DOE/WIPP 91-005
Revision 6

Resource Conservation and Recovery Act Part B Permit Application

Volume X of XIII

Appendices D9 through D16

Waste Isolation Pilot Plant
Carlsbad, New Mexico

APPENDIX D9

EXPOSURE ASSESSMENT FOR PROTECTION OF THE ATMOSPHERE

D9-1 Introduction

The purpose of this analysis is for the assessment of potential human exposure to waste emissions in the atmosphere, and a comparison of that potential exposure to acceptable regulatory levels. 20 NMAC 4.1, Subpart V, §264.601 requires such an assessment for disposal of hazardous waste in a miscellaneous unit.

This assessment applies only to potential air emissions from waste containers during normal operations and the closure time period of the Waste Isolation Pilot Plan (WIPP) facility. In response to a request from the NMED, a calculation of releases during an offnormal event is also included. After final facility closure of the repository, no credible pathway will exist for air emissions. Once sealed, the waste is confined by engineered and natural barriers, which prevent the release of waste constituents in the atmosphere. In this assessment, only gaseous emissions will be considered as a source, because any particulate matter will be contained in the waste containers or panel closures and no liquid waste will be accepted for disposal. Of the gaseous constituents, the assessment is limited to volatile organic compounds (VOC), which comprise approximately 99 percent of the risk.

This appendix provides calculation details and summaries of risk assessments and worker exposures for the operational phase of the WIPP facility. The analyses included here are the

- risk to a hypothetical member of the public at the boundary of the site
- risk to potential members of the public within the boundary of the site
- assessments of worker exposure on the surface within the site
- assessments of worker exposure in the underground portion of the facility

The exhaust shaft concentration of VOCs, which are used in the exposure and risk assessments included in this appendix, are given in Section D9-2. The exposure scenarios are described in Section D9-3. The air dispersion modeling factors for the assessments are given in Section D9-4. Section D9-5 details the calculations for each risk and worker exposure assessment, and Section D9-6 summarizes the assessment results.

D9-2 Exhaust Shaft Concentrations of VOCs

During waste disposal at the WIPP facility, closure systems will be used to isolate waste in a filled panel and to eliminate ventilation through these filled panels. Similarly, as individual rooms within a panel are filled, ventilation barriers will be placed on the filled rooms to prevent the flow of ventilation air through these filled rooms and to isolate the rooms. Exhaust shaft concentrations of VOCs will thus vary with the number of filled, closed panels, the number of filled rooms with ventilation barriers within an open panel, and the number of drums in an open room.

D9-2.1 Exhaust Shaft Concentrations of VOCs from a Closed Panel

Exhaust shaft concentrations of VOCs from a single closed panel are calculated as follows:

$$SCPE = \frac{X \times GR \times HS \times \left(\frac{1\ mole\ fraction}{1\times10^6\ ppmv}\right) \times MW \times (1 \times 10^6\ \mu g/g) \times P_c}{V \times 0.0283\ m^3/ft^3 \times (525{,}600\ min/year)} \quad \text{(D9-1)}$$

where,

$SCPE$	=	exhaust shaft concentration of the VOC from a single closed panel, $\mu g/m^3$
X	=	number of drums in a closed panel, 81,000 drums/panel
GR	=	effective gas generation rate, 0.5 moles/drum/year
HS	=	weighted average headspace concentration of the VOC, ppmv
MW	=	molecular weight of the VOC, g/mole
P_c	=	number of closed panel equivalents, 1 panel
V	=	mine ventilation exhaust rate, 425,000 ft^3/min

Weighted average headspace concentrations are based on sampling and analysis of wastes from the Idaho National Engineering Laboratory (INEL) and the Rocky Flats Environmental Technology Site (RFETS). The weighted average headspace concentrations are derived in Appendix D13.

During the placement of waste at WIPP, closure systems will be used to isolate wastes in a full panel and to eliminate ventilation through these filled panels. Assuming a continuous fresh air flow across the filters, VOCs will diffuse from the drums at a rate that is dependent on the concentration gradient across the filters and the diffusion properties of the VOCs, as described in Appendix D12. After a panel is filled and the ventilation barrier is installed, which is the first step in the closure process, fresh air will no longer flow across the waste drums, and VOC concentrations in the dead air space above the filter will begin to buildup and approach the concentrations in the drum headspace. Therefore, the maximum concentration of VOCs that would be present in the panel atmosphere would be equivalent to the average drum headspace concentration. For the risk assessments, it is conservatively assumed that the average drum headspace concentrations serve as a constant source of VOCs.

The ventilation barrier design includes the use of low-permeability materials that restrict the diffusion of VOCs from the panel; therefore, gas pressurization is assumed to be the only process that would cause VOCs to migrate beyond a panel with a ventilation barrier installed (Appendix I1). Pressurization within a panel will be caused by gas generation and volume reduction due to creep closure of the repository. The panel closure systems will be designed to withstand some pressure buildup; however, for this evaluation, the leakage rate from the panel closure system is conservatively assumed to be equivalent to the effective gas generation rate.

Appendix D11 includes information on gas generation by WIPP waste. Of the gas-generating mechanisms described in Appendix D11, microbial degradation will contribute the most to the generation rate during the time periods of interest. The best estimate for gas generation from microbial degradation under humid conditions is 0.1 moles of gas per drum per year (see Appendix D11 and D16-5). The recommendation in D16-5 is for a rate of 0.02 moles/kg/year. This results in 0.2 moles/drum/year, based on 10kg of cellulosics per drum. However, the memo in D11 states that mocrobial degradation only occurs half of the time. This time results in a 0.1 mole/drum/year rate. For the period of time in this analysis, there is not expected to be enough brine flow into panels to create an inundated environment, which would be necessary to produce these and higher gas generation rates. This analysis conservatively assumes that a humid condition will exist to produce gas at a rate of 0.1 moles per drum per year.

Although Appendix D11 states that the maximum expected value for any one drum of waste is 0.4 moles per drum per year, the lowest expected value for any one drum is 0 moles per drum per year. A discussion of the relationship between gas generation, brine inflow, and creep closure can be found in Section I-1e(4). In reality, under the conditions that will initially exist in a closed panel, the predominant degradation mechanisms may consume gas at a rate faster than it is produced. This outcome is a function of the availability of nutrients to sustain microbial activities. Indications of gas consumption activities are in Francis and Gillow (1994), where they reported 200-day experiments (see Appendix D11).

The average creep closure rate, as discussed in Appendix I1, will result in a reduction of the panel void volume of 812 m^3 per year for each panel. Converting this volumetric reduction rate to a molar (gas) displacement rate, using the Ideal Gas Law:

$$GDR = \frac{812\ m^3}{panel/year} \times \frac{P}{RT} \qquad \text{(D9-2)}$$

Since one full panel contains 81,000 drums of waste, this rate expressed on a drum basis is:

$$GDR = \frac{812\ m^3}{panel/year} \times \frac{1\ atm}{\left(\frac{0.082\ L \bullet atm}{mole \bullet K}\right) \times (298K)} \times \left(\frac{1\times10^3\ L}{m^3}\right) \times (panel/81{,}000 drum)$$

$$GDR = 0.4\ mole/drum/year$$

$$GDR = (4.74\ x\ 10^3\ mole/panel/year) \times (panel/81{,}000 drum)$$

An effective gas generation rate (gas generation rate plus gas displacement rate) can be calculated as follows:

$$GR = GGR + GDR \qquad \text{(D9-3)}$$

where,

GR	=	effective gas generation rate, mole/drum/year
GGR	=	gas generation rate due to microbial degradation in a humid environment, 0.1 mole/drum/year
GDR	=	gas displacement rate due to salt creep (creep closure), 0.4 mole/drum/year

$$GR = (0.1\ mole/drum/year) + (0.4\ mole/drum/year)$$

$$GR = 0.5\ mole/drum/year$$

D9-2.2 Exhaust Shaft Concentrations of VOCs from an Open Panel without Ventilation Barriers

Exhaust shaft concentrations of VOCs from an open panel without ventilation barriers on the filled rooms are calculated using the equation

$$SOPE = \frac{X \times ADE_{VOC} \times MW \times (1 \times 10^6\ \mu g/g) \times P_o}{V \times 0.0283\ m^3/ft^3 \times \left(\frac{1}{60\ s/min}\right)} \qquad \text{(D9-4)}$$

where,

$SOPE$	=	exhaust shaft concentration of the VOC from a full open panel without ventilation barriers on the filled rooms, $\mu g/m^3$
X	=	number of drums in a full panel, 81,000 drums/panel
ADE_{VOC}	=	the average drum VOC emission rate, mole/s/drum
MW	=	molecular weight of the VOC, g/mole
P_o	=	number of open panel equivalents, 1 panel
V	=	mine ventilation exhaust rate, 425,000 ft^3/min

The average drum emission rate for each VOC is calculated from the diffusion rate using the following equation:

$$ADE_{VOC} = D_{VOC} \times MF_{VOC} \times 31{,}536{,}000\ s/year \qquad \text{(D9-5)}$$

where,

ADE_{VOC} = average drum VOC emission rate, mole/drum/year
D_{VOC} = the VOC diffusion characteristic through a model NFT-013 carbon composite filter, mole/s/mole fraction/drum
MF_{VOC} = mole fraction of the VOC, mole/mole

The mole fraction of each VOC is calculated from its weighted average headspace concentration by:

$$MF_{VOC} = (HS_{VOC}) \times (10^{-6}\ mole\ fraction/ppmv) \qquad \text{(D9-6)}$$

where,

MF_{VOC} = mole fraction of the VOC, mole/mole
HS_{VOC} = average headspace concentration for VOC, ppmv.

For filter-specific diffusion characteristics, the ratio of VOC-to-H_2 diffusivities in air are calculated as follows:

$$\frac{D_{VOC\text{ - }air}}{D_{H_2\text{ - }air}} = \left(\frac{P_{c,VOC}}{P_{c,H_2}}\right)^{1/3} \times \left(\frac{T_{c,VOC}}{T_{c,H_2}}\right)^{-1/2} \times \left[\frac{\left(\frac{1}{MW_{air}} + \frac{1}{MW_{VOC}}\right)}{\left(\frac{1}{MW_{air}} + \frac{1}{MW_{H_2}}\right)}\right]^{1/2} \qquad \text{(D9-7)}$$

where,

$D_{VOC\text{-}air}$ = diffusivity of the VOC in air, mole/s/mole fraction/drum
$D_{H2\text{-}air}$ = diffusivity of hydrogen in air, mole/s/mole fraction/drum
$P_{c,\,VOC}$ = critical pressure of the VOC, atm
$P_{c,H2}$ = critical pressure of hydrogen, 12.8 atm
$T_{c,VOC}$ = critical temperature of the VOC, K
$T_{c,air}$ = critical temperature of hydrogen, 33.2K
MW_{VOC} = molecular weight of the VOC, g/mole
MW_{H2} = molecular weight of hydrogen, 2.016 g/mole
MW_{air} = molecular weight of air, 28.946 g/mole

The filter-specific VOC diffusion characteristics from the ratio of VOC-to-H_2 diffusivities in air are calculated using the following equation:

$$D_{VOC} = \left(\frac{D_{VOC\text{ - }air}}{D_{H_2\text{- }air}} \right) \times D_{H_2} \qquad \text{(D9-8)}$$

where,

D_{VOC} = the VOC diffusion characteristic through a model NFT-013 carbon composite filter, mole/s/mole fraction/drum

D_{H2} = the diffusion characteristic for hydrogen through a model NFT-013 carbon composite filter, 1.17E-5 mole/s/mole fraction/drum.

VOC-specific properties for calculating diffusion rates, the SOPE, and the SCPE are given in Table D9-1.

VOCs considered in all calculations are indicator VOCs selected using the screening technique in EPA (1989, p 5-23). These indicator VOCs represent approximately 99 percent of the risk due to air emissions. This screening methodology is described in detail in Appendix D13.

TABLE D9-1

PROPERTIES USED IN CALCULATING DIFFUSION RATES AND EMISSION CONCENTRATIONS

Constituent	*Pc* Critical Pressure (atm)	*Tc* Critical Temperature (K)	*MW* Molecular Weight (g/mole)	*Dvoc* Diffusivity (mole/s/mole fraction/ drum)	*HS* Weighted Average Concentration (ppmv)
Carbon Tetrachloride	45	556.4	153.84	1.21E-06	375.5
Chlorobenzene	44.6	632.4	112.56	1.16E-06	12.5
Chloroform	54	536.4	119.39	1.34E-06	25.3
1,1-Dichloroethylene	51.3	495	96.95	1.40E-06	11.5
1,2-Dichloroethane	53	561.6	98.97	1.32E-06	9.1
Methylene Chloride	60	510	84.94	1.47E-06	368.5
1,1,2,2-Tetrachloroethane	57.6	644.5	167.86	1.21E-06	9.4
Toluene	40.6	591.7	92.13	1.19E-06	19.4
1,1,1-Trichloroethane	42.4	545	133.42	1.21E-06	317.1

ppmv = parts per million by volume

D9-2.3 Public Exposure Concentrations of VOCs

As the waste disposal operations proceed, an increasing number of drums are emplaced in the open panel contributing to the exhaust shaft concentration. In addition, an increasing number of closed panels contribute to the exhaust shaft concentration over time.

The exhaust shaft concentrations for 9 closed and one open panel are conservative for any exposure prior to filling the last panel. From the full open panel, maximum VOC emissions will depend on the presence of ventilation barriers outside the filled rooms. Two levels of conservatism are possible: (1) assuming that rooms in the full panel do not have ventilation barriers installed and VOC emissions are from all drums (i.e., 81,000) in the panel and (2) assuming that the filled rooms within the open panel have ventilation barriers installed and only the drums (i.e., 11,571) in the last room are freely contributing to VOC emissions. The average exhaust shaft VOC concentration over the operational period of the facility will be lower than the maximum for 9 closed panels and 1 full open panel.

The maximum exhaust shaft concentrations of VOCs from 9 closed panels and one open panel without ventilation barriers outside the filled rooms is calculated as EC_{max} using the equation

$$EC_{max} = \left(P_c \times SCPE \right) + \left(P_o \times SOPE \right) \qquad \text{(D9-9)}$$

where,

EC_{max} = exhaust shaft concentration of the VOC from 9 closed panels and 1 full open panel without ventilation barriers outside the filled rooms, $\mu g/m^3$

P_c = number of closed panel equivalents, 9 panels

P_o = number of open panel equivalents, 1 panel

D9-2.4 Surface Worker Exposure Concentration

The maximum exposure concentration for the worker on the surface of the facility is based on emissions from 9 closed and 1 full open panel with ventilation barriers on 6 of the seven rooms. The surface worker exposure concentration is calculated from the exhaust shaft concentration multiplied by the ADF. The exhaust shaft concentration is calculated:

$$ECS_{MAX} = \frac{(AOPE_{VOC}) + (P_C \times R_C \times ACRE) \times MW \times 1 \times 10^6 \ \mu g/g}{Q \times 0.0283 \ m^3/f^3 \times 525{,}600 \ min/yr} \qquad \text{(D9-11)}$$

where,

ECS_{MAX} = exhaust shaft concentration of the VOC from 9 closed panels and 1 full open panel with ventilation barriers, $\mu g/m^3$

$AOPE_{VOC}$ = average open panel VOC emission rate, mole/panel/year

P_c = number of closed panel equivalents, 9 panels
R_c = number of closed rooms in the open panel, 7 rooms/panel
$ACRE_{VOC}$ = average closed room VOC emission rate, mole/room/year
MW = molecular weight of the VOC, g/mole
Q = ventilation rate through the mine, 425,000 ft^3 /minute

The average open panel yearly emission rate (AOPE) for each VOC is based on the number of full rooms, the number of drums in the open room, and the emission rates from each type of room. AOPE for 1 open and 6 closed rooms is calculated as:

$$AOPE_{VOC} = (R_o \times AORE_{VOC}) + (R_c \times ACRE_{VOC}) \qquad \text{(D9-12)}$$

where,

$AOPE_{VOC}$ = average open panel VOC emission rate, mole/panel/year
$AORE_{VOC}$ = average open room VOC emission rate, mole/room/year
$ACRE_{VOC}$ = average closed room VOC emission rate, mole/room/year
R_o = number of open rooms in the open panel, 1 room/panel
R_c = number of closed rooms in the open panel, 6 room/panel

The open room emission rate (AORE) is dependent on the number of drums that have been emplaced in the room and the diffusion of VOCs across the drum vent filters. Assuming a continuous fresh air flow across the filters, VOCs will diffuse from the drums at a rate that is dependent on the concentration gradient across the filters and the diffusion properties of the VOCs, as described in Appendix D12. The AORE is calculated using the equation

$$AORE_{VOC} = ADE_{VOC} \times D \qquad \text{(D9-13)}$$

where,

$AORE_{VOC}$ = average open room VOC emission rate, mole/room/year
ADE_{VOC} = average drum VOC emission rate, mole/drum/year
D = number of drums in the room, drum/room.

The average yearly closed room emission rate (ACRE) for each VOC is calculated as:

$$ACRE_{VOC} = (GR) \times (11{,}571\ drum/room) \times MF_{VOC} \qquad \text{(D9-14)}$$

where,

$ACRE_{VOC}$ = average yearly closed room VOC emission rate, mole/room/year
GR = effective gas generation rate, mole/drum/year
MF_{VOC} = VOC mole fraction, mole/mole

GR is defined as above for gas generation through closed panels. Similar to panel closures, ventilation barriers will be used to isolate wastes in a full room and to eliminate ventilation through these filled rooms. As for panels (Section D9-2.1), gas pressurization is assumed to be the only process that would cause VOCs to migrate beyond a closed room. The effective gas generation rate used for calculating ACRE, then, is 0.5 moles/drum/year.

D9-2.5 Underground Worker Exposure Concentration

The maximum exposure concentrations of VOCs to workers is the hazardous waste worker who is emplacing waste at the beginning of the next open room, which will place the worker downstream in the ventilation air of previously filled rooms with ventilation barriers, but always upstream of the open room waste. This concentration is calculated as folows:

$$ECU_{max} = \frac{(R_C \times ACRE_{VOC}) \times MW \times 10^6\ \mu g/g \times P_o}{Q \times 0.0283\ m^3/ft^3 \times 525{,}600\ \text{min}/year} \qquad \text{(D9-10)}$$

where,

ECU_{max}	=	exposure concentration of the VOC from 1 full open panel with ventilation barriers on the filled rooms, $\mu g/m^3$
R_c	=	number of closed rooms in the open panel, 6 room/panel
$ACRE_{VOC}$	=	average closed room VOC emission rate, mole/room/year
MW	=	molecular weight of the VOC, g/mole
P_o	=	number of open panel equivalents, 1 panel
Q	=	ventilation rate through the open room, 35,000 ft^3 /minute

D9-3 Exposure Assessment

In order to assess the potential public exposure to hazardous constituents in the air, first the probable public activities both outside and inside the WIPP site boundary during the 35-year operational/closure time frame are evaluated. Exposure scenarios for potential receptors both outside and inside the WIPP site boundary are then described.

D9-3.1 Public Activity Outside the WIPP Site Boundary

The most prevalent public activity currently outside the WIPP site boundary is oil and gas production. Several wells are located along the boundary, and drilling activities may require oil workers to be present continuously, but not for several years at a time. Oil activities could be ongoing 24 hours-a-day, 7 days-a-week, up to six months at a time, but the same oil workers are not likely to be present for several years.

Since the land immediately adjacent to the WIPP site boundary is federal or state land, a family could not theoretically build a house or dwelling at the boundary; however, one could

potentially occupy that space for long periods of time. Currently, there are only 27 residents within a 10-mile radius of the WIPP facility, and the closest dwelling is the Mills ranch house approximately 3/4 miles south of the southwest corner of the WIPP site boundary (Figure D9-1).

D9-3.2 Public Activity Inside the WIPP Site Boundary

As shown in Figure D9-1, the area of land that lies within the WIPP site boundary contains approximately 10,240 acres including Sections 15-22 and 27-34 in Township 22 South and Range 31 East. This area contains three other distinct boundaries that limit public access. The innermost boundary, which contains most of the WIPP facility structures, is surrounded by a chain link fence and covers approximately 35 acres in Sections 20 and 21. This fenced area is known as the Property Protection Area. Only persons on official business are allowed within this area. Access is controlled by a 24-hour per day security force. The next area is surrounded by a barbed-wire fence, covers approximately 424 acres, and is posted "No Trespassing." This area is known as the Exclusive Use Area. The public may access this area for short periods of time for limited purposes. This area is patrolled frequently by the security force. The third area covers approximately 1,450 acres, is posted "No Trespassing," and is known as the Off Limits Area. Within this area, certain activities, such as hunting, are prohibited. Other forms of public access are allowed with permission of the DOE. The fourth area covers approximately 10,240 acres and is leased for cattle grazing.

Public access is allowed inside the WIPP site boundary for various activities and for various periods of time. Activities that take place inside the WIPP site boundary are described in detail in DOE (1993).

D9-3.2.1 Agricultural Uses

All the land within the WIPP site boundary outside the Exclusive Use Area has been leased for grazing, which is the only significant agricultural activity in the vicinity. There are two leaseholders as shown in Figure D9-1. The Livingston Ridge Allotment, currently leased by Kenneth Smith, Inc., of Carlsbad, New Mexico, includes 2,880 acres within the northern portion of the WIPP Site. J.C. Mills of Abernathy, Texas, current lessee of the Antelope Ridge Allotment, has lease rights to 7,360 acres within the southern portion of the WIPP Site.

D9-3.2.3 Recreational Activities

Hunting, camping, horseback riding, hiking, wildlife watching, and sightseeing are all activities that may be permitted inside the WIPP site boundary up to the boundaries marked "No Trespassing". Campers are required to check in with WIPP Security personnel before establishing camp. Although all of these activities are allowed and managed (DOE 1993), no member of the public is expected to perform any of these activities on WIPP property for long periods of time. Hunting durations are short and are established and enforced by the State of New Mexico. The other activities mentioned above are not likely to occur, because the WIPP facility is in a hot, arid environment, and much more scenic areas are in the vicinity for these activities (e.g., Guadalupe Mountains).

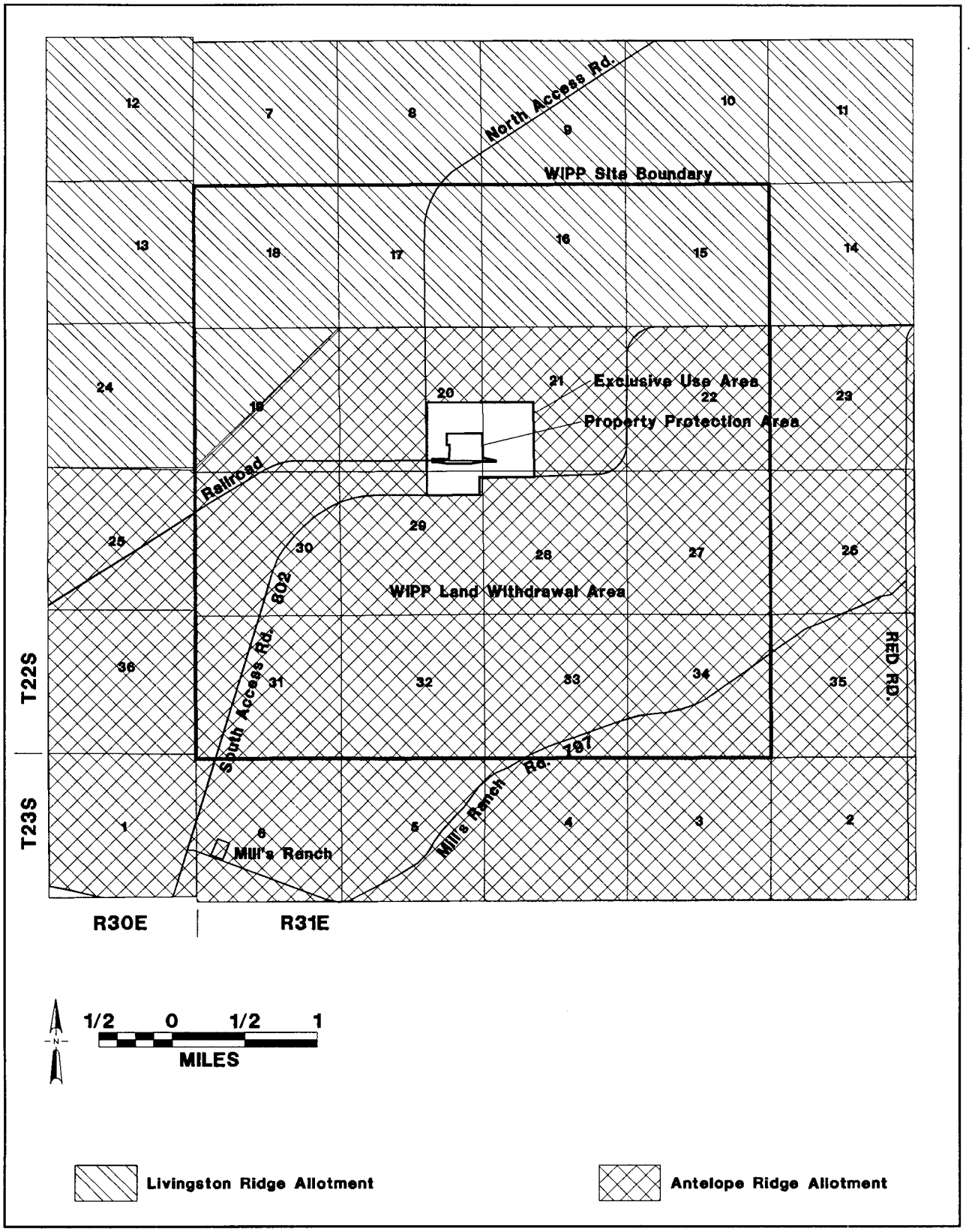

Figure D9-1
Grazing Allotments in the Vicinity of the WIPP Land Withdrawal Area

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D9-3.2.4 Scientific Research

Some scientific research is conduced for WIPP-related activities (i.e., archaeological and geological studies), but public research inside the WIPP site boundary does not typically occur. If such studies were to occur in the future, the time frame for such studies would be short-term (hours, days, or weeks at most) and would not pose significant exposure concerns for the public.

D9-3.3 Public Exposure Outside the WIPP Site Boundary

The worst-case exposure just outside the WIPP site boundary is conservatively assumed to occur to the hypothetical member of the public who could occupy space on the boundary up to 24 hours-a-day, 365 days-a-year, for 35 years (EF = 8760 hours/year, ED = 35 years, AT = 613,200 hours). This exposure scenario is referred to in following sections as the ***Boundary Public Receptor***. The Boundary Public Receptor exposure scenario is not considered a realistic scenario because residents around the facility live some distance away from the site boundary. More realistic exposure scenarios are those relating to ranching activities within the site boundary as discussed below.

D9-3.4 Public Exposure Inside the WIPP Site Boundary

The worst-case exposure of a member of the public to hazardous constituents released into the air around the WIPP facility is assumed to occur to the rancher who may be on land leased for cattle grazing. The exposure is assumed to be equally likely for any point within the area. The assumption is conservative, because the ranch hand is typically inspecting fences and watering facilities, which takes him to isolated locations either on the periphery of the grazing area or to locations which are not principle downwind locations. DOE is responsible for inspecting the fence on the boundary of the grazing allotment adjacent to WIPP. Because no actual statistics exist regarding the amount of time a ranch hand may spend at any field location on a ranch, the DOE had to make several assumptions in order to prepare the exposure analysis. The exposure time assumptions have been made in a manner that tends to overestimate exposures. First, it is assumed that a ranch hand spends 8 hours per day, 5 days per week (EF = 2080 hours/year) for 35 years (ED = 35 years, AT = 613,200 hours)working the ranch. This is conservative, because ranchers rotate pastures to protect them from overgrazing. As a result, there will be extended periods of time when there will be no activity in the grazing areas within the WIPP site boundary. Second, it is assumed that a single ranch hand from each ranch works only on the portions of the leases within the WIPP site boundary. This is conservative, because the lease covers a much larger area than what lies within the WIPP site boundary. Third, the exposure assessment is based on the average ground-level, rather than inhalation level, concentrations of hazardous constituents for each area of grazing-leased land between the WIPP site boundary and the Exclusive Use Area.

For the exposure assessment, two hypothetical receptors are evaluated, corresponding to ranchers working on each of the two grazing allotments within the WIPP site boundary. The exposure scenarios are referred to in following sections as ***Livingston Ridge Rancher*** and ***Antelope Ridge Rancher***.

D9-3.5 Occupational Exposure Inside the WIPP Site Boundary

Two additional exposure scenarios that hypothetically occur within the WIPP site boundary are also evaluated in this appendix. One additional scenario is that of a worker who works on site 1,920 hours/year (EF = 1,920 hours/year), for 10 years (ED = 10 years, AT = 613,200 hours) on the surface near the exhaust shaft. The 1920 hours are the hours for an employee after removing vacations and holidays. This is conservative since workers spend approximately ten percent of their time off site at training, travel, and meetings. The ten year exposure duration represents normal turnover in employees. Turnover, in this case includes new employment, new positions and new locations at the facility. The exposure location chosen corresponds to the maximum VOC exposure at the surface within the site boundary and is located in the property protection area. The scenario is referred to in following sections as ***Surface Worker***.

The second scenario is that of an underground worker who works "downwind" of a full, but closed room. This worker performs hazardous waste duties and is estimated to be working downstream of a closed room while beginning to fill each subsequent room 33 hours/year for 10 years. The underground worker exposure scenario is a worst-case exposure scenario, and is referred to in the following sections as ***Underground Worker***. The exposure frequency was developed based on the expected operational throughput times in Figure D-36 and the number of waste locations in the area of a room (130) that is downwind from a room exhaust. The 130 positions represents stacks that are 3 high, so 390 waste units (7-pack, SWB, 4-pack, or TDOP) are involved. These configurations represent approximately 100 pallets of waste, which take 30 minutes per pallet to emplace or 50 hours per room. Backfill requires 30 minutes every time a row of 5 stacks is complete. Since there are 26 rows in this area (130 ÷ 5), 13 hours for emplacing backfill is needed. This results in a total of 63 hours per room that are spent downwind from full rooms. Finally, a waste worker will be downwind for Rooms 6 through 1; however, the amount of waste in the Room 1 entry is 32 positions (1/4 of Rooms 2-6) so that the total exposure time in a panel is 63 × 5.25 = 330 hours. This exposure occurs over the 2.5 years required to fill the panel and is shared equally by four waste workers resulting in an annual exposure of 330 ÷ 2.5 ÷ 4 = 33 hours/year.

D9-4 Air Dispersion Modeling

This section presents the results of specific air dispersion modeling performed inside and outside the WIPP site boundary that are used in assessing the scenarios described in Section D9-3 for exposures at the surface, that is, for the Boundary Public, Livingston Ridge Rancher, Antelope Ridge Rancher, and Surface Worker. The Long-Term Version of the Industrial Source Complex (ISCLT3) model, EPA (1995), was used for the air dispersion modeling. Concentrations were modeled in accordance with EPA (1992). Details of the modeling is described in Appendix D10.

To determine areas where the maximum concentrations may occur, the air dispersion model was run with a coarse receptor grid of 400 meters (see Figure D9-2). To model the boundary public exposures, the air dispersion model was run with a fine receptor grid of 10 meters around the point of highest concentration predicted on the boundary during the coarse grid

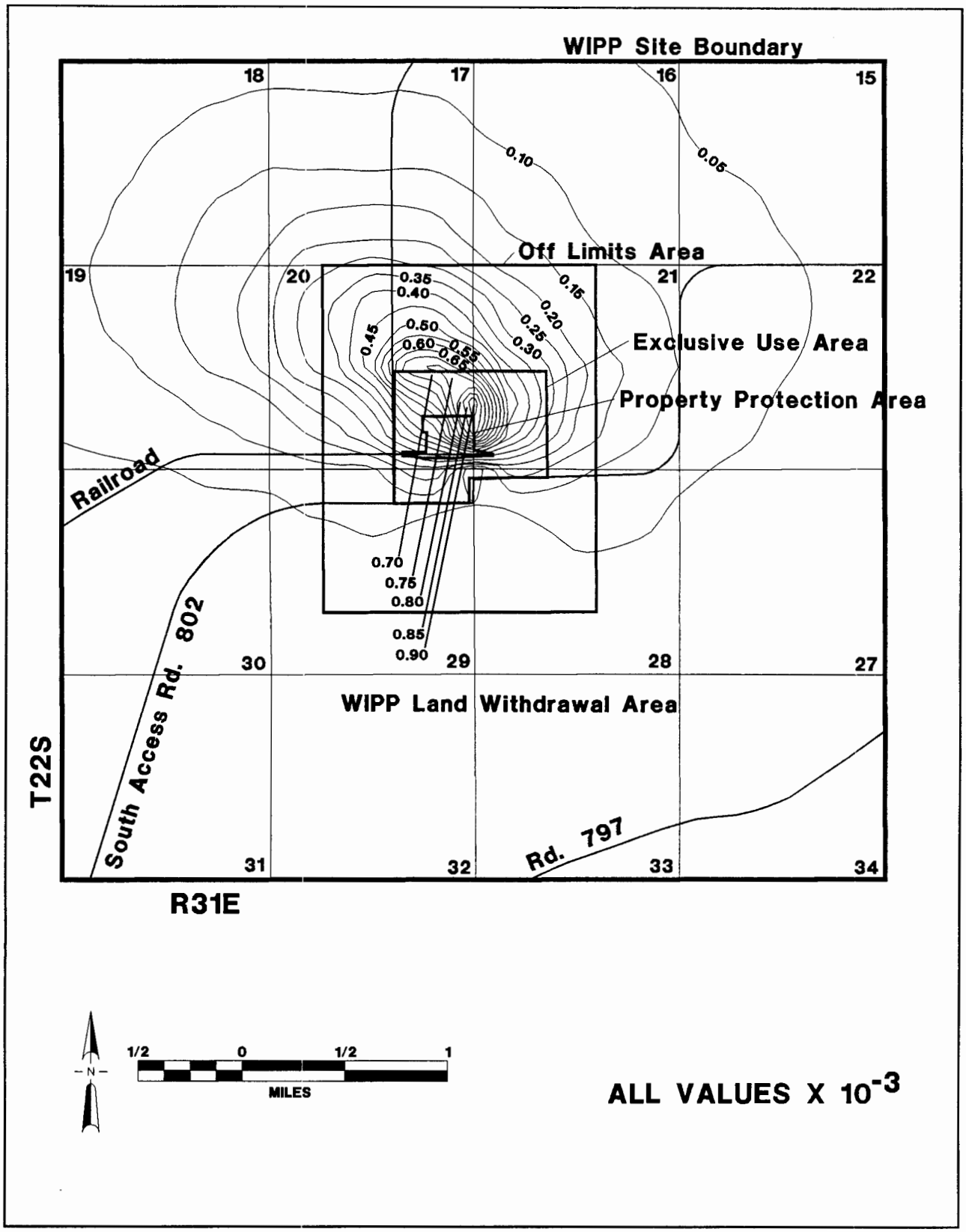

Figure D9-2
Air Dispersion Factors at WIPP

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run. To determine the exposure concentrations at the WIPP site boundary, the annual average concentration anywhere on the boundary is used to determine the ADF for the boundary public receptor. That average concentration, which was modeled from an arbitrary 1,000 $\mu g/m^3$ source, is divided by 1,000 $\mu g/m^3$ to arrive at the air dispersion factor (ADF) used in the risk calculations presented in Section D9-5. The ADF for the boundary public receptor is 1.2×10^{-4} (Table D9-2).

For the rancher exposure assessments, the coarse grid run mentioned above was used. This grid covers all of the leased land within the WIPP site boundary as shown in Figure D9-1. All concentrations derived in the model run were then averaged for each lease, representing an average exposure concentration throughout the leased land inside the boundary. The resulting ADF for the Livingston Ridge Allotment is 9.8×10^{-5} and the ADF for the Antelope Ridge Allotment is 6.7×10^{-5}.

For determining the exposure concentrations to the surface worker, the model was run with a fine receptor grid of 10 meters around the area with the highest concentration inside the WIPP site boundary predicted during the coarse grid run (see Figure D9-3). This area was near the exhaust fans. The ADF for the surface worker is 1.23×10^{-2}.

TABLE D9-2
AIR DISPERSION FACTORS FOR WIPP SITE AREAS

Area	Averaged/Modeled Concentration ($\mu g/m^3$)	Air Dispersion Factor (ADF)
WIPP Site Boundary	1.2E-01	1.2E-04
Livingston Ridge Allotment	9.8E-02	9.8E-05
Antelope Ridge Allotment	6.7E-02	6.7E-05
WIPP Property Protection Area	1.23E+01	1.23E-02

D9-5 Receptor Concentrations and Risk Calculations

Risks and hazards for the public exposure scenarios described in Section D9-3 are described in this section. Also presented are evaluations of VOC concentration levels to worker receptors. The equations used in assessing excess risk from carcinogens and hazard from noncarcinogens are derived and given. The calculations use exposure factors as appropriate for the exposure scenarios. ADFs are used for the Boundary Public, Livingston Ridge Rancher, Antelope Ridge Rancher, and Surface Worker scenarios. The calculations assume the receptors are subjected to concentrations based on maximum exhaust shaft VOC concentrations, which are those concentrations that result from emissions from 9 closed and

1 full open panels. The full open panel is conservatively assumed to contain no room closures for assessing impacts to the public at the surface, that is, the Boundary Public, Livingston Ridge Rancher, Antelope Ridge Rancher, and Surface Worker scenarios. These scenarios also include model estimates of concentrations from air dispersion. For assessing impact to an underground worker, only one full open panel is used and is assumed to contain room closures. Since this worker is exposed to underground concentrations, no air dispersion takes place before exposure.

D9-5.1 Public Risk Outside the WIPP Site Boundary

The Boundary Public exposure scenario is evaluated in this section. An ADF of 1.2×10^{-4} is used in assessing risk from emissions from 9 closed and 1 open panel equivalents, with no credit taken for room closures within the open panel.

D9-5.1.1 Carcinogens

For carcinogens, risk is calculated as follows:

$$Risk = \frac{EC \times ADF \times URF \times EF \times ED}{AT} \qquad \text{(D9-15)}$$

where,

- $Risk$ = a unitless probability (e.g., 2×10^{-5}) of an individual developing cancer
- EC = maximum exhaust shaft concentration for the VOC, $\mu g/m^3$, EC_{max}
- ADF = air dispersion factor, unitless, 1.2×10^{-4}
- URF = unit risk factor for VOC, $(\mu g/m^3)^{-1}$
- EF = exposure frequency, 8,760 hours/year (24 hours/day × 365 days/year)
- ED = exposure duration, 35 years
- AT = averaging time, 613,200 hours (24 hours/day × 365 days/year × 70 years)

Equation D9-15 was derived from equations in EPA (1989); the derivation is shown below.

EPA (1989), page 6-44, provides the calculation of residential exposure from inhalation of airborne (vapor phase) chemicals as:

$$Intake = \frac{CA \times IR \times EF \times ED}{BW \times AT} \times \left(\frac{mg}{1 \times 10^3\ \mu g} \right) \qquad \text{(D9-16)}$$

where,

- $Intake$ = receptor intake, mg/kg-day
- CA = contaminant concentration in air, $\mu g/m^3$
- IR = inhalation rate, 20 m^3/day

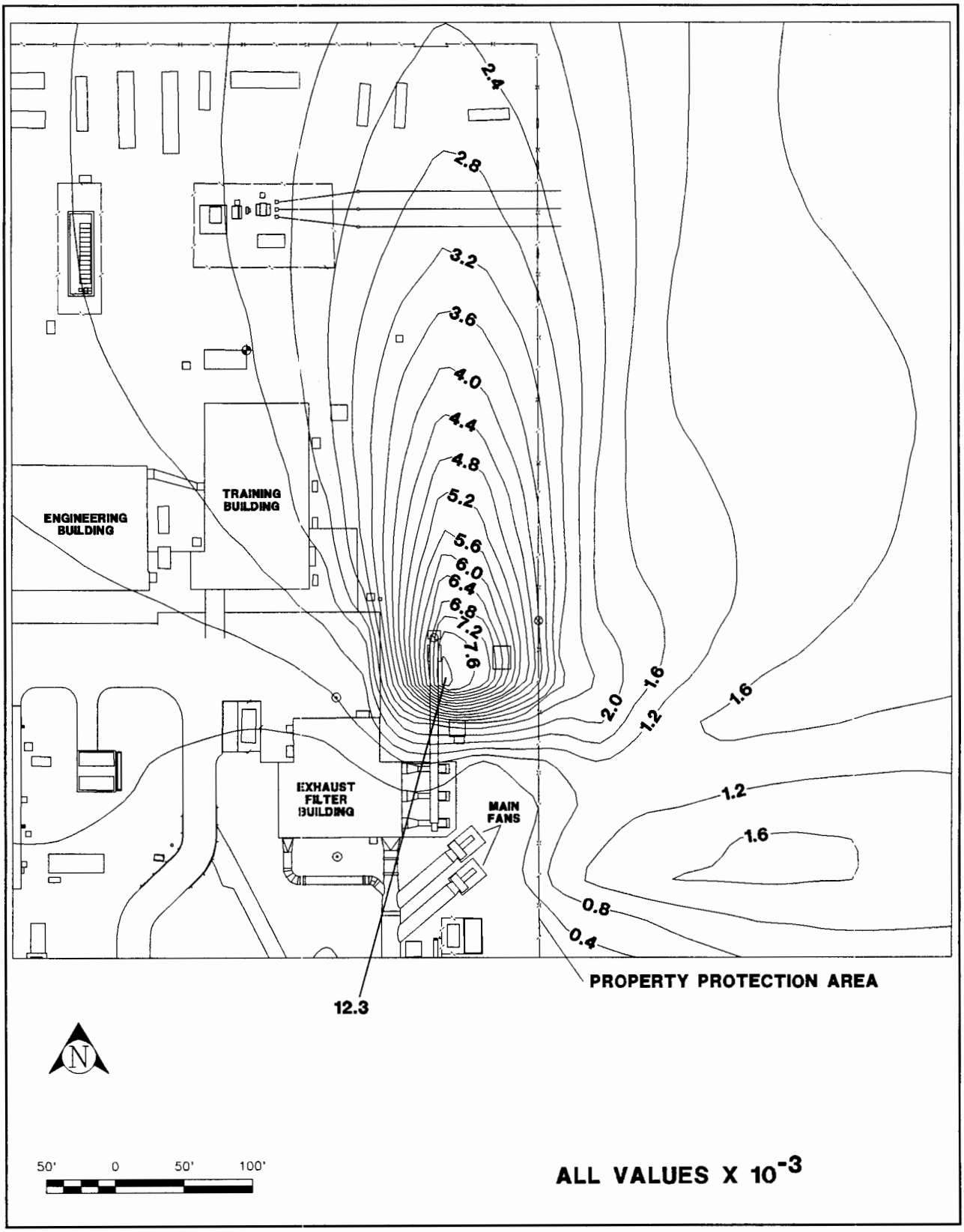

Figure D9-3
Air Dispersion Factors Inside the Property Protection Area

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EF = exposure frequency, hours/year
ED = exposure duration, years
BW = body weight, 70 kg
AT = averaging time, days

EPA (1989), page 8-6, also describes chronic intake as:

$$Intake = \frac{Risk}{SF} \qquad \text{(D9-17)}$$

where,
Intake = receptor intake, mg/kg-day
Risk = a unitless probability (e.g., 2×10^{-5}) of an individual developing cancer
SF = cancer slope factor, $(mg/kg\text{-}day)^{-1}$

To express the carcinogenic effect in terms of unit risk factor, as provided in EPA (1989), page 7-13, the following equation is used:

$$URF = \frac{SF \times IR}{BW} \times \left(\frac{mg}{1 \times 10^3\ \mu g} \right) \qquad \text{(D9-18)}$$

where,
URF = unit risk factor, unitless
IR = inhalation rate, 20 m^3/day
BW = body weight, 70 kg
SF = cancer slope factor, $(mg/kg\text{-}day)^{-1}$

Solving for slope factor in equation D9-18:

$$SF = \frac{URF \times BW}{IR} \times \left(\frac{1 \times 10^3\ \mu g}{mg} \right) \qquad \text{(D9-19)}$$

where,
SF = cancer slope factor, $(mg/kg\text{-}day)^{-1}$
URF = unit risk factor, unitless
BW = body weight, 70 kg
IR = inhalation rate, 20 m^3/day

Combining equation D9-17 and D9-19:

$$Intake = \frac{Risk \times IR}{URF \times BW} \times \left(\frac{mg}{1 \times 10^3\ \mu g}\right) \qquad \text{(D9-20)}$$

where,

Intake	=	receptor intake, mg/kg-day
Risk	=	a unitless probability (e.g., 2×10^{-5}) of an individual developing cancer
IR	=	inhalation rate, 20 m^3/day
URF	=	unit risk factor, unitless
BW	=	body weight, 70 kg

Setting equations D9-16 and D9-20 equal to each other:

$$\frac{Risk \times IR}{URF \times BW} \times \left(\frac{mg}{1 \times 10^3\ \mu g}\right) = \frac{CA \times IR \times EF \times ED}{BW \times AT} \times \left(\frac{mg}{1 \times 10^3\ \mu g}\right)$$

and solving for risk yields equation D9-21:

$$Risk = \frac{CA \times URF \times EF \times ED}{AT} \qquad \text{(D9-21)}$$

where,

Risk	=	a unitless probability (e.g., 2×10^{-5}) of an individual developing cancer
CA	=	contaminant concentration in air, $\mu g/m^3$
URF	=	unit risk factor, unitless
EF	=	exposure frequency, hours/year
ED	=	exposure duration, years
AT	=	averaging time, days

For this assessment, the contaminant concentration in air is the exhaust shaft concentration in air (EC) multiplied by the ADF as follows:

$$CA = EC \times ADF \qquad \text{(D9-22)}$$

where,

CA	=	contaminant concentration in air, $\mu g/m^3$
EC	=	exhaust shaft concentration for the VOC, $\mu g/m^3$
ADF	=	air dispersion factor, unitless

Combining equations D9-21 and D9-22 yields equation D9-15:

$$Risk = \frac{EC \times ADF \times URF \times EF \times ED}{AT}$$

Excess cancer risks to the Boundary Public Receptor are calculated using Equation D9-15 with an ADF of 1.2×10^{-4} and are presented in Table D9-3. For this assessment, excess cancer risk to the public ranges from one and one-half to three and one-half orders-of-magnitude below acceptable risk levels. All risks given in Table D9-3 are for a receptor being subjected to concentrations based on maximum exhaust shaft VOC concentrations, that is, those resulting from emissions from 9 closed and 1 full open panels, over the entire exposure period. Room closures within the open panel are not considered.

D9-5.1.2 Noncarcinogens

For noncarcinogens, excess health effects are quantified in terms of a hazard quotient. The hazard quotient is computed as:

$$Hazard\ Quotient = \frac{EC \times ADF \times EF \times ED}{AT \times RfC} \times \left(\frac{1\ mg}{1 \times 10^3 \mu g}\right) \qquad \text{(D9-23)}$$

where,

Hazard Quotient = receptor hazard quotient, unitless
EC = exhaust shaft concentration for the VOC, $\mu g/m^3$
ADF = air dispersion factor, unitless
ED = exposure duration, years
RfC = reference concentration, mg/m^3
AT = averaging time, 306,600 hours (24 hours/day × 365 days/year × 35 years)

Note that the averaging time for noncarcinogens is one-half that for carcinogens. If the hazard quotient is below 1.0, no excess health effects to the receptor is expected. Equation D9-23 was derived from equations in EPA (1989); the derivation is shown below.

EPA (1989), page 8-11 provides the calculation for intake as:

$$Intake = Hazard\ Quotient \times RfD \qquad \text{(D9-24)}$$

where,

Intake = receptor intake, mg/kg-day
Hazard Quotient = receptor hazard quotient, unitless
RfD = reference dose, mg/kg-day

TABLE D9-3
EXCESS CANCER RISKS OUTSIDE THE WIPP SITE BOUNDARY

Compound	*Receptor Concentration (EC x ADF)* Boundary Public Receptor (μg/m³)	*URF* Unit Risk Factor	Carcinogen Class	*Risk* Boundary Public Receptor	Acceptable Risk Level
Carbon Tetrachloride	3.79E-03	1.50E-05[a]	B2	3E-08	1E-06
Chloroform	2.17E-04	2.30E-05[a]	B2	2E-09	1E-06
1,1,-Dichloroethylene	8.34E-05	5.00E-05[a]	C	2E-09	1E-05
1,2-Dichloroethane	6.38E-05	2.60E-05[a]	B2	8E-10	1E-06
Methylene Chloride	2.45E-03	4.70E-07[a]	B2	6E-10	1E-06
1,1,2,2-Tetrachloroethane	1.03E-04	5.80E-05[b]	C	3E-09	1E-05
1,1,1-Trichloroethane	2.77E-03	1.60E-05[b]	C	2E-08	1E-05

a. Data from EPA (1994a)
b. Data from Superfund Technical Support Center

EPA (1989), page 8-5 provides the calculation for the reference dose as:

$$RfD = \frac{RfC \times IR}{BW} \qquad \text{(D9-25)}$$

where,

RfD = reference dose, mg/kg-day
RfC = reference concentration, mg/m³
IR = inhalation rate, 20 m³/day
BW = body weight, 70 kg

Combining equations D9-24 and D9-25:

$$Intake = \frac{Hazard\ Quotient \times RfC \times IR}{BW} \qquad \text{(D9-26)}$$

where,

Intake	=	receptor intake, mg/kg-day
Hazard Quotient	=	receptor hazard quotient, unitless
RfC	=	reference concentration, mg/m^3
IR	=	inhalation rate, 20 m^3/day
BW	=	body weight, 70 kg

Setting equations D9-15 and D9-26 equal to each other:

$$\frac{Hazard\ Quotient \times RfC \times IR}{BW} = \frac{CA \times IR \times EF \times ED}{BW \times AT} \times \left(\frac{1\ mg}{1 \times 10^3\ \mu g}\right)$$

and solving for Hazard Quotient:

$$Hazard\ Quotient = \frac{CA \times EF \times ED}{AT \times RfC} \times \left(\frac{1\ mg}{1 \times 10^3\ \mu g}\right) \qquad \text{(D9-27)}$$

where,

Hazard Quotient	=	receptor hazard quotient, unitless
CA	=	contaminant concentration in air, µg/m^3
EF	=	exposure frequency, hours/year
ED	=	exposure duration, years
AT	=	averaging time, 306,600 hours (24 hours/day × 365 days/year × 35 years)
RfC	=	reference concentration, mg/m^3

Combining equations D9-22 and D9-27 yields equation D9-23:

$$Hazard\ Quotient = \frac{EC \times ADF \times EF \times ED}{AT \times RfC} \times \left(\frac{1\ mg}{1 \times 10^3\ \mu g}\right)$$

Excess non-cancer health effects to a Boundary Public Receptor are calculated using Equation D9-23 with an ADF of 1.2×10^{-4} and are presented in Table D9-4. Non-cancer health effects range from five and one-half to six and one-half orders-of-magnitude below acceptable levels for a hypothetical Boundary Public Receptor. All hazard quotients given in Table D9-4 are a receptor being subjected to concentrations based on maximum exhaust shaft VOC concentrations, that is, those resulting from emissions from 9 closed and 1 full open panels, over the entire exposure period.

TABLE D9-4
EXCESS NON-CANCER HEALTH EFFECTS OUTSIDE THE WIPP SITE BOUNDARY

	Receptor Concentration (EC x ADF)	*RfC*	*Hazard Quotient*	
Compound	**Boundary Public Receptor ($\mu g/m^3$)**	**Reference Concentration (mg/m^3)**	**Boundary Public Receptor**	**Acceptable Hazard Level**
Chlorobenzene	8.88E-05	2.00E-02[a]	4E-06	1E+00
Toluene	1.15E-04	4.00E-01[b]	3E-07	1E+00

a. Data from EPA (1994b)
b. Data from EPA (1994a)

D9-5.2 Receptor Concentrations and Risk Inside the WIPP Site Boundary

The Livingston Ridge Rancher, Antelope Ridge Rancher, Surface Worker, and Underground Worker exposure scenarios are evaluated in this section. ADFs of 9.8×10^{-5}, 6.7×10^{-5}, and 1.23×10^{-2} are used for the Livingston Ridge Rancher, Antelope Ridge Rancher, and Surface Worker exposure scenarios, respectively. For all public exposure scenarios, the maximum exhaust concentration from emissions from 9 closed and 1 open panel equivalents is used in assessing risk, with no credit taken for room closures within the open panel. Room closures are used in evaluating the Underground Worker exposure scenario.

D9-5.2.1 Carcinogens

The excess cancer risks calculated for each VOC inside the WIPP site boundary for the Livingston Ridge Rancher and the Antelope Ridge Rancher are presented in Table D9-5. The excess cancer risks to the Livingston Ridge Rancher and the Antelope Ridge Rancher range from two and one-half to four and one-half orders of magnitude below acceptable levels. Acceptable levels for these receptors are 1×10^{-6} for Class B carcinogens and 1×10^{-5} for Class C carcinogens.

Risks given in Table D9-5 are for receptors being subjected to concentrations based on maximum exhaust shaft VOC concentrations, that is, those resulting from emissions from 9 closed and 1 full open panels, over the entire period of exposure.

TABLE D9-5
EXCESS CANCER RISKS INSIDE THE WIPP SITE BOUNDARY FOR LIVINGSTON RIDGE RANCHER AND ANTELOPE RIDGE RANCHER SCENARIOS

	Receptor Concentration (EC x ADF)		*URF*		*Risk*		
Compound	Livingston Ridge Rancher (μg/m³)	Antelope Ridge Rancher (μg/m³)	Unit Risk Factor	Carcinogen Class	Livingston Ridge Rancher Risk	Antelope Ridge Rancher Risk	Acceptable Risk Level
Carbon Tetrachloride	3.09E-03	2.11E-03	1.50E-05	B2	6E-09	4E-09	1E-06
Chloroform	1.77E-04	1.21E-04	2.30E-05	B2	5E-10	3E-10	1E-06
1,1,-Dichloroethylene	6.81E-05	4.65E-05	5.00E-05	C	4E-10	3E-10	1E-05
1,2-Dichloroethane	5.21E-05	3.56E-05	2.60E-05	B2	2E-10	1E-10	1E-06
Methylene Chloride	2.00E-03	1.37E-03	4.70E-07	B2	1E-10	8E-11	1E-06
1,1,2,2-Tetrachloroethane	8.45E-05	5.78E-05	5.80E-05	C	6E-10	4E-10	1E-05
1,1,1-Trichloroethane	2.27E-03	1.55E-03	1.60E-05	C	4E-09	3E-09	1E-05

TABLE D9-6
EXCESS NON-CANCER HEALTH EFFECTS INSIDE THE WIPP SITE BOUNDARY FOR LIVINGSTON RIDGE RANCHER AND ANTELOPE RIDGE RANCHER SCENARIOS

	Receptor Concentration (EC x ADF)		*RfC*	*Calculated Hazard Quotient*		
Compound	**Livingston Ridge Rancher (µg/m³)**	**Antelope Ridge Rancher (µg/m³)**	**Reference Concentration (mg/m³)**	**Livingston Ridge Rancher**	**Antelope Ridge Rancher**	**Acceptable Hazard Level**
Chlorobenzene	7.25E-05	4.96E-05	2.00E-02	9E-07	6E-07	1E+00
Toluene	9.43E-05	6.45E-05	4.00E-01	6E-08	4E-08	1E+00

D9-5.2.2 Noncarcinogens

The excess non-cancer health effect calculation results for each VOC inside the WIPP site boundary are presented in Table D9-6. The ADFs used are the same as those described in Section D9-5.2.1. Excess non-cancer health effects range from six to seven and one-half orders-of-magnitude below a hazard quotient of one; this implies that there will be no adverse health effects from noncarcinogens to any of the evaluated receptors inside the WIPP site boundary. All hazard quotients given in Table D9-6 are for receptors being subjected to concentrations based on exhaust shaft VOC concentrations for emissions from 9 closed panels and 1 full open panel over the entire period of exposure.

D9-5.3 Worker Concentrations and Risk on the Surface and Underground

Worker Concentrations are calculated using the maximum allowable average VOC headspace concentration as established in Table C-5 of Chapter C. The Table C-5 limits are the highest average concentrations that can exist in any waste room. This assumption is very conservative, since the average headspace concentration clearly shows that concentrations are much lower on average. The Table C-5 limits are listed in Table D9-7.

As described in Section D-9b(4)(a) of Chapter D, occupational and public risk measures are different. For example, occupational exposure is calculated by assessing the effects on healthy adults of working age and public risk includes effects on children, adults, the elderly and the infirm. See D-9b(4)(a) for more information.

TABLE D9-7
MAXIMUM AVERAGE HEADSPACE CONCENTRATION LIMITS

Compound	Table C-5 Limit (ppmv)
Carbon Tetrachloride	7,510
Chlorobenzene	17,660
Chloroform	6,325
1,1,-Dichloroethylene	28,750
1,2-Dichloroethane	9,100
Methylene Chloride	100,000
1,1,2,2-Tetrachloroethane	7,924
Toluene	41,135
1,1,1-Trichloroethane	100,000

D9-5.3.1 Carcinogens

VOC contaminant concentrations in air for the Surface Worker and the Underground Worker are given in Table D9-8 along with Occupational Safety and Health Administration (OSHA) 8 hour time-weighted averages (TWAs). This information provides a mechanism for evaluating occupational exposures. The receptor concentrations for the Surface Worker range from four to nearly seven orders of magnitude below the TWAs. The receptor concentrations for the Underground Worker range from two to nearly six orders of magnitude below the TWAs.

Human health risk from carcinogens can be calculated using equation D9-15 with EF = 1920 hours/year for the surface worker and 33 hours per year for the underground worker, ED = 10 years, EC = ECS in Table 9-8, and ADF = 1.2×10^{-2}. The calculated risk from Carbon Tetrachloride is 9E-07 for the surface worker and 6E-07 for the underground worker. The risk from Chloroform is 9E-07 for the surface worker and 6E-07 for the underground worker. The risk from 1,1-Dichloroethene is 8E-06 for the surface worker and 5E-06 for the underground worker. The risk from 1,2-Dichloroethane is 1E-06 for the surface worker and 8E-07 for the underground worker. The risk from Methylene Chloride is 2E-07 for the surface worker and 1E-07 for the underground worker. The risk from 1,1,2,2-Tetrachloroethane is 4E-06 for the surface worker and 3E-06 for the underground worker. The risk from 1,1,1-Trichloroethane is 1E-05 for the surface worker and 8E-06 for the underground worker.

D9-5.3.2 Non-Carcinogens

As for carcinogens, noncarcinogen VOC contaminant concentrations in air for the Surface Worker and the Underground Worker and OSHA 8 hour TWAs are presented (Table D9-9). This information provides a mechanism for evaluating occupational exposures in addition to the risk assessment approach. The receptor concentrations for the Surface Worker are seven orders of magnitude below the TWAs and those for the Underground Worker are more than six orders of magnitude below the TWAs.

Human health risk from non-carcinogens can be calculated using equation D9-23 with EF = 1920 hours/year for the surface worker and 33 hours per year for the underground worker, ED = 10 years, and EC = ECS in Table 9-9. The calculated hazard quotient from Chlorobenzene is 4E-01 for the surface worker and 3E-02 for the underground worker. The risk from Toluene, the hazard quotient is 3E-02 for the surface worker and 3E-03 for the underground worker.

TABLE D9-8
VOC CONTAMINANT CONCENTRATIONS IN AIR FOR THE SURFACE WORKER AND THE UNDERGROUND WORKER

	ECS_{max}	ECU_{max}	*Receptor Concentration*		
Compound	**Exhaust Shaft Concentration for Surface Worker (µg/m³)**	**Exposure Concentration for Underground Worker (µg/m³)**	**(ECS x ADF) Surface Worker (ppmv)**	**Underground Worker (ppmv)**	**OSHA TWA[a] (ppmv)**
Carbon Tetrachloride	1.54E+02	7.70E+01	3.00E-04	1.22E-02	10
Chloroform	1.06E+02	5.03E+01	2.67E-04	1.03E-02	50
1,1,-Dichloroethylene	4.01E+02	1.86E+02	1.24E-03	4.68E-02	5[b]
1,2-Dichloroethane	1.25E+02	6.00E+01	3.81E-04	1.48E-01	100
Methylene Chloride	1.26e+02	5.66E+02	4.45E-03	1.63E-02	500
1,1,2,2-Tetrachloroethane	1.77E+02	8.86E+01	3.17E-04	1.29E-02	5
1,1,1-Trichloroethane	1.77E+03	8.89E+02	4.00E-03	1.63E-01	350

a. 8 hour TWAs except chloroform TWA for up to a 10 hour day in a 40 hour work week.
b. TWA from ACGIH

TABLE D9-9
VOC CONTAMINANT CONCENTRATIONS IN AIR FOR THE SURFACE WORKER AND THE UNDERGROUND WORKER

	ECS_{max}	ECU_{max}	Receptor Concentration		
Compound	Exhaust Shaft Concentration for Surface Worker (µg/m³)	Exposure Concentration for Underground Worker (µg/m³)	Surface Worker (ppmv)	Underground Worker (ppmv)	OSHA TWA (ppmv)
Chlorobenzene	2.58E+02	1.32E+02	6.91E-04	2.88E-02	75
Toluene	4.99E+02	2.53E+02	1.63E-03	6.70E-02	200

D9-6 Summary

Based on estimated maximum VOC emissions from emplaced waste, there are no significant exposures expected to occur to the public or workers. Risks and hazards to members of the public range from one and one-half to seven and one-half orders-of-magnitude below acceptable levels. Worker exposure VOC concentrations are approximately two to over five orders-of-magnitude below 8 hour OSHA TWAs.

The worker exposure and public risk assessment used the following conservative assumptions:

- Table C-5 limits for headspace concentrations of VOCs represent the average container concentration
- All drums are fitted with the model NFT-013 carbon composite filter
- The effective gas generation rate is constant in closed panels
- The actual source of VOCs will exist throughout the operational/closure phase and will maintain the average concentrations in drum and panel headspaces (i.e., no depletion of the source over time)
- VOC concentrations in the closed panel atmosphere are instantaneously equivalent to the drum average headspace concentrations
- There is no decrease in closure system permeability due to creep closure over time
- The hypothetical Boundary Public receptor is exposed every hour of every day during the span of facility operations
- Public risk to developing excess cancer does not include the probability that the receptor is one of the 27 residents within 10 miles (16 kilometers) of WIPP

WIPP

- Enough moisture will exist to create humid environmental conditions for gas generation
- A full repository of waste exists for the duration of the operational/closure
- There will be 81,000 drums disposed of in each panel. The actual configuration may include 60% Standard Waste Boxes (2 vents, 7-drum equivalent) and 40% drums (1 vent), meaning less than 81,000 filter vents will be venting in a panel (approximately 58,000).
- The assessments for the public and surface worker assume that no room ventilation barriers are installed, and emissions from 9 closed and 1 open panel full of waste exists for 35 years

Other assumptions that may contribute to the overall uncertainty of the receptor concentration and risk estimates are as follows:

- The mine ventilation flow rate will remain constant throughout the operational/closure phase
- Weighted average drum headspace concentrations of VOCs are representative of all waste to be disposed of at the WIPP

Although the uncertainties in the receptor concentration and risk estimates that result from these assumptions are not quantifiable, it is believed that they are far outweighed by the conservative assumptions used in the estimates.

D9-7 REFERENCES

DOE (U.S. Department of Energy). 1993. *Waste Isolation Pilot Plant Land Management Plan.* DOE/WIPP-93-004. Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM.

EPA (U.S. Environmental Protection Agency). 1989. *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A), Interim Final.* EPA/540/1-89/002. Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1992. *"No Migration" Variances to the Hazardous Waste Land Disposal Prohibitions: A Guidance Manual for Petitioners* [Draft]. EPA530-R-92-023. Office of Solid Waste, Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1994a. *Integrated Risk Information System (IRIS).* Retrievals made during October 1995. Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1994b. *Health Effects Assessment Summary Tables, FY-1994 Annual.* EPA 540-R-94-020. Office of Solid Waste and Emergency Response, Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1995. *User's Guide for the Industrial Source Complex (ISC3) Dispersion Models (Revised).* EPA-454/B-95-003a. Office of Air Quality Planning and Standards, Research Triangle Park, NC.

Francis, A.J. and J.B. Gillow. 1994. *Effects of Microbial Processes on Gas Generation Under Expected Waste Isolation Pilot Plant Repository Conditions, Progress Report Through 1992.* SAND93-7036, Sandia National Laboratories, Albuquerque, NM.

ATTACHMENT 1
EXAMINATION OF ROOF COLLAPSE SCENARIO

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ATTACHMENT 1
EXAMINATION OF ROOF COLLAPSE SCENARIO

D9-ATT 1-1.0 Background Information from WIPP SAR

An unexpected roof collapse in panels two through eight is considered to be an incredible ($\leq 10^{-6}$) accident because the panels will be mined, filled with waste, and closed before a roof fall in these panels becomes a concern (WIPP 1995). However, Panel 1, having a longer life span, has been addressed for this scenario as a special case. The WIPP safety analysis report (SAR) (WIPP 1995) determined that the unexpected roof collapse event in Panel 1 during emplacement operations in the underground bounds all other roof collapses due to the total number of waste containers in the area during these operations. Even in Panel 1, such a roof fall would require the failure of preventive and mitigative systems and controls identified in the SAR for this scenario, and is considered unlikely (frequency of occurrence of 10^{-2} to 10^{-4}).

The number of drums that can be placed under this hypothetical room collapse, stacked 3 layers high in seven pack configurations, is 3,843 (WIPP). The maximum drum weight allowed by the WIPP WAC is 1,000 pounds. Assuming the top two layers of drums in the waste stack are loaded to the maximum weight of 1,000 lb (454 kg), a loading of 2,000 pounds (907 kg) would be applied to a drum in the bottom layer. Based on the roof collapse in room 1 in the Site Preliminary Design Validation (SPDV), the section that collapsed was irregularly shaped and approximately 33 ft (10 m) wide by 7 ft (2.1 m) thick by 180 ft (54.9 m) long and weighed 700 tons (636 metric tons). With the added weight of the 7 ft (2.1 m) high collapsed roof material, the load on a drum on the bottom layer is 3,100 lb (1407 kg) (WIPP 1995). Backfill added to the top of the drum stack contributes 4200 lb (1907 kg) to each seven pack or 600 lb (272 kg) to each drum. Thus, the total load on a drum on the bottom layer is 3,700 lb (1680 kg). Conservatively assuming this entire mass as dynamic loading, the maximum load on a drum from 3,700 lb (1680 kg) of material falling a distance 1.5 ft (0.4572 m) is approximately 5,550 ft-lb (7,540 N-m).

Sandia National Laboratories, in report SAND80-2157, *Analysis, Scale Modeling, and Full-Scale Tests of Low-Level Nuclear Waste Drum Response to Accident Environments* (Sandia 1980), concluded that the energy required to crush an empty drum 10 inches in the axial direction requires a dynamic load of greater than 16,947 N-m . The lid did not separate from the drum and the drum did not breach during the dynamic tests. Therefore, the roof fall scenario, when conservatively considering the dynamic effects of falling roof material on drums, is not expected to result in any breached drums.

Even if some of the drums are breached, the material falling is expected to encapsulate the waste and the material available to be released will be minimal. Therefore, no release of radioactive or nonradioactive hazardous materials is expected from the loading of drums due to the added weight of the collapsed roof material. However, for conservatism the SAR assumed that an underground roof collapse causes 21 drums to fall from the top of the stack resulting in a breach of those drums.

D9-ATT 1- 2.0 Methodology

Two scenarios were evaluated: (1) a roof collapse in an open room that is being filled with drums, and (2) a roof collapse in a closed room with ventilation barriers in place. In addition two cases are evaluated for each scenario based on the concentrations of VOCs in the headspace of the drums. These cases are: (1) drum headspace VOC concentrations corresponding to the values given in Table C-5, representing the maximum average headspace concentrations for a container of waste, and; (2) concentrations of VOCs in the drum headspace corresponding to the weighted average concentrations as calculated in Appendix C2. Assumptions used to quantify exposure levels associated with the scenarios and cases examined are presented in the following sections.

D9-ATT 1- 2.1 Open Room Scenario

D9-ATT 1- 2.1.1 Assumptions

1) The underground roof (back) collapse may occur during waste emplacement causing 21 drums to fall from the top of the stack resulting in a breach of the drums, although the roof life has been extended by a supplementary roof support system (WIPP 1995). Two cases are examined one based on the Table C-5 limits of VOCs in the containers and the second based on the Appendix C2 headspace concentrations.

2) The room is backfilled to 1.5 ft from the ceiling (i.e., no credit is taken for the air between the drums).

3) Room dimensions are 300 ft x 33 ft x 13 ft.

4) The void space in each drum is 5.2 ft^3 (WIPP 1995).

5) The room headspace air volume and the void space gas volume in the breached containers, mix completely and instantaneously.

6) Dilution of the contaminated air from the collapsed room with the air flowing by the workers is negligible because
   a) the rate of displacement of the contaminated air is much greater than the rate of fresh air flow by the workers.
   b) the collapse of the room will preclude fresh air ventilation.

7) The contaminated air is cleared from the vicinity of the workers based on the rate of the fresh air flowing by them (i.e., 35,000 ft^3/min) (WID 1996).

8) Duration of exposure is dependent on the rate at which the contaminated air is cleared from the vicinity of the worker. Averaging time for calculation of risk and hazard quotient is 70 yrs and 0.014 hrs, respectively.

9) A worker is assumed to be downstream of this event. In reality, for as low as reasonable achievable (ALARA) reasons, few workers spend time downstream of the emplaced radioactive waste.

D9-ATT 1- 2.1.2 Calculations

1) Volume of clean air in the room headspace (RHV)

300 ft (length) x 33 ft (width) x 1.5 ft (headspace) = 14,850 ft^3

2) Volume of contaminated air released from the containers (CAC)

(number of drums) x 5.2 ft^3/drum = 109.2 ft^3 (for 21 drums)

3) Concentration of the contaminant in the room air (CCR) (NOTE - the room air is hereafter referred to as the cloud)

(VOC concentration) x (CAC/(RHV+CAC)) = ppmv

4) Duration of worker exposure (DWE)

(RHV + CAC)/35,000 ft^3/min = (14,850 ft^3 + 109.2 ft^3)/35,000 ft^3 = 0.43 min

5) 8-hour time weighted average

(CCR x DWE x hr/60 min)/8 hrs

D9-ATT 1- 2.2 Closed Room Scenario

The time dependent VOC concentration expressed as mole fraction VOC in a closed room may be evaluated by solving the following differential equation describing the accumulation of VOC in the sealed room due to the diffusion of VOC through the drum filter from the drum headspace into the room.

$$\frac{dX_R}{dt} = NR_f\,(X_H - X_R)$$

subject to the initial condition that no VOC is present in the closed room initially, i.e.

$X_R(t = 0) = 0$

where,

$$R_f = \frac{D_{VOC} \times R \times T}{V_{air} \times P}$$

R_f	VOC filter release coefficient (1/day mol fraction)
D_{VOC}	VOC diffusivity through filter on drum, mol s^{-1} mol $fraction^{-1}$
R	Gas law constant, 8.2057 x 10^{-5} atm m^3 mol^{-1} K^{-1}
T	Absolute temperature, 298 K
V_R	Room headspace volume, 14,850 ft^3
P	Absolute pressure, 1 atm
X_R	Mole fraction VOC in the closed room, dimensionless
N	Number of drums in closed room, 11,571 drums
X_H	Mole fraction VOC in drum headspace, dimensionless
t	Time, yr.

The solution to the differential equation yields the time dependent VOC concentration in a closed room as:

$$X_R(t) = X_H(1-e^{-NRt})$$

The time dependent concentrations of VOCs in the closed room are presented in Figure D9-ATT 1-1. After 0.1 years, the concentrations in all regions of the room have equilibrated and the concentrations are equal to the concentrations inside the drum headspace.

D9-ATT 1- 2.2.1 Assumptions

1) The underground roof collapse occurs in a closed room (i.e. a room with ventilation barriers). Six rooms are closed and each room contains 11, 751 drums. The last room is open and is about to be closed with 11,751 drums inside.

2) The room is backfilled to 1.5 ft from the ceiling.

3) Room dimensions are 300 ft x 33 ft x 13 ft.

4) Based on the previous analyses to predict VOC concentrations in a closed room as a function of time, the concentrations of the VOCs in the air gap have equilibrated with the VOC concentrations in the headspace of the containers (i.e, the VOC concentration in the room is equal to the VOC concentration in the drum headspace).

5) Based on the Sandia experiments, the collapse of the roof material onto the drum stacks does not provide sufficient energy to breach the drums. Thus, only the contaminated air gap is available for release. Based on examination of the material that collapsed in room 1 in the SPDV, the collapse of the roof material cannot be simply described as a piston system that expels the contaminated air gap into the panel access drifts. The majority (90%) of the contaminated air will escape into the overlying void space created by the collapsed section and will not be available for release into the fresh air flowing through the panel. Ten percent of the room air is released with 5% escaping through each side of the room. Thus a worker is exposed to 5% of the room air.

6) In calculating the 8 hr TWA, the contaminated air is cleared from the vicinity of the worker based on the rate of the fresh air flowing by them (i.e., 35,000 ft^3/min) (WID 1996).

7) In calculating the 8 hr TWA, the duration of exposure is dependent on the rate at which the contaminated air is cleared from the vicinity of the worker based on 5% of the contaminated air being released into the fresh air flowing through the access drift in the panel.

8) A worker is assumed to be downstream of this event. In reality, for as low as reasonable achievable (ALARA) reasons, few workers spend time downstream of the emplaced radioactive waste.

D9-ATT 1- 2.2.2 Calculations

1) Duration of worker exposure (DWE) is calculated as

$$(f \times RHV)/(35{,}000\ ft^3/min)$$

where,

f Fraction of room headspace volume that is released to an access drift and available for worker exposure, 0.05 dimensionless

RHV Room headspace volume, 14,850 ft^3

2) The 8-hour time weighted average (TWA) assuming one closed room with a roof collapse is calculated as:

(CCR x DWE x hr/60 min)/8 hr

where,

CCR Concentration of the contaminant in the room air, ppmv

3) The maximum 1-minute concentration that the worker is exposed to is calculated as:

$MAXC = CCR \times f \times RHV/(35{,}000\ ft^3 + f \times RHV)$

D9-ATT 1- 3.0 Discussion

The VOC concentrations to which the workers would be exposed in the scenarios examined were compared to various exposure limits, including threshold limit values (TLVs), permissible exposure limits (PELs), and recommended exposure limits (RELs). These exposure limits were compiled from various sources and are presented in Table D9-ATT 1-1.

D9-ATT 1- 3.1 Open Room Scenario

The calculated worker exposures, given as the contaminant concentration in the cloud (CCR), were then compared to the most restrictive exposure limits; this comparison is presented in Table D9-ATT 1-2 and Table D9-ATT 1-3 for each of the two cases examined. Based on the analyses, the immediate VOC concentrations in air (i.e., in the CCRs) are below the respective IDLH exposure limits for both of the scenarios. The 8-Hr TWA concentrations are below the respective TWA exposure limits for both of the scenarios.

D9-ATT 1- 3.2 Closed Room Scenario

The calculated worker exposures, in terms of 8 hr TWA concentrations were then compared to the most restrictive exposure limits. This comparison is presented in Table D9-ATT 1-4 andTable D9-ATT 1-5 for each of the two cases examined. Based on the Table C-5 limits for VOCs in the drum headspace, the 1 minute maximum VOC concentrations are below the IDLH limits for all VOCs. Using the Table C-5 VOC concentrations in the drum headspace, the 8 Hr TWA are below the 8 Hr TWA limits. Based on the Appendix C2 concentrations for VOCs in the drum headspace, the 1 minute maximum concentrations are well below the IDLH values in all cases and the calculated worker exposure 8 hr TWA concentrations are well below the 8 hr TWA limits.

REFERENCES

29 CFR 1910.1000. "Occupational Safety and Health Standards Subpart Z - Toxic and Hazardous Substances." *Code of Federal Regulations*, Washington, D.C., Office of the Federal Register National Archives and Records Administration.

ACGIH. 1995. *1995 - 1996 Threshold Limit Values for Chemical Substances, Physical Constants, and Biological Exposure Indices*, American Conference of Governmental Industrial Hygienists (ACGIH), Cincinnati, Ohio.

NIOSH. 1994. *Pocket Guide to Chemical Hazards*, U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health (NIOSH), Washington, D.C., U.S. Government Printing Office, Superintendent of Documents.

Sandia. 1980. SAND80-2157, *Analysis, Scale Modeling, and Full-Scale Tests of Low-Level Nuclear Waste Drum Response to Accident Environments*, Albuquerque, New Mexico, Sandia National Laboratory, U.S. Department of Energy.

WIPP. 1995. *Waste Isolation Pilot Plant Safety Analysis Report*, DOE/WIPP-95-2065, Rev. 0, Carlsbad, New Mexico, Waste Isolation Pilot Plant, U.S. Department of Energy.

TABLES

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Table D9-ATT 1-1. Exposure Limits[a]

Substance	OSHA PEL[b]	ACGIH TLV	NIOSH REL[c]
Carbon tetrachloride (Tetrachloromethane)	10 ppm TWA (C) 25 ppm 200 ppm peak for 5 min in any 4 hrs	5 ppm TWA, 31 mg/m^3 10 ppm STEL, 63 mg/m^3 Animal carcinogen	2 ppm STEL (60 min), 12.6 mg/m^3 Carcinogen 200 ppm IDLH
Chlorobenzene	75 ppm TWA, 350 mg/m^3	10 ppm TWA, 46 mg/m^3	NL[d] 1,000 ppm IDLH
Chloroform (Trichloromethane)	(C) 50 ppm, (C) 240 mg/m^3	10 ppm TWA, 49 mg/m^3 Suspected human carcinogen	NL[e] 2 ppm STEL (60 min), 9.78 mg/m^3 Carcinogen 500 ppm IDLH
1,1-Dichloroethylene (Vinylidene chloride)	NL	5 ppm TWA, 20 mg/m^3 20 ppm STEL, 79 mg/m^3	NL[e] Carcinogen IDLH not determined
1,2-Dichloroethane (Ethylene dichloride)	100 ppm TWA (C) 200 ppm 300 ppm peak for 5 min in any 3 hrs	10 ppm TWA, 40 mg/m^3	NL[e,f] 1 ppm TWA, 4 mg/m^3 2 ppm STEL, 8 mg/m^3 Carcinogen 50 ppm IDLH
Methylene chloride (Dichloromethane)	500 ppm TWA (C) 1,000 ppm 2,000 ppm peak for 5 min in any 2 hrs	50 ppm TWA, 174 mg/m^3 Suspected human carcinogen	NL[e] Carcinogen 2,300 ppm IDLH
1,1,2,2-Tetrachloroethane	5 ppm TWA, 35 mg/m^3 Skin designation	1 ppm TWA, 6.9 mg/m^3 Skin designation	NL[e,f] 1 ppm TWA, 7 mg/m^3 Carcinogen, skin designation 100 ppm IDLH
Toluene	200 ppm TWA (C) 300 ppm 500 ppm peak for 10 min	50 ppm TWA, 188 mg/m^3 Skin designation	100 ppm TWA, 375 mg/m^3 150 ppm STEL, 560 mg/m^3 500 ppm IDLH
1,1,1-Trichloroethane (Methyl chloroform)	350 ppm TWA, 1,900 mg/m^3	350 ppm TWA, 1,910 mg/m^3 450 ppm STEL, 2,460 mg/m^3	(C) 350 ppm (15 min), (C) 1,900 mg/m^3 700 ppm IDLH

Table D9-ATT 1-1. Exposure Limits[a]

(continued)

Substance	OSHA PEL[b]	ACGIH TLV	NIOSH REL[c]

[a]SOURCE: 29 CFR 1910.1000; ACGIH 1995; NIOSH 1994.
[b]8 hr TWA unless noted otherwise, (C) denotes ceiling limit

[c]Up to a 10 hr day in a 40 hr workweek TWA, STEL is a 15 min TWA unless noted otherwise
[d]NIOSH questions whether the OSHA PEL TWA of 75 ppm is adequate to protect workers from recognized health hazards but does not offer an alternative.
[e]NIOSH usually recommends that occupational exposures to carcinogens be limited to the lowest feasible level
[f]NIOSH considers the substance to be a potential occupational carcinogen

Acronyms and Units for Table D9-ATT 1-1

OSHA	Occupational Safety and Health Act
PEL	permissible exposure limit
ACGIH	American Conference of Governmental Industrial Hygienists
TLV	threshold limit value
NIOSH	National Institute for Occupational Safety and Health
REL	recommended exposure limit
ppm	parts of vapor or gas per million parts of contaminated air by volume at 25C and 760 torr
TWA	time-weighted average
(C)	ceiling limit
STEL	short-term exposure limit
IDLH	immediately dangerous to life or health concentration
mg/m^3	milligrams per cubic meter
NL	not listed

Table D9-ATT 1-2. Open Room Scenario: Comparison of Calculated Cloud Concentrations from 21 Drum Source and Table C-5 VOC Concentrations to Most Restrictive Exposure Limits

Chemical	Headspace Table C-5 Limit VOC Concentration (ppm)	Concentration in Air (ppm)		Exposure Limit (ppm)	Source
		Immediate	8-Hr TWA		
Carbon tetrachloride	7,510	27.51	0.05	2 (STEL) 5 (TWA) 200 (IDLH)	NIOSH ACGIH NIOSH
Chlorobenzene	-	–[a]	–	10 (TWA) 1000 (IDLH)	ACGIH NIOSH
Chloroform	6,325	23.17	0.04	2 (STEL) 10 (TWA) 500 (IDLH)	NIOSH ACGIH NIOSH
1,1-Dichloroethylene	28,750	105.3	0.19	20 (STEL) 5 (TWA)	ACGIH ACGIH
1,2-Dichloroethane	9,100	33.34	0.06	2 (STEL) 1 (TWA) 50 (IDLH)	NIOSH NIOSH NIOSH
Methylene chloride	100,000	366.3	0.65	50 (TWA) 2,300 (IDLH)	ACGIH NIOSH
1,1,2,2-Tetrachloroethane	-	–	–	1 (TWA) 100 (IDLH)	NIOSH NIOSH
Toluene	-	–	–	150 (STEL) 50 (TWA) 500 (IDLH)	NIOSH ACGIH NIOSH
1,1,1-Trichloroethane	-	–	–	450 (STEL) 350 (TWA) 700 (IDLH)	ACGIH ACGIH NIOSH

a No Table C-5 limit assigned.

Table D9-ATT 1-3. Open Room Scenario Comparison of Calculated Cloud Concentrations from 21 Drum Source and Appendix C2 VOC Concentrations to Most Restrictive Exposure Limits

Chemical	Appendix C2 Headspace VOC Concentration (ppm)	Concentration in Air (ppm)		Exposure Limit (ppm)	Source
		Immediate	8-Hr TWA		
Carbon tetrachloride	375.5	1.38	2.44×10^{-3}	2 (STEL) 5 (TWA) 200 (IDLH)	NIOSH ACGIH NIOSH
Chlorobenzene	12.5	0.05	8.13×10^{-5}	10 (TWA) 1000 (IDLH)	ACGIH NIOSH
Chloroform	25.3	0.09	1.64×10^{-4}	2 (STEL) 10 (TWA) 500 (IDLH)	NIOSH ACGIH NIOSH
1,1-Dichloroethylene	11.5	0.04	7.48×10^{-5}	20 (STEL) 5 (TWA)	ACGIH ACGIH
1,2-Dichloroethane	9.1	0.03	5.92×10^{-5}	2 (STEL) 1 (TWA) 50 (IDLH)	NIOSH NIOSH NIOSH
Methylene chloride	368.5	1.35	2.40×10^{-3}	50 (TWA) 2,300 (IDLH)	ACGIH NIOSH
1,1,2,2-Tetrachloroethane	9.4	0.03	6.11×10^{-5}	1 (TWA) 100 (IDLH)	NIOSH NIOSH
Toluene	19.4	0.07	1.26×10^{-4}	150 (STEL) 50 (TWA) 500 (IDLH)	NIOSH ACGIH NIOSH
1,1,1-Trichloroethane	317.1	1.16	2.06×10^{-3}	450 (STEL) 350 (TWA) 700 (IDLH)	ACGIH ACGIH NIOSH

Table D9-ATT 1-4. Closed Room Scenario Comparisons of Concentrations Based on Table C-5 VOC Concentration Limits to the Most Restrictive Exposure Limits

VOC	Table C-5 VOC Concentration Limit (ppmv)	Calculated 8 Hr TWA (ppmv)	Maximum 1 min Concentration (ppmv)	IDLH	8 Hr TWA Limits (ppmv)
Carbon tetrachloride	7,510	0.33	156	200	5
Chlorobenzene	-	-	-	-	10
Chloroform	6,325	0.28	131	500	10
1,1-Dichloroethylene	28,750	1.27	597	-	5
1,2-Dichloroethane	9,100	0.40	189	50	1
Methylene chloride	100,000	4.42	2,080	2,300	50
1,1,2,2-Tetrachloroethane	-	-	-	100	1
Toluene	-	-	-	500	50
1,1,1,1-Trichloroethane	-	-	-	700	350

Table D9-ATT 1-5. Closed Room Scenario Comparisons of Concentrations Based on Appendix C2 Weighted Average Headspace Concentrations to the Most Restrictive Exposure Limits

VOC	Appendix C2 VOC Concentration (ppmv)	Calculated 8 Hr TWA (ppmv)	Maximum 1 min Conc. (ppmv)	IDLH	8 Hr TWA Limits (ppmv)
Carbon tetrachloride	376	0.0166	7.80	200	5
Chlorobenzene	13	0.0006	0.26	-	10
Chloroform	25	0.0011	0.53	500	10
1,1-Dichloroethylene	12	0.0005	0.24	-	5
1,2-Dichloroethane	9	0.0004	0.19	50	1
Methylene chloride	369	0.0163	7.66	2,300	50
1,1,2,2-Tetrachloroethane	9	0.0004	0.20	100	1
Toluene	19	0.0009	0.40	500	50
1,1,1,1-Trichloroethane	317	0.0140	6.59	700	350

FIGURES

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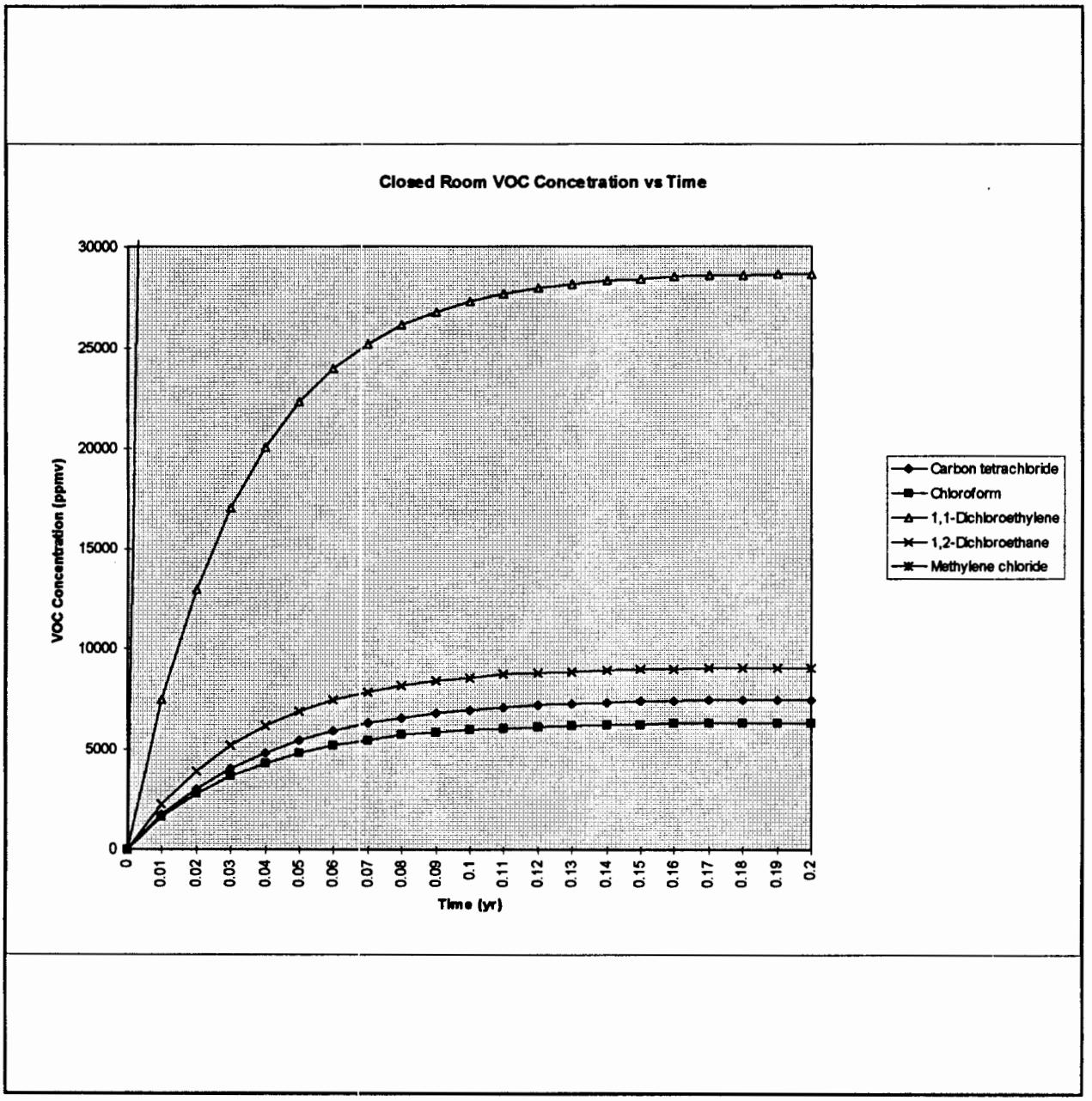

Figure D9-ATT 1-1 Closed Room VOC Concentration Versus Time

APPENDIX D10
AIR DISPERSION MODELING

APPENDIX D10
AIR DISPERSION MODELING

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1.0 SCOPE

The purpose of this modeling was to determine the air dispersion factors (ADF) representing the maximum concentrations of any gaseous airborne hazardous constituent that would be released from the mine air exhaust system during Waste Isolation Pilot Plant (WIPP) disposal operations. The main function of this calculation was performed by using the Environmental Protection Agency (EPA) computer-based Industrial Source Complex Long-Term (ISCLT3) air dispersion model. The model was used to predict a maximum concentration in $\mu g/m^3$, given an arbitrary input of a gas concentration of 1,000 $\mu g/m^3$. The ADF was then calculated using the following ratio:

$$\textit{Air Dispersion Factor} = \frac{\textit{maximum concentration } (\mu g/m^3)}{\textit{release concentration } (\mu g/m^3)} \qquad \text{(D10-1)}$$

2.0 BACKGROUND

The calculations and model runs were performed for the No-Migration Variance Petition (NMVP) and the Resource Conservation and Recovery Act (RCRA) Part B Permit Application. In the petition, the Department of Energy (DOE) must demonstrate that there will be no migration of hazardous constituents above heath-based levels (HBL) beyond the unit boundary. In its guidance manual, the EPA recommends that no-migration variance petitioners assess the air pathway using the ISC model. Given a concentration of a volatile organic compounds (VOC) in air released from the mine ventilation exhaust ducts, the air dispersion factor determines the resulting maximum concentration for the NMVP. This concentration is then compared to HBLs to demonstrate no-migration. In the permit application the DOE must demonstrate that there will be no release that may have an adverse effect on human health and the environment due to migration of waste constituents in the air. For the permit application the maximum concentration is used to calculate the long-term risk to the public, and then compared to acceptable risk levels. Occupational exposure is also required to be assessed in the application.

To perform the assessments above, four ADFs were determined. One ADF was determined for the maximum concentration point on the WIPP Site Boundary, two ADFs were determined for public exposure inside the WIPP Site Boundary, and one ADF was determined for the maximum worker exposure inside the Property Protection Area.

The EPA guidance on the air pathway assessment for NMVPs has specific requirements related to the ISC model run(s) for a NMVP. The model runs should:

1. estimate annual average concentrations using ISCLT3;
2. use five years of preferable on-site meteorological data, evaluate one year at a time, and use the run that produces the maximum boundary concentration;
3. include receptors up to 328 feet (100 meters) beyond the unit boundary to verify that the maximum concentration occurs at the boundary;
4. include a fine receptor grid in the maximum concentration area;
5. use Cartesian receptor grids;

6. correct for the vertical wind profile, if the source is at ground level; and
7. specify receptor heights at 5 feet (1.5 meters) (inhalation height).

Although the WIPP facility has an on-site meteorological monitoring program, the wind speed and direction data recorded under that program for the last five years do not meet EPA guidance for completeness (90 percent). As a whole, the data represent approximately 50 percent of the past five years. However, the data collected during 1993 represents approximately 70 percent coverage for that year. In addition to the on-site data, a complete set of meteorological data from the Carlsbad, New Mexico National Weather Service (NWS) Station at the Carlsbad Municipal Airport was available. The environmental conditions at the Carlsbad airport are similar to those at the WIPP facility, which is located approximately 30 miles east/southeast of the airport. Data from this station are based on hourly observations, 24 hours a day, and it is the closest NWS station to the WIPP site.

Yearly meteorological data for the Carlsbad, New Mexico NWS Station from 1990 to 1994 and the WIPP on-site meteorological station from 1993 were used during the analyses. In each model run, each set of meteorological data were used, and the run that yielded the highest concentration of concern was used to determine the next run or the ADF.

3.0 MODEL INPUT PARAMETERS

3.1 General

The ISCLT3 model is a FORTRAN computer program that requires an input file with parameters for the model run. The input file uses a keyword/parameter approach. The keywords specify the type of option or input data entered on each line of the input file and the parameters following the keyword define the specific options selected or the actual input data. The input file is divided into five functional "pathways." The pathway keywords and description are as follows:

CO - for specifying overall job COntrol options;
SO - for specifying SOurce information;
RE - for specifying REceptor information;
ME - for specifying MEteorology information; and
OU - for specifying OUtput options.

The input parameters described below are the only ones applicable to these model runs. Also note that all parameter values are expressed in SI units unless otherwise specified.

3.2 Job Control Options

TITLEONE and TITLETWO - specify a title for the model run
MODELOPT - CONC specifies an output in concentration of a gas per unit volume of air, and RURAL specifies the facility is in a rural area.
AVERTIME - time interval for averaging long-term concentrations
POLLUTID - name or other identifier of the pollutant modeled
TERRHGTS - elevation differences between source and receptors
ELEVUNIT - elevation unit

FLAGPOLE - height of receptor above ground-level

3.3 Source Information

LOCATION - coordinates for each source
SRCPARAM - source parameters, such as emission rate (mass/time), stack height, stack temperature, exit velocity, and equivalent stack diameter

Stack Tip Downwash and Building Wake - ISC incorporates the effects of wind turbulence at the exit of the stack (exhaust duct) and near other buildings around the stack using the Building Profile Input Program (BPIP). Data representing the buildings and structures around the stack are required.

BUILDHGT - height of buildings near the exhaust stack
BUILDWID - apparent width of buildings near the exhaust stack

3.4 Receptor Information

GRIDCART - Cartesian coordinates of a grid of receptors
DISCCART - Cartesian coordinates of discrete receptors

3.5 Meteorological Information

INPUTFIL - directory and filename containing STAR data
ANEMHGHT - height of the anemometer
SURFDATA - surface meteorological station number, year data represents, and a name for the information
UAIRDATA - upper air meteorological station number, year data represents, and a name for the information
STARDATA - time interval STAR data represents
AVESPEED - median values of wind speed categories represented in the STAR data
AVETEMPS - time interval, and average temperature for each wind speed category
AVEMIXHT - time interval, average mixing height for each wind speed category and each stability class
DTHETADZ - vertical temperature gradients for each wind speed category and each stability class

3.6 Output Options

RECTABLE - print a receptor concentration table
MAXTABLE - print maximum ground-level concentrations for the number specified

4.0 INPUT PARAMETERS

4.1 Job Control Options (most are self-explanatory)

TERRHGTS - ELEV, use elevations for complex terrain as indicated on topographic

maps provided in Attachment C

ELEVUNIT - units are in feet to correspond to US Geological Survey (USGS) maps

4.2 Source Information

LOCATION - the center of the outer edge of the exhaust fan discharge duct of one main fan represents the origin (0,0) for all other coordinates. The other fan discharge coordinate is 23.6 feet (7.2 meters) north of the origin.

SRCPARAM - The "stack" in this case is the exhaust fan discharge duct, which is rectangular. The emission rate is calculated assuming that 1000 $\mu g/m^3$ (0.001 g/m^3) of any gas is released from 425,000 ft^3/min of air.

$$air\ release\ rate = (425{,}000\,ft^3/\text{min})\,x\,(1\,m^3/35.32\,ft^3)\,x\,(1\,\text{min}/60\ s)$$

$$= 200.6\ m^3/s$$

$$release\ rate\ for\ each\ fan = \frac{(200.6\ m^3/s)}{2\ fans} = 100.3\ m^3/s$$

$$emission\ rate = (0.001\ g/m^3)\ x\ (100.3\ m^3/s) = 0.1\ g/s$$

stack height = 8.2 meter
stack temperature = 288 Kelvin

Because the exhaust fans actually emit the mine air at approximately a 45° angle, the vector equivalent velocity is input as (velocity) x (SIN 45°):

$$stack\,vel. = \frac{(vol.\,flow\,rate)\,x\,(\sin 45°)}{\pi\ x\ (d/2)^2} = \frac{70.92\,m^3/s}{\pi\ x\ (4.4\ m/2)^2} = 4.66\ m/s$$

$$stack\,exit\,area = (178\,in)\ x\ (130\,in)\ x\ (m^2/1549.4\,in^2) = 14.93\,m^2$$

$$equivalent\ dia. = 2\ x\ (A/\pi)^{1/2} = 2\ x\ (14.93\ m^2/\pi)^{1/2} = 4.4\ m$$

BUILDHGT and BUILDWID - Apparent width is the width of a structure perpendicular to the 16 evenly-spaced sectors around the stack (Figure 1). For example, the apparent width of Building 413 in the northwest direction is 28.9 feet (8.8 meters).

4.3 Receptor Information

4.3.1 Receptor Grid

4.3.1.1 Coarse Receptor Grid

The first five runs (Attachment 1) were coarse grid runs covering the WIPP property from the source (exhaust fans) to the WIPP Site Boundary. The receptors in these runs were generated in a Cartesian Grid of 1,312 feet (ft) by 1,312 ft (400 meters (m) by 400 m), which is the maximum number of receptors that can be used in one run to cover the property. One run was performed with the 1993 WIPP meteorological data, and the other five runs were performed with 1990 to 1994 Carlsbad meteorological data.

To determine the two ADFs for public inside the WIPP Site Boundary, the coarse grid concentrations were averaged for two areas. The two areas represent the cattle grazing leases on the WIPP property as shown in Figure D9-1 in Appendix D9 of the permit application (Appendix RA of the NMVP).

4.3.1.2 Fine Receptor Grid

To determine the WIPP Site Boundary ADF and the Property Protection Area ADF, two fine grids runs were performed. Based on the highest concentration at or beyond the WIPP Site Boundary from the six coarse grid runs, a fine grid run of 32 ft by 32 ft (10m by 10m) was performed around that point. In the other run a fine grid run of 32 ft by 32 ft (10m by 10m) was performed around the highest concentration, which was in the Property Protection Area from the six coarse runs.

4.4 Meteorological Information

INPUTFIL	- STAR file consisting of the normal frequency distribution of wind speed and wind direction, grouped by stability class. The data used in these model runs is from the Carlsbad, New Mexico Municipal Airport NWS Station.
ANEMHGHT	- self-explanatory
SURFDATA	- self-explanatory
UAIRDATA	- self-explanatory
STARDATA	- self-explanatory
AVESPEED	- self-explanatory
AVETEMPS	- 288 Kelvin for each stability class
AVEMIXHT	- 4,708 feet (1,435 meters) for each stability class and each wind speed category
DTHETADZ	- 0.01° - stability class E, 0.03° - stability class F

4.5 Output Options

MAXTABLE	- print the top 10 maximum ground-level concentrations and associated receptor coordinate and type

5.0 AIR DISPERSION FACTORS

Using equation D10-1, the four ADFs were calculated and are presented in Table D10-1 below.

In conclusion, any concentration of a gas released from the exhaust ducts can be multiplied by these ADFs to determine the maximum annual average concentration at the point or area of concern.

TABLE D10-1
AIR DISPERSION FACTORS

Area	ADF
WIPP Site Boundary	1.2×10^{-4}
Grazing Lease Area - North	9.8×10^{-5}
Grazing Lease Area - South	6.7×10^{-5}
Property Protection Area	1.2×10^{-2}

BIBLIOGRAPHY

EPA (U.S. Environmental Protection Agency). 1986. *Guideline on Air Quality Models (Revised).* EPA-450/2-78-027R, with supplements A, B, and C. Office of Air Quality Planning and Standards, Research Triangle Park, NC

EPA (U.S. Environmental Protection Agency). 1995a. *User's Guide for the Industrial Source Complex (ISC3) Dispersion Models.* EPA-454/B-95-003a. Office of Air Quality Planning and Standards, Research Triangle Park, NC.

EPA (U.S. Environmental Protection Agency). 1995b. *On-Site Meteorological Program Guidance for Regulatory Modeling Applications.* EPA-450/4-87-013. Office of Air Quality Planning and Standards, Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1992. *"No Migrations" Variances to the Hazardous Waste Land Disposal Restrictions: A Guidance Manual for Petitioners, Draft.* EPA-530-R-92-023. Office of Air Quality Planning and Standards, Washington, D.C.

DOE (U.S. Department of Energy). 1980. *Final Environmental Impact Statement for the Waste Isolation Pilot Plant.* DOE/EIS-0026.

DOE (U.S. Department of Energy). 1995. *Safety Analysis Report for the Waste Isolation Pilot Plant.* DOE/WIPP-95-2065.

Trinity Consultants, Inc. 1995. *Letter on Quality of WIPP On-Site Meteorological Data for ISCLT2 model runs.* Contract 75WJM66763SZ.

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ATTACHMENT A - MODEL OUTPUT LIST FILES

TABLE OF CONTENTS

Coarse Grid Run with WIPP Meteorological Data D10-10

Coarse Grid Run with 1990 Carlsbad Meteorological Data D10-34

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Coarse Grid Run with 1993 Carlsbad Meteorological Data D10-106

Coarse Grid Run with 1994 Carlsbad Meteorological Data D10-130

WIPP Site Boundary Fine Grid Run with WIPP Meteorological Data D10-154

WIPP Site Boundary Fine Grid Run with 1990 Carlsbad Meteorological Data . . . D10-190

Property Protection Area Fine Grid Run with WIPP Meteorological Data D10-226

Property Protection Area Fine Grid Run with 1990 Carlsbad Meteorological Data D10-257

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
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CO TITLEONE CONCENTRATIONS AT THE WIPP SITE BOUNDARY (93 WIPP Met)
CO TITLETWO Coarse Receptor Grid(400x400m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
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SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
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SO BUILDWID  1             30.72    30.72     7.29    31.62
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SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
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RE ELEVUNIT FEET
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RE FINISHED

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ME ANEMHGHT   10.000 METERS

ME SURFDATA 11111 1993 WIPP

ME UAIRDATA 11111 1993

ME STARDATA ANNUAL

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ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

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ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00

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ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03

ME FINISHED

OU STARTING

OU RECTABLE SRCGRP

OU MAXTABLE 10 SRCGRP

OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMCW93A.GPH 70

OU FINISHED

***********************************
*** SETUP Finishes Successfully ***
***********************************
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 *** MODELING OPTIONS USED:  CONC    RURAL  ELEV   FLGPOL

                                    ***     MODEL SETUP OPTIONS SUMMARY       ***
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
-


**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
          1. Final Plume Rise.
          2. Stack-tip Downwash.
          3. Buoyancy-induced Dispersion.
          4. Default Wind Profile Exponents.
          5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates   1 STAR Average(s) for the Following Months:  0  0  0  0  0  0  0  0  0  0  0  0
                                                Seasons/Quarters:  0  0  0  0
                                                      and Annual:  1

**Data File Includes  1 STAR Summaries for the Following Months:  0  0  0  0  0  0  0  0  0  0  0  0
                                                Seasons/Quarters:  0  0  0  0
                                                      and Annual:  1

**This Run Includes:    2 Source(s);      1 Source Group(s); and    289 Receptor(s)

**The Model Assumes A Pollutant Type of:  ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
        Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
        Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
        Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs:  Anem. Hgt. (m) =    10.00 ;    Decay Coef. =    .0000     ;    Rot. Angle =      .0
                 Emission Units = GRAMS/SEC                                ;  Emission Rate Unit Factor =    .10000E+07
                 Output Units   = MICROGRAMS/M**3

**Input Runstream File: ADMCW93A.DAT                          ;  **Output Print File: ADMCW93A.LST
```

2

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

4
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-3189.5,	-2789.5,	-2389.5,	-1989.5,	-1589.5,	-1189.5,	-789.5,	-389.5,	10.5,	410.5,
810.5,	1210.5,	1610.5,	2010.5,	2410.5,	2810.5,	3210.5,			

*** Y-COORDINATES OF GRID ***
(METERS)

-3469.8,	-3069.8,	-2669.8,	-2269.8,	-1869.8,	-1469.8,	-1069.8,	-669.8,	-269.8,	130.2,
530.2,	930.2,	1330.2,	1730.2,	2130.2,	2530.2,	2930.2,			

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1021.08	1024.13	1024.13	1027.18	1030.22	1033.27	1036.32	1042.42	1042.42
2530.19	1021.08	1024.13	1027.18	1030.22	1033.27	1036.32	1036.32	1045.46	1048.51
2130.19	1024.13	1027.18	1030.22	1030.22	1036.32	1036.32	1039.37	1045.46	1054.61
1730.19	1027.18	1030.22	1033.27	1036.32	1036.32	1039.37	1042.42	1048.51	1054.61
1330.19	1030.22	1033.27	1036.32	1036.32	1036.32	1042.42	1045.46	1051.56	1057.66
930.19	1033.27	1036.32	1039.37	1039.37	1039.37	1042.42	1042.42	1048.51	1051.56
530.19	1036.32	1036.32	1039.37	1039.37	1039.37	1039.37	1039.37	1045.46	1045.46
130.19	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32
-269.81	1030.22	1030.22	1030.22	1030.22	1030.22	1030.22	1033.27	1036.32	1039.37
-669.81	1024.13	1021.08	1027.18	1027.18	1027.18	1030.22	1030.22	1033.27	1036.32
-1069.81	1021.08	1018.03	1021.08	1024.13	1021.08	1027.18	1030.22	1033.27	1036.32
-1469.81	1018.03	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18	1030.22	1033.27
-1869.81	1014.98	1014.98	1018.03	1018.03	1018.03	1021.08	1024.13	1027.18	1030.22
-2269.81	1011.94	1014.98	1014.98	1018.03	1018.03	1021.08	1021.08	1024.13	1030.22
-2669.81	1011.94	1014.98	1014.98	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18
-3069.81	1011.94	1011.94	1014.98	1014.98	1018.03	1018.03	1018.03	1018.03	1024.13
-3469.81	1008.89	1011.94	1011.94	1014.98	1014.98	1018.03	1014.98	1018.03	1018.03

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1045.46	1045.46	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2530.19	1051.56	1051.56	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2130.19	1054.61	1054.61	1054.61	1057.66	1057.66	1057.66	1060.70	1069.85
1730.19	1057.66	1057.66	1057.66	1060.70	1060.70	1060.70	1063.75	1066.80
1330.19	1057.66	1057.66	1060.70	1063.75	1063.75	1063.75	1066.80	1066.80
930.19	1051.56	1054.61	1057.66	1066.80	1066.80	1066.80	1069.85	1072.90
530.19	1045.46	1051.56	1057.66	1063.75	1069.85	1069.85	1075.94	1078.99
130.19	1042.42	1048.51	1054.61	1060.70	1069.85	1072.90	1078.99	1078.99
-269.81	1042.42	1048.51	1051.56	1063.75	1066.80	1069.85	1075.94	1078.99
-669.81	1039.37	1045.46	1051.56	1060.70	1063.75	1066.80	1069.85	1072.90
-1069.81	1039.37	1042.42	1051.56	1060.70	1057.66	1060.70	1063.75	1066.80
-1469.81	1039.37	1042.42	1051.56	1057.66	1054.61	1057.66	1057.66	1057.66
-1869.81	1039.37	1042.42	1048.51	1057.66	1054.61	1051.56	1051.56	1051.56
-2269.81	1036.32	1039.37	1042.42	1051.56	1051.56	1048.51	1048.51	1048.51
-2669.81	1030.22	1036.32	1039.37	1042.42	1048.51	1048.51	1048.51	1048.51
-3069.81	1027.18	1030.22	1033.27	1039.37	1042.42	1054.61	1048.51	1045.46
-3469.81	1021.08	1027.18	1033.27	1036.32	1042.42	1048.51	1045.46	1042.42

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	ANNUAL WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: WIPP NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00017000	.00000000	.00000000	.00000000	.00000000
90.000	.00019600	.00034000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00034000	.00000000	.00000000	.00000000	.00000000
135.000	.00019600	.00136200	.00000000	.00000000	.00000000	.00000000
157.500	.00039200	.00238300	.00000000	.00000000	.00000000	.00000000
180.000	.00195900	.00187200	.00000000	.00000000	.00000000	.00000000
202.500	.00195900	.00153200	.00000000	.00000000	.00000000	.00000000
225.000	.00215500	.00221300	.00000000	.00000000	.00000000	.00000000
247.500	.00195900	.00119100	.00000000	.00000000	.00000000	.00000000
270.000	.00078400	.00085100	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00068100	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00019600	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00058800	.00017000	.00051100	.00000000	.00000000	.00000000
67.500	.00078400	.00085100	.00017000	.00000000	.00000000	.00000000
90.000	.00156700	.00102100	.00051100	.00000000	.00000000	.00000000
112.500	.00333100	.00306400	.00255300	.00000000	.00000000	.00000000
135.000	.00293900	.00425500	.00425500	.00000000	.00000000	.00000000
157.500	.00293900	.00766000	.00680900	.00000000	.00000000	.00000000
180.000	.00411400	.00697900	.00510600	.00000000	.00000000	.00000000
202.500	.00489800	.00646800	.00306400	.00000000	.00000000	.00000000
225.000	.00391800	.00459600	.00187200	.00000000	.00000000	.00000000
247.500	.00509400	.00527700	.00153200	.00000000	.00000000	.00000000
270.000	.00117600	.00170200	.00204300	.00000000	.00000000	.00000000
292.500	.00098000	.00187200	.00221300	.00000000	.00000000	.00000000
315.000	.00098000	.00102100	.00119100	.00000000	.00000000	.00000000
337.500	.00000000	.00017000	.00000000	.00000000	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: WIPP NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00039200	.00034000	.00000000	.00000000	.00000000	.00000000
22.500	.00019600	.00034000	.00034000	.00000000	.00000000	.00000000
45.000	.00000000	.00068100	.00238300	.00000000	.00000000	.00000000
67.500	.00098000	.00085100	.00102100	.00000000	.00000000	.00000000
90.000	.00137100	.00136200	.00187200	.00000000	.00000000	.00000000
112.500	.00450600	.00391500	.00629800	.00034000	.00000000	.00000000
135.000	.00352700	.00544700	.01787200	.00442600	.00000000	.00000000
157.500	.00450600	.00425500	.01123400	.00289400	.00000000	.00000000
180.000	.00293900	.00595700	.01089400	.00340400	.00017000	.00000000
202.500	.00176300	.00459600	.00595700	.00017000	.00000000	.00000000
225.000	.00313500	.00425500	.00187200	.00017000	.00000000	.00000000
247.500	.00156700	.00340400	.00459600	.00170200	.00000000	.00000000
270.000	.00195900	.00289400	.00204300	.00170200	.00034000	.00000000
292.500	.00137100	.00153200	.00221300	.00000000	.00000000	.00000000
315.000	.00039200	.00136200	.00221300	.00051100	.00000000	.00000000
337.500	.00000000	.00017000	.00034000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00017000	.00017000	.00000000	.00000000	.00000000
22.500	.00000000	.00102100	.00119100	.00102100	.00034000	.00034000
45.000	.00039200	.00255300	.00493600	.00851100	.00153200	.00000000
67.500	.00078400	.00425500	.00595700	.00697900	.00068100	.00017000
90.000	.00313500	.00527700	.01293600	.00987200	.00119100	.00017000
112.500	.00372300	.01293600	.02706400	.01344700	.00136200	.00000000
135.000	.00372300	.01004300	.03285100	.04204300	.00306400	.00000000
157.500	.00176300	.00663800	.01855300	.01991500	.00238300	.00017000
180.000	.00274300	.00612800	.01072300	.00425500	.00051100	.00000000
202.500	.00117600	.00425500	.00731900	.00357400	.00000000	.00000000
225.000	.00019600	.00408500	.00510600	.00340400	.00136200	.00017000
247.500	.00058800	.00357400	.00595700	.01123400	.00306400	.00136200
270.000	.00058800	.00238300	.00527700	.00748900	.00357400	.00187200
292.500	.00039200	.00153200	.00221300	.00238300	.00102100	.00000000
315.000	.00000000	.00068100	.00204300	.00391500	.00136200	.00034000
337.500	.00000000	.00000000	.00034000	.00051100	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: WIPP NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00034000	.00034000	.00000000	.00000000	.00000000
22.500	.00000000	.00017000	.00034000	.00000000	.00000000	.00000000
45.000	.00000000	.00085100	.00187200	.00000000	.00000000	.00000000
67.500	.00000000	.00170200	.00272300	.00000000	.00000000	.00000000
90.000	.00000000	.00272300	.00783000	.00000000	.00000000	.00000000
112.500	.00000000	.00680900	.02314900	.00000000	.00000000	.00000000
135.000	.00000000	.01123400	.02961700	.00000000	.00000000	.00000000
157.500	.00000000	.00868100	.01038300	.00000000	.00000000	.00000000
180.000	.00000000	.00323400	.00238300	.00000000	.00000000	.00000000
202.500	.00000000	.00340400	.00068100	.00000000	.00000000	.00000000
225.000	.00000000	.00221300	.00119100	.00000000	.00000000	.00000000
247.500	.00000000	.00187200	.00442600	.00000000	.00000000	.00000000
270.000	.00000000	.00034000	.00272300	.00000000	.00000000	.00000000
292.500	.00000000	.00068100	.00204300	.00000000	.00000000	.00000000
315.000	.00000000	.00085100	.00170200	.00000000	.00000000	.00000000
337.500	.00000000	.00034000	.00085100	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00051100	.00000000	.00000000	.00000000	.00000000
22.500	.00039200	.00187200	.00000000	.00000000	.00000000	.00000000
45.000	.00156700	.00374500	.00000000	.00000000	.00000000	.00000000
67.500	.00313500	.00476600	.00000000	.00000000	.00000000	.00000000
90.000	.00607400	.00748900	.00000000	.00000000	.00000000	.00000000
112.500	.01097200	.02059600	.00000000	.00000000	.00000000	.00000000
135.000	.01195100	.02348900	.00000000	.00000000	.00000000	.00000000
157.500	.01136400	.01293600	.00000000	.00000000	.00000000	.00000000
180.000	.00881700	.00561700	.00000000	.00000000	.00000000	.00000000
202.500	.00607400	.00357400	.00000000	.00000000	.00000000	.00000000
225.000	.00470200	.00493600	.00000000	.00000000	.00000000	.00000000
247.500	.00450600	.00510600	.00000000	.00000000	.00000000	.00000000
270.000	.00254700	.00272300	.00000000	.00000000	.00000000	.00000000
292.500	.00176300	.00238300	.00000000	.00000000	.00000000	.00000000
315.000	.00195900	.00238300	.00000000	.00000000	.00000000	.00000000
337.500	.00058800	.00187200	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99999

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	.065769	.075666	.075780	.079804	.081915	.081094	.081777	.083849	.070873
2530.19	.067632	.081635	.095510	.102764	.107807	.108443	.099799	.110719	.095228
2130.19	.073869	.090523	.112253	.124712	.145173	.138825	.136338	.142826	.120694
1730.19	.079878	.099408	.125793	.161919	.185073	.199953	.199806	.204437	.159140
1330.19	.085004	.107306	.138573	.169472	.211444	.300336	.322220	.298857	.224387
930.19	.080948	.106643	.145621	.185914	.240418	.359329	.451964	.483030	.350081
530.19	.072245	.088150	.120204	.158123	.218275	.317410	.476453	.917824	.612324
130.19	.054653	.064879	.078691	.098137	.126338	.171871	.258387	.463141	1.323298
-269.81	.037627	.042552	.048406	.055372	.062816	.070488	.086707	.135155	.008444
-669.81	.026443	.026068	.033451	.035338	.036063	.046215	.054874	.037382	.007953
-1069.81	.019342	.018214	.020776	.024879	.024502	.032864	.030024	.011820	.006235
-1469.81	.014561	.014330	.016571	.019192	.020345	.019743	.013360	.007162	.004183
-1869.81	.012035	.012644	.014329	.014919	.013677	.011276	.006051	.004785	.002989
-2269.81	.009958	.011094	.011439	.011572	.009621	.007182	.004134	.003390	.002423
-2669.81	.008863	.009715	.009233	.008065	.006831	.004607	.003366	.002752	.001864
-3069.81	.007879	.007546	.007273	.006108	.004879	.003072	.002554	.001935	.001479
-3469.81	.006286	.006149	.005374	.004656	.003229	.002601	.001989	.001650	.001123

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	.066410	.056593	.048034	.043285	.038518	.034008	.029928	.027224
2530.19	.082451	.067745	.056212	.049549	.043027	.037143	.033284	.030229
2130.19	.101205	.079013	.066837	.056789	.047865	.042030	.037472	.033408
1730.19	.127230	.096333	.080074	.065013	.055390	.048156	.041883	.036636
1330.19	.164793	.123308	.095632	.077998	.065039	.054529	.046222	.039642
930.19	.223003	.159887	.120366	.094147	.074690	.058938	.046259	.037427
530.19	.319253	.219602	.150175	.100331	.071171	.053443	.041806	.033791
130.19	.383190	.209957	.120484	.080131	.057873	.044206	.035118	.028769
-269.81	.124966	.111276	.080921	.059900	.045995	.036565	.029873	.024988
-669.81	.034933	.068361	.055900	.042052	.035401	.029833	.025326	.021767
-1069.81	.012542	.034125	.044029	.035685	.028957	.023784	.020545	.018336
-1469.81	.009032	.018355	.029486	.029455	.025083	.021319	.018228	.015741
-1869.81	.006659	.010426	.018769	.021687	.021414	.018801	.016506	.014526
-2269.81	.004544	.006680	.010799	.015312	.016718	.016477	.014803	.013270
-2669.81	.002962	.004742	.006755	.009889	.012624	.013419	.013210	.012050
-3069.81	.002251	.003177	.004158	.006800	.008794	.010596	.011077	.010600
-3469.81	.001605	.002434	.003479	.004744	.006831	.008440	.008778	.008703

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	1.323298	AT (	10.47,	130.19)	GC	6.	.463141	AT (	-389.53,	130.19)	GC
2.	.917824	AT (	-389.53,	530.19)	GC	7.	.451964	AT (	-789.53,	930.19)	GC
3.	.612324	AT (	10.47,	530.19)	GC	8.	.383190	AT (	410.47,	130.19)	GC
4.	.483030	AT (	-389.53,	930.19)	GC	9.	.359329	AT (	-1189.53,	930.19)	GC
5.	.476453	AT (	-789.53,	530.19)	GC	10.	.350081	AT (	10.47,	930.19)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

18
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE CONCENTRATIONS AT THE WIPP SITE BOUNDARY (90 Carlsbad Met)
CO TITLETWO Coarse Receptor Grid(400x400m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -3189.53 17 400.00 -3469.81 17 400.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
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RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50			
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50			
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50			
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50			
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50			
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50			
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50			
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50			
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50

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RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50
RE GRIDCART COARSE   ELEV 1   3310.00   3320.00   3320.00   3330.00
RE GRIDCART COARSE   ELEV 1   3330.00   3340.00   3330.00   3340.00
RE GRIDCART COARSE   ELEV 1   3340.00   3350.00   3370.00   3390.00
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RE GRIDCART COARSE   ELEV 1  3400.00  3420.00  3440.00  3430.00
RE GRIDCART COARSE   ELEV 1  3420.00
RE GRIDCART COARSE   ELEV 2  3320.00  3320.00  3330.00  3330.00
RE GRIDCART COARSE   ELEV 2  3340.00  3340.00  3340.00  3340.00
RE GRIDCART COARSE   ELEV 2  3360.00  3370.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 2  3410.00  3420.00  3460.00  3440.00
RE GRIDCART COARSE   ELEV 2  3430.00
RE GRIDCART COARSE   ELEV 3  3320.00  3330.00  3330.00  3330.00
RE GRIDCART COARSE   ELEV 3  3340.00  3350.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 3  3370.00  3380.00  3400.00  3410.00
RE GRIDCART COARSE   ELEV 3  3420.00  3440.00  3440.00  3440.00
RE GRIDCART COARSE   ELEV 3  3440.00
RE GRIDCART COARSE   ELEV 4  3320.00  3330.00  3330.00  3340.00
RE GRIDCART COARSE   ELEV 4  3340.00  3350.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 4  3380.00  3400.00  3410.00  3420.00
RE GRIDCART COARSE   ELEV 4  3450.00  3450.00  3440.00  3440.00
RE GRIDCART COARSE   ELEV 4  3440.00
RE GRIDCART COARSE   ELEV 5  3330.00  3330.00  3340.00  3340.00
RE GRIDCART COARSE   ELEV 5  3340.00  3350.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 5  3380.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 5  3470.00  3460.00  3450.00  3450.00
RE GRIDCART COARSE   ELEV 5  3450.00
RE GRIDCART COARSE   ELEV 6  3340.00  3330.00  3340.00  3350.00
RE GRIDCART COARSE   ELEV 6  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 6  3390.00  3410.00  3420.00  3450.00
RE GRIDCART COARSE   ELEV 6  3470.00  3460.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 6  3470.00
RE GRIDCART COARSE   ELEV 7  3350.00  3340.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 7  3350.00  3370.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 7  3400.00  3410.00  3420.00  3450.00
RE GRIDCART COARSE   ELEV 7  3480.00  3470.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 7  3500.00
RE GRIDCART COARSE   ELEV 8  3360.00  3350.00  3370.00  3370.00
RE GRIDCART COARSE   ELEV 8  3370.00  3380.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 8  3400.00  3410.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 8  3480.00  3490.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 8  3520.00
RE GRIDCART COARSE   ELEV 9  3380.00  3380.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 9  3380.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 9  3410.00  3420.00  3440.00  3450.00
RE GRIDCART COARSE   ELEV 9  3490.00  3500.00  3510.00  3530.00
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RE GRIDCART COARSE   ELEV 9  3540.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3420.00  3440.00  3460.00
RE GRIDCART COARSE   ELEV 10  3480.00  3510.00  3520.00  3540.00
RE GRIDCART COARSE   ELEV 10  3540.00
RE GRIDCART COARSE   ELEV 11  3400.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 11  3430.00  3430.00  3450.00  3470.00
RE GRIDCART COARSE   ELEV 11  3490.00  3510.00  3510.00  3530.00
RE GRIDCART COARSE   ELEV 11  3540.00
RE GRIDCART COARSE   ELEV 12  3390.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3420.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 12  3450.00  3450.00  3460.00  3470.00
RE GRIDCART COARSE   ELEV 12  3500.00  3500.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 12  3520.00
RE GRIDCART COARSE   ELEV 13  3380.00  3390.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 13  3400.00  3420.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 13  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 13  3490.00  3490.00  3490.00  3500.00
RE GRIDCART COARSE   ELEV 13  3500.00
RE GRIDCART COARSE   ELEV 14  3370.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 14  3400.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 14  3460.00  3470.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 14  3480.00  3480.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 14  3500.00
RE GRIDCART COARSE   ELEV 15  3360.00  3370.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 15  3400.00  3400.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 15  3460.00  3460.00  3460.00  3460.00
RE GRIDCART COARSE   ELEV 15  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 15  3510.00
RE GRIDCART COARSE   ELEV 16  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 16  3390.00  3400.00  3400.00  3430.00
RE GRIDCART COARSE   ELEV 16  3440.00  3450.00  3450.00  3440.00
RE GRIDCART COARSE   ELEV 16  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 16  3510.00
RE GRIDCART COARSE   ELEV 17  3350.00  3360.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 17  3380.00  3390.00  3400.00  3420.00
RE GRIDCART COARSE   ELEV 17  3420.00  3430.00  3430.00  3440.00
RE GRIDCART COARSE   ELEV 17  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 17  3510.00
```

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RE GRIDCART COARSE   END

RE FINISHED

ME STARTING

ME INPUTFIL C:\MODELS\MET\CBD90.STR (7X,6F7.5)

