECT NO.: **KUCC**

WRPLOT View - Lakes Environmental Software

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APPENDIX C-3

E-mail from UDAQ

From: Tom Orth [torth@utah.gov]
Sent: Monday, May 18, 2009 10:21 AM
To: Frohning, John/SAC
Subject: RE: KUC: Comments on the AERMOD Modeling Analysis

John,

It does appear that there is a section of missing wind direction data for Oct 1 – 12 in 2004. Would recommend setting theses values to 999. to reflect missing data.

Need some further clarification on a couple of thing.

1. Please expand more in-depth how you came up with the different particle size distributions. Not sure which sections you are referring to.

2. I cannot find reason to invalidate the July 21, 2005 ambient monitoring data. The mere presents of gusting winds does not constitute voiding the data, and the wind speeds are moderate for most of the day. PM_{10} monitoring data from magna suggests that a background concentration of 80 µg/m^3 for the westside of the valley would be appropriate. Unless you have more information to support invalidating this day, I believe that the 81.5 µg/m^3 value collected on July 21, 2005 should be a valid value. I would also like more information on the sample collected on May 18, 2007 and why you feel that is not a valid sample.

I am still researching monitoring data and have not arrived at an appropriate background concentration for this analysis.

Tom Orth

Meteorologist / Air Quality Modeler
Utah Division of Air Quality
150 N. 1950 W.
Salt Lake City, Utah 84114-4820
Office Phone 801-536-4005
Cell Phone 801-414-6959
Fax. 801-536-4099
-Quality of Life Starts With Clean Air

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APPENDIX D

Airflow Patterns and Pit-Retention of Fugitive Dust for the Bingham Canyon Mine

APPENDIX D-1

Study Summary

Summary of "Airflow Patterns and Pit-Retention of Fugitive Dust for the Bingham Canyon Mine"

This memo is a summary of the 1996 report "Airflow Patterns and Pit-Retention of Fugitive Dust for the Bingham Canyon Mine" by Ragula Bhaskar and Navin Tandon, Department of Mining Engineering, University of Utah.

When particles, such as fugitive dust, are emitted within a mining pit, only a fraction of what is originally emitted ever escapes the top of the pit to enter the general atmosphere (the so-called escape fraction). Being able to predict the escape fraction for different mine characteristics (such as shape, size, and depth) and different meteorological conditions is an active area of research.

In this report the authors use a well established, commercially available Computational Fluid Dynamics (CFD) model to examine airflow patterns and pit-retention in a fully three-dimensional digital representation of the Bingham Canyon Mine. In the horizontal direction an area of 23,000 feet in the north-south direction by 20,000 feet in the east–west direction was represented. Vertically the model extended up to nearly 10,000 feet above the ground and one-half mile down to the bottom of the pit. This area, which includes the Bingham Canyon Mine and part of Bingham Canyon, was digitally entered into the model from topographic data. This was represented in the model by 19,872 nodal points and 22,862 three-dimensional elements.

The authors examine the influence that varying wind speed, wind direction, atmospheric stability, source location, source height, and particle size have on the calculated escape fraction. For the simulations they did for the Bingham Canyon Mine, the escape fraction for the pit ranged from about 10 to 20 percent. Some important points to remember are:

- Use of a standard CFD packages (FIDAP) ensures the fundaments of the Finite Element Method (FEM) code have been tested and validated.
- The FEM is more technically rigorous – with generally fewer simplifying assumptions – than used in the regulatory model, AERMOD.
- The part of the authors work that examines results from real pit geometry in comparison to results from idealized pit geometries (as were used in the development of the pit retention algorithms used in AERMOD) indicates a possibly very important limitation to the pit retention algorithm used in EPA's ISC and AERMOD models.

Selecting an Escape Factor for Use in AERMOD Modeling

Table D-1 below provides a summary of the six sensitivity analyses done by the authors. The fixed variables of the "Base Case," around which the sensitivity analyses varied, are given in the "Base Case" column. Except for source location and source height, all variations produce escape fractions of 12.6 percent or less.

TABLE D-1
Summary of Sensitivity Analyses

Variable	Base Case	Range	Escape Fraction
Wind Speed (miles per hour)	6	4	10.2%
		6	11.8%
		10	12.4%
		30	12.6%
Wind Direction	North	North	11.8%
		South	12.6%
		East	12.2%
		West	12.4%
Atmospheric Stability	D (neutrally stable)	A (unstable)	12.6%
		D (neutrally stable)	11.8%
		F (stable)	12.2%
Source Location	Pit bottom	Pit bottom	11.8%
		Pit boundary in downwind direction	19.2%
		Near in-pit crusher	16.6%
Source Height (feet)	7	7	11.8
		30	13.4
Particle Size (microns)	10	1	12.6%
		2	12.5%
		5	12.4%
		7	12.2%
		10	11.8%

In Appendix A of the study, the authors compare two so-called “worst-case” scenarios. Table D-2 summarizes the conditions and resulting escaped fractions. The authors chose the parameters for all the “worst case” results from the sensitivity results and examined the influence of another condition, the assumption used for deposition. As the authors point out, it is physically impossible to have a stability class of A (unstable) in combination with a high wind speed of 30 mph. However, this physical impossibility was modeled so as to combine all the worst case conditions from all of the sensitivity studies.

In the first of the two worst case scenarios they used the so-called “trap” condition - where 100 percent of the particles that collide with the ground are deposited. In the second worst case scenario the authors used the opposite extreme, the so-called “ricochet” condition – where all particles reflect back with the same velocity as the incoming velocity on collision with the ground. The escape fractions were 22 percent for trap and 33 percent for ricochet.

TABLE D-2
Comparison of “Trap” and “Ricochet” deposition

“Worst Case” Scenario	Wind Speed (mph)	Wind Direction	Atmospheric Stability	Source Location	Source Height (feet)	Particle Size (microns)	Escape Fraction
100% Trap	30	From the South	A (unstable)	Pit boundary in downwind direction	30	10	22%
100% Ricochet	30	From the South	A (unstable)	Pit boundary in downwind direction	30	10	33%

To estimate emissions and perform the current AERMOD modeling for the 24-hour PM_{10} impact, the approach of applying one escape fraction to all sources in the pit and for all times is being taken. This approach requires the selection of a single value for the escape fraction that is representative but also conservative. While the conditions modeled for the two “worst-case” scenarios are not realistic and too conservative to be considered representative, they may indicate the difference between results for 100 percent trap and 100 percent ricochet is approximately 5.5 percent. All other cases were run with the 100 percent trap boundary condition. In reality the percentage of particles that deposit lays between the two extreme that were modeled.

For all but two cases the maximum escape fraction from the sensitivity analyses is 12.6 percent or less. Therefore a value of 12.6 percent - once adjusted upwards to represent a more realistic percentage of the particles that deposit – would be the most representative of real conditions at the mine. As noted earlier, the change from 100 percent trapped to 100 percent ricochet is 5.5 percentage points. Adjusting 12.5 percent upwards by 5.5 percentage points yields 18.0 percent. To be even more conservative and adjust for the level of uncertainty, an escape fraction of 20 percent was chosen for the emission estimates and the AERMOD modeling of PM_{10} impacts for comparison with the NAAQS.

Using similar reasoning, an escape fraction of 21 percent was chosen for $PM_{2.5}$. As discussed above, using the available data from the 1996 report by Bhaskar and Tandon, an escape fraction of 20 percent was selected to be conservatively representative for AERMOD modeling of PM_{10} impacts for comparison with the NAAQS. Just as PM_{10} represents all particles with aerodynamic diameters of 10 microns and smaller, $PM_{2.5}$ represents all particles with aerodynamic diameters of 2.5 microns and smaller. Since larger particles have larger settling velocities, the escape fraction for larger particles is expected to be smaller. The sensitivity study for particle size showed this expected relationship (see Table 1 above). Of the particles sizes examined in the sensitivity study, two are smaller than 2.5 microns: 1 micron and 2 microns. These had escape fraction 0.6 and 0.5 percent larger, respectively, than the 11.8 percent escape fraction for the base case 10 micron particle. As $PM_{2.5}$ represents all particles equal to or smaller than 2.5 microns, this would include particles even smaller than 1 micron, which would presumably have even larger escape fractions. Fortunately, it is known that the relationship of decreasing deposition with decreasing particle size only continues until particles with size on the order of 0,1 microns. At that point deposition values begin to increase for even smaller particles due to other physical phenomena in addition to gravitational settling. Consequently, to account for particles down to 0.1 microns, an upward adjustment of 1 percentage point from the 20.0 percent escape fraction used for PM_{10} was chosen for the escape fraction chosen to use in the AERMOD modeling of $PM_{2.5}$ impacts for comparison to the NAAQS.

APPENDIX D-2

Airflow Patterns and Pit-retention of Fugitive Dust for the Bingham Canyon Mine Study

AIRFLOW PATTERNS AND PIT-RETENTION OF FUGITIVE DUST FOR THE BINGHAM CANYON MINE

by

Ragula Bhaskar and Navin Tandon
Department of Mining Engineering
313 WBB, University of Utah
Salt Lake City, UT 84112

A report submitted to

Kennecott Utah Copper
Environmental Affairs Department

Project Officers:
Fred Fox
Jon Cherry
Rich Borden

August 1996

ABSTRACT

A 3-dimensional finite-element numerical model was developed for analyzing the airflow patterns and pit retention of fugitive dust for Kennecott's Bingham Canyon mine, the world's largest man-made excavation. The Fluid Dynamics Analysis Package (FIDAP 7.5) was used for the study. The standard κ-ϵ turbulence model (with the near-wall approach) was used along with the Reynolds-averaged turbulent flow equations. A Lagrangian stochastic model was used to predict the particle trajectories for a given flow simulation. Sensitivity studies were conducted to perform a "what if" analysis to better understand the particle transport, dispersion and pit retention phenomena. The sensitivity to the following parameters were studied: wind speed, wind direction, atmospheric stability, source location and height, and particle size. The model predicted significantly lower values for the escape fraction of PM-10 from the Bingham pit. Escape fraction was found to be a function of different meteorological and source parameters. The escape fraction range for the various simulations conducted in the present study for the Bingham pit was found to be roughly 10-20%.

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CHAPTER 1

INTRODUCTION

Surface mining operations (such as blasting, loading, hauling, crushing, etc.) are sources of airborne particles. The estimation of concentrations of fugitive dust/PM-10 for an open-pit mining situation has traditionally been done using Environmental Protection Agency (EPA) models such as the Industrial Source Complex (ISC) model. There is a regulatory applicability of air quality dispersion models in the review and preparation of new source permits and State Implementation Plan (SIP) revisions.

The different dust-producing operations at open-pit mines occur inside the pit, sometimes at depths of many hundreds of feet below grade. It is reasonable to suspect that only a fraction of fugitive dust generated at the pit floor escapes to the surface where it then may be transported to mine boundaries. This tendency for particulate matter to remain inside the pit has been called pit retention (TRC, 1985). There are two separate mechanisms occurring simultaneously that contribute to the pit retention phenomenon. The first is a de-coupling of the wind field in the pit from the wind field at the surface, inhibiting or suppressing the vertical transport of particulate from the bottom of the pit to the surface. This pit retention mechanism can be expected to be most pronounced during stable low wind speed conditions, such as that occurring at night. The second mechanism by which particulate are retained is through deposition and settling on the mine pit surface and along the pit walls. It is also reasonable to expect that the presence of the mine pit would disturb the airflow above and inside the pit, so that the "plume" of dust might not have the familiar Gaussian distribution imposed by many dispersion models, or might have a significantly different trajectory which would alter plume location. Although the altered plume shape or location is technically different than pit retention, it is certainly a related issue. Until recently, most air quality models neglected the pit retention. Neglecting the plume perturbation can cause overpredictions or underpredictions, depending upon how the pit is simulated. On the other hand, if a dispersion model ignores the influence of pit retention, then the model will overpredict the downwind concentrations.

The 1990 Clean Air Act Amendments directed the EPA to analyze the accuracy of the ISC model and the AP-42 emission factors, and to make revisions as would be necessary to eliminate any significant overprediction of fugitive dust concentrations from sources such as surface mines. Historically, most air quality dispersion models which have been used to predict particulate concentrations in the vicinity of surface mines simulated emissions as if they were released at grade level. This led to significant overpredictions in the past. The EPA's new ISC3 model (1995), with its algorithm for modeling impacts of particulate emissions from open-pit sources, considers the pit retention phenomenon and hence attempts to eliminate overprediction of PM-10 concentrations.

This chapter will examine the various investigations concerning pit retention and pit airflow which have been done in the past.

1.1 Literature Review

1.1.1 Approaches Used to Study Problems in Air Pollution

Presently, three main approaches are used to study problems in air pollution - field experiments, wind tunnel modeling and mathematical modeling.

1.1.1.1 Field experiments. Full-scale experiments, while important, are expensive and time-consuming, especially in complex terrain. Extensive measurements and analyses are required for wind, temperature and concentration distribution to gain a sufficient understanding of the fundamental physics. Generalization from field data is difficult because of peculiarities of specific sites and meteorological conditions. Controlled variation of independent variables is generally not possible, and complicating factors are abundant. However, it is understood that field experiments can provide the "real-world" data to test the models.

Although field studies in the vicinity of surface mines have undoubtedly been influenced by pit retention, very few studies have specifically addressed pit retention. As mentioned by TRC (1985), there are two reported studies in which the investigators detected discrepancies between the measured and modeled concentrations at surface mines, and attributed the discrepancies to pit retention. After a year-long emission factor study conducted at two surface coal mines in Wyoming, it was hypothesized that only one-third of the particulate emitted in the pit was escaping. At another study conducted at the Berkeley pit in Butte, Montana, it was hypothesized that only one-half of the particulate matter emitted in the pit escaped to the surface. There is some doubt about the reliability of these two studies, as they were not specifically designed to look at pit retention, and the difference in emissions could have been caused by other errors.

One field study that specifically examined pit retention and flow fields at surface mines was the EPA funded work performed by Air Sciences, Inc., in the summer of 1983. The field data collected was reduced, analyzed and interpreted to investigate relationships between in-pit and out-of-pit parameters, as well as calculate the escape fraction/pit retention (TRC, 1985). The data had been collected from over 800 smoke release experiments at four mines in Colorado, Wyoming and Montana. At each of the mines, smoke generators at the bottom of the pits were used to release discrete 10 second puffs of diesel fuel smoke, and these smoke releases were recorded on a video cassette recorder (VCR). An escape velocity, essentially the net upward velocity within each pit, was computed from the observed retention time of the tracers and the depth of each pit. This upward velocity, when compared to the downward settling and deposition velocity for different size particles, was the basis for the calculation of an escape fraction. The escape velocity was found to be positively correlated with wind speed and negatively correlated with the stability category. Although the study provided some important description and trends in the value of pit retention, it was understood that the computation methodology was an oversimplification of the actual phenomenon. The exact details of smoke plume trajectory or plume-ground interaction was not considered, which could be very important when the plume is very close to the pit floor and the pit walls. This simplification may cause an overestimation of the true escape fraction.

1.1.1.2 <u>Wind tunnel modeling</u> Wind tunnel modeling comes under the general category of physical modeling or fluid modeling. It is, in effect, the analog modeling of fluid-dynamical processes. Certain nondimensional parameters must be duplicated in the model. Due to employment of scale models, it is actually possible to keep only some of the parameters the same or similar in both the full-scale and the wind tunnel model.

Wind tunnel modeling has been typically employed to study plants in complex terrain or to determine the effect of building turbulence on dispersion from stacks. A detailed guide (Snyder, 1981) has been published by the EPA to establish the procedures for fluid modeling. In fluid modeling, a scale model of terrain, plant, buildings, and obstructions is used. The plume rise could be simulated by using a lighter-than-air gas such as methane or helium. The surface roughness can be simulated by placing gravel or other roughness elements on the modeled floor. Fluid modeling has been found to be most effective in simulating neutral atmospheric conditions. Limited success has been achieved in modeling stable or unstable atmospheric conditions by cooling or heating the floor of the wind tunnel. In spite of its limitations, wind tunnel modeling is very important. The flow in a wind tunnel can be controlled and specific parameters can be independently adjusted. Ideally, the fluid models should be used to bridge-the-gap between the mathematical models and their applications to the field.

There is evidence in the literature that wind tunnel studies have been extensively employed to study the effect of topographical obstacles on flow and dispersion characteristics (Khurshudyan, et al., 1982; Costa, et al., 1994).

The wind tunnel study most relevant to this project was conducted after the requirement by the Clean Air Act Amendments of 1990 to reexamine the EPA's methods for modeling fugitive particulate (PM-10) for open-pit mines (Thompson, 1994; Perry, et al., 1994). The wind tunnel study was performed at the EPA's Fluid Modeling Facility to investigate dispersion from surface coal mines (or similar sources) in support of the dispersion modeling activities. The effort was aimed at mainly assessing the ISCST2 model for applications to surface mines. In the wind tunnel study, a neutral boundary-layer approach flow with a freestream speed of 2 m/s was used for all the measurements. The study involved the measurement of steady-state, tracer-gas (ethane) concentration fields downwind of model mines of various shapes, sizes and orientations with low-momentum, point-source releases of a neutrally buoyant gas from various locations in the pit. It was assumed that due to generally high levels of turbulence in the pit, relevant information about the behavior of PM-10 could be obtained from a laboratory study using a neutrally buoyant gaseous tracer. All the model pits were rectangular and the scaling ratio was 300 to 1. The concentrations were measured using flame ionization detectors and velocity measurements were made in and around the model using a pulsed-wire anemometer. In the study, the sensitivity of downwind concentrations to a wide range of parameters related to pit geometry and source locations were studied. The mean flow in a mine model was observed as a large vortex with the flow at the top of the mine in the direction of flow aloft. At the downwind wall of the mine, the flow was towards the mine floor. The flow moved upwind (against the direction of mean flow aloft) along the floor and then upward at the upwind face of the mine. The performance of the ISCST2 model was also assessed by comparing its results to wind tunnel results. By representing the entire opening of the rectangular pit as a surface level area source (with emissions uniform over that area), it was shown that results with ISCST2 are an overestimation over observed values. Considering the effect of recirculation phenomenon, it was stated that only the upwind edge of the model contributes to emissions. Modeling the pit using ISCST2 with an area source (a fraction of the total rectangular area), aligned with the upwind side of the actual pit demonstrated better results with slight overpredictions. Hence, it was concluded that an open pit would act as a modified area source where the emissions are greatest near the upwind side of the actual pit.

1.1.1.3 Mathematical modeling Mathematical models encompass such concepts as empirical box and statistical models, semi-empirical Gaussian plume and trajectory models, and numerical multibox, grid and particle models. Mathematical models, more generally called numerical models, use mathematical techniques to represent the actual physical processes governing atmospheric flow dynamics and pollutant transport. Numerical models are very versatile. By making varying degrees of approximations and assumptions, numerical models can be tuned to each application. Advection by wind components, turbulent diffusion, chemical reactions, wet and dry deposition of pollutants, and other atmospheric processes can all be included in the numerical models.

Several studies utilizing mathematical modeling methodologies were found in the literature. Lee (1977) applied the finite element technique to solve the model for computing the turbulent field and diffusion in the atmospheric planetary boundary layer. Herwehe (1984) developed a 2-dimensional finite-element model to simulate the transport, diffusion and dry deposition of fugitive dust emitted from an idealized open-pit surface mine. Zhang, et al. (1993) investigated the effects of incident shear and turbulence on flows around a cubical building using a turbulent kinetic energy/dissipation (κ-ϵ) model. One of their conclusions was that turbulence in the approach flow tends to dampen the wake strength behind the building. Perdikaris and Mayinger (1995) employed numerical analysis for predicting the dispersion of continuously released neutral gases from elevated or near-ground sources in regions of complex topography.

The major advantages in using numerical models are:

the control over input data specification; and the capability to provide useful information for meteorological and air pollution scenarios in a fast, reliable and inexpensive way compared with the observational approach.

1.1.2 Surface Mine Escape Fraction Models

There are two simple equations which attempt to simulate pit retention by deriving mass escape fractions. These equations have been discussed in detail by TRC (1985).

1.1.2.1 Fabrick escape fraction. Fabrick derived a mine pit escape fraction equation that depends upon the width of the pit, the wind speed at the top of the pit and a particle size distribution:

$$\varepsilon = 1 - V_d \left[\frac{C}{u} \left(\frac{1}{2} + \ln \frac{w}{4} \right) \right] \tag{1.1}$$

where ε is the escape fraction, u is the wind speed (m/s), w is the pit width (m), V_d is the larger of deposition or settling velocity (m/s), and C is an empirical dimensionless constant with a value of 7.

1.1.2.2 Winges escape fraction. Winges developed an equation to calculate the particulate escape fraction from surface mine pits. The escape fraction is given by:

$$\varepsilon = \frac{1}{1 + \left(\frac{V_d}{K_z}\right) H} \tag{1.2}$$

where ε is the escape fraction, V_d is the larger of deposition or settling velocity (m/s), K_z is the vertical diffusivity (m^2/sec) and H is the pit depth (m). This equation attempted to treat a very simplified dispersion scenario. Some of its assumptions were: emissions occurring at the bottom of the pit; turbulent diffusion being the only mechanism for transport of material out of the pit; and the constant eddy diffusivity assumption.

In an effort to incorporate other physical and meteorological parameters (especially wind speed) into the original Winges escape fraction equation, four alternative modifications to the Winges equation were later derived (TRC, 1986).

1.1.3 EPA's New Industrial Source Complex (ISC3) Dispersion Models

The ISC models are especially designed to support the EPA's regulatory modeling programs. These models are steady-state Gaussian plume models that provide options to model emissions from a wide range of sources that might be present at a typical industrial source complex. The ISC3 models are based on revisions to the algorithms contained in the ISC2 models. The user's guides for the ISC3 dispersion models have been published (September 1995) by the EPA, which explain user instructions and model algorithms in detail.

The ISC3 models include several new features. One of the features that has been added is an algorithm for modeling impacts of particulate emissions from open pit sources. The ISC open pit source model can be used to simulate fugitive emissions from below-grade open pits. The ISC models allow the open pit source to be characterized by a rectangular shape with an aspect ratio (length/width) of up to 10 to 1. Since the open pit model does not apply to receptors located within the boundary of the pit, the concentrations at those receptors are set to zero by the ISC models.

The open pit model accounts for partial retention of emissions within the pit by calculating an escape fraction for each particle size category. The escape fraction for each particle size category, ε_i, is calculated as follows (EPA, 1995):

$$\varepsilon_i = \frac{1}{1 + V_g/(\alpha U_r)} \qquad (1.3)$$

where V_g is the gravitational settling velocity (m/s), U_r is the approach wind speed at 10 m (m/s) and α is the proportionality constant whose value is set as 0.029. The gravitational settling velocity, V_g (cm/sec), is calculated as:

$$v_g = \frac{(\rho - \rho_{AIR})\, g\, d_p^2\, c_2}{18\mu} S_{CF} \qquad (1.4)$$

where, ρ is the particle density (g/cm^3), ρ_{AIR} is the air density ($\approx 1.2 \times 10^{-3}$ g/cm^3), d_p is the particle diameter (μm), μ is the absolute viscosity of air ($\approx 1.81 \times 10^{-4}$ gm/cm/sec), c_2 is the units conversion constant (1×10^{-8} $cm^2/\mu m^2$), and S_{CF} is the slip correction factor, which is computed as:

$$S_{CF} = 1. + \frac{2x_2\ (a_1 + a_2\ e^{-(a_3\ d_p/x_2)})}{10^{-4}\ d_p} \qquad (1.5)$$

and, x_2, a_1, a_2, a_3 are constants with values of 6.5×10^{-6}, 1.257, 0.4 and 0.55×10^{-4}, respectively.

The variations in escape fractions across the particle sizes result in a modified distribution of mass escaping from the pit. Based on the fluid modeling (explained earlier), within-pit emissions are assumed to have a tendency to escape from the upwind side of the pit. The open pit algorithm simulates the escaping pit emissions by using an effective rectangular area source (a fraction of the entire pit opening) using the ISC area source algorithm. The shape, size and location of the effective area source varies with the wind direction and the relative depth of the pit. It is assumed that because of the high level of turbulence in the mine, the pollutant is initially mixed prior to exiting the pit.

As can be observed from the discussion above, the open pit algorithm in the ISC3 models has some strong simplifying assumptions. The actual open pit mine could have a geometry much different than the assumption of a rectangular shape. The escape fraction equation considers very few parameters, which may not be sufficient to characterize all the complexities of the pit retention phenomenon. The calculation of effective area is based on the assumption that due to the recirculation phenomenon, emissions escape from the upwind side of the pit, which might not always be the case in the real field situation. Also, the specific heights of various emission points from the floor of the pit cannot be explicitly accounted for in the model. Although ISC3 incorporates the complex terrain screening algorithms, these cannot be applied to open pit sources.

Even with these simplifying conditions, the new ISC3 is expected to play an important role in the regulatory modeling, mainly because of ease of its use and the hardware requirements of only a PC. However, if more site-specific and accurate results are desired, advanced mathematical tools, such as finite element modeling, should be used.

1.2 Overview of the Study

Kennecott's Bingham Canyon mine is the world's largest man-made excavation: one-half mile deep and covering 1900 acres. At the top, it is nearly 2½ miles from one side of the mine to the other. Different mining operations are sources of dust emissions in the Bingham pit. Due to the size of the Bingham pit, it can be expected that a large fraction of emitted dust will not escape the pit boundaries and will have a tendency to be retained inside the pit. This, in particular, can be expected for ground level sources deep inside the pit.

The purpose of the present study is to simulate the transport and diffusion of fugitive dust, and to quantify the pit retention/escape fraction of dust emitted in the Bingham Canyon mine. The objective is achieved through the development of a 3-dimensional finite element model. Reynolds averaged flow equations are solved to generate the turbulent flow field. Use is made of the standard κ-ϵ turbulence model and the near-wall modeling methodology. The particle transport, diffusion, and pit retention is evaluated through the use of a Lagrangian stochastic model. Sensitivity studies are then performed in order to better understand the behavior of fugitive dust under given meteorological and emission source conditions.

Chapter 2 describes the theoretical background for the Bingham pit model. The governing equations for airflow and particle trajectories, as well as some meteorological considerations are discussed. Chapter 3 discusses the steps involved in creating a 3-dimensional finite-element model. It also explains specification of input data which can be considered common to all the simulations. Chapter 4 provides detailed descriptions of the simulation studies and presents the analyses of the results. The simulation-specific input data used to obtain the results are also discussed. Chapter 5 contains information regarding numerical validation of the model, and comparison of idealized versus actual pit geometries. Chapter 6 gives the concluding remarks with an overall assessment of the usefulness and practicality of the model and recommendations for future work.

CHAPTER 2

THEORETICAL ANALYSIS

This chapter discusses some of the theoretical aspects of the present analysis. The various motions of the air in the earth's atmosphere, from a slight breeze in the surface layer up to a general atmospheric circulation of planetary scale, are turbulent. Atmospheric turbulence plays a fundamental role in the thermal and dynamic interaction between the atmosphere and the underlying surface. Atmospheric turbulence also determines the spreading of admixtures in the air.

2.1 Turbulence Modeling

2.1.1 Mean Flow Equations

It is believed that the solution of time-dependent three-dimensional Navier-Stokes equations can describe turbulent flows completely. However, the computers are not large and fast enough yet to solve the equations directly, for the required range of length and time scales, even for simple flows (Nallasamy, 1985). Turbulent flows are represented in a majority of flow simulations by the ensemble averaged conservation equations - the so-called Reynolds-averaged equations. The mean flow equations to simulate a turbulent isothermal flow with constant fluid properties may be presented as follows (Haroutunian and Engelman, 1991 and 1993),

Continuity:

$$\frac{\partial u_i}{\partial x_i} = 0 \tag{2.1}$$

Momentum:

$$\rho \frac{\partial u_i}{\partial t} + \rho u_j \frac{\partial u_i}{\partial x_j} = - \frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j} \left[\mu \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) - \rho \overline{u_i' u_j'} \right] \tag{2.2}$$

In the above equations, u_i are the components of the mean velocity vector in the Cartesian coordinate system x_i, t is the time coordinate, p and ρ are the mean fluid pressure and density, respectively, and μ is the molecular viscosity. This formulation allows the characteristics of the mean flow to be investigated without having to resolve all the intricate details of the turbulence field. A significant drawback of this approach, however, is that unknown statistical correlation $\rho \overline{u_i' u_j'}$ enters the flow equations as a result of the averaging process. This Reynolds stress tensor represents the mean turbulent flux of momentum in the three principal spatial directions. The notation used for the Reynolds stress tensor is that prime denotes a fluctuating variable. As these turbulent fluxes are not known a priori, mathematical models are needed to approximate these in terms of mean flow characteristics. This process is referred to as turbulence modeling. A large number of turbulence models have been explained by Rodi (1984).

2.1.2 Standard κ-ϵ Model

The standard κ-ϵ model is one of the turbulence models which has enjoyed a great deal of success. The κ-ϵ model was first proposed by Launder and Spalding (1974), and has since been universally adopted as the standard form of the κ-ϵ model. From the generalized Boussinesq eddy viscosity concept, by analogy with the laminar flow, the Reynolds stresses can be expressed as (Haroutunian and Engelman, 1993):

$$-\rho\overline{u_i' u_j'} \cong \mu_t\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) - \frac{2}{3}\rho\delta_{ij}\kappa \qquad (2.3)$$

where δ_{ij} is the Kronecker delta function, μ_t is the turbulent viscosity, and κ is the turbulent kinetic energy. In contrast to the laminar viscosity, μ, the turbulent viscosity, μ_t, is not a property of the fluid, but depends on the flow process.

The turbulent kinetic energy can be expressed as:

$$\kappa = \frac{\overline{u'^2} + \overline{v'^2} + \overline{w'^2}}{2} \qquad (2.4)$$

where u', v', and w' are the velocity fluctuations in the x, y, and z directions.

The advantage of the Boussinesq's approach is that it shifts the emphasis from modeling many unknown turbulent fluxes to a single unknown μ_t. In the context of the κ-ϵ model, the expression for μ_t can be written as:

$$\mu_t = c_\mu \, \rho \, \frac{\kappa^2}{\epsilon} \tag{2.5}$$

where c_μ = 0.09 is an empirical model coefficient, and ϵ is the viscous dissipation rate of turbulent kinetic energy κ. The transport equations for κ and ϵ can be written as:

$$\rho \frac{\partial \kappa}{\partial t} + \rho u_j \frac{\partial \kappa}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_\kappa}\right)\frac{\partial \kappa}{\partial x_j}\right] + G - \rho\epsilon \tag{2.6}$$

$$\rho \frac{\partial \epsilon}{\partial t} + \rho u_j \frac{\partial \epsilon}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_\epsilon}\right)\frac{\partial \epsilon}{\partial x_j}\right] + c_1 \frac{\epsilon}{\kappa} G - c_2 \rho \frac{\epsilon^2}{\kappa} \tag{2.7}$$

In the above equations,

$$G = -\rho \overline{u_i' u_j'} \frac{\partial u_i}{\partial x_j} \cong \mu_t \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\frac{\partial u_i}{\partial x_j} \tag{2.8}$$

is the turbulence shear generation term, and the values of various constants are:

$$(\sigma_\kappa, \sigma_\epsilon, c_1, c_2) = (1.0, 1.3, 1.44, 1.92).$$

A review of simulating turbulent flows using two-equation turbulence models (including κ-ϵ) has been provided by Haroutunian and Engelman (1993). The limitation of the standard κ-ϵ model is that it is only appropriate for modeling flow regions of high turbulence levels (called high-Reynolds number regions). Another limitation of the standard κ-ϵ model is its inability to handle turbulence anisotropy.

2.1.3 Modeling of the Near-Wall Region

As mentioned earlier, the standard κ-ϵ model is not appropriate for modeling low turbulence level regions (i.e., near-wall regions adjacent to solid boundaries which contain the viscous sublayer). Another challenging aspect of turbulence modeling is that in order to resolve the sharply varying flow variables in the near-wall regions, a disproportionately large number of grid points are required in the immediate vicinity of the solid boundary. This could lead to prohibitively expensive computations.

The viscosity affected layers between the wall and the fully turbulent regions above the wall are bridged by a single layer of specialized elements. In order to accurately resolve the velocity profiles in these elements, specialized shape functions are used. These shape functions are based on the universal near-wall velocity profile. A functional form that can be used for the velocity profile the near wall region is that due to Reichardt (as explained in Haroutunian and Engelman, 1991), which is as follows,

$$u^+ = f_R(y^+) = \frac{1}{k}\ln(1+0.4y^+) + 7.8[1 - \exp(-\frac{y^+}{11}) - \frac{y^+}{11}\exp(-0.33y^+)]. \quad (2.9)$$

In this equation, k is the von Karman constant, u^+ and y^+ are the dimensionless velocity and distance which are defined as:

$$u^+ = \frac{u}{u_*} \quad (2.10)$$

$$y^+ = \frac{\rho u_* y}{\mu} \quad (2.11)$$

where u_* is the friction velocity. Reichardt's law closely matches the experimentally observed velocity profile across the viscous sublayer ($y^+ < 5$), the transitional sublayer ($5 < y^+ < 30$), and the fully turbulent layer beyond ($y^+ > 30$). It corresponds to the conditions where the near-wall flow is in local equilibrium, where the effects of streamwise variations and body forces are small and there is no transpiration at the wall.

In the viscosity affected near-wall layers bridged by the special element layer, the standard κ-ϵ model is not solved. The variation of turbulent viscosity μ_t in the special elements is formulated by using van Driest's mixing-length model (explained by Haroutunian and Engelman, 1991). Thus, μ_t is expressed as:

$$\mu_t = \rho \ell_m^2 \left[\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) \frac{\partial u_i}{\partial x_j} \right]^{1/2} \qquad (2.12)$$

where ℓ_m is the mixing length obtained from the van Driest's expression

$$\ell_m = ky[1 - \exp(-y^+/A)]. \qquad (2.13)$$

In the above equation, y is the normal distance from the wall and A is an empirical constant which assumes a value of about 26 for smooth walls in the equilibrium near-wall layers. The dimensionless normal distance from the wall, y^+, is defined here in terms of turbulent kinetic energy at the top of the element, viz.

$$y^+ = \rho (c_\mu^{1/2}\, \kappa_t)^{1/2}\, \frac{y}{\mu}. \qquad (2.14)$$

The computational domain for the mean momentum and continuity equation encompasses the entire flow domain down to the solid boundary, while the corresponding computational domain for the κ and ϵ equations extends only to the top of the near-wall elements. So appropriate boundary conditions are needed at the boundary of the truncated domain for the κ and ϵ equations, and are:

$$\frac{\partial \kappa}{\partial y} = 0 \tag{2.15}$$

$$\epsilon = \frac{(C_\mu^{\frac{1}{2}}\ \kappa_t)^{1.5}}{ky}. \tag{2.16}$$

The viscous and buffer sublayers should be fully contained within the special near-wall elements in order for the near-wall model to function correctly.

2.2 Meteorological Considerations

2.2.1 Structure and General Characteristics of the Atmosphere

2.2.1.1 Atmospheric turbulence. Atmospheric motions come under the regime of turbulent flows. These turbulent flows are highly irregular and chaotic (random). Due to the chaotic movement of fluid parcels called turbulent eddies, an intensive mixing and transporting of heat, momentum, water vapor, and other admixtures is realized. This kind of mechanism is specified as turbulent diffusion and is analogous to the mechanism of molecular diffusion, but is much more intensive.

2.2.1.2 Planetary boundary layer. Most air pollution phenomena occur in the lower part of the atmosphere called the planetary boundary layer, or PBL. The PBL is defined as the region in which the atmosphere experiences surface effects through vertical exchanges of momentum, heat and moisture (Panofsky and Dutton, 1984). The traditional approach is to divide the PBL vertically into various layers, each characterized by different "scaling" parameters. According to Zannetti (1990), the PBL can be divided into three major sublayers: the roughness layer, surface layer and transition (or Ekman) layer.

The roughness layer is defined as the region above the ground in which turbulence is intermittent or not fully developed, and this layer is present near the ground up to the height of the roughness length z_o. Roughly, this is the height where the wind becomes zero. The value of z_o can be obtained from standard tables or computed approximately as (Zannetti, 1990)

$$z_o = \epsilon/30 \tag{2.17}$$

where ϵ is the average height of the obstacles in the study area.

The surface layer is defined as a constant stress layer in which the fluxes of momentum, heat and moisture are assumed to be independent of height. The surface layer exists from z_o to h_s, where h_s is the height of the surface layer. For h_s, Zannetti (1990) suggests a value of 10-200 m, while Csanady (1972) suggests 30-100 m.

The transition layer exists from h_s to z_i, where z_i varies from about 100 m to 2 km. The top of the boundary layer z_i is the lowest level in the atmosphere at which the ground surface no longer influences the dependent variables through the turbulent transfer.

2.2.1.3 **<u>Mixing height</u>.** In air pollution meteorology, mixing height is an important concept. The mixing height sets the upper limit to the dispersion of atmospheric pollutants. It is possible for pollutants released at ground level to be mixed practically uniformly up to the mixing height, but not above it (DeNevers, 1995).

2.2.1.4 **<u>Atmospheric stability</u>.** The stability of the atmosphere can be characterized as unstable, neutral and stable. There are six predominant stability classes: A, B and C represent unstable conditions, D is neutral, and E and F are stable conditions.

Neutral conditions are characterized by the presence of an isentropic (or adiabatic) vertical temperature profile in the PBL (i.e., $\Delta T/\Delta z \approx 9.86\times10^{-3}$ deg/m in dry air, where T is the temperature and z the altitude). They typically occur during daytime-nighttime transitions, cloud overcasts or with strong winds (Zannetti, 1990). For flat terrain, under neutral conditions, the average wind speed shows a classical logarithmic wind profile for $z > z_o$, which is given by

$$u(z) = \frac{u_*}{k} \ln \frac{z}{z_o} \tag{2.18}$$

where k is the von Karman constant ($\simeq 0.4$) and u_* is the friction velocity, which by definition is equal to $\sqrt{\tau_o/\rho}$, where τ_o is the stress of the wind at ground level and ρ is the air density.

Unstable conditions are typical in the daytime when maximum amount of warming of the surface and the air adjacent to the ground can take place. These conditions are characterized by the super-adiabatic vertical temperature profile and they tend to enhance the vertical air motion. Stable conditions are typical during clear nights with weak winds. These conditions are characterized by the sub-adiabatic vertical temperature profile and they tend to inhibit vertical air motion (DeNevers, 1995).

2.2.1.5 K-Theory. In the planetary boundary layer, generally, only vertical velocity gradients and momentum fluxes are important (Panofsky and Dutton, 1984). According to the classical K-Theory, the momentum fluxes are assumed to be proportional to the velocity gradients. Approximate horizontal homogeneity and stationarity are assumed in the boundary layer for the K-Theory (McBean, et al., 1979). Fluxes in the vertical direction can be formulated as (Zannetti, 1990):

$$\tau(z) = K_m \rho \frac{\partial \mathbf{u}}{\partial z} \qquad (2.19)$$

where K_m is the scalar eddy viscosity (= $\nu_t = \mu_t/\rho$), and **u** is the average horizontal wind vector.

Several models for eddy viscosity have been summarized by Panchev (1985) to explain its variability with height in the PBL. These include the step-like model, linear and power models, exponential model, and linearly-exponential model. One of the models (two-layer linear model) under neutral stratification has been explained as

$$K_m(z) = \begin{cases} ku_* z, & z \le h_s \\ ku_* h_s, & z \ge h_s \end{cases} \qquad (2.20)$$

2.2.1.6 **Surface layer.** In the surface layer, the characteristics of turbulence and the vertical distribution of mean variables are relatively simple. (Panofsky and Dutton, 1984).

As will be explained later, use can be made of the Monin-Obukhov similarity theory in the parameterization of the surface layer. One of the concepts in this theory is of Monin-Obukhov length L, the value of which can also be used in the characterization of atmospheric stability. As mentioned in Zannetti (1990), these criteria are:

$1/L < 0$ for unstable conditions

$1/L \simeq 0$ for neutral conditions

$1/L > 0$ for stable conditions.

The magnitude of L, i.e., $|L|$, describes the thickness of the layer of dynamic influence near the surface in which shear or friction effects are active participants in the physics (Azad, 1993).

Csanady (1972) explains that given a steady wind and near-neutral conditions the mean velocity distribution within the first 50 m or so from the ground is very much as in the "wall" layer portion of a two-dimensional boundary layer over a flat plate. Experimentally the logarithmic law of the wall may be verified in the "surface" portion of the PBL.

2.2.2 Wind Turbulence

In standard meteorological notation (u parallel to the mean wind, v the horizontal crosswind component, and w the vertical component), the horizontal and vertical wind fluctuations are characterized by their intensities σ_u, σ_v and σ_w, i.e., the standard deviations of the instantaneous u, v and w values, respectively. In an analysis by Panchev (1985), it was specified that

$$\sigma_f^2 = \overline{f'^2} \tag{2.21}$$

where f could be u, v or w.

Turbulent intensities in the atmosphere depend on the height of measurement, the roughness of the ground, and the stability of the atmosphere. Values of σ_v and σ_w are related to horizontal and vertical turbulence intensities (i_y and i_z, respectively) as follows (Zannetti, 1990):

$$i_y = \frac{\sigma_v}{\overline{u}} \quad (\simeq \sigma_\theta \textit{ for small angles}) \tag{2.22}$$

$$i_z = \frac{\sigma_w}{\overline{u}} \quad (\simeq \sigma_\phi \textit{ for small angles}) \tag{2.23}$$

where $\overline{u}$ is the mean wind speed at the particular height of observation, σ_θ and σ_ϕ are the standard deviations of horizontal and vertical wind direction fluctuations (for small angles, tan $\sigma_\theta \simeq \sigma_\theta$ in radians, likewise for σ_ϕ).

2.2.3 Scaling in the Surface Layer

Many of the idealizations generally made for the PBL as a whole are more realistic in the surface layer. Principal among these are horizontal homogeneity and stationarity. In the surface layer, use can be made of Monin-Obukhov's similarity theory.

In the surface-layer theory, eddy viscosities are generally described by (Panofsky, 1975):

$$K_m = \frac{k u_* z}{\phi_m} \tag{2.24}$$

where k is the von Karman constant, u_* the friction velocity, z the height above the ground, and ϕ_m the normalized wind shear.

The similarity theory of Monin and Obukhov introduced in 1954 allows a valid parameterization of the surface layer. According to this theory (Panofsky and Dutton, 1984), the nondimensional wind shear $\phi_m(z/L)$ is defined by

$$\phi_m(z/L) = \frac{kz}{u_*}\frac{\partial u}{\partial z} \quad (2.25)$$

where, in neutral conditions,

$$\phi_m = 1 \quad (2.26)$$

in unstable conditions

$$\phi_m = (1 - 16\ z/L)^{-1/4} \quad (2.27)$$

and in stable conditions

$$\phi_m = 1 + 5\ z/L. \quad (2.28)$$

According to Zannetti (1990), the standard deviation of the vertical wind velocity can be scaled by

$$\sigma_w/u_* = \phi_3(z/L) \quad (2.29)$$

In neutral conditions,

$$\phi_3 = constant = 1.25 \pm 0.03 \quad (2.30)$$

and in unstable conditions,

$$\phi_3 \simeq 1.25(1 - 3\ z/L)^{1/3} \tag{2.31}$$

For stable conditions, Zannetti (1990) reports that the large scatter of the data points do not allow a clear interpolation. However, according to Panofsky (1973) the ratio σ_w/u_* is invariant in neutral and stable layer. Hence for this study, σ_w/u_* for stable conditions will be approximated by the value for neutral conditions.

Additionally, Zannetti (1990) summarizes the following two relations:
In stable and unstable conditions,

$$\sigma_u = \sigma_v \tag{2.32}$$

and in neutral conditions,

$$\sigma_u/u_* = 2.39 \pm 0.03 \tag{2.33}$$

All the above formulations have been shown to be successful in flat terrain cases. It is expected the real surface layers (such as those on hilly terrain) will depart to some extent for the idealizations inherent in the Monin-Obukhov theory.

2.2.4 Complex Terrain

The presence of mountainous terrain introduces significant complexities in the atmospheric transport and diffusion process (Egan, 1986). Modeling air quality in complex terrain remains a difficult task simply because of the difficulty in parameterizing the complex wind flow regimes. Dispersion in complex terrain is poorly understood, even though recent dispersion experiments and studies, such as the U.S. E.P.A. Complex Terrain Model Development Project, have allowed important parameterizations of simplified cases (e.g., dispersion near an isolated small hill and possible plume impact on it) (Zannetti, 1990).

The terrain acts to distort otherwise organized flow patterns, resulting in enhanced shear effects and turbulent eddies. This will affect the flow trajectories and ambient turbulence levels. It is realized that some simplifying assumptions become necessary while characterizing flow in complex terrain.

2.3 Particle Dispersion in Turbulent Flow

2.3.1 Two-Phase Flows

To predict particulate two-phase flows, two approaches are possible. The Lagrangian approach treats the fluid phase as a continuum and predicts the trajectories of particles in the fluid flow as the result of various forces acting on the particles. Treating the particle phase as a continuum too, and solving the appropriate equations for the fluid and particle phases makes up the basic feature of the Eulerian approach. In this study, the Lagrangian approach has been used as it can handle particulate two-phase flows consisting of polydispersed particle size distributions. The underlying assumption in the formulation is that particle-particle interactions are neglected. The criterion for the validity of this assumption is that the dispersed phase is sufficiently dilute.

Depending on certain characteristics of the problem under examination, there are different ways the interaction between particles and turbulence can be specified. As summarized by Elghobashi (1994), the interaction will be dependent on the volume fraction of particles, which is defined as:

$$\phi_p = \frac{MV_p}{V} \tag{2.34}$$

where M is the number of particles, V_p is the volume of a single particle, and V is the volume occupied by particles and fluid. For very low values of ϕ_p ($\leq 10^{-6}$) the particles have negligible effect on turbulence, and the interaction between the particles and the turbulence is termed as one-way coupling. This means that particle dispersion, in this regime, depends on the state of turbulence. But due to the negligible concentration of the particles, the momentum transfer from the particles to the turbulence has an insignificant effect on the flow. For higher values of ϕ_p, higher-order coupling may be present in the two-phase flow.

In two-phase flows, the particles might impact with a solid wall. According to Hinds (1982), aerosol particles will attach firmly to any surface they contact, and hence exhibit characteristics different from gas molecules. But particles are known to escape collection and rebound from surfaces when impact velocity exceeds a characteristic critical velocity, which is determined by the particle size and the materials involved (Wall, S., et al., 1990). The capture of particles on impact with a surface remains an incompletely understood phenomenon. Also, it is possible for settled particles to be re-entrained in the flow.

2.3.2 Lagrangian Formulation of Two-Phase Flows

In the Lagrangian approach, the motion of each particle of the dispersed phase is governed by an equation that balances the mass-acceleration of the particle with the forces acting on it. The particles are assumed to be spherical in this analysis. Considering that only drag and gravity forces are acting on the particle, the relevant governing equation for the motion of the particle (adapted from the FIDAP Manual) is:

$$\frac{d\boldsymbol{u}_p}{dt} = \frac{(\boldsymbol{u}_f - \boldsymbol{u}_p)}{\tau} + \frac{(\rho_p - \rho_f)}{\rho_p}\boldsymbol{g} \tag{2.35}$$

where $\mathbf{u}_p$ is the particle velocity, $\mathbf{u}_f$ is the velocity of the fluid, ρ_p is the particle density, ρ_f is the fluid density, and τ is the particle relaxation time.

The parameter τ is an important term. It is a measure of the particle's responsiveness to changes in the surrounding flow field. The magnitude of the particle relaxation time, sometimes called the particle time constant, is important in understanding particle dynamics. A small particle relaxation time (relative to the time scale of the fluid) means that the particle has a chance to reach a local equilibrium with the fluid before the fluid itself has a chance to change.

τ is defined by:

$$\tau = \frac{4\rho_p D_p^2}{3\mu C_D Re_p} \tag{2.36}$$

where D_p is the particle diameter, μ is the viscosity of the fluid, C_D is the drag coefficient, and Re_p is the particle Reynolds number. The particle Reynolds number is defined by

$$Re_p = \frac{D_p\ |\boldsymbol{u}_f - \boldsymbol{u}_p|\ \rho_f}{\mu} \tag{2.37}$$

and, following Clift et al. (1978), for $Re_p < 200$,

$$C_D = \frac{24}{Re_p}\ (1 + 0.15\ Re_p^{0.687}). \tag{2.38}$$

2.3.3 Particles in Turbulent Flows

Predicting the behavior of particles in a turbulent flow is an ambitious aim. The large number of papers about the subject shows that it is hard to reach it (Ormancey and Martinon, 1984). Turbulence is the dominant mechanism for the transfer of momentum and in the absence of particle-particle interactions, it is the only mechanism which can lead to the spreading of particles.

By solving the time-averaged flow equations, the field variables obtained are the mean values. The turbulence model for the particles described via the Lagrangian approach requires some information about the fluctuations of velocities. These fluid velocity variations directly determine the extent of particle dispersion.

The typical approach for the approximation of the velocity experienced by the particle is a "random walk" model which assumes a carrier phase velocity to be the sum of a local mean velocity and random fluctuations. The random fluctuations are selected from a Gaussian distribution with zero mean and a variance related to the turbulent velocity scale coming from the model used in the mean flow solution. A stochastic approach can be used in conjunction with the κ-ϵ model which, under the assumption of isotropic turbulence, will allow the evaluation of velocity fluctuation from the turbulent kinetic energy κ obtained as field variable from the solution of the flow problem:

$$u' = \lambda(\frac{2}{3}\kappa)^{\frac{1}{2}} \tag{2.39}$$

where λ is the random generated number sampled from a normal distribution (between 1 and -1). Information about the frequency of the fluctuation sampling is also required to model the particle-eddy interactions. For this purpose, the "eddy lifetime" concept, initially developed by Gosman and Ioannides (1981) is used. Based on the local kinetic energy κ, and dissipation ϵ, an assumed eddy length, L_e, is computed:

$$L_e = C_\mu^{3/4} \frac{\kappa^{3/2}}{\epsilon} \tag{2.40}$$

and the eddy lifetime, t_e, is computed by

$$t_e = \frac{L_e}{(\frac{2}{3}\kappa)^{\frac{1}{2}}}. \tag{2.41}$$

The transit time, t_t, is also computed to account for the possibility that the particle can leave the eddy before the end of eddy lifetime.

$$t_t = -2 \ln\left(1 - \frac{L_e}{\tau\,|\mathbf{u}_f - \mathbf{u}_p|}\right) \tag{2.42}$$

where $|\mathbf{u}_f - \mathbf{u}_p|$ is the relative velocity at the start of the interval. During the computation of trajectories, whenever an interval of time equal to the minimum of t_e or

t_t is elapsed, it is assumed that the interaction with a new eddy has begun and a new fluctuation is sampled. During computation of t_t, if $L_e > \tau \, |\mathbf{u}_f - \mathbf{u}_p|$, then the interaction time is always taken to be t_e. This technique ensures that the information about the particle-turbulence interactions are not lost.

CHAPTER 3

MODEL DEVELOPMENT

In this chapter, the information and processes necessary to create the 3-dimensional Bingham pit model are discussed. FIDAP 7.5 (Fluid Dynamics Analysis Package) was used for the analysis. The model was developed and the simulations were generated using the Silicon Graphics Power Challenge XL supercomputer housed at the Utah Supercomputing Institute. The steps involved in the model development include specifying:

- 3-dimensional geometry and finite element mesh generation
- boundary and initial conditions
- model definition data and control information.

After the model was developed, the simulations were generated and the results of airflow patterns and particle trajectories were analyzed. The details of model development and execution are explained in FIDAP manuals (Fluid Dynamics International).

3.1 Geometry and Finite Element Mesh Generation

In order to perform a computer simulation of the problem, it is necessary to create a model of the flow domain. This involves two distinct phases - description of the geometry of the flow domain, and generation of a finite element mesh.

3.1.1 Geometry Definition

The geometry for the Bingham Canyon mine was defined using a contour map (1" = 1000′ scale), marked with a photo date of 7-5-95. In order to study the airflow patterns and pit retention of fugitive dust, it was essential that the model covers the pit as well as the surrounding area. This area was determined to be 23,000 feet (North-South) by 20,000 feet (East-West). It should be noted that the directions refer to the true directions, and not the mine directions.

The geometry definition process is illustrated in Figure 3.1. The X-axis points in the direction of TE (True East) and the Y-axis points in the direction of TN (True North). The Z axis points vertically upward. A grid comprised of several North-South parallel lines was placed on the contour map (actual 1"=1000' scale map) and several points were chosen on each line. The map was digitized using AUTOCAD to generate (X,Y) pairs of points and the Z-coordinate was read by interpolating between the contour intervals. There were enough numbers of points chosen to represent the complex terrain effectively. Using the defined points in FIDAP, order-3 curves were created and subsequently a rectangular surface (in plan

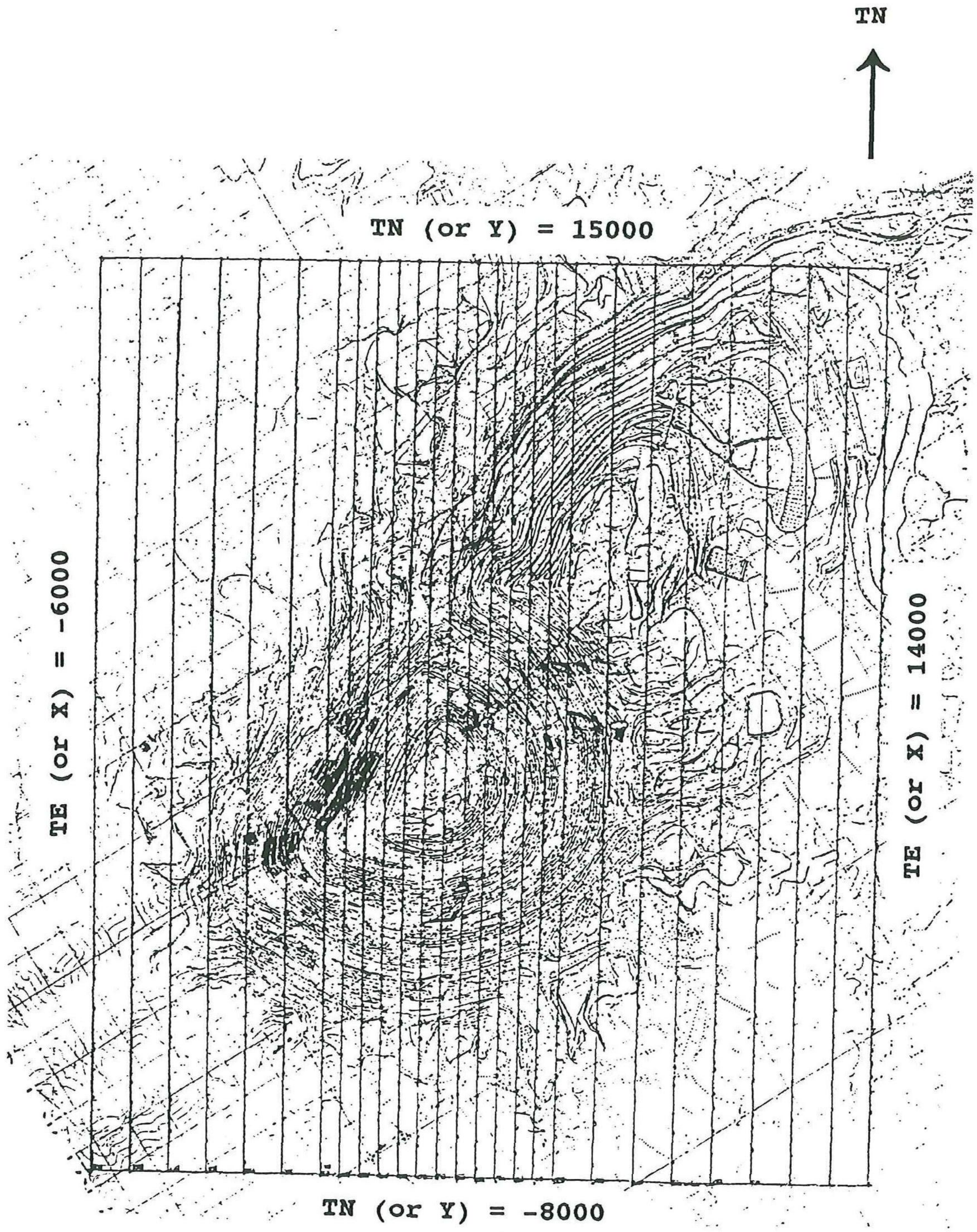

Figure 3.1 Bingham Canyon Mine Geometry (reduced in size from the 1"=1000' scale map).

view) was generated which represents the lower boundary of the domain.

3.1.2 Mesh Generation

After the geometry of the ground surface was defined, a mapped mesh was created on the surface. This mapped mesh consists of 4-node linear elements.

The upper boundary of the domain was specified using the study by Draxler and Heffter (1981). In that study, the height of the mixed layer was determined from the rawindsonde (air sounding) data collected over a five-year period at 70 stations throughout the U.S. The annual average value of the mixing depth for Salt Lake City was specified as 2959 m (9705.5 ft). With the elevation of ground as 4221 feet (from Local Climatological Data, Salt Lake City), the average mixing height was calculated as 13,926.5 feet above mean sea level (AMSL). It is recognized that the mixing height varies diurnally and seasonally, and will be affected by the presence of the Oquirrh mountains. However, this data was chosen due to the lack of better data.

After the upper boundary had been specified, the mapped mesh generated on the ground surface was projected in the Z-direction to generate a 3-dimensional finite element mesh composed of 8-node linear elements. The grading of the mesh was changed from fine to coarse in the Z-direction. This is appropriate as large gradients of variables are not expected at higher altitudes.

The mapped mesh generated on the ground surface is illustrated in Figure 3.2 and the 3-dimensional finite element mesh for the entire computational domain is illustrated in Figure 3.3. In all, there are 19,872 nodal points and 22,862 3-dimensional elements in the domain.

3.2 <u>Boundary and Initial Conditions</u>

A steady-state flow field is required first in order to compute the time dependent particle trajectories. Appropriate boundary conditions are needed to be specified at all the boundaries of the computational domain. The six faces which define the domain for the Bingham Canyon mine were named "north", "south", "east", "west", "top", and "bingham". The entity names "north", "south", "east", and "west" refer to vertical faces of the domain, "top" refers to the mixing height, and "bingham" refers to the ground at the mine and surrounding areas. The location of these six faces has been shown on figure 3.2.

Since the κ-ϵ turbulence model is being used, appropriate boundary conditions have to be prescribed for κ and ϵ, along with those for the three components (u_x, u_y, u_z) of velocity. The boundary conditions for the variables are assigned in the following manner.

<u>Inlet planes:</u> Inlet planes refer to planes from where the wind enters the domain. For instance, in the case of northerly winds, the face "north" is the inlet

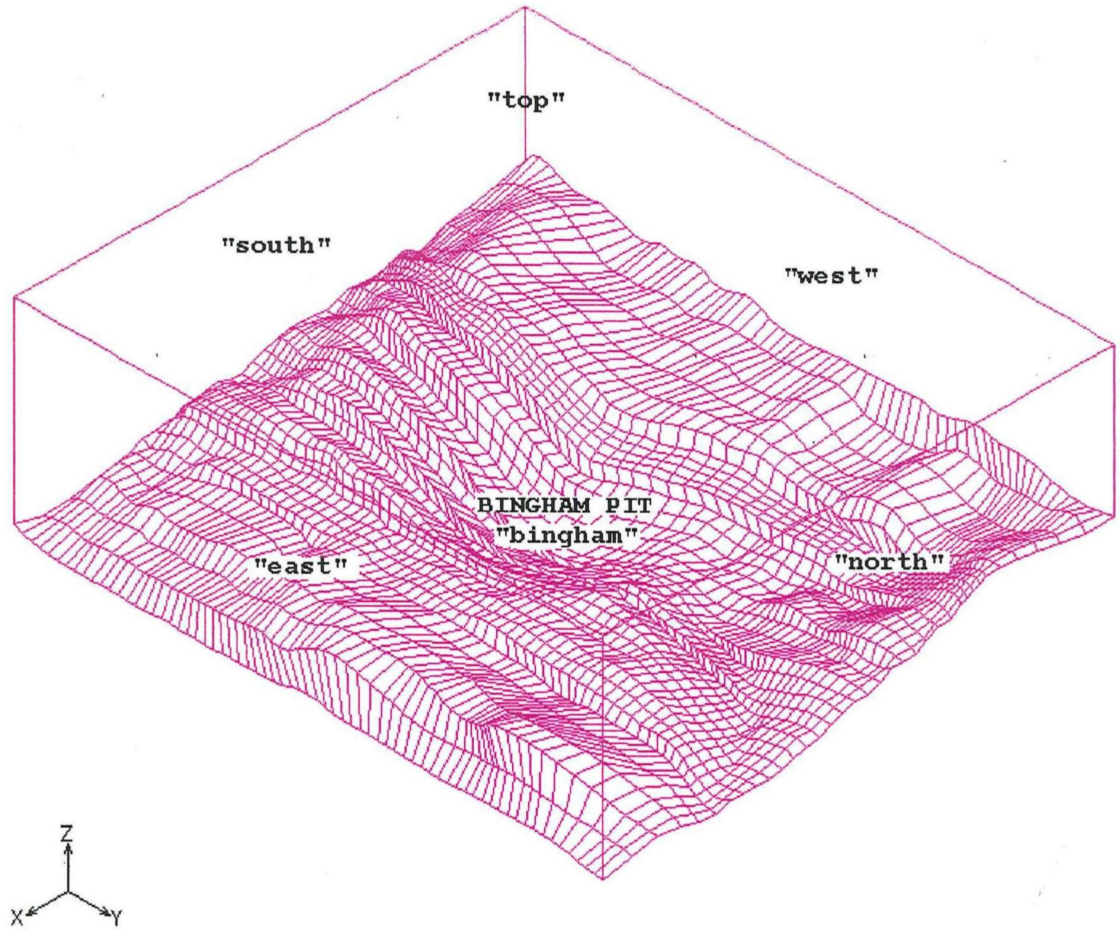

Figure 3.2 Two-dimensional mesh on the ground surface

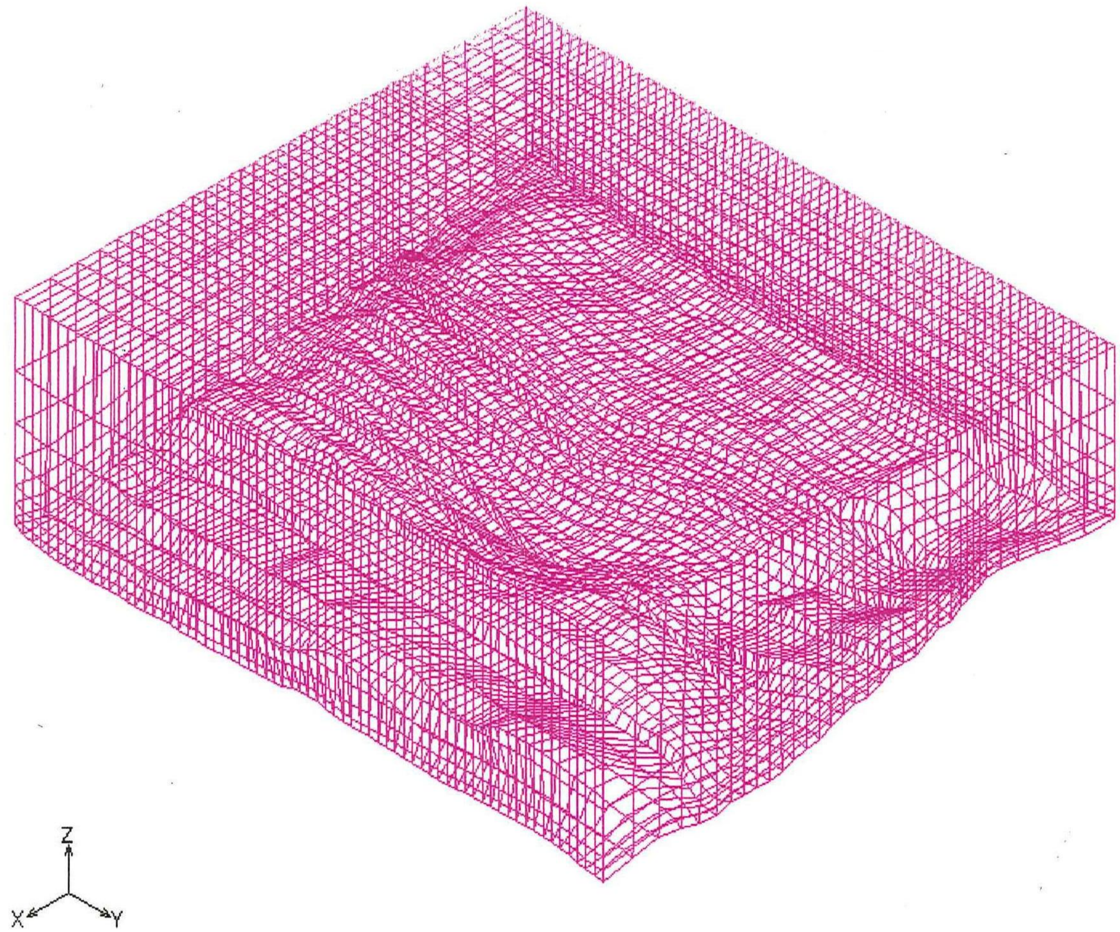

Figure 3.3 Three-dimensional mesh in the computational domain

plane. Dirichlet (i.e., prescribed or essential) boundary conditions are applied to all the variables at an inlet plane. Values for u_x, u_y and u_z are assigned based on the wind speed and direction. The value for the turbulent kinetic energy κ is calculated based on the wind speed and the stability of the atmosphere. The value of the eddy viscosity (ν_t or K_m) is also computed and the dissipation at the inlet plane is specified by $\epsilon = C_\mu \kappa^2/\nu_t$. The specific values used for the simulations will be specified when individual cases are discussed. Strictly speaking, the values prescribed should ideally be obtained from experimental measurements. It is however recognized that such experimental data is rarely available for typical simulations.