ME ANEMHGHT   10.000 METERS

ME SURFDATA 11111 1990 CARLSBAD

ME UAIRDATA 11111 1990

ME STARDATA ANNUAL

ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50

ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80

ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01

ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03

ME FINISHED

OU STARTING

OU RECTABLE SRCGRP

OU MAXTABLE 10 SRCGRP

OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMCC90A.GPH 70

OU FINISHED

***********************************
*** SETUP Finishes Successfully ***
***********************************
```

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

- -

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates 1 STAR Average(s) for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**Data File Includes 1 STAR Summaries for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**This Run Includes: 2 Source(s); 1 Source Group(s); and 289 Receptor(s)

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs: Anem. Hgt. (m) = 10.00 ; Decay Coef. = .0000 ; Rot. Angle = .0
Emission Units = GRAMS/SEC ; Emission Rate Unit Factor = .10000E+07
Output Units = MICROGRAMS/M**3

**Input Runstream File: ADMCC90A.DAT ; **Output Print File: ADMCC90A.LST

2
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

4
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-3189.5,	-2789.5,	-2389.5,	-1989.5,	-1589.5,	-1189.5,	-789.5,	-389.5,	10.5,	410.5,
810.5,	1210.5,	1610.5,	2010.5,	2410.5,	2810.5,	3210.5,			

*** Y-COORDINATES OF GRID ***
(METERS)

-3469.8,	-3069.8,	-2669.8,	-2269.8,	-1869.8,	-1469.8,	-1069.8,	-669.8,	-269.8,	130.2,
530.2,	930.2,	1330.2,	1730.2,	2130.2,	2530.2,	2930.2,			

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1021.08	1024.13	1024.13	1027.18	1030.22	1033.27	1036.32	1042.42	1042.42
2530.19	1021.08	1024.13	1027.18	1030.22	1033.27	1036.32	1036.32	1045.46	1048.51
2130.19	1024.13	1027.18	1030.22	1030.22	1036.32	1036.32	1039.37	1045.46	1054.61
1730.19	1027.18	1030.22	1033.27	1036.32	1036.32	1039.37	1042.42	1048.51	1054.61
1330.19	1030.22	1033.27	1036.32	1036.32	1036.32	1042.42	1045.46	1051.56	1057.66
930.19	1033.27	1036.32	1039.37	1039.37	1039.37	1042.42	1042.42	1048.51	1051.56
530.19	1036.32	1036.32	1039.37	1039.37	1039.37	1039.37	1039.37	1045.46	1045.46
130.19	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32
-269.81	1030.22	1030.22	1030.22	1030.22	1030.22	1030.22	1033.27	1036.32	1039.37
-669.81	1024.13	1021.08	1027.18	1027.18	1027.18	1030.22	1030.22	1033.27	1036.32
-1069.81	1021.08	1018.03	1021.08	1024.13	1021.08	1027.18	1030.22	1033.27	1036.32
-1469.81	1018.03	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18	1030.22	1033.27
-1869.81	1014.98	1014.98	1018.03	1018.03	1018.03	1021.08	1024.13	1027.18	1030.22
-2269.81	1011.94	1014.98	1014.98	1018.03	1018.03	1021.08	1021.08	1024.13	1030.22
-2669.81	1011.94	1014.98	1014.98	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18
-3069.81	1011.94	1011.94	1014.98	1014.98	1018.03	1018.03	1018.03	1018.03	1024.13
-3469.81	1008.89	1011.94	1011.94	1014.98	1014.98	1018.03	1014.98	1018.03	1018.03

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1045.46	1045.46	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2530.19	1051.56	1051.56	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2130.19	1054.61	1054.61	1054.61	1057.66	1057.66	1057.66	1060.70	1069.85
1730.19	1057.66	1057.66	1057.66	1060.70	1060.70	1060.70	1063.75	1066.80
1330.19	1057.66	1057.66	1060.70	1063.75	1063.75	1063.75	1066.80	1066.80
930.19	1051.56	1054.61	1057.66	1066.80	1066.80	1066.80	1069.85	1072.90
530.19	1045.46	1051.56	1057.66	1063.75	1069.85	1069.85	1075.94	1078.99
130.19	1042.42	1048.51	1054.61	1060.70	1069.85	1072.90	1078.99	1078.99
-269.81	1042.42	1048.51	1051.56	1063.75	1066.80	1069.85	1075.94	1078.99
-669.81	1039.37	1045.46	1051.56	1060.70	1063.75	1066.80	1069.85	1072.90
-1069.81	1039.37	1042.42	1051.56	1060.70	1057.66	1060.70	1063.75	1066.80
-1469.81	1039.37	1042.42	1051.56	1057.66	1054.61	1057.66	1057.66	1057.66
-1869.81	1039.37	1042.42	1048.51	1057.66	1054.61	1051.56	1051.56	1051.56
-2269.81	1036.32	1039.37	1042.42	1051.56	1051.56	1048.51	1048.51	1048.51
-2669.81	1030.22	1036.32	1039.37	1042.42	1048.51	1048.51	1048.51	1048.51
-3069.81	1027.18	1030.22	1033.27	1039.37	1042.42	1054.61	1048.51	1045.46
-3469.81	1021.08	1027.18	1033.27	1036.32	1042.42	1048.51	1045.46	1042.42

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	ANNUAL					
	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1990 YEAR: 1990

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00064000	.00083000	.00000000	.00000000	.00000000	.00000000
22.500	.00018000	.00024000	.00000000	.00000000	.00000000	.00000000
45.000	.00066000	.00059000	.00000000	.00000000	.00000000	.00000000
67.500	.00048000	.00035000	.00000000	.00000000	.00000000	.00000000
90.000	.00094000	.00095000	.00000000	.00000000	.00000000	.00000000
112.500	.00057000	.00047000	.00000000	.00000000	.00000000	.00000000
135.000	.00126000	.00083000	.00000000	.00000000	.00000000	.00000000
157.500	.00045000	.00059000	.00000000	.00000000	.00000000	.00000000
180.000	.00066000	.00059000	.00000000	.00000000	.00000000	.00000000
202.500	.00018000	.00024000	.00000000	.00000000	.00000000	.00000000
225.000	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
247.500	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
270.000	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00036000	.00047000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00103000	.00213000	.00189000	.00000000	.00000000	.00000000
22.500	.00130000	.00213000	.00071000	.00000000	.00000000	.00000000
45.000	.00083000	.00177000	.00118000	.00000000	.00000000	.00000000
67.500	.00118000	.00307000	.00106000	.00000000	.00000000	.00000000
90.000	.00169000	.00284000	.00130000	.00000000	.00000000	.00000000
112.500	.00105000	.00402000	.00189000	.00000000	.00000000	.00000000
135.000	.00116000	.00556000	.00355000	.00000000	.00000000	.00000000
157.500	.00225000	.00721000	.00343000	.00000000	.00000000	.00000000
180.000	.00248000	.00520000	.00343000	.00000000	.00000000	.00000000
202.500	.00039000	.00071000	.00095000	.00000000	.00000000	.00000000
225.000	.00043000	.00095000	.00012000	.00000000	.00000000	.00000000
247.500	.00009000	.00059000	.00024000	.00000000	.00000000	.00000000
270.000	.00035000	.00047000	.00035000	.00000000	.00000000	.00000000
292.500	.00045000	.00024000	.00024000	.00000000	.00000000	.00000000
315.000	.00034000	.00130000	.00012000	.00000000	.00000000	.00000000
337.500	.00071000	.00189000	.00071000	.00000000	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1990 YEAR: 1990

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00080000	.00366000	.00816000	.00248000	.00012000	.00000000
22.500	.00035000	.00284000	.00343000	.00059000	.00000000	.00000000
45.000	.00025000	.00319000	.00118000	.00012000	.00000000	.00000000
67.500	.00036000	.00296000	.00130000	.00000000	.00000000	.00000000
90.000	.00056000	.00390000	.00343000	.00071000	.00000000	.00000000
112.500	.00067000	.00366000	.00473000	.00142000	.00000000	.00000000
135.000	.00029000	.00366000	.01017000	.00355000	.00012000	.00000000
157.500	.00069000	.00556000	.01324000	.00248000	.00035000	.00000000
180.000	.00040000	.00508000	.01206000	.00284000	.00024000	.00000000
202.500	.00034000	.00106000	.00106000	.00071000	.00000000	.00000000
225.000	.00016000	.00047000	.00047000	.00012000	.00024000	.00000000
247.500	.00030000	.00059000	.00177000	.00083000	.00071000	.00047000
270.000	.00047000	.00118000	.00225000	.00213000	.00165000	.00071000
292.500	.00031000	.00071000	.00083000	.00083000	.00024000	.00000000
315.000	.00035000	.00118000	.00095000	.00035000	.00000000	.00000000
337.500	.00033000	.00095000	.00189000	.00059000	.00012000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00043000	.00461000	.00875000	.01572000	.00307000	.00059000
22.500	.00042000	.00248000	.00402000	.00449000	.00047000	.00035000
45.000	.00044000	.00284000	.00496000	.00343000	.00035000	.00012000
67.500	.00037000	.00177000	.00366000	.00201000	.00000000	.00000000
90.000	.00058000	.00307000	.00579000	.00496000	.00035000	.00000000
112.500	.00042000	.00248000	.00603000	.00378000	.00035000	.00000000
135.000	.00100000	.00556000	.01312000	.01820000	.00201000	.00059000
157.500	.00073000	.00520000	.02506000	.02376000	.00225000	.00024000
180.000	.00096000	.00496000	.01962000	.01466000	.00071000	.00047000
202.500	.00028000	.00225000	.00319000	.00366000	.00118000	.00035000
225.000	.00064000	.00201000	.00390000	.00319000	.00106000	.00024000
247.500	.00034000	.00130000	.00544000	.01253000	.00532000	.00189000
270.000	.00021000	.00307000	.00768000	.02624000	.01548000	.00662000
292.500	.00049000	.00165000	.00402000	.00922000	.00213000	.00071000
315.000	.00039000	.00213000	.00366000	.00485000	.00047000	.00012000
337.500	.00046000	.00307000	.00721000	.00969000	.00414000	.00059000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111
NAME: CARLSBAD
YEAR: 1990

UPPER AIR STATION NO.: 11111
NAME: UNKNOWN
YEAR: 1990

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00390000	.00473000	.00000000	.00000000	.00000000
22.500	.00000000	.00130000	.00130000	.00000000	.00000000	.00000000
45.000	.00000000	.00071000	.00118000	.00000000	.00000000	.00000000
67.500	.00000000	.00118000	.00154000	.00000000	.00000000	.00000000
90.000	.00000000	.00165000	.00189000	.00000000	.00000000	.00000000
112.500	.00000000	.00154000	.00236000	.00000000	.00000000	.00000000
135.000	.00000000	.00414000	.00863000	.00000000	.00000000	.00000000
157.500	.00000000	.00721000	.01797000	.00000000	.00000000	.00000000
180.000	.00000000	.01005000	.02364000	.00000000	.00000000	.00000000
202.500	.00000000	.00284000	.00934000	.00000000	.00000000	.00000000
225.000	.00000000	.00366000	.00792000	.00000000	.00000000	.00000000
247.500	.00000000	.00236000	.01206000	.00000000	.00000000	.00000000
270.000	.00000000	.00390000	.01478000	.00000000	.00000000	.00000000
292.500	.00000000	.00461000	.01229000	.00000000	.00000000	.00000000
315.000	.00000000	.00260000	.00603000	.00000000	.00000000	.00000000
337.500	.00000000	.00154000	.00402000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00468000	.00993000	.00000000	.00000000	.00000000	.00000000
22.500	.00242000	.00520000	.00000000	.00000000	.00000000	.00000000
45.000	.00155000	.00201000	.00000000	.00000000	.00000000	.00000000
67.500	.00120000	.00248000	.00000000	.00000000	.00000000	.00000000
90.000	.00258000	.00390000	.00000000	.00000000	.00000000	.00000000
112.500	.00174000	.00461000	.00000000	.00000000	.00000000	.00000000
135.000	.00246000	.00745000	.00000000	.00000000	.00000000	.00000000
157.500	.00425000	.01430000	.00000000	.00000000	.00000000	.00000000
180.000	.00608000	.02352000	.00000000	.00000000	.00000000	.00000000
202.500	.00264000	.00981000	.00000000	.00000000	.00000000	.00000000
225.000	.00254000	.00674000	.00000000	.00000000	.00000000	.00000000
247.500	.00388000	.00768000	.00000000	.00000000	.00000000	.00000000
270.000	.00378000	.01312000	.00000000	.00000000	.00000000	.00000000
292.500	.00431000	.01678000	.00000000	.00000000	.00000000	.00000000
315.000	.00265000	.00827000	.00000000	.00000000	.00000000	.00000000
337.500	.00287000	.00603000	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99995

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	.022464	.028361	.034472	.044335	.056847	.072193	.089532	.113674	.123982
2530.19	.021706	.027825	.036289	.048397	.064506	.085263	.103321	.143887	.164025
2130.19	.021497	.028269	.037662	.048331	.072147	.094252	.128997	.178953	.210257
1730.19	.020338	.027520	.037958	.053405	.072924	.109823	.163067	.239090	.280215
1330.19	.017830	.024912	.035751	.049487	.070491	.122227	.206454	.322363	.406299
930.19	.020287	.025082	.031689	.043172	.066094	.116623	.205432	.445746	.660715
530.19	.022812	.026786	.034521	.042627	.054131	.076806	.160422	.531248	1.217078
130.19	.023551	.027818	.033536	.041513	.052964	.071434	.106884	.194960	2.262964
-269.81	.018822	.021657	.025233	.029875	.035789	.044056	.061384	.121488	.523172
-669.81	.013823	.014191	.018360	.020379	.022538	.033083	.048256	.075833	.218682
-1069.81	.010565	.010474	.012567	.016347	.018645	.028092	.039994	.062925	.145736
-1469.81	.008578	.009208	.011458	.014534	.017467	.023013	.030569	.053754	.096444
-1869.81	.007895	.008965	.010988	.012721	.014909	.018936	.024112	.044123	.069358
-2269.81	.007203	.008599	.009721	.011948	.013776	.017139	.022168	.036036	.057429
-2669.81	.006930	.008164	.009232	.010476	.012784	.015636	.021766	.032461	.044529
-3069.81	.006619	.007370	.008804	.009858	.011860	.013885	.019154	.024798	.035557
-3469.81	.006032	.007087	.007842	.009288	.010208	.013889	.016755	.022596	.026799

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	.100222	.070500	.044037	.039338	.034801	.030574	.026843	.024955
2530.19	.120657	.077389	.051090	.044829	.038671	.033196	.030467	.028556
2130.19	.143723	.079188	.060532	.050928	.042671	.038511	.035514	.032549
1730.19	.170609	.088108	.072023	.057753	.050757	.045906	.041166	.036917
1330.19	.197812	.111353	.084735	.071653	.062466	.054197	.047211	.041463
930.19	.207465	.141859	.110917	.091540	.075443	.064470	.056715	.050016
530.19	.286015	.203941	.148718	.121117	.098925	.081786	.068598	.058484
130.19	.409863	.352419	.232682	.165746	.124619	.097972	.079483	.066194
-269.81	.225604	.322464	.229455	.166763	.126264	.099530	.080818	.067300
-669.81	.126210	.152287	.164296	.141260	.113140	.092062	.076270	.064401
-1069.81	.101663	.090620	.099557	.098313	.090134	.080547	.069933	.060250
-1469.81	.087050	.072617	.072669	.065999	.066279	.062950	.058367	.053647
-1869.81	.073077	.058039	.059140	.051543	.047717	.048254	.046881	.044560
-2269.81	.056408	.047125	.043377	.043766	.038914	.036567	.037192	.036585
-2669.81	.041113	.039159	.034253	.033893	.034059	.030823	.029233	.029783
-3069.81	.033470	.030403	.026559	.027766	.027440	.027522	.025211	.023402
-3469.81	.025618	.025710	.024794	.023044	.024340	.024603	.022222	.019694

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	2.262964	AT (	10.47,	130.19)	GC	6.	.445746	AT (	-389.53,	930.19)	GC
2.	1.217078	AT (	10.47,	530.19)	GC	7.	.409863	AT (	410.47,	130.19)	GC
3.	.660715	AT (	10.47,	930.19)	GC	8.	.406299	AT (	10.47,	1330.19)	GC
4.	.531248	AT (	-389.53,	530.19)	GC	9.	.352419	AT (	810.47,	130.19)	GC
5.	.523172	AT (	10.47,	-269.81)	GC	10.	.322464	AT (	810.47,	-269.81)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE CONCENTRATIONS AT THE WIPP SITE BOUNDARY (91 Carlsbad Met)
CO TITLETWO Coarse Receptor Grid(400x400m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -3189.53 17 400.00 -3469.81 17 400.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
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RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50			
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50			
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50			
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50			
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50			
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50			
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50			
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50			
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50

RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50			
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50			
RE GRIDCART COARSE	FLAG 12	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 12	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 12	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 12	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 12	1.50			
RE GRIDCART COARSE	FLAG 13	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 13	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 13	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 13	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 13	1.50			
RE GRIDCART COARSE	FLAG 14	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 14	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 14	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 14	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 14	1.50			
RE GRIDCART COARSE	FLAG 15	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 15	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 15	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 15	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 15	1.50			
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50			
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50			
RE GRIDCART COARSE	ELEV 1	3310.00	3320.00	3320.00	3330.00
RE GRIDCART COARSE	ELEV 1	3330.00	3340.00	3330.00	3340.00
RE GRIDCART COARSE	ELEV 1	3340.00	3350.00	3370.00	3390.00

RE GRIDCART COARSE	ELEV 1	3400.00	3420.00	3440.00	3430.00
RE GRIDCART COARSE	ELEV 1	3420.00			
RE GRIDCART COARSE	ELEV 2	3320.00	3320.00	3330.00	3330.00
RE GRIDCART COARSE	ELEV 2	3340.00	3340.00	3340.00	3340.00
RE GRIDCART COARSE	ELEV 2	3360.00	3370.00	3380.00	3390.00
RE GRIDCART COARSE	ELEV 2	3410.00	3420.00	3460.00	3440.00
RE GRIDCART COARSE	ELEV 2	3430.00			
RE GRIDCART COARSE	ELEV 3	3320.00	3330.00	3330.00	3330.00
RE GRIDCART COARSE	ELEV 3	3340.00	3350.00	3350.00	3360.00
RE GRIDCART COARSE	ELEV 3	3370.00	3380.00	3400.00	3410.00
RE GRIDCART COARSE	ELEV 3	3420.00	3440.00	3440.00	3440.00
RE GRIDCART COARSE	ELEV 3	3440.00			
RE GRIDCART COARSE	ELEV 4	3320.00	3330.00	3330.00	3340.00
RE GRIDCART COARSE	ELEV 4	3340.00	3350.00	3350.00	3360.00
RE GRIDCART COARSE	ELEV 4	3380.00	3400.00	3410.00	3420.00
RE GRIDCART COARSE	ELEV 4	3450.00	3450.00	3440.00	3440.00
RE GRIDCART COARSE	ELEV 4	3440.00			
RE GRIDCART COARSE	ELEV 5	3330.00	3330.00	3340.00	3340.00
RE GRIDCART COARSE	ELEV 5	3340.00	3350.00	3360.00	3370.00
RE GRIDCART COARSE	ELEV 5	3380.00	3410.00	3420.00	3440.00
RE GRIDCART COARSE	ELEV 5	3470.00	3460.00	3450.00	3450.00
RE GRIDCART COARSE	ELEV 5	3450.00			
RE GRIDCART COARSE	ELEV 6	3340.00	3330.00	3340.00	3350.00
RE GRIDCART COARSE	ELEV 6	3350.00	3360.00	3370.00	3380.00
RE GRIDCART COARSE	ELEV 6	3390.00	3410.00	3420.00	3450.00
RE GRIDCART COARSE	ELEV 6	3470.00	3460.00	3470.00	3470.00
RE GRIDCART COARSE	ELEV 6	3470.00			
RE GRIDCART COARSE	ELEV 7	3350.00	3340.00	3350.00	3360.00
RE GRIDCART COARSE	ELEV 7	3350.00	3370.00	3380.00	3390.00
RE GRIDCART COARSE	ELEV 7	3400.00	3410.00	3420.00	3450.00
RE GRIDCART COARSE	ELEV 7	3480.00	3470.00	3480.00	3490.00
RE GRIDCART COARSE	ELEV 7	3500.00			
RE GRIDCART COARSE	ELEV 8	3360.00	3350.00	3370.00	3370.00
RE GRIDCART COARSE	ELEV 8	3370.00	3380.00	3380.00	3390.00
RE GRIDCART COARSE	ELEV 8	3400.00	3410.00	3430.00	3450.00
RE GRIDCART COARSE	ELEV 8	3480.00	3490.00	3500.00	3510.00
RE GRIDCART COARSE	ELEV 8	3520.00			
RE GRIDCART COARSE	ELEV 9	3380.00	3380.00	3380.00	3380.00
RE GRIDCART COARSE	ELEV 9	3380.00	3380.00	3390.00	3400.00
RE GRIDCART COARSE	ELEV 9	3410.00	3420.00	3440.00	3450.00
RE GRIDCART COARSE	ELEV 9	3490.00	3500.00	3510.00	3530.00

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RE GRIDCART COARSE   ELEV 9  3540.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3420.00  3440.00  3460.00
RE GRIDCART COARSE   ELEV 10  3480.00  3510.00  3520.00  3540.00
RE GRIDCART COARSE   ELEV 10  3540.00
RE GRIDCART COARSE   ELEV 11  3400.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 11  3430.00  3430.00  3450.00  3470.00
RE GRIDCART COARSE   ELEV 11  3490.00  3510.00  3510.00  3530.00
RE GRIDCART COARSE   ELEV 11  3540.00
RE GRIDCART COARSE   ELEV 12  3390.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3420.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 12  3450.00  3450.00  3460.00  3470.00
RE GRIDCART COARSE   ELEV 12  3500.00  3500.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 12  3520.00
RE GRIDCART COARSE   ELEV 13  3380.00  3390.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 13  3400.00  3420.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 13  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 13  3490.00  3490.00  3490.00  3500.00
RE GRIDCART COARSE   ELEV 13  3500.00
RE GRIDCART COARSE   ELEV 14  3370.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 14  3400.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 14  3460.00  3470.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 14  3480.00  3480.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 14  3500.00
RE GRIDCART COARSE   ELEV 15  3360.00  3370.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 15  3400.00  3400.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 15  3460.00  3460.00  3460.00  3460.00
RE GRIDCART COARSE   ELEV 15  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 15  3510.00
RE GRIDCART COARSE   ELEV 16  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 16  3390.00  3400.00  3400.00  3430.00
RE GRIDCART COARSE   ELEV 16  3440.00  3450.00  3450.00  3440.00
RE GRIDCART COARSE   ELEV 16  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 16  3510.00
RE GRIDCART COARSE   ELEV 17  3350.00  3360.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 17  3380.00  3390.00  3400.00  3420.00
RE GRIDCART COARSE   ELEV 17  3420.00  3430.00  3430.00  3440.00
RE GRIDCART COARSE   ELEV 17  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 17  3510.00
```

```
RE GRIDCART COARSE   END

RE FINISHED

ME STARTING

ME INPUTFIL C:\MODELS\MET\CBD91.STR (7X,6F7.5)

ME ANEMHGHT   10.000 METERS

ME SURFDATA 11111 1991 CARLSBAD

ME UAIRDATA 11111 1991

ME STARDATA ANNUAL

ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50

ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80

ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01

ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03

ME FINISHED

OU STARTING

OU RECTABLE SRCGRP

OU MAXTABLE 10 SRCGRP

OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMCC91A.GPH 70

OU FINISHED

************************************
*** SETUP Finishes Successfully ***
************************************
```

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

```
**Model Calculates   1 STAR Average(s) for the Following Months:  0  0  0  0  0  0  0  0  0  0  0  0
                                          Seasons/Quarters:  0  0  0  0
                                                and Annual:  1

**Data File Includes  1 STAR Summaries for the Following Months:  0  0  0  0  0  0  0  0  0  0  0  0
                                          Seasons/Quarters:  0  0  0  0
                                                and Annual:  1
```

**This Run Includes: 2 Source(s); 1 Source Group(s); and 289 Receptor(s)

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

```
**Misc. Inputs:  Anem. Hgt. (m) =    10.00 ;    Decay Coef. =    .0000     ;    Rot. Angle =      .0
                 Emission Units = GRAMS/SEC                                ;  Emission Rate Unit Factor =    .10000E+07
                 Output Units   = MICROGRAMS/M**3
```

**Input Runstream File: ADMCC91A.DAT ; **Output Print File: ADMCC91A.LST

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-3189.5,	-2789.5,	-2389.5,	-1989.5,	-1589.5,	-1189.5,	-789.5,	-389.5,	10.5,	410.5,
810.5,	1210.5,	1610.5,	2010.5,	2410.5,	2810.5,	3210.5,			

*** Y-COORDINATES OF GRID ***
(METERS)

-3469.8,	-3069.8,	-2669.8,	-2269.8,	-1869.8,	-1469.8,	-1069.8,	-669.8,	-269.8,	130.2,
530.2,	930.2,	1330.2,	1730.2,	2130.2,	2530.2,	2930.2,			

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1021.08	1024.13	1024.13	1027.18	1030.22	1033.27	1036.32	1042.42	1042.42
2530.19	1021.08	1024.13	1027.18	1030.22	1033.27	1036.32	1036.32	1045.46	1048.51
2130.19	1024.13	1027.18	1030.22	1030.22	1036.32	1036.32	1039.37	1045.46	1054.61
1730.19	1027.18	1030.22	1033.27	1036.32	1036.32	1039.37	1042.42	1048.51	1054.61
1330.19	1030.22	1033.27	1036.32	1036.32	1036.32	1042.42	1045.46	1051.56	1057.66
930.19	1033.27	1036.32	1039.37	1039.37	1039.37	1042.42	1042.42	1048.51	1051.56
530.19	1036.32	1036.32	1039.37	1039.37	1039.37	1039.37	1039.37	1045.46	1045.46
130.19	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32
-269.81	1030.22	1030.22	1030.22	1030.22	1030.22	1030.22	1033.27	1036.32	1039.37
-669.81	1024.13	1021.08	1027.18	1027.18	1027.18	1030.22	1030.22	1033.27	1036.32
-1069.81	1021.08	1018.03	1021.08	1024.13	1021.08	1027.18	1030.22	1033.27	1036.32
-1469.81	1018.03	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18	1030.22	1033.27
-1869.81	1014.98	1014.98	1018.03	1018.03	1018.03	1021.08	1024.13	1027.18	1030.22
-2269.81	1011.94	1014.98	1014.98	1018.03	1018.03	1021.08	1021.08	1024.13	1030.22
-2669.81	1011.94	1014.98	1014.98	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18
-3069.81	1011.94	1011.94	1014.98	1014.98	1018.03	1018.03	1018.03	1018.03	1024.13
-3469.81	1008.89	1011.94	1011.94	1014.98	1014.98	1018.03	1014.98	1018.03	1018.03

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1045.46	1045.46	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2530.19	1051.56	1051.56	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2130.19	1054.61	1054.61	1054.61	1057.66	1057.66	1057.66	1060.70	1069.85
1730.19	1057.66	1057.66	1057.66	1060.70	1060.70	1060.70	1063.75	1066.80
1330.19	1057.66	1057.66	1060.70	1063.75	1063.75	1063.75	1066.80	1066.80
930.19	1051.56	1054.61	1057.66	1066.80	1066.80	1066.80	1069.85	1072.90
530.19	1045.46	1051.56	1057.66	1063.75	1069.85	1069.85	1075.94	1078.99
130.19	1042.42	1048.51	1054.61	1060.70	1069.85	1072.90	1078.99	1078.99
-269.81	1042.42	1048.51	1051.56	1063.75	1066.80	1069.85	1075.94	1078.99
-669.81	1039.37	1045.46	1051.56	1060.70	1063.75	1066.80	1069.85	1072.90
-1069.81	1039.37	1042.42	1051.56	1060.70	1057.66	1060.70	1063.75	1066.80
-1469.81	1039.37	1042.42	1051.56	1057.66	1054.61	1057.66	1057.66	1057.66
-1869.81	1039.37	1042.42	1048.51	1057.66	1054.61	1051.56	1051.56	1051.56
-2269.81	1036.32	1039.37	1042.42	1051.56	1051.56	1048.51	1048.51	1048.51
-2669.81	1030.22	1036.32	1039.37	1042.42	1048.51	1048.51	1048.51	1048.51
-3069.81	1027.18	1030.22	1033.27	1039.37	1042.42	1054.61	1048.51	1045.46
-3469.81	1021.08	1027.18	1033.27	1036.32	1042.42	1048.51	1045.46	1042.42

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	ANNUAL WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD91.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1991 YEAR: 1991

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00010000	.00059000	.00000000	.00000000	.00000000	.00000000
22.500	.00018000	.00106000	.00000000	.00000000	.00000000	.00000000
45.000	.00027000	.00082000	.00000000	.00000000	.00000000	.00000000
67.500	.00020000	.00035000	.00000000	.00000000	.00000000	.00000000
90.000	.00027000	.00082000	.00000000	.00000000	.00000000	.00000000
112.500	.00025000	.00070000	.00000000	.00000000	.00000000	.00000000
135.000	.00045000	.00106000	.00000000	.00000000	.00000000	.00000000
157.500	.00037000	.00141000	.00000000	.00000000	.00000000	.00000000
180.000	.00022000	.00047000	.00000000	.00000000	.00000000	.00000000
202.500	.00004000	.00023000	.00000000	.00000000	.00000000	.00000000
225.000	.00008000	.00047000	.00000000	.00000000	.00000000	.00000000
247.500	.00014000	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00004000	.00023000	.00000000	.00000000	.00000000	.00000000
292.500	.00014000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00006000	.00035000	.00000000	.00000000	.00000000	.00000000
337.500	.00002000	.00012000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00152000	.00211000	.00129000	.00000000	.00000000	.00000000
22.500	.00115000	.00211000	.00106000	.00000000	.00000000	.00000000
45.000	.00090000	.00223000	.00164000	.00000000	.00000000	.00000000
67.500	.00107000	.00282000	.00082000	.00000000	.00000000	.00000000
90.000	.00114000	.00388000	.00117000	.00000000	.00000000	.00000000
112.500	.00086000	.00341000	.00211000	.00000000	.00000000	.00000000
135.000	.00180000	.00623000	.00294000	.00000000	.00000000	.00000000
157.500	.00206000	.00634000	.00599000	.00000000	.00000000	.00000000
180.000	.00156000	.00458000	.00446000	.00000000	.00000000	.00000000
202.500	.00034000	.00129000	.00070000	.00000000	.00000000	.00000000
225.000	.00021000	.00129000	.00023000	.00000000	.00000000	.00000000
247.500	.00031000	.00082000	.00023000	.00000000	.00000000	.00000000
270.000	.00116000	.00047000	.00059000	.00000000	.00000000	.00000000
292.500	.00017000	.00059000	.00000000	.00000000	.00000000	.00000000
315.000	.00015000	.00035000	.00012000	.00000000	.00000000	.00000000
337.500	.00052000	.00023000	.00047000	.00000000	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD91.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1991 YEAR: 1991

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00115000	.00305000	.00587000	.00106000	.00012000	.00000000
22.500	.00036000	.00211000	.00294000	.00012000	.00000000	.00000000
45.000	.00037000	.00223000	.00141000	.00023000	.00000000	.00000000
67.500	.00052000	.00282000	.00106000	.00000000	.00000000	.00000000
90.000	.00037000	.00235000	.00223000	.00035000	.00000000	.00000000
112.500	.00042000	.00317000	.00388000	.00047000	.00023000	.00000000
135.000	.00058000	.00399000	.00893000	.00294000	.00000000	.00000000
157.500	.00027000	.00505000	.01480000	.00258000	.00012000	.00000000
180.000	.00062000	.00470000	.01081000	.00258000	.00012000	.00012000
202.500	.00017000	.00082000	.00141000	.00047000	.00000000	.00012000
225.000	.00030000	.00094000	.00106000	.00082000	.00012000	.00000000
247.500	.00028000	.00059000	.00153000	.00164000	.00047000	.00012000
270.000	.00040000	.00059000	.00200000	.00270000	.00223000	.00070000
292.500	.00078000	.00070000	.00129000	.00070000	.00012000	.00023000
315.000	.00069000	.00141000	.00153000	.00012000	.00000000	.00000000
337.500	.00023000	.00200000	.00211000	.00035000	.00012000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00134000	.00564000	.01304000	.01527000	.00200000	.00035000
22.500	.00074000	.00611000	.00493000	.00364000	.00035000	.00000000
45.000	.00065000	.00505000	.00411000	.00223000	.00023000	.00000000
67.500	.00082000	.00388000	.00576000	.00223000	.00000000	.00012000
90.000	.00138000	.00458000	.00505000	.00211000	.00035000	.00000000
112.500	.00063000	.00470000	.00529000	.00317000	.00047000	.00023000
135.000	.00049000	.00623000	.00904000	.01386000	.00282000	.00012000
157.500	.00075000	.00623000	.02185000	.01903000	.00188000	.00023000
180.000	.00108000	.00717000	.01797000	.01269000	.00059000	.00012000
202.500	.00040000	.00188000	.00411000	.00458000	.00129000	.00035000
225.000	.00038000	.00164000	.00317000	.00388000	.00164000	.00035000
247.500	.00046000	.00106000	.00435000	.01269000	.00305000	.00223000
270.000	.00065000	.00176000	.00646000	.02784000	.01457000	.00916000
292.500	.00049000	.00294000	.00317000	.00928000	.00317000	.00164000
315.000	.00091000	.00352000	.00670000	.00634000	.00082000	.00023000
337.500	.00093000	.00376000	.00975000	.01480000	.00270000	.00035000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD91.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1991 YEAR: 1991

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00470000	.00611000	.00000000	.00000000	.00000000
22.500	.00000000	.00200000	.00200000	.00000000	.00000000	.00000000
45.000	.00000000	.00223000	.00141000	.00000000	.00000000	.00000000
67.500	.00000000	.00200000	.00106000	.00000000	.00000000	.00000000
90.000	.00000000	.00223000	.00094000	.00000000	.00000000	.00000000
112.500	.00000000	.00305000	.00106000	.00000000	.00000000	.00000000
135.000	.00000000	.00411000	.00341000	.00000000	.00000000	.00000000
157.500	.00000000	.00705000	.00975000	.00000000	.00000000	.00000000
180.000	.00000000	.00975000	.01809000	.00000000	.00000000	.00000000
202.500	.00000000	.00411000	.00916000	.00000000	.00000000	.00000000
225.000	.00000000	.00247000	.00646000	.00000000	.00000000	.00000000
247.500	.00000000	.00388000	.01010000	.00000000	.00000000	.00000000
270.000	.00000000	.00576000	.01797000	.00000000	.00000000	.00000000
292.500	.00000000	.00470000	.01081000	.00000000	.00000000	.00000000
315.000	.00000000	.00388000	.00634000	.00000000	.00000000	.00000000
337.500	.00000000	.00270000	.00458000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00407000	.00858000	.00000000	.00000000	.00000000	.00000000
22.500	.00238000	.00446000	.00000000	.00000000	.00000000	.00000000
45.000	.00137000	.00258000	.00000000	.00000000	.00000000	.00000000
67.500	.00193000	.00176000	.00000000	.00000000	.00000000	.00000000
90.000	.00248000	.00305000	.00000000	.00000000	.00000000	.00000000
112.500	.00159000	.00552000	.00000000	.00000000	.00000000	.00000000
135.000	.00319000	.00564000	.00000000	.00000000	.00000000	.00000000
157.500	.00544000	.01339000	.00000000	.00000000	.00000000	.00000000
180.000	.00568000	.02408000	.00000000	.00000000	.00000000	.00000000
202.500	.00352000	.00951000	.00000000	.00000000	.00000000	.00000000
225.000	.00358000	.00893000	.00000000	.00000000	.00000000	.00000000
247.500	.00376000	.01151000	.00000000	.00000000	.00000000	.00000000
270.000	.00579000	.01515000	.00000000	.00000000	.00000000	.00000000
292.500	.00469000	.01480000	.00000000	.00000000	.00000000	.00000000
315.000	.00281000	.00904000	.00000000	.00000000	.00000000	.00000000
337.500	.00281000	.00693000	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99990

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	.019249	.024130	.029853	.039158	.051144	.066098	.083581	.108031	.119059
2530.19	.019175	.023922	.030932	.042250	.057558	.077617	.095635	.136585	.157667
2130.19	.019873	.025281	.032618	.041267	.063551	.084606	.118548	.169107	.202014
1730.19	.020068	.026044	.034492	.046651	.062602	.097250	.148346	.224837	.269042
1330.19	.019471	.025746	.035015	.045800	.061710	.105548	.185034	.299209	.389580
930.19	.021274	.026629	.034221	.044709	.063165	.103509	.176123	.401561	.631541
530.19	.022852	.026964	.035042	.043685	.056231	.078602	.142697	.450585	1.150348
130.19	.022470	.026486	.031831	.039214	.049634	.065912	.095132	.165023	2.016856
-269.81	.018642	.021525	.025198	.030041	.036417	.045857	.068567	.129945	.493748
-669.81	.015027	.015760	.020960	.024335	.028702	.040558	.055672	.084380	.228139
-1069.81	.012844	.013333	.016271	.020679	.022824	.033409	.046633	.071240	.154415
-1469.81	.011198	.011846	.014443	.017910	.020923	.027219	.035820	.059753	.102383
-1869.81	.010099	.011277	.013557	.015354	.017784	.022463	.028363	.048599	.073632
-2269.81	.009050	.010623	.011785	.014351	.016464	.020315	.025575	.039514	.060585
-2669.81	.008569	.009935	.011141	.012588	.015241	.018445	.024628	.035264	.047059
-3069.81	.008073	.008926	.010598	.011820	.014086	.016260	.021521	.027104	.037650
-3469.81	.007327	.008564	.009447	.011095	.012159	.015944	.018760	.024544	.028652

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	.098536	.071909	.048265	.043493	.038803	.034378	.030414	.028312
2530.19	.119177	.080302	.056162	.049717	.043295	.037519	.034500	.032293
2130.19	.142791	.084579	.066692	.056700	.048035	.043459	.040057	.036703
1730.19	.171203	.096164	.079623	.064657	.057012	.051584	.046266	.041500
1330.19	.202562	.121830	.094254	.080067	.069864	.060669	.052893	.046496
930.19	.223035	.155707	.122868	.101780	.084070	.072486	.064664	.057612
530.19	.304282	.221675	.163617	.136646	.113504	.094904	.080250	.068842
130.19	.405533	.395611	.268741	.194128	.147230	.116463	.094923	.079334
-269.81	.250126	.326000	.244856	.183358	.141532	.113090	.092766	.077861
-669.81	.155750	.174367	.167761	.137793	.115014	.096405	.081599	.070029
-1069.81	.121217	.110859	.115030	.104158	.091193	.079209	.069355	.061340
-1469.81	.098983	.087516	.087497	.076883	.071802	.065288	.058805	.052945
-1869.81	.080862	.069267	.070648	.061945	.055839	.053058	.049501	.045731
-2269.81	.061720	.054809	.051852	.052278	.046698	.042912	.041329	.039155
-2669.81	.044973	.044628	.040872	.040525	.040667	.036936	.034363	.033355
-3069.81	.036465	.034383	.031520	.033163	.032801	.032840	.030174	.027590
-3469.81	.028037	.028833	.028775	.027503	.028975	.029249	.026548	.023657

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	2.016856	AT (	10.47,	130.19)	GC	6.	.405533	AT (	410.47,	130.19)	GC
2.	1.150348	AT (	10.47,	530.19)	GC	7.	.401561	AT (	-389.53,	930.19)	GC
3.	.631541	AT (	10.47,	930.19)	GC	8.	.395611	AT (	810.47,	130.19)	GC
4.	.493748	AT (	10.47,	-269.81)	GC	9.	.389580	AT (	10.47,	1330.19)	GC
5.	.450585	AT (	-389.53,	530.19)	GC	10.	.326000	AT (	810.47,	-269.81)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE CONCENTRATIONS AT THE WIPP SITE BOUNDARY (92 Carlsbad Met)
CO TITLETWO Coarse Receptor Grid(400x400m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -3189.53 17 400.00 -3469.81 17 400.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
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RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50			
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50			
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50			
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50			
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50			
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50			
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50			
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50			
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50

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RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50
RE GRIDCART COARSE   ELEV 1  3310.00  3320.00  3320.00  3330.00
RE GRIDCART COARSE   ELEV 1  3330.00  3340.00  3330.00  3340.00
RE GRIDCART COARSE   ELEV 1  3340.00  3350.00  3370.00  3390.00
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RE GRIDCART COARSE   ELEV 1  3400.00  3420.00  3440.00  3430.00
RE GRIDCART COARSE   ELEV 1  3420.00
RE GRIDCART COARSE   ELEV 2  3320.00  3320.00  3330.00  3330.00
RE GRIDCART COARSE   ELEV 2  3340.00  3340.00  3340.00  3340.00
RE GRIDCART COARSE   ELEV 2  3360.00  3370.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 2  3410.00  3420.00  3460.00  3440.00
RE GRIDCART COARSE   ELEV 2  3430.00
RE GRIDCART COARSE   ELEV 3  3320.00  3330.00  3330.00  3330.00
RE GRIDCART COARSE   ELEV 3  3340.00  3350.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 3  3370.00  3380.00  3400.00  3410.00
RE GRIDCART COARSE   ELEV 3  3420.00  3440.00  3440.00  3440.00
RE GRIDCART COARSE   ELEV 3  3440.00
RE GRIDCART COARSE   ELEV 4  3320.00  3330.00  3330.00  3340.00
RE GRIDCART COARSE   ELEV 4  3340.00  3350.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 4  3380.00  3400.00  3410.00  3420.00
RE GRIDCART COARSE   ELEV 4  3450.00  3450.00  3440.00  3440.00
RE GRIDCART COARSE   ELEV 4  3440.00
RE GRIDCART COARSE   ELEV 5  3330.00  3330.00  3340.00  3340.00
RE GRIDCART COARSE   ELEV 5  3340.00  3350.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 5  3380.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 5  3470.00  3460.00  3450.00  3450.00
RE GRIDCART COARSE   ELEV 5  3450.00
RE GRIDCART COARSE   ELEV 6  3340.00  3330.00  3340.00  3350.00
RE GRIDCART COARSE   ELEV 6  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 6  3390.00  3410.00  3420.00  3450.00
RE GRIDCART COARSE   ELEV 6  3470.00  3460.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 6  3470.00
RE GRIDCART COARSE   ELEV 7  3350.00  3340.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 7  3350.00  3370.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 7  3400.00  3410.00  3420.00  3450.00
RE GRIDCART COARSE   ELEV 7  3480.00  3470.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 7  3500.00
RE GRIDCART COARSE   ELEV 8  3360.00  3350.00  3370.00  3370.00
RE GRIDCART COARSE   ELEV 8  3370.00  3380.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 8  3400.00  3410.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 8  3480.00  3490.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 8  3520.00
RE GRIDCART COARSE   ELEV 9  3380.00  3380.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 9  3380.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 9  3410.00  3420.00  3440.00  3450.00
RE GRIDCART COARSE   ELEV 9  3490.00  3500.00  3510.00  3530.00
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RE GRIDCART COARSE   ELEV 9  3540.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3420.00  3440.00  3460.00
RE GRIDCART COARSE   ELEV 10  3480.00  3510.00  3520.00  3540.00
RE GRIDCART COARSE   ELEV 10  3540.00
RE GRIDCART COARSE   ELEV 11  3400.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 11  3430.00  3430.00  3450.00  3470.00
RE GRIDCART COARSE   ELEV 11  3490.00  3510.00  3510.00  3530.00
RE GRIDCART COARSE   ELEV 11  3540.00
RE GRIDCART COARSE   ELEV 12  3390.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3420.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 12  3450.00  3450.00  3460.00  3470.00
RE GRIDCART COARSE   ELEV 12  3500.00  3500.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 12  3520.00
RE GRIDCART COARSE   ELEV 13  3380.00  3390.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 13  3400.00  3420.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 13  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 13  3490.00  3490.00  3490.00  3500.00
RE GRIDCART COARSE   ELEV 13  3500.00
RE GRIDCART COARSE   ELEV 14  3370.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 14  3400.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 14  3460.00  3470.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 14  3480.00  3480.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 14  3500.00
RE GRIDCART COARSE   ELEV 15  3360.00  3370.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 15  3400.00  3400.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 15  3460.00  3460.00  3460.00  3460.00
RE GRIDCART COARSE   ELEV 15  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 15  3510.00
RE GRIDCART COARSE   ELEV 16  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 16  3390.00  3400.00  3400.00  3430.00
RE GRIDCART COARSE   ELEV 16  3440.00  3450.00  3450.00  3440.00
RE GRIDCART COARSE   ELEV 16  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 16  3510.00
RE GRIDCART COARSE   ELEV 17  3350.00  3360.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 17  3380.00  3390.00  3400.00  3420.00
RE GRIDCART COARSE   ELEV 17  3420.00  3430.00  3430.00  3440.00
RE GRIDCART COARSE   ELEV 17  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 17  3510.00
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RE GRIDCART COARSE   END

RE FINISHED

ME STARTING

ME INPUTFIL C:\MODELS\MET\CBD92.STR (7X,6F7.5)

ME ANEMHGHT   10.000 METERS

ME SURFDATA 11111 1992 CARLSBAD

ME UAIRDATA 11111 1992

ME STARDATA ANNUAL

ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50

ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80

ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01

ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03

ME FINISHED

OU STARTING

OU RECTABLE SRCGRP

OU MAXTABLE 10 SRCGRP

OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMCC92A.GPH 70

OU FINISHED

************************************
*** SETUP Finishes Successfully ***
************************************
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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates 1 STAR Average(s) for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**Data File Includes 1 STAR Summaries for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**This Run Includes: 2 Source(s); 1 Source Group(s); and 289 Receptor(s)

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs: Anem. Hgt. (m) = 10.00 ; Decay Coef. = .0000 ; Rot. Angle = .0
Emission Units = GRAMS/SEC ; Emission Rate Unit Factor = .10000E+07
Output Units = MICROGRAMS/M**3

**Input Runstream File: ADMCC92A.DAT ; **Output Print File: ADMCC92A.LST

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-3189.5,	-2789.5,	-2389.5,	-1989.5,	-1589.5,	-1189.5,	-789.5,	-389.5,	10.5,	410.5,
810.5,	1210.5,	1610.5,	2010.5,	2410.5,	2810.5,	3210.5,			

*** Y-COORDINATES OF GRID ***
(METERS)

-3469.8,	-3069.8,	-2669.8,	-2269.8,	-1869.8,	-1469.8,	-1069.8,	-669.8,	-269.8,	130.2,
530.2,	930.2,	1330.2,	1730.2,	2130.2,	2530.2,	2930.2,			

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1021.08	1024.13	1024.13	1027.18	1030.22	1033.27	1036.32	1042.42	1042.42
2530.19	1021.08	1024.13	1027.18	1030.22	1033.27	1036.32	1036.32	1045.46	1048.51
2130.19	1024.13	1027.18	1030.22	1030.22	1036.32	1036.32	1039.37	1045.46	1054.61
1730.19	1027.18	1030.22	1033.27	1036.32	1036.32	1039.37	1042.42	1048.51	1054.61
1330.19	1030.22	1033.27	1036.32	1036.32	1036.32	1042.42	1045.46	1051.56	1057.66
930.19	1033.27	1036.32	1039.37	1039.37	1039.37	1042.42	1042.42	1048.51	1051.56
530.19	1036.32	1036.32	1039.37	1039.37	1039.37	1039.37	1039.37	1045.46	1045.46
130.19	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32
-269.81	1030.22	1030.22	1030.22	1030.22	1030.22	1030.22	1033.27	1036.32	1039.37
-669.81	1024.13	1021.08	1027.18	1027.18	1027.18	1030.22	1030.22	1033.27	1036.32
-1069.81	1021.08	1018.03	1021.08	1024.13	1021.08	1027.18	1030.22	1033.27	1036.32
-1469.81	1018.03	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18	1030.22	1033.27
-1869.81	1014.98	1014.98	1018.03	1018.03	1018.03	1021.08	1024.13	1027.18	1030.22
-2269.81	1011.94	1014.98	1014.98	1018.03	1018.03	1021.08	1021.08	1024.13	1030.22
-2669.81	1011.94	1014.98	1014.98	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18
-3069.81	1011.94	1011.94	1014.98	1014.98	1018.03	1018.03	1018.03	1018.03	1024.13
-3469.81	1008.89	1011.94	1011.94	1014.98	1014.98	1018.03	1014.98	1018.03	1018.03

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1045.46	1045.46	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2530.19	1051.56	1051.56	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2130.19	1054.61	1054.61	1054.61	1057.66	1057.66	1057.66	1060.70	1069.85
1730.19	1057.66	1057.66	1057.66	1060.70	1060.70	1060.70	1063.75	1066.80
1330.19	1057.66	1057.66	1060.70	1063.75	1063.75	1063.75	1066.80	1066.80
930.19	1051.56	1054.61	1057.66	1066.80	1066.80	1066.80	1069.85	1072.90
530.19	1045.46	1051.56	1057.66	1063.75	1069.85	1069.85	1075.94	1078.99
130.19	1042.42	1048.51	1054.61	1060.70	1069.85	1072.90	1078.99	1078.99
-269.81	1042.42	1048.51	1051.56	1063.75	1066.80	1069.85	1075.94	1078.99
-669.81	1039.37	1045.46	1051.56	1060.70	1063.75	1066.80	1069.85	1072.90
-1069.81	1039.37	1042.42	1051.56	1060.70	1057.66	1060.70	1063.75	1066.80
-1469.81	1039.37	1042.42	1051.56	1057.66	1054.61	1057.66	1057.66	1057.66
-1869.81	1039.37	1042.42	1048.51	1057.66	1054.61	1051.56	1051.56	1051.56
-2269.81	1036.32	1039.37	1042.42	1051.56	1051.56	1048.51	1048.51	1048.51
-2669.81	1030.22	1036.32	1039.37	1042.42	1048.51	1048.51	1048.51	1048.51
-3069.81	1027.18	1030.22	1033.27	1039.37	1042.42	1054.61	1048.51	1045.46
-3469.81	1021.08	1027.18	1033.27	1036.32	1042.42	1048.51	1045.46	1042.42

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	ANNUAL WIND SPEED CATEGORY 1	ANNUAL WIND SPEED CATEGORY 2	ANNUAL WIND SPEED CATEGORY 3	ANNUAL WIND SPEED CATEGORY 4	ANNUAL WIND SPEED CATEGORY 5	ANNUAL WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD92.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1992 YEAR: 1992

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00025000	.00071000	.00000000	.00000000	.00000000	.00000000
22.500	.00029000	.00095000	.00000000	.00000000	.00000000	.00000000
45.000	.00035000	.00047000	.00000000	.00000000	.00000000	.00000000
67.500	.00037000	.00059000	.00000000	.00000000	.00000000	.00000000
90.000	.00042000	.00178000	.00000000	.00000000	.00000000	.00000000
112.500	.00034000	.00130000	.00000000	.00000000	.00000000	.00000000
135.000	.00052000	.00154000	.00000000	.00000000	.00000000	.00000000
157.500	.00032000	.00118000	.00000000	.00000000	.00000000	.00000000
180.000	.00039000	.00071000	.00000000	.00000000	.00000000	.00000000
202.500	.00006000	.00036000	.00000000	.00000000	.00000000	.00000000
225.000	.00019000	.00036000	.00000000	.00000000	.00000000	.00000000
247.500	.00006000	.00036000	.00000000	.00000000	.00000000	.00000000
270.000	.00006000	.00036000	.00000000	.00000000	.00000000	.00000000
292.500	.00007000	.00047000	.00000000	.00000000	.00000000	.00000000
315.000	.00004000	.00024000	.00000000	.00000000	.00000000	.00000000
337.500	.00031000	.00024000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00124000	.00261000	.00201000	.00000000	.00000000	.00000000
22.500	.00093000	.00201000	.00107000	.00000000	.00000000	.00000000
45.000	.00073000	.00273000	.00059000	.00000000	.00000000	.00000000
67.500	.00114000	.00296000	.00095000	.00000000	.00000000	.00000000
90.000	.00204000	.00616000	.00273000	.00000000	.00000000	.00000000
112.500	.00115000	.00308000	.00284000	.00000000	.00000000	.00000000
135.000	.00123000	.00403000	.00355000	.00000000	.00000000	.00000000
157.500	.00156000	.00344000	.00201000	.00000000	.00000000	.00000000
180.000	.00091000	.00332000	.00190000	.00000000	.00000000	.00000000
202.500	.00065000	.00012000	.00047000	.00000000	.00000000	.00000000
225.000	.00020000	.00083000	.00024000	.00000000	.00000000	.00000000
247.500	.00019000	.00071000	.00036000	.00000000	.00000000	.00000000
270.000	.00044000	.00071000	.00059000	.00000000	.00000000	.00000000
292.500	.00042000	.00047000	.00036000	.00000000	.00000000	.00000000
315.000	.00049000	.00130000	.00036000	.00000000	.00000000	.00000000
337.500	.00079000	.00178000	.00083000	.00000000	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD92.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1992 YEAR: 1992

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00067000	.00273000	.00699000	.00095000	.00024000	.00000000
22.500	.00047000	.00367000	.00391000	.00024000	.00000000	.00000000
45.000	.00050000	.00201000	.00213000	.00036000	.00000000	.00000000
67.500	.00027000	.00237000	.00237000	.00036000	.00000000	.00000000
90.000	.00035000	.00367000	.00450000	.00083000	.00000000	.00000000
112.500	.00046000	.00355000	.00533000	.00190000	.00000000	.00000000
135.000	.00045000	.00545000	.01102000	.00308000	.00024000	.00000000
157.500	.00081000	.00308000	.00984000	.00237000	.00000000	.00000000
180.000	.00047000	.00367000	.00711000	.00166000	.00000000	.00000000
202.500	.00016000	.00059000	.00142000	.00024000	.00000000	.00000000
225.000	.00029000	.00071000	.00130000	.00024000	.00000000	.00000000
247.500	.00004000	.00071000	.00118000	.00059000	.00012000	.00000000
270.000	.00050000	.00213000	.00142000	.00130000	.00083000	.00024000
292.500	.00058000	.00130000	.00154000	.00047000	.00000000	.00000000
315.000	.00046000	.00142000	.00344000	.00130000	.00000000	.00000000
337.500	.00027000	.00237000	.00438000	.00130000	.00036000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00040000	.00652000	.01244000	.01232000	.00308000	.00059000
22.500	.00046000	.00344000	.00403000	.00320000	.00024000	.00000000
45.000	.00057000	.00320000	.00296000	.00201000	.00012000	.00000000
67.500	.00054000	.00261000	.00296000	.00261000	.00012000	.00000000
90.000	.00061000	.00581000	.00462000	.00628000	.00012000	.00000000
112.500	.00063000	.00415000	.00841000	.00806000	.00095000	.00012000
135.000	.00083000	.00545000	.01600000	.01766000	.00130000	.00000000
157.500	.00103000	.00450000	.01517000	.01090000	.00012000	.00000000
180.000	.00027000	.00438000	.01161000	.01007000	.00083000	.00012000
202.500	.00009000	.00142000	.00355000	.00379000	.00059000	.00000000
225.000	.00029000	.00059000	.00379000	.00415000	.00036000	.00000000
247.500	.00010000	.00166000	.00510000	.00841000	.00462000	.00083000
270.000	.00014000	.00225000	.00652000	.02003000	.01149000	.00474000
292.500	.00022000	.00367000	.00557000	.01090000	.00379000	.00130000
315.000	.00044000	.00308000	.00640000	.01019000	.00296000	.00059000
337.500	.00039000	.00427000	.00723000	.01232000	.00510000	.00059000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD92.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1992 YEAR: 1992

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00450000	.00415000	.00000000	.00000000	.00000000
22.500	.00000000	.00154000	.00036000	.00000000	.00000000	.00000000
45.000	.00000000	.00237000	.00059000	.00000000	.00000000	.00000000
67.500	.00000000	.00201000	.00190000	.00000000	.00000000	.00000000
90.000	.00000000	.00284000	.00284000	.00000000	.00000000	.00000000
112.500	.00000000	.00438000	.00332000	.00000000	.00000000	.00000000
135.000	.00000000	.00747000	.00806000	.00000000	.00000000	.00000000
157.500	.00000000	.00948000	.01505000	.00000000	.00000000	.00000000
180.000	.00000000	.00865000	.02145000	.00000000	.00000000	.00000000
202.500	.00000000	.00391000	.00960000	.00000000	.00000000	.00000000
225.000	.00000000	.00284000	.00521000	.00000000	.00000000	.00000000
247.500	.00000000	.00450000	.01066000	.00000000	.00000000	.00000000
270.000	.00000000	.00865000	.01967000	.00000000	.00000000	.00000000
292.500	.00000000	.00664000	.01612000	.00000000	.00000000	.00000000
315.000	.00000000	.00687000	.00640000	.00000000	.00000000	.00000000
337.500	.00000000	.00320000	.00403000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00298000	.00936000	.00000000	.00000000	.00000000	.00000000
22.500	.00238000	.00427000	.00000000	.00000000	.00000000	.00000000
45.000	.00155000	.00225000	.00000000	.00000000	.00000000	.00000000
67.500	.00134000	.00178000	.00000000	.00000000	.00000000	.00000000
90.000	.00245000	.00569000	.00000000	.00000000	.00000000	.00000000
112.500	.00214000	.00545000	.00000000	.00000000	.00000000	.00000000
135.000	.00388000	.00995000	.00000000	.00000000	.00000000	.00000000
157.500	.00524000	.01469000	.00000000	.00000000	.00000000	.00000000
180.000	.00448000	.01695000	.00000000	.00000000	.00000000	.00000000
202.500	.00396000	.00960000	.00000000	.00000000	.00000000	.00000000
225.000	.00204000	.00664000	.00000000	.00000000	.00000000	.00000000
247.500	.00322000	.00912000	.00000000	.00000000	.00000000	.00000000
270.000	.00428000	.01742000	.00000000	.00000000	.00000000	.00000000
292.500	.00555000	.01588000	.00000000	.00000000	.00000000	.00000000
315.000	.00466000	.01256000	.00000000	.00000000	.00000000	.00000000
337.500	.00208000	.00877000	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99998

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	.027330	.033317	.037275	.044599	.053435	.063734	.074869	.090264	.093142
2530.19	.026870	.033866	.042381	.051777	.063539	.077760	.087226	.115360	.123151
2130.19	.027430	.035316	.046148	.055945	.075846	.088896	.111470	.144621	.157874
1730.19	.027063	.035632	.047924	.065875	.083954	.111033	.146387	.196268	.210358
1330.19	.025298	.034050	.047210	.063034	.086327	.139039	.198620	.268633	.305086
930.19	.027814	.034676	.044291	.058955	.085737	.143986	.220988	.378586	.496048
530.19	.030140	.035674	.046296	.057874	.074715	.105428	.194937	.503573	.910924
130.19	.030035	.035614	.043138	.053703	.069015	.093696	.139984	.252262	1.649730
-269.81	.023349	.026834	.031192	.036754	.043607	.052445	.068736	.115836	.489327
-669.81	.016587	.016898	.021453	.023216	.024571	.034758	.047039	.073413	.216893
-1069.81	.012089	.011738	.013724	.017496	.019282	.028111	.039275	.061869	.144413
-1469.81	.009382	.009947	.012157	.015101	.017565	.022820	.030073	.052940	.095015
-1869.81	.008474	.009475	.011424	.012908	.014863	.018751	.023678	.043389	.067980
-2269.81	.007596	.008947	.009916	.012053	.013726	.016894	.021829	.035396	.055667
-2669.81	.007214	.008400	.009360	.010493	.012668	.015295	.021323	.031632	.043119
-3069.81	.006825	.007499	.008872	.009821	.011673	.013577	.018778	.024337	.034423
-3469.81	.006155	.007169	.007848	.009193	.010011	.013534	.016448	.022043	.026171

16

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	.080924	.063599	.048285	.040622	.033769	.027844	.022898	.021460
2530.19	.098824	.073300	.054343	.044410	.035646	.028416	.026317	.025506
2130.19	.120068	.081346	.061650	.047699	.036674	.033436	.032015	.030172
1730.19	.147265	.093188	.069013	.049913	.044363	.041867	.038685	.035474
1330.19	.181911	.110348	.073926	.063300	.057885	.051852	.046209	.041297
930.19	.216612	.125704	.099645	.086842	.073984	.065349	.059407	.053582
530.19	.260264	.188162	.146313	.126399	.106859	.090290	.076871	.066255
130.19	.363926	.383500	.263674	.191204	.145207	.114985	.093773	.078396
-269.81	.333619	.387678	.271410	.197261	.149655	.118273	.096261	.080313
-669.81	.176695	.230217	.210681	.167564	.133585	.108747	.090223	.076301
-1069.81	.123678	.136590	.154004	.133171	.113121	.096176	.082117	.070839
-1469.81	.097529	.097535	.112426	.103736	.093047	.082255	.072549	.064259
-1869.81	.078066	.071390	.083577	.080992	.075749	.069455	.063119	.057141
-2269.81	.058823	.054619	.057091	.063902	.061754	.058448	.054522	.050406
-2669.81	.042494	.043711	.042489	.046574	.050814	.049244	.046953	.044277
-3069.81	.034225	.033264	.031560	.036201	.038842	.041689	.040476	.037742
-3469.81	.026189	.027634	.028400	.028718	.032829	.035527	.034062	.031761

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	1.649730	AT (	10.47,	130.19)	GC	6.	.387678	AT (	810.47,	-269.81)	GC
2.	.910924	AT (	10.47,	530.19)	GC	7.	.383500	AT (	810.47,	130.19)	GC
3.	.503573	AT (	-389.53,	530.19)	GC	8.	.378586	AT (	-389.53,	930.19)	GC
4.	.496048	AT (	10.47,	930.19)	GC	9.	.363926	AT (	410.47,	130.19)	GC
5.	.489327	AT (	10.47,	-269.81)	GC	10.	.333619	AT (	410.47,	-269.81)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE CONCENTRATIONS AT THE WIPP SITE BOUNDARY (93 Carlsbad Met)
CO TITLETWO Coarse Receptor Grid(400x400m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -3189.53 17 400.00 -3469.81 17 400.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
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RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50			
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50			
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50			
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50			
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50			
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50			
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50			
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50			
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50

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RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50
RE GRIDCART COARSE   ELEV 1  3310.00  3320.00  3320.00  3330.00
RE GRIDCART COARSE   ELEV 1  3330.00  3340.00  3330.00  3340.00
RE GRIDCART COARSE   ELEV 1  3340.00  3350.00  3370.00  3390.00
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RE GRIDCART COARSE	ELEV 1	3400.00	3420.00	3440.00	3430.00
RE GRIDCART COARSE	ELEV 1	3420.00			
RE GRIDCART COARSE	ELEV 2	3320.00	3320.00	3330.00	3330.00
RE GRIDCART COARSE	ELEV 2	3340.00	3340.00	3340.00	3340.00
RE GRIDCART COARSE	ELEV 2	3360.00	3370.00	3380.00	3390.00
RE GRIDCART COARSE	ELEV 2	3410.00	3420.00	3460.00	3440.00
RE GRIDCART COARSE	ELEV 2	3430.00			
RE GRIDCART COARSE	ELEV 3	3320.00	3330.00	3330.00	3330.00
RE GRIDCART COARSE	ELEV 3	3340.00	3350.00	3350.00	3360.00
RE GRIDCART COARSE	ELEV 3	3370.00	3380.00	3400.00	3410.00
RE GRIDCART COARSE	ELEV 3	3420.00	3440.00	3440.00	3440.00
RE GRIDCART COARSE	ELEV 3	3440.00			
RE GRIDCART COARSE	ELEV 4	3320.00	3330.00	3330.00	3340.00
RE GRIDCART COARSE	ELEV 4	3340.00	3350.00	3350.00	3360.00
RE GRIDCART COARSE	ELEV 4	3380.00	3400.00	3410.00	3420.00
RE GRIDCART COARSE	ELEV 4	3450.00	3450.00	3440.00	3440.00
RE GRIDCART COARSE	ELEV 4	3440.00			
RE GRIDCART COARSE	ELEV 5	3330.00	3330.00	3340.00	3340.00
RE GRIDCART COARSE	ELEV 5	3340.00	3350.00	3360.00	3370.00
RE GRIDCART COARSE	ELEV 5	3380.00	3410.00	3420.00	3440.00
RE GRIDCART COARSE	ELEV 5	3470.00	3460.00	3450.00	3450.00
RE GRIDCART COARSE	ELEV 5	3450.00			
RE GRIDCART COARSE	ELEV 6	3340.00	3330.00	3340.00	3350.00
RE GRIDCART COARSE	ELEV 6	3350.00	3360.00	3370.00	3380.00
RE GRIDCART COARSE	ELEV 6	3390.00	3410.00	3420.00	3450.00
RE GRIDCART COARSE	ELEV 6	3470.00	3460.00	3470.00	3470.00
RE GRIDCART COARSE	ELEV 6	3470.00			
RE GRIDCART COARSE	ELEV 7	3350.00	3340.00	3350.00	3360.00
RE GRIDCART COARSE	ELEV 7	3350.00	3370.00	3380.00	3390.00
RE GRIDCART COARSE	ELEV 7	3400.00	3410.00	3420.00	3450.00
RE GRIDCART COARSE	ELEV 7	3480.00	3470.00	3480.00	3490.00
RE GRIDCART COARSE	ELEV 7	3500.00			
RE GRIDCART COARSE	ELEV 8	3360.00	3350.00	3370.00	3370.00
RE GRIDCART COARSE	ELEV 8	3370.00	3380.00	3380.00	3390.00
RE GRIDCART COARSE	ELEV 8	3400.00	3410.00	3430.00	3450.00
RE GRIDCART COARSE	ELEV 8	3480.00	3490.00	3500.00	3510.00
RE GRIDCART COARSE	ELEV 8	3520.00			
RE GRIDCART COARSE	ELEV 9	3380.00	3380.00	3380.00	3380.00
RE GRIDCART COARSE	ELEV 9	3380.00	3380.00	3390.00	3400.00
RE GRIDCART COARSE	ELEV 9	3410.00	3420.00	3440.00	3450.00
RE GRIDCART COARSE	ELEV 9	3490.00	3500.00	3510.00	3530.00

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RE GRIDCART COARSE   ELEV 9  3540.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3420.00  3440.00  3460.00
RE GRIDCART COARSE   ELEV 10  3480.00  3510.00  3520.00  3540.00
RE GRIDCART COARSE   ELEV 10  3540.00
RE GRIDCART COARSE   ELEV 11  3400.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 11  3430.00  3430.00  3450.00  3470.00
RE GRIDCART COARSE   ELEV 11  3490.00  3510.00  3510.00  3530.00
RE GRIDCART COARSE   ELEV 11  3540.00
RE GRIDCART COARSE   ELEV 12  3390.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3420.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 12  3450.00  3450.00  3460.00  3470.00
RE GRIDCART COARSE   ELEV 12  3500.00  3500.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 12  3520.00
RE GRIDCART COARSE   ELEV 13  3380.00  3390.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 13  3400.00  3420.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 13  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 13  3490.00  3490.00  3490.00  3500.00
RE GRIDCART COARSE   ELEV 13  3500.00
RE GRIDCART COARSE   ELEV 14  3370.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 14  3400.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 14  3460.00  3470.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 14  3480.00  3480.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 14  3500.00
RE GRIDCART COARSE   ELEV 15  3360.00  3370.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 15  3400.00  3400.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 15  3460.00  3460.00  3460.00  3460.00
RE GRIDCART COARSE   ELEV 15  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 15  3510.00
RE GRIDCART COARSE   ELEV 16  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 16  3390.00  3400.00  3400.00  3430.00
RE GRIDCART COARSE   ELEV 16  3440.00  3450.00  3450.00  3440.00
RE GRIDCART COARSE   ELEV 16  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 16  3510.00
RE GRIDCART COARSE   ELEV 17  3350.00  3360.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 17  3380.00  3390.00  3400.00  3420.00
RE GRIDCART COARSE   ELEV 17  3420.00  3430.00  3430.00  3440.00
RE GRIDCART COARSE   ELEV 17  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 17  3510.00
```

```
RE GRIDCART COARSE   END

RE FINISHED

ME STARTING

ME INPUTFIL C:\MODELS\MET\CBD93.STR (7X,6F7.5)

ME ANEMHGHT   10.000 METERS

ME SURFDATA 11111 1993 CARLSBAD

ME UAIRDATA 11111 1993

ME STARDATA ANNUAL

ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50

ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80

ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01

ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03

ME FINISHED

OU STARTING

OU RECTABLE SRCGRP

OU MAXTABLE 10 SRCGRP

OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMCC93A.GPH 70

OU FINISHED

************************************
*** SETUP Finishes Successfully ***
************************************
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```
*** MODELING OPTIONS USED:  CONC    RURAL  ELEV   FLGPOL

                        ***     MODEL SETUP OPTIONS SUMMARY       ***
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
-

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
          1. Final Plume Rise.
          2. Stack-tip Downwash.
          3. Buoyancy-induced Dispersion.
          4. Default Wind Profile Exponents.
          5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates   1 STAR Average(s) for the Following Months:  0  0  0  0  0  0  0  0  0  0  0  0
                                            Seasons/Quarters:  0  0  0  0
                                                  and Annual:  1

**Data File Includes  1 STAR Summaries for the Following Months:  0  0  0  0  0  0  0  0  0  0  0  0
                                            Seasons/Quarters:  0  0  0  0
                                                  and Annual:  1

**This Run Includes:    2 Source(s);      1 Source Group(s); and    289 Receptor(s)

**The Model Assumes A Pollutant Type of:  ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
        Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
        Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
        Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs:  Anem. Hgt. (m) =    10.00 ;    Decay Coef. =    .0000     ;    Rot. Angle =      .0
                 Emission Units = GRAMS/SEC                               ;  Emission Rate Unit Factor =    .10000E+07
                 Output Units   = MICROGRAMS/M**3

**Input Runstream File: ADMCC93A.DAT                          ;  **Output Print File: ADMCC93A.LST
```

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

4
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-3189.5,	-2789.5,	-2389.5,	-1989.5,	-1589.5,	-1189.5,	-789.5,	-389.5,	10.5,	410.5,
810.5,	1210.5,	1610.5,	2010.5,	2410.5,	2810.5,	3210.5,			

*** Y-COORDINATES OF GRID ***
(METERS)

-3469.8,	-3069.8,	-2669.8,	-2269.8,	-1869.8,	-1469.8,	-1069.8,	-669.8,	-269.8,	130.2,
530.2,	930.2,	1330.2,	1730.2,	2130.2,	2530.2,	2930.2,			

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1021.08	1024.13	1024.13	1027.18	1030.22	1033.27	1036.32	1042.42	1042.42
2530.19	1021.08	1024.13	1027.18	1030.22	1033.27	1036.32	1036.32	1045.46	1048.51
2130.19	1024.13	1027.18	1030.22	1030.22	1036.32	1036.32	1039.37	1045.46	1054.61
1730.19	1027.18	1030.22	1033.27	1036.32	1036.32	1039.37	1042.42	1048.51	1054.61
1330.19	1030.22	1033.27	1036.32	1036.32	1036.32	1042.42	1045.46	1051.56	1057.66
930.19	1033.27	1036.32	1039.37	1039.37	1039.37	1042.42	1042.42	1048.51	1051.56
530.19	1036.32	1036.32	1039.37	1039.37	1039.37	1039.37	1039.37	1045.46	1045.46
130.19	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32
-269.81	1030.22	1030.22	1030.22	1030.22	1030.22	1030.22	1033.27	1036.32	1039.37
-669.81	1024.13	1021.08	1027.18	1027.18	1027.18	1030.22	1030.22	1033.27	1036.32
-1069.81	1021.08	1018.03	1021.08	1024.13	1021.08	1027.18	1030.22	1033.27	1036.32
-1469.81	1018.03	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18	1030.22	1033.27
-1869.81	1014.98	1014.98	1018.03	1018.03	1018.03	1021.08	1024.13	1027.18	1030.22
-2269.81	1011.94	1014.98	1014.98	1018.03	1018.03	1021.08	1021.08	1024.13	1030.22
-2669.81	1011.94	1014.98	1014.98	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18
-3069.81	1011.94	1011.94	1014.98	1014.98	1018.03	1018.03	1018.03	1018.03	1024.13
-3469.81	1008.89	1011.94	1011.94	1014.98	1014.98	1018.03	1014.98	1018.03	1018.03

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1045.46	1045.46	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2530.19	1051.56	1051.56	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2130.19	1054.61	1054.61	1054.61	1057.66	1057.66	1057.66	1060.70	1069.85
1730.19	1057.66	1057.66	1057.66	1060.70	1060.70	1060.70	1063.75	1066.80
1330.19	1057.66	1057.66	1060.70	1063.75	1063.75	1063.75	1066.80	1066.80
930.19	1051.56	1054.61	1057.66	1066.80	1066.80	1066.80	1069.85	1072.90
530.19	1045.46	1051.56	1057.66	1063.75	1069.85	1069.85	1075.94	1078.99
130.19	1042.42	1048.51	1054.61	1060.70	1069.85	1072.90	1078.99	1078.99
-269.81	1042.42	1048.51	1051.56	1063.75	1066.80	1069.85	1075.94	1078.99
-669.81	1039.37	1045.46	1051.56	1060.70	1063.75	1066.80	1069.85	1072.90
-1069.81	1039.37	1042.42	1051.56	1060.70	1057.66	1060.70	1063.75	1066.80
-1469.81	1039.37	1042.42	1051.56	1057.66	1054.61	1057.66	1057.66	1057.66
-1869.81	1039.37	1042.42	1048.51	1057.66	1054.61	1051.56	1051.56	1051.56
-2269.81	1036.32	1039.37	1042.42	1051.56	1051.56	1048.51	1048.51	1048.51
-2669.81	1030.22	1036.32	1039.37	1042.42	1048.51	1048.51	1048.51	1048.51
-3069.81	1027.18	1030.22	1033.27	1039.37	1042.42	1054.61	1048.51	1045.46
-3469.81	1021.08	1027.18	1033.27	1036.32	1042.42	1048.51	1045.46	1042.42

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	ANNUAL WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD93.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00049000	.00047000	.00000000	.00000000	.00000000	.00000000
22.500	.00026000	.00071000	.00000000	.00000000	.00000000	.00000000
45.000	.00020000	.00035000	.00000000	.00000000	.00000000	.00000000
67.500	.00035000	.00047000	.00000000	.00000000	.00000000	.00000000
90.000	.00016000	.00095000	.00000000	.00000000	.00000000	.00000000
112.500	.00014000	.00083000	.00000000	.00000000	.00000000	.00000000
135.000	.00010000	.00059000	.00000000	.00000000	.00000000	.00000000
157.500	.00008000	.00047000	.00000000	.00000000	.00000000	.00000000
180.000	.00008000	.00047000	.00000000	.00000000	.00000000	.00000000
202.500	.00006000	.00035000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00004000	.00024000	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00002000	.00012000	.00000000	.00000000	.00000000	.00000000
315.000	.00020000	.00035000	.00000000	.00000000	.00000000	.00000000
337.500	.00008000	.00047000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00136000	.00213000	.00248000	.00000000	.00000000	.00000000
22.500	.00041000	.00296000	.00142000	.00000000	.00000000	.00000000
45.000	.00098000	.00201000	.00083000	.00000000	.00000000	.00000000
67.500	.00125000	.00248000	.00106000	.00000000	.00000000	.00000000
90.000	.00137000	.00473000	.00166000	.00000000	.00000000	.00000000
112.500	.00055000	.00331000	.00260000	.00000000	.00000000	.00000000
135.000	.00071000	.00390000	.00343000	.00000000	.00000000	.00000000
157.500	.00101000	.00485000	.00367000	.00000000	.00000000	.00000000
180.000	.00091000	.00296000	.00379000	.00000000	.00000000	.00000000
202.500	.00028000	.00059000	.00047000	.00000000	.00000000	.00000000
225.000	.00014000	.00035000	.00024000	.00000000	.00000000	.00000000
247.500	.00042000	.00083000	.00035000	.00000000	.00000000	.00000000
270.000	.00027000	.00047000	.00047000	.00000000	.00000000	.00000000
292.500	.00029000	.00071000	.00024000	.00000000	.00000000	.00000000
315.000	.00026000	.00024000	.00024000	.00000000	.00000000	.00000000
337.500	.00020000	.00142000	.00130000	.00000000	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD93.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00023000	.00379000	.00769000	.00142000	.00024000	.00000000
22.500	.00056000	.00296000	.00343000	.00083000	.00012000	.00000000
45.000	.00042000	.00272000	.00213000	.00024000	.00000000	.00000000
67.500	.00057000	.00308000	.00130000	.00035000	.00000000	.00000000
90.000	.00056000	.00296000	.00438000	.00095000	.00000000	.00000000
112.500	.00010000	.00166000	.00355000	.00166000	.00000000	.00000000
135.000	.00052000	.00426000	.01112000	.00402000	.00035000	.00000000
157.500	.00063000	.00414000	.01219000	.00331000	.00035000	.00000000
180.000	.00038000	.00414000	.01088000	.00402000	.00024000	.00000000
202.500	.00032000	.00106000	.00095000	.00035000	.00035000	.00000000
225.000	.00028000	.00047000	.00154000	.00012000	.00047000	.00000000
247.500	.00005000	.00083000	.00154000	.00130000	.00047000	.00035000
270.000	.00006000	.00095000	.00189000	.00189000	.00177000	.00035000
292.500	.00018000	.00095000	.00095000	.00012000	.00000000	.00000000
315.000	.00044000	.00106000	.00118000	.00047000	.00000000	.00000000
337.500	.00025000	.00201000	.00367000	.00154000	.00024000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00055000	.00627000	.01088000	.01645000	.00355000	.00130000
22.500	.00006000	.00213000	.00402000	.00544000	.00106000	.00012000
45.000	.00019000	.00225000	.00260000	.00390000	.00000000	.00000000
67.500	.00020000	.00284000	.00319000	.00272000	.00024000	.00000000
90.000	.00050000	.00450000	.00639000	.00284000	.00000000	.00012000
112.500	.00046000	.00331000	.00911000	.00710000	.00059000	.00012000
135.000	.00037000	.00450000	.02011000	.02437000	.00213000	.00000000
157.500	.00031000	.00639000	.01952000	.02047000	.00035000	.00012000
180.000	.00043000	.00651000	.01633000	.01503000	.00154000	.00035000
202.500	.00004000	.00154000	.00450000	.00414000	.00047000	.00047000
225.000	.00003000	.00118000	.00414000	.00461000	.00142000	.00024000
247.500	.00014000	.00059000	.00556000	.02082000	.00663000	.00284000
270.000	.00007000	.00248000	.00580000	.02449000	.01195000	.00876000
292.500	.00043000	.00237000	.00355000	.00450000	.00047000	.00012000
315.000	.00018000	.00189000	.00319000	.00521000	.00083000	.00035000
337.500	.00017000	.00177000	.00722000	.01633000	.00213000	.00035000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD93.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00213000	.00603000	.00000000	.00000000	.00000000
22.500	.00000000	.00237000	.00248000	.00000000	.00000000	.00000000
45.000	.00000000	.00118000	.00166000	.00000000	.00000000	.00000000
67.500	.00000000	.00166000	.00189000	.00000000	.00000000	.00000000
90.000	.00000000	.00402000	.00154000	.00000000	.00000000	.00000000
112.500	.00000000	.00556000	.00379000	.00000000	.00000000	.00000000
135.000	.00000000	.00615000	.01041000	.00000000	.00000000	.00000000
157.500	.00000000	.00816000	.01313000	.00000000	.00000000	.00000000
180.000	.00000000	.01065000	.02236000	.00000000	.00000000	.00000000
202.500	.00000000	.00509000	.00899000	.00000000	.00000000	.00000000
225.000	.00000000	.00603000	.00615000	.00000000	.00000000	.00000000
247.500	.00000000	.00532000	.01029000	.00000000	.00000000	.00000000
270.000	.00000000	.00521000	.01230000	.00000000	.00000000	.00000000
292.500	.00000000	.00331000	.00899000	.00000000	.00000000	.00000000
315.000	.00000000	.00225000	.00509000	.00000000	.00000000	.00000000
337.500	.00000000	.00201000	.00473000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00286000	.01053000	.00000000	.00000000	.00000000	.00000000
22.500	.00118000	.00461000	.00000000	.00000000	.00000000	.00000000
45.000	.00162000	.00308000	.00000000	.00000000	.00000000	.00000000
67.500	.00154000	.00343000	.00000000	.00000000	.00000000	.00000000
90.000	.00189000	.00473000	.00000000	.00000000	.00000000	.00000000
112.500	.00134000	.00473000	.00000000	.00000000	.00000000	.00000000
135.000	.00215000	.00710000	.00000000	.00000000	.00000000	.00000000
157.500	.00548000	.01881000	.00000000	.00000000	.00000000	.00000000
180.000	.00448000	.01609000	.00000000	.00000000	.00000000	.00000000
202.500	.00308000	.00935000	.00000000	.00000000	.00000000	.00000000
225.000	.00150000	.00568000	.00000000	.00000000	.00000000	.00000000
247.500	.00300000	.01053000	.00000000	.00000000	.00000000	.00000000
270.000	.00454000	.01479000	.00000000	.00000000	.00000000	.00000000
292.500	.00363000	.01100000	.00000000	.00000000	.00000000	.00000000
315.000	.00343000	.00899000	.00000000	.00000000	.00000000	.00000000
337.500	.00217000	.00722000	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99986

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	.025631	.031651	.037206	.046424	.058133	.072358	.084341	.100313	.102406
2530.19	.025209	.031808	.040458	.051914	.067125	.086715	.098770	.128454	.135031
2130.19	.025430	.032816	.042949	.053807	.076848	.096538	.126800	.161861	.173588
1730.19	.024731	.032689	.044113	.060826	.080780	.115448	.164823	.220882	.232365
1330.19	.022680	.030723	.042852	.058104	.081293	.134520	.213555	.305117	.338638
930.19	.024668	.030795	.039419	.053095	.078981	.135145	.224011	.435618	.554834
530.19	.026442	.031381	.040772	.051194	.066546	.095712	.191274	.548981	1.043133
130.19	.026100	.030984	.037576	.046835	.060246	.081616	.120537	.212560	2.107513
-269.81	.021046	.024313	.028445	.033790	.040518	.049485	.068268	.119985	.559448
-669.81	.015925	.016407	.021453	.023996	.026587	.036660	.048264	.079659	.232464
-1069.81	.012557	.012500	.014865	.018632	.019856	.028447	.040623	.065943	.150057
-1469.81	.010194	.010521	.012672	.015457	.017531	.023095	.031270	.055210	.097928
-1869.81	.008899	.009756	.011580	.012784	.014829	.019112	.024560	.044780	.069768
-2269.81	.007742	.008992	.009757	.011931	.013785	.017180	.022470	.036337	.056937
-2669.81	.007200	.008262	.009206	.010434	.012720	.015442	.021741	.032293	.044037
-3069.81	.006683	.007340	.008765	.009782	.011683	.013722	.019116	.024854	.035115
-3469.81	.005999	.007049	.007770	.009145	.010038	.013617	.016733	.022447	.026678

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	.086425	.065443	.046732	.039948	.033760	.028307	.023706	.022647
2530.19	.105091	.074299	.053164	.044304	.036271	.029510	.027913	.027482
2130.19	.127181	.080647	.061270	.048568	.038265	.035732	.034767	.033129
1730.19	.154928	.091930	.070206	.052388	.047900	.045939	.042906	.039640
1330.19	.188465	.111991	.078083	.069225	.064396	.058250	.052230	.046834
930.19	.217861	.134353	.111231	.098412	.084486	.072567	.062719	.054704
530.19	.283730	.217953	.170873	.134607	.107551	.087926	.073275	.062229
130.19	.456576	.363636	.239411	.170887	.128759	.101428	.082436	.068764
-269.81	.182143	.251154	.196432	.149834	.116850	.093981	.077441	.065224
-669.81	.136197	.139457	.129271	.103108	.088882	.076058	.065264	.056560
-1069.81	.111315	.094418	.096192	.082941	.070374	.059801	.052663	.047461
-1469.81	.091011	.076893	.076280	.065452	.058467	.051561	.045408	.040182
-1869.81	.074277	.061481	.062096	.054281	.048090	.043906	.039793	.035956
-2269.81	.056692	.049011	.045515	.045980	.041110	.037273	.034630	.031925
-2669.81	.041327	.040100	.035938	.035484	.035852	.032658	.030050	.028228
-3069.81	.033481	.030992	.027808	.029021	.028743	.029037	.026779	.024167
-3469.81	.025738	.026035	.025526	.024067	.025411	.025839	.023471	.020874

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	2.107513	AT (	10.47,	130.19)	GC	6.	.456576	AT (	410.47,	130.19)	GC
2.	1.043133	AT (	10.47,	530.19)	GC	7.	.435618	AT (	-389.53,	930.19)	GC
3.	.559448	AT (	10.47,	-269.81)	GC	8.	.363636	AT (	810.47,	130.19)	GC
4.	.554834	AT (	10.47,	930.19)	GC	9.	.338638	AT (	10.47,	1330.19)	GC
5.	.548981	AT (	-389.53,	530.19)	GC	10.	.305117	AT (	-389.53,	1330.19)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

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 *** MODELING OPTIONS USED:  CONC   RURAL  ELEV   FLGPOL


 *** Message Summary : ISCLT3 Model Execution ***

  --------- Summary of Total Messages --------

 A Total of           0 Fatal Error Message(s)
 A Total of           0 Warning Message(s)
 A Total of           0 Informational Message(s)


    ******** FATAL ERROR MESSAGES ********
              ***  NONE  ***


    ********   WARNING MESSAGES   ********
              ***  NONE  ***


    ************************************
    *** ISCLT3 Finishes Successfully ***
    ************************************
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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE CONCENTRATIONS AT THE WIPP SITE BOUNDARY (94 Carlsbad Met)
CO TITLETWO Coarse Receptor Grid(400x400m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -3189.53 17 400.00 -3469.81 17 400.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50
RE GRIDCART COARSE   FLAG 2     1.50     1.50     1.50     1.50
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RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50			
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50			
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50			
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50			
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50			
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50			
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50			
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50			
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50

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RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 10     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 12     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 13     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 14     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 15     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 16     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 17     1.50
RE GRIDCART COARSE   ELEV 1  3310.00  3320.00  3320.00  3330.00
RE GRIDCART COARSE   ELEV 1  3330.00  3340.00  3330.00  3340.00
RE GRIDCART COARSE   ELEV 1  3340.00  3350.00  3370.00  3390.00
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RE GRIDCART COARSE   ELEV 1  3400.00  3420.00  3440.00  3430.00
RE GRIDCART COARSE   ELEV 1  3420.00
RE GRIDCART COARSE   ELEV 2  3320.00  3320.00  3330.00  3330.00
RE GRIDCART COARSE   ELEV 2  3340.00  3340.00  3340.00  3340.00
RE GRIDCART COARSE   ELEV 2  3360.00  3370.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 2  3410.00  3420.00  3460.00  3440.00
RE GRIDCART COARSE   ELEV 2  3430.00
RE GRIDCART COARSE   ELEV 3  3320.00  3330.00  3330.00  3330.00
RE GRIDCART COARSE   ELEV 3  3340.00  3350.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 3  3370.00  3380.00  3400.00  3410.00
RE GRIDCART COARSE   ELEV 3  3420.00  3440.00  3440.00  3440.00
RE GRIDCART COARSE   ELEV 3  3440.00
RE GRIDCART COARSE   ELEV 4  3320.00  3330.00  3330.00  3340.00
RE GRIDCART COARSE   ELEV 4  3340.00  3350.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 4  3380.00  3400.00  3410.00  3420.00
RE GRIDCART COARSE   ELEV 4  3450.00  3450.00  3440.00  3440.00
RE GRIDCART COARSE   ELEV 4  3440.00
RE GRIDCART COARSE   ELEV 5  3330.00  3330.00  3340.00  3340.00
RE GRIDCART COARSE   ELEV 5  3340.00  3350.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 5  3380.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 5  3470.00  3460.00  3450.00  3450.00
RE GRIDCART COARSE   ELEV 5  3450.00
RE GRIDCART COARSE   ELEV 6  3340.00  3330.00  3340.00  3350.00
RE GRIDCART COARSE   ELEV 6  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 6  3390.00  3410.00  3420.00  3450.00
RE GRIDCART COARSE   ELEV 6  3470.00  3460.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 6  3470.00
RE GRIDCART COARSE   ELEV 7  3350.00  3340.00  3350.00  3360.00
RE GRIDCART COARSE   ELEV 7  3350.00  3370.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 7  3400.00  3410.00  3420.00  3450.00
RE GRIDCART COARSE   ELEV 7  3480.00  3470.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 7  3500.00
RE GRIDCART COARSE   ELEV 8  3360.00  3350.00  3370.00  3370.00
RE GRIDCART COARSE   ELEV 8  3370.00  3380.00  3380.00  3390.00
RE GRIDCART COARSE   ELEV 8  3400.00  3410.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 8  3480.00  3490.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 8  3520.00
RE GRIDCART COARSE   ELEV 9  3380.00  3380.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 9  3380.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 9  3410.00  3420.00  3440.00  3450.00
RE GRIDCART COARSE   ELEV 9  3490.00  3500.00  3510.00  3530.00
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RE GRIDCART COARSE   ELEV 9  3540.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3400.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 10  3400.00  3420.00  3440.00  3460.00
RE GRIDCART COARSE   ELEV 10  3480.00  3510.00  3520.00  3540.00
RE GRIDCART COARSE   ELEV 10  3540.00
RE GRIDCART COARSE   ELEV 11  3400.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 11  3430.00  3430.00  3450.00  3470.00
RE GRIDCART COARSE   ELEV 11  3490.00  3510.00  3510.00  3530.00
RE GRIDCART COARSE   ELEV 11  3540.00
RE GRIDCART COARSE   ELEV 12  3390.00  3400.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3420.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 12  3450.00  3450.00  3460.00  3470.00
RE GRIDCART COARSE   ELEV 12  3500.00  3500.00  3500.00  3510.00
RE GRIDCART COARSE   ELEV 12  3520.00
RE GRIDCART COARSE   ELEV 13  3380.00  3390.00  3400.00  3400.00
RE GRIDCART COARSE   ELEV 13  3400.00  3420.00  3430.00  3450.00
RE GRIDCART COARSE   ELEV 13  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 13  3490.00  3490.00  3490.00  3500.00
RE GRIDCART COARSE   ELEV 13  3500.00
RE GRIDCART COARSE   ELEV 14  3370.00  3380.00  3390.00  3400.00
RE GRIDCART COARSE   ELEV 14  3400.00  3410.00  3420.00  3440.00
RE GRIDCART COARSE   ELEV 14  3460.00  3470.00  3470.00  3470.00
RE GRIDCART COARSE   ELEV 14  3480.00  3480.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 14  3500.00
RE GRIDCART COARSE   ELEV 15  3360.00  3370.00  3380.00  3380.00
RE GRIDCART COARSE   ELEV 15  3400.00  3400.00  3410.00  3430.00
RE GRIDCART COARSE   ELEV 15  3460.00  3460.00  3460.00  3460.00
RE GRIDCART COARSE   ELEV 15  3470.00  3470.00  3470.00  3480.00
RE GRIDCART COARSE   ELEV 15  3510.00
RE GRIDCART COARSE   ELEV 16  3350.00  3360.00  3370.00  3380.00
RE GRIDCART COARSE   ELEV 16  3390.00  3400.00  3400.00  3430.00
RE GRIDCART COARSE   ELEV 16  3440.00  3450.00  3450.00  3440.00
RE GRIDCART COARSE   ELEV 16  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 16  3510.00
RE GRIDCART COARSE   ELEV 17  3350.00  3360.00  3360.00  3370.00
RE GRIDCART COARSE   ELEV 17  3380.00  3390.00  3400.00  3420.00
RE GRIDCART COARSE   ELEV 17  3420.00  3430.00  3430.00  3440.00
RE GRIDCART COARSE   ELEV 17  3450.00  3460.00  3480.00  3490.00
RE GRIDCART COARSE   ELEV 17  3510.00
```

```
RE GRIDCART COARSE   END

RE FINISHED

ME STARTING

ME INPUTFIL C:\MODELS\MET\CBD94.STR (7X,6F7.5)

ME ANEMHGHT   10.000 METERS

ME SURFDATA 11111 1994 CARLSBAD

ME UAIRDATA 11111 1994

ME STARDATA ANNUAL

ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50

ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80

ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00

ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00

ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01

ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03

ME FINISHED

OU STARTING

OU RECTABLE SRCGRP

OU MAXTABLE 10 SRCGRP

OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMCC94A.GPH 70

OU FINISHED

************************************
*** SETUP Finishes Successfully ***
************************************
```

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

- -

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

```
**Model Calculates   1 STAR Average(s) for the Following Months:  0 0 0 0 0 0 0 0 0 0 0 0
                                             Seasons/Quarters:  0 0 0 0
                                                  and Annual:  1

**Data File Includes  1 STAR Summaries for the Following Months:  0 0 0 0 0 0 0 0 0 0 0 0
                                             Seasons/Quarters:  0 0 0 0
                                                  and Annual:  1

**This Run Includes:    2 Source(s);      1 Source Group(s); and    289 Receptor(s)
```

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

```
**Misc. Inputs:  Anem. Hgt. (m) =    10.00 ;    Decay Coef. =    .0000     ;    Rot. Angle =      .0
                 Emission Units = GRAMS/SEC                                ;  Emission Rate Unit Factor =    .10000E+07
                 Output Units   = MICROGRAMS/M**3
```

**Input Runstream File: ADMCC94A.DAT ; **Output Print File: ADMCC94A.LST

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

4

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-3189.5,	-2789.5,	-2389.5,	-1989.5,	-1589.5,	-1189.5,	-789.5,	-389.5,	10.5,	410.5,
810.5,	1210.5,	1610.5,	2010.5,	2410.5,	2810.5,	3210.5,			

*** Y-COORDINATES OF GRID ***
(METERS)

-3469.8,	-3069.8,	-2669.8,	-2269.8,	-1869.8,	-1469.8,	-1069.8,	-669.8,	-269.8,	130.2,
530.2,	930.2,	1330.2,	1730.2,	2130.2,	2530.2,	2930.2,			

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1021.08	1024.13	1024.13	1027.18	1030.22	1033.27	1036.32	1042.42	1042.42
2530.19	1021.08	1024.13	1027.18	1030.22	1033.27	1036.32	1036.32	1045.46	1048.51
2130.19	1024.13	1027.18	1030.22	1030.22	1036.32	1036.32	1039.37	1045.46	1054.61
1730.19	1027.18	1030.22	1033.27	1036.32	1036.32	1039.37	1042.42	1048.51	1054.61
1330.19	1030.22	1033.27	1036.32	1036.32	1036.32	1042.42	1045.46	1051.56	1057.66
930.19	1033.27	1036.32	1039.37	1039.37	1039.37	1042.42	1042.42	1048.51	1051.56
530.19	1036.32	1036.32	1039.37	1039.37	1039.37	1039.37	1039.37	1045.46	1045.46
130.19	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32	1036.32
-269.81	1030.22	1030.22	1030.22	1030.22	1030.22	1030.22	1033.27	1036.32	1039.37
-669.81	1024.13	1021.08	1027.18	1027.18	1027.18	1030.22	1030.22	1033.27	1036.32
-1069.81	1021.08	1018.03	1021.08	1024.13	1021.08	1027.18	1030.22	1033.27	1036.32
-1469.81	1018.03	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18	1030.22	1033.27
-1869.81	1014.98	1014.98	1018.03	1018.03	1018.03	1021.08	1024.13	1027.18	1030.22
-2269.81	1011.94	1014.98	1014.98	1018.03	1018.03	1021.08	1021.08	1024.13	1030.22
-2669.81	1011.94	1014.98	1014.98	1014.98	1018.03	1021.08	1021.08	1024.13	1027.18
-3069.81	1011.94	1011.94	1014.98	1014.98	1018.03	1018.03	1018.03	1018.03	1024.13
-3469.81	1008.89	1011.94	1011.94	1014.98	1014.98	1018.03	1014.98	1018.03	1018.03

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1045.46	1045.46	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2530.19	1051.56	1051.56	1048.51	1051.56	1054.61	1060.70	1063.75	1069.85
2130.19	1054.61	1054.61	1054.61	1057.66	1057.66	1057.66	1060.70	1069.85
1730.19	1057.66	1057.66	1057.66	1060.70	1060.70	1060.70	1063.75	1066.80
1330.19	1057.66	1057.66	1060.70	1063.75	1063.75	1063.75	1066.80	1066.80
930.19	1051.56	1054.61	1057.66	1066.80	1066.80	1066.80	1069.85	1072.90
530.19	1045.46	1051.56	1057.66	1063.75	1069.85	1069.85	1075.94	1078.99
130.19	1042.42	1048.51	1054.61	1060.70	1069.85	1072.90	1078.99	1078.99
-269.81	1042.42	1048.51	1051.56	1063.75	1066.80	1069.85	1075.94	1078.99
-669.81	1039.37	1045.46	1051.56	1060.70	1063.75	1066.80	1069.85	1072.90
-1069.81	1039.37	1042.42	1051.56	1060.70	1057.66	1060.70	1063.75	1066.80
-1469.81	1039.37	1042.42	1051.56	1057.66	1054.61	1057.66	1057.66	1057.66
-1869.81	1039.37	1042.42	1048.51	1057.66	1054.61	1051.56	1051.56	1051.56
-2269.81	1036.32	1039.37	1042.42	1051.56	1051.56	1048.51	1048.51	1048.51
-2669.81	1030.22	1036.32	1039.37	1042.42	1048.51	1048.51	1048.51	1048.51
-3069.81	1027.18	1030.22	1033.27	1039.37	1042.42	1054.61	1048.51	1045.46
-3469.81	1021.08	1027.18	1033.27	1036.32	1042.42	1048.51	1045.46	1042.42

8

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1730.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1330.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
930.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
530.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.19	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-1869.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2269.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-2669.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3069.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-3469.81	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	ANNUAL					
	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD94.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1994 YEAR: 1994

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00017000	.00086000	.00000000	.00000000	.00000000	.00000000
22.500	.00028000	.00058000	.00000000	.00000000	.00000000	.00000000
45.000	.00023000	.00115000	.00000000	.00000000	.00000000	.00000000
67.500	.00057000	.00115000	.00000000	.00000000	.00000000	.00000000
90.000	.00031000	.00158000	.00000000	.00000000	.00000000	.00000000
112.500	.00020000	.00101000	.00000000	.00000000	.00000000	.00000000
135.000	.00028000	.00058000	.00000000	.00000000	.00000000	.00000000
157.500	.00031000	.00158000	.00000000	.00000000	.00000000	.00000000
180.000	.00063000	.00144000	.00000000	.00000000	.00000000	.00000000
202.500	.00026000	.00043000	.00000000	.00000000	.00000000	.00000000
225.000	.00026000	.00043000	.00000000	.00000000	.00000000	.00000000
247.500	.00003000	.00014000	.00000000	.00000000	.00000000	.00000000
270.000	.00003000	.00014000	.00000000	.00000000	.00000000	.00000000
292.500	.00023000	.00029000	.00000000	.00000000	.00000000	.00000000
315.000	.00023000	.00029000	.00000000	.00000000	.00000000	.00000000
337.500	.00003000	.00014000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00093000	.00359000	.00244000	.00000000	.00000000	.00000000
22.500	.00089000	.00316000	.00144000	.00000000	.00000000	.00000000
45.000	.00120000	.00316000	.00115000	.00000000	.00000000	.00000000
67.500	.00125000	.00374000	.00115000	.00000000	.00000000	.00000000
90.000	.00116000	.00446000	.00302000	.00000000	.00000000	.00000000
112.500	.00119000	.00489000	.00331000	.00000000	.00000000	.00000000
135.000	.00178000	.00805000	.00633000	.00000000	.00000000	.00000000
157.500	.00121000	.00690000	.00561000	.00000000	.00000000	.00000000
180.000	.00110000	.00374000	.00374000	.00000000	.00000000	.00000000
202.500	.00001000	.00014000	.00043000	.00000000	.00000000	.00000000
225.000	.00002000	.00029000	.00029000	.00000000	.00000000	.00000000
247.500	.00068000	.00072000	.00029000	.00000000	.00000000	.00000000
270.000	.00023000	.00086000	.00043000	.00000000	.00000000	.00000000
292.500	.00032000	.00014000	.00014000	.00000000	.00000000	.00000000
315.000	.00054000	.00086000	.00058000	.00000000	.00000000	.00000000
337.500	.00041000	.00115000	.00058000	.00000000	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD94.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1994 YEAR: 1994

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00044000	.00403000	.00748000	.00173000	.00000000	.00000000
22.500	.00076000	.00259000	.00158000	.00058000	.00000000	.00000000
45.000	.00062000	.00273000	.00187000	.00029000	.00000000	.00000000
67.500	.00068000	.00187000	.00273000	.00058000	.00000000	.00000000
90.000	.00071000	.00359000	.00690000	.00187000	.00029000	.00000000
112.500	.00079000	.00288000	.00748000	.00359000	.00000000	.00000000
135.000	.00035000	.00316000	.01308000	.00719000	.00000000	.00000000
157.500	.00054000	.00489000	.01251000	.00518000	.00000000	.00000000
180.000	.00073000	.00230000	.00762000	.00345000	.00014000	.00000000
202.500	.00013000	.00115000	.00086000	.00029000	.00014000	.00000000
225.000	.00003000	.00029000	.00101000	.00058000	.00000000	.00000000
247.500	.00003000	.00029000	.00072000	.00072000	.00014000	.00029000
270.000	.00029000	.00115000	.00244000	.00216000	.00072000	.00058000
292.500	.00041000	.00086000	.00101000	.00029000	.00000000	.00000000
315.000	.00021000	.00043000	.00144000	.00029000	.00000000	.00000000
337.500	.00017000	.00158000	.00331000	.00144000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00059000	.00417000	.01352000	.01380000	.00273000	.00043000
22.500	.00019000	.00187000	.00388000	.00460000	.00144000	.00014000
45.000	.00022000	.00216000	.00532000	.00374000	.00043000	.00014000
67.500	.00074000	.00259000	.00388000	.00374000	.00058000	.00000000
90.000	.00077000	.00288000	.00676000	.00834000	.00129000	.00000000
112.500	.00051000	.00345000	.00820000	.01050000	.00129000	.00014000
135.000	.00038000	.00374000	.01481000	.02574000	.00316000	.00101000
157.500	.00095000	.00460000	.01107000	.01308000	.00072000	.00014000
180.000	.00089000	.00403000	.01869000	.01251000	.00072000	.00014000
202.500	.00015000	.00144000	.00661000	.00345000	.00144000	.00000000
225.000	.00041000	.00086000	.00489000	.00417000	.00129000	.00043000
247.500	.00029000	.00288000	.00604000	.01107000	.00604000	.00288000
270.000	.00046000	.00144000	.00561000	.01596000	.01050000	.00374000
292.500	.00016000	.00158000	.00446000	.00417000	.00173000	.00029000
315.000	.00022000	.00216000	.00388000	.00359000	.00187000	.00029000
337.500	.00025000	.00244000	.00791000	.01107000	.00359000	.00058000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD94.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1994 YEAR: 1994

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00460000	.00690000	.00000000	.00000000	.00000000
22.500	.00000000	.00230000	.00187000	.00000000	.00000000	.00000000
45.000	.00000000	.00216000	.00086000	.00000000	.00000000	.00000000
67.500	.00000000	.00158000	.00115000	.00000000	.00000000	.00000000
90.000	.00000000	.00359000	.00331000	.00000000	.00000000	.00000000
112.500	.00000000	.00474000	.00676000	.00000000	.00000000	.00000000
135.000	.00000000	.00575000	.01395000	.00000000	.00000000	.00000000
157.500	.00000000	.00561000	.01265000	.00000000	.00000000	.00000000
180.000	.00000000	.00676000	.02631000	.00000000	.00000000	.00000000
202.500	.00000000	.00417000	.01222000	.00000000	.00000000	.00000000
225.000	.00000000	.00230000	.00561000	.00000000	.00000000	.00000000
247.500	.00000000	.00489000	.01050000	.00000000	.00000000	.00000000
270.000	.00000000	.00388000	.01035000	.00000000	.00000000	.00000000
292.500	.00000000	.00403000	.00848000	.00000000	.00000000	.00000000
315.000	.00000000	.00374000	.00403000	.00000000	.00000000	.00000000
337.500	.00000000	.00302000	.00359000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00240000	.00848000	.00000000	.00000000	.00000000	.00000000
22.500	.00140000	.00446000	.00000000	.00000000	.00000000	.00000000
45.000	.00081000	.00288000	.00000000	.00000000	.00000000	.00000000
67.500	.00115000	.00187000	.00000000	.00000000	.00000000	.00000000
90.000	.00210000	.00561000	.00000000	.00000000	.00000000	.00000000
112.500	.00145000	.00474000	.00000000	.00000000	.00000000	.00000000
135.000	.00228000	.00978000	.00000000	.00000000	.00000000	.00000000
157.500	.00402000	.01725000	.00000000	.00000000	.00000000	.00000000
180.000	.00542000	.02070000	.00000000	.00000000	.00000000	.00000000
202.500	.00266000	.01006000	.00000000	.00000000	.00000000	.00000000
225.000	.00169000	.00618000	.00000000	.00000000	.00000000	.00000000
247.500	.00261000	.01179000	.00000000	.00000000	.00000000	.00000000
270.000	.00517000	.01510000	.00000000	.00000000	.00000000	.00000000
292.500	.00307000	.01050000	.00000000	.00000000	.00000000	.00000000
315.000	.00286000	.00820000	.00000000	.00000000	.00000000	.00000000
337.500	.00203000	.00518000	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = 1.00005

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -3189.53	-2789.53	-2389.53	-1989.53	-1589.53	-1189.53	-789.53	-389.53	10.47
2930.19	.027723	.033436	.036959	.043365	.050958	.060005	.076655	.099575	.109831
2530.19	.027553	.034492	.042668	.051068	.061385	.073591	.087275	.125846	.145124
2130.19	.028253	.036123	.046864	.056592	.074429	.085548	.107947	.155584	.185865
1730.19	.028043	.036658	.048948	.066797	.084782	.109022	.139422	.206617	.247315
1330.19	.026441	.035321	.048614	.065084	.089513	.140362	.193626	.273932	.358111
930.19	.028701	.035855	.045950	.061597	.090083	.150568	.229704	.364660	.581493
530.19	.030709	.036606	.047628	.060319	.079594	.115927	.219760	.542058	1.073149
130.19	.030349	.036133	.044010	.055229	.071921	.099782	.155454	.306972	2.181532
-269.81	.023709	.027359	.031977	.037963	.045580	.055891	.075811	.145016	.537889
-669.81	.017032	.017551	.022231	.024347	.026315	.038401	.055645	.079837	.232956
-1069.81	.012528	.012358	.014552	.018752	.021489	.031883	.042912	.062593	.149783
-1469.81	.009831	.010620	.013074	.016407	.019588	.024793	.030779	.053660	.097278
-1869.81	.008953	.010123	.012266	.014111	.016078	.019441	.023261	.043827	.069050
-2269.81	.008071	.009528	.010693	.012766	.014219	.016852	.021589	.035665	.055958
-2669.81	.007633	.008893	.009844	.010847	.012711	.014843	.021080	.031655	.043255
-3069.81	.007178	.007844	.009085	.009891	.011444	.013149	.018617	.024460	.034489
-3469.81	.006411	.007331	.007920	.009071	.009692	.013152	.016348	.022053	.026336

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 410.47	810.47	1210.47	1610.47	2010.47	2410.47	2810.47	3210.47
2930.19	.092410	.069271	.048529	.040260	.033000	.026811	.021707	.020889
2530.19	.112066	.078206	.054443	.043760	.034502	.026982	.025742	.025857
2130.19	.135086	.084342	.061461	.046499	.034905	.032915	.032784	.031738
1730.19	.163671	.094676	.068067	.047677	.044068	.043437	.041278	.038597
1330.19	.198338	.111082	.071057	.063701	.061162	.056382	.051191	.046294
930.19	.228190	.122524	.102463	.094213	.082534	.071201	.061214	.053227
530.19	.266195	.201395	.165671	.129905	.103377	.084401	.070318	.059728
130.19	.370747	.329572	.220979	.159321	.120821	.095606	.077972	.065218
-269.81	.182576	.238432	.183420	.140051	.109569	.088403	.073050	.061678
-669.81	.126557	.135363	.124135	.098541	.084218	.071905	.061701	.053518
-1069.81	.101700	.089039	.092056	.079143	.066985	.056807	.049911	.044931
-1469.81	.085012	.070388	.071574	.062326	.055584	.048944	.043044	.038044
-1869.81	.069840	.055239	.057089	.050974	.045653	.041638	.037695	.034025
-2269.81	.053691	.044612	.041394	.042496	.038610	.035305	.032775	.030190
-2669.81	.039526	.036975	.032380	.032502	.033234	.030662	.028411	.026674
-3069.81	.032140	.028955	.025163	.026361	.026442	.026962	.025132	.022848
-3469.81	.024902	.024497	.023294	.021718	.023155	.023767	.021846	.019647

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	2.181532	AT (	10.47,	130.19)	GC	6.	.370747	AT (	410.47,	130.19)	GC
2.	1.073149	AT (	10.47,	530.19)	GC	7.	.364660	AT (	-389.53,	930.19)	GC
3.	.581493	AT (	10.47,	930.19)	GC	8.	.358111	AT (	10.47,	1330.19)	GC
4.	.542058	AT (	-389.53,	530.19)	GC	9.	.329572	AT (	810.47,	130.19)	GC
5.	.537889	AT (	10.47,	-269.81)	GC	10.	.306972	AT (	-389.53,	130.19)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE MAX CONCENTRATION AT WIPP SITE BOUNDARY (93 WIPP Met)
CO TITLETWO Fine Receptor Grid(10x10m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -609.53 45 10.00 2974.73 11 10.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
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RE GRIDCART COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 1	1.50			
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50			
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50			
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50

RE GRIDCART COARSE	FLAG 4	1.50			
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50			
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50			
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50			
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50

RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50			
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50			
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50			
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50

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RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
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RE GRIDCART COARSE	ELEV 4	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 4	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 4	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 4	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 4	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 4	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 4	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 4	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 4	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 4	3410.00			
RE GRIDCART COARSE	ELEV 5	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 5	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 5	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 5	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 5	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 5	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 5	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 5	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 5	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 5	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 5	3410.00			
RE GRIDCART COARSE	ELEV 6	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 6	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 6	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 6	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 6	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 6	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 6	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 6	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 6	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 6	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 6	3410.00			
RE GRIDCART COARSE	ELEV 7	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 7	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 7	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 7	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 7	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 7	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 7	3410.00	3410.00	3410.00	3410.00

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RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00
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RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00
RE GRIDCART COARSE   END
RE FINISHED
ME STARTING
ME INPUTFIL C:\MODELS\MET\WP3093.STR  FREE
ME ANEMHGHT   10.000 METERS
ME SURFDATA 11111 1993 WIPP
ME UAIRDATA 11111 1993
ME STARDATA ANNUAL
ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50
ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80
ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01
ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03
ME FINISHED
OU STARTING
OU RECTABLE SRCGRP
OU MAXTABLE 10 SRCGRP
OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMFW93B.GPH 70
OU FINISHED
************************************
*** SETUP Finishes Successfully ***
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1
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates 1 STAR Average(s) for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**Data File Includes 1 STAR Summaries for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**This Run Includes: 2 Source(s); 1 Source Group(s); and 495 Receptor(s)

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs: Anem. Hgt. (m) = 10.00 ; Decay Coef. = .0000 ; Rot. Angle = .0
Emission Units = GRAMS/SEC ; Emission Rate Unit Factor = .10000E+07
Output Units = MICROGRAMS/M**3

**Input Runstream File: ADMFW93B.DAT ; **Output Print File: ADMFW93B.LST

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-609.5,	-599.5,	-589.5,	-579.5,	-569.5,	-559.5,	-549.5,	-539.5,	-529.5,	-519.5,
-509.5,	-499.5,	-489.5,	-479.5,	-469.5,	-459.5,	-449.5,	-439.5,	-429.5,	-419.5,
-409.5,	-399.5,	-389.5,	-379.5,	-369.5,	-359.5,	-349.5,	-339.5,	-329.5,	-319.5,
-309.5,	-299.5,	-289.5,	-279.5,	-269.5,	-259.5,	-249.5,	-239.5,	-229.5,	-219.5,
-209.5,	-199.5,	-189.5,	-179.5,	-169.5,					

*** Y-COORDINATES OF GRID ***
(METERS)

2974.7,	2984.7,	2994.7,	3004.7,	3014.7,	3024.7,	3034.7,	3044.7,	3054.7,	3064.7,
3074.7,									

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -609.53	-599.53	-589.53	-579.53	-569.53	-559.53	-549.53	-539.53	-529.53
3074.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3064.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3054.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3044.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3034.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3024.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3014.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3004.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2994.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2984.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2974.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -519.53	-509.53	-499.53	-489.53	-479.53	-469.53	-459.53	-449.53	-439.53
3074.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3064.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3054.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3044.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3034.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3024.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3014.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3004.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2994.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2984.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2974.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -429.53	-419.53	-409.53	-399.53	-389.53	-379.53	-369.53	-359.53	-349.53
3074.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3064.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3054.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3044.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3034.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3024.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3014.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3004.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2994.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2984.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2974.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -339.53	-329.53	-319.53	-309.53	-299.53	-289.53	-279.53	-269.53	-259.53
3074.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3064.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3054.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3044.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3034.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3024.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3014.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3004.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2994.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2984.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2974.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -249.53	-239.53	-229.53	-219.53	-209.53	-199.53	-189.53	-179.53	-169.53
3074.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3064.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3054.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3044.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3034.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3024.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3014.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
3004.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2994.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2984.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
2974.73	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -609.53	-599.53	-589.53	-579.53	-569.53	-559.53	-549.53	-539.53	-529.53
3074.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3064.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3054.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3044.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3034.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3024.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3014.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3004.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2994.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2984.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2974.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -519.53	-509.53	-499.53	-489.53	-479.53	-469.53	-459.53	-449.53	-439.53
3074.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3064.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3054.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3044.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3034.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3024.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3014.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3004.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2994.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2984.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2974.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -429.53	-419.53	-409.53	-399.53	-389.53	-379.53	-369.53	-359.53	-349.53
3074.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3064.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3054.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3044.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3034.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3024.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3014.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3004.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2994.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2984.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2974.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -339.53	-329.53	-319.53	-309.53	-299.53	-289.53	-279.53	-269.53	-259.53
3074.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3064.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3054.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3044.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3034.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3024.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3014.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3004.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2994.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2984.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2974.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -249.53	-239.53	-229.53	-219.53	-209.53	-199.53	-189.53	-179.53	-169.53
3074.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3064.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3054.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3044.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3034.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3024.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3014.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3004.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2994.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2984.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2974.73	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	ANNUAL					
	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: WIPP NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00017000	.00000000	.00000000	.00000000	.00000000
90.000	.00019600	.00034000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00034000	.00000000	.00000000	.00000000	.00000000
135.000	.00019600	.00136200	.00000000	.00000000	.00000000	.00000000
157.500	.00039200	.00238300	.00000000	.00000000	.00000000	.00000000
180.000	.00195900	.00187200	.00000000	.00000000	.00000000	.00000000
202.500	.00195900	.00153200	.00000000	.00000000	.00000000	.00000000
225.000	.00215500	.00221300	.00000000	.00000000	.00000000	.00000000
247.500	.00195900	.00119100	.00000000	.00000000	.00000000	.00000000
270.000	.00078400	.00085100	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00068100	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00019600	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00058800	.00017000	.00051100	.00000000	.00000000	.00000000
67.500	.00078400	.00085100	.00017000	.00000000	.00000000	.00000000
90.000	.00156700	.00102100	.00051100	.00000000	.00000000	.00000000
112.500	.00333100	.00306400	.00255300	.00000000	.00000000	.00000000
135.000	.00293900	.00425500	.00425500	.00000000	.00000000	.00000000
157.500	.00293900	.00766000	.00680900	.00000000	.00000000	.00000000
180.000	.00411400	.00697900	.00510600	.00000000	.00000000	.00000000
202.500	.00489800	.00646800	.00306400	.00000000	.00000000	.00000000
225.000	.00391800	.00459600	.00187200	.00000000	.00000000	.00000000
247.500	.00509400	.00527700	.00153200	.00000000	.00000000	.00000000
270.000	.00117600	.00170200	.00204300	.00000000	.00000000	.00000000
292.500	.00098000	.00187200	.00221300	.00000000	.00000000	.00000000
315.000	.00098000	.00102100	.00119100	.00000000	.00000000	.00000000
337.500	.00000000	.00017000	.00000000	.00000000	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: WIPP NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00039200	.00034000	.00000000	.00000000	.00000000	.00000000
22.500	.00019600	.00034000	.00034000	.00000000	.00000000	.00000000
45.000	.00000000	.00068100	.00238300	.00000000	.00000000	.00000000
67.500	.00098000	.00085100	.00102100	.00000000	.00000000	.00000000
90.000	.00137100	.00136200	.00187200	.00000000	.00000000	.00000000
112.500	.00450600	.00391500	.00629800	.00034000	.00000000	.00000000
135.000	.00352700	.00544700	.01787200	.00442600	.00000000	.00000000
157.500	.00450600	.00425500	.01123400	.00289400	.00000000	.00000000
180.000	.00293900	.00595700	.01089400	.00340400	.00017000	.00000000
202.500	.00176300	.00459600	.00595700	.00017000	.00000000	.00000000
225.000	.00313500	.00425500	.00187200	.00017000	.00000000	.00000000
247.500	.00156700	.00340400	.00459600	.00170200	.00000000	.00000000
270.000	.00195900	.00289400	.00204300	.00170200	.00034000	.00000000
292.500	.00137100	.00153200	.00221300	.00000000	.00000000	.00000000
315.000	.00039200	.00136200	.00221300	.00051100	.00000000	.00000000
337.500	.00000000	.00017000	.00034000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00017000	.00017000	.00000000	.00000000	.00000000
22.500	.00000000	.00102100	.00119100	.00102100	.00034000	.00034000
45.000	.00039200	.00255300	.00493600	.00851100	.00153200	.00000000
67.500	.00078400	.00425500	.00595700	.00697900	.00068100	.00017000
90.000	.00313500	.00527700	.01293600	.00987200	.00119100	.00017000
112.500	.00372300	.01293600	.02706400	.01344700	.00136200	.00000000
135.000	.00372300	.01004300	.03285100	.04204300	.00306400	.00000000
157.500	.00176300	.00663800	.01855300	.01991500	.00238300	.00017000
180.000	.00274300	.00612800	.01072300	.00425500	.00051100	.00000000
202.500	.00117600	.00425500	.00731900	.00357400	.00000000	.00000000
225.000	.00019600	.00408500	.00510600	.00340400	.00136200	.00017000
247.500	.00058800	.00357400	.00595700	.01123400	.00306400	.00136200
270.000	.00058800	.00238300	.00527700	.00748900	.00357400	.00187200
292.500	.00039200	.00153200	.00221300	.00238300	.00102100	.00000000
315.000	.00000000	.00068100	.00204300	.00391500	.00136200	.00034000
337.500	.00000000	.00000000	.00034000	.00051100	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: WIPP NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00034000	.00034000	.00000000	.00000000	.00000000
22.500	.00000000	.00017000	.00034000	.00000000	.00000000	.00000000
45.000	.00000000	.00085100	.00187200	.00000000	.00000000	.00000000
67.500	.00000000	.00170200	.00272300	.00000000	.00000000	.00000000
90.000	.00000000	.00272300	.00783000	.00000000	.00000000	.00000000
112.500	.00000000	.00680900	.02314900	.00000000	.00000000	.00000000
135.000	.00000000	.01123400	.02961700	.00000000	.00000000	.00000000
157.500	.00000000	.00868100	.01038300	.00000000	.00000000	.00000000
180.000	.00000000	.00323400	.00238300	.00000000	.00000000	.00000000
202.500	.00000000	.00340400	.00068100	.00000000	.00000000	.00000000
225.000	.00000000	.00221300	.00119100	.00000000	.00000000	.00000000
247.500	.00000000	.00187200	.00442600	.00000000	.00000000	.00000000
270.000	.00000000	.00034000	.00272300	.00000000	.00000000	.00000000
292.500	.00000000	.00068100	.00204300	.00000000	.00000000	.00000000
315.000	.00000000	.00085100	.00170200	.00000000	.00000000	.00000000
337.500	.00000000	.00034000	.00085100	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00051100	.00000000	.00000000	.00000000	.00000000
22.500	.00039200	.00187200	.00000000	.00000000	.00000000	.00000000
45.000	.00156700	.00374500	.00000000	.00000000	.00000000	.00000000
67.500	.00313500	.00476600	.00000000	.00000000	.00000000	.00000000
90.000	.00607400	.00748900	.00000000	.00000000	.00000000	.00000000
112.500	.01097200	.02059600	.00000000	.00000000	.00000000	.00000000
135.000	.01195100	.02348900	.00000000	.00000000	.00000000	.00000000
157.500	.01136400	.01293600	.00000000	.00000000	.00000000	.00000000
180.000	.00881700	.00561700	.00000000	.00000000	.00000000	.00000000
202.500	.00607400	.00357400	.00000000	.00000000	.00000000	.00000000
225.000	.00470200	.00493600	.00000000	.00000000	.00000000	.00000000
247.500	.00450600	.00510600	.00000000	.00000000	.00000000	.00000000
270.000	.00254700	.00272300	.00000000	.00000000	.00000000	.00000000
292.500	.00176300	.00238300	.00000000	.00000000	.00000000	.00000000
315.000	.00195900	.00238300	.00000000	.00000000	.00000000	.00000000
337.500	.00058800	.00187200	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99999

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -609.53	-599.53	-589.53	-579.53	-569.53	-559.53	-549.53	-539.53	-529.53
3074.73	.078429	.078223	.078015	.077806	.077595	.077381	.077167	.076950	.076731
3064.73	.078795	.078588	.078379	.078169	.077956	.077742	.077526	.077308	.077088
3054.73	.079164	.078956	.078746	.078534	.078321	.078105	.077888	.077669	.077448
3044.73	.079537	.079327	.079116	.078903	.078688	.078471	.078253	.078032	.077810
3034.73	.079912	.079701	.079489	.079275	.079058	.078840	.078620	.078399	.078175
3024.73	.080289	.080078	.079864	.079649	.079431	.079212	.078991	.078768	.078543
3014.73	.080670	.080457	.080243	.080026	.079808	.079587	.079365	.079141	.078914
3004.73	.081054	.080840	.080624	.080406	.080187	.079965	.079742	.079516	.079289
2994.73	.081441	.081226	.081009	.080790	.080569	.080346	.080121	.079894	.079665
2984.73	.081831	.081615	.081396	.081176	.080954	.080730	.080503	.080275	.080045
2974.73	.082224	.082006	.081787	.081565	.081342	.081116	.080889	.080659	.080428

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -519.53	-509.53	-499.53	-489.53	-479.53	-469.53	-459.53	-449.53	-439.53
3074.73	.076511	.076289	.076065	.075839	.075612	.075383	.075152	.074919	.074684
3064.73	.076866	.076643	.076418	.076191	.075962	.075731	.075499	.075265	.075029
3054.73	.077225	.077000	.076773	.076545	.076315	.076083	.075849	.075614	.075376
3044.73	.077586	.077360	.077132	.076902	.076671	.076437	.076202	.075965	.075727
3034.73	.077949	.077722	.077493	.077262	.077029	.076795	.076558	.076320	.076080
3024.73	.078316	.078088	.077857	.077625	.077391	.077155	.076917	.076677	.076435
3014.73	.078686	.078456	.078225	.077991	.077755	.077517	.077278	.077037	.076793
3004.73	.079059	.078828	.078595	.078359	.078122	.077883	.077642	.077399	.077154
2994.73	.079435	.079202	.078967	.078730	.078492	.078251	.078009	.077764	.077518
2984.73	.079813	.079579	.079342	.079104	.078864	.078622	.078378	.078132	.077884
2974.73	.080194	.079958	.079721	.079481	.079239	.078996	.078750	.078503	.078253

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -429.53	-419.53	-409.53	-399.53	-389.53	-379.53	-369.53	-359.53	-349.53
3074.73	.074448	.074210	.073971	.073730	.073487	.073242	.072996	.072748	.072498
3064.73	.074792	.074552	.074311	.074069	.073824	.073578	.073330	.073080	.072829
3054.73	.075138	.074897	.074654	.074410	.074164	.073916	.073667	.073416	.073163
3044.73	.075486	.075244	.075000	.074754	.074506	.074257	.074006	.073753	.073499
3034.73	.075838	.075594	.075348	.075101	.074851	.074601	.074348	.074093	.073837
3024.73	.076192	.075946	.075699	.075450	.075199	.074947	.074692	.074436	.074178
3014.73	.076548	.076301	.076053	.075802	.075550	.075295	.075039	.074782	.074522
3004.73	.076908	.076659	.076409	.076157	.075903	.075647	.075389	.075130	.074868
2994.73	.077270	.077020	.076768	.076514	.076258	.076001	.075741	.075480	.075217
2984.73	.077634	.077383	.077129	.076874	.076616	.076357	.076096	.075833	.075568
2974.73	.078002	.077749	.077493	.077236	.076977	.076716	.076453	.076189	.075922

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -339.53	-329.53	-319.53	-309.53	-299.53	-289.53	-279.53	-269.53	-259.53
3074.73	.072247	.071994	.071739	.071483	.071225	.070966	.070705	.070442	.070178
3064.73	.072576	.072322	.072065	.071807	.071548	.071287	.071024	.070759	.070493
3054.73	.072908	.072652	.072394	.072134	.071873	.071610	.071345	.071079	.070811
3044.73	.073242	.072984	.072725	.072463	.072200	.071935	.071669	.071401	.071131
3034.73	.073579	.073319	.073058	.072795	.072530	.072264	.071995	.071726	.071454
3024.73	.073919	.073657	.073394	.073129	.072863	.072594	.072324	.072053	.071779
3014.73	.074260	.073997	.073732	.073466	.073197	.072927	.072656	.072382	.072107
3004.73	.074605	.074340	.074074	.073805	.073535	.073263	.072989	.072714	.072437
2994.73	.074952	.074685	.074417	.074147	.073875	.073601	.073325	.073048	.072769
2984.73	.075301	.075033	.074763	.074491	.074217	.073941	.073664	.073385	.073104
2974.73	.075654	.075383	.075111	.074837	.074562	.074284	.074005	.073724	.073441

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -249.53	-239.53	-229.53	-219.53	-209.53	-199.53	-189.53	-179.53	-169.53
3074.73	.069912	.069645	.069376	.069105	.068833	.068560	.068285	.068008	.067730
3064.73	.070226	.069956	.069686	.069413	.069140	.068864	.068587	.068309	.068029
3054.73	.070542	.070271	.069998	.069724	.069448	.069171	.068892	.068612	.068330
3044.73	.070860	.070587	.070313	.070037	.069759	.069480	.069199	.068917	.068633
3034.73	.071181	.070906	.070630	.070352	.070073	.069792	.069509	.069225	.068939
3024.73	.071504	.071228	.070950	.070670	.070388	.070105	.069821	.069535	.069247
3014.73	.071830	.071552	.071272	.070990	.070706	.070421	.070135	.069847	.069557
3004.73	.072158	.071878	.071596	.071312	.071027	.070740	.070451	.070161	.069869
2994.73	.072489	.072206	.071922	.071637	.071349	.071060	.070770	.070478	.070184
2984.73	.072821	.072537	.072251	.071963	.071674	.071383	.071091	.070796	.070501
2974.73	.073157	.072870	.072582	.072293	.072001	.071708	.071414	.071117	.070819

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	.082224	AT (	-609.53,	2974.73)	GC	6.	.081565	AT (	-579.53,	2974.73)	GC
2.	.082006	AT (	-599.53,	2974.73)	GC	7.	.081441	AT (	-609.53,	2994.73)	GC
3.	.081831	AT (	-609.53,	2984.73)	GC	8.	.081396	AT (	-589.53,	2984.73)	GC
4.	.081787	AT (	-589.53,	2974.73)	GC	9.	.081342	AT (	-569.53,	2974.73)	GC
5.	.081615	AT (	-599.53,	2984.73)	GC	10.	.081226	AT (	-599.53,	2994.73)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE MAX CONCENTRATION AT WIPP SITE BOUNDARY (90 Carlsbad Met)
CO TITLETWO Fine Receptor Grid(10x10m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -209.53 45 10.00 2978.51 11 10.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
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RE GRIDCART COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 1	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 1	1.50			
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50			
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50			
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50

RE GRIDCART COARSE	FLAG 4	1.50			
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50			
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50			
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50			
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50

RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50			
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50			
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50			
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50

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RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 11     1.50
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 1  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 2  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 3  3420.00
RE GRIDCART COARSE   ELEV 4  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 4  3420.00  3420.00  3420.00  3420.00
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RE GRIDCART COARSE	ELEV 4	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 4	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 4	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 4	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 4	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 4	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 4	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 4	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 4	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 4	3420.00			
RE GRIDCART COARSE	ELEV 5	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 5	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 5	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 5	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 5	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 5	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 5	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 5	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 5	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 5	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 5	3420.00			
RE GRIDCART COARSE	ELEV 6	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 6	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 6	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 6	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 6	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 6	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 6	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 6	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 6	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 6	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 6	3420.00			
RE GRIDCART COARSE	ELEV 7	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 7	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 7	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 7	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 7	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 7	3420.00	3420.00	3420.00	3420.00
RE GRIDCART COARSE	ELEV 7	3420.00	3420.00	3420.00	3420.00

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RE GRIDCART COARSE   ELEV 7  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 7  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 7  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 7  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 7  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 8  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 9  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 10  3420.00
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RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00  3420.00  3420.00  3420.00
RE GRIDCART COARSE   ELEV 11  3420.00
RE GRIDCART COARSE   END
RE FINISHED
ME STARTING
ME INPUTFIL C:\MODELS\MET\CBD90.STR (7X,6F7.5)
ME ANEMHGHT   10.000 METERS
ME SURFDATA 11111 1990 CARLSBAD
ME UAIRDATA 11111 1990
ME STARDATA ANNUAL
ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50
ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80
ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01
ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03
ME FINISHED
OU STARTING
OU RECTABLE SRCGRP
OU MAXTABLE 10 SRCGRP
OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMFC90B.GPH 70
OU FINISHED
************************************
*** SETUP Finishes Successfully ***
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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates 1 STAR Average(s) for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**Data File Includes 1 STAR Summaries for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**This Run Includes: 2 Source(s); 1 Source Group(s); and 495 Receptor(s)

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs: Anem. Hgt. (m) = 10.00 ; Decay Coef. = .0000 ; Rot. Angle = .0
Emission Units = GRAMS/SEC ; Emission Rate Unit Factor = .10000E+07
Output Units = MICROGRAMS/M**3

**Input Runstream File: ADMFC90B.DAT ; **Output Print File: ADMFC90B.LST

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-209.5,	-199.5,	-189.5,	-179.5,	-169.5,	-159.5,	-149.5,	-139.5,	-129.5,	-119.5,
-109.5,	-99.5,	-89.5,	-79.5,	-69.5,	-59.5,	-49.5,	-39.5,	-29.5,	-19.5,
-9.5,	.5,	10.5,	20.5,	30.5,	40.5,	50.5,	60.5,	70.5,	80.5,
90.5,	100.5,	110.5,	120.5,	130.5,	140.5,	150.5,	160.5,	170.5,	180.5,
190.5,	200.5,	210.5,	220.5,	230.5,					

*** Y-COORDINATES OF GRID ***
(METERS)

2978.5,	2988.5,	2998.5,	3008.5,	3018.5,	3028.5,	3038.5,	3048.5,	3058.5,	3068.5,
3078.5,									

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -209.53	-199.53	-189.53	-179.53	-169.53	-159.53	-149.53	-139.53	-129.53
3078.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3068.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3058.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3048.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3038.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3028.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3018.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3008.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2998.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2988.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2978.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -119.53	-109.53	-99.53	-89.53	-79.53	-69.53	-59.53	-49.53	-39.53
3078.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3068.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3058.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3048.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3038.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3028.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3018.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3008.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2998.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2988.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2978.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -29.53	-19.53	-9.53	.47	10.47	20.47	30.47	40.47	50.47
3078.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3068.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3058.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3048.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3038.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3028.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3018.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3008.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2998.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2988.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2978.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 60.47	70.47	80.47	90.47	100.47	110.47	120.47	130.47	140.47
3078.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3068.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3058.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3048.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3038.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3028.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3018.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3008.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2998.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2988.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2978.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 150.47	160.47	170.47	180.47	190.47	200.47	210.47	220.47	230.47
3078.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3068.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3058.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3048.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3038.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3028.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3018.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
3008.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2998.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2988.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42
2978.51	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42	1042.42

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -209.53	-199.53	-189.53	-179.53	-169.53	-159.53	-149.53	-139.53	-129.53
3078.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3068.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3058.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3048.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3038.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3028.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3018.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3008.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2998.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2988.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2978.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -119.53	-109.53	-99.53	-89.53	-79.53	-69.53	-59.53	-49.53	-39.53
3078.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3068.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3058.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3048.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3038.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3028.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3018.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3008.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2998.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2988.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2978.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -29.53	-19.53	-9.53	.47	10.47	20.47	30.47	40.47	50.47
3078.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3068.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3058.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3048.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3038.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3028.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3018.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3008.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2998.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2988.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2978.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 60.47	70.47	80.47	90.47	100.47	110.47	120.47	130.47	140.47
3078.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3068.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3058.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3048.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3038.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3028.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3018.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3008.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2998.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2988.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2978.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 150.47	160.47	170.47	180.47	190.47	200.47	210.47	220.47	230.47
3078.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3068.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3058.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3048.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3038.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3028.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3018.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
3008.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2998.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2988.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
2978.51	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	ANNUAL WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1990 YEAR: 1990

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00064000	.00083000	.00000000	.00000000	.00000000	.00000000
22.500	.00018000	.00024000	.00000000	.00000000	.00000000	.00000000
45.000	.00066000	.00059000	.00000000	.00000000	.00000000	.00000000
67.500	.00048000	.00035000	.00000000	.00000000	.00000000	.00000000
90.000	.00094000	.00095000	.00000000	.00000000	.00000000	.00000000
112.500	.00057000	.00047000	.00000000	.00000000	.00000000	.00000000
135.000	.00126000	.00083000	.00000000	.00000000	.00000000	.00000000
157.500	.00045000	.00059000	.00000000	.00000000	.00000000	.00000000
180.000	.00066000	.00059000	.00000000	.00000000	.00000000	.00000000
202.500	.00018000	.00024000	.00000000	.00000000	.00000000	.00000000
225.000	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
247.500	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
270.000	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00036000	.00047000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00103000	.00213000	.00189000	.00000000	.00000000	.00000000
22.500	.00130000	.00213000	.00071000	.00000000	.00000000	.00000000
45.000	.00083000	.00177000	.00118000	.00000000	.00000000	.00000000
67.500	.00118000	.00307000	.00106000	.00000000	.00000000	.00000000
90.000	.00169000	.00284000	.00130000	.00000000	.00000000	.00000000
112.500	.00105000	.00402000	.00189000	.00000000	.00000000	.00000000
135.000	.00116000	.00556000	.00355000	.00000000	.00000000	.00000000
157.500	.00225000	.00721000	.00343000	.00000000	.00000000	.00000000
180.000	.00248000	.00520000	.00343000	.00000000	.00000000	.00000000
202.500	.00039000	.00071000	.00095000	.00000000	.00000000	.00000000
225.000	.00043000	.00095000	.00012000	.00000000	.00000000	.00000000
247.500	.00009000	.00059000	.00024000	.00000000	.00000000	.00000000
270.000	.00035000	.00047000	.00035000	.00000000	.00000000	.00000000
292.500	.00045000	.00024000	.00024000	.00000000	.00000000	.00000000
315.000	.00034000	.00130000	.00012000	.00000000	.00000000	.00000000
337.500	.00071000	.00189000	.00071000	.00000000	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111
NAME: CARLSBAD
YEAR: 1990

UPPER AIR STATION NO.: 11111
NAME: UNKNOWN
YEAR: 1990

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00080000	.00366000	.00816000	.00248000	.00012000	.00000000
22.500	.00035000	.00284000	.00343000	.00059000	.00000000	.00000000
45.000	.00025000	.00319000	.00118000	.00012000	.00000000	.00000000
67.500	.00036000	.00296000	.00130000	.00000000	.00000000	.00000000
90.000	.00056000	.00390000	.00343000	.00071000	.00000000	.00000000
112.500	.00067000	.00366000	.00473000	.00142000	.00000000	.00000000
135.000	.00029000	.00366000	.01017000	.00355000	.00012000	.00000000
157.500	.00069000	.00556000	.01324000	.00248000	.00035000	.00000000
180.000	.00040000	.00508000	.01206000	.00284000	.00024000	.00000000
202.500	.00034000	.00106000	.00106000	.00071000	.00000000	.00000000
225.000	.00016000	.00047000	.00047000	.00012000	.00024000	.00000000
247.500	.00030000	.00059000	.00177000	.00083000	.00071000	.00047000
270.000	.00047000	.00118000	.00225000	.00213000	.00165000	.00071000
292.500	.00031000	.00071000	.00083000	.00083000	.00024000	.00000000
315.000	.00035000	.00118000	.00095000	.00035000	.00000000	.00000000
337.500	.00033000	.00095000	.00189000	.00059000	.00012000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00043000	.00461000	.00875000	.01572000	.00307000	.00059000
22.500	.00042000	.00248000	.00402000	.00449000	.00047000	.00035000
45.000	.00044000	.00284000	.00496000	.00343000	.00035000	.00012000
67.500	.00037000	.00177000	.00366000	.00201000	.00000000	.00000000
90.000	.00058000	.00307000	.00579000	.00496000	.00035000	.00000000
112.500	.00042000	.00248000	.00603000	.00378000	.00035000	.00000000
135.000	.00100000	.00556000	.01312000	.01820000	.00201000	.00059000
157.500	.00073000	.00520000	.02506000	.02376000	.00225000	.00024000
180.000	.00096000	.00496000	.01962000	.01466000	.00071000	.00047000
202.500	.00028000	.00225000	.00319000	.00366000	.00118000	.00035000
225.000	.00064000	.00201000	.00390000	.00319000	.00106000	.00024000
247.500	.00034000	.00130000	.00544000	.01253000	.00532000	.00189000
270.000	.00021000	.00307000	.00768000	.02624000	.01548000	.00662000
292.500	.00049000	.00165000	.00402000	.00922000	.00213000	.00071000
315.000	.00039000	.00213000	.00366000	.00485000	.00047000	.00012000
337.500	.00046000	.00307000	.00721000	.00969000	.00414000	.00059000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1990 YEAR: 1990

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00390000	.00473000	.00000000	.00000000	.00000000
22.500	.00000000	.00130000	.00130000	.00000000	.00000000	.00000000
45.000	.00000000	.00071000	.00118000	.00000000	.00000000	.00000000
67.500	.00000000	.00118000	.00154000	.00000000	.00000000	.00000000
90.000	.00000000	.00165000	.00189000	.00000000	.00000000	.00000000
112.500	.00000000	.00154000	.00236000	.00000000	.00000000	.00000000
135.000	.00000000	.00414000	.00863000	.00000000	.00000000	.00000000
157.500	.00000000	.00721000	.01797000	.00000000	.00000000	.00000000
180.000	.00000000	.01005000	.02364000	.00000000	.00000000	.00000000
202.500	.00000000	.00284000	.00934000	.00000000	.00000000	.00000000
225.000	.00000000	.00366000	.00792000	.00000000	.00000000	.00000000
247.500	.00000000	.00236000	.01206000	.00000000	.00000000	.00000000
270.000	.00000000	.00390000	.01478000	.00000000	.00000000	.00000000
292.500	.00000000	.00461000	.01229000	.00000000	.00000000	.00000000
315.000	.00000000	.00260000	.00603000	.00000000	.00000000	.00000000
337.500	.00000000	.00154000	.00402000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00468000	.00993000	.00000000	.00000000	.00000000	.00000000
22.500	.00242000	.00520000	.00000000	.00000000	.00000000	.00000000
45.000	.00155000	.00201000	.00000000	.00000000	.00000000	.00000000
67.500	.00120000	.00248000	.00000000	.00000000	.00000000	.00000000
90.000	.00258000	.00390000	.00000000	.00000000	.00000000	.00000000
112.500	.00174000	.00461000	.00000000	.00000000	.00000000	.00000000
135.000	.00246000	.00745000	.00000000	.00000000	.00000000	.00000000
157.500	.00425000	.01430000	.00000000	.00000000	.00000000	.00000000
180.000	.00608000	.02352000	.00000000	.00000000	.00000000	.00000000
202.500	.00264000	.00981000	.00000000	.00000000	.00000000	.00000000
225.000	.00254000	.00674000	.00000000	.00000000	.00000000	.00000000
247.500	.00388000	.00768000	.00000000	.00000000	.00000000	.00000000
270.000	.00378000	.01312000	.00000000	.00000000	.00000000	.00000000
292.500	.00431000	.01678000	.00000000	.00000000	.00000000	.00000000
315.000	.00265000	.00827000	.00000000	.00000000	.00000000	.00000000
337.500	.00287000	.00603000	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99995

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -209.53	-199.53	-189.53	-179.53	-169.53	-159.53	-149.53	-139.53	-129.53
3078.51	.111547	.111800	.112052	.112301	.112549	.112795	.113039	.113282	.113522
3068.51	.112035	.112290	.112544	.112796	.113046	.113294	.113540	.113784	.114027
3058.51	.112527	.112784	.113040	.113294	.113546	.113796	.114044	.114290	.114535
3048.51	.113023	.113282	.113540	.113795	.114049	.114301	.114552	.114800	.115047
3038.51	.113522	.113783	.114043	.114301	.114557	.114811	.115064	.115314	.115563
3028.51	.114025	.114288	.114550	.114810	.115068	.115325	.115579	.115832	.116082
3018.51	.114531	.114797	.115061	.115323	.115584	.115842	.116099	.116353	.116606
3008.51	.115041	.115309	.115576	.115840	.116102	.116363	.116622	.116878	.117134
2998.51	.115556	.115826	.116094	.116361	.116626	.116888	.117149	.117408	.117665
2988.51	.116074	.116346	.116617	.116886	.117153	.117418	.117681	.117942	.118201
2978.51	.116596	.116871	.117144	.117415	.117684	.117951	.118217	.118480	.118741

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -119.53	-109.53	-99.53	-89.53	-79.53	-69.53	-59.53	-49.53	-39.53
3078.51	.113761	.113998	.114233	.114467	.114698	.114927	.115155	.115380	.115605
3068.51	.114267	.114507	.114744	.114979	.115212	.115443	.115672	.115900	.116125
3058.51	.114778	.115018	.115258	.115494	.115729	.115963	.116194	.116423	.116650
3048.51	.115292	.115534	.115775	.116014	.116252	.116486	.116719	.116950	.117179
3038.51	.115809	.116054	.116297	.116538	.116777	.117014	.117249	.117482	.117712
3028.51	.116331	.116578	.116823	.117066	.117306	.117545	.117782	.118017	.118249
3018.51	.116857	.117106	.117353	.117597	.117840	.118081	.118320	.118557	.118791
3008.51	.117386	.117637	.117886	.118133	.118378	.118620	.118861	.119099	.119336
2998.51	.117920	.118173	.118424	.118673	.118920	.119165	.119407	.119648	.119886
2988.51	.118458	.118713	.118966	.119217	.119466	.119712	.119958	.120200	.120441
2978.51	.119000	.119258	.119512	.119766	.120017	.120265	.120513	.120756	.120999

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -29.53	-19.53	-9.53	.47	10.47	20.47	30.47	40.47	50.47
3078.51	.115827	.116046	.116264	.116487	.115839	.115235	.114628	.114021	.113413
3068.51	.116349	.116570	.116788	.117015	.116364	.115753	.115142	.114530	.113916
3058.51	.116876	.117100	.117319	.117547	.116889	.116275	.115659	.115042	.114423
3048.51	.117406	.117632	.117855	.118083	.117417	.116800	.116181	.115559	.114936
3038.51	.117941	.118168	.118395	.118624	.117953	.117328	.116703	.116079	.115450
3028.51	.118480	.118708	.118936	.119168	.118493	.117862	.117229	.116595	.115965
3018.51	.119023	.119254	.119480	.119717	.119035	.118400	.117762	.117123	.116483
3008.51	.119570	.119803	.120033	.120269	.119580	.118942	.118299	.117655	.117009
2998.51	.120122	.120356	.120590	.120827	.120134	.119488	.118840	.118191	.117540
2988.51	.120678	.120915	.121151	.121389	.120692	.120039	.119387	.118733	.118076
2978.51	.121239	.121477	.121714	.121955	.121251	.120595	.119937	.119277	.118616

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 60.47	70.47	80.47	90.47	100.47	110.47	120.47	130.47	140.47
3078.51	.112803	.112191	.111578	.110964	.110349	.109732	.109114	.108494	.107874
3068.51	.113302	.112685	.112067	.111448	.110828	.110206	.109584	.108959	.108334
3058.51	.113804	.113183	.112560	.111936	.111311	.110684	.110057	.109428	.108797
3048.51	.114311	.113684	.113057	.112428	.111797	.111166	.110533	.109899	.109264
3038.51	.114821	.114189	.113557	.112923	.112287	.111651	.111013	.110374	.109733
3028.51	.115329	.114698	.114061	.113422	.112781	.112139	.111496	.110852	.110206
3018.51	.115840	.115197	.114560	.113925	.113279	.112632	.111984	.111334	.110683
3008.51	.116362	.115714	.115064	.114412	.113769	.113116	.112474	.111819	.111163
2998.51	.116889	.116234	.115579	.114923	.114264	.113605	.112956	.112295	.111647
2988.51	.117418	.116759	.116099	.115437	.114773	.114108	.113442	.112774	.112106
2978.51	.117953	.117288	.116622	.115954	.115285	.114615	.113944	.113271	.112596

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 150.47	160.47	170.47	180.47	190.47	200.47	210.47	220.47	230.47
3078.51	.107252	.106630	.106006	.105381	.104757	.104130	.103504	.102876	.102247
3068.51	.107708	.107080	.106452	.105822	.105191	.104560	.103928	.103295	.102662
3058.51	.108166	.107534	.106900	.106265	.105630	.104993	.104356	.103717	.103078
3048.51	.108628	.107990	.107352	.106712	.106071	.105429	.104787	.104143	.103499
3038.51	.109092	.108450	.107806	.107162	.106516	.105869	.105221	.104572	.103923
3028.51	.109560	.108912	.108263	.107614	.106963	.106311	.105658	.105004	.104350
3018.51	.110031	.109378	.108724	.108069	.107412	.106755	.106098	.105439	.104779
3008.51	.110506	.109848	.109188	.108528	.107866	.107203	.106540	.105876	.105211
2998.51	.110985	.110321	.109656	.108990	.108323	.107655	.106986	.106316	.105646
2988.51	.111451	.110781	.110128	.109456	.108784	.108110	.107436	.106760	.106084
2978.51	.111921	.111244	.110585	.109907	.109247	.108568	.107889	.107208	.106526

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	.121955	AT (	.47,	2978.51)	GC	6.	.121239	AT (	-29.53,	2978.51)	GC
2.	.121714	AT (	-9.53,	2978.51)	GC	7.	.121151	AT (	-9.53,	2988.51)	GC
3.	.121477	AT (	-19.53,	2978.51)	GC	8.	.120999	AT (	-39.53,	2978.51)	GC
4.	.121389	AT (	.47,	2988.51)	GC	9.	.120915	AT (	-19.53,	2988.51)	GC
5.	.121251	AT (	10.47,	2978.51)	GC	10.	.120827	AT (	.47,	2998.51)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE MAX CONCENTRATION INSIDE WIPP SITE BOUNDARY (93 WIPP Met)
CO TITLETWO Fine Receptor Grid(10x10m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -100 22 10.00 -20.00 22 10.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50
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RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50		
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50		
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50		
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50		
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50		
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50		
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50

RE GRIDCART COARSE	FLAG 8	1.50	1.50		
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50		
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50		
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50		
RE GRIDCART COARSE	FLAG 12	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 12	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 12	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 12	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 12	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 12	1.50	1.50		
RE GRIDCART COARSE	FLAG 13	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 13	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 13	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 13	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 13	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 13	1.50	1.50		
RE GRIDCART COARSE	FLAG 14	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 14	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 14	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 14	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 14	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 14	1.50	1.50		
RE GRIDCART COARSE	FLAG 15	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 15	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 15	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 15	1.50	1.50	1.50	1.50

RE GRIDCART COARSE	FLAG 15	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 15	1.50	1.50		
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50		
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50		
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50		
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50		
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50		
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50		
RE GRIDCART COARSE	FLAG 22	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 22	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 22	1.50	1.50	1.50	1.50

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RE GRIDCART COARSE   FLAG 22     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 22     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 22     1.50     1.50
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 1  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 2  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 3  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 4  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 5  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 6  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
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RE GRIDCART COARSE	ELEV 7	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 7	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 7	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 7	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 8	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 8	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 8	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 8	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 8	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 8	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 9	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 9	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 9	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 9	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 9	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 9	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 10	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 10	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 10	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 10	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 10	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 10	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 11	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 11	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 11	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 11	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 11	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 11	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 12	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 12	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 12	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 12	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 12	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 12	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 13	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 13	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 13	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 13	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 13	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 13	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 14	3410.00	3410.00	3410.00	3410.00

RE GRIDCART COARSE	ELEV 14	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 14	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 14	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 14	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 14	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 15	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 15	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 15	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 15	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 15	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 15	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 16	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 16	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 16	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 16	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 16	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 16	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 17	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 17	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 17	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 17	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 17	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 17	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 18	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 18	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 18	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 18	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 18	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 18	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 19	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 19	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 19	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 19	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 19	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 19	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 20	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 20	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 20	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 20	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 20	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 20	3410.00	3410.00		

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RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00
RE GRIDCART COARSE   END
RE FINISHED
ME STARTING
ME INPUTFIL C:\MODELS\MET\WP3093.STR  FREE
ME ANEMHGHT   10.000 METERS
ME SURFDATA 11111 1993 WIPP
ME UAIRDATA 11111 1993
ME STARDATA ANNUAL
ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50
ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80
ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01
ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03
ME FINISHED
OU STARTING
OU RECTABLE SRCGRP
OU MAXTABLE 10 SRCGRP
OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMFW93A.GPH 70
OU FINISHED
************************************
*** SETUP Finishes Successfully ***
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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

**Model Calculates 1 STAR Average(s) for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**Data File Includes 1 STAR Summaries for the Following Months: 0 0 0 0 0 0 0 0 0 0 0 0
Seasons/Quarters: 0 0 0 0
and Annual: 1

**This Run Includes: 2 Source(s); 1 Source Group(s); and 484 Receptor(s)

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

**Misc. Inputs: Anem. Hgt. (m) = 10.00 ; Decay Coef. = .0000 ; Rot. Angle = .0
Emission Units = GRAMS/SEC ; Emission Rate Unit Factor = .10000E+07
Output Units = MICROGRAMS/M**3

**Input Runstream File: admfW93a.dat ; **Output Print File: admfW93A.lst

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-100.0,	-90.0,	-80.0,	-70.0,	-60.0,	-50.0,	-40.0,	-30.0,	-20.0,	-10.0,
.0,	10.0,	20.0,	30.0,	40.0,	50.0,	60.0,	70.0,	80.0,	90.0,
100.0,	110.0,								

*** Y-COORDINATES OF GRID ***
(METERS)

-20.0,	-10.0,	.0,	10.0,	20.0,	30.0,	40.0,	50.0,	60.0,	70.0,
80.0,	90.0,	100.0,	110.0,	120.0,	130.0,	140.0,	150.0,	160.0,	170.0,
180.0,	190.0,								

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -100.00	-90.00	-80.00	-70.00	-60.00	-50.00	-40.00	-30.00	-20.00
190.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
180.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
170.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
160.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
150.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
140.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
130.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
120.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
110.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
100.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
90.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
80.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
70.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
60.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
50.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
40.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
30.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
20.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
10.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
-10.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
-20.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -10.00	.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00
190.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
180.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
170.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
160.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
150.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
140.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
130.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
120.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
110.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
100.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
90.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
80.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
70.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
60.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
50.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
40.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
30.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
20.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
10.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
-10.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
-20.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 80.00	90.00	100.00	110.00
190.00	1039.37	1039.37	1039.37	1039.37
180.00	1039.37	1039.37	1039.37	1039.37
170.00	1039.37	1039.37	1039.37	1039.37
160.00	1039.37	1039.37	1039.37	1039.37
150.00	1039.37	1039.37	1039.37	1039.37
140.00	1039.37	1039.37	1039.37	1039.37
130.00	1039.37	1039.37	1039.37	1039.37
120.00	1039.37	1039.37	1039.37	1039.37
110.00	1039.37	1039.37	1039.37	1039.37
100.00	1039.37	1039.37	1039.37	1039.37
90.00	1039.37	1039.37	1039.37	1039.37
80.00	1039.37	1039.37	1039.37	1039.37
70.00	1039.37	1039.37	1039.37	1039.37
60.00	1039.37	1039.37	1039.37	1039.37
50.00	1039.37	1039.37	1039.37	1039.37
40.00	1039.37	1039.37	1039.37	1039.37
30.00	1039.37	1039.37	1039.37	1039.37
20.00	1039.37	1039.37	1039.37	1039.37
10.00	1039.37	1039.37	1039.37	1039.37
.00	1039.37	1039.37	1039.37	1039.37
-10.00	1039.37	1039.37	1039.37	1039.37
-20.00	1039.37	1039.37	1039.37	1039.37

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -100.00	-90.00	-80.00	-70.00	-60.00	-50.00	-40.00	-30.00	-20.00
190.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
180.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
170.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
160.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
150.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
140.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
120.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
110.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
100.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
90.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
80.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
70.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
60.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
50.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
40.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
30.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
20.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
10.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-10.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-20.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -10.00	.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00
190.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
180.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
170.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
160.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
150.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
140.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
120.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
110.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
100.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
90.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
80.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
70.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
60.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
50.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
40.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
30.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
20.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
10.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-10.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-20.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 80.00	90.00	100.00	110.00
190.00	1.50	1.50	1.50	1.50
180.00	1.50	1.50	1.50	1.50
170.00	1.50	1.50	1.50	1.50
160.00	1.50	1.50	1.50	1.50
150.00	1.50	1.50	1.50	1.50
140.00	1.50	1.50	1.50	1.50
130.00	1.50	1.50	1.50	1.50
120.00	1.50	1.50	1.50	1.50
110.00	1.50	1.50	1.50	1.50
100.00	1.50	1.50	1.50	1.50
90.00	1.50	1.50	1.50	1.50
80.00	1.50	1.50	1.50	1.50
70.00	1.50	1.50	1.50	1.50
60.00	1.50	1.50	1.50	1.50
50.00	1.50	1.50	1.50	1.50
40.00	1.50	1.50	1.50	1.50
30.00	1.50	1.50	1.50	1.50
20.00	1.50	1.50	1.50	1.50
10.00	1.50	1.50	1.50	1.50
.00	1.50	1.50	1.50	1.50
-10.00	1.50	1.50	1.50	1.50
-20.00	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

* SOURCE-RECEPTOR COMBINATIONS FOR WHICH CALCULATIONS MAY NOT BE PERFORMED *
LESS THAN 1.0 METER OR 3*ZLB IN DISTANCE, OR WITHIN OPEN PIT SOURCE

SOURCE ID	- - RECEPTOR LOCATION - - XR (METERS)	YR (METERS)	DISTANCE (METERS)
1	-20.0	-20.0	28.28
1	-10.0	-10.0	14.14
1	10.0	-10.0	14.14
1	-10.0	.0	10.00
1	.0	.0	.00
1	10.0	.0	10.00
1	.0	10.0	10.00
1	10.0	10.0	14.14
1	.0	20.0	20.00
1	10.0	20.0	22.36
1	20.0	20.0	28.28
1	.0	30.0	30.00
1	10.0	30.0	31.62
2	10.0	.0	12.32
2	-10.0	10.0	10.38
2	.0	10.0	2.80
2	-10.0	20.0	16.24
2	.0	20.0	12.80
2	10.0	20.0	16.24
2	.0	30.0	22.80
2	10.0	30.0	24.90
2	20.0	30.0	30.33

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	ANNUAL					
	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111
NAME: WIPP
YEAR: 1993

UPPER AIR STATION NO.: 11111
NAME: UNKNOWN
YEAR: 1993

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00017000	.00000000	.00000000	.00000000	.00000000
90.000	.00019600	.00034000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00034000	.00000000	.00000000	.00000000	.00000000
135.000	.00019600	.00136200	.00000000	.00000000	.00000000	.00000000
157.500	.00039200	.00238300	.00000000	.00000000	.00000000	.00000000
180.000	.00195900	.00187200	.00000000	.00000000	.00000000	.00000000
202.500	.00195900	.00153200	.00000000	.00000000	.00000000	.00000000
225.000	.00215500	.00221300	.00000000	.00000000	.00000000	.00000000
247.500	.00195900	.00119100	.00000000	.00000000	.00000000	.00000000
270.000	.00078400	.00085100	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00068100	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00019600	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00058800	.00017000	.00051100	.00000000	.00000000	.00000000
67.500	.00078400	.00085100	.00017000	.00000000	.00000000	.00000000
90.000	.00156700	.00102100	.00051100	.00000000	.00000000	.00000000
112.500	.00333100	.00306400	.00255300	.00000000	.00000000	.00000000
135.000	.00293900	.00425500	.00425500	.00000000	.00000000	.00000000
157.500	.00293900	.00766000	.00680900	.00000000	.00000000	.00000000
180.000	.00411400	.00697900	.00510600	.00000000	.00000000	.00000000
202.500	.00489800	.00646800	.00306400	.00000000	.00000000	.00000000
225.000	.00391800	.00459600	.00187200	.00000000	.00000000	.00000000
247.500	.00509400	.00527700	.00153200	.00000000	.00000000	.00000000
270.000	.00117600	.00170200	.00204300	.00000000	.00000000	.00000000
292.500	.00098000	.00187200	.00221300	.00000000	.00000000	.00000000
315.000	.00098000	.00102100	.00119100	.00000000	.00000000	.00000000
337.500	.00000000	.00017000	.00000000	.00000000	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: WIPP NAME: UNKNOWN
YEAR: 1993 YEAR: 1993

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00039200	.00034000	.00000000	.00000000	.00000000	.00000000
22.500	.00019600	.00034000	.00034000	.00000000	.00000000	.00000000
45.000	.00000000	.00068100	.00238300	.00000000	.00000000	.00000000
67.500	.00098000	.00085100	.00102100	.00000000	.00000000	.00000000
90.000	.00137100	.00136200	.00187200	.00000000	.00000000	.00000000
112.500	.00450600	.00391500	.00629800	.00034000	.00000000	.00000000
135.000	.00352700	.00544700	.01787200	.00442600	.00000000	.00000000
157.500	.00450600	.00425500	.01123400	.00289400	.00000000	.00000000
180.000	.00293900	.00595700	.01089400	.00340400	.00017000	.00000000
202.500	.00176300	.00459600	.00595700	.00017000	.00000000	.00000000
225.000	.00313500	.00425500	.00187200	.00017000	.00000000	.00000000
247.500	.00156700	.00340400	.00459600	.00170200	.00000000	.00000000
270.000	.00195900	.00289400	.00204300	.00170200	.00034000	.00000000
292.500	.00137100	.00153200	.00221300	.00000000	.00000000	.00000000
315.000	.00039200	.00136200	.00221300	.00051100	.00000000	.00000000
337.500	.00000000	.00017000	.00034000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00017000	.00017000	.00000000	.00000000	.00000000
22.500	.00000000	.00102100	.00119100	.00102100	.00034000	.00034000
45.000	.00039200	.00255300	.00493600	.00851100	.00153200	.00000000
67.500	.00078400	.00425500	.00595700	.00697900	.00068100	.00017000
90.000	.00313500	.00527700	.01293600	.00987200	.00119100	.00017000
112.500	.00372300	.01293600	.02706400	.01344700	.00136200	.00000000
135.000	.00372300	.01004300	.03285100	.04204300	.00306400	.00000000
157.500	.00176300	.00663800	.01855300	.01991500	.00238300	.00017000
180.000	.00274300	.00612800	.01072300	.00425500	.00051100	.00000000
202.500	.00117600	.00425500	.00731900	.00357400	.00000000	.00000000
225.000	.00019600	.00408500	.00510600	.00340400	.00136200	.00017000
247.500	.00058800	.00357400	.00595700	.01123400	.00306400	.00136200
270.000	.00058800	.00238300	.00527700	.00748900	.00357400	.00187200
292.500	.00039200	.00153200	.00221300	.00238300	.00102100	.00000000
315.000	.00000000	.00068100	.00204300	.00391500	.00136200	.00034000
337.500	.00000000	.00000000	.00034000	.00051100	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\WP3093.STR FORMAT: FREE

SURFACE STATION NO.: 11111
NAME: WIPP
YEAR: 1993

UPPER AIR STATION NO.: 11111
NAME: UNKNOWN
YEAR: 1993

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00034000	.00034000	.00000000	.00000000	.00000000
22.500	.00000000	.00017000	.00034000	.00000000	.00000000	.00000000
45.000	.00000000	.00085100	.00187200	.00000000	.00000000	.00000000
67.500	.00000000	.00170200	.00272300	.00000000	.00000000	.00000000
90.000	.00000000	.00272300	.00783000	.00000000	.00000000	.00000000
112.500	.00000000	.00680900	.02314900	.00000000	.00000000	.00000000
135.000	.00000000	.01123400	.02961700	.00000000	.00000000	.00000000
157.500	.00000000	.00868100	.01038300	.00000000	.00000000	.00000000
180.000	.00000000	.00323400	.00238300	.00000000	.00000000	.00000000
202.500	.00000000	.00340400	.00068100	.00000000	.00000000	.00000000
225.000	.00000000	.00221300	.00119100	.00000000	.00000000	.00000000
247.500	.00000000	.00187200	.00442600	.00000000	.00000000	.00000000
270.000	.00000000	.00034000	.00272300	.00000000	.00000000	.00000000
292.500	.00000000	.00068100	.00204300	.00000000	.00000000	.00000000
315.000	.00000000	.00085100	.00170200	.00000000	.00000000	.00000000
337.500	.00000000	.00034000	.00085100	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00051100	.00000000	.00000000	.00000000	.00000000
22.500	.00039200	.00187200	.00000000	.00000000	.00000000	.00000000
45.000	.00156700	.00374500	.00000000	.00000000	.00000000	.00000000
67.500	.00313500	.00476600	.00000000	.00000000	.00000000	.00000000
90.000	.00607400	.00748900	.00000000	.00000000	.00000000	.00000000
112.500	.01097200	.02059600	.00000000	.00000000	.00000000	.00000000
135.000	.01195100	.02348900	.00000000	.00000000	.00000000	.00000000
157.500	.01136400	.01293600	.00000000	.00000000	.00000000	.00000000
180.000	.00881700	.00561700	.00000000	.00000000	.00000000	.00000000
202.500	.00607400	.00357400	.00000000	.00000000	.00000000	.00000000
225.000	.00470200	.00493600	.00000000	.00000000	.00000000	.00000000
247.500	.00450600	.00510600	.00000000	.00000000	.00000000	.00000000
270.000	.00254700	.00272300	.00000000	.00000000	.00000000	.00000000
292.500	.00176300	.00238300	.00000000	.00000000	.00000000	.00000000
315.000	.00195900	.00238300	.00000000	.00000000	.00000000	.00000000
337.500	.00058800	.00187200	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99999

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -100.00	-90.00	-80.00	-70.00	-60.00	-50.00	-40.00	-30.00	-20.00
190.00	1.222216	1.189521	1.160668	1.164512	1.184652	1.204184	1.222966	1.240891	1.257879
180.00	1.283754	1.249361	1.219119	1.203540	1.228386	1.252902	1.276950	1.300391	1.323104
170.00	1.348213	1.313030	1.279943	1.252702	1.271748	1.302379	1.333016	1.363471	1.393562
160.00	1.415336	1.379260	1.343307	1.314602	1.313425	1.351671	1.390678	1.430208	1.469992
150.00	1.484756	1.447678	1.410153	1.378297	1.356255	1.398866	1.448436	1.499660	1.552146
140.00	1.556017	1.517758	1.478760	1.442415	1.418277	1.441429	1.504558	1.571133	1.640598
130.00	1.628485	1.588775	1.547932	1.508438	1.481075	1.474993	1.555274	1.641854	1.733975
120.00	1.701342	1.659803	1.616559	1.574385	1.540788	1.526155	1.595042	1.707753	1.830310
110.00	1.773597	1.729647	1.683175	1.637277	1.596744	1.578863	1.614689	1.761066	1.924307
100.00	1.741381	1.796891	1.746073	1.694989	1.648776	1.617727	1.621725	1.789309	2.010427
90.00	1.608979	1.738308	1.803424	1.745203	1.691144	1.649764	1.637326	1.772110	2.077041
80.00	1.458563	1.577693	1.707730	1.785825	1.721147	1.668990	1.641741	1.673053	2.097031
70.00	1.293218	1.398021	1.513495	1.639201	1.736757	1.668695	1.626088	1.626077	2.033510
60.00	1.118833	1.205525	1.301585	1.407336	1.522238	1.648854	1.574736	1.522967	1.759072
50.00	.944682	1.010898	1.083720	1.163570	1.251361	1.344994	1.453261	1.392034	1.423658
40.00	.858367	.878867	.882496	.929054	.983400	.999142	1.062658	1.273805	1.228390
30.00	.756011	.782375	.809363	.825210	.772004	.732243	.745177	.789834	1.089679
20.00	.653725	.670959	.687632	.703172	.680724	.680496	.595170	.471521	.503250
10.00	.556981	.566267	.574095	.579815	.550247	.536957	.513441	.483457	.403385
.00	.465547	.464818	.460872	.452696	.414352	.384345	.340939	.281998	.203035
-10.00	.373324	.356310	.331922	.297996	.239443	.176663	.102610	.048739	.004869
-20.00	.288197	.257509	.216454	.162422	.107067	.058804	.255871	.772106	.009054

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -10.00	.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00
190.00	1.274003	1.289266	1.235893	1.179796	1.121798	1.062732	1.003397	.944519	.886952
180.00	1.345123	1.366405	1.305957	1.242323	1.176540	1.109641	1.042621	.976456	.912039
170.00	1.423265	1.452461	1.383696	1.311045	1.236064	1.159955	1.083966	1.009411	.939638
160.00	1.509914	1.549701	1.470833	1.387612	1.301451	1.214437	1.127524	1.043121	.972912
150.00	1.605609	1.659555	1.568311	1.471951	1.372644	1.272538	1.173320	1.078568	1.007727
140.00	1.712427	1.785739	1.678948	1.566203	1.450285	1.334180	1.220520	1.121051	1.043908
130.00	1.830676	1.930538	1.804295	1.671011	1.534556	1.398807	1.267296	1.166658	1.081523
120.00	1.960920	2.097628	1.945393	1.785615	1.625370	1.465837	1.319829	1.212177	1.119813
110.00	2.101557	2.289079	2.102841	1.908514	1.716258	1.527908	1.379498	1.258339	1.156437
100.00	2.255842	2.517848	2.285388	2.043751	1.804340	1.581970	1.423794	1.299171	1.189304
90.00	2.424623	2.800235	2.500512	2.190561	1.889271	1.643099	1.475119	1.330322	1.206993
80.00	2.598319	3.149501	2.752333	2.345571	1.958831	1.716557	1.523323	1.356006	1.213497
70.00	2.748115	3.574750	3.043500	2.508001	2.063106	1.793717	1.560961	1.367728	1.178338
60.00	2.851949	4.124789	3.389175	2.664995	2.189933	1.855830	1.581498	1.311532	1.053055
50.00	2.849340	4.879751	3.804641	2.832660	2.298095	1.884561	1.488543	1.111831	.865873
40.00	2.534865	6.016435	4.333626	3.084569	2.355063	1.717775	1.148562	.804859	.604234
30.00	1.471623	.000442	.604355	1.629417	2.045253	1.106030	.619992	.439520	.408313
20.00	.345729	.000676	.000352	.011077	.750117	.404347	.315704	.413885	.491487
10.00	.000889	.000308	.000379	.188312	.320818	.442107	.526602	.581765	.629444
.00	.000330	.000000	.000178	.351980	.454882	.540981	.600972	.636146	.669957
-10.00	.001734	.000000	.039682	.173429	.215109	.293281	.386997	.455324	.510914
-20.00	.010449	.000000	.032517	.194948	.236259	.245222	.272537	.323537	.370826

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 80.00	90.00	100.00	110.00
190.00	.835229	.795602	.761086	.728997
180.00	.861283	.818430	.781410	.746254
170.00	.888129	.842850	.801938	.763351
160.00	.916187	.867754	.822449	.780050
150.00	.946513	.892814	.842605	.795998
140.00	.978057	.917730	.861866	.810695
130.00	1.008913	.941805	.879601	.823541
120.00	1.037922	.963118	.895298	.833553
110.00	1.064012	.981032	.906644	.835756
100.00	1.085662	.993762	.905015	.821569
90.00	1.099998	.986808	.878241	.795698
80.00	1.077953	.940610	.834117	.755413
70.00	.993459	.864048	.768541	.697991
60.00	.875575	.755124	.675821	.620620
50.00	.710720	.614299	.555860	.538435
40.00	.497927	.488576	.498901	.523666
30.00	.454641	.500153	.528027	.542934
20.00	.535056	.559590	.570302	.571674
10.00	.638707	.635777	.624930	.609606
.00	.664295	.649660	.629844	.607801
-10.00	.530452	.536392	.533309	.524846
-20.00	.408209	.430259	.441200	.444592

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*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR)	OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)	OF TYPE
1.	6.016435	AT (	.00, 40.00)	GC	6.	3.574750	AT (	.00, 70.00)	GC
2.	4.879751	AT (	.00, 50.00)	GC	7.	3.389175	AT (	10.00, 60.00)	GC
3.	4.333626	AT (	10.00, 40.00)	GC	8.	3.149501	AT (	.00, 80.00)	GC
4.	4.124789	AT (	.00, 60.00)	GC	9.	3.084569	AT (	20.00, 40.00)	GC
5.	3.804641	AT (	10.00, 50.00)	GC	10.	3.043500	AT (	10.00, 70.00)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** Message Summary : ISCLT3 Model Execution ***

--------- Summary of Total Messages --------

A Total of 0 Fatal Error Message(s)
A Total of 0 Warning Message(s)
A Total of 0 Informational Message(s)

******** FATAL ERROR MESSAGES ********
*** NONE ***

******** WARNING MESSAGES ********
*** NONE ***

****
*** ISCLT3 Finishes Successfully ***
****

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*** TRINITY DOWNWASH FILE NAME: C:\MODELS\EXFAN.WAK
CO STARTING
CO TITLEONE MAX CONCENTRATION INSIDE WIPP SITE BOUNDARY (90 Carlsbad Met)
CO TITLETWO Fine Receptor Grid(10x10m)/1000 µg/m^3 SrcConc
CO MODELOPT CONC RURAL
CO AVERTIME ANNUAL
CO POLLUTID ANY
CO TERRHGTS ELEV
CO FLAGPOLE 1.500000
CO RUNORNOT RUN
CO FINISHED
SO STARTING
SO LOCATION 1 POINT       0.00       0.00    1039.37
SO SRCPARAM 1 0.100000       8.20     288.80     4.6598      4.400
SO LOCATION 2 POINT       0.00       7.20    1039.37
SO SRCPARAM 2 0.100000       8.20     288.80     4.6598      4.400
SO BUILDHGT 1    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 1     6.55     6.55     0.00     0.00    11.22     0.00
SO BUILDHGT 1     6.55     6.55     2.04     6.55
SO BUILDWID  1             10.51    11.82    13.05      .00    30.72    33.44
SO BUILDWID  1             34.97    31.62      .00      .00    13.05      .00
SO BUILDWID  1             30.72    30.72     7.29    31.62
SO BUILDHGT 2    11.22    11.22    11.22     0.00     6.55     6.55
SO BUILDHGT 2     6.55     6.55     0.00     0.00     0.00     0.00
SO BUILDHGT 2     6.55     6.55     6.55     6.55
SO BUILDWID  2             10.51    11.82    12.68      .00    26.82    33.44
SO BUILDWID  2             34.97    33.72      .00      .00      .00      .00
SO BUILDWID  2             26.82    33.44    34.97    33.72
SO EMISUNIT 1000000.000000 GRAMS/SEC MICROGRAMS/M**3
SO SRCGROUP ALL
SO FINISHED
RE STARTING
RE ELEVUNIT FEET
RE GRIDCART COARSE   STA
RE GRIDCART COARSE   XYINC -100 22 10.00 -20.00 22 10.00
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50     1.50     1.50
RE GRIDCART COARSE   FLAG 1     1.50     1.50
```

RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 2	1.50	1.50		
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 3	1.50	1.50		
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 4	1.50	1.50		
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 5	1.50	1.50		
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 6	1.50	1.50		
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 7	1.50	1.50		
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 8	1.50	1.50	1.50	1.50

RE GRIDCART COARSE	FLAG 8	1.50	1.50		
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 9	1.50	1.50		
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 10	1.50	1.50		
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 11	1.50	1.50		
RE GRIDCART COARSE	FLAG 12	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 12	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 12	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 12	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 12	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 12	1.50	1.50		
RE GRIDCART COARSE	FLAG 13	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 13	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 13	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 13	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 13	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 13	1.50	1.50		
RE GRIDCART COARSE	FLAG 14	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 14	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 14	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 14	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 14	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 14	1.50	1.50		
RE GRIDCART COARSE	FLAG 15	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 15	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 15	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 15	1.50	1.50	1.50	1.50

RE GRIDCART COARSE	FLAG 15	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 15	1.50	1.50		
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 16	1.50	1.50		
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 17	1.50	1.50		
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 18	1.50	1.50		
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 19	1.50	1.50		
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 20	1.50	1.50		
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 21	1.50	1.50		
RE GRIDCART COARSE	FLAG 22	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 22	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 22	1.50	1.50	1.50	1.50

RE GRIDCART COARSE	FLAG 22	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 22	1.50	1.50	1.50	1.50
RE GRIDCART COARSE	FLAG 22	1.50	1.50		
RE GRIDCART COARSE	ELEV 1	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 1	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 1	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 1	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 1	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 1	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 2	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 2	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 2	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 2	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 2	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 2	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 3	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 3	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 3	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 3	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 3	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 3	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 4	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 4	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 4	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 4	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 4	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 4	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 5	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 5	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 5	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 5	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 5	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 5	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 6	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 6	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 6	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 6	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 6	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 6	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 7	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 7	3410.00	3410.00	3410.00	3410.00

```
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 7  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 8  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 9  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 10  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 11  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 12  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 13  3410.00  3410.00
RE GRIDCART COARSE   ELEV 14  3410.00  3410.00  3410.00  3410.00
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RE GRIDCART COARSE	ELEV 14	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 14	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 14	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 14	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 14	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 15	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 15	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 15	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 15	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 15	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 15	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 16	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 16	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 16	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 16	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 16	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 16	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 17	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 17	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 17	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 17	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 17	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 17	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 18	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 18	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 18	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 18	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 18	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 18	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 19	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 19	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 19	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 19	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 19	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 19	3410.00	3410.00		
RE GRIDCART COARSE	ELEV 20	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 20	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 20	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 20	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 20	3410.00	3410.00	3410.00	3410.00
RE GRIDCART COARSE	ELEV 20	3410.00	3410.00		

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RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 21  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00  3410.00  3410.00
RE GRIDCART COARSE   ELEV 22  3410.00  3410.00
RE GRIDCART COARSE   END
RE FINISHED
ME STARTING
ME INPUTFIL C:\MODELS\MET\CBD90.STR (7X,6F7.5)
ME ANEMHGHT   10.000 METERS
ME SURFDATA 11111 1990 CARLSBAD
ME UAIRDATA 11111 1990
ME STARDATA ANNUAL
ME AVESPEED   1.00   2.25   4.05   6.55   9.25  12.50
ME AVETEMPS ANNUAL 288.80 288.80 288.80 288.80 288.80 288.80
ME AVEMIXHT ANNUAL A 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL B 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL C 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL D 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL E 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME AVEMIXHT ANNUAL F 1435.00 1435.00 1435.00 1435.00 1435.00 1435.00
ME DTHETADZ A   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ B   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ C   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ D   0.00   0.00   0.00   0.00   0.00   0.00
ME DTHETADZ E   0.01   0.01   0.01   0.01   0.01   0.01
ME DTHETADZ F   0.03   0.03   0.03   0.03   0.03   0.03
ME FINISHED
OU STARTING
OU RECTABLE SRCGRP
OU MAXTABLE 10 SRCGRP
OU PLOTFILE ANNUAL ALL C:\MODELS\ADM\ADMFC90A.GPH 70
OU FINISHED
**********************************
*** SETUP Finishes Successfully ***
```

****

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** MODEL SETUP OPTIONS SUMMARY ***

- -

**Model Is Setup For Calculation of Average CONCentration Values.
**Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

**Model Uses NO plume DEPLETION.

**Model Uses RURAL Dispersion.

**Model Uses User-Specified Options:
1. Final Plume Rise.
2. Stack-tip Downwash.
3. Buoyancy-induced Dispersion.
4. Default Wind Profile Exponents.
5. User-Specified Vertical Potential Temperature Gradients.

**Model Accepts Receptors on ELEV Terrain.

**Model Accepts FLAGPOLE Receptor Heights.

```
**Model Calculates   1 STAR Average(s) for the Following Months: 0  0  0  0  0  0  0  0  0  0  0  0
                                             Seasons/Quarters: 0  0  0  0
                                                   and Annual: 1

**Data File Includes  1 STAR Summaries for the Following Months: 0  0  0  0  0  0  0  0  0  0  0  0
                                             Seasons/Quarters: 0  0  0  0
                                                   and Annual: 1

**This Run Includes:    2 Source(s);      1 Source Group(s); and    484 Receptor(s)
```

**The Model Assumes A Pollutant Type of: ANY

**Model Set To Continue RUNning After the Setup Testing.

**Output Options Selected:
Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)
Model Outputs External File(s) of Long Term Values for Plotting (PLOTFILE Keyword)

```
**Misc. Inputs: Anem. Hgt. (m) =    10.00 ;    Decay Coef. =    .0000     ;    Rot. Angle =      .0
                Emission Units = GRAMS/SEC                               ;  Emission Rate Unit Factor =    .10000E+07
                Output Units   = MICROGRAMS/M**3

**Input Runstream File: admfc90a.dat                           ;  **Output Print File: admfc90a.lst
```

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (USER UNITS)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BUILDING EXISTS	EMISSION RATE SCALAR VARY BY
1	0	.10000E+00	.0	.0	1039.4	8.20	288.80	4.66	4.40	YES	
2	0	.10000E+00	.0	7.2	1039.4	8.20	288.80	4.66	4.40	YES	

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 ,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: 1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	13.1,	0	4	.0,	.0,	0
5	6.6,	30.7,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	31.6,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	11.2,	13.1,	0	12	.0,	.0,	0
13	6.6,	30.7,	0	14	6.6,	30.7,	0	15	2.0,	7.3,	0	16	6.6,	31.6,	0

SOURCE ID: 2

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	11.2,	10.5,	0	2	11.2,	11.8,	0	3	11.2,	12.7,	0	4	.0,	.0,	0
5	6.6,	26.8,	0	6	6.6,	33.4,	0	7	6.6,	35.0,	0	8	6.6,	33.7,	0
9	.0,	.0,	0	10	.0,	.0,	0	11	.0,	.0,	0	12	.0,	.0,	0
13	6.6,	26.8,	0	14	6.6,	33.4,	0	15	6.6,	35.0,	0	16	6.6,	33.7,	0

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

*** X-COORDINATES OF GRID ***
(METERS)

-100.0,	-90.0,	-80.0,	-70.0,	-60.0,	-50.0,	-40.0,	-30.0,	-20.0,	-10.0,
.0,	10.0,	20.0,	30.0,	40.0,	50.0,	60.0,	70.0,	80.0,	90.0,
100.0,	110.0,								

*** Y-COORDINATES OF GRID ***
(METERS)

-20.0,	-10.0,	.0,	10.0,	20.0,	30.0,	40.0,	50.0,	60.0,	70.0,
80.0,	90.0,	100.0,	110.0,	120.0,	130.0,	140.0,	150.0,	160.0,	170.0,
180.0,	190.0,								

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -100.00	-90.00	-80.00	-70.00	-60.00	-50.00	-40.00	-30.00	-20.00
190.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
180.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
170.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
160.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
150.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
140.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
130.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
120.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
110.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
100.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
90.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
80.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
70.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
60.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
50.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
40.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
30.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
20.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
10.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
-10.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
-20.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -10.00	.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00
190.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
180.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
170.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
160.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
150.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
140.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
130.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
120.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
110.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
100.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
90.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
80.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
70.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
60.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
50.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
40.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
30.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
20.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
10.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
-10.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37
-20.00	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37	1039.37

8
*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* ELEVATION HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 80.00	90.00	100.00	110.00
190.00	1039.37	1039.37	1039.37	1039.37
180.00	1039.37	1039.37	1039.37	1039.37
170.00	1039.37	1039.37	1039.37	1039.37
160.00	1039.37	1039.37	1039.37	1039.37
150.00	1039.37	1039.37	1039.37	1039.37
140.00	1039.37	1039.37	1039.37	1039.37
130.00	1039.37	1039.37	1039.37	1039.37
120.00	1039.37	1039.37	1039.37	1039.37
110.00	1039.37	1039.37	1039.37	1039.37
100.00	1039.37	1039.37	1039.37	1039.37
90.00	1039.37	1039.37	1039.37	1039.37
80.00	1039.37	1039.37	1039.37	1039.37
70.00	1039.37	1039.37	1039.37	1039.37
60.00	1039.37	1039.37	1039.37	1039.37
50.00	1039.37	1039.37	1039.37	1039.37
40.00	1039.37	1039.37	1039.37	1039.37
30.00	1039.37	1039.37	1039.37	1039.37
20.00	1039.37	1039.37	1039.37	1039.37
10.00	1039.37	1039.37	1039.37	1039.37
.00	1039.37	1039.37	1039.37	1039.37
-10.00	1039.37	1039.37	1039.37	1039.37
-20.00	1039.37	1039.37	1039.37	1039.37

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -100.00	-90.00	-80.00	-70.00	-60.00	-50.00	-40.00	-30.00	-20.00
190.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
180.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
170.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
160.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
150.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
140.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
120.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
110.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
100.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
90.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
80.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
70.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
60.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
50.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
40.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
30.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
20.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
10.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-10.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-20.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) -10.00	.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00
190.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
180.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
170.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
160.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
150.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
140.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
130.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
120.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
110.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
100.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
90.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
80.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
70.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
60.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
50.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
40.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
30.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
20.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
10.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-10.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
-20.00	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

* RECEPTOR FLAGPOLE HEIGHTS IN METERS *

Y-COORD (METERS)	X-COORD (METERS) 80.00	90.00	100.00	110.00
190.00	1.50	1.50	1.50	1.50
180.00	1.50	1.50	1.50	1.50
170.00	1.50	1.50	1.50	1.50
160.00	1.50	1.50	1.50	1.50
150.00	1.50	1.50	1.50	1.50
140.00	1.50	1.50	1.50	1.50
130.00	1.50	1.50	1.50	1.50
120.00	1.50	1.50	1.50	1.50
110.00	1.50	1.50	1.50	1.50
100.00	1.50	1.50	1.50	1.50
90.00	1.50	1.50	1.50	1.50
80.00	1.50	1.50	1.50	1.50
70.00	1.50	1.50	1.50	1.50
60.00	1.50	1.50	1.50	1.50
50.00	1.50	1.50	1.50	1.50
40.00	1.50	1.50	1.50	1.50
30.00	1.50	1.50	1.50	1.50
20.00	1.50	1.50	1.50	1.50
10.00	1.50	1.50	1.50	1.50
.00	1.50	1.50	1.50	1.50
-10.00	1.50	1.50	1.50	1.50
-20.00	1.50	1.50	1.50	1.50

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

* SOURCE-RECEPTOR COMBINATIONS FOR WHICH CALCULATIONS MAY NOT BE PERFORMED *
LESS THAN 1.0 METER OR 3*ZLB IN DISTANCE, OR WITHIN OPEN PIT SOURCE

SOURCE ID	- - RECEPTOR LOCATION - - XR (METERS)	YR (METERS)	DISTANCE (METERS)
1	-20.0	-20.0	28.28
1	-10.0	-10.0	14.14
1	10.0	-10.0	14.14
1	-10.0	.0	10.00
1	.0	.0	.00
1	10.0	.0	10.00
1	.0	10.0	10.00
1	10.0	10.0	14.14
1	.0	20.0	20.00
1	10.0	20.0	22.36
1	20.0	20.0	28.28
1	.0	30.0	30.00
1	10.0	30.0	31.62
2	10.0	.0	12.32
2	-10.0	10.0	10.38
2	.0	10.0	2.80
2	-10.0	20.0	16.24
2	.0	20.0	12.80
2	10.0	20.0	16.24
2	.0	30.0	22.80
2	10.0	30.0	24.90
2	20.0	30.0	30.33

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***
(METERS/SEC)

1.00, 2.25, 4.05, 6.55, 9.25, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***
(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
C	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
D	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
E	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01	.10000E-01
F	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01	.30000E-01

*** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN) ***

	STABILITY CATEGORY A	STABILITY CATEGORY B	STABILITY CATEGORY C	STABILITY CATEGORY D	STABILITY CATEGORY E	STABILITY CATEGORY F
ANNUAL	288.8000	288.8000	288.8000	288.8000	288.8000	288.8000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	ANNUAL WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY B	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY C	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY D	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY E	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000
STABILITY CATEGORY F	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000	1435.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1990 YEAR: 1990

ANNUAL: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00064000	.00083000	.00000000	.00000000	.00000000	.00000000
22.500	.00018000	.00024000	.00000000	.00000000	.00000000	.00000000
45.000	.00066000	.00059000	.00000000	.00000000	.00000000	.00000000
67.500	.00048000	.00035000	.00000000	.00000000	.00000000	.00000000
90.000	.00094000	.00095000	.00000000	.00000000	.00000000	.00000000
112.500	.00057000	.00047000	.00000000	.00000000	.00000000	.00000000
135.000	.00126000	.00083000	.00000000	.00000000	.00000000	.00000000
157.500	.00045000	.00059000	.00000000	.00000000	.00000000	.00000000
180.000	.00066000	.00059000	.00000000	.00000000	.00000000	.00000000
202.500	.00018000	.00024000	.00000000	.00000000	.00000000	.00000000
225.000	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
247.500	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
270.000	.00027000	.00035000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00036000	.00047000	.00000000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00103000	.00213000	.00189000	.00000000	.00000000	.00000000
22.500	.00130000	.00213000	.00071000	.00000000	.00000000	.00000000
45.000	.00083000	.00177000	.00118000	.00000000	.00000000	.00000000
67.500	.00118000	.00307000	.00106000	.00000000	.00000000	.00000000
90.000	.00169000	.00284000	.00130000	.00000000	.00000000	.00000000
112.500	.00105000	.00402000	.00189000	.00000000	.00000000	.00000000
135.000	.00116000	.00556000	.00355000	.00000000	.00000000	.00000000
157.500	.00225000	.00721000	.00343000	.00000000	.00000000	.00000000
180.000	.00248000	.00520000	.00343000	.00000000	.00000000	.00000000
202.500	.00039000	.00071000	.00095000	.00000000	.00000000	.00000000
225.000	.00043000	.00095000	.00012000	.00000000	.00000000	.00000000
247.500	.00009000	.00059000	.00024000	.00000000	.00000000	.00000000
270.000	.00035000	.00047000	.00035000	.00000000	.00000000	.00000000
292.500	.00045000	.00024000	.00024000	.00000000	.00000000	.00000000
315.000	.00034000	.00130000	.00012000	.00000000	.00000000	.00000000
337.500	.00071000	.00189000	.00071000	.00000000	.00000000	.00000000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1990 YEAR: 1990

ANNUAL: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00080000	.00366000	.00816000	.00248000	.00012000	.00000000
22.500	.00035000	.00284000	.00343000	.00059000	.00000000	.00000000
45.000	.00025000	.00319000	.00118000	.00012000	.00000000	.00000000
67.500	.00036000	.00296000	.00130000	.00000000	.00000000	.00000000
90.000	.00056000	.00390000	.00343000	.00071000	.00000000	.00000000
112.500	.00067000	.00366000	.00473000	.00142000	.00000000	.00000000
135.000	.00029000	.00366000	.01017000	.00355000	.00012000	.00000000
157.500	.00069000	.00556000	.01324000	.00248000	.00035000	.00000000
180.000	.00040000	.00508000	.01206000	.00284000	.00024000	.00000000
202.500	.00034000	.00106000	.00106000	.00071000	.00000000	.00000000
225.000	.00016000	.00047000	.00047000	.00012000	.00024000	.00000000
247.500	.00030000	.00059000	.00177000	.00083000	.00071000	.00047000
270.000	.00047000	.00118000	.00225000	.00213000	.00165000	.00071000
292.500	.00031000	.00071000	.00083000	.00083000	.00024000	.00000000
315.000	.00035000	.00118000	.00095000	.00035000	.00000000	.00000000
337.500	.00033000	.00095000	.00189000	.00059000	.00012000	.00000000

ANNUAL: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00043000	.00461000	.00875000	.01572000	.00307000	.00059000
22.500	.00042000	.00248000	.00402000	.00449000	.00047000	.00035000
45.000	.00044000	.00284000	.00496000	.00343000	.00035000	.00012000
67.500	.00037000	.00177000	.00366000	.00201000	.00000000	.00000000
90.000	.00058000	.00307000	.00579000	.00496000	.00035000	.00000000
112.500	.00042000	.00248000	.00603000	.00378000	.00035000	.00000000
135.000	.00100000	.00556000	.01312000	.01820000	.00201000	.00059000
157.500	.00073000	.00520000	.02506000	.02376000	.00225000	.00024000
180.000	.00096000	.00496000	.01962000	.01466000	.00071000	.00047000
202.500	.00028000	.00225000	.00319000	.00366000	.00118000	.00035000
225.000	.00064000	.00201000	.00390000	.00319000	.00106000	.00024000
247.500	.00034000	.00130000	.00544000	.01253000	.00532000	.00189000
270.000	.00021000	.00307000	.00768000	.02624000	.01548000	.00662000
292.500	.00049000	.00165000	.00402000	.00922000	.00213000	.00071000
315.000	.00039000	.00213000	.00366000	.00485000	.00047000	.00012000
337.500	.00046000	.00307000	.00721000	.00969000	.00414000	.00059000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: C:\MODELS\MET\CBD90.STR FORMAT: (7X,6F7.5)

SURFACE STATION NO.: 11111 UPPER AIR STATION NO.: 11111
NAME: CARLSBAD NAME: UNKNOWN
YEAR: 1990 YEAR: 1990

ANNUAL: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00390000	.00473000	.00000000	.00000000	.00000000
22.500	.00000000	.00130000	.00130000	.00000000	.00000000	.00000000
45.000	.00000000	.00071000	.00118000	.00000000	.00000000	.00000000
67.500	.00000000	.00118000	.00154000	.00000000	.00000000	.00000000
90.000	.00000000	.00165000	.00189000	.00000000	.00000000	.00000000
112.500	.00000000	.00154000	.00236000	.00000000	.00000000	.00000000
135.000	.00000000	.00414000	.00863000	.00000000	.00000000	.00000000
157.500	.00000000	.00721000	.01797000	.00000000	.00000000	.00000000
180.000	.00000000	.01005000	.02364000	.00000000	.00000000	.00000000
202.500	.00000000	.00284000	.00934000	.00000000	.00000000	.00000000
225.000	.00000000	.00366000	.00792000	.00000000	.00000000	.00000000
247.500	.00000000	.00236000	.01206000	.00000000	.00000000	.00000000
270.000	.00000000	.00390000	.01478000	.00000000	.00000000	.00000000
292.500	.00000000	.00461000	.01229000	.00000000	.00000000	.00000000
315.000	.00000000	.00260000	.00603000	.00000000	.00000000	.00000000
337.500	.00000000	.00154000	.00402000	.00000000	.00000000	.00000000

ANNUAL: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.000 M/S)	WIND SPEED CATEGORY 2 (2.250 M/S)	WIND SPEED CATEGORY 3 (4.050 M/S)	WIND SPEED CATEGORY 4 (6.550 M/S)	WIND SPEED CATEGORY 5 (9.250 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00468000	.00993000	.00000000	.00000000	.00000000	.00000000
22.500	.00242000	.00520000	.00000000	.00000000	.00000000	.00000000
45.000	.00155000	.00201000	.00000000	.00000000	.00000000	.00000000
67.500	.00120000	.00248000	.00000000	.00000000	.00000000	.00000000
90.000	.00258000	.00390000	.00000000	.00000000	.00000000	.00000000
112.500	.00174000	.00461000	.00000000	.00000000	.00000000	.00000000
135.000	.00246000	.00745000	.00000000	.00000000	.00000000	.00000000
157.500	.00425000	.01430000	.00000000	.00000000	.00000000	.00000000
180.000	.00608000	.02352000	.00000000	.00000000	.00000000	.00000000
202.500	.00264000	.00981000	.00000000	.00000000	.00000000	.00000000
225.000	.00254000	.00674000	.00000000	.00000000	.00000000	.00000000
247.500	.00388000	.00768000	.00000000	.00000000	.00000000	.00000000
270.000	.00378000	.01312000	.00000000	.00000000	.00000000	.00000000
292.500	.00431000	.01678000	.00000000	.00000000	.00000000	.00000000
315.000	.00265000	.00827000	.00000000	.00000000	.00000000	.00000000
337.500	.00287000	.00603000	.00000000	.00000000	.00000000	.00000000

SUM OF FREQUENCIES, FTOTAL = .99995

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -100.00	-90.00	-80.00	-70.00	-60.00	-50.00	-40.00	-30.00	-20.00
190.00	1.102467	1.158826	1.221442	1.335687	1.478873	1.629453	1.786217	1.947673	2.112065
180.00	1.108006	1.166693	1.232545	1.325720	1.485780	1.655425	1.833302	2.017618	2.206207
170.00	1.110313	1.172082	1.240023	1.317314	1.481780	1.673673	1.876571	2.088318	2.306204
160.00	1.108625	1.173278	1.243332	1.323659	1.462888	1.681128	1.914168	2.159425	2.413485
150.00	1.102139	1.169359	1.242580	1.325761	1.430493	1.672364	1.941714	2.228032	2.526997
140.00	1.090064	1.159320	1.235601	1.320534	1.420285	1.640335	1.953996	2.291446	2.647181
130.00	1.071608	1.142087	1.220724	1.308417	1.412293	1.574123	1.941687	2.342966	2.770954
120.00	1.046065	1.116609	1.196473	1.286967	1.392416	1.518340	1.891523	2.373039	2.894079
110.00	1.012981	1.081949	1.161345	1.253055	1.359217	1.491089	1.782566	2.362982	3.002623
100.00	.946023	1.037508	1.114075	1.204594	1.311843	1.441171	1.629657	2.288250	3.084090
90.00	.870382	.950278	1.053997	1.139880	1.245013	1.373527	1.533482	2.112102	3.122024
80.00	.783733	.858496	.939507	1.058276	1.156421	1.282051	1.440517	1.763442	3.064848
70.00	.687611	.754665	.827817	.907427	1.045721	1.161001	1.316196	1.517582	2.832734
60.00	.585130	.641940	.703992	.772023	.846804	1.010851	1.141904	1.321118	2.208583
50.00	.481347	.526024	.574064	.626066	.683683	.748959	.913546	1.080104	1.419055
40.00	.448285	.453338	.451162	.480793	.515724	.539853	.591363	.827733	1.062451
30.00	.435156	.436432	.432954	.420929	.384346	.362097	.381464	.427686	.754075
20.00	.424749	.423508	.416431	.401472	.365341	.330117	.269820	.203071	.251146
10.00	.418483	.416601	.408721	.392685	.353464	.315500	.269236	.220799	.166939
.00	.383468	.377385	.365132	.344824	.303126	.261321	.211207	.157361	.105733
-10.00	.292492	.273326	.246593	.210869	.159542	.105825	.051661	.021203	.002275
-20.00	.207180	.176707	.138051	.090643	.048322	.016322	.165609	.539415	.007677

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) -10.00	.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00
190.00	2.277956	2.443372	2.207652	1.968591	1.729608	1.493948	1.264542	1.043898	.834366
180.00	2.397167	2.587957	2.323422	2.055116	1.787310	1.524015	1.268813	1.024829	.794608
170.00	2.527712	2.749530	2.450901	2.147902	1.846122	1.550493	1.265426	.994861	.769218
160.00	2.672992	2.933516	2.593692	2.249133	1.906514	1.572536	1.252183	.950846	.794262
150.00	2.834061	3.143243	2.753217	2.357932	1.966337	1.586568	1.225357	.900772	.825806
140.00	3.014986	3.386605	2.934243	2.476148	2.024133	1.588859	1.179376	.913216	.860183
130.00	3.216894	3.669590	3.139112	2.602521	2.075820	1.573220	1.105785	.956714	.898157
120.00	3.441535	4.001420	3.369303	2.732254	2.115532	1.530689	1.076593	1.003624	.939970
110.00	3.682908	4.382370	3.619835	2.854147	2.121549	1.437962	1.138203	1.055661	.984647
100.00	3.944575	4.833965	3.901471	2.967979	2.079447	1.326708	1.184012	1.105480	1.031727
90.00	4.238219	5.401286	4.231628	3.068095	1.978955	1.359204	1.250487	1.152921	1.067722
80.00	4.547877	6.115063	4.606899	3.122836	1.768957	1.459049	1.328982	1.210057	1.104469
70.00	4.831633	7.014118	5.017674	3.085256	1.757011	1.578395	1.413924	1.268212	1.109375
60.00	5.039189	8.194150	5.446136	2.859057	1.944157	1.708555	1.501276	1.269848	1.031841
50.00	5.036280	9.822060	5.824366	2.606087	2.156241	1.842127	1.488406	1.129595	.900220
40.00	4.398587	12.252350	5.940111	2.914804	2.381149	1.790908	1.219995	.887612	.696962
30.00	2.163015	.000305	1.236609	1.604103	2.227657	1.243222	.755251	.620023	.653762
20.00	.391404	.000466	.000168	.030706	.903163	.687474	.709382	.937521	1.109186
10.00	.000770	.000212	.001068	.670649	1.048137	1.345416	1.510961	1.593307	1.671337
.00	.000172	.000018	.000290	1.272013	1.544162	1.702706	1.780133	1.801134	1.844003
-10.00	.002017	.002822	.202214	.320476	.565019	.780483	1.002190	1.154784	1.286605
-20.00	.013557	.026502	.490767	.271745	.296861	.404241	.496856	.642007	.774705

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE ANNUAL AVERAGE CONCENTRATION VALUES FOR SOURCE GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

*** NETWORK ID: COARSE ; NETWORK TYPE: GRIDCART ***

** CONC OF ANY IN MICROGRAMS/M**3 **

Y-COORD (METERS)	X-COORD (METERS) 80.00	90.00	100.00	110.00
190.00	.683746	.655306	.630528	.607161
180.00	.705799	.675252	.648839	.623245
170.00	.729179	.697219	.667996	.639881
160.00	.754542	.720568	.688080	.657044
150.00	.783120	.745327	.709102	.674740
140.00	.814639	.771610	.730931	.692834
130.00	.847679	.799628	.753409	.711137
120.00	.882144	.827693	.777020	.729154
110.00	.917954	.856218	.799397	.741855
100.00	.954756	.884393	.812003	.739074
90.00	.990778	.897658	.802347	.728452
80.00	.995857	.875833	.780407	.708148
70.00	.944282	.830234	.742995	.674893
60.00	.869848	.758822	.683074	.625730
50.00	.754627	.661355	.600071	.596148
40.00	.598160	.627236	.672544	.739627
30.00	.773469	.873812	.934084	.966002
20.00	1.185242	1.219140	1.224944	1.212520
10.00	1.641400	1.592988	1.534444	1.471329
.00	1.775496	1.698348	1.618179	1.538657
-10.00	1.312974	1.310662	1.290192	1.258751
-20.00	.877298	.939111	.972013	.984821

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL

*** THE MAXIMUM 10 ANNUAL AVERAGE CONCENTRATION VALUES FOR GROUP: ALL ***
INCLUDING SOURCE(S): 1 , 2 ,

** CONC OF ANY IN MICROGRAMS/M**3 **

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE			RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE		
1.	12.252350	AT (	.00,	40.00)	GC	6.	5.940111	AT (	10.00,	40.00)	GC
2.	9.822060	AT (	.00,	50.00)	GC	7.	5.824366	AT (	10.00,	50.00)	GC
3.	8.194150	AT (	.00,	60.00)	GC	8.	5.446136	AT (	10.00,	60.00)	GC
4.	7.014118	AT (	.00,	70.00)	GC	9.	5.401286	AT (	.00,	90.00)	GC
5.	6.115063	AT (	.00,	80.00)	GC	10.	5.039189	AT (	-10.00,	60.00)	GC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

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*** MODELING OPTIONS USED:  CONC   RURAL  ELEV   FLGPOL


*** Message Summary : ISCLT3 Model Execution ***

 --------- Summary of Total Messages --------

A Total of           0 Fatal Error Message(s)
A Total of           0 Warning Message(s)
A Total of           0 Informational Message(s)


   ******** FATAL ERROR MESSAGES ********
              ***  NONE  ***


   ********   WARNING MESSAGES   ********
              ***  NONE  ***


   ************************************
   *** ISCLT3 Finishes Successfully ***
   ************************************
```

ATTACHMENT B

TOPOGRAPHIC MAPS

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

LIVINGSTON RIDGE QUADRANGLE
NEW MEXICO-EDDY CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
CONTROL BY . . . . . USGS, NOS/NOAA
COMPILED FROM AERIAL PHOTOGRAPHS TAKEN 1977
FIELD CHECKED . . . . . 1978 MAP EDITED 1985
PROJECTION . . . . . TRANSVERSE MERCATOR
GRID: 1000-METER UNIVERSAL TRANSVERSE MERCATOR . . . . . ZONE 13
10,000-FOOT STATE GRID TICKS . . . . . NEW MEXICO, EAST ZONE
UTM GRID DECLINATION . . . . . 0°38' EAST
1985 MAGNETIC NORTH DECLINATION . . . . . 9°30' EAST
VERTICAL DATUM . . . . . NATIONAL GEODETIC VERTICAL DATUM OF 1929
HORIZONTAL DATUM . . . . . 1927 NORTH AMERICAN DATUM

To place on the predicted North American Datum of 1983, move the projection lines as shown by dashed corner ticks (9 meters south and 46 meters east)

There may be private inholdings within the boundaries of any Federal and State Reservations shown on this map

All marginal data and lettering generated and positioned by automated type placement procedures

PROVISIONAL MAP
Produced from original manuscript drawings. Information shown as of date of field check. 3

SCALE 1:24 000

1 5 0 1
1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10 000
MILES
FEET
1 5 0 1 2
1000 0 1000 2000
KILOMETERS
METERS

CONTOUR INTERVAL 10 FEET

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225
OR RESTON, VIRGINIA 22092

NEW MEXICO
QUADRANGLE LOCATION

1	2	3
4		5
6	7	8

1 Tower Hill North
2 Williams Sink
3 Laguna Gatuna
4 Tower Hill South
5 The Divide
6 Remuda Basin
7 Los Medaños
8 Bootleg Ridge

ADJOINING 7.5' QUADRANGLE NAMES

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1985

ROAD LEGEND

Improved Road . . . . . .
Unimproved Road . . . . . .
Trail . . . . . .

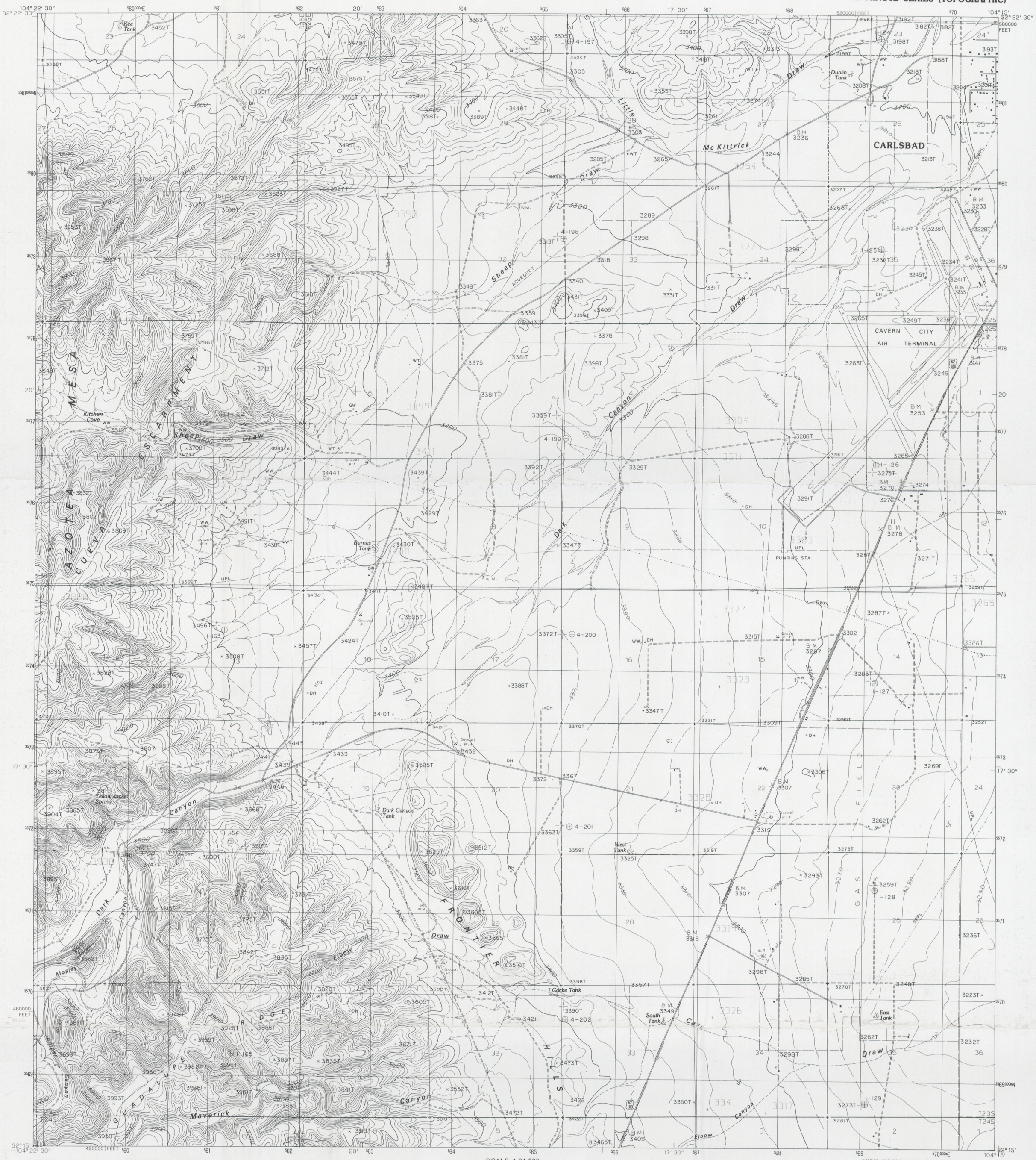
Interstate Route U.S. Route State Route

LIVINGSTON RIDGE, NEW MEXICO
PROVISIONAL EDITION 1985

32103-D7-TF-024

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

KITCHEN COVE QUADRANGLE
NEW MEXICO–EDDY CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
CONTROL BY ..... USGS, NOS/NOAA
COMPILED FROM AERIAL PHOTOGRAPHS TAKEN 1977
FIELD CHECKED ..... 1978 MAP EDITED 1985
PROJECTION ..... TRANSVERSE MERCATOR
GRID: 1000-METER UNIVERSAL TRANSVERSE MERCATOR ..... ZONE 13
10,000-FOOT STATE GRID TICKS ..... NEW MEXICO, EAST ZONE
UTM GRID DECLINATION ..... 0°22′ EAST
1985 MAGNETIC NORTH DECLINATION ..... 10° EAST
VERTICAL DATUM ..... NATIONAL GEODETIC VERTICAL DATUM OF 1929
HORIZONTAL DATUM ..... 1927 NORTH AMERICAN DATUM

To place on the predicted North American Datum of 1983, move the projection lines as shown by dashed corner ticks
(9 meters south and 46 meters east)

There may be private inholdings within the boundaries of any Federal and State Reservations shown on this map

NORTH

PROVISIONAL MAP
Produced from original manuscript drawings. Information shown as of date of field check.
3

SCALE 1:24 000

1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
SUPPLEMENTAL CONTOUR INTERVAL 10 FEET

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225
OR RESTON, VIRGINIA 22092

NEW MEXICO
QUADRANGLE LOCATION

1	2	3
4		5
6	7	8

1 Azotea Peak
2 Carlsbad West
3 Carlsbad East
4 Carmeto Peak
5 Otis
6 Carlsbad Caverns
7 Black River Village
8 Bond Draw

ADJOINING 7.5 QUADRANGLE NAMES

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1985

ROAD LEGEND

Improved Road
Unimproved Road
Trail

Interstate Route U.S. Route State Route

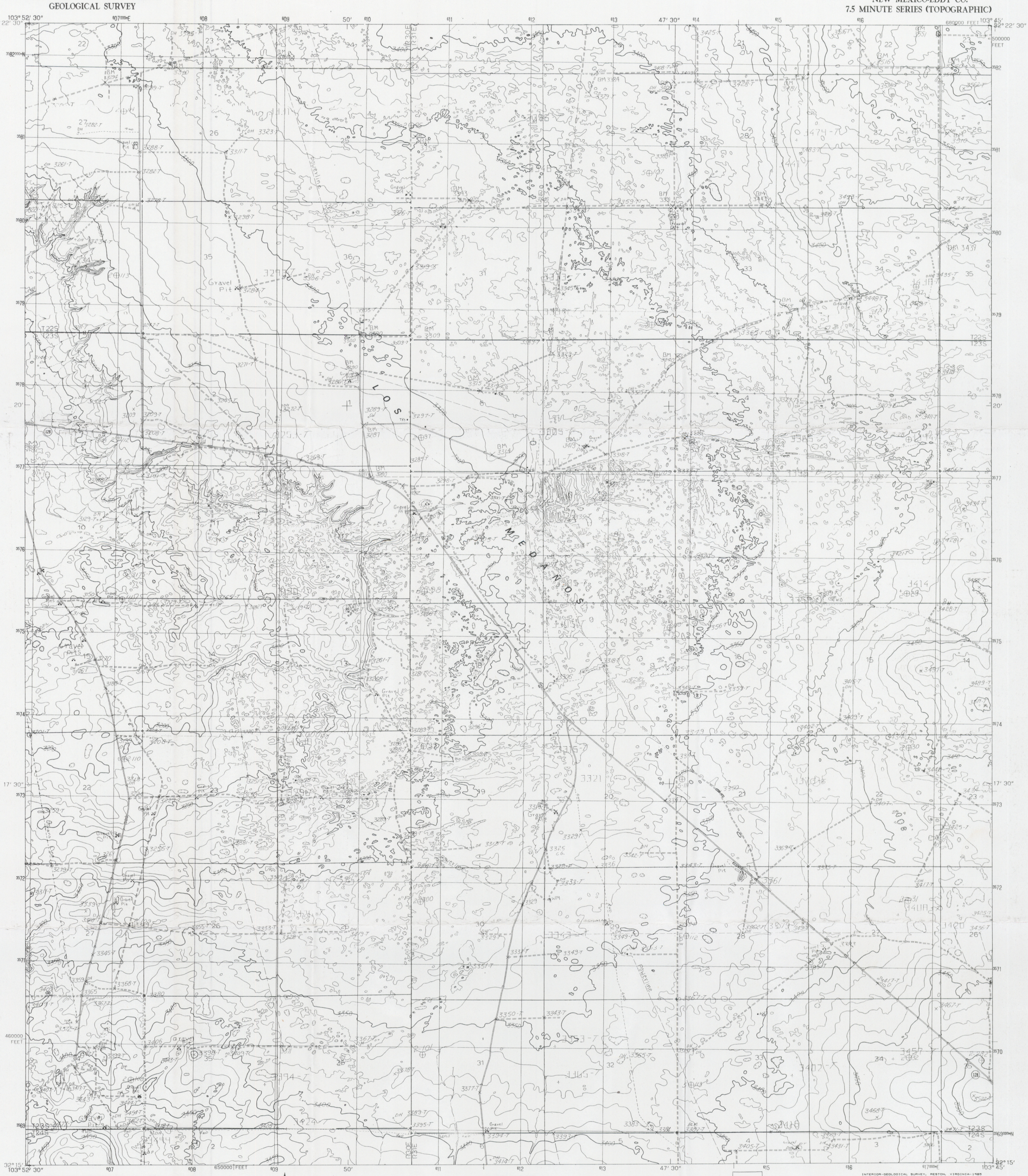
KITCHEN COVE, NEW MEXICO

PROVISIONAL EDITION 1985

32104-C3-TF-024

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

LOS MEDAÑOS QUADRANGLE
NEW MEXICO-EDDY CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
CONTROL BY . . . . . USGS, NOS/NOAA
COMPILED FROM AERIAL PHOTOGRAPHS TAKEN 1977
FIELD CHECKED . . . . . 1978 MAP EDITED 1985
PROJECTION . . . . . TRANSVERSE MERCATOR
GRID: 1000-METER UNIVERSAL TRANSVERSE MERCATOR . . . . . ZONE 13
10,000-FOOT STATE GRID TICKS . . . . . NEW MEXICO, EAST ZONE
UTM GRID DECLINATION . . . . . 0°38′ EAST
1985 MAGNETIC NORTH DECLINATION . . . . . 9°30′ EAST
VERTICAL DATUM . . . . . NATIONAL GEODETIC VERTICAL DATUM OF 1929
HORIZONTAL DATUM . . . . . 1927 NORTH AMERICAN DATUM

To place on the predicted North American Datum of 1983, move the projection lines as shown by dashed corner ticks (9 meters south and 45 meters east)

There may be private inholdings within the boundaries of any Federal and State Reservations shown on this map

All marginal data and lettering generated and positioned by automated type placement procedures

NORTH

PROVISIONAL MAP
Produced from original manuscript drawings. Information shown as of date of field check. 3

SCALE 1:24 000

1 5 0 1 MILES
1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10 000 FEET
1 .5 0 1 2 KILOMETERS
1000 0 1000 2000 METERS

CONTOUR INTERVAL 10 FEET

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225
OR RESTON, VIRGINIA 22092

NEW MEXICO

QUADRANGLE LOCATION

1	2	3
4		5
6	7	8

1 Tower Hill South
2 Livingston Ridge
3 The Divide
4 Rennada Basin
5 Booing Ridge
6 Pierce Canyon
7 Big Sinks
8 Puduca Breaks NW

ADJOINING 7.5′ QUADRANGLE NAMES

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1985

ROAD LEGEND

Improved Road . . . . . .
Unimproved Road . . . . . .
Trail . . . . . .

Interstate Route U.S. Route State Route

LOS MEDAÑOS, NEW MEXICO
PROVISIONAL EDITION 1985

32103-C7-TF-024

INSERT WIPP AND CARLSBAD AIRPORT TOPO MAPS HERE

ATTACHMENT C

QUALITY ASSURANCE

QUALITY ASSURANCE SUMMARY

Quality Assurance (QA) for the model runs consists of: 1) a summary of QA tests performed by the Environmental Protection Agency (EPA) on the Industrial Source Complex (ISC)2 model and 2) an independent review of the Department of Energy's (DOE's) model runs by Trinity Consultants, Inc. Both reports are attached.

The EPA QA test summary serves as the validation of the ISC2 model. For model verification, Trinity Consultants Inc. reviewed the model input and ran the input files to ensure that the data were derived and input correctly, the copy of the model code used was unchanged, and the hardware used to run the code did not influence the results of the model runs. Upon incorporation of Trinity's comments, the results of their model runs were exactly the same as those contained in this attachment.

SUMMARY OF THE QUALITY ASSURANCE AND EQUIVALENCE TESTS PERFORMED ON THE ISC2 MODELS

(From the EPA Support Center for Regulatory Air Models [SCRAM] Bulletin Board System [BBS] on April 24, 1995)

MARCH 1992

1 INTRODUCTION

This report presents a summary of the quality assurance and testing procedures that were used during the development of the ISC2 models, and summarizes the results of the ISC2 testing. A brief overview of the QA/Test Plan is presented in Section 2, followed in Section 3 by a summary of the tests performed at various stages in the software development cycle, and concluding with a discussion of the results of equivalence tests using standard EPA test data sets.

2 OVERVIEW OF QA/TEST PLAN

The ISC2 reprogramming effort included the preparation of a detailed Quality Assurance (QA) and Test Plan for the software development process as one of the earliest steps. The QA/Test Plan included a discussion of the goals of the reprogramming effort, established standard operating procedures for programming that addressed coding style, language standards, and documentation practices, and outlined a detailed test plan. The test plan stressed the importance of testing the code at each phase of the development process, including independent review of the design of individual modules, testing individual modules with standard test data, testing of groups of modules during the module integration phase, extensive system level testing, and outside review and testing of beta (draft) versions of the ISC2 software.

3 SUMMARY OF ISC2 TESTING

3.1 Module Level Testing

Individual modules were designed using structured English diagrams, or pseudo-code, to document the overall flow and structure of the program. The actual code was developed from these pseudocode files as a natural extension to executable Fortran statements. In many cases, the pseudocode remained in the actual Fortran source code files as comments to clarify the processing steps. Important modules were tested by code walkthroughs and other independent review mechanisms.

Most individual modules, particularly the calculation modules, underwent testing with standard test data once the Fortran code was written and compiled. In the absence of functioning module interfaces and data input routines, the module testing made use of the Fortran NAMELIST extension for inputting and outputting list-directed data. In this way, the input and output

variables specific to a module could be conveniently read in and written out without the need for burdensome I/O statements.

The most intensive module level testing was performed for certain modules that are involved with the more complex model computations. These included the modules that calculate the vertical term of the concentration equation, the module that solves the cubic equation for Schulman-Scire plume rise and for urban virtual distances for stabilities A and B, and the module that calculates the error function term for the finite line segment area source algorithm in the Short Term model. Using the NAMELIST test driver, the input parameters for these modules were systematically varied over the full range of possible inputs, and the results were compared with the comparable algorithms from the original ISC model. The tests of the CUBIC module were particularly intensive since the new model uses Newton's method to solve the cubic equation, which is a different method from that used in the original ISC models. This method was chosen for its efficiency, accuracy and stability over the full range of inputs, and for the better clarity of the code involved. One result of these detailed tests of the CUBIC module was the adjustment of the convergence criterion to obtain more accurate results for cases with very small plume rise. The development and testing of the error function module included an examination and comparison of several methods extracted from different models. The method used in the original ISCST model was retained, although restructured, because it appeared to be the most efficient, and gave comparable results to the other methods.

3.2 Module Integration Testing

Additional testing was performed during the module integration phase of the software development. The NAMELIST test driver approach was also used during this phase, particularly for the calculation modules. The setup processing modules were integrated and tested for each of the functional pathways using live input runstream data. This included testing of the data entry and extraction, as well as the error handling capabilities of the setup modules.

Module integration testing for the calculation modules was performed in stages, from the initial integration of the dispersion parameter modules to the full testing of the Schulman-Scire plume rise algorithms. In order to perform the latter testing, essentially all of the plume rise and dispersion parameter modules had to be integrated. The integration testing served to check the module interfaces and the flow of data.

Another important area of module integration testing involved the averaging and sorting routines of the model. In order to test these routines independent of the calculation modules, a binary concentration file of hourly results was generated by the original ISCST model to provide the raw concentration values for input to the new ISCST2 modules. In this way, all of the "bookkeeping" routines of the new model could be tested by direct comparison to the original model. As part of this testing, it was discovered that the original ISCST model contains an inconsistency between the high value by receptor and the overall maximum value summaries in the treatment of cases

with the same concentration (or deposition) value. The high value by receptor routines retain the earlier occurrence of the value, while the overall maximum 50 value routines keep the most recent occurrence. The sorting routines in the ISCST2 model consistently retain the earlier occurrence in these situations.

3.3 System Level Testing

Once all of the modules were integrated and the model input processing routines were fully functional, system level testing could be performed. System testing involved a broad range of activities. These included re-testing conditions tested under the previous stages of development, testing cases with predetermined results, systematically varying inputs to test transition points in the algorithms (especially important for the building downwash algorithms), testing normal and extreme ranges of input parameters, and testing realtime applications. An important part of this testing involved comparisons of results between the ISC2 models and the original ISC models. It was out of the need to make side-by-side comparisons for the same input data that the file conversion utility, STOLDNEW, was developed in stages.

The most intensive system level testing involved exercising the regulatory default options, since these are the most important to the user community. The building downwash algorithms were also tested intensively due to their complexity and in light of the numerous bugs associated with those algorithms in the earlier versions of ISC. The non-regulatory default options, including gradual plume rise, no BID, no stack tip downwash, and no calms processing, were also tested thoroughly. Tests were performed for both concentration calculations and deposition calculations. In addition to several realtime meteorological data sets, smaller test data sets of meteorological data were developed with variables covering a full range of possible inputs.

During the various phases of testing the models, several discrepancies were discovered between the ISC2 models and the earlier versions of ISC. Many of these discrepancies involved the building downwash algorithms, and especially the calculation of gradual momentum plume rise. Each discrepancy identified was carefully evaluated, and a resolution was reached for incorporation into the ISC2 models. An effort was also made to incorporate fixes for these discrepancies into the original ISC models, primarily for testing of the ISC2 corrections and to verify the cause and resolution of the discrepancy. The ISCST fixes are considered to be fairly complete, although they are in draft form and have not been released. Due to some fundamental flaws in the design of the ISCLT model's treatment of the direction-specific building downwash algorithms, it was not possible to complete the fixes for that model without major rewriting of the original code. Due to the number of discrepancies and the sometimes obscure nature of the causes, it is not practical to list all of them here. A brief description of some of the main problem areas was included with the original READ-ME.TXT file included with the first draft of ISC2 placed on the SCRAM BBS in September 1991. Overall, the discrepancies are not likely to effect design values significantly for most routine applications of the models for buoyant point sources or for volume sources. All values for area sources modeled with the ISCST2 model will be about 11.4 percent lower than corresponding values generated by the original

ISCST model. The most significant differences are likely to be for point sources dominated by momentum plume rise with no downwash and with Huber-Snyder downwash.

An important phase of the system testing involved automated point-by-point comparisons of the ISCST2 results with the original ISCST results for a large number of sources where the input parameters were varied systematically across a broad range of expected values. The results were compared on a point-by-point and hour-by-hour basis by a program that was developed to read the binary concentration files generated by each of the models. One of the ISC2 beta reviewers, Mark Garrison of United Engineers and Constructors, provided input data sets for this purpose that were developed during a performance evaluation of another dispersion model. Results from some of these comparisons are presented below in Section 4 of this report.

3.4 Beta Review and Testing

In addition to the system testing performed by the developers of the ISC2 code, draft versions of the models were sent to selected individuals and organizations for independent testing and beta review. The beta reviewers included EPA Regional and State modelers, as well as modelers from other Federal agencies, private industry and consulting firms. Additional system testing was being performed concurrent with the beta review. The beta reviewers were given draft versions of the models including source code, draft versions of the user's guide, and a list of specific issues for which feedback was solicited. Comments and suggestions from the beta reviewers were evaluated and incorporated into the final versions of the models where appropriate and practical.

3.5 Final Acceptance Testing

The final phase of testing for the ISC2 models is referred to as final acceptance testing. This involved review of the complete ISC2 package by EPA, and included the release of draft versions of the ISC2 models and draft user's guide to the modeling community by placing them on the SCRAM BBS. The first drafts were placed on SCRAM in September 1991, followed about two months later by revised drafts of the Short Term models, and by revised drafts of all models in early February 1992. Comments were received from several users through a special public message area in the Model Conference section of SCRAM. This final acceptance testing resulted in several bugs being identified and corrected. Additional system testing was performed concurrent with final acceptance testing. This was focused primarily on testing the lesser used options of the model and on challenging the error handling and reporting capabilities of the models. Also performed as part of the final acceptance testing were standard equivalence tests used by EPA in evaluating past changes to the models. These equivalence tests, which focus on a comparison of design values for a small number of representative sources, are summarized in the next section.

4 ISC2 EQUIVALENCE TESTS

This section describes tests that were performed on the ISC2 models to document their equivalence to the original ISC models. Two types of tests are summarized here. The first involves comparisons of predicted design values based on standard test data sets used by EPA in evaluating past changes to the models. This type of comparison is presented below for both the ISCST2 and ISCLT2 models. Another type of test for the ISCST2 model involves automated comparisons of results on a point-by-point and hour-by-hour basis using the binary concentration files generated by both models.

4.1 ISCST2 vs. ISCST Design Value Comparisons

The results of the equivalence tests involving comparisons of design values showed the ISCST2 results to be nearly identical to the ISCST (Version 90346) design values. The tests included six point sources with flat terrain, two point sources with elevated terrain, an elevated volume source, and an elevated area source. The sources were modeled using a 180 receptor polar network with one year of Pittsburgh (1964) meteorological data and one year of Oklahoma City (1984) meteorological data. All cases were modeled with both rural dispersion coefficients and with urban dispersion coefficients. The point source characteristics were as follows:

Stack Height (m)	Stack Temp. (K)	Exit Vel. (m/s)	Stack Diam. (m)	Bldg. Height (m)	Bldg. Width (m)	Elev. Terrain
35	432	11.7	2.4	NA	NA	No
35	432	11.7	2.4	34	60	No
35	432	11.7	2.4	34	30	No
35	432	11.7	2.4	34	180	No
100	416	18.8	4.6	NA	NA	No
200	425	26.5	5.6	NA	NA	No
35	432	11.7	2.4	NA	NA	Yes
200	425	26.5	5.6	NA	NA	Yes

The volume source had a release height of 35 meters, an initial lateral dimension of 14 meters and an initial vertical dimension of 16 meters. The area source had a release height of 35 meters and a width of 1000 meters. Receptor distances (in meters) for the six point sources with no terrain and for the volume and area sources were 125, 250, 400, 800, and 2000. The receptor distances for the cases with elevated terrain were 800, 2000, 4000, 7000, and 15000.

The design values examined included the highest and high-second-high 1-hour, 3-hour and 24-hour averages, and the highest annual averages. A total of 280 design values were compared. With the exception of the 24-hour Oklahoma City averages for the three building downwash sources for rural dispersion, all of the design values agreed to within a few hundredths or a few thousandths of a percent difference. The 24-hour Oklahoma City rural downwash values differed by a few tenths of percent, with the difference attributed to an error in the treatment of enhanced lateral dispersion for cases with the wake plume height less than 1.2 building heights by the original ISCST model. This difference

was resolved with the "fixed" version of the ISCST model.

4.2 ISCLT2 vs. ISCLT Design Value Comparisons

The same six point sources without elevated terrain used for the Short Term equivalence tests were also used in the Long Term model equivalence tests. The 200-meter release with elevated terrain was also examined, along with a volume source (10-meter release height and 10-meter initial lateral and vertical dispersion), and an area source (10-meter release height and 100-meter width). All sources were modeled with an annual STAR summary for the 1964 Pittsburgh data. The results of the equivalence tests for the Long Term model also showed only insignificant differences (less than 0.1 percent) between the highest annual averages from ISCLT2 and ISCLT (Version 90008) for the point sources, but showed larger differences for the area and volume sources examined. The highest annual average for the volume source for ISCLT2 was about 1.4 percent larger than the ISCLT high annual value, and the highest annual average for the area source for ISCLT2 was about 5 percent lower than the ISCLT high annual value. These differences are attributed, at least in part, to an error in the original ISCLT model in the treatment of lateral virtual distances. The differences were largest at the closer receptor distances, especially for the area source.

4.3 ISCST2 vs. ISCST Binary File Comparisons

A more intensive and complete testing of the ISCST2 model involved automated comparisons of hourly results using the binary concentration output file options of both the ISCST2 and ISCST models for a large number of source scenarios. A total of 365 different sources were included in these tests, which were broken down as follows:

100 point sources with no downwash
100 point sources with Huber-Snyder downwash
100 point sources with Schulman-Scire downwash
48 volume sources
17 area sources

The stack parameters for the point sources included a range of inputs for the release height, exit temperature, exit velocity and stack diameter covering a broad spectrum of source scenarios. These included momentum dominated plumes with no buoyancy as well as highly buoyant plumes. The volume and area source scenarios also covered a broad range of inputs, with five of the area sources including variable emission rate factors.

Receptors were located at various distances ranging from very near the source out to 100,000 meters downwind, with locations along the plume centerline and at about 10 degrees off-centerline. At each distance, receptors were placed at ground level and at two terrain elevations for the point sources. A total of 60 receptors were used for the point sources with no downwash, 54 receptors were used for the points sources with downwash, and 88 receptors were used for the volume and area sources.

The input meteorological data included 144 hours for the point sources and 24 hours for the volume and area sources. The larger number of hours for the point sources were to account for the dependence of plume rise on input meteorological conditions. The meteorological data for point sources included wind speeds at 0.5 m/s increments for the valid range of speeds for each stability category for two different mixing heights. The meteorological data for the volume and area sources also included each stability class with a smaller range of wind speeds and with two different mixing heights. Altogether, over 5 million data points were compared between the ISCST2 and ISCST models.

The results of these comparisons are presented in the following tables. The tables present the number of occurrences for various categories of the percent difference, stratified by the absolute value of the original ISCST result. Totals are given for each column, as well as for the total number of comparisons for each case and the total number of cases where both models indicated a value of 0.0. The percent differences were calculated as follows: [(New-Old)/Old]*100. Thus, a negative percent difference indicates that the ISCST2 value was less than the original or "fixed" ISCST value. Also, values in a particular column are for cases that were less than or equal to the percent difference given above the column and greater than the percent difference for the column to the left. Thus, cases under the column labeled ".20" are for cases where the percent difference was less than or equal to 0.20 percent but greater than -0.20 percent. For the ISCST2 vs. Original ISCST cases, about 92.8 percent of the cases fell into this category, while for the ISCST2 vs. "Fixed" ISCST cases, about 99.5 percent fell into this category. About 95.5 percent of the ISCST2 vs. Original ISCST occurrences fell with the range of plus or minus 2.0 percent, while about 99.5 percent of the ISCST2 vs. "Fixed" ISCST occurrences fell within this range. Most of the remaining occurrences for the ISCST2 vs. "Fixed" ISCST cases were for instances where the ISCST2 model predicted a value of 0.0 and the ISCST model predicted a very small value (less than or equal to 1.0E-6). These values are included in the upper left hand "cell" of the tables, and are indicative of slight differences in the lateral "truncation" of the plume between the two models due to rounding errors.

The results are presented in the following order:

100 Point Sources; No Downwash; Rural Dispersion; ISCST2 vs. Original ISCST
100 Point Sources; No Downwash; Rural Dispersion; ISCST2 vs. "Fixed" ISCST
100 Point Sources; No Downwash; Urban Dispersion; ISCST2 vs. Original ISCST
100 Point Sources; No Downwash; Urban Dispersion; ISCST2 vs. "Fixed" ISCST

100 Point Sources; H-S Downwash; Rural Dispersion; ISCST2 vs. Original ISCST
100 Point Sources; H-S Downwash; Rural Dispersion; ISCST2 vs. "Fixed" ISCST
100 Point Sources; H-S Downwash; Urban Dispersion; ISCST2 vs. Original ISCST
100 Point Sources; H-S Downwash; Urban Dispersion; ISCST2 vs. "Fixed" ISCST

100 Point Sources; S-S Downwash; Rural Dispersion; ISCST2 vs. Original ISCST
100 Point Sources; S-S Downwash; Rural Dispersion; ISCST2 vs. "Fixed" ISCST
100 Point Sources; S-S Downwash; Urban Dispersion; ISCST2 vs. Original ISCST

100 Point Sources; S-S Downwash; Urban Dispersion; ISCST2 vs. "Fixed" ISCST

48 Volume Sources; Rural Dispersion; ISCST2 vs. Original ISCST
48 Volume Sources; Rural Dispersion; ISCST2 vs. "Fixed" ISCST
48 Volume Sources; Urban Dispersion; ISCST2 vs. Original ISCST
48 Volume Sources; Urban Dispersion; ISCST2 vs. "Fixed" ISCST

17 Area Sources; Rural Dispersion; ISCST2 vs. Original ISCST
17 Area Sources; Rural Dispersion; ISCST2 vs. "Fixed" ISCST
17 Area Sources; Urban Dispersion; ISCST2 vs. Original ISCST
17 Area Sources; Urban Dispersion; ISCST2 vs. "Fixed" ISCST

Most of the largest differences in the ISCST2 vs. Original ISCST tables are associated with point sources with plume rise dominated by momentum. The consistent differences between the area source results of about -11.4 percent are due to an error in the derivation of the equation for the finite line segment algorithm for modeling area sources in ISCST. The vast majority of occurrences for the ISCST2 vs. "Fixed" ISCST cases fall within the range of plus or minus 0.2 percent, or fall into the category of a zero ISCST2 value and a very small ISCST value. A few occurrences for the rural downwash scenarios fall outside the +/- 0.2 percent range, but most of those are still within +/- 2.0 percent. These are primarily attributable to an error in the original ISCST model that was not practical to fix. The original ISCST model occasionally uses an incorrect set of coefficients for the calculation of vertical virtual distance in the rural mode. This calculation is performed by an iterative process in both models, where an estimate of virtual distance is made based on the coefficients corresponding to the source-receptor distance, and then the value of X+Xz is checked to see if it falls within the same distance range for coefficients. The original ISCST model occasionally selects coefficients for the distance range beyond the correct range, but does not allow for stepping back to the previous distance range.

---

100 POINT SOURCES; NO DOWNWASH; RURAL DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 60
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	6028	474	378	316	516	233567	2774	852	796	310
5300										
.1000E-04	0	108	44	26	64	7677	623	64	70	74
436										
.1000E-03	0	62	60	52	92	8034	691	60	110	94
384										
.1000E-02	6	46	60	6	20	26065	930	40	108	148
338										
.1000E-01	6	64	62	54	140	67649	1020	16	92	180
440										
.1000	0	90	72	40	60	87815	990	0	114	206
386										
1.000	0	46	74	68	168	132611	1472	120	218	229
1498										
10.00	0	30	72	50	168	118777	3632	348	602	123
852										
100.0	0	38	84	36	206	66300	6836	2503	2024	498
1118										
1000.	0	42	18	68	238	25861	2805	1770	7594	4932
2890										
.1000E+05	0	42	96	36	58	4492	676	558	1722	5194
3318										
.1000E+06	0	46	20	2	12	882	650	100	302	702
468										
.1000E+07	0	8	2	2	2	34	14	6	6	118
14										
	0	0	0	0	0	0	0	0	0	0
0										
TOTAL=	6040	1096	1042	756	1744	779764	23113	6437	13758	12808
17442										

TOTAL NUMBER OF COMPARISONS = 864000

NUMBER OF ZERO COMBINATIONS = 201756

---

100 POINT SOURCES; NO DOWNWASH; RURAL DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 60
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	6494	0	0	0	0	243653	0	0	0	0
.1000E-04	0	0	0	0	0	9258	0	0	0	0
.1000E-03	0	0	0	0	0	9810	0	0	0	0
.1000E-02	0	0	0	0	0	27865	0	0	0	0
.1000E-01	0	0	0	0	0	69575	0	0	0	0
.1000	0	0	0	0	0	89513	0	0	0	0
1.000	0	0	0	0	0	135054	0	0	0	0
10.00	0	0	0	0	0	123793	0	0	0	0
100.0	0	0	0	0	0	78293	0	0	0	0
1000.	0	0	0	0	0	42752	0	0	0	0
.1000E+05	0	0	0	0	0	15694	0	0	0	0
.1000E+06	0	0	0	0	0	10352	0	0	0	0
.1000E+07	0	0	0	0	0	1894	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	6494	0	0	0	0	857506	0	0	0	0

TOTAL NUMBER OF COMPARISONS = 864000

NUMBER OF ZERO COMBINATIONS = 201292

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100 POINT SOURCES; NO DOWNWASH; URBAN DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 60
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	3862	410	296	102	274	183306	1719	279	690	626	4821
.1000E-04	0	44	74	20	20	11367	322	26	104	248	468
.1000E-03	0	42	34	16	4	21828	393	79	133	361	479
.1000E-02	0	60	30	14	80	19677	482	76	123	478	476
.1000E-01	0	50	86	26	106	49418	369	146	138	636	240
.1000	0	64	24	16	88	80097	581	148	278	637	164
1.000	0	86	92	54	86	144069	498	184	379	625	24
10.00	0	34	126	36	112	168582	952	288	668	313	8
100.0	0	54	82	56	132	86456	7436	1503	1004	146	628
1000.	0	32	58	52	132	29078	3530	2404	8544	162	1400
.1000E+05	0	44	30	6	26	3132	1258	254	1676	2500	4826
.1000E+06	0	16	0	6	4	868	248	60	386	614	590
.1000E+07	0	0	0	0	0	20	0	0	4	72	0
	0	0	0	0	0	0	0	0	0	0	0
TOTAL=	3862	936	932	404	1064	797898	17788	5447	14127	7418	14124

TOTAL NUMBER OF COMPARISONS = 864000

NUMBER OF ZERO COMBINATIONS = 151488

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100 POINT SOURCES; NO DOWNWASH; URBAN DISPERSION; ISCST2 vs. 'Fixed' ISCST

NUMREC = 60
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	4496	0	0	0	0	191113	0	0	0	0
.1000E-04	0	0	0	0	0	12785	0	0	0	0
.1000E-03	0	0	0	0	0	23513	0	0	0	0
.1000E-02	0	0	0	0	0	21647	0	0	0	0
.1000E-01	0	0	0	0	0	51403	0	0	0	0
.1000	0	0	0	0	0	82198	0	0	0	0
1.000	0	0	0	0	0	146157	0	0	0	0
10.00	0	0	0	0	0	171127	0	0	0	0
100.0	0	0	0	0	0	96815	0	0	0	0
1000.	0	0	0	0	0	43878	0	0	0	0
.1000E+05	0	0	0	0	0	11262	0	0	0	0
.1000E+06	0	0	0	0	0	6994	0	0	0	0
.1000E+07	0	0	0	0	0	612	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	4496	0	0	0	0	859504	0	0	0	0

TOTAL NUMBER OF COMPARISONS = 864000

NUMBER OF ZERO COMBINATIONS = 150854

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100 POINT SOURCES; H-S DOWNWASH; RURAL DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 54
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	3002	280	166	24	190	147590	2243	234	102	269
4381										
.1000E-04	0	26	14	0	2	6164	466	14	2	69
270										
.1000E-03	0	14	26	22	16	5402	511	18	6	94
269										
.1000E-02	0	38	28	14	48	22184	557	16	2	76
180										
.1000E-01	0	6	42	16	80	64306	683	8	2	99
44										
.1000	0	40	84	26	308	84357	644	10	0	159
6										
1.000	0	28	76	100	476	128681	794	128	44	140
14										
10.00	0	34	134	394	790	127305	3262	196	316	10
0										
100.0	0	10	320	712	1280	95183	7968	1988	1506	106
86										
1000.	0	2	442	780	452	33054	3330	2942	7956	1418
314										
.1000E+05	0	0	104	50	16	3110	444	320	2776	1496
448										
.1000E+06	0	0	0	0	0	22	18	6	30	24
16										
.1000E+07	0	0	0	0	0	0	0	0	0	0
0										
	0	0	0	0	0	0	0	0	0	0
0										
TOTAL=	3002	478	1436	2138	3658	717358	20920	5880	12742	3960
6028										

TOTAL NUMBER OF COMPARISONS = 777600

NUMBER OF ZERO COMBINATIONS = 127209

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100 POINT SOURCES; H-S DOWNWASH; RURAL DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 54
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	3800	6	0	0	8	154078	0	0	0	0
.1000E-04	0	0	4	0	0	7259	0	0	0	0
.1000E-03	0	0	0	0	2	6477	0	0	0	0
.1000E-02	0	0	0	0	0	23261	0	0	0	0
.1000E-01	0	0	2	0	2	65381	0	0	0	0
.1000	0	0	2	0	2	85649	0	0	0	0
1.000	0	0	0	0	2	130441	52	0	0	0
10.00	0	0	0	0	0	132365	48	0	0	0
100.0	0	0	0	0	0	108985	6	0	0	0
1000.	0	0	0	0	2	50118	0	0	0	0
.1000E+05	0	0	0	0	0	9340	2	0	0	0
.1000E+06	0	0	0	0	0	304	2	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	3800	6	8	0	18	773658	110	0	0	0

TOTAL NUMBER OF COMPARISONS = 777600

NUMBER OF ZERO COMBINATIONS = 126411

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100 POINT SOURCES; H-S DOWNWASH; URBAN DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 54
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	2219	128	38	42	186	122110	1563	0	33	359
4958										
.1000E-04	0	12	4	4	26	10159	192	0	12	264
456										
.1000E-03	0	4	44	12	22	20234	198	4	30	387
442										
.1000E-02	0	60	0	4	2	17404	324	13	66	494
305										
.1000E-01	0	12	0	12	50	46857	162	14	178	660
138										
.1000	0	0	78	18	10	77437	324	30	321	561
74										
1.000	0	64	82	0	0	139038	216	118	479	417
0										
10.00	0	0	6	98	292	167999	526	223	528	180
0										
100.0	0	6	240	330	1450	100766	7258	1536	868	6
0										
1000.	0	0	516	838	542	26750	2834	2742	6078	736
0										
.1000E+05	0	0	48	8	12	1430	212	132	1628	614
0										
.1000E+06	0	0	0	0	0	0	4	0	0	0
0										
.1000E+07	0	0	0	0	0	0	0	0	0	0
0										
	0	0	0	0	0	0	0	0	0	0
0										
TOTAL=	2219	286	1056	1366	2592	730184	13813	4812	10221	4678
6373										

TOTAL NUMBER OF COMPARISONS = 777600

NUMBER OF ZERO COMBINATIONS = 98178

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100 POINT SOURCES; H-S DOWNWASH; URBAN DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 54
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	3008	0	0	0	0	127885	0	0	0	0
.1000E-04	0	0	0	0	0	11262	0	0	0	0
.1000E-03	0	0	0	0	0	21466	0	0	0	0
.1000E-02	0	0	0	0	0	18915	0	0	0	0
.1000E-01	0	0	0	0	0	48140	0	0	0	0
.1000	0	0	0	0	0	79009	0	0	0	0
1.000	0	0	0	0	0	140435	12	0	0	0
10.00	0	0	0	0	0	169870	12	0	0	0
100.0	0	0	0	0	0	112432	0	0	0	0
1000.	0	0	0	0	0	40932	0	0	0	0
.1000E+05	0	0	0	0	0	4210	0	0	0	0
.1000E+06	0	0	0	0	0	12	0	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	3008	0	0	0	0	774568	24	0	0	0

TOTAL NUMBER OF COMPARISONS = 777600

NUMBER OF ZERO COMBINATIONS = 97389

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100 POINT SOURCES; S-S DOWNWASH; RURAL DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 54
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	1218	0	0	0	0	149165	1265	744	124	58
.1000E-04	0	0	0	0	0	4206	447	56	0	38
.1000E-03	0	0	0	0	0	4092	574	70	6	46
.1000E-02	0	0	0	0	0	19946	676	44	8	32
.1000E-01	0	0	0	0	0	60717	1067	36	0	18
.1000	0	0	0	0	0	78974	1151	26	14	40
1.000	0	0	154	67	230	127990	1091	27	101	29
10.00	0	0	3060	401	1228	134599	2203	184	2403	587
100.0	0	12	2030	2337	998	96110	3964	180	6696	2220
1000.	0	0	308	332	380	46414	2198	78	1830	1928
.1000E+05	0	0	0	4	340	7322	80	12	262	726
.1000E+06	0	0	0	0	0	86	0	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	1218	12	5552	3141	3176	729621	14716	1457	11444	5722

TOTAL NUMBER OF COMPARISONS = 777600

NUMBER OF ZERO COMBINATIONS = 138501

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100 POINT SOURCES; S-S DOWNWASH; RURAL DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 54
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	1384	0	0	0	0	152107	0	0	0	0
.1000E-04	0	0	0	0	0	4919	0	0	0	0
.1000E-03	0	0	0	0	0	4988	0	0	0	0
.1000E-02	0	0	0	0	0	20838	0	0	0	0
.1000E-01	0	0	0	0	0	61921	0	0	0	0
.1000	0	0	0	0	0	80236	0	0	0	0
1.000	0	0	0	0	0	129692	0	0	0	0
10.00	0	0	0	0	8	144434	0	0	0	0
100.0	0	0	0	56	20	114409	0	0	0	0
1000.	0	0	0	52	28	53572	0	0	0	0
.1000E+05	0	0	0	4	0	8826	0	0	0	0
.1000E+06	0	0	0	0	0	106	0	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	1384	0	0	112	56	776048	0	0	0	0

TOTAL NUMBER OF COMPARISONS = 777600

NUMBER OF ZERO COMBINATIONS = 138335

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100 POINT SOURCES; S-S DOWNWASH; URBAN DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 54
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	553	16	0	0	0	143059	407	154	8	26
.1000E-04	0	0	0	0	0	8345	126	6	2	39
.1000E-03	0	0	0	0	0	19223	136	6	16	71
.1000E-02	0	0	0	0	0	15470	288	4	18	100
.1000E-01	0	0	8	0	0	44251	354	12	14	136
.1000	0	0	12	0	0	73521	416	0	6	138
1.000	0	0	88	76	152	135705	530	10	31	99
10.00	0	4	58	71	350	168349	399	14	68	12
100.0	0	0	30	46	169	113895	474	20	8	0
1000.	0	0	4	10	18	42998	148	4	0	0
.1000E+05	0	0	0	0	0	4806	20	0	0	0
.1000E+06	0	0	0	0	0	8	0	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	553	20	200	203	689	769630	3298	230	171	621

TOTAL NUMBER OF COMPARISONS = 777600

NUMBER OF ZERO COMBINATIONS = 125921

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100 POINT SOURCES; S-S DOWNWASH; URBAN DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 54
NUMBER OF HOURS OF METEOROLOGY = 144

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	766	0	0	0	0	144598	0	0	0	0
.1000E-04	0	0	0	0	0	8697	0	0	0	0
.1000E-03	0	0	0	0	0	19708	0	0	0	0
.1000E-02	0	0	0	0	0	16062	0	0	0	0
.1000E-01	0	0	0	0	0	44936	0	0	0	0
.1000	0	0	0	0	0	74141	0	0	0	0
1.000	0	0	0	0	0	136707	0	0	0	0
10.00	0	0	0	0	0	169324	0	0	0	0
100.0	0	0	0	0	0	114643	0	0	0	0
1000.	0	0	0	0	0	43180	0	0	0	0
.1000E+05	0	0	0	0	0	4830	0	0	0	0
.1000E+06	0	0	0	0	0	8	0	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	766	0	0	0	0	776834	0	0	0	0

TOTAL NUMBER OF COMPARISONS = 777600

NUMBER OF ZERO COMBINATIONS = 125708

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48 VOLUME SOURCES; RURAL DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 88
NUMBER OF HOURS OF METEOROLOGY = 24

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	370	0	0	0	0	43068	144	15	32	0	0
.1000E-04	0	0	0	0	0	396	42	8	24	0	0
.1000E-03	0	0	0	0	0	645	46	20	0	0	0
.1000E-02	0	0	0	0	0	974	41	41	0	0	0
.1000E-01	0	0	0	0	0	679	76	50	0	0	0
.1000	0	0	0	0	0	1067	148	4	0	0	0
1.000	0	0	0	0	0	5668	222	4	0	0	0
10.00	0	0	0	0	0	12965	471	24	0	0	0
100.0	0	0	0	0	0	22272	720	16	0	0	0
1000.	0	0	0	0	0	9884	313	0	0	0	0
.1000E+05	0	0	0	0	0	923	4	0	0	0	0
.1000E+06	0	0	0	0	0	0	0	0	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0
TOTAL=	370	0	0	0	0	98541	2227	182	56	0	0

TOTAL NUMBER OF COMPARISONS = 101376

NUMBER OF ZERO COMBINATIONS = 41424

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48 VOLUME SOURCES; RURAL DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 88
NUMBER OF HOURS OF METEOROLOGY = 24

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	370	0	0	0	0	43255	0	0	0	0
.1000E-04	0	0	0	0	0	474	0	0	0	0
.1000E-03	0	0	0	0	0	711	0	0	0	0
.1000E-02	0	0	0	0	0	1056	0	0	0	0
.1000E-01	0	0	0	0	0	805	0	0	0	0
.1000	0	0	0	0	0	1219	0	0	0	0
1.000	0	0	0	0	0	5894	0	0	0	0
10.00	0	0	0	0	0	13458	0	0	0	0
100.0	0	0	0	0	0	23008	0	0	0	0
1000.	0	0	0	0	0	10199	0	0	0	0
.1000E+05	0	0	0	0	0	927	0	0	0	0
.1000E+06	0	0	0	0	0	0	0	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	370	0	0	0	0	101006	0	0	0	0

TOTAL NUMBER OF COMPARISONS = 101376

NUMBER OF ZERO COMBINATIONS = 41424

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48 VOLUME SOURCES; URBAN DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 88
NUMBER OF HOURS OF METEOROLOGY = 24

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	192	0	0	0	0	41301	0	0	0	0
.1000E-04	0	0	0	0	0	271	0	0	0	0
.1000E-03	0	0	0	0	0	326	2	0	0	0
.1000E-02	0	0	0	0	0	365	6	0	0	0
.1000E-01	0	0	0	0	0	669	4	0	0	0
.1000	0	0	0	0	0	1133	48	0	0	0
1.000	0	0	0	0	0	9688	92	0	0	0
10.00	0	0	0	0	0	19147	158	0	0	0
100.0	0	0	0	0	0	19150	229	0	0	0
1000.	0	0	0	0	0	8075	129	0	0	0
.1000E+05	0	0	0	0	0	387	4	0	0	0
.1000E+06	0	0	0	0	0	0	0	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	192	0	0	0	0	100512	672	0	0	0

TOTAL NUMBER OF COMPARISONS = 101376

NUMBER OF ZERO COMBINATIONS = 39808

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48 VOLUME SOURCES; URBAN DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 88
NUMBER OF HOURS OF METEOROLOGY = 24

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	192	0	0	0	0	41301	0	0	0	0
.1000E-04	0	0	0	0	0	271	0	0	0	0
.1000E-03	0	0	0	0	0	328	0	0	0	0
.1000E-02	0	0	0	0	0	371	0	0	0	0
.1000E-01	0	0	0	0	0	673	0	0	0	0
.1000	0	0	0	0	0	1181	0	0	0	0
1.000	0	0	0	0	0	9778	0	0	0	0
10.00	0	0	0	0	0	19307	0	0	0	0
100.0	0	0	0	0	0	19378	0	0	0	0
1000.	0	0	0	0	0	8205	0	0	0	0
.1000E+05	0	0	0	0	0	391	0	0	0	0
.1000E+06	0	0	0	0	0	0	0	0	0	0
.1000E+07	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	192	0	0	0	0	101184	0	0	0	0

TOTAL NUMBER OF COMPARISONS = 101376

NUMBER OF ZERO COMBINATIONS = 39808

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17 AREA SOURCES; RURAL DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 88
NUMBER OF HOURS OF METEOROLOGY = 24

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	2766	288	0	0	0	10514	0	0	0	0
.1000E-04	325	99	0	0	0	0	0	0	0	0
.1000E-03	239	287	2	0	0	0	0	0	0	0
.1000E-02	31	235	12	0	0	0	0	0	0	0
.1000E-01	0	399	8	0	0	0	0	0	0	0
.1000	0	461	2	0	0	0	0	0	0	0
1.000	0	594	0	0	0	0	0	0	0	0
10.00	0	1498	0	0	0	0	0	0	0	0
100.0	0	5169	0	0	0	0	0	0	0	0
1000.	0	7384	0	0	0	0	0	0	0	0
.1000E+05	0	4229	0	0	0	0	0	0	0	0
.1000E+06	0	1121	0	0	0	0	0	0	0	0
.1000E+07	0	241	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	3361	22005	24	0	0	10514	0	0	0	0

TOTAL NUMBER OF COMPARISONS = 35904

NUMBER OF ZERO COMBINATIONS = 10514

---

17 AREA SOURCES; RURAL DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 88
NUMBER OF HOURS OF METEOROLOGY = 24

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	2776	0	0	0	0	10818	0	0	0	0
.1000E-04	371	0	0	0	0	85	0	0	0	0
.1000E-03	184	0	0	0	0	300	0	0	2	0
.1000E-02	30	0	0	0	0	228	0	0	12	0
.1000E-01	0	0	0	0	0	439	1	0	8	0
.1000	0	0	0	0	0	433	4	0	2	0
1.000	0	0	0	0	0	652	0	0	0	0
10.00	0	0	0	0	0	1993	0	0	0	0
100.0	0	0	0	0	0	4829	0	0	0	0
1000.	0	0	0	0	0	7463	0	0	0	0
.1000E+05	0	0	0	0	0	4033	0	0	0	0
.1000E+06	0	0	0	0	0	1022	0	0	0	0
.1000E+07	0	0	0	0	0	219	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	3361	0	0	0	0	32514	5	0	24	0

TOTAL NUMBER OF COMPARISONS = 35904

NUMBER OF ZERO COMBINATIONS = 10514

---

17 AREA SOURCES; URBAN DISPERSION; ISCST2 vs. Original ISCST

NUMREC = 88
NUMBER OF HOURS OF METEOROLOGY = 24

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	1952	68	0	0	0	9188	0	0	0	0
.1000E-04	124	36	0	0	0	0	0	0	6	0
.1000E-03	49	94	0	0	0	0	0	0	4	0
.1000E-02	12	189	0	0	0	0	0	0	0	0
.1000E-01	0	509	0	0	0	0	0	0	0	0
.1000	0	749	0	0	0	0	0	0	0	0
1.000	0	938	0	0	0	0	0	0	0	0
10.00	0	3582	0	0	0	0	0	0	0	0
100.0	0	6004	0	0	0	0	0	0	0	0
1000.	0	7466	0	0	0	0	0	0	0	0
.1000E+05	0	4113	0	0	0	0	0	0	0	0
.1000E+06	0	729	0	0	0	0	0	0	0	0
.1000E+07	0	92	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	2137	24569	0	0	0	9188	0	0	10	0

TOTAL NUMBER OF COMPARISONS = 35904

NUMBER OF ZERO COMBINATIONS = 9188

---

17 AREA SOURCES; URBAN DISPERSION; ISCST2 vs. "Fixed" ISCST

NUMREC = 88
NUMBER OF HOURS OF METEOROLOGY = 24

DELTA PERCENT (_=)

RANGE (_=):	-100.00	-10.00	-2.00	-1.00	-.20	.20	1.00	2.00	10.00	100.00
.1000E-05	1960	0	0	0	0	9256	0	0	0	0
.1000E-04	124	0	0	0	0	36	0	0	6	0
.1000E-03	41	0	0	0	0	100	0	0	4	0
.1000E-02	12	0	0	0	0	201	6	0	0	0
.1000E-01	0	0	0	0	0	512	20	0	0	0
.1000	0	0	0	0	0	713	8	0	0	0
1.000	0	0	0	0	0	980	0	0	0	0
10.00	0	0	0	0	0	3623	0	0	0	0
100.0	0	0	0	0	0	6301	0	0	0	0
1000.	0	0	0	0	0	7414	0	0	0	0
.1000E+05	0	0	0	0	0	3821	0	0	0	0
.1000E+06	0	0	0	0	0	681	0	0	0	0
.1000E+07	0	0	0	0	0	85	0	0	0	0
	0	0	0	0	0	0	0	0	0	0
TOTAL=	2137	0	0	0	0	33723	34	0	10	0

TOTAL NUMBER OF COMPARISONS = 35904

NUMBER OF ZERO COMBINATIONS = 9188

```
** This is a simple example problem for the ISC Long Term Model, ISCLT.
** This example makes use of the new area source algorithm, and corresponds
** to the same source and receptor inputs as used in the TESTST.INP file.
** To run the example type: ISCLT3EM TESTLT.INP outfil.nam
** The results for this test are in file TESTLT.OUT

CO STARTING
   TITLEONE  TEST RUN FOR NEW ISCLT MODEL - TEST OF NEW AREA SOURCE ALGORITHM
   MODELOPT  DFAULT  CONC  RURAL
   AVERTIME  WINTER
   TERRHGTS  ELEV
   FLAGPOLE
   POLLUTID  OTH
   RUNORNOT  RUN
   ELEVUNIT  FEET
CO FINISHED

SO STARTING

**            SRCID  SRCTYP    XS       YS        ZS
**            -----  ------   -----    -----     -----
SO LOCATION     1     AREA     800.     400.     .0000
SO LOCATION     2     AREA      40.     360.     .0000
SO LOCATION     3     AREA     480.      20.     .0000
SO LOCATION     4     AREA     420.     260.     .0000
SO LOCATION     5     AREA     420.     180.     .0000
```

```
SO LOCATION     6    AREA     420.     100.     .0000

SO LOCATION     7    AREA     260.     340.     .0000

SO LOCATION     8    AREA      40.     100.     .0000

SO LOCATION     9    AREA      40.      20.     .0000

SO LOCATION    10    AREA     300.     360.     .0000


**            SRCID    QS       HS     XINIT   YINIT

**            -----   ----     ----    -----   -----

SO SRCPARAM     1     1.0      1.0      60.    100.

SO SRCPARAM     2     1.0      1.0      20.     20.

SO SRCPARAM     3     1.0      1.0      30.    300.

SO SRCPARAM     4     1.0      1.0      40.     40.

SO SRCPARAM     5     1.0      1.0      40.     40.

SO SRCPARAM     6     1.0      1.0      40.     40.

SO SRCPARAM     7     1.0      1.0     140.    200.

SO SRCPARAM     8     1.0      1.0     220.    100.

SO SRCPARAM     9     1.0      1.0     220.     70.

SO SRCPARAM    10    -1.0      1.0      80.     40.


SO EMISUNIT     1.000 (GRAMS/(SEC-M**2))          grams/cubic-meter


SO SRCGROUP ALL

SO FINISHED
```

```
RE STARTING

RE DISCCART     20.    60.  1.0    1.0

RE DISCCART    150.    95.  1.0    1.0

RE DISCCART    360.   100.  1.0    1.0

RE DISCCART    520.   120.  1.0    1.0

RE DISCCART    490.   240.  1.0    1.0

RE DISCCART    320.   240.  1.0    1.0

RE DISCCART    150.   260.  1.0    1.0

RE DISCCART     50.   330.  1.0    1.0

RE DISCCART     70.   390.  1.0    1.0

RE DISCCART    190.   350.  1.0    1.0

RE DISCCART    310.   370.  1.0    1.0

RE DISCCART    420.   380.  1.0    1.0

RE DISCCART     70.   460.  1.0    1.0

RE DISCCART    200.   460.  1.0    1.0

RE DISCCART    330.   470.  1.0    1.0

RE DISCCART     40.   560.  1.0    1.0

RE DISCCART    480.   660.  1.0    1.0

RE DISCCART    800.   700.  1.0    1.0

RE FINISHED



ME STARTING

   INPUTFIL  TEST.STA  FREE

   ANEMHGHT  10.

   SURFDATA  99999  1990  TESTDATA
```

```
UAIRDATA  99999  1990  TESTDATA

STARDATA  SEASON


**                  - AMBIENT AIR TEMPERATURE (DEGREES KELVIN) -

**

**                    STAB    STAB    STAB    STAB    STAB    STAB

**                    CAT 1   CAT 2   CAT 3   CAT 4   CAT 5   CAT 6

**                    -----   -----   -----   -----   -----   -----


AVETEMPS  WINTER   283.0   283.0   283.0   283.0   283.0   283.0



**                        - MIXING LAYER HEIGHT (METERS) -

**                  S

**                  T    WS       WS       WS       WS       WS       WS

**            SEAS  A   CAT 1    CAT 2    CAT 3    CAT 4    CAT 5    CAT 6

**            ----  B   -----    -----    -----    -----    -----    -----


AVEMIXHT  WINTER 1 .225E+04 .225E+04 .225E+04 .225E+04 .225E+04 .225E+04

AVEMIXHT  WINTER 2 .150E+04 .150E+04 .150E+04 .150E+04 .150E+04 .150E+04

AVEMIXHT  WINTER 3 .150E+04 .150E+04 .150E+04 .150E+04 .150E+04 .150E+04

AVEMIXHT  WINTER 4 .100E+04 .100E+04 .100E+04 .100E+04 .100E+04 .100E+04

AVEMIXHT  WINTER 5 .100E+05 .100E+05 .100E+05 .100E+05 .100E+05 .100E+05

AVEMIXHT  WINTER 6 .100E+05 .100E+05 .100E+05 .100E+05 .100E+05 .100E+05
```

```
**            - Roughness Length (m) -

**

**            SEAS     ZO (m)

**            ----     -----

**

**   AVEROUGH  WINTER    0.10


ME FINISHED


**TG STARTING

**TG FINISHED


OU STARTING

   RECTABLE  SRCGRP

   MAXTABLE  10 INDSRC SRCGRP

OU FINISHED


 *** Message Summary For ISC3 Model Setup ***

 --------- Summary of Total Messages --------

A Total of           0 Fatal Error Message(s)
A Total of           2 Warning Message(s)
A Total of           0 Informational Message(s)


   ******** FATAL ERROR MESSAGES ********
              ***  NONE  ***


   ********   WARNING MESSAGES   ********
CO W205   12 FLAGDF: No Option Parameter Setting.  Forced by Default to ZFLAG=0.
CO W151   15 COCARD: CO ELEVUNIT card obsolescent: use RE ELEVUNIT card instead
```

```
************************************
*** SETUP Finishes Successfully ***
************************************
```

```
  *** ISCLT3 - VERSION 95250 ***     ***  TEST RUN FOR NEW ISCLT MODEL - TEST OF NEW
AREA SOURCE ALGORITHM    ***         09/07/95
                                     ***
                     ***        16:26:53

                                PAGE   1
  *** MODELING OPTIONS USED:  CONC   RURAL  ELEV   FLGPOL DFAULT


                                          ***     MODEL SETUP OPTIONS SUMMARY
***
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - - - - - - - - - - - - - - - -

 **Model Is Setup For Calculation of Average CONCentration Values.
 **Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

 **Model Uses NO plume DEPLETION.

 **Model Uses RURAL Dispersion.

 **Model Uses Regulatory DEFAULT Options:
           1. Final Plume Rise.
           2. Stack-tip Downwash.
           3. Buoyancy-induced Dispersion.
           4. Default Wind Profile Exponents.
           5. Default Vertical Potential Temperature Gradients.
           6. "Upper Bound" Values For Supersquat Buildings.
           7. No Exponential Decay for RURAL Mode

 **Model Accepts Receptors on ELEV Terrain.

 **Model Accepts FLAGPOLE Receptor Heights.

 **Model Calculates   1 STAR Average(s) for the Following Months:  0  0  0  0  0  0  0
0  0  0  0  0
                                                Seasons/Quarters:  1  0  0  0
                                                      and Annual:  0

 **Data File Includes  4 STAR Summaries for the Following Months:  0  0  0  0  0  0  0
0  0  0  0  0
                                                Seasons/Quarters:  1  1  1  1
                                                      and Annual:  0

 **This Run Includes:   10 Source(s);      1 Source Group(s); and     18 Receptor(s)

 **The Model Assumes A Pollutant Type of:  OTH

 **Model Set To Continue RUNning After the Setup Testing.

 **Output Options Selected:
```

```
          Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)
          Model Outputs Tables of Maximum Long Term Values (MAXTABLE Keyword)

 **Misc. Inputs:  Anem. Hgt. (m) =    10.00 ;    Decay Coef. =    .0000     ;    Rot.
Angle =      .0
                  Emission Units = (GRAMS/(SEC-M**2))                        ;
Emission Rate Unit Factor =    1.0000
                  Output Units   = GRAMS/CUBIC-METER

 **Input Runstream File: areatest.inp                                  ;  **Output Print
File: areatest.out
```

```
  *** ISCLT3 - VERSION 95250 ***     ***  TEST RUN FOR NEW ISCLT MODEL - TEST OF NEW
AREA SOURCE ALGORITHM    ***         09/07/95
                                     ***
                     ***        16:26:53

                                PAGE   2
  *** MODELING OPTIONS USED:  CONC   RURAL  ELEV   FLGPOL DFAULT


                                                    *** AREA SOURCE DATA ***

              NUMBER EMISSION RATE  COORD (SW CORNER)  BASE     RELEASE  X-DIM
Y-DIM    ORIENT.    INIT.  EMISSION RATE
    SOURCE     PART. (USER UNITS       X        Y      ELEV.    HEIGHT  OF AREA   OF
AREA   OF AREA     SZ     SCALAR VARY
      ID       CATS.   /METER**2)   (METERS) (METERS) (METERS) (METERS) (METERS)
(METERS)   (DEG.)  (METERS)      BY
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - - - - - - - - - - - - - - - -

   1             0    .10000E+01     800.0     400.0      .0     1.00     60.00
100.00       .00      .00
   2             0    .10000E+01      40.0     360.0      .0     1.00     20.00
20.00       .00      .00
   3             0    .10000E+01     480.0      20.0      .0     1.00     30.00
300.00       .00      .00
   4             0    .10000E+01     420.0     260.0      .0     1.00     40.00
40.00       .00      .00
   5             0    .10000E+01     420.0     180.0      .0     1.00     40.00
40.00       .00      .00
   6             0    .10000E+01     420.0     100.0      .0     1.00     40.00
40.00       .00      .00
   7             0    .10000E+01     260.0     340.0      .0     1.00    140.00
200.00       .00      .00
   8             0    .10000E+01      40.0     100.0      .0     1.00    220.00
100.00       .00      .00
   9             0    .10000E+01      40.0      20.0      .0     1.00    220.00
70.00       .00      .00
   10            0   -.10000E+01     300.0     360.0      .0     1.00     80.00
40.00       .00      .00
```

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	1 , 2 , 3 , 4 , 5 , 6 , 7 , 8 , 9 , 10 ,

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** DISCRETE CARTESIAN RECEPTORS ***
(X-COORD, Y-COORD, ZELEV, ZFLAG)
(METERS)

```
   (     20.0,      60.0,        .3,       1.0);          (    150.0,      95.0,
.3,       1.0);
   (    360.0,     100.0,        .3,       1.0);          (    520.0,     120.0,
.3,       1.0);
   (    490.0,     240.0,        .3,       1.0);          (    320.0,     240.0,
.3,       1.0);
   (    150.0,     260.0,        .3,       1.0);          (     50.0,     330.0,
.3,       1.0);
   (     70.0,     390.0,        .3,       1.0);          (    190.0,     350.0,
.3,       1.0);
   (    310.0,     370.0,        .3,       1.0);          (    420.0,     380.0,
.3,       1.0);
   (     70.0,     460.0,        .3,       1.0);          (    200.0,     460.0,
.3,       1.0);
   (    330.0,     470.0,        .3,       1.0);          (     40.0,     560.0,
.3,       1.0);
   (    480.0,     660.0,        .3,       1.0);          (    800.0,     700.0,
.3,       1.0);
```

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY ***

(METERS/SEC)

1.50, 2.50, 4.30, 6.80, 9.50, 12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***

(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00

```
                    C          .00000E+00     .00000E+00     .00000E+00     .00000E+00
  .00000E+00     .00000E+00
                    D          .00000E+00     .00000E+00     .00000E+00     .00000E+00
  .00000E+00     .00000E+00
                    E          .20000E-01     .20000E-01     .20000E-01     .20000E-01
  .20000E-01     .20000E-01
                    F          .35000E-01     .35000E-01     .35000E-01     .35000E-01
  .35000E-01     .35000E-01


                                        *** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN)
***

                                 STABILITY   STABILITY   STABILITY   STABILITY
STABILITY   STABILITY
                                CATEGORY A  CATEGORY B  CATEGORY C  CATEGORY D
CATEGORY E  CATEGORY F

                       WINTER      283.0000    283.0000    283.0000    283.0000
283.0000    283.0000
```

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WINTER WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	2250.0000	2250.0000	2250.0000	2250.0000	2250.0000	2250.0000
STABILITY CATEGORY B	1500.0000	1500.0000	1500.0000	1500.0000	1500.0000	1500.0000
STABILITY CATEGORY C	1500.0000	1500.0000	1500.0000	1500.0000	1500.0000	1500.0000
STABILITY CATEGORY D	1000.0000	1000.0000	1000.0000	1000.0000	1000.0000	1000.0000
STABILITY CATEGORY E	10000.0000	10000.0000	10000.0000	10000.0000	10000.0000	10000.0000
STABILITY CATEGORY F	10000.0000	10000.0000	10000.0000	10000.0000	10000.0000	10000.0000

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: TEST.STA FORMAT: FREE

SURFACE STATION NO.: 99999 UPPER AIR STATION NO.: 99999

NAME: TESTDATA NAME: TESTDATA

YEAR: 1990 YEAR: 1990

WINTER: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.25000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.25000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	

						.00000000
247.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

WINTER: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.25000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.25000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	

```
.00000000
    337.500      .00000000     .00000000     .00000000     .00000000     .00000000
.00000000
```

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: TEST.STA FORMAT: FREE

SURFACE STATION NO.: 99999 UPPER AIR STATION NO.: 99999

NAME: TESTDATA NAME: TESTDATA

YEAR: 1990 YEAR: 1990

WINTER: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	

.00000000
247.500 .00000000 .00000000 .00000000 .00000000 .00000000
.00000000
270.000 .00000000 .00000000 .00000000 .00000000 .00000000
.00000000
292.500 .00000000 .00000000 .00000000 .00000000 .00000000
.00000000
315.000 .00000000 .00000000 .00000000 .00000000 .00000000
.00000000
337.500 .00000000 .00000000 .00000000 .00000000 .00000000
.00000000

WINTER: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

```
.00000000
    337.500     .00000000     .00000000     .00000000     .00000000     .00000000
.00000000
```

*** ISCLT3 - VERSION 95250 *** *** TEST RUN FOR NEW ISCLT MODEL - TEST OF NEW AREA SOURCE ALGORITHM *** 09/07/95 ***

*** 16:26:53

PAGE 9

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: TEST.STA FORMAT: FREE

SURFACE STATION NO.: 99999 UPPER AIR STATION NO.: 99999

NAME: TESTDATA NAME: TESTDATA

YEAR: 1990 YEAR: 1990

WINTER: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	

.00000000						
247.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000

WINTER: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	

```
.00000000
    337.500      .00000000     .00000000     .00000000     .00000000     .00000000
.00000000

                 SUM OF FREQUENCIES, FTOTAL =      1.00000
```

```
  *** ISCLT3 - VERSION 95250 ***    ***  TEST RUN FOR NEW ISCLT MODEL - TEST OF NEW
AREA SOURCE ALGORITHM    ***        09/07/95
                                    ***
                     ***        16:26:53

                                PAGE  10
  *** MODELING OPTIONS USED:  CONC   RURAL  ELEV   FLGPOL DFAULT


                              *** THE WINTER AVERAGE CONCENTRATION   VALUES FOR SOURCE
GROUP: ALL      ***
                                 INCLUDING SOURCE(S):      1       , 2       , 3
, 4       , 5       , 6       , 7       ,
          8       , 9       , 10      ,

                                           *** DISCRETE CARTESIAN RECEPTOR POINTS
***

                                        ** CONC OF OTH      IN GRAMS/CUBIC-METER
                **

       X-COORD (M)   Y-COORD (M)         CONC                        X-COORD (M)
Y-COORD (M)         CONC
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - - - - - - - - - - - - - - - - - - -
             20.00         60.00        1.461732                        150.00
95.00        6.278599
            360.00        100.00        1.107130                        520.00
120.00        1.776145
            490.00        240.00        7.055643                        320.00
240.00        1.317164
            150.00        260.00        1.304899                         50.00
330.00         .920154
             70.00        390.00         .618355                        190.00
350.00         .919853
            310.00        370.00        3.915823                        420.00
380.00        1.159203
             70.00        460.00         .503892                        200.00
460.00         .930905
            330.00        470.00        8.712571                         40.00
560.00         .234258
            480.00        660.00         .148282                        800.00
700.00         .120108
```

```
  *** ISCLT3 - VERSION 95250 ***     ***  TEST RUN FOR NEW ISCLT MODEL - TEST OF NEW
AREA SOURCE ALGORITHM    ***         09/07/95
                                     ***
                     ***        16:26:53

                                PAGE  11
  *** MODELING OPTIONS USED:  CONC   RURAL  ELEV   FLGPOL DFAULT


                    *** THE MAXIMUM   10  WINTER  AVERAGE CONCENTRATION    VALUES FOR
SOURCE:  1        ***

                         ** CONC OF OTH      IN GRAMS/CUBIC-METER
  **

 RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE       RANK       CONC     AT
  RECEPTOR (XR,YR) OF TYPE
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - - - - - - - - - - - - - - - - - -
   1.        .106338 AT (     800.00,     700.00)  DC          6.        .005187 AT (
  190.00,     350.00)  DC
   2.        .018014 AT (     420.00,     380.00)  DC          7.        .004079 AT (
  480.00,     660.00)  DC
   3.        .012828 AT (     330.00,     470.00)  DC          8.        .003953 AT (
  490.00,     240.00)  DC
   4.        .009823 AT (     310.00,     370.00)  DC          9.        .003938 AT (
  320.00,     240.00)  DC
   5.        .006498 AT (     200.00,     460.00)  DC         10.        .003682 AT (
   70.00,     460.00)  DC

                    *** THE MAXIMUM   10  WINTER  AVERAGE CONCENTRATION    VALUES FOR
SOURCE:  2        ***

 RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE       RANK       CONC     AT
  RECEPTOR (XR,YR) OF TYPE
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - - - - - - - - - - - - - - - - - -
   1.        .378019 AT (      50.00,     330.00)  DC          6.        .008402 AT (
   20.00,      60.00)  DC
   2.        .074267 AT (      70.00,     390.00)  DC          7.        .004482 AT (
  310.00,     370.00)  DC
   3.        .044939 AT (      70.00,     460.00)  DC          8.        .003663 AT (
  150.00,      95.00)  DC
   4.        .013317 AT (      40.00,     560.00)  DC          9.        .002255 AT (
  420.00,     380.00)  DC
   5.        .012170 AT (     190.00,     350.00)  DC         10.        .001280 AT (
  330.00,     470.00)  DC

                    *** THE MAXIMUM   10  WINTER  AVERAGE CONCENTRATION    VALUES FOR
SOURCE:  3        ***
```

RANK	CONC	AT	RECEPTOR (XR,YR)	OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)	OF TYPE
1.	6.790764	AT	(490.00, 240.00)	DC	6.	.039687	AT	(480.00, 660.00)	DC
2.	1.374194	AT	(520.00, 120.00)	DC	7.	.031461	AT	(150.00, 95.00)	DC
3.	.123926	AT	(360.00, 100.00)	DC	8.	.029688	AT	(150.00, 260.00)	DC
4.	.092051	AT	(420.00, 380.00)	DC	9.	.022130	AT	(310.00, 370.00)	DC
5.	.089242	AT	(320.00, 240.00)	DC	10.	.018005	AT	(190.00, 350.00)	DC

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE: 4 ***

RANK	CONC	AT	RECEPTOR (XR,YR)	OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)	OF TYPE
1.	.152196	AT	(420.00, 380.00)	DC	6.	.012970	AT	(150.00, 260.00)	DC
2.	.044282	AT	(320.00, 240.00)	DC	7.	.011296	AT	(190.00, 350.00)	DC
3.	.028833	AT	(490.00, 240.00)	DC	8.	.011080	AT	(480.00, 660.00)	DC
4.	.021732	AT	(360.00, 100.00)	DC	9.	.008672	AT	(330.00, 470.00)	DC
5.	.019270	AT	(520.00, 120.00)	DC	10.	.007012	AT	(310.00, 370.00)	DC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE: 5 ***

** CONC OF OTH IN GRAMS/CUBIC-METER **

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	.055564	AT (	420.00,	380.00)	DC	6.	.007075	AT (	360.00,	100.00)	DC
2.	.044280	AT (	320.00,	240.00)	DC	7.	.006960	AT (	480.00,	660.00)	DC
3.	.038800	AT (	490.00,	240.00)	DC	8.	.005860	AT (	150.00,	95.00)	DC
4.	.010134	AT (	150.00,	260.00)	DC	9.	.003783	AT (	310.00,	370.00)	DC
5.	.009423	AT (	330.00,	470.00)	DC	10.	.003289	AT (	520.00,	120.00)	DC

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE: 6 ***

RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)		OF TYPE
1.	.147215	AT (	520.00,	120.00)	DC	6.	.007564	AT (	330.00,	470.00)	DC
2.	.125256	AT (	360.00,	100.00)	DC	7.	.006338	AT (	310.00,	370.00)	DC
3.	.054108	AT (	490.00,	240.00)	DC	8.	.004861	AT (	20.00,	60.00)	DC
4.	.027218	AT (	420.00,	380.00)	DC	9.	.004489	AT (	480.00,	660.00)	DC
5.	.012740	AT (	150.00,	95.00)	DC	10.	.003246	AT (	150.00,	260.00)	DC

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE: 7 ***

RANK	CONC	AT	RECEPTOR (XR,YR)	OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)	OF TYPE
1.	8.914557	AT	(330.00, 470.00)	DC	6.	.476067	AT	(360.00, 100.00)	DC
2.	8.621045	AT	(310.00, 370.00)	DC	7.	.399267	AT	(190.00, 350.00)	DC
3.	1.220750	AT	(320.00, 240.00)	DC	8.	.231648	AT	(70.00, 460.00)	DC
4.	1.127268	AT	(420.00, 380.00)	DC	9.	.209623	AT	(70.00, 390.00)	DC
5.	.667998	AT	(200.00, 460.00)	DC	10.	.115042	AT	(50.00, 330.00)	DC

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE: 8 ***

RANK	CONC	AT	RECEPTOR (XR,YR)	OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR)	OF TYPE
1.	3.515034	AT	(150.00, 95.00)	DC	6.	.247998	AT	(360.00, 100.00)	DC
2.	.919383	AT	(150.00, 260.00)	DC	7.	.247827	AT	(70.00, 390.00)	DC
3.	.404632	AT	(190.00, 350.00)	DC	8.	.192060	AT	(200.00, 460.00)	DC
4.	.348773	AT	(20.00, 60.00)	DC	9.	.165306	AT	(70.00, 460.00)	DC
5.	.304241	AT	(50.00, 330.00)	DC	10.	.119560	AT	(520.00, 120.00)	DC

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR
DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

*** MODELING OPTIONS USED: CONC RURAL ELEV FLGPOL DFAULT

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE: 9 ***

** CONC OF OTH IN GRAMS/CUBIC-METER **

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE
1.	2.644321	AT	(150.00, 95.00) DC	6.	.119259	AT	(50.00, 330.00) DC
2.	1.076195	AT	(20.00, 60.00) DC	7.	.100372	AT	(70.00, 390.00) DC
3.	.286411	AT	(150.00, 260.00) DC	8.	.078936	AT	(200.00, 460.00) DC
4.	.185585	AT	(360.00, 100.00) DC	9.	.070402	AT	(70.00, 460.00) DC
5.	.150859	AT	(190.00, 350.00) DC	10.	.067230	AT	(520.00, 120.00) DC

*** THE MAXIMUM 10 WINTER AVERAGE CONCENTRATION VALUES FOR SOURCE: 10 ***

RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE	RANK	CONC	AT	RECEPTOR (XR,YR) OF TYPE
1.	.000000	AT	(.00, .00)	6.	.000000	AT	(.00, .00)
2.	.000000	AT	(.00, .00)	7.	.000000	AT	(.00, .00)
3.	.000000	AT	(.00, .00)	8.	.000000	AT	(.00, .00)
4.	.000000	AT	(.00, .00)	9.	.000000	AT	(.00, .00)
5.	.000000	AT	(.00, .00)	10.	.000000	AT	(.00, .00)