Symmetry planes: At the symmetry planes, all gradients normal to the plane and the normal velocity itself are set to zero. In the computational domain for Bingham Canyon mine, the entity "top" is a symmetry plane. At this plane, u_z (vertical component of velocity) is set to zero. As a part of the finite element discretization, the zero-gradient condition is automatically applied if no other boundary conditions are explicitly specified.

Outlet planes: Outlet planes are those through which the wind leaves the domain. For example, in the case of northerly winds, the entities "south", "west" and "east" are outlet planes. The gradients of all the variables normal to the outlet plane are set to zero. The location of an outlet plane should be sufficiently far from regions of the flow where large perturbations occur in the flow field.

Walls: At the wall (ground surface), all components of velocity are set to zero to satisfy the no-slip boundary condition. The near wall methodology (explained earlier in Chapter 2) is invoked in the near-wall region.

In order to improve the convergence characteristics of the κ-ϵ runs, nonzero initial guess fields are used for the variables. The values prescribed at the inlet plane are used as initial conditions for the entire domain.

3.3 Model Definition Data and Control Information

Equations Solved: The model is a 3-dimensional model which considers air to be incompressible and a Newtonian fluid. Isothermal conditions were assumed for the purposes of generating the simulations. The standard κ-ϵ turbulence model was used for the simulation of flows. One of the limitations of the κ-ϵ model is that it is isotropic.

Solution Approach: In solving the flow equations numerically, a highly nonlinear set of equations are being solved. Invoking the κ-ϵ turbulence model entails the solution of two additional transport equations. This can significantly increase the CPU requirements of the numerical solution. Moreover, the introduction of the κ and ϵ equations significantly increases the nonlinearity and coupling of the overall flow equations and this, in general, acts to destabilize the convergence characteristics of the numerical solution. For the numerical solution of the problem, the "Segregated" solver (FIDAP Manuals) using direct Gaussian elimination was used. The Segregated solver creates a set of equations for a single degree of freedom at a time and cycles sequentially through all unknowns at each iteration. Compared to so-called fully-coupled solvers (which solve all unknowns at the same time), the Segregated solver requires significantly less computer memory and disk storage to perform a solution to a given large problem. During the iteration process, the convergence criterion to be satisfied is:

$$\frac{\|\boldsymbol{U}_i - \boldsymbol{U}_{i-1}\|}{\|\boldsymbol{U}_i\|} \leq DTOL \tag{3.1}$$

where $\|.\|$ is a root mean square norm. The vector **U** comprises of all the nodal values of a particular degree of freedom. The convergence criterion is checked for each degree of freedom, i.e., three components of velocity (u_x, u_y and u_z), pressure, turbulence kinetic energy, and dissipation. Convergence is considered to be obtained when the criterion is met for all degrees of freedom. The recommended value of the DTOL tolerance is 0.001.

<u>Fluid Properties:</u> The viscosity μ of the air was set to 1.8×10^{-5} Pa-sec (1.21×10^{-5} lbm/ft-sec). Normally

the density (ρ) of air is specified as 1.2 kg/m^3 (at 1 atm pressure and 20°C). But due to higher altitudes, the use of the value of 1 kg/m^3 (6.25 x 10^{-2} lbm/ft^3) seemed more appropriate.

3.4 Model Execution

After the model was created (geometry and mesh generation, specification of initial and boundary conditions and, finally, entering the model definition data and control information), the model was run on the Utah Supercomputing Institute's Silicon Graphics Power Challenge. The Power Challenge is a 12 processor shared memory computer that has 2 Gbytes of 4-way interleaved core (RAM) memory, and 12 Gbytes of disk space.

A typical model run consumed about 70-80 hours of CPU time, which by conventional standards, is a extremely large computer usage time.

3.5 Particle Characteristics and Trajectories

Due to an extremely small volume fraction of particles with respect to the volume of the carrier phase (air) in the pit, the assumption of one-way coupling is reasonable. This means that while the dynamics of the carrier phase drives the motion of the dispersed phase (particulate), the presence of the dispersed phase has no effect on the dynamics of the carrier phase. Because of the one-way coupling in the model, it was possible to solve the problems in sequence, i.e., first the flow field for the carrier phase was solved, and then the particle dynamics equations were solved based on the flow field computed earlier.

For the particle dynamics, the Lagrangian formulation was used. The drag, as well as the gravity forces, were included in the computations. The particles were introduced at desired locations in the domain and were then tracked as they interacted with the turbulence in the flow field. EPA refers to emissions in terms of aerodynamic particle sizes, therefore a unit density (1 g/cm^3) was assigned to the particles. Since the $\kappa-\epsilon$ model was used for the flow fields, several particles were introduced at each location, and the stochastic model (explained earlier in Chapter 2) was used to track the particles through the domain. Individual trajectories of the particles having the same initial attributes differed because of the turbulent nature of the flow.

Information had to be specified regarding the interaction of particles if they came in contact with a boundary of the computational domain. This interaction could be that the particles escape, rebound or remain trapped when they come in contact with the domain boundary. The "escape" condition means that when the particle exits the domain, it carries with it its mass and momentum. The "rebound" condition means that the particle exchanges momentum with the boundary. The exchange of momentum is determined by the value of the restitution coefficient. A restitution coefficient less than one would imply that the particle lost some momentum to the wall. For the "trap" condition the particle velocity becomes zero at the wall, and the particle loses its entire momentum to the wall. In the simulations generated for the Bingham Canyon mine, the entities "north", "south", "east", and "west" were specified as "escape" boundaries, "bingham" (ground surface) was specified as a trap boundary and "top" was specified as a "rebound" boundary with a restitution coefficient of 1.

The details of the particle characteristics, including the particle sizes, emission points, number of trajectories, etc., will be specified when the individual cases of simulation studies are discussed.

CHAPTER 4

SIMULATION STUDIES AND ANALYSIS OF RESULTS

4.1 Choice of Simulations

Unlike many manufacturing plants, the mode of operation of a mine is highly variable, and so are its dust emissions. The relative amounts of ore and overburden mined can vary tremendously. Haulage of ore and waste is the largest single source of dust emissions at the Bingham Canyon mine. The location of the dust emissions depends on where the material is being mined, handled or hauled. Along with the variability in the emission sources, the meteorological parameters are also highly variable. These meteorological parameters are wind speed, wind direction and atmospheric stability. Also, the features of the local terrain may have some critical effects on the impacts of emissions.

Because of almost infinite possible combinations of various source characteristics and meteorological parameters, it would be almost impossible to model all the cases. Perhaps it would be more feasible to study the effects of individual parameters. In this study, the simulations were planned so that the "sensitivity analyses" could be conducted. In this scheme of work, only one parameter at a time could be altered, keeping all other parameters constant. Thus, meaningful conclusions could be drawn about the effects of the parameter on the dispersion and pit retention of dust.

Site-specific data was analyzed in order to prepare the input data to generate the simulations. Wind rose data collected at 6290 level Mine Office for the year 1994 was analyzed to determine most frequent wind directions. One such wind rose (for January 1994) is presented as Figure 4.1. It was determined that the northerly, north-easterly and north-westerly winds were more frequent, with the frequency of northerly winds the highest. Winds from other directions were present, but their frequencies were lower. Also, the mine environmental data from the period May 1994 to May 1995 was examined for the range of wind speeds. The wind sensor was about 15′ high above the ground level. One such wind speed data (for July 1994) is presented as Figure 4.2. In general, while the average speed range was typically 1 to 10 miles/hour, a peak gust could even be higher than 50 miles/hour.

The site-specific wind speed and direction data was used to make the simulations more representative of the actual conditions. For instance, because of the very high frequency of the northerly winds, the wind direction was set as northerly in all cases, except when the effect of wind direction had to be evaluated. Likewise, because of a typical wind speed range of 1 to 10 miles/hour, wind

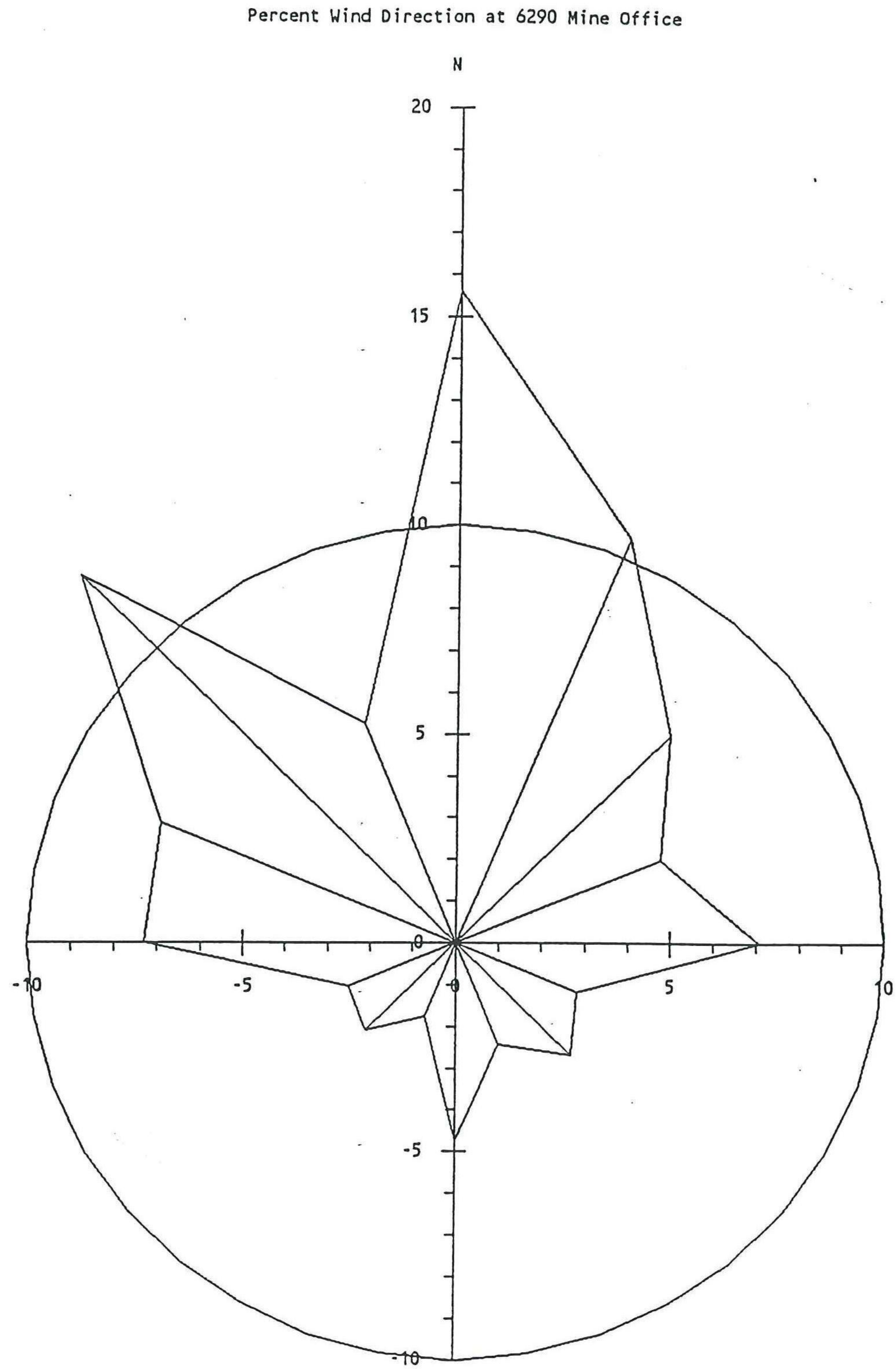

Figure 4.1 Wind rose for January 1994

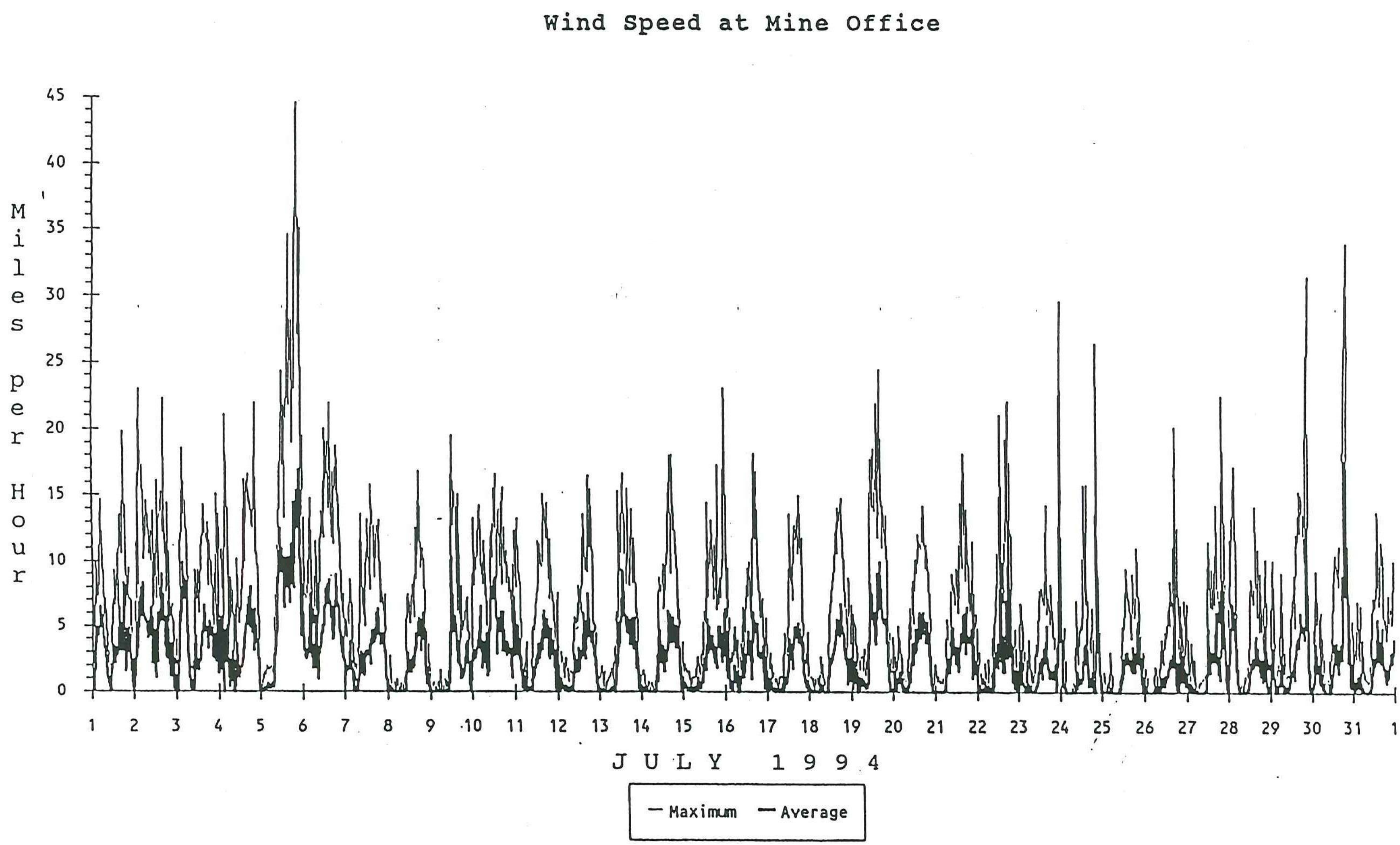

Figure 4.2 Wind speed data for July 1994

speed was set to 6 miles/hour (in the mid-range) in all cases, except when the effect of wind speed had to be evaluated. The turbulence or stability data was not available. So neutral stability (D) was used in all cases, except when the effect of stability had to be evaluated.

It was decided that nine "flow" situations would be enough to present a representative profile of the meteorological conditions. These nine cases are tabulated in Table 4.1. To study the effects of emission source characteristics, it was decided that a wind speed of 6 miles/hour, northerly wind direction and neutral stability would be used.

4.2 Specification of Input Data

This section discusses the specification of input data which was required to generate the individual simulations. The data explained here is supplementary to general input data explained in Chapter 3.

4.2.1 Wind Profile

An important characteristic of wind is the variation of speed with height. The wind speed is zero at the surface, and it increases with height above ground, up to the top of the atmospheric boundary layer. Above this layer, gradient wind exists, which does not vary with height. Either a classical logarithmic profile (Equation (2.18)) or a simple power-law is generally used to

Table 4.1 Simulation Cases

Case Number	Wind Speed (miles/hour)	Wind Direction (coming from)	Atmospheric Stability
1	6	north	D (neutral)
2	6	north	A (extremely unstable)
3	6	north	F (moderately stable)
4	2	north	D (neutral)
5	10	north	D (neutral)
6	30	north	D (neutral)
7	6	south	D (neutral)
8	6	west	D (neutral)
9	6	east	D (neutral)

describe the wind variation with height. However, these empirical formulas are valid for speed variation over flat (horizontal) areas. For the complex terrain in the Bingham Canyon area, use of these formulas as boundary conditions (for the upstream boundary of the domain) is not appropriate simply because of the complex wind flow regimes that might be present.

In the Bingham pit model, the boundaries were chosen to be sufficiently far from the area of interest, and a uniform profile was used to describe the wind on the upstream boundary. The assumption was that because of the no-slip boundary condition assigned to the ground, the wind would adjust to an appropriate profile depending on the terrain, before the flow reaches the area of interest (the emission points).

4.2.2 Turbulent Kinetic Energy κ and Dissipation ϵ

This section discusses the values of turbulent kinetic energies and dissipation which were used as upstream boundary conditions to generate various simulations. The values of κ and ϵ govern the turbulence structure of the atmosphere. As mentioned earlier, ideally these values should be obtained from field or experimental measurements. These measurements were not available in this study. Since the primary objective of this study was a comparative analysis of different meteorological and source parameters, it was considered appropriate to calculate the values of κ and ϵ based on formulations that exist in the literature. All the necessary formulations have been explained in Chapter 2.

Table 4.2 presents the wind fluctuation data that was used. The data has been adapted from Tables 7-1 and 7-2 of Zannetti (1990), where he tabulates the wind fluctuation data in order to classify different stability categories. The footnotes of the tables explain that the data presented was for steady-state conditions, a measurement height of 10 m, for level terrain, and an aerodynamic surface roughness length of 15 cm. Because of lack of better data, use of this data was considered appropriate for the Bingham pit model.

For the calculations, values of the Monin-Obukhov length L were also required for different stability categories. The following power law function was used to characterize L (Zannetti, 1990)

$$1/L = az_o^b \qquad (4.1)$$

where a and b are constants, and z_o is the roughness length in meters. Table 4.3 provides the values of constants a and b. Using Equation (2.17) and the height of obstacles (pit benches) as 50 feet (or 15.2 m), the value of z_o was specified as 0.5 m. Based on the values of a, b and z_o, values of L were calculated for each stability category.

Table 4.2 Wind fluctuation data (adapted from Tables 7-1 and 7-2 of Zannetti, 1990)

Pasquill Stability Category	Standard Deviation of the Horizontal Wind Direction Fluctuations (σ_θ)	Standard Deviation of the Vertical Wind Direction Fluctuations (σ_ϕ)
A	25°	12.2°
D	10°	6.4°
F	2.5°	1.5°

Table 4.3 Coefficients a and b to calculate Monin-Obukhov Length (adapted from Table 3-4 of Zannetti, 1990).

Stability Class	a	b
A	-0.0875	-0.1029
D	0.	0.
F	0.03849	-0.1714

As explained earlier, several models for eddy viscosity (K_m or ν_t) have been proposed in the literature. One such model was mentioned earlier by Equation (2.20). During simulation of the LNG (Liquified Natural Gas) vapor spread and dispersion by finite element methods, Chan, et al. (1980) used the eddy viscosity values of 0.1, 1 or 10 m^2/sec to represent different atmospheric conditions. Yu (1977) examined several parameterization schemes for the vertical turbulent exchange processes in the atmospheric boundary layer. One of the parameterizations examined by Yu was a constant eddy viscosity model where K_m was set constant from the top of the constant flux layer (surface layer) throughout the entire boundary layer. His conclusion was that a constant eddy viscosity model performs quite well near the lower levels, but becomes less satisfactory at higher levels. In the Bingham pit model, since the emissions take place near the ground level, it was important to characterize the lower levels as accurately as possible. The values of eddy viscosities were calculated at the top of the surface layer (assumed 70 m) and were used to assign the upstream boundary conditions of turbulent kinetic energies κ and dissipations ϵ.

Calculations for κ and ϵ: Calculations were done for the nine test cases tabulated in Table 4.1 and the values were used as prescribed boundary conditions on the upstream boundary. For a given stability category, σ_θ and

σ_ϕ were obtained from Table 4.2. For a given wind speed, σ_v and σ_w were calculated by the expressions (2.22) and (2.23) (using tan $\sigma_\theta \approx \sigma_\theta$, likewise for σ_ϕ). Next, the value of u_* was computed using the relations (2.29), (2.30) and (2.31). The value of σ_u was then obtained through Equations (2.32) and (2.33). Knowing the values of σ_u, σ_v and σ_w, the value of turbulent kinetic energy κ was calculated from (2.4) and (2.21). Next, the value of ϕ_m was computed from (2.26), (2.27) and (2.28), and then the value of K_m (or $\nu_t = \mu_t/\rho$) was calculated using Equation (2.24). Knowing K_m and κ, ϵ was estimated using Equation (2.5).

The values of κ and ϵ computed and used in the simulations are listed in Table 4.4.

4.3 Sensitivity Studies and Analyses

One of the major objectives of the Bingham pit modeling study was to provide the basis for developing a better understanding of the release of dust from the pit and the sensitivity of the dust dispersion and pit retention to a wide range of meteorological and source parameters. In this study, the analysis was conducted to understand the sensitivity to:

- wind speed
- wind direction
- atmospheric stability
- source location and height

Table 4.4 Values of computed turbulent kinetic energy κ and dissipation ϵ.

Wind Speed ft/sec (mi/hr)	Stability Category	Simulation Case(s)	Turbulent Kinetic Energy κ (ft^2/sec^2)	Dissipation ϵ (ft^2/sec^3)
8.8 (6)	A	2	18.6378	1.0892×10^{-1}
8.8 (6)	D	1,7,8,9	3.4703	1.4952×10^{-2}
8.8 (6)	F	3	0.174	2.6068×10^{-3}
2.93 (2)	D	4	0.3856	5.5262×10^{-4}
14.67 (10)	D	5	9.6391	6.9214×10^{-2}
44.0 (30)	D	6	86.7512	1.8684

- particle size

The sensitivity analysis for each parameter involves either individual cases or combination of cases outlined in Table 4.1. These cases will be referenced by number in the analysis.

As mentioned earlier, a stochastic model for particles was used because of the turbulent nature of the atmosphere. To evaluate the results of the stochastic model, a number of particles were introduced at a dust emission point and their trajectories were tracked through the time. The particles were tracked in 10 seconds increments. Due to the turbulence, different particles with the same initial conditions could have different trajectories and dispersion. This required introduction of a very large number of particles at each emission point. After a few test runs, it was concluded that 500 particles (all of the same size) introduced at each dust source location would yield consistent results. Since the total massflow could be divided equally among the 500 particles, the fraction of the total number of trajectories escaping the domain boundaries could be used as a measure of escape fraction. Thus, the escape fraction ε can be computed as

$$\varepsilon = \frac{n}{N} x\ 100\% \tag{4.2}$$

where n is the number of trajectories leaving the domain and N is the total number of trajectories (500). If desired, the pit retention could be calculated as (100-ε)%.

As tabulated in Bingham Canyon Mine Emission Inventory (1994), a majority of PM-10 emissions (70-75%) are due to haul roads. It is clear that near-ground level sources such as haul roads are the major contributors of dust emissions. Hence, greater emphasis was placed on these sources in this study. In the model evaluation protocol for modeling fugitive dust impacts from surface coal mining operations, the EPA (1994) suggested a release height of 2 m to be used in representing haul roads. The release height of 2 m approximates the level in the dust plume that equally divides the mass flux. In the Bingham pit study, a release height of approximately 7 feet above the ground was used for representation of ground-level sources.

4.3.1 Sensitivity to Wind Speed

Four cases (4,1,5,6) were used to examine the sensitivity of pit retention of dust to the wind speed. In all the cases, northerly winds and neutral atmospheric stability was assumed. Further, the emission source was introduced at the pit bottom (Coordinates: X = 3000 ft, Y = 2000 ft, based on True North) at the release height of 7 feet. The aerodynamic particle size introduced in all these cases was 10 μ. In order to examine the effect of only the wind speed, it was essential to hold all other parameters constant.

Results: The patterns of winds in all the test cases, i.e. with wind speeds of 2 miles/hr, 6 miles/hr, 10 miles/hr, and 30 miles/hr were found to be similar. Figure 4.3 and 4.4 illustrate the wind patterns for Case 1. Figure 4.3 shows the wind flow pattern at a vertical section taken at X = 3000 feet, while Figure 4.4 shows the wind flow pattern at a horizontal section taken at Z = 6290 feet. It was observed that wind is affected by the terrain features. In particular, it was seen that wind changed directions while it moved in the Bingham Canyon.

The dust trajectories generated for the four cases are presented as Figures 4.5 through 4.8. In general, as the wind speed increases, the dispersion pattern spreads more horizontally and vertically. This can be attributed to increased turbulent kinetic energies, as wind speed increases. Figure 4.9 illustrates the trajectories for case 1 (wind speed 6 miles/hr) viewing along the X-direction. As mentioned earlier, the escape fraction can be estimated as the fraction of escaping particle trajectories out of the total 500 trajectories introduced at the emission point. The escape fractions were found to be 10.2%, 11.8%, 12.4%, and 12.6% for test cases 4, 1, 5, and 6, respectively. Thus, it can be concluded that as wind speed increases, a higher fraction of particles will leave the boundaries of the pit. The result is also

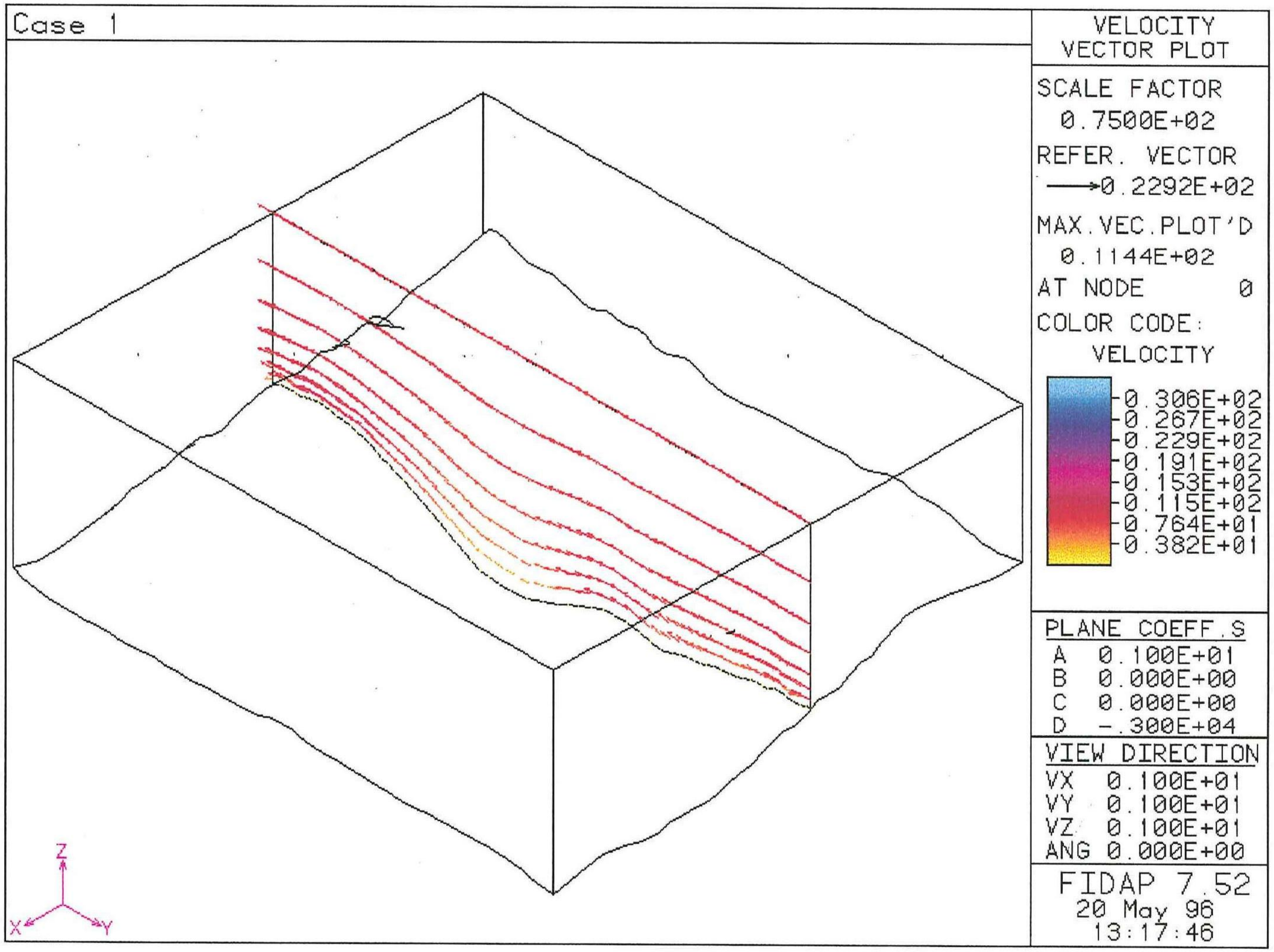

Figure 4.3 Wind flow patterns for case 1
(at section TE (or X)=3000 feet)

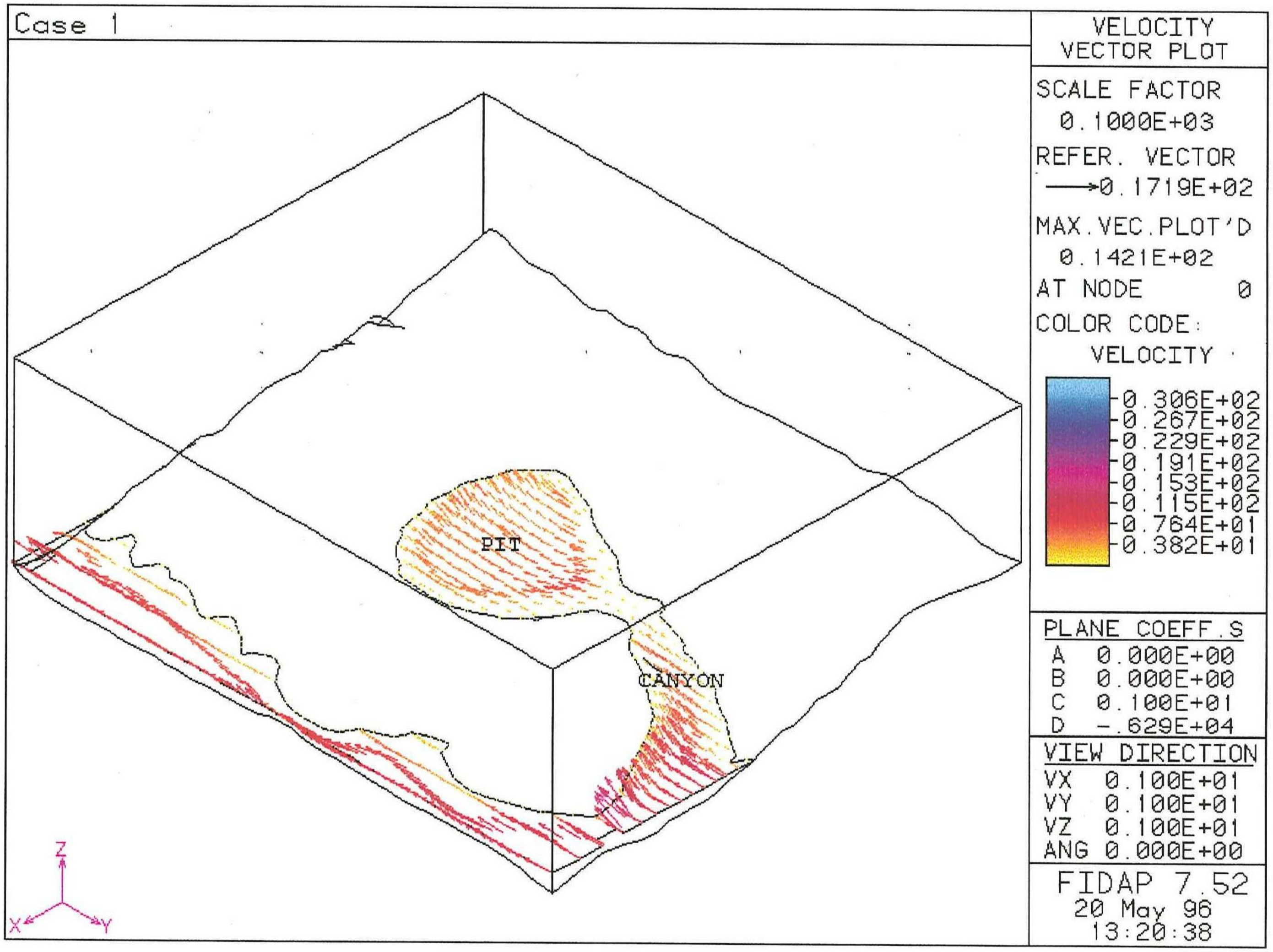

Figure 4.4 Wind flow patterns for case 1
(at section Z=6290 feet)