*** RECEPTOR TYPES: GC = GRIDCART
GP = GRIDPOLR

DC = DISCCART
DP = DISCPOLR
BD = BOUNDARY

```
  *** ISCLT3 - VERSION 95250 ***     ***  TEST RUN FOR NEW ISCLT MODEL - TEST OF NEW
AREA SOURCE ALGORITHM    ***         09/07/95
                                     ***
                     ***        16:26:53

                                PAGE  14
  *** MODELING OPTIONS USED:  CONC   RURAL  ELEV   FLGPOL DFAULT


                     *** THE MAXIMUM   10  WINTER  AVERAGE CONCENTRATION    VALUES FOR
GROUP:  ALL      ***
                         INCLUDING SOURCE(S):      1       , 2       , 3       , 4
, 5       , 6       , 7       ,
        8       , 9       , 10      ,

                          ** CONC OF OTH      IN GRAMS/CUBIC-METER
  **

 RANK       CONC     AT       RECEPTOR (XR,YR) OF TYPE       RANK       CONC     AT
  RECEPTOR (XR,YR) OF TYPE
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - - - - - - - - - - - - - - - - - - - -
   1.       8.712571 AT (     330.00,     470.00)  DC          6.       1.461732 AT (
   20.00,      60.00)  DC
   2.       7.055643 AT (     490.00,     240.00)  DC          7.       1.317164 AT (
  320.00,     240.00)  DC
   3.       6.278599 AT (     150.00,      95.00)  DC          8.       1.304899 AT (
  150.00,     260.00)  DC
   4.       3.915823 AT (     310.00,     370.00)  DC          9.       1.159203 AT (
  420.00,     380.00)  DC
   5.       1.776145 AT (     520.00,     120.00)  DC         10.       1.107130 AT (
  360.00,     100.00)  DC

  *** RECEPTOR TYPES:  GC = GRIDCART
                       GP = GRIDPOLR
                       DC = DISCCART
                       DP = DISCPOLR
                       BD = BOUNDARY
```

```
 *** ISCLT3 - VERSION 95250 ***     ***  TEST RUN FOR NEW ISCLT MODEL - TEST OF NEW
AREA SOURCE ALGORITHM    ***         09/07/95
                                     ***
                    ***        16:26:53

                                PAGE  15
 *** MODELING OPTIONS USED:  CONC   RURAL  ELEV   FLGPOL DFAULT


*** Message Summary : ISCLT3 Model Execution ***

 --------- Summary of Total Messages --------

A Total of           0 Fatal Error Message(s)
A Total of           2 Warning Message(s)
A Total of           0 Informational Message(s)


   ******** FATAL ERROR MESSAGES ********
              ***  NONE  ***


   ********   WARNING MESSAGES   ********
CO W205   12 FLAGDF: No Option Parameter Setting.  Forced by Default to ZFLAG=0.
CO W151   15 COCARD: CO ELEVUNIT card obsolescent: use RE ELEVUNIT card instead

   ************************************
   *** ISCLT3 Finishes Successfully ***
   ************************************
```

```
CO STARTING

   TITLEONE  Test case for long-term deposition model DEPLT

   TITLETWO  Model deposition for an urban site with no plume depletion

   MODELOPT  DFAULT  DEPOS  RURAL

   AVERTIME  WINTER

   POLLUTID  TSP

   RUNORNOT  RUN

   ERRORFIL  ERRORS.OUT

CO FINISHED


SO STARTING


   LOCATION  STACK1  POINT  0.0   0.0   0.0

** Point Source       QS    HS    TS    VS   DS

** Parameters:       ----  ----  ----  ----  ---

   SRCPARAM  STACK1  1.00  35.0  432.  11.7  2.4


   BUILDHGT  STACK1  16*34.

   BUILDWID  STACK1  36.45 34.00 25.50 15.00

             STACK1  25.50 34.00 36.45 33.33

             STACK1  36.45 34.00 25.50 15.00

             STACK1  25.50 34.00 36.45 33.33


   PARTDIAM  STACK1  10.

   MASSFRAX  STACK1  1.

   PARTDENS  STACK1  1.
```

```
SO SRCGROUP ALL

SO FINISHED



RE STARTING

RE GRIDPOLR POL ORIG    0.0     0.0

RE GRIDPOLR POL STA

RE GRIDPOLR POL DIST   300.  20000.

RE GRIDPOLR POL GDIR   36    10.0   10.0

RE GRIDPOLR POL END

RE FINISHED



ME STARTING

   INPUTFIL  BOSTON.JFD  FREE

   ANEMHGHT  10.

   SURFDATA  14739  1990  BOSTON

   UAIRDATA  14764  1990  PORTLAND

   STARDATA  WINTER


**                  - AMBIENT AIR TEMPERATURE (DEGREES KELVIN) -

**

**                     STAB    STAB    STAB    STAB    STAB    STAB

**                     CAT 1   CAT 2   CAT 3   CAT 4   CAT 5   CAT 6
```

```
**                    -----   -----   -----   -----   -----   -----

  AVETEMPS  WINTER  250.00    282.77  277.51  275.99  273.72  273.40


**                        - MIXING LAYER HEIGHT (METERS) -
**                  S
**                  T    WS       WS       WS       WS       WS       WS
**            SEAS  A   CAT 1    CAT 2    CAT 3    CAT 4    CAT 5    CAT 6
**            ----  B   -----    -----    -----    -----    -----    -----

  AVEMIXHT  WINTER 1    0.       0.        0.        0.        0.        0.
  AVEMIXHT  WINTER 2    0.     502.      619.        0.        0.        0.
  AVEMIXHT  WINTER 3  370.     462.      891.     1795.        0.        0.
  AVEMIXHT  WINTER 4  385.     375.      601.      846.      802.      755.
  AVEMIXHT  WINTER 5  400.     402.      526.      490.        0.        0.
  AVEMIXHT  WINTER 6  386.     294.       58.        0.        0.        0.


**            - Roughness Length (m) -
**
**            SEAS     Z0 (m)
**            ----     -----

  AVEROUGH  WINTER    0.10
```

```
ME FINISHED


OU STARTING

   RECTABLE  SRCGRP

OU FINISHED

************************************
*** SETUP Finishes Successfully ***
************************************
```

```
  *** ISCLT3 - VERSION 95250 ***     ***  Test case for long-term deposition model
DEPLT                        ***        09/07/95
                                        ***  Model deposition for an urban site with no
plume depletion           ***           16:31:32

                                PAGE   1
  *** MODELING OPTIONS USED:  DEPOS  RURAL  FLAT          DFAULT


                                            ***     MODEL SETUP OPTIONS SUMMARY
***
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - - - - - - - - - - - - - - - - -

 **Model Is Setup For Calculation of Total DEPOSition Values.
 **Model Does NOT Use GRIDDED TERRAIN Data for Depletion Calculations

 **Model Uses NO plume DEPLETION.

 **Model Uses RURAL Dispersion.

 **Model Uses Regulatory DEFAULT Options:
           1. Final Plume Rise.
           2. Stack-tip Downwash.
           3. Buoyancy-induced Dispersion.
           4. Default Wind Profile Exponents.
           5. Default Vertical Potential Temperature Gradients.
           6. "Upper Bound" Values For Supersquat Buildings.
           7. No Exponential Decay for RURAL Mode

 **Model Assumes Receptors on FLAT Terrain.

 **Model Assumes No FLAGPOLE Receptor Heights.

 **Model Calculates   1 STAR Average(s) for the Following Months:  0  0  0  0  0  0  0
0  0  0  0  0
                                                Seasons/Quarters:  1  0  0  0
                                                      and Annual:  0

 **Data File Includes  1 STAR Summaries for the Following Months:  0  0  0  0  0  0  0
0  0  0  0  0
                                                Seasons/Quarters:  1  0  0  0
                                                      and Annual:  0

 **This Run Includes:    1 Source(s);      1 Source Group(s); and     72 Receptor(s)

 **The Model Assumes A Pollutant Type of:  TSP

 **Model Set To Continue RUNning After the Setup Testing.

 **Output Options Selected:
```

Model Outputs Tables of Long Term Values by Receptor (RECTABLE Keyword)

```
 **Misc. Inputs:  Anem. Hgt. (m) =    10.00 ;    Decay Coef. =    .0000     ;    Rot.
Angle =      .0
                  Emission Units = GRAMS/SEC                                   ;
Emission Rate Unit Factor =    3600.0
                  Output Units   = GRAMS/M**2

 **Input Runstream File: deptest.inp                                   ;  **Output Print
File: deptest.out
 **Error Message File: ERRORS.OUT
```

```
  *** ISCLT3 - VERSION 95250 ***    ***  Test case for long-term deposition model
DEPLT                        ***        09/07/95
                                       ***  Model deposition for an urban site with no
plume depletion          ***           16:31:32

                                 PAGE   2
  *** MODELING OPTIONS USED:  DEPOS  RURAL  FLAT          DFAULT


                                                   *** POINT SOURCE DATA ***


              NUMBER EMISSION RATE                     BASE     STACK   STACK    STACK
  STACK    BUILDING EMISSION RATE
    SOURCE     PART.  (GRAMS/SEC)     X        Y      ELEV.    HEIGHT  TEMP.   EXIT
VEL. DIAMETER   EXISTS   SCALAR VARY
      ID       CATS.                (METERS) (METERS) (METERS) (METERS) (DEG.K)
(M/SEC)  (METERS)                BY
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - - - - - - - - - - - - - - -

   STACK1        1    .10000E+01        .0        .0      .0    35.00   432.00
11.70     2.40      YES
```

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	STACK1 ,

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** SOURCE PARTICULATE DATA ***

*** SOURCE ID = STACK1 ; SOURCE TYPE = POINT ***

MASS FRACTION =
1.00000,

PARTICLE DIAMETER(MICRONS) =
10.00000,

PARTICLE DENSITY (G/CM**3) =
1.00000,

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** DIRECTION SPECIFIC BUILDING DIMENSIONS ***

SOURCE ID: STACK1

IFV	BH	BW	WAK	IFV	BH	BW	WAK	IFV	BH	BW	WAK
1	34.0,	36.5,	0	2	34.0,	34.0,	0	3	34.0,	25.5,	0
4	34.0,	15.0,	0								
5	34.0,	25.5,	0	6	34.0,	34.0,	0	7	34.0,	36.5,	0
8	34.0,	33.3,	0								
9	34.0,	36.5,	0	10	34.0,	34.0,	0	11	34.0,	25.5,	0
12	34.0,	15.0,	0								
13	34.0,	25.5,	0	14	34.0,	34.0,	0	15	34.0,	36.5,	0
16	34.0,	33.3,	0								

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** GRIDDED RECEPTOR NETWORK SUMMARY ***

*** NETWORK ID: POL ; NETWORK TYPE: GRIDPOLR
***

*** ORIGIN FOR POLAR NETWORK ***
X-ORIG = .00 ; Y-ORIG = .00 (METERS)

*** DISTANCE RANGES OF NETWORK ***
(METERS)

300.0, 20000.0,

*** DIRECTION RADIALS OF NETWORK ***
(DEGREES)

10.0, 20.0, 30.0, 40.0, 50.0, 60.0, 70.0,
80.0, 90.0, 100.0,
110.0, 120.0, 130.0, 140.0, 150.0, 160.0, 170.0,
180.0, 190.0, 200.0,
210.0, 220.0, 230.0, 240.0, 250.0, 260.0, 270.0,
280.0, 290.0, 300.0,
310.0, 320.0, 330.0, 340.0, 350.0, 360.0,

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** AVERAGE SPEED FOR EACH WIND SPEED CATEGORY
***

(METERS/SEC)

1.50, 2.50, 4.30, 6.80, 9.50,
12.50,

*** WIND PROFILE EXPONENTS ***

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
B	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01	.70000E-01
C	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00	.10000E+00
D	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00	.15000E+00
E	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00	.35000E+00
F	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00	.55000E+00

*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS
***

(DEGREES KELVIN PER METER)

STABILITY CATEGORY	WIND SPEED CATEGORY 1	2	3	4	5	6
A	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
B	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00

```
                    C          .00000E+00     .00000E+00     .00000E+00     .00000E+00
  .00000E+00     .00000E+00
                    D          .00000E+00     .00000E+00     .00000E+00     .00000E+00
  .00000E+00     .00000E+00
                    E          .20000E-01     .20000E-01     .20000E-01     .20000E-01
  .20000E-01     .20000E-01
                    F          .35000E-01     .35000E-01     .35000E-01     .35000E-01
  .35000E-01     .35000E-01


                                        *** AVERAGE AMBIENT AIR TEMPERATURE (KELVIN)
***

                                 STABILITY   STABILITY   STABILITY   STABILITY
STABILITY   STABILITY
                                CATEGORY A  CATEGORY B  CATEGORY C  CATEGORY D
CATEGORY E  CATEGORY F

                       WINTER     250.0000    282.7700    277.5100    275.9900
273.7200    273.4000
```

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** AVERAGE MIXING LAYER HEIGHT (METERS) ***

	WIND SPEED CATEGORY 1	WIND SPEED CATEGORY 2	WINTER WIND SPEED CATEGORY 3	WIND SPEED CATEGORY 4	WIND SPEED CATEGORY 5	WIND SPEED CATEGORY 6
STABILITY CATEGORY A	.0000	.0000	.0000	.0000	.0000	.0000
STABILITY CATEGORY B	.0000	502.0000	619.0000	.0000	.0000	.0000
STABILITY CATEGORY C	370.0000	462.0000	891.0000	1795.0000	.0000	.0000
STABILITY CATEGORY D	385.0000	375.0000	601.0000	846.0000	802.0000	755.0000
STABILITY CATEGORY E	400.0000	402.0000	526.0000	490.0000	.0000	.0000
STABILITY CATEGORY F	386.0000	294.0000	58.0000	.0000	.0000	.0000

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** AVERAGE SURFACE ROUGHNESS LENGTH (METERS) ***

WINTER .1000

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: BOSTON.JFD FORMAT: FREE

SURFACE STATION NO.: 14739 UPPER AIR STATION NO.:
14764
NAME: BOSTON NAME:
PORTLAND
YEAR: 1990 YEAR:
1990

WINTER: STABILITY CATEGORY A

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	

.00000000
247.500 .00000000 .00000000 .00000000 .00000000 .00000000
.00000000
270.000 .00000000 .00000000 .00000000 .00000000 .00000000
.00000000
292.500 .00000000 .00000000 .00000000 .00000000 .00000000
.00000000
315.000 .00000000 .00000000 .00000000 .00000000 .00000000
.00000000
337.500 .00000000 .00000000 .00000000 .00000000 .00000000
.00000000

WINTER: STABILITY CATEGORY B

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
67.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00138900	.00000000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00092600	.00000000	.00000000	.00000000
135.000	.00000000	.00092600	.00046300	.00000000	.00000000	.00000000
157.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
202.500	.00000000	.00046300	.00000000	.00000000	.00000000	.00000000
225.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
247.500	.00000000	.00092600	.00000000	.00000000	.00000000	.00000000
270.000	.00000000	.00000000	.00092600	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
315.000	.00000000	.00000000	.00000000	.00000000	.00000000	

```
.00000000
    337.500     .00000000     .00000000     .00000000     .00000000     .00000000
.00000000
```

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: BOSTON.JFD FORMAT: FREE

SURFACE STATION NO.: 14739 UPPER AIR STATION NO.:
14764
NAME: BOSTON NAME:
PORTLAND
YEAR: 1990 YEAR:
1990

WINTER: STABILITY CATEGORY C

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00000000	.00046300	.00092600	.00000000	.00000000	.00000000
22.500	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
45.000	.00000000	.00046300	.00000000	.00000000	.00000000	.00000000
67.500	.00046300	.00046300	.00046300	.00000000	.00000000	.00000000
90.000	.00000000	.00046300	.00463000	.00000000	.00000000	.00000000
112.500	.00000000	.00000000	.00185200	.00000000	.00000000	.00000000
135.000	.00000000	.00092600	.00416700	.00000000	.00000000	.00000000
157.500	.00000000	.00092600	.00092600	.00000000	.00000000	.00000000
180.000	.00000000	.00092600	.00231500	.00046300	.00000000	.00000000
202.500	.00000000	.00000000	.00046300	.00000000	.00000000	.00000000
225.000	.00046300	.00000000	.00324100	.00000000	.00000000	

247.500	.00000000	.00092600	.00370400	.00000000	.00000000	.00000000
270.000	.00000000	.00092600	.00416700	.00000000	.00000000	.00000000
292.500	.00000000	.00000000	.00231500	.00046300	.00000000	.00000000
315.000	.00000000	.00000000	.00416700	.00000000	.00000000	.00000000
337.500	.00000000	.00000000	.00138900	.00092600	.00000000	.00000000

WINTER: STABILITY CATEGORY D

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00156300	.00370400	.01481500	.03101900	.00648200	.00000000
22.500	.00006400	.00185200	.00509300	.00555600	.00231500	.00046300
45.000	.00009500	.00277800	.00463000	.00694500	.00324100	.00324100
67.500	.00009500	.00277800	.00740800	.01203800	.00509300	.00092600
90.000	.00201000	.00277800	.01018600	.02037100	.00694500	.00092600
112.500	.00059000	.00324100	.00509300	.01203800	.00370400	.00000000
135.000	.00007900	.00231500	.00416700	.00648200	.00046300	.00000000
157.500	.00015800	.00463000	.00787100	.00555600	.00000000	.00000000
180.000	.00022100	.00648200	.01805600	.01203800	.00185200	.00000000
202.500	.00003200	.00092600	.00926000	.03703800	.01481500	.00138900
225.000	.00003200	.00092600	.01435200	.04907500	.03426000	.00833400
247.500	.00004800	.00138900	.01620400	.04953800	.01435200	.00231500
270.000	.00000000	.00000000	.00833400	.05046300	.01666700	.00231500
292.500	.00001600	.00046300	.00972300	.06759300	.02824100	.00926000
315.000	.00049500	.00046300	.00972300	.03472300	.01527800	

.00555600
337.500 .00099000 .00092600 .00694500 .02963000 .00694500
.00277800

*** MODELING OPTIONS USED: DEPOS RURAL FLAT DFAULT

*** FREQUENCY OF OCCURRENCE OF WIND SPEED, DIRECTION AND STABILITY ***

FILE: BOSTON.JFD FORMAT: FREE

SURFACE STATION NO.: 14739 UPPER AIR STATION NO.:
14764
NAME: BOSTON NAME:
PORTLAND
YEAR: 1990 YEAR:
1990

WINTER: STABILITY CATEGORY E

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00046300	.00138900	.00601900	.00000000	.00000000	.00000000
22.500	.00000000	.00185200	.00046300	.00000000	.00000000	.00000000
45.000	.00000000	.00138900	.00092600	.00000000	.00000000	.00000000
67.500	.00000000	.00092600	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00231500	.00000000	.00000000	.00000000	.00000000
112.500	.00046300	.00138900	.00046300	.00000000	.00000000	.00000000
135.000	.00000000	.00138900	.00185200	.00000000	.00000000	.00000000
157.500	.00046300	.00000000	.00231500	.00046300	.00000000	.00000000
180.000	.00000000	.00231500	.00879700	.00000000	.00000000	.00000000
202.500	.00000000	.00138900	.00277800	.00000000	.00000000	.00000000
225.000	.00000000	.00138900	.00787100	.00092600	.00000000	

.00000000
247.500 .00000000 .00092600 .00879700 .00000000 .00000000
.00000000
270.000 .00000000 .00231500 .00740800 .00000000 .00000000
.00000000
292.500 .00000000 .00092600 .01574100 .00046300 .00000000
.00000000
315.000 .00000000 .00000000 .01111200 .00000000 .00000000
.00000000
337.500 .00000000 .00000000 .00740800 .00000000 .00000000
.00000000

WINTER: STABILITY CATEGORY F

DIRECTION (DEGREES)	WIND SPEED CATEGORY 1 (1.500 M/S)	WIND SPEED CATEGORY 2 (2.500 M/S)	WIND SPEED CATEGORY 3 (4.300 M/S)	WIND SPEED CATEGORY 4 (6.800 M/S)	WIND SPEED CATEGORY 5 (9.500 M/S)	WIND SPEED CATEGORY 6 (12.500 M/S)
.000	.00101900	.00046300	.00000000	.00000000	.00000000	.00000000
22.500	.00009300	.00138900	.00000000	.00000000	.00000000	.00000000
45.000	.00006200	.00092600	.00000000	.00000000	.00000000	.00000000
67.500	.00101900	.00046300	.00000000	.00000000	.00000000	.00000000
90.000	.00000000	.00000000	.00000000	.00000000	.00000000	.00000000
112.500	.00098800	.00000000	.00000000	.00000000	.00000000	.00000000
135.000	.00055600	.00092600	.00000000	.00000000	.00000000	.00000000
157.500	.00049400	.00000000	.00000000	.00000000	.00000000	.00000000
180.000	.00018600	.00277800	.00000000	.00000000	.00000000	.00000000
202.500	.00006200	.00092600	.00000000	.00000000	.00000000	.00000000
225.000	.00015500	.00231500	.00046300	.00000000	.00000000	.00000000
247.500	.00015500	.00231500	.00000000	.00000000	.00000000	.00000000
270.000	.00009300	.00138900	.00000000	.00000000	.00000000	.00000000
292.500	.00006200	.00092600	.00000000	.00000000	.00000000	.00000000
315.000	.00055600	.00092600	.00000000	.00000000	.00000000	

```
.00000000
    337.500     .00006200     .00092600     .00000000     .00000000     .00000000
.00000000

                    SUM OF FREQUENCIES, FTOTAL =      1.00006
```

```
  *** ISCLT3 - VERSION 95250 ***    ***  Test case for long-term deposition model
DEPLT                        ***        09/07/95
                                        ***  Model deposition for an urban site with no
plume depletion            ***        16:31:32

                                 PAGE  13
  *** MODELING OPTIONS USED:  DEPOS  RURAL  FLAT          DFAULT


                              *** THE WINTER   TOTAL DEPOSITION      VALUES FOR SOURCE
GROUP: ALL      ***
                                  INCLUDING SOURCE(S):      STACK1  ,

                                   *** NETWORK ID: POL      ;  NETWORK TYPE: GRIDPOLR
***

                                       ** DEPO OF TSP      IN GRAMS/M**2
                **

   DIRECTION ¶                                                DISTANCE (METERS)
   (DEGREES) ¶        300.00     20000.00
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - - - - - - - - - - - - - - - - - - -

       10.00 ¶       .228236      .001296
       20.00 ¶       .322830      .001672
       30.00 ¶       .392019      .002252
       40.00 ¶       .450586      .002861
       50.00 ¶       .383487      .002988
       60.00 ¶       .191753      .002627
       70.00 ¶       .078565      .002335
       80.00 ¶       .205135      .002347
       90.00 ¶       .331275      .002326
      100.00 ¶       .496848      .002884
      110.00 ¶       .660746      .003395
      120.00 ¶       .597187      .003032
      130.00 ¶       .457595      .002357
      140.00 ¶       .360605      .001873
      150.00 ¶       .306703      .001609
      160.00 ¶       .265054      .001405
      170.00 ¶       .261846      .001442
      180.00 ¶       .258021      .001458
      190.00 ¶       .170774      .000978
      200.00 ¶       .083149      .000487
      210.00 ¶       .065123      .000415
      220.00 ¶       .070123      .000482
      230.00 ¶       .059794      .000552
      240.00 ¶       .034442      .000622
      250.00 ¶       .028965      .000716
      260.00 ¶       .083070      .000892
      270.00 ¶       .136956      .001056
```

280.00 ¶	.125380	.000863
290.00 ¶	.113265	.000659
300.00 ¶	.093438	.000528
310.00 ¶	.071074	.000421
320.00 ¶	.057906	.000367
330.00 ¶	.053929	.000371
340.00 ¶	.060047	.000432
350.00 ¶	.096707	.000668
360.00 ¶	.132976	.000897

```
  *** ISCLT3 - VERSION 95250 ***     ***  Test case for long-term deposition model
DEPLT                        ***        09/07/95
                                        ***  Model deposition for an urban site with no
plume depletion           ***           16:31:32

                                PAGE  14
  *** MODELING OPTIONS USED:  DEPOS  RURAL  FLAT          DFAULT



 *** Message Summary : ISCLT3 Model Execution ***

  --------- Summary of Total Messages --------

 A Total of           0 Fatal Error Message(s)
 A Total of           0 Warning Message(s)
 A Total of           0 Informational Message(s)


    ******** FATAL ERROR MESSAGES ********
               ***  NONE  ***


    ********   WARNING MESSAGES   ********
               ***  NONE  ***


    ************************************
    *** ISCLT3 Finishes Successfully ***
    ************************************
```

APPENDIX D11

GAS GENERATION INFORMATION

Sandia National Laboratories

Albuquerque, New Mexico 87185-

date: January 26, 1996

to: Martin S. Tierney (6741)

Yifeng Wang Larry Brush

from: Yifeng Wang & Larry Brush (Org. 6748)

subject: Estimates of Gas-Generation Parameters for The Long-Term WIPP Performance Assessment

Introduction

Steel corrosion and organic-material biodegradation have been identified as major gas-generation processes in the WIPP repository (Brush, 1995). Gas production will affect room closure and chemistry (Butcher, 1990; Brush, 1990). This memorandum provides the current estimates of gas-generation parameters for the long-term WIPP performance assessment. The parameters provided here include the rates of gas generation under inundated and humid conditions, the stoichiometric factors of gas generation reactions, and the probability of the occurrence of organic material biodegradation (Table 1). To satisfy the quality assurance (QA) requirement (QAP 9-5), we summarize all hand calculations for estimating these parameters in Appendices I and II.

Biodegradation of Organic Materials

Cellulosics, plastics, and rubbers have been identified as the major organic materials to be emplaced in the WIPP repository (DOE/CAO, 1996) and could be degraded by microbes in 10,000 years. Cellulosics has been demonstrated experimentally to be the most biodegradable among these materials (Francis et al., 1995). The occurrence of significant microbial gas generation in the repository will depend on: (1) whether microbes capable of consuming the emplaced organic materials will be present and active; (2) whether sufficient electron acceptors will be present and available; (3) whether enough nutrients will be present and available. Considering uncertainties in evaluation of these factors and also in order to bracket all possible effect of gas generation on the WIPP performance assessment, we assign a 50% probability to the occurrence of significant microbial gas generation.

• *Microbial Reactions*

Microorganism will consume cellulosics mainly via the following reaction pathways in the repository (Brush, 1995):

$$C_6H_{10}O_5 + 4.8\ H^+ + 4.8\ NO_3^- \rightarrow 7.4\ H_2O + 6\ CO_2 + 2.4\ N_2 \quad (1)$$

$$C_6H_{10}O_5 + 6\ H^+ + 3\ SO_4^{2-} \rightarrow 5\ H_2O + 6\ CO_2 + 3\ H_2S \quad (2)$$

$$C_6H_{10}O_5 \rightarrow 3\ CH_4 + 3\ CO_2. \quad (3)$$

We assume that Reactions 1 to 3 will proceed sequentially according to the energy yield of each reaction. Here we ignore the reaction pathways of aerobic respiration, Mn(IV) and Fe(III) dissimilatory reduction, since the quantities of O_2, Mn(IV) and Fe(III) initially present in the repository will be negligible relative to the other electron acceptors. In Reactions 1 to 3, biomass accumulation is also not taken into account. This is because significant biomass accumulation seems unlikely in the WIPP repository and the accumulated biomass, if any, will be recycled by microbes after all biodegradable cellulosics is consumed.

In addition to Reaction (3), methanogenesis may proceed via:

$$4\ H_2 + CO_2 \rightarrow CH_4 + 2\ H_2O. \quad (4)$$

However, this reaction will be ignored in our calculations, because (1) no experimental data are available to evaluate the rate of this reaction and (2) the net effect of this reaction is to reduce the total gas generation and the amount of CO_2 in the repository and, therefore, it is conservative to ignore this reaction in respect of repository pressurization and actinide solubility.

- *Rates of Cellulosics Biodegradation*

The rate of cellulosics biodegradtion was measured by incubating representative cellulose materials (filter paper, paper towels, and tissue) in WIPP brine with microbes enriched from various WIPP environments (Francis & Gillow, 1994; Francis et al., 1995). The incubation experiments were conducted under various conditions: aerobic or anaerobic, inundated or humid, with or without bentonite, amended or unamended with nutrients or NO_3^-. Because the repository is expected to become anoxic shortly after waste emplacement and also because bentonite will not be added as a backfill according to the current waste emplacement plan, we think that the experimental data from anaerobic incubation without bentonite present are most relevant to expected WIPP conditions. Considering that the current experimental data are mostly for denitrification (Reaction 1), but not sulfate reduction (Reaction 2) and methanogenesis (Reaction 3) (Francis & Gillow, 1994; Francis et al., 1995), we assume that the ranges of the rates of cellulosics biodegradation via sulfate reduction and methanogenesis are equal to those observed for denitrification.

We use CO_2 production data to estimate the rates of cellulosics biodegradation. There are two advantages of using CO_2 production data: (1) there are experimental data available on the CO_2 dissolution in WIPP brine (Telander & Westerman, 1995) and, therefore, it is easy to correct the CO_2 production data for gas dissolution (Appendix I); (2) since cellulosics biodegradation did not reach the stage of methanogenesis in the experiments, according to

Reactions 1 and 2, the consumption of one mole carbon of cellulosics will produce one mole of CO_2. This 1:1 relationship is independent of oxidation state of carbon in cellulosics. Therefore, it is rather straightforward to determine the amount of cellulosics biodegraded from the amount of CO_2 produced.

Experimental data show a strong dependence of CO_2 generation on the concentrations of nutrients and nitrate (Francis & Gillow, 1994; Francis et al., 1995). The maximum CO_2 generation was observed in nitrate-and-nutrient-amended samples. In those experiments, after a short lag phase, CO_2 first linearly increased with time and then approached some limiting value as its production rate diminished. If we assume that biodegradation is nitrate- or nutrient-limited, the experimental data can be explained by Michaelis-Menton kinetics (Chapelle, 1993). Michaelis-Menton kinetics, which describes the dependence of microbial reaction rate on substrate concentration, can be expressed by:

$$V = \frac{V_{max} S}{K_s + S} \tag{5}$$

where V is the microbial reaction rate; V_{max} is the maximum value of the rate; S is the concentration of the limiting substrate; K_s is a constant. Equation (5) states that the microbial reaction rate becomes independent of the substrate concentration, if the latter is high enough, i.e. $S >> K_s$ and $V = V_{max}$. In this circumstance, the reaction product will accumulate linearly with time before the substrate is sufficiently depleted. In other words, in our cases, the linear part of CO_2 vs. time curve will give the estimate of the maximum rate of cellulosics biodegradation.

From the experimental data of Francis & Gillow (1994) and Francis et al. (1995), we estimate the maximum and minimum rates of cellulosics biodegradation under inundated conditions to be 0.3 and 0.01 mole C/kg/year, respectively (Appendix I). The maximum rate is estimated from the data obtained from both NO_3^-- and nutrients-amended experiments, whereas the minimum rate is derived from the data obtained from the inoculated-only experiments without any nutrient and NO_3^- amendment. Under humid conditions, experimental data show no clear correlation between CO_2 production and nutrient concentration. The best estimate of the maximum rate of cellulosics biodegradation under humid condition is 0.04 mole C/kg/year (Appendix I). The minimum of the humid biodegradation rate is set to 0, corresponding to the cases where microbes become inactive due to nutrient and water stress.

- *Biodegradation of Plastics and Rubbers*

The rates of plastics and rubber biodegradation under expected WIPP conditions were

measured by Francis et al.(1995). The experimental data show that plastics and rubbers are much less biodegradable than cellulosics, although the data themselves are not sufficient for us to constrain the long-term biodegradation rate for plastics and rubbers. There are two factor that may potentially increase the biodegradibility of those materials: long time scale and cometabolism. Over a time scale of 10,000 years, plastics and rubbers may change their chemical properties and therefore their biodegradibility. Cometabolism means that microbes degrade an organic compound but do not use it as a source of energy or of their constituent elements, all of which are derived from other substrates (Alexander, 1994). In the WIPP repository, plastics and rubbers, which are resistant to biodegradation, may still be cometabolized with cellulosics and other more biodegradable organic compounds. Because of these uncertainties, we recommend a 50% chance for the biodegradation of plastics and rubbers in the event of significant microbial gas generation. We further suggest lumping plastics and rubbers into cellulosics and applying the ranges of cellulosics biodegradation rate to plastics and rubbers. This treatment is conservative in respect of repository pressurization and actinide solubility. We propose to use the following equation to convert plastics and rubbers to the carbon-equivalent quantity of cellulosics (Appendix I):

$$\text{total cellulosics (kg)} = \text{actual cellulosics (kg)} + 1.7\ \text{plastics (kg)} + \text{rubbers (kg)}. \qquad (6)$$

Anoxic Steel Corrosion

According to current waste inventory estimates, a large amount of steels will be emplaced in the WIPP repository (DOE/CAO, 1996). Those steels will be capable of reacting with the repository brine to form H_2 gas. Both thermodynamic calculations and experimental observations indicate that the H_2 gas can be generated to pressures exceeding the lithostatic pressure at the WIPP horizon, if enough brine enters the repository (Brush, 1990; Telander & Westerman, 1993, 1995). Since the repository will become anoxic shortly after waste emplacement and sealing, we here focus only on anoxic steel corrosion.

- *Steel Corrosion in the Absence of CO_2 and H_2S*

In this case, steel corrosion will follow the reaction (Telander & Westerman, 1993, 1995):

$$Fe + 2\ H_2O \rightarrow Fe(OH)_2 + H_2. \qquad (7)$$

In the Mg-rich WIPP brines (exemplified by Brine A), a significant fraction of Fe in the corrosion product is substituted by Mg. This substitution can substantially increase the stability of the corrosion product. Experimental observations indicate that steel corrosion can still proceed even at an 127 atm H_2 pressure (Telander & Westerman, 1995). Aside from this thermodynamic stability argument, the experimental observations indicate no

essential effect of Mg in the brine on the corrosion rate. As a matter of fact, the corrosion rates measured in Mg-rich Brine A are not significantly different from those measured in Mg-depleted Brine ERDA-6 (Telander & Westerman, 1995).

It was observed in the experiments that the steel corrosion rate decreased with time until some limiting rate was achieved (Telander & Westerman, 1995). Our long-term corrosion rate is estimated from the longest-term data available in a WIPP-relevant Brine A environment. The estimated inundated rate is 0.5 μm/year or 0.07 mole Fe /m^2/year (Appendix II). In addition, the corrosion rate is also found to increase with decreasing brine pH (Telander & Westerman, 1993, 1995). Without addition of CO_2 from microbial reactions, the pH in the repository is unlikely to go below its experimental value, which is about 10 (Telander & Westerman, 1993, 1995). Therefore, we recommend using 0.5 μm/year as the upper limit of inundated corrosion rate for the cases without microbial gas generation. On the other hand, the pH in the repository can be ~2 units higher than its experimental value due to the presence of $Ca(OH)_2$ as a cementious material in the waste, and thus, based on the scaling factor (= 0.01) given by Telander & Westerman (1995), the steel corrosion rate could be as low as 0.005 μm/year. In addition, the experimental work for Source Term Test Program (STTP) at Los Alamose National Laboratory indicates that salt crystallization on steel surface may possibly prevent the steel from corrosion. To include this possibility, we set the minimum inundated steel corrosion rate to 0.

The corrosion rate observed on specimens exposed to humid conditions is negligible, based on essentially non-existent presence of corrosion product and lack of apparent H_2 generation (Telander & Westerman, 1995). Therefore, we set the humid steel corrosion rate to 0.

- *Steel Corrosion in the Presence of CO_2 and H_2S*

In the event of significant microbial gas generation, steel corrosion can proceed via the following reactions in addition to Reaction (7) (Telander & Westerman, 1993, 1995):

$$Fe + CO_2 + H_2O \rightarrow FeCO_3 + H_2 \quad (8)$$
$$Fe + H_2S \rightarrow FeS + H_2. \quad (9)$$

One possible effect of CO_2 and H_2S on steel corrosion is that they may cause passivation of the steel. Steel passivation was observed in the experiments in which large quantities of CO_2 and H_2S were added to the reaction vessels. It usually took place after tens of days and was caused by the formation of a protective layer of $FeCO_3$ or FeS on steel surfaces (Telander & Westerman, 1995). However, we think that this passivation is unlikely to occur under the repository conditions. This is because the microbial production rate of CO_2 and H_2S is too slow and it will take an exceedingly long time period (relative to the experimental time scale) for these gases in the repository to reach their concentration levels required for

passivation under the experimental conditions. The conclusion of no steel passivation under the WIPP repository conditions is consistent with other studies (e.g., Ikeda et al., 1983; Schmitt, 1983). In fact, aside from the previously cited work of Telander & Westerman (1993), total passivation of steel by CO_2 and H_2S in low-temperature solutions has not been reported, though varying degrees of corrosion inhibition have been observed.

In the absence of passivation, the microbial generation of CO_2 and H_2S will increase steel corrosion rates in the repository either by lowering the repository pH or by initiating additional reaction pathways (Reactions 8 and 9) (Telander & Westerman, 1995). We take this effect into account by modifying the sampling range of steel corrosion rate. Obviously, Reactions 8 and 9 will be limited by microbial CO_2 and H_2S production, and therefore the upper limit of the reaction rate can be estimated from the maximum cellulosics biodegradation rate, which is 0.3 mole/kg cellulosics/year, equivalent to 6 μm/year of steel corrosion rate (Appendix II). Thus, in the event of significant microbial gas generation, the upper limit of steel corrosion rate is 6.5 μm/year, the sum of the maximum rates of Reactions 7 through 9. The corresponding lower limit will be kept the same as that estimated for the cases without CO_2 production, i.e. 0.0 μm/year. Under humid conditions, experimental results show a negligible effect of CO_2 and H_2S on steel corrosion (Telander & Westerman, 1995). We thus set the humid corrosion rate to 0.

Stoichiometric Factors in the Average-Stoichiometry Model

In the Average-Stoichiometry Model, which is currently implemented in BRAGFLO, microbial gas generation is represented by the overall reaction:

$$\frac{1}{6}C_6H_{10}O_5 + \textit{unknown} \rightarrow y\ \textit{gas} + \textit{unknown} \tag{10}$$

and H_2 production due to steel corrosion is described by:

$$Fe + \frac{4+2x}{3}H_2O \rightarrow \frac{4-x}{3}H_2 + x\,Fe(OH)_2 + \frac{1-x}{3}Fe_3O_4. \tag{11}$$

The stoichiometric factors x and y in Reaction 10 and 11 are estimated as follows.

• *Average-Stoichiometric FactorY in Microbial Reaction*

The stoichiometric factor y depends on the extent of the progress of each individual reaction pathway (Reactions 1 through 3). It can be estimated based on the inventory estimates of the transuranic waste to be emplaced in the Waste Isolation Pilot Plant (DOE/CAO, 1996; Drez, 1996).

First, we estimate the maximum quantities (in moles) of cellulosics and steels that will be potentially consumed in 10,000 years:

$$M'_{cel} = \min \left\{ \frac{6000 M_{cel}}{162},\ 10000 R'_C M_{cel} \right\} \tag{12}$$

$$M'_{Fe} = \min \left\{ \frac{1000 M_{Fe}}{56},\ 1410 R_{c,i} A \right\} \tag{13}$$

with

$$R'_c = \max \left\{ R_{m,i},\ R_{m,h} \right\} \tag{14}$$

where M_{cel} and M_{Fe} are the quantities (in kg) of cellulosics and steels initially present in the repository; $R_{c,i}$ is the inundated steel-corrosion rate (μm/year); $R_{m,i}$ and $R_{m,h}$ are the sampled rates of cellulosics biodegradation under inundated and humid conditions respectively (mole/kg/year). In Equation (13), we use the factor of 0.141 mole/μm/m^2 to convert steel-corrosion-rate unit from μm/year to mole/m^2/year (Telander and Westerman, 1995). Here, we assume that cellulosics biodegradation and steel corrosion both follow zero order reaction kinetics. Next, we calculate the average stoichiometric factor y by distributing M'_{cel} into individual biodegradation pathways. Consider two extreme cases, corresponding to the maximum and minimum values of y: (1) no reaction of microbially produced CO_2 and H_2S with steel and steel-corrosion products; (2) complete reaction of microbially produced CO_2 and H_2S with steel and steel-corrosion products.

If no CO_2 or H_2S is consumed by reactions with steel and steel-corrosion products, we would expect the maximum quantity of microbial gas production in the repository and therefore the maximum value for y. We assume that Reactions 1 to 3 will proceed sequentially. The maximum value of y can be estimated by averaging the gas-yields for all reaction pathways:

$$y_{max} = \frac{\frac{8.4 M_{NO3}}{4.8} + \frac{9 M_{SO4}}{3} + \left(M'_{cel} - \frac{6 M_{NO3}}{4.8} - \frac{6 M_{SO4}}{3} \right)}{M'_{cel}} \tag{15}$$

where M_{NO3} and M_{SO4} are the quantities of NO_3^- and SO_4^{2-} (in moles) initially present in the repository.

If CO_2 or H_2S reacts with steel and steel-corrosion products, we expect that a significant quantity or, perhaps, all of these microbially produced gases would be consumed, thus forming $FeCO_3$ and FeS. This would result in the minimum value of y. The total gas consumed by those reactions (G) is:

$$G = \min\left\{\frac{6M_{NO3}}{4.8} + \frac{9M_{SO4}}{3} + \frac{3}{6}\left(M'_{cel} - \frac{6M_{NO3}}{4.8} - \frac{6M_{SO4}}{3}\right),\ M'_{Fe}\right\} \tag{16}$$

The minimum value of y can then be estimated by:

$$y_{\min} = \frac{\frac{8.4M_{NO3}}{4.8} + \frac{9M_{SO4}}{3} + \left(M'_{cel} - \frac{6M_{NO3}}{4.8} - \frac{6M_{SO4}}{3}\right) - G}{M'_{cel}} = y_{\max} - \frac{G}{M'_{cel}} \tag{17}$$

For each BRAGFLO simulation, *y* will be uniformly sampled over $[y_{min}, y_{max}]$:

$$y = y_{\min} + \beta(y_{\max} - y_{\min}) \tag{18}$$

with $0 \le \beta \le 1.0$. The calculational scheme proposed here automatically correlates *y* with waste inventory estimates as well as with reaction rates.

The above calculational scheme does not take into account the SO_4^{2-} that will be brought into repository by brine inflow. Based the previous BRAGFLO simulations for undisturbed cases, the total volume of the brine entering the repository in 10000 years is unlikely to be larger than 2.2×10^7 liters, the value corresponding to the case with unrealistically low gas generation and therefore the worst repository flooding. With a typical SO_4^{2-} concentration of 200 mM in WIPP brines (Brush, 1990), we estimate that the amount of SO_4^{2-} brought into the repository by brine inflow would be less than 0.4×10^7 moles. This amount of SO_4^{2-} will increase the fraction of sulfate reduction pathway in total cellulosics biodegradation only by less than 1%. Therefore, neglecting the sulfate brought by brine inflow would introduce an error of no more than a few percents in y values.

• *Average-Stoichiometric FactorX in Steel Corrosion Reaction*

While magnetite (Fe_3O_4) has been observed to form on steel as a corrosion product in low-Mg anoxic brines at elevated temperatures (Telander & Westerman, 1995) and in oxic brine (Haberman & Frydrych, 1988), there is no evidence that it will form at WIPP repository temperatures. If Fe_3O_4 were to form, it would be expected that H_2 would be produced (on a molar basis) in excess of Fe consumed. But, the anoxic corrosion experiments did not show the production of H_2 in excess of Fe reacted. Therefore, we set the stoichiometric factor x to 1.0 in Reaction 11.

Table 1. Gas-Generation Parameters for the Long-Term WIPP Performance Assessment

Parameter	Estimated Value
Probability of occurrence of significant microbial gas generation	50%
Probability of occurrence of plastics and rubber biodegradation in the event of significant gas generation	50%
Rate of inundated cellulosics biodegradation	0.01 - 0.3 mole C/kg/year
Rate of humid cellulosics biodegradation	0.0 - 0.04 mole C/kg/year
Rate of inundated steel corrosion for the cases without microbial gas generation	0.0 - 0.5 μm/year[1]
Rate of humid steel corrosion for the cases without microbial gas generation	0.0 μm/year
Rate of inundated steel corrosion for the cases with microbial gas generation	0.0 - 6.5 μm/year
Rate of humid steel corrosion for the cases with microbial gas generation	0.0 μm/year
Stoichiometric factor x in Reaction 11	1.0
Stoichiometric factor y in Reaction 10	calculated from Eqn. (18)
Factor β in Equation 18	0 - 1.0
NO_3^- initially present in the waste[2]	2.6×10^7 moles
SO_4^{2-} initial present in the waste[2]	6.6×10^6 moles

1. Multiplying 0.141 mole/μm/m^2 will convert the unit of steel corrosion rate from μm/year to mole/m^2/year (Telander & Westerman, 1993). 2. See Appendix I.6.

References

Alexander M. (1994) *Biodegradation and Bioremediation.* Academic Press, NY.

Brush L. H. (1990) *Test Plan for Laboratory and Modeling Studies of Repository and Radionuclide Chemistry for the Waste Isolation Pilot Plant.* SAND90-0266, Sandia national Laboratories, Albuquerque, NM.

Brush L. H. (1995) *Systems Priority Method - Iteration 2 Baseline Position Paper: Gas Generation in the Waste Isolation Pilot Plant.* Sandia National Laboratories, Albuquerque, NM.

Butcher B. M. (1990) *Preliminary Evaluation of Potential Engineered Modifications for the Waste Isolation Pilot Plant (WIPP).* SAND89-3095, Sandia National Laboratories, Albuquerque, NM.

Chapelle F. H. (1993) *Ground-Water Microbiology and Geochemistry.* John Wiley & Sons, NY.

DOE/CAO (1996) *Transuranic Waste Baseline Inventory Report.* (Rev. 2)

Drez P. (1996) Preliminary estimate for SNL/NM performance assessment calculations of nitrate, sulfate, and phosphate content in transuranic solidified wastes destine for disposal in WIPP. CTAC. (memo, 1/26/1996)

Francis A. J & Gillow J. B. (1994) *Effects of Microbial Processes on Gas Generation under Expected WIPP Repository Conditions: Progress Report through 1992.* SAND93-7036, Sandia National Laboratories, Albuquerque, NM.

Francis A. J., Gillow J. B. & Giles M. R. (1995) *Effects of Microbial Processes on Gas Generation under Expected WIPP Repository Conditions: Data Report for the Period 1993 - 1995.* (draft)

Haberman J. H. & Frydrych D. J. (1988) Corrosion studies of A216 Grade WCA steel in hydrothermal magnesium-containing brines. *Scientific Basis for Nuclear Waste Management XI, Materials Research Society Symposium Proceedings, Boston, MA, November 30 - December 3, 1987.* Eds. M. J. Apted and R. E. Westerman. Materials Research Society, Pittsburgh, PA. 112, 761-772.

Ikeda A., Ueda M. & Mukai S. (1983) CO_2 corrosion behavior and mechanism of carbon steel and alloy steel. *Corrosion '83, Anaheim, CA, April 18 - 22, 1983.* Paper no. 45. National Association of Corrosion Engineers, Huston, TX.

Molecke M. A. (1979) *Gas Generation from Transuranic Waste Degradation: Data Summary and Interpretation.* SAND79-1245, Sandia National Laboratories, Albuquerque, NM.

Schmitt G. (1983) CO_2 corrosion of steels - An attempt to range parameters and their effects. *Advances in CO_2 Corrosion in the Oil and Gas Industry, Proceedings of the*

Corrosion/83 Symposium, Anaheim, CA, April 18 - 19. Ed. R. H. Hausler. National Association of Corrosion Engineers, Huston, TX. 1, 1-2.

Telander M. R. & Westerman (1993) *Hydrogen Generation by Metal Corrosion in Simulated Waste Isolation Pilot Plant Environments: Progress Report for the Period November 1989 through December 1992.* SAND92-7347, Sandia National Laboratories, Albuquerque, NM.

Telander M. R. & Westerman (1995) *Hydrogen Generation by Metal Corrosion in Simulated Waste Isolation Pilot Plant Environments: Final Report.* (draft)

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Appendix I. Hand Calculations for Estimating Microbial Gas generation Parameters

Name of person performing the calculations: Yifeng Wang, Jan. 26, 1996 Yifeng Wang
Name of person reviewing the calculations: Larry Brush, Jan. 26, 1996 Larry Brush

I.1 Correction for CO_2 Dissolution in the Brine

Data and definition of variables:

- TCO_2: Total CO_2 produced in an incubating experiment (moles)
- n: Measured CO_2 in headspace (moles)
- C_l: Dissolved CO_2 (moles/l)
- V_l: Brine volume = 0.104 (l) (Gillow, per. comm.)
- V_g: Headspace volume 0.046 (l) (Francis & Gillow, 1994)
- P: Partial pressure of CO_2 (atm)
- K: Partition coefficient of CO_2 between brine and gas phase = 0.01 (mole/l/atm) (Telander & Westerman, 1995)
- R: Gas constant = 0.082 (l•atm/mole/K)
- T: Temperature = 303.15 (K)

Assumption: Gaseous CO_2 approximately follows the idea gas law during these experiments.

Calculations:

$$TCO_2 = V_l*C_l + n = K*P*V_l + n = K*V_l*n*R*T/V_g + n = (K*V_l*R*T/V_g + 1)*n = (0.01*0.104*0.082*303.15/0.046 + 1)*n = 1.56*n \text{ (moles).}$$

I.2 Estimate of the Maximum Inundated Cellulosics Biodegradation Rate

Data:

Source: Francis et al. 1995, p. 41, 148-149.
Experimental conditions: anaerobic inoculated, nutrients and nitrate amended

We only take the linear part of CO_2 vs. time curve:

time	CO_2
69 days	6.1 µmol/g of cel.
411 days	163 µmol/g of cel.

Calculations:

(1) Rate = (163 - 6.1)/(411 - 69) = 0.459 micro-moles/g/day = 0.168 mole/kg/year.
(2) Correcting it for dissolved CO_2 (see I.1), we finally have:
maximum rate = 0.168*1.56 = 0.3 mole/kg/year.

I.3 Estimate of the Minimum Inundated Cellulosics Biodegradation Rate

Data:
Source: Francis et al. 1995, p. 148-149.
Experimental conditions: anaerobic, inoculated only,

time	CO_2
0 days	2.1 µmol/g of cel.
1034 days	14.0 µmol/g of cel.

Calculations:
(1) Rate = (14.0 - 2.1)/(1034 - 0) = 0.0115 µmol/g/day = 0.004 mole/kg/year.
(2) Correcting it for dissolved CO_2 (Appendix I.1), we finally have:
minimum rate = 0.004*1.56 = 0.01 mole/kg/year.

I.4 Estimate of the Maximum Humid Cellulosics Biodegradation Rate

Data:
Source: Francis et al. 1995, p. 80.
Experimental conditions: anaerobic, inoculated only;
anaerobic, inoculated and amended

time	CO_2
6 days	(7.7 + 13.3)/2 = 10.5 µmol/g of cel.
415 days	(83.1 + 28.8)/2 = 56 µmol/g of cel.

Calculations:
Maximum rate = (56 - 10.5)/(415 - 6) = 0.11µmol/g/day = 0.04 mole/kg/year.

I.5 Convert Plastics and Rubbers to the Equivalent Quantity of Cellulosics

Data:

Source: Molecke (1979)

Celllulosics: $C_6H_{10}O_5$	M. W. = 162 g/mole
Polyethylene: $(-C_2H_4-)n$	M. W. = 28 g/mole
Polyvinychloride: $(-C_2H_3Cl-)n$	M. W. = 62 g/mole
Neoprene: $(-C_4H_5Cl-)n$	M. W. = 88 g/mole
Hypalon: $.(-(C_7H_{13}Cl)_{12}-(CHSO_2Cl)_{17}-]n$	M. W. = 3488 g/mole

Assumption:

Plastics: 80% polyethylene, 20% polyvinychloride

Rubbers: 50% neoprene, 50% hypalon

Based on Molecke (1979).

Calculations:

The P kilograms of plastics and R kilograms of rubbers are equivalent to the Q kilograms of cellulosics, based on carbon equivalence:

$$Q = (0.8*2*162/28/6 + 0.2*2*162/62/6)*P + (0.5*4*162/88/6 + 0.5*101*162/3488/6)*R = 1.7\ P + R \text{ (kilograms)}$$

I.6 Moles of NO_3^- and SO_4^{2-} Initially Present in the Waste

NO_3^- : $1.62x10^6$ kg (Drez, 1996) = $1000/62*1.62x10^6 = 2.6x10^7$ moles

SO_4^{2-} : $6.33x10^5$ kg (Drez, 1996) = $1000/96*6.33x10^5 = 6.6x10^6$ moles

Appendix II. Hand Calculations for Estimating Steel Corrosion Parameters

Name of person performing the calculations: Yifeng Wang, Jan. 26, 1996 Yifeng Wang
Name of person reviewing the calculations: Larry Brush, Jan. 26, 1996 Larry Brus

II.1 Estimate of the Maximum Inundated Steel Corrosion Rate for the Cases without Microbial Gas Generation

Data:

(1) Anoxic corrosion rate obtained from the 12th to 24th month experimental data = 0.71 μm/year (Telander & Westerman, 1993, p. 6-14).

(2) Scaling factor for the long-term rate = 70% (Telander & Westerman, 1995, p. 6 - 19).

Calculation:

The maximum long-term steel corrosion rate = 0.71*70% = 0.5 μm/year.

II.2 Estimate the Maximum Inundated Steel Corrosion Rate for the Cases with Microbial Gas Generation

Data:

Total transuranic waste volume: 1.5×10^5 m^3 (DOE/CAO, 1996)
Drum volume: 0.208 m^3 (DOE/CAO, 1996)
Surface area of steel: 6 m^2/drum (Brush, 1995)
Maximum cellulosics biodegradation rate: 0.3 mole/kg/year (Appendix I.2)
Maximum inundated steel corrosion rate for the cases without microbial gas generation: 0.5 μm/year.
Total cellulosics (including plastics and rubbers): 2.1×10^7 kg (DOE/CAO, 1996; Appendix I.5)
NO_3^- initially present in the waste: 2.6×10^7 moles (Appendix I.6)
SO_4^{2-} initial present in the waste: 6.6×10^6 moles (Appendix I.6)

Assumption:

Reactions 8 and 9 will be limited by microbial CO_2 and H_2S production rate.

Calculations:

(1) Number of drums = $1.5 \times 10^5 / 0.208 = 7.2 \times 10^5$ drums.

(2) Total moles of C in cellulosics = $6 * 2.1 \times 10^7 * 1000/162 = 7.74 \times 10^8$ moles of C.

Molar fraction of cellulosics biodegraded via denitrification = $2.6 \times 10^7 / 7.74 \times 10^8 = 3\%$.

Molar fraction of cellulosics biodegraded via sulfate reduction = $6.6 \times 10^6 / 7.74 \times 10^8 = 1\%$.

(3) Maximum CO_2 and H_2S production rate for the whole repository = $(0.03 + 1.5*0.01 + 0.5*0.96)*0.3*2.1 \times 10^7 = 3.3 \times 10^6$ moles CO2/year.

(4) Total steel surface area = $6*7.2 \times 10^5 = 4.32 \times 10^6$ m^2.

(5) The maximum rate of steel corrosion via Reactions 8 and 9 = $3.3 \times 10^6 / 4.32 \times 10^6$ = 0.8 mole Fe/m^2/year = 6 μm/year.

(6) The upper limit of inundated steel corrosion rate for the cases with microbial gas generation = 0.5 + 6 = 6.5 μm/year.

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Sandia National Laboratories

Albuquerque, New Mexico 87185-

date: February 29, 1996

to: Palmer Vaughn (Org. 6749)

Yifeng Wang Larry Brush

from: Yifeng Wang & Larry Brush (Org. 6748)

subject: An Adjustment for Using Steel Corrosion Rates in BRAGFLO to Reflect Repository Chemical Condition Changes due to Adding MgO as a Backfill

In order to control the repository chemistry, a sufficient amount of MgO will be added to the repository as a backfill. Through chemical reaction, this backfill will practically remove all CO_2 generated by microbial reactions and thus prevent any possibility of CO_2 accumulation in the repository. Therefore, the previously-suggested enhancement of steel corrosion by CO_2 (Wang & Brush, 1996) will be no longer possible. In our previous memo (Wang & Brush, 1996), two set of inundated steel corrosion rates were provided: one is 0.0 to 0.5 μm/year for the cases without CO_2 present and another is 0.0 to 6.5 μm/year for the cases with CO_2 present. *Considering the chemical condition changes due to adding MgO as a backfill, we suggest using the rate of 0 to 0.5 μm/year for* <u>*all*</u> *BRAGFLO simulations.*

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Effects of Microbial Processes on Gas Generation Under Expected Waste Isolation Pilot Plant Repository Conditions

Progress Report Through 1992

A. J. Francis and J. B. Gillow
Brookhaven National Laboratory
Upton, NY 11973

Prepared by Sandia National Laboratories Albuquerque, New Mexico 87185 and Livermore, California 94550 for the United States Department of Energy under Contract DE-AC04-94AL85000

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EFFECTS OF MICROBIAL PROCESSES ON GAS GENERATION UNDER EXPECTED WASTE ISOLATION PILOT PLANT REPOSITORY CONDITIONS

Progress Report Through 1992

A. J. Francis and J. B. Gillow
Brookhaven National Laboratory
Upton, NY 11973

ABSTRACT

Microbial processes involved in gas generation from degradation of the organic constituents of transuranic waste under conditions expected at the Waste Isolation Pilot Plant (WIPP) repository are being investigated at Brookhaven National Laboratory. These laboratory studies are part of the Sandia National Laboratories - WIPP Gas Generation Program. Gas generation due to microbial degradation of representative cellulosic waste was investigated in short-term (< 6 months) and long-term (> 6 months) experiments by incubating representative paper (filter paper, paper towels, and tissue) in WIPP brine under initially aerobic (air) and anaerobic (nitrogen) conditions. Samples from the WIPP surficial environment and underground workings harbor gas-producing halophilic microorganisms, the activities of which were studied in short-term experiments. The microorganisms metabolized a variety of organic compounds including cellulose under aerobic, anaerobic, and denitrifying conditions. In long-term experiments, the effects of added nutrients

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Performed under Contract No. 67-8602 for Sandia National Laboratories, Waste Isolation Pilot Plant Gas Generation Program.

(trace amounts of ammonium nitrate, phosphate, and yeast extract), nutrients plus excess nitrate, and no nutrients on gas production from cellulose degradation were investigated. Results to date (up to 200 days of incubation) show that: (i) gas production was not detected in abiotic control samples; (ii) cellulose incubated without nutrients showed limited but sustained gas production; (iii) the addition of nutrients enhanced the biodegradation of cellulose as evidenced by an increase in the production of total gas, carbon dioxide, and nitrous oxide; (iv) in the presence of excess nitrate, gas production was the highest and nitrous oxide accumulated to varying amounts; (v) the addition of bentonite increased the background carbon-dioxide concentration and stimulated microbial activity specifically in aerobic samples; and (vi) in addition to total gas and carbon dioxide production, cellulose degradation in nutrient-amended samples was evidenced by the gradual bleaching of brown paper towel, the formation of gas bubbles, the formation of paper pulp, and the appearance of a red color at the bottom of the sample bottles, indicating the growth of halophilic microorganisms. Estimates of the total gas production on the basis of initial results ranged from 0.001 to 0.039 mL g^{-1} cellulose day^{-1}.

ACKNOWLEDGMENTS

The authors acknowledge the encouragement and programmatic guidance provided by Drs. L. H. Brush and M. A. Molecke, Sandia National Laboratories; the technical assistance of J. Ruggieri and S. Melloy; P. Carr and V. Gutierrez for their assistance with the Quality Assurance aspects of the project; A. Woodhead for editorial assistance; and C. Messana for preparing the final report.

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1.0 INTRODUCTION

Transuranic (TRU) wastes contain alpha-emitting transuranium nuclides with half-lives greater than twenty years and concentrations greater than 100 nCi per gram. TRU wastes are generated from nuclear-weapons production and other related nuclear-processing procedures. The wastes include adsorbed liquids, sludges, organics, and cemented materials containing the following radionuclides: ^{232}Th, ^{233}U, ^{235}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{241}Am, ^{244}Cm, ^{252}Cf, and a variety of metals. Typically, TRU waste is classified as either contact-handled (CH), which does not require shielding, or remote-handled (RH), which requires shielding because of the hazard of gamma-radiation exposure. The Waste Isolation Pilot Plant (WIPP) is a mined, geologic repository developed to demonstrate that radioactive transuranic wastes generated in defense-related activities can be safely and permanently disposed of underground. The WIPP is a U.S. Department of Energy facility located in southeastern New Mexico, about 2150 ft (656 m) below the surface, in a bedded salt, evaporite Permian formation. A major long-term concern is the potential for gas generation from the corrosion of Fe and Fe-based alloys, microbial degradation of cellulosic, plastic, and rubber materials, and radiolysis of brine and waste material by alpha-emitting radionuclides (Molecke, 1979; Brush, 1990). Gas generation can cause pressurization and the formation of fractures which could allow the radionuclides to migrate away from the disposal site.

Anoxic corrosion and microbiological activity are the two most important processes that may generate appreciable amounts of gas. The current estimate of gas production due to anoxic corrosion is 900 moles per drum of waste (Brush, 1991). Caldwell et al. (1979) reported that microbial gas production due to biodegradation of TRU waste could be significant. Recently, Lappin et al. (1989) estimated such production rates at 1 mole of gas per drum of waste per year for 600 years. Brush (1991) and Brush et al., (1990) proposed a minimum and maximum range at 0 to 5 moles per drum per year, as did the earlier estimates by Molecke (1979).

Laboratory studies are under way to determine the rate and extent of gas production due to radiolysis, corrosion, and microbial activity, to support the Sandia National Laboratories-WIPP Gas Generation Program efforts to assess the long-term performance of the WIPP repository. This report summarizes the progress and status of the WIPP-funded work at BNL and presents the microbiological data obtained from initiation through 1992. Studies of the effects of microbial processes have been underway at Brookhaven National Laboratory since 1991, funded under Sandia National Laboratories contract no. 67-8602.

Brookhaven National Laboratory has developed a Quality Assurance Program that complies with DOE Order 5700.6C. For EM projects the Laboratory interprets the requirements of 5700.6C in accordance with the applicable guidance provided in the EM Quality Assurance Requirements Document (QARD). This will ensure that the data generated will be valid, accurate, repeatable, and protected, and will withstand critical peer and other reviews.

1.1 Background

The WIPP waste repository is located 2150 ft (656 m) below ground surface, with 56 rooms planned or under construction in a bedded salt formation. About 6,800 drums of waste in 55-gallon (208-L) containers will be placed in each room of 3,640-m^3 capacity. Each drum will contain, on average, about 10 kg of cellulosic waste (approx. 70,000 kg of cellulosic per room), 70% of which is paper (Brush, 1990). The rest of the potentially biodegradable portion of the waste consists of plastic and rubber, and other organic compounds. Wastes consisting of inorganic process sludges from secondary waste treatment, containing a total of ~3 million moles of nitrate and a much smaller amount of phosphate, will also be emplaced in the WIPP (Brush, 1990; Brush et al., 1991).

Microorganisms can enter the WIPP from several sources, including: (i) association with the TRU waste; (ii) the surface environment via the mine ventilation systems and human intrusion; and (iii) resident populations in the salt crystals and brine formations. Alpha

radiation from TRU waste is not expected to have significant effects on microbial activity (Barnhart et al., 1980; Francis, 1990). Previous studies of low-level radioactive wastes and waste leachates have shown that microbes in the wastes can metabolize organic carbon compounds (Francis et al., 1980a,b; Francis, 1985). Halotolerant and halophilic microorganisms (10^1 to 10^5 colony forming units/mL) including aerobic, nitrate-reducing, and anaerobic bacteria were detected in the WIPP surficial environment and underground workings (R. Vreeland, West Chester University, Pennsylvania, to be published). Cellulose-degrading extreme halophiles from the underground workings also have been isolated (R. Vreeland, West Chester University, Pennsylvania, to be published). Introduced microorganisms, as well as resident or indigenous halotolerant and halophilic bacteria, can metabolize organic compounds and nitrate in the waste, and may generate metabolic byproducts, such as organic acids, alcohols, carbon dioxide, nitrous oxide, nitrogen, hydrogen, hydrogen sulfide, and methane.

1.2 Biochemistry of Cellulose Degradation

1.2.1 Biodegradation of Cellulose

The cellulosic portion of the TRU waste will approximately be comprised of the following (Brush, 1990): paper (70%), cloth (4%), plywood (10%), and lumber (16%) (untreated: 10% and, treated: 6%). In addition, the waste contains plastic materials (primarily polyethylene and polyvinylchloride) and rubber materials (primarily neoprene and hypalon), the characteristics of which may be altered by alpha-irradiation, which may enhance their biodegradability and potential for gas generation.

Cellulose, hemicellulose, and lignin make up the three major components of plant vascular material, lignocellulose. Lignin is a highly branched, constitutionally undefined aromatic polymer that makes up 15 to 38% of hardwood and softwood trees. It is considered highly resistant to biodegradation, although thermochemically modified lignin has been shown to biodegrade (Colberg and Young, 1982).

Cellulose is an unbranched polymer of several thousand D-glucose units linked together by β-1,4 glucosidic bonds. The strength of the polymer is derived from the multitude of hydrogen bonds, with concentrations of hydrogen bonds in microcrystalline regions and fewer bonds in amorphous regions. Cellulose is insoluble; therefore, hydrolysis is a prerequisite to microbial degradation. Hydrolysis of cellulose results in the formation of cellobiose, which is then hydrolyzed to glucose (Figure 1).

Biodegradation of cellulose by white-rot fungus *Trichoderma reesei* and the bacteria *Cellulomonas* has provided insights into the enzymology, the mechanisms of action, and the pathways of cellulose degradation. Several extracellular enzymes are involved in the breakdown of cellulose. The cellulase enzymes, consisting of exoglucanase (exoenzyme) and endoglucanase (endoenzyme), break the cellulose chains into various smaller fragments, starting with: (i) different 1,4-β-endoglucanases that attack the 1,4-β-linkages, randomly depolymerizing internal units; (ii) 1,4-β-exoglucanases that remove cellobiose from the non-reducing chain end of the molecule, and (iii) 1,4-β-glucosidases (cellobiase) that hydrolyze cellobiose to glucose (Priest, 1984). Amorphous regions of cellulose are degraded by both the endo- and exo-glucanases separately. Synergistic action of the two enzymes is necessary for degrading crystalline cellulose (Poulsen and Peterson, 1992). These enzymes (produced by a variety of aerobic and anaerobic bacteria, fungi, and protozoa) coordinate to hydrolyze cellulose into soluble components, which then are converted into a variety of end products. Bacteria, including aerobes such as *Cellulomonas sp.* and *Cellvibrio gilvus* (Bott and Kaplan, 1991), and anaerobes, such as *Clostridium sp.* (Benoit et al., 1992), *Clostridium thermocellum* (Lynd et al., 1989), *Acetovibrio celluloyticus* (Laube and Martin, 1981), and *Ruminococcus albus* (Pavlostathis et al., 1988) produce extracellular cellulase enzymes in the presence of cellulosics. These enzymes are induced by the presence of substrate (Hrmova et al., 1991) and are attenuated by soil and other absorptive materials (Hope and Burns, 1985). Close proximity of the cell to the substrate is necessary for degradation. A purified enzyme extract of *T. reesei* was shown to effectively degrade cellulose (Priest, 1984), and non-oxygen labile endoglucanase from *Clostridium thermocellum* was shown to strongly absorb to native

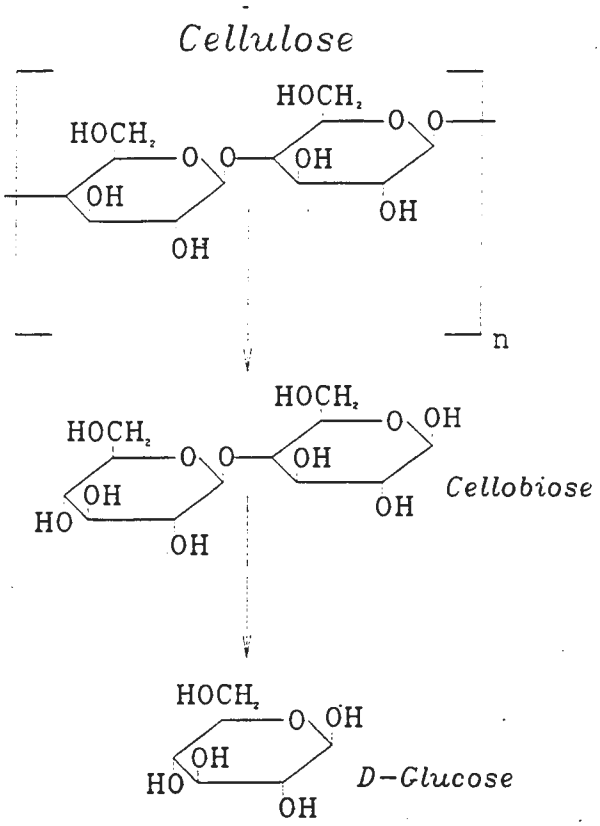

Figure 1. Cellulose Degradation Pathway.

cellulose (Ng et al., 1977). The rate of enzyme induction also depends upon the presence of the necessary nutrients, nitrogen and phosphorus (Skujins, 1976). Upon induction, hydrolysis by the cellulases is the rate-limiting step which, once achieved, follows first-order kinetics (Pavlostathis and Giraldo-Gomez, 1991). The available surface area is an important determinant of the rate of digestion of cellulose. In vitro studies of cellulytic bacteria from cow rumen demonstrated the importance for degradation of adherence of microbial cells to the cellulose surface, with fermentation rates correlated to surface area (Weimer et al., 1990). The primary hydrolysis products of cellulose are cellobiose and glucose, which then are converted to organic acids, carbon dioxide, hydrogen, and methane by various microbial processes.

Glucose, generated from cellulose, is readily used by a variety of microorganisms. The specific process depends on the availability of electron acceptors such as oxygen, nitrate, sulfate, and CO_2. In the presence of oxygen, carbon dioxide and water are formed during the oxidation of glucose:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

As oxygen is consumed, the alternate electron acceptors are used: nitrate, iron (III) oxides and hydroxides, manganese (IV) oxides and hydroxides, sulfate, and carbon dioxide. In the case of nitrate, dissimilatory reduction transforms nitrate to ammonium (dissimilatory nitrate reduction to ammonium (DNRA)) or to nitrous oxide, and then nitrogen (denitrification):

$$NO_3^- \rightarrow NO_2^- \rightarrow NH_4^+ \text{ (DNRA)}$$

$$NO_3^- \rightarrow NO_2^- \rightarrow N_2O \rightarrow N_2 \text{ (Denitrification)}$$

Both processes are affected by the concentration of oxygen; the organisms catalyzing these transformations are microaerophiles or facultative anaerobes, capable of metabolism under low oxygen conditions or in its absence. Denitrification will slow down or cease with higher oxygen concentrations which inhibit the production of specific enzymes (Tiedje, 1988). Denitrifiers use several substrates, such as glucose and low molecular weight organic

acids and alcohols. The use of nitrate as an alternate electron acceptor may be significant in the WIPP because of the presence of nitrate in the waste, predominantly from process sludges.

In the absence of oxygen and nitrate, anaerobic microorganisms will dissipate electrons via fermentation of the carbohydrate:

$$C_6H_{12}O_6 \rightarrow 2C_3H_4O_3 \text{ (pyruvic acid)} + 4H^+$$
$$4H^+ + 2C_3H_4O_3 \rightarrow 2C_3H_6O_3 \text{ (lactic acid)}$$

Fermentation products, such as low molecular-weight organic acids and alcohols are available for preferential use by denitrifiers, sulfate reducers, and methanogens. Brines from the WIPP contain 160 to 300 mM sulfate (Brush, 1990); sulfate-reduction could be significant in the presence of metabolizable carbon. It occurs under reducing conditions (Eh -150 to -200mV, pH = 7.00), resulting in a change in Eh (-250mV) with growth and sulfide formation (Postgate, 1984):

$$2 \text{ lactate}^- + SO_4^= \rightarrow 2 \text{ acetate}^- + 2CO_2 + 2H_2O + S^=$$

Sulfate reduction results in the formation of H_2S and insoluble metal sulfides. Sulfate-reducing bacteria (SRB) convert lactate, pyruvate, alcohols, amino acids, and acids of the tricarboxylic acid cycle to acetate and CO_2. Glucose and other sugars seldom seem to be used directly by SRB.

The presence of CO_2, H_2, organic acids, and a low Eh generated by these anaerobic microbial processes provide a conducive environment for the growth of methanogenic bacteria. Methanogens can use (i) acetate; (ii) methanol; or (iii) carbon dioxide and hydrogen and produce methane:

(i) $CH_3COO^- + H^+ \rightarrow CH_4 + CO_2$

(ii) $4CH_3OH \rightarrow 3CH_4 + CO_2 + 2H_2O$

(iii) $4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$

Approximately 70% of the methane formed in sludge and freshwater sediments is due to reaction (i), whereas halophiles predominantly carry out reaction (ii).

Additionally, iron(III) reduction may be a significant process in the WIPP because of the presence of oxidized forms of iron. Iron reduction involves the oxidation of organic carbon concomitant with the reduction of iron, whereby iron is used as the electron acceptor in the absence of oxygen, resulting in the reduction and dissolution of Fe(III) to Fe(II). Manganese reduction results in the formation of soluble Mn(II) from Mn(IV). Soluble uranyl ions can be reduced to insoluble U(IV) by anaerobic bacteria (Francis et al., 1991; Lovely et al., 1992). Corrosion caused by microbes could transform metal ions at a passive surface, resulting in metal sulfide precipitates (Kearns et al., 1992). The use of hydrogen solely from passivation can result in the formation of methane by methanogens, accelerating cathodic depolarization and increasing corrosion (Lorowitz et al., 1992). Figure 2 shows microbiologically mediated redox processes.

1.2.2 Metabolic Diversity of Halophilic Microorganisms

Halobacteria isolated from hypersaline environments can metabolize a wide variety of organic compounds under aerobic and anaerobic conditions. Most of the extreme halophiles are archaebacteria; that is, they are a distinct group of microorganisms, apart from the eubacteria that make up the majority of prokaryotes, with an ancient lineage composed of other types of organisms adapted to extreme environments, such as alkaliphiles, thermophiles, and methanogens. Moderate halophiles grow best in an environment containing 0.5 to 2.5 M NaCl, while extreme halophiles grow best in 2.5 to 5.2 M NaCl (Kushner and Kamekur, 1988; Ventosa, 1988). Brines in the WIPP repository consist of 5.1-5.3 M chloride and 1.83-4 M sodium, 0.63-1.44 M magnesium, and 0.04-0.30 M potassium (Brush, 1990; Molecke, 1983).

Halophiles grow anaerobically by: (i) fermenting glucose, fructose, glycerol, citrate, and lactate (Javor, 1984); (ii) reducing nitrate to nitrogen gas using a variety of carbohydrates

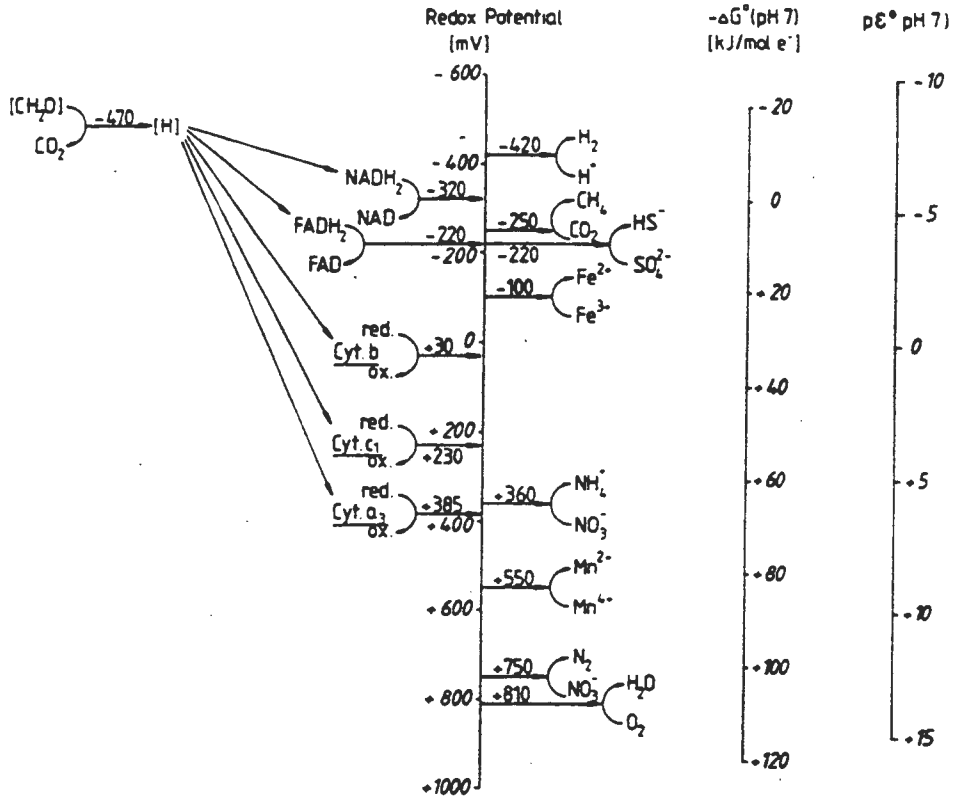

Figure 2. Electron-free energy for biologically mediated redox sequence with organic carbon (CH_2O) acting as the electron donor. Calculated for standard conditions at pH 7. (CH_2O) represents one-sixth of glucose (i.e. -153 kJ mol^{-1}), *from* Zehnder, A.J., and W. Stumm. 1988. "Geochemistry and Biogeochemistry of Anaerobic Habitats," *Biology of Anaerobic Microorganisms*. Ed. A. J. Zehnder. New York, NY: John Wiley and Sons. 19.

(Tomlinson et al., 1986); (iii) degrading chitin; and (iv) producing methane from methylamines, CO_2 and H_2 (Zhilina and Zavarzin, 1990). In hypersaline environments acetate-utilizing methanogens have been difficult to isolate (Zhilina and Zavarzin, 1990). Sulfate reducers also have been difficult to isolate, although saltmarsh sediments harbor abundant SRB populations (Dicker and Smith, 1985). The WIPP site contains a variety of halotolerant and halophilic bacterial populations. Isolates from underground brine seepages and salt crystals, and from brine and sediment from surficial lakes near the WIPP site, revealed a great diversity of colony characteristics when grown on solid media (R. Vreeland, West Chester University, Pennsylvania, to be published); these isolates used amino acids, glucose, and cellulose.

2.0 EXPERIMENTAL APPROACH

Laboratory experiments were designed to determine the potential gas generation due to biodegradation of cellulose under conditions expected in the WIPP repository (Figure 3). The experiments were divided into short-term (<6 months) and long-term (>2 years) ones. In the short-term experiments, we examined the influence of electron donors and acceptors on the activities of specific microbial processes relevant to the WIPP disposal environment. In the long-term experiments, we measured gas generation due to biodegradation of cellulose under realistic conditions expected in the WIPP repository after the waste was in place. The conditions include humid and inundated, and initially aerobic and anaerobic environments. The effects of addition of nutrients and bentonite also was investigated.

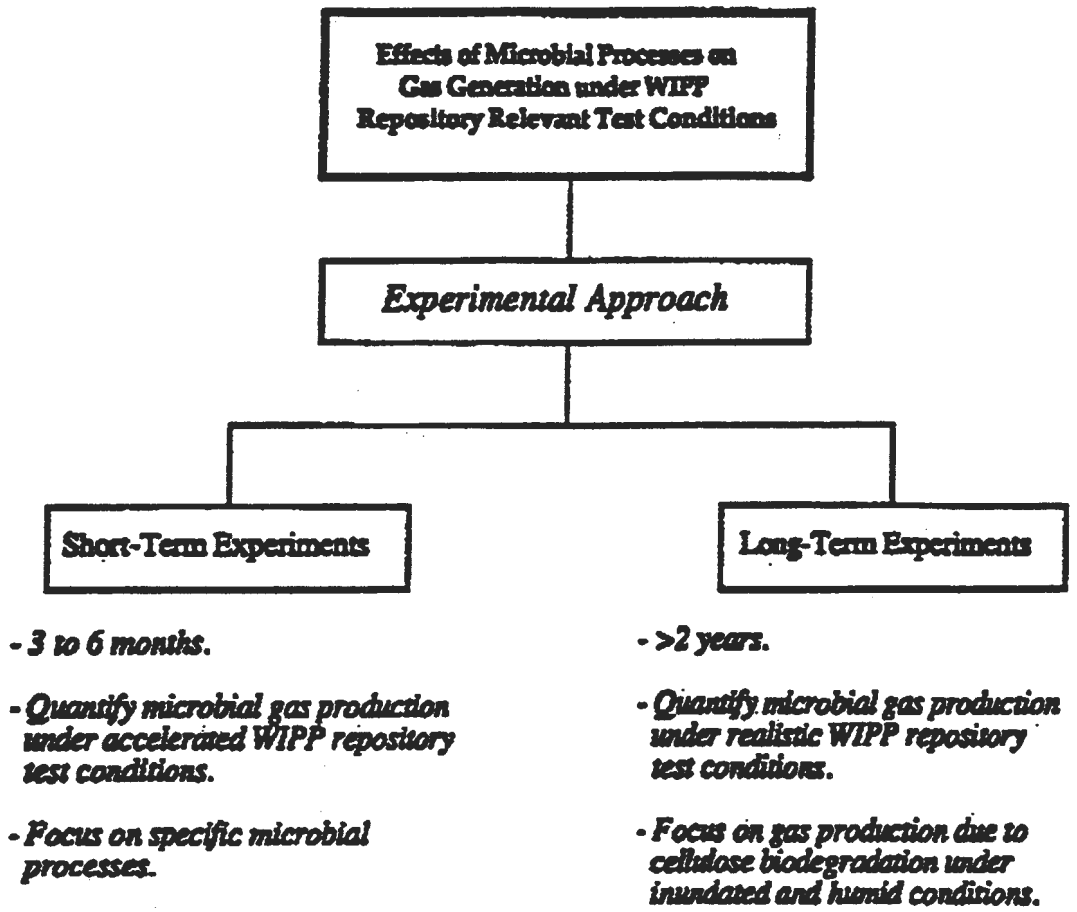

Figure 3. Experimental Approach

3.0 SHORT-TERM EXPERIMENTS

3.1 Rationale

The two main objectives of the short-term experiments were: (i) to determine gas production due to the activity of aerobes and anaerobes in the presence of specific electron donors (cellulose, glucose, succinate) and acceptors (oxygen, nitrate, sulfate) under hypersaline conditions; and (ii) to evaluate the suitability of inocula for use in the long-term experiments.

Anaerobic microbial processes were emphasized in the short-term experiments because they are expected to have the greatest impact on the long-term performance of the WIPP repository. These experiments provided an opportunity to specify aspects of the long-term investigations by manipulating the experimental variables. The microbes tested include those present in the brine collected from WIPP underground workings, surficial sediment slurries from the surrounding lakes at the WIPP site, and in axenic (pure) or mixed cultures isolated from these sources. In addition, analytical methods were tested and standardized during this phase.

3.2 Methodology

3.2.1 Sample Collection

Sediment and water samples from Nash Draw (near the WIPP site) and muck pile salt, rib salt, and brine (from the WIPP underground workings) were collected from August 21 to 25, 1991. Core samples of mud from Laguna Cinco, Quatro, Tres, and Surprise Springs, all in Nash Draw, were obtained using sterile iron pipes. Air was excluded by driving the core deep into the mud and capping it while submersed. Corrosion of iron end-caps also prevented contamination by oxygen. Lake brine samples were collected in sterile polyethylene containers from the four lakes as well as from Lindsey Lake, also in Nash

Draw. Mud and brine from all the lakes were also collected with sterile glass serum bottles, which were then stoppered and crimped to exclude air. Salt from the WIPP underground was collected using sterile spatulas and sterile containers. G-Seep brine from the WIPP underground was collected in sterile polyethylene bottles by Glen Barker, SNL.

The samples were shipped to BNL within two days after collection. The mud samples were extruded in a nitrogen-filled glove box and transferred to sterile serum bottles, fitted with butyl rubber stoppers, and stored at 4°C. Brine from Lindsey Lake and the WIPP site was also stored at 4°C. Viable bacteria in these samples were counted by Russell Vreeland, West Chester University, and the total number of bacteria and microbial activity were determined at BNL.

3.2.2 Direct Counts of Bacteria

Samples were shaken on a wrist-action shaker for 45 minutes to disperse the contents. One mL was removed with a sterile needle and syringe, dispensed into a snap-cap vial and preserved with 5% (v/v) glutaraldehyde. Double-stranded DNA specific stain 4'6-diamidino-2 phenylindole dihydrochloride (DAPI, Polysciences, Inc.) was added to the sample and it was incubated for seven minutes in the dark. The sample was filtered through a 0.2 μm black membrane filter (Poretics Corp.), and then placed on a slide and examined under oil-immersion at 1875 x magnification. Slides were prepared in triplicate for each sample, the blue-fluorescing cells were counted directly using a calibrated grid eyepiece under ultraviolet light. The DAPI stain differentiated the cells from salt grains: DNA-containing material was blue and the salt yellow (Coleman, 1980).

3.2.3. Activity Measurements

Production of gas by aerobes, anaerobes, and denitrifiers was determined in a mixed inoculum of WIPP salt and brine and Nash Draw brine and sediment. The carbon sources tested included glucose ($C_6H_{12}O_6$), cellulose ($[C_6H_{10}O_5]_n$), and succinate ($C_4H_6O_4$).

Two hundred g of S2180, W30 WIPP muck-pile salt were dissolved in sterile, deionized water and diluted to 1 L. To a 450 mL aliquot of the solution, 10 mL of Laguna Cinco mud slurry and 40 mL of Laguna Cinco lake water were added. The mixture was kept in an anaerobic glove box. Nine and a half mL of the mixture were added with a sterile syringe to 20 mL sterile serum bottles containing 0.5 mL of a sterile, concentrated nutrient stock solution containing 5 mg yeast extract, 10 mg potassium phosphate, 125 μmol ammonium nitrate, and 275 μmol glucose (See Appendix A). Aerobic samples were incubated with an initial headspace of air in sealed containers, whereas anaerobic samples were incubated in a nitrogen atmosphere after purging the samples several times with nitrogen. The serum bottles were fitted and sealed with butyl rubber stoppers. Denitrification activity was determined by adding a nutrient solution containing 5 mg yeast extract, 10 mg potassium phosphate, 125 μmol nitrate added as ammonium nitrate, 99 μmol nitrate added as potassium nitrate, and 185 μmol of succinate. These samples contained a total of 224 μmol of nitrate and were prepared anaerobically. A set of aerobe, anaerobe, and denitrifier treatments were also prepared by including approximately 0.5 g filter paper instead of the respective carbon sources, glucose and succinate.

Six samples were prepared for each treatment, two of which were treated with 1 mL of 10% formaldehyde to serve as abiotic controls. Brine samples without nutrients were also prepared, and two were treated with formalin to determine endogenous activity. The headspace gas of all the samples was analyzed after 48, 83, and 147 days of incubation at 30°C, and the total volume of gas, carbon dioxide, and nitrous oxide in the headspace determined (see Appendix B).

3.2.4 Denitrification Studies

In the absence of oxygen and in the presence of metabolizable organic carbon, some aerobic bacteria can use nitrate as an alternate electron acceptor. This process, called denitrification, or the reduction of nitrate, converts 80% or more of the available nitrate-N

to nitrogen gas (Tiedje, 1988). Nitrate is reduced to nitrogen by denitrifying bacteria via the following steps:

$$NO_3^- \rightarrow NO_2^- \rightarrow N_2O \rightarrow N_2$$

Nitrate is also reduced by dissimilatory nitrate reduction to ammonium, but with either incomplete conversion to nitrogen or a far lesser yield of nitrogen (Tiedje, 1988). Nitrous oxide is an intermediate product and does not generally accumulate, although some halophiles accumulate nitrous oxide under certain conditions (Tomlinson et al., 1986).

Denitrification was observed in Nash Draw sediment slurry, G-seep, and a pure culture by the acetylene blockage technique (Yoshinari and Knowles, 1976). Acetylene inhibits the conversion (reduction) of N_2O to N_2, resulting in the stoichiometric accumulation of N_2O in the headspace (Balderston et al., 1976):

$$NO_3^- \rightarrow NO_2^- \rightarrow N_2O \underset{C_2H_2}{\overset{}{\not\rightarrow}} N_2$$

Acetylene was injected into the duplicate samples of each treatment to give a final concentration of 10%. Nitrous oxide in the headspace of each sample was measured with a gas chromatograph equipped with a ^{63}Ni electron capture detector (see Appendix B). Samples were analyzed at 0, 21, and 43 hours, and at appropriate intervals thereafter.

3.2.4.1 DENITRIFICATION IN SEDIMENT SLURRY SAMPLE

Laguna Cinco sediment (collected on August 22, 1991 and stored anoxically at 4°C for two months), and a fresh sample from the same site (collected on December 10, 1991) were examined for denitrifier activity. The fresh sample was examined within 48 hours of collection. The sample was mixed well, and a 1 mL slurry (August: 0.56 ± 0.01 g dry sediment; December: 0.59 ± 0.01 g dry sediment) was pipetted into sterile 20 mL serum bottles in a glove box filled with nitrogen. One mL of filter-sterilized (0.22 μm) brine (20%

w/v WIPP halite) was added to the slurries resulting in a final volume of 2 mL. The slurry contained the following nutrients: (i) no additions (unamended); (ii) 3 μmol succinate (carbon-amended); (iii) 300 nmol nitrate (nitrate-amended); and (iv) 3 μmol succinate and 300 nmol nitrate (carbon-and nitrate-amended at a C:N ratio of 10:1). Succinate was used as the carbon source to discourage the growth of fermentative organisms. Triplicate samples of each treatment were prepared. The pH of each treatment was measured at the beginning and end of the experiment. Formaldehyde-treated samples served as controls. The serum bottles containing samples were sealed with rubber stoppers in the glove box in a nitrogen atmosphere and incubated at 30°C. Denitrification was determined by the acetylene blockage technique.

3.2.4.2 DENITRIFICATION IN G-SEEP

G-Seep brine collected on December 10, 1991 from the WIPP underground workings was prepared within 48 hours of collection to assay for denitrification activity. Five mL aliquots of G-Seep brine were transferred into sterile serum bottles in an anaerobic glove box. One mL of filter-sterilized (0.22 μm) brine (20% w/v WIPP halite) with nutrients was added. The G-Seep samples contained the following nutrients: (i) no additions (unamended); (ii) 1.5 μmol succinate (carbon-amended); (iii) 150 nmol nitrate (nitrate-amended); and (iv) 1.5 μmol succinate and 150 nmol nitrate (carbon- and nitrate-amended). Formaldehyde-treated samples served as controls. Triplicate samples of each treatment were prepared, sealed with butyl rubber stoppers in the glove box in a nitrogen atmosphere, and incubated at 30°C. Denitrification was determined by the acetylene blockage technique. Samples were analyzed after 0, 3, 30, and 60 days.

3.3 RESULTS AND DISCUSSION

3.3.1 Bacterial Population

Table 1 shows the numbers of bacteria, both viable and non-viable, in brine samples from Nash Draw and in G-Seep from the WIPP underground. The direct counts of bacteria in Nash Draw samples range from 5.5×10^6 to 1.0×10^7 cells/mL. The G-Seep brine contained 7.2×10^4 to 3.2×10^6 cells/mL.

3.3.2 Activity Measurements

3.3.2.1 AEROBIC GLUCOSE METABOLISM

Table 2 shows the total gas, carbon dioxide, and nitrous-oxide production in the mixed inoculum slurry samples incubated initially under aerobic conditions with glucose, ammonium nitrate, yeast extract, and potassium phosphate. In the control samples, there was a slight increase in carbon dioxide due to abiotic reactions, but no nitrous oxide was detected. In amended samples, the concentration of both carbon dioxide and nitrous oxide increased.

3.3.2.2 ANAEROBIC GLUCOSE METABOLISM

Mixed inoculum incubated anaerobically with glucose, ammonium nitrate, yeast extract, and potassium phosphate showed little activity (Table 3). There was no significant production of carbon dioxide in amended samples. The reason for the lack of anaerobic metabolism of glucose in these samples is not known.

Table 1. Bacterial Populations in Nash Draw and G-Seep Samples

Brine Source	Number of Cells/mL
Nash Draw	
Surprise Springs	5.5×10^6
Laguna Cinco	6.8×10^6
Lindsey Lake	7.0×10^6
Laguna Tres South	9.0×10^6
Laguna Quatro	1.0×10^7
WIPP Underground Workings	
G-Seep #9	7.2×10^4
G-Seep #23	3.4×10^6

Table 2. Aerobic glucose metabolism by mixed inoculum.

Treatment*	Incubation Time (Days) 48 Gas Produced**			83 Gas Produced**			147 Gas Produced**		
	Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	Total (ml)	CO_2 (µmoles)	N_2O (µmoles)
Control (n=2) [Formalin treated]	0.80 ± 0.10	14.0 ± 0.6	nd	1.31 ± 0.57	15.8 ± 0.2	nd	0.79 ± 0.60	20.1 ± 0.1	nd
Amended (n=4)	0.20 ± 0.20	76.9 ± 6.2	7.20 ± 4.58	0.83 ± 0.48	83.0 ± 15.3	8.75 ± 6.14	0.55 ± 0.43	80.4 ± 14.8	8.27 ± 5.71

* Each sample contained 125 µmoles of ammonium nitrate, 278 µmoles of glucose, 5 mg yeast extract, and 10 mg potassium phosphate
** Dissolved gas concentration not included

Table 3. Anaerobic Glucose Metabolism by Mixed Inoculum.

Treatment*	Incubation Time (Days) 48 Gas Produced**			83 Gas Produced**			147 Gas Produced**		
	Total (ml)	CO_2 (μmoles)	N_2O (μmoles)	Total (ml)	CO_2 (μmoles)	N_2O (μmoles)	Total (ml)	CO_2 (μmoles)	N_2O (μmoles)
Control (n=2) [Formalin treated]	0.60 ± 0.50	12.6 ± 0.3	nd	1.03 ± 0.23	13.5 ± 0.2	nd	0.13 ± 0.14	16.2 ± 0.1	nd
Amended (n=4)	nd	5.6 ± 0.15	nd	0.34 ± 0.20	7.72 ± 0.18	0.478 ± 0.030	-0.12 ± 0.12	8.00 ± 0.20	2.32 ± 1.59

* Each sample contained 125 μmoles of ammonium nitrate, 278 μmoles of glucose, 5 mg yeast extract, and 10 mg potassium phosphate
** Dissolved gas concentration not included
nd = not detected

3.3.2.3 CELLULOSE DEGRADATION

3.3.2.3.1 Aerobic

Table 4 shows cellulose degradation in samples incubated initially under aerobic conditions with filter paper, ammonium nitrate, yeast extract, and potassium phosphate. Control samples showed no activity. A significant increase in carbon dioxide was observed after 83 days in amended samples. One sample produced 136 μmol of carbon dioxide, and the pressure increased to 4.47 psi. The paper in the bottle disintergrated and dissolved. Blackening of specific samples was noted after 147 days, indicative of sulfate reduction.

3.3.2.3.2 Anaerobic

Samples incubated anaerobically with filter paper, ammonium nitrate, yeast extract, and potassium phosphate showed a significant increase in activity after 48 days (Table 5). Nitrous oxide was detected in amended samples, but not in the controls. An increase in carbon dioxide was observed after 83 days. There was a large variation in gas production of anaerobic samples; one sample produced 103 μmol of carbon dioxide and the pressure reached 5.12 psi. The filter paper in this sample also disintegrated.

3.3.2.3.3 Cellulose Degradation in the Presence of Excess Nitrate

Mixed inoculum incubated anaerobically with filter paper, ammonium nitrate, yeast extract, potassium phosphate, and excess nitrate produced less nitrous oxide than the succinate-amended samples (Table 6). Only 20% of the nitrate was converted to nitrous oxide in the samples with acetylene. Carbon dioxide production was not significant until 147 days.

Table 4. Cellulose degradation by mixed inoculum under aerobic conditions.

Treatment*	Incubation Time (Days)								
	48			83			147		
	Gas Produced**			Gas Produced**			Gas Produced**		
	Total (ml)	CO_2 (μmoles)	N_2O (μmoles)	Total (ml)	CO_2 (μmoles)	N_2O (μmoles)	Total (ml)	CO_2 (μmoles)	N_2O (μmoles)
Control (n=2) [Formalin treated]	0.90 ± 0.20	10.9 ± 0.5	nd	1.65 ± 0.49	12.7 ± 0.1	nd	1.00 ± 0.43	14.7 ± 0.0	nd
Amended (n=4)**	nd	32.0 ± 1.9	7.29 ± 1.84	0.95 ± 0.61	57.1 ± 22.8	4.12 ± 1.38	nd	63.9 ± 20.7	5.97 ± 2.12

* Each sample contained 125 μmoles of ammonium nitrate, 0.5 grams of filter paper, 5 mg yeast extract, and 10 mg potassium phosphate

** Dissolved gas concentration not included

*** Samples exhibited disintegration of the filter paper at 83 days

nd = not detected

Table 5. Cellulose Degradation by Mixed Inoculum Under Anaerobic Conditions.

Treatment*	Incubation Time (Days) 48 Gas Produced**			83 Gas Produced**			147 Gas Produced**		
	Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	Total (ml)	CO_2 (µmoles)	N_2O (µmoles)
Control (n=2) [Formalin treated]	0.60 ± 0.00	11.3 ± 0.1	nd	1.02 ± 0.22	12.5 ± 0	nd	0.17 ± 0.17	14.3 ± 0.0	nd
Amended (n=4)									
1	nd	8.85	9.29	0.12	10.7	5.79	0.05	13.1	nd
2***	nd	6.83	10.7	3.48	65.0	nd	1.90	95.6	nd
3***	nd	9.12	nd	3.76	103	nd	0.77	90.8	nd
4***	nd	9.73	9.43	2.18	53.0	nd	3.81	105	nd
Mean	nd	8.63 ± 0.54	7.36 ± 2.14	2.39 ± 0.72	57.9 ± 16.5	1.45 ± 1.25	1.63 ± 0.71	76.1 ± 18.4	nd

* Each sample contained 125 µmoles of ammonium nitrate, 0.5 grams of filter paper, 5 mg yeast extract, and 10 mg potassium phosphate

** Dissolved gas concentration not included

*** At 83 days, samples exhibited disintegration of filter paper

nd = not detected

Table 6. Cellulose Degradation by Mixed Inoculum in the Presence of Excess Nitrate.

Treatment*	Incubation Time (Days) 48 Gas Produced**			83 Gas Produced**			147 Gas Produced**		
	Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	Total (ml)	CO_2 (µmoles)	N_2O (µmoles)
Control(n=2 [Formalin treated]									
(w/acetyl.)	nd	8.93	nd	1.03	11.9	nd	0.73	12.7	nd
(w/o acetyl.)	nd	9.90	nd	0.24	10.9	nd	-0.44	12.0	nd
Amended (n=4)									
(w/acetyl., n=2)	nd	5.24 ± 0.40	23.6 ± 1.2	0.38 ± 0.27	20.3 ± 11.4	19.5 ± 2.1	1.39 ± 1.97	56.7 ± 36.2	14.4 ± 1.7
(w/o acetyl., n=2)	nd	8.00 ± 0.95	5.59 ± 4.00	0.06 ± 0.02	8.13 ± 0.41	4.94 ± 0.78	3.62 ± 0.88	78.0 ± 5.2	nd

* Each sample contained 224 µmoles of nitrate, 0.5 grams of filter paper, 5 mg yeast extract, and 10 mg potassium phosphate
** Dissolved gas concentration not included
nd = not detected

Cellulose degradation by mixed inoculum was observed in samples incubated under aerobic and anaerobic conditions and in the presence of excess nitrate. Disintegration of the filter paper in aerobic and anaerobic samples was noted after 83 days, indicating cellulose degradation. Analysis of these samples showed an increase in total gas, carbon dioxide, and nitrous-oxide production (Tables 4 and 5). The filter paper exhibited areas of thinning and clearing at 83 days in samples containing excess nitrate. At 147 days, the filter paper had fully disintegrated and carbon dioxide content had increased (Table 6). Aerobic samples containing cellulose showed little increase in carbon dioxide at 147 days; one sample turned black, possibly indicating the onset of sulfate reduction. This sample was checked after 220 days and the presence of hydrogen sulfide was confirmed by gas chromatography. Anaerobic samples also produced hydrogen sulfide at 147 days, and one sample showed blackening (Sample 2, Table 5).

3.3.2.4 DENITRIFICATION

Mixed inoculum samples incubated anaerobically with succinate, ammonium nitrate, yeast extract, potassium phosphate, and excess nitrate exhibited denitrification activity. Complete conversion of nitrate (224 μmol) to nitrous oxide (129 μmol) was noted in the presence of acetylene after 48 days of incubation (Table 7). The accumulation of nitrous oxide in amended samples without acetylene was much less than in the samples containing acetylene, indicating that nitrous oxide was converted to nitrogen. Control samples showed no activity. Additional studies on denitrification by WIPP sediment slurry brine and an axenic culture isolated from the brine are described next.

3.3.3 Denitrification Studies

3.3.3.1 DENITRIFICATION IN SEDIMENT

Microbial denitrification was analyzed in freshly collected sediment and stored sediment. Nitrous oxide was both being produced and converted to N_2 at the same time (acetylene was

Table 7. Denitrification Activity by Mixed Inoculum.

Treatment*	Incubation Time (Days) 48 Gas Produced**			83 Gas Produced**			147 Gas Produced**		
	Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	Total (ml)	CO_2 (µmoles)	N_2O (µmoles)	Total (ml)	CO_2 (µmoles)	N_2O (µmoles)
Control(n=2 [Formalin treated]									
(w/acetyl.)	nd	8.93	nd	1.37	10.2	nd	1.08	11.8	nd
(w/o acetyl.)	nd	8.26	nd	nd	11.5	nd	nd	12.9	nd
Amended (n=4)									
(w/acetyl., n=2)	nd	3.43 ± 0.24	129 ± 2	0.50 ± 0.20	6.41 ± 0.05	114 ± 5	-0.12 ± 0.24	na	na
(w/o acetyl., n=2)	nd	51.0 ± 36.1	6.97 ± 2.12	1.07 ± 0.20	30.4 ± 21.5	12.1 ± 2.0	1.01 ± 0.39	na	nd

* Each sample contained 224 µmoles of nitrate, 185 µmoles of succinate, 5 mg yeast extract, and 10 mg potassium phosphate

** Dissolved gas concentration not included

nd = not detected

na = not analyzed

not added to the samples) as shown in Figures 4A and 4B. The nitrous oxide concentrations reported in these studies do not include N_2O dissolved in the brine solution. Nitrous oxide was not detected in the control sample, which had been treated with formaldehyde. In unamended samples and samples amended with succinate, ~5 nmol of N_2O was detected at about 45 hours of incubation, and N_2O was not detected in the headspace thereafter. In samples amended with nitrate, the N_2O concentration reached its maximum (30 nmol gdw^{-1}) at about 200 hours and then disappeared rapidly by conversion to N_2 (Figure 4A). In the succinate-and nitrate-amended samples, much less N_2O was detected than in the nitrate-amended samples. Freshly collected samples showed little accumulation of N_2O in the headspace (Figure 4B), most probably due to rapid and complete denitrification.

The rates of denitrification in the unamended and amended (succinate and nitrate) sediment samples were determined by the acetylene blockage technique. Addition of acetylene inhibits the reduction of N_2O to N_2 and allows N_2O to accumulate in the headspace which is analyzed by gas chromatography. In Figures 5A and 5B and Table 8a and 8b, denitrification in stored (2 months) and freshly collected (assayed within 48 hours) samples are compared. In the stored samples, Figure 5A, denitrifying activity initially in the unamended sample was minimal. After a lag phase, denitrification proceeded at about 0.14 nmol N_2O gdw^{-1} h^{-1}. The rate is presented in Table 9a. The sediment contained sufficient indigenous carbon and nitrate to produce 23 nmoles of N_2O gdw^{-1}. Denitrification in the stored, carbon- amended samples was similar to that in the unamended samples (0.22 nmol N_2O gdw^{-1} h^{-1}). Denitrification activity in the stored sample was stimulated by the addition of nitrate. After an initial lag, the rate of denitrification was 1.36 nmol nitrous oxide gdw^{-1} h^{-1}.

A stimulatory effect on the rate and extent of denitrification was seen in both stored and fresh samples when carbon and nitrate were added. Denitrification proceeded at 1.78 nmol N_2O gdw^{-1} h^{-1}, finally producing 209 nmol nitrous oxide gdw^{-1} in the stored sample, translating to denitrification of 80% of the added nitrate. In the freshly collected sediment, without added carbon or nitrate, 205 nmoles of nitrous oxide gdw^{-1} were produced at a rate

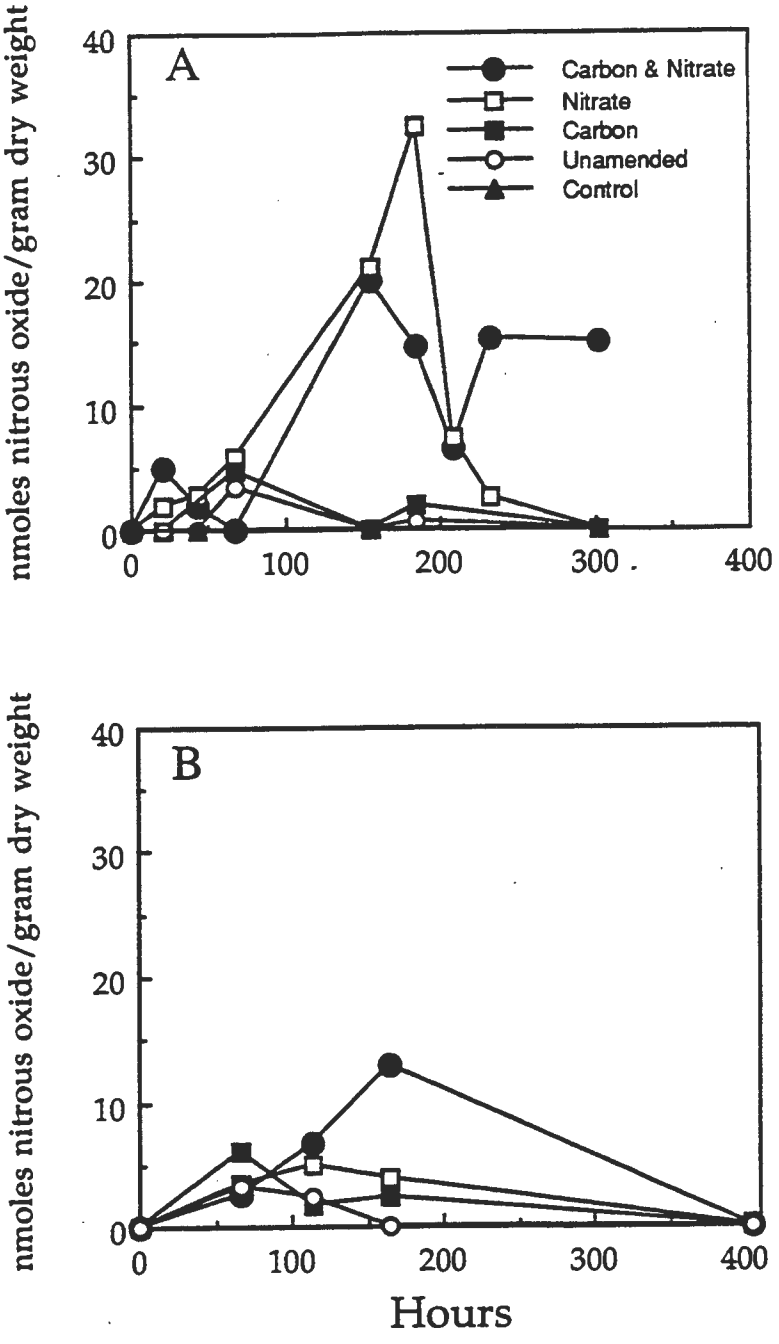

Figure 4. Denitrification by Laguna Cinco sediment; (A) stored sample. (B) fresh sample

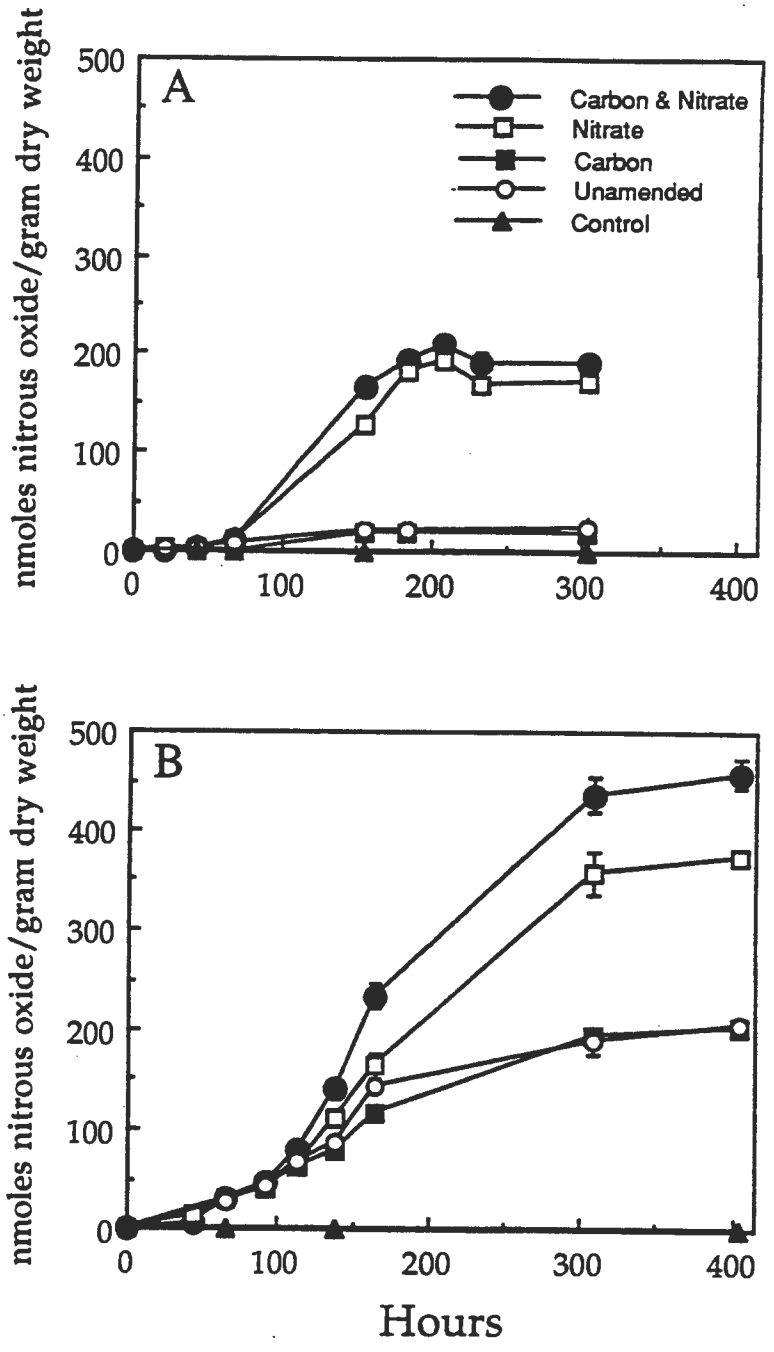

Figure 5. Denitrification determined by the acetylene blockage technique in (A) stored sample, (B) fresh sample

Table 8a. Denitrification in Laguna Cinco Sediment (Stored 2 Months)

Time	Control*	Addition: None	Carbon	Nitrate	Carbon & Nitrate
(Hours)	nmol nitrous oxide**/sample				
0	nd	nd	nd	nd	nd
21		1.96 ± 0.58	2.16	1.50 ± 0.11	0.514
42.5	nd	3.44 ± 0.64	na	3.21	3.86 ± 0.22
67		8.16	0.00 ± 0.00	9.64 ± 0.74	9.64
155	nd	20.7 ± 1.4	19.6 ± 0.1	129 ± 5	166 ± 6
183		22.3 ± 3.0	19.4 ± 0.9	183 ± 0	194 ± 2
207		na	na	192 ± 0	209 ± 2
231		na	na	168 ± 4	191 ± 9
303	nd	23.3 ± 1.5	18.3 ± 0.2	171 ± 8	191 ± 5

Table 8b. Denitrification in Laguna Cinco Sediment (Assayed Within 48 Hours)

Time	Control*	Addition: None	Carbon	Nitrate	Carbon & Nitrate
(Hours)	nmol nitrous oxide**/sample				
0	nd	nd	nd	nd	nd
45		na	na	13.6 ± 0.1	5.58 ± 3.94
66	nd	26.5 ± 1.1	29.0 ± 1.0	30.5	30.5
91.5		43.0 ± 0.3	44.2 ± 4.6	39.4 ± 1.2	45.2 ± 0.5
114	nd	68.6 ± 3.1	61.6 ± 1.8	65.6 ± 2.1	79.6 ± 1.2
138		86.0 ± 3.7	78.1 ± 1.5	110 ± 3	141 ± 5
165		142 ± 5	115 ± 3	164 ± 12	233 ± 12
309		188 ± 11	194 ± 2	357 ± 21	436 ± 18
405	nd	205 ± 1	202 ± 8	372 ± 3	458 ± 15

* Formalin treated samples
** Dissolved gas concentration not included
nd = none detected
na = not analyzed

Table 9a. Denitrification Rate (Stored Sample)*

Addition	Rate (nmol nitrous oxide/g dry weight/hour)
None (Unamended)	0.14
Carbon	0.22
Nitrate	1.36
Carbon and Nitrate	1.78

*Rate after lag phase, from 67 to 155 hours (see Table 8a).

Table 9b. Denitrification Rate (Fresh Sample)*

Addition	Rate (nmol nitrous oxide/g dry weight/hour)
None (Unamended)	1.17
Carbon	0.87
Nitrate	1.93
Carbon and Nitrate	3.00

*Rate after lag phase, from 66 to 165 hours (see Table 8b).

of 1.44 nmol nitrous oxide gdw^{-1} h^{-1}, as shown in Table 9b. These samples are not carbon-limited. Addition of nitrate, however, increased N_2O production, suggesting that these samples are nitrate-limited. In the absence of carbon or nitrate limitations in the freshly collected sediment, denitrification proceeded at 3.00 nmol N_2O gdw^{-1} h^{-1}, and resulted in the production of 458 nmol nitrous oxide gdw^{-1} (Table 8b); all of the total nitrate present was reduced.

These experiments show that microorganisms present in mud from Laguna Cinco denitrified 70-80% of the added nitrate in nitrate-amended samples and 80%-100% of the nitrate in carbon and nitrate samples. We added 540 nmol nitrate gdw^{-1} to each sample; therefore, complete conversion of the nitrate to nitrous oxide should yield 270 nmol N_2O gdw^{-1}. About 70% of the added nitrate was reduced to nitrous oxide in the stored sample, or 192 nmoles N_2O gdw^{-1} was produced. Freshly collected sediment with added nitrate produced 372 nmoles N_2O gdw^{-1}; 81% of the total nitrate present was reduced. This sediment contained a large quantity of indigenous nitrate.

Denitrification in unamended samples provides information about the nutrient conditions in the sediment. If all the available indigenous nitrate was converted to nitrous oxide in the carbon-amended sample, then the stored sediment contained about 40 nmoles of nitrate gdw^{-1}, and the fresh sediment contained 410 nmol gdw^{-1}. Similar conversions of nitrate to nitrous oxide using a pure culture were used to determine sub-ppb concentrations of nitrate in lake waters (Christensen and Tiedje, 1988). Thus, the assay can be used not only to detect the presence and activities of denitrifying organisms, but also to detect easily metabolizable low-molecular-weight organic carbon compounds in the environment (Francis et al., 1989).

The presence of metabolizable carbon and nitrogen compounds in the WIPP surficial environments has important implications. For example, a steady mix of microbial populations can be actively maintained when presented with an adequate supply of a

limiting nutrient. From the standpoint of the long-term experiment, we have shown, in part, that the organisms are active in the proposed inoculum.

The results also show that active denitrification under anaerobic conditions occurred in Laguna Cinco mud collected in August 1991 and stored for two months, and in mud collected in December 1991, and assayed within 48 hours. Therefore, the stored and fresh samples contain viable organisms that can be used as an inoculum for the long-term experiment.

3.3.3.2 DENITRIFICATION IN G-SEEP

Figure 6 and Table 10 show denitrification in G-Seep brine. In the carbon and nitrogen amended samples ~ 84% of the added nitrate (150 nmoles) was converted to N_2O (62.7 nmoles) after two months of incubation. The dissolved N_2O in the brine was not determined; hence, the N_2O values reported are not corrected for N_2 solubility. Lack of N_2O production in the unamended and carbon amended samples suggests that G-Seep brine is nitrate-limited. However, in the nitrate-amended samples, 45% of the added nitrate was converted to N_2O, indicating metabolizable carbon is present which eventually became limiting. These results also suggest that the microbes in the brine were able to readily metabolize the added carbon and nitrate via denitrification.

3.3.3.3 DENITRIFICATION BY AN AXENIC PURE CULTURE

A pure culture of a denitrifying bacterium was isolated from the sediment slurry sample during the initial denitrification experiments. The isolate was grown in the following medium: sodium succinate, 5 g; potassium nitrate, 1 g; yeast extract, 0.5 g; WIPP salt (20% w/v), 1000 mL; pH 6.85. The isolate, designated as BWFG-1, was a gram-negative rod, facultative anaerobe, and grew rapidly within 48 hours in the liquid medium. On solid medium, the culture produced circular, convex, light-orange colonies with entire margins.

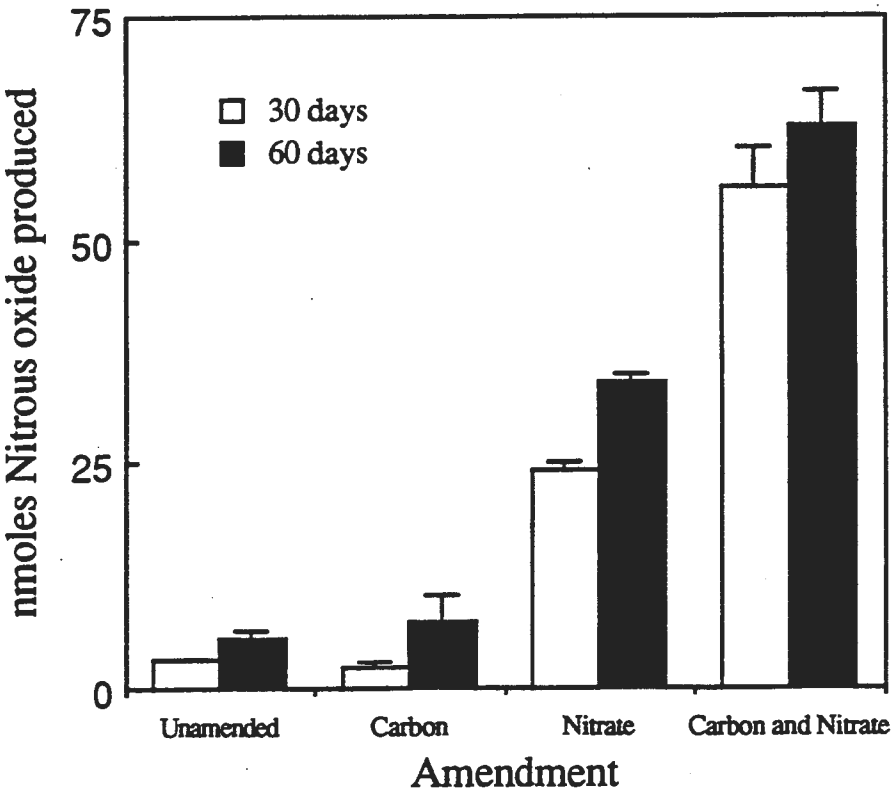

Figure 6. Denitrification in G-Seep Brine. [In C&N amended samples, 84% of the added nitrate was converted to nitrous oxide]

Table 10. Denitrification in G-Seep Brine

		Amendment*			
Time	Control*	Unamended	Carbon	Nitrate	Carbon & Nitrate
(Days)	---nmoles nitrous oxide***/sample---				
0	nd	nd	nd	nd	nd
3.25	nd	nd	nd	nd	nd
30	nd	3.30 ± 0.01	2.53 ± 0.43	24.2 ± 0.8	55.9 ± 4.4
60	nd	5.72 ± 0.72	7.58 ± 2.98	34.0 ± 0.9	62.7 ± 4.0

Samples injected with acetylene to accumulate nitrous oxide
* Amendment: Carbon = 1.5 umol succinate, Nitrate = 150 nmol
** Formalin treated samples
*** Dissolved gas concentration not included
nd = none detected

BWFG-1 is an archaebacterium. This was confirmed by hybridization with fluorescently labeled oligodeoxynucleotide probes complementary to the 16S ribosomal RNA segment specific for archaebacteria (DeLong et al., 1989). Extreme halophiles were previously described in the literature as being archaebacteria, placing them in a distinct phylogenetic group of organisms that contains other genera from extreme environments, such as methanogens, thermoacidophiles, and alkalophiles (Ross et al., 1981).

The rate of denitrification by BWFG-1 was determined by adding 2.5 mL of a 24 h culture to 40 mL of medium in the presence of acetylene. Control samples included uninoculated medium, inoculated samples treated with 0.5% v/v formaldehyde, and inoculated samples without acetylene. Triplicate samples were incubated anaerobically at 30°C. The number of bacterial cells were counted using the DAPI method.

Production of nitrous oxide by the pure culture is shown in Figure 7 and Table 11. The bacterium denitrified nitrate at a rate 2.5 μmol h^{-1}. About 72% of the added nitrate (392 μmol) was converted to N_2O (142 μmol) in about three days; these N_2O values do not include the amount of N_2O dissolved in the growth medium. There was no accumulation of nitrous oxide in samples incubated without acetylene, indicating complete reduction of nitrate to N_2. In Figure 8, the direct counts of the bacteria during the course of denitrification are presented. A marked increase in the number of cells corresponding to nitrous oxide production was observed. The pH of the growth medium increased from 6.85 to 8.00 after three days, and turbidity measured spectrophotometrically at 600 nm was 0.08 at 0h, 0.58 at 29h, and 0.80 at 50h.

3.4 Summary, Short-Term Experiments

1. Direct microscopic examination of brine from Nash Draw lakes and from G-Seep showed that between 10^4 to 10^7 cells/mL bacteria are present.

2. Cellulose was degraded by a mixed culture derived from samples consisting of Nash Draw sediment slurry, salt crystals, and G-Seep brine in the presence of added nutrients (nitrate, phosphate, and yeast extract). Cellulose degradation was confirmed by an increase in carbon dioxide production and disintegration of filter paper.

3. Storage of sediment and lake water at 4°C for about two months did not significantly affect the activity of microbes in the samples.

4. The denitrification assay is a useful method to rapidly determine the activity of dentrifying microbes in WIPP samples. The assay also confirmed the presence of metabolizable carbon in the sediment and in WIPP brine.

5. Denitrifiers were detected in G-Seep, although their source was not identified.

6. An axenic culture of archaebacteria was isolated from the WIPP site and denitrified nitrate at a rate of 2.5 μmol h^{-1}. The characteristics and growth rate of this culture have been elucidated for future studies to examine the influence of environmental variables on specific microbial processes in the WIPP repository.

7. Short-term experiments have provided useful information on microbial activity under accelerated test conditions that are relevant to the WIPP repository; further work will include examination of the other anaerobic processes such as fermentation, sulfate reduction, and methanogenesis.

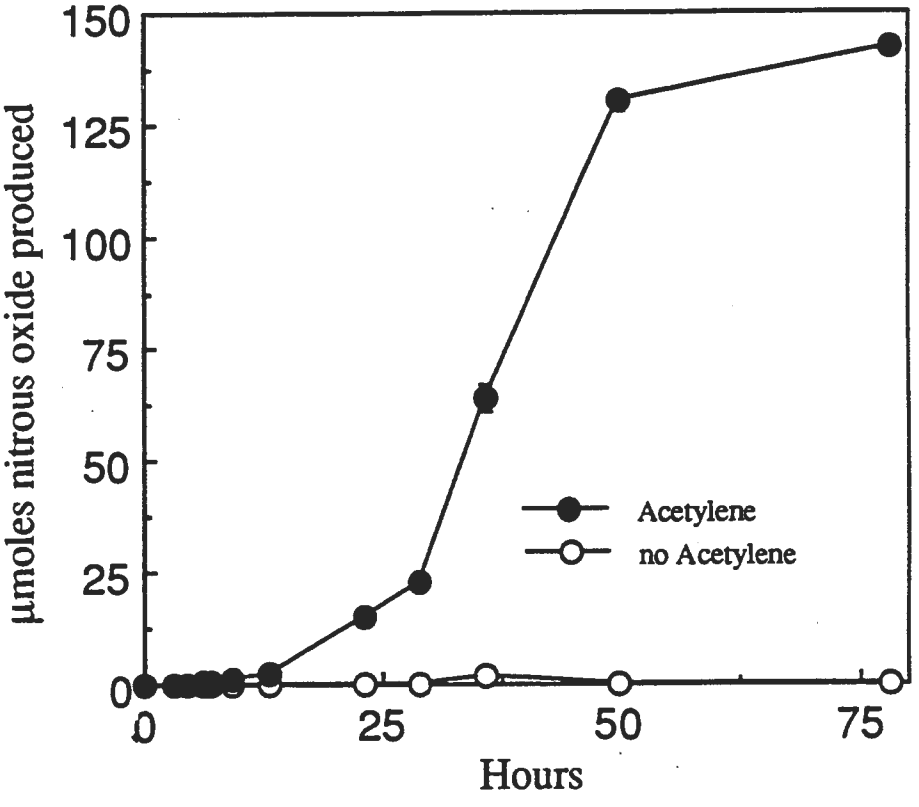

Figure 7. Denitrification by a pure culture of bacteria isolated from the WIPP site. [72% of added nitrate was converted to nitrous oxide at a rate of 2.5 µmoles/h]

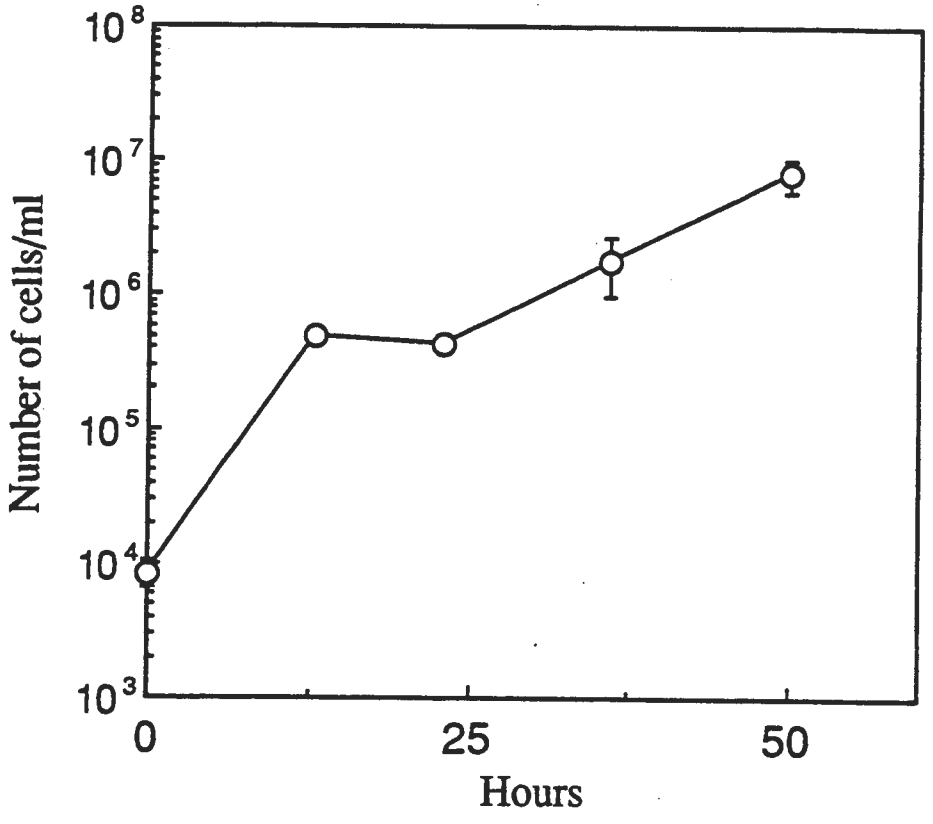

Figure 8. Growth of denitrifying bacteria.

Table 11. Denitrification by a Pure Culture Isolated from the WIPP Environment: Nitrous Oxide Production Over Time

Time (Hours)	Inoculated (w/o acetylene)	Inoculated (w/ acetlyene)	Inoc.* (w/o acet.)	Inoc.* (w/acet.)	Uninoc. (w/o acet.)	Uninoc. (w/acet.)
	----------µmoles nitrous oxide**/sample----------					
0	nd	nd	nd	nd	nd	nd
3	0.001 ± 0.001	0.011 ± 0.034	nd	nd	nd	nd
4.5	0.007 ± 0.002	0.245 ± 0.081	nd	nd	nd	nd
6	0.009 ± 0.002	0.434 ± 0.090	nd	nd	nd	nd
7	0.010 ± 0.003	0.563 ± 0.016	nd	nd	nd	nd
9.25	0.009 ± 0.003	0.990 ± 0.027	nd	nd	nd	nd
13	0.014 ± 0.003	2.33 ± 0.03	nd	nd	nd	nd
23	0.019 ± 0.003	15.2 ± 0.9	nd	nd	nd	nd
29	0.187 ± 0.084	23.0 ± 0.5	nd	nd	nd	nd
36	1.50 ± 0.38	63.8 ± 2.6	nd	nd	nd	nd
50	0.086 ± 0.059	130 ± 2	nd	nd	nd	nd
78	0.140 ± 0.030	142*** ± 1	nd	nd	nd	nd

Defined culture medium (per sample): 740 umoles succinate, 392 umoles nitrate, 20% w/v WIPP salt.
* = Sample treated with formalin (0.5%)
** = Dissolved gas concentration not included
*** = 72% of nitrate added converted to nitrous oxide
ND = none detected

4.0 LONG-TERM EXPERIMENTS

4.1 Objective

The objective of the long-term study is to determine the rate and extent of gas generation over the long term (>2 years) from cellulose biodegradation under humid and inundated conditions, in the presence and absence of added nutrients.

4.2 Rationale

The TRU waste that will be placed in the WIPP repository contains an average of about 10 kg of cellulosic material per drum, approximately 70% of which is paper (Brush 1990). Initially, the repository will be ventilated, but the addition of backfill (salt, or bentonite/salt mixture to fill void spaces around waste containers) will seal the drums inside the disposal rooms. Initially, the repository will also be dry, but after sealing, humid conditions will develop. The ambient humidity is expected to be 18 to 27 g/m^3 (about 74% relative humidity, RH), and the temperature about 30°C (Brush, 1990). Microenvironments of condensed liquid brine may exist under humid conditions. Diffusion of water vapor through high-efficiency particulate (HEPA) air filters on waste containers will result in humid conditions inside the containers. Eventually, corrosion or rupturing of the containers due to salt creep-room closure will expose the waste to salt and backfill. Process sludges from other breached waste containers are expected to be leached by the brine. This is presumed to be the major source of nitrate and phosphate (nutrients) in the repository. The accumulation of potentially intruding brines from the surrounding Salado Formation will most likely begin after sealing the rooms, which will inundate them. In the event of potential, inadvertent human intrusion, fluids may also seep in from the Castille Formation into the Salado Formation. The atmosphere inside the disposal environment will become anaerobic in the short-term (months to years) due to consumption of oxygen by corrosion, radiolysis, and microbial processes acting on the waste materials. Microenvironments of trapped air that contain oxygen will continue to exist after sealing. Radiolysis of organic

wastes will deplete oxygen, whereas radiolysis of nitrate-bearing sludges will release oxygen. Radiolysis of brines may also produce some oxygen.

A succession of microbial processes will occur under the changing environmental conditions inside the repository. Environment changes from aerobic to anaerobic, humid to inundated (and possibly back to humid), and asaline to saline will affect the activities of (i) microbes initially present in the waste, and (ii) resident and indigenous halotolerant or halophilic bacteria in the brine and salt. To examine the influences of various microbial processes on gas generation, samples were treated to simulate the following scenarios.

4.2.1 Aerobic (Sealed) Treatments

During the early stages of waste emplacement, the environment will be aerobic but will become anaerobic over time after closure because of corrosion, aerobic microbial activity, and radiolytic processes. In these long-term experiments, the cellulose samples will be placed in serum bottles, sealed with air, and incubated. The conditions will be initially aerobic and become anaerobic with time due to consumption of oxygen by aerobes, thus paving the way for anaerobic microbial activity.

4.2.1.1 SCENARIO 1

After emplacement and sealing of waste containers in WIPP disposal rooms, the intact and nearly intact containers will be isolated from backfill and brine. The humidity inside the disposal rooms is expected to be 18 to 27 g/m^3 (about 74% RH), and humidity inside the containers is expected to reach equilibrium with the room environment. The cellulose will be in an asaline, humid, aerobic environment for possibly months, years, or up to a few decades, as water vapor diffuses through the waste drum particulate filters. Microorganisms capable of cellulose degradation and gas production under these conditions will be active probably in an environment with a sub-optimal moisture content.

4.2.1.2 SCENARIO 2

Room closure and corrosion will breach many of the containers and expose the waste material to backfill, salt, and brine. The cellulose is expected to contact the salt and backfill material, and microbial degradation of the cellulose is expected to occur under saline, humid conditions.

4.2.1.3 SCENARIO 3

Influx of intruding brines from the Salado Formation, capillary rise through the backfill, and dissolution of brine will all tend to inundate some portion or all of the disposal rooms with brine. Inundation will accelerate the onset of anoxic conditions as any residual air pockets are flooded. Process sludge TRU wastes contain significant quantities of nitrate and lesser quantities of phosphate. The breach of these sludge containers and inundation by brine will then transport the nitrate and bring nonhalophilic, halotolerant and halophilic microbes into contact with cellulose.

Inundation of the WIPP waste by brine by the above or other processes will accelerate the activities of halophilic and halotelerant microbes. In particular, dentrification activity under microaerophilic and anaerobic conditions could be significant and may contribute to the total quantity and to the proportion of gases produced (N_2, N_2O, and CO_2).

4.2.2 Anaerobic Treatments

At least a portion of the WIPP repository wastes will be anaerobic at the start (within their containers possibly due to radiolysis and microbial action at the initial stages) and remain anaerobic thereafter. Under these conditions, short-term (i.e., operational phase) and long-term degradation of cellulosic waste by anaerobic microorganisms could be significant.

4.2.2.1 SCENARIO 4

Some of the cellulose in the disposal environment may become anaerobic before any significant aerobic microbial activity. Cessation of air flow from closure of the disposal rooms, and oxic corrosion plus radiolysis, may bring about anoxic conditions in a humid environment. If the cellulose is exposed to salt under humid conditions, halotolerant or halophilic microbes that can grow in humid and anoxic environments may be involved in degrading cellulose. With the onset of anoxic conditions, alternate electron acceptors such as nitrate and sulfate will be used by microbes in degrading cellulose and its degradation product intermediates.

4.2.2.2 SCENARIO 5

With the onset of brine intrusion in the disposal rooms, inundation will be more likely to cause anaerobiosis by forcing out any residual trapped air. Cellulose in contact with brine may undergo degradation by halophilic and halotolerant microbes present in the brine and waste. Because of the breaching of the waste containers, it is likely that nitrate originating in the sludges will be transported by the brine. It may come in contact with cellulosic wastes and enhance the degradation of cellulose.

Scenarios 3 and 5 will be examined in the long-term inundated experiment. Scenarios 1, 2 and 4 will be examined in a long-term humid experiment in CY1993. Figures 9 through 12 give the complete treatment matrix for the long-term inundated experiments.