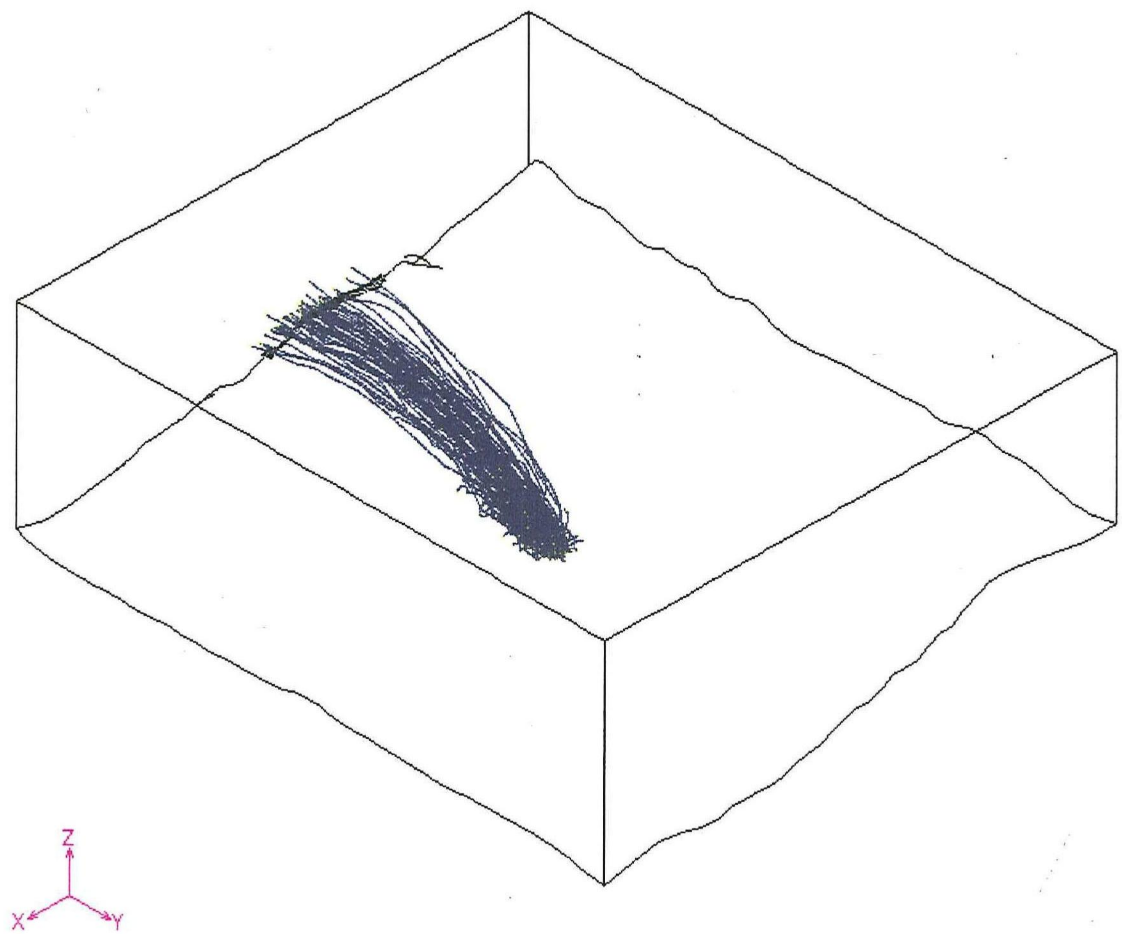

Figure 4.5 Particle trajectories for case 4
(wind speed 2 miles/hour)

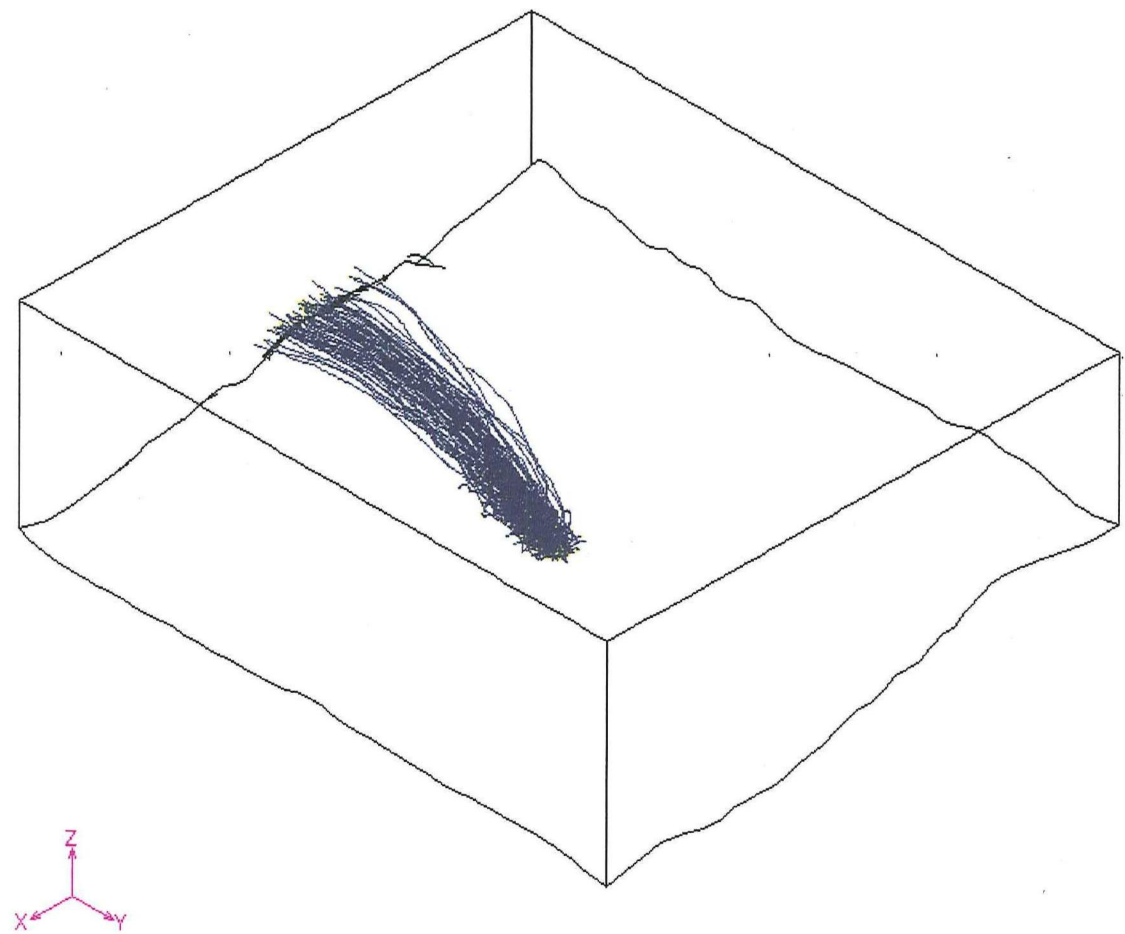

Figure 4.6 Particle trajectories for case 1
(wind speed 6 miles/hour)

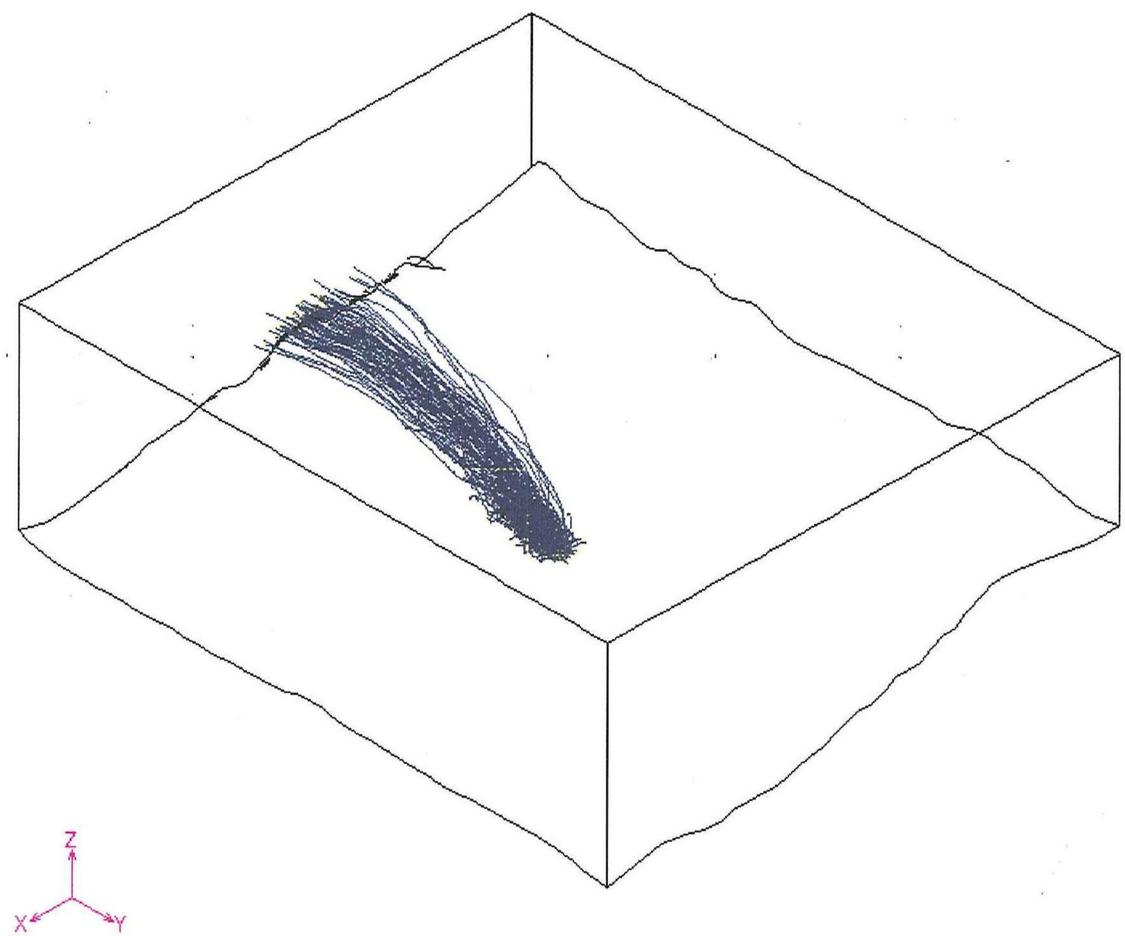

Figure 4.7 Particle trajectories for case 5
(wind speed 10 miles/hour)

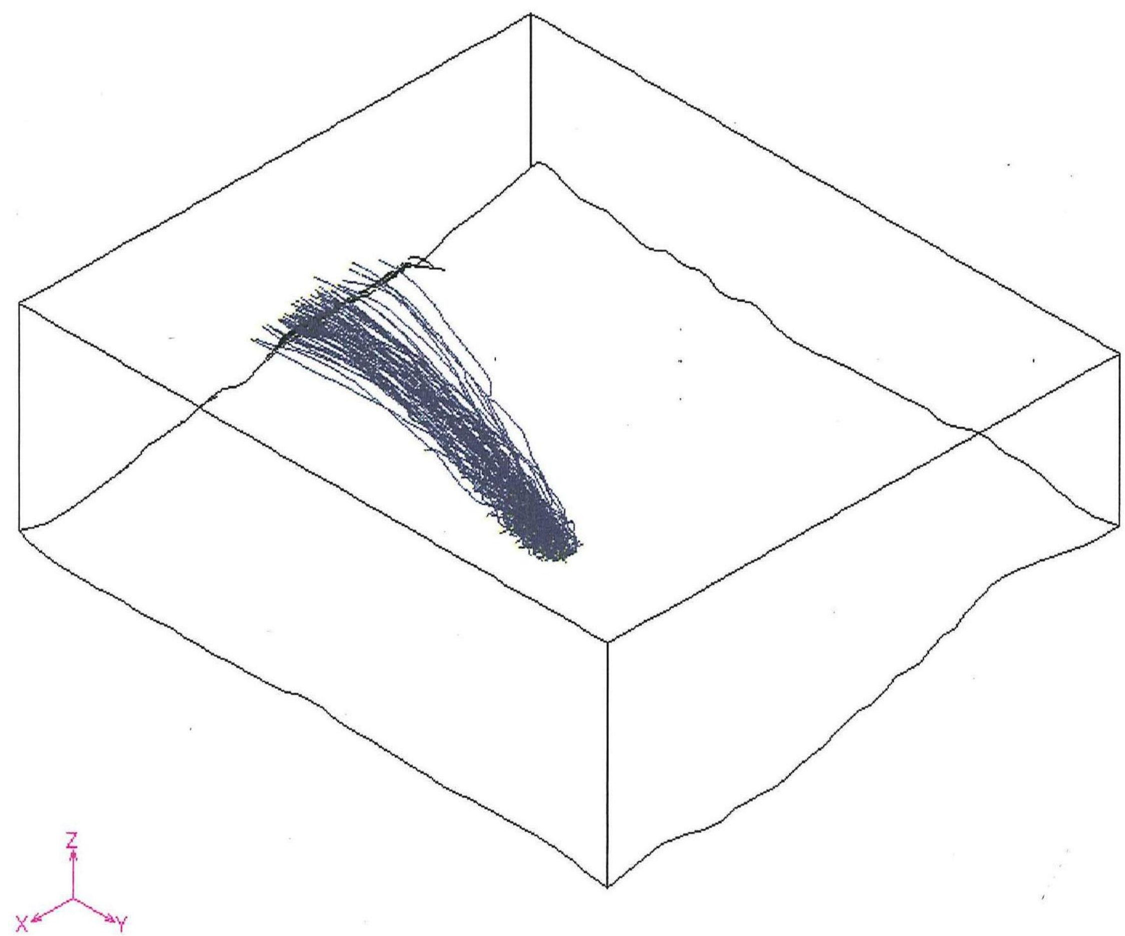

Figure 4.8 Particle trajectories for case 6
(wind speed 30 miles/hour)

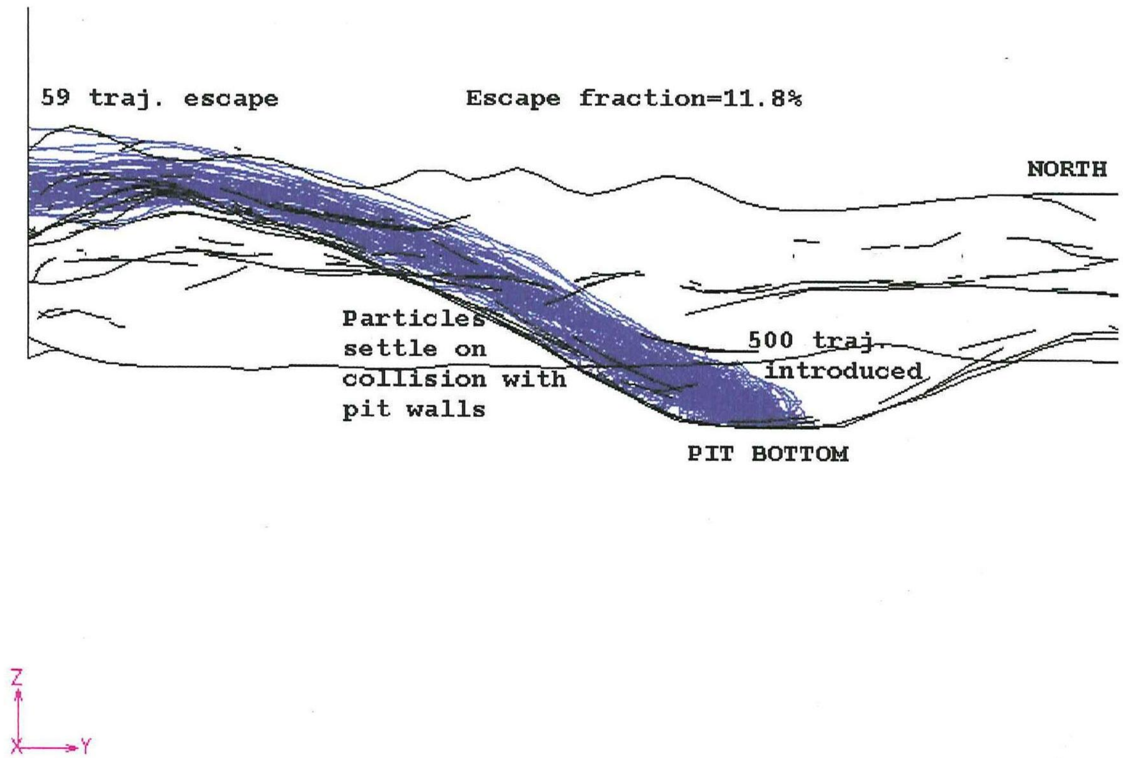

Figure 4.9 Particle trajectories for case 1 (wind speed 6 miles/hour), view along X-direction

illustrated in Figure 4.10. It seems that at higher speeds, the increase of escape fraction with wind speed becomes less pronounced.

4.3.2 Sensitivity to Wind Direction

Four cases (1,7,8,9) were used to examine the sensitivity of pit retention to the wind direction. In all cases, a wind speed of 6 miles/hr and neutral stability was assumed. The emissions were introduced at pit bottom at the coordinates X = 3000 feet, Y = 2000 feet at a release height of 7 feet, and the aerodynamic particle size of 10 μ.

Results: The results for Case 1 with a pit bottom source at a release height of 7 feet have already been discussed. The results for cases 7,8 and 9 were additionally evaluated.

After analysis of the particle trajectories, the escape fractions were computed to be 11.8%, 12.6%, 12.2%, and 12.4% for the northerly, southerly, westerly, and easterly winds, respectively. Since the emission point is not equidistant from the respective downstream boundaries, the pit retention/escape fraction cannot be compared based on the wind direction. However, one conclusion that can be drawn is that in the case of southerly winds (Case 7), the particles which escape from the pit somewhat follow the contours of the Bingham Canyon. This effect is shown by Figure 4.11 and Figure 4.12. Figure 4.11 is a velocity

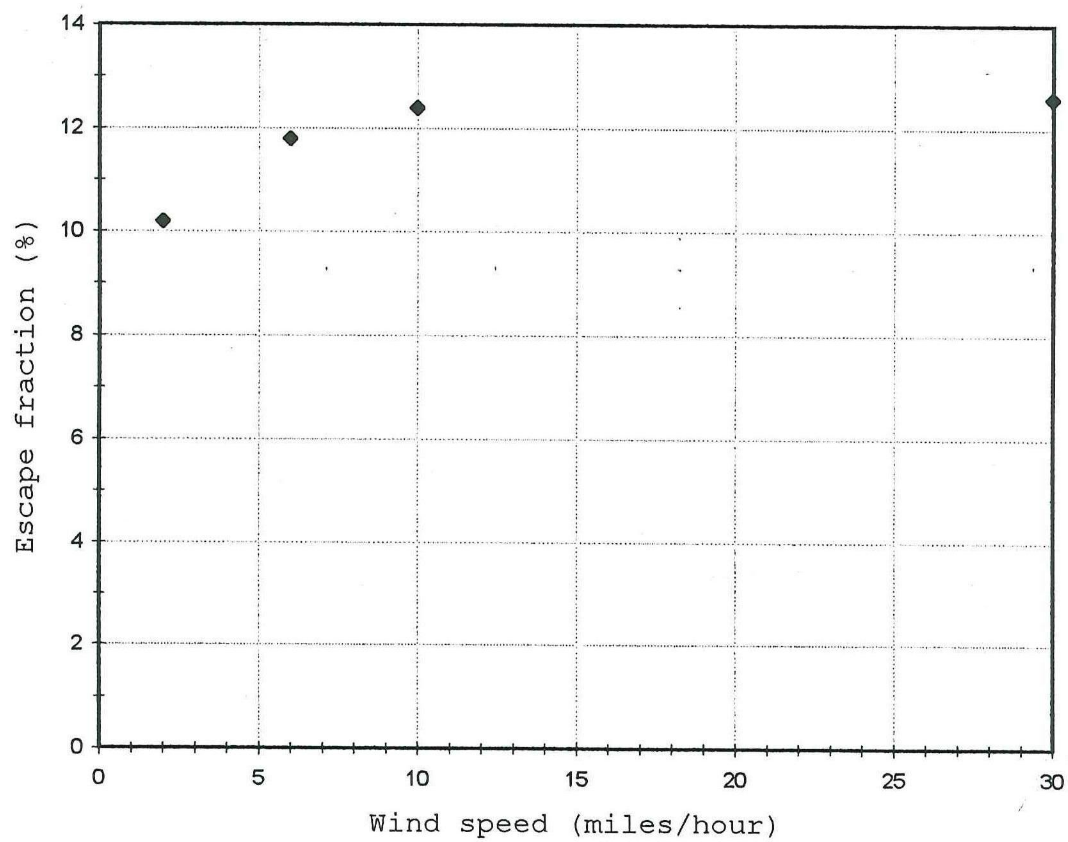

Figure 4.10 Sensitivity of escape fraction to wind speed

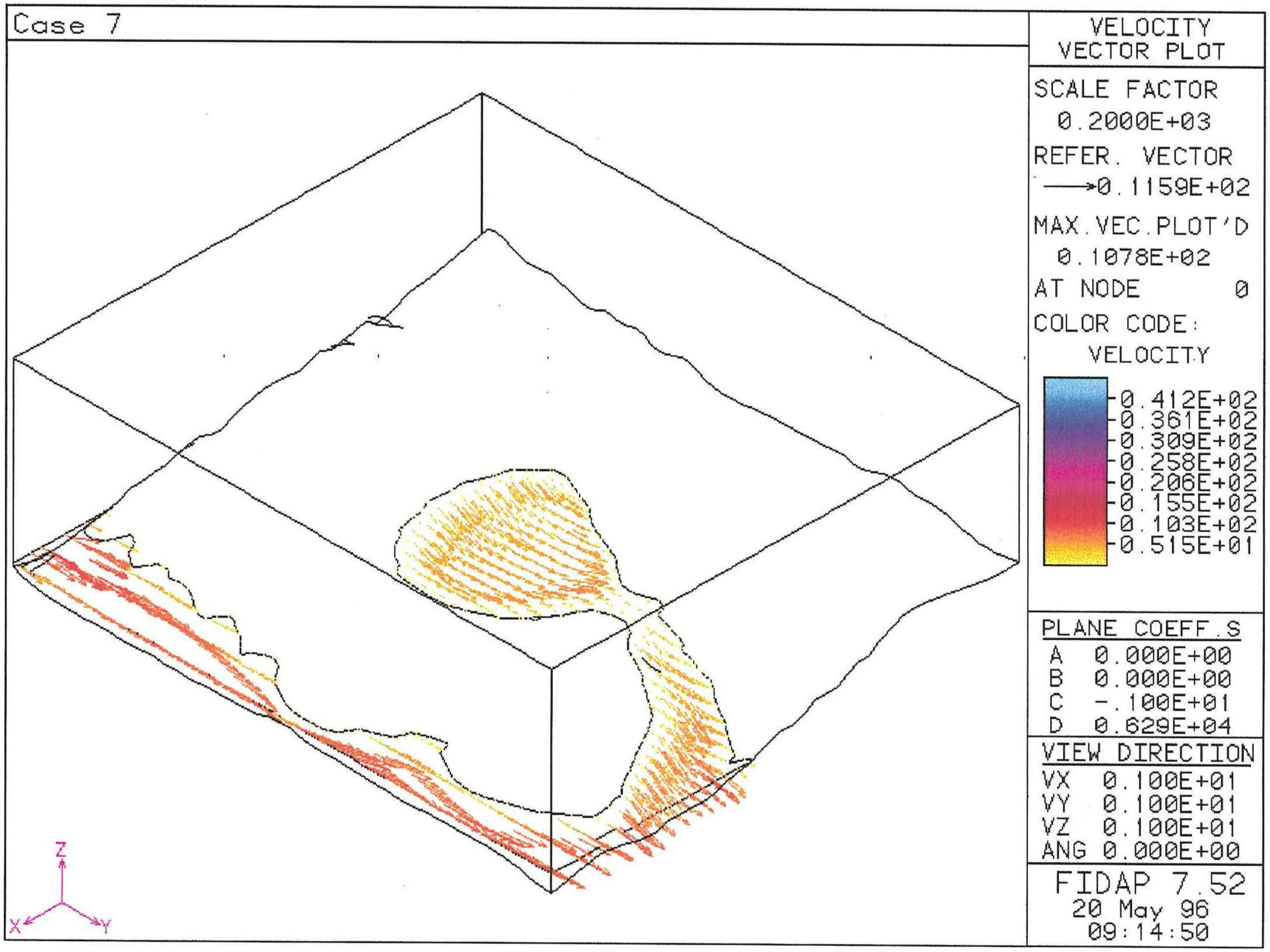

Figure 4.11 Velocity vector plot for southerly winds at Z=6290 feet

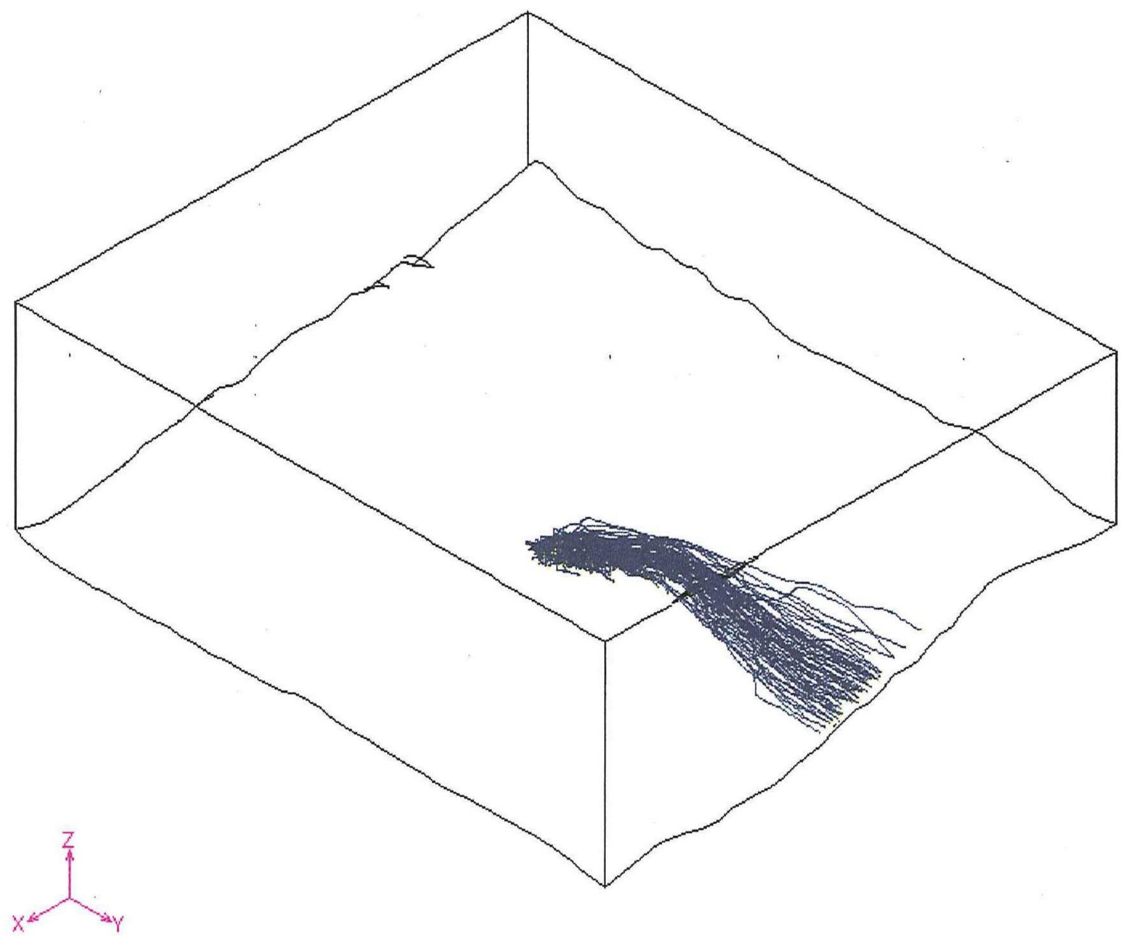

Figure 4.12 Particle trajectories for southerly winds

vector plot at the horizontal section taken at Z = 6290 feet, and Figure 4.12 is the corresponding particle trajectory plot. Hence, a slightly higher escape fraction (12.6%) was obtained for southerly winds in spite of the greater distance of travel to the downstream boundary.

4.3.3 Sensitivity to Atmospheric Stability

Three cases (2,1,3) which represent stabilities A, D and F, respectively, were used to examine the sensitivity to atmospheric stability. In all the cases, northerly winds with speeds of 6 miles/hour were assumed. Again, the emission point was located at X = 3000 feet, Y = 2000 feet at a release height of 7 feet above ground, and was releasing 10 μ particles.

Results: The particle trajectories obtained for the three situations are shown by Figures 4.13, 4.6 and 4.14. As anticipated, the spread in the horizontal and vertical directions was found to be maximum for unstable conditions (Case 2), minimum for stable conditions (Case 3) and intermediate for neutral conditions (Case 1). This is because as the air becomes more unstable, the higher magnitude of wind fluctuations and eddy sizes cause more dispersion/spread of the trajectories. Quantitatively, the escape fractions were found to be 12.6%, 11.8% and 12.2% for unstable, neutral and stable conditions, respectively.

If a relationship such as Winges equation (Equation

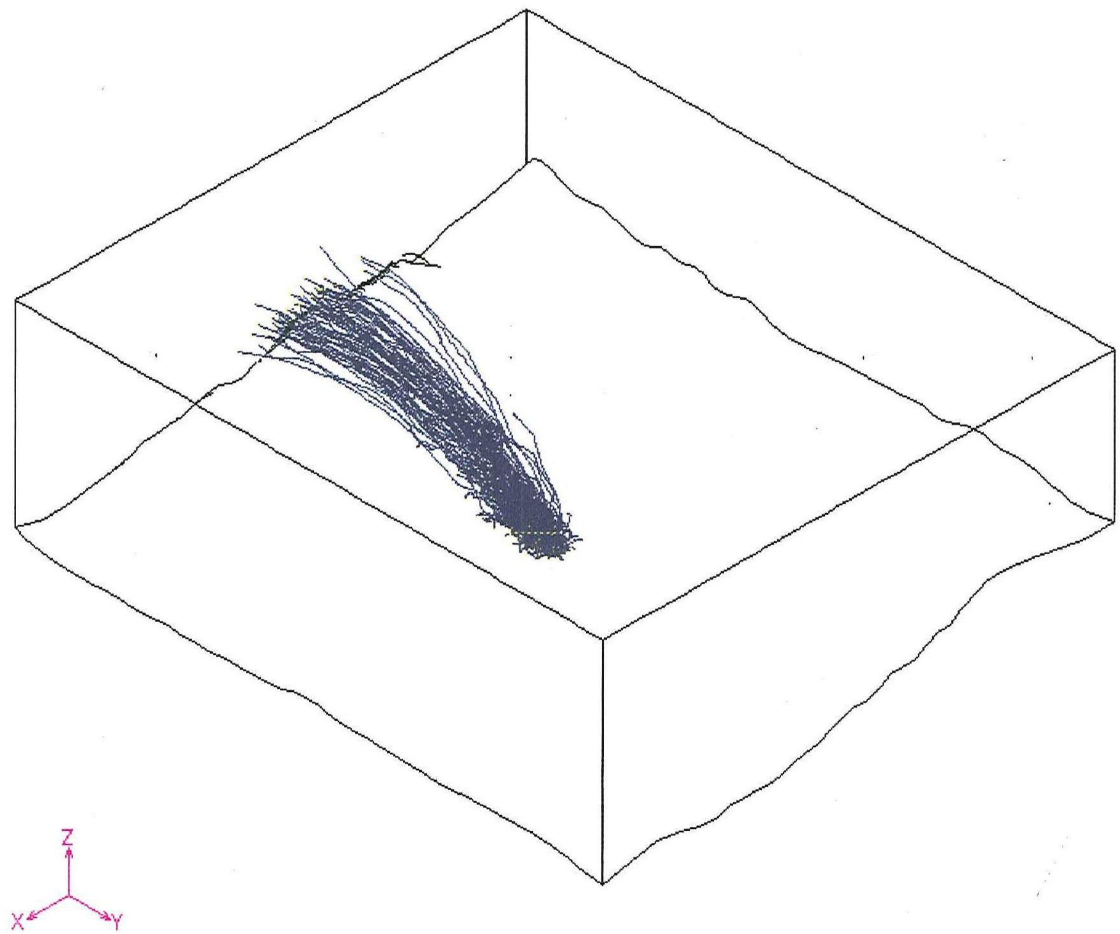

Figure 4.13 Particle trajectories for unstable (case 2) conditions

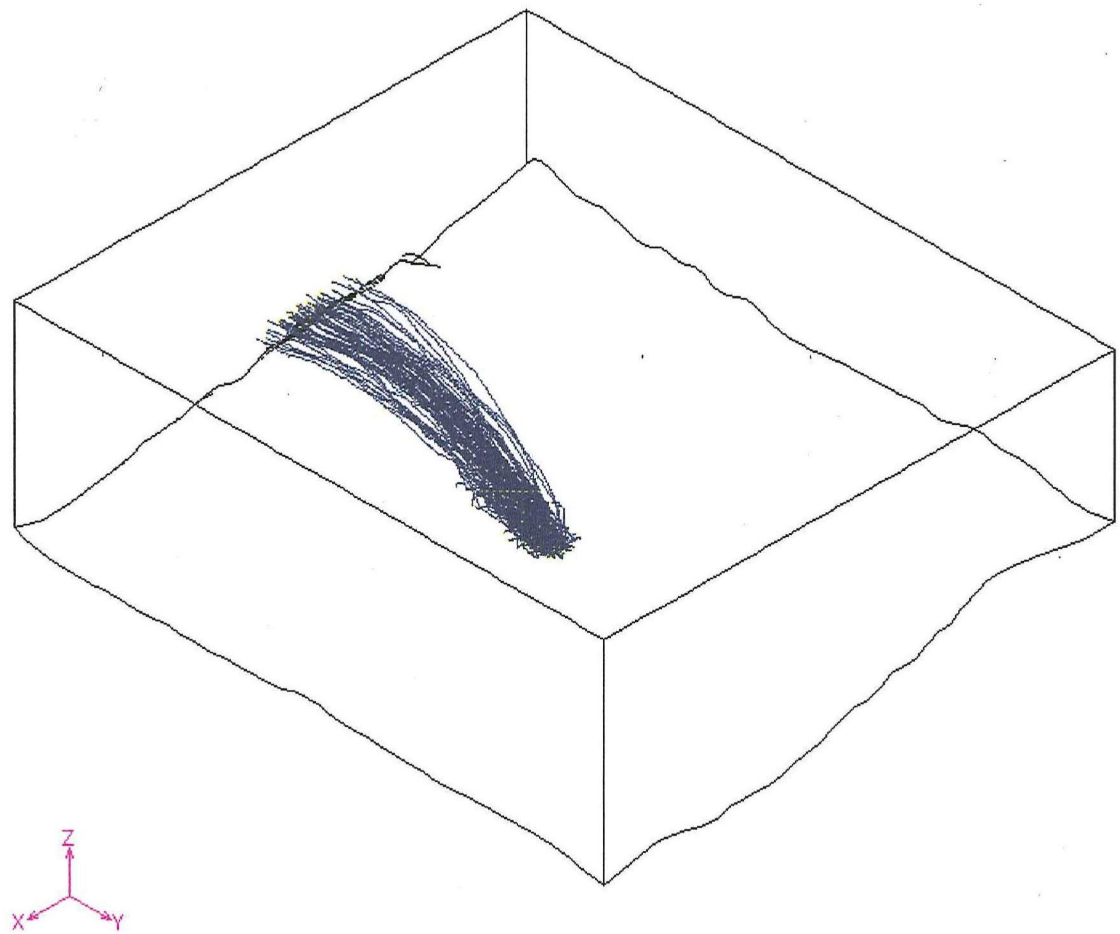

Figure 4.14 Particle trajectories for stable (case 3) conditions

(1.2)) was being used to estimate the escape fraction, one would conclude that the escape fraction should be maximum for unstable conditions and should decrease as the atmosphere becomes more stable. However, as mentioned earlier, Winges equation treats a very simplified dispersion scenario. One of the limiting assumptions of the Winges equation is that turbulent diffusion is the only mechanism for the transport of material out of the pit, and the convection due to the wind is ignored.

Realistically speaking, the convection by wind is probably a very important phenomenon which causes transfer of the material downwind. Hence, it is possible that under stable conditions (where the spread of trajectories is minimum), fewer particles might get trapped due to the interaction with the pit walls and a higher fraction could be transported downwind. This explains the probable cause of the higher value of escape fraction obtained for stable conditions (12.2%) in the Bingham pit study.

4.3.4 Sensitivity to Source Location and Height

4.3.4.1 Source location. Case 1 was used to analyze the sensitivity of the pit retention/escape fraction to source location. In Case 1, northerly wind with a speed of 6 miles/hr and neutral stability was used. Particles with an aerodynamic diameter of 10 μ were introduced at three locations in the pit. For all three locations, the release height of 7 feet above the ground was used. The three locations evaluated were:

- pit bottom (X = 3000 feet, Y = 2000 feet)
- a source near the downwind boundary of the domain (X = 3000 feet, Y = -3000 feet), which represents the so-called "worst" case scenario
- a source near the in-pit crusher (X = 4190 feet, Y = 3220 feet), chosen as this is a high-activity area.

<u>Results:</u> Under the conditions of the simulations, the escape fractions were found to be 11.8%, 19.2% and 16.6% for the three locations (in the same order mentioned earlier). These escape fractions follow the expected trend: the deeper the source in the pit, the lesser the escape fraction. The particle trajectories for the source near the downwind boundary and for the source near the in-pit crusher is illustrated by Figures 4.15 and 4.16.

4.3.4.2 **<u>Source height</u>.** Case 1 was used to analyze the sensitivity to source height. Particles with an aerodynamic size of 10 μ were introduced at the pit bottom (X = 3000 feet, Y = 2000 feet) in both cases. Two source heights were considered in the evaluation: 7 feet (to represent sources such as haul roads) and 30 feet (to represent sources such as truck loading by a shovel).

<u>Results:</u> As explained earlier, the escape fraction for the 7 feet high source was calculated to be 11.8%. For the release height of 30 feet, the escape fraction was

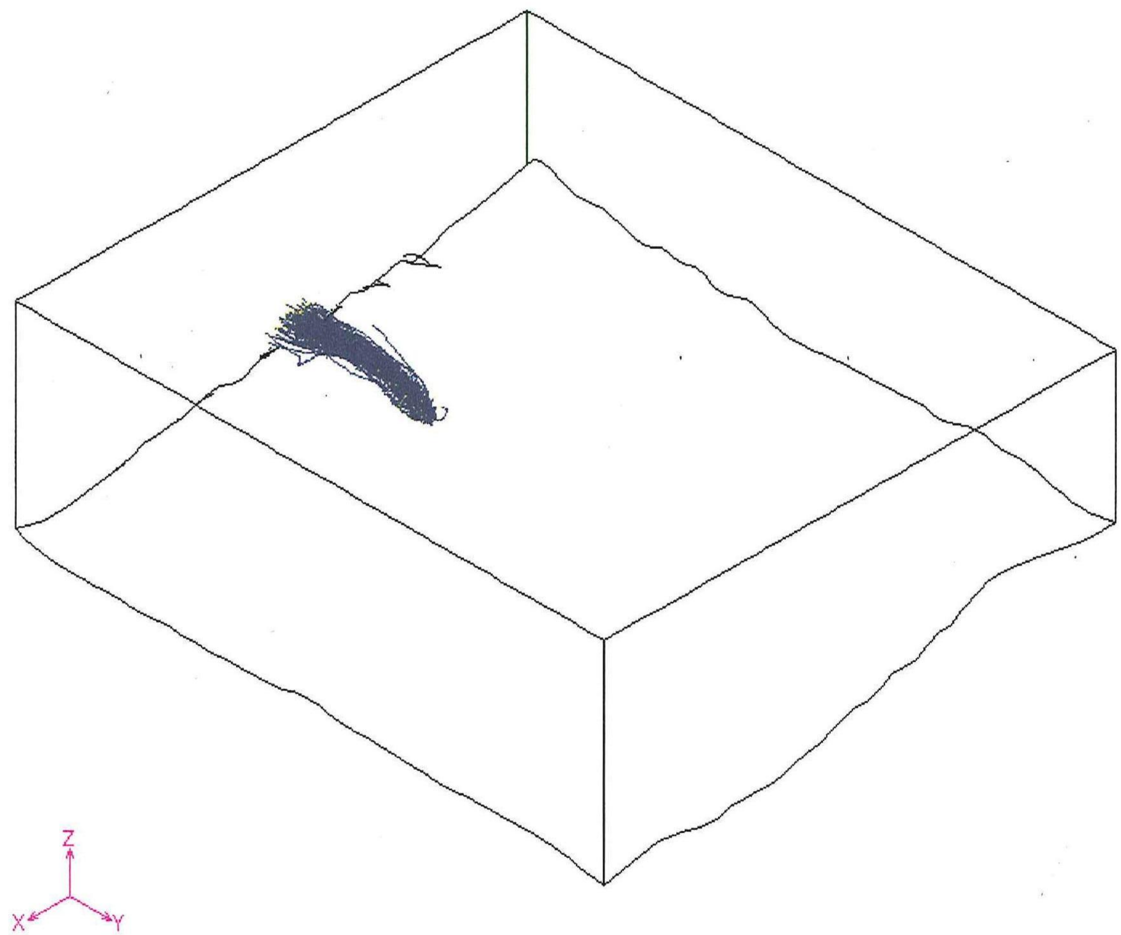

Figure 4.15 Particle trajectories for near-downwind boundary emission source ("worst-case scenario")

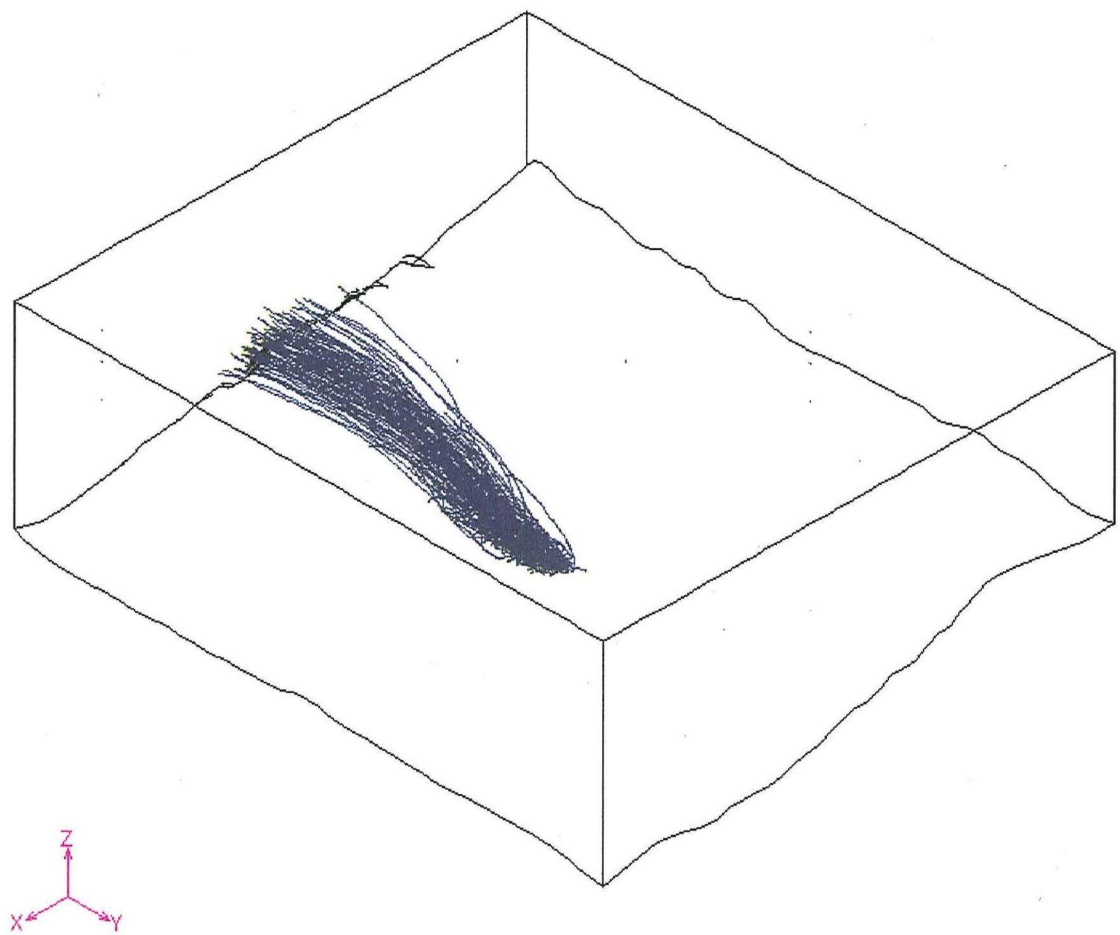

Figure 4.16 Particle trajectories for near-in-pit crusher emission source

found to be 13.4%. A higher value of escape fraction was obtained for the 30 feet high source as it encounters higher wind speeds and thus, the probability for the trajectories to cross the downstream domain becomes greater.

4.3.5 Sensitivity to Particle Sizes

Case 1 was again used to study the sensitivity of the escape fraction to particle sizes. In all the cases, the source location used was the pit bottom (X = 3000 feet, Y = 2000 feet) at the release height of 7 feet.

It should be clarified that the particle sizes used here are aerodynamic particle sizes (with unit density). This was done as EPA's standards for air quality exist for PM-10, and PM-10 refers to particles with aerodynamic diameters smaller than 10 μ.

Results: Several aerodynamic particle sizes (1 μ, 2 μ, 5 μ, 7 μ, 10 μ, 15 μ, 20 μ, 30 μ, 50 μ and 80 μ) were introduced at the emission point. The results are shown in Figure 4.17. As the particle size was increased, the escape fraction decreased. This is due to increased values of terminal settling velocities (and hence more gravitational settling) for larger particles. The escape fraction for PM-10 in this case is approximately 12.4%.

Figure 4.18 illustrates comparison of the results obtained with the different escape fraction equations. The mathematical expressions for all these equations have

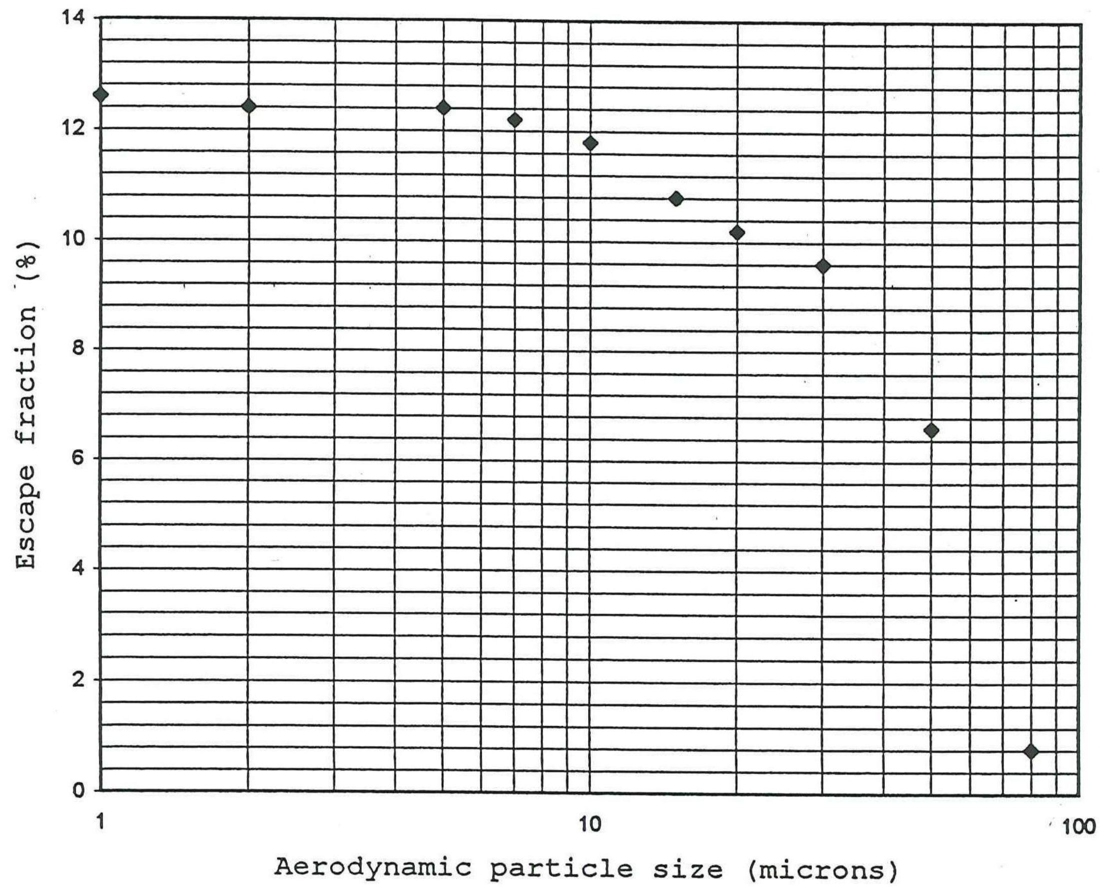

Figure 4.17 Sensitivity of escape fraction to aerodynamic particle size

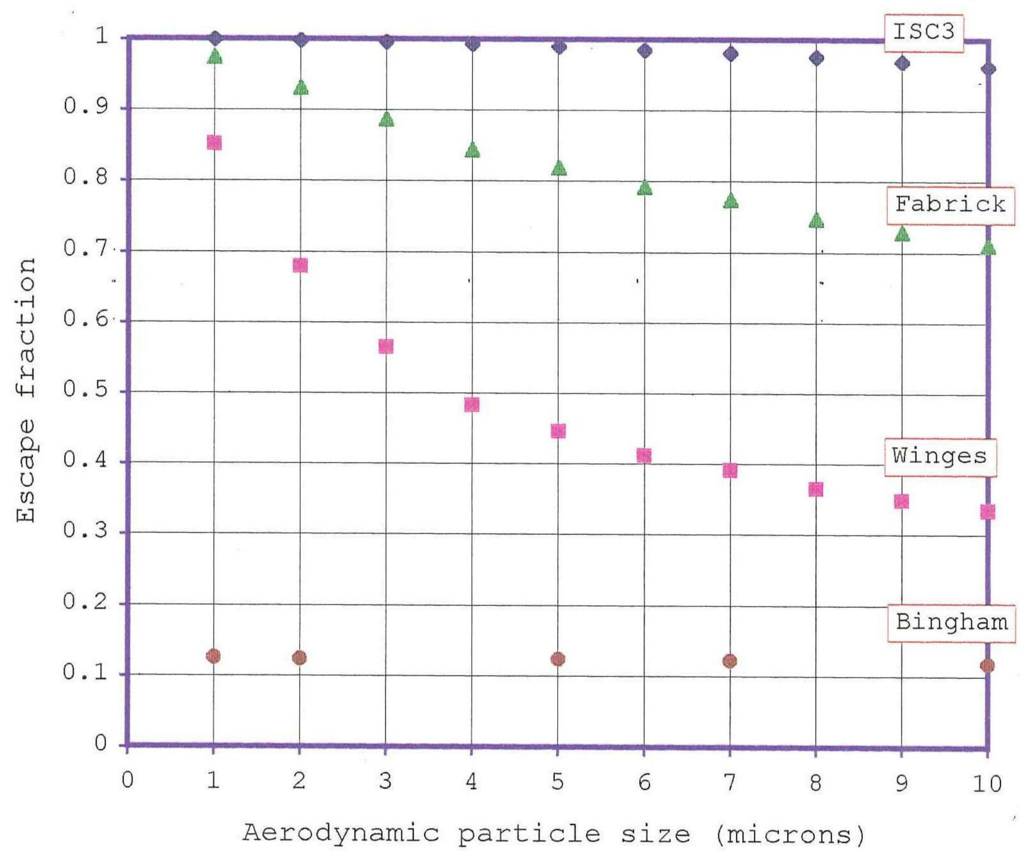

Figure 4.18 Comparison with different escape fraction equations

been explained in Chapter 1. Due to the simplified nature of these equations, certain assumptions were necessary to apply these for the Bingham pit. For instance, H was specified as 2750 feet (838.4 m), and K_z was specified as 6.74 m^2/sec (same as eddy viscosity computed for neutral, 6 miles/hour conditions) in the Winges model. The width of the pit was specified as 8150 feet (2484.7 m) in the Fabrick's equation. The value of deposition velocities for different particle sizes were computed using Figure 10.4 of Hanna, et al., 1982, using z_0=10 cm and density of particles as 1 gm/cm^3. The size dependent escape fractions were then computed. As shown by Figure 4.18, it can be concluded that the model predicts values of escape fraction much lower than the values that are computed using simple escape fraction equations. This observation highlights existence of unique conditions regarding pit retention for the Bingham Canyon mine. Due to the large size of the pit, much of the emissions that are released tend to remain inside the pit and this leads to low values of escape fraction.

CHAPTER 5

VALIDATION AND COMPARISON

5.1 Numerical Tests and Validation

Numerical models are mathematical tools which use a set of numerical algorithms that describe the physical aspects of the problem. It is therefore essential to conduct numerical tests and validation on the model to develop an understanding of its performance. The performance of the numerical model can be demonstrated by comparing its results with experimental/analytical results for some classical simple problems. If the model predicts the results similar to those obtained with analytical or experimental studies, the model can be applied to more complex situations for which analytical/experimental results do not exist.

The analysis of airflow patterns and pit retention of dust for the Bingham Canyon mine involved simulation of flow fields and particle trajectories. For the simulation of turbulent flow, the standard $\kappa-\epsilon$ model (along with near wall modeling) was used. The particle behavior was predicted with the Lagrangian formulation.

Although FIDAP is a commercial software whose validity has been checked over the years, it was still considered important to perform numerical tests for particular aspects of the Bingham model. Mainly, two validation studies were conducted to test the performance of the flow and particle models.

5.1.1 Turbulent Flow

In the FIDAP Examples manual, there are several cases where the validation of the numerical algorithms have been conducted. For the present study, example 18 of the FIDAP Examples manual, which involves 2-dimensional, steady, turbulent, incompressible flow over a backward-facing step, was used as a basis for the analysis. The values of the different parameters specified are identical to those specified in the manual.

The region of interest consists of a single backward-facing step in a channel. The walls are smooth and impermeable. The geometry of the flow situation, along with the mesh that was generated, is illustrated in Figure 5.1. The height of the step and the channel are one and three, respectively. A constant inflow velocity of one was imposed at the inflow which is located six step heights upstream. The assumption was that fully developed flow is attained before the flow reaches the step. Values for turbulent kinetic energy and dissipation were also specified at the inflow. The outflow boundary was located 24 step heights downstream. A no-slip boundary condition was applied for the wall. The standard

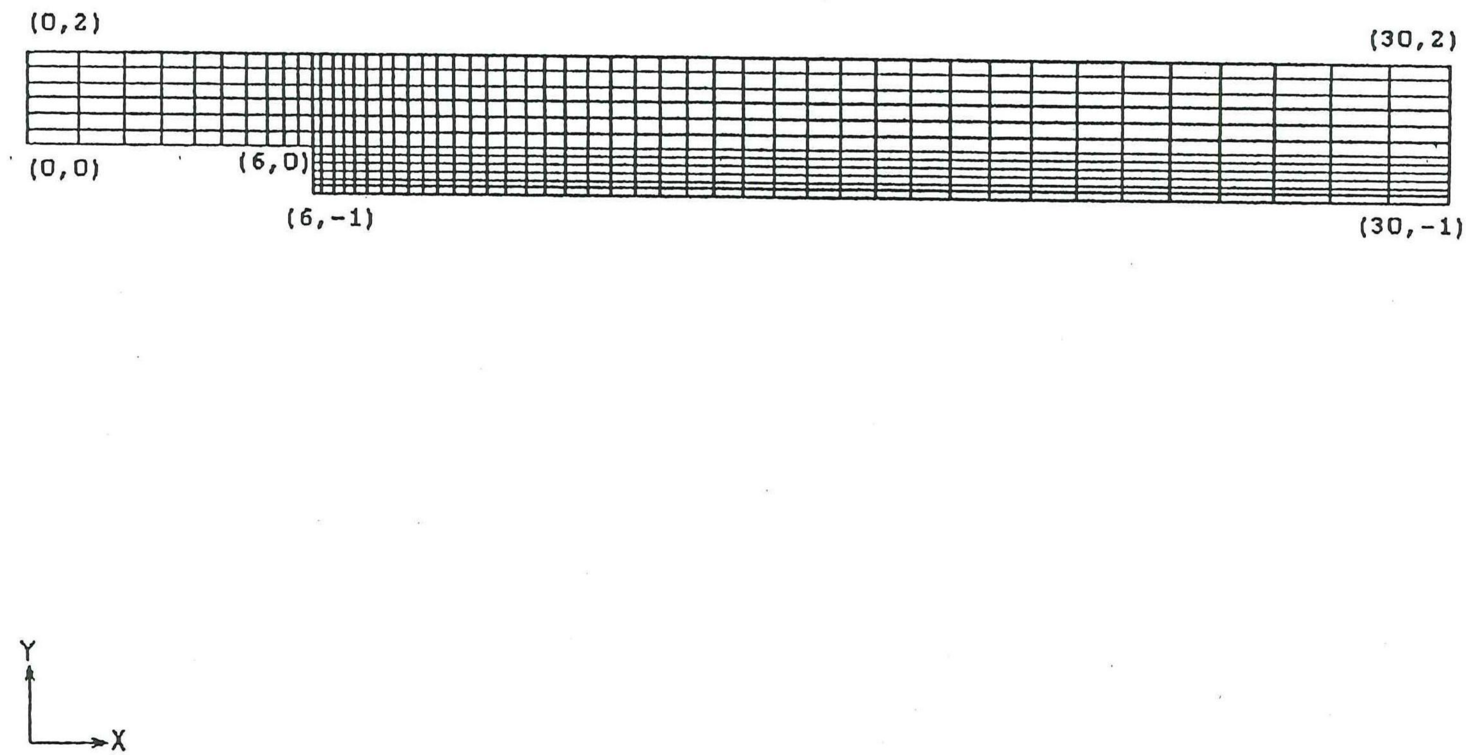

Figure 5.1 Geometry and mesh for the backward-facing step problem

$\kappa-\epsilon$ model with the near wall modeling approach was used for the validation study. The Reynolds number for the simulation was chosen to be 45,000 so as to allow comparison with the experimental data of Kim (1978) (as cited in the FIDAP Examples manual).

The results of the simulation are illustrated in Figure 5.2, which shows the different streamlines. The experimentally observed length of the recirculation region, X_R, was found to be (7.0 ± 0.5) times the step height (Kim, 1978, as cited in the FIDAP Examples manual). The reattachment length from the FIDAP simulation was 6.43. Although there is a slight underprediction, it is still reasonable to say that the $\kappa-\epsilon$ model performs quite well for the simulation of turbulent flows.

5.1.2 Lagrangian Particle Formulation

The Lagrangian particle formulation of FIDAP was validated using a simple 2-dimensional laminar flow problem. The flow domain was a rectangular area 3 m (along the flow) by 2 m (crossflow vertical direction). The rectangular mapped mesh generated for the domain is illustrated in Figure 5.3. A constant velocity of 1×10^{-2} m/s was assigned to the inflow boundary. The alongwind boundaries of the domain were specified as symmetry boundaries, which means that the vertical component of velocity was specified to be zero. Air viscosity and density were specified as 1.8×10^{-5} Pa-sec

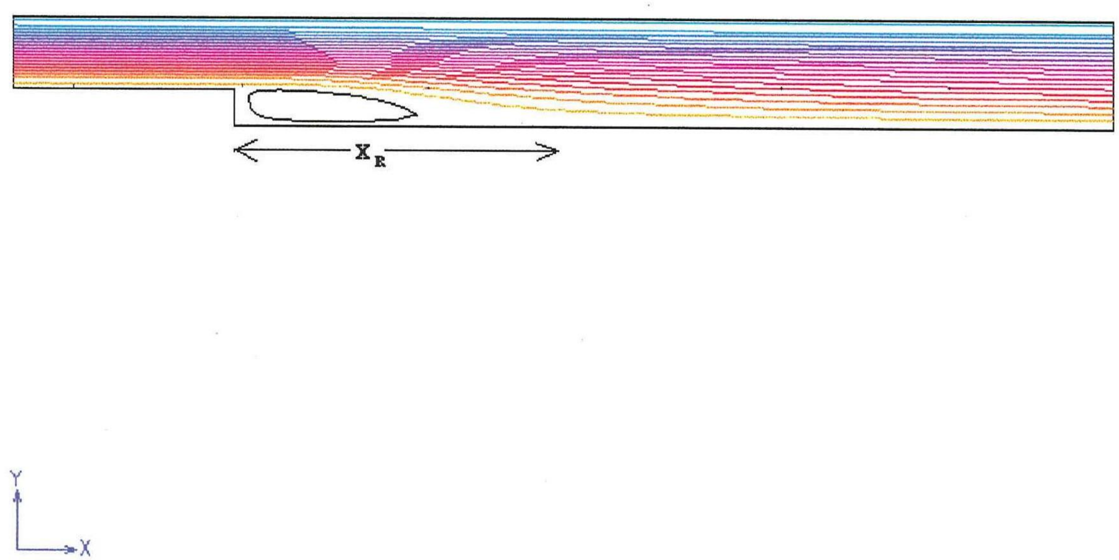

Figure 5.2 Streamlines for the backward-facing step problem

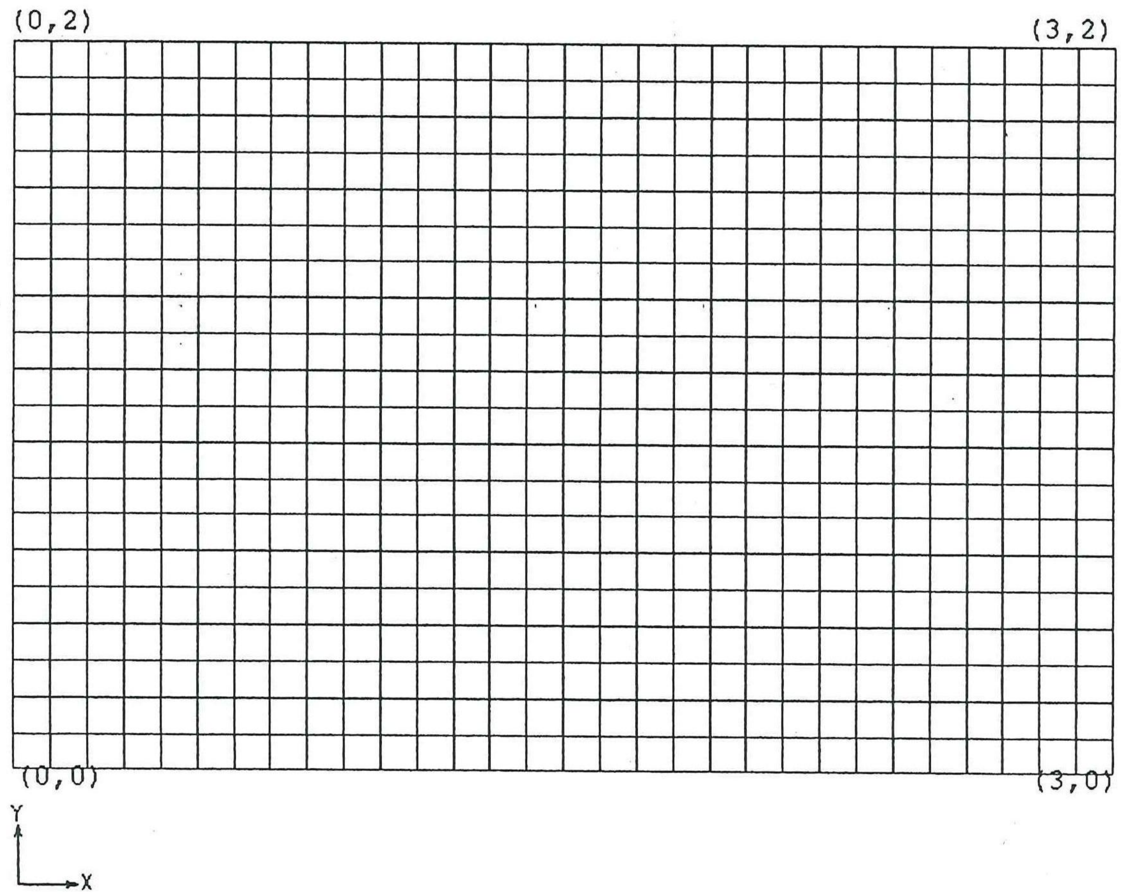

Figure 5.3 Rectangular mapped mesh for the particle formulation validation problem

and 1.2 kg/m^3, respectively. Based on the data mentioned, FIDAP was used to calculate the flow field in the domain.

After the laminar flow problem was solved, a single 10 μ particle of density 2000 kg/m^3 was introduced in the domain at the coordinate (X = 1, Y = 1). The acceleration due to gravity was specified as 9.81 m/sec^2. The trajectory of the particle was tracked with 0.01 second increments for 100 seconds. The computed flow field and the particle trajectory is illustrated in Figure 5.4. In 100 sec, the particle was carried about 0.995 m along the flow and about 0.604 m vertically downwards. Only Stokes drag and gravity forces were considered in this evaluation.