4.3 Materials and Methods

4.3.1 Cellulosics

Simulated TRU cellulosic waste material was composed of four types of paper: (i) filter paper, (ii) white paper towel, (iii) brown paper towel, and (iv) Kimwipes® (lintless tissue

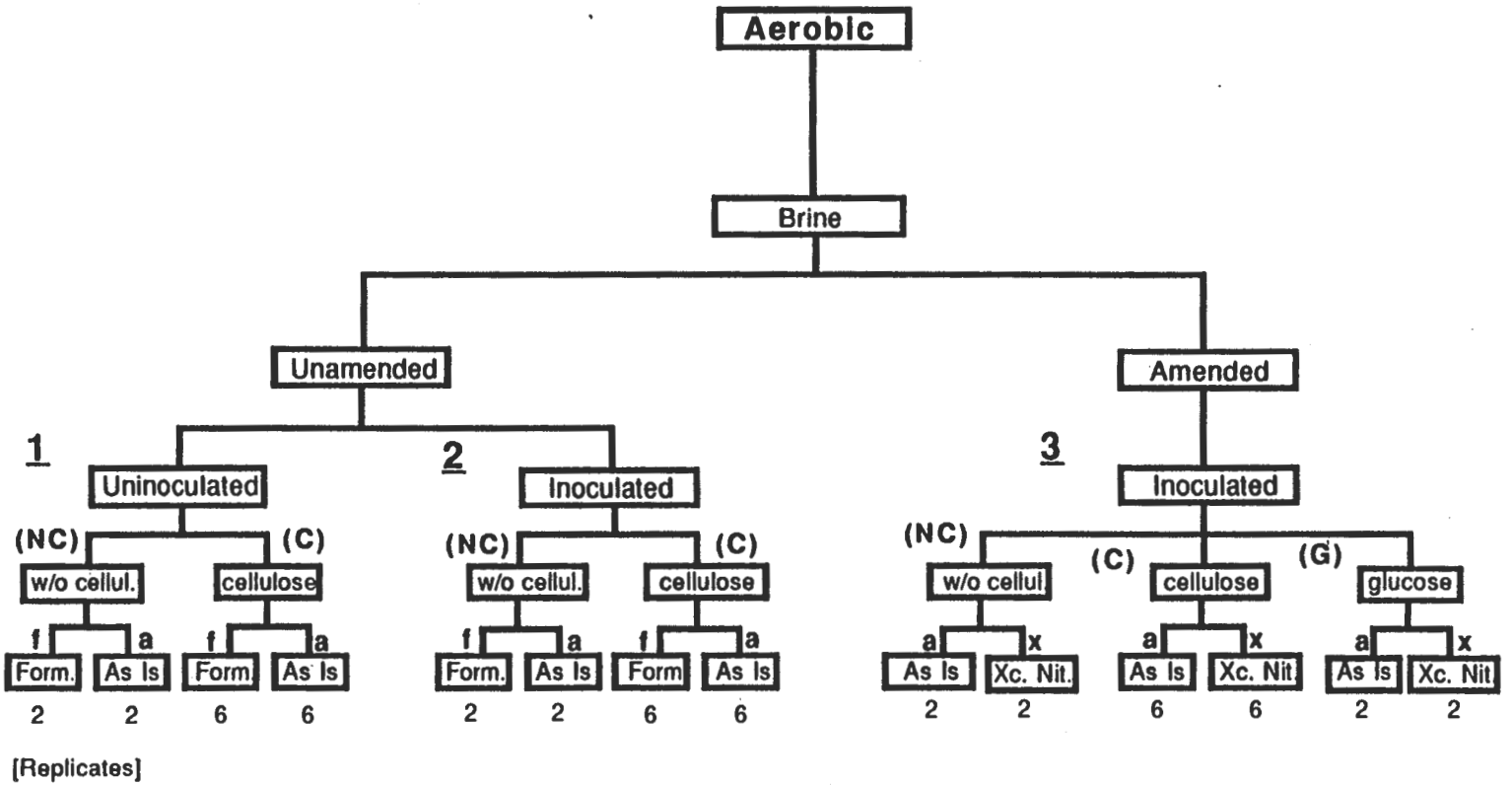

Figure 9. Long-term inundated experiment treatment matrix (aerobic samples).

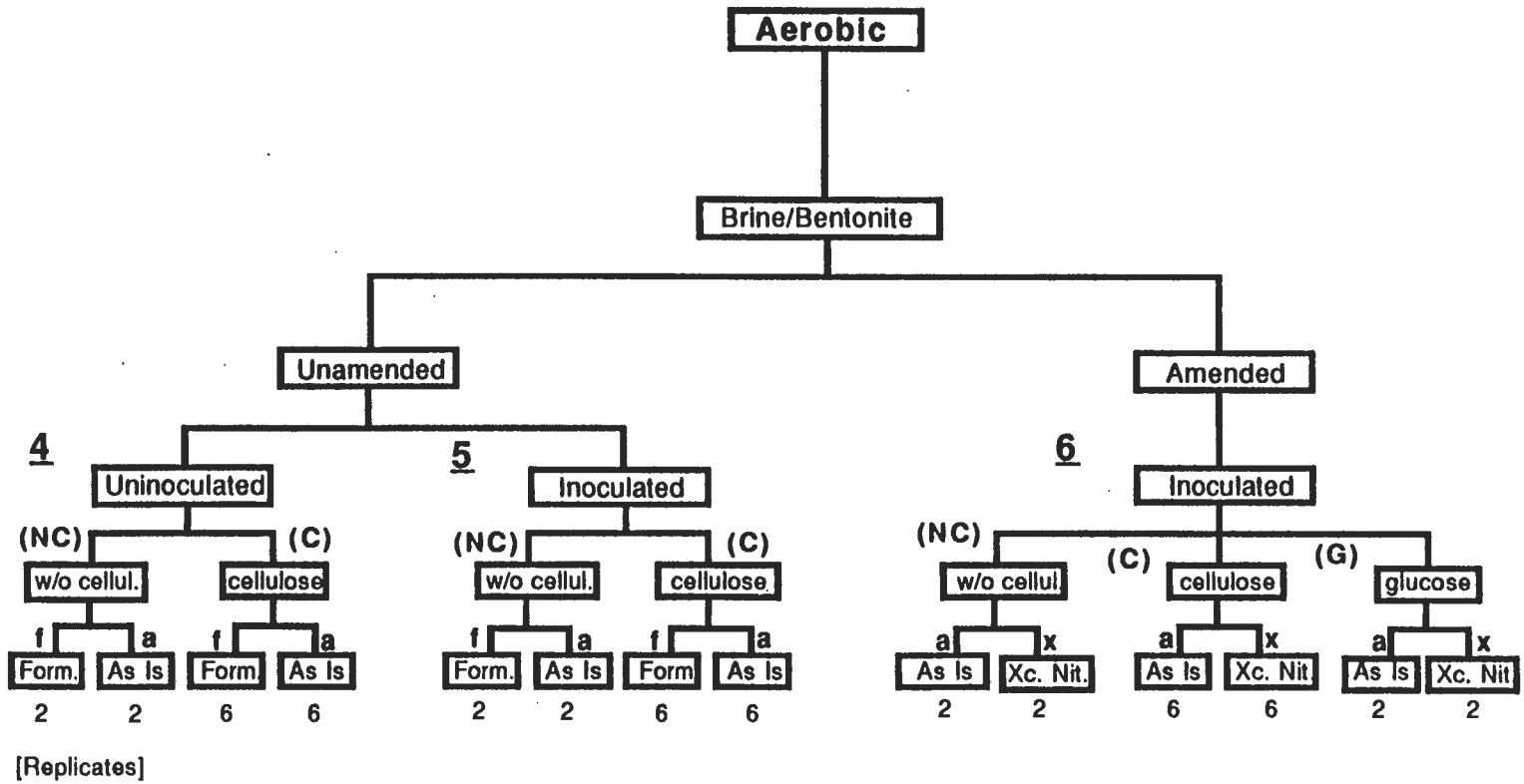

Figure 10. Long-term inundated experiment treatment matrix (aerobic samples containing bentonite).

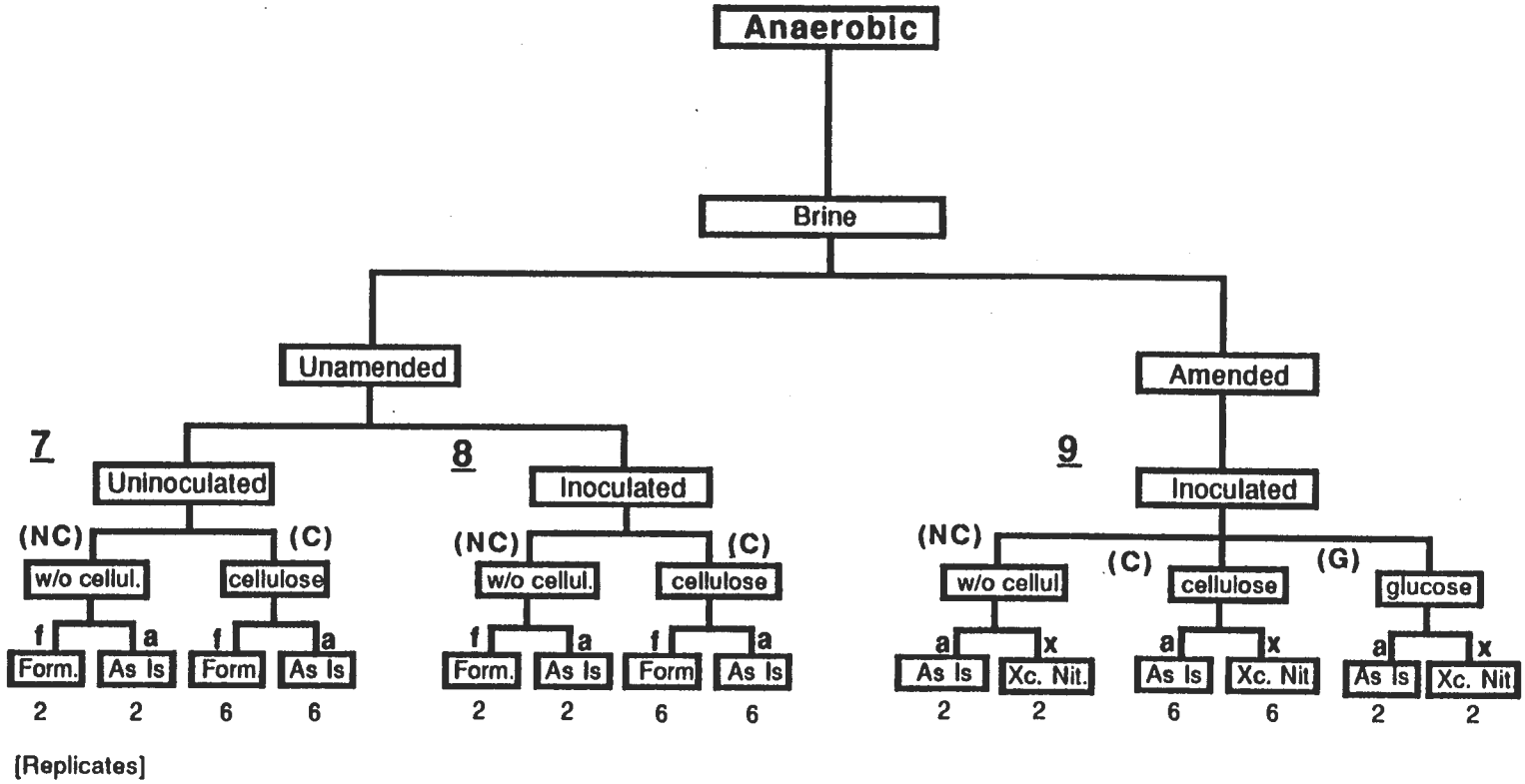

Figure 11. Long-term inundated experiment treatment matrix (anaerobic samples).

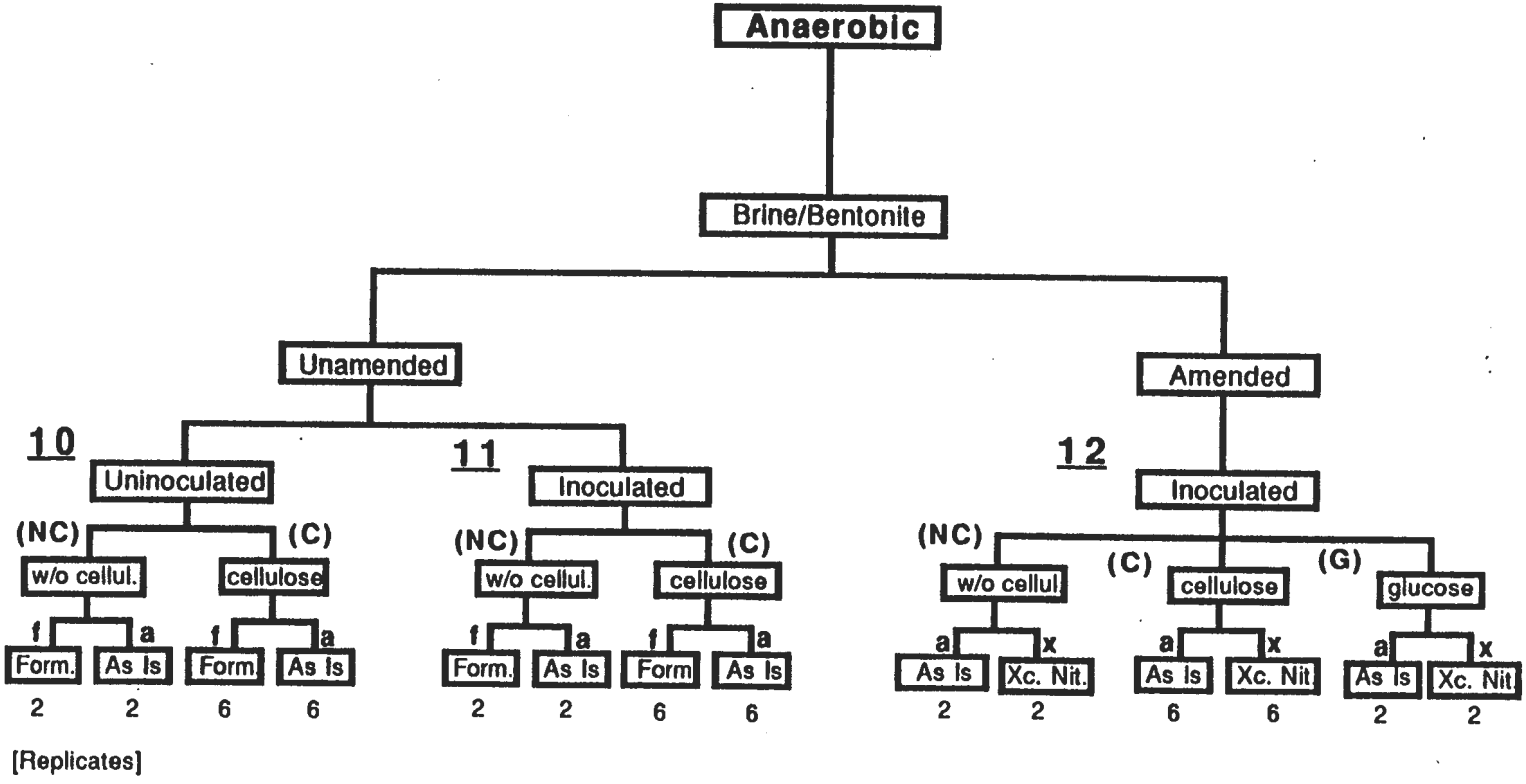

Figure 12. Long-term inundated experiment treatment matrix (anaerobic samples containing bentonite).

wipes). These papers are typical cellulosic wastes from laboratory and process activities. The four paper types were cut into strips in a large paper shredder, and then cut into 1 cm x 1 cm squares.

Samples of shredded paper types, each weighing 1.25 g, were thoroughly mixed and added to 160 mL acid washed (10% HCl), rinsed, sterile (autoclaved at 120°C, 20 psi for 20 min) serum bottles.

4.3.2 WIPP Brine

Fifteen liters of G-Seep #9 brine were provided by SNL and stored at 4°C until use.

4.3.3 Bentonite

Bentonite clay in two one-L containers was provided by SNL. The bentonite was a granular MX-80 Volclay bentonite available from the American Colloid Company of Belle Fourche, SD (Table 12).

4.3.4 Inoculum

The microbial inoculum used in these studies were obtained from the following three sources (Table 13): (i) mud and brine from Nash Draw: collected on December 12, 1991 and stored at 4°C, the mud was stored anoxically in serum bottles, (mud samples were filtered through sterile cotton in a nitrogen-filled glove box to remove large particulates); (ii) brine from the WIPP underground workings: 200 mL of G-Seep were collected on December 12, 1991; and (iii) asaline inoculum from laboratory contamination: 2.5 g of dust containing asaline microorganisms was gathered from laboratories in Bldg. 318 at BNL.

The mud, brine, and dust samples were then mixed together in a sterile beaker in a nitrogen-filled glove box. The total volume of the mixed inoculum was 583 mL. The

Table 12. Composition of Bentonite*.

Chemical Composition	$(NaCa)_{.35}$ $(Al_{1.60}Fe_{.15}Mg_{.25})$ $(Si_{3.90}Al_{.10})$ 0_{10} $(OH)_2$		
Montmorillonite Content	90 Percent		
Typical Chemical Analysis	Silica		63.02% SiO_2
	Alumina		21.08% Al_2O_3
	Iron (Ferric)		3.25% Fe_2O_3
	Iron (Ferrous)		0.35% FeO
	Magnesium		2.67% MgO
	Sodium and Potassium		2.57% Na_2O
	Calcium		0.67% CaO
	Crystal Water		5.64% H_2O
	Trace Elements		0.72%
Exchangeable Ions (Milli-equivalents/ 100 g)	Sodium	55-65	
	Calcium	15-25	
	Magnesium	10-15	
Moisture Content	10% Maximum as Shipped		
pH	8.5 - 10.5		

* Data provided by the American Colloid Company, Skokie, IL.

Table 13. Composition of Mixed Inoculum.

Source	Mud Slurry (mL)	Brine (mL)
Laguna Quatro Mud and Brine	60	40
Laguna Cinco Mud and Brine	35	40
Laguna Tres South Mud and Brine	13	40
Lindsey Lake Mud and Brine	50	40
Surprise Springs Mud and Brine	25	40
G-Seep Brine		200
Total	183	400

activity of the mixed inoculum was examined by incubation under aerobic and anaerobic conditions in the presence of metabolizabled substrate. The results are presented in Appendix E.

4.4 Sample Treatments

The treatments consisted of (a) 100 mL of brine, and (b) 100 mL of brine and 5 g mixed cellulosic papers. The samples were incubated with and without nutrients, which consisted of yeast extract (0.05%), potassium phosphate dibasic (0.1%), and ammonium nitrate (0.1%). Some samples also received excess nitrate as potassium nitrate (0.5%).

4.4.1 Anaerobic Sample Preparation

The serum bottles containing the mixed cellulosic papers were flushed with nitrogen and placed inside an anaerobic, nitrogen-containing glove box for 24 hours before inoculation to remove any trapped air. G-Seep brine (10 L) was removed from storage at 4°C and equilibrated overnight at room temperature. One hundred mL of the brine solutions (with and without nutrients or excess nitrate) were added to sample bottles with and without bentonite containing either no cellulose, cellulose, or glucose. Bentonite (6 g) was added to separate sample bottles inside the glove box to determine its influence on gas production. The samples were gently mixed to distribute the bentonite.

The microbial inoculum prepared from various sources was continually mixed and 4 mL was added to specific samples (3.8% V/V inoculum). The samples were gently mixed (to blend the inoculum) and then capped with butyl rubber stoppers. Control samples received 3 mL of 37% formaldehyde to give a final concentration of 1% formaldehyde.

4.4.2 Aerobic Sample Preparation

Aerobic (sealed) samples were prepared as described above with the following exceptions: 1) brine solutions were not purged with ultra high-purity (UHP) N_2, 2) the mixed inoculum was removed from the glove box; 3) brine was added to the bottles, inoculated, and capped with butyl rubber stoppers outside the glove box, thereby sealing air in the headspace. Appendix C has a detailed description of all the treatments (aerobic and anaerobic) and the number of replicate samples. All samples were placed in a 30 ± 2°C incubator.

4.4.3 Gas Analyses

The headspace gas of select samples was analyzed for total gas production, carbon dioxide, and nitrous oxide at time 0 (January 29, 1992) and thereafter at monthly intervals. Control samples were analyzed less frequently. The methods used for the headspace gas analyses are presented in Appendix B.

5.0 RESULTS AND DISCUSSION

The treatments consist of cellulose samples which were (i) uninoculated, (ii) inoculated with a mixed inoculum, (iii) inoculated and amended with nutrients, (yeast extract (0.05%), potassium phosphate (0.1%), and ammonium nitrate (0.1%)), and (iv) inoculated with nutrients plus excess nitrate (0.5% potassium nitrate).

The results presented for aerobic and anaerobic samples represent the amount of gas produced per gram of cellulose plus or minus 1 standard error of the mean (Figures 13 through 24) . A detailed description of the procedure used to calculate the results are given in Appendix D. Tables 1 through 12 in Appendix D present data on a per sample basis, and Tables 13 through 24 in Appendix D present data on a per gram cellulose basis. Gas production rates on a per gram cellulose per day basis are presented in this section in Table 14, and on a per drum of waste per year basis in Table 15.

5.1 Aerobic Treatments

5.1.1 Total Gas Production

Figure 13 shows the total gas produced in samples incubated with an initial atmosphere of air (aerobic). The formalin-treated control samples showed no increase in total gas production, and, in fact, showed a slight decrease. Likewise, uninoculated and inoculated samples which received no nutrients showed a slight decrease in total gas production (-0.18 mL g^{-1} cellulose and -0.34 mL g^{-1} cellulose respectively (Table 13, Appendix D)). The decrease in total gas may be due, in part, to sampling. A decrease in gas production was more evident in inoculated samples because of oxygen consumption, indicating the start of microbial activity, (oxygen was not analyzed in these samples but is planned for the future). In the nutrient-amended inoculated samples, an initial decrease in gas volume (-0.27 mL g^{-1} cellulose at 45 days) was followed by an increase after 69 days to 0.86 mL g^{-1} cellulose at 200 days at a rate of 0.008 mL g^{-1} cellulose day^{-1}. This rate was calculated from linear slope

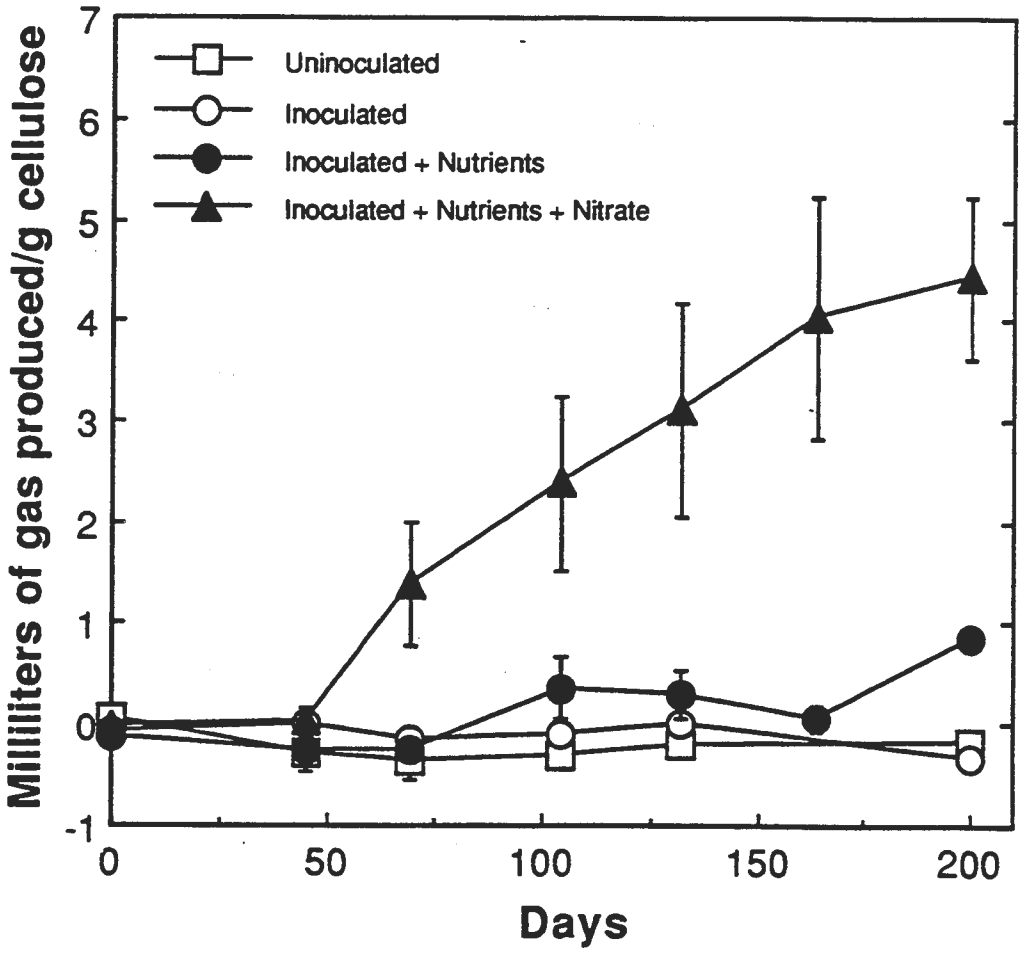

Figure 13. Total gas produced in samples incubated with an initial atmosphere of air.

of gas production from 69 to 200 days. Excess nitrate stimulated the rate of gas production (0.023 mL g^{-1} cellulose day^{-1} after 69 days) resulting in a total of 4.42 mL g^{-1} cellulose at 200 days. This stimulatory effect was also evidenced by the lack of a long lag-phase (see Figure 13) and was a result of the metabolism of dissolved carbon in the presence of nitrate.

Total gas production in aerobic samples containing bentonite is presented in Figure 14. Uninoculated and inoculated samples, with no added nutrients, did not produce gas. Inoculated samples containing nutrients produced 4.38 mL of gas g^{-1} cellulose after 200 days (Table 14, Appendix D), at a rate of 0.028 mL g^{-1} cellulose day^{-1}. In the presence of excess nitrate, the total production increased to 6.07 mL g^{-1} cellulose at 200 days at a rate of 0.034 mL g^{-1} cellulose day^{-1}. Enhanced total gas production was seen in samples containing bentonite, and was apparently due to a combination of abiotic and biotic factors, which are evident upon examining carbon dioxide evolution in the presence of bentonite.

Extrapolation of the gas production rates from mL per g cellulose per day to mol per drum of waste per year is accomplished with the following conversion factors: for an assumed average drum of transuranic waste, with about 10 Kg of cellulosic materials, a total gas generation rate of 0.01 mL g^{-1} cellulose day^{-1} corresponds to a gas generation rate of 1.6 mol gas per drum per year.

5.1.2 Carbon Dioxide Production

Uninoculated samples produced 4.00 μmol of CO_2 g^{-1} cellulose at 200 days, which was slightly less than the formalin treated controls (7.62 μmol g $cellulose^{-1}$), as shown in Figure 15 (and Table 15, Appendix D). However, inoculated samples produced 8.30 μmol of CO_2 g^{-1} cellulose, slightly higher than uninoculated and formalin-treated controls, due to the onset of microbial activity. Inoculated samples containing nutrients produced 40.8 μmol carbon dioxide g^{-1} cellulose at 200 days, at a rate of 0.283 μmol g^{-1} cellulose day^{-1}. In the presence of excess nitrate, 95.6 μmol carbon dioxide g^{-1} cellulose were produced at a rate of 0.484 μmol g^{-1} cellulose day^{-1}, more than twice that of samples without excess nitrate.

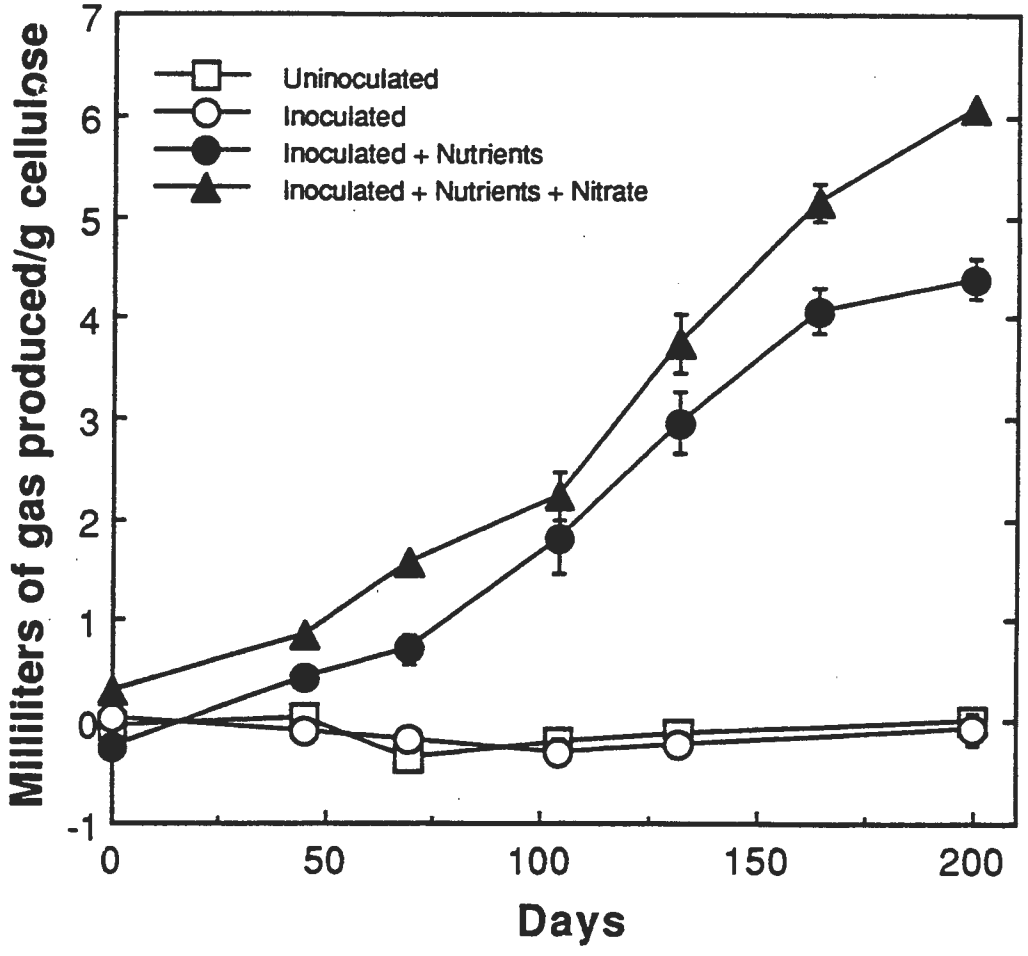

Figure 14. Total gas produced in samples containing bentonite incubated with an initial atmosphere of air.

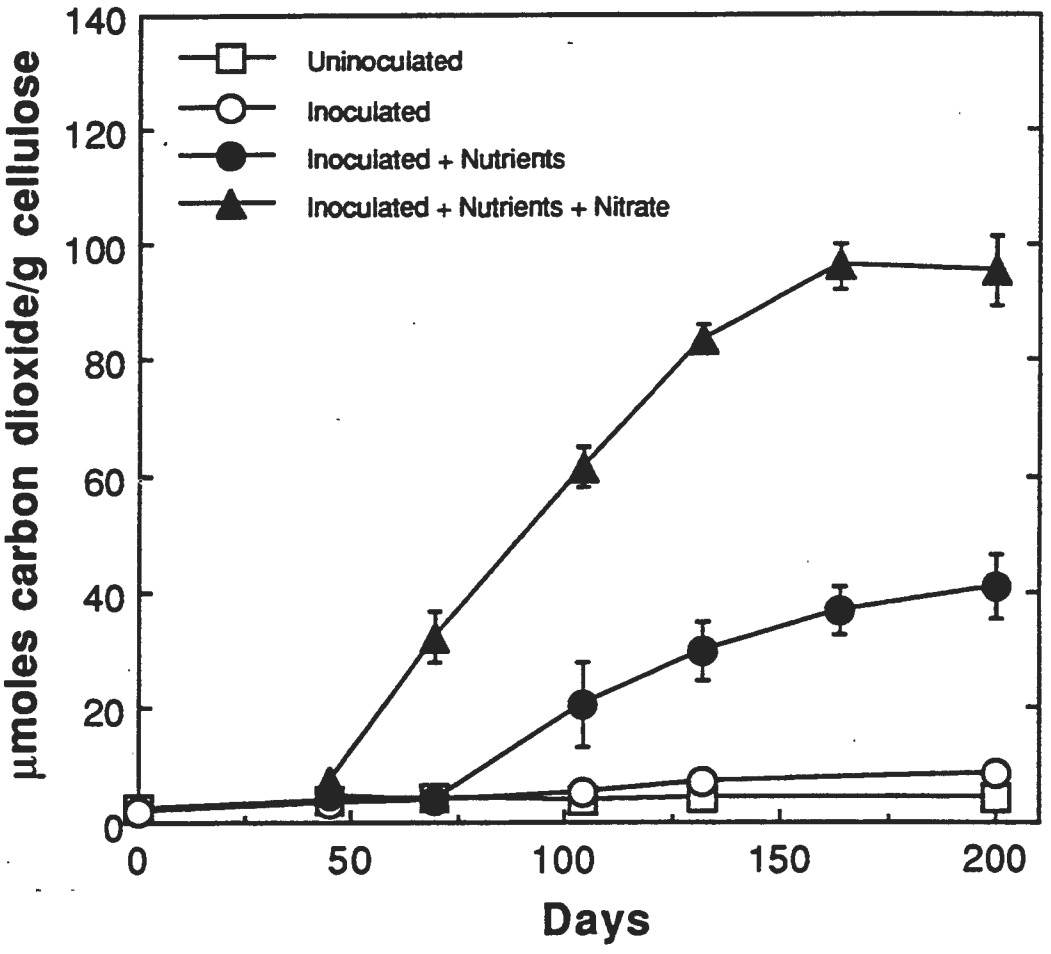

Figure 15. Carbon dioxide produced in samples incubated with an initial atmosphere of air.

Evidence of the growth of halophilic bacteria was noted in nutrient-amended samples by a red/pink color at the bottom of the bottles. This red coloration, characteristic of halophiles, is caused by the presence of bacterioruberin, a 50-carbon carotenoid pigment. This coloration was not seen in formalin-treated controls or unamended samples.

The addition of bentonite resulted in the production of a significant amount of abiotically produced carbon dioxide in samples without cellulose. Table 5, Appendix D shows that carbon dioxide increased from 17.7 μmol sample^{-1} to 40.0 μmol sample^{-1} without cellulose, inoculum and nutrients (sample 4(NC)-a), compared to the same treatment without bentonite. The latter treatment showed a slight increase, from 1.38 to 2.18 μmol sample^{-1} (see Table 2, Appendix D). Formalin-treated control samples also showed the same trend. The net effect was an increase in abiotically produced carbon dioxide (approximately 40 μmol sample^{-1}, (Table 5) by the addition of bentonite. Carbon dioxide production was insignificant in uninoculated unamended samples, (Figure 16). The inoculated unamended samples with bentonite produced 21.5 μmol g^{-1} cellulose at 200 days (Figure 16), whereas the samples without bentonite produced 8.30 μmol g^{-1} cellulose (Table 15, Appendix D). Nutrient-amended inoculated samples produced 69.8 μmol carbon dioxide g^{-1} cellulose, whereas nutrient-amended inoculated samples with excess nitrate produced 116 μmol g^{-1} cellulose at 200 days. After an initial lag of 69 days, carbon dioxide was produced at a rate of 0.533 and 0.869 μmol g^{-1} cellulose day^{-1} in nutrient-amended and nutrient-amended plus excess nitrate samples, respectively. These rates of carbon dioxide production are higher than the same treatments without bentonite (0.283 and 0.484 μmol g cellulose^{-1} day^{-1}, respectively). The buffering effect of $CaCO_3$, as well as minerals and trace elements including Fe, Al, Si and exchangeable cations (Na^+, Ca^{2+}, Mg^{2+}) and anions (SO_4^{2-}) present in the bentonite (Wanner et. al., 1992), may enhance microbial activity. Bentonite also provides an attachment site for microorganisms that may favor their growth.

Extrapolation of the carbon dioxide production rates from μmol per g^{-1} cellulose day^{-1} to mol drums^{-1} of waste year^{-1} is accomplished with the following conversion factor: for an assumed average drum of transuranic waste, with about 10 Kg of cellulosic materials, a

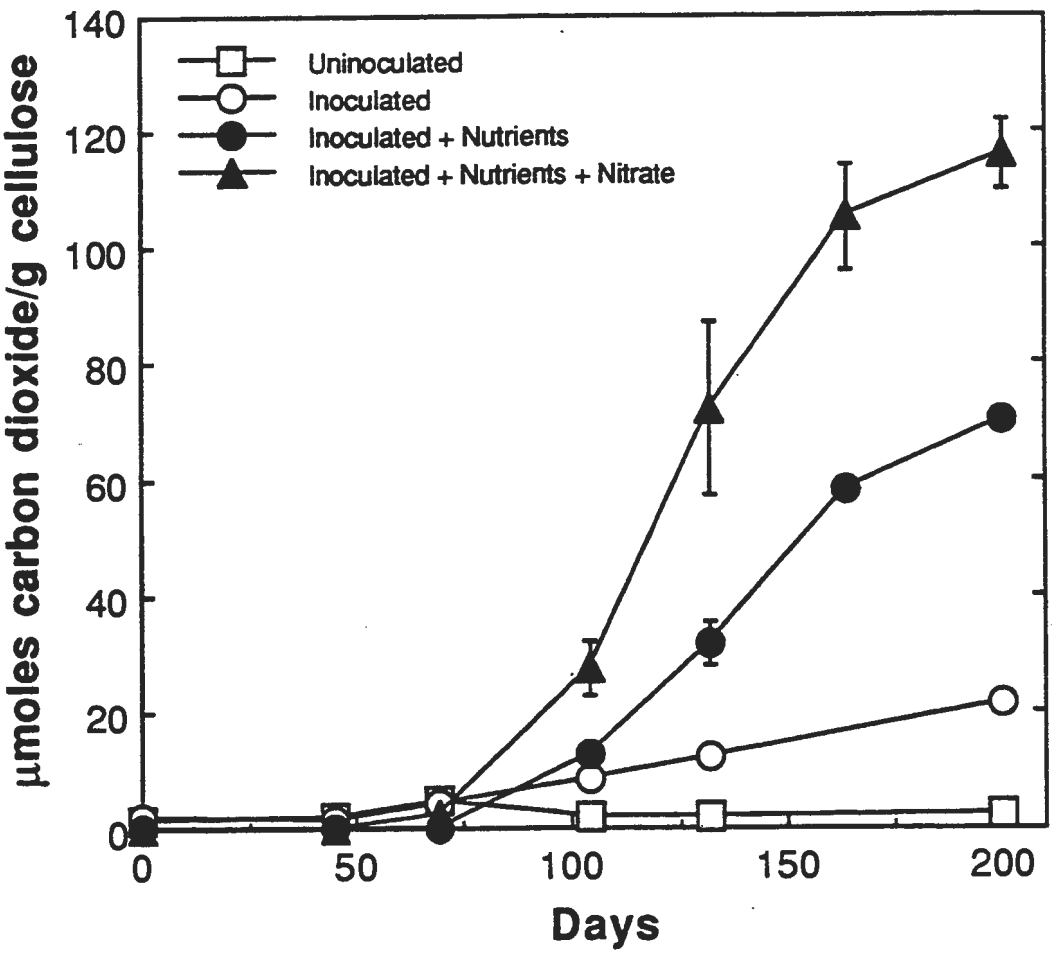

Figure 16. Carbon dioxide produced in samples containing bentonite incubated in an initial atmosphere of air.

carbon dioxide gas generation rate of 1.0 μmol CO_2 g^{-1} cellulose day^{-1} corresponds to 3.7 mol of gas $drum^{-1}$ $year^{-1}$.

5.1.3 Nitrous-Oxide Production

Nutrient-amended samples contained 250 μmol nitrate g^{-1} cellulose, while nutrient-amended samples plus excess nitrate contained 1240 μmol nitrate g^{-1} cellulose. Acetylene was not added to samples and, therefore, the nitrous oxide is both being produced and reduced to N_2 in these samples. Nitrous oxide was not detected in uninoculated or inoculated samples without amendments, indicative of the lack of microbial activity (see Figure 17). Nitrous oxide accumulated in the inoculated nutrient-amended samples, with production peaking at 24.4 μmol g^{-1} cellulose at 132 days and then declining to 1.76 μmol g^{-1} cellulose at 164 days (Table 17, Appendix D). Nitrous-oxide was produced at a rate of 0.674 μmol g^{-1} cellulose day^{-1} from 69 to 104 days. In the presence of excess nitrate, nitrous oxide was produced at the rate of 0.835 μmol g^{-1} cellulose day^{-1}, reaching 115 μmol g^{-1} cellulose at 200 days.

In the presence of bentonite, nitrous oxide was not detected in uninoculated and inoculated unamended samples (see Table 18, Appendix D and Figure 18). The addition of nutrients to inoculated samples stimulated nitrous oxide production from 69 to 104 days at 1.00 μmol g^{-1} cellulose day^{-1}. Thereafter, N_2O did not accumulate in the headspace, probably because of depletion of available nitrate, or rapid conversion of N_2O to nitrogen gas. In the presence of excess nitrate, nitrous oxide was produced at a rate of 0.589 μmol g^{-1} cellulose day^{-1}, reaching a maximum (82.7 μmol g^{-1} cellulose) at 200 days. The continued accumulation of nitrous oxide at 200 days was probably due to the abundance of available nitrate. Addition of bentonite did not result in a substantial accumulation of N_2O in the headspace, suggesting that N_2O was rapidly converted to N_2 as soon as it was formed. Samples with and without bentonite exhibited the same trend (Figures 17 and 18), although less N_2O was detected in the former.

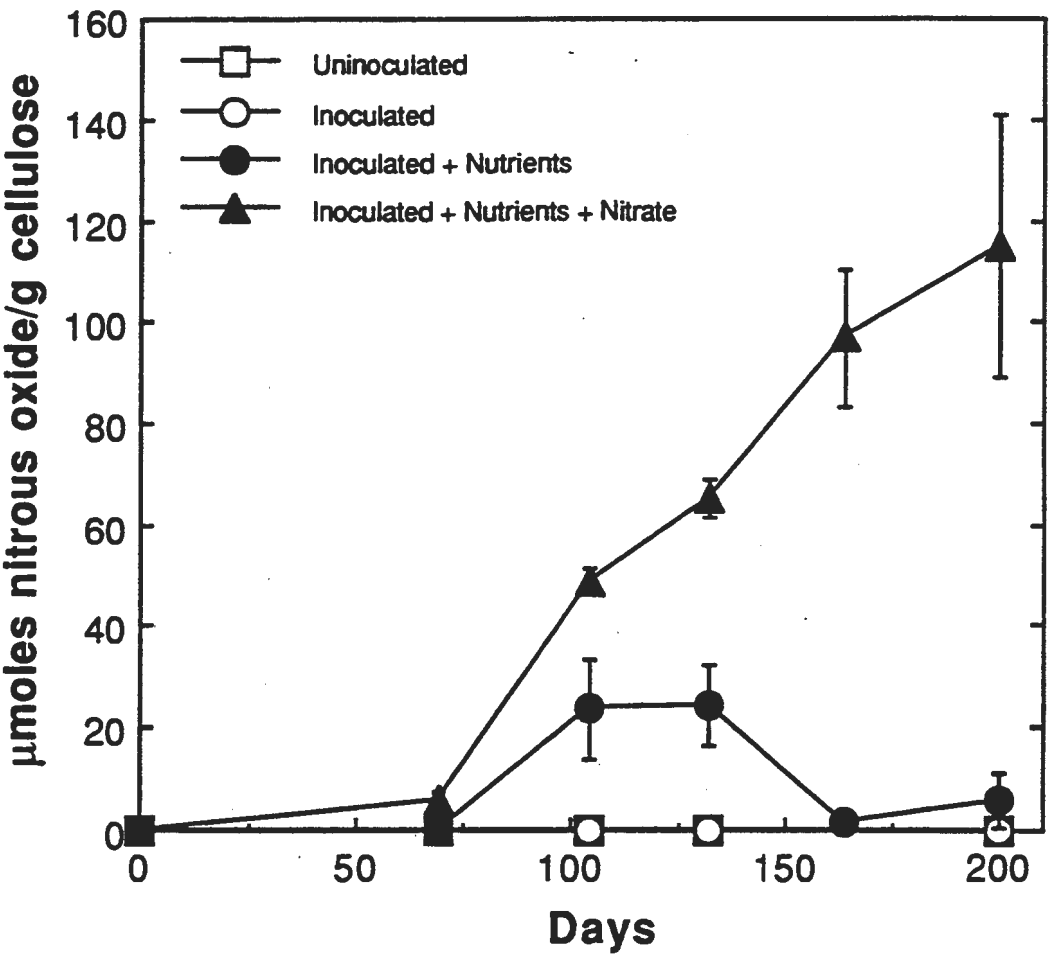

Figure 17. Nitrous oxide produced in samples incubated with an initial atmosphere of air.

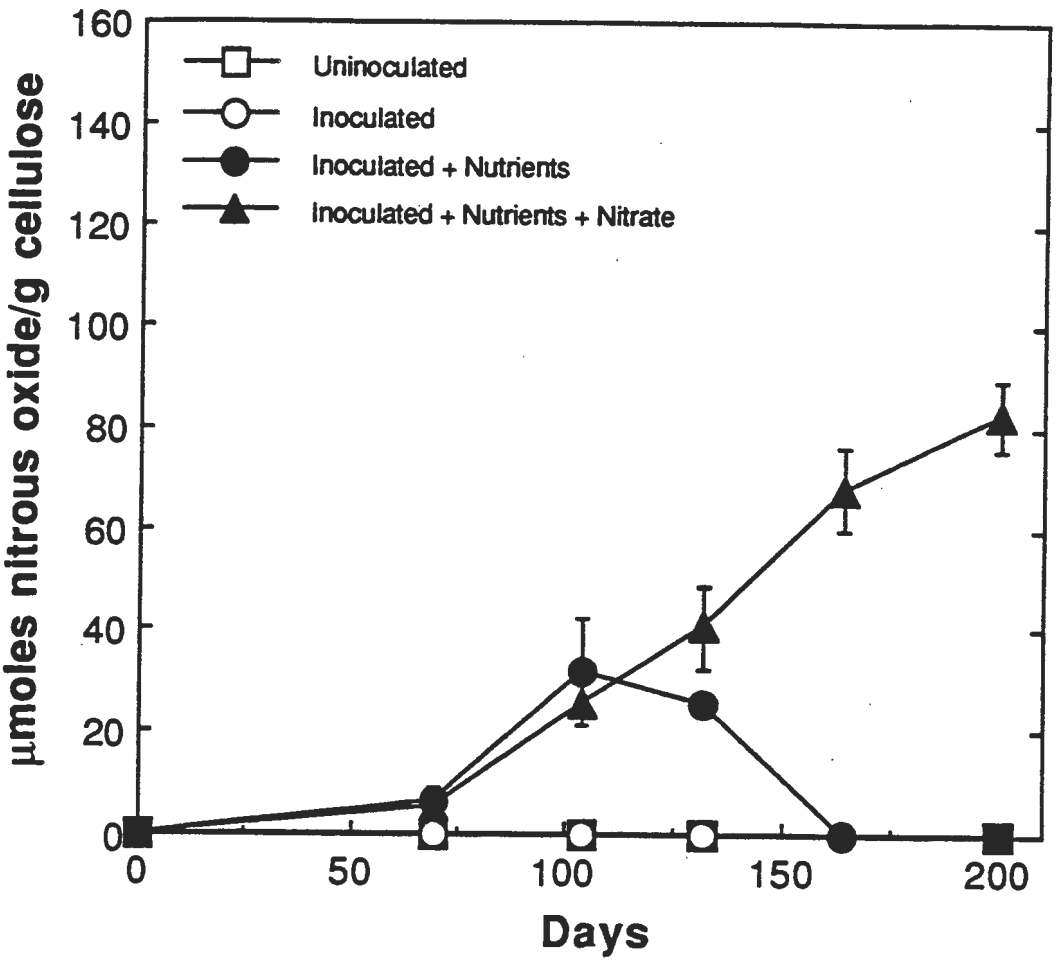

Figure 18. Nitrous oxide produced in samples containing bentonite incubated with an initial atmosphere of air.

5.2 Anaerobic Treatments

5.2.1 Total Gas Production

Figure 19 shows the total gas produced in samples incubated under anaerobic conditions in the presence of nitrogen. Uninoculated samples showed a slight loss of gas of about 3.20 mL sample^{-1}, presumably due to sampling. Inoculated samples without nutrients produced 0.59 mL g^{-1} cellulose at 200 days (see Table 19, Appendix D). After a lag of about 45 days, total gas production increased in inoculated samples containing nutrients, which produced 2.27 mL g^{-1} cellulose at a rate of 0.021 mL g^{-1} cellulose day^{-1}. With nutrients plus excess nitrate, 5.44 mL of gas were produced at a rate of 0.039 mL g^{-1} cellulose day^{-1}.

Figure 20 shows total gas produced in anaerobic samples containing bentonite. Uninoculated, unamended samples showed a net loss at 200 days to -0.28 mL g^{-1} cellulose (Table 20, Appendix D), due to a combination of sampling and data correction. Inoculated, unamended samples produced 0.81 mL g^{-1} cellulose after a lag of 69 days, at a rate of 0.007 mL g^{-1} cellulose day. In nutrient-amended samples, the addition of bentonite had no significant effect and gas production was similar to samples without bentonite (Figure 19). In contrast the addition of bentonite increased gas production in aerobic-amended samples. Inoculated amended samples produced 1.92 mL of gas at a rate of 0.013 g^{-1} cellulose day^{-1}, and inoculated samples with excess nitrate produced 3.52 mL of gas at a rate of 0.025 g^{-1} cellulose day^{-1}.

5.2.2 Carbon Dioxide Production

Uninoculated samples produced only about 3.59 μmol carbon dioxide g^{-1} cellulose over 200 days (Figure 21), but in the presence of inoculum, carbon dioxide increased to 5.47 μmol g^{-1} cellulose (Table 21, Appendix D). After a lag of 69 days, inoculated samples amended with nutrients produced 26.0 μmol carbon dioxide at a rate of 0.198 μmol g^{-1}

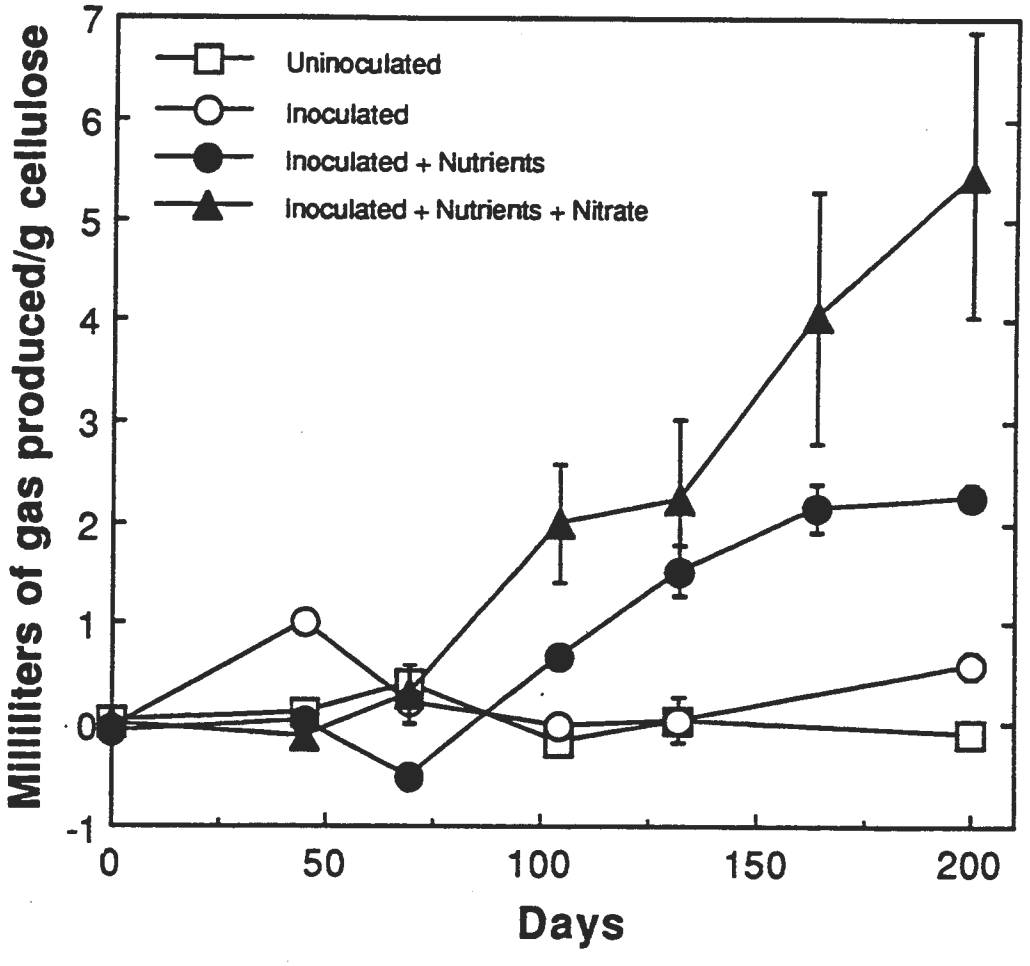

Figure 19. Total gas produced in anaerobic samples.

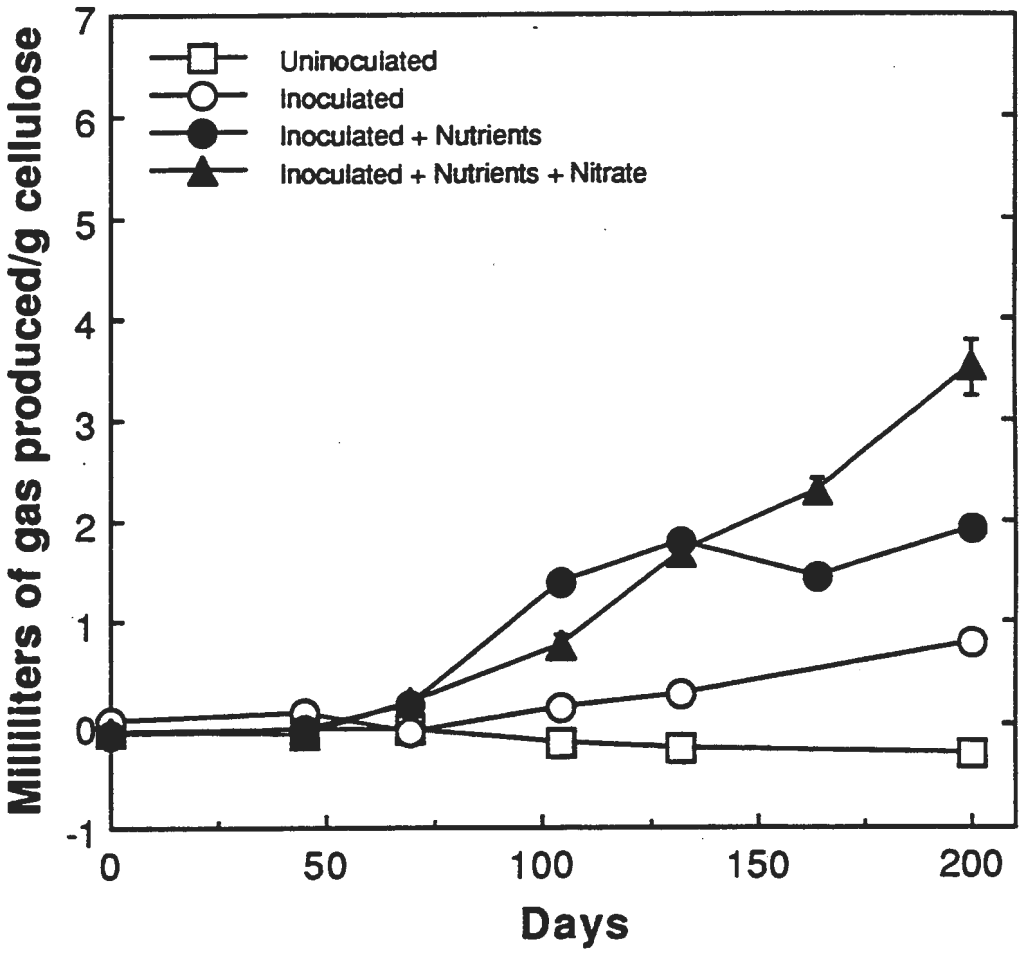

Figure 20. Total gas produced in anaerobic samples containing bentonite.

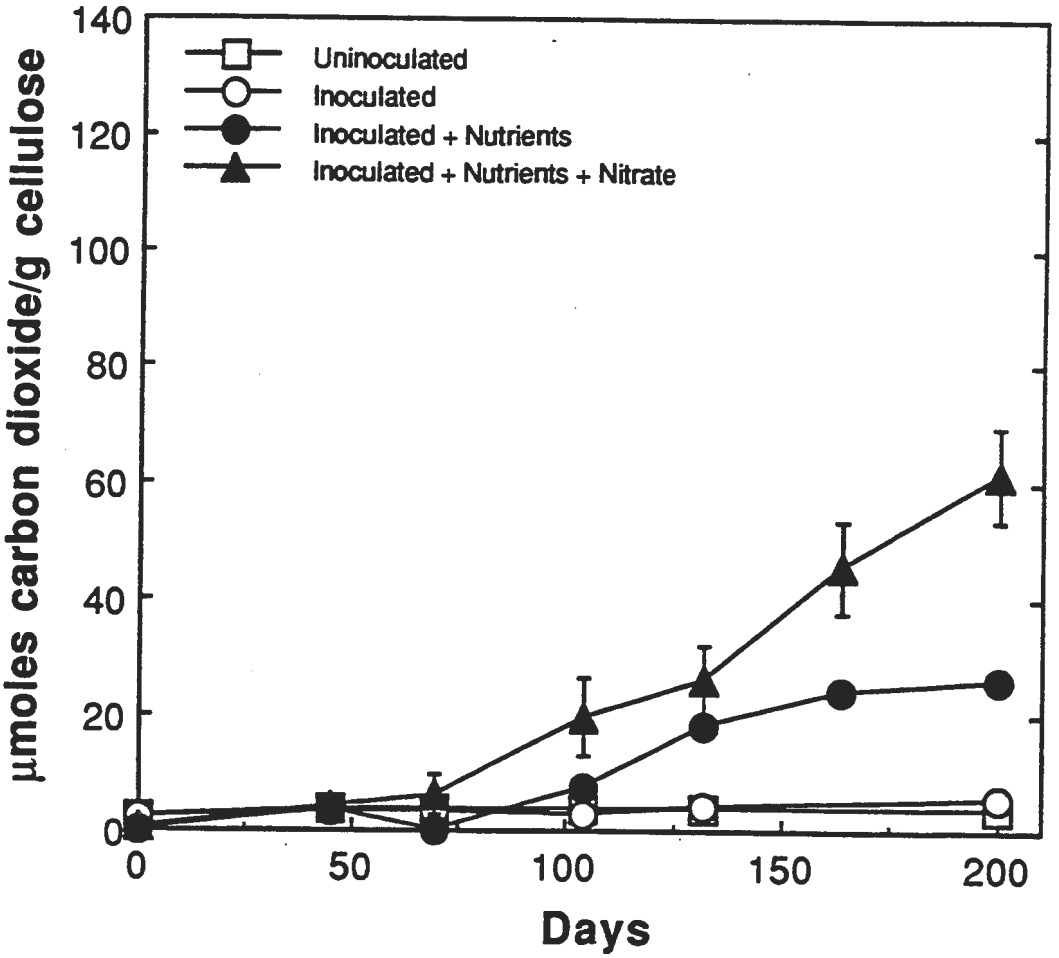

Figure 21. Carbon dioxide produced in anaerobic samples.

cellulose day^{-1} (Table 21, Appendix D). Addition of excess nitrate stimulated carbon dioxide production to 61.4 μmol at the rate of 0.422 μmol g^{-1} cellulose day^{-1}.

Figure 22 shows carbon dioxide production in anaerobic samples containing bentonite. Uninoculated unamended samples produced 0.22 μmol g^{-1} cellulose at 200 days, while inoculated unamended samples produced 8.28 μmol g^{-1} cellulose. The addition of bentonite enhanced the background (abiotic) carbon dioxide concentration by about 40.0 μmol (Table 22, Appendix D). Inoculated samples plus nutrients produced 31.8 μmol carbon dioxide g^{-1} cellulose over 200 days at a rate of 0.236 μmol g^{-1} cellulose day^{-1}. Inoculated samples with nutrients plus excess nitrate produced 35.0 μmol carbon dioxide g^{-1} cellulose over 200 days at a rate of 0.252 μmol g^{-1} cellulose day^{-1}.

5.2.3 Nitrous Oxide Production

The rate of nitrous oxide accumulation in anaerobic samples is shown in Figure 23. Nitrous oxide was not detected in either uninoculated or inoculated samples (Table 23, Appendix D). In the inoculated, amended samples, nitrous oxide accumulated to 15.5 μmol after 100 days and remained relatively unchanged up to 200 days. In the presence of excess nitrate, nitrous oxide was produced after 69 days at a rate of 0.602 μmol g^{-1} cellulose day^{-1}, reaching a concentration of 79 μmol at 200 days. In contrast, nitrous oxide accumulation was higher in aerobic samples (see Figure 15) than anaerobic samples.

Figure 24 shows nitrous oxide production in anaerobic samples containing bentonite. Nitrous oxide was not detected in uninoculated and inoculated samples (see Table 24, Appendix D). In inoculated samples with nutrients, only trace amounts of nitrous oxide were detected at 104 and 164 days. In the inoculated samples containing excess nitrate, nitrous oxide was produced at a rate of 0.647 μmol g^{-1} cellulose day^{-1} after 104 days and reached 62.1 μmol g^{-1} cellulose at 200 days. In comparison to treatments without bentonite, less nitrous oxide accumulated when bentonite was present. This may be caused by either a suppression or an enhancement of denitrification activity (enabling the complete conversion of nitrous oxide to nitrogen without accumulation of nitrous oxide).

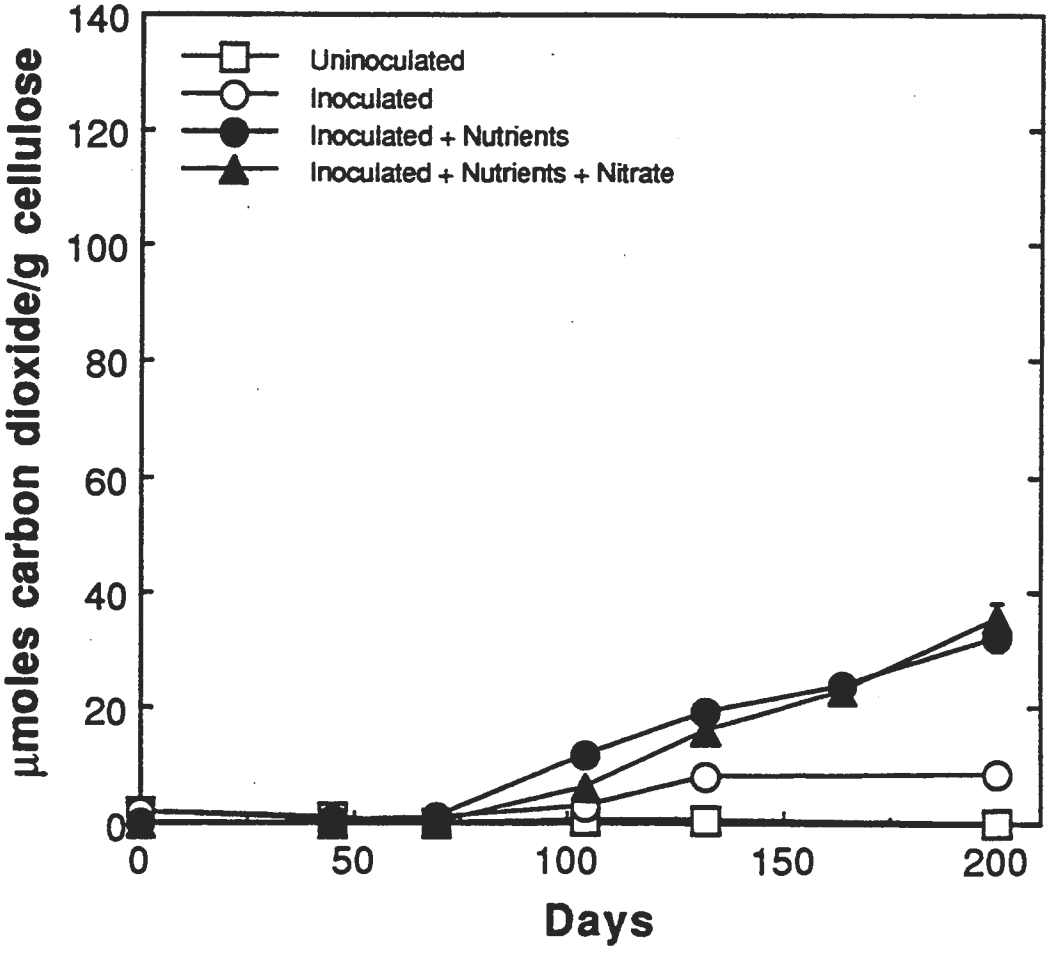

Figure 22. Carbon dioxide produced in anaerobic samples containing bentonite.

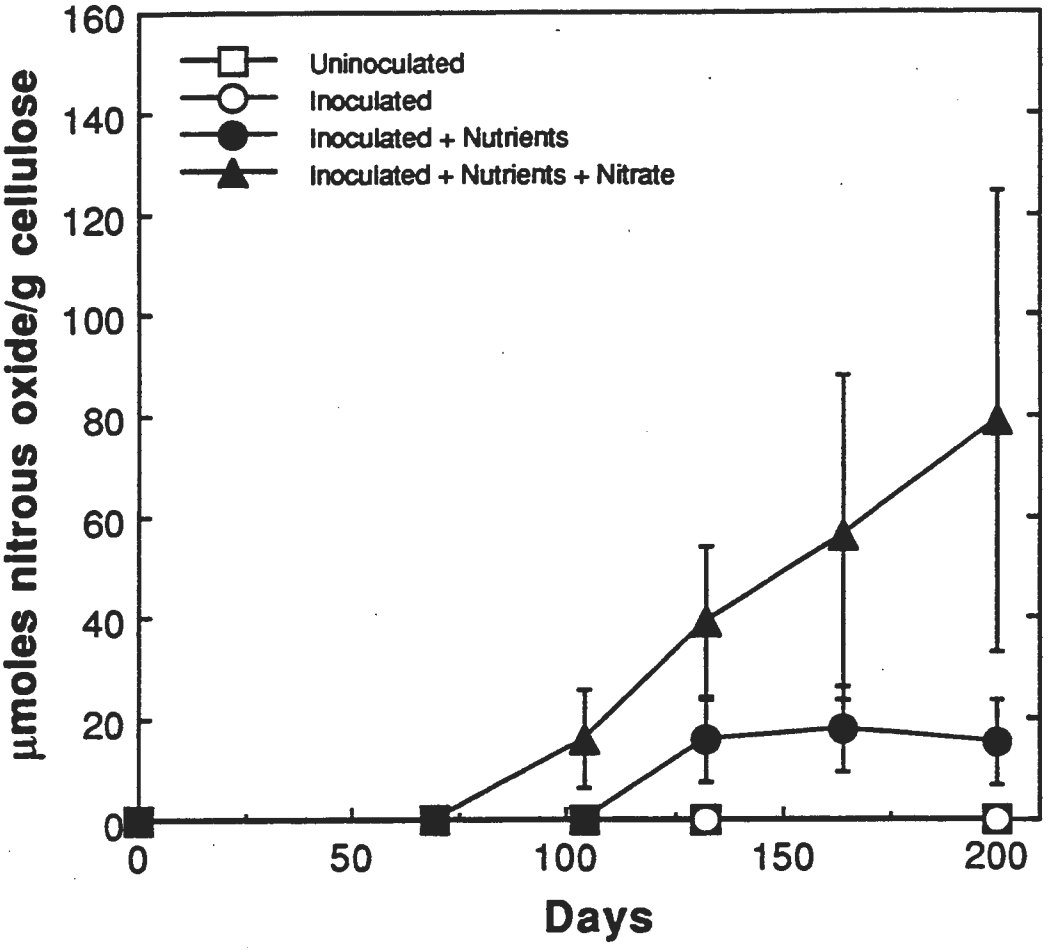

Figure 23. Nitrous oxide produced in anaerobic samples.

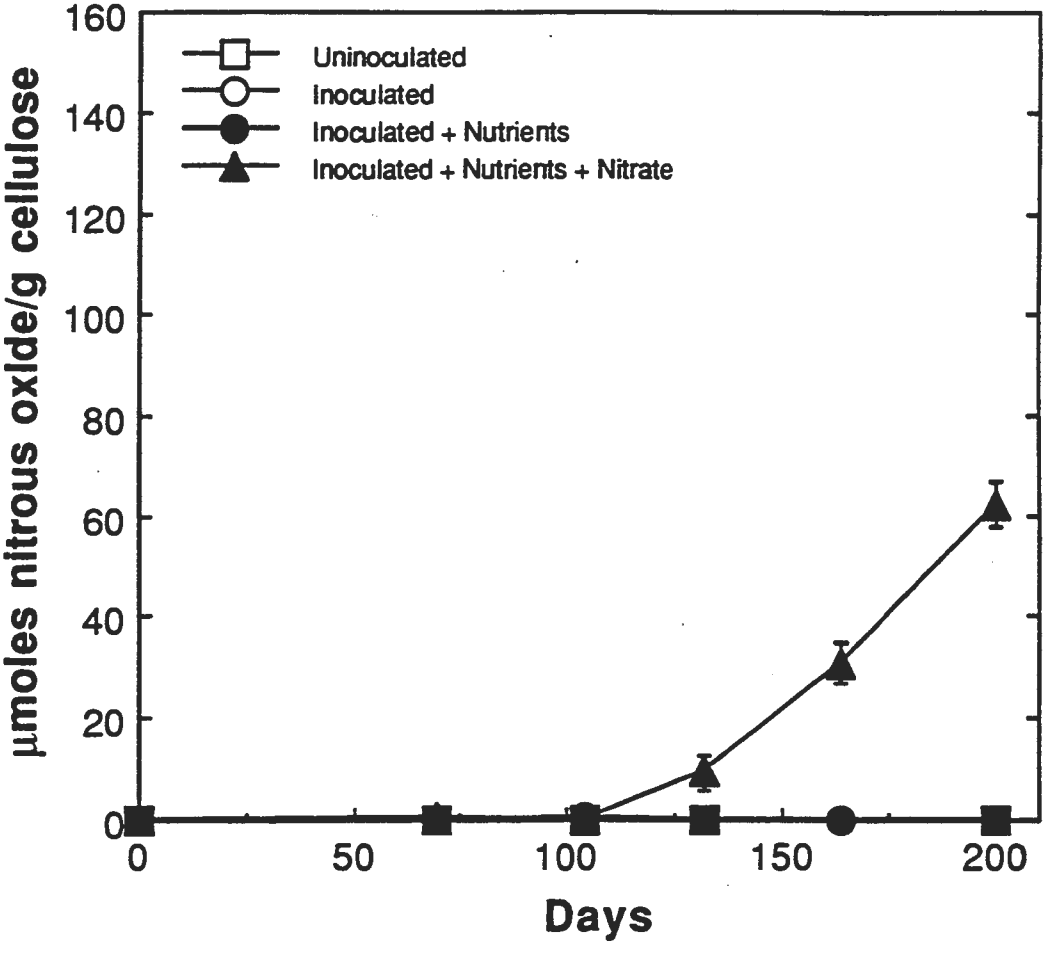

Figure 24. Nitrous oxide produced in anaerobic samples containing bentonite.

6.0 SUMMARY

Gas generation from microbial degradation of a mixture of cellulosic waste was investigated. Cellulosic waste consisting of a mixture of filter paper, paper towels, and Kimwipes® were incubated in the presence of WIPP brine with and without a mixed inoculum, nutrients, or nutrients plus excess nitrate and bentonite. Abiotic (control) samples were treated with formalin and showed no microbial activity. Nitrogen (anaerobic) or air-containing (aerobic) samples with cellulose showed an increase in total gas, CO_2, and N_2O when inoculated with a mixed inoculum without any added nutrients, with nutrients, or nutrients plus excess nitrate and bentonite. In particular, samples which received nutrients plus excess nitrate produced much more gas, CO_2, and N_2O than samples which did not. Bentonite increased the background level of CO_2 concentration due to abiotic reactions and also appears to have a stimulatory effect on aerobic microbial activity.

Table 14 summarizes the rate and extent of gas production due to the presence of cellulose from 69 to 200 days (131 days). Before 69 days, gas production in most treatments was not directly attributable to the presence of cellulose because the samples without cellulose also produced gas due to carry over of nutrients in the mixed inoculum, and metabolism of added nutrients. After 69 days, gas production in samples with cellulose exceeded those without cellulose. Gas production rates were calculated from the linear slope between 69 and 200 days. Negative values in the table denote a loss in gas volume. The negative rate reported for carbon dioxide in uninoculated treatments is the result of inactivity in these samples, and should be interpreted as "zero".

The total volume of gas produced in air-containing (aerobic) samples was highest in the presence of bentonite. Gas was produced at a rate of 0.028 mL g^{-1} cellulose day^{-1} in inoculated, nutrient-amended samples, and at 0.034 mL g^{-1} cellulose day^{-1} in inoculated, nutrient-amended samples containing excess nitrate. The highest amount of gas was produced in the presence of excess nitrate (6.07 mL g^{-1} cellulose).

Table 14. Summary of Rate and Net Gas Production in Samples Containing Cellulose

Sample	Total Volume of Gas		Carbon Dioxide		Nitrous Oxide	
	Rate* (ml/g cell./day)	Total Produced at 200 Days (ml/g cell.)	Rate* (µmol/g cell./day)	Total Produced at 200 Days (µmol/g cell.)	Rate* (µmol/g cell./day)	Total Produced at 200 Days (µmol/g cell.)
Aerobe						
Uninoculated	0.001	-0.18	-0.001	4.00	--	ND
Inoculated	-0.001	-0.34	0.033	8.30	--	ND
Inoc. + Nutrients	0.008	0.86	0.283	40.8	0.674****	24.4
Inoc. + Nut. + Nitr.	0.023***	4.42	0.484****	95.6	0.835	115
Aerobe + Bentonite						
Uninoculated	0.003	0.00	-0.016	2.32	--	0.048
Inoculated	0.001	-0.08	0.134	21.5	--	ND
Inoc. + Nutrients	0.028	4.38	0.533	69.8	1.00****	31.8****
Inoc. + Nut. + Nitr.	0.034	6.07	0.869	116	0.589	82.7
Anaerobe						
Uninoculated	-0.004	-0.09	-0.003	3.59	--	ND
Inoculated	0.003	0.59	0.016	5.47	--	ND
Inoc. + Nutrients	0.021	2.27	0.198	26.0	0.564*****	15.8*****
Inoc. + Nut. + Nitr.	0.039	5.44	0.422	61.4	0.602	79.0
Anaerobe + Bentonite						
Uninoculated	-0.003	-0.28	0.005	0.22	--	ND
Inoculated	0.007	0.81	0.057	8.28	--	ND
Inoc. + Nutrients	0.013	1.92	0.236	31.8	--	ND
Inoc. + Nut. + Nitr.	0.025	3.52	0.252	35.0	0.647******	62.1*****

* Rate calculated from 69 days (end of lag phase) to 200 days (131 days) except where noted; rate assumed linear and averaged over available data.

**For an assumed average drum of transuranic waste, with 10 kg of cellulosic material, the following rate conversion factors are applicable:

0.01 ml/g/day = 1.6 moles/drum/year

1.0 µmole/g/day = 3.7 moles/drum/year

*** Lag phase not present, gas production started at T=0

**** Nitrous oxide reached maximum at 104 days, rate is over 35 days

***** Nitrous oxide reached maximum concentration at 132 days, rate is over 32 days.

****** Lag phase lasted 104 days

Negative values denote gas volume loss or decrease in concentration over time.

ND - not detected

In anaerobic samples, gas production was highest in the absence of bentonite. Gas was produced at a rate of 0.021 mL g^{-1} cellulose day^{-1} in inoculated, nutrient-amended samples, and 0.039 ml g^{-1} cellulose day^{-1} in inoculated, nutrient-amended samples containing excess nitrate.

The concentration of carbon dioxide was highest in aerobic treatments in the presence of bentonite. In samples containing excess nitrate, 116 μmol CO_2 g^{-1} cellulose was produced at a rate of 0.869 μmol g^{-1} cellulose day^{-1}. Inoculated, unamended samples of this treatment also showed the highest amount of carbon dioxide, with 21.5 μmol g^{-1} cellulose produced over 200 days. In the absence of bentonite, aerobic samples that were inoculated with nutrients produced 40.8 μmol CO_2 g^{-1} cellulose, whereas the samples containing excess nitrate produced 95.6 μmol CO_2 g^{-1} cellulose. Aerobic samples produced more carbon dioxide than anaerobic samples. In the absence of bentonite, anaerobic samples produced 0.422 μmol CO_2 g^{-1} cellulose day^{-1} with a total yield 61.4 μmol CO_2 g^{-1} cellulose in the presence of excess nitrate. However, in the presence of bentonite, 35.0 μmol g^{-1} cellulose was produced in anaerobic samples containing excess nitrate, about one third of that produced in aerobic samples. Therefore, initially aerobic processes were more efficient in producing CO_2.

In the presence of cellulose and nutrients, there is significantly greater amount of gas production than in samples without nutrients. In the absence of nutrients, microbial activity was minimal. Aerobic, denitrifying, and anaerobic, primarily fermentative, activities, were the predominant microbial processes noted.

Production of nitrous oxide correlated with the presence of excess nitrate (1240 μmol g^{-1} cellulose), and 115 μmol g^{-1} cellulose was produced in aerobic samples without bentonite. Nitrous oxide did not accumulate in nutrient-amended samples which contained 0.1% nitrate (250 μmol g^{-1} cellulose); it quickly disappeared after about 30 days. Bentonite did not stimulate the accumulation of nitrous-oxide, but instead, was correlated with a lower accumulation of N_2O.

The long-term inundated experiments showed enhanced halophilic bacterial activity in the presence of cellulose under aerobic and anaerobic conditions. Up to 200 days, gas production was highest in nutrient amended samples including excess nitrate treatments containing an initial concentration of oxygen; this was enhanced by the addition of bentonite.

Table 15 presents gas production data scaled up to total gas and carbon dioxide produced per drum of waste per year. Nitrous oxide is not presented because this gas, the production of which is significant as a marker of microbial activity, is converted to nitrogen which affects the production rate. The rates drum^{-1} of waste year^{-1} were calculated on the basis of an assumed average drum of transuranic waste with about 10 Kg of cellulosic material. A total gas generation rate of 0.01 mL of gas g^{-1} cellulose day^{-1} corresponds to a generation rate of 1.6 mol of gas drum^{-1} year^{-1}. A carbon dioxide generation rate of 1.0 μmol CO_2 g^{-1} cellulose day^{-1} corresponds to a generation rate of 1.6 mol gas drum^{-1} year^{-1}.

The data contained in this report is a summarization of work in progress, (a status report) and should not be interpreted as final values. Most of the long-term studies are still in progress. Gas production rates will undoubtedly be modified after long-term data, up to about two years or longer, are obtained and analyzed. The preliminary data included herein, and resultant gas production rates, should only be used for preliminary interpretations and tentative conclusions. Further data and interpretation from this microbial degradation-gas generation study will be documented in the future.

Table 15. Summary of Gas Production Rates Expressed as per g Cellulose/Day and Scaled up to per Drum/Year.

Sample	Total Volume of Gas		Carbon Dioxide	
	Rate* (ml/g cell./day)	Calculated Amount Produced per Waste Drum** (moles/drum/year)	Rate* (μmol/g cell./day)	Calculated Amount Produced per Waste Drum** (moles/drum/year)
Aerobe				
Uninoculated	0.001	0.16	-0.001	--
Inoculated	-0.001	-0.16	0.033	0.12
Inoc. + Nutrients	0.008	1.28	0.283	1.05
Inoc. + Nut. + Nitr.	0.023***	3.68	0.484***	1.79
Aerobe + Bentonite				
Uninoculated	0.003	0.48	-0.016	--
Inoculated	0.001	0.16	0.134	0.5
Inoc. + Nutrients	0.028	4.48	0.533	1.97
Inoc. + Nut. + Nitr.	0.034	5.44	0.869	3.21
Anaerobe				
Uninoculated	-0.004	-0.64	-0.003	--
Inoculated	0.003	0.48	0.016	0.06
Inoc. + Nutrients	0.021	3.36	0.198	0.73
Inoc. + Nut. + Nitr.	0.039	6.24	0.422	1.56
Anaerobe + Bentonite				
Uninoculated	-0.003	-0.48	-0.005	--
Inoculated	0.007	1.12	0.057	0.21
Inoc. + Nutrients	0.013	2.08	0.236	0.87
Inoc. + Nut. + Nitr.	0.025	4.00	0.252	0.93

* Rate calculated from 69 days (end of lag phase) to 200 days (131 days) except where noted; rate assumed linear and averaged over available data.

**For an assumed average drum of transuranic waste, with 10 kg of cellulosic material, the following rate conversion factors were used:

0.01 ml/g/day = 1.6 moles/drum/year

1.0 μmole/g/day = 3.7 moles/drum/year

*** Lag phase not present, gas production started at T=0

Negative values denote gas volume loss or decrease in concentration over time

7.0 REFERENCES

Balderston, W.L., B. Sherr, and W.J. Payne. 1976. "Blockage by Acetylene of Nitrous Oxide Reduction in *Pseudomonas perfectomarinus*," *Applied Environmental Microbiology*. Vol. 31, No.4, 504-508.

Barnhart, B.J., E.W. Campbell, E. Martinez, D.E. Caldwell, and R. Hallett. 1980. *Potential Microbial Impact on Transuranic Wastes Under Conditions Expected in the Waste Isolation Pilot Plant (WIPP), Annual Report, October 1, 1978 - September 30, 1979*. LA-8297-PR. Los Alamos National, NM: Los Alamos Scientific Laboratory.

Benoit, L., C. Cailliez, E. Petitdemange, and J. Gitton. 1992. "Isolation of Cellulolytic Mesophilic *Clostridia* from a Municipal Solid Waste Digestor," *Microbial Ecology*. Vol. 23, No.2, 117-125.

Black, J., X. Tong, and D. Grbic-Galic. 1991. *Laboratory Studies of Microbial Degradation of Transuranic (TRU) Waste, Final Progress Report January 1, 1989 - April 30, 1991*. Stanford, CA: Environmental Engineering and Science, Department of Civil Engineering, Stanford University. (Copy on file in the Sandia WIPP Central Files, Waste Management and Transportation Library, Sandia National Laboratories, Albuquerque, NM).

Bott, T.L., and L.A. Kaplan. 1991. "Selection of Surrogates for a Genetically Engineered Microorganism with Cellulolytic Capability for Ecological Studies in Streams," *Canadian Journal of Microbiology*. Vol. 37, No. 11, 848-857.

Brush, L.H. 1990. *Test Plan for Laboratory and Modeling Studies of Repository and Radionuclide Chemistry for the Waste Isolation Pilot Plant*. SAND90-0266. Albuquerque, NM: Sandia National Laboratories.

Brush, L.H. 1991. "Appendix A: Current Estimates of Gas Production Rates, Gas Production Potentials, and Expected Chemical Conditions Relevant to Radionuclide Chemistry for the Long-Term WIPP Performance Assessment," *Preliminary Comparison with 40 CFR Part 191, Subpart B for the Waste Isolation Pilot Plant, December 1991. Vol. 3: Reference Data.* WIPP Performance Assessment Division. Eds. R.P. Rechard, A.C. Peterson, J.D. Schreiber, H.J. Iuzzolino, M.S. Tierny, and J.S. Sandha. SAND91-0893/3. Albuquerque, NM: Sandia National Laboratories. A-25 through A-36.

Brush, L.H. , D. Grbic-Galic, D.T. Reed, X. Tong, R.H. Vreeland, and R.E. Westerman. 1990. "Preliminary Results of Laboratory Studies of Repository Chemistry for the Waste Isolation Pilot Plant," *Scientific Basic for Nuclear Waste Management XIV, Boston, MA, November 26-29, 1990.* Eds. T.A. Abrajano, Jr. and L.H. Johnson. SAND90-1031C. Pittsburgh, PA: Materials Research Society. Vol. 212, 893-900.

Caldwell, D.E., R.C. Hallet, M.A. Molecke, E. Martinez, and B.J. Barnhart. 1988. *Rates of CO_2 Production from the Microbial Degradation of Transuranic Wastes Under Simulated Geologic Isolation Conditions.* SAND87-7170. Albuquerque, NM: Sandia National Laboratories.

Christensen, S., and J.M. Tiedje. 1988. "Sub-Parts-Per-Billion Nitrate Method: Use of an N_2O-Producing Denitrifier to Convert NO_3- or $^{15}NO_3$- to N_2O," *Applied Environmental Microbiology*. Vol. 54, No. 6, 1409-1413.

Colberg, P.J., and L.Y. Young. 1982. "Biodegradation of Lignin-Derived Molecules Under Anaerobic Conditions," *Canadian Journal of Microbiology*. Vol. 28, No.7, 886-889.

Coleman, A.W. 1980. "Enhanced Detection of Bacteria in Natural Environments by Fluorochrome Staining of DNA," *Limnology and Oceanography*. Vol. 25, No. 5, 948-951.

DeLong, E.F., G.S. Wickham, and N.R. Pace. 1989. "Phylogenetic Stains: Ribosomal RNA-Based Probes for the Identification of Single Cells," *Science*. Vol. 243, No.4896, 1360-1363.

Dicker, H.J., and D.W. Smith. 1985. "Effects of Organic Amendments on Sulfate Reduction Activity, H_2 Consumption, and H_2 Production in Salt Marsh Sediments," *Microbial Ecology*. Vol. 11, No. 4, 299-315.

Francis, A.J. 1985. Low-level Radioactive Wastes in Subsurface Soils," *Soil Reclamation Processes: Microbiological Analyses and Applications*. Eds. R.L. Tate III and D.A. Klein, New York, NY: Marcel Decker, Inc., 279-331.

Francis, A.J. 1990. "Microbial Dissolution and Stabilization of Toxic Metals and Radionuclides in Mixed Wastes," *Experientia*. Vol. 46, No. 8, 840-851.

Francis, A.J., S. Dobbs, and R.F. Doering. 1980a. "Biogenesis of Tritiated and Carbon-14 Methane from Low-Level Radioactive Waste," *Nuclear Chemical Waste Management*. Vol. 1, No. 1, 153-159.

Francis, A.J., S. Dobbs, and B.J. Nine. 1980b. "Microbial Activity of Trench Leachates from Shallow-Land, Low-Level Radioactive Waste Disposal Sites," *Applied and Environmental Microbiology*. Vol. 40, No. 1, 108-113.

Francis, A.J., J.M. Slater, and C.J. Dodge. 1989. "Denitrification in Deep Subsurface Sediments," *Geomicrobiology Journal*. Vol. 7, No. 1-2, 103-116.

Francis, A.J., C.J. Dodge, J.B. Gillow, and J.E. Cline. 1991. "Microbial Transformations of Uranium in Wastes," *Radiochimica Acta*. Vol. 52/53, pt. 2, 311-316.

Hope, C.F.A., and R.G. Burns. 1985. "The Barrier-Ring Plate Technique for Studying Extracellular Enzyme Diffusion and Microbial Growth in Model Soil Environments," *Journal of General Microbiology*. Vol. 131, pt. 5, 1237-1243.

Hrmová, M., E. Petráková and P.Belly. 1991. "Induction of Cellulose- and Xylan-Degrading Enzyme Systems in *Aspergillus terreus* by Homo- and Hetero-Disaccharides Composed of Glucose and Xylose," *Journal of General Microbiology*. Vol. 137, pt. 3, 541-547.

Javor, B.J. 1984. "Growth Potential of Halophilic Bacteria Isolated from Solar Salt Environments: Carbon Sources and Salt Requirements," *Applied and Environmental Microbiology*. Vol. 48, No.2, 352-360.

Kearns, J.T., C.R. Clayton, G.P. Halala, J.B. Gillow, and A.J. Francis. 1992. "Application of XPS to the Study of MIC," *Materials Performance*. Vol. 31, No. 10, 48-51.

Kushner, D.J., and M. Kamekura. 1988. "Chapter 5: Physiology of Halophilic Eubacteria," *Halophilic Bacteria*. Ed. F. Rodriquez-Valera. Boca Raton, FL: CRC Press, Inc. Vol. I, 110.

Lappin, A.R., R.L. Hunter, D.P. Garber, and P.B. Davies, eds. 1989. *Systems Analysis, Long-Term Radionuclide Transport, and Dose Assessments, Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico; March 1989*. SAND89-0462, Albuquerque, NM: Sandia National Laboratories.

Laube, V.M., and S.M. Martin. 1981. "Conversion of Cellulose to Methane and Carbon Dioxide by Triculture of *Acetovibrio cellulyticus*, *Desulfovibrio sp.*, and *Methanosarcina barkeri*," *Applied and Environmental Microbiology*, Vol. 42, No. 3, 413-420.

Lovely, D.R., E.J. Phillips, Y.A. Gorby, and E.R. Landa. 1992. "Microbial Reduction of Uranium," *Nature*. Vol. 350, 413-416.

Lorowitz, W.H., D.P. Nagle, Jr., and R.S. Tanner. 1992. "Anaerobic Oxidation of Elemental Metals Coupled to Methanogenesis by *Methanobacterium thermoautotrophicum*," *Environmental Science and Technology*. Vol. 26, No. 8, 1606-1610.

Lynd, L.R., H.E. Grethlein, and R.H. Wolkin. 1989. "Fermentation of Cellulosic Substrates in Batch and Continuous Culture by *Clostridium thermocellum*," *Applied and Environmental Microbiology*. Vol. 55, No. 12, 3131-3139.

Molecke, M.A. 1979. *Gas Generation from Transuranic Waste Degradation: Data Summary and Interpretation*. SAND79-1245. Albuquerque, NM: Sandia National Laboratories.

Molecke, M.A. 1983. *A Comparison of Brines Relevant to Nuclear Waste Experimentation*. SAND83-0516. Albuquerque, NM: Sandia National Laboratories.

Ng, T.K., P.J. Weimer, and J.G. Zeikus. 1977. "Cellulolytic and Physiological Properties of *Clostridium thermocellum*," *Archives Microbiology*. Vol. 114, No. 1, 1-7.

Pavlostathis, S.G., and E. Giraldo-Gomez. 1991. "Kinetics of Anaerobic Treatment: A Critical Review," *Critical Reviews in Environmental Control*. Vol. 21, No. 5-6, 411-490.

Pavlostathis, S.G., T.L. Miller, and M.J. Wolin. 1988. "Fermentation of Insoluble Cellulose by Continuous Cultures of *Ruminococcus albus*," *Applied and Environmental Microbiology*. Vol. 54, No. 11, 2655-2659.

Postgate, J.R. 1984. *The Sulphate-Reducing Bacteria*. 2nd ed. New York, NY: Cambridge University Press. 56-100.

Poulsen, O.M., and L.W. Petersen. 1992. "Degradation of Microcrystalline Cellulose: Synergism Between Different Endoglucanases of *Cellulomonas sp*. ATCC 21399," *Biotechnology and Bioengineering*. Vol. 39, No.1, 121-123.

Priest, F.G. 1984. *Extracellular Enzymes*. Wokingham Berkshire , England: Van Nostrad Reinhold (UK) Co. Ltd. 42-43.

Rodriquez-Valera, F., ed. 1988. *Halophilic Bacteria*. Boca Raton, FL: CRC Press, Inc. Vol. I, 72.

Ross, H.N.M., M.D. Collins, B.J. Tindall, and W.D. Grant. 1981. "A Rapid Procedure for the Detection of Archaebacterial Lipids in Halophilic Bacteria," *Journal of General Microbiology*. Vol. 123, pt. 1, 75-80.

Skujins, J. 1976. "Extracellular Enzymes in Soil," *CRC Critical Reviews in Microbiology*. Vol. 4, No. 4, 383-421.

Tiedje, J.M. 1988. "Ecology of Denitrification and Dissimilatory Nitrate Reduction to Ammonium," *Biology of Anaerobic Microorganisms*. Ed. A.J.B. Zehnder, New York, NY: John Wiley and Sons. 179-186.

Tomlinson, G.A., L.L Jahnke, and L.I. Hochstein. 1986. "*Halobacterium denitrificans* sp. nov., an Extremely Halophilic Denitrifying Bacterium," *International Journal of Syst. Bacteriology*. Vol. 36, No. 1, 66-70.

Ventosa, A. 1988. "Chapter 3: Taxonomy of Moderately Halophilic Heterotrophic Eubacteria," *Halophilic Bateria.* Ed. F. Rodriquez-Valera. Boca Raton, FL: CRC Press, Inc. Vol. I, 72.

Vreeland, R., 1991. West Chester University, Pennsylania, personal communication.

Wanner H., P. Wersin, and N. Sierro. 1992. *Thermodynamic modelling of beutonite-ground interaction and implications for near field chemistry in a repository for spent fuel.* SKB Technical Report 92-37. Stockholm, Sweden: Swedish Nuclear Fuel and Waste Management, Co. 1-6.

Weimer, P.J., J.M. Lopez-Guisa, and A.D. French. 1990. "Effect of Cellulose Fine Structure on Kinetics of its Digestion by Mixed Ruminal Microorganisms in Vitro," *Applied and Environmental Microbiology*. Vol. 56, No. 8, 2421-2419.

Yoshinari, T., and R. Knowles. 1976. "Acetylene Inhibition of Nitrous Oxide Reduction by Denitrifying Bacteria," *Biochemical Biophysical Research Communications*. Vol. 69, No. 3, 705-710.

Zehnder, A.J., and W. Stumm. 1988. "Geochemistry and Biogeochemistry of Anaerobic Habitats," *Biology of Anaerobic Microorganisms*. Ed. A. J. Zehnder. New York, NY: John Wiley and Sons. 19.

Zhilina, T.N., and G.A. Zavarzin. 1990. "Extremely Halophilic Methylotrophic, Anaerobic Bacteria," *FEMS Microbiology Reviews*. Vol. 87, No. 3-4, 315-322.

APPENDIX A: DETAILS OF THE SHORT-TERM ACTIVITY MEASUREMENTS

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The short-term experiments were developed to determine the activity of specific groups of organisms (aerobes, anaerobes, and denitrifiers) by using WIPP salt from the underground and Nash Draw brine as a basal medium and inoculum.

A concentrated stock solution of nutrients (20x) was prepared and 0.5mL dispensed into 20-mL serum bottles. Medium for anaerobes (glucose fermenters) and denitrifiers was dispensed and sealed inside a nitrogen-filled glove box. Medium for aerobes was prepared outside of the glove box in air. The samples were capped with butyl rubber stoppers and aluminum crimps and autoclaved (120°C, 20 psi, 15 minutes).

The nutrient solution was added prior to the addition of inoculum to achieve a final concentration of nutrients in the samples as follows:

<u>Aerobe and Anaerobe Series</u>

glucose	5.0 g/L
yeast extract	0.5 g/L
potassium phosphate	1.0 g/L
ammonium nitrate	1.0 g/L
inoculum	9.5 mL/bottle
pH=6.8	

<u>Denitrifier Series</u>

sodium succinate	5.0 g/L
yeast extract	0.5 g/L
potassium phosphate (dibasic)	1.0 g/L
ammonium nitrate	1.0 g/L
potassium nitrate	1.0 g/L
inoculum	9.5 mL/bottle
pH = 6.8	

To determine denitrification, 2 mL of acetylene was injected into the headspace and nitrous oxide production was determined by gas chromatography.

Cellulose degradation was investigated by replacing the carbon source with 0.5 g Whatman #1 filter paper.

A large volume of inoculum was prepared by dissolving 200 g of S2180, W30 muck pile salt from the WIPP underground workings into 1 L of sterile water. A 450 mL aliquot was poured into a sterile beaker and 10 mL of Laguna Cinco mud slurry and 50 mL of Laguna Cinco brine from Nash Draw were added. This was done inside the anaerobic glove box. A total of 510 mL of inoculum was prepared; 9.5 mL of this inoculum was added to each bottle of sterile nutrient medium through a sterile needle and syringe to attain a final volume of 10 mL in each bottle. The pressure was equalized after the addition of inoculum with a sterile syringe and 0.22 μm filter.

A total of 6 samples were prepared per series. Two of the 6 were treated with 1 mL of 10 % formalin to serve as a control. Six samples were also prepared without nutrient additions, 2 treated with formalin.

Samples were incubated at 30°C and analyzed for gas production (total gas, carbon dioxide and nitrous oxide) at specific time periods.

APPENDIX B: GAS ANALYSIS

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Total Gas

Headspace pressure was measured with a Wallace & Tiernan® digital pressure model 661-D/A035 gauge calibrated to National Institute of Standards and Technology (NIST) standard.

Carbon Dioxide

Carbon dioxide analysis was performed on a gas chromatograph equipped with a thermal conductivity detector. Instrument conditions are listed below:

Column	SS 12' x 1/8" Porapak QS
Column temp (°C)	100
Carrier gas	He
Carrier flow (mL/min)	35
Injector temp (°C)	150
Manifold temp (°C)	210
Detector temp (°C)	250
Detector current (mA)	225
Detection limit (nmol/mL)	1

Instrument calibrated with gas standards traceable to NIST.

Nitrous Oxide

Nitrous oxide analysis was performed on a gas chromatograph equipped with an electron capture detector (^{63}Ni). Instrument conditions are listed below:

Column	SS 12' x 1/8" Porapak QS
Column temp (°C)	70
Carrier gas	N_2
Carrier flow (mL/min)	30
Injector temp (°C)	270
Detector temp (°C)	270
Detector current (nA)	2
Detection limit (pmol/mL)	100

Instrument calibrated with gas standards traceable to NIST.

APPENDIX C: DETAILS OF THE LONG-TERM EXPERIMENT

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The following is a detailed description of the samples prepared for the long-term inundated experiment, including the number and chemical composition of treatments.

Sample Preparation

Detergent (Alconox®) and acid-washed (10% HCl) 160 mL serum bottles were rinsed with deionized water. They were then dried in a drying oven, covered with aluminum foil and autoclaved, thus completing preparation of the bottles.

Four paper types were used for the experiment:

Whatman #1 filter paper
Brown paper towel
White paper towel
Kimwipes

The papers were reduced to approximately 1 cm by 1 cm squares.

The bottles were filled with the processed paper. The papers were mixed together prior to filling and 1.25 g of each paper type were added to each bottle for a total of 5 grams of paper per bottle.

Anaerobic Samples

Ten liters of G-Seep #9 were removed from storage at 4°C and equilibrated overnight to room temperature. Storage at 4°C was necessary in order to prevent microbial activity in the storage containers; which could possibly pre-enrich the brine with specific microbes.

Sixty filled bottles (w/ paper) were arranged and prepared for treatment as follows:

<u>36 w/paper: unamended (G-Seep w/o additions)</u>
18 w/o bentonite
18 w/ bentonite

<u>12 w/paper: amended (G-Seep w/ nutrients)</u>
6 w/o bentonite
6 w/ bentonite

12 w/paper: amended w/ excess nitrate (G-Seep w/ nutrients and excess nitrate)
6 w/o bentonite
6 w/ bentonite

Thirty-two bottles w/o paper were arranged and prepared for treatment as follows:

16 unamended (G-Seep w/o additions)
8 w/o bentonite
8 w/ bentonite

8 amended (G-Seep w/ nutrients)
4 w/o bentonite
4 w/ bentonite

8 amended w/ excess nitrate (G-Seep w/ nutrients and excess nitrate)
4 w/o bentonite
4 w/ bentonite

A total of 92 bottles were prepared for anaerobic treatment.

Aerobic Samples

Sixty filled bottles (w/ paper) were arranged and prepared for treatment as follows:

36 w/paper: unamended (G-Seep w/o additions)
18 w/o bentonite
18 w/ bentonite

12 w/paper: amended (G-Seep w/ nutrients)
6 w/o bentonite
6 w/ bentonite

12 w/paper: amended w/ excess nitrate (G-Seep w/ nutrients and excess nitrate)
6 w/o bentonite
6 w/ bentonite

Thirty-two bottles w/o paper were arranged and prepared for treatment as follows:

16 unamended (G-Seep w/o additions)
8 w/o bentonite
8 w/ bentonite

8 amended (G-Seep w/ nutrients)
4 w/o bentonite
4 w/ bentonite

8 amended w/ excess nitrate (G-Seep w/ nutrients and excess nitrate)
4 w/o bentonite
4 w/ bentonite

A total of 92 bottles were prepared for aerobic treatment.

Nutrient Additions

The following lists the quantities added and final concentrations of nutrients in the samples. This list applies to both the aerobic and anaerobic samples with and without paper.

(a) Amended: The following quantities of nutrients were used for the amended treatments:

	grams/L	mM
Ammonium nitrate	1	12.5
Potassium phosphate (dibasic)	1	7.35
Yeast extract (0.05%)	0.5	--

Each 100 mL sample contained the following final concentration of nutrients:

	grams/100mL	µmoles
Ammonium nitrate	0.1	1250
Potassium phosphate (dibasic)	0.1	735
Yeast extract (0.05%)	0.05	--

(b) Amended and excess nitrate added: Potassium nitrate was added in addition to the ammonium nitrate:

	grams/L	mM
Ammonium nitrate	1	12.5
Potassium phosphate (dibasic)	1	7.35
Potassium nitrate	5	49.5
Yeast extract (0.05%)	0.5	--

Each 100 mL sample contained the following final concentration of nutrients:

	grams/100mL	µmoles
Ammonium nitrate	0.1	1250
Potassium phosphate (dibasic)	0.1	735
Potassium nitrate	0.5	4950
Yeast extract (0.05%)	0.05	--

(c) Glucose added (instead of paper): Samples were prepared without paper with a glucose addition to determine the ability of the inoculum to grow in the amended samples. The treatment was composed of the following:

	grams/L	mM
Glucose	5	27.7
Ammonium nitrate	1	12.5
Potassium phospate (dibasic)	1	7.35
Yeast extract (0.05%)	0.5	--

Each 100 mL sample contains the following quantity of nutrients:

	grams/100mL	µmoles
Glucose	0.5	2770
Ammonium nitrate	0.1	1250
Potassium phosphate (dibasic)	0.1	735
Yeast extract (0.05%)	0.05	--

(d) Glucose added (instead of paper) and excess nitrate: Samples were prepared without paper with a glucose addition and additional nitrate. The treatment was composed of the following:

	grams/L	mM
Glucose	5	27.7
Ammonium nitrate	1	12.5
Potassium phospate (dibasic)	1	7.35
Potassium nitrate	5	49.5
Yeast extract (0.05%)	0.5	--

Each 100 mL sample contained the following final concentration of nutrients:

	grams/100mL	µmoles
Glucose	0.5	2770
Ammonium nitrate	0.1	1250
Potassium phosphate (dibasic)	0.1	735
Potassium nitrate	0.5	4950
Yeast extract (0.05%)	0.05	--

Sample Volumes

The final sample volume (displacement of liquid plus cellulose or liquid w/o cellulose) and the headspace volume of each treatment is as follows:

Cellulose Treatments	sample vol. (mL	hdsp. vol (mL*
U (uninoculated)	110	50
I (inoculated)	114	46
UC (uninoculated control)	113	47
IC (inoculated control)	117	43

"No paper" Treatments	sample vol. (mL	hdsp. vol (mL*
NU (uninoculated)	100	60
NI (inoculated)	104	56
NUC (uninoculated control)	103	57
NIC (inoculated control)	107	53

*Headspace vol. (hdsp. vol) calculated by subtracting sample volume from volume of bottle (160ml).

Acetylene was not injected into the headspace of any of the samples in order to prevent pertubation of the headspace gas.

APPENDIX D: GAS PRODUCTION DATA (GROSS AND NET) FOR THE LONG-TERM INUNDATED EXPERIMENT

APPENDIX D: GAS PRODUCTION DATA (GROSS AND NET) FOR THE LONG-TERM INUNDATED EXPERIMENT

i. Data Reduction

Total gas, carbon dioxide, and nitrous oxide produced by aerobic and anaerobic samples up to 200 days incubation is present in Appendix D, Tables 1-12, on a per sample basis. This data was used to prepare Tables 13-24 in which total gas, carbon dioxide, and nitrous oxide production in aerobic and anaerobic treatments is presented on a per gram cellulose basis. Figures 13-24 are based on the data from Tables 13-24. The data in Tables 13-24 have been corrected for gas production in the absence of cellulose by subtracting the measured gas values in respective treatments prepared without cellulose. As an example, total gas production in aerobic samples was corrected (Table 13) by subtracting total gas production in treatments without cellulose (designated "NC", Appendix D, Table 1) from samples with cellulose (designated "C") at each period. The resultant number was divided by the total amount of cellulose in each sample bottle (5 grams) to arrive at a value that represents the total gas produced per gram of cellulose. Tables 13 to 24 represent the gas produced strictly due to the presence of cellulose in the samples, and are corrected for gas produced due to metabolism of dissolved organic carbon present in the brine or in the nutrient addition as measured in specific control treatments. Carbon dioxide was produced in certain samples in the absence of cellulose, specifically, before 69 days. After this period, gas production reported is that which is above and beyond the control treatments. Significant quantities of NO_2 were not detected in the absence of cellulose. Gas produced at time 0 was not subtracted from later values, as many seem neccessary to normalize the starting values at 0. This was not done because time 0 measurements were taken 3 days after sample preparation; therefore gas present at time 0 is due to evolution of dissolved gases and headspace equilibration. These processes contribute to the overall gas production.

Figures 13 to 24 present data from Table 13 to 24. All data in these figures are presented as gas produced per gram cellulose, and have been corrected for gas production

in the absence of cellulose. The data plotted are the mean values of three samples, and error bars represent the standard error of the mean. In the legend: "uninoculated" refers to samples that have received no mixed inoculum or nutrients; "inoculated" refers to samples that have received mixed inoculum but no nutrients; "inoculated + nutrients" refers to samples that have received both mixed inoculum and nutrients (amended), and; "inoculated + nutrients + nitrate" refers to samples that have received (i) mixed inoculum, (ii) nutrients, and (iii) excess nitrate in the form of potassium nitrate (amended plus excess nitrate).

Data for treatments prepared with glucose to determine activity of the mixed inoculum are persented in Figures 25-30. Data for gas analysis of these samples, along with formalin-treated controls for all cellulose and no-cellulose treatments, are presented in Appendix D, Tables 1(a) to 4(c).

Analysis of the samples will continue at selected intervals (as determined by gas-producing activity) past 200 days and up to 800 days. The analyses then will stop if activity ceases, as indicated by cessation of gas production, or be extended if gas-producing activity continues in the samples. If this occurs in select samples only, then only these samples will be reserved for long-term monitoring, and analyses of inactive samples will stop.

Table 1. Gross Data for the Long-Term Inundated Experiment: Total Volume of Gas Produced in Aerobic Samples.

Treatments* [Brine]	Sample Designation	Volume of Gas Produced (ml) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (1)								
Formalin treated, w/o cellulose	1(NC)-f	4.22 ± 0.13	-0.35 ± 0.13	-0.06 ± 0.45	-0.26 ± 0.06	-0.13 ± 0.13	NA	-1.44 ± 0.00
Formalin treated, with cellulose	1(C)-f	5.44 ± 0.32	4.09 ± 0.16	4.19 ± 0.10	2.08 ± 1.06	1.37 ± 0.93	NA	0.67 ± 0.90
As is, w/o cellulose	1(NC)-a	4.39 ± 0.03	3.71 ± 0.03	3.84 ± 0.03	1.90 ± 0.61	1.33 ± 0.85	NA	-0.61 ± 0.75
As is, with cellulose	1(C)-a	4.63 ± 0.10	2.28 ± 0.95	2.04 ± 0.92	0.34 ± 0.68	0.34 ± 0.61	NA	-1.53 ± 0.51
Unamended/Inoculated (2)								
Formalin treated, w/o cellulose	2(NC)-f	4.96 ± 0.02	2.88 ± 0.04	3.50 ± 0.00	2.49 ± 0.04	2.45 ± 0.14	NA	0.07 ± 0.25
Formalin treated, with cellulose	2(C)-f	4.89 ± 0.06	2.72 ± 0.38	1.76 ± 0.56	0.91 ± 0.41	0.41 ± 0.53	NA	-0.50 ± 0.44
As is, w/o cellulose	2(NC)-a	3.56 ± 0.02	2.90 ± 0.15	2.21 ± 0.30	0.53 ± 0.11	-0.91 ± 0.04	NA	-2.86 ± 0.04
As is, with cellulose	2(C)-a	3.16 ± 0.03	2.97 ± 0.22	1.44 ± 0.16	-0.44 ± 0.22	-1.28 ± 0.25	NA	-4.57 ± 0.34
Amended/Inoculated (3)								
As is, w/o cellulose	3(NC)-a	3.20 ± 0.04	1.37 ± 0.04	0.30 ± 0.00	0.11 ± 0.04	-1.49 ± 0.15	-2.48 ± 0.38	-4.53 ± 0.46
As is, with cellulose	3(C)-a	2.60 ± 0.16	0.03 ± 0.69	-0.94 ± 0.31	1.91 ± 1.53	1.44 ± 1.19	0.34 ± 0.63	-0.22 ± 0.41
As is, with glucose	3(G)-a	3.73 ± 0.08	2.29 ± 0.15	1.83 ± 0.38	-1.79 ± 0.34	-1.22 ± 1.37	1.87 ± 2.63	-1.83 ± 1.30
Excess nitrate, w/o cellulose	3(NC)-x	3.16 ± 0.08	0.84 ± 0.46	-1.30 ± 0.08	-0.78 ± 0.30	-1.14 ± 0.04	-1.80 ± 0.18	-2.82 ± 0.27
Excess nitrate, with cellulose	3(C)-x	3.04 ± 0.06	0.94 ± 0.72	5.66 ± 3.04	11.9 ± 4.4	15.5 ± 5.3	18.3 ± 6.1	19.3 ± 4.0
Excess nitrate, with glucose	3(G)-x	3.52 ± 0.02	2.74 ± 0.50	0.88 ± 0.76	-1.49 ± 0.27	-1.30 ± 0.04	-0.86 ± 0.72	2.90 ± 2.02

NA = not analyzed

Table 2. Gross Data for the Long-Term Inundated Experiment: Production of Carbon Dioxide* in Aerobic Samples

Treatments [Brine]	Sample Designation	Carbon Dioxide (μmoles/sample) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (1)								
Formalin treated, w/o cellulose	1(NC)-f	2.59 ± 0.01	2.50 ± 0.01	3.40 ± 0.40	3.32 ± 0.00	3.61 ± 0.00	NA	3.68 ± 0.01
Formalin treated, with cellulose	1(C)-f	30.5 ± 2.7	40.8 ± 0.1	44.4 ± 0.2	40.6 ± 0.8	41.8 ± 0.3	NA	41.8 ± 0.5
As is, w/o cellulose	1(NC)-a	1.38 ± 0.01	1.49 ± 0.01	0.94 ± 0.00	1.66 ± 0.01	1.83 ± 0.06	NA	2.18 ± 0.04
As is, with cellulose	1(C)-a	13.8 ± 0.5	21.1 ± 0.3	22.0 ± 0.1	21.3 ± 0.1	23.1 ± 0.1	NA	22.2 ± 0.1
Unamended/Inoculated (2)								
Formalin treated, w/o cellulose	2(NC)-f	4.97 ± 0.45	4.38 ± 0.29	4.70 ± 0.11	4.88 ± 0.3	5.02 ± 0.30	NA	4.94 ± 0.27
Formalin treated, with cellulose	2(C)-f	34.5 ± 0.8	35.6 ± 0.0	38.7 ± 0.7	34.3 ± 0.6	35.2 ± 0.1	NA	33.2 ± 1.1
As is, w/o cellulose	2(NC)-a	2.30 ± 0.02	2.97 ± 0.03	2.92 ± 0.09	5.88 ± 0.08	6.56 ± 0.11	NA	7.01 ± 0.11
As is, with cellulose	2(C)-a	12.1 ± 0.3	19.7 ± 0.8	22.6 ± 0.9	30.8 ± 0.9	40.9 ± 1.0	NA	48.5 ± 1.4
Amended/Inoculated (3)								
As is, w/o cellulose	3(NC)-a	2.87 ± 0.03	27.8 ± 1.2	72.9 ± 2.6	113 ± 5	130 ± 2	150 ± 1	142 ± 1
As is, with cellulose	3(C)-a	2.80 ± 0.10	50.9 ± 1.4	91.8 ± 5.9	215 ± 37	278 ± 25	333 ± 21	346 ± 27
As is, with glucose	3(G)-a	2.41 ± 0.03	4.03 ± 0.13	30.8 ± 2.1	94.9 ± 7.5	167 ± 32	325 ± 108	323 ± 95
Excess nitrate, w/o cellulose	3(NC)-x	2.79 ± 0.03	17.2 ± 1.9	48.9 ± 0.2	92.2 ± 0.59	115 ± 3	131 ± 2	126 ± 2
Excess nitrate, with cellulose	3(C)-x	2.60 ± 0.10	51.6 ± 0.0	210 ± 21	399 ± 18	533 ± 13	612 ± 20	604 ± 30
Excess nitrate, with glucose	3(G)-x	2.51 ± 0.01	4.05 ± 0.25	24.1 ± 5.9	72.0 ± 7.7	121 ± 4	211 ± 6	296 ± 20

*Dissolved carbon dioxide concentrations not included.

NA = not analyzed

Table 3. Gross Data for the Long-Term Inundated Experiment: Production of Nitrous Oxide* in Aerobic Samples

Treatments [Brine]	Sample Designation	Nitrous Oxide (µmoles/sample) Incubation Time (Days) 0	69	104	132	164	200
Unamended/Uninoculated (1)							
Formalin treated, w/o cellulose	1(NC)-f	0.000 ± 0.000	0.003 ± 0.002	0.000 ± 0.000	0.000 ± 0.000	NA	0.001 ± 0.001
Formalin treated, with cellulose	1(C)-f	0.000 ± 0.000	0.003 ± 0.001	0.003 ± 0.001	0.013 ± 0.001	NA	0.005 ± 0.002
As is, w/o cellulose	1(NC)-a	0.000 ± 0.000	0.162 ± 0.110	0.000 ± 0.000	0.000 ± 0.000	NA	0.051 ± 0.035
As is, with cellulose	1(C)-a	0.000 ± 0.000	0.003 ± 0.001	0.006 ± 0.001	0.015 ± 0.001	NA	0.008 ± 0.000
Unamended/Inoculated (2)							
Formalin treated, w/o cellulose	2(NC)-f	0.000 ± 0.000	0.025 ± 0.018	0.000 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
Formalin treated, with cellulose	2(C)-f	0.000 ± 0.000	0.001 ± 0.000	0.002 ± 0.000	0.014 ± 0.002	NA	0.004 ± 0.000
As is, w/o cellulose	2(NC)-a	0.003 ± 0.000	0.001 ± 0.001	0.000 ± 0.000	0.016 ± 0.011	NA	0.062 ± 0.007
As is, with cellulose	2(C)-a	0.014 ± 0.000	0.002 ± 0.001	0.000 ± 0.000	0.000 ± 0.000	NA	0.009 ± 0.006
Amended/Inoculated (3)							
As is, w/o cellulose	3(NC)-a	0.000 ± 0.000	0.061 ± 0.043	0.087 ± 0.061	0.024 ± 0.003	0.000 ± 0.000	0.050 ± 0.033
As is, with cellulose	3(C)-a	0.004 ± 0.000	0.182 ± 0.147	118 ± 48	122 ± 39	8.81 ± 5.98	29.2 ± 25.2
As is, with glucose	3(G)-a	0.000 ± 0.000	0.056 ± 0.010	0.252 ± 0.122	5.64 ± 3.40	114 ± 80	105 ± 74
Excess nitrate, w/o cellulose	3(NC)-x	0.000 ± 0.000	0.001 ± 0.000	0.004 ± 0.002	0.006 ± 0.004	0.006 ± 0.001	0.023 ± 0.006
Excess nitrate, with cellulose	3(C)-x	0.000 ± 0.000	28.2 ± 8.8	245 ± 11	326 ± 18	484 ± 67	577 ± 129
Excess nitrate, with glucose	3(G)-x	0.000 ± 0.000	0.000 ± 0.000	2.97 ± 2.10	2.99 ± 2.08	11.2 ± 7.3	66.0 ± 41.2

*Dissolved nitrous oxide concentrations not included.

NA = not analyzed

Table 4. Gross Data for the Long-Term Inundated Experiment: Total Volume of Gas Produced in Aerobic Samples

Treatments [Brine/Bentonite]	Sample Designation	Volume of Gas Produced (ml) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (4)								
Formalin treated, w/o cellulose	4(NC)-f	5.93 ± 0.04	1.24 ± 2.02	1.43 ± 1.74	1.09 ± 1.05	-0.31 ± 0.00	NA	-2.17 ± 0.00
Formalin treated, with cellulose	4(C)-f	6.59 ± 0.16	4.38 ± 0.13	3.77 ± 0.13	1.82 ± 0.13	0.10 ± 0.03	NA	-1.98 ± 0.03
As is, w/o cellulose	4(NC)-a	5.43 ± 0.04	3.63 ± 0.53	4.78 ± 0.78	2.65 ± 0.45	1.92 ± 0.20	NA	-0.82 ± 0.20
As is, with cellulose	4(C)-a	5.17 ± 0.10	3.74 ± 0.10	2.99 ± 0.20	1.67 ± 0.24	1.26 ± 0.20	NA	-0.82 ± 0.27
Unamended/Inoculated (5)								
Formalin treated, w/o cellulose	5(NC)-f	5.08 ± 0.36	2.56 ± 0.83	1.19 ± 1.73	0.76 ± 0.94	0.54 ± 0.65	NA	-2.02 ± 0.36
Formalin treated, with cellulose	5(C)-f	5.65 ± 0.12	3.63 ± 0.03	2.72 ± 0.00	2.22 ± 0.00	0.88 ± 0.15	NA	-1.23 ± 0.12
As is, w/o cellulose	5(NC)-a	3.66 ± 0.30	3.62 ± 0.04	2.78 ± 0.08	1.64 ± 0.15	1.14 ± 0.11	NA	-2.06 ± 0.34
As is, with cellulose	5(C)-a	3.79 ± 0.06	3.13 ± 0.09	1.88 ± 0.19	0.16 ± 0.66	-1.94 ± 0.47	NA	-2.47 ± 0.78
Amended/Inoculated (6)								
As is, w/o cellulose	6(NC)-a	3.85 ± 0.04	0.84 ± 0.84	1.52 ± 0.84	1.56 ± 0.80	0.11 ± 0.53	-1.49 ± 0.34	-3.47 ± 0.15
As is, with cellulose	6(C)-a	2.60 ± 0.16	3.00 ± 0.06	5.07 ± 0.75	10.7 ± 1.8	14.9 ± 1.5	18.9 ± 1.1	18.4 ± 1.0
As is, with glucose	6(G)-a	1.60 ± 0.04	1.10 ± 0.69	0.69 ± 0.50	-0.34 ± 0.19	-1.07 ± 0.27	-1.62 ± 0.19	-1.52 ± 0.61
Excess nitrate, w/o cellulose	6(NC)-x	1.41 ± 0.08	-1.45 ± 0.04	-0.99 ± 0.08	0.00 ± 0.00	-0.27 ± 0.08	-1.30 ± 0.04	-3.05 ± 0.08
Excess nitrate, with cellulose	6(C)-x	2.91 ± 0.06	2.82 ± 0.09	6.79 ± 0.09	11.2 ± 1.2	18.7 ± 1.5	24.4 ± 0.9	27.3 ± 0.2
Excess nitrate, with glucose	6(G)-x	2.29 ± 0.23	2.51 ± 1.71	0.69 ± 0.57	-0.38 ± 0.5	-0.53 ± 0.11	-1.49 ± 0.15	-1.94 ± 0.69

NA = not analyzed

Table 5. Gross Data for the Long-Term Inundated Experiment: Production of Carbon Dioxide* in Aerobic Samples

Treatments [Brine/Bentonite]	Sample Designation	Carbon Dioxide (µmoles/sample) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (4)								
Formalin treated, w/o cellulose	4(NC)-f	50.3 ± 0.4	88.8 ± 1.0	98.8 ± 0.4	101 ± 1	115 ± 2	NA	121 ± 4
Formalin treated, with cellulose	4(C)-f	71.1 ± 1.2	95.3 ± 0.2	110 ± 0	114 ± 0	127 ± 1	NA	137 ± 1
As is, w/o cellulose	4(NC)-a	17.7 ± 0.3	38.8 ± 0.4	44.5 ± 0.4	40.2 ± 0.3	42.7 ± 0.2	NA	40.0 ± 0.1
As is, with cellulose	4(C)-a	25.3 ± 1.5	47.6 ± 0.3	66.9 ± 11.8	49 ± 0.7	51.8 ± 0.5	NA	51.6 ± 0.1
Unamended/Inoculated (5)								
Formalin treated, w/o cellulose	5(NC)-f	37.3 ± 10.1	59.6 ± 15.7	66.1 ± 18.4	77.4 ± 18.1	76.0 ± 26.5	NA	79.0 ± 33.0
Formalin treated, with cellulose	5(C)-f	61.9 ± 0.9	83.5 ± 0.0	94.0 ± 0.2	93.2 ± 0.6	100 ± 0	NA	102 ± 0
As is, w/o cellulose	5(NC)-a	13.5 ± 2.9	36.7 ± 0.7	41.3 ± 0.2	38.7 ± 0.7	41.4 ± 0.7	NA	37.6 ± 0.7
As is, with cellulose	5(C)-a	23.7 ± 0.2	43.6 ± 0.4	61.3 ± 4.0	80.3 ± 2.1	101 ± 3	NA	145 ± 6
Amended/Inoculated (6)								
As is, w/o cellulose	6(NC)-a	11.3 ± 0.1	103 ± 3	169 ± 3	185 ± 2	201 ± 2	203 ± 0	181 ± 1
As is, with cellulose	6(C)-a	8.60 ± 0.00	72.4 ± 1.0	156 ± 5	247 ± 11	358 ± 19	492 ± 6	530 ± 6
As is, with glucose	6(G)-a	8.50 ± 2.80	67.1 ± 0.2	73.1 ± 0.4	72.9 ± 0.2	75.8 ± 0.4	79.5 ± 1.0	75.7 ± 1.7
Excess nitrate, w/o cellulose	6(NC)-x	10.5 ± 0.4	84.6 ± 0.0	153 ± 1	171 ± 3	139 ± 37	184 ± 4	159 ± 4
Excess nitrate, with cellulose	6(C)-x	8.9 ± 0.1	68.0 ± 1.2	164 ± 3	307 ± 23	499 ± 75	711 ± 46	741 ± 30
Excess nitrate, with glucose	6(G)-x	9.40 ± 0.90	65.0 ± 2.0	71.4 ± 1.2	71.2 ± 0.6	76.5 ± 0.2	80.1 ± 1.5	81.1 ± 5.0

*Dissolved carbon dioxide concentrations not included.

NA = not analyzed

Table 6. Gross Data for the Long-Term Inundated Experiment: Production of Nitrous Oxide* in Aerobic Samples

Treatments [Brine/Bentonite]	Sample Designation	Nitrous Oxide (µmoles/sample) Incubation Time (Days) 0	69	104	132	164	200
Unamended/Uninoculated (4)							
Formalin treated, w/o cellulose	4(NC)-f	0.000 ± 0.000	0.002 ± 0.002	0.213 ± 0.146	0.010 ± 0.007	NA	0.000 ± 0.000
Formalin treated, with cellulose	4(C)-f	0.000 ± 0.000	0.008 ± 0.002	0.001 ± 0.001	0.019 ± 0.000	NA	0.006 ± 0.001
As is, w/o cellulose	4(NC)-a	0.000 ± 0.000	0.006 ± 0.001	0.003 ± 0.002	0.017 ± 0.000	NA	0.005 ± 0.003
As is, with cellulose	4(C)-a	0.000 ± 0.000	0.731 ± 0.489	0.188 ± 0.054	0.222 ± 0.070	NA	0.245 ± 0.101
Unamended/Inoculated (5)							
Formalin treated, w/o cellulose	5(NC)-f	0.000 ± 0.000	0.070 ± 0.049	0.009 ± 0.002	0.166 ± 0.106	NA	0.076 ± 0.049
Formalin treated, with cellulose	5(C)-f	0.000 ± 0.000	0.012 ± 0.001	0.011 ± 0.002	0.025 ± 0.001	NA	0.009 ± 0.002
As is, w/o cellulose	5(NC)-a	0.000 ± 0.000	0.038 ± 0.024	0.195 ± 0.065	0.210 ± 0.066	NA	0.161 ± 0.050
As is, with cellulose	5(C)-a	0.000 ± 0.000	0.010 ± 0.006	0.000 ± 0.000	0.000 ± 0.000	NA	0.064 ± 0.027
Amended/Inoculated (6)							
As is, w/o cellulose	6(NC)-a	0.000 ± 0.000	0.002 ± 0.001	1.21 ± 0.36	6.06 ± 4.21	4.96 ± 3.51	4.27 ± 2.55
As is, with cellulose	6(C)-a	0.000 ± 0.000	31.6 ± 13.2	160 ± 53	132 ± 8	0.528 ± 0.459	0.000 ± 0.000
As is, with glucose	6(G)-a	0.000 ± 0.000	0.003 ± 0.000	0.003 ± 0.000	0.028 ± 0.001	0.007 ± 0.001	0.015 ± 0.004
Excess nitrate, w/o cellulose	6(NC)-x	0.000 ± 0.000	0.000 ± 0.000	14.6 ± 2.7	13.9 ± 5.2	13.8 ± 5.4	11.6 ± 4.9
Excess nitrate, with cellulose	6(C)-x	0.000 ± 0.000	27.1 ± 6.5	142 ± 22	217 ± 41	354 ± 41	425 ± 35
Excess nitrate, with glucose	6(G)-x	0.000 ± 0.000	0.005 ± 0.001	0.010 ± 0.001	0.022 ± 0.003	0.092 ± 0.063	0.011 ± 0.001

*Dissolved nitrous oxide concentrations not included.

NA = not analyzed

Table 7. Gross Data for the Long-Term Inundated Experiment: Total Volume of Gas Produced in Anaerobic Samples

Treatments [Brine]	Sample Designation	Volume of Gas Produced (ml)						
		Incubation Time (Days)						
		0	45	69	104	132	164	200
Unamended/Uninoculated (7)								
Formalin treated, w/o cellulose	7(NC)-f	2.99 ± 0.10	2.65 ± 0.10	2.01 ± 0.03	1.09 ± 0.06	1.66 ± 0.00	NA	0.06 ± 0.03
Formalin treated, with cellulose	7(C)-f	4.28 ± 0.06	3.49 ± 0.06	3.10 ± 0.03	1.95 ± 0.03	2.37 ± 0.03	NA	1.37 ± 0.00
As is, w/o cellulose	7(NC)-a	3.20 ± 0.34	2.96 ± 0.07	0.99 ± 0.14	2.24 ± 0.00	2.07 ± 0.10	NA	0.65 ± 0.31
As is, with cellulose	7(C)-a	3.37 ± 0.27	3.47 ± 0.10	2.99 ± 0.07	1.33 ± 0.34	2.28 ± 1.17	NA	0.20 ± 0.17
Unamended/Inoculated (8)								
Formalin treated, w/o cellulose	8(NC)-f	3.79 ± 0.04	2.31 ± 0.07	1.73 ± 0.18	0.76 ± 0.11	1.55 ± 0.11	NA	-0.07 ± 0.11
Formalin treated, with cellulose	8(C)-f	3.89 ± 0.03	3.39 ± 0.09	2.54 ± 0.15	1.58 ± 0.00	2.14 ± 0.06	NA	1.02 ± 0.03
As is, w/o cellulose	8(NC)-a	3.66 ± 0.08	-1.37 ± 0.99	1.41 ± 0.23	1.87 ± 0.08	2.10 ± 0.08	NA	-0.50 ± 0.00
As is, with cellulose	8(C)-a	3.47 ± 0.06	3.63 ± 0.13	2.53 ± 0.16	1.78 ± 0.13	2.22 ± 0.06	NA	2.44 ± 0.63
Amended/Inoculated (9)								
As is, w/o cellulose	9(NC)-a	3.77 ± 0.04	3.35 ± 0.08	6.63 ± 0.30	7.96 ± 1.33	9.07 ± 0.88	8.41 ± 0.48	8.04 ± 0.46
As is, with cellulose	9(C)-a	3.35 ± 0.09	3.44 ± 0.16	4.04 ± 0.03	11.3 ± 0.5	16.7 ± 1.3	19.2 ± 1.2	19.4 ± 0.6
As is, with glucose	9(G)-a	2.97 ± 0.08	2.59 ± 0.15	2.36 ± 0.15	1.64 ± 0.15	1.52 ± 0.27	0.18 ± 0.16	-1.26 ± 0.30
Excess nitrate, w/o cellulose	9(NC)-x	3.24 ± 0.04	2.86 ± 0.08	4.30 ± 0.23	6.59 ± 0.76	9.18 ± 0.23	8.65 ± 0.67	6.93 ± 0.27
Excess nitrate, with cellulose	9(C)-x	3.29 ± 0.13	2.28 ± 0.38	5.76 ± 1.47	16.6 ± 2.9	14.2 ± 3.9	28.9 ± 6.2	34.1 ± 7.1
Excess nitrate, with glucose	9(G)-x	3.01 ± 0.11	0.61 ± 0.15	0.19 ± 0.11	0.46 ± 0.04	0.46 ± 0.61	1.33 ± 2.08	1.14 ± 2.90

NA = not analyzed

Table 8. Gross Data for the Long-Term Inundated Experiment: Production of Carbon Dioxide* in Anaerobic Samples

Treatments [Brine]	Sample Designation	Carbon Dioxide (µmoles/sample) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (7)								
Formalin treated, w/o cellulose	7(NC)-f	2.26 ± 0.01	1.92 ± 0.03	2.20 ± 0.20	2.24 ± 0.04	2.33 ± 0.01	NA	2.39 ± 0.01
Formalin treated, with cellulose	7(C)-f	31.7 ± 0.5	38.0 ± 0.1	38.0 ± 0.1	35.0 ± 0.2	36.4 ± 0.1	NA	36.3 ± 0.1
As is, w/o cellulose	7(NC)-a	1.12 ± 0.01	0.58 ± 0.13	0.90 ± 0.00	1.37 ± 0.01	1.35 ± 0.01	NA	1.46 ± 0.03
As is, with cellulose	7(C)-a	13.0 ± 0.4	19.3 ± 0.1	20.5 ± 0.1	19.5 ± 0.1	20.5 ± 0.2	NA	19.4 ± 0.2
Unamended/Inoculated (8)								
Formalin treated, w/o cellulose	8(NC)-f	4.42 ± 0.01	3.88 ± 0.08	3.89 ± 0.13	3.88 ± 0.04	3.99 ± 0.03	NA	3.97 ± 0.03
Formalin treated, with cellulose	8(C)-f	32.1 ± 0.7	34.3 ± 0.4	33.5 ± 0.2	31.2 ± 0.0	32.5 ± 0.5	NA	32.8 ± 0.4
As is, w/o cellulose	8(NC)-a	1.96 ± 0.02	1.37 ± 0.01	2.29 ± 0.02	2.75 ± 0.01	2.86 ± 0.01	NA	2.74 ± 0.01
As is, with cellulose	8(C)-a	12.5 ± 0.2	18.4 ± 0.2	19.0 ± 0.1	17.8 ± 0.7	22.7 ± 0.5	NA	30.1 ± 1.7
Amended/Inoculated (9)								
As is, w/o cellulose	9(NC)-a	3.02 ± 0.00	6.86 ± 0.02	58.9 ± 3.1	95.9 ± 9.5	109 ± 4	119 ± 3	120 ± 1
As is, with cellulose	9(C)-a	2.70 ± 0.00	25.8 ± 0.2	42.5 ± 1.7	132 ± 3	200 ± 7	240 ± 3	250 ± 4
As is, with glucose	9(G)-a	2.25 ± 0.01	3.36 ± 0.04	2.96 ± 0.04	3.50 ± 0.05	3.88 ± 0.06	4.26 ± 0.09	4.31 ± 0.07
Excess nitrate, w/o cellulose	9(NC)-x	3.07 ± 0.03	5.17 ± 0.28	35.3 ± 5.3	94.5 ± 4.4	120 ± 1	125 ± 1	123 ± 1
Excess nitrate, with cellulose	9(C)-x	5.40 ± 0.00	26.6 ± 0.2	65.8 ± 17.1	193 ± 33	249 ± 32	352 ± 40	430 ± 41
Excess nitrate, with glucose	9(G)-x	1.81 ± 0.27	2.88 ± 0.19	2.65 ± 0.25	8.64 ± 3.62	23.6 ± 13.3	53.6 ± 31.4	74.9 ± 40.9

*Dissolved carbon dioxide concentrations not included.
NA = not analyzed

Table 9. Gross Data for the Long-Term Inundated Experiment: Production of Nitrous Oxide* in Anaerobic Samples

Treatments [Brine]	Sample Designation	Nitrous Oxide (µmoles/sample) Incubation Time (Days) 0	69	104	132	164	200
Unamended/Uninoculated (7)							
Formalin treated, w/o cellulose	7(NC)-f	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
Formalin treated, with cellulose	7(C)-f	0.000 ± 0.000	0.009 ± 0.007	0.004 ± 0.001	0.007 ± 0.005	NA	0.002 ± 0.002
As is, w/o cellulose	7(NC)-a	0.000 ± 0.000	0.003 ± 0.002	0.001 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
As is, with cellulose	7(C)-a	0.000 ± 0.000	0.002 ± 0.002	0.003 ± 0.002	0.000 ± 0.000	NA	0.002 ± 0.002
Unamended/Inoculated (8)							
Formalin treated, w/o cellulose	8(NC)-f	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
Formalin treated, with cellulose	8(C)-f	0.000 ± 0.000	0.002 ± 0.001	0.002 ± 0.000	0.014 ± 0.001	NA	0.008 ± 0.000
As is, w/o cellulose	8(NC)-a	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
As is, with cellulose	8(C)-a	0.000 ± 0.000	0.001 ± 0.001	0.000 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
Amended/Inoculated (9)							
As is, w/o cellulose	9(NC)-a	0.000 ± 0.000	0.376 ± 0.262	35.5 ± 25.1	7.55 ± 5.34	0.000 ± 0.000	0.359 ± 0.235
As is, with cellulose	9(C)-a	0.000 ± 0.000	0.359 ± 0.145	13.2 ± 10.1	86.5 ± 41.3	89.3 ± 43.0	77.8 ± 42.2
As is, with glucose	9(G)-a	0.000 ± 0.000	0.002 ± 0.001	0.000 ± 0.000	0.005 ± 0.003	0.005 ± 0.000	0.015 ± 0.010
Excess nitrate, w/o cellulose	9(NC)-x	0.000 ± 0.000	0.081 ± 0.021	5.13 ± 2.48	0.014 ± 0.002	0.000 ± 0.000	0.000 ± 0.000
Excess nitrate, with cellulose	9(C)-x	0.000 ± 0.000	0.870 ± 0.422	85.7 ± 50.2	196 ± 75	280 ± 160	395 ± 228
Excess nitrate, with glucose	9(G)-x	0.000 ± 0.000	0.028 ± 0.020	3.84 ± 2.72	0.523 ± 0.006	0.539 ± 0.381	13.8 ± 0.5

*Dissolved nitrous oxide concentrations not included.