Hand calculations were performed to evaluate the performance of the Lagrangian formulation used in FIDAP. In this case where the flow field is horizontal, Equation (2.35) reduced to the following form for the vertical component of particle velocity

$$\frac{du_{py}}{dt} = \frac{-u_{py}}{\tau} + \left(\frac{\rho_p - \rho_f}{\rho_p}\right) g \tag{5.1}$$

where u_{py} is the vertical component of particle velocity. All other parameters have been explained earlier. The terminal settling velocity can be obtained by using the relation

$$\frac{du_{py}}{dt} = 0 \tag{5.2}$$

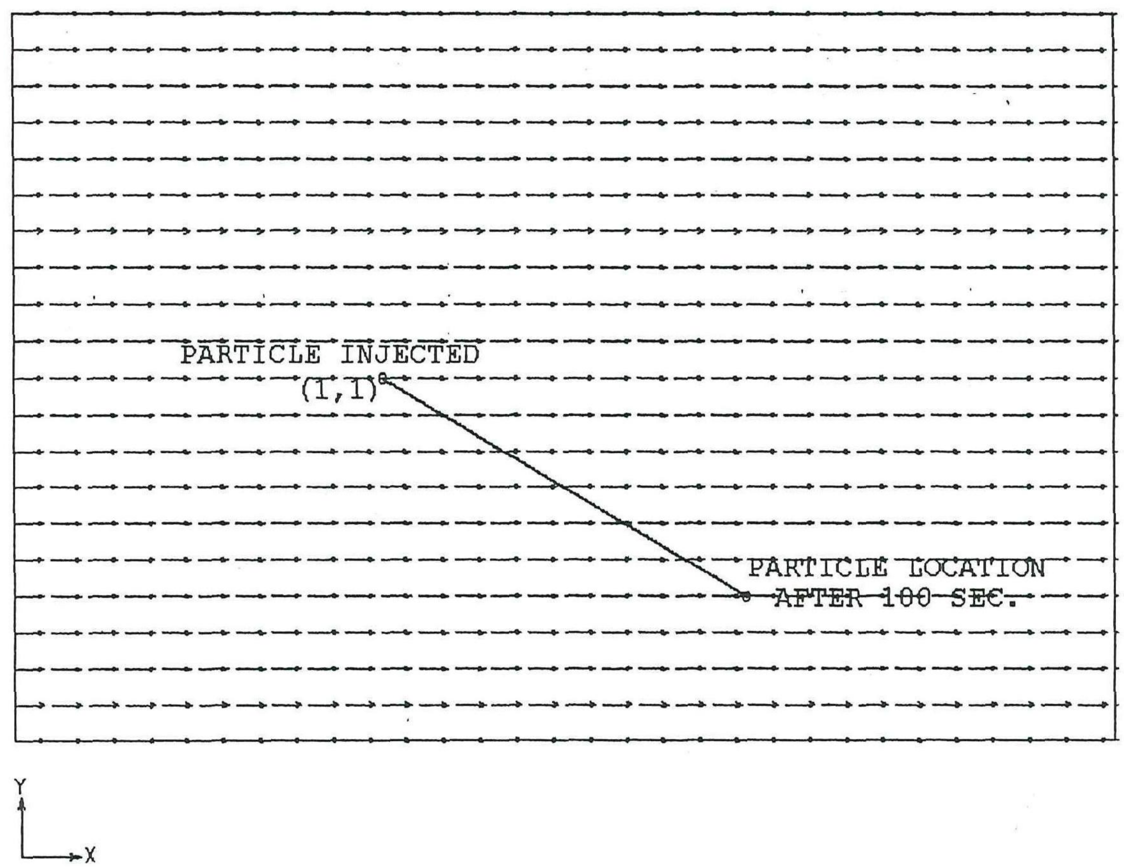

Figure 5.4 Flow field and particle trajectory for the particle formulation validation problem

$$\Rightarrow \quad \frac{-u_{py}}{\tau} + \left(\frac{\rho_p - \rho_f}{\rho_p}\right) g = 0. \qquad (5.3)$$

Using Stokes drag coefficient, $C_D = 24/Re_p$, in the expression for τ (Equation 2.36), Equation 5.3 simplifies to the relation for Stokes terminal settling velocity.

$$u_{py} = \frac{g\, D_p^2\, (\rho_p - \rho_f)}{18\, \mu}. \qquad (5.4)$$

Using the same value of parameters that were used for FIDAP simulation, u_{py} was computed using Equation 5.4 to be 6.052 x 10^{-3} m/s. Hence, for a total time period of 100 seconds, the particle will travel 0.6052 m vertically downward. Since the uniform flow field (speed 10^{-2} m/s) also transports the particle downwind, the particle travels 1 m in 100 seconds.

Since the hand calculated values closely match the computed values using FIDAP, the objective of validation was satisfied for the Lagrangian formulation.

5.2 Idealized vs. actual geometries for open-pit mines

The EPA's Industrial Source Complex (ISC) models are especially designed to support the agency's regulatory modeling programs. The ISC3 model (September 1995) includes an algorithm for modeling impacts of particulate emissions from open-pit sources. In the ISC3 models, one of the main assumptions is that pit emissions have a tendency to escape from the upwind side of the pit. This is due to the presence of a recirculatory profile inside the pit. Wind tunnel modeling studies have demonstrated the presence of such a profile. These concepts/studies have been explained in sections 1.1.1.2 and 1.1.3.

In conducting the present study using 3-dimensional finite element modeling for the Bingham Canyon mine, such recirculatory profiles were not observed. This discrepancy led to the investigations presented in this section.

The ISC models allow the open-pit source to be characterized by a rectangular shape with an aspect ratio (length/width) of up to 10 to 1. Different wind tunnel modeling studies (Thompson, R. S., 1994; Perry, S. G., et al., 1994) have also considered idealized rectangular shapes for mine models. The vertical cross-section of the scaled wind tunnel models have a trapezoidal shape if the steps are included. In the case of the Bingham Canyon mine, the actual terrain geometry is much different from an idealized rectangular or trapezoidal shape. In the study presented in this section, three numerical models were developed to study the effect of pit geometries on the airflow patterns. It was decided that 2-dimensional analyses will be sufficient to develop a better understanding of the phenomena involved.

The three vertical cross-sectional 2-dimensional models evaluated were:

- actual Bingham pit geometry at section True-East (or X)= 3000 feet. This is a vertical north-south section that approximately passes through the center of the mine,
- an idealized trapezoidal cross-section, and
- an idealized rectangular cross-section.

In all the cases, the evaluation was conducted for neutral atmospheric conditions and a wind speed of 6 miles/hour. The values of meteorological parameters were kept identical to the 3-dimensional Bingham model for a wind speed of 6 miles/hour and neutral stability. The 2-dimensional finite element mesh was created in all cases. Suitable boundary conditions were then applied. Inlet boundaries had prescribed values for components of velocity (u_x and u_y), turbulent kinetic energy, κ, and dissipation, ϵ. The top boundary (mixing height) was defined as a symmetry boundary, whereas the ground was represented as a wall boundary. The downwind boundary was considered as an outflow boundary. These concepts have been discussed in detail in Chapters 3 and 4 for the 3-dimensional case, and are similarly applied for the 2-dimensional case.

5.2.1 Actual Bingham Geometry

As mentioned earlier, a vertical cross-section at True-East (TE) = 3000 feet with northerly winds was used for this case. This case was intended to serve as the basis for comparison against idealized rectangular and trapezoidal cases. The terrain profile and the 2-dimensional mesh generated for this case is shown in Figure 5.5. Appropriate boundary conditions were then assigned and model definition data and fluid properties were specified. A turbulent flow field was generated as a result for this case. It was observed that a recirculation zone was nonexistent. Thus, the results were similar to those in the 3-dimensional case. These results have been presented as Figure 5.6.

5.2.2 Idealized Trapezoidal Geometry

The model for an idealized trapezoidal section was developed in a similar manner as outlined above for the actual geometry case. The only difference in this case was that an idealized trapezoidal shape was used to represent the Bingham pit. The geometry and finite element mesh is illustrated by Figure 5.7. Figure 5.8 is the vector and streamline plot for this case. Recirculation phenomenon was obtained inside the pit in this case. The wind pattern obtained was almost identical to patterns observed by wind tunnel modeling studies (Figure 7 of Thompson, R. S., 1994; or Figure 2 of Perry,

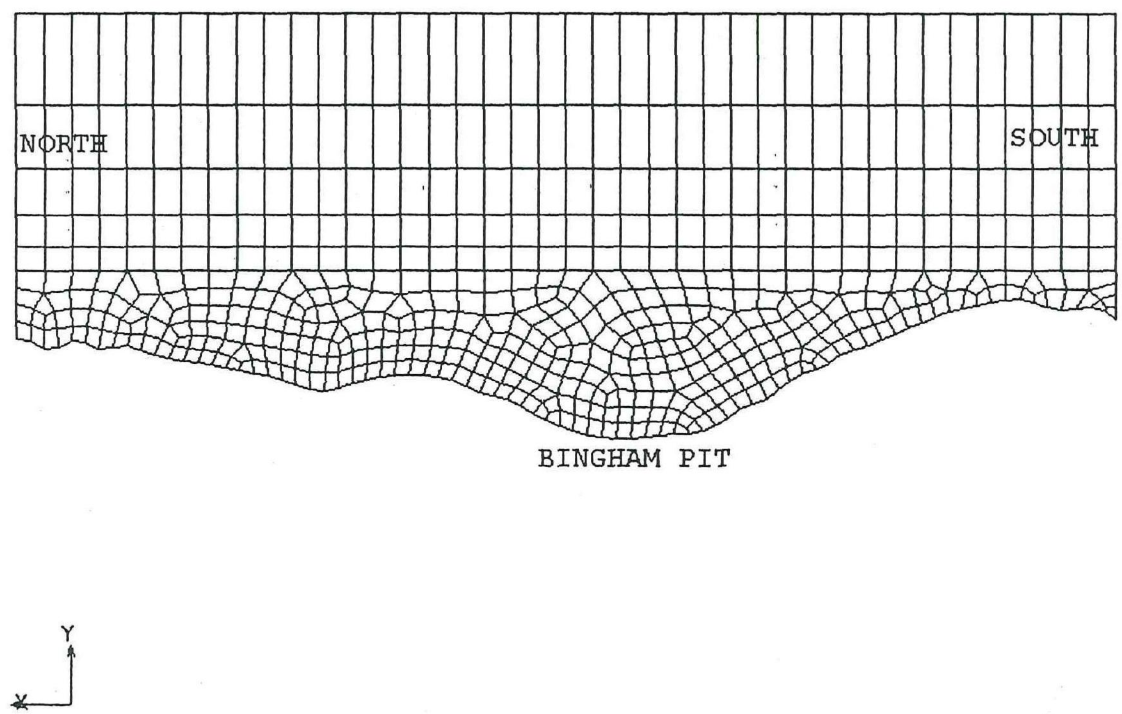

Figure 5.5 Two-dimensional geometry and mesh for the "actual" Bingham case (section at TE=3000 feet)

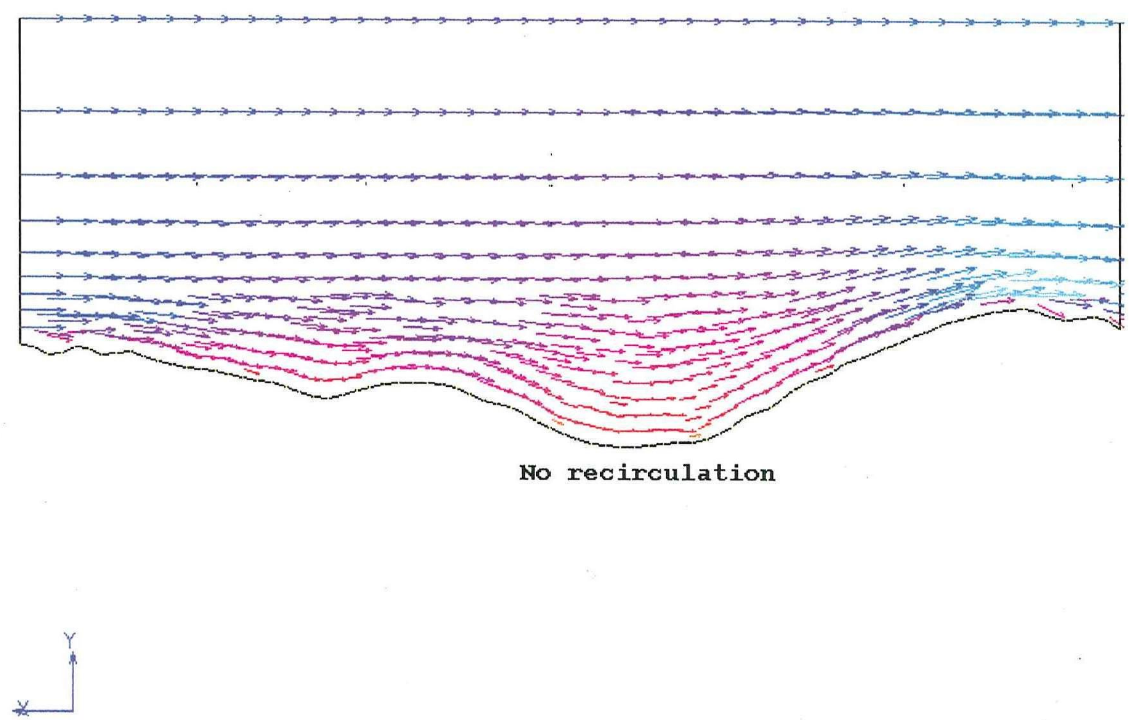

Figure 5.6 Velocity vectors for the "actual" case

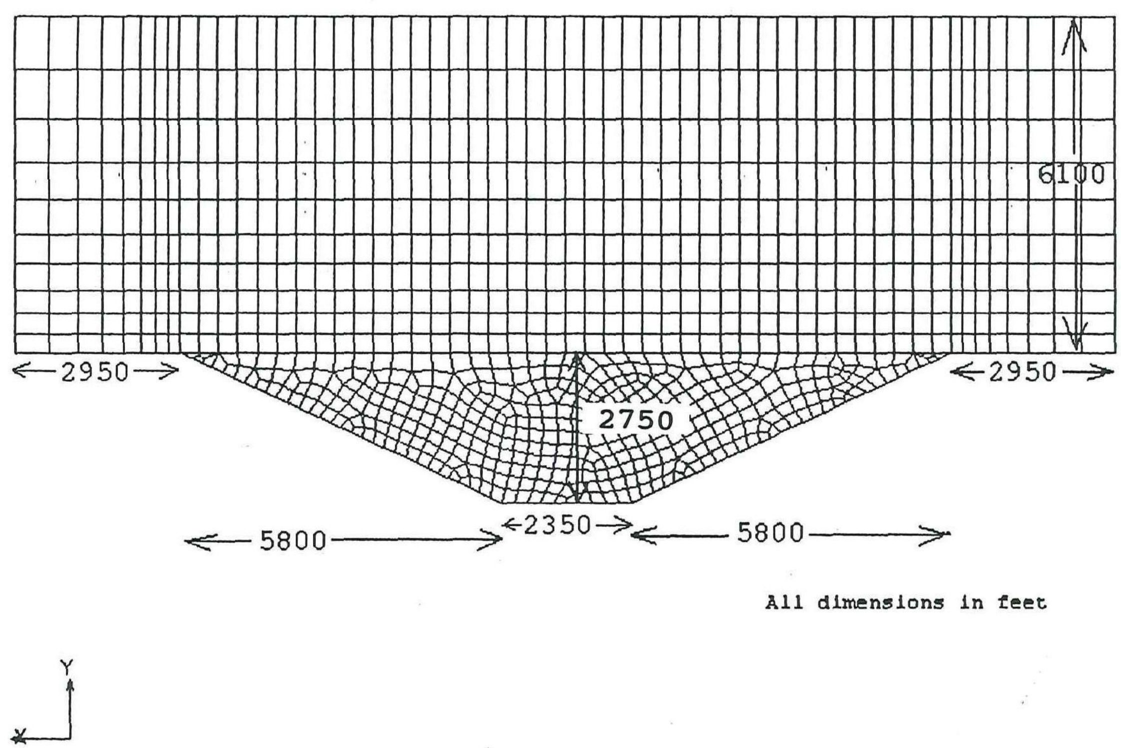

Figure 5.7 Geometry and finite element mesh for the trapezoidal section

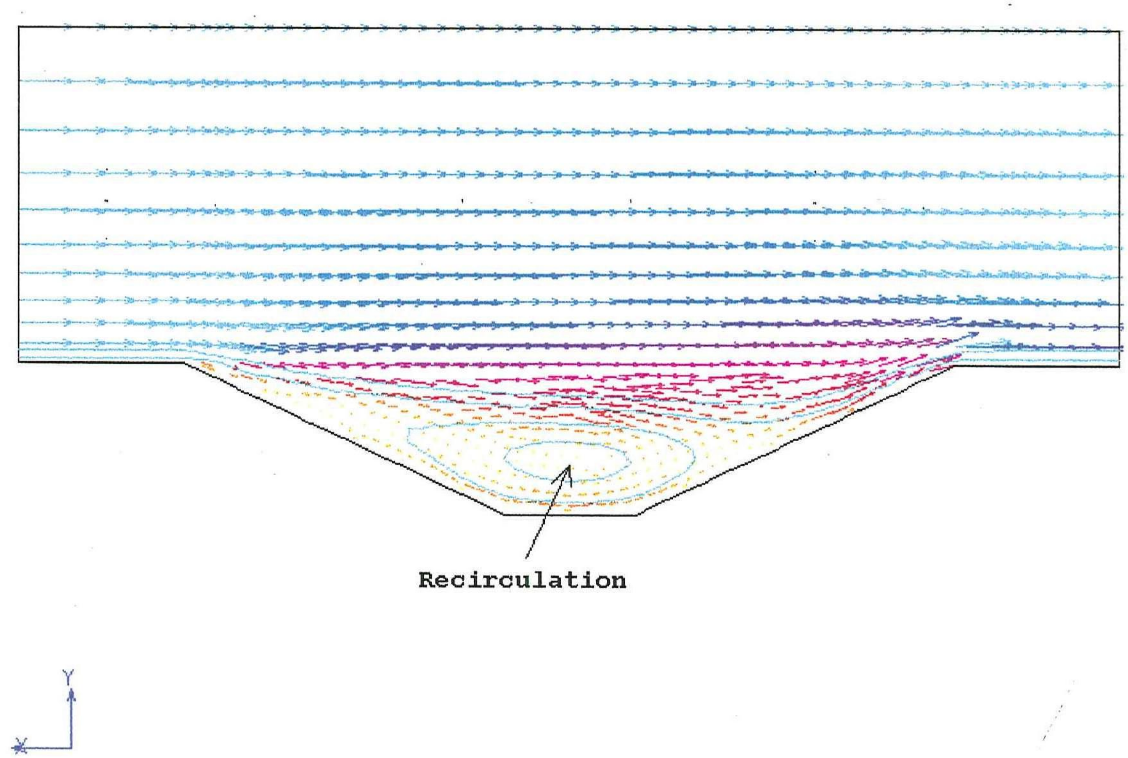

Figure 5.8 Vector and streamline plot for the trapezoidal section

S. G., et al., 1994). Since the idealized Bingham geometry can mimic the wind tunnel results, this provides additional validation of the Bingham numerical model. It should however be realized that this validation is only a qualitative one. For an idealized trapezoidal section, the emissions would escape out of the pit from the upwind side, as assumed by the ISC3 model.

5.2.3 Idealized Rectangular Geometry

The model was developed with exactly the same steps that have been discussed earlier, using a rectangular cross-section. Figures 5.9 and 5.10 illustrate the geometry/mesh plot and the wind vector/streamline plot, respectively. The dimensions of the pit were chosen so as to keep the same depth and cross-sectional area of the pit as used in the idealized trapezoidal case. Recirculation phenomenon was more pronounced here than the idealized trapezoidal shape.

5.2.4 Discussion

The exercise in this section demonstrates that the presence (or absence) of the recirculatory vortex depends on how the pit is represented. As presented, idealization of pit geometry (trapezoidal or rectangular cross-section) induces the flow separation on the upwind edge of the pit, thereby causing a recirculatory wind profile to be set up inside the mine. Since the numerical model could mimic wind tunnel results for idealized geometries

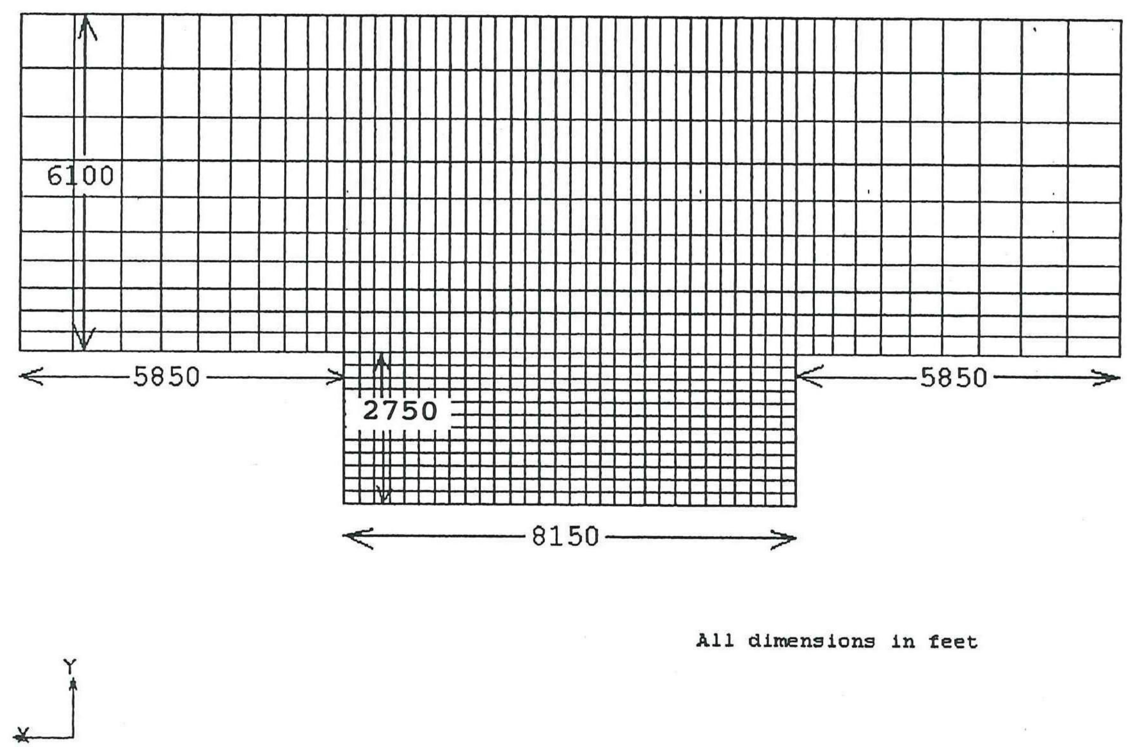

Figure 5.9 Geometry and finite element mesh for the rectangular section

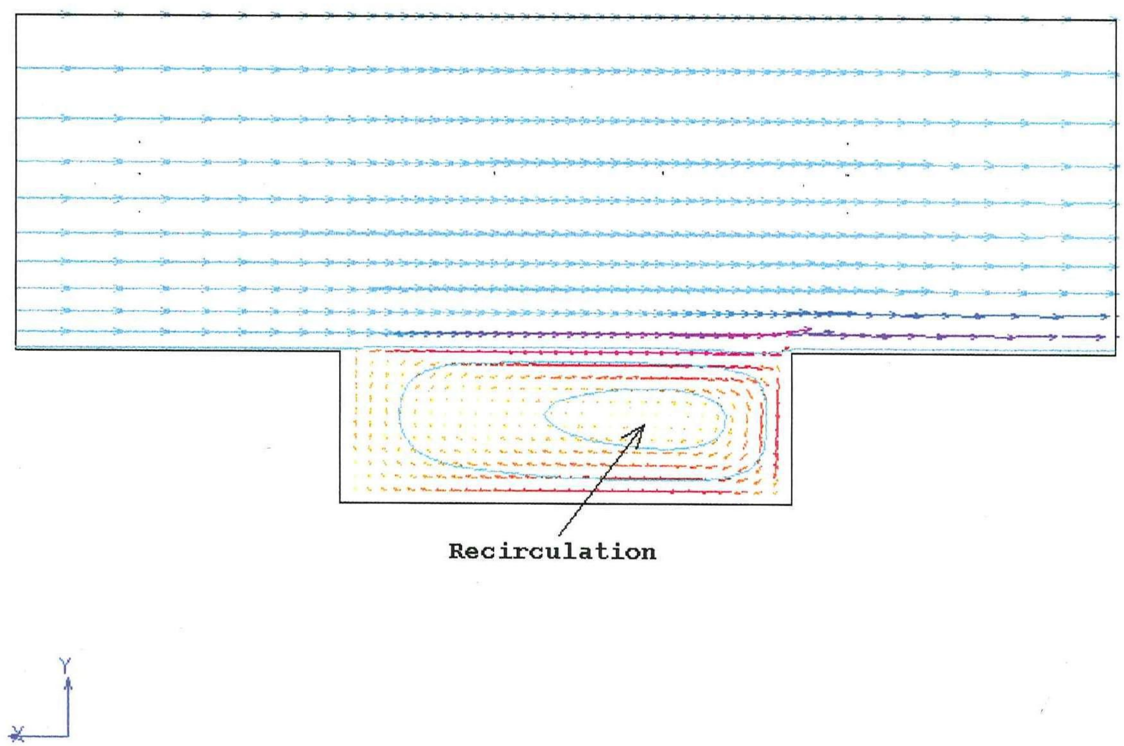

Figure 5.10 Vector and streamline plot for the rectangular section

qualitatively, it is reasonable to conclude that the model will predict airflow patterns for the "actual" pit correctly. The possible cause of the recirculatory profile being absent for the actual case is that the airflow does not encounter steep upwind edges which can induce flow separation and, hence, recirculation in the real case, at least for the Bingham pit.

CHAPTER 6

SUMMARY AND CONCLUSIONS

The purpose of the present study was to numerically simulate the turbulent diffusion, transport and pit retention of fugitive dust from the Bingham Canyon mine. A 3-dimensional finite-element numerical model was developed to meet the objectives of the study. Reynolds averaged equations, along with the $\kappa-\epsilon$ turbulence model and near-wall modeling approach, were used to generate the flow patterns, and the particle dispersion was subsequently simulated using a Lagrangian stochastic model. Simulation studies were conducted with the 3-dimensional numerical model to examine the sensitivity of the particle behavior (primarily pit-retention) to various meteorological and emission source parameters. The model predicted significantly lower escape fraction values for the simulations conducted in the study. Numerical tests, validation studies, and comparative analyses among different pit geometries were also performed to evaluate the performance of the Bingham pit model.

The simulations in this study exhibit realistic-looking wind patterns and particle trajectories. With some degree of accuracy, the present model can predict the airflow and particle behavior for the Bingham pit. Unfortunately, the observational data for a direct comparison with the results of this study is not presently available. The primary aim of the present study was to provide a comparative analysis in order to understand the sensitivity of dust dispersion and retention to a wide range of parameters. Therefore, the use of data available in the literature to represent the turbulent characteristics of the atmosphere was considered appropriate.

The sensitivity analyses presented in Chapter 4 provide useful insights into the dust dispersion and pit retention phenomena for the Bingham pit as a function of the varying parameters. The results demonstrate that, generally, only a small fraction of the fugitive dust/PM-10 emitted in the Bingham Canyon mine actually leaves the boundary of the pit. The model is capable of simulating non-Gaussian dispersion and, hence, can be expected to provide results closer to real situations. However, because the analysis of 3-dimensional turbulent two-phase flows (as in this case) can be computationally expensive, the use of advanced methods such as finite-element techniques in a typical industrial setting is presently limited. Also, the increased complexity of the model demands specification of a large number of input parameters, the values of which might not be always available.

Although the model is quite useful in its present form to perform comparative simulation studies, nevertheless, several recommendations for future work and improvements are outlined below:

- In order to improve the numerical accuracy, the 3-dimensional finite element mesh should be made finer, especially near the ground level. However, it should be kept in mind that this can lead to computationally expensive calculations.
- Incorporation of the roughness features of the ground, which might spatially vary, should be investigated.
- The presence of mountainous terrain introduces significant complexities in the atmospheric transport and diffusion processes. The parameterizing of complex wind flow regimes and other turbulence parameters is a difficult task. Incorporation of these parameterizations is an area that needs further research. It is expected that use of more sophisticated and more realistic time-dependent meteorological conditions will make the predictions more accurate. Also, the use of temperature-dependent air density will increase the accuracy of the model.
- The model should be tested against the observational data, which characterizes the dust dispersion and retention phenomena based on the

meteorological and source parameters. Hi-vol samplers could be used in the field experiment study. However, this could be a challenging proposition because of the size and extent of the Bingham pit, time-dependent meteorological conditions and difficulty in isolating a particular dust source which has to be studied.

- The standard $\kappa-\epsilon$ model used for the present analysis is an isotropic model, which means there is no directional preference for turbulence. In order to include a more realistic scenario, the use of an anisotropic turbulence model should be investigated.
- In this study, the mixing height was chosen to be a constant value. The use of a spatially and temporally varying mixing height (top of the domain) should be investigated.
- The present study assumed that particles settle when they come in contact with the ground surface. Once settled, they cannot be resuspended. These assumptions could lead to underpredictions in estimating the value of escape fraction. The dust plume-ground interaction is an area which should be further investigated.

The preceding list represents just a few of the possibilities for future improvement of the model, which could lead to better characterization of the dust advection, dispersion and pit retention for the Bingham Canyon mine.

The present study has demonstrated how advanced tools such as finite-element modeling can be employed to characterize the airflow patterns and pit retention of fugitive dust. There is still scope for improving the performance of the model by investigating some of the recommendations mentioned. Better parameterization of flows in complex terrain, use of field turbulence data to create model input, and testing the model against observed data are the areas on which maximum emphasis should be placed for future investigations.

APPENDIX A

"WORST" CASE SCENARIO FOR THE BINGHAM PIT

Due to Kennecott's interest in evaluating the worst-case escape fraction, Appendix A was added as a supplement.

A.1 Simulation Conditions

A simulation was generated in order to develop the worst-case escape fraction values for the Bingham pit. The conditions specified in the simulation were as follows:

Wind speed:	30 miles/hour
Wind direction:	From the south
Atmospheric stability:	Extremely Unstable (A) [This is a conservative assumption. In reality, atmosphere can only be Neutral (D) at such high wind speeds]
Source location and height:	30 feet high emission source at the north-wall [At the notch between the pit and the Bingham Canyon (TE = 2500 feet, TN = 6000 feet)]
Particle size:	PM-10

A.2 Results

Using the simulation conditions specified in section A.1, the following two cases were evaluated to quantify the worst-case escape fraction for the Bingham pit:

- "Trap" boundary condition for the ground.
- "Ricochet" boundary condition with restitution coefficient equal to 1 for the ground.

"Trap" boundary condition signifies that particles settle when they collide with the ground. "Ricochet" boundary condition (with restitution coefficient of 1) means that particles reflect back with the same velocity as the incoming velocity on collision with the ground. Figure A.1 illustrates the particle trajectory plot for "Trap" boundary condition for the aerodynamic particle size of 10 μ. As shown in the figure, 108 trajectories (out of 500 released at the dust emission point) escape the north boundary of the domain, thereby suggesting an escape fraction of 21.6% for these test conditions.

The approximate values of the escape fractions for "Trap" and "Ricochet" conditions were calculated as 22% and 33%, respectively, for the conditions specified in Section A.1. For the "Ricochet" conditions, particles can reflect back on collision with the ground. Therefore, the value of the escape fraction for "Ricochet" boundary condition is higher than the value for the "Trap" boundary condition. Specification of "Ricochet" boundary condition at the ground is a more conservative assumption.

The simulation results demonstrate that under the worst-case conditions, about one-third of the PM-10 can escape the boundaries of the computational domain.