NA = not analyzed

Table 10. Gross Data for the Long-Term Inundated Experiment: Total Volume of Gas Produced in Anaerobic Samples.

Treatments* [Brine/Bentonite]	Sample Designation	Volume of Gas Produced (ml) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (10)								
Formalin treated, w/o cellulose	10(NC)-f	4.65 ± 0.23	4.61 ± 0.47	2.37 ± 1.47	3.41 ± 0.19	4.07 ± 0.04	NA	2.33 ± 0.00
Formalin treated, with cellulose	10(C)-f	4.96 ± 0.06	4.64 ± 0.03	4.22 ± 0.00	2.94 ± 0.16	3.39 ± 0.16	NA	2.05 ± 0.16
As is, w/o cellulose	10(NC)-a	4.24 ± 0.33	4.04 ± 0.04	3.51 ± 0.69	2.86 ± 0.08	3.27 ± 0.20	NA	1.55 ± 0.08
As is, with cellulose	10(C)-a	3.84 ± 0.48	3.84 ± 0.14	3.33 ± 0.27	2.01 ± 0.41	2.18 ± 0.48	NA	0.14 ± 0.44
Unamended/Inoculated (11)								
Formalin treated, w/o cellulose	11(NC)-f	5.16 ± 0.07	5.01 ± 0.14	3.89 ± 0.22	2.85 ± 0.25	3.57 ± 0.25	NA	1.23 ± 0.22
Formalin treated, with cellulose	11(C)-f	4.65 ± 0.03	4.53 ± 0.00	3.66 ± 0.03	1.73 ± 1.14	2.16 ± 1.08	NA	0.94 ± 1.20
As is, w/o cellulose	11(NC)-a	4.23 ± 0.11	3.62 ± 0.08	3.47 ± 0.19	2.06 ± 0.19	2.44 ± 0.30	NA	0.34 ± 0.34
As is, with cellulose	11(C)-a	4.38 ± 0.03	4.19 ± 0.06	3.19 ± 0.16	2.88 ± 0.22	3.88 ± 0.19	NA	4.38 ± 0.38
Amended/Inoculated (12)								
As is, w/o cellulose	12(NC)-a	3.85 ± 0.08	4.53 ± 0.15	6.97 ± 0.15	9.90 ± 0.08	10.9 ± 0.1	11.1 ± 0.3	9.87 ± 0.80
As is, with cellulose	12(C)-a	3.32 ± 0.25	4.29 ± 0.09	7.92 ± 0.44	16.8 ± 0.4	19.8 ± 0.4	18.3 ± 0.3	19.5 ± 0.4
As is, with glucose	12(G)-a	3.50 ± 0.04	5.52 ± 0.34	9.49 ± 2.40	24.7 ± 3.3	33.9 ± 0.6	38.8 ± 1.8	37.8 ± 2.3
Excess nitrate, w/o cellulose	12(NC)-x	3.66 ± 0.00	4.19 ± 0.15	8.19 ± 0.69	11.8 ± 0.3	12.4 ± 0.0	12.8 ± 0.1	11.2 ± 0.1
Excess nitrate, with cellulose	12(C)-x	3.38 ± 0.09	3.76 ± 0.16	9.36 ± 0.31	15.7 ± 0.4	20.8 ± 0.5	23.8 ± 0.7	28.9 ± 1.4
Excess nitrate, with glucose	12(G)-x	3.09 ± 0.08	2.29 ± 0.19	2.21 ± 0.46	23.4 ± 0.6	52.3 ± 6.7	77.4 ± 20.2	80.7 ± 21.1

NA = not analyzed

Table 11. Gross Data for the Long-Term Inundated Experiment: Production of Carbon Dioxide* in Anaerobic Samples

Treatments [Brine/Bentonite]	Sample Designation	Carbon Dioxide (µmoles/sample) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (10)								
Formalin treated, w/o cellulose	10(NC)-f	55.8 ± 0.6	82.9 ± 1.1	85.5 ± 0.8	86.4 ± 1.7	92.8 ± 2.0	NA	94.9 ± 1.1
Formalin treated, with cellulose	10(C)-f	65.5 ± 1.0	85.5 ± 0.2	88.6 ± 0.4	81.9 ± 0.3	88.7 ± 0.9	NA	90.2 ± 0.3
As is, w/o cellulose	10(NC)-a	16.4 ± 0.4	37.7 ± 0.0	38.4 ± 0.1	38.1 ± 0.3	39.8 ± 0.3	NA	40.0 ± 0.4
As is, with cellulose	10(C)-a	26.6 ± 0.5	42.6 ± 0.2	43.0 ± 0.4	41.3 ± 0.2	43.1 ± 0.5	NA	41.1 ± 0.2
Unamended/Inoculated (11)								
Formalin treated, w/o cellulose	11(NC)-f	53.0 ± 0.2	76.9 ± 0.6	80.2 ± 0.4	76.5 ± 0.0	83.7 ± 0.6	NA	83.5 ± 0.2
Formalin treated, with cellulose	11(C)-f	64.4 ± 1.3	76.3 ± 0.5	78.6 ± 0.2	75.1 ± 1.9	78.6 ± 1.6	NA	80.4 ± 0.8
As is, w/o cellulose	11(NC)-a	20.8 ± 0.0	35.0 ± 0.1	36.3 ± 0.1	35.2 ± 0.2	19.6 ± 11.9	NA	36.2 ± 0.2
As is, with cellulose	11(C)-a	30.1 ± 0.6	38.1 ± 0.2	40.5 ± 0.1	48 ± 2.5	59.9 ± 0.7	NA	77.6 ± 1.0
Amended/Inoculated (12)								
As is, w/o cellulose	12(NC)-a	14.0 ± 0.0	60.2 ± 0.2	99.8 ± 4.7	150 ± 4	16.6 ± 0.4	177 ± 1	179 ± 0
As is, with cellulose	12(C)-a	12.0 ± 0.8	55.0 ± 0.3	104 ± 5	209 ± 2	260 ± 8	295 ± 10	338 ± 10
As is, with glucose	12(G)-a	15.2 ± 0.6	76.0 ± 2.4	144 ± 28	375 ± 36	590 ± 15	691 ± 20	786 ± 25
Excess nitrate, w/o cellulose	12(NC)-x	13.9 ± 0.3	69.2 ± 0.0	121 ± 3	166 ± 1	186 ± 2	196 ± 2	196 ± 2
Excess nitrate, with cellulose	12(C)-x	10.3 ± 0.6	57.4 ± 1.7	122 ± 3	195 ± 5	264 ± 6	309 ± 7	371 ± 14
Excess nitrate, with glucose	12(G)-x	15.1 ± 0.0	69.4 ± 1.2	111 ± 4	422 ± 12	916 ± 35	1370 ± 19	1610 ± 43

*Dissolved carbon dioxide concentrations not included.

NA = not analyzed

Table 12. Gross Data for the Long-Term Inundated Experiment: Production of Nitrous Oxide* in Anaerobic Samples

Treatments [Brine/Bentonite]	Sample Designation	Nitrous Oxide (μmoles/sample) Incubation Time (Days) 0	69	104	132	164	200
Unamended/Uninoculated (10)							
Formalin treated, w/o cellulose	10(NC)-f	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
Formalin treated, with cellulose	10(C)-f	0.000 ± 0.000	0.000 ± 0.000	0.001 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
As is, w/o cellulose	10(NC)-a	0.000 ± 0.000	0.004 ± 0.003	0.102 ± 0.065	1.040 ± 0.490	NA	1.73 ± 0.10
As is, with cellulose	10(C)-a	0.000 ± 0.000	0.005 ± 0.002	0.008 ± 0.004	0.021 ± 0.009	NA	0.031 ± 0.011
Unamended/Inoculated (11)							
Formalin treated, w/o cellulose	11(NC)-f	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	NA	0.002 ± 0.001
Formalin treated, with cellulose	11(C)-f	0.000 ± 0.000	0.000 ± 0.000	0.006 ± 0.002	0.024 ± 0.003	NA	0.000 ± 0.000
As is, w/o cellulose	11(NC)-a	0.000 ± 0.000	0.001 ± 0.001	0.000 ± 0.000	0.037 ± 0.026	NA	0.007 ± 0.005
As is, with cellulose	11(C)-a	0.000 ± 0.000	0.001 ± 0.001	0.000 ± 0.000	0.000 ± 0.000	NA	0.000 ± 0.000
Amended/Inoculated (12)							
As is, w/o cellulose	12(NC)-a	0.000 ± 0.000	0.016 ± 0.006	0.534 ± 0.378	0.000 ± 0.000	0.000 ± 0.000	3.35 ± 2.19
As is, with cellulose	12(C)-a	0.000 ± 0.000	0.111 ± 0.056	2.34 ± 1.92	0.000 ± 0.000	0.301 ± 0.246	0.000 ± 0.000
As is, with glucose	12(G)-a	0.000 ± 0.000	1.56 ± 1.10	40.1 ± 28.3	0.782 ± 0.557	0.016 ± 0.011	0.000 ± 0.000
Excess nitrate, w/o cellulose	12(NC)-x	0.000 ± 0.000	0.007 ± 0.001	0.081 ± 0.057	0.000 ± 0.000	0.003 ± 0.002	0.481 ± 0.340
Excess nitrate, with cellulose	12(C)-x	0.004 ± 0.000	3.80 ± 2.39	0.022 ± 0.018	47.1 ± 17.8	154 ± 20	311 ± 23
Excess nitrate, with glucose	12(G)-x	0.005 ± 0.000	0.077 ± 0.049	2.31 ± 1.59	261 ± 184	616 ± 428	585 ± 406

*Dissolved nitrous oxide concentrations not included.

NA = not analyzed

Table 13. Total Volume of Gas Produced in Aerobic Samples in the Presence of Cellulose*

Treatments [Brine]	Sample Desig.	Milliliters of Gas Produced/Gram Cellulose						
		Incubation Time (Days)						
		0	45	69	104	132	164	200
Unamended/Uninoculated (1)								
Formalin	1(C)-f	0.24 ± 0.06	0.89 ± 0.03	0.85 ± 0.02	0.42 ± 0.21	0.27 ± 0.19	NA	0.42 ± 0.18
As is	1(C)-a	0.05 ± 0.02	-0.29 ± 0.19	-0.36 ± 0.18	-0.31 ± 0.14	-0.20 ± 0.12	NA	-0.18 ± 0.10
Unamended/Inoculated (2)								
Formalin	2(C)-f	-0.01 ± 0.01	-0.03 ± 0.08	-0.35 ± 0.11	-0.32 ± 0.08	-0.41 ± 0.11	NA	-0.11 ± 0.09
As is	2(C)-a	-0.08 ± 0.01	0.01 ± 0.04	-0.15 ± 0.03	-0.11 ± 0.04	0.00 ± 0.05	NA	-0.34 ± 0.07
Amended/Inoculated (3)								
As is	3(C)-a	-0.12 ± 0.03	-0.27 ± 0.14	-0.25 ± 0.06	0.36 ± 0.31	0.29 ± 0.24	0.07 ± 0.13	0.86 ± 0.08
Exc. nitrate	3(C)-x	-0.02 ± 0.01	0.02 ± 0.14	1.39 ± 0.61	2.38 ± 0.87	3.10 ± 1.06	4.02 ± 1.21	4.42 ± 0.80

* All values have been corrected with specific controls for gas production in the absence of cellulose
NA = not analyzed

Table 14. Total Volume of Gas Produced in Aerobic Samples in the Presence of Cellulose and Bentonite*

Treatments [Brine/Bent.]	Sample Designation	Milliliters of Gas Produced/Gram Cellulose — Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (4)								
Formalin	4(C)-f	0.13 ± 0.03	0.63 ± 0.03	0.47 ± 0.03	0.15 ± 0.03	0.02 ± 0.01	NA	0.04 ± 0.01
As is	4(C)-a	-0.05 ± 0.02	0.02 ± 0.02	-0.36 ± 0.04	-0.20 ± 0.05	-0.13 ± 0.04	NA	0.00 ± 0.05
Unamended/Inoculated (5)								
Formalin	5(C)-f	0.11 ± 0.02	0.21 ± 0.01	0.31 ± 0.00	0.29 ± 0.00	0.07 ± 0.03	NA	0.16 ± 0.02
As is	5(C)-a	0.03 ± 0.01	-0.10 ± 0.02	-0.18 ± 0.04	-0.30 ± 0.13	-0.23 ± 0.09	NA	-0.08 ± 0.16
Amended/Inoculated (6)								
As is	6(C)-a	-0.25 ± 0.03	0.43 ± 0.01	0.71 ± 0.15	1.82 ± 0.35	2.96 ± 0.30	4.07 ± 0.22	4.38 ± 0.20
Exc. nitrate	6(C)-x	0.30 ± 0.01	0.85 ± 0.02	1.56 ± 0.02	2.23 ± 0.24	3.74 ± 0.29	5.15 ± 0.18	6.07 ± 0.04

* All values have been corrected with specific controls for gas production in the absence of cellulose
NA = not analyzed

Table 15. Production of Carbon Dioxide in Aerobic Samples in the Presence of Cellulose*

Treatments [Brine]	Sample Desig.	Carbon Dioxide (μmoles/gram cellulose) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (1)								
Formalin	1(C)-f	5.58 ± 0.54	7.66 ± 0.02	8.20 ± 0.04	7.46 ± 0.16	7.64 ± 0.06	NA	7.62 ± 0.10
As is	1(C)-a	2.48 ± 0.10	3.92 ± 0.06	4.21 ± 0.02	3.93 ± 0.02	4.25 ± 0.02	NA	4.00 ± 0.02
Unamended/Inoculated (2)								
Formalin	2(C)-f	5.91 ± 0.16	6.24 ± 0.00	6.80 ± 0.14	5.88 ± 0.12	6.04 ± 0.02	NA	5.65 ± 0.22
As is	2(C)-a	1.96 ± 0.06	3.35 ± 0.16	3.94 ± 0.18	4.98 ± 0.18	6.87 ± 0.20	NA	8.30 ± 0.28
Amended/Inoculated (3)								
As is	3(C)-a	ND	4.62 ± 0.28	3.78 ± 1.18	20.4 ± 7.4	29.6 ± 5	36.6 ± 4.2	40.8 ± 5.4
Exc. nitrate	3(C)-x	ND	6.88 ± 0.00	32.2 ± 4.2	61.4 ± 3.6	83.6 ± 2.6	96.2 ± 4.0	95.6 ± 6.0

* All values have been corrected with specific controls for gas production in the absence of cellulose; dissolved gas concentration not included
ND - not detected

Table 16. Production of Carbon Dioxide in Aerobic Samples in the Presence of Cellulose and Bentonite*

Treatments [Brine/Bent.]	Sample Desig.	Carbon Dioxide (μmoles/gram cellulose) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (4)								
Formalin	4(C)-f	4.16 ± 0.24	1.30 ± 0.04	2.24 ± 0.00	2.60 ± 0.00	2.40 ± 0.20	NA	3.20 ± 0.20
As is	4(C)-a	1.52 ± 0.30	1.76 ± 0.06	4.48 ± 2.36	1.76 ± 0.14	1.82 ± 0.10	NA	2.32 ± 0.02
Unamended/Inoculated (5)								
Formalin	5(C)-f	4.92 ± 0.18	4.78 ± 0.00	5.58 ± 0.04	3.16 ± 0.12	4.80 ± 0.00	NA	4.60 ± 0.00
As is	5(C)-a	2.04 ± 0.04	1.38 ± 0.08	4.00 ± 0.80	8.32 ± 0.42	11.9 ± 0.6	NA	21.5 ± 1.2
Amended/Inoculated (6)								
As is	6(C)-a	ND	ND	ND	12.4 ± 2.2	31.4 ± 3.8	57.8 ± 1.2	69.8 ± 1.2
Exc. nitrate	6(C)-x	ND	ND	2.20 ± 0.60	27.2 ± 4.6	72.0 ± 15.0	105 ± 9	116 ± 6

* All values have been corrected with specific controls for gas production in the absence of cellulose; dissolved gas concentration not included
ND - not detected

Table 17. Production of Nitrous Oxide in Aerobic Samples in the Presence of Cellulose*

Treatments [Brine]	Sample Desig.	Nitrous Oxide (μmoles/gram cellulose) Incubation Time (Days) 0	69	104	132	164	200
Unamended/Uninoculated (1)							
Formalin	1(C)-f	ND	ND	0.001 ± 0.000	0.003 ± 0.000	NA	0.001 ± 0.000
As is	1(C)-a	ND	ND	0.001 ± 0.000	0.003 ± 0.000	NA	ND
Unamended/Inoculated (2)							
Formalin	2(C)-f	ND	ND	ND	0.003 ± 0.000	NA	0.001 ± 0.000
As is	2(C)-a	0.002 ± 0.000	ND	ND	ND	NA	ND
Amended/Inoculated (3)							
As is	3(C)-a	0.001 ± 0.000	0.024 ± 0.029	23.6 ± 9.6	24.4 ± 7.8	1.76 ± 1.20	5.83 ± 5.04
Exc. nitrate	3(C)-x	ND	5.64 ± 1.77	49.0 ± 2.2	65.2 ± 3.6	96.8 ± 13.4	115 ± 26

* All values have been corrected with specific controls for gas production in the absence of cellulose; dissolved gas concentration not included
ND - not detected
NA - not analyzed

Table 18. Production of Nitrous Oxide in Aerobic Samples in the Presence of Cellulose and Bentonite*

Treatments [Brine/Bent.]	Sample Desig.	Nitrous Oxide (µmoles/gram cellulose) Incubation Time (Days) 0	69	104	132	164	200
Unamended/Uninoculated (4)							
Formalin	4(C)-f	ND	0.001 ± 0.000	ND	0.002 ± 0.000	NA	0.001 ± 0.000
As is	4(C)-a	ND	0.145 ± 0.098	0.037 ± 0.011	0.041 ± 0.014	NA	0.048 ± 0.020
Unamended/Inoculated (5)							
Formalin	5(C)-f	ND	ND	ND	ND	NA	ND
As is	5(C)-a	ND	0.000 ± 0.001	ND	ND	NA	ND
Amended/Inoculated (6)							
As is	6(C)-a	ND	6.32 ± 2.64	31.8 ± 10.6	25.2 ± 1.6	ND	ND
Exc. nitrate	6(C)-x	ND	5.42 ± 1.30	25.5 ± 4.4	40.6 ± 8.2	68.0 ± 8.2	82.7 ± 7.0

* All values have been corrected with specific controls for gas production in the absence of cellulose; dissolved gas concentration not included
ND - not detected
NA - not analyzed

Table 19. Total Volume of Gas Produced in Anaerobic Samples in the Presence of Cellulose*

Treatments [Brine]	Sample Designation	Milliliters of Gas Produced/Gram Cellulose						
		Incubation Time (Days)						
		0	45	69	104	132	164	200
Unamended/Uninoculated (7)								
Formalin	7(C)-f	0.26 ± 0.01	0.17 ± 0.01	0.22 ± 0.01	0.17 ± 0.01	0.14 ± 0.01	NA	0.26 ± 0.00
As is	7(C)-a	0.03 ± 0.05	0.10 ± 0.02	0.40 ± 0.01	-0.18 ± 0.07	0.04 ± 0.23	NA	-0.09 ± 0.03
Unamended/Inoculated (8)								
Formalin	8(C)-f	0.02 ± 0.01	0.22 ± 0.02	0.16 ± 0.03	0.16 ± 0.00	0.12 ± 0.01	NA	0.22 ± 0.00
As is	8(C)-a	-0.04 ± 0.01	1.00 ± 0.03	0.22 ± 0.03	-0.02 ± 0.03	0.02 ± 0.01	NA	0.59 ± 0.13
Amended/Inoculated (9)								
As is	9(C)-a	-0.08 ± 0.02	0.02 ± 0.03	-0.52 ± 0.01	0.66 ± 0.09	1.52 ± 0.25	2.15 ± 0.24	2.27 ± 0.12
Exc. nitrate	9(C)-x	0.01 ± 0.03	-0.12 ± 0.08	0.29 ± 0.29	2.00 ± 0.58	2.24 ± 0.78	4.04 ± 1.24	5.44 ± 1.42

* All values have been corrected with specific controls for gas production in the absence of cellulose
NA = not analyzed

Table 20. Total Volume of Gas Produced in Anaerobic Samples in the Presence of Cellulose and Bentonite*

Treatments [Brine/Bent.]	Sample Designation	Milliliters of Gas Produced/Gram Cellulose — Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (10)								
Formalin	10(C)-f	0.06 ± 0.01	0.01 ± 0.01	0.37 ± 0.00	-0.09 ± 0.03	-0.14 ± 0.03	NA	-0.06 ± 0.03
As is	10(C)-a	-0.08 ± 0.10	-0.04 ± 0.03	-0.04 ± 0.05	-0.17 ± 0.08	-0.22 ± 0.10	NA	-0.28 ± 0.09
Unamended/Inoculated (11)								
Formalin	11(C)-f	-0.10 ± 0.01	-0.10 ± 0.00	-0.05 ± 0.01	-0.22 ± 0.23	-0.28 ± 0.22	NA	-0.06 ± 0.24
As is	11(C)-a	0.03 ± 0.01	0.11 ± 0.01	-0.06 ± 0.03	0.16 ± 0.04	0.29 ± 0.04	NA	0.81 ± 0.08
Amended/Inoculated (12)								
As is	12(C)-a	-0.11 ± 0.05	-0.05 ± 0.02	0.19 ± 0.09	1.39 ± 0.09	1.78 ± 0.08	1.44 ± 0.07	1.92 ± 0.08
Exc. nitrate	12(C)-x	-0.06 ± 0.02	-0.09 ± 0.03	0.23 ± 0.06	0.78 ± 0.09	1.68 ± 0.10	2.19 ± 0.14	3.52 ± 0.28

* All values have been corrected with specific controls for gas production in the absence of cellulose
NA = not analyzed

Table 21. Production of Carbon Dioxide in Anaerobic Samples in the Presence of Cellulose*

Treatments [Brine]	Sample Desig.	Carbon Dioxide (μmoles/gram cellulose) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (7)								
Formalin	7(C)-f	5.89 ± 0.10	7.22 ± 0.02	7.16 ± 0.02	6.55 ± 0.04	6.81 ± 0.02	NA	6.78 ± 0.02
As is	7(C)-a	2.38 ± 0.08	3.74 ± 0.02	3.92 ± 0.02	3.63 ± 0.02	3.83 ± 0.04	NA	3.59 ± 0.04
Unamended/Inoculated (8)								
Formalin	8(C)-f	5.54 ± 0.14	6.08 ± 0.08	5.92 ± 0.04	5.46 ± 0.00	5.70 ± 0.10	NA	5.77 ± 0.08
As is	8(C)-a	2.11 ± 0.04	3.41 ± 0.04	3.34 ± 0.02	3.01 ± 0.14	3.97 ± 0.10	NA	5.47 ± 0.34
Amended/Inoculated (9)								
As is	9(C)-a	ND	3.79 ± 0.04	ND	7.22 ± 0.60	18.2 ± 1.4	24.2 ± 0.6	26.0 ± 0.8
Exc. nitrate	9(C)-x	0.47 ± 0.00	4.29 ± 0.04	6.10 ± 3.42	19.7 ± 6.6	25.8 ± 6.4	45.4 ± 8.0	61.4 ± 8.2

* All values have been corrected with specific controls for gas production in the absence of cellulose; dissolved gas concentration not included
ND - not detected

Table 22. Production of Carbon Dioxide in Anaerobic Samples in the Presence of Cellulose and Bentonite*

Treatments [Brine/Bent.]	Sample Desig.	Carbon Dioxide (μmoles/gram cellulose) Incubation Time (Days) 0	45	69	104	132	164	200
Unamended/Uninoculated (10)								
Formalin	10(C)-f	1.94 ± 0.2	0.52 ± 0.04	0.62 ± 0.08	ND	ND	NA	ND
As is	10(C)-a	2.04 ± 0.1	0.98 ± 0.04	0.92 ± 0.08	0.64 ± 0.04	0.66 ± 0.10	NA	0.22 ± 0.04
Unamended/Inoculated (11)								
Formalin	11(C)-f	2.28 ± 0.26	ND	ND	ND	ND	NA	ND
As is	11(C)-a	1.86 ± 0.12	0.62 ± 0.04	0.84 ± 0.02	2.56 ± 0.50	8.06 ± 0.14	NA	8.28 ± 0.20
Amended/Inoculated (12)								
As is	12(C)-a	ND	ND	0.84 ± 1.00	11.8 ± 0.4	48.68 ± 1.6	23.6 ± 2.0	31.8 ± 2.0
Exc. nitrate	12(C)-x	ND	ND	0.20 ± 0.60	5.80 ± 1.00	15.6 ± 1.2	22.6 ± 1.4	35.0 ± 2.8

* All values have been corrected with specific controls for gas production in the absence of cellulose; dissolved gas concentration not included
ND - not detected

Table 23. Production of Nitrous Oxide in Anaerobic Samples in the Presence of Cellulose*

Treatments [Brine]	Sample Desig.	Nitrous Oxide (µmoles/gram cellulose) Incubation Time (Days) 0	69	104	132	164	200
Unamended/Uninoculated (7)							
Formalin	7(C)-f	ND	0.002 ± 0.001	0.001 ± 0.000	0.001 ± 0.001	NA	ND
As is	7(C)-a	ND	ND	ND	ND	NA	ND
Unamended/Inoculated (8)							
Formalin	8(C)-f	ND	ND	ND	0.003 ± 0.000	NA	0.002 ± 0.000
As is	8(C)-a	ND	ND	ND	ND	NA	ND
Amended/Inoculated (9)							
As is	9(C)-a	ND	ND	ND	15.8 ± 8.3	17.9 ± 8.6	15.5 ± 8.4
Exc. nitrate	9(C)-x	ND	0.158 ± 0.084	16.1 ± 10.0	39.2 ± 15.0	56.0 ± 32.0	79.0 ± 45.6

* All values have been corrected with specific controls for gas production in the absence of cellulose; dissolved gas concentration not included
ND - not detected
NA - not analyzed

Table 24. Production of Nitrous Oxide* in Anaerobic Samples in the Presence of Cellulose and Bentonite

Treatments [Brine/Bent.]	Sample Desig.	Nitrous Oxide (µmoles/gram cellulose) Incubation Time (Days) 0	69	104	132	164	200
Unamended/Uninoculated (10)							
Formalin	10(C)-f	ND	ND	ND	ND	NA	ND
As is	10(C)-a	ND	ND	ND	ND	NA	ND
Unamended/Inoculated (11)							
Formalin	11(C)-f	ND	ND	0.001 ± 0.000	0.005 ± 0.001	NA	ND
As is	11(C)-a	ND	ND	ND	ND	NA	ND
Amended/Inoculated (12)							
As is	12(C)-a	ND	0.019 ± 0.011	0.361 ± 0.384	ND	0.060 ± 0.049	ND
Exc. nitrate	12(C)-x	0.001 ± 0.000	0.759 ± 0.478	0.000 ± 0.000	9.42 ± 3.56	30.8 ± 4.0	62.1 ± 4.6

* All values have been corrected with specific controls for gas production in the absence of cellulose; dissolved gas concentration not included
ND - not detected
NA - not analyzed

APPENDIX E: MEASUREMENT OF MIXED INOCULUM ACTIVITY

APPENDIX E: MEASUREMENTS OF MIXED INOCULUM ACTIVITY

To determine the activity of the mixed inoculum, brine samples were incubated with glucose with an initial air and N_2 atmosphere. Total gas, CO_2 and N_2O were periodically monitored.

Aerobic Samples

Total Gas Production

Samples containing glucose, nutrients, excess nitrates with and without bentonite did not show an increase in total gas production (Figure 25, Tables 1(a)-2(a) Appendix D).

Carbon Dioxide Production

Production of carbon dioxide was evident after 132 days in amended and in amended plus excess nitrate samples without bentonite. After 200 days, amended samples produced 323 μmol of CO_2, whereas amended plus excess nitrate samples produced 296 μmol CO_2. Samples with bentonite did not produce significant amounts of CO_2 beyond the initial background level (~70-80 μmol) (Figure 26, Tables 1(b)-2(b) Appendix D).

Nitrous Oxide Production

Nitrous oxide was detected at 132 days in aerobic samples without bentonite (Figure 27, Tables 1(c)-2(c) Appendix D). Less N_2O was detected in amended samples with excess nitrate, and in samples containing bentonite, N_2O was not detected.

Anaerobic Samples

Total Gas Production

Amended and amended samples with excess nitrate showed no increase in total gas production. However, in the presence of bentonite, production in amended samples increased after 45 days of incubation and reached to 37.8 mL at 200 days (Figure 28, Tables 3(a)-4(a) Appendix D). Amended samples plus excess nitrate produced more gas (80.65 mL of gas at 200 days) than the other samples.

Carbon Dioxide Production

Production of carbon dioxide was not detected in the amended samples, whereas the amended samples with excess nitrate produced a small amount of CO_2. Carbon dioxide production in samples containing bentonite was significant (Figure 29, Tables 3(b)-4(b) Appendix D). Amended samples containing excess nitrate produced 1610 μmol of CO_2 at 200 days while the basic amended samples produced 786 moles. Carbon dioxide production was much higher in the glucose/bentonite samples than in the cellulose/bentonite samples, indicating the potential of the microorganisms to produce significant amounts of CO_2 under hypersaline conditions when a simple sugar is present. In addition, bentonite seems to enhance the overall gas production.

Nitrous Oxide Production

Accumulation of nitrous oxide was detected only in samples containing bentonite (Figure 30, Tables 3(c)-4(c) Appendix D). With excess nitrate, the N_2O concentration reached 585 μmol and then started to decline.

Summary

We examined glucose metabolism by the mixed inoculum used in the long-term experiments. Total gas production in samples incubated under aerobic conditions was not evident, but anaerobic samples produced significant amounts of gas, especially the samples with bentonite plus excess nitrate. Production of carbon dioxide in the aerobic samples was observed only in the amended and excess-nitrate samples without bentonite. Bentonite enhanced the activity of anaerobes. Carbon-dioxide production in anaerobic samples with excess nitrate reached a higher amount than any of the totals reached thus far in the long-term inundated experiment. Substantial amounts of N_2O also accumulated in the headspace of these samples.

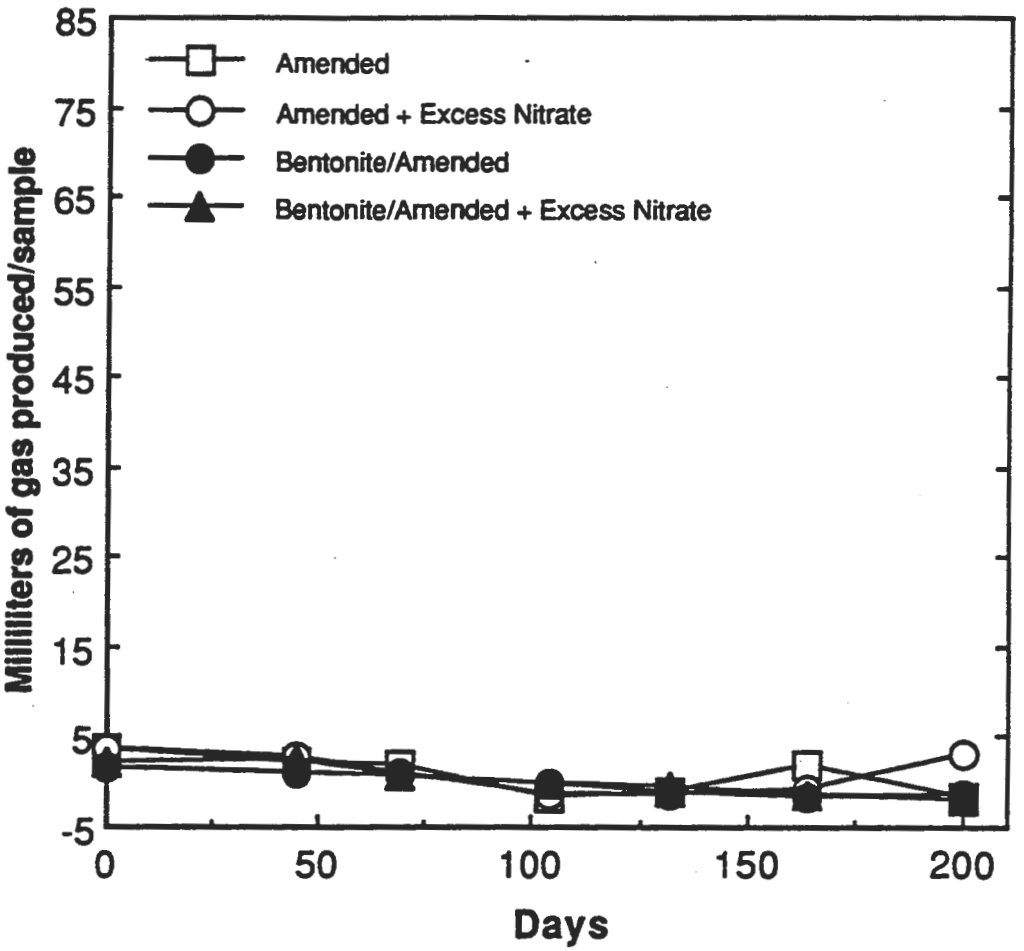

Figure 25. Total gas produced in samples containing glucose incubated with an initial atmosphere of air.

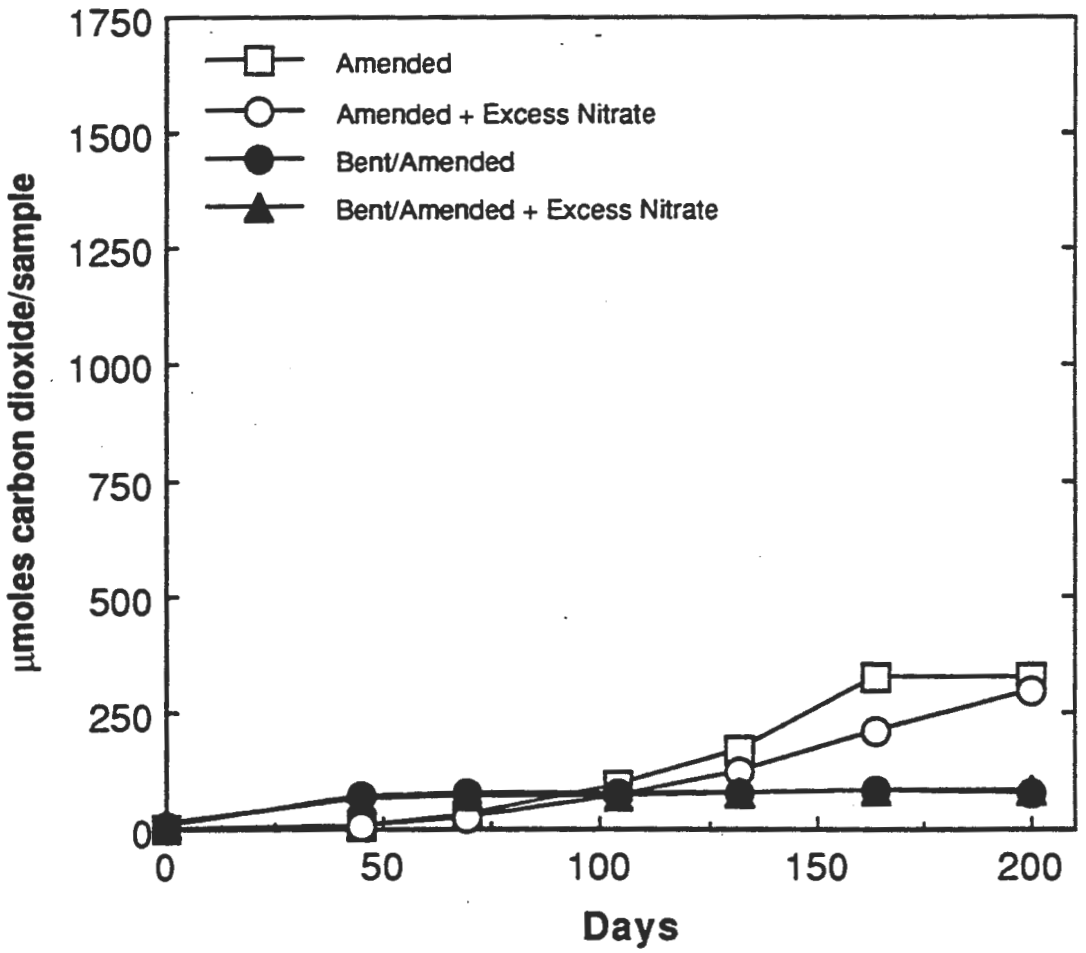

Figure 26. Carbon dioxide produced in samples containing glucose incubated with an initial atmosphere of air.

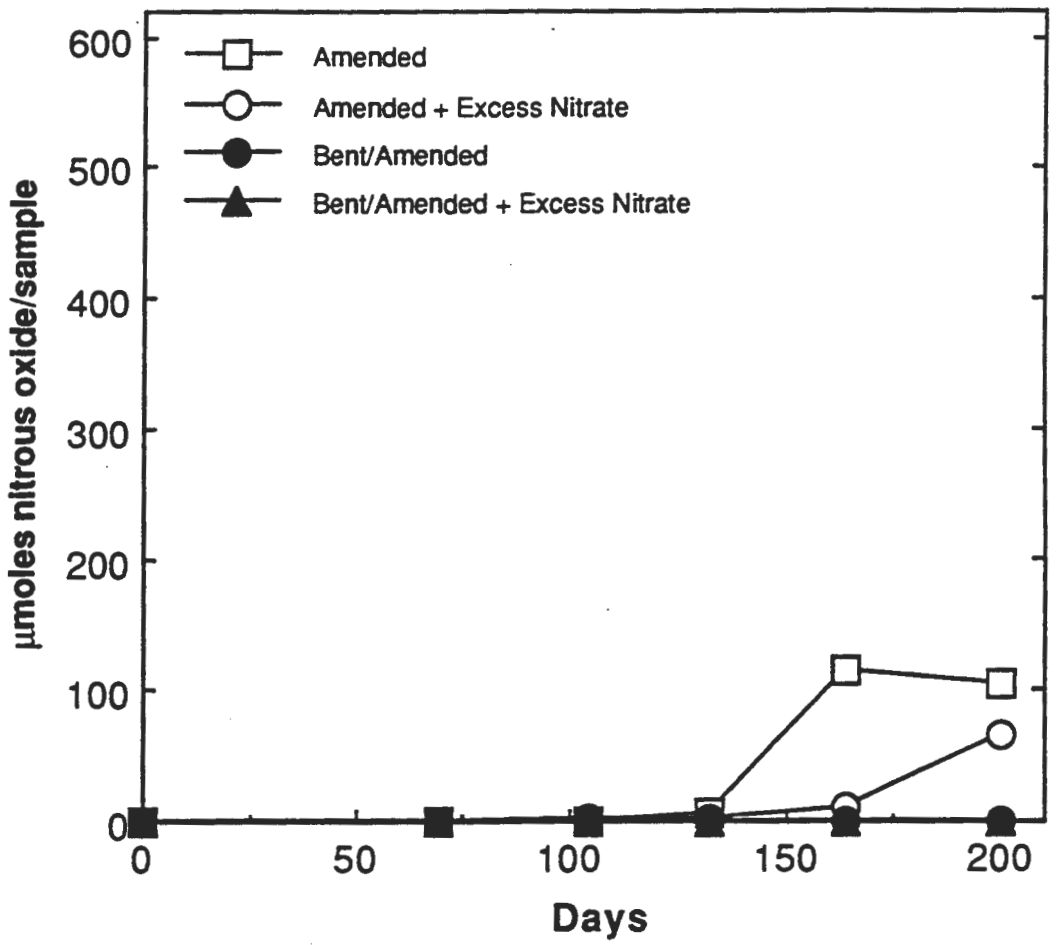

Figure 27. Nitrous oxide produced in samples containing glucose incubated with an initial atmosphere of air.

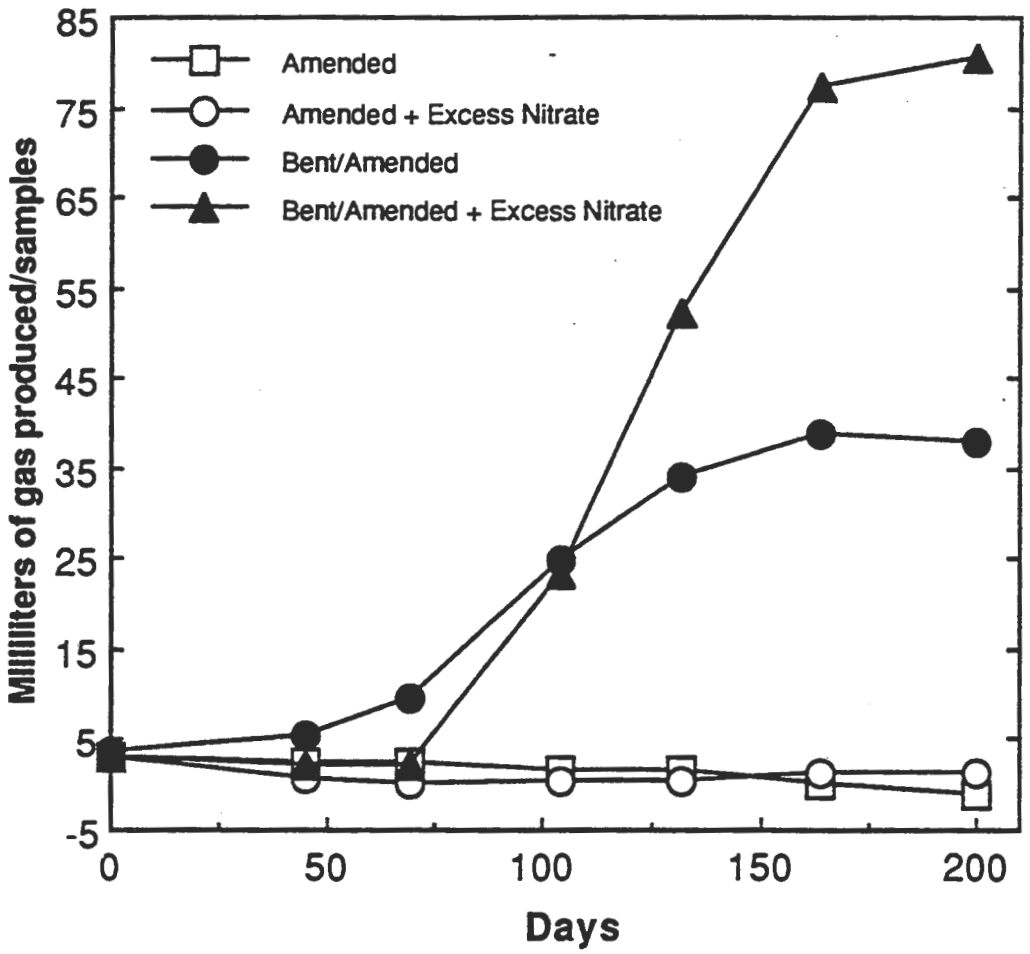

Figure 28. Total gas produced in anaerobic samples containing glucose.

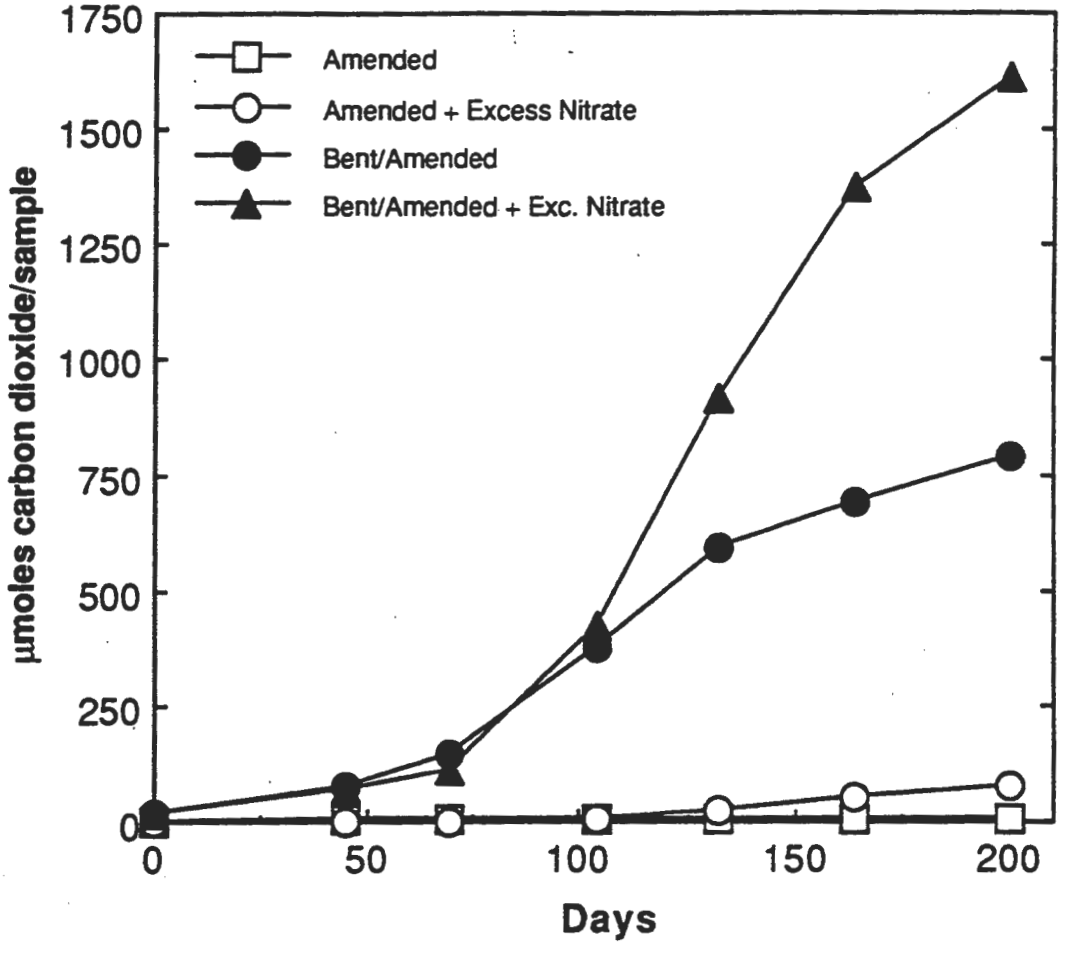

Figure 29. Carbon dioxide produced in anaerobic samples containing glucose.

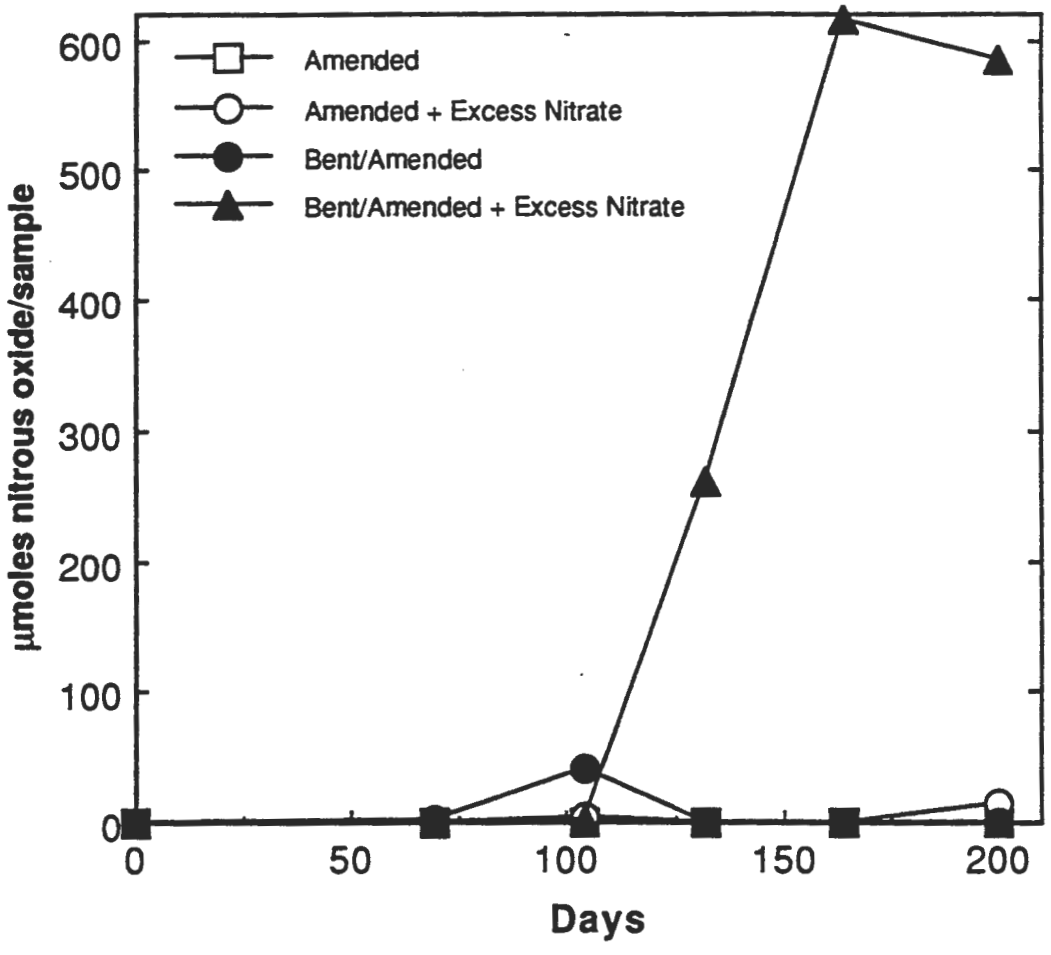

Figure 30. Nitrous oxide produced in anaerobic samples containing glucose.

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APPENDIX D12

TRANSPORT CHARACTERISTICS ACROSS DRUM FILTER VENTS AND POLYMER BAGS

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Transport Characteristics Across Drum Filter Vents and Polymer Bags

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ABSTRACT

The rate at which hydrogen (H_2) or a volatile organic compound (VOC) exits a layer of confinement in a vented waste drum is proportional to the concentration difference across the layer. The proportionality constant is the gas transport characteristic. A series of transport experiments were conducted to determine H_2 and VOC transport characteristics across different drum filter vents and polymer bags. This report reviews the methods and results of past investigators in defining transport characteristics across filter vents and polymer bags, describes the apparatus and procedures used in these experiments, compares the reported and estimated transport characteristics with earlier results, and discusses the impact of changing the transport characteristic values used in model calculations.

SUMMARY

This report reviews the methods and results of past investigators in defining hydrogen (H_2) and volatile organic compound (VOC) transport characteristics across drum filter vents and polymer bags, describes the apparatus and procedures used in experiments performed at the Idaho National Engineering Laboratory (INEL) to quantify transport characteristics across drum filter vents and polymer bags, compares the reported and estimated transport characteristics with earlier results, and discusses the impact of changing transport characteristic values in model calculations.

A review of experiments conducted to measure H_2 and VOC diffusion characteristics across drum filter vents identified a wide variety of test vessel designs. In most cases, insufficient care was taken to minimize concentration gradient formation inside the test vessel. A series of filter vent diffusion tests were conducted at the INEL using a test vessel specifically designed to ensure that the assumption of uniform gas concentration in the test volume was valid. A cylindrical stainless steel vessel with a flat lid and base was designed to have a drum filter vent screwed in the center of the top lid. Separate side ports allowed for the introduction of gas and the sample collection with a gas-tight syringe. Because of variations in the filter housing assemblies, two different test vessels with internal volume between 55 and 60 cm^3 were constructed. The H_2 and VOC diffusion characteristics of NFT-012, NFT-013, and NFT-020 drum filter vents were determined. Pure hydrogen gas was used in the H_2 diffusion characteristic experiments. Two different gas mixtures—each containing 5 VOCs—were used in the VOC diffusion characteristic measurements. Each VOC concentration was between about 100 and 1,000 ppm. The gas mixture was introduced into a test vessel at a rate of 1,000 cm^3 min^{-1} for one minute to purge the vessel. Samples were withdrawn by gas syringe at regular time intervals and injected into a gas chromatograph to determine gas concentrations.

Multivariable two-level experiments with one replicate were designed to investigate the effect of bag closure type on H_2 and VOC transport from small polymer bags. Polyethylene and polyvinyl chloride (PVC) bags with heat-sealed or taped closures were prepared. In preparing the bags with taped closures, an effort was made to ensure that the surface area was the same as for the heat-sealed bags. Trichloroethylene (TCE) and 1,1,2-trichloro-1,2,2-trifluoroethane (Freon-113) were used in the experiments.

Filter vent diffusion test results confirmed that test vessel configuration affects the calculated gas diffusion characteristic. Hydrogen diffusion characteristics calculated from experimental data using the INEL test vessels were about 10 to 25% greater than the highest previously reported values. In the TRUPACT-II safety analysis report (SAR), a hydrogen diffusion characteristic of 19×10^{-7} mol s^{-1} was used to calculate the maximum allowable decay heat limit per innermost layer of confinement. This value was the lowest value determined across six NFT-012 drum filter vents. However, NFT-012 drum filter vents are no longer used in the transportation of vented waste drums. The NFT-013 and NFT-020 drum filter vents are currently used in waste drum transshipment. The lowest H_2 diffusion characteristic measured for these drum filter vents using the INEL test vessels was 41×10^{-7} mol s^{-1}. The use of a H_2 diffusion characteristic of a different drum filter vent will have a far more significant impact on model results than higher values resulting from improved test vessel design and experimental procedure. A larger H_2 diffusion characteristic would result in a higher minimum allowable decay heat limit.

Results from unsteady-state experiments indicated that the H_2 transport characteristic for polymer bags with a taped closure was not significantly greater than for similar bags with no taped closure. Tests on PVC bags with a surface area between 2,000 and 3,000 cm^2 and bag thickness between 2.8 and 3.0 x 10^{-2} cm (11—12 mil) show that the H_2 transport from bags with a taped closure was only 20 to 30% greater than from heat-sealed bags. The relative percentage increase in the H_2 transport characteristic for bags with a taped closure compared to similar heat-sealed bags will decrease further with increasing bag surface area or decreasing bag thickness. Tests on polyethylene bags with a surface area of 2,000 cm^2 and bag thickness of 7.6 x 10^{-3} cm (3 mil) showed no difference at all in the H_2 transport characteristic for bags with different types of closure. Under these conditions, H_2 transport from small polymer bags was not significantly affected by the type of bag closure. This means that most small bags placed in vented waste drums could have either a taped closure or heat seal without significantly affecting H_2 transport from the bags. It was similarly concluded that gas transport from polymer bags containing TCE or Freon-113 in actual waste drums would not be significantly affected by bag closure type.

In model calculations in the TRUPACT-II SAR of the maximum allowable decay heat limit per layer of confinement, a H_2 transport characteristic of 5.60 x 10^{-7} mol s^{-1} had been used to estimate gas transport from a polymer bag with a taped closure. This value reported in the TRUPACT-II SAR was the difference of two H_2 transport characteristics measured across PVC bags with and without taped closures. Review of the original data indicates that the transport characteristic for at least one bag was not measured under steady-state conditions, as assumed. In addition, two unsteady-state experiments demonstrated that total H_2 transport across a small PVC bag with a taped closure is not significantly greater than a similarly sized PVC bag with no taped closure. The maximum allowable decay heat limit should have been calculated using the H_2 permeation characteristic reported in the TRUPACT-II SAR for a heat-sealed PVC bag which was 4.94 x 10^{-7} mol s^{-1}. This transport characteristic is 12% less than the value used in original calculations and would result in a slightly lower calculated decay heat limit, all other variables remaining the same. The average H_2 permeation characteristic across heat-sealed PVC bags measured in the INEL transport experiments was 2.04 x 10^{-7} mol s^{-1} and was less than the transport characteristic reported in the TRUPACT-II SAR because of smaller bag surface area.

The VOC diffusion characteristic across a filter vent is used in the Waste Isolation Pilot Plant (WIPP) no-migration determination (NMD) variance petition to estimate the rate of VOC emissions from a vented drum. The diffusion characteristics for carbon tetrachloride and 1,1,1-trichloroethane across different drum filter vent types listed in the WIPP NMD variance petition were on the order of 10^{-11} mol s^{-1}. The explanation offered for the lower than expected VOC transport characteristics was a complex combination of Fickian and surface diffusion. A more likely explanation is that the experimental set-up resulted in significant concentration gradient across the test vessel volume. Several transport experiments, including one performed at the INEL, measured VOC diffusion characteristics on the order of 10^{-7} mol s^{-1}. This is approximately four orders of magnitude greater and significantly affects the calculation of the total anticipated VOC emissions from vented waste drums at the WIPP facility.

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ACRONYMS AND ABREVIATIONS

Freon-113	1,1,2-trichloro-1,2,2-trifluoroethane
GC	gas chromatograph
H_2	hydrogen
INEL	Idaho National Engineering Laboratory
NFT	Nuclear Filter Technology
NMD	no-migration determination
RFP	Rocky Flats Plant
SRP	Savannah River Plant
STP	standard temperature and pressure
TCA	trichloroethane
TCE	trichloroethylene
SAR	safety analysis report
VOC	volatile organic compound
WIPP	Waste Isolation Pilot Plant

Transport Characteristics Across Drum Filter Vents and Polymer Bags

1. INTRODUCTION

The rate at which hydrogen (H_2) or a volatile organic compound (VOC) exits a layer of confinement in a vented waste drum is proportional to the concentration difference across the layer. The proportionality constant is the gas transport characteristic. Gas permeates through polymer bags or diffuses through openings in the layer boundary. The gas transport characteristic is the product of the gas transport property, such as permeability or diffusivity, and surface area divided by a characteristic length. Knowledge of the H_2 transport characteristics across drum filter vents and polymer bags was used in the safety analysis report for the TRUPACT-II Shipping Package (TRUPACT-II SAR) to calculate the maximum allowable decay heat limit per innermost confinement layer to ensure that the hydrogen concentration in payload materials does not exceed 5% by volume.[1] Knowledge of VOC transport characteristics is important in estimating VOC emission rates from vented waste drums[2] and VOC concentrations in the void volumes of a waste drum.[3,4]

Several investigators have measured H_2 and VOC transport characteristics across filter vents and polymer bags. All drum filter vent diffusion experiments used test vessels with different volumes and dimensions. Different experiments investigating H_2 transport from sealed polymer bags reached opposite conclusions whether gas transport across a taped closure was significantly greater than across a heat-sealed closure. The differences in reported values resulting from variations in test apparatus and procedures raise questions as to which values should be used in calculations concerning decay heat limits, total emissions rate, and other health and safety issues. A series of experiments was conducted at the Idaho National Engineering Laboratory (INEL) to measure H_2 and VOC transport characteristics across drum filter vents and polymer bags. The experiments were designed to address past discrepancies in the test vessel configuration and test procedures.

This report reviews the methods and results of past investigators in defining transport characteristics across filter vents and polymer bags, describes the apparatus and procedures used in a new set of transport experiments, compares the reported and estimated transport characteristics with earlier results, and discusses the impact of changing the transport characteristic values in model calculations. First, mathematical definitions of the transport characteristics are presented. Second, transport characteristics reported in earlier studies are reviewed with particular attention given to the experimental apparatus and procedures used. The report then describes experimental apparatus and test procedures used in the most recent INEL transport experiments to determine H_2 and VOC transport characteristics across different filter vents and polymers. Experimental test apparatus, procedures, and results from these experiments are compared with those described in earlier experiments. In addition, methods of estimating VOC diffusion characteristic across filter vents are examined. Finally, the implications of using these new H_2 and VOC transport characteristics in model calculations related to health and safety issues are discussed.

2. TRANSPORT CHARACTERISTICS

The primary mechanisms for gas transport from the void volume inside a layer of confinement with a polymer boundary are permeation across the polymer, diffusion across an opening in the boundary, and gas accumulation in the boundary as the result of the gas solubility in the polymer. The total unsteady-state gas transport rate is defined by summing the contribution of each transport mechanism

$$Vc\,\frac{d(\Delta y_p)}{dt} = -\left(\frac{\phi \rho A_p P}{x_p} + \frac{D A_d}{x_d}\right) c\,\Delta y_p - V_p \frac{ds}{dt} \tag{1}$$

where

V = void volume confined by polymer, cm^3

c = total gas concentration, mol cm^{-3}

Δy_p = gas mole fraction difference across polymer

t = time, s

ϕ = 76 T/(273.15 P)

T = temperature, K

P = pressure, cm Hg

ρ = gas permeability coefficient, cm^3 (STP) cm cm^{-2} (cm Hg)$^{-1}$ s^{-1}

A_p = polymer surface area across which VOC permeates, cm^2

x_p = polymer thickness, cm

D = gas diffusivity in air, cm^2 s^{-1}

A_d = cross-sectional area of opening across polymer boundary, cm^2

x_d = diffusional length across opening, cm

V_p = volume of polymer boundary, cm^3 polymer

s = gas concentration in polymer, cm^3 gas cm^{-3} polymer.

In the case where the gas concentration in the polymer has reached a near-constant value, the gas transport rate is the sum of the transport rates via permeation and diffusion

$$Vc\,\frac{d(\Delta y_p)}{dt} = -\left(\frac{\phi \rho A_p P}{x_p} + \frac{DA_d}{x_d}\right) c\,\Delta y_p \quad . \tag{2}$$

The total gas concentration is defined by the ideal gas law

$$c = \frac{P}{RT} \tag{3}$$

where R is the gas constant and equals 6236.6 cm^3 (cm Hg) mol^{-1} K^{-1}. Combining Equations (2) and (3) yields

$$Vc\,\frac{d(\Delta y_p)}{dt} = -(K_p + K_d)\,\Delta y_p \tag{4}$$

where

K_p = permeation characteristic, $4.46 \times 10^{-5}\ \rho A_p P\ x_p^{-1}$, mol s^{-1}

K_d = diffusion characteristic, $DA_d P\ (RTx_d)^{-1}$, mol s^{-1}.

Solving Equation (4), the gas mole fraction difference is a function of time

$$\ln\left(\frac{\Delta y_p}{\Delta y_{p,0}}\right) = -\frac{(K_p + K_d)}{Vc}\,(t - t_0) \quad . \tag{5}$$

Plotting $\ln(\Delta y_p/\Delta y_{p,0})$ versus $(t-t_0)$ yields a straight line with a slope defined by Equation (5).

The unsteady-state rate of gas transport across a filter vent is defined as

$$Vc\,\frac{d(\Delta y_f)}{dt} = -D^{*}\,\Delta y_f \tag{6}$$

where

D^{*} = gas filter vent diffusion characteristic, mol s^{-1}

Δy_f = gas mole fraction difference across filter vent.

In the case of steady-state transport, the gas transport rates across all layers of confinement, including the filter vent, are equal to a constant rate r

$$r = (K_p + K_d)\,\Delta y_p = D^{*}\Delta y_f \quad . \tag{7}$$

3. PREVIOUS TRANSPORT CHARACTERISTIC MEASUREMENTS

This section summarizes the reported transport characteristics across drum filter vents and polymer bags from earlier investigations. Discussion is focused on the experimental apparatus and test procedures that may have affected the calculated transport characteristics.

3.1 Drum Filter Vents

Hydrogen or VOC diffusion characteristics across different filter vent types have been reported by a number of investigators. Three filter vent types studied, which contained a carbon-composite filter, were manufactured by Nuclear Filter Technology. Filter vent NFT-012, shown in Figure 1, was initially used at the Rocky Flats Plant (RFP). Filter vent NFT-013, shown in Figure 2, is now used at the RFP and the Savannah River Plant (SRP) in waste drums prepared for transshipment. The NFT-013 filter vent is an adaptation of the NFT-012; the NFT-013 has larger openings in the bottom and top of the filter housing assembly. The changes in the filter assembly were designed to increase the overall hydrogen diffusion characteristic across the filter vent. The NFT-020 filter vent, shown in Figure 3, is used at the INEL.

Peterson[a] determined hydrogen diffusion characteristics across carbon-composite filter vents identified as the types used at the RFP, the INEL, and the SRP. A schematic of the test vessel used to perform the diffusion experiments is shown in Figure 4. The test vessel volume was approximately 75 cm^3. An adapter connecting the filter vent to the test vessel probably resulted in the development of a concentration gradient within the vessel. Peterson did not identify the types of filter vents other than by the site where they were used. This author believes that the RFP and INEL filters were NFT-012 and NFT-020, respectively. The SRP filter vents tested are not thought to be NFT-013 filter vents because of NFT-013 filter vent was not being made at the date of the tests. Experimental results yielded H_2 diffusion characteristics across the NFT-012 and NFT-020 filter vents of $(23 \pm 2) \times 10^{-7}$ mol s^{-1} and $(39 \pm 10) \times 10^{-7}$ mol s^{-1}, respectively.

The Waste Isolation Pilot Plant (WIPP) no-migration determination (NMD) variance petition[2] reported diffusion characteristics for carbon tetrachloride and 1,1,1-trichloroethane (TCA) across NFT filters on the order of 10^{-11} mol s^{-1}. These values were approximately four orders of magnitude lower than values estimated using kinetic gas theory for ordinary diffusion. In a study by Peterson and Marshall,[b] VOC diffusion characteristics on the order of 10^{-7} were reported. The test vessel used in their VOC diffusion experiments, shown in Figure 5, had a internal volume of 60 cm^3 abd attempted to minimize the potential for concentration gradients in the system. The VOC diffused through the filter into another 60-cm^3 vessel with its lid removed. Peterson and Marshall assumed that this vessel configuration allowed sufficient convection to maintain the gas concentration immediately outside the filter at zero. They determined that the test vessel and gas sampling configuration in the earlier VOC diffusion study, shown in Figure 6, resulted in significant concentration gradients across the system. The average H_2 diffusion

---

a. Unpublished research results of determination of hydrogen diffusion characteristics across different filter types; S. H. Peterson, Westinghouse R&D Center, (July 1988).

b. Unpublished research results of VOC diffusion characteristics measurements across carbon-composite filters; S. H. Peterson and G. R. Marshall, Westinghouse R&D Center (October 1990).

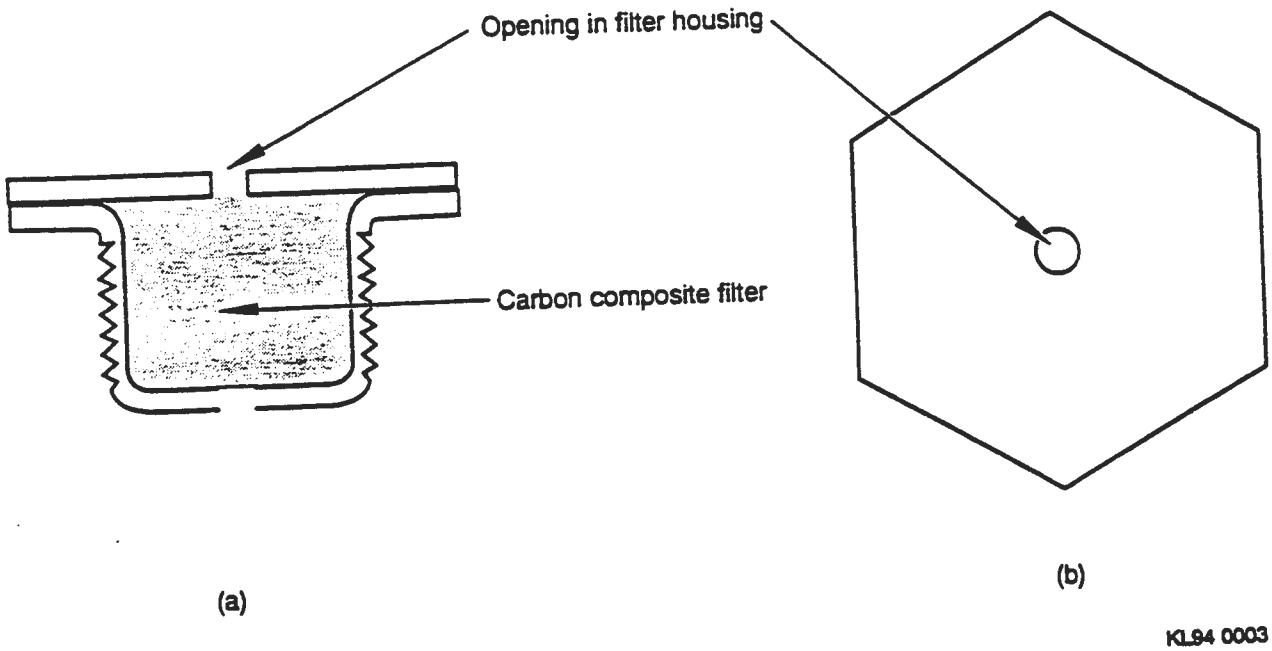

Figure 1. Schematic of NFT-012 filter vent (a) cross-section; (b) top.

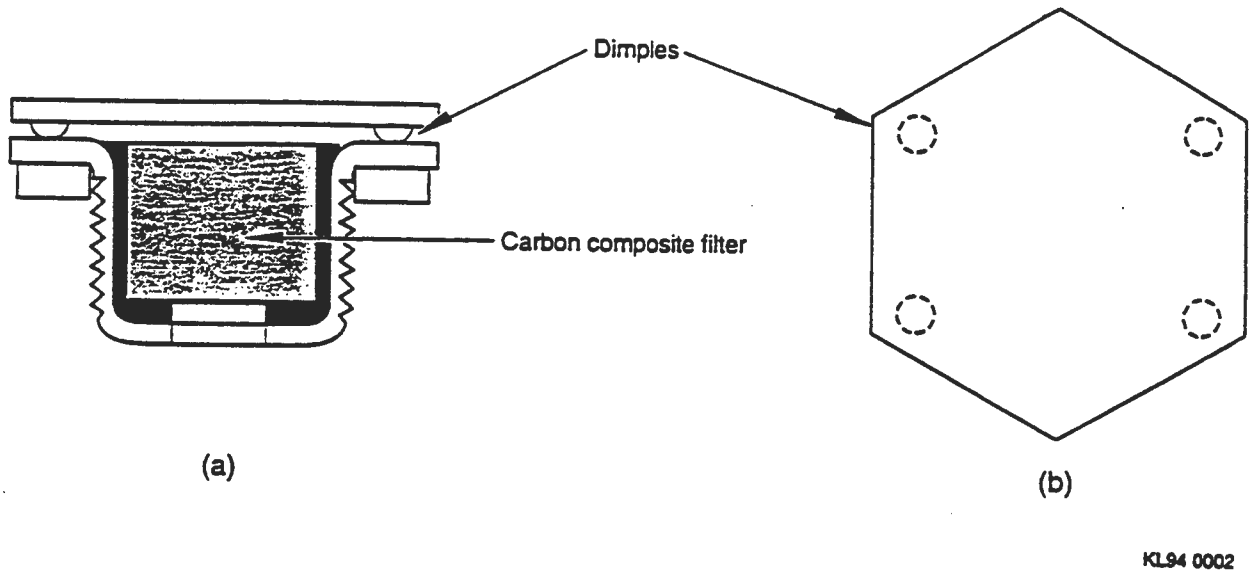

Figure 2. Schematic of NFT-013 filter vent (a) cross-section; (b) top.

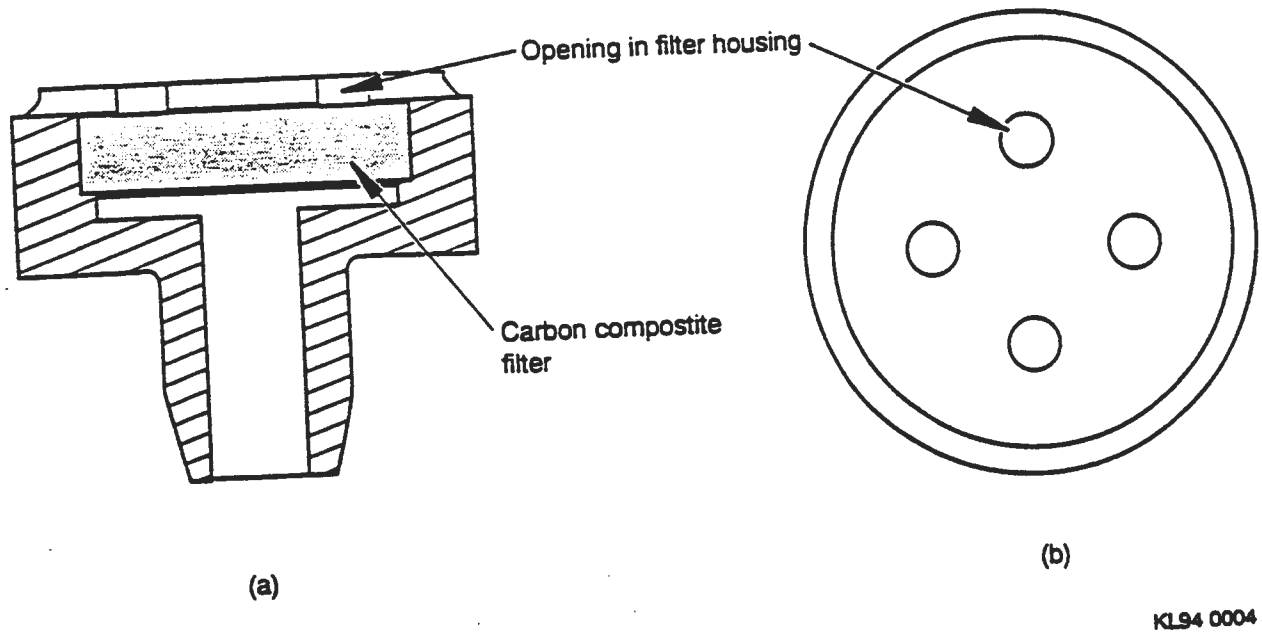

Figure 3. Schematic of NFT-020 filter vent (a) cross-section; (b) top.

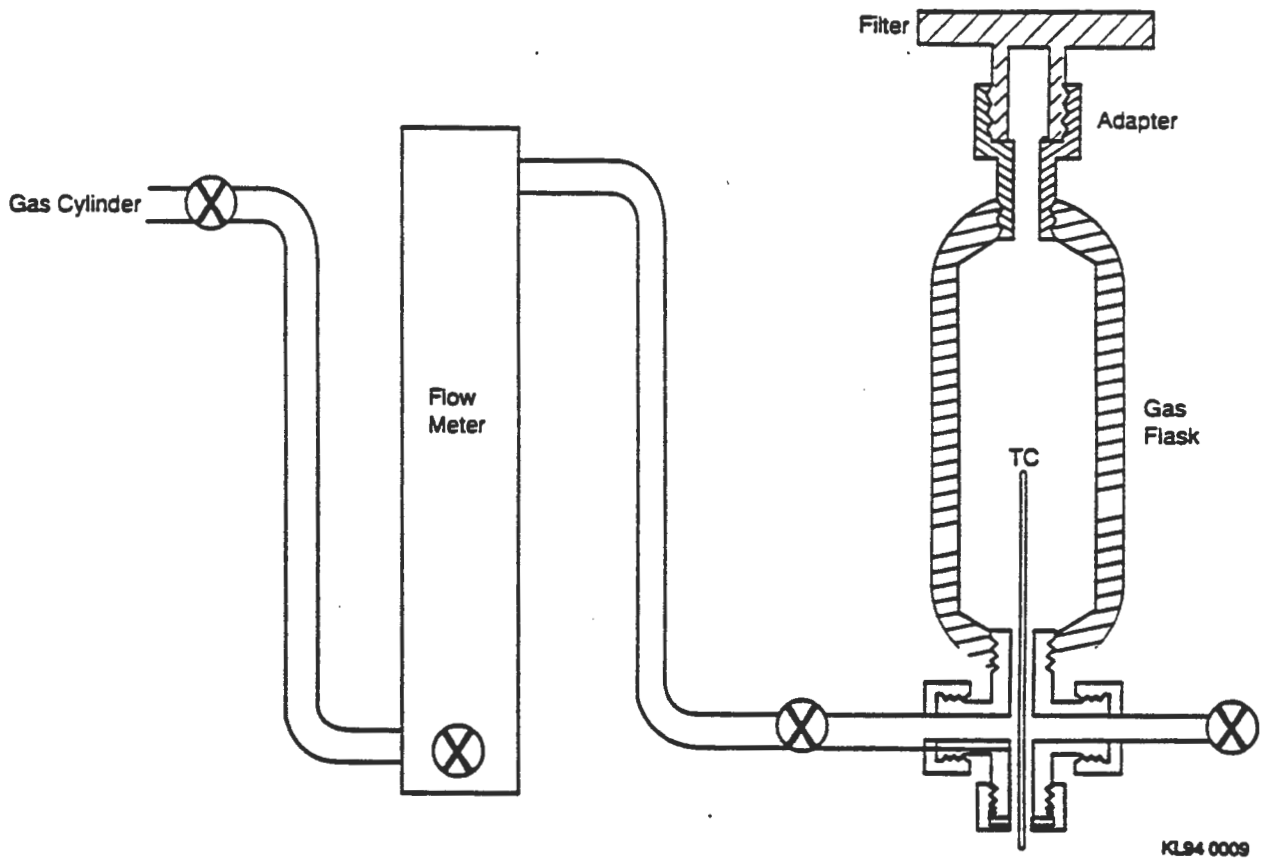

Figure 4. Schematic of experimental set-up used at Westinghouse to determine hydrogen diffusion characteristic across NFT filter vents (from unpublished research results of S. H. Peterson, Westinghouse R&D Center, July 1988).

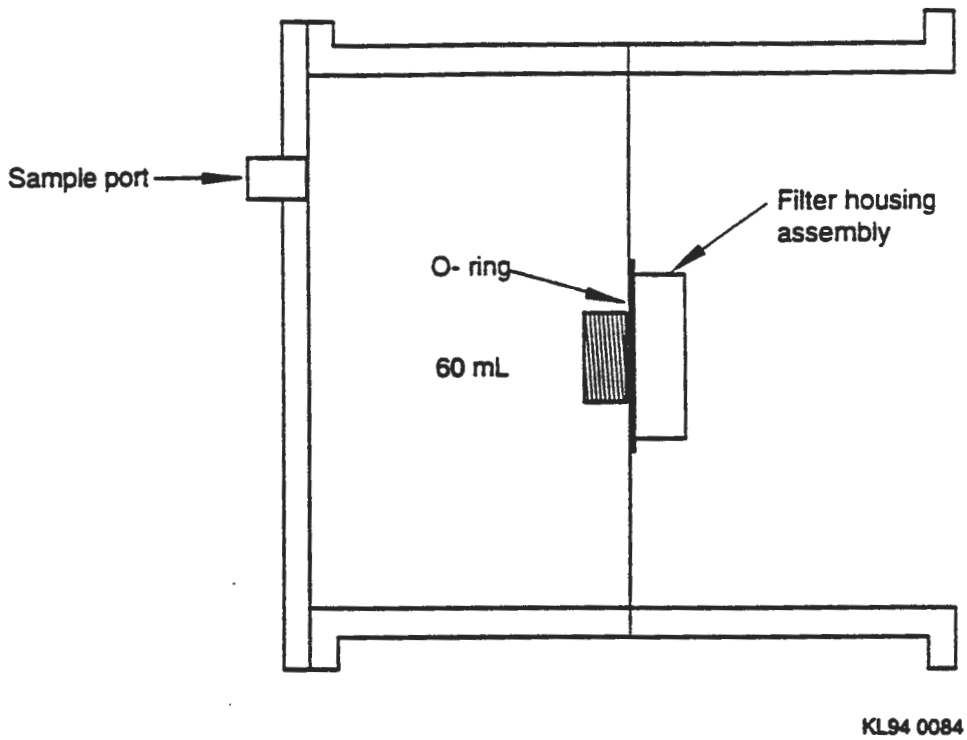

Figure 5. Schematic of experimental test vessel used at Westinghouse to determine VOC diffusion characteristics across NFT filter vents (from unpublished research result of S. H. Peterson and G. R. Marshall, Westinghouse R&D Center, October 1990).

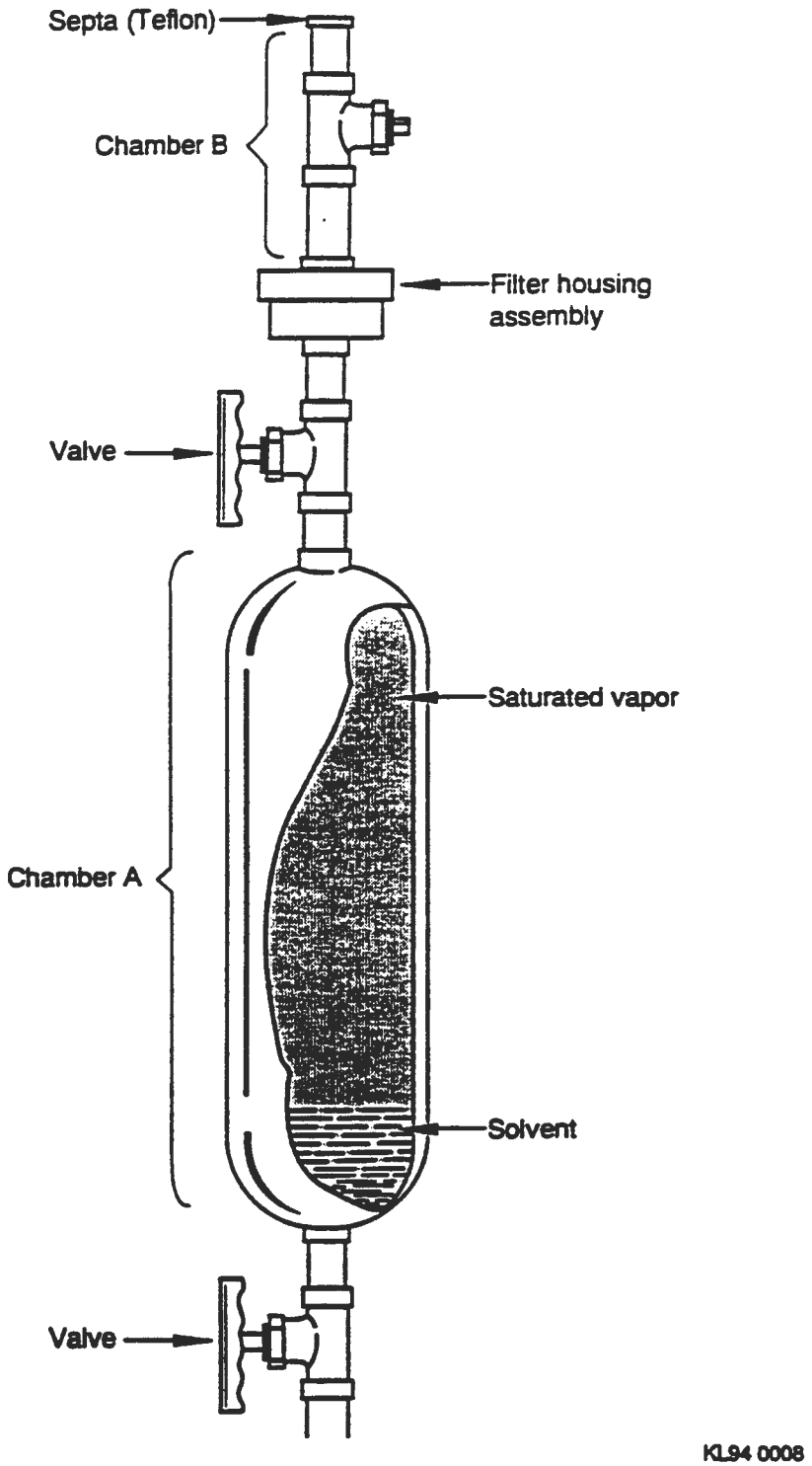

Figure 6. Schematic of experimental set-up used to determine VOC diffusion characteristics reported in the WIPP NMD variance petition.[2]

characteristic for NFT-013 filter vents was determined to be 74 x 10^{-7} mol s^{-1} using a different test vessel shown in Figure 7. The test vessel had a volume of 110 cm^3 with an approximate length of 20 cm and diameter of 3 cm. In addition, the filter vent was attached using an adapter that probably resulted in a concentration gradient across the gas chamber.

Another set of diffusion experiments was performed across NFT-013 filter vents.[c] The experimental equipment consisted of a 4.33-L container inside a larger vessel with a volume of 47.3 L. A H_2 gas mixture was introduced inside the smaller vessel. The H_2 concentration was measured inside each vessel. Hydrogen diffused across the filter vent located on the smaller vessel. Data from these experiments were used to calculate H_2 diffusion characteristics.[d] The average H_2 diffusion characteristic for five NFT-013 filter vents was (105 ± 3) x 10^{-7} mol s^{-1}. The hydrogen diffusion characteristic was determined for four NFT-013 filter vents using a 1.5-l test vessel.[5] The sample port was located near the top of the vessel to minimize its distance from the filter. The average value reported was (85 ± 3) x 10^{-7} mol s^{-1}.

A series of diffusion experiments was conducted that demonstrated the importance of the test vessel configuration on the calculated diffusion characteristic. The average H_2 diffusion characteristic for NFT-020 filter vents in the first set of experiments, using a test vessel shown in Figure 8a, was (24 ± 3) x 10^{-7} mol s^{-1}.[e] A modified test vessel configuration, shown in Figure 8b, reduced the distance between the filter vent and the vessel base.[f] The average H_2 diffusion characteristic for NFT-020 filter vents using the modified test vessel was (40 ± 2) x 10^{-7} mol s^{-1}. The increase in the reported diffusion characteristic was directly attributed to the test vessel modification.

The hydrogen diffusion characteristic across filter vents with sintered metal filters have been reported.[g] The filter vents were manufactured by Pall Advanced Separation Systems. The test vessel shown in Figure 8b was used in the diffusion tests. The average hydrogen diffusion characteristic for six filter vents comparable in size and dimensions to a NFT-020 filter vent was (39 ± 1) x 10^{-7} mol s^{-1}. The average hydrogen diffusion characteristic across two filter vents comparable in size and dimensions to a NFT-013 filter vent was (256 ± 45) x 10^{-7} mol s^{-1}. The large standard deviation was attributed to rapid transport from the test vessel which made it difficult to accurately reproduce experimental results.

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c. Unpublished report evaluating hydrogen diffusion across filter vents; D. T. Hobbs, Westinghouse Savannah River Corp. (July 1990).

d. Unpublished report evaluating hydrogen and VOC diffusion characteristics across NFT-012 and NFT-013 filter vents; K. J. Liekhus and D. A. Johnson, EG&G Idaho, Inc. (June 1994).

e. Unpublished research results concerning hydrogen diffusion characteristic measurements across NFT-020 filters; E. B. McNew and D. A. Johnson, EG&G Idaho Inc. (April 1992).

f. Unpublished research results concerning measurements of hydrogen diffusion characteristic across NFT-020 filter vents; E. B. McNew, EG&G Idaho Inc. (June 1992).

g. Unpublished research results reporting hydrogen diffusion characteristics measured across carbon composite and sintered metal filters; D. A. Johnson and K. Messick, EG&G Idaho Inc. (May 1993).

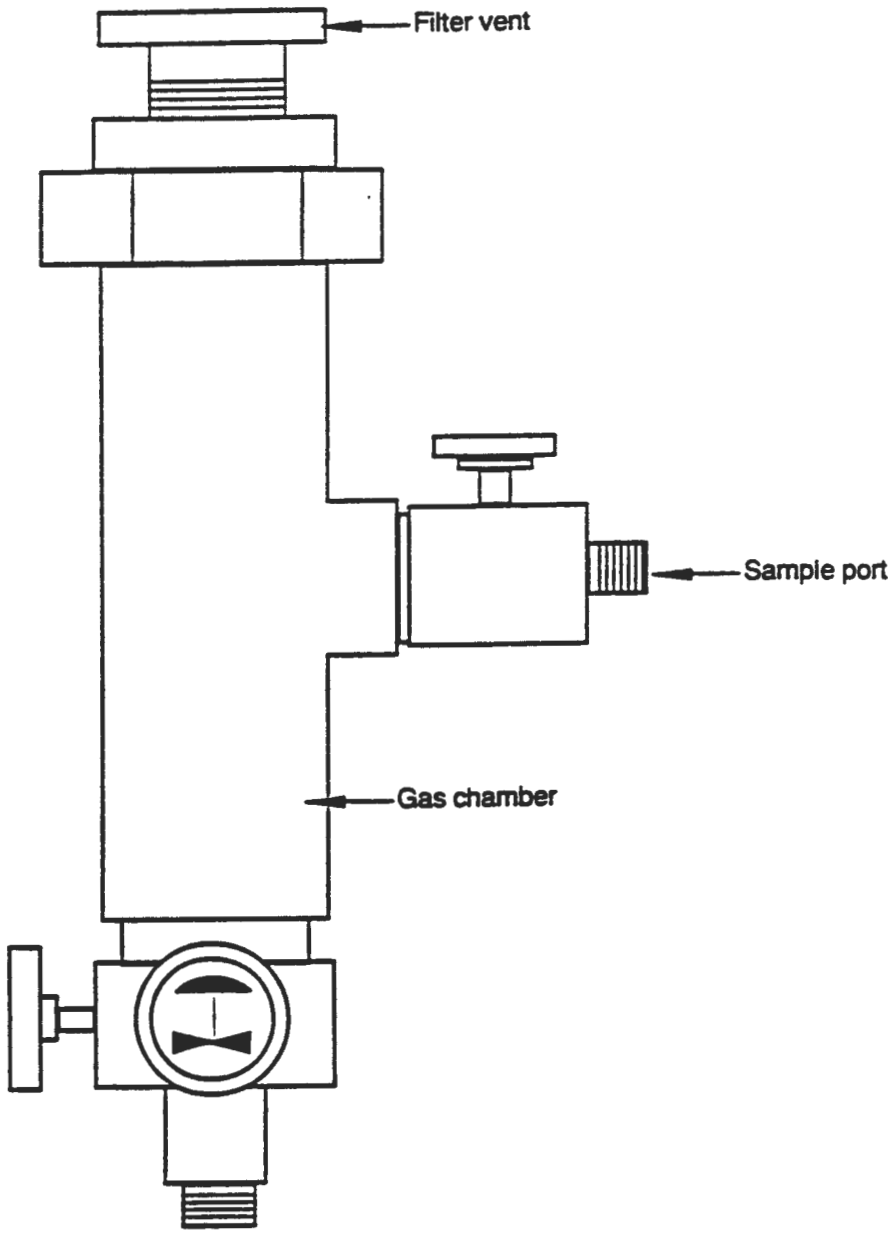

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Figure 7. Schematic of experimental test vessel used at Westinghouse to determine H_2 diffusion characteristics across NFT filter vents (from unpublished research result of S. H. Peterson and G. R. Marshall, Westinghouse R&D Center, October 1990).

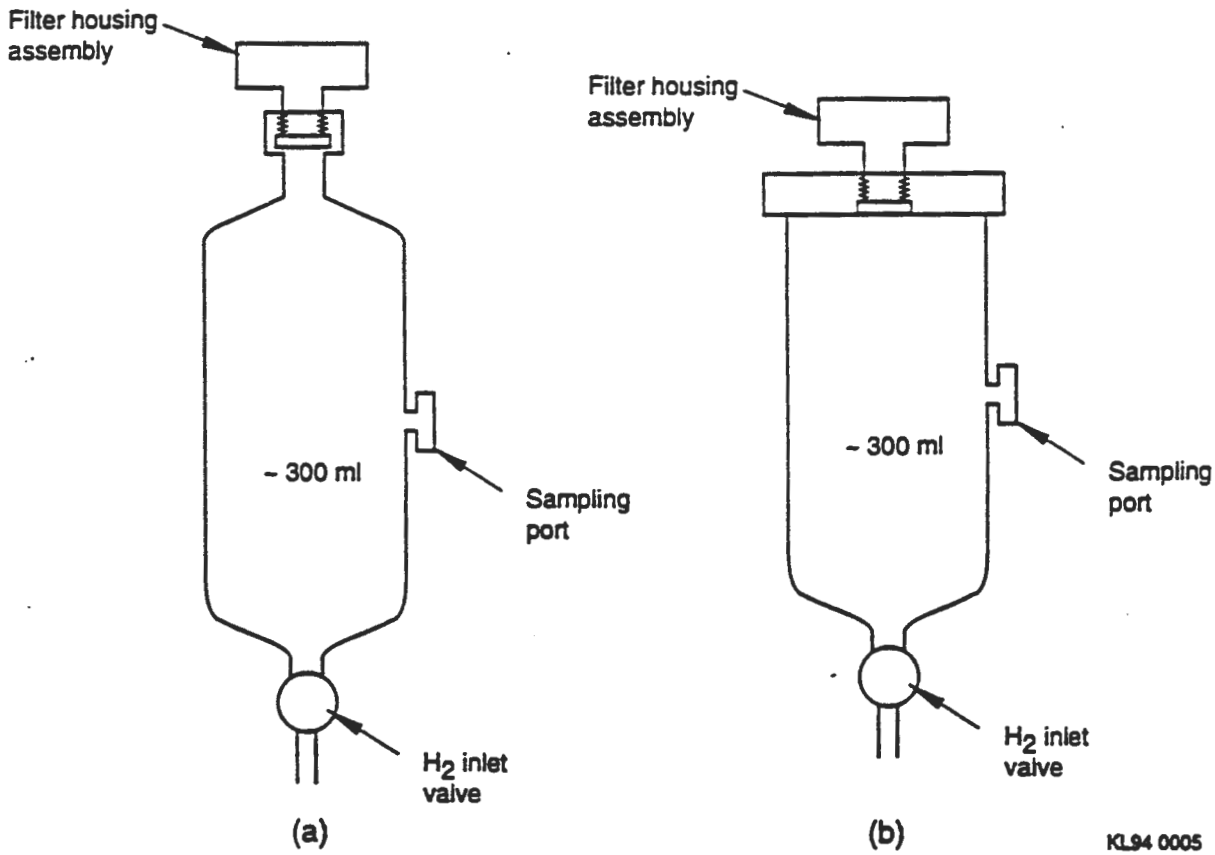

Figure 8. Schematic of test vessels used at the INEL to determine H_2 diffusion characteristic across NFT-020 filter vents (a) original design; (b) modified design (unpublished research results of E. B. McNew and D. A. Johnson, EG&G Idaho, Inc., April 1992; E. B. McNew, EG&G Idaho, Inc., June 1992).

3.2 Polymer Bags

The gas diffusion characteristic across different filter vents of the same design will be similar, allowing for variations in construction. Equation (4) shows that the permeation characteristics of different polymer bags do not have to be similar because, besides being a function of the gas-polymer permeability, they are also a function of the permeable surface area and bag thickness. The permeable area is the parameter that can have the greatest variation and depends upon how much waste is placed inside the bag and the type of bag closure.

Hydrogen transport characteristics for different layers of confinement in vented waste drums have been determined under assumed steady-state conditions.[1] The layers of confinement included polyethylene and polyvinyl chloride (PVC) bags as well as drum liners and drum filter vents. The polymer bags were sealed by a twist-and-tape or fold-and-tape method. The experiments consisted of simulating hydrogen generation by maintaining a controlled release of hydrogen gas in the innermost bag and monitoring the hydrogen concentration in all void volumes between the layers of confinement. The tests were terminated when it was determined that H_2 concentrations in all layers of confinement remained constant for at least twelve hours. A hydrogen mass balance at steady state allowed calculation of the gas transport characteristic across each layer of confinement.

The hydrogen diffusion characteristic of a taped bag closure of a small PVC bag was calculated as the difference between the H_2 transport characteristics of polymer bags with and without taped closures. A H_2 diffusion characteristic of 5.6×10^{-7} mol s^{-1} was reported for a taped closure. A hydrogen permeation characteristic of 4.9×10^{-7} mol s^{-1} was calculated for a 0.036-cm (14-mil) PVC heat-sealed bag with a permeable surface area of approximately 5,800 cm^3. The reported hydrogen flow rates into the bags at the time steady state was declared were not identical and ranged between 1.5 and 3.7 cm^3 hr^{-1}. The gas feed rate was not maintained at a constant value but adjusted as necessary to maintain H_2 concentration in the innermost bag at or near 4%.

Two experiments were conducted to identify hydrogen diffusion characteristics for 0.030-cm (12-mil) thick PVC bags with and without a taped closure.[5] In the first test, a bag was sealed over a circular plate with a surface area of approximately 2,800 cm^2 and a depth of approximately 2.5 cm. The bag was filled to atmospheric pressure with a 6% hydrogen/94% argon gas mixture. The plate was fitted with a sample port and samples were collected at regular intervals and analyzed by mass spectrometry. The hydrogen diffusion characteristic was calculated to be 2.8×10^{-7} mol s^{-1}. Another bag was prepared with a taped closure. The open end was twisted between 6 and 8 times, folded over so that the length of the twisted section end was halved, and then secured with tape wrapped around the folded material. The taped closure and sufficient bag material were removed and secured over the circular plate. Five different bags with a taped closure were prepared and tested. The average hydrogen diffusion characteristic across these samples was 3.6×10^{-7} mol s^{-1}.

4. NEW TRANSPORT CHARACTERISTIC MEASUREMENTS

The review of earlier drum filter vent diffusion experiments showed a wide variety of test vessel designs. In most cases, insufficient care was taken to minimize concentration gradient formation within the test vessel. A series of diffusion tests was conducted at the INEL using a test vessel specifically designed to minimize development of concentration gradients. A series of transport experiments was also conducted to identify H_2 and VOC transport characteristics across polymer bags and determine whether hydrogen transport across a small polymer bag with a taped closure is significant compared with permeation across the bag surface.

4.1 Experimental Apparatus

4.1.1 Drum Filter Vents

A cylindrical stainless steel vessel with a flat lid and base was constructed with an external diameter of 6.0 cm (2.4 in.) and an external height of 3.8 cm (1.5 in.). The vessel was designed for a drum filter vent to be screwed into the center of the top lid. Separate side ports allowed for the introduction of gas and the sample collection with a gas-tight syringe. Because of variations in the filter housing assemblies, two different test vessels were constructed. The internal volume of the test vessel used with NFT-012 and NFT-013 filter vents was 55 cm^3 and for the test vessel used with NFT-020 filter vents was 59 cm^3.

4.1.2 Polymer Bags

Polyethylene and PVC bags were heat-sealed or taped closed in a manner that ensured that the final surface area of the taped bags was approximately equal to that of the heat-sealed bags. The heat-sealed bags had a width of 30.5 cm (12 in.) and length of 33 cm (13 in.). The width of the taped bags was identical to that of the heat-sealed bags. The taped portion was approximately 15 cm (6 in.) long. Each bag held 3,750 cm^3 of gas without making the bag surface taut which meant that the internal bag and ambient pressures were equal. The average thickness of the polyethylene bags was 7.6×10^{-3} cm (3 mil) and of the PVC bags was 2.8×10^{-2} cm (11 mil).

Bag feedthroughs were fabricated from modified brass bulkhead unions with two backing washers, two teflon sealing washers, and an n-butyl O-ring. The outer sealing washer was machined to allow the O-ring to seat between the sealing washer and bag. The outer backing washer and outer teflon sealing washer were epoxied to the body of the bulkhead union. The teflon ferrules were used to seal the sample transfer lines.

The transport experiments were performed on an automated lab-scale system[3,4] that sampled and analyzed gas concentrations in the bags. The automated gas sampling system included a high- and low-level gas sampling manifold, a gas chromatograph (GC) with flame ionization and thermal conductivity detectors, a GC data station, a 10-port gas sampling valve, a mechanical vacuum pump, a microcontroller, and a process controller.

4.2 Experimental Procedure

In each experiment, the void volume of the filter vent test vessel or polymer bag was filled with a gas mixture and the average gas concentration was measured as a function of time. The rate of change in the gas concentration is directly dependent on the transport characteristic of the drum filter vent or polymer bag.

4.2.1 Drum Filter Vents

Pure hydrogen gas was used in the H_2 diffusion characteristic experiments. Two different gas mixtures were used in the VOC diffusion characteristic measurements. A VOC-gas mixture was introduced into the chamber that initially contained 1,010 ppmv methylene chloride, 1,020 ppmv TCA, 1,010 ppmv 1,1,2-trichloro-1,2,2-trifluoroethane (Freon-113), 301 ppmv carbon tetrachloride, and 297 ppmv trichloroethylene (TCE) in hydrocarbon-free air. Another VOC-gas mixture containing 764 ppmv methanol, 980 ppmv TCA, 398 ppmv toluene, 746 ppmv cyclohexane, and 99 ppmv p-xylene in hydrocarbon-free air was also used.

4.2.1.1 NFT-020 Filter Vent.[h] Two sets of experiments were conducted to determine if VOC loading of the carbon-composite material significantly affected the rate of VOC transport through a filter vent. A VOC gas mixture was introduced into the test vessel through the fill port at an approximate rate of 1,000 cm^3 min^{-1} for one minute to purge air out from the vessel. After the gas flow was discontinued, a clean filter was installed in the lid. The feed line was disconnected from the vessel and the feed port was capped. Gas samples were withdrawn by gas syringe at regular time intervals over 2 to 3 hours. Samples were injected into a gas chromatograph to determine VOC concentrations. In other tests, approximately one liter of VOC gas was introduced into a test vessel with the filter vent attached to the vessel. This procedure increased the amount of VOCs absorbed onto the carbon composite filter.

Hydrogen was introduced into a test vessel with a filter vent at about of 1,000 cm^3 min^{-1} for a period of one minute to purge air out from the vessel. Samples were collected over 40 minutes. The H_2 and VOC diffusion characteristics were determined for six filters. The room temperature during the tests was 298 K and the average ambient pressure was 64.4 cm Hg.

4.2.1.2 NFT-012 and NFT-013 Filter Vents. The gas mixture was introduced into a test vessel with filter vent attached through the fill port at about 1,000 cm^3 min^{-1} for one minute to purge the vessel. The feed line was disconnected from the vessel and the feed port was capped. Gas samples were withdrawn by gas syringe at regular time intervals. Samples were injected into a gas chromatograph to determine gas concentrations. The room temperature during the tests was 298 K and the average ambient pressure was 64.4 cm Hg.

Total sample duration for the VOC gas mixtures was approximately 45 minutes. For the NFT-013 filter vents, only four accurate measurements of the H_2 concentration in the test vessel could be obtained within the first 12 minutes. As a result, tests to determine the H_2 diffusion

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h. Unpublished report concerning measurement and estimation of gas diffusion characteristic across NFT-020 drum filter vents; K. J. Liekhus and D. A. Johnson, EG&G Idaho, Inc. (December 1993).

characteristic were performed in triplicate for each filter vent. For NFT-012 filter vents, the turnaround time between samples was reduced, and six gas samples were collected during each test; thus, only one H_2 diffusion test was performed for each filter vent.

4.2.2 Polymer Bags

Multivariable two-level experiments with one replicate were designed to investigate the effect of bag closure type on H_2 and VOC transport from small polymer bags. Trichloroethylene and Freon-113 were used in the experiments. The process variables were the bag (0.0076 cm (3 mil) polyethylene or 0.028 cm (11 mil) PVC) and bag closure type (taped closure or heat-sealed). For each combination of bag and closure type, three bags were prepared. The bags were randomly distributed between the experiments and each bag was used twice.

5. RESULTS

5.1 Hydrogen Transport Characteristics

The average and minimum H_2 diffusion characteristics for each drum filter vent type are summarized in Table 1. The H_2 transport characteristics for polyethylene and PVC bags with a heat-sealed or taped closure are listed in Table 2. A general linear regression model was used on the experimental data to determine that at a level of significance of $\alpha = 0.05$, there was no significant difference in the H_2 transport characteristic across polyethylene or PVC bags with different closure types.

5.2 VOC Transport Characteristics

In experiments using the NFT-020 filter vents, the natural logarithm of the fraction of the initial VOC concentration in the test vessel was plotted as a function of time. Linear regression analysis was performed on each set of data to identify the slope and the correlation coefficient. The correlation coefficient, in all cases, was greater than 0.98. The VOC diffusion characteristics measured across six different clean and used filters are listed in Table 3. A students t-test at an α=0.05 level of significance showed that the difference in VOC diffusion characteristics for clean and used filter vents was significant for all VOCs except Freon-113. This was attributed to VOCs being adsorbed onto the carbon-composite materials. As a result, all later experiments had filter vents in place on the test vessel during gas purging instead of being put in place after purging. The average diffusion characteristics of nine different VOCs for NFT-012 and NFT-013 filter vents using this procedure are listed in Table 4.

A statistical linear model analysis of VOC transport characteristic experimental data was performed to identify if the total transport characteristic varied significantly as result of the bag closure type. The bag closure type did not significantly affect the TCE transport rate from polymer bags. A bag material-bag closure interaction was observed with Freon-113. Specifically, the transport characteristic for PVC bags with a taped closure was significantly higher than for any other bag material-closure type combination.

Table 1. Average and minimum H_2 diffusion characteristics (mol $s^{-1} \times 10^7$) across different NFT drum filter vents.

	Average	Minimum
NFT-012	28 ± 6[a]	17
NFT-013	117 ± 11	102
NFT-020	42 ± 1	41

a. One standard deviation.

Table 2. Hydrogen transport characteristics (mol $s^{-1} \times 10^7$) for polyethylene and PVC bags.

	Polyethylene	PVC
Twist-and-tape closure	5.93	2.99
	6.76	1.98
Heat-sealed closure	3.65	1.99
	8.72	2.09

Table 3. VOC diffusion characteristics (mol s^{-1} x 10^7) for clean and used NFT-020 drum filter vents.

Filter ID number	Methylene chloride	Freon-113	TCA	Carbon tetrachloride	TCE
HC7: Clean	3.75	2.74	2.87	2.85	3.32
HC7: Used	3.71	2.73	2.69	2.61	3.16
JD8: Clean	4.90	3.41	3.33	3.28	3.38
JD8: Used	4.75	3.64	3.39	3.08	3.27
NB5: Clean	4.84	3.69	3.54	3.39	3.37
NB5: Used	4.90	3.66	3.40	3.07	3.27
IE8: Clean	5.09	3.68	3.51	3.43	3.44
IE8: Used	4.44	3.59	3.38	3.24	3.43
GD9:Clean	5.11	3.72	3.62	3.49	3.68
GD9: Used	4.30	3.48	3.23	3.14	3.09
OE4: Clean	4.87	3.70	3.51	3.41	3.32
OE4: Used	4.44	3.43	3.14	3.02	2.86

Table 4. VOC diffusion characteristic (mol s^{-1} x 10^7) for NFT-012 and NFT-013 drum filter vents.

	NFT-012	NFT-013
Freon-113	3.20 ± 0.51[a]	10.4 ± 0.6
Methylene chloride	4.50 ± 0.67	17.7 ± 0.9
1,1,1-trichloroethane[b]	3.85 ± 0.60	10.4 ± 0.5
1,1,1-trichloroethane[c]	3.79 ± 0.57	11.0 ± 0.6
Carbon tetrachloride	3.83 ± 0.57	10.6 ± 0.5
Trichloroethylene	4.21 ± 0.53	13.9 ± 1.8
Methanol	6.00 ± 1.11	9.7 ± 0.9
Cyclohexane	4.00 ± 0.59	11.2 ± 0.5
Toluene	4.29 ± 0.50	13.2 ± 2.5
p-xylene	3.55 ± 0.29	11.7 ± 2.3

a. One standard deviation.

b. Gas mixture containing TCA, Freon-113, TCE, carbon tetrachloride, and methylene chloride.

c. Gas mixture containing TCA, methanol, cyclohexane, toluene, and p-xylene.

6. DISCUSSION

6.1 Drum Filter Vents

6.1.1 Hydrogen Diffusion Characteristic

The H_2 diffusion characteristics from this report and past investigations are summarized in Table 5 by the types of NFT drum filter vents. In all cases, values determined using the current INEL test vessel were greater than previously reported values. The higher values of H_2 diffusion characteristic are attributed to the test vessel configuration, the position of the filter vent relative to the gas sample location, and the validity of assuming a well-mixed gas volume. The test vessel used in the new diffusion studies minimized the distance between the base of the filter vent and had an internal volume between 55 and 60 cm^3. The lower diffusion characteristics in other small test vessels (75-110 cm^3) are attributed to the elongated geometry of the test cylinder. Filter vents were located at the top usually attached to an adapter and gas samples were collected from the middle of the test vessel. The design of these test vessels increased the likelihood of developing a concentration gradient in or near the test vessel. The larger diffusion characteristic value reported by Liekhus[d] was attributed to the fact that the H_2 concentration outside the 4.33-L test vessel was also measured which resulted in a more accurate knowledge of the concentration gradient across the vent.

6.1.2 VOC Diffusion Characteristic

6.1.2.1 Clean and Used Filter Vents. The filter treatment procedure passed approximately 100% of the molar capacity of the carbon-composite media over the filter in one minute, although only a fraction of the VOCs adsorbed onto the filter. The VOC diffusion characteristics for treated filters were slightly less than values calculated for untreated filters. This was attributed to a decrease in the VOC-adsorption capacity of the filters. The adsorption capacity of a clean filter may have enhanced the VOC transport rate across the filter. Thus, a more conservative estimate of VOC diffusion characteristics requires that tests be performed across filters exposed to VOC gas mixture before gas sampling.

It was assumed that the diffusion characteristic for each VOC was not influenced by the presence of the other VOCs. Values for TCA diffusion characteristics using two different gas mixtures (see Table 4) indicates that this was a valid assumption.

6.1.2.2 Estimating VOC Diffusion Characteristic. It has been proposed that the ratio of the VOC-to-H_2 diffusion characteristics is equal to the ratio of VOC-to-H_2 diffusivity in air

$$\frac{D^*_{voc}}{D^*_{H_2}} = \frac{D_{voc-air}}{D_{H_2-air}} \quad . \tag{8}$$

The VOC diffusion characteristic has been estimated using the hydrogen as a reference gas and the inverse ratio of molecular weights.[1] Thus, the ratio of diffusion characteristics is

Table 5. Comparison of reported H_2 diffusion characteristics (mol $s^{-1} \times 10^7$) for different drum filter vents.

	NFT-012	NFT-013	NFT-020
This report	28 ± 6[a]	117 ± 11	42 ± 1
Peterson[b]	23 ± 2	—	39 ± 10
Peterson[c]	—	74	—
Hobbs[d], Liekhus[e]	—	105 ± 3	—
McNew[f]	—	—	24 ± 3
McNew[g]	—	—	40 ± 2
Smith[h]	—	85 ± 3	—

a. One standard deviation

b. Unpublished report, S. H. Peterson, Westinghouse R&D Center (July 1988).

c. Unpublished report, S. H. Peterson and G. R. Marshall, Westinghouse R&D Center (October 1990).

d. Unpublished report, D. T. Hobbs, Westinghouse Savannah River Corp. (July 1990).

e. Unpublished report, K. J. Liekhus and D. A. Johnson, EG&G Idaho, Inc. (June 1994).

f. Unpublished report, E. B. McNew and D. A. Johnson, EG&G Idaho, Inc. (April 1992).

g. Unpublished report, E. B. McNew, EG&G Idaho, Inc. (June 1992).

h. Reference 5.

estimated as

$$\frac{D_{voc-air}}{D_{H_2-air}} = \sqrt{\frac{MW_{H_2}}{MW_{voc}}} \quad . \tag{9}$$

Gas diffusivity in air can be estimated at low pressures using an equation developed from a combination of kinetic theory and corresponding-states arguments[6]

$$D_{AB} = 2.745 \times 10^{-4} \; \frac{T^{1.823}}{P} \; \left[p_{cA}\, p_{cB}\right]^{1/3} \; \left[T_{cA}\, T_{cB}\right]^{-1/2} \; \left[\frac{1}{M_A} + \frac{1}{M_B}\right]^{1/2} \tag{10}$$

where

D_{AB} = mass diffusivity for gas(A)-gas(B) system, $cm^2\ s^{-1}$

p_{ci} = critical pressure of species i. atm

T_{ci} = critical temperature of species i, K

M_i = molecular weight of species i.

The ratio of VOC-to-H_2 diffusivity in air can be estimated using Equation (10)

$$\left[\frac{D_{voc-air}}{D_{H_2-air}}\right] = \left[\frac{p_{c,voc}}{p_{c,H_2}}\right]^{1/3} \left[\frac{T_{c,voc}}{T_{c,H_2}}\right]^{-1/2} \left[\frac{\frac{1}{M_{air}} + \frac{1}{M_{voc}}}{\frac{1}{M_{air}} + \frac{1}{M_{H_2}}}\right]^{1/2} . \tag{11}$$

The experimental VOC-to-H_2 diffusion characteristic ratios and estimated ratio values predicted using Equations (9) and (11) are listed in Table 6.

The VOC-to-H_2 ratios for NFT-012 filter vents was greater than the corresponding ratios in the other filter vents. This phenomenon is attributed to the difference in the filter vent designs and highlights the limitation of using gas diffusivity data to estimate diffusion through porous media. The smaller openings at both ends of the NFT-012 filter vent result in decreased

Table 6. Experimental and estimated VOC/H_2 diffusion characteristic ratios.

	NFT-012	NFT-013	NFT-020	Eqn (9)	Eqn (11)
Freon-113	0.116 ± 0.014[a]	0.089 ± 0.005	0.081 ± 0.005	0.104	0.100
Methylene chloride	0.163 ± 0.020	0.151 ± 0.007	0.104 ± 0.010	0.154	0.128
1,1,1-trichloroethane	0.139 ± 0.016	0.092 ± 0.004	0.093 ± 0.007	0.122	0.105
Carbon tetrachloride	0.139 ± 0.017	0.091 ± 0.004	0.071 ± 0.005	0.114	0.105
Trichloroethylene	0.152 ± 0.015	0.119 ± 0.009	0.075 ± 0.005	0.123	0.108
Methanol	0.218 ± 0.028	0.083 ± 0.005	0.142 ± 0.033	0.250	0.168
Cyclohexane	0.145 ± 0.018	0.096 ± 0.005	0.104 ± 0.016	0.154	0.108
Toluene	0.155 ± 0.018	0.113 ± 0.011	0.086 ± 0.010	0.147	0.104
p-xylene	0.129 ± 0.014	0.100 ± 0.010	0.059 ± 0.009	0.137	0.095

a. One standard deviation.

diffusion rates for both hydrogen and the VOCs. However, the diffusion rate of the larger VOC molecules through the filter vent is more influenced by the carbon composite medium than H_2. Thus, compared with the other filter vents, the vent constrictions cause a relative larger decrease in H_2 diffusion characteristic than in the VOC diffusion characteristic, which results in an increase in the VOC-to-H_2 ratio. A comparison of predicted diffusion characteristic ratios using Equations (9) and (11) indicate that Equation (9) predicts larger VOC-to-H_2 ratios. Equation (9) was generally more accurate in estimating the ratio for NFT-012 vents. Equation (11) was generally more accurate in estimating the ratio for NFT-013 and NFT-020 filter vents. Neither equation adequately predicted the diffusion characteristic ratio for methanol across the filter vents. Methanol is difficult to analyze because of its propensity as a polar compound to adhere to surfaces.

6.2 Polymer Bags

In determining the best straight line fit of the VOC data for PVC bags, data taken in approximately the first 2.5 hours (9,000 s) were excluded. For hydrogen, data collected during the first 1,000 s were excluded. The nonlinear behavior over these times is attributed to the accumulation of gas in the polymer at the beginning of each trial. At the beginning of each trial, the polymer is relatively free of these compounds. During the course of the experiment, the gas content in the polymer approaches an equilibrium value. This equilibrium concentration may change during the experiment as the gas phase concentration in the void volume decreases, but the greatest rate of change occurs early in the experiment. For polyethylene bags, the data point at time zero was the only data excluded in the straight line fit for both H_2 and the VOCs. Freon-113 and TCE may have different solubility in each polymer, but the main reason for different times over which data exhibits nonlinear behavior is attributed to the total mass of the bags. The mass of the PVC bag was nearly four times greater than that of the polyethylene bag.

The statistical test identified a bag material-closure type interaction in the bags containing Freon-113. Specifically, the transport characteristic from the PVC bags with a taped closure were significantly greater than from any other polymer-closure type combination. Several possibilities exist that may explain this discrepancy. The PVC bags are thicker and, thus, the taped closure may be more difficult to seal tightly. However, since H_2 diffuses approximately an order of magnitude more quickly than the VOCs, H_2 transport rate from the PVC bags with a taped closure should be significantly greater than from heat-sealed bags; this was not observed. This indicates that a pathway that allows significant vapor or gas diffusion does not exist. A more likely explanation is that Freon-113 accumulates in new PVC bags during the initial stage of the experiments while it permeates relatively slowly from the bags. Unlike the bag holding the gas, the polymer in the taped closure is not directly exposed to the VOC vapor and will take longer to achieve an equilibrium concentration. As a result, Freon-113 is steadily drawn up through the base of the taped closure. Since H_2 has relatively low solubility in both polymers, the presence of the taped closure has a lesser effect on the total H_2 transport rate.

Two other studies investigated H_2 transport through PVC bags with heat-sealed and taped closures.[1,5] The differences in total bag surface area, bag material, and bag thickness make it difficult to draw any conclusions from direct comparison of transport characteristics. Hydrogen permeability across a polymer can be calculated from the transport characteristic of the heat-sealed bags given the bag surface area, thickness, gas volume, temperature, and pressure.

Assuming that the primary transport mechanism from heat-sealed bags is permeation and no pressure differential across the bag exists, the H_2 permeability across polyethylene and PVC were calculated to be 10 and 12 Ba (Ba = 10^{-10} cm^3(STP) cm cm^{-2} s^{-1} (cm Hg)$^{-1}$), respectively. This compares with reported values of 10 Ba across polyethylene and between 4 and 9 Ba across PVC.[7] Hydrogen permeabilities estimated from the H_2 transport characteristics in the TRUPACT-II SAR[1] and Smith et al.[5] were 9 and 14 Ba, respectively.

Comparison of the ratio of transport characteristics from taped closure and heat-sealed bags with similar bag thickness and surface area eliminates most of the effect of these variables. The ratios of the average H_2 transport characteristics from this report and two earlier investigations are listed in Table 7. The ratio of transport characteristics for polymers determined in unsteady-state experiments indicates that an increase in the overall transport characteristic resulting from the presence of a taped closure is not significant. This conclusion is different from that made from the steady-state experiment.[1] In the steady-state tests, the H_2 transport characteristic across the taped closure was determined as the difference between transport characteristics measured across similar PVC bags with and without a taped closure. The original data showed the H_2 concentration in the polymer bag with a taped closure was increasing during the final 12-hour period and was not at steady state.[1] Hydrogen gas flow was also not maintained at a constant rate, but continuously adjusted to maintain H_2 concentration at 4%. In addition, duplicate tests were not performed. In contrast, the unsteady-state experiment described in this report included tests across two different bags of the same material and closure type to calculate the average H_2 transport characteristic. Under these conditions, H_2 transport from small polymer bags was not significantly affected by the type of bag closure. This means that most small bags placed in vented waste drums could have either a taped closure or heat seal without significantly affecting H_2 transport from the bags.

Table 7. Ratio of average H_2 transport characteristic for bags with taped closures to average H_2 transport characteristic for heat-sealed bags.

Bag polymer	Ratio	Bag polymer	Ratio
Polyethylene	1.0	PVC[a]	1.2
PVC[b]	1.3	PVC[c]	2.1

a. 11-mil thick; 2,000 cm^2.

b. 12-mil thick; 2,800 cm^2 (Reference 5).

c. 14-mil thick; 5,800 cm^2 (Reference 1).

7. IMPACT OF TRANSPORT CHARACTERISTICS ON MODEL CALCULATIONS

The impact of different H_2 and VOC transport characteristics for filter vents and polymer bags used in earlier model calculations is discussed in this section.

7.1 Hydrogen Transport Characteristics

Test results showed that the configuration of the test vessel affects the calculated filter vent gas diffusion characteristic. Hydrogen diffusion characteristics calculated from experimental data using the INEL test vessels were about 10 to 25% greater than the highest previously reported values. A larger diffusion characteristic would result in higher minimum allowable decay heat limit. A hydrogen diffusion characteristic of 19×10^{-7} mol s^{-1} was used to calculate the maximum allowable decay heat limit per innermost layer of confinement in the TRUPACT-II SAR.[1] This value was the lowest value determined across six NFT-012 filters. However, NFT-012 filter vents are no longer used in the transportation of vented waste drums. The NFT-013 and NFT-020 filter vents are used. The lowest H_2 diffusion characteristic measured across these filter vents using the smaller INEL test vessel was 41×10^{-7} mol s^{-1}. The use of a H_2 diffusion characteristic of a different drum filter vent will have a far more significant impact on model results than higher values resulting from improved test vessel design and experimental procedure.

In model calculations of the maximum allowable decay heat limit per layer of confinement,[1] a H_2 transport characteristic of 5.60×10^{-7} mol s^{-1} was used as a conservative estimate of gas transport from a polymer bag with a taped closure. This value was the difference of two H_2 transport characteristics measured across PVC bags with and without taped closures, and was meant to describe H_2 transport through the taped closure. Experimental evidence indicates that the transport characteristic for at least one bag was not measured under steady-state conditions as assumed. In addition, two unsteady-state experiments demonstrated that total H_2 transport across a small PVC bag with a taped closure is not significantly greater than a similarly sized PVC bag with no taped closure. As a result, the maximum allowable decay heat limit should have been calculated using a H_2 permeation characteristic for a heat-sealed PVC bag. The H_2 permeation characteristic for a heat-sealed PVC bag reported in the TRUPACT-II SAR was 4.94×10^{-7} mol s^{-1}.[1] This transport characteristic is 12% less than the value used in original calculations and would result in a slightly lower calculated decay heat limit, all other variables remaining the same. In this report, the average H_2 permeation characteristic for heat-sealed PVC bags was 2.04×10^{-7} mol s^{-1} and is less than the transport characteristic reported in the TRUPACT-II SAR because of smaller bag surface area.

7.2 VOC-Filter Vent Diffusion Characteristic

The VOC diffusion characteristic across a filter vent is used in the WIPP NMD variance petition[2] to estimate the rate of VOC emissions from a vented drum. The diffusion characteristics for carbon tetrachloride and TCA across different drum filter vent types are on the order of 10^{-11} mol s^{-1}. It was estimated that rate of TCA emissions from a waste drum containing waste form Benelex/Plexiglass was 3.2×10^{-14} mol s^{-1}. The explanation for the lower than expected values was a complex combination of FIckian and surface diffusion. A more likely explanation is

that the experimental set-up resulted in significant concentration gradient across the test vessel volume. Peterson and Marshall[b] and this report demonstrated that actual VOC diffusion characteristics are on the order of 10^{-7} mol s^{-1}. Using the same TCA headspace concentration from a drum containing waste form Benelex/Plexiglass, the TCA emission rate from a drum with a NFT-012 filter vent is 1.0×10^{-9} mol s^{-1}. This is over four orders of magnitude greater and significantly changes the total anticipated VOC emissions from vented waste drums at the WIPP facility. The rate of VOC emissions will still decrease as the VOC drum headspace concentration decreases.

8. CONCLUSIONS

1. Higher H_2 and VOC diffusion characteristics for NFT drum filter vents were calculated using the INEL test vessels than measured in earlier experiments. The higher values are considered to be more accurate because of the small test vessel volume and the vessel configuration specifically designed to minimize concentration gradient formation.

2. Tests on PVC bags with a surface area between 2,000 and 3,000 cm^2 and bag thickness between 2.8 and 3.0×10^{-2} cm (11-12 mil) show that the H_2 transport characteristic from bags with a taped closure was only 20 to 30% greater than from heat-sealed bags. Tests on polyethylene bags with a surface area of 2,000 cm^2 and bag thickness of 7.6×10^{-3} cm (3 mil) showed no difference at all in the H_2 transport characteristic for bags with different types of closure. Under these conditions, H_2 transport from small polymer bags was not significantly affected by the type of bag closure. This means that most small bags placed in vented waste drums could have either a taped closure or heat seal without significantly affecting H_2 transport from the bags.

3. Gas transport from polyethylene or PVC bags containing TCE or Freon-113, or other VOCs with similar permeability across the polymer, would not be significantly affected by bag closure type in actual waste drums.

4. Two methods of estimating a VOC diffusion characteristic across a filter vent based on the measured H_2 diffusion characteristic and the estimated ratio of VOC-air diffusivity to hydrogen-air diffusivity were examined. The method estimating the ratio by the square root of the H_2-to-VOC molecular weight ratio was best for NFT-012 drum filter vents. The method estimating the ratio using the critical temperature and pressure of H_2 and the VOC as well as the molecular weight of H_2, VOC, and air was a better method for NFT-013 and NFT-020 drum filter vents.

5. Direct comparison of H_2 permeation characteristics measured in different experiments is difficult because the transport characteristic is a function of the total permeable surface area, bag thickness, and gas-polymer permeability. Instead, hydrogen-PVC permeabilities were estimated from hydrogen permeation characteristics for heat-sealed PVC bags from the INEL and earlier transport experiments, and were approximately equal.

6. The H_2 transport characteristic for a PVC bag with a taped closure reported in the TRUPACT-II SAR[1] was based on flawed experimental data. Steady-state conditions were assumed despite evidence that steady state had not been achieved. This led to the incorrect conclusion that significant gas transport occurred through the taped closure.

7. The H_2 permeation characteristic reported in the TRUPACT-II SAR for the heat-sealed PVC bag should have been used in model calculations of the maximum allowable decay heat limit per layer of confinement, instead of the H_2 transport characteristic reported for a taped closure of a PVC bag. This would have resulted in a slightly smaller calculated maximum allowable decay heat limit per innermost layer of confinement.

8. Model calculations of the maximum allowable decay heat limit per layer of confinement in the TRUPACT-II SAR used the minimum H_2 diffusion characteristic across a NFT-012 drum filter vent. The NFT-012 drum filter vent is no longer used in the transshipment of waste drums. The minimum H_2 diffusion characteristic across a NFT-020 filter vent should now be used in calculating the maximum allowable decay heat limit per innermost layer of confinement. The average H_2 diffusion characteristic across the NFT-020 filter vent is over two times greater than the NFT-012 value used in original calculations. This will result in an increase in the maximum allowable decay heat limit per innermost layer of confinement.

9. The VOC diffusion characteristics used in the WIPP NMD Variance Petition to estimate the rate of VOC emissions from a vented drum were too low as a result of flawed experimental set-up. The VOC diffusion characteristics across different NFT filter vents were found to be at least four orders of magnitude greater than values listed in the WIPP NMD Variance Petetion. This significantly changes the total anticipated VOC emissions from vented waste drums at the WIPP facility.

9. REFERENCES

1. *Safety Analysis Report for the TRUPACT-II Shipping Package*, Rev. 12, Nuclear Packaging, Inc., September 1992.

2. *Waste Isolation Pilot Plant No-Migration Variance Petition*, Vol. 1, DOE/WIPP 89-003, Rev. 1, Westinghouse Electric Corp., March 1990.

3. K. J. Liekhus, G. L. Gresham, E. S. Peterson, C. Rae, N. J. Hotz, and M. J. Connolly, *Modeling Unsteady-state VOC Transport in Simulated Waste Drums*, EGG-WM-10823, Rev. 1, EG&G Idaho, Inc., 1994.

4. K. J. Liekhus, G. L. Gresham, C. Rae, and M. J. Connolly, *VOC Transport in Vented Drums Containing Simulated Waste Sludge*, EGG-WM-11205, EG&G Idaho, Inc., 1994.

5. M. C. Smith, et al., *Hydrogen generation and release in stored ^{238}Pu waste at Los Alamos National Laboratory*. Health Physics Society 27th Midyear Meeting, Albany, NY, February 1994.

6. R. B. Bird, W. E. Stewart, and E. N. Lightfoot, *Transport Phenomena*, John Wiley: New York, 1960.

7. H. Yasuda and V. Stannett, in *Polymer Handbook*, 2nd edition, J. Brandup and E.H. Immergut (eds.), John Wiley: New York, 1975.

APPENDIX D13

VOC SCREENING METHODOLOGY

APPENDIX D13
VOC SCREENING METHODOLOGY

Screening the volatile organic compounds (VOCs) for inclusion in the exposure assessment was a two-step process. The first step was determining that only those VOCs listed in both Appendix VIII of Title 40 of the Code of Federal Regulations (CFR) Part 261 and in the Waste Isolation Pilot Plant (WIPP) Quality Assurance Program Plan (QAPP) were eligible for inclusion in the demonstration. The second step was to score the VOCs based on the concentration-toxicity screening technique presented by the U.S. Environmental Protection Agency (EPA) in the *Risk Assessment Guidance for Superfund* (EPA 1989, p. 5-23). The scoring was performed using the weighted average VOC concentrations reported in the Idaho National Engineering Laboratory (INEL) and Rocky Flats Environmental Technology Site (RFETS) headspace sampling (Appendix C2, Table C2-1). The methodology used in calculating the average VOC headspace concentrations is described in Appendix C2.

The listing in Appendix VIII and/or the QAPP was used as a rough screening. VOCs that were to be analyzed on a site-specific basis (i.e., formaldehyde and hydrazine) were also screened out. VOCs listed in these sources are presented in Table D13-1; VOCs selected from this listing are as follows:

- Benzene
- Bromoform
- Carbon disulfide*
- Carbon tetrachloride
- Chlorobenzene
- Chloroform
- 1,2-Dichloroethane
- (cis)-1,2-Dichloroethylene
- 1,1-Dichloroethylene
- Isobutanol*
- Methyl ethyl ketone
- Methylene chloride
- 1,1,2,2-Tetrachloroethane
- Tetrachloroethylene
- Toluene
- 1,1,1-Trichloroethane
- 1,1,2-Trichloroethane*
- Trichloroethylene
- Trichlorofluoromethane*
- Vinyl chloride*

* No headspace data available

TABLE D13-1
Chemicals in 40 CFR Part 261 Appendix VIII and WIPP QAPP

Compound	Synonyms	CAS Number	Appendix VIII Constituent	QAPP
Acetone	2-Propanone	67-64-1		+
Antimony		7440-36-0		+
Arsenic		7440-38-2	+	+
Barium		7440-39-3	+	+
Benzene		71-43-2	+	+
Beryllium		7440-41-7	+	+
Bromoform	Tribromomethane	75-25-2	+	+
n-Butyl alcohol	Butanol, 1-Butanol	71-36-3		+
Cadmium		7440-43-9	+	+
Carbon disulfide	Carbon bisulfide	75-15-0	+	+
Carbon tetrachloride		56-23-5	+	+
Chlorobenzene		108-90-7	+	+
Chloroform		67-66-3	+	+
Chromium		7440-47-3	+	+
Cresol	Cresylic acid	1319-77-3	+	+
Cyclohexane		110-87-7		+
1,4-Dichlorobenzene	p-Dichlorobenzene	106-46-7	+	+
ortho-Dichlorobenzene	1,2-Dichlorobenzene	95-50-1	+	+
1,1-Dichloroethane	Ethylidene chloride	75-34-3		+
1,2-Dichloroethane	Ethylene dichloride	107-06-2	+	+
(cis)-1,2-Dichloroethylene	(cis)-1,2-Dichloroethene, sym-Dichloroethylene	540-59-0	+	+
1,1-Dichloroethylene	1,1-Dichloroethene, Vinylidene chloride	75-35-4	+	+
2,4 Dinitrophenol		51-28-5	+	+
2,4-Dinitrotoluene		121-14-2	+	+
Ethyl benzene		100-41-4		+
Ethyl ether	Diethyl ether, Ether	60-29-7		+
Formaldehyde		50-00-0	+	SS
Hexachlorobenzene		118-74-1	+	+
Hexachloroethane		67-72-1	+	+
Hydrazine		302-01-2	+	SS
Isobutanol	Isobutyl alcohol	78-83-1	+	+
Lead		7439-92-1	+	+
Mercury		7439-97-6	+	+
Methanol	Methyl alcohol	67-56-1		+
Methyl ethyl ketone	2-Butanone	78-93-3	+	+
Methyl isobutyl ketone	4-Methyl-2-pentanone	108-10-1		+
Methylene chloride	Dichloromethane	75-09-2	+	+
Nickel		7440-02-0	+	+
Nitrobenzene		98-95-3	+	+
Pentachlorophenol		87-86-5	+	+
Polychlorinated Biphenyls (PCBs)		1336-36-3	+	+
Pyridine		110-86-1	+	+
Selenium		7782-49-2	+	+
Silver		7440-22-4	+	+
1,1,2,2-Tetrachloroethane		79-34-5	+	+
Tetrachloroethylene	Tetrachloroethene, Perchloroethylene	127-18-4	+	+
Thallium		7440-28-0	+	+
Toluene		108-88-3	+	+
1,1,1-Trichloroethane	Methyl chloroform	71-55-6	+	+
1,1,2-Trichloroethane		79-00-5	+	+
Trichloroethylene	Trichloroethene	79-01-6	+	+
Trichlorofluoromethane	Freon-11	75-69-4	+	+
1,1,2-Trichloro-1,2,2-trifluoroethane	Freon-113	76-13-1		+
1,2,4-Trimethylbenzene	Pseudocumene	95-63-6		+
1,3,5-Trimethylbenzene	Mesitylene	108-67-8		+
Vanadium Pentoxide	Vanadium Oxide	1314-62-1	+	+
Vinyl chloride	Chloroethylene	75-01-4	+	+
m-Xylene	1,3-Dimethylbenzene	108-38-3		+
o-Xylene	1,2-Dimethylbenzene	95-47-6		+
p-Xylene	1,4-Dimethylbenzene	106-42-3		+
Zinc		7440-66-0		+

SS=Site Specific

The VOCs listed were further screened using the scoring technique outlined by EPA (EPA, 1989). First, the headspace concentration in parts per million by volume was converted to a concentration in micrograms per cubic meter for carcinogens and milligrams per cubic meter for noncarcinogens. Several VOCs did not have sample quantitation limits (SQLs) reported by the laboratories providing the headspace sampling data; for these VOCs (carbon disulfide, isobutanol, 1,1,2-trichloroethane, trichlorofluoromethane, and vinyl chloride), SQLs were calculated (Appendix C2), and one-half the calculated SQL (rounded to two decimal places) was used for the headspace concentration in the scoring process.

A risk factor was calculated for each VOC from the weighted average headspace concentration and the toxicity value. The risk factors for all VOCs were summed to yield a total risk factor. The contribution of each VOC to this risk factor was then calculated by dividing the individual risk factor by the total risk factor. The chemicals cumulatively responsible for approximately 99 percent of the total risk factor were selected for use in the assessments.

The conversion of headspace VOC concentration in parts per million per volume to micrograms per cubic meter (for carcinogens) was performed using the following equation:

$$HS_c = (HS)(10^{-6}\ mol\,fraction/ppmv)\left(\frac{P \times MW}{R \times T}\right)(10^6\ \mu g/g)(10^3\ L/m^3) \qquad \text{(D13-1)}$$

where

HS_c = weighted average headspace concentration for carcinogens, $\mu g/m^3$
P = pressure, 1 atm
MW = molecular weight, g/mol
R = ideal gas constant, 0.082057 L atm/mol K
T = temperature, 298 K
HS = weighted average headspace concentration, ppmv.