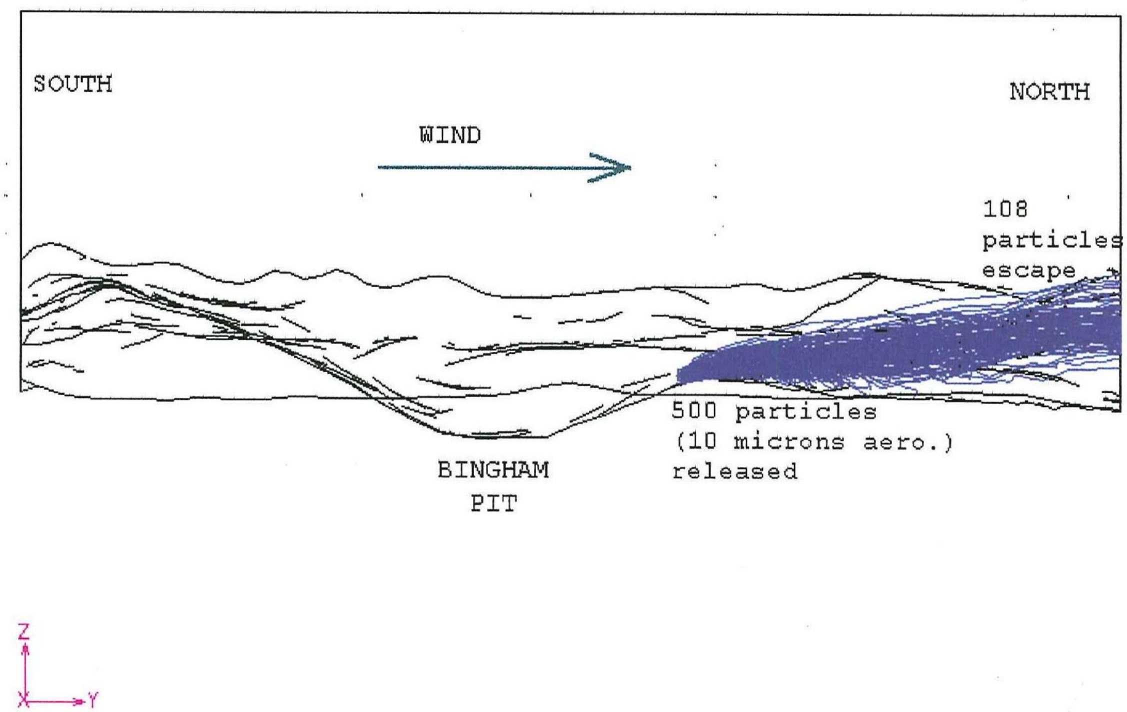

Figure A.1 Particle trajectories for the worst-case scenario ("Trap" condition)