The conversion of headspace VOC concentration in parts per million per volume to milligrams per cubic meter (for noncarcinogens) was performed using the following equation:

$$HS_n = (HS)(10^{-6}\ mol\,fraction/ppmv)\left(\frac{P \times MW}{R \times T}\right)(10^3\ mg/g)(10^3\ L/m^3) \qquad \text{(D13-2)}$$

where

HS_n = weighted average headspace concentration for noncarcinogens, mg/m^3.

The equation used to calculate the individual risk factors for carcinogens was:

$$R_{ci} = HS_c \times UR \qquad \text{(D13-3)}$$

where

R_{ci} = risk factor for carcinogenic VOC i
UR = unit risk factor for VOC i, $(\mu g/m^3)^{-1}$.

The equation used to calculate the individual risk factors for noncarcinogens was:

$$R_{ni} = \frac{HS_n}{RfC} \qquad \text{(D13-4)}$$

where

R_{ni} = risk factor for noncarcinogenic VOC i
RfC = reference concentration for VOC i, mg/m^3.

The total risk factor was calculated using the equation:

$$R_t = R_1 + R_2 + R_3 + \ldots + R_i \qquad \text{(D13-5)}$$

where

R_t = total risk factor
$R_1 + \ldots + R_i$ = risk factors for VOCs 1 through i.

Separate values of R_t were calculated for carcinogens and noncarcinogens. Finally, the ratio of the individual risk to the total risk (R_{ci}/R_t or R_{ni}/R_t) was calculated for each VOC. Based on this ratio, the VOCs responsible for approximately 99 percent of the total risk factor were selected for inclusion in the assessments.

Table D13-2 presents the VOC screening results using the headspace concentrations of the VOCs. The following chemicals were selected to be included in the no-migration demonstration:

- Carcinogens
  - Carbon tetrachloride
  - Chloroform
  - 1,1-Dichloroethylene
  - Methylene chloride
  - 1,1,2,2-Tetrachloroethane

- Noncarcinogens
  - Carbon disulfide
  - Chlorobenzene
  - Methyl ethyl ketone
  - Toluene.

TABLE D13-2
Results of the VOC Screening Using Headspace Concentrations

Carcinogen	Molecular Weight (grams per mole)	Headspace Concentration (parts per million by volume)		Headspace Concentration (micrograms per cubic meter)	Chemical Class	UR (cubic meters per microgram)		Calculated Score	Absolute Score	Percent of total	
Benzene	78.11	9.25	a	2.95e+04	A	8.30e-06	c	0.245241838	0.245241838	0.0033066001	
Bromoform	252.77	9.38	a	9.70e+04	B2	1.10e-06	c	0.106656948	0.106656948	0.0014380576	
Carbon tetrachloride	153.84	375.5	a	2.36e+06	B2	1.50e-05	c	35.43550059	35.43550059	0.4777774952	*
Chloroform	119.39	25.33	a	1.24e+05	B2	2.30e-05	c	2.844455073	2.844455073	0.0383518392	*
Methylene chloride	84.94	368.5	a	1.28e+06	B2	4.70e-07	c	0.601610915	0.601610915	0.0081115309	*
1,1-Dichloroethylene	96.95	11.46	a	4.54e+04	C	5.00e-05	c	2.271802306	2.271802306	0.0306307516	*
1,2-Dichloroethane	98.96	9.07	a	3.67e+04	B2	2.60e-05	c	0.954351636	0.954351636	0.0128675404	*
1,1,2,2-Tetrachloroethane	167.86	9.35	a	6.42e+04	C	5.80e-05	c	3.722673296	3.722673296	0.0501928714	*
Tetrachloroethylene	165.85	9.4	a	6.38e+04	C-B2	5.80e-07	c	0.036977659	0.036977659	0.0004985705	
1,1,1-Trichloroethane	133.4	317.1	b	1.73e+06	C	1.60e-05	c	27.67834734	27.67834734	0.3731876576	*
1,1,2-Trichloroethane	133.42	0.07	b	3.82e+02	C	1.60e-05	c	0.006110926	0.006110926	0.0000823937	
Trichloroethylene	131.4	25.1	a	1.35e+05	C-B2	1.70e-06	c	0.229290525	0.229290525	0.0030915283	
Vinyl chloride	62.5	0.16	b	4.09e+02	A	8.40e-05	d	0.034351633	0.034351633	0.0004631637	
								Total=	~~46.3959077~~ 74.16203242	1.00000	

*VOCs account for approximately 99 percent of total score.

Noncarcinogen	Molecular Weight (grams per mole)	Headspace Concentration (parts per million by volume)		Headspace Concentration (milligrams per cubic meter)	Chemical Class	RfC (milligrams per cubic meter)		Calculated Score	Absolute Score	Percent of total	
Carbon disulfide	76.14	0.13	b	4.05e-01	ND	7.00e-01	d	0.578264172	0.578264172	0.0001886173	
Chlorobenzene	112.56	12.52	a	5.76e+01	D	2.00e-02	d	2881.552379	2881.552379	0.9399003669	*
(cis)-1,2-Dichloroethylene	96.95	8.97	a	3.56e+01	D	ND		—	0	0	
Isobutanol	74.12	0.13	b	3.94e-01	ND	ND		—	0	0	
Methyl ethyl ketone	72.1	63.66	a	3.83e+01	D	1.00e+00	c	0.383306971	0.383306971	0.0001250265	
Toluene	92.13	19.4	a	7.31e+01	D	4.00e-01	c	182.7304444	182.7304444	0.0596027381	*
Trichlorofluoromethane	137.38	0.07	b	3.93e-01	ND	7.00e-01	d	0.561812778	0.561812778	0.0001832512	
								Total=	2136.94983	1.00000	

*VOCs account for approximately 99 percent of total score.

[a]Measure data from INEL and RFETS sampling.
[b]One-half the calculated sample quantitation limit.
ND = No data available.
[c]Toxicity data from *Integrated Risk Information System.*
[d]Toxicity data from *Health Effects Assessment Summary Tables, Annual Update.*

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REFERENCE

EPA (U.S. Environmental Protection Agency). 1989. *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A)*. EPA 540/1-89/002. Washington, D.C.

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BIBLIOGRAPHY

DOE (U.S. Department of Energy). 1995. *Transuranic Waste Characterization Quality Assurance Program Plan*. Rev. 0. Carlsbad, New Mexico.

EPA (U.S. Environmental Protection Agency). 1989. *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A)*. EPA 540/1-89/002. Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1994a. *Health Effects Assessment Summary Tables, Annual Update*. EPA 540-R-93-058. Office of Solid Waste and Emergency Response, Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1994b. *Integrated Risk Information System (IRIS)*. Retrievals made during September 1994. Washington, D.C.

APPENDIX D14

LIQUID CONTENT MEMO

From: Environment, Safety and Health
Phone: 234-8291
Date: October 8, 1993
Subject: FREE LIQUID CONTENT OF WASTE STORED AT IDAHO NATIONAL ENGINEERING LABORATORY AND DISPOSITIONED AS WASTE ISOLATION PILOT PLANT CERTIFIED

DA:93:10052

To:

L. R. Fitch

cc: W. H. Bodily
R. F. Kehrman
L. L. Reed
W. W. Weston

With regard to the determination of estimates on the amount of free liquid resident within the TRU waste certified for disposal at the WIPP repository, a standard approach is to bound the estimate and thereby provide the underpinnings for establishing numerous best case/worst case scenarios. Several compelling arguments for taking this approach can be made. First and foremost, without sufficient data to establish an accurate statistical sampling of percent free liquid content by volume within the TRU waste inventory, bounding the problem is the only alternative. Secondly, should the performance assessment using the bounding values for free liquid demonstrate a benign repository response to the resulting gas generation, this result in conjunction with supporting laboratory-scale, bin-scale, and alcove-scale test data would constitute compelling evidence to justify the WIPP's request for a no migration determination during the disposal phase.

Unfortunately, by incorporating multiple bounding conditions including a free liquid content of one (1) gallon per each 55-gallon drum received into the Waste Isolation Pilot Plant (WIPP), Sandia National Laboratory's (SNL's) calculations have not unequivocally demonstrated the repository's response function to be independent of the generated gas pressure. In light of this result and the fact that there now exists a large waste characterization data base resident at the Idaho National Engineering Laboratory (INEL), it is now possible for SNL to input a more realistic estimate for the percent free liquid volume into their performance assessment calculations. Although the INEL data base is specific to waste derived from operations at the Rocky Flats Plant (RFP), there is a growing consensus that this information be used as the first step in a "phased approach" to resolving issues associated with gas generation - even if it should only relate to waste received from past RFP operations in addition to the current decommissioning and decontamination activities.

This examination of the EG&G/INEL data is the most exhaustive inquiry to date into the question of how much free liquid is resident in waste dispositioned as WIPP certified. Attached are the results of this inquiry. Several items need to be clarified in order to preclude any misinterpretations. First, the attached report only accounts for free residual liquid within the waste packages. No accounting of absorbed or adsorbed liquids is made in this report. Second, only waste dispositioned as WIPP certified is included in this report; i.e., of the approximately 17,000 drums examined, 9,171 drums were certified as acceptable per the WIPP Waste Acceptance Criteria (WAC). The majority of those waste drums rejected were on the basis they constituted Low Level Waste (LLW). Only a minority of the waste drums were rejected due to the presence of various non-conforming waste forms. Third, input to this study was also solicited from the RFP; however, due to the fact their data was not readily accessible from a computer data base, the submittal of this report on a timely basis did not allow for that additional information to be included at this time.

Upon perusing the data, the most striking observation is the small average liquid volume measured for the thirty four content codes. These values can be seen to span the range from 0.00000 to 0.39208 pints with an average of the averages equal to 0.18109 pints. Since the WAC prohibits free liquids in excess of one volume percent of the 55-gallon container, this equates to an upper bound of 0.55 gallons or 4.4 pints per 55-gallon drum. Comparison of these values indicates that on average the free residual liquid volume observed within this data base is much less than the upper bound established by the WAC. Also of importance is the fact that the free residual liquid volume averages are small relative to their corresponding standard deviations. This is indicative of a skewed frequency distribution. Thus, Waste Compliance would like to suggest that SNL use a Poisson distribution with a mean equal to the average specified above in place of their previous probability distributions for available water.

It is the intent of Waste Compliance to continue working with both INEL and RFP personnel to refine this data. Specifically a determination of the nature of the skewed frequency distributions is needed in order to more accurately model the residual free liquid volume parameter for each content code. In addition, since the LLW and TRU waste forms are in many instances derived from the same processes, it is of interest to determine if the water content of these waste categories are the same. An inquiry of this nature will provide insight on the relative importance of process knowledge to the characterization of waste.

For purposes of validating the information in this report, cognizant personnel to contact at EG&G/INEL that were instrumental in this study include Ms. Diane Hartley (208) 526-2484 and Mr. Tom Clements (208) 526-0664. Personnel to be contacted at EG&G/RFP include Mr. Jerry O'Leary (303) 966-3268 and Mr. Steve Tallman (303) 966-2257.

J. R. Elliott, Manager
Waste Compliance

alt

Attachment

ORT NO.: POLDSR01

AVERAGE AMOUNT AND STANDARD DEVIATION OF LIQUID
IN CONTAINERS DESTINED FOR WIPP

CONTENT CODE	NUMBER OF CONTAINERS	AVERAGE LIQUID (PINTS)	STANDARD DEVIATION OF LIQUID
1	3,733	0.14808	0.45
2	42	0.34048	0.62
3	550	0.13800	0.42
4	283	0.11131	0.40
7	2,621	0.32030	0.64
292	186	0.33710	0.67
300	344	0.00087	0.01
302	6	0.00000	0.00
303	72	0.00000	0.00
312	7	0.00000	0.00
320	93	0.00000	0.00
330	49	0.08571	0.41
335	4	0.12500	0.25
336	60	0.15667	0.44
337	101	0.39208	0.56
338	13	0.00000	0.00
339	78	0.00000	0.00
370	1	0.00000	0.00
371	83	0.00000	0.00
374	2	0.00000	0.00
377	1	0.00000	0.00
409	5	0.00000	0.00
411	10	0.00000	0.00
414	4	0.00000	0.00
432	72	0.05139	0.19
440	205	0.06000	0.16
441	2	0.00000	0.00
442	241	0.00249	0.03
464	1	0.00000	0.00
480	268	0.04739	0.23
481	29	0.02759	0.11
490	1	0.00000	0.00
900	1	0.00000	0.00
970	3	0.00000	0.00
	9,171		

APPENDIX D15

BACKGROUND INFORMATION ON PERMITTED EMISSIONS IN THE VICINITY OF WIPP

APPENDIX D15

COMPARISON OF WIPP FACILITY EMISSIONS TO PERMITTED EMISSIONS AT SURROUNDING FACILITIES

To compare the emissions from the WIPP repository to other area sources of air contamination, the emissions from the repository as converted to tons/year as follows:

$$PE_{voc}\ (tons/year) = APE_{voc}\ (mole/panel/year) \times MW\ (g/mole) \times (1\ kg/1000\ g) \times (0.0011\ tons/kg)$$

where,

PE_{voc}	=	panel emissions, tons/year
APE_{voc}	=	average panel emissions, mole/panel/year
MW	=	molecular weight, g/mole

The average emission rates for 1 open and 9 closed panels are used to give the maximum emission rate of the reposotiry as follows:

$$TPE_{voc} = (1 \times OPE_{voc}) + (9 \times CPE_{voc})$$

where,

TPE_{voc}	=	total panel emissions, tons/year
OPE_{voc}	=	open panel emission rate for the VOC, PEvoc for an open panel, tons/year
CPE_{voc}	=	closed panel emission rate for the VOC, PEvoc for a closed panel, tons/year

The maximum emission rates for each VOC, expressed in tons/year, are presented in Table 1. The values in Table 1 reflect no room closures in the open panel. Table 2 contains th epermitted emission rates for surrounding facilities.

TABLE D15-1

REPOSITORY MAXIMUM EMISSION RATES[a]

VOC	OPE (tons/year)	CPE (tons/year)	Total Emissions (tons/year)
Carbon tetrachloride	0.196	0.0026	0.219
Chlorobenzene	0.0046	0.00006	0.0052
Chloroform	0.011	0.00013	0.0126
1,1-Dichloroethylene	0.0044	0.00005	0.0048
1,2-Dichloroethane	0.0033	0.00004	0.0037
Methylene chloride	0.13	0.0014	0.142
1,1,2,2-Tetrachloroethane	0.0054	0.00007	0.0060
Toluene	0.0060	0.00008	0.0067
1,1,1-Trichloroethane	0.14	0.0019	0.161
		TOTAL	**0.561**

a. The values presented reflect no room closures in the open panel

TABLE D15-2
SOUTHEASTERN NEW MEXICO PERMITTED EMISSION RATES

	Facility	Pollutant	Tons/yr
1.	**Navajo Refinery** 5 Miles South of Lovington on Highway 18 (505) 748-3311 **Permit # 273**	VOC's Toluene Benzene Ethyl Benzene Xylene Hex Napthalene	779.73 12.353 4.311 1.863 13.581 7.524 1.841
2.	**SPS - Cunningham Plant** 15 Miles West of Hobbs on U.S. Highway 62-180 (505) 391-3200 **Permit # 622**	No_x	20
3.	**SPS - Maddox Plant** 8 Miles West of Hobbs on U.S. Highway 62-180 (505) 391-3200 **Permit # 747**	VOC's CO N_2	8 489 4155
4.	**IMC Fertilizer, Inc.** 26 Miles SE of Carlsbad on Highway 31 (505) 887-2871 **Permit # 495-M-5**	TSP	567.2*/535.1
5.	**New Mexico Potash Corp.** 35 Miles East of Carlsbad on U.S. Highway 62-180 (505) 887-1117 **Permit # 755**	TSP	1007.8*/394.2
6.	**Navajo Refinery** 501 E. Main St. Artesia, NM 88210 (505) 748-3311 **Permit # 195-M-5**	VOC's Toluene Benzene Ethyl Benzene Xylene Hexane Napthalene HF Acid	1760.70 68.536 26.546 36.743 22.411 24.696 1.744 9.248

	Facility	Pollutant	Tons/yr
7.	**GPM - Lea Plant** 28 Miles West of Hobbs on U.S. Highway 62-180 (505) 397-5720 **Permit # 76**	SO_2 VOC's CO NO_x	818.000 45.70 789.10 2540.60
8.	**GPM - Eunice Plant** 1 Mile North 1 Mile West of Oil Center (505) 397-5591 **Permit # 44-M-5**	SO_2 VOC's CO NO_x	34,264.70 420.20 634.50 4339.90
9.	**GPM - Artesia Plant** 12 Miles East of Artesia on Hwy 82 and 3 Miles South on County Rd. 206 (505) 397-5594 **Permit # 434**	SO_2 VOC's CO NO_x	1459.00 69.20 886.50 2040.60
10.	**El Paso Natural Gas** 9 miles NW of Carlsbad, NM (505) 885-0615 **Permit # 1009**	VOC's CO NO_x	4.73 26.00 83.00
11.	**Mississippi Chemical Corp.** 18 Miles East and 2 Miles South of Carlsbad on Highway 41 (505) 887-5591 **Permit # 421**	TSP	801.5*/146.7
12.	**Western AG-Minerals Co.** 20 Miles East of Carlsbad on U.S. Highway 62-180 (505) 885-3175 **Permit # 163-M-2**	TSP PM_{10} NO_x CO	3822.0*/102.2 1834.6*/49.1 14.4*/14.4 3.6*/3.6
13.	**Anderson Ranch Station** 10,000 bbl Oil Storage Tank 15 Miles West of Lovington **Permit # 1524**	VOC's	1.5/1.36(actual)

	Facility	Pollutant	Tons/yr
14.	**Cabin Lake Compressor Sta.** 21 Miles West of Carlsbad **Permit # 1120**	NO_x CO VOC's	50.00 46.00 18.00
15.	**Lea Crude Oil Storage Fac.** 4 Miles North of Oil Center, NM **Permit # 1430**	VOC's	9.80
16.	**Thomas Station Alt. #1** Crude Oil Storage Tank 20,000 bbl Capacity 28 Miles West of Jal, NM **Permit # 1504**	VOC's	1.52
17.	**City of Hobbs** Soil Vapor Extraction Sys. Ground Water Vapor Extrac. Hobbs, NM 88240 **Permit # 1486**	VOC's Ethyl Benzene Benzene Toluene Xylene Ethyl Dichloride Ethyl Dibromide	35.400 0.200 1.800 0.920 0.500 0.070 0.013
18.	**Monument Lateral Comp. Sta.** 16 Miles Southwest of Monument, NM **Permit # 1242-Revision**	NO_x CO VOC's	14.40 18.60 0.40
19.	**Texaco, Inc.** **Bilbrey Compressor Station 1** 27 Miles Northeast of Loving **Permit # 1505**	NO_x CO VOC's	79.70*/21.50 57.80*/21.50 10.90*/7.40
20.	**Vaca Compressor Station** 20 Miles West of Jal, NM **Permit # 1448**	NO_x CO VOC's	23.60 23.60 14.80
21.	**Conoco Oil, Inc.** **Maljamar Gas Plant** Maljamar, NM **Permit # 319-M-4**	NO_x CO SO_2 VOC's	959.80 136.10 3573.40 42.70

	Facility	Pollutant	Tons/yr
22.	**Livingston Ridge** **Crude Oil Storage Facility** Lea County, NM **Permit # 1096-M-1**	VOC's	2.10
23.	**Shoe Bar Compressor Station** 5 Miles South of Lovington **Permit # 1472**	NO_x CO VOC's	6.70 27.40 0.20
24.	**Mike's Super Fina and** **Detail Shop** (Gas/Oil Station) **Soil Vapor Extraction System** Hobbs, NM **Permit # 1330**	VOC's	9.60
25.	**Grama Ridge Number 1** **Compressor Station** 18 Miles Northwest of Eunice **Permit # 944-M-2**	NO_2 CO VOC's	139.20 187.40 44.40
26.	**Rattlesnake Compressor Sta.** 9 Miles South-Southwest of Jal, NM **Permit # 477-M-1**	NO_2 CO VOC's	21.20 31.80 8.01
27.	**Commanche Compressor Station** 20 Miles West of Oil Center **Permit # 1288-M-1**	NO_x CO VOC's	14.10 2.00 2.00
28.	**Texaco Oil Co., Inc.** **Bilbrey Compressor Station 2** 26 Miles Northeast of Loving **Permit # 1425**	NO_x CO VOC's	28.90 28.90 9.60
29.	**Hat Mesa Compressor Station** 24 Miles West of Oil City, NM **Permit # 1018-M-2**	NO_2 CO VOC's	245.80 245.80 16.60
30.	**Lynch Booster Compressor Sta.** 25 Miles Southwest of Hobbs **Permit # 609-M-3**	NO_2 CO SO_2 VOC's	225.70 225.70 2.80 7.90
	Facility	Pollutant	Tons/yr

31.	**Asphalt Plant and Rock Crushing Plant** Loco Hills, NM **Permits # 1345 and # 1346**	TSP's NO_x CO SO_2 VOC's	29.80 59.00 22.30 37.50 25.10
32.	**WGI Compressor Station** **Notice of Intent 1542 -**	Per AQCR 702, no permit is needed if the uncontrolled emission rate of air pollutants from a particular facility is less than 10 lbs/hr or 25 tons/yr.	
33.	**127 hp Waukeska WAKC Natural Gas Engine** **Notice of Intent 1084 -**	Per AQCR 702 and AQCR 703.1, no permit is needed if the uncontrolled emission rate of air pollutants from a particular facility is less than 10 lbs/hr or 25 tons/yr. If the uncontrolled emission rate of air pollutants from a particular facility is less than 10 tons/yr, the Notice of Intent itself serves as the complete application.	
34.	**Armstrong Construction** 3 Miles West of Hobbs **Permit # 827-M-3**	NO_x CO TSP's PM_{10} VOC's	42.25 25.10 21.20 10.20 7.30
35.	**Compressor Station** 22 Miles West of Jal **Permit # 261-M-3**	TSP's NO_x VOC's	4647.12 32.00 43.40
36.	**Portable Natural Gas Comp.** Portable with locations between Hobbs and Carlsbad **Permit # 1543**	NO_x CO VOC's	18.40 39.00 0.30
37.	**125 tph Portable Rock Crushing Facility** 6.8 Miles Southeast of Maljamar, NM **Permit # 1474**	NO_2 CO SO_2 VOC's	23.10 1.00 2.10 0.60

	Facility	Pollutant	Tons/yr
38.	**Chiso BCD Compressor Station** 20 Miles Southwest of Eunice **Permit # 1398**	NO_x CO VOC's	30.30 56.70 6.30
39.	**Mitchell Energy Technology** Geronimo Compressor Site 26 Miles South of Maljamar **Permit # 1392**	NO_x CO VOC's	6.60 27.00 1.50
40.	**TSTA Oil Producers** **Antelope Ridge Comp. Station** 22 Miles Southwest of Eunice **Permit # 1377**	NO_x CO VOC's	28.80 36.00 14.40
41.	**TSTA Oil Producers** **Antelope Ridge L.P.Comp. Sta.** 22 Miles Southwest of Eunice **Permit # 1378**	NO_x CO VOC's	30.50 31.60 13.80
42.	**Ojo Chiso No. 3 Comp. Station** 21 Miles Southwest of Eunice **Permit # 1376**	NO_x CO VOC's	9.70 16.90 4.90
43.	**Antelope Ridge Gas Plant** 20 Miles Southwest of Eunice **Permit # 401-M-3**	NO_2 CO VOC's	180.80 119.00 430.20
44.	**El Paso Natural Gas Co.** **Eunice B Compressor Station** 9 Miles Northwest of Eunice **Permit # 1009-Revision**	NO_2 CO VOC's	83.10 26.10 4.80
45.	**Llano, Inc.** **Apex Compressor Station** 8 Miles West of Hobbs **Permit # 696-M-2**	NO_x CO VOC's	168.30 93.20 23.80
46.	**Northland Sweet Booster Sta.** 17.50 Miles Southeast of Artesia, NM **Permit # 1289**	NO_x CO VOC's	20.30 30.40 10.20

	Facility	Pollutant	Tons/yr
47.	**Northland Sour Booster Sta.** 7 Miles Southeast of Artesia **Permit # 1290**	NO_x CO VOC's	15.00 22.50 7.50
48.	**Ranger Lake Booster Station** 10 Miles East of Tatum **Permit # 1136-M-1**	NO_x CO VOC's	35.10 35.10 1.40
49.	**Warren Petroleum Co.** **Monument Gas Processing Plant** 3 Miles West of Monument, NM **Permit # 110-M-2**	NO_2 CO SO_2 VOC's	2802.90 387.40 1460.00 113.70
50.	**DA Natural Gas Comp. Station** 10 Miles West of Eunice, NM **Permit # 1134**	NO_x CO VOC's	0.91 7.30 0.10
51.	**Mid-America Pipeline, Inc.** **Caprock Compressor Station** Near Caprock, NM **Permit # 920-M-1**	NO_2 CO	36.00 47.40
52.	**Texaco Oil Co., Inc.** **Eunice South** **Gas Processing Plant** 6 Miles South of Eunice **Permit # 278-M-3**	NO_x CO SO_2 VOC's	1179.80 249.50 5476.40 56.90
53.	**ENRON Gas Processing Co.** **Siete O&G Compressor Station** 30 Miles Northeast of Lovington, NM **Permit # 1203**	NO_x CO VOC's	15.90 15.90 0.40
54.	**Shoebar Compressor Station** Section 34, Range 35E, Township 16S - Lea County **Permit # 1116**	NO_x CO VOC's	5.10 5.10 2.60

	Facility	Pollutant	Tons/yr
55.	**Warren Petroleum Co.**	NO_x	2743.50
	Eunice Gas Processing Plant	CO	344.75
	Eunice, NM	SO_2	632.80
	Permit # 67-M-2	VOC's	105.00
56.	**Jal Number 3 Gas Plant**	NO_x	3490.80
	Jal, NM	CO	518.40
	Permit # 1092	SO_2	1205.90
		VOC's	123.50

APPENDIX D16

PARAMETER VALUES USED TO SIMULATE REPOSITORY PROCESSES

APPENDIX D16
PARAMETER VALUES USED TO SIMULATE REPOSITORY PROCESSES

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105 tot. 1

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APPENDIX D16: PARAMETER VALUES

D16-1 Introduction

Appendix D16 documents the basis for a number of important parameters used in the computer simulation.

Model parameters are not necessarily analogous to data obtained through experimental means. In some cases, statistical distributions based strictly on experimental data do not capture uncertainty associated with experimental design, completeness of the data set, or extrapolation of the experimental results to spatial and/or temporal scales required for the no-migration demonstration. For model parameters characterized by such uncertainty, Appendix D16 notes the type of distribution function that characterizes the range of possible parameter values. For model parameters derived from standard reference materials or those that otherwise cannot be characterized by a distribution function, Appendix D16 parameter sheets document the constant values used in the analysis.

The development of parameter values is covered in several Sandia National Laboratories Quality Assurance Procedures (QAP), including QAP 9-2, *Quality Assurance Requirements for the Selection and Documentation of Parameter Values used in WIPP Performance Assessment* and QAP 9-6, *Data Packages that Support Compliance Parameters; Package Assembly and Traceability*. The process includes assembly of "data packages" by those responsible for completion of a particular experimental investigation, development of a system design, or by staff involved in the modeling process. Depending on the nature of the data, data packages may include letters and memoranda of transmittal or other records package formats that document the traceability of information used in developing each parameter (i.e., bibliography). Data packages are components of "Parameter Records Packages," the highest level record documenting parameter development, including application of statistical tests and interpretation.

Parameters are classified as follows:

Category 1)	parameters based on data derived from experimental sources (e.g., laboratory and field experiments);
Category 2)	parameters based on data taken from the Department of Energy (DOE) Baseline Inventory report for characteristics of the transuranic (TRU) waste;
Category 3)	parameters based on data taken from handbooks, archive journals and standard reference information;

Category 4a) parameters used in model configuration: geometric descriptions of geologic, hydrologic and engineered features and components used in configuring the computer model; and

Category 4b) parameter values that are assigned based on a correlation, either with an existing disposal system material parameter or through investigator or analyst judgment based upon information derived from peer-reviewed literature or knowledge of the disposal system and engineering principles.

D16-2 Parameter Distributions

Probability distribution and probability density functions can be used to characterize knowledge about the parameter in terms of standard probability theory and statistics, including the range, the mean, median and mode. Statistical terms used to characterize parameters include:

Range. The range of a distribution can be denoted by (a,b), the pair of numbers in which a and b are minimum and maximum values, respectively, that may be used to represent parameter values.

Mean. Analogous to the arithmetic average of a series of numbers, the mean value of a parameter distribution is one measure of the central tendency of a distribution. For non-symmetrical distributions that are considerably skewed, the mean value may not provide a representative average.

Median. The median value of a cdf is denoted by x_{50} (50th percentile or 0.5 quantile), the value in the distribution range at which 50 percent of all values lie above and below. Except for shaft parameters with triangular distributions, the median value is selected as the best value if the parameter is characterized by a parameter distribution.

Mode. The mode is the most is the most frequently occurring value in a set of data points. The mode is the best value for shaft parameters associated with triangular distributions.

The DOE has chosen to use a single vector of parameters as input to this simulation. The elements of this vector (i.e., each distinct parameter needed by the computational models) have been assigned values that are deemed to be "best values." In most cases, "best value" means either the single number assigned to a "constant" parameter, if the parameter is uncertain and has been assigned a probability distribution, the median or mode of the assigned distribution.

D16-3 Key to Parameter Sheets

The parameter sheets included in this appendix contain a variety of information. Only a subset of parameters used in the simulation are included in Appendix D16. Information presented in the parameter sheets is grouped into boxes labeled as follows:

Parameter(s): The Parameters box lists the name of the parameter and the disposal system feature with which it is associated (e.g., Residual Brine Saturation for Marker Beds 138 &139). In most cases, there is a one-to-one correspondence between the parameter sheet title and the parameter listed in the relevant table in Section 8.2 of the main body of the report. (Note: One exception is maximum capillary pressure (PC_MAX), which is assigned the same value for all material regions. The PC_MAX parameter sheet for all regions is appended to the Repository and Panel Closures section).

Parameter Description: The Parameter Description box defines the parameter and, where appropriate, explains the role of the parameter in the modeling.

Material and Parameter Name(s): This box provides a link to the parameter database. The parameter label listed first is taken from the parameter database field IDMTRL, which identifies the type of material in the disposal system being modeled (e.g., S_ANH_AB means Salado anhydrite beds a & b). The second label describes the parameter name for the physical or operational meaning for the parameter (e.g., SAT_RBRN means residual brine saturation). The number associated with a parameter is the unique identification number (ID).

Parameter Value: The parameter value selected for the simulation is identified in this section.

Units/Parameter Statistics: If the parameter is a constant, the units of the parameter are identified in this box. For parameters represented by a distribution, this box is replaced by a parameter statistics box identifying the units, and the mean, median, maximum and minimum values of the parameter distribution.

Distribution Type: This box identifies the type of parameter distribution selected.

Data: The basis for the parameter values or parameter distribution is provided in this section. For the no-migration variance petition, parameters are generally classified as follows:

- *Site-specific or waste-specific experimental data.* These data include information obtained from in-situ experiments and from research conducted at off-site laboratories performing work for the WIPP project (e.g., permeability data, microbial gas generation). The category also includes

simulated waste experiments and may indicate correlations made with other material regions based on professional judgment.

- *Waste-specific observational data.* This category includes data obtained through observation or empirical analysis, such as semi-quantitative and qualitative visual characterization or process knowledge of TRU waste (e.g., waste components).

- *Investigator judgment.* Parameter distributions or parameter values may rely to some extent on evidence or arguments provided by subject matter experts. This category of information may involve correlating experimental or observational data to other regions, interpreting information obtained from the general literature, or may be based on general engineering knowledge (see below). In many cases, the parameter must be assigned in the course of model configuration and is often assigned by qualified staff involved in the PA modeling process.

- *General Literature Data.* This category of information includes that obtained from reports, journal articles or handbooks relevant to systems or processes being modeled for the WIPP. It is often employed in conjunction with investigator judgment.

- *General Engineering Knowledge.* This category of information identifies parameter values obtained from knowledge of standard engineering principles.

Discussion: This section identifies the source(s) of parameter value(s) and the rationale for selecting the value used in the no-migration simulation. Other relevant background information is also included in this section, where clarification is appropriate.

References: All of the references pertaining to parameter selection are contained within PA parameter records packages. The PA parameter records packages contain the WIPP Data Entry Form 464 and supporting documentation, including data packages and statistical calculations and analysis. Data packages include raw data, data analysis, and data interpretation, including a data and distribution summary, a QA summary, and where applicable, a summary of the experimental data collection. Data packages also cite SAND reports and other published references as their source of data. Selected references cited in the parameter records packages are included in the parameter sheet to establish the quality of data.

D16-5

AVERAGE STOCHIOMETRY GAS GENERATION MODEL PARAMETER VALUES

Factor for Microbial Reaction Rates
Anoxic Corrosion Stoichiometric Factor X
Inundated Corrosion Rate for Steel without CO_2 Present
Inundated Corrosion Rate for Steel with CO_2 Present
Humid Corrosion Rate for Steel
Gas Generation Rate for Microbial Degradation under Humid Conditions
Gas Generation Rate for Microbial Degradation under Brine-Inundated Conditions
Average Density of Cellulosics in CH Waste
Average Density of Cellulosics in RH Waste
Average Density of Iron-Based Materials in CH Waste
Average Density of Iron-Based Materials in RH Waste
Average Density of Plastics in CH Waste
Average Density of Plastics in RH Waste
Average Density of Rubber in CH Waste
Average Density of Rubber in RH Waste
Bulk Density of Steel Containers, CH Waste
Bulk Density of Steel Containers Plus Steel Plugs, RH Waste
Bulk Density of Plastic Liners, CH Waste
Bulk Density of Plastic Liners, RH Waste
Total Volume of RH Waste
Total Volume of CH Waste
Wicking Saturation

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Parameter(s): Factor β for Microbial Reaction Rates

Parameter Description:

Gas may be generated due to microbial degradation of cellulosics. The coefficient addresses uncertainty in the major reactions governing degradation, and is required for the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

CELLULS FBETA (#2294)

Parameter Value: 0.5

mean	median	minimum	maximum	units
0.5	0.5	0	1.0	None

Distribution Type: Uniform

Data: Site-Specific Experimental Data

See: Wang, Y. and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Discussion:

Factor β characterizes the extent of micobially generated gas reacting with steel and steel corrosion products.

References:

Wang, Y. and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Parameter(s): Anoxic Corrosion Stoichiometric Factor X

Parameter Description:

Gas will be generated due to anoxic corrosion of steel by liquid water. The coefficient addresses uncertainty in the major reactions governing corrosion, and is required for the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

STEEL STOIFX (#2898)

Parameter Value: 1.0

Units: None

Distribution Type: Constant

Data: Site-Specific Experimental Data

See: Wang, Y. and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Discussion:

In the iron corrosion reaction $Fe + [(4+2x)/3]H_2O = [(4-x)/3]H_2 + xFe(OH)_2 + [(1-x)/3]Fe_3O_4$, the stoichiometric factor, x, equals 1.0. It is assumed that Fe_3O_4 is not a corrosion product under WIPP conditions.

References:

Wang, Y. and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Parameter(s): Inundated Corrosion Rate for Steel Without CO_2 Present

Parameter Description:

The inundated corrosion rate for steel without CO_2 present is required for the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

STEEL CORRMCO2 (#2907)

Parameter Value: 7.937×10^{-15}

mean	median	minimum	maximum	units
7.937×10^{-15}	7.937×10^{-15}	0	1.587×10^{-14}	m/s

Distribution Type: Uniform

Data: Site-Specific Experimental Data

See: Wang, Y. and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Discussion:

Without CO_2 present, anoxic steel corrosion will proceed via the reaction: $Fe^{\circ} + 2H_2O = Fe(OH)_2 + H_2$. The upper limit of the parameter is determined from long-term steel corrosion experiments. The minimum rate is set to zero because of the possibility that salt crystallization on the steel surface could potentially prevent steel corrosion.

References:

Wang, Y. and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Parameter (s): Inundated Corrosion Rate for Steel With CO_2 Present

Parameter Description:

The inundated corrosion rate for steel with CO_2 present is required for the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

STEEL CORRWCO2 (#2908)

Parameter Value: 1.0318×10^{-13}

mean	median	minimum	maximum	units
1.0318×10^{-13}	1.0318×10^{-13}	0	2.0635×10^{-13}	m/s

Distribution Type: Uniform

Data: Site-Specific Experimental Data

See: Wang, Y. and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Discussion:

Carbon dioxide,CO_2, can enhance anoxic corrosion rate by both lowering brine pH and initiating the additional reaction of $Fe^{\circ} + CO_2 + H_2O = FeCO_3 + H_2$. This rate will not be used due to the addition of backfill MgO which will remove practically all of the CO_2 in the repository.

References:

Wang, Y. and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Parameter(s): Humid Corrosion Rate for Steel

Parameter Description:

The humid corrosion rate for steel is required for the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

STEEL HUMCORR (#2910)

Parameter Value: 0

Units: m/s

Distribution Type: Constant

Data: Site-Specific Experimental Data

See: Wang, Y. and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Discussion:

The humid corrosion rate for steel is set to zero because the corrosion observed on test specimens exposed to humid conditions was negligible.

References:

Wang, Y. and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Parameter(s): Gas Generation Rate for Microbial Degradation Under Humid Conditions

Parameter Description:

Gas may be generated due to microbial degradation of cellulosics under humid conditions. The gas generation rate is required for the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA GRATMICH (#656)
REPOSIT GRATMICH (#2127)

Parameter Value: 6.342×10^{-10}

mean	median	minimum	maximum	units
6.342×10^{-10}	6.342×10^{-10}	0.0	1.2684×10^{-9}	mol/kg*s

Distribution Type: Uniform

Data: Site-Specific Experimental Data

See: Wang, Y. and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Discussion:

The maximum gas generation rate for microbial degradation under humid conditions was estimated from cellulosics-biodegradation experiments under anaerobic, humid, inoculated conditions.

References:

Wang, Y. and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Parameter(s): Gas Generation Rate for Microbial Degradation Under Brine-Inundated Conditions

Parameter Description:

Gas may be generated due to microbial degradation of cellulosics under brine-inundated conditions. The gas generation rate is required for the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA GRATMICI (#657)
REPOSIT GRATMICI (#2128)

Parameter Value: 4.915×10^{-9}

mean	median	minimum	maximum	units
4.915×10^{-9}	4.915×10^{-9}	3.171×10^{-10}	9.5129×10^{-9}	mol/kg*s

Distribution Type: Uniform

Data: Site-Specific Experimental Data

See: Wang, Y. and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Discussion:

The gas generation rate for microbial degradation under brine-inundated conditions was determined from the CO_2 production rate observed in anaerobic incubation experiments.

References:

Wang, Y. and L. Brush. 1996. Memorandum to Martin Tierney, Re: Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment, January 26, 1996.

Parameter(s): Average Density of Cellulosics in Contact-Handled Waste

Parameter Description:

The average density of cellulosics in CH-TRU waste; this value is used in the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DCELLCHW (#2041)
REPOSIT	DCELLCHW (#2113)

Parameter Value: 54.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1*. DOE/CAO-95-1121. December 1995.

Discussion:

The value provided in DOE (1995) for the average density of cellulosics in the contact-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1*. DOE/CAO-95-1121. December 1995.

Parameter(s): Average Density of Cellulosics in Remote-Handled Waste

Parameter Description:

The average density of cellulosics in RH-TRU waste; this value is used in the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DCELLRHW (#2274)
REPOSIT	DCELLRHW (#2114)

Parameter Value: 17.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1*. DOE/CAO-95-1121. December 1995.

Discussion:

The value provided in DOE (1995) for the average density of cellulosics in the remote-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1*. DOE/CAO-95-1121. December 1995.

Parameter(s): Average Density of Iron-Based Materials in Contact-Handled Waste

Parameter Description:

The average density of iron-based materials in CH-TRU waste; this value is used in the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DIRONCHW (#2040)
REPOSIT	DIRONCHW (#2117)

Parameter Value: 170.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1*. DOE/CAO-95-1121. December 1995.

Discussion:

The value provided in DOE (1995) for the average density of iron-based materials in the contact-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1*. DOE/CAO-95-1121. December 1995.

Parameter(s): Average Density of Iron-Based Material in Remote-Handled Waste

Parameter Description:

The average density of iron-based materials in RH-TRU waste; this value is used in the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DIRONRHW (#2044)
REPOSIT	DIRONRHW (#2118)

Parameter Value: 100.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Discussion:

The value provided in DOE (1995) for the average density of iron-based materials in the remote-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Parameter(s): Average Density of Plastics in Contact-Handled Waste

Parameter Description:

The average density of plastics in CH-TRU waste; this value is used in the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DPLASCHW (#2043)
REPOSIT	DPLASCHW (#2119)

Parameter Value: 34.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Discussion:

The value provided in DOE (1995) for the average density of plastics in the contact-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Parameter(s): Average Density of Plastics in Remote-Handled Waste

Parameter Description:

The average density of plastics in RH-TRU waste; this value is used in the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DPLASRHW (#2275)
REPOSIT	DPLASRHW (#2120)

Parameter Value: 15.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Discussion:

The value provided in DOE (1995) for the average density of plastics in the remote-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Parameter(s): Average Density of Rubber in Contact-Handled Waste

Parameter Description:

The average density of rubber materials in CH-TRU waste; this value is used in the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DRUBBCHW (#2042)
REPOSIT	DRUBBCHW (#2122)

Parameter Value: 10.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Discussion:

The value provided in DOE (1995) for the average density of rubber materials in the contact-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Parameter(s): Average Density of Rubber in Remote-Handled Waste

Parameter Description:

The average density of rubber materials in RH-TRU waste; this value is used in the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DRUBBRHW (#2046)
REPOSIT	DRUBBRHW (#2123)

Parameter Value: 3.3

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Discussion:

The value provided in DOE (1995) for the average density of rubber materials in the remote-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Parameter(s): Bulk Density of Steel Containers in Contact-Handled Waste

Parameter Description:

The bulk density of steel containers in CH-TRU waste; this value is used in the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DIRNCCHW (#1992)
REPOSIT	DIRNCCHW (#2115)

Parameter Value: 139.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Discussion:

The value provided in DOE (1995) for the bulk density of steel containers in the contact-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Parameter(s): Bulk Density of Steel Canisters Plus Steel Plugs in Remote-Handled Waste

Parameter Description:

The bulk density of steel canisters plus the steel plug in RH-TRU waste; this value is used in the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DIRNCRHW (#1993)
REPOSIT	DIRNCRHW (#2116)

Parameter Value: 2,591.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Discussion:

The value provided in DOE (1995) for the bulk density of steel canisters in the remote-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams. This average density of steel is equal to that of the remote-handled canisters (446 kg/m^3) plus that of the steel plugs (2,145 kg/m^3).

References:

DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Parameter(s): Bulk Density of Plastic Liners in Contact-Handled Waste

Parameter Description:

The bulk density of plastic liners in CH-TRU waste; this value is used in the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	DPLSCCHW (#1995)
REPOSIT	DPLSCCHW (#2121)

Parameter Value: 26.0

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Discussion:

The value provided in DOE (1995) for the bulk density of plastic liners in the contact-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Parameter(s): Bulk Density of Plastic Liners in Remote-Handled Waste

Parameter Description:

The bulk density of plastic liners in RH-TRU waste; this value is used in the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA DPLSCRHW (#2228)

Parameter Value: 3.1

Units: kg/m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Discussion:

The value provided in DOE (1995) for the bulk density of plastic liners in the remote-handled waste was derived from a combination of physical measurements and acceptable knowledge of the stored and projected WIPP waste streams.

References:

DOE. 1995. *Transuranic Waste Baseline Inventory Report (Revision 2), Volume 1.* DOE/CAO-95-1121. December 1995.

Parameter(s): Total Volume of Remote-Handled Waste

Parameter Description:

The total volume of RH-TRU waste; this value is used in the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	VOLRHW (#2233)
REPOSIT	VOLRHW (#2142)

Parameter Value: 7,080.0

Units: m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: DOE (U.S. Department of Energy) and State of New Mexico (1981, originally). Agreement for Consultation and Cooperation between Department of Energy and the State of New Mexico on the Waste Isolation Pilot Plant, Updated April 18, 1988; Article VI (WIPP Mission), Page 4.

Discussion:

The value for the total volume of remote-handled waste was identified in the Agreement for Consultation and Cooperation between DOE and the State of New Mexico on the WIPP.

References:

DOE (U.S. Department of Energy) and State of New Mexico (1981, originally). Agreement for Consultation and Cooperation between Department of Energy and the State of New Mexico on the Waste Isolation Pilot Plant, Updated April 18, 1988; Article VI (WIPP Mission), Page 4.

Parameter(s): Total Volume of Contact-Handled Waste

Parameter Description:

The total volume of CH-TRU waste; this value is used in the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	VOLCHW (#2232)
REPOSIT	VOLCHW (#2141)

Parameter Value: 1.69×10^5

Units: m^3

Distribution Type: Constant

Data: Waste-Specific Observational Data

See: Public Law 102-579, 102d Congress, October 30, 1992, Waste Isolation Pilot Plant Land Withdrawal Act; Section 7, subpart (a)(3) and DOE (U.S. Department of Energy) and State of New Mexico (1981 originally), Agreement for Consultation and Cooperation between Department of Energy and the State of New Mexico on the Waste Isolation Pilot Plant, Updated April 18, 1988; Article VI (WIPP Mission), Page 4.

Discussion:

The value for the total volume of contact-handled waste is the total volume identified in the Land Withdrawal Act (1992) minus the volume of remote-handled waste identified in the Agreement for Consultation and Cooperation between DOE and the State of New Mexico on the WIPP.

References:

Public Law 102-579, 102d Congress. October 30, 1992. Waste Isolation Pilot Plant Land Withdrawal Act; Section 7, subpart (a)(3).

Parameter(s): Total Volume of Contact-Handled Waste

References: (continued)

DOE (U.S. Department of Energy) and State of New Mexico (1981, originally). Agreement for Consultation and Cooperation between Department of Energy and the State of New Mexico on the Waste Isolation Pilot Plant, Updated April 18, 1988; Article VI (WIPP Mission), Page 4.

Parameter(s): Wicking Saturation

Parameter Description:

The wicking saturation in the waste is used in the gas generation model (see Section BRAGFLO.13 of Appendix BRAGFLO).

Material and Parameter Name(s):

WAS_AREA	SATWICK (#2231)
REPOSIT	SATWICK (#2138)

Parameter Value: 0.5

Units: None

Data: Investigator Judgment

Discussion:

Wicking is the ability of a material to carry a fluid by capillary action above the level it would normally seek in response to gravity. The use of a two-phase Darcy flow model in BRAGFLO includes possible effects of capillary action, but uncertainty remains about the extent to which the assumed homogeneous properties of the waste adequately characterize wicking. Because estimated rates of gas generation are higher for waste that is in direct contact with brine, brine saturation in the repository is adjusted in BRAGFLO to account for the possibility of wicking in the waste.

The adjustment is done as follows:

$S_b,eff = S_b + S_w,$

and

$S_b,eff \leq 1.0,$

where S_b is the brine saturation in the waste calculated by BRAGFLO, S_w is the wicking saturation that describes the additional amount of brine that may be present and in contact with the waste because of wicking, and S_b,eff is the effective brine saturation used to determine the gas generation rates used in the analysis. The wicking saturation is assigned a constant value of 0.5 for this analysis.

Parameter(s): Wicking Saturation

References:

N/A

D16-6

SALADO FORMATION PARAMETER VALUES

HALITE

Intrinsic Permeability
Effective Porosity
Threshold Pressure
Residual Brine Saturation
Residual Gas Saturation
Pore Distribution
Rock Compressibility

NON HALITE

Intrinsic Permeability
Effective Porosity
Threshold Pressure P_t
Residual Brine Saturation
Residual Gas Saturation
Pore Distribution
Rock Compressibility
Maximum Capillary Pressure

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Parameter(s): Log of Intrinsic Permeability - Halite

Parameter Description:

The Salado Formation halite is assigned an intrinsic permeability intended to reflect the stratigraphic variability of Salado halite and far-field hydraulic conditions. The permeability parameters in the x and y direction are assigned the same value as S_HALITE PRMX_LOG.

Material and Parameter Name(s):

S_HALITE PRMX_LOG (#547)
S_HALITE PRMY_LOG (#548)
S_HALITE PRMZ_LOG (#549)

Parameter Value: -22.5

mean	median	low	high	units
- 22.5	-22.5	-24.0	-21.0	$\log(m^2)$

Distribution Type: Uniform

Data: Site-Specific Experimental Data

The reported permeability range of undisturbed impure halite is based on four selected in-situ hydraulic tests: three flow tests believed representative of far-field permeability and one flow test that measured permeability in a zone including a range of halite lithologies. Computer-derived permeabilities based upon brine inflow data from Room Q fall within the range derived from flow tests. The reader is referred to the relevant parameter record package for more detail; the following data packages are included in the records package:

SCWF-A:WBS1.2.07.1:PDD:QA: SALADO:PKG 7:Halite Permeability (x,y,z)
SCWF-A:WBS1.2.07.1:PDD:QA: SALADO:PKG 7:Salado Halite Permeability

Discussion:

Impure halite denotes a broad range of lithologic types ranging from "pure" halite to lithologies with various degrees of impurities, including polyhalite, argillaceous and anhydritic halite. Three hydraulic tests believed representative of far-field permeability were conducted in the present location of Room Q in map units with relatively low

Parameter(s): Log of Intrinsic Permeability - Halite

Discussion: (continued)

impurities: a halite with less than 0.5 percent impurity, a halite containing approximately 1 percent impurity and a halite/polyhalite zone with a 1-2 percent impurity. These units were tested before the large-scale brine inflow excavation was mined and at stratigraphic intervals located over 20 meters from the excavation. These tests are believed to represent the lower end of the permeability range for Salado halite (see attached table).

Far-field hydraulic tests data do not exist for relatively impure halites, which tend to show higher permeabilities in the near-field. Although located within the influence of the DRZ, one flow test (C2H01-BGZ) measured within map units 0-4 is used to bound the maximum permeability of Salado halite containing relatively high impurities. The median value of $\log_{10}$ -22.5 is believed to be the best value.

A summary of selected interpretative results of these four flow and pressure tests is compiled in the attached table. A schematic representation of Salado map units near the disposal area horizon, adapted from Deal et. al. (1989), is attached for information purposes.

References:

Beauheim, R.L., G.J. Saulnier, Jr., and J.D. Avis. 1991. *Interpretation of Brine-Permeability Tests of the Salado Formation at the Waste Isolation Pilot Plant Site: First Interim Report.* SAND90-0083. Albuquerque, NM: Sandia National Laboratories.

Beauheim, R.L., R.M. Roberts, T.F. Dale, M.D. Port, and W.A. Stensrud. 1993. *Hydraulic Testing of Salado Formation Evaporites at the Waste Isolation Pilot Plant Site: Second Interpretive Report.* SAND92-0533. Albuquerque, NM: Sandia National Laboratories.

Jensen, A.L., C.I., Howard, R.L. Jones, and T.P. Peterson. 1993. *Room Q Data Report: Test Borehole Data from April 1989 through November 1991.* SAND92-1172. Albuquerque, NM: Sandia National Laboratories.

Saulnier, Jr., G.J., P.S. Domski, J.B. Palmer, R.M. Roberts, and W.A. Stensrud. 1991. *WIPP Salado Hydrology Program Data Report #1.* SAND90-7000. Albuquerque, NM: Sandia National Laboratories.

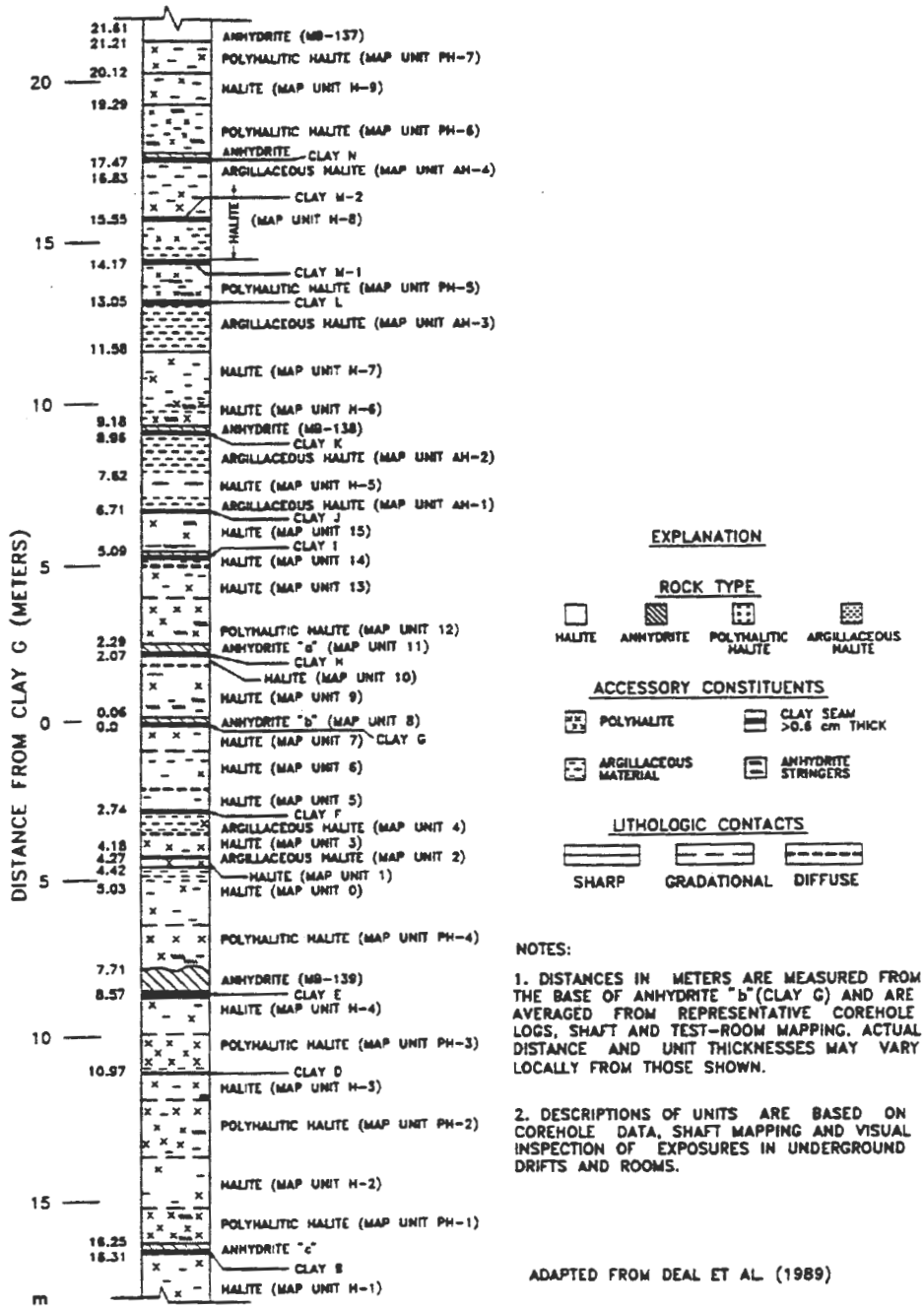
Stensrud, W.A., T.P. Dale, P.S. Domski, J.B. Palmer, R.M. Roberts, M.D. Port, and G.J. Saulnier, Jr. 1992. *Waste Isolation Pilot Plant Salado Hydrology Program Data Report #2.* SAND92-7072. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Log of Intrinsic Permeability - Halite

Table 1. Summary of Permeability Test-Interpretations Results from In Situ Permeability Tests Representing Undisturbed Impure Halite

TEST INTERVAL (meters from excavation)	HOLE	MAP UNIT(s)	ANALYSIS METHOD	PERMEABILITY K (m^2)
20.13-21.03	QPPO5	MU 6	GTFM6.0	1.12×10^{-24}
23.35-24-20	QPP12	H3	GTFM6.0	2.69×10^{-22}
20.19-21.09	QPP15	MU O - MU PH-4	GTFM6.0	5.5×10^{-24}
4.50-5.58	C2H01-BGZ	MU O - MU 4	GTFM6.0	1.38×10^{-21}

Note: See Record Parameter Package for additional detail.



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NMVP-6342-164-0

Figure A-1. Detailed Stratigraphy Near the WIPP Site

Parameter(s): Effective Porosity - Halite

Parameter Description:

The effective porosity of Salado Formation halite and polyhalite refers to the ratio of the interconnected pore volume to bulk volume; total porosity, is defined as the ratio of interconnected plus non-connected pore space to bulk volume.

Material and Parameter Name(s):

S_HALITE POROSITY (#544)

Parameter Value: 0.01

mean	median	minimum	maximum	units
0.0128	0.01	0.001	0.03	None

Distribution Type: Cumulative

Data: Site-Specific Experimental Data

The effective porosity of Salado halite used in the NMVP analysis is supported by three separate porosity calculations: 1) Skokan et al., (1989; p. 15) determined from electromagnetic and DC resistivity experiments, 2) drying experiments described in Powers et al., (1978; p. 7-30), and 3) drying experiments reported in Deal et al., (1993). The data package associated with this parameter is as follows:

SCWF-A:WBS 1.2.07.1:PDD:QA:SALADO:PKG8:POROSITY effective porosity/hal

Discussion:

The high value (.03) for the range of porosity is suggested in Skokan et al. (1989; p.6,13), based on the low end (10 ohm) of the DC resistivity measurements registered in the underground. The low value (.001) is suggested in Powers et al. (1970) based on drying experiments. The median value of .01 is suggested in Skokan et al.(1989; p.15). Deal et al. (1993) found an average value of .016 for total porosity from a different series of drying experiments, providing support for selecting a reasonable constant value of .01 used in the NMVP simulation.

Parameter(s): Effective Porosity - Halite

References:

Deal, D.E., R.J. Abitz, J. Myers, M.L. Martin, D.J. Millgan, R.W. Sobocinski, P.P.J. Lipponer, and D. S. Belski. 1993. *Brine Sampling and Evaluation Program, 1991 Report*. DOE-WIPP-93-026. Carlsbad, NM: Westinghouse Electric Corporation, Waste Isolation Division.

Powers, D.W., S.J. Lambert, S.E. Shaffer, L.R. Hill, and W.D. Weart, eds. 1978. *Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico*. SAND78-1596. Albuquerque, NM: Sandia National Laboratories. Vols. 1-2.

Skokan, C.K., Pfeifer, M.C., Keller, G.V., and H.T. Andersen. 1989. *Studies of Electrical and Electromagnetic Methods for Characterizing Salt Properties at the WIPP Site, New Mexico*. SAND87-7174. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_A Threshold Pressure Parameter - Halite

Parameter Description:

PCT_A is linear factor used to calculate threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to characterize incipient gas flow through a porous media. The sum of the existing pore pressure in the rock and the threshold pressure is the gas-pressure level that must be reached to overcome capillary resistance and drive gas into brine-filled rock pores.

Material and Parameter Name(s):

S_HALITE PCT_A (#2779)

Parameter Values: .56

Units: Pa/m^2

Distribution Type: Constant

Data: General Literature and Investigator Judgment

There is no site-specific PCT_A parameter measurement for halite. The linear threshold parameter value is based on a best-fit power correlation of threshold pressures and intrinsic permeabilities published for several types of consolidated lithologies, referred to as the Davies correlation (Davies, 1991 p. 25-26).

Discussion:

Threshold pressure (P_t) is calculated by the following relationship:

$$P_t = PCT\_A \cdot k^{(PCT\_EXP)}$$

where k is the permeability. Use of the Davies correlation is appropriate based on gross similarities between halite rock and the consolidated carbonate, anhydrite, shale and sandstone lithologies used to derive the Davies exponential threshold pressure parameter. Halite possesses a relatively tight crystalline textures with interconnected pore space occurring along grain boundaries.

Parameter(s): PCT_A Threshold Pressure Parameter - Halite

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant*. SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Halite

Parameter Description:

PCT_EXP is an exponential factor used to calculate threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to characterize incipient gas flow through a porous media. The sum of the existing pore pressure in the rock and the threshold pressure is the gas-pressure level that must be reached to overcome capillary resistance and drive gas into brine-filled rock pores.

Material and Parameter Name(s):

S_HALITE PCT_EXP (#2780)

Parameter Values: -0.346

Units: None

Distribution Type: Constant

Data: General Literature and Investigator Judgment

There is no site-specific PCT_EXP parameter measurement for halite. The exponential threshold parameter value is based on a best-fit power correlation of threshold pressures and intrinsic permeabilities published for several types of consolidated lithologies, referred to as the Davies correlation (Davies, 1991 p. 25-26).

Discussion:

Threshold pressure (P_t) is calculated by the following relationship:

$$P_t = PCT\_A \cdot k^{(PCT\_EXP)}$$

where k is the permeability. Use of the Davies correlation is appropriate based on gross similarities between halite rock and the consolidated carbonate, anhydrite, shale and sandstone lithologies used to derive the Davies exponential threshold pressure parameter (e.g. relatively tight crystalline textures with interconnected pore space occurring along grain boundaries). The analog comparison is also supported by a general agreement between the PCT_EXP value of -0.346 and the -0.348 exponential value predicted from measurements of capillary pressure on MB 139 laboratory specimens.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Halite

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant*. SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Residual Brine Saturation - Halite

Parameter Description:

The residual brine saturation (S_{br}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves. Referred to also as S_{wr} (wetting phase) or S_{lr} (liquid phase), residual brine saturation is the point reached under high gas saturation conditions when brine is no longer continuous throughout the pore network and relative brine permeability becomes zero.

Material and Parameter Name(s):

S_HALITE SAT_RBRN (#555)

Parameter Value: 0.3

mean	median	minimum	maximum	units
0.3	0.3	0.0	0.6	None

Distribution Type: Uniform

Data: General Literature and Investigator Judgment

There have been no measurements of residual brine saturation in halite rock materials for the WIPP project. Consequently, natural analog data are used to justify the range and best value used in the NMPB BRAGFLO simulation (Brooks and Cory, 1964). In past brine and gas flow simulations, this range was also applied to anhydrite marker beds, which have since been shown by laboratory data to have a minimum S_{br} from about 0-7 percent to a maximum of 17.4 percent.

Discussion:

Brooks and Corey (1964) report a residual wetting phase saturation (S_{wr}) range of 0.08 to 0.56 based on curve fitting capillary pressure data for several types of porous unconsolidated and consolidated analog materials. The selected S_{br} value of .30 is representative of the Berea Sandstone tested in the Brooks and Corey study.

Parameter(s): Residual Brine Saturation - Halite

References:

Brooks , R.H., and A.T. Corey. 1964. *Hydraulic Properties of Porous Media*. Hydrology Paper No. 3. Fort Collins, CO: Colorado State University.

Parameter(s): Residual Gas Saturation - Halite

Parameter Description:

The residual (critical) gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves. S_{gr} corresponds to the degree of waste-generated gas saturation necessary to create an incipient interconnected pathway in porous material, a condition required for porous rock to be permeable to gas.

Material and Parameter Name(s):

S_HALITE SAT_RGAS (#556)

Parameter Value: 0.2

mean	median	minimum	maximum	units
0.2	0.2	0.0	0.4	None

Distribution Type: Uniform

Data: General Literature and Investigator Judgment

Two-phase flow parameters have not been measured for halite rock material. In past brine and gas flow simulations, this range was also applied to anhydrite marker beds, which have since been shown by laboratory data to have smaller range: 1.4 - 19.7 percent.

Discussion:

The range, mean and median values developed for this analysis are the same as those used in the 1992 40 CFR 191 analysis, when the range was defined simply by doubling the median value. In a review of studies in the general literature, Solutions Engineering (1995) documents a natural analog S_{gr} range from 0-27 percent. In developing empirical equations for two-phase flow in consolidated rock, of sandstone, dolomite, limestone and conglomerate lithologies, Hornapour et al. (1982) reports a range of 0-40 percent for residual gas saturation based on several hundred data points. The value of 20 percent used in the NMVP is considered the best value.

Parameter(s): Residual Gas Saturation - Halite

References:

Solutions Engineering. 1996. "Critical Gas Saturation Recommendations for WIPP," Letter Report to D.M. Stoelzel, November 15, 1995, Albuquerque, NM: Sandia National Laboratories.

Hornapour M, Koederitz, L.F., and Harvey, H.A. 1982. "Empirical Equations for Estimating Two-Phase Relative Permeability in Consolidated Rock," *Journal of Petroleum Technology*, December 1982, p. 2905-2908.

Parameter(s): Pore Distribution - Halite

Parameter Description:

The pore size distribution parameter (λ) is used in the calculation of capillary pressure and relative permeability in the second modification to the Brooks-Corey model implemented in BRAGFLO.

Material and Parameter Name(s):

S_HALITE PORE_DIS(#543)

Parameter Value: 0.7

mean	median	minimum	maximum	units
2.9	0.7	0.2	10.0	None

Distribution Type: Cumulative

Data: General Literature, Site-Specific Experimental Data and Investigator Judgment

Pore size distribution has not been measured in halite. The range and distribution of parameter values is derived from natural-analog data, but is supported by site-specific experimental data measured in the laboratory for marker bed anhydrites.

Discussion:

The range limits for the pore-size distribution parameter λ for halite is based on Mualem (1976) who fit the Brooks and Corey model to data for 45 soils. Because the pore size distribution is affected by the particle size and skeleton structure of solid mineral grains, the higher end of the pore size distribution range derived from soil materials likely results from the character of porosity in unconsolidated materials.

The median value of 0.7 used in the NMVP analysis was originally based on a study by Morrow et al. (1986) on Multiwell Tight Gas Sands Project. The justification was that the permeabilities in the tight sands, ranging from 2.3×10^{-17} to $4.3 \times 10^{-17} m^2$, were the lowest permeability materials for which pore size information was available. The WIPP project now has site-specific experimental data for low permeability anhydrite marker beds. The parameter range specified for the anhydrites (.558 to .842) further supports the median parameter value assigned to the halite.

Parameter(s): Pore Distribution - Halite

References:

Morrow, N.R., J.S. Ward, and K.R. Brower. 1986. *Rock Matrix and Fracture Analysis of Flow in Western Tight Gas Sands - 1985 Annual Report.* DOE/MC/21179-2032. Socorro, NM: New Mexico Institute of Mining and Technology, New Mexico Petroleum Recovery Research Center.

Mualem, Y. 1976. "A New Model of Predicting the Hydraulic Conductivity of Unsaturated Porous Media," *Water Resources Research.* Vol. 12, no.3, 513-522.

Parameter(s): Rock Compressibility - Halite

Parameter Description:

Rock compressibility of Salado Formation halite is used in BRAGFLO to calculate pore compressibility. Pore compressibility is used to predict the effect of material compressibility on porosity and mass storage in the equation of state for flow through porous media as follows:

$$\phi = \phi_o \exp(c_r(p-p_o))$$

where,

ϕ = porosity of solid matrix (dimensionless)
ϕ_o = porosity at reference pressure p_o
c_r = pore compressibility of solid matrix (Pa^{-1})

COMP_RCK is divided by material porosity to calculate pore compressibility.

Material and Parameter Name(s):

S_HALITE COMP_RCK (#541)

Parameter Value: 9.75×10^{-11}

mean	median	minimum	maximum	units
9.75×10^{-11}	9.75×10^{-11}	2.94×10^{-12}	1.92×10^{-10}	Pa^{-1}

Distribution Type: Uniform

Data: Site-Specific Experimental Data

The parameter distribution for halite rock compressibility is based upon data from two hydraulic tests in Room Q: QPP05 and QPP15. Another data point calculated from sensitivity studies using brine inflow data from Room Q is within the range derived from the hydraulic tests.

Data packages associated with this parameter are located at:
SCWF-A:WBS1.2.07.1:PDD:QA: SALADO:PKG 4: Halite Rock Compressibility
SCWF-A:WBS1.2.07.1:PDD:QA: SALADO:PKG 5: Salado Halite Rock Compressibility

Parameter(s): Rock Compressibility - Halite

Discussion:

The two *in situ* hydraulic tests were conducted in the location of Room Q before the large-scale brine inflow excavation was mined. Test intervals were located over 65 feet (20 meters) from the excavation. Map units (MU) represented included MU 6 (halite) and MU 0 (halite)/MU PH-4 (polyhalite) within a radius of about one meter of each borehole. Raw data included pressure, fluid volume, temperature, axial test-tool movement, and radial borehole closure.

Interpretation of all flow tests in the WIPP facility is based on the assumption that Darcy flow and borehole closure are the only forms of pressure/flow transmission during hydraulic tests. References related to data collection and interpretation are listed in the references section.

References:

Beauheim, R.L., G.J. Saulnier, Jr., and J.D. Avis. 1991. *Interpretation of Brine-Permeability Tests of the Salado Formation at the Waste Isolation Pilot Plant Site: First Interim Report.* SAND90-0083. Albuquerque, NM: Sandia National Laboratories.

Beauheim, R.L., R.M. Roberts, T.F. Dale, M.D. Port, and W.A. Stensrud. 1993. *Hydraulic Testing of Salado Formation Evaporites at the Waste Isolation Pilot Plant Site: Second Interpretive Report.* SAND92-0533. Albuquerque, NM: Sandia National Laboratories.

Jensen, A.L., C.I., Howard, R.L. Jones, and T.P. Peterson. 1993. *Room Q Data Report: Test Borehole Data from April 1989 through November 1991.* SAND92-1172. Albuquerque, NM: Sandia National Laboratories.

Saulnier, Jr., G.J., P.S. Domski, J.B. Palmer, R.M. Roberts, and W.A. Stensrud. 1991. *WIPP Salado Hydrology Program Data Report #1.* SAND90-7000. Albuquerque, NM: Sandia National Laboratories.

Stensrud, W.A., T.P. Dale, P.S. Domski, J.B. Palmer, R.M. Roberts, M.D. Port, and G.J. Saulnier, Jr. 1992. *Waste Isolation Pilot Plant Salado Hydrology Program Data Report #2.* SAND92-7072. Albuquerque, NM: Sandia National Laboratories.

Table 1. Summary of Rock Compressibility Test-Interpretations Results from In Situ Permeability Tests for Undisturbed Halite and Polyhalite Map Units

TEST INTERVAL (meters from excavation)	HOLE AND LOCATION	ZONE	MAP UNIT(s)	ANALYSIS METHOD	ROCK COMPRESSIBILITY K (1/Pa)	FORMATION PORE PRESSURE (Mpa)*
20.13-21.03 down	QPPO5 Room Q	undisturbed	MU 6	GTFM6.0	2.94×10^{-12}	13.89
20.19-21.09 down	QPP15 Room Q	undisturbed	MU 0 MU PH-4	GTFM6.0	1.92×10^{-10}	11.04

* - Mean

Note: See Record Parameter Package for additional detail.

Parameter(s): Log of Intrinsic Permeability - Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139

Parameter Description:

Intrinsic undisturbed permeabilities along the three principal axes of the BRAGFLO grid for Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139 are set equal to the value for S_MB139 PRMX_LOG.

Material and Parameter Name(s):

S_ANH_AB	PRMX_LOG	(#531)	S_MB138	PRMX_LOG	(#570)
S_ANH_AB	PRMY_LOG	(#532)	S_MB138	PRMY_LOG	(#571)
S_ANH_AB	PRMZ_LOG	(#533)	S_MB138	PRMZ_LOG	(#572)
S_MB139	PRMX_LOG	(#591)			
S_MB139	PRMY_LOG	(#592)			
S_MB139	PRMZ_LOG	(#593)			

Parameter Value: -18.89

mean	median	minimum	maximum	units
-18.89	-18.89	-21.0	-17.1	$\log(m^2)$

Distribution Type: Student-t

Data: Site-Specific Experimental Data and Laboratory-Measured Data

The reported parameter range of undisturbed Salado anhydrite permeabilities is based upon selected data collected from *in situ* hydraulic tests and measurements conducted in the laboratory: 1) five hydraulic tests conducted in the underground experimental area; and 2) 31 Klinkenberg-corrected gas permeabilities measured in the laboratory on specimens collected from MB 139 core samples. Summary data tables are attached for both in-situ and laboratory tests.

Data packages associated with this parameter are located at: SCWF-A:WBS1.2.07.1:PDD:QA: SALADO:PKG 13:Anhydrite Permeability (x,y,z)
A:WBS1.2.07.1:PDD:QA: SALADO:PKG 13:PRMX_LOG Log of Permeability in x direction/anh

Parameter(s): Log of Intrinsic Permeability - Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139

Discussion:

Out of fifteen borehole and field permeability tests conducted in MB 140, MB 139, MB 138 and anhydrites a & b, five *in situ* hydraulic tests are considered representative of undisturbed anhydrite permeability. Located from about 33 to 79 feet (10 to 24 meters) from the excavation, the test intervals for these five boreholes were outside of the disturbed rock zone; the radius of visibility ranged from 13 to 82 feet (4 to 25 meters). The five successful tests are summarized as follows:

Borehole	Location	Map Unit	Testing Period	
QPP03	Room Q	Anhydrite b	4/89	11/91
QPP13	Room Q	MB 139	4/89	11/91
C2H02	Room C2	MB 139	4/89	12/89
L4P51-C1	Room L4	MB 140	4/92	6/94
SCP01-A	Core Storage	MB 139	4/90	10/90

Klinkenberg-corrected gas permeabilities measured in the laboratory can be used as an equivalent measure of liquid permeabilities. Gas-corrected test specimen data exist from six whole cores taken from MB 139 in the northern experimental area: E1X07, E1X08, E1X10, E1X11 (E140 Drift) P3X10 and P3X11 (Room L3).

For purposes of parameterization, *in situ* test data are treated differently than laboratory-derived data. Uncertainty exists in regards to the spatial representativeness of the core samples, as well as the consideration of *in situ* stress conditions in laboratory measurements. In general, *in situ* hydraulic tests are considered representative of expected permeability conditions on the scale of the grid system used in the BRAGFLO mesh. Consequently, for the parameter distribution above, laboratory data are averaged as one data point, whereas each of the five hydraulic tests is considered an individual data point. The parameter value used in the NMVP simulation is considered appropriate: it is higher than the mean/median value as determined from *in situ* data.

References:

Beauheim, R.L., G.J. Saulnier, Jr., and J.D. Avis. 1991. *Interpretation of Brine-Permeability Tests of the Salado Formation at the Watts Isolation Pilot Plant Site: First Interim Report*. SAND90-0083. Albuquerque, NM: Sandia National Laboratories.

Beauheim, R.L., R.M. Roberts, T.F. Dale, M.D. Fort, and W.A. Stensrud. 1993. *Hydraulic Testing of Salado Formation Evaporites at the Waste Isolation Pilot Plant Site: Second Interpretive Report*. SAND92-0533. Albuquerque, NM; Sandia National Laboratories.

Parameter(s): Log of Intrinsic Permeability - Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139

Reference(s): (continued)

Howarth S.M., and Christian-Frear T. 1996. *Porosity, Single-Phase Permeability, and Capillary Pressure Data from Preliminary Laboratory Experiments on Selecied Samples from Marker Bed 139 at the Waste Isolation Pilot Plant.* SAND94-0472. Albuquerque, NM: Sandia National Laboratories.

Jensen, A.L., C.L. Howard, R.L. Jones, and T.P. Peterson. 1993. *Room Q Data Report: Test Borehole Data from April 1989 through November 1991.* SAND92-1172. Albuquerque, NM: Sandia National Laboratories

Saulnier, G.J., Jr., P.S. Domski, J.B. Palmer, R.M. Roberts, W.A. Stensrud, and A.L. Jensen. 1991. *WIPP Salado Hydrology Program Data Report #1.* SAND90-7000. Albuquerque, NM: Sandia National Laboratories.

Stensrud, W.A., T.F. Dale, P.S. Domski, J.B. Palmer, R.M. Roberts, M.D. Fort, G.J. Saulnier, Jr., and A.L. Jensen. 1992. *Waste Isolation Pilot Plant Salado Hydrology Program Data Report #2.* SAND92-7072. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Log of Intrinsic Permeability - Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139

Table 1. Summary of Test-Interpretations Results from In Situ Permeability Tests for Undisturbed Anhydrite Map Units

TEST INTERVAL (meters from excavation)	HOLE	ZONE	MAP UNIT	ANALYSIS METHOD	PERMEABILITY K (m^2)	FORMATION PORE PRESSURE (Mpa)*
10.68-14.78 down	SCP01-A	undisturbed	MB139	GTFM6.0	1.4×10^{-19}	12.27
9.47-10.86 down	C2H02	undisturbed	MB139	GTFM6.0	1.0×10^{-21}	11.11
20.50-21.40 up	QPPO3	undisturbed	anhydrite "b"	GTFM6.0	7.6×10^{-20}	12.9
20.62-21.52 down	QPP13	undisturbed	MB139	GTFM6.0	6.0×10^{-20}	12.43
17.44-22.20 down	L4P51-C1	undisturbed	MB140	GTFM6.0	8.7×10^{-18}	9.38

* - Mean

Note: See Record Parameter Package for additional detail.

Table 3a, 3b, 3c

Lab	Bore Hole	Sample No.	Zone	Depth	Flow Dir.	Bulk Vol	*Grain Den.	Porosity					Permeability (pressure values are net effective stress)					
								Total	Effective				Gas (Klinkenberg Corrected)			Log of Permeability		
									0 MPa	3.4 MPa	6 MPa	10 MPa	3.4 MPa	6 MPa	10 MPa	2 MPa	6 MPa	10 MPa
	No.			(feet)		(cc)	(g/cc)	(%)	(%)	(%)	(%)	(%)	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)	(m^2)
CL	E1X10	1	2	4.50	H	11.88	2.64			0.6								
CL	E1X10	2	2	4.50	H	10.70	2.59			0.8	0.7		6.5E-19	4.6E-19	2.3E-19	-18.19	-18.33	-18.64
CL	E1X10	3	2	5.00	H													
CL	E1X10	4	2	5.00	H	12.69	2.62			0.9	0.9		1.3E-18	8.8E-19	6.5E-19	-17.89	-18.06	-18.19
CL	E1X10	5	3	5.25	H	12.45	2.62			0.7	0.6		5.1E-19	3.8E-19	1.8E-19	-18.29	-18.42	-18.75
CL	E1X10	6	3	5.25	H	12.43	2.62			0.7			5.8E-19	3.0E-19	5.0E-20	-18.24	-18.53	-19.30
CL	E1X10	7	3	5.25	V	12.65	2.95			1.1	1.0		9.5E-19	5.5E-19		-18.02	-18.26	
CL	E1X10	8	3	5.25	V	12.98	2.95			1.1	1.0		8.2E-19	4.9E-19	1.4E-19	-18.08	-18.31	-18.86
CL	E1X10	9	3	5.50	H	12.65	2.85			0.9			4.7E-19			-18.33		
CL	E1X10	10	3	5.50	H	12.65	2.94			1.0			1.1E-18	1.8E-19	1.1E-18	-17.97	-18.75	
CL	E1X10	11	3	5.75	H	12.53	2.89			1.7	1.7	1.6	1.8E-18	1.6E-18	7.3E-19	-17.74	-17.81	-17.94
CL	E1X10	12	3	5.75	H	12.93	2.92			1.4	1.3		1.4E-18	1.0E-18		-17.87	-17.99	-18.13
CL	E1X10	13	3	5.75	V	12.70	2.96			1.6	1.5	1.5	1.6E-18	3.1E-19	1.7E-19	-17.79	-18.51	
CL	E1X10	14	3	5.75	V	10.78	2.95			1.2	1.1		6.1E-19	3.1E-19	6.4E-20	-18.21	-18.51	-18.76
CL	E1X10	15	4	6.25	V	12.60	2.96			1.0	0.9		5.9E-19	1.3E-19		-18.23	-18.89	-19.19
CL	E1X10	16	4	6.25	V	12.37	2.96			0.6								
CL	E1X11	17	2	4.50	H	11.38	2.63			0.8			4.0E-19	3.4E-19	1.0E-19	-18.40	-18.47	-19.00
CL	E1X11	18	2	4.50	H	11.88	2.63			1.8								
CL	E1X11	19	3	4.75	H	12.91	2.72			0.9			4.7E-19	3.2E-19	1.0E-19	-18.32	-18.49	-19.00
CL	E1X11	20	3	4.75	H	12.83	2.79			0.9	0.8		3.9E-19			-18.41		
CL	E1X11	21	3	5.00	H	12.04	2.82			1.1	1.0		7.7E-19	5.7E-19	2.6E-19	-18.12	-18.25	-18.58
CL	E1X11	22	3	5.00	H	12.29	2.69			1.4	1.3		1.5E-18	8.4E-19		-17.83	-18.07	
CL	E1X11	23	3	5.25	H	12.62	2.65			2.1			1.3E-18	5.9E-19		-17.88	-18.23	
CL	E1X11	24	3	5.25	H	12.20	2.67			1.4	1.4		1.5E-18	5.7E-19		-17.82	-18.24	
CL	E1X11	25	3	5.25	V	13.00	2.61			0.9	0.8		2.0E-18	5.6E-19	2.9E-19	-17.70	-18.25	-18.53
CL	E1X11	26	3	5.25	V	12.93	2.74			1.6			2.2E-18	7.5E-19	3.3E-19	-17.66	-18.13	-18.48
CL	E1X11	27	4	5.75	H	12.72	2.75			1.6	1.4	1.2						
CL	E1X11	28	4	5.75	H	13.67	2.91											
CL	E1X11	29	4	5.75	V	12.69	2.96			0.8								
CL	E1X11	30	4	5.75	V	12.72	2.96			1.0			1.5E-18	5.9E-19		-17.84	-18.23	
RS	P3X11	5-2-SP1	2	5.50	H	823.5							3.2E-18	1.7E-18	1.4E-18	-17.49	-17.77	-17.87
RS	P3X11	5-2-SP1	2	5.50	H	12.62	2.73											
RS	P3X11	5-2-SP1	2	5.50	H	13.97	2.73											
RS	P3X10	6-SP2	3	5.70	H	820.5												
RS	P3X10	6-SP2T	3	5.70	H	14.59	2.69											
RS	P3X10	6-SP2B	3	5.70	H	13.19	2.57											
RS	P3X11	5-3-SP3	4	7.05	H	813.0							1.6E-17	8.9E-18	5.1E-18	-16.79	-17.05	-17.29
RS	P3X11	5-3-SP3	4	7.05	H	14.97	2.53											
RS	P3X11	5-3-SP3	4	7.05	H	17.88	2.70											
RS	P3X11	5-3-2-TS	3	5.93	H													
RS	P3X11	5-3-2-TS	3	5.93	V													
RS	P3X11	5-3-2-TS	3	5.93	V													
RS	P3X11	5-3-2-TS	3	5.93	V													
RS	P3X10	5-3-2-TS	2	5.28	H													
RS	P3X10	5-3-2-TS	2	5.28	V													
RS	P3X10	5-3-2-TS	2	5.28	V													
RS	P3X10	5-3-2-TS	2	5.28	V													
RS	P3X11	6-TS3-1	4	7.60	H													
RS	P3X11	6-TS3-2	4	7.60	V													
RS	P3X11	6-TS3-3	4	7.60	V													
RS	P3X11	6-TS3-4	4	7.60	V													
TT	E1X08	A	2	3.82	H	822.8	2.65		1.9				8.2E-18	5.7E-18	5.0E-18	-17.08	-17.24	-17.30
TT	E1X08	B	3	4.66	H	776.8	2.60		0.5				1.3E-17	7.4E-18	4.6E-18	-16.90	-17.13	-17.34
TT	E1X08	C	4	5.53	H	819.6	2.72		1.0				4.6E-18	2.6E-18	2.0E-18	-17.34	-17.58	-17.70
TT	E1X08	EP1	2	3.57	H	83.47	2.56	1.4	1.3									
TT	E1X08	EP2	3	4.40	H	84.39	2.66		0.8									
TT	E1X08	EP3	3	5.12	H	83.54	2.58	0.4	0.4									
TT	E1X08	EP4	4	5.93	H	83.35	2.88	1.6	1.6									
TT	E1X08	PX1	2	4.07														
TT	E1X08	PX2	3	4.93														
TT	E1X08	PX3	4	5.78														
TT	E1X07	D	2	4.32	H	803.8	2.71		0.7				1.5E-19	5.9E-20	5.5E-20	-18.84	-19.23	-19.26
TT	E1X07	E	3	4.82	H	843.1	2.71		1.5				8.3E-16	3.0E-16	1.5E-16	-15.08	-15.52	-15.82
TT	E1X07	F	4	5.38	H	815.3	2.88		1.0				1.1E-18	6.9E-19	5.7E-19	-17.95	-18.16	-18.25
TT	E1X07	EP5	2	4.07	H	84.85	2.64		1.9									
TT	E1X07	EP6	2	4.57	H	84.04	2.70		2.7									
TT	E1X07	EP7	3	5.07	H	83.73	2.80		0.6									
TT	E1X07	EP8	4	5.66	H	84.52	2.75		1.6									
TT	E1X07	PX4	2	4.07														
TT	E1X07	PX5	3	5.07														
TT	E1X07	PX6	4	5.80														

* Grain densities from effective grain volume measurements

Minimum	2.53	0.4	0.4	0.6	0.6	1.2	1.5E-19	5.9E-20	5.0E-20	-18.84	-19.23	-19.30
Maximum	2.96	1.6	2.7	2.1	1.7	1.6	8.3E-16	3.0E-16	1.5E-16	-15.08	-15.52	-15.82
Sum	134.8	3.4	17.4	31.4	17.3	4.4	9.0E-16	3.4E-16	1.8E-16	-552.29	-524.43	-402.17
Points	49	3	14	28	16	3	31	29	22	31	29	22
Mean	2.75	1.1	1.2	1.1	1.1	1.5	29E-17	1.2E-17	8.0E-18	-17.82	-18.08	-18.28
Median	2.72	1.4	1.2	1.0	1.0	1.5	1.3E-18	5.7E-19	3.1E-19	-17.89	-18.24	-18.51
Std Deviation	0.14	0.63	0.66	0.40	0.32	0.20	1.5E-16	5.6E-17	3.2E-17	0.67	0.69	0.83
Variance	0.02	0.40	0.44	0.16	0.10	0.04	2.2E-32	3.2E-33	1.1E-33	0.45	0.48	0.69

Parameter(s): Effective Porosity - Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139

Parameter Description:

The effective porosity of Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139 refers to the ratio of the interconnected pore volume to bulk volume, as opposed to total porosity, defined as ratio of interconnected plus non-connected pore space to bulk volume.

Material and Parameter Name(s):

S_ANH_AB	POROSITY (#528)
S_MB138	POROSITY (#567)
S_MB139	POROSITY (#588)

Parameter Value: 0.011

mean	median	minimum	maximum	units
0.011	0.011	0.006 - 0.009	0.017	None

Distribution Type: Student-t

Data: Site-Specific Laboratory-Measured Data

As part of the Two-Phase Flow Laboratory Program for the Waste Isolation Pilot Plant, effective porosity was successfully measured on forty-two specimens under various conditions of net effective stress (e.g., lithostatic minus hydrostatic pressure). See the attached table (k_ANH) for a summary of porosity and permeability data measured as part of the two-phase flow program.

The data package associated with this parameter is located at: SCWF-A:WBS1.2.07.1: PDD:QA: SALADO:PKG11:POROSITY:effective porosity/anh.

Discussion:

Data exist from 42 specimens ranging in size from 10 to 825 cc cut from MB 139 core samples measured at the following conditions of net effective stress: 0MPa (14), 3.4 MPa (28), 6 MPa (16), and 10 MPa (3). The median value of .011 used in the NMVP calculation is the same for all units and is consistent with mean and median data values ranging from .010 to .015 representing all net effective stress levels. Note that anhydrites a and b and MB 138 are assigned a lower minimum parameter value (0.006). The reader is referred to the anhydrite porosity parameter record package for more detail.

Parameter(s): Effective Porosity - Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139

References:

Howarth S.M., and T. Christian-Frear. 1996. *Porosity, Single-Phase Permeability, and Capillary Pressure Data from Preliminary Laboratory Experiments on Selected Samples from Marker Bed 139 at the Waste Isolation Pilot Plant.* SAND94-0472. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_A Threshold Pressure Parameter- Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139.

Parameter Description:

PCT_A is used to calculate threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to characterize incipient gas flow through a porous media. The sum of the existing pore pressure in the rock and the threshold pressure is the gas-pressure level that must be reached to overcome capillary resistance and drive gas into brine-filled rock pores.

Material and Parameter Name(s):

S_ANH_AB	PCT_A (#2774)
S_MB138	PCT_A (#2784)
S_MB139	PCT_A (#2789)

Parameter Value: 0.26

Units: Pa/m^2

Distribution Type: Constant

Data: Site-Specific Experimental Data

PCT_A is based on curve fit values of P_t predicted from measurements of capillary pressure on laboratory specimens. The data package associated with this parameter is retained in Sandia National Laboratories WIPP Central Files:
SWCF-A: 1.2.07.1:PDD:QA:SALADO:PKG 10:Anh 2-Phase Parameters

Discussion:

Defined in the experiment as the first gas bubble to enter a 100 percent liquid saturated rock, threshold pressure (P_t) is equal to the entry pressure. P_t values derived by curve fitting are the threshold pressures at critical (residual) gas saturation and are consistent with the Brooks and Corey definition of threshold pressure. Experimental data supporting this threshold pressure value is published in Howarth and Christian-Frear (1996).

The measured threshold pressure (P_t) is used to determine values for PCT_A and PCT_EXP, constants used in modeling to calculate P_t by the following relationship:

Parameter(s): PCT_A Threshold Pressure Parameter- Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139.

Discussion: (continued)

$$P_t = PCT\_A \cdot k^{(PCT\_EXP)}$$

where k is the permeability. These constants can be used to derive threshold pressures for similar or analog materials in the disposal system.

References:

Howarth, S.M., and T. Christian-Frear. 1996. *Porosity, Single-Phase Permeability, and Capillary Pressure Data from Preliminary Laboratory Experiments on Selected Samples from Marker Bed 139 at the Waste Isolation Pilot Plant*. SAND94-0472. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_EXP Threshold Pressure Parameter- Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139.

Parameter Description:

The exponential pressure threshold parameter (PCT_EXP) is used to calculate threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model. See the discussion of the linear threshold pressure parameter PCT_A.

Material and Parameter Name(s):

S_ANH_AB	PCT_EXP (#2775)
S_MB138	PCT_EXP (#2785)
S_MB139	PCT_EXP (#2790)

Parameter Value: -0.348

Units: None

Distribution Type: Constant

Data: Site-Specific Experimental Data

PCT_EXP is based on curve fit values of P_t predicted from measurements of capillary pressure on laboratory specimens. The data package associated with this parameter is retained in Sandia National Laboratories WIPP Central Files:
SWCF-A 1.2.07.1:PDD:QA:SALADO:PKG 10:Anh 2-Phase Parameters

Discussion:

Defined in the experiment as the first gas bubble to enter a 100 percent liquid saturated rock, threshold pressure (P_t) is equal to the entry pressure. P_t values derived by curve fitting are the threshold pressures at the critical (residual) gas saturation and are consistent with the Brooks and Corey definition of threshold pressure. Experimental data supporting this threshold pressure value is published in Howarth and Christian-Frear (1996).

The measured threshold pressure (P_t) is used to determine values for PCT_A and PCT_EXP, constants used in modeling to calculate P_t by the following relationship:

$$P_t = PCT\_A \cdot k^{(PCT\_EXP)}$$

Parameter(s): PCT_EXP Threshold Pressure Parameter- Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139.

Discussion: (continued)

where k is the permeability. These constants can be used to derive threshold pressures for similar or analog materials in the disposal system.

References:

Howarth, S.M., and T. Christian-Frear. 1996. *Porosity, Single-Phase Permeability, and Capillary Pressure Data from Preliminary Laboratory Experiments on Selected Samples from Marker Bed 139 at the Waste Isolation Pilot Plant*. SAND94-0472. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Residual Brine Saturation - Marker Beds 138, Anhydrite Layers a & b, and Marker Bed 139

Parameter Description:

The residual brine saturation (S_{br}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves. Referred to also as S_{wr} (wetting phase) or S_{lr} (liquid phase), residual brine saturation is the point reached under high gas saturation conditions when brine is no longer continuous throughout the pore network and relative brine permeability becomes zero.

Material and Parameter Name(s):

S_MB138	SAT_RBRN (#577)
S_MB139	SAT_RBRN (#598)
S_ANH_AB	SAT_RBRN (#538)

Parameter Value: 0.08363

mean	median	minimum	maximum	units
0.08363	0.8363	0.008, 0.069	0.174	None

Distribution Type: Student-t

Data: Site-Specific Experimental Data

Residual brine saturation parameter values for the marker beds are based on curve fit parameter values predicted from laboratory measurements of capillary pressure. The data package associated with this parameter is retained in Sandia National Laboratories WIPP Central Files: SWCF-A 1.2.07.1:PDD:QA:SALADO:PKG 10:Anh 2-Phase Parameters.

Discussion:

Parameter values are based on curve fit capillary pressure data measured using a mercury injection technique. The two-phase flow program reports the results of curve-fitted measurements of capillary pressure on six marker bed samples (Howarth and Christian-Frear, 1996). Specimens were collected from intact MB 139 core samples taken from the experimental area of the repository. Note that although anhydrite layers a and b are assigned a slightly higher "minimum" residual brine saturation (.069) due to extrapolation of MB 139 data, the 0.084 value assigned for all anhydrite units is not affected.

Parameter(s): Residual Brine Saturation - Marker Beds 138, Anhydrite Layers a & b, and Marker Bed 139

References:

Howarth, S.M., and T. Christian-Frear. 1996. *Porosity, Single-Phase Permeability, and Capillary Pressure Data from Preliminary Laboratory Experiments on Selected Samples from Marker Bed 139 at the Waste Isolation Pilot Plant*. SAND94-0472. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Residual Gas Saturation - Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139

Parameter Description:

The residual (critical) gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves. S_{gr} corresponds to the degree of waste-generated gas saturation necessary to create an incipient interconnected pathway in porous material, a condition required for porous rock to be permeable to gas.

Material and Parameter Name(s):

S_ANH_AB SAT_RGAS (#539)
S_MB138 SAT_RGAS (#578)
S_MB139 SAT_RGAS (#599)

Parameter Value: 0.077

mean	median	minimum	maximum	units
0.077	0.077	0.014	0.197	None

Distribution: Student-t

Data: Site-Specific Experimental Data

Residual gas saturation parameter values for the marker beds are based on curve-fitted laboratory measurements of capillary pressure. The data package is retained in Sandia National Laboratories WIPP Central Files: SWCF-A 1.2.07.1:PDD:QA:SALADO:PKG 10:Anh 2-Phase Parameters

Discussion:

The two-phase flow program reports the results of curve-fitted measurements of capillary pressure on six marker bed samples tested using mercury injection (Howarth and Christian-Frear, 1996). The samples were taken from intact MB 139 core samples collected from the northern experimental area of the repository. The measurements were conducted at ambient conditions (no stress) and were assumed to be 100 percent saturated at the initiation of capillary pressure tests.

Parameter(s): Residual Gas Saturation - Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139

References:

Howarth, S.M., and T. Christian-Frear. 1996. *Porosity, Single-Phase Permeability, and Capillary Pressure Data from Preliminary Laboratory Experiments on Selected Samples from Marker Bed 139 at the Waste Isolation Pilot Plant.* SAND94-0472. Albuquerque, New Mexico: Sandia National Laboratories.

Parameter(s): Pore Distribution - Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139

Parameter(s) Description:

The pore size distribution parameter (λ) is used calculate capillary pressure and relative permeabilities for gas and brine flow in the Brooks-Corey two-phase flow model.

Material and Parameter Name(s):

S_MB138 PORE_DIS (#566)
S_ANH_AB PORE_DIS (#527)
S_MB139 PORE_DIS (#587)

Parameter Value: 0.644

mean	median	minimum	maximum	units
0.644	0.644	0.491	0.842	None

Distribution Type: Student-t

Data: Site-Specific Experimental Data

Pore size distribution parameter values for all anhydrite units are based on curve fit values predicted from laboratory measurements of capillary pressure. The data package associated with this parameter is retained in Sandia National Laboratories WIPP Central Files: SWCF-A 1.2.07.1:PDD:QA:SALADO:PKG 10:Anh 2-Phase Parameters.

Discussion:

Curve fit parameter values are derived from six specimens cut from intact MB 139 core samples collected from the northern experimental area of the repository. Reported data and parameters are based on mercury injection capillary pressure tests. As with other two-phase flow parameters, the median value assigned to MB 138 and anhydrite "a" and "b" is supported by and based on MB 139 data.

Parameter(s): Pore Distribution - Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139

References:

Howarth, S.M., and T. Christian-Frear. 1996. *Porosity, Single-Phase Permeability, and Capillary Pressure Data from Preliminary Laboratory Experiments on Selected Samples from Marker Bed 139 at the Waste Isolation Pilot Plant*. SAND94-0472. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Rock Compressibility - Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139

Parameter Description:

Rock compressibility of the Salado Formation Anhydrite Interbeds a & b and Marker Beds 138 and 139 is used in BRAGFLO to calculate pore compressibility. Pore compressibility is used to predict the effect of material compressibility on porosity and mass storage in the equation of state for flow through porous media as follows:

$$\phi = \phi_o \exp(c_r(p-p_o))$$

where,

ϕ = porosity of solid matrix (dimensionless)
ϕ_o = porosity at reference pressure p_o
c_r = pore compressibility of solid matrix (Pa^{-1})

COMP_RCK is divided by material porosity to calculate pore compressibility.

Material and Parameter Name(s):

S_ANH_AB	COMP_RCK (#521)
S_MB138	COMP_RCK (#560)
S_MB139	COMP_RCK (#580)

Parameter Value: 8.26×10^{-11}

mean	median	minimum	maximum	units
8.26×10^{-11}	8.26×10^{-11}	1.09×10^{-11}	2.75×10^{-10}	Pa^{-1}

Distribution Type: Student-t

Data: Site-Specific Experimental Data

The parameter distribution for anhydrite rock compressibility is based upon data from four hydraulic tests in the underground WIPP facility. The boreholes and map units tested include: C2H02 (MB 139); QPP03 (Anhydrite b); QPP13 (MB 139); SCP01 (Marker Bed 139).

The data package associated with this parameter is located at:
SCWF-A:WBS1.2.07.1:PDD:QA: SALADO:PKG 19:Rock Compressibility

Parameter(s): Rock Compressibility - Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139

Discussion:

The four successful tests include:

Borehole	Location	Start Date of Testing	End Date of Testing
QPP03	Room Q	4/89	11/91
QPP13	Room Q	4/89	11/91
C2H02	Room C2	4/89	12/89
SCP01-A	Core Storage	4/90	10/90

Raw data collected during hydraulic tests include pressure, fluid volume, temperature, axial test-tool movement and radial borehole closure. Pressure/flow transmission during hydraulic tests is assumed to be a result of Darcy flow and borehole closure. The reader is referred to the anhydrite porosity parameter record package for more detail.

References:

Beauheim, R.L., G.J. Saulnier, Jr., and J.D. Avis. 1991. *Interpretation of Brine-Permeability Tests of the Salado Formation at the Watts Isolation Pilot Plant Site: First Interim Report.* SAND90-0083. Albuquerque, NM: Sandia National Laboratories.

Beauheim, R.L., R.M. Roberts, T.F. Dale, M.D. Fort, and W.A. Stensrud. 1993. *Hydraulic Testing of Salado Formation Evaporites at the Waste Isolation Pilot Plant Site: Second Interpretive Report.* SAND92-0533. Albuquerque, NM: Sandia National Laboratories.

Jensen, A.L., C.L. Howard, R.L. Jones, and T.P. Peterson. 1993. *Room Q Data Report: Test Borehole Data from April 1989 through November 1991.* SAND92-1172. Albuquerque, NM: Sandia National Laboratories.

Saulnier, G.J., Jr., P.S. Domski, J.B. Palmer, R.M. Roberts, W.A. Stensrud, and A.L. Jensen. 1991. *WIPP Salado Hydrology Program Data Report #1.* SAND90-7000. Albuquerque, NM: Sandia National Laboratories.

Stensrud, W.A., T.F. Dale, P.S. Domski, J.B. Palmer, R.M. Roberts, M.D. Fort, G.J. Saulnier, Jr., and A.L. Jensen. 1992. *Waste Isolation Pilot Plant Salado Hydrology Program Data Report #2.* SAND92-7072. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Rock Compressibility - Marker Bed 138, Anhydrite Layers a & b, and Marker Bed 139

Table 1. Summary of Rock Compressibility Test-Interpretations Results from In Situ Permeability Tests for Undisturbed Anhydrite Marker Beds

TEST INTERVAL (meters from excavation)	HOLE	ZONE	MAP UNIT(s)	ANALYSIS METHOD	ROCK COMPRESSIBILITY K (1/Pa)	FORMATION PORE PRESSURE (Mpa)*
9.47-10.86 down	C2H02	undisturbed	MB 139	GTFM6.0	1.09×10^{-11}	11.11
20.62-21.52 down	QPP13	undisturbed	MB 139	GTFM6.0	3.37×10^{-11}	12.43
10.68-14.78 down	SCP01	undisturbed	MB 139	GTFM6.0	1.09×10^{-11}	12.27
20.50-21.40 up	QPP03	undisturbed	Anhydrite b	GTFM6.0	2.75×10^{-10}	12.94

* - Mean

Note: See Record Parameter Package for additional detail.

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REPOSITORY AND PANEL CLOSURES AND DISTURBED ROCK ZONE PARAMETER VALUES

Repository and Panel Closures

Intrinsic Permeability -	Waste and Repository Regions Operations/Experimental Regions Panel Closures
Effective Porosity -	Waste and Repository Regions Operations/Experimental Region Panel Closures
Threshold Pressure -	
PCT_A	Repository Panel Closures
PCT_EXP	Repository Panel Closures
Residual Gas Saturation -	Repository Operation/Experimental Panel Closures
Residual Brine Saturation -	Repository Operational/Experimental Panel Closures
Pore Distribution -	Repository Operational/Experimental Panel Closures
Rock Compressibility - Pore-Volume	Repository
Compressibility -	Panel Closures

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REPOSITORY AND PANEL CLOSURES AND DISTURBED ROCK ZONE PARAMETER VALUES (CONTINUED)

Disturbed Rock Zone

Intrinsic Permeability (T = -5 - 0 yrs)
Intrinsic Permeability (T = 0 - 10,000 yrs)
Effective Porosity
PCT-A Threshold Pressure Parameter
PCT-EXP Threshold Pressure Parameter
Residual Brine Saturation
Residual Gas Saturation
Pore Distribution
Rock Compressibility
Maximum Capillary Pressure

Parameter(s): Log of Intrinsic Permeability - Waste and Repository Regions

Parameter Description:

Intrinsic permeability of the Waste Region and Repository region refers to the effective hydraulic conductivity of a collapsed drum-filled waste-disposal room or panel. The Waste Region corresponds to a single excavated panel. The Repository Region refers to the waste disposal area outside the single panel and is important only in instances of disturbed performance. Consequently, for the NMVP, both regions are assigned the same intrinsic permeability.

Material and Parameter Name(s):

WAS_AREA	PRMX_LOG (#663)	REPOSIT PRMX_LOG (#2131)
WAS_AREA	PRMY_LOG (#664)	REPOSIT PRMY_LOG (#2132)
WAS_AREA	PRMZ_LOG (#665)	REPOSIT PRMZ_LOG (#2133)

Parameter Value: -12.769

Units: log (m^2)

Distribution Type: Constant

Data: Simulated Waste Specific Data and Investigator Judgment

The recommended overall waste region permeability is unchanged from the value of 1.7×10^{-13} m^2 derived in the 1991 Preliminary Comparison with 40 CFR 191B (SAND91-0893/3, Volume 3, Section 3.4.7, pp. 3-130 to 3-134). The data supporting the analysis in SAND91-0893/3 is published in Luker et al. (1991), Table 4.1 p. 700. Luker et al. (1991) supersedes Butcher (1991) cited in SAND 91-0893/3.

Discussion:

The data supporting the permeability value of 1.7×10^{-13} m^2 is based on laboratory brine permeability tests involving simulated waste compacted to lithostatic conditions. Luker et al. (1991) reports compacted permeabilities for simulated combustible, metals/glass and sludge waste ranging on the order of 10^{-12} to 10^{-16} m^2. Assuming that the volume fractions of waste components are 40 percent combustibles, 40 percent metals/glass and 20 percent sludge, a weighting scheme is used to derive the expected permeability of an average drum. SAND91-0893/3 documents scaling of drum-scale permeability to the effective

Parameter(s): Log of Intrinsic Permeability - Waste and Repository Regions

Discussion: (continued)

permeability of a collapsed waste-filled room. The relatively high permeability value of 1.7×10^{-13} m^2 and low coefficient of variation (1.48×10^{-2} m^2) suggest it is appropriate to assign a constant value to waste region permeability (Butcher, 1996).

References:

Butcher, B.M. 1996. QAP 9-2 "Documentation of the Overall Waste Permeability and Flow and Flow Property Values for the CCA." Sandia National Laboratories Memorandum of Record, January, 29, SCWF-A1.1.0.1.2.3; DRM.

Luker, R.S., T.W. Thompson, and B.M. Butcher. 1991. "Compaction and Permeability of Simulated Waste," *Rock Mechanics as a Multidisciplinary Science: Proceedings of U.S. Symposium, University of Oklahoma, Norman, Ok, July 10-12, 1991.* J-C. Roegiers, ed. SAND90-2368C. pp.693-702. A.A. Balkema, Brookfield, VT.

WIPP Performance Assessment. 1991. *Preliminary Comparison with 40 CFR 191, Subpart B for the Waste Isolation Pilot Plant, December 1991, Vol. 3: Reference Data.* SAND91-0893/3. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Log of Intrinsic Permeability
Operations and Experimental Regions

Parameter Description:

Intrinsic permeability refers to the hydraulic conductivity of the operations and the experimental regions. These regions correspond to the excavated area between the panel closures and the base of the shaft, and to the excavated drifts and decommissioned experimental area situated north of the shaft, respectively.

Material and Parameter Name(s):

OPS_AREA	PRMX_LOG (#14)	EXP_AREA	PRMX_LOG (#214)
OPS_AREA	PRMY_LOG (#15)	EXP_AREA	PRMX_LOG (#215)
OPS_AREA	PRMZ_LOG (#16)	EXP_AREA	PRMX_LOG (#216)

Parameter Value: -11.0

Units: log (m^2)

Distribution Type: Constant

Data: Investigator Judgment

The assignment of permeability to the operational and experimental regions is required for model configuration and is a modeling assumption.

Discussion:

The Operational and Experimental regions are assigned a permeability value of $1.0 \times 10^{-11}\ m^2$ to assure that fluid flow is not impeded from the waste and repository regions to these areas. The value assigned is the highest permeability in the model and is believed to overestimate the expected permeability of a closed excavation containing no waste or backfill.

References:

N/A

Parameter(s): Log of Intrinsic Permeability - Panel Closures

Parameter Description:

Intrinsic permeability of the panel closures refers to the effective hydraulic conductivity of the panel closures designed to control exposure of various waste constituents during the operational period.

Material and Parameter Name(s):

PAN_SEAL PRMX_LOG (#259)
PAN_SEAL PRMY_LOG (#260)
PAN_SEAL PRMZ_LOG (#261)

Parameter Value: -15.0

Units: $\log(m^2)$

Distribution Type: Constant

Data: Investigator Judgment and General Engineering Knowledge

There has been no direct measurement of the permeability of panel closures as proposed in the conceptual design. However, the materials proposed for the panels possess established properties with predictable performance.

Discussion:

The conceptual design of the panel closure system includes a plug of crushed salt 1.5 times the drift entry diameter in length and a 2.0 entry diameter long concrete bulkhead. Concrete block retaining walls are proposed to separate the two closure materials, as is a grouted region in the DRZ surrounding the concrete bulkhead.

The panel closure intrinsic permeability is assigned based on the premise that the salt backfill component will attain at least the same permeability as the undergrouted DRZ surrounding the excavation.

References:

N/A

Parameter(s): Effective Porosity - Waste and Repository Regions

Parameter Description:

The initial effective porosity of the Waste and Repository regions is used in the BRAGFLO analyses. Porosity is adjusted during the simulation based on the porosity surface calculated by SANTOS to account for pressure-dependent consolidation of the waste by creep closure. (initial condition)

Material and Parameter Name(s):

WAS_AREA	POROSITY (#660)
REPOSIT	POROSITY (#2130)

Parameter Value: 8.48×10^{-1}

Units: None

Distribution Type: Constant (initial condition)

Data: Waste-Specific Observational Data and Investigator Judgment

There has been no direct measurement of the effective porosity of a collapsed drum-filled waste disposal room or panel. However, this parameter can be estimated given knowledge of the disposal room configuration and the representative porosity of TRU waste published in the Transuranic Waste Baseline Inventory Report (DOE/CAO, 1995).

Discussion:

The initial porosity of the waste panel is derived from assumptions of the disposal room configuration and information about the relative abundance of waste forms and their estimated initial void volumes. The current analyses consider a disposal room containing 6804 drums of uniformly distributed unprocessed waste and no backfill. The disposal room model consists of rectangular room 13 feet (3.96 meters) high by 33 feet (10.06 meters) wide by 300 feet (91.44 meters) long resulting in an initial room volume of 3642.75 m^3.

Stone (1995) reports a waste material porosity of 0.681 calculated from densities of 12 waste material parameters identified in the Transuranic Waste Baseline Inventory Report (DOE/CAO, 1995).

Parameter(s): Effective Porosity - Waste and Repository Regions

Discussion: (continued)

Given waste material porosity and disposal room volume, the solid volume of a typical disposal room is calculated to be 551.2 m^3. The initial void volume of the waste room is 3642.75 m^3 - 551.2 m^3 = 3091.55 m^3. The initial disposal region porosity of .848 is calculated as follows:

$$\frac{\text{initial void volume of waste room}}{3091.55\ m^3 + 551.2\ m^3}$$

References:

Stone. 1995. "Proposed Model for the Final Porosity Surface Calculations," Sandia National Laboratories Memorandum of Record to B.M. Butcher, October 27, 1995.

DOE/CAO. 1995. *Transuranic Waste Baseline Inventory Report.* DOE/CAO 95-1121 Revision 2 December, 1995, Carlsbad Area Office Technical Assistance Contractor, Carlsbad, New Mexico

Parameter(s): Effective Porosity - Operations and Experimental Regions

Parameter Description:

The initial effective porosity of the operations and experimental regions must be assigned in the BRAGFLO analyses.

Material and Parameter Name(s):

OPS_AREA	POROSITY (#11)
EXP_AREA	POROSITY (#211)

Parameter Value: 1.8×10^{-1}

Units: None

Distribution Type: Constant

Data: Investigator Judgment and General Engineering Knowledge

The porosity value for both the Operations and Experimental regions is based on a backfill sensitivity study that modeled the closure behavior of an "equivalent" empty room in the experimental area (Arguello, 1994).

Discussion:

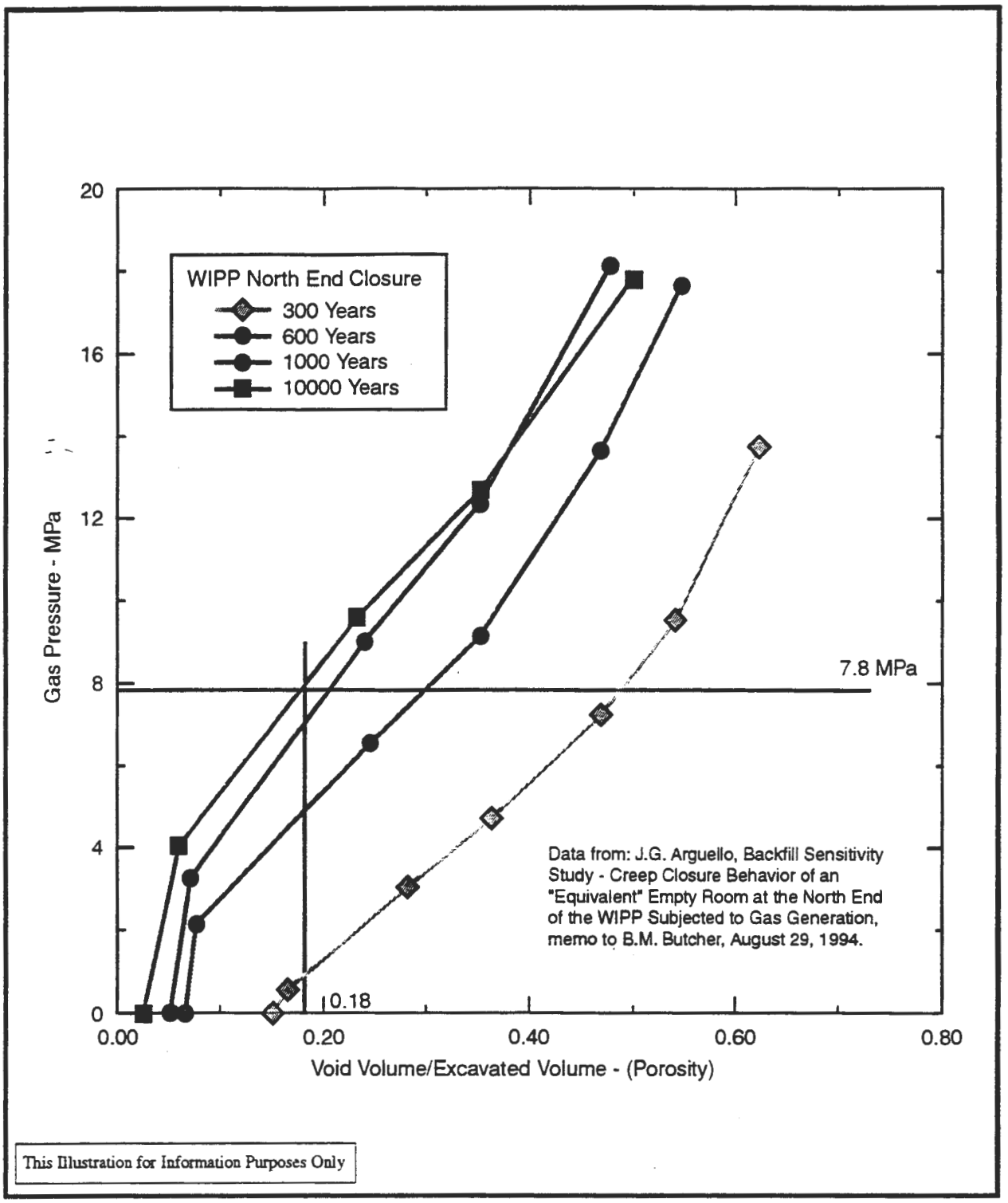
The attached figure shows the results of the backfill sensitivity study as a series of curves plotting the ratio of time-dependent void volume to excavated volume against gas pressure for various conditions of gas generation. The results of the backfill study indicate closure is virtually complete at 1,000 years after the room is isolated. The assumption of constant porosity is based on a study that shows that time-dependent closure for the north end of the repository is an unimportant process (FEP DR3, Closure of Unfilled North End). The single value of .18 is based on the void volume/excavated volume ratio corresponding to a repository pressure of 7.8 MPa after 10,000 years (Butcher, 1996).

Parameter(s): Effective Porosity - Operations and Experimental Regions

References:

Arguello, J.G. 1994. "Backfill Sensitivity Study - Creep Closure Behavior of an Equivalent Empty Room at the North End of the WIPP Subjected to Gas Generation" Sandia National Laboratories Memorandum of Record to B.M. Butcher, August 29, 1994.

Butcher, B.M. 1996. "Porosity of the WIPP North End Excavations" Sandia National Laboratories Memorandum of Record to M.S. Tierney, February 6, 1996.



NMVP-6342-165-0

Figure X-X. Operations/Experiment Regions n_OPEX.DOC

Parameter(s): Effective Porosity - Panel Closures

Parameter Description:

Effective porosity of the panel closures.

Material and Parameter Name(s):

PAN_SEAL POROSITY (#256)

Parameter Value: 7.5×10^{-2}

Units: None

Distribution Type: Constant

Data: Investigator Judgment and General Engineering Knowledge

The effective porosity of the panel closures is a modeling assumption.

Discussion:

The conceptual design for the panel closures proposes several component features, including crushed salt backfill, a concrete bulkhead and concrete block retaining walls. The assigned 7.5 percent constant value for panel closure porosity is slightly higher than the 5.0 percent porosity assigned to Salado Mass Concrete proposed for use in the shaft. The value is lower than the constant 18 percent porosity assigned to the Operations and Experimental regions. In general, lower porosity materials provide less potential for gas storage.

References:

N/A

Parameter(s): PCT_A Threshold Pressure Parameter - Repository

Parameter Description:

PCT_A is used to calculate threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to characterize incipient gas flow through a porous media.

Material and Parameter Name(s):

WAS_AREA	PCT_A (#2805)	OPS_AREA	PCT_A (#2605)
REPOSIT	PCT_A (#2737)	EXP_AREA	PCT_A (#2712)

Parameter Value: 0

Units: Pa/m^2

Distribution Type: Constant

Data: Investigator Judgment and General Engineering Knowledge

PCT_A is a modeling assumption.

Discussion:

The Threshold Pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the correlation established by Davies (1991):

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where PCT_A and PCT_EXP are constants and k is the permeability. Given the relatively unconsolidated and high permeability environment of the waste region, capillary pressure should be zero. Therefore, the threshold pressure linear parameter (PCT_A) is set to zero. The simulation assumes no pressure threshold for flow of gas through any material region in the repository.

Parameter(s): PCT_A Threshold Pressure Parameter - Repository

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_A Threshold Pressure Parameter - Panel Closures

Parameter Description:

PCT_A is used to calculate threshold pressure (P_t) as required in the Brooks-Corey two-phase flow model to characterize incipient gas flow through a porous media

Material and Parameter Name(s):

PAN_SEAL PCT_A (#2732)

Parameter Value: 0.56

Units: Pa/m^2

Distribution Type: Constant

Data: General Literature and Investigator Judgment

There are no PCT_A data for panel closures. The linear threshold parameter value is based on a best-fit power correlation of threshold pressures and intrinsic permeabilities published for several types of consolidated lithologies, referred to as the Davies correlation (Davies, 1991 p. 25-26).

Discussion:

The Threshold Pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media. P_t is determined from the correlation established by Davies (1991):

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where PCT_A and PCT_EXP are constants and k is the permeability. Use of the Davies correlation is appropriate based on assumed gross similarities between compacted salt backfill and engineered concrete and the consolidated carbonate, anhydrite, shale and sandstone lithologies used to derive the Davies exponential threshold pressure parameter.

Parameter(s): PCT_A Threshold Pressure Parameter - Panel Closures

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Repository

Parameter Description:

PCT_EXP is used to calculate threshold pressure (P_t), a parameter required in the Brooks-Corey two-phase flow model to characterize incipient gas flow through a porous media.

Material and Parameter Name(s):

WAS_AREA	PCT_EXP (#2806)	OPS_AREA	PCT_EXP (#2606)
REPOSIT	PCT_EXP (#2737)	EXP_AREA	PCT_EXP (#2713)

Parameter Value: 0

Units: None

Distribution Type: Constant

Data: Investigator Judgment and General Engineering Knowledge

PCT_A is a modeling assumption.

Discussion:

The Threshold Pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the correlation established by Davies (1991):

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where PCT_A and PCT_EXP are constants and k is the permeability. Given the relatively unconsolidated and high permeability environment of the waste region, capillary pressure should be zero. Consequently, as assumed for the threshold pressure linear parameter (PCT_A), PCT_EXP is set to zero. The simulation assumes no pressure threshold for flow of gas through any material region in the repository.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Repository

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Panel Closures

Parameter Description:

PCT_EXP is used to calculate threshold pressure (P_t), a parameter required in the Brooks-Corey two-phase flow model to characterize incipient gas flow through a porous media.

Material and Parameter Name(s):

PAN_SEAL PCT_EXP (#2733)

Parameter Value: -0.346

Units: None

Distribution Type: Constant

Data: General Literature and Investigator Judgment

PCT_EXP has not been directly measured for panel closures. The exponential threshold parameter value is based on a best-fit power correlation of threshold pressures and intrinsic permeabilities published for several types of consolidated lithologies, referred to as the Davies correlation (Davies, 1991, p. 25-26).

Discussion:

Threshold pressure (P_t) is calculated by the following relationship:

$$P_t = PCT\_A \cdot k^{(PCT\_EXP)}$$

where k is the permeability. Use of the Davies correlation is appropriate based on assumed gross similarities between panel closure materials and the consolidated carbonate, anhydrite, shale and sandstone lithologies used to derive the Davies exponential threshold pressure parameter (i.e., relatively tight crystalline textures with interconnected pore space occurring along grain boundaries). Panel closures and halite are assigned the same values for PCT_A and PCT-EXP.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Panel Closures

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant*. SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Residual Gas Saturation - Repository

Parameter Description:

The residual gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

WAS_AREA	SAT_RGAS (#671)
REPOSIT	SAT_RGAS (#2137)

Parameter Value: 0.075

mean	median	minimum	maximum	units
0.075	0.075	0	0.15	None

Distribution Type: Uniform

Data: General Literature and Investigator Judgment

The parameter values are based on a November 15, 1995 Solutions Engineering letter report to D.M. Stoelzel of Sandia National Laboratories entitled "Critical (residual) Gas Saturation Recommendations for WIPP."

Discussion:

Under conditions of chemical and biochemical gas generation and repository closure, gas saturation may increase to a level where the pore network in repository material regions becomes connected and gas permeability begins to increase. The lowest gas saturation at which continuous gas flow will occur is the residual (critical) gas saturation (S_{gr}). In a review of studies involving S_{gr}, Solutions Engineering (1995) reports values ranging from 0 to 27 percent. The assigned range for S_{gr} between 0 to 15 percent is consistent with recommendations in the Solutions Engineering report. Assigning a constant and relatively low 7.5 percent residual gas saturation facilitates migration of gas through the waste region.

Parameter(s): Residual Gas Saturation - Repository

References:

Solutions Engineering. 1996. "Critical Gas Saturation Recommendations for WIPP." Letter Report to D.M. Stoelzel, Sandia National Laboratories, November 15, 1995, Albuquerque, New Mexico.

Parameter(s): Residual Gas Saturation - Operational and Experimental Regions

Parameter Description:

The residual gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

OPS_AREA	SAT_RGAS (#22)
EXP_AREA	SAT_RGAS (#222)

Parameter Value: 0.0

Units: None

Distribution Type: Constant

Data: Investigator Judgment and General Engineering Knowledge

SAT_RGAS is a modeling assumption that overestimates migration of the gas phase in the operational and experimental regions.

Discussion:

Residual gas saturation is the gas saturation corresponding to the point on the relative permeability curve where gas permeability becomes nonzero and gas begins to flow through the porous media. Assigning a zero residual gas saturation assumes no gas saturation constraint for gas to flow through the operational and experimental regions.

References:

N/A

Parameter(s): Residual Gas Saturation - Panel Closures

Parameter Description:

The residual gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

PAN_SEAL SAT_RGAS (#266)

Parameter Value: 0.2

Units: None

Distribution Type: Constant

Data: General Literature and Investigator Judgment

The parameter value is substantiated in a November 15, 1995 Solutions Engineering letter report to D.M. Stoelzel of Sandia National Laboratories entitled "Critical (residual) Gas Saturation Recommendations for WIPP."

Discussion:

Under conditions of chemical and biochemical gas generation and repository closure, gas pressure will build and may cause gas to be "injected" into panel closures. The lowest gas saturation at which continuous gas flow will occur is the residual (critical) gas saturation (S_{gr}). Solutions Engineering (1995) reports laboratory residual measurements of S_{gr} ranging from 0 to 27 percent. The assigned S_{gr} value of .20 is consistent with the recommendations reported by Solutions Engineering.

References:

Solutions Engineering. 1996. "Critical Gas Saturation Recommendations for WIPP" Letter Report to D.M. Stoelzel, Sandia National Laboratories, November 15, 1995, Albuquerque, New Mexico.

Parameter(s): Residual Brine Saturation - Repository

Parameter Description: This

The residual brine saturation (S_{br}) is a parameter of the Brooks-Corey two-phase flow model defining the relative permeability for brine. Referred to also as S_{wr} (wetting phase) or S_{lr} (liquid phase), residual brine saturation in the waste region corresponds to the brine saturation required to create an incipient interconnected brine-filled pore network in the waste (See Appendix BRAGFLO). Below the S_{br}, brine contained in the effective porosity of the waste is immobile.

Material and Parameter Name(s):

WAS_AREA SAT_RBRN (#670) REPOSIT SAT_RBRN (#2741)

Parameter Value: 0.276

mean	median	minimum	maximum	units
0.276	0.276	0	0.552	None

Distribution Type: Uniform

Data: General Literature and Investigator Judgment

Two-phase flow parameters have not been measured for materials representative of a collapsed empty, back-filled, or waste-filled room. This demonstration uses literature-based residual brine saturation data measured for unconsolidated analog materials as the basis for assigning parameter values.

Discussion:

Brooks and Corey evaluated their two-phase characteristic equations against capillary pressure and relative permeability data obtained in laboratory experiments (Brooks and Corey, 1964). Mualem (1976a) proposed a modified procedure to that of Brooks and Corey for determining the wetting phase permeability curve by adding the constraint that the extrapolated curve should pass through the highest capillary pressure data point. Although their wetting phase relative permeability predictions are similar to each other and to the data, the Mualem procedure, in some cases, results in S_{wr} values less than those predicted by the Brooks and Corey model. Consequently, Table 1 lists the Mualem

Parameter(s): Residual Brine Saturation - Repository

Discussion: (continued)

(1976a) residual wetting phase saturations (Swr) to ensure that the potential for brine mobility is not underestimated.

As indicated in Table 1, single-phase liquid permeabilities of the Brooks and Corey materials are of the same order of magnitude as those assigned to waste disposal regions (10^{-13} m^2). The selected S_{br} value for the BRAGFLO simulation of .276 is consistent with the fragmented mixture of clay, sandstone and volcanic sand evaluated in the Brooks and Corey study. The lowest S_{br} value of 0.0783 for glass bead materials is considered a reasonable lower bound for assessing brine mobility in the waste region. Other S_{br} values reported in Mualem (1976a) support this assumption.

References:

Brooks , R.H., and A.T. Corey. 1964. *Hydraulic Properties of Porous Media.* Hydrology Paper No. 3. Fort Collins, CO: Colorado State University.

Mualem, Y. 1976a. *A New Model for Predicting the Hydraulic Conductivity of Unsaturated Porous Media.* Water Resources Research. Vol. 12, no. 3, 513-522.

Table 1: Brooks and Cory Materials Parameters - Unconsolidated Media[a]

Material	Permeability (m^2)[b]	Porosity	S_{wr}[c]
Volcanic Sand	1.1×10^{-11}	.365	0.137
Fine Sand	2.85×10^{-12}	.360	0.140
Glass Beads	1.05×10^{-11}	.383	0.0783[d]
Fragmented Mixture	1.50×10^{-11}	.441	0.275
Fragmented Fox Hill Sandstone	1.61×10^{-11}	.503	0.318
Touchet Silt Loam	5.00×10^{-13}	.469	0.277
Poudre River Sand	2.26×10^{-11}	.364	0.0824
Amarillo Silty Clay Loam	2.34×10^{-12}	.455	0.242
Consolidated Berea Sandstone	4.81×10^{-13}	.206	0.243
Consolidated Hygiene Sandstone	1.78×10^{-13}	.250	0.560

a - Consolidated materials are identified in the material column
b - Single-phase liquid permeability
c - Mualem S_{wr} corrected for comparison to Brooks and Corey (1964)
d - Considered reasonable lower bound; however, for statistical purposes zero is the assigned lower bound.

λ - Pore size distribution
Swr - Wetting phase residual saturation

Parameter(s): Residual Brine Saturation - Operational and Experimental Regions

Parameter Description:

The residual brine saturation (S_{br}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves. Referred to also as S_{wr} (wetting phase) or S_{lr} (liquid phase), residual brine saturation is used in the second modification of the Brooks and Corey two-phase flow model to calculate the effective saturation (S_e) for the gas and brine phases.

Material and Parameter Name(s):

EXP_AREA	SAT_RBRN (#221)	OPS_AREA	SAT_RBRN (#21)

Parameter Value: 0

Units: None

Data: Investigator Judgment and General Engineering Knowledge

SAT_RBRN is a modeling assumption that overestimates migration of the liquid phase in the operational and experimental regions.

Discussion:

Residual brine saturation is the brine saturation corresponding to the point on the relative permeability curve where liquid permeability becomes zero within increasing gas saturation or becomes nonzero with increasing brine saturation. Assigning a zero residual brine saturation assumes no gas saturation constraint on the flow of the liquid phase through the operational and experimental regions.

References:

N/A

Parameter(s): Residual Brine Saturation - Panel Closures

Parameter Description:

The residual brine saturation (S_{br}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves. S_{br} is sometimes denoted as S_{wr} (wetting phase) or S_{lr} (liquid phase). (See RBRN_REP.DOC and Appendix BRAGFLO).

Material and Parameter Name(s):

PAN_SEAL SAT_RBRN (#265)

Parameter Value: 0.2

Units: None

Distribution Type: Constant

Data: General Literature and Investigator Judgment

Two-phase flow parameters have not been measured for panel closure materials.

Discussion:

The conceptual design for the panel closures suggests panel closure materials may include concrete blocks for retaining walls, crushed salt backfill and a concrete bulkhead. The basis for the value assigned to the panel closure materials is residual wetting phase saturations (S_{wr}) reported by Brooks and Corey (1964) for several types of porous unconsolidated and consolidated analog materials. Selection of a constant parameter value at the lower end of the range of 0.08 to 0.56 reported by Brooks and Corey (1964) necessitates relatively low brine saturation conditions be achieved before the liquid permeability of brine becomes nonzero and brine begins to flow through the seal materials.

References:

Brooks , R.H., and A.T. Corey. 1964. *Hydraulic Properties of Porous Media.* Hydrology Paper No. 3. Fort Collins, CO: Colorado State University.

Parameter(s): Pore Distribution - Repository

Parameter Description:

The pore size distribution parameter (λ) is used in the calculation of capillary pressure and relative permeability in the second modification to the Brooks-Corey model implemented in BRAGFLO.

Material and Parameter Name(s):

WAS_AREA PORE_DIS (#659) REPOSIT PORE_DIS (#2129)

Parameter Value: 2.89

mean	median	minimum	maximum	units
3.25	2.89	1.44	5.78	None

Distribution Type: Cumulative

Data: General Literature and Investigator Judgment

Two-phase flow parameters have not been measured for materials representative of a collapsed empty, back-filled or waste-filled room. Consequently, two-phase flow parameters are selected from the literature and assigned as a modeling assumption. Brooks and Corey (1964) is used as the literature reference.

Discussion:

Brooks and Corey (1964) fit capillary pressure data to predict pore size distribution for several types of unconsolidated and consolidated material mixtures. The selected pore size distribution parameter of 2.89 is representative of a fragmented mixture of clay, sandstone and volcanic sand tested in the Brooks and Corey study. The analog material permeability and porosity measured 1.50×10^{-11} m^2 and 0.441, respectively.

References:

Brooks , R.H., and A.T. Corey. 1964. *Hydraulic Properties of Porous Media.* Hydrology Paper No. 3. Fort Collins, CO: Colorado State University.

Parameter(s): Pore Distribution - Operational and Experimental Regions

Parameter Description:

The pore size distribution parameter (λ) is used in the calculation of capillary pressure and relative permeability in the second modification to the Brooks-Corey model implemented in BRAGFLO.

Material and Parameter Name(s):

EXP_AREA	PORE_DIS (#210)	OPS_AREA	PORE_DIS (#10)

Parameter Value: 0.70

Units: None

Distribution Type: Constant

Data: General Literature and Investigator Judgment

Two-phase flow parameters have not been measured for materials representative of a collapsed empty, back-filled or waste-filled room. Consequently, two-phase flow parameters are selected from the literature.

Discussion:

The pore size distribution parameter value of 0.7 used in the NMVP analysis is based on a study by Morrow et al. (1986) on the Multiwell Tight Gas Sands Project. The parameter value selected for the closed experimental and operational regions falls within the same range of pore size distribution determined experimentally for anhydrites (.558 to .842).

References:

Morrow, N.R., J.S. Ward, and K.R. Brower. 1986. *Rock Matrix and Fracture Analysis of Flow in Western Tight Gas Sands - 1985 Annual Report.* DOE/MC/21179-2032. Socorro, NM: New Mexico Institute of Mining and Technology, New Mexico Petroleum Recovery Research Center.

Parameter(s): Pore Distribution - Panel Closures

Parameter Description:

The pore size distribution parameter (λ) is used in the calculation of capillary pressure and relative permeability in the second modification to the Brooks-Corey model implemented in BRAGFLO.

Material and Parameter Name(s):

PAN_SEAL PORE_DIS (#255)

Parameter Value: 0.94

Units: None

Distribution Type: Constant

Data: Investigator Judgment

Two-phase flow parameters have not been measured for panel closure materials. The parameter is assigned as a modeling assumption.

Discussion:

The conceptual design for the panel closures suggests panel closure materials may include concrete blocks for retaining walls, crushed salt backfill and a concrete bulkhead. The parameter value selected is similar to the maximum pore size distribution derived by the Two-Phase Flow Laboratory Program for intact Salado rock (see Salado anhydrite parameter section).

References:

N/A

Parameter(s): Rock Compressibility - Repository

Parameter Description:

Rock compressibility is used in BRAGFLO to calculate pore compressibility to predict the effect of material compressibility on porosity and mass storage in the equation of state for flow through porous media.

Material and Parameter Name(s):

WAS_AREA	COMP_RCK (#653)	EXP_AREA	COMP_RCK (#208)
REPOSIT	COMP_RCK (#2112)	OPS_AREA	COMP_RCK (#8)

Parameter Value: 0

Units: Pa^{-1}

Distribution Type: Constant

Data: Investigator Judgment

COMP_RCK is a modeling assumption.

Discussion:

Except for the shaft material regions, COMP_RCK in the parameter database must be divided by material porosity to calculate pore compressibility. Pore compressibility is used in BRAGFLO to evaluate material porosity and mass storage as follows:

$$\phi = \phi_o \exp(c_r(p-p_o))$$

where,

ϕ = porosity of solid matrix (dimensionless)
ϕ_o = porosity at reference pressure p_o
c_r = pore compressibility of solid matrix (Pa^{-1})

Calculating a zero pore compressibility constrains porosity to a constant value, or in the waste disposal areas, allows the SANTOS porosity surface to be used to account for pressure-dependent consolidation of the waste.

Parameter(s): Rock Compressibility - Repository

References:

N/A

Parameter(s): Pore-Volume Compressibility - Panel Closures

Parameter Description:

Pore compressibility is used in BRAGFLO to predict the effect of material compressibility on porosity and mass storage in the equation of state for flow through porous media.

Material and Parameter Name(s):

PAN_SEAL COMP_RCK (#253)

Parameter Value: 2.64×10^{-9}

Units: Pa^{-1}

Distribution Type: Constant

Data: Investigator Judgment

COMP_RCK for panel closures is a modeling assumption.

Discussion:

The COMP_RCK value in the parameter data base is usually divided by material porosity to calculate pore compressibility. However, as done for shaft materials, COMP_RCK for panel closures is listed as pore compressibility. Pore compressibility is used in BRAGFLO to evaluate material porosity and mass storage as follows:

$$\phi = \phi_o \exp(c_r(p-p_o))$$

where,

ϕ = porosity of solid matrix (dimensionless)
ϕ_o = porosity at reference pressure p_o
c_r = pore compressibility of solid matrix (Pa^{-1})

Pore compressibility for the panel closures is assigned on the assumption that the concrete component of the panel closures will have the same pore compressibility as concrete material in the shaft.

References:

N/A

Parameter(s): Maximum Capillary Pressure - All Material Regions

Parameter Description:

Designation of maximum capillary pressure is required in BRAGFLO for two-phase flow modeling. Maximum capillary pressure is assigned the same value for all material regions. See Appendix BRAGFLO for an explanation of the capillary pressure curve defined by the Second Modified Brooks-Corey Model.

Material and Parameter Name(s):

PARAMETER NAME: PC_MAX

MATERIAL NAMES:

WAS_AREA (#658)	REPOSIT (#2242)
EXP_AREA (#209)	OPS_AREA (#9)
PAN_SEAL (#254)	EARTH (#2498)
CLAY_RUS (#3003)	CL_L_T1 (#2329)
CL_L_T2 (#2346)	CL_L_T3 (#2363)
CL_L_T4 (#3073)	CL_M_T1 (#2380)
CL_M_T2 (#2397)	CL_M_T3 (#2414)
CL_M_T4 (#2431)	CL_M_T5 (#2448)
CLAY_BOT (#2312)	CONC_T1 (#2465)
CONC_T2 (#2482)	CONC_MON (#3054)
ASPHALT (#2278)	SALT_T1 (#2515)
SALT_T2 (#2532)	SALT_T3 (#2549)
SALT_T4 (#2566)	SALT_T5 (#2583)
SALT_T6 (#2986)	S_HALITE (#542)
S_ANH_AB (#522)	S_MB138 (#561)
S_MB139 (#582)	DRZ_0 (#176)
DRZ_1 (#193)	CULEBRA (#137)
MAGENTA (#2098)	DEWYLAKE (#156)
SANTAROS (#339)	

Parameter Value: 10^8

Units: Pa

Distribution Type: Constant

Parameter(s): Maximum Capillary Pressure - All Material Regions

Data: Investigator Judgment and General Engineering Knowledge

The anhydrite two-phase flow parameter data package retained in Sandia National Laboratories WIPP Central Files shows similar data values for maximum capillary pressure in anhydrite, specifically at conditions reached when the liquid expelled during centrifuge tests became constant. However, the basis of the assigned value is general engineering knowledge.

SWCF-A 1.2.07.1:PDD:QA:SALADO:PKG 10:Anh 2-Phase Parameters.

Discussion:

For all material regions, the maximum capillary pressure is merely a model configuration assumption required to implement the capillary pressure function defined in the Second Modified Brooks-Corey Model.

References:

N/A

Parameter(s): Log of the Intrinsic Permeability (T = -5 to 0 yrs) - Disturbed Rock Zone

Parameter Description:

The log of the intrinsic permeability of the Disturbed Rock Zone (DRZ) from time -5 to 0 years.

Material and Parameter Name(s):

DRZ_0	PRMX_LOG (#181)
DRZ_0	PRMY_LOG (#182)
DRZ_0	PRMZ_LOG (#183)

Parameter Value: -17.0

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data

See: RE/SPEC (1996).

Discussion:

Parameter values for the DRZ are defined for two time periods: 1) the 'waste emplacement' time associated with a fresh panel (-5 to 0 years), and 2) the sealed repository time period from 0 to 10,000 years. The first time period is intended to represent the time from the initial excavation of a new panel (at -5 years) to the sealing of that panel after waste is emplaced (at time 0 years).At the start of this time period (the instant the excavation is made) the surrounding formation is assumed to have the properties of intact rock. During this first five years this initially intact rock becomes depressurized and partially desaturated do to the presence of the excavation. Therefore the initial (at t= -5 years) pressure and brine saturation of this material is assumed to be fully brine saturated and in hydrostatic equilibrium with the rest of the Salado formation. The model will calculated the degree of desaturation and depressurization which occurs over this five year period. Also, during this first five years the formation will alter becoming more permeable and perhaps more porous as a result of the influence of the excavation. Because these hydrologic properties are not dynamically adjusted within the

Parameter(s): Log of the Intrinsic Permeability (T = -5 to 0 yrs) - Disturbed Rock Zone

Discussion: (continued)

numerical simulation during this five year drainage period, the appropriate values should represent the average values.

For this time period the DRZ because of its proximity to the excavation is characterized by a higher permeability than its intact counterpart. Alteration of this material is not complete at the end of this time period so that further deterioration of its hydrological properties (at least permeability) is expected.

References:

Vaughn, P. 1996. E-mail communication to Margaret Chu. Revision to DRZ and TZ properties to be used in BRAGFLO CCA Calculations, January 24, 1996.

Parameter(s): PCT_A Threshold Pressure Parameter - Disturbed Rock Zone

Parameter Description:

PCT_A is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

DRZ_0	PCT_A (#2702)
DRZ_1	PCT_A (#3128)

Parameter Value: 0

Units: Pa/m^2

Data: Investigator Judgment

Discussion:

The Threshold Pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Disturbed Rock Zone

Parameter Description:

PCT_EXP is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

DRZ_0	PCT_EXP (#2703)
DRZ_1	PCT_EXP (#3129)

Parameter Value: 0

Units: None

Data: Investigator Judgment

Discussion:

The Threshold Pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Residual Brine Saturation - Disturbed Rock Zone

Parameter Description:

The residual brine saturation (S_{br}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

DRZ_0	SAT_RBRN (#188)
DRZ_1	SAT_RBRN (#205)

Parameter Value: 0

Units: None

Distribution Type: Constant

Data: Investigator Judgment

Discussion:

A value of zero for residual brine saturation is in general very conservative and is reasonable for a fractured media. Given the lack of site-specific data, this value was chosen for the DRZ.

References:

Vaughn, Palmer. 1996. E-mail from Palmer Vaughn to Margaret Chu, Re: Revision to DRZ and TZ Properties to be used in the BRAGFLO CCA Calculations. January 24, 1996.

Parameter(s): Residual Gas Saturation - Disturbed Rock Zone

Parameter Description:

The residual gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

DRZ_0	SAT_RGAS (#189)
DRZ_1	SAT_RGAS (#206)

Parameter Value: 0

Units: None

Distribution Type: Constant

Data: Investigator Judgment

Discussion:

A value of zero for residual gas saturation is in general very conservative and is reasonable for a fractured media. Given the lack of site-specific data, this value was chosen for the DRZ.

References:

Vaughn, Palmer. 1996. E-mail from Palmer Vaughn to Margaret Chu, Re: Revision to DRZ and TZ Properties to be used in the BRAGFLO CCA Calculations. January 24, 1996.

Parameter(s): Pore Distribution - Disturbed Rock Zone

Parameter Description:

The pore size distribution parameter (λ) is required for the Brooks-Corey two-phase flow model.

Material and Parameter Name(s):

DRZ_0	PORE_DIS (#177)
DRZ_1	PORE_DIS (#194)

Parameter Value: 0.7

Units: None

Distribution Type: Constant

Data: Investigator Judgment

The median value measured for the Salado Halite is considered reasonable.

See Also: Data section of Parameter Sheet for "Pore Distribution - Halite."

Discussion:

Given the lack of site-specific data, using the median value measured for the Salado Halite for PORE_DIS is reasonable.

See Also: Discussion section of Parameter Sheet for "Pore Distribution - Halite."

References:

See: References section of Parameter Sheet for "Pore Distribution - Halite."

Parameter(s): Rock Compressibility - Disturbed Rock Zone

Parameter Description:

Rock compressibility of the Disturbed Rock Zone (DRZ).

Material and Parameter Name(s):

DRZ_0	COMP_RCK (#175)
DRZ_1	COMP_RCK (#191)

Parameter Value: 7.41×10^{-10}

Units: Pa^{-1}

Distribution Type: Constant

Data: Site-Specific Experimental Data

Three hydraulic tests were performed in boreholes where the tested interval included DRZ anhydrite and/or halite in the underground WIPP facility. The radius of visibility for the DRZ tests ranged from 0.6 feet (0.2 meters) to several feet (meters). The test in QPP05 is considered representative of the DRZ not because of the depth of the test interval, but because of the proximity of the test interval to Room Q. A clear distinction is visible between the tests performed in halite (C2H01-A & QPP05) and the test performed in anhydrite (OH-36). The halite tests have much lower values of k and compressibility and higher pore pressure, while the anhydrite test displays high relative k and compressibility and zero pore pressure. The difference being caused by the style of deformation - brittle for anhydrite and ductile for halite.

See: Data Package for DRZ Rock Compressibility (SWCF-A:WBS1.2.07.1:PDD:QA: SALADO:PKG16:DRZ ROCK COMPRESSIBILITY)

Discussion:

Parameter values for the DRZ are defined for two time periods: 1) the 'waste emplacement' time associated with a fresh panel (-5 to 0 years), and 2) the sealed repository time period from 0 to 10,000 years. Data for the first time period was used for the entire lifetime of the facility.

Parameter(s): Rock Compressibility - Disturbed Rock Zone

References:

SWCF-A:WBS1.2.07.1:PDD:QA:SALADO:PKG16:DRZ ROCK COMPRESSIBILITY

D16-8

SHAFT MATERIAL PARAMETER VALUES

ALL SHAFT MATERIALS

Residual Brine Saturation - All Shaft Materials
Residual Gas Saturation - All Shaft Materials
Pore Distribution - All Shaft Materials
PCT-A Threshold Parameter - All Shaft Materials Except Asphalt
PCT-EXP Threshold Parameter - All Shaft Materials Except Asphalt
Maximum Capillary Pressure - All Shaft Materials

CLAY SHAFT MATERIALS

Intrinsic Permeability - All Clay Shaft Materials
Effective Porosity - All Clay Shaft Materials
Pore-volume Compressibility - Rustler Clay
Pore-volume Compressibility - Upper Clay
Pore-volume Compressibility - Lower Salado and Bottom Clays

SALT SHAFT MATERIAL

Intrinsic Permeability (mode) - Salt (T = 0 - 50 yrs)
Intrinsic Permeability (low value) - Salt (T = 0 - 50 yrs)
Intrinsic Permeability (high value) - Salt (T = 0 - 50 yrs)
Intrinsic Permeability (mode) - Salt (T = 50 - 100 yrs)
Intrinsic Permeability (low value) - Salt (T = 50 - 100 yrs)
Intrinsic Permeability (high value) - Salt (T = 50 - 100 yrs)
Intrinsic Permeability (mode) - Salt (T = 100 - 200 yrs)

Intrinsic Permeability (low value) - Salt (T = 100 - 200 yrs)
Intrinsic Permeability (high value) - Salt (T = 100 - 200 yrs)
Intrinsic Permeability (mode) - Salt (T > 200 yrs)
Intrinsic Permeability (low value) - Salt (T > 200 yrs)
Intrinsic Permeability (high value) - Salt (T > 200 yrs)
Effective Porosity - Salt Shaft Material
Pore-volume Compressibility - Salt Shaft Material

D16-8

SHAFT MATERIAL PARAMETER VALUES (CONTINUED)

CONCRETE AND CONCRETE MONOLITH SHAFT MATERIALS

Intrinsic Permeability - Concrete (T = 0 - 400 yrs)
Intrinsic Permeability- Concrete (T > 400 yrs) and
Concrete Monolith (T = 0 - 10,000 yrs)
Effective Porosity - Concrete and Concrete Monolith
Pore-volume Compressibility - Concrete and Concrete Monolith

ASPHALT SHAFT MATERIAL

Intrinsic Permeability - Asphalt Shaft Material
Effective Porosity - Asphalt Shaft Material
PCT-A Threshold Pressure Parameter - Asphalt Shaft Material
PCT-EXP Threshold Pressure Parameter - Asphalt Shaft Material
Pore-volume Compressibility - Asphalt Shaft Material

EARTHEN FILL SHAFT MATERIAL

Intrinsic Permeability - Earthen Fill Shaft Material
Effective Porosity - Earthen Fill Shaft Material
Pore-volume Compressibility - Earthen Fill Shaft Material

[a]Maximum Capillary Pressure parameters for all material regions are appended to "Repository and Panel Closures" section.

Parameter(s): Residual Brine Saturation - All Shaft Materials

Parameter Description:

The residual brine saturation (S_{br}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

EARTH	SAT_RBRN (#2511)
CLAY_RUS	SAT_RBRN (#3014)
CL_L_T1	SAT_RBRN (#2342)
CL_L_T2	SAT_RBRN (#2359)
CL_L_T3	SAT_RBRN (#2376)
CL_L_T4	SAT_RBRN (#3082)
CL_M_T1	SAT_RBRN (#2393)
CL_M_T2	SAT_RBRN (#2427)
CL_M_T4	SAT_RBRN (#2444)
CL_M_T5	SAT_RBRN (#2461)
CLAY_BOT	SAT_RBRN (#2325)
CONC_T1	SAT_RBRN (#2478)
CONC_T2	SAT_RBRN (#2494)
CONC_MON	SAT_RBRN (#3063)
ASPHALT	SAT_RBRN (#2291)
SALT_T1	SAT_RBRN (#2528)
SALT_T2	SAT_RBRN (#2545)
SALT_T3	SAT_RBRN (#2562)
SALT_T4	SAT_RBRN (#2579)
SALT_T5	SAT_RBRN (#2596)
SALT_T6	SAT_RBRN (#2992)

Parameter Value: 0.20

Parameter(s): Residual Brine Saturation - All Shaft Materials

mean	median	minimum	maximum	units
0.25	0.20	0	0.60	None

Distribution Type: Cumulative

Data: General Literature-Investigator Judgment

Data is based on a review of the available literature.

Discussion:

A literature search was conducted to obtain residual liquid saturation values for consolidated geologic materials, concrete, and asphalt. Residual liquid saturations for geologic materials were found in four references (Brooks and Corey, 1964; Lappala et al., 1987; Parker et al., 1987; and Rawls et al., 1982). Brooks and Corey (1964) determined residual saturations for five unconsolidated samples based on measured values of liquid saturation as a function of capillary pressure. Lappala et al. (1987) determined residual moisture content for 11 soils by obtaining best fits to measured moisture content versus pressure head data using three models. The residual moisture contents determined for each soil using the three models were averaged and divided by the reported porosity to obtain a residual liquid saturation for each soil. Parker et al. (1987) fit their saturation-pressure relationship to observed data to obtain residual saturations for a sandy and clayey porous media. Residual water contents reported by Rawls et al. (1982) for 11 soil texture classes were divided by the reported porosity to obtain residual saturations.

Mayer et al. (1992) reported a residual liquid saturation for normal concrete of 0.30 based on gas permeability testing. Data regarding residual liquid saturations in asphalt materials were not found in the literature.

The literature values of residual liquid saturation for geologic materials and concrete fall within the range of 0.0 to 0.6 with all but two values falling within the range of 0.0 to 0.4. An expected value of 0.2 is used for the residual liquid saturation of all seal components. The recommended range is 0.0 to 0.6 with a uniform distribution.

References:

Brooks, R.H., and A.T. Corey. 1964. *Hydraulic Properties of Porous Media*. Fort Collins, CO: Colorado State University.

References: (continued)

Lappala, E.G., R.W. Healy, and E.P. Weeks. 1987. *Documentation of Computer Program VS2D to Solve the Equations of Fluid Flow in Variably Saturated Porous Media.* Water-Resources Investigations Report 83-4099. Denver, CO: U.S. Geological Survey.

Mayer, G., F. Jacobs, and F.H. Wittmann. 1992. "Experimental Determination and Numerical Simulation of the Permeability of Cementitious Materials," *Nuclear Engineering and Design*. Vol. 138, 171-177.

Parker, J.C., R.J. Lenhard, and T. Kuppusamy. 1987. "A Parametric Model for Constitutive Properties Governing Multiphase Flow in Porous Media," *Water Resources Research.* Vol. 23, no. 4, 618-624.

Rawls, W.J., D.L. Brakensiek, and K.E. Saxton. 1982. "Estimation of Soil Water Properties," *Transactions of the ASAE.* 1316-1328.

Parameter(s): Residual Gas Saturation - All Shaft Materials

Parameter Description:

The residual gas saturation (S_{gr}) is required in the Brooks-Corey two-phase flow model to define the relative permeability and capillary pressure curves.

Material and Parameter Name(s):

EARTH	SAT_RGAS (#2512)
CLAY_RUS	SAT_RGAS (#3015)
CL_L_T1	SAT_RGAS (#2343)
CL_L_T2	SAT_RGAS (#2360)
CL_L_T3	SAT_RGAS (#2377)
CL_L_T4	SAT_RGAS (#3083)
CL_M_T1	SAT_RGAS (#2394)
CL_M_T2	SAT_RGAS (#2411)
CL_M_T3	SAT_RGAS (#2428)
CL_M_T4	SAT_RGAS (#2445)
CL_M_T5	SAT_RGAS (#2462)
CLAY_BOT	SAT_RGAS (#2326)
CONC_T1	SAT_RGAS (#2479)
CONC_T2	SAT_RGAS (#2495)
CONC_MON	SAT_RGAS (#3064)
ASPHALT	SAT_RGAS (#2292)
SALT_T1	SAT_RGAS (#2529)
SALT_T2	SAT_RGAS (#2546)
SALT_T3	SAT_RGAS (#2563)
SALT_T4	SAT_RGAS (#2580)
SALT_T5	SAT_RGAS (#2597)
SALT_T6	SAT_RGAS (#2993)

Parameter Value: 0.20

Parameter(s): Residual Gas Saturation - All Shaft Materials

mean	median	minimum	maximum	units
0.20	0.20	0	0.40	None

Distribution Type: Uniform

Data: General Literature-Investigator Judgment

Data is based on a review of the available literature.

Discussion:

A literature search was conducted to obtain residual gas saturation values for consolidated geologic materials, concrete, and asphalt. Mayer et al. (1992) reported a residual gas saturation for normal concrete of 0.18 based on gas permeability testing. Literature values for residual gas saturation of geologic materials and asphalt were not found. Due to this lack of literature data, an expected value and range are assumed for the seal components. The expected value is 0.2 and the expected range is 0.0 to 0.4 with a uniform distribution.

References:

Mayer, G., F. Jacobs, and F.H. Wittmann. 1992. "Experimental Determination and Numerical Simulation of the Permeability of Cementitious Materials," *Nuclear Engineering and Design*. Vol. 138, 171-177.

Parameter(s): Pore Distribution - All Shaft Materials

Parameter Description:

The pore size distribution parameter (λ) is required for the Brooks-Corey two-phase flow model.

Material and Parameter Name(s):

EARTH	PORE_DIS (#2499)
CLAY_RUS	PORE_DIS (#3006)
CL_L_T1	PORE_DIS (#2330)
CL_L_T2	PORE_DIS (#2347)
CL_L_T3	PORE_DIS (#2364)
CL_L_T4	PORE_DIS (#3076)
CL_M_T1	PORE_DIS (#2381)
CL_M_T2	PORE_DIS (#2398)
CL_M_T3	PORE_DIS (#2415)
CL_M_T4	PORE_DIS (#2432)
CL_M_T5	PORE_DIS (#2449)
CLAY_BOT	PORE_DIS (#2313)
CONC_T1	PORE_DIS (#2466)
CONC_T2	PORE_DIS (#2483)
CONC_MON	PORE_DIS (#3057)
ASPHALT	PORE_DIS (#2279)
SALT_T1	PORE_DIS (#2516)
SALT_T2	PORE_DIS (#2533)
SALT_T3	PORE_DIS (#2550)
SALT_T4	PORE_DIS (#2567)
SALT_T5	PORE_DIS (#2484)
SALT_T6	PORE_DIS (#2989)

Parameter Value: 0.94

Parameter(s): Pore Distribution - All Shaft Materials

mean	median	minimum	maximum	units
2.52	0.94	0.11	8.1	None

Distribution Type: Cumulative

Data: General Literature-Investigator Judgment

Data is based on a review of the available literature.

Discussion:

A literature search was conducted to find pore distribution (i.e., lambda) values for geologic materials and concrete. For geologic materials, 81 lambda values were found in five references (Brooks and Corey, 1964; Mualem, 1976; Rawls et al., 1982; Haverkamp and Parlange, 1986; and Lappala et al., 1987). In addition, 38 lambda values were calculated from values of the van Genuchten parameter n found in six references (van Genuchten, 1980; van Genuchten and Nielsen, 1985; Hopmans and Overmars, 1986; Parker et al., 1987; Stephens et al., 1988; and Wosten and van Genuchten, 1988).

The total number of lambda values found in the literature or calculated from n values found in the literature was 119. In a few cases, different literature sources reported different values of lambda and/or n for the same materials. For this situation, the different lambda values were arithmetically averaged to obtain a single value for the material. This procedure yielded lambda values for a total of 85 different geologic materials.

Brooks and Corey (1964) report lambda values for five unconsolidated samples and two consolidated samples determined by fitting to observed capillary pressure curves. Lambda values for 42 soils determined by fitting to observed drainage data are presented in Mualem (1976). Rawls et al. (1982) give lambda values for the 11 USDA soil texture classes. They fit the measured water retention-matrix potential data reported in 26 sources and averaged within texture classes. Haverkamp and Parlange (1986) report lambda values for ten sandy soils. They estimated the value of lambda using the cumulative particle-size distribution function. Lambda values determined by fitting to experimental data for 11 soils are given in Lappala et al. (1987).

van Genuchten (1980) reports n values for five soils. These values were determined by fitting his model to measured conductivity curves. Values of n for four soils determined by fitting to observed data are given in van Genuchten and Nielsen (1985). Hopmans and Overmars (1986) determined n values for a Norfolk sandy loam at two soil temperatures by fitting to experimental data. Parker et al. (1987) report n values for a sandy porous

Discussion: (continued)

media and a clayey porous media which they determined by fitting to observed data. Stephens et al. (1988) determined five n values for three stratigraphic units underlying the IT Corporation's Imperial Valley Facility located in southern California. The n values were determined by fitting to the data obtained from in-situ field testing. A single n value was determined for two units and three n values were determined for a third stratified unit. The latter were for individual clay and silt layers and for the composite unit. Observed hydraulic conductivity and water retention data from soils in the Netherlands were used by Wosten and van Genuchten (1988) to obtained n values. They report 20 average n values for 105 coarse-textured samples, 43 medium-textured samples, and 49 fine-textured samples.

The lambda values range from 0.11 to 11.67 and have a median of 0.94. Based on the shape of the histogram and cumulative distribution function, it appears that the lambda values are lognormally distributed. The Lilliefors test for normality (Iman and Conover, 1983) was applied to the data to verify that the logarithm of the lambda values can be described by a normal distribution. The mean of the log lambda values was found to be -0.064 with a standard deviation of 1.08. The Lilliefors bounds represent the region within which 95 percent of normally distributed values will fall.

For concrete, a literature search yielded only one reference (Mayer et al., 1992). This reference indicates that the Corey (1954) relationships are appropriate for describing the two-phase characteristic curves for the normal concretes they tested. For asphalt materials, data regarding lambda values were not found in the literature.

In summary, the lambda values found in the literature for geologic materials were found to have a lognormal distribution. In the absence of literature data, the same lambda distribution type, expected value, and range were also used for the concrete and asphalt seal components.

References:

Brooks, R.H., and A.T. Corey. 1964. *Hydraulic Properties of Porous Media*. Fort Collins, CO: Colorado State University.

Corey, A.T. 1954. "The Interrelation Between Gas and Oil Relative Permeabilities," *Producer's Monthly*. Vol. XIX, no. 1, 38-41

Haverkamp, R., and J.Y. Parlange. 1986. "Predicting the Water-Retention Curve From Particle-Size Distribution: 1. Sandy Soils Without Organic Matter," *Soil Science*. Vol. 142, No. 6, 325-339.

References: (continued)

Hopmans, J.W., and B. Overmars. 1986. "Presentation and Application of an Analytical Model to Describe Soil Hydraulic Properties," *Journal of Hydrology*. Vol. 87, 135-143.

Iman, R.L., and W.J. Conover. 1983. *Modern Business Statistics*. New York, NY: John Wiley & Sons, Inc.

Lappala, E.G., R.W. Healy, and E.P. Weeks. 1987. *Documentation of Computer Program VS2D to Solve the Equations of Fluid Flow in Variably Saturated Porous Media.* Water-Resources Investigations Report 83-4099. Denver, CO: U.S. Geological Survey.

Mualem, Y. 1976. "A New Model for Predicting the Hydraulic Conductivity of Unsaturated Porous Media," *Water Resources Research*. Vol.12, no. 3, 513-522.

Parker, J.C., R.J. Lenhard, and T. Kuppusamy. 1987. "A Parametric Model for Constitutive Properties Governing Multiphase Flow in Porous Media," *Water Resources Research.* Vol. 23, no. 4, 618-624.

Rawls, W.J., D.L. Brakensiek, and K.E. Saxton. 1982. "Estimation of Soil Water Properties," *Transactions of the ASAE.* 1316-1328.

Stephens, D.B., M. Unruh, J. Havlena, R.G. Knowlton, Jr., E. Mattson, and W. Cox. 1988. "Vadose Zone Characterization of Low-Permeability Sediments Using Field Permeameters," *Ground Water Monitoring Review.* Vol. 8, 59-66.

van Genuchten, M. Th. 1980. "A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils," *Soil Science Society of America Journal.* Vol. 44, 892-898.

van Genuchten, M. Th., and D.R. Nielsen. 1985. "On Describing and Predicting the Hydraulic Properties of Unsaturated Soils," *Annales Geophysicae*. Vol. 3, no. 5, 615-628.

Wosten, J.H.M., and M. Th. van Genuchten. 1988. "Using Texture and Other Soil Properties to Predict the Unsaturated Soil Hydraulic Functions," *Soil Science Society of America Journal.* Vol. 52, 1762-1770.

Mayer, G., F. Jacobs, and F.H. Wittmann. 1992. "Experimental Determination and Numerical Simulation of the Permeability of Cementitious Materials," *Nuclear Engineering and Design*. Vol. 138, 171-177.

Parameter(s): PCT_A Threshold Pressure Parameter - All Shaft Materials Except Asphalt

Parameter Description:

PCT_A is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

EARTH	PCT_A (#2707)
CLAY_RUS	PCT_A (#3004)
CL_L_T1	PCT_A (#2642)
CL_L_T2	PCT_A (#2647)
CL_L_T3	PCT_A (#2652)
CL_L_T4	PCT_A (#3074)
CL_M_T1	PCT_A (#2657)
CL_M_T2	PCT_A (#2662)
CL_M_T3	PCT_A (#2667)
CL_M_T4	PCT_A (#2672)
CL_M_T5	PCT_A (#2677)
CLAY_BOT	PCT_A (#2637)
CONC_T1	PCT_A (#2682)
CONC_T2	PCT_A (#2687)
CONC_MON	PCT_A (#3055)
SALT_T1	PCT_A (#2745)
SALT_T2	PCT_A (#2750)
SALT_T3	PCT_A (#2755)
SALT_T4	PCT_A (#2760)
SALT_T5	PCT_A (#2765)
SALT_T6	PCT_A (#2987)

Parameter Value: 0.56

Units: Pa/m^2

Parameter(s): PCT_A Threshold Pressure Parameter - All Shaft Materials Except Asphalt

Distribution Type: Constant

Data: General Literature - Investigator Judgment

The two-phase flow parameters which, along with intrinsic permeability, describe the threshold capillary pressure (i.e., PCT_A and PCT_EXP) have not been measured for the Shaft Materials.

Discussion:

The Threshold Pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

For consolidated material, literature values for the coefficient range from 3×10^{-7} to 9×10^{-7} and literature values for the exponent range from -0.34 to -0.37 (Davies, 1991). The literature correlations separately considered carbonate, anhydrite, shale, and sandstone materials. Davies (1991) constructed a best-fit power curve to the combined data for all lithologies to obtain:

$$P_t = 5.6 \times 10^7 k^{0.346}$$

where P_t is the threshold pressure in MPa and k is the intrinsic permeability in m^2.

For intrinsic permeabilities less than 10^{-17} m^2, Davies (1991) found the threshold pressures estimated using the capillary tube model to be less accurate than those estimated using the intrinsic permeability correlations.

Pihlajavaara (1991) conducted gas permeability tests on normal concretes under wet conditions. Based on the results of 23 tests, he developed a relationship between threshold pressure and permeability. His results cover a threshold pressure range of about 10 to 0.3 MPa and a permeability range of about 10^{-21} to 10^{-18} m^2. The results of Pihlajavaara (1991) were compared to the threshold pressure-permeability correlation given in Davies (1991) above. Using, the calculated threshold pressures for permeabilities of 10^{-21}, 10^{-20}, 10^{-19}, and 10^{-18} m^2 are 10.3, 4.7, 2.1, and 0.9 MPa, respectively. These calculated values fall within the experimental data from Pihlajavaara (1991) for

Parameter(s): PCT_A Threshold Pressure Parameter - All Shaft Materials Except Asphalt

Discussion: (continued)

permeabilities between 10^{-20} and 10^{-18} m^2. It appears, however, that the experimental threshold pressure data of Pihlajavaara (1991) is limited for low permeability. This suggests that the correlation between threshold pressure and permeability given in the Davies equation is appropriate to use for the concrete seal materials as well as for seal components based on geologic materials.

Based on Davies (1991) work, the correlation between the threshold pressure and the intrinsic permeability given in the above equation is recommended for determination of the threshold pressure for all seal materials in future performance assessment calculations. The expected value and distribution for the threshold pressure will, therefore, be controlled by the expected value and distribution for the intrinsic permeability for each seal material.

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Pihlajavaara, S.E. 1991. "Long-Term Gas Permeability Properties of Concrete in Wet Repository Conditions," *Nuclear Engineering and Design.* Vol. 129, 41-48.

Parameter(s): PCT_EXP Threshold Pressure Parameter - All Shaft Materials Except Asphalt

Parameter Description:

PCT_EXP is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

EARTH	PCT_EXP (#2708)
CLAY_RUS	PCT_EXP (#3005)
CL_L_T1	PCT_EXP (#2643)
CL_L_T2	PCT_EXP (#2648)
CL_L_T3	PCT_EXP (#2653)
CL_L_T4	PCT_EXP (#3075)
CL_M_T1	PCT_EXP (#2658)
CL_M_T2	PCT_EXP (#2663)
CL_M_T3	PCT_EXP (#2668)
CL_M_T4	PCT_EXP (#2673)
CL_M_T5	PCT_EXP (#2678)
CLAY_BOT	PCT_EXP (#2638)
CONC_T1	PCT_EXP (#2683)
CONC_T2	PCT_EXP (#2688)
CONC_MON	PCT_EXP (#3056)
SALT_T1	PCT_EXP (#2746)
SALT_T2	PCT_EXP (#2751)
SALT_T3	PCT_EXP (#2756)
SALT_T4	PCT_EXP (#2761)
SALT_T5	PCT_EXP (#2766)
SALT_T6	PCT_EXP (#2988)

Parameter Value: -0.346

Units: None

Parameter(s): PCT_EXP Threshold Pressure Parameter - All Shaft Materials Except Asphalt

Distribution Type: Constant

Data: General Literature - Investigator Judgment

The two-phase flow parameters which, along with intrinsic permeability, describe the threshold capillary pressure (i.e., PCT_A and PCT_EXP) have not been measured for the Shaft Materials.

Discussion:

The Threshold Pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

For consolidated material, literature values for the coefficient range from 3×10^{-7} to 9×10^{-7} and literature values for the exponent range from -0.34 to -0.37 (Davies, 1991). The literature correlations separately considered carbonate, anhydrite, shale, and sandstone materials. Davies (1991) constructed a best-fit power curve to the combined data for all lithologies to obtain:

$$P_t = 5.6 \times 10^7 k^{0.346}$$

where P_t is the threshold pressure in MPa and k is the intrinsic permeability in m^2.

For intrinsic permeabilities less than 10^{-17} m^2, Davies (1991) found the threshold pressures estimated using the capillary tube model to be less accurate than those estimated using the intrinsic permeability correlations.

Pihlajavaara (1991) conducted gas permeability tests on normal concretes under wet conditions. Based on the results of 23 tests, he developed a relationship between threshold pressure and permeability. His results cover a threshold pressure range of about 10 to 0.3 MPa and a permeability range of about 10^{-21} to 10^{-18} m^2. The results of Pihlajavaara (1991) were compared to the threshold pressure-permeability correlation given in Davies (1991) above. Using , the calculated threshold pressures for permeabilities of 10^{-21}, 10^{-20}, 10^{-19}, and 10^{-18} m^2 are 10.3, 4.7, 2.1, and 0.9 MPa,

Parameter(s): PCT_EXP Threshold Pressure Parameter - All Shaft Materials Except Asphalt

Discussion: (continued)

respectively. These calculated values fall within the experimental data from Pihlajavaara (1991) for permeabilities between 10^{-20} and 10^{-18} m^2. It appears, however, that the experimental threshold pressure data of Pihlajavaara (1991) is limited for low permeability. This suggests that the correlation between threshold pressure and permeability given in the Davies equation is appropriate to use for the concrete seal materials as well as for seal components based on geologic materials.

Based on Davies (1991) work, the correlation between the threshold pressure and the intrinsic permeability given in the above equation is recommended for determination of the threshold pressure for all seal materials in future performance assessment calculations. The expected value and distribution for the threshold pressure will, therefore, be controlled by the expected value and distribution for the intrinsic permeability for each seal material.

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Pihlajavaara, S.E. 1991. "Long-Term Gas Permeability Properties of Concrete in Wet Repository Conditions," *Nuclear Engineering and Design.* Vol. 129, 41-48.

Parameter(s): Log of Intrinsic Permeability - All Clay Shaft Materials

Parameter Description:

Log of the vertical and horizontal intrinsic permeability for the Rustler compacted clay, the lower Salado compacted clay, and the upper Salado compacted clay, and the bottom clay column from 0 to 10,000 yrs.

Material and Parameter Name(s):

CLAY_RUS	PRMX_LOG (#3009)
CLAY_RUS	PRMY_LOG (#3010)
CLAY_RUS	PRMZ_LOG (#3011)
CL_L_T1	PRMX_LOG (#2334)
CL_L_T1	PRMY_LOG (#2335)
CL_L_T1	PRMZ_LOG (#2336)
CL_L_T2	PRMX_LOG (#2351)
CL_L_T2	PRMY_LOG (#2352)
CL_L_T2	PRMZ_LOG (#2353)
CL_L_T3	PRMX_LOG (#2368)
CL_L_T3	PRMY_LOG (#2369)
CL_L_T3	PRMZ_LOG (#2370)
CL_L_T4	PRMX_LOG (#3078)
CL_L_T4	PRMY_LOG (#3079)
CL_L_T4	PRMZ_LOG (#3080)
CL_M_T1	PRMX_LOG (#2385)
CL_M_T1	PRMY_LOG (#2386)
CL_M_T1	PRMZ_LOG (#2387)
CL_M_T2	PRMX_LOG (#2402)
CL_M_T2	PRMY_LOG (#2403)
CL_M_T2	PRMZ_LOG (#2404)
CL_M_T3	PRMX_LOG (#2419)
CL_M_T3	PRMY_LOG (#2420)
CL_M_T3	PRMZ_LOG (#2421)
CL_M_T4	PRMX_LOG (#2436)
CL_M_T4	PRMY_LOG (#2437)
CL_M_T4	PRMZ_LOG (#2438)

Parameter(s): Log of Intrinsic Permeability - All Clay Shaft Materials

Material and Parameter Name(s): (continued)

CL_M_T5	PRMX_LOG (#2453)
CL_M_T5	PRMY_LOG (#2454)
CL_M_T5	PRMZ_LOG (#2455)
CLAY_BOT	PRMX_LOG (#2317)
CLAY_BOT	PRMY_LOG (#2318)
CLAY_BOT	PRMZ_LOG (#2319)

Parameter Value: -18.3010 5×10^{-19}

mean	median	minimum	maximum	units
-18.8670	-18.3010	-21.0000	-17.3010	$\log(m^2)$

Distribution Type: Triangular

Data: General Literature - Investigator Judgment and Site-Specific Experimental Data

Data is based on a review of the available literature and a series of small-scale in-situ tests.

Discussion:

A significant body of literature regarding compacted bentonite permeability was reviewed. Most literature sources report hydraulic conductivity rather than intrinsic permeability. Hydraulic conductivity can be related to intrinsic permeability through the fluid density and viscosity and the acceleration of gravity. The permeability of reported bentonites ranges from 1×10^{-21} m^2 to 1×10^{-15} m^2.

A series of in-situ tests were conducted to evaluate the feasibility of various candidate materials to be used for sealing materials at the WIPP Site. These tests are referred to as the Small Scale Seal Performance Tests (SSSPT). Results from these tests support the use of compacted bentonite as a sealing material at the WIPP Site and in the Salado Formation. Test Series D tested two 100 percent bentonite vertical seals emplaced in vertical boreholes within the Salado Formation at the repository horizon. The diameter of each seal was 2.9 feet (0.91 meters) and the length of each seal was 2.9 feet (0.91 meters). Cores of the two bentonite seals had initial dry densities of 1.8 and 2.0 g/cm^3. Pressure differentials of 0.72 and 0.32 MPa were maintained across the bentonite seals with a brine

Discussion: (continued)

reservoir on the upstream (bottom) of the seals for several years. Over the course of the seal test, no visible brine was observed at the downstream end of the seals. Because the saturation state of the bentonite seals is unknown, determination of the absolute permeability of the bentonite seals cannot be estimated precisely. However, a bounding calculation of permeability was reported by Knowles and Howard (1996) for the bentonite seals of 1×10^{-19} m^2.

The compacted bentonite material specification (Hansen, 1995) specifies that the clay seals will be emplaced at a dry density of 1.8 to 2.0 g/cm^3. Based upon this information, a distribution function for clay permeability was developed. The basis for the proposed distribution is the following:

(1) A practical minimum for the distribution can be specified at 1×10^{-21} m^2.

(2) Assuming that the effective dry density of the bentonite emplaced in the seals only varies from 1.8 to 2.0 g/cm^3, then a maximum expected permeability can be extrapolated as 1×10^{-19} m^2.

(3) The material specification does require that the bentonite be emplaced at a high density, between 1.8 and 2.0 g/cm^3. However, the effective dry density of emplacement is somewhat uncertain. Uncertainty exists in being able to emplace mass columns of bentonite at such high densities. To address this uncertainty, it is assumed that the compacted clay may be emplaced at a dry density as low as 1.6 g/cm^3. This actuality is not considered to be a high probability, but cannot be completely ruled out. At 1.6 g/cm^3, the maximum permeability for the clay would be approximately 5×10^{-19} m^2. Therefore, assuming no salinity effects, a range of permeability from 1×10^{-21} to 5×10^{-19} m^2 with a best estimate of less than 1×10^{-19} m^2 is defined (assuming a best estimate emplacement density of 1.8 g/cm^3). It could be argued that the best estimate could be as low as 2×10^{-20} m^2.

(4) The literature reports that salinity increases permeability. However, these effects are greatly reduced at the emplacement densities specified for the shaft seal. At seawater salinities, Pusch et al. (1987) report the effects on permeability could be as much as a factor of 5 (one-half of an order of magnitude). Salinity effects are currently uncertain at the WIPP.

(5) To account for salinity effects, the maximum permeability is increased from 5×10^{-19} to 5×10^{-18} m^2. The best estimate permeability is increased by one-half order of magnitude to 5×10^{-19} m^2. The lower limit is held at 1×10^{-21} m^2. Because salinity effects are greatest at higher densities, the maximum is adjusted one full order of magnitude while the best estimate (assumed to reside at a density of 1.8 g/cm^3) is adjusted one-half of an order.

Parameter(s): Log of Intrinsic Permeability - All Clay Shaft Materials

Discussion: (continued)

The DRZ permeability adjacent to the Salado clay columns is explicitly calculated and is combined with the clay seal permeability in the BRAGFLO model. The resulting permeabilities are given below:

Clay Layer	Time Period	Intrinsic Permeability
Rustler	0 - 10,000 yrs	5.00×10^{-19}
Upper Salado	0 - 10 yrs	7.65×10^{-17}
Upper Salado	10 - 25 yrs	5.02×10^{-17}
Upper Salado	25 - 50 yrs	3.02×10^{-17}
Upper Salado	50 - 100 yrs	1.16×10^{-17}
Upper Salado	> 100 yrs	5.00×10^{-17}
Lower Salado	0 - 10	9.32×10^{-17}
Lower Salado	10 - 25	1.74×10^{-17}
Lower Salado	25 - 50	7.07×10^{-19}
Lower Salado	> 50	5.00×10^{-19}
Bottom Clay	0 - 10,000 yrs	5.00×10^{-19}

References:

Hansen, F.D. 1995. *Draft Report - Shaft Seal Material Specifications Framework.* Albuquerque, NM: Sandia National Laboratories.

Knowles, K.K., and Howard, C. L. 1996. "Field and Laboratory Testing of Seal Materials Proposed for the Waste Isolation Pilot Plant," *Proceedings of the Waste Management 1996-Symposium.* Tucson, AZ.

Pusch, R., L. Borgesson, and G. Ramqvist. 1987. *Final Report of the Borehole, Shaft, and Tunnel Sealing Test -- Volume I: Borehole Plugging.* SKB 87-01. Stockholm, Sweden: SKB.

Parameter(s): Effective Porosity - All Clay Shaft Materials

Parameter Description:

Effective porosity of the Rustler compacted clay, the lower Salado compacted clay, and the upper Salado compacted clay, and the bottom clay column from 0 to 10,000 yrs.

Material and Parameter Name(s):

CLAY_RUS	POROSITY (#3007)
CL_L_T1	POROSITY (#2331)
CL_L_T2	POROSITY (#2348)
CL_L_T3	POROSITY (#2365)
CL_L_T4	POROSITY (#3077)
CL_M_T1	POROSITY (#2382)
CL_M_T2	POROSITY (#2399)
CL_M_T3	POROSITY (#2416)
CL_M_T4	POROSITY (#2433)
CL_M_T5	POROSITY (#2450)
CLAY_BOT	POROSITY (#2314)

Parameter Value: 0.24

Units: m^3/m^3

Distribution Type: Constant

Data: Investigator Judgment

The effective porosity was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

The porosity of natural unconsolidated clays can vary from 0.4 to 0.8 (Freeze and Cherry, 1979). Consolidated clay formations such as shales have much smaller porosities ranging from 0.01 to 0.4 (Touloukian et al, 1981). The compacted clay seal will be composed of sodium bentonite.

Discussion: (continued)

The specific gravity of a commercial bentonite (Volclay GPG-30) is 2.5 (Ran and Daemen, 1995). The expected water content of the compacted clay may vary from 0.1 to 0.12 (Hansen, 1995b). The dry density of the compacted clay is specified to be from 1.8 to 2.0 g/cm^3 (Hansen, 1995a). Based upon estimates of the compacted clay water content, dry density, and specific gravity, the porosity of the compacted clay can be calculated. The calculated void ratio of the compacted clay varies from 0.25 to 0.39 and the corresponding porosity varies from 0.2 to 0.28. An average value of 0.24 is chosen as the compacted clay total porosity. Diamond (1970) found that the effective porosity of montmorillonites was approximately 35 percent less than the calculated porosity. Therefore, a constant value of 0.24 for effective porosity is very conservative.

References:

Diamond, S. 1970. "Pore Size Distributions in Clays," *Clays & Clay Minerals*. Vol. 18, 7-23.

Freeze, R.A., and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Hansen, F.D. 1995a. *Draft Report - Shaft Seal Material Specifications Framework*. 18 December 1995. Albuquerque, NM: Sandia National Laboratories.

Hansen, F.D. 1995b. Memorandum to T. Jones, INTERA Inc., November 30, 1995.

Ran, C., and J. Daemen. 1995. *Bentonite Properties with Corrections*. Memorandum to F. Hansen, Sandia National Laboratories, December 4, 1995.

Touloukian, Y.S., W.R. Judd, and R.F. Roy. 1981. *Physical Properties of Rocks and Minerals*. Volume II-2 of McGraw-Hill/Cindas Data Series on Material Properties, Y.S. Touloukian and C.Y. Ho, Editors. New York, NY: McGraw-Hill Book Company.

Parameter(s): Pore-Volume Compressibility - Rustler Clay

Parameter Description:

Pore-volume compressibility of the Rustler compacted clay column is used to calculate the specific storage of the porous medium which is required in BRAGFLO.

Material and Parameter Name(s):

CLAY_RUS COMP_RCK (#3001)

Parameter Value: 1.96×10^{-9}

Units: Pa^{-1}

Distribution Type: Constant

Data: Investigator Judgment

The pore-volume compressibility was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

The bulk modulus of the Rustler clay column will not change as a function of time because the Rustler will not creep in towards the shaft after closure. Therefore, the initial (emplaced) bulk modulus of 2.129×10^{9} (RE/SPEC, 1995) was used to calculate the Rustler clay column compressibility. Assuming a compacted clay porosity of 0.24, the pore-volume compressibility is 1.96×10^{-9} Pa^{-1} for the Rustler compacted clay column.

References:

RE/SPEC. 1995. *Transmittal of Bulk Modulus Values for Various Sealing Materials.* Memorandum to V. Kelley, INTERA Inc., December 27, 1995.

Parameter(s): Pore-Volume Compressibility - Upper Salado Clay

Parameter Description:

Pore-volume compressibility of the upper Salado compacted clay column is used to calculate the specific storage of the porous medium which is required in BRAGFLO.

Material and Parameter Name(s):

CL_M_T1	COMP_RCK (#2379)
CL_M_T2	COMP_RCK (#2396))
CL_M_T3	COMP_RCK (#2413)
CL_M_T4	COMP_RCK (#2430)
CL_M_T5	COMP_RCK (#2447)

Parameter Value: 1.81×10^{-9}

Units: Pa^{-1}

Distribution Type: Constant

Data: Investigator Judgment

The pore-volume compressibility was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

The bulk modulus is reported to be 2.297×10^{9} Pa for the Upper Salado compacted clay component at 150 years (RE/SPEC, 1995). The pore-volume compressibility will be treated as a constant in the BRAGFLO simulations. Therefore, the bulk modulus value at 150 years has been used to calculate the seal compressibility. Assuming a compacted clay porosity of 0.24, the pore-volume compressibility is 1.81×10^{-9} Pa^{-1} for the Upper Salado compacted clay.

References:

RE/SPEC. 1995. *Transmittal of Bulk Modulus Values for Various Sealing Materials*. Memorandum to V. Kelley, INTERA Inc., December 27, 1995.

Parameter(s): Pore-Volume Compressibility - Lower Salado and Bottom Clays

Parameter Description:

Pore-volume compressibility of the lower Salado compacted clay and the bottom clay column is used to calculate the specific storage of the porous medium which is required in BRAGFLO.

Material and Parameter Name(s):

CL_L_T1	COMP_RCK (#2328)
CL_L_T2	COMP_RCK (#2345)
CL_L_T3	COMP_RCK (#2362)
CL_L_T4	COMP_RCK (#3071)
CLAY_BOT	COMP_RCK (#2311)

Parameter Value: 1.59×10^{-9}

Units: Pa^{-1}

Distribution Type: Constant

Data: Investigator Judgment

The pore-volume compressibility was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

The bulk modulus is reported to be 2.627×10^{9} Pa for the Lower Salado compacted clay column at 150 years (RE/SPEC, 1995). The pore-volume compressibility will be treated as a constant in the BRAGFLO simulations. Therefore, the bulk modulus value at 150 years has been used to calculate the seal compressibility. Assuming a compacted clay porosity of 0.24, the pore-volume compressibility is 1.59×10^{-9} Pa^{-1} for the Lower Salado compacted clay column.

Parameter(s): Pore-Volume Compressibility - Lower Salado and Bottom Clays

References:

RE/SPEC. 1995. *Transmittal of Bulk Modulus Values for Various Sealing Materials.* Memorandum to V. Kelley, INTERA Inc., December 27, 1995.

Parameter(s): Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T = 0-50 yrs)

Parameter Description:

Log of the triangular distribution for the mode of the intrinsic permeability of the compacted salt column during the first 50 yrs.

Material and Parameter Name(s):

SALT_T1	PMLT_MD (#2940)
SALT_T2	PMLT_MD (#2948)
SALT_T3	PMLT_MD (#2956)

Parameter Value: -14.7825

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Investigator Judgment

Discussion:

Brodsky (1994) measured permeability as part of a comprehensive study to characterize both the consolidation characteristics and permeability of WIPP crushed salt. A total of 16 brine permeability tests were performed in the study including 15 tests performed on crushed salt specimens consolidated by Brodsky (1994) and one test performed on a crushed salt specimen. All tests were performed using brine as the permeant and specimens having nominal dimensions of 100 mm in diameter by 200 mm in length. The brine was manufactured by saturating distilled water with WIPP crushed salt ground to a fine powder. Saturation of the brine was assumed when salt precipitated out of solution. The permeability tests were performed using a brine-filled accumulator located on the upstream side of the specimen to induce brine pressure gradients that ranged from 0.05 MPa to 2.01 MPa and a buret located on the downstream side of the specimen to measure flow. In all tests, the flow-versus-time curves were nonlinear with higher flow rates measured early in the test and lower rates measured later in the test. The permeabilities reported by Brodsky (1994) represent values calculated from the high flow rates measured during the early portion of each test. These data show that permeability decreases as the fractional density increases.

Parameter(s): Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T = 0-50 yrs)

Discussion: (continued)

Hansen and Ahrens (1996) have reported gas permeability measurements from testing performed as part of a large-scale dynamic compaction demonstration using WIPP crushed salt. In this test, about 40 m^3 of WIPP crushed salt was placed in a steel cylindrical chamber and compacted in three lifts by dropping a 9,000-kg weight 15 m in a systematic pattern to achieve an input energy of three times Modified Proctor Energy. The chamber had a diameter of 3.65 m and a height of 3.65 m. Each lift was 1.2 m in original thickness and sufficient water was added to the lifts to bring the moisture content of the crushed salt up to about 1.0 percent (by weight). After the mass was compacted, seven vertical test holes were drilled into the compacted crushed salt to recover cores for density determinations and also to provide access for in situ gas permeability equipment. The fractional density of the compacted mass was determined to be about 0.88. A total of 14 permeability measurements were made in the test holes with a reported average permeability of 9.0×10^{-14} m^2.

RE/SPEC (1996) performed permeability tests on specimens prepared from cores recovered from the large-scale dynamic compaction test (described above) and from two small-scale dynamic compaction tests performed earlier (Hansen et al., 1995). The specimens tested were nominally 100 mm in diameter with lengths that varied from 100 mm to 200 mm. The tests were performed with nitrogen gas using a steady-state flow technique. Pressure gradients of 0.345 MPa or smaller were used in each test and rotameter flowmeters were used to measure gas flow rates. The specimens were confined with a pressure of 1 MPa during the permeability measurements. A total of 14 tests were performed including eight tests on specimens recovered from the large-scale dynamic compaction test, two tests on specimens from the first small-scale dynamic compaction test, and four tests on specimens from the second small-scale dynamic compaction test. The density of each specimen was determined before the permeability test was conducted. The data from these test are included in the attached table.

References:

Brodsky, N.S. 1994. *Hydrostatic and Shear Consolidation Tests With Permeability Measurements on Waste Isolation Pilot Plant Crushed Salt*. SAND93–7058. Albuquerque, NM: Sandia National Laboratories.

Hansen, F.D. and E.H. Ahrens. 1996. "Large-Scale Dynamic Compaction Demonstration Using WIPP Salt: Fielding and Preliminary Results," *Proceedings of the 4th Conference on the Mechanical Behavior of Salt, Montreal, Quebec, Canada, June*.

Parameter(s): Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T = 0-50 yrs)

References: (continued)

Hansen, F.D., E.. Ahrens, V.C. Tidwell, J.R. Tillerson, and N.S. Brodsky. 1995. "Dynamic Compaction of Salt: Initial Demonstration and Performance Testing," *Proceedings of the 35th U.S. Symposium on Rock Mechanics, University of Nevada, Reno, NV, June 5–7.*

RE/SPEC. 1996. *Probability Distribution Functions for Hydrologic Parameters of Waste Isolation Pilot Plant Shaft Sealing Materials for Handoff to WIPP Performance Assessment*. Calculation No. 325/13/02. February 1996.

Parameter(s): Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T = 0-50 yrs)

Table 1. Summary of Permeability Measurements for WIPP Crushed Salt

Specimen Identification No.	Fractional Density[a]	Permeability (m^2)	Reference
HC1A	0.8953	6.34 E-18	Brodsky, 1994
HC2A	0.9377	4.88 E-18	
HC3A	0.9333	2.14 E-19	
HC4A	0.9272	1.37 E-19	
HC5A	0.9907	3.42 E-22	
HC6A	0.9907	1.00 E-20	
SC1B	0.9546	3.54 E-19	
SC2A	0.9788	1.23 E-18	
SC3A	0.9607	3.22E-19	
SC4A	0.9428	5.18 E-19	
SC5A	1.0051	6.90 E-19	
SC6A	0.9678	2.56 E-20	
SC7A	0.9691	9.24 E-20	
SC8A	0.9629	1.29 E-19	
SC9A	0.9804	3.31 E-20	
19JUN90	0.9709	5.77 E-20	
In Situ	0.8800	9.00 E-14	Hansen and Ahrens, 1996
CS/DC1-4-1/3/1	0.9026	2.50 E-15	RE/SPEC Inc.
CS/DC1-8-3	0.8644	2.43 E-13	
CS/DC2/MM-1/1	0.8782	1.71 E-13	
CS/DC2/MM-2/1	0.8220	4.11 E-13	
CS/DC2/T2S-1/1	0.8626	5.71 E-13	
CS/DC2/T2S-3/2	0.8349	1.10 E-12	
DCCS3/3/3-1	0.8892	7.88 E-14	
DCCS3/2/1-1	0.9012	4.99 E-14	
DCCS3/1/1-4	0.8886	5.51 E-14	
DCCS3/3/1-4	0.9007	4.99 E-14	
	0.9160	2.63 E-14	
	0.9289	4.58 E-15	
	0.9339	4.95 E-15	

(a) Fractional density is based on an intact salt density of 2,160 kg m^{-3}.

Parameter(s): Log Triangular Distribution Low Value for Intrinsic Permeability - Salt Shaft Material (T = 0-50 yrs)

Parameter Description:

Log of the triangular distribution for the low value of the intrinsic permeability of the compacted salt column during the first 50 yrs.

Material and Parameter Name(s):

SALT_T1	PMLT_LO (#2941)
SALT_T2	PMLT_LO (#2949)
SALT_T3	PMLT_LO (#2957)

Parameter Value: -17.301

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Investigator Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution High Value for Intrinsic Permeability - Salt Shaft Material (T = 0-50 yrs)

Parameter Description:

Log of the triangular distribution for the high value of the intrinsic permeability of the compacted salt column during the first 50 yrs.

Material and Parameter Name(s):

SALT_T1	PMLT_HI (#2942)
SALT_T2	PMLT_HI (#2950)
SALT_T3	PMLT_HI (#2958)

Parameter Value: -12.2652

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Investigator Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T = 50-100 yrs)

Parameter Description:

Log of the triangular distribution for the mode of the intrinsic permeability of the compacted salt column from 50 to 100 yrs.

Material and Parameter Name(s):

SALT_T4 PMLT_MD (#2964)

Parameter Value: -17.1656

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Investigator Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution Low Value for Intrinsic Permeability - Salt Shaft Material (T = 50-100 yrs)

Parameter Description:

Log of the triangular distribution for the low value of the intrinsic permeability of the compacted salt column from 50-100 yrs.

Material and Parameter Name(s):

SALT_T4 PMLT_LO (#2965)

Parameter Value: -22.8761

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Investigator Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution High Value for Intrinsic Permeability - Salt Shaft Material (T = 50-100 yrs)

Parameter Description:

Log of the triangular distribution for the high value of the intrinsic permeability of the compacted salt column from 50 to 100 yrs.

Material and Parameter Name(s):

SALT_T4 PMLT_HI (#2966)

Parameter Value: -13.9508

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Investigator Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T = 100-200yrs)

Parameter Description:

Log of the triangular distribution for the mode of the intrinsic permeability of the compacted salt column from 100 to 200 yrs.

Material and Parameter Name(s):

SALT_T5 PMLT_MD (#2972)

Parameter Value: -19.2782

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Investigator Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution High Value for Intrinsic Permeability - Salt Shaft Material (T=100-200yrs)

Parameter Description:

Log of the triangular distribution for the high value of the intrinsic permeability of the compacted salt column from 100-200 yrs.

Material and Parameter Name(s):

SALT_T5 PMLT_HI (#2974)

Parameter Value: -15.4260

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Investigator Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution Low Value for Intrinsic Permeability - Salt Shaft Material (T= 100 -200 yrs)

Parameter Description:

Log of the triangular distribution for the low value of the intrinsic permeability of the compacted salt column from 100-200 yrs.

Material and Parameter Name(s):

SALT_T6 PMLT_LO (#2973)

Parameter Value: -22.8761

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Investigator Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T > 200 yrs)

Parameter Description:

Log of the triangular distribution for the mode of the intrinsic permeability of the compacted salt column after 200 yrs.

Material and Parameter Name(s):

SALT_T6 PMLT_MD (#2980)

Parameter Value: -20.2716

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Investigator Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution Low Value for Intrinsic Permeability - Salt Shaft Material (T > 200 yrs)

Parameter Description:

Log of the triangular distribution for the low value of the intrinsic permeability of the compacted salt column after 200 yrs.

Material and Parameter Name(s):

SALT_T6 PMLT_LO (#2981)

Parameter Value: -22.8761

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Investigator Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Log Triangular Distribution High Value for Intrinsic Permeability - Salt Shaft Material (T > 200 yrs)

Parameter Description:

Log of the triangular distribution for the high value of the intrinsic permeability of the compacted salt column after 200 yrs.

Material and Parameter Name(s):

SALT_T6 PMLT_HI (#2982)

Parameter Value: -17.6676

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data and Investigator Judgment

Discussion:

See: Discussion on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

References:

See: References on Parameter Sheet for "Log Triangular Distribution Mode for Intrinsic Permeability - Salt Shaft Material (T=0-50 yrs)."

Parameter(s): Effective Porosity - Salt Shaft Material

Parameter Description:

Effective porosity of the compacted salt column.

Material and Parameter Name(s):

SALT_T1	POROSITY (#2517)
SALT_T2	POROSITY (#2534)
SALT_T3	POROSITY (#2551)
SALT_T4	POROSITY (#2568)
SALT_T5	POROSITY (#2585)
SALT_T6	POROSITY (#2585)

Parameter Value: 0.05

Units: m^3/m^3

Distribution Type: Constant

Data: Investigator Judgment

The effective porosity was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

Data used in the development of transient best estimators for effective porosity are based on predictions of crushed salt density with time and subsequent calculation of porosity. Density predictions of the crushed salt column midheight have been made by Chieslar (1996). Porosity values determined from these density predictions are given in the attached table.

References:

Chieslar, J.D. 1996. *Material Property (Permeability, Bulk Moduli) Determination for Material WIPP Shaft Seals/Components, Calculation File 325/13/01*. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Effective Porosity - Salt Shaft Material

Table 1. Best Estimators for Porosity of Compacted Crushed Salt

Time After Seal Emplacement (years)	Density[a] ($kg\ m^{-3}$)	Porosity (percent)
0	1,944	10.0[b]
50	2,038	5.6[b]
100	2,121	1.8[b]
200	2,160	1.0[c]
400	2,160	1.0[c]

(a) After Chieslar (1996).
(b) Calculated from Equation 5-2.
(c) Equal to the porosity of Salado salt.

Parameter(s): Pore-Volume Compressibility - Salt Shaft Material

Parameter Description:

Pore-volume compressibility of the compacted salt column is used to calculate the specific storage of the porous medium which is required in BRAGFLO.

Material and Parameter Name(s):

SALT_T1	COMP_RCK (#2514)
SALT_T2	COMP_RCK (#2531)
SALT_T3	COMP_RCK (#2548)
SALT_T4	COMP_RCK (#2565)
SALT_T5	COMP_RCK (#2582)
SALT_T6	COMP_RCK (#2984)

Parameter Value: 1.60×10^{-9}

Units: Pa^{-1}

Distribution Type: Constant

Data: Investigator Judgment

The pore-volume compressibility was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

The bulk modulus of crushed salt has been measured in the laboratory at different levels of density; however, these measurements were performed on crushed salt obtained from the Mississippi Chemical Co. mine rather than from the WIPP. Although Holcomb and Hannum (1982) did not compare the bulk moduli of Mississippi Chemical Co. crushed salt and WIPP crushed salt directly, they did perform paired quasi-static compression tests on both materials and concluded that their respective quasi-static behaviors was similar.

RE/SPEC (1996) performed limited testing on specimens prepared from cores recovered from a large-scale dynamic compaction test (Hansen and Ahrens, 1996). The objectives of the testing were to (1) compare the elastic behavior of dynamically compacted crushed salt from the WIPP with the elastic behavior of Mississippi Chemical Co. crushed salt, and

Discussion: (continued)

(2) to obtain bulk modulus at fractional densities ranging from 0.9 to 1.0. Bulk modulus values were obtained as a function of density from a single test specimen by subjecting the specimen to repeated stages of hydrostatic consolidation followed by hydrostatic unload/reload cycles. The stages of hydrostatic consolidation were performed at hydrostatic stresses that ranged from 10 to 15 MPa and were conducted to induce changes in density. The hydrostatic unload/reload cycles were performed to obtain data appropriate for calculating bulk modulus. The data from these tests are summarized in the attached table along with the values of bulk modulus reported by Holcomb and Hannum (1982). The data indicate that the nonlinear elastic model for bulk modulus proposed by Sjaardema and Krieg (1987) is a reasonably good approximation both for Mississippi Chemical Co. crushed salt and for dynamically-compacted WIPP crushed salt.

References:

Hansen, F.D. and E.H. Ahrens. 1996. "Large-Scale Dynamic Compaction Demonstration Using WIPP Salt: Fielding and Preliminary Results," *Proceedings of the 4th Conference on the Mechanical Behavior of Salt, Montreal, Quebec, Canada, June*.

Holcomb, D.J. and D.W. Hannum. 1982. *Consolidation of Crushed Salt Backfill Under Conditions Appropriate to the WIPP Facility*. SAND82-0630. Albuquerque, NM: Sandia National Laboratories.

RE/SPEC. 1996. *Probability Distribution Functions for Hydrologic Parameters of Waste Isolation Pilot Plant Shaft Sealing Materials for Handoff to WIPP Performance Assessment. Calculation No. 325/13/02*. February 1996.

Sjaardema, G.D. and R.D. Krieg. 1987. *A Constitutive Model for the Consolidation of WIPP Crushed Salt and Its Use in Analyses of Backfilled Shaft and Drift Configurations*. SAND87-1977. Albuquerque, NM: Sandia National Laboratories.

Table 1. Summary of Crushed Salt Bulk Modulus Values

Specimen Identification No.	Dry Density ($kg\ m^{-3}$)	Bulk Modulus (GPa)
24MAY82[a]	1,540	0.562
	1,620	0.855
	1,670	1.269
	1,720	1.381
	1,760	1.823
	1,790	1.557
	1,830	1.938
	1,870	2.290
	1,900	2.700
DCCS3/3/1-4[b]	1,978	9.640
	2,006	11.300
	2,017	12.180

(a) Mississippi Chemical Co. Crushed salt [Holcomb and Hannum, 1982].

(b) Dynamically compacted WIPP crushed salt (test performed by RE/SPEC Inc.)

Parameter(s): Log of Intrinsic Permeability - Concrete (T = 0-400 yrs)

Parameter Description:

Log of the vertical and horizontal intrinsic permeability for the concrete column during the first 400 yrs.

Material and Parameter Name(s):

CONC_T1 PRMX_LOG (#2470)
CONC_T1 PRMY_LOG (#2471)
CONC_T1 PRMZ_LOG (#2472)

Parameter Value: -18.7496

mean	median	minimum	maximum	units
-18.8160	-18.7496	-20.699	-17.000	$\log(m^2)$

Distribution Type: Triangular

Data: Site-Specific Experimental Data

The intrinsic permeability of the concrete column is based on laboratory data.

Discussion:

As reported by Hansen (1995), traditional fresh-water concrete has been widely used for hydraulic applications such as water storage tanks, water and sewer systems, and massive dams because it has exceptionally low permeability (less than 10^{-20} m^2 upon hydration). Salado Mass Concrete (SMC) is a specially-designed mix that has been developed only recently (Wakeley et al., 1994; Wakeley et al., 1995), and as a result, no permeability testing has been performed and reported in the literature.

RE/SPEC (1996) performed two permeability tests on concrete specimens prepared from cores recovered from the WIPP SSSPT field experiments and one test on an SMC specimen prepared from a sample batched by the Waterways Experiment Station (WES). The specimens were tested as received with no attempts made to dry the specimens or to determine their moisture contents. Each test was performed using nitrogen gas as the permeant, flowmeters to measure gas flow, and fluid pressure gradients of either 0.3, 0.6,

Discussion: (continued)

or 0.75 MPa. Attempts were made to apply Klinkenberg corrections to measured values of permeability, but the range in pressure gradients used in the testing was not large enough to establish any particular trend when the permeability data were plotted as a function of reciprocal mean fluid pressure.

A total of 18 permeability measurements were made on the three specimens. The data suggest that the permeabilities of SMC are different from the permeabilities of the SSSPT concrete. Permeability of the SMC specimens ranged from 2.1×10^{-21} m^2 to 7.51×10^{-21} m^2 with an average of 4.71×10^{-21} m^2. Permeability of the SSSPT specimens ranged from 3.00×10^{-20} m^2 to 5.04×10^{-19} m^2 with and average of 2.18×10^{-19} m^2. Knowles and Howard (1995) presented results of field permeability tests performed in the WIPP SSSPT boreholes during 1985–1987 and 1993–1995. Although individual seal system component material permeabilities for concrete, DRZ salt, and salt were not determined, overall seal system permeabilities were determined and ranged from 1.0×10^{-20} m^2 to 1.0×10^{-17} m^2 and from 1.0×10^{-23} m^2 to 1.0×10^{-19} m^2 for the 1985–1987 tests and the 1993–1995 tests, respectively. These ranges encompass the laboratory values measured by RE/SPEC (1996).

References:

Hansen, F.D. 1995. *Shaft Seal Material Specifications Framework*. Albuquerque, NM: Sandia National Laboratories.

Knowles, M.K. and C.L. Howard. 1995. *Field and Laboratory Testing of Seal Materials Proposed for the Waste Isolation Pilot Plant*. SAND95-2082C. Albuquerque, NM: Sandia National Laboratories.

RE/SPEC. 1996. *Probability Distribution Functions for Hydrologic Parameters of Waste Isolation Pilot Plant Shaft Sealing Materials for Handoff to WIPP Performance Assessment*. Calculation No. 325/13/02. February 1996.

Wakeley, L.D., T.S. Poole, and J.P. Burkes. 1994. *Durability of Concrete Materials in High-Magnesium Brine*. SAND93-7073. Albuquerque, NM: Sandia National Laboratories.

Wakeley, L.D., P.T. Harrington, and F.D. Hansen. 1995. *Variability in Properties of Salado Mass Concrete*. SAND94-1495. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Log of Intrinsic Permeability - Concrete (T > 400 yrs) and Concrete Monolith (T = 0 - 10,000 yrs)

Parameter Description:

Log of the vertical and horizontal intrinsic permeability for the concrete column after 400 yrs. and the degraded concrete monolith at the base of the shaft from 0 to 10,000 yrs.

Material and Parameter Name(s):

CONC_T2	PRMX_LOG (#2486)
CONC_T2	PRMY_LOG (#2487)
CONC_T2	PRMZ_LOG (#2488)
CONC_MON	PRMX_LOG (#3059)
CONC_MON	PRMY_LOG (#3060)
CONC_MON	PRMZ_LOG (#3061)

Parameter Value: -14.0

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data

The intrinsic permeability of the concrete column is based on laboratory data.

Discussion:

As reported by Hansen (1995), traditional fresh-water concrete has been widely used for hydraulic applications such as water storage tanks, water and sewer systems, and massive dams because it has exceptionally low permeability (less than 10^{-20} m^2 upon hydration). Salado Mass Concrete (SMC) is a specially-designed mix that has been developed only recently (Wakeley et al., 1994; Wakeley et al., 1995), and as a result, no permeability testing has been performed and reported in the literature.

RE/SPEC (1996) performed two permeability tests on concrete specimens prepared from cores recovered from the WIPP SSSPT field experiments and one test on an SMC specimen prepared from a sample batched by the Waterways Experiment Station (WES).

Parameter(s): Log of Intrinsic Permeability - Concrete (T > 400 yrs) and Concrete Monolith (T = 0 - 10,000 yrs)

Discussion: (continued)

The specimens were tested as received with no attempts made to dry the specimens or to determine their moisture contents. Each test was performed using nitrogen gas as the permeant, flowmeters to measure gas flow, and fluid pressure gradients of either 0.3, 0.6, or 0.75 MPa. Attempts were made to apply Klinkenberg corrections to measured values of permeability, but the range in pressure gradients used in the testing was not large enough to establish any particular trend when the permeability data were plotted as a function of reciprocal mean fluid pressure.

A total of 18 permeability measurements were made on the three specimens. The data suggest that the permeabilities of SMC are different from the permeabilities of the SSSPT concrete. Permeability of the SMC specimens ranged from 2.1×10^{-21} m^2 to 7.51×10^{-21} m^2 with an average of 4.71×10^{-21} m^2. Permeability of the SSSPT specimens ranged from 3.00×10^{-20} m^2 to 5.04×10^{-19} m^2 with and average of 2.18×10^{-19} m^2. Knowles and Howard (1995) presented results of field permeability tests performed in the WIPP SSSPT boreholes during 1985–1987 and 1993–1995. Although individual seal system component material permeabilities for concrete, DRZ salt, and salt were not determined, overall seal system permeabilities were determined and ranged from 1.0×10^{-20} m^2 to 1.0×10^{-17} m^2 and from 1.0×10^{-23} m^2 to 1.0×10^{-19} m^2 for the 1985–1987 tests and the 1993–1995 tests, respectively. These ranges encompass the laboratory values measured by RE/SPEC (1996).

References:

Hansen, F.D. 1995. *Shaft Seal Material Specifications Framework*. Albuquerque, NM: Sandia National Laboratories.

Knowles, M.K. and C.L. Howard. 1995. *Field and Laboratory Testing of Seal Materials Proposed for the Waste Isolation Pilot Plant*. SAND95-2082C. Albuquerque, NM: Sandia National Laboratories.

RE/SPEC. 1996. *Probability Distribution Functions for Hydrologic Parameters of Waste Isolation Pilot Plant Shaft Sealing Materials for Handoff to WIPP Performance Assessment*. Calculation No. 325/13/02. February 1996.

Wakeley, L.D., T.S. Poole, and J.P. Burkes. 1994. *Durability of Concrete Materials in High-Magnesium Brine*. SAND93-7073. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Log of Intrinsic Permeability - Concrete (T > 400 yrs) and Concrete Monolith (T = 0 - 10,000 yrs)

References: (continued)

Wakeley, L.D., P.T. Harrington, and F.D. Hansen. 1995. *Variability in Properties of Salado Mass Concrete*. SAND94-1495. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Effective Porosity - Concrete and Concrete Monolith

Parameter Description:

Effective porosity of the concrete column and the degraded concrete monolith at the base of the shaft.

Material and Parameter Name(s):

CONC_T1	POROSITY (#2467)
CONC_T2	POROSITY (#2484)
CONC_MON	POROSITY (#3058)

Parameter Value: 0.05

Units: m^3/m^3

Distribution Type: Constant

Data: Site-Specific Experimental Data

The effective porosity of the concrete is based on air entrainment measurements made both on "green" concrete and on cured concrete cores.

Discussion:

Data used in the development of the best estimator of porosity for Salado Mass Concrete (SMC) were derived exclusively from a single literature source. Wakeley et al. (1995) measured air entrainment in both "green" SMC and cured SMC concrete cores. Measurements of air entrainment were made for 19 batches of "green" SMC. For each batch, air entrainment was determined at two distinct times, once at the beginning of the mixing process and once near the end of the mixing process (~2 hours). Air entrainment values of "green" SMC ranged from 1.1 to 3.3 percent with an average of 2.0 percent. Wakeley et al. (1995) also determined air entrainment from concrete cores recovered from two SMC cast monoliths identified as 161SM3 and 231SM3. These monoliths were prepared by discharging the portions of the SMC into oval galvanized metal tanks with approximate dimensions of 4 feet × 8 feet × 3 feet (1.2 meters × 2.4 meters × .9 meters). The SMC was allowed to flow freely from one end of the tank to the opposite end of the tank. After the monoliths had cured (six months), cores were recovered from six locations within the monolith to obtain samples for determining air entrainment (and other

Parameter(s): Effective Porosity - Concrete and Concrete Monolith

Discussion: (continued)

characteristics). The locations included three horizontal sampling positions; i.e., at discharge, near middle, and at far end, and two vertical sampling depths; i.e., top and bottom. Air voids were determined by sectioning the samples and using petrographic techniques Air entrainment values of the cast SMC ranged from 1.5 to 4.5 percent with an average of 3.2 percent.

References:

Wakeley, L.D., P.T. Harrington, and F.D. Hansen. 1995. *Variability in Properties of Salado Mass Concrete*. SAND94-1495. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Pore-Volume Compressibility - Concrete and Concrete Monolith

Parameter Description:

Pore-volume compressibility of the concrete column and the degraded concrete monolith at the base of the shaft is used to calculate the specific storage of the porous medium which is required in BRAGFLO.

Material and Parameter Name(s):

CONC_T1	COMP_RCK (#2464)
CONC_T2	COMP_RCK (#2481)
CONC_MON	COMP_RCK (#3052)

Parameter Value: 2.64×10^{-9}

Units: Pa^{-1}

Distribution Type: Constant

Data: General Literature - Investigator Judgment and Site-Specific Experimental Data

Data used in the development of the best estimator of bulk modulus for SMC were derived from two sources: (1) literature reviews; and (2) testing of both SMC cores and concrete cores recovered from the WIPP Small Scale Seal Performance Test (SSSPT).

Discussion:

Chen and Loken (1994) performed a literature review to develop material properties for use in rock mechanics analyses of SMC sealing materials. Their review revealed relatively few references, primarily because the SMC is a specially-designed mix that has been developed only recently (Wakeley et al., 1994; Wakeley et al.,1995), and, thus, has been subjected to very little mechanical testing. Citing Wakeley et al. (1994) and Van Sambeek (1987), Chen and Loken (1994) selected values for Young's modulus and Poisson's ratio for use in their analyses. The values selected for Young's modulus and Poisson's ratio were 30 GPa and 0.2, respectively. The bulk modulus for SMC was calculated to be 16.667 GPa. Wakeley et al. (1995) have reported values for Young's modulus as determined from unconfined compression tests of SMC; however, no lateral strain measurements were made during the testing so Poisson's ratio could not be determined.

Parameter(s): Pore-Volume Compressibility - Concrete and Concrete Monolith

Discussion: (continued)

Furthermore, bulk modulus could not be determined because only values of Young's modulus were determined from the testing.

A total of three compression tests were performed to measure Young's modulus and Poisson's ratio (RE/SPEC, 1996). These values were then used to compute bulk modulus. One test was performed on SMC batched and cast at the Waterways Experiment Station (WES); while two tests were performed on concrete recovered from the WIPP SSSPT. The results of the testing show that the value of bulk modulus determined for SMC concrete is 19.2 GPa which is approximately 15 percent higher than that used in rock mechanics analyses (Chen and Loken, 1994); while the average of the two values determined for SSSPT concrete is 30.1 GPa which is approximately 80 percent higher than that used in rock mechanics analyses. The concrete components emplaced in the Salado Formation are expected to comprise materials nearly identical to the SMC tested in the laboratory by RE/SPEC (1996). In view of the fact that only one test was performed on the SMC, the difference between the laboratory determined value and the rock mechanics analysis value is relatively small.

References:

Chen, R.U. and M.C. Loken. 1994. *Concrete/Steel Panel Seal Structural Response, Calculation File 325/03/01*. Albuquerque, NM: Sandia National Laboratories..

Van Sambeek, L.L., D.D. Luo, M.S. Lin, W. Ostrowski, and D. Oyenuga. 1993. *Seal Design Alternatives Study*. SAND92-7340. Albuquerque, NM: Sandia National Laboratories.

RE/SPEC. 1996. *Probability Distribution Functions for Hydrologic Parameters of Waste Isolation Pilot Plant Shaft Sealing Materials for Handoff to WIPP Performance Assessment. Calculation No. 325/13/02*. February 1996.

Wakeley, L.D., T.S. Poole, and J.P. Burkes. 1994. *Durability of Concrete Materials in High-Magnesium Brine*. SAND93-7073. Albuquerque, NM: Sandia National Laboratories.

Wakeley, L.D., P.T. Harrington, and F.D. Hansen. 1995. *Variability in Properties of Salado Mass Concrete*. SAND94-1495. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Log of Intrinsic Permeability - Asphalt Shaft Material

Parameter Description:

Log of the vertical and horizontal intrinsic permeability for the asphalt shaft material.

Material and Parameter Name(s):

ASPHALT	PRMX_LOG (#2283)
ASPHALT	PRMY_LOG (#2284)
ASPHALT	PRMZ_LOG (#2285)

Parameter Value: -20.000

mean	median	minimum	maximum	units
-19.667	-20.000	-21.000	-18.000	$\log(m^2)$

Distribution Type: Triangular

Data: Investigator Judgment

Discussion:

The WIPP asphalt will consist of an asphalt mastic mix (AMM) with a mineral filler. It will be approximately 10-20 percent asphalt by weight and air voids (porosity) will be 1 percent or less. The material specifications for the WIPP asphalt component (i.e., low void volume) are such that the permeability will be very low.

Several sources were reviewed in an attempt to find relevant information on the permeability of asphalt and asphaltic based construction materials. A large body of literature exists on applications of using asphalt as a barrier to water flow such as in the case of dams. Asphalt is routinely referred to in the literature as being impermeable, waterproof, etc. However, very little quantitative information exists regarding the permeability of asphalt. No permeability values were found for an AMM which shares the expected low void volume and high asphalt content that will exist in the shaft seal.

Robert Romine, a Research Scientist in the Environmental Technology Division of Pacific Northwest National Laboratories (PNNL) and technical expert to Sandia in the design and development of the specifications for the shaft seal AMM, expects the permeability for the WIPP AMM seal to be less than 1×10^{-20} m^2 (Romine, 1995).

Parameter(s): Log of Intrinsic Permeability - Asphalt Shaft Material

References:

Kelly, V., T. Jones, and J. Ogintz. 1996. Memorandum to Diane Hurtado, Re: WIPP Seal System Parameters for Performance Assessment BRAGFLO Compliance Calculations, January 15, 1996 (with updates).

Romine, R. 1995. E-mail communication to V. Kelley, INTERA Inc., November 29, 1995.

Parameter(s): Effective Porosity - Asphalt Shaft Material

Parameter Description:

Effective porosity of the asphalt shaft material.

Material and Parameter Name(s):

ASPHALT POROSITY (#2280)

Parameter Value: 0.01

Units: m^3/m^3

Distribution Type: Constant

Data: Investigator Judgment

The effective porosity of the asphalt shaft material is specified in the material specifications.

Discussion:

The WIPP asphalt will consist of an asphalt mastic mix (AMM) with a mineral filler. It will be approximately 10-20 percent asphalt by weight. Hansen (1995) reports that the asphalt column composed of an AMM will have an extremely low air void content (porosity), between 1 and 2 percent. It is assumed that the asphalt column has a porosity of 0.01.

References:

Hansen, F.D. 1995. *Draft Report - Shaft Seal Material Specifications Framework.* Albuquerque, NM: Sandia National Laboratories.

Kelly, V., T. Jones, and J. Ogintz. 1996. Memorandum to Diane Hurtado, Re: WIPP Seal System Parameters for Performance Assessment BRAGFLO Compliance Calculations, January 15, 1996 (with updates).

Parameter(s): PCT_A Threshold Pressure Parameter - Asphalt Shaft Material

Parameter Description:

PCT_A is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

ASPHALT PCT_A (#2600)

Parameter Value: 0

Units: Pa/m^2

Data: Investigator Judgment

The two-phase flow parameters which, along with intrinsic permeability, describe the threshold capillary pressure (i.e., PCT_A and PCT_EXP) have not been measured for the Asphalt Shaft Material.

Discussion:

The Threshold Pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

Data regarding threshold pressures in asphalt materials were not found in the literature. Therefore, the Davies (1991) relationship is assumed to be applicable for the asphalt seal material.

Parameter(s): PCT_A Threshold Pressure Parameter - Asphalt Shaft Material

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Asphalt Shaft Material

Parameter Description:

PCT_EXP is used to calculate the threshold pressure (P_t), as required in the Brooks-Corey two-phase flow model to define the capillary pressure curve.

Material and Parameter Name(s):

ASPHALT PCT_EXP (#2601)

Parameter Value: 0

Units: None

Data: Investigator Judgment

The two-phase flow parameters which, along with intrinsic permeability, describe the threshold capillary pressure (i.e., PCT_EXP and PCT_EXP) have not been measured for the Asphalt Shaft Material.

Discussion:

The Threshold Pressure (P_t), as defined by Davies (1991), is the pressure at which gas begins to flow through porous media at the residual gas saturation. P_t is determined from the relationship:

$$P_t = PCT\_A \bullet k^{(PCT\_EXP)}$$

where P_t is the threshold pressure in units of Pa, PCT_A and PCT_EXP are constants, and k is the permeability in units of m^2.

Data regarding threshold pressures in asphalt materials were not found in the literature. Therefore, the Davies (1991) relationship is assumed to be applicable for the asphalt seal material.

Parameter(s): PCT_EXP Threshold Pressure Parameter - Asphalt Shaft Material

References:

Davies, P.B. 1991. *Evaluation of the Role of Threshold Pressure in Controlling Flow of Waste-Generated Gas into Bedded Salt at the Waste Isolation Pilot Plant.* SAND90-3246. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Pore-Volume Compressibility - Asphalt Shaft Material

Parameter Description:

Pore-volume compressibility of the asphalt shaft material is required for specification in BRAGFLO and makes up part of the hydraulic diffusivity term for a porous medium.

Material and Parameter Name(s):

ASPHALT COMP_RCK (#2277)

Parameter Value: 2.97×10^{-8}

Units: Pa^{-1}

Distribution Type: Constant

Data: Investigator Judgment

The pore-volume compressibility was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

The bulk modulus reported for asphalt is 3.371×10^{9} Pa (RE/SPEC, 1995). Assuming an asphalt porosity of 0.01, the pore-volume compressibility for the asphalt column is 2.97×10^{-8} Pa^{-1}.

References:

RE/SPEC. 1995. *Transmittal of Bulk Modulus Values for Various Sealing Materials*. Memorandum to V. Kelley, INTERA Inc., December 27, 1995.

Parameter(s): Log of Intrinsic Permeability - Earthen Fill Shaft Material

Parameter Description:

Log of the vertical and horizontal intrinsic permeability for the earthen fill material.

Material and Parameter Name(s):

EARTH PRMX_LOG (#2503)
EARTH PRMY_LOG (#2504)
EARTH PRMZ_LOG (#2505)

Parameter Value: -14.0

mean	median	minimum	maximum	units
-14.333	-14.000	-17.000	-12.000	$\log(m^2)$

Distribution Type: Triangular

Data: General Literature-Investigator Judgment

Data is based on a review of the available literature.

Discussion:

The intrinsic permeability values for the earthen fill material are based upon literature values of permeability for soils which are classified as SC or SM (clayey sand or silty sand) according to the Unified Soil Classification System. These references include Freeze and Cherry (1979), Davis and DeWiest (1966), and deMarsily (1986). All of the literature sources, with the exception of one, report a maximum permeability for these types of soils of 1×10^{-12} m^2. Freeze and Cherry (1979) report a maximum hydraulic conductivity for unconsolidated silty sand of 0.002 m/s which converts to a permeability of 2.04×10^{-10} m^2. This value is not considered for a maximum value because the earthen fill in the shaft will be consolidated through compaction. Because the earthen fill will be consolidated and because the permeability of the earthen fill column will be controlled by low permeability lifts (layers), the maximum permeability assumed for earthen fill is 1×10^{-12} m^2. The best estimate permeability is assumed to be 1×10^{-14} m^2 and the minimum permeability is assumed to be 1×10^{-17} m^2. The minimum value is based upon actual measurements of hydraulic conductivity of compacted SM and SC soils (U.S. Department of Interior, 1977; 1987). The permeability distribution is therefore log triangular with the preceding maximum, best estimate, and minimum values.

Parameter(s): Log of Intrinsic Permeability - Earthen Fill Shaft Material

References:

Davis, S.N. and R.J.M. DeWiest. 1966. *Hydrogeology*. New York, NY: John Wiley & Sons.

deMarsily, G. 1986. *Quantitative Hydrogeology*. Orlando, FL: Academic Press, Inc.

Freeze, R.A. and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Parameter(s): Effective Porosity - Earthen Fill Shaft Material

Parameter Description:

Effective porosity of the earthen fill material.

Material and Parameter Name(s):

EARTH POROSITY (#2500)

Parameter Value: 0.32

Units: m^3/m^3

Distribution Type: Constant

Data: Investigator Judgment

The effective porosity was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

The effective porosity of the earthen fill can be calculated from knowing the void ratio of the earthen fill. The void ratio for SM and SC (clayey sand or silty sand) soils is reported to be 0.48 (U.S. Department of Interior, 1977). Therefore, the calculated effective porosity of the earthen fill is 0.32.

References:

Kelly, V., T. Jones, and J. Ogintz. 1996. Memorandum to Diane Hurtado, Re: WIPP Seal System Parameters for Performance Assessment BRAGFLO Compliance Calculations, January 15, 1996 (with updates).

U.S. Department of Interior. 1977.

Parameter(s): Pore-Volume Compressibility - Earthen Fill Shaft Material

Parameter Description:

Pore-volume compressibility of the earthen fill material is required for specification in BRAGFLO and makes up part of the hydraulic diffusivity term for a porous medium.

Material and Parameter Name(s):

EARTH COMP_RCK (#2497)

Parameter Value: 3.1×10^{-8}

Units: Pa^{-1}

Distribution Type: Constant

CDF Graph: Not applicable

Data: Investigator Judgment

The pore-volume compressibility was calculated based upon the material specifications and standard geotechnical relationships.

Discussion:

The range of compressibility reported by Freeze and Cherry (1979) for clays is from 1×10^{-8} to 1×10^{-6} Pa^{-1}. The range of compressibility for sands reported by Freeze and Cherry (1979) is from 1×10^{-9} to 1×10^{-7} Pa^{-1}. The earthen fill represents a mixture of clay, silt and sand. Assuming a mixture and the ranges listed above, a representative compressibility is 1×10^{-8} Pa^{-1}. Dividing this compressibility by a porosity of 0.32 yields a pore-volume compressibility of 3.1×10^{-8} Pa^{-1}.

References:

Freeze, R.A., and J.A. Cherry. 1979. *Groundwater*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

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SUPPLEMENTARY INFORMATION

1. "Estimates of Gas-generation Parameters for the Lon-Term WIPP Performance" by Y. Wang and L. Brush, January 26, 1996.

2. "Implications of Geophysical Surveys in the WIPP Underground on the interpretation of the Relative Roles of the Three Proposed Conceptual Models for Salado Fluid Flow" by D. Barns, October 3, 1994.

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Sandia National Laboratories

Albuquerque, New Mexico 87185-

date: January 26, 1996

to: Martin S. Tierney (6741)

Yifeng Wang Larry Brush

from: Yifeng Wang & Larry Brush (Org. 6748)

subject: Estimates of Gas-Generation Parameters for The Long-Term WIPP Performance Assessment

Introduction

Steel corrosion and organic-material biodegradation have been identified as major gas-generation processes in the WIPP repository (Brush, 1995). Gas production will affect room closure and chemistry (Butcher, 1990; Brush, 1990). This memorandum provides the current estimates of gas-generation parameters for the long-term WIPP performance assessment. The parameters provided here include the rates of gas generation under inundated and humid conditions, the stoichiometric factors of gas generation reactions, and the probability of the occurrence of organic material biodegradation (Table 1). To satisfy the quality assurance (QA) requirement (QAP 9-5), we summarize all hand calculations for estimating these parameters in Appendices I and II.

Biodegradation of Organic Materials

Cellulosics, plastics, and rubbers have been identified as the major organic materials to be emplaced in the WIPP repository (DOE/CAO, 1996) and could be degraded by microbes in 10,000 years. Cellulosics has been demonstrated experimentally to be the most biodegradable among these materials (Francis et al., 1995). The occurrence of significant microbial gas generation in the repository will depend on: (1) whether microbes capable of consuming the emplaced organic materials will be present and active; (2) whether sufficient electron acceptors will be present and available; (3) whether enough nutrients will be present and available. Considering uncertainties in evaluation of these factors and also in order to bracket all possible effect of gas generation on the WIPP performance assessment, we assign a 50% probability to the occurrence of significant microbial gas generation.

• *Microbial Reactions*

Microorganism will consume cellulosics mainly via the following reaction pathways in the repository (Brush, 1995):

$$C_6H_{10}O_5 + 4.8\ H^+ + 4.8\ NO_3^- \rightarrow 7.4\ H_2O + 6\ CO_2 + 2.4\ N_2 \quad (1)$$

$$C_6H_{10}O_5 + 6\ H^+ + 3\ SO_4^{2-} \rightarrow 5\ H_2O + 6\ CO_2 + 3\ H_2S \quad (2)$$

$$C_6H_{10}O_5 \rightarrow 3\ CH_4 + 3\ CO_2. \quad (3)$$

We assume that Reactions 1 to 3 will proceed sequentially according to the energy yield of each reaction. Here we ignore the reaction pathways of aerobic respiration, Mn(IV) and Fe(III) dissimilatory reduction, since the quantities of O_2, Mn(IV) and Fe(III) initially present in the repository will be negligible relative to the other electron acceptors. In Reactions 1 to 3, biomass accumulation is also not taken into account. This is because significant biomass accumulation seems unlikely in the WIPP repository and the accumulated biomass, if any, will be recycled by microbes after all biodegradable cellulosics is consumed.

In addition to Reaction (3), methanogenesis may proceed via:

$$4\ H_2 + CO_2 \rightarrow CH_4 + 2\ H_2O. \quad (4)$$

However, this reaction will be ignored in our calculations, because (1) no experimental data are available to evaluate the rate of this reaction and (2) the net effect of this reaction is to reduce the total gas generation and the amount of CO_2 in the repository and, therefore, it is conservative to ignore this reaction in respect of repository pressurization and actinide solubility.

- *Rates of Cellulosics Biodegradation*

The rate of cellulosics biodegradtion was measured by incubating representative cellulose materials (filter paper, paper towels, and tissue) in WIPP brine with microbes enriched from various WIPP environments (Francis & Gillow, 1994; Francis et al., 1995). The incubation experiments were conducted under various conditions: aerobic or anaerobic, inundated or humid, with or without bentonite, amended or unamended with nutrients or NO_3^-. Because the repository is expected to become anoxic shortly after waste emplacement and also because bentonite will not be added as a backfill according to the current waste emplacement plan, we think that the experimental data from anaerobic incubation without bentonite present are most relevant to expected WIPP conditions. Considering that the current experimental data are mostly for denitrification (Reaction 1), but not sulfate reduction (Reaction 2) and methanogenesis (Reaction 3) (Francis & Gillow, 1994; Francis et al., 1995), we assume that the ranges of the rates of cellulosics biodegradation via sulfate reduction and methanogenesis are equal to those observed for denitrification.

We use CO_2 production data to estimate the rates of cellulosics biodegradation. There are two advantages of using CO_2 production data: (1) there are experimental data available on the CO_2 dissolution in WIPP brine (Telander & Westerman, 1995) and, therefore, it is easy to correct the CO_2 production data for gas dissolution (Appendix I); (2) since cellulosics biodegradation did not reach the stage of methanogenesis in the experiments, according to

Reactions 1 and 2, the consumption of one mole carbon of cellulosics will produce one mole of CO_2. This 1:1 relationship is independent of oxidation state of carbon in cellulosics. Therefore, it is rather straightforward to determine the amount of cellulosics biodegraded from the amount of CO_2 produced.

Experimental data show a strong dependence of CO_2 generation on the concentrations of nutrients and nitrate (Francis & Gillow, 1994; Francis et al., 1995). The maximum CO_2 generation was observed in nitrate-and-nutrient-amended samples. In those experiments, after a short lag phase, CO_2 first linearly increased with time and then approached some limiting value as its production rate diminished. If we assume that biodegradation is nitrate- or nutrient-limited, the experimental data can be explained by Michaelis-Menton kinetics (Chapelle, 1993). Michaelis-Menton kinetics, which describes the dependence of microbial reaction rate on substrate concentration, can be expressed by:

$$V = \frac{V_{max} S}{K_s + S} \tag{5}$$

where V is the microbial reaction rate; V_{max} is the maximum value of the rate; S is the concentration of the limiting substrate; K_s is a constant. Equation (5) states that the microbial reaction rate becomes independent of the substrate concentration, if the latter is high enough, i.e. $S >> K_s$ and $V = V_{max}$. In this circumstance, the reaction product will accumulate linearly with time before the substrate is sufficiently depleted. In other words, in our cases, the linear part of CO_2 vs. time curve will give the estimate of the maximum rate of cellulosics biodegradation.

From the experimental data of Francis & Gillow (1994) and Francis et al. (1995), we estimate the maximum and minimum rates of cellulosics biodegradation under inundated conditions to be 0.3 and 0.01 mole C/kg/year, respectively (Appendix I). The maximum rate is estimated from the data obtained from both NO_3^-- and nutrients-amended experiments, whereas the minimum rate is derived from the data obtained from the inoculated-only experiments without any nutrient and NO_3^- amendment. Under humid conditions, experimental data show no clear correlation between CO_2 production and nutrient concentration. The best estimate of the maximum rate of cellulosics biodegradation under humid condition is 0.04 mole C/kg/year (Appendix I). The minimum of the humid biodegradation rate is set to 0, corresponding to the cases where microbes become inactive due to nutrient and water stress.

- *Biodegradation of Plastics and Rubbers*

The rates of plastics and rubber biodegradation under expected WIPP conditions were

measured by Francis et al.(1995). The experimental data show that plastics and rubbers are much less biodegradable than cellulosics, although the data themselves are not sufficient for us to constrain the long-term biodegradation rate for plastics and rubbers. There are two factor that may potentially increase the biodegradibility of those materials: long time scale and cometabolism. Over a time scale of 10,000 years, plastics and rubbers may change their chemical properties and therefore their biodegradibility. Cometabolism means that microbes degrade an organic compound but do not use it as a source of energy or of their constituent elements, all of which are derived from other substrates (Alexander, 1994). In the WIPP repository, plastics and rubbers, which are resistant to biodegradation, may still be cometabolized with cellulosics and other more biodegradable organic compounds. Because of these uncertainties, we recommend a 50% chance for the biodegradation of plastics and rubbers in the event of significant microbial gas generation. We further suggest lumping plastics and rubbers into cellulosics and applying the ranges of cellulosics biodegradation rate to plastics and rubbers. This treatment is conservative in respect of repository pressurization and actinide solubility. We propose to use the following equation to convert plastics and rubbers to the carbon-equivalent quantity of cellulosics (Appendix I):

$$\text{total cellulosics (kg)} = \text{actual cellulosics (kg)} + 1.7\ \text{plastics (kg)} + \text{rubbers (kg)}. \qquad (6)$$

Anoxic Steel Corrosion

According to current waste inventory estimates, a large amount of steels will be emplaced in the WIPP repository (DOE/CAO, 1996). Those steels will be capable of reacting with the repository brine to form H_2 gas. Both thermodynamic calculations and experimental observations indicate that the H_2 gas can be generated to pressures exceeding the lithostatic pressure at the WIPP horizon, if enough brine enters the repository (Brush, 1990; Telander & Westerman, 1993, 1995). Since the repository will become anoxic shortly after waste emplacement and sealing, we here focus only on anoxic steel corrosion.

- *Steel Corrosion in the Absence of CO_2 and H_2S*

In this case, steel corrosion will follow the reaction (Telander & Westerman, 1993, 1995):

$$Fe + 2\ H_2O \rightarrow Fe(OH)_2 + H_2. \qquad (7)$$

In the Mg-rich WIPP brines (exemplified by Brine A), a significant fraction of Fe in the corrosion product is substituted by Mg. This substitution can substantially increase the stability of the corrosion product. Experimental observations indicate that steel corrosion can still proceed even at an 127 atm H_2 pressure (Telander & Westerman, 1995). Aside from this thermodynamic stability argument, the experimental observations indicate no

essential effect of Mg in the brine on the corrosion rate. As a matter of fact, the corrosion rates measured in Mg-rich Brine A are not significantly different from those measured in Mg-depleted Brine ERDA-6 (Telander & Westerman, 1995).

It was observed in the experiments that the steel corrosion rate decreased with time until some limiting rate was achieved (Telander & Westerman, 1995). Our long-term corrosion rate is estimated from the longest-term data available in a WIPP-relevant Brine A environment. The estimated inundated rate is 0.5 μm/year or 0.07 mole Fe /m^2/year (Appendix II). In addition, the corrosion rate is also found to increase with decreasing brine pH (Telander & Westerman, 1993, 1995). Without addition of CO_2 from microbial reactions, the pH in the repository is unlikely to go below its experimental value, which is about 10 (Telander & Westerman, 1993, 1995). Therefore, we recommend using 0.5 μm/year as the upper limit of inundated corrosion rate for the cases without microbial gas generation. On the other hand, the pH in the repository can be ~2 units higher than its experimental value due to the presence of $Ca(OH)_2$ as a cementious material in the waste, and thus, based on the scaling factor (= 0.01) given by Telander & Westerman (1995), the steel corrosion rate could be as low as 0.005 μm/year. In addition, the experimental work for Source Term Test Program (STTP) at Los Alamose National Laboratory indicates that salt crystallization on steel surface may possibly prevent the steel from corrosion. To include this possibility, we set the minimum inundated steel corrosion rate to 0.

The corrosion rate observed on specimens exposed to humid conditions is negligible, based on essentially non-existent presence of corrosion product and lack of apparent H_2 generation (Telander & Westerman, 1995). Therefore, we set the humid steel corrosion rate to 0.

- *Steel Corrosion in the Presence of CO_2 and H_2S*

In the event of significant microbial gas generation, steel corrosion can proceed via the following reactions in addition to Reaction (7) (Telander & Westerman, 1993, 1995):

$$Fe + CO_2 + H_2O \rightarrow FeCO_3 + H_2 \quad (8)$$
$$Fe + H_2S \rightarrow FeS + H_2. \quad (9)$$

One possible effect of CO_2 and H_2S on steel corrosion is that they may cause passivation of the steel. Steel passivation was observed in the experiments in which large quantities of CO_2 and H_2S were added to the reaction vessels. It usually took place after tens of days and was caused by the formation of a protective layer of $FeCO_3$ or FeS on steel surfaces (Telander & Westerman, 1995). However, we think that this passivation is unlikely to occur under the repository conditions. This is because the microbial production rate of CO_2 and H_2S is too slow and it will take an exceedingly long time period (relative to the experimental time scale) for these gases in the repository to reach their concentration levels required for

passivation under the experimental conditions. The conclusion of no steel passivation under the WIPP repository conditions is consistent with other studies (e.g., Ikeda et al., 1983; Schmitt, 1983). In fact, aside from the previously cited work of Telander & Westerman (1993), total passivation of steel by CO_2 and H_2S in low-temperature solutions has not been reported, though varying degrees of corrosion inhibition have been observed.

In the absence of passivation, the microbial generation of CO_2 and H_2S will increase steel corrosion rates in the repository either by lowering the repository pH or by initiating additional reaction pathways (Reactions 8 and 9) (Telander & Westerman, 1995). We take this effect into account by modifying the sampling range of steel corrosion rate. Obviously, Reactions 8 and 9 will be limited by microbial CO_2 and H_2S production, and therefore the upper limit of the reaction rate can be estimated from the maximum cellulosics biodegradation rate, which is 0.3 mole/kg cellulosics/year, equivalent to 6 µm/year of steel corrosion rate (Appendix II). Thus, in the event of significant microbial gas generation, the upper limit of steel corrosion rate is 6.5 µm/year, the sum of the maximum rates of Reactions 7 through 9. The corresponding lower limit will be kept the same as that estimated for the cases without CO_2 production, i.e. 0.0 µm/year. Under humid conditions, experimental results show a negligible effect of CO_2 and H_2S on steel corrosion (Telander & Westerman, 1995). We thus set the humid corrosion rate to 0.

Stoichiometric Factors in the Average-Stoichiometry Model

In the Average-Stoichiometry Model, which is currently implemented in BRAGFLO, microbial gas generation is represented by the overall reaction:

$$\frac{1}{6}C_6H_{10}O_5 \;+\; unknown \;\rightarrow\; y\;\; gas \;+\; unknown \qquad (10)$$

and H_2 production due to steel corrosion is described by:

$$Fe + \frac{4+2x}{3}H_2O \rightarrow \frac{4-x}{3}H_2 + x\,Fe(OH)_2 + \frac{1-x}{3}Fe_3O_4. \qquad (11)$$

The stoichiometric factors x and y in Reaction 10 and 11 are estimated as follows.

• *Average-Stoichiometric FactorY in Microbial Reaction*

The stoichiometric factor y depends on the extent of the progress of each individual reaction pathway (Reactions 1 through 3). It can be estimated based on the inventory estimates of the transuranic waste to be emplaced in the Waste Isolation Pilot Plant (DOE/CAO, 1996; Drez, 1996).

First, we estimate the maximum quantities (in moles) of cellulosics and steels that will be potentially consumed in 10,000 years:

$$M'_{cel} = \min \left\{ \frac{6000 M_{cel}}{162},\ 10000 R'_C M_{cel} \right\} \tag{12}$$

$$M'_{Fe} = \min \left\{ \frac{1000 M_{Fe}}{56},\ 1410 R_{c,i} A \right\} \tag{13}$$

with

$$R'_c = \max \left\{ R_{m,i},\ R_{m,h} \right\} \tag{14}$$

where M_{cel} and M_{Fe} are the quantities (in kg) of cellulosics and steels initially present in the repository; $R_{c,i}$ is the inundated steel-corrosion rate (μm/year); $R_{m,i}$ and $R_{m,h}$ are the sampled rates of cellulosics biodegradation under inundated and humid conditions respectively (mole/kg/year). In Equation (13), we use the factor of 0.141 mole/μm/m^2 to convert steel-corrosion-rate unit from μm/year to mole/m^2/year (Telander and Westerman, 1995). Here, we assume that cellulosics biodegradation and steel corrosion both follow zero order reaction kinetics. Next, we calculate the average stoichiometric factor y by distributing M'_{cel} into individual biodegradation pathways. Consider two extreme cases, corresponding to the maximum and minimum values of y: (1) no reaction of microbially produced CO_2 and H_2S with steel and steel-corrosion products; (2) complete reaction of microbially produced CO_2 and H_2S with steel and steel-corrosion products.

If no CO_2 or H_2S is consumed by reactions with steel and steel-corrosion products, we would expect the maximum quantity of microbial gas production in the repository and therefore the maximum value for y. We assume that Reactions 1 to 3 will proceed sequentially. The maximum value of y can be estimated by averaging the gas-yields for all reaction pathways:

$$y_{\max} = \frac{\frac{8.4 M_{NO3}}{4.8} + \frac{9 M_{SO4}}{3} + \left(M'_{cel} - \frac{6 M_{NO3}}{4.8} - \frac{6 M_{SO4}}{3} \right)}{M'_{cel}} \tag{15}$$

where M_{NO3} and M_{SO4} are the quantities of NO_3^- and SO_4^{2-} (in moles) initially present in the repository.

If CO_2 or H_2S reacts with steel and steel-corrosion products, we expect that a significant quantity or, perhaps, all of these microbially produced gases would be consumed, thus forming $FeCO_3$ and FeS. This would result in the minimum value of y. The total gas consumed by those reactions (G) is:

$$G = \min\left\{\frac{6M_{NO3}}{4.8} + \frac{9M_{SO4}}{3} + \frac{3}{6}\left(M'_{cel} - \frac{6M_{NO3}}{4.8} - \frac{6M_{SO4}}{3}\right),\ M'_{Fe}\right\} \tag{16}$$

The minimum value of y can then be estimated by:

$$y_{\min} = \frac{\frac{8.4M_{NO3}}{4.8} + \frac{9M_{SO4}}{3} + \left(M'_{cel} - \frac{6M_{NO3}}{4.8} - \frac{6M_{SO4}}{3}\right) - G}{M'_{cel}} = y_{\max} - \frac{G}{M'_{cel}} \tag{17}$$

For each BRAGFLO simulation, ***y*** will be uniformly sampled over $[y_{min}, y_{max}]$:

$$y = y_{\min} + \beta(y_{\max} - y_{\min}) \tag{18}$$

with $0 \le \beta \le 1.0$. The calculational scheme proposed here automatically correlates ***y*** with waste inventory estimates as well as with reaction rates.

The above calculational scheme does not take into account the SO_4^{2-} that will be brought into repository by brine inflow. Based the previous BRAGFLO simulations for undisturbed cases, the total volume of the brine entering the repository in 10000 years is unlikely to be larger than 2.2×10^7 liters, the value corresponding to the case with unrealistically low gas generation and therefore the worst repository flooding. With a typical SO_4^{2-} concentration of 200 mM in WIPP brines (Brush, 1990), we estimate that the amount of SO_4^{2-} brought into the repository by brine inflow would be less than 0.4×10^7 moles. This amount of SO_4^{2-} will increase the fraction of sulfate reduction pathway in total cellulosics biodegradation only by less than 1%. Therefore, neglecting the sulfate brought by brine inflow would introduce an error of no more than a few percents in y values.

• *Average-Stoichiometric FactorX in Steel Corrosion Reaction*

While magnetite (Fe_3O_4) has been observed to form on steel as a corrosion product in low-Mg anoxic brines at elevated temperatures (Telander & Westerman, 1995) and in oxic brine (Haberman & Frydrych, 1988), there is no evidence that it will form at WIPP repository temperatures. If Fe_3O_4 were to form, it would be expected that H_2 would be produced (on a molar basis) in excess of Fe consumed. But, the anoxic corrosion experiments did not show the production of H_2 in excess of Fe reacted. Therefore, we set the stoichiometric factor x to 1.0 in Reaction 11.

Table 1. Gas-Generation Parameters for the Long-Term WIPP Performance Assessment

Parameter	Estimated Value
Probability of occurrence of significant microbial gas generation	50%
Probability of occurrence of plastics and rubber biodegradation in the event of significant gas generation	50%
Rate of inundated cellulosics biodegradation	0.01 - 0.3 mole C/kg/year
Rate of humid cellulosics biodegradation	0.0 - 0.04 mole C/kg/year
Rate of inundated steel corrosion for the cases without microbial gas generation	0.0 - 0.5 μm/year[1]
Rate of humid steel corrosion for the cases without microbial gas generation	0.0 μm/year
Rate of inundated steel corrosion for the cases with microbial gas generation	0.0 - 6.5 μm/year
Rate of humid steel corrosion for the cases with microbial gas generation	0.0 μm/year
Stoichiometric factor x in Reaction 11	1.0
Stoichiometric factor y in Reaction 10	calculated from Eqn. (18)
Factor β in Equation 18	0 - 1.0
NO_3^- initially present in the waste[2]	2.6×10^7 moles
SO_4^{2-} initial present in the waste[2]	6.6×10^6 moles

1. Multiplying 0.141 mole/μm/m^2 will convert the unit of steel corrosion rate from μm/year to mole/m^2/year (Telander & Westerman, 1993). 2. See Appendix I.6.

References

Alexander M. (1994) *Biodegradation and Bioremediation.* Academic Press, NY.

Brush L. H. (1990) *Test Plan for Laboratory and Modeling Studies of Repository and Radionuclide Chemistry for the Waste Isolation Pilot Plant.* SAND90-0266, Sandia national Laboratories, Albuquerque, NM.

Brush L. H. (1995) *Systems Priority Method - Iteration 2 Baseline Position Paper: Gas Generation in the Waste Isolation Pilot Plant.* Sandia National Laboratories, Albuquerque, NM.

Butcher B. M. (1990) *Preliminary Evaluation of Potential Engineered Modifications for the Waste Isolation Pilot Plant (WIPP).* SAND89-3095, Sandia National Laboratories, Albuquerque, NM.

Chapelle F. H. (1993) *Ground-Water Microbiology and Geochemistry.* John Wiley & Sons, NY.

DOE/CAO (1996) *Transuranic Waste Baseline Inventory Report.* (Rev. 2)

Drez P. (1996) Preliminary estimate for SNL/NM performance assessment calculations of nitrate, sulfate, and phosphate content in transuranic solidified wastes destine for disposal in WIPP. CTAC. (memo, 1/26/1996)

Francis A. J & Gillow J. B. (1994) *Effects of Microbial Processes on Gas Generation under Expected WIPP Repository Conditions: Progress Report through 1992.* SAND93-7036, Sandia National Laboratories, Albuquerque, NM.

Francis A. J., Gillow J. B. & Giles M. R. (1995) *Effects of Microbial Processes on Gas Generation under Expected WIPP Repository Conditions: Data Report for the Period 1993 - 1995.* (draft)

Haberman J. H. & Frydrych D. J. (1988) Corrosion studies of A216 Grade WCA steel in hydrothermal magnesium-containing brines. *Scientific Basis for Nuclear Waste Management XI, Materials Research Society Symposium Proceedings, Boston, MA, November 30 - December 3, 1987.* Eds. M. J. Apted and R. E. Westerman. Materials Research Society, Pittsburgh, PA. 112, 761-772.

Ikeda A., Ueda M. & Mukai S. (1983) CO_2 corrosion behavior and mechanism of carbon steel and alloy steel. *Corrosion '83, Anaheim, CA, April 18 - 22, 1983.* Paper no. 45. National Association of Corrosion Engineers, Huston, TX.

Molecke M. A. (1979) *Gas Generation from Transuranic Waste Degradation: Data Summary and Interpretation.* SAND79-1245, Sandia National Laboratories, Albuquerque, NM.

Schmitt G. (1983) CO_2 corrosion of steels - An attempt to range parameters and their effects. *Advances in CO_2 Corrosion in the Oil and Gas Industry, Proceedings of the*

Corrosion/83 Symposium, Anaheim, CA, April 18 - 19. Ed. R. H. Hausler. National Association of Corrosion Engineers, Huston, TX. 1, 1-2.

Telander M. R. & Westerman (1993) *Hydrogen Generation by Metal Corrosion in Simulated Waste Isolation Pilot Plant Environments: Progress Report for the Period November 1989 through December 1992.* SAND92-7347, Sandia National Laboratories, Albuquerque, NM.

Telander M. R. & Westerman (1995) *Hydrogen Generation by Metal Corrosion in Simulated Waste Isolation Pilot Plant Environments: Final Report.* (draft)

Appendix I. Hand Calculations for Estimating Microbial Gas generation Parameters

Name of person performing the calculations: Yifeng Wang, Jan. 26, 1996 Yifeng Wang
Name of person reviewing the calculations: Larry Brush, Jan. 26, 1996 Larry Brush

I.1 Correction for CO_2 Dissolution in the Brine

Data and definition of variables:

- TCO_2: Total CO_2 produced in an incubating experiment (moles)
- n: Measured CO_2 in headspace (moles)
- C_l: Dissolved CO_2 (moles/l)
- V_l: Brine volume = 0.104 (l) (Gillow, per. comm.)
- V_g: Headspace volume 0.046 (l) (Francis & Gillow, 1994)
- P: Partial pressure of CO_2 (atm)
- K: Partition coefficient of CO_2 between brine and gas phase = 0.01 (mole/l/atm) (Telander & Westerman, 1995)
- R: Gas constant = 0.082 (l•atm/mole/K)
- T: Temperature = 303.15 (K)

Assumption: Gaseous CO_2 approximately follows the idea gas law during these experiments.

Calculations:

$$TCO_2 = V_l*C_l + n = K*P*V_l + n = K*V_l*n*R*T/V_g + n = (K*V_l*R*T/V_g + 1)*n = (0.01*0.104*0.082*303.15/0.046 + 1)*n = 1.56*n \text{ (moles)}.$$

I.2 Estimate of the Maximum Inundated Cellulosics Biodegradation Rate

Data:

Source: Francis et al. 1995, p. 41, 148-149.
Experimental conditions: anaerobic inoculated, nutrients and nitrate amended

We only take the linear part of CO_2 vs. time curve:

time	CO_2
69 days	6.1 μmol/g of cel.
411 days	163 μmol/g of cel.

Calculations:

(1) Rate = (163 - 6.1)/(411 - 69) = 0.459 micro-moles/g/day = 0.168 mole/kg/year.
(2) Correcting it for dissolved CO_2 (see I.1), we finally have:
maximum rate = 0.168*1.56 = 0.3 mole/kg/year.

I.3 Estimate of the Minimum Inundated Cellulosics Biodegradation Rate

Data:
Source: Francis et al. 1995, p. 148-149.
Experimental conditions: anaerobic, inoculated only,

time	CO_2
0 days	2.1 µmol/g of cel.
1034 days	14.0 µmol/g of cel.

Calculations:
(1) Rate = (14.0 - 2.1)/(1034 - 0) = 0.0115 µmol/g/day = 0.004 mole/kg/year.
(2) Correcting it for dissolved CO_2 (Appendix I.1), we finally have:
minimum rate = 0.004*1.56 = 0.01 mole/kg/year.

I.4 Estimate of the Maximum Humid Cellulosics Biodegradation Rate

Data:
Source: Francis et al. 1995, p. 80.
Experimental conditions: anaerobic, inoculated only;
anaerobic, inoculated and amended

time	CO_2
6 days	(7.7 + 13.3)/2 = 10.5 µmol/g of cel.
415 days	(83.1 + 28.8)/2 = 56 µmol/g of cel.

Calculations:
Maximum rate = (56 - 10.5)/(415 - 6) = 0.11µmol/g/day = 0.04 mole/kg/year.

I.5 Convert Plastics and Rubbers to the Equivalent Quantity of Cellulosics

Data:

Source: Molecke (1979)

Celllulosics: $C_6H_{10}O_5$	M. W. = 162 g/mole
Polyethylene: $(-C_2H_4-)n$	M. W. = 28 g/mole
Polyvinychloride: $(-C_2H_3Cl-)n$	M. W. = 62 g/mole
Neoprene: $(-C_4H_5Cl-)n$	M. W. = 88 g/mole
Hypalon: $.(-(C_7H_{13}Cl)_{12}-(CHSO_2Cl)_{17}-]n$	M. W. = 3488 g/mole

Assumption:

Plastics: 80% polyethylene, 20% polyvinychloride
Rubbers: 50% neoprene, 50% hypalon
Based on Molecke (1979).

Calculations:

The P kilograms of plastics and R kilograms of rubbers are equivalent to the Q kilograms of cellulosics, based on carbon equivalence:

$$Q = (0.8*2*162/28/6 + 0.2*2*162/62/6)*P + (0.5*4*162/88/6 + 0.5*101*162/3488/6)*R = 1.7\ P + R \text{ (kilograms)}$$

I.6 Moles of NO_3^- and SO_4^{2-} Initially Present in the Waste

NO_3^- : $1.62x10^6$ kg (Drez, 1996) = $1000/62*1.62x10^6 = 2.6x10^7$ moles
SO_4^{2-} : $6.33x10^5$ kg (Drez, 1996) = $1000/96*6.33x10^5 = 6.6x10^6$ moles

Appendix II. Hand Calculations for Estimating Steel Corrosion Parameters

Name of person performing the calculations: Yifeng Wang, Jan. 26, 1996 Yifeng Wang
Name of person reviewing the calculations: Larry Brush, Jan. 26, 1996 Larry Brush

II.1 Estimate of the Maximum Inundated Steel Corrosion Rate for the Cases without Microbial Gas Generation

Data:

(1) Anoxic corrosion rate obtained from the 12th to 24th month experimental data = 0.71 μm/year (Telander & Westerman, 1993, p. 6-14).

(2) Scaling factor for the long-term rate = 70% (Telander & Westerman, 1995, p. 6 - 19).

Calculation:

The maximum long-term steel corrosion rate = 0.71*70% = 0.5 μm/year.

II.2 Estimate the Maximum Inundated Steel Corrosion Rate for the Cases with Microbial Gas Generation

Data:

Total transuranic waste volume: 1.5×10^5 m^3 (DOE/CAO, 1996)
Drum volume: 0.208 m^3 (DOE/CAO, 1996)
Surface area of steel: 6 m^2/drum (Brush, 1995)
Maximum cellulosics biodegradation rate: 0.3 mole/kg/year (Appendix I.2)
Maximum inundated steel corrosion rate for the cases without microbial gas generation: 0.5 μm/year.
Total cellulosics (including plastics and rubbers): 2.1×10^7 kg (DOE/CAO, 1996; Appendix I.5)
NO_3^- initially present in the waste: 2.6×10^7 moles (Appendix I.6)
SO_4^{2-} initial present in the waste: 6.6×10^6 moles (Appendix I.6)

Assumption:

Reactions 8 and 9 will be limited by microbial CO_2 and H_2S production rate.

Calculations:

(1) Number of drums = $1.5 \times 10^5 / 0.208 = 7.2 \times 10^5$ drums.

(2) Total moles of C in cellulosics = $6 * 2.1 \times 10^7 * 1000/162 = 7.74 \times 10^8$ moles of C.

Molar fraction of cellulosics biodegraded via denitrification = $2.6 \times 10^7 / 7.74 \times 10^8 = 3\%$.

Molar fraction of cellulosics biodegraded via sulfate reduction = $6.6 \times 10^6 / 7.74 \times 10^8 = 1\%$.

(3) Maximum CO_2 and H_2S production rate for the whole repository = $(0.03 + 1.5*0.01 + 0.5*0.96)*0.3*2.1 \times 10^7 = 3.3 \times 10^6$ moles CO2/year.

(4) Total steel surface area = $6*7.2 \times 10^5 = 4.32 \times 10^6$ m^2.

(5) The maximum rate of steel corrosion via Reactions 8 and 9 = $3.3 \times 10^6 / 4.32 \times 10^6$ = 0.8 mole Fe/m^2/year = 6 μm/year.

(6) The upper limit of inundated steel corrosion rate for the cases with microbial gas generation = 0.5 + 6 = 6.5 μm/year.

Distribution:

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MS 1341 L. H. Brush (Org. 6748)
MS 1341 Y. Wang (Org. 6748)
MS 1330 SWCF (Org. 6352), WBS 1.1.09.1.1(R)

Sandia National Laboratories

Albuquerque, New Mexico 87185-

date: February 29, 1996

to: Palmer Vaughn (Org. 6749)

Yifeng Wang Larry Brush

from: Yifeng Wang & Larry Brush (Org. 6748)

subject: An Adjustment for Using Steel Corrosion Rates in BRAGFLO to Reflect Repository Chemical Condition Changes due to Adding MgO as a Backfill

In order to control the repository chemistry, a sufficient amount of MgO will be added to the repository as a backfill. Through chemical reaction, this backfill will practically remove all CO_2 generated by microbial reactions and thus prevent any possibility of CO_2 accumulation in the repository. Therefore, the previously-suggested enhancement of steel corrosion by CO_2 (Wang & Brush, 1996) will be no longer possible. In our previous memo (Wang & Brush, 1996), two set of inundated steel corrosion rates were provided: one is 0.0 to 0.5 μm/year for the cases without CO_2 present and another is 0.0 to 6.5 μm/year for the cases with CO_2 present. *Considering the chemical condition changes due to adding MgO as a backfill, we suggest using the rate of 0 to 0.5 μm/year for* ***all*** *BRAGFLO simulations.*

Distribution:

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MS 1341 L. H. Brush (Org. 6748)
MS 1341 Y. Wang (Org. 6748)
MS 1330 SWCF (Org. 6352), WBS 1.1.09.1.1(RC)

Sandia National Laboratories

Albuquerque, New Mexico 87185-0750

date: October 3, 1994

to: Paul Davis, Org. 6307/MS-1345

from: David J. Borns, Org. 6116/MS-0750

subject: Implications of Geophysical Surveys in the WIPP Underground on the Interpretation of the Relative Roles of the Three Proposed Conceptual Models for Salado Fluid Flow

Introduction

The Technical Baseline Document for Salado Fluid Flow proposes three conceptual models for the observed brine inflow at the repository level. The three models are *1. Far-field Flow, 2. Redistribution of brine with the pore structure of the Disturbed Rock Zone, and 3. Clay consolidation within the Disturbed Rock Zone.* As we witnessed at the stakeholder's meeting in Carlsbad on 29 October, the relative roles and importance of these models for fluid flow appear unclear. The strategy to test these models remains uncertain..

However, observations based on geophysical surveys, predominantly electrical, suggest that *Far-Field Flow* is the dominant mechanism. In summary, these observations are:

1. The Disturbed Rock Zone (DRZ) is observed to resaturate in a sealed room, Room Q. This observation suggests that there is a source of brine external to the DRZ that with time is able to resaturate the porosity of the DRZ.
2. The Salado halites and interbeds can support electrical current flow, which suggests that even in low permeability units there exists an interconnected pore structure to support ionic flow. Measured resistivities in the Salado halites and interbeds have successfully predicted permeabilities.
3. Distinct electrical self potentials within the individual map units of the facility horizon suggest that far field flow is ongoing around the excavation.

In the remainder of this memo, I will elaborate on these points in detail.

Electrical Methods

The flow of electrical current in rocks takes place through ionic conduction in the pore space or conduction through conducting minerals. In rocks of the upper crust including evaporites, ionic conduction in the pore space dominates as a mechanism. For the units of the Salado, clays possibly act as a conducting mineral, which facilitates electrical flow in addition to ionic flow. To support current flow as a mineral conductor, the clays must link as a continuous phase in the rock matrix or along a pore channel pore. Since clays comprise less that 5% of Salado halites and anhydrite, where a modal distribution of greater than 30% is generally required to form a continuous phase in the matrix, mineral conductance in the matrix probably is limited to the clay interbeds. Clays lining pore networks, such as

diagenetic dewatering conduits, or fractures may support mineral conductance rather than ionic flow. The time dependent variations in resistivity are, however, more consistent with ionic flow in pore network of the Salado units since the clay distribution in the matrix and pores does vary significantly with time. The measured resistivities of the Salado units range from hundred to a thousand ohm-m. In comparison, the measured resistivities of domal salts range from tens of thousands to hundred of thousand ohm-m. Therefore, our assumption is that the electrical current flow that we induce or observe is supported by an interconnected partially (probably greater than 70%) to completely brine saturated pore network. Based on this assumption, we can relate the resistivity to the porosity, pore saturation and the tortuosity of the pore network and chemistry of the pore fluid. Brace (1977) utilized resistivity methods to determine permeabilities of tight crystalline rocks undergoing deformation in a laboratory.

At WIPP, we have used Poiseuille's equation as developed by Brace to estimate variations in permeability along the length of a borehole for the Salado Two-Phase Flow Laboratory Program: anhydrite core damage assessment and properties restoration (Howarth, 1993). In Figure 1, resistivity measurements where made in and between two vertical boreholes (E25 and E26) that penetrate Marker Bed 139. From these measurements, we calculated permeabilities for the halite and anhydrite intercepted by the boreholes (Borns and others, 1994). The calculated permeabilities duplicate the range for anhydrite and halite determined in laboratory and field experiments (Howarth, 1993). *This suggests that the interconnected pore network model represents the electrical current flow in the Salado.*

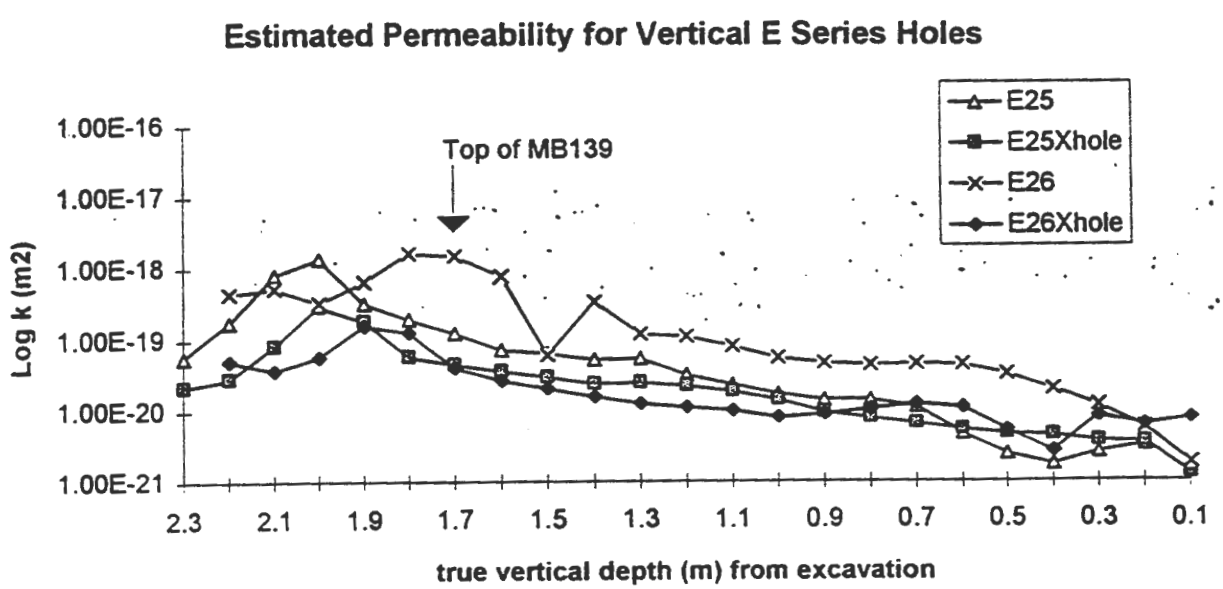


Figure 1: Calculated Permeabilities from Resistivity Surveys in Halite and Anhydrite beneath the Repository Floor

Room Q Arrays

We emplaced two electrical arrays in Room Q in the autumn of 1989 and have monitored the electrical response (changes are resistance and self potential) around Room Q through August 1993 (Pfeifer and others, 1989; Jensen and others 1992; Truskowski, 1994).These are sensitive to changes in electrical properties in a region four meters radially outward from the excavation. Figures 3 a, b, and c show the change in resistance along a series of lines parallel to the length of Room Q *along the centerline of the array, Ring 13 (Fig. 3a), on the floor (Fig. 3b), the rib (Fig. 3c), and the roof (Fig. 3d)*. Along the x-axis is time sine 1/1/90 to 8/20/93 (0 to 2.63 fractional years). From these plots, apparently the resistance increased (blue and yellow contours) in the first six months after we had access to the room (12/89). This increase is interpreted to mirror desaturation of the DRZ based on forward modeling (Pfeifer and others, 1989). After this increase, the resistance decreases (toward red contours) for two years. Based on forward modeling, this decrease in resistance is interpreted to represent *resaturation* of the DRZ. At 2 years, a rapid rise in resistance especially in the floor occurs followed by a decrease in resistance. Again based on modeling, this behavior is interpreted as a fracture opening between the floor and the far field electrode. In turn this fracture resaturated resulting in the decrease in resistance.

Another way to view the changes around Room Q with time is a series of graphs showing the percentage change in resistance between an index measurement (6/20/90 in most analyses) and the date of a following measurement. Figure 4 displays the cylindrical surface of Room Q projected onto a plane with the floor at Row 13, the rib at Row 9, and the roof at Row 3. These figures show the change in resistance for the periods **a) 3/11/90 to 6/22/90** (the period within a year of excavation and before an effective seal was installed), **b) 6/22/90 to 8/14/90** (the period for which access was beginning to be limited and partially seals were in place); **c) 6/22/90 to 8/12/91** (a period covering over a year of operation); and **d) 6/22/90 to 8/20/93** (a period covering the last documented measurement of the array in Room Q). These figures covering almost three years of the room's history show the initial increase in resistance with the opening of the DRZ and its desaturation (Figure 4a) and the subsequent reduction in resistance with resaturation of the DRZ (Figures 4b, c, and d). *In conclusion, we observe that the field data suggests that the DRZ can resaturate over a 2.6 year period.*

Figure 3a: Resistance change with time for all electrodes along Ring 13 (centerline of array) in Room Q

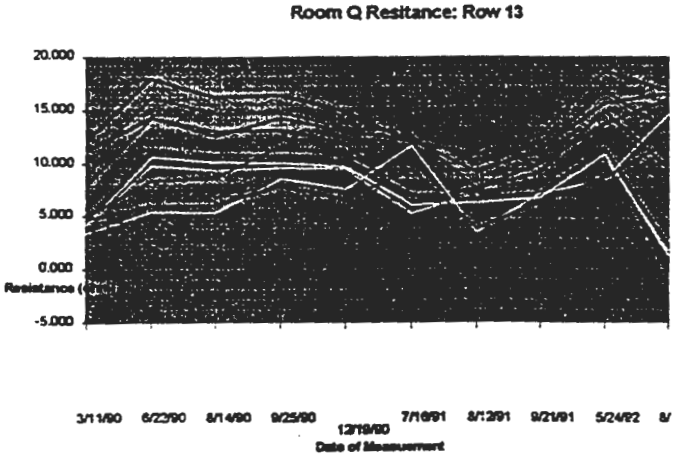
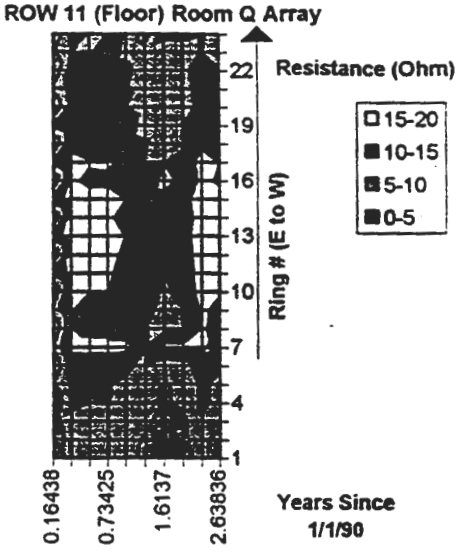


Figure 3b: Change in resistance with time along Room Q floor



re 3c: Change in resistance with time along Room Q rib

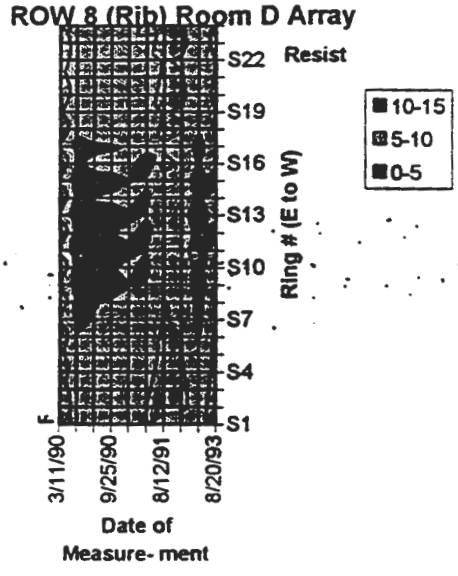


Figure 3d: Change in resistance with time along Room Q roof

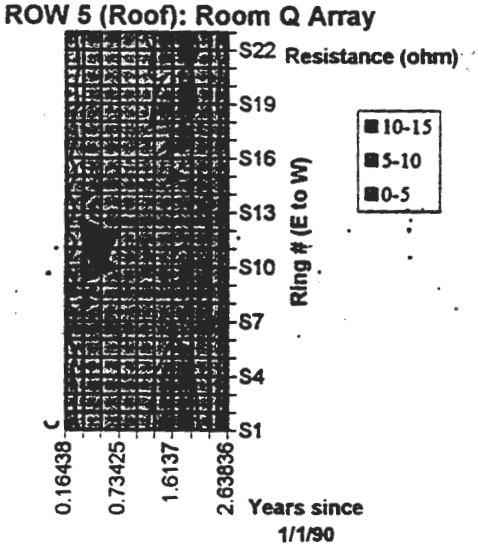


Figure 4a: Change in resistance (resistance increasing with development and desaturation of DRZ)

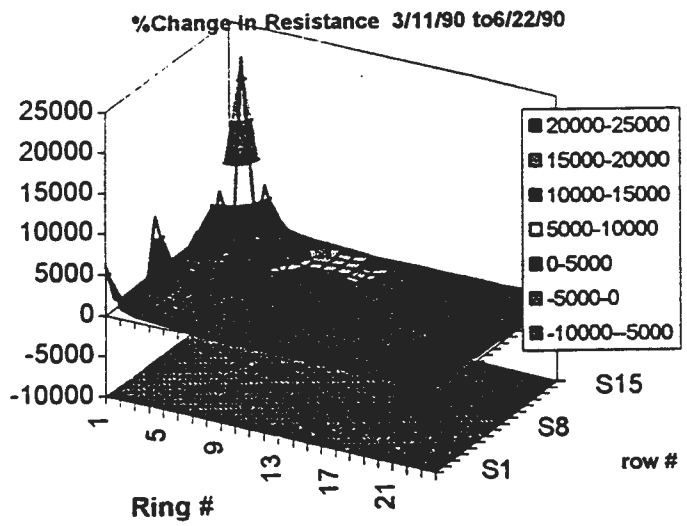


Figure 4b: Change in resistance (resistance decreasing with resaturation of DRZ)

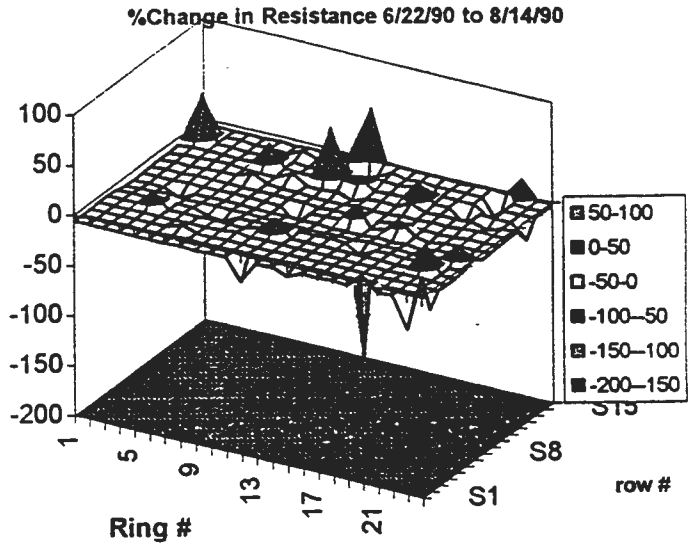


Figure 4c: Change in resistance (resistance decreasing with resaturation of DRZ)

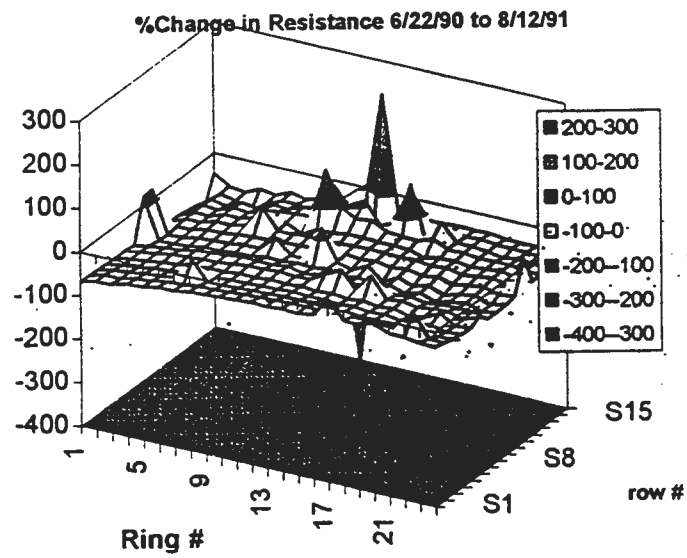