APPENDIX B

EXAMPLE PROBLEM INPUT FILE

FOR FIDAP 7.5 RUN

```
/
/ FIPREP INPUT FILE CREATED ON 29 May 96 AT  20:50:27
/

TITLE
/ specify title

FIPREP
/ invoke the FIPREP module

 PROB (3-D, INCO, STEA, TURB, NONL, NEWT, MOME, ISOT, FIXE, SING)
 / specify equations to be solved

 EXEC (NEWJ)
 / specify mode of execution

 SOLU (SEGR = 10000, PREC = 21, ACCF = 0.000000000000E+00, NOLI, PPRO,
      SCHA = 0.000000000000E+00)
 / specify nonlinear iterative solution method

 OPTI (UPWI)
 / specify various optional equation terms

 DATA (CONT)
 / specify input data printout options

 RELA ( )
   0.8000000000E+00,  0.8000000000E+00,  0.8000000000E+00,  0.2000000000E+00,
   0.0000000000E+00,  0.0000000000E+00,  0.7000000000E+00,  0.7000000000E+00,
   0.0000000000E+00,  0.0000000000E+00,  0.0000000000E+00,  0.0000000000E+00,
   0.0000000000E+00,  0.0000000000E+00,  0.0000000000E+00,  0.0000000000E+00,
   0.0000000000E+00,  0.0000000000E+00,  0.0000000000E+00,  0.0000000000E+00,
   0.0000000000E+00,  0.0000000000E+00,  0.0000000000E+00,  0.0000000000E+00,
   0.0000000000E+00,  0.0000000000E+00,  0.0000000000E+00,  0.0000000000E+00
 / specify relaxation factors

 PRIN (NONE, BOUN)
 / specify printout time steps
```

```
ENTI (NAME = "fluid", FLUI, PROP = "air")
ENTI (NAME = "bingham", WALL, TRAP)
ENTI (NAME = "north", PLOT, ESCA)
ENTI (NAME = "south", PLOT, ESCA)
ENTI (NAME = "west", PLOT, ESCA)
ENTI (NAME = "east", PLOT, ESCA)
ENTI (NAME = "top", PLOT, RICO, REST = 1.0)
/ group various material properties and options into a single entity    definition

DENS (SET = "air", CONS = 0.625000000000E-01)
DENS (SET = "dust", CONS = 62.48)
/ specify a density model

VISC (SET = "air", CONS = 0.121000000000E-04, TWO-)
/ specify a viscosity model

BCNO (UZ, ENTI = "top", ZERO)
BCNO (UX, ENTI = "north", ZERO)
BCNO (UZ, ENTI = "north", ZERO)
BCNO (UY, ENTI = "north", CONS = -8.8)
BCNO (KINE, ENTI = "north", CONS = 3.4703)
BCNO (DISS, ENTI = "north", CONS = 0.149520000000E-01)
BCNO (VELO, ENTI = "bingham", ZERO)
/ specify constrained nodal values

ICNO (UY, CONS = -8.8, ENTI = "fluid")
ICNO (UY, CONS = -8.8, ENTI = "bingham")
ICNO (UY, CONS = -8.8, ENTI = "north")
ICNO (UY, CONS = -8.8, ENTI = "south")
ICNO (UY, CONS = -8.8, ENTI = "west")
ICNO (UY, CONS = -8.8, ENTI = "east")
ICNO (UY, CONS = -8.8, ENTI = "top")
ICNO (KINE, CONS = 3.4703, ENTI = "fluid")
ICNO (KINE, CONS = 3.4703, ENTI = "bingham")
ICNO (KINE, CONS = 3.4703, ENTI = "north")
ICNO (KINE, CONS = 3.4703, ENTI = "south")
ICNO (KINE, CONS = 3.4703, ENTI = "west")
ICNO (KINE, CONS = 3.4703, ENTI = "east")
ICNO (KINE, CONS = 3.4703, ENTI = "top")
ICNO (DISS, CONS = 0.149520000000E-01, ENTI = "fluid")
ICNO (DISS, CONS = 0.149520000000E-01, ENTI = "bingham")
ICNO (DISS, CONS = 0.149520000000E-01, ENTI = "north")
ICNO (DISS, CONS = 0.149520000000E-01, ENTI = "south")
ICNO (DISS, CONS = 0.149520000000E-01, ENTI = "west")
ICNO (DISS, CONS = 0.149520000000E-01, ENTI = "east")
ICNO (DISS, CONS = 0.149520000000E-01, ENTI = "top")
/ specify initial nodal values for the various degrees of freedom

CLIP (MINI)
 0.0000000000E+00,  0.0000000000E+00,  0.0000000000E+00,  0.0000000000E+00,
```

```
0.0000000000E+00, 0.0000000000E+00, 0.1000000000E-19, 0.1000000000E-24,
0.0000000000E+00, 0.0000000000E+00, 0.0000000000E+00, 0.0000000000E+00,
0.0000000000E+00, 0.0000000000E+00, 0.0000000000E+00, 0.0000000000E+00,
0.0000000000E+00, 0.0000000000E+00, 0.0000000000E+00, 0.0000000000E+00,
0.0000000000E+00, 0.0000000000E+00, 0.0000000000E+00, 0.0000000000E+00,
0.0000000000E+00, 0.0000000000E+00, 0.0000000000E+00, 0.0000000000E+00
/ specify upper and lower bounds for any degree of freedom

END
/ terminate execution
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APPENDIX E

Response to Technical Comments

APPENDIX E-1

Response to NOI Technical Review Comments

Rio Tinto

UDAQ Review	KUC Responses
2.1 Point Sources	
2.1.1 In-pit Crusher New Crusher – 0.007 gr/dscf 12,989 hr/yr	KUC is proposing to add a new in-pit crusher at the BCM. The new crusher will be nearly identical to the existing in-pit crusher. Based on the design of the existing crusher and the discussions with vendors, the baghouse on the new in-pit crusher will have an estimated air flow of 12,989 dscfm and a grain loading of 0.007 gr/dscf.
2.2 Fugitive Dust Sources	
2.2.1 Drilling & Blasting 90,000 holes per year with 90% efficiency (how was 90% determined)	The control efficiency listed is based on previous determinations of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling.
2.2.2 Material Movement Ore stockpiled not double counted (Separate limit for Stockpiles?). Top soil movement, road base and reclamation material not counted towards limit (separate limit?)	The total material moved (ore and waste) limit is applied to tons mined at the shovel face. Fugitive emissions from operations such as ore stockpiling, road base crushing, work completed by dozers and loaders, etc. have been included in the NOI. Tonnage of material handled for these operations is not double counted against the ore and waste limit.
2.2.2 Material Movement 85,000,000 tpy of ore crushed – this project represented as a no production increase? Fugitive dust from conveyors controlled at 90% (how was it estimated?). Crushers to remain below pit line with canyon? If reclaim tunnel conveyor processes 85,000,000 tpy, is remainder stockpiled? If so, is reprocessing emissions counted?	The proposed modification will result in an increase in ore crushed. This increase in necessary to accommodate decreasing ore quality and to maintain current level of metal production. 85,000,000 tpy is a typical long term average value. UDAQ has previously specified enclosures (current levels of controls) on conveyor transfer points as BACT. The control efficiency is based on previous determinations of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling. Field observation indicates minimal dust generation from conveyor transfer points. The in-pit crushers will be located within the pit influence boundary as discussed in the NOI. For conservative emission estimates, KUC will be revising emissions calculations to include emissions associated with transfer of ore to the ore stockpile (BCM205).
2.2.2 Material Movement Calculation of rock transferred outside of pit influence?	Emissions calculations for waste rock haulage are provided in Appendix B, Table B1-19.
2.2.3 Low-grade Ore Stockpiles How is movement calculated and monitored for movement of stockpiles? How effective is water application and where did assumptions originate?	KUC monitors and maintains records of material movement to the stockpiles. Water application and dumping practices are consistent with waste dumping applications. Fugitive emissions from the stockpile, as well as ore dumping at the stockpile, are calculated in the NOI (BCM1.13 and BCM205).

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2.2.4 Disturbed Areas How estimated and verified that 1,485 acres of additional land disturbed in summer? 371 acres in winter?	It is estimated, according to proposed mine plan, that approximately 565 total acres of land is disturbed per year. Of that total, 310 acres (55%) are within the Pit Influence Boundary. KUC monitors and maintains records of areas disturbed for mining.
2.2.5 Haul Roads How often water applied? How is application determined? How testing of road base for specification? What specification used?	Application of water and commercial dust suppressant on the haulroads will be maintained and monitored through the fugitive dust control plan. A copy of the revised fugitive dust control plan is provided as Attachment C. Water application practices have been refined by years of experience. Detailed truck movement data are tracked by GPS and maintained for inspection. Effectiveness of dust control measures has been regularly inspected by UDAQ for several years without incident. The road base is applied as necessary on the haulroads. During the winter months, the waste rock is screened to approximately 2-inch diameter and is screened to approximately 1.5-inch diameter during the remainder of the year. The application of the road base material will be regulated through the fugitive dust control plan.
Is FDCP being revised?	A copy of the revised fugitive dust control plan is provided as Attachment C.
2.3 VOC Sources	
2.3.1 Degreasing Degreasers – 500 gpy. Lids closed as all time.	As discussed Section 2.3.1 of the NOI – “The annual use of solvent from all the degreasers combined is approximately 500 gallons. When not in use, the lids on the degreasers are kept closed at all times to minimize emissions. The solvent is recycled frequently, and no significant loss in volume is observed, implying minimal losses as emissions. For purposes of estimating emissions, a conservative estimate of one solvent change-out lost per year is assumed.”
2.3.2 Fuel Stations 530,000 gpy gasoline 55,000,000 gpy diesel	As discussed in Section 2.3.2 of the NOI – “For the proposed modification, the peak year annual throughput at the fueling stations will be approximately 530,000 gallons of gasoline and 55,000,000 gallons of diesel fuel.”
2.3.3 SX/EW plant SX/EW plant with 1,100 ft2. How is settlers covered? How is the control efficiency estimated at 80%? How is exhaust air routed through mist eliminators?	The settlers will be covered with insulated stainless panels. These panels are used to lower VOC emissions and prevent heat loss. The control efficiency is based on the design of the process. Control of 80% will be achieved by the placement of covers at all times except during inspection, sampling, and adjustment. The exhaust air will be routed through the mist eliminators and then outside the building into the atmosphere.

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3.0 Emissions Summary	
3.1 Emissions from Point Sources How was $PM_{2.5}$ = to 40% of PM_{10} determined for input crushers, ventilation systems, silos? Is the emissions below the valley floor have a higher pit retention?	Emissions of $PM_{2.5}$ from sources handling ore material are based on factors from AP-42, Table B.2.2, Category 3 – Mechanically Generated Aggregate and Unprocessed Ore. Emissions of $PM_{2.5}$ from the Lime Bins are based on factors from AP-42, Table B.2.2, Category 4 – Mechanically Processed Ores and Nonmetallic Minerals. A revised Emissions Summary section is provided as Attachment A. Based on the University of Utah study, a single pit escape factor of 20 percent was applied to PM_{10} emissions and 21 percent was applied to $PM_{2.5}$ emissions for sources located within the pit influence boundary. A summary of the University of Utah study was included in Appendix D-1 in the NOI. This pit escape factor is intended to be a simple conservative approach to quantification of in-pit settling. While it would be possible to model in-pit settling as a function of numerous variables, this would significantly complicate downstream analysis and modeling.
3.2 Emissions from Fugitive Sources	
3.2.1 Drilling and Blasting AP-42 11.9-1 is for horizontal area and does not include vertical for bench. Is for blasting depth <70 ft.	Based on discussions with the mine, the average blasting depth is less than 70 ft.
3.2.2 Material Movement What are material characteristics that limit dust? What is natural moisture content of soil? How monitor for dust control? Watering?	The characteristics of the waste rock/ore material, such as large diameter material, and inherent material moisture content of 4 percent, limit dust being generated during the transfer operations. The run-of-mine material consists of large diameter material with very little fine dust. Blowing dust from the material is a one-time occurrence. Visual observations have shown that the large diameter material left behind results in no further generation of dust. The current AO limits the visible emissions from all conveyor transfer points at 10 percent opacity.
3.2.3 Low-grade Ore Stockpile How was engineering estimate determined for PM_{10} and $PM_{2.5}$? How does material characteristics and compaction minimize emissions?	Please see attached revised Emissions Summary section (Section 3) of the NOI provided as Attachment A. The revised includes assumptions for PM_{10} and $PM_{2.5}$ emissions based on ratio of transfer particle size multipliers in AP-42, *Fifth Edition*, Table 13.2.4 (EPA, 2006) for Aggregate Handling and Storage Piles. The ratio of transfer particle size multipliers are 0.74 for PM, 0.35 for PM_{10} and 0.053 for $PM_{2.5}$. Therefore, PM_{10} is estimated to be 47 percent of PM (0.35/0.74) and $PM_{2.5}$ is estimated to be 15 percent of PM_{10} (0.053/0.35). The run-of-mine material consists of large diameter material with very little fine dust. Blowing dust from the material is a one-time occurrence. Visual observations have shown that the large diameter material left behind results in no further generation of dust.

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3.2.4 Disturbed Areas What engineering estimates used to determine $PM_{2.5}$ = 15% PM_{10}. How is topsoil removal within pit boundary?	Please see attached revised Emissions Summary section (Section 3) of the NOI provided as Attachment A. The revised includes assumptions for PM_{10} and $PM_{2.5}$ emissions based on ratio of transfer particle size multipliers in AP-42, *Fifth Edition*, Table 13.2.4 (EPA, 2006). The ratio of transfer particle size multipliers are 0.74 for PM, 0.35 for PM_{10} and 0.053 for $PM_{2.5}$. Therefore, PM_{10} is estimated to be 47 percent of PM (0.35/0.74) and $PM_{2.5}$ is estimated to be 15 percent of PM_{10} (0.053/0.35). Fugitive emissions from Disturbed Areas are included in the NOI workbook (BCM1.9)
3.2.5 Haul Roads Haul road emissions limited to 8.3 miles roundtrip. When is application of water or chemicals determined to control dust? What portion of haul roads outside pit boundary? Hours of operation for haul trucks? Loaders? Tier level of trucks phased in? 85% for chemical dust suppressant when applied?	Detailed emissions calculations for the haul roads are provided in Appendix B-1, Table B1-12 of the NOI. Per UDAQ policy, for haulroads within the pit influence boundary, a control efficiency of 75 percent is used for watering and road base application. For haulroads outside the pit influence boundary, a control efficiency of 85 percent is used for application of commercial dust suppressants. Details of this activity will be regulated through the fugitive dust control plan, which is updated and submitted annually to UDAQ. Hours of operation and details on tier levels of the haul truck engines can be found in Appendix B-1, Table B1-36 of the NOI. Hours of operation and details on tier levels of the support equipment engines can be found in Appendix B-1, Table B1-37 of the NOI.
3.2.6 Road Base What is specification road base? When is it applied? When or how often is existing road base tested? Is road base used outside of pit?	The road base is applied as necessary to the haulroads. During the winter months, the waste rock is screened to approximately 2-inch diameter and is screened to approximately 1.5-inch diameter during the remainder of the year. The application of the road base, generally to haulroads inside the pit influence boundary, will be regulated through the fugitive dust control plan.
3.3 VOC Sources	
3.3.3 SX/EW Plant How assume 33% emissions? How assumed 0.004 gr/dscf H_2SO_4 emissions	As discussed in the May 12, 2008 NOI for SX/EW plant, the design of the plant estimates that less than one-third (maximum 33 percent) of the residual organic in the raffinate from the proposed plant will evaporate and result in emissions. The design of the electrowinning process estimates the exhaust gas sulfuric acid concentration to be 0.004 gr/dscf.
3.4 Support Equipment	
3.4.1 Trackers, Dozers, Graders, Loaders Tier level of existing vehicles	Detailed calculations for tailpipe emissions from support equipment are provided in Appendix B-1, Table B1-37 of the NOI.

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3.5 Miscellaneous Sources 3.5.1 Emergency Generators	The existing emergency generators are currently limited to 500 hours per year for testing and maintenance activities. Detailed calculations for emergency generator emissions are provided in Appendix B-1, Table B1-34 of the NOI. Emission calculations for a proposed emergency generator are provided in Appendix B-1, Table B1-41 of the NOI. The proposed generator will be limited to 100 hours per year for testing and maintenance activities.
5.0 BACT	
5.1 BACT for Haul Roads **5.2 BACT for Ore and Waste**	Please see attached revised BACT section (Section 5) of the NOI provided as Attachment B.
Appendix A	
Tier 0,1,2,4f emissions	Detailed calculations for tailpipe emissions from the haultrucks and the support equipment are provided in Appendix B-1, Tables B1-36 and B1-37 of the NOI. Appendix A, of the NOI, discusses the methodology for estimation of tailpipe emissions from haultrucks and support equipment using NONROAD. Tables in Appendix A of the NOI are meant to provide a summary of emissions.
Appendix B-1 Post Mod emission calculations	
How were $PM_{2.5}$ percentages determined? What are their justifications? What are engineering estimates and how are they justified? Copy of 2007 AEI? How is AEI verified? Copy of Colorado guidance? Why not use AP-42?	Please see attached revised Emissions Summary section (Section 3) of the NOI provided as Attachment A. The revised includes assumptions for PM_{10} and $PM_{2.5}$ emissions. Volatile organic compound emissions from diesel fueling stations are estimated using emission factors from Colorado Department of Public Health and Environment's guidance on *Gasoline and Diesel Fuel Dispensing Stations*. A copy of the guidance was provided in Appendix B-2 of the NOI. EPA's *AP-42, Fifth Edition*, does not provide emission factors for diesel fueling stations.
Appendix B1-2 PM_{10} escape factor – 20%, what is $PM_{2.5}$ escape factor? Control $PM_{2.5}$ = 0.21 $PM_{2.5}$. What is the justification? How is 0.4 PM_{10} = $PM_{2.5}$	The escape factor for $PM_{2.5}$ was determined to be 21 percent as discussed in Appendix D-1 of the NOI. This escape factor was applied to determine controlled emissions for the emission source located within the pit influence boundary. Please see attached revised Emissions Summary section (Section 3) of the NOI provided as Attachment A. The revised includes assumptions for $PM_{2.5}$ emissions based on factors from AP-42, Table B.2.2, Category 3 - Mechanically Generated Aggregate and Unprocessed Ores. The table shows PM_{10} to be 51% of the particle distribution and $PM_{2.5}$ to be 15%. Therefore $PM_{2.5}$ is estimated to be 29% (0.15/0.51) of PM_{10} for operations including material handling and processing of aggregate and unprocessed ore such as milling, grinding, crushing, screening, conveying, cooling and drying.

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Appendix B1-3 New in-pit crusher. 12,898 dscf/min * 0.007 gr/dscf. How is 0.4 PM_{10} = $PM_{2.5}$. Controlled $PM_{2.5}$ = 0.21*$PM_{2.5}$	The escape factor for $PM_{2.5}$ was determined to be 21 percent as discussed in Appendix D-1 of the NOI. This escape factor was applied to determine controlled emissions for the emission source located within the pit influence boundary. Please see attached revised Emissions Summary section (Section 3) of the NOI provided as Attachment A. The revised includes assumptions for $PM_{2.5}$ emissions based on factors from AP-42, Table B.2.2, Category 3 - Mechanically Generated Aggregate and Unprocessed Ores. The table shows PM_{10} to be 51% of the particle distribution and $PM_{2.5}$ to be 15%. Therefore $PM_{2.5}$ is estimated to be 29% (0.15/0.51) of PM_{10} for operations including material handling and processing of aggregate and unprocessed ore such as milling, grinding, crushing, screening, conveying, cooling and drying.
Appendix B1-4 C6/C7 conveyor transfer point 0.007 gr/dscf @ 5,120 dscf/min. DAQE-AN0105710023-08 August 13, 2008. Condition 18.B is 0.016 gr/dscf. Condition 13 is 5,000 acfm.	As discussed in Section 2.1.1 of the NOI – "The BCM has two ore conveyor transfer drop points near Copperton that are equipped with baghouses—Point C6/C7 and Point C7/C8. All exhaust air from each transfer drop point is routed through the respective baghouse before being vented to the atmosphere. The C6/C7 drop point baghouse is designed to handle 5,120 dscfm, and the C7/C8 drop point baghouse is designed to handle 3,168 dscfm (UDAQ, 2008). Both baghouses are permitted to operate 8,760 hours per year. KUC is proposing to upgrade both baghouses. The upgrades will include replacing the bags and modifying hopper discharge design to provide a higher PM_{10} capture rate. This will result in reducing grain loading from 0.016 gr/dscf to 0.007 gr/dscf.". Condition 13 of the AO states – "The controlled transfer point C6/C7 baghouse shall control process streams from the drop point. This baghouse shall be sized to handle at least 5,000 acfm for the existing conditions…" As discussed in the NOI, the air flow from the baghouse will be greater than 5,000 acfm.
Table B1-1 260 MM case	KUC proposal is based on a 260,000,000 ton ore and waste combined mine plan.
Table B1-2 In Pit Crusher Which category in AP-42 B.2.2 was used to define emission factors? How was $PM_{2.5}$ conversion performed? In Category #4 PM_{10} = 85% and $PM_{2.5}$ = 30% (30/85) 7.75 tpy = 2.735 tpy $PM_{2.5}$ PM_{10} emissions calculated using the escape factor of 20%, The $PM_{2.5}$ calculations are not designated.	Emissions for $PM_{2.5}$ based on factors from AP-42, Table B.2.2, Category 3 - Mechanically Generated Aggregate and Unprocessed Ores. The table shows PM_{10} to be 51% of the particle distribution and $PM_{2.5}$ to be 15%. Therefore $PM_{2.5}$ is estimated to be 29% (0.15/0.51) of PM_{10} for operations including material handling and processing of aggregate and unprocessed ore such as milling, grinding, crushing, screening, conveying, cooling and drying. Based on a University of Utah study, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI.

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Table B1-3 New Pit Crusher Which category in AP-42 B.2.2 was used to define emission factors? How was $PM_{2.5}$ conversion performed? PM_{10} emissions calculated using the escape factor of 20%, The $PM_{2.5}$ calculations are not designated.	Emissions for $PM_{2.5}$ based on factors from AP-42, Table B.2.2, Category 3 - Mechanically Generated Aggregate and Unprocessed Ores. The table shows PM_{10} to be 51% of the particle distribution and $PM_{2.5}$ to be 15%. Therefore $PM_{2.5}$ is estimated to be 29% (0.15/0.51) of PM_{10} for operations including material handling and processing of aggregate and unprocessed ore such as milling, grinding, crushing, screening, conveying, cooling and drying. Based on a University of Utah study, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI.
Table B1-4 C6/C7 Conveyor Transfer Point Which category in AP-42 B.2.2 was used to define emission factors? How was $PM_{2.5}$ conversion performed?	Emissions for $PM_{2.5}$ based on factors from AP-42, Table B.2.2, Category 3 - Mechanically Generated Aggregate and Unprocessed Ores. The table shows PM_{10} to be 51% of the particle distribution and $PM_{2.5}$ to be 15%. Therefore $PM_{2.5}$ is estimated to be 29% (0.15/0.51) of PM_{10} for operations including material handling and processing of aggregate and unprocessed ore such as milling, grinding, crushing, screening, conveying, cooling and drying.
Table B1-5 C7/C8 Conveyor Transfer Point Which category in AP-42 B.2.2 was used to define emission factors? How was $PM_{2.5}$ conversion performed?	Emissions for $PM_{2.5}$ based on factors from AP-42, Table B.2.2, Category 3 - Mechanically Generated Aggregate and Unprocessed Ores. The table shows PM_{10} to be 51% of the particle distribution and $PM_{2.5}$ to be 15%. Therefore $PM_{2.5}$ is estimated to be 29% (0.15/0.51) of PM_{10} for operations including material handling and processing of aggregate and unprocessed ore such as milling, grinding, crushing, screening, conveying, cooling and drying.
Table B1-6 Lime Bin Which category in AP-42 B.2.2? How was $PM_{2.5}$ conversion performed? This is a refined material and its size distribution is not the same as a crushed ore size distribution. Size distribution used here is same as distribution used for crushed ore.	Emissions for $PM_{2.5}$ based on factors from AP-42, Table B.2.2, Category 4 - Mechanically Generated Processed Ores and Nonmetallic Minerals. Lime is an industrial nonmetalic mineral. The table shows PM_{10} to be 85% of the particle distribution and $PM_{2.5}$ to be 30%. Therefore $PM_{2.5}$ is estimated to be 35% (0.30/0.85) of PM_{10} for operations including material handling and processing of processed ores and nonmetallic minerals such as lime.
Table B1-7 Lime Bin Which category in AP-42 B.2.2? How was $PM_{2.5}$ conversion performed? This is a refined material and its size distribution is not the same as a crushed ore size distribution. Size distribution used here is same as distribution used for crushed ore.	Emissions for $PM_{2.5}$ based on factors from AP-42, Table B.2.2, Category 4 - Mechanically Generated Processed Ores and Nonmetallic Minerals. Lime is an industrial nonmetalic mineral. The table shows PM_{10} to be 85% of the particle distribution and $PM_{2.5}$ to be 30%. Therefore $PM_{2.5}$ is estimated to be 35% (0.30/0.85) of PM_{10} for operations including material handling and processing of processed ores and nonmetallic minerals such as lime.

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Table B1-8 Sample Preparation How was 0.016 gr/dscf determined? Justified? Is the sample preparation the same as crushed ore? Is the size distribution the same as crushed ore distribution? How is it justified? PM_{10} emissions calculated using the escape factor of 20%, The $PM_{2.5}$ calculations are not designated.	Baghouse grain loading rate is based on vendor data. Material handled during sample preparation is ore and waste rock material and size distribution is the same. Emissions of $PM_{2.5}$ based on factors from AP-42, Table B.2.2, Category 3 - Mechanically Generated Aggregate and Unprocessed Ores. The table shows PM_{10} to be 51% of the particle distribution and $PM_{2.5}$ to be 15%. Therefore $PM_{2.5}$ is estimated to be 29% (0.15/0.51) of PM_{10} for operations including material handling and processing of aggregate and unprocessed ore such as milling, grinding, crushing, screening, conveying, cooling and drying. Based on a University of Utah study, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI.
Table B1-9 Gas and Diesel Fueling Where are MSDS used to calculate HAPs for gasoline and diesel?	HAP emissions from gasoline and diesel fueling are calculated using the *Composition, Information on Ingredients* section of the MSDS.
Table B1-10 Truck Offloading Ore at In-Pit Crusher AP-42 13.2.4 Reference #12 states that 90% may be used if water and chemical are used for fugitive dust control. Research 1994 SIP control efficiency of 90%. PM_{10} emissions calculated using the escape factor of 20%, The $PM_{2.5}$ calculations are not designated. How was 4% moisture determined? How was wind speed determined at crusher? The wind speed at the SLC airport is 9 mph and is used along the Wasatch front for data requiring wind speeds. The SLC airport is a value that is accepted by DAQ for determining emissions. Also rawinsonde data indicate that wind speeds increase and change direction as altitudes increase.	Control efficiency of 90% is based on previous determination of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling. Based on a University of Utah study, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI. Moisture content of 4% for ore and waste rock handled at the BCM is based on a site sampling effort during the summer of 1994. This sampling effort is the best available site specific data for the BCM. Wind speed of 7 mph is a historical average based on meteorological stations located at BCM.
Table B1-39 Truck Offloading Ore at New In-Pit Crusher AP-42 13.2.4 Reference #12 states that 90% may be used if water and chemical are used for fugitive dust control. Research 1994 SIP control efficiency of 90%. PM_{10} emissions calculated using the escape factor of 20%, The $PM_{2.5}$ calculations are not designated. How was 4% moisture determined? How was wind speed determined at crusher?	Control efficiency of 90% is based on previous determination of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling. Based on a University of Utah study, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI. Moisture content of 4% for ore and waste rock handled at the BCM is based on a site sampling effort during the summer of 1994. This sampling effort is the best available site specific data for the BCM. Wind speed of 7 mph is a historical average based on meteorological stations located at BCM.

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Table B1-40 Truck Offloading Ore at Stockpile AP-42 13.2.4 Reference #12 states that 90% may be used if water and chemical are used for fugitive dust control. Research 1994 SIP control efficiency of 90%. How was 4% moisture determined? How was wind speed determined at crusher?	Control efficiency of 90% is based on previous determination of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling. Moisture content of 4% for ore and waste rock handled at the BCM is based on a site sampling effort during the summer of 1994. This sampling effort is the best available site specific data for the BCM. Wind speed of 7 mph is a historical average based on meteorological stations located at BCM.
Table B1-11 In-Pit Enclosed Transfer Points 1, 2, & 3 AP-42 13.2.4 Reference #12 states that 90% may be used if water and chemical are used for fugitive dust control. Research 1994 SIP control efficiency of 90%. How was 4% moisture determined after it is crushed? How was wind speed determined at transfer points?	Control efficiency of 90% is based on previous determination of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling. Moisture content of 4% for ore and waste rock handled at the BCM is based on a site sampling effort during the summer of 1994. This sampling effort is the best available site specific data for the BCM. Wind speed of 7 mph is a historical average based on meteorological stations located at BCM.
Table B1-12 New In-Pit Enclosed Transfer Points 1, 2, & 3 AP-42 13.2.4 Reference #12 states that 90% may be used if water and chemical are used for fugitive dust control. Research 1994 SIP control efficiency of 90%. How was 4% moisture determined after it is crushed? How was wind speed determined at transfer points?	Control efficiency of 90% is based on previous determination of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling. Moisture content of 4% for ore and waste rock handled at the BCM is based on a site sampling effort during the summer of 1994. This sampling effort is the best available site specific data for the BCM. Wind speed of 7 mph is a historical average based on meteorological stations located at BCM.
Table B1-13 In-Pit Enclosed Transfer Points 4 & 5 AP-42 13.2.4 Reference #12 states that 90% may be used if water and chemical are used for fugitive dust control. Research 1994 SIP control efficiency of 90%.How was 4% moisture determined after it is crushed? How was wind speed determined at transfer points?	Control efficiency of 90% is based on previous determination of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling. Moisture content of 4% for ore and waste rock handled at the BCM is based on a site sampling effort during the summer of 1994. This sampling effort is the best available site specific data for the BCM. Wind speed of 7 mph is a historical average based on meteorological stations located at BCM.
Table B1-14 Conveyor-Stacker Transfer Point AP-42 13.2.4 Reference #12 states that 90% may be used if water and chemical are used for fugitive dust control. Research 1994 SIP control efficiency of 90%. How was 4% moisture determined after it is crushed? How was wind speed determined at transfer points?	Control efficiency of 90% is based on previous determination of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling. Moisture content of 4% for ore and waste rock handled at the BCM is based on a site sampling effort during the summer of 1994. This sampling effort is the best available site specific data for the BCM. Wind speed of 7 mph is a historical average based on meteorological stations located at BCM.

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Table B1-15 Coarse Ore Stacker AP-42 13.2.4 Reference #12 states that 90% may be used if water and chemical are used for fugitive dust control. Research 1994 SIP control efficiency of 90%. How was 4% moisture determined after it is crushed? How was wind speed determined at stacker?	Control efficiency of 90% is based on previous determination of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling. Moisture content of 4% for ore and waste rock handled at the BCM is based on a site sampling effort during the summer of 1994. This sampling effort is the best available site specific data for the BCM. Wind speed of 7 mph is a historical average based on meteorological stations located at BCM.
Table B1-16 Reclaim Tunnels AP-42 13.2.4 Reference #12 states that 90% may be used if water and chemical are used for fugitive dust control. Research 1994 SIP control efficiency of 90%. How was 4% moisture determined after it is crushed? How was wind speed determined at reclaim tunnels?	Control efficiency of 90% is based on previous determination of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling. Moisture content of 4% for ore and waste rock handled at the BCM is based on a site sampling effort during the summer of 1994. This sampling effort is the best available site specific data for the BCM. Wind speed of 7 mph is a historical average based on meteorological stations that were located in at and near BCM.
Table B1-17 Disturbed Areas Spreadsheet notes state that PM emission factors derived from ration in AP-42 Table 13.2.4 Tasble 13.2.4.1 is for silt & moisture content. Also assumption of PM_{10} = 47% of PM and $PM_{2.5}$ is 15% of PM_{10}. What is the basis for this assumption? How was $PM_{2.5}$emission factor obtained? Controlled PM_{10} shows PM_{10}*escape/100, How is $PM_{2.5}$ emissions calculated. Reference #12 states that 90% may be used if water and chemical are used for fugitive dust control.	PM emission factor estimated using methodology in AP-42, Section 11.9-4 (Wind Erosion of Exposed Areas). PM_{10} and $PM_{2.5}$ emission factors derived from ratio of transfer particle size multipliers in AP 42, Fifth Edition, Table 13.2.4 (EPA, 2006). The ratio of transfer particle size multipliers are 0.74 for PM, 0.35 for PM_{10} and 0.053 for $PM_{2.5}$. Therefore, PM_{10} is estimated to be 47 percent of PM (0.35/0.74) and $PM_{2.5}$ is estimated to be 15 percent of PM_{10} (0.053/0.35). Based on a University of Utah study, for sources located in the pit, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI.
Table B1-18 Cold Solvent Degreasing Parts What are the HAPs from degreasing parts?	Degreasing solvent does not contain HAPs.
Table B1-19 Haul Roads How was an average vehicle weight limit of 293 tons determined? How will the weight of the haul trucks be verified to be an average of 293 tons and not the lower vehicle weight limit of 240 tons? How is mileage determined?	By the current Approval Order, "Minimum design payload per ore and waste haul truck shall not be less than 240-tons." PTE emissions for this source were estimated by assuming the full 260 MMT of ore and waste rock are hauled by 240-ton trucks as a maximum emissions case. Year by year round trip haulage mile projections are provided by the KUC mine group. KUC operates larger trucks during any given year, so that emissions from haul truck traffic would be less than predicted.

UDAQ Review	KUC Responses
Table B1-20 Low-Grade Coarse Ore Storage Piles Spreadsheet notes state that PM emission factors derived from ratio in AP-42 Table 13.2.4Tasble 13.2.4.1 is for silt & moisture content. Also assumption of PM_{10} = 47% of PM and $PM_{2.5}$ is 15% of PM_{10}. What is the basis for this assumption? How was $PM_{2.5}$ emission factor obtained? Controlled PM_{10} shows PM_{10}*escape/100, How is $PM_{2.5}$ emissions calculated. Research 1994 SIP control efficiency of 80%. How was 4% moisture determined after it is crushed? How was wind speed determined at ore storage piles?	PM emission factor estimated using methodology in AP-42, Table 11.9-1 (Active Storage Pile). PM_{10} and $PM_{2.5}$ emission factors derived from ratio of transfer particle size multipliers in AP 42, Fifth Edition, Table 13.2.4 (EPA, 2006). The ratio of transfer particle size multipliers are 0.74 for PM, 0.35 for PM_{10} and 0.053 for $PM_{2.5}$. Therefore, PM_{10} is estimated to be 47 percent of PM (0.35/0.74) and $PM_{2.5}$ is estimated to be 15 percent of PM_{10} (0.053/0.35). Based on a University of Utah study, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI. Moisture content of 4% for ore and waste rock handled at the BCM is based on a site sampling effort during the summer of 1994. This sampling effort is the best available site specific data for the BCM. Wind speed of 7 mph is a historical average based on meteorological stations located at BCM.
Table B1-21 Front-End Loaders How was 4% moisture determined? Controlled PM_{10} shows PM_{10}*escape/100, How is $PM_{2.5}$ emissions calculated.	Moisture content of 4% for ore and waste rock handled at the BCM is based on a site sampling effort during the summer of 1994. This sampling effort is the best available site specific data for the BCM. Based on a University of Utah study, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI.
Table B1-22 Truck Loading How was 4% moisture determined? Research 1994 SIP control efficiency of 80%. Controlled PM_{10} shows PM_{10}*escape/100, How is $PM_{2.5}$ emissions calculated. How was wind speed determined at truck loading sites?	Moisture content of 4% for ore and waste rock handled at the BCM is based on a site sampling effort during the summer of 1994. This sampling effort is the best available site specific data for the BCM. Based on a University of Utah study, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI. Wind speed of 7 mph is a historical average based on meteorological stations located at BCM.
Table B1-23 Truck Offloading of Waste Rock How was 4% moisture determined? How was 7 mph wind speed determined? The SLC airport reports a & mph wind speed but the wind speed would be higher for a higher elevation and at the edge of the dumping area. Research 1994 SIP control efficiency of 80%. How was wind speed determined at truck offloading sites?	Moisture content of 4% for ore and waste rock handled at the BCM is based on a site sampling effort during the summer of 1994. This sampling effort is the best available site specific data for the BCM. Wind speed of 7 mph is a historical average based on meteorological stations located at BCM.
Table B1-24 Graders Controlled PM_{10} shows PM10*escape/100, How is $PM_{2.5}$ emissions calculated? How was vehicle speed determined?	Based on a University of Utah study, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI. Grader operation speed at the BCM is provided by the KUC mine group.

UDAQ Review	KUC Responses
Table B1-25 Bulldozers (Track Dozers) Controlled PM_{10} shows PM_{10}*escape/100, How is $PM_{2.5}$ emissions calculated. How was 8% silt content determined? What is the historical data for 4% moisture content?	Based on a University of Utah study, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI. Bulldozers operate mainly on haulroads and waste rock disposal areas performing "cleanup" operations. Thus, material handled by dozers is subject to FDCP measures. Per the EPA Compilation of Emission Factors, "In the absence of locally derived surface material silt content, users may choose to use the values in this table as default values." The default silt content for the State of Utah, 4%, was applied. (http://www.epa.gov/ttnchie1/ap42/ch13/related/c13s02-2.html) Moisture content of 4% for ore and waste rock handled at the BCM is based on a site sampling effort during the summer of 1994. This sampling effort is the best available site specific data for the BCM.
Table B1-26 Wheeled Dozers Controlled PM_{10} shows PM_{10}*escape/100, How is $PM_{2.5}$ emissions calculated. How was 8% silt content determined? What is the historical data for 4% moisture content?	Based on a University of Utah study, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI. Dozers operate mainly on haulroads and waste rock disposal areas performing "cleanup" operations. Thus, material handled by dozers is subject to FDCP measures. Per the EPA Compilation of Emission Factors, "In the absence of locally derived surface material silt content, users may choose to use the values in this table as default values." The default silt content for the State of Utah, 4%, was applied. (http://www.epa.gov/ttnchie1/ap42/ch13/related/c13s02-2.html) Moisture content of 4% for ore and waste rock handled at the BCM is based on a site sampling effort during the summer of 1994. This sampling effort is the best available site specific data for the BCM.

UDAQ Review	KUC Responses
Table B1-27 Drilling with Water Injection How was 90% control efficiency determined for water injection? How was 90.000 holes per year determined? How is 47% of PM = to PM_{10} and 15% = to $PM_{2.5}$ PM10 emissions calculated using the escape factor of 20%, The $PM_{2.5}$ calculations are not designated.	The control efficiency listed is based on previous determinations of BACT by UDAQ. This control efficiency has been applied in the 1994 SIP and 2005 SIP calculations and modeling. KUC mine group has projected 90,000 holes per year based on 260,000,000 ton mine plan. PM_{10} and $PM_{2.5}$ emission factors derived from ratio of transfer particle size multipliers in AP 42, Fifth Edition, Table 13.2.4 (EPA, 2006). The ratio of transfer particle size multipliers are 0.74 for PM, 0.35 for PM_{10} and 0.053 for $PM_{2.5}$. Therefore, PM_{10} is estimated to be 47 percent of PM (0.35/0.74) and $PM_{2.5}$ is estimated to be 15 percent of PM_{10} (0.053/0.35). Based on a University of Utah study, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI.
Table B1-28 Blasting with Minimized Area What is basis of historical Industrial Hygiene assessment for ammonia? How is blasting area and # of blasts determined? PM_{10} emissions calculated using the escape factor of 20%, The $PM_{2.5}$ calculations are not designated.	In the absence of an applicable emission factor, ammonia emissions are estimated based on a site Industrial Hygiene assessment. The basis of the assessment was the conversion of odorless Ammonium Nitrate to Ammonia, odor threshold of 5 ppm. Blasting area and the number of blasts are projections provided by the KUC mine group. Based on a University of Utah study, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI.
Table B1-29 Tertiary Crushing Controlled PM_{10} shows PM_{10}*escape/100, How is $PM_{2.5}$ emissions calculated.	Based on a University of Utah study, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI.
Table B1-30 Screening Controlled PM_{10} shows PM_{10}*escape/100, How is $PM_{2.5}$ emissions calculated.	Based on a University of Utah study, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI.
Table B1-31 Transfer Points Controlled PM_{10} shows PM_{10}*escape/100, How is $PM_{2.5}$ emissions calculated.	Based on a University of Utah study, emissions of $PM_{2.5}$ are calculated using an escape factor of 21%. A summary of the University of Utah study was included in Appendix D-1 in the NOI.
Table B1-32 SX/EW Copper Extraction How is 80% control determined? How is vaporization rate determined?	The control efficiency is based on the design of the process. Control of 80% will be achieved by the placement of covers at all times except during inspection, sampling, and adjustment. As discussed in the May 12, 2008 NOI for SX/EW plant, the design of the plant estimates that less than one-third (maximum 33 percent) of the residual organic in the raffinate from the proposed plant will evaporate and result in emissions.

UDAQ Review	KUC Responses
Table B1-33 Electrowinning When acf is converted to dscf the atmospheric pressure based upon altitude, is required as is shown here, but the temperature and Humidity are also required for the conversion. How is concentration determined?	Table B1-33 converts acfm to dscfm based on Salt Lake City average temperature, atmospheric pressure and humidity.
Table B1-34 LPG Generators Text states emission data taken from previous NOIs, which NOIs were they taken from?	KUC NOI submitted 12/21/2005 included details for the generators located at Production Control Building, Communication 6190, and Lark Gate. KUC NOI submitted 05/12/2008 included details for the Galena Gulch emergency generator.
Table B1-35 Metal HAP Emissions The HAPs are calculated by PM_{10}*HAP ration on mg/kg, where were these HAP ratios obtained?	Metal HAP concentrations are based on ore and waste rock sampling at the BCM.
Table B1-36 2011 – 2029 Haul Truck Emissions – 260 Mtpy	Tailpipe emissions from haul trucks are summarized in Table B1-36 for the 260,000,000 ton mine plan.
Table B1-37 2011 – 2029 Haul Truck Emissions – 260 Mtpy	Tailpipe emissions from mobile support equipment are summarized in Table B1-37 for the 260,000,000 ton mine plan.
Table B1-38 Emissions Summary	Table B1-38 is a summary table of Point and Fugitive source emissions.
Appendix D-1	
Comments on the University of Utah study	CH2M HILL staff, an expert on CFD modeling, provided a briefing on the study at UDAQ offices on November 3, 2010.

APPENDIX E-2

Response to AERMOD Comments

Response to UDAQ NOI – Appendix C, AERMOD Comments

TO: UDAQ

COPIES: KUC

FROM: CH2M HILL

DATE: January 3, 2011

On August 17, 2010, Kennecott Utah Copper (KUC) submitted a notice of intent (NOI) to the Utah Division of Air Quality (UDAQ) to increase the annual material moved limit at the Bingham Canyon Mine (BCM) from 197 million tons per year (tpy) to 260 million tpy of ore and waste rock combined. Included as an attachment to the NOI, an ambient air quality analysis for PM_{10} was submitted using the EPA-approved AERMOD modeling system.

On November 1, 2010, UDAQ supplied comments on the AERMOD analysis attachment to the NOI. The intention of this memorandum is to provide responses to UDAQ's comments and to provide the additional information necessary to document that the analysis is representative of the BCM.

The format of this document is to first present UDAQ's comment (in order as received), and then follow each comment with a response.

Comment 1: *Page C-1, p2, the first sentence in the second paragraph states that the BCM expansion project is not subject to UAC-R307-410, since it is located in a NAA. Yet on C-5, p3, the NOI states that the analysis was conducted following guidance and procedures outlined in 40 CFR 51, Appendix W. This is similar to the requirement spelled out in R307-410-3. If R307-410-3 does not apply to the analysis, what benchmarks or criteria should the analysis meet for it to be considered representative and complete?*

Response to Comment 1: While modeling is not required under UAC-R307-410, modeling guidelines have long been established by EPA. These guidelines and procedures, outlined in 40 CFR 51, Appendix W, have been developed to ensure models are correctly applied. Wherever possible, source-specific information and model set-ups have been implemented. The use of source-specific model applications within the guidance established by EPA are intended to improve the model's ability to more accurately estimate the impacts of sources such as the BCM. Additionally, KUC and its consultants have engaged UDAQ to discuss key decisions relating to the modeling effort due to the unique nature of the source being modeled. For example, we discussed with UDAQ the use of a third-party study, specific to KUC's pit, to address pit retention in lieu of the more generic algorithm offered by AERMOD.

Comment 2: *The coordinate system used in the analysis is unclear. The placement of point sources is not consistent with NAD 27 or NAD 83 when overlaid onto Google Earth. Limebin 1 & 2 and conveyor drops c6_c7 and c7_c8 do not appear to be properly located under either coordinate system. The receptor grid locations may also be off at some locations. For review purposes, the analysis would best be served if it appeared in NAD 83, which is consistent and verifiable through Google Earth.*

Response to Comment 2: The source locations and facility boundaries were provided by GIS mapping using the KUC BCM layout. Small and insignificant discrepancies converting from the KUC BCM layout to UTM NAD27 used in AERMOD could be the result of converting between coordinate systems. Additionally, most of the discrepancies occur north of where a majority of the mining operations and resulting emissions occur. Between the two coordinate systems, distances between emission locations and receptors at the northern end of the mine controlled area are preserved; therefore, updating the coordinate system to a NAD83 would not alter the main model conclusions.

Comment 3: *The dispersion analysis uses a traveled road width of 100 feet to simulate the entrainment of wheel dust in the model. The actual initial width of a plume release from tire traffic should be equal to the width of the wheel stance on the vehicle, plus a reasonable amount of distance on either side of the vehicle to account for wheel turbulence(~60 ft). The mine trucks move somewhere between 7 - 25 MPH and do not produce very much wheel turbulence. Please provide a rational for using an initial source width of 100 ft to represent fugitive dust entrainment from a moving vehicle.*

Response to Comment 3: The lateral distance of 100 ft is consistent with an approximate representation of a line source by a series of volume sources as described in the ISC users manual Volume 2 Pages 1-82, Figures 1-8. According to the user's manual, the length of a side is 50 ft and the center to center distance between the successive volume sources is 100 ft. The 100 ft distance corresponds to the larger of the two lateral dimensions and is representative of fugitive dust entrainment from a haul truck at the BCM.

Comment 4: *The dispersion analysis uses a single-size area source to simulate emissions released from the Bingham Mine below pit-top elevation. The area source is rectangular in shape, uses a base elevation of 7425 feet, and is aligned 24 degrees from north. The model appears sensitive to the base elevation and alignment of the rectangular source. Dependent on the elevation, the maximum area of impact will shift around to boundaries with elevation levels consistent with the base elevation. This base elevation is consistent with the south wall height, but is 600-700 higher than the east and north facing walls where emissions would also escape into the Salt Lake Valley. It is unclear why the base elevation was chosen, and another base height may be more representative.*

Response to Comment 4: The base elevation of the main pit was calculated by the EPA AERMAP program using 7.5-minute digital elevation model (DEM) data obtained from the United States Geological Survey (USGS). Using AERMAP to determine the base elevation for the source is an acceptable method for determining the base elevation of the source.

The alignment and dimensions of the area source were selected to best cover a majority of the pit and provide conservative (potentially higher) modeled impacts from mine emissions. Using a smaller area to represent the entire pit would result in a higher emissions rate per area squared coming out the top of the pit compared to the actual foot print of the pit opening - a full oval covering the entire pit. The area of an oval used to represent the pit would be approximately 7.3 million square meters while the current rectangular area source in the model is approximately 5.6 million square meters, therefore making the analysis conservative.

Comment 5: *The mine area over which the source is laid is fairly round in shape, and does not appear to take on an oval shape consistent with the chosen rectangular dimensions. Some clarification on this would be helpful.*

Response to Comment 5: Similar to *Response to Comment 4*, the rectangular shape covering the pit was used to simplify the pit source since emissions generated from the pit already account for control efficiency due to pit retention. The rectangular area modeled covers a majority of the pit area, while also being smaller than the overall existing pit area. The modeled smaller area is more conservative based on emissions generated per square area coming out of the top of the pit since the same total lb/hr emission rate is used out the top of the pit. The higher lb/hr per square area emission rate would lead to higher ground level impacts predicted by the AERMOD model. The rectangular source is aligned to best cover the pit and is a conservative assumption.

Comment 6: *The size and location of the area source used to simulate emission releases from inside the pit area are inconsistent with dimensions commonly associated with pit –type releases. The model uses a single area source the approximate size of the mine pit located over the center of the mine. This type of area source representation would be appropriate for a very shallow pit. Kennecott's pit is deep and the analysis assumes pit retention physics apply. In such cases, the pollutant would be released from a limited area at the upwind or downwind side of the pit, depending on the pit shape. If the pit is shaped such that there is recirculation of the air in the pit, the pollutant will be released from a small area on the upwind side of the pit. In Kennecott's fluid analysis however, the north-south flow test indicated there would not be recirculation, and the pollutant would be released from a small area on the downwind side. Other wind directions were evaluated for recirculation, and the analysis assumed the air flowed through the pit without any recirculation. The AERMOD model's own pit retention algorithm resizes and relocates the area source, depending on the particular hourly wind conditions. Kennecott's does not incorporate these physical aspects into part of the pit retention methodology, and assumes the emissions are released across the entire top of the mining area. Overestimating a pollutants release area increasing the initial plume volume and decreases the mass per unit volume ratio, resulting in lower concentration predictions from the model. Please provide more information to support the dimensions used for the MAIN area source parameters, and its location.*

Response to Comment 6: The AERMOD pit retention algorithm and source type are not appropriate for the BCM due to the unique conditions that exist at the mine. Therefore, the source was modeled as an area source because the emission calculations for the BCM expansion already used the characteristics of the pit to control emissions released from the top. The emissions escape fraction was determined by evaluating the University of Utah Computational Fluid Dynamics computer modeling of the pit. See section D-1 of the original NOI for a review of the study. The pit retention factor applied was conservative (large fraction of emissions escaping) regardless of the location of the source (upwind or downwind). Therefore, source placement was already being conservatively accounted for.

The angle orientation of the pit was selected to best place a rectangular area source within the pit extents. Also, as noted in *Response to Comment 5*, the pit was modeled as an area source that has a smaller overall area compared to the full top of the pit area. Therefore, the emissions would be more conservative because the emissions per square area being emitted from the top of the pit would be higher.

Comment 7: *The hourly emission rate used to simulate the 24-hour period was 1.2 times higher than the annual estimate divided by 8760 hours of operation. It is unclear if this factor accurately reflects a worst-case fluctuation in the hourly emission rate. More information on this issue would be helpful.*

Response to Comment 7: The emissions calculations for the mine were calculated on an annual basis assuming that operations occur 8760 hours per year. However, previous conversations with UDAQ indicated that dividing the annual lb/yr emissions by 8760 and distributing throughout the mine may underestimate the worst case daily emissions. To address this, 20% was added to the average daily emissions to conservatively account for any daily variability in regards to operation or location of the activities during a single day. The 20% variability would be conservative because the mine activity has little variability in day-to-day operations.

Comment 8: *The model apportions truck hauling emissions outside the pit into three areas. More information is needed to determine if truck haul emissions are apportioned correctly.*

Response to Comment 8: Haul truck traffic apportionment was based on conversations with KUC BCM staff and representative of the mine plan. See attached Figure 1 for apportionment of haul road traffic outside the pit.

Comment 9: *Kennecott staff said that a fair amount of dozer work takes place on the bench dumping areas to distribute the overburden and building up the dumping-off areas. This was evident during our recent site visit. The analysis did not include emissions of any other fugitive dust activity other than truck haul traffic and dumping outside the pit area.*

Response to Comment 9: The PM_{10} bulldozer emissions at the mine are approximately 13 tpy of the total 1,425 tpy PM_{10} emissions generated by the mine. The emissions generated by the bulldozers are currently placed completely within the main pit for the AERMOD analysis. However, if the bulldozer PM_{10} emissions are distributed outside of the main pit along the haul roads, little impact on the AERMOD modeling analysis is expected since the increase in the hourly emission rate at each volume source would be minimal.

Comment 10: *Appendix C1 - PM_{10} Ambient Monitoring: The methodology used to choose a representative background concentration excludes seemingly valid representative background values. The methodology relies on the assumption that the sample should be discarded if:*

a. the alignment of the winds were such to place the mining operation in the upwind quadrant of the monitor at any time during the 24-hour period during which the sample was collected, or
b. the sample is influenced by natural dust events during days with high wind gust. Specific to this analysis are the landfills and dry sand beaches of the Great Salt Lake.

The analysis excludes the top six values based on an assumption that during the sample day, the winds were from the southwest, and the source may have significantly contributed to the sample concentration collected. A review of the meteorology associated with six cases indicated that during five of the sample periods, winds were from that quadrant for less than six hours during the 24-hour sample period, sometimes only for one or two hours. The analysis also dismissed the values 'due to the presence of gusting winds during the sample period'. Most of these events are simple diurnal shift in wind direction or moderate frontal passages which are commonly occurring events, and have not been classified as exceptional events by UDAQ or EPA.

Further review of the associated meteorology for the 24-hour sample period indicated that several of the sample concentrations were incorrectly excluded. Kennecott's dispersion model analysis was run to estimate the source's contribution to the monitor on the reported sample days. The model was run using the analysis' meteorology for the sample days listed in Table 1 on page C1-2. A list of the sample dates, monitored values and the contribution to the sample from the source during the sample period are listed below. Contributions from point source C6_C7 were also evaluated since this source is located about 350 feet WSW of the monitor.

Sample Date	Monitored Concentration (μg/m³)	Contribution from Source (μg/m³)	Contribution from C6_C7 (μg/m³)	% of Sample
05/18/2007	139.3[ad]	2.2	0.1	1
09/10/2005	93.9[d]	1.1	0.3	1
07/21/2005	81.5[be]	4.3	1.1	5
12/30/2003	77.7[d]	Not Modeled		
07/15/2005	67.1[e]	6.4	3.2	10
07/06/2005	66.9[e]	7.6	3.0	11
10/27/2007	65.0[e]	Not Modeled		
02/04/2004	59.1[cd]	11.8	1.0	20

a. Value excluded due to missed collection period.
b. UDAQ Selected Representative Background Concentration
c. Kennecott NOI Selected Representative Background Concentration
d. Sample excludable due to extreme high wind event or significant contribution to the sample from the subject source.
e. Valid as a sample for consideration as a representative background concentration minus source's modeled contribution. Average hourly wind speed for the sample period equal to or less than average wind speed reported by KUC Mine AEI

The sample collected on 05/18/2007 was excluded due to a missed sample period.

The 09/10/2005 sample with its average wind speed of 13.1 mph should be excluded since it was collected during an extremely high-wind event. The 24-hour period of meteorology associated with the sample period is inconsistent with meteorological conditions that result

> *in the highest model predicted impacts, such that the pairing of the two concentrations would represent a physical impossibility.*
>
> *The sample collected on 07/21/2005 best meets the criteria for a representative background concentration for the area east of the Bingham Mine. The sample was collected during a period where the winds were moderate and contribution from the mine was minimal. Samples collected on 07/06/05, 07/15/05, and 10/27/07 also meet the criteria for consideration as background concentrations; however, the sample collected on 10/27/07 should be modeled to estimate any contribution from the source prior to its inclusion.*

It is unclear from the review why the sample collected on 02/04/2004 is considered more representative as a background concentration then the samples collected on 7/21/05, 7/06/05, 7/15/05, or 10/27/07. Clarification is needed.

Response to Comment 10: The justification for determining appropriate PM_{10} background concentration for the BCM AERMOD modeling followed the procedures outlined in 40 CFR 51 Appendix W Section 8.2. Only days when winds blew from the predominant sector based on the meteorological monitoring data were removed from determining a representative PM_{10} background concentration. This is because the AERMOD modeling analysis conservatively modeled all emissions associated with the 260 million tpy extraction and not just the incremental increase from the currently permitted 197 million tpy at the BCM. The value selected in the NOI is conservatively the 8th highest monitored value at the Copperton monitor since the current operations are included in the monitored concentrations.

The BCM is currently listed in the PM_{10} SIP, and it can be assumed that emissions from the mine, during periods when the meteorological data show winds blowing from the mine to the monitor, would influence the monitor values. As mentioned above, since the AERMOD modeling conservatively assumes emissions from all operations concurrently, not just the incremental increase in operations from the mine, any periods when mine operations could contribute to the monitored concentration were removed as not representative only to the AERMOD modeling background analysis. These excluded values were not labeled as invalid monitor values.

Therefore, the 59.1 $\mu g/m^3$ is an appropriate background concentration for the AERMOD analysis. The technical memorandum in Appendix C-1 of the NOI supports the conclusion following guidance from 40 CFR 51 Appendix W.

APPENDIX E-3

Proposed Fugitive Dust Control Plan

Rio Tinto

PROPOSED BINGHAM CANYON MINE FUGITIVE DUST CONTROL PLAN MEASURES

1.0 Introduction

In compliance with the NOI submitted to the Utah Division of Air Quality on August 17, 2010 (proposal to modify Bingham Canyon Mine Approval Order DAQE-AN0105710023-08) and R307-309, the following report describes dust control measures proposed for the Bingham Canyon Mine.

2.0 Proposed Dust Control Measures

- Total material moved of ore and waste rock combined at the mine shall not exceed 260,000,000 tons under the AO.
- Maximum daily total mileage for ore and waste haul trucks shall not exceed 30,000 miles.
- Primary ore and waste haul truck fleet shall have a minimum design payload of 240 tons and a maximum of 6 wheels each.
- Mine waste dumps to not exceed a height of 1,000 feet.
- Active ore and waste haulage roads within the Pit Influence Boundary (see attached map) shall be water sprayed and/or treated with commercial dust suppressant as conditions warrant. Additionally, crushed road base material shall be applied as necessary to active ore and waste haulage road within the Pit Influence Boundary to enhance the effectiveness of fugitive dust control measures.
- Commercial dust suppressant shall be applied to active ore and waste haulage roads outside of the Pit Influence Boundary (see attached map) no less than twice per year.
- Use of 5-mile ore conveyors, reduces fugitive emissions by displacing transport by truck.
- Integration of higher capacity haul trucks results in a decrease in round trips and vehicle miles travelled reducing fugitive emissions.
- KUC shall report annually volume of water applied, commercial dust suppressant activity, road base placement, and dust suppression fleet composition.

2.1 Active Haul Roads

Opacity surveys from haul roads shall be conducted as specified in the Bingham Canyon Mine AO. If observations are determined to be in excess of those allowed by the AO, dust control measures will be implemented.

Within Pit Influence Boundary:

Dust control measures proposed at the Bingham Canyon Mine include continued water application on active ore and waste haul roads within the Pit Influence Boundary, as governed by continual monitoring of road and meteorological (dry) conditions. A portable road base crushing and screening unit has been permitted, tested and operating since October 2006 to crush road base material. Based on testing and application of the road base material, results observed general road quality and surfaces improved while reducing fine particulate matter. Rock is screened to approximately 2-inch diameter during winter months and to 1.5-inch diameter for the remainder of the year. KUC will continue to operate the road base crusher and place material as necessary on haul roads within the Pit Influence Boundary. KUC will annually report roads that received road base application.

Outside Pit Influence Boundary:

Commercial dust suppressant shall be applied on active ore and waste haul roads outside of the Pit Influence Boundary no less than two times per year. The attached Pit Influence Boundary map details these areas.

The crushing and conveying department will continue to water roads along the conveyor as conditions warrant. In addition, the crushing and conveying department at the Copperton Concentrator utilizes a 4,000 gallon capacity water truck which is primarily dedicated to dust control measures associated with the conveyor belt between the mine and the ore stockpile.

2.2 Active Access Roads

Continued use of commercial dust suppressant is planned for unpaved access roads that receive minimal haul truck traffic and elevated light vehicle traffic. The application of the commercial dust suppressant will be through the use of contractors as in previous years and under close KUC operations supervision. The dust suppressant may be reapplied as necessary.

2.3 Dust Suppression Fleet

The active dust suppression fleet will consist of:

- Five (5) 50,000 gallon trucks (two 58,500 gallons and three 52,000 gallons)
- Two (2) 4,000 gallon trucks (one 4,000 gallons and one 3,600 gallons)
- One (1) 1,800 gallon truck

KUC uses graders to perform road maintenance as well as other operational functions. The number of graders used for road maintenance at any given time varies as road conditions warrant. Experience has determined that rapid removal of mud slurry after a storm event eliminates a saturation source for the road base and also helps to ultimately reduce fugitive emissions caused when the slurry dries. In this effort the mine uses 90-ton trucks as road service vehicles to haul the mud off the haul road and import new road surface material. A loader is used to load the 90-ton trucks.

The five (5) 50,000 gallon capacity water trucks are outfitted with a GPS computerized tracking system to provide an accurate count of ready down, standby and delay hours on each truck. That data is recorded and used to calculate the number of water loads each truck applies per month. The three smaller trucks (4,000 gallon, 3,600 gallon and 1,800 gallon) will be primarily dedicated to areas of drilling and blasting but will also apply water on smaller access roads that are too narrow for the large capacity water trucks to reach and trafficked by light vehicles.

2.4 Waste Rock Disposal Areas

Opacity surveys will be conducted monthly in areas where waste rock is being dumped. The observation shall be conducted in accordance the Bingham Canyon Mine Approval Order. If the average of the three minute trigger opacity readings described in the AO are determined to be in excess of those allowed, control measures such as dumping and pushing with dozers, or wetting with water will be implemented in order to maintain compliance.

APPENDIX E-4

Proposed Conditions for New Ambient Monitor

Ambient Monitoring Requirements

KUC shall operate an ambient monitoring station as described in this Approval Order. The monitoring plan will be periodically reviewed by UDAQ and revised as necessary. [R307-401]

The air monitoring installation and set-up shall be completed within 90 days of the AO issuance. KUC shall complete the calibration and equipment testing within 30 days of the final set-up and installation date.
If three consecutive years of monitoring data indicates compliance with the NAAQS, KUC may petition UDAQ to remove the air monitoring station.

KUC shall operate and maintain one (1) monitoring site in the vicinity of one of the top five highest modeled ground level emission concentrations. The monitor shall be sited in a location impacted by the highest modeled concentration of emissions near lower Butterfield Canyon area. This site is along the mine's southwest property boundary. The exact location of the monitoring site shall be approved by the UDAQ and meet all of the citing requirements established by the UDAQ.

KUC shall utilize air monitoring and quality assurance procedures which are equal to or exceed the requirements described in the EPA Quality Assurance Manual including revisions 40 CFR Parts 53 and 58.

The air monitoring shall track the long-term impacts of emissions from the facility. Should monitoring data indicate that project emissions are producing ambient air impacts that could produce an exceedance of the NAAQS, additional air monitoring or analyses will be required. If this situation occurs, an additional data assessment plan shall be developed that is mutually acceptable to both UDAQ and KUC.
KUC shall monitor the following parameters listed below:

Site Name:	TBD
UTM Coordinates	TBD
Parameter	PM_{10}
Frequency	Every 6th day

Note: PM_{10} is defined as particulate matter less than 10 microns in aerodynamic diameter.

Any ambient air monitoring changes proposed by KUC must be approved in writing by the Executive Secretary or representative. [R307-401]

KUC shall submit quarterly data reports within 45 days after the end of the calendar quarter and an annual data report within 90 days after the end of the calendar year. [R307-401]
The quarterly report shall consist of a narrative data summary and a submittal of all data points in EPA-AIRS record format. The data shall be submitted in compact disk (CD) format. The narrative data summary shall include:

A. A topographic map of appropriate scale with UTM coordinates and a true north arrow showing the air monitoring site locations in relation to the mine and the general area;
B. A hard copy of the individual data points;

C. The quarterly and monthly arithmetic means for PM_{10} and wind speed;
D. The first and second highest 24-hour concentrations for PM_{10};
E. The quarterly and monthly wind roses;
F. A summary of the data collection efficiency;
G. A summary of the reasons for missing data;
H. A precision and accuracy (audit) summary;
I. A summary of any ambient air standard exceedances; and
J. Calibration information.

[R307-401]

The annual data report shall consist of a narrative data summary containing:

A. A topographic map of appropriate scale with UTM coordinates and a true north arrow showing the air monitoring site locations in relation to the mine and the general area;
B. A pollution trend analysis;
C. The annual arithmetic means for PM_{10} and wind speed;
D. The first and second highest 24-hour concentrations for PM_{10};
E. The annual wind rose;
F. An annual summary of data collection frequency;
G. An annual summary of precision and accuracy (audit) data;
H. An annual summary of any ambient standard exceedance;
I. Annual mine material moved in tpy; and
J. Recommendations on future monitoring.

[R307-401]

The Executive Secretary may audit, or may require KUC to contract with an independent firm to audit, the air monitoring network, the laboratory performing associated analysis, and any data handling procedures at unspecified times. On the basis of the audits and subsequent reports, the UDAQ may recommend or require changes in the air monitoring system and associated activities in order to improve precision, accuracy, and data completeness. [R307-401]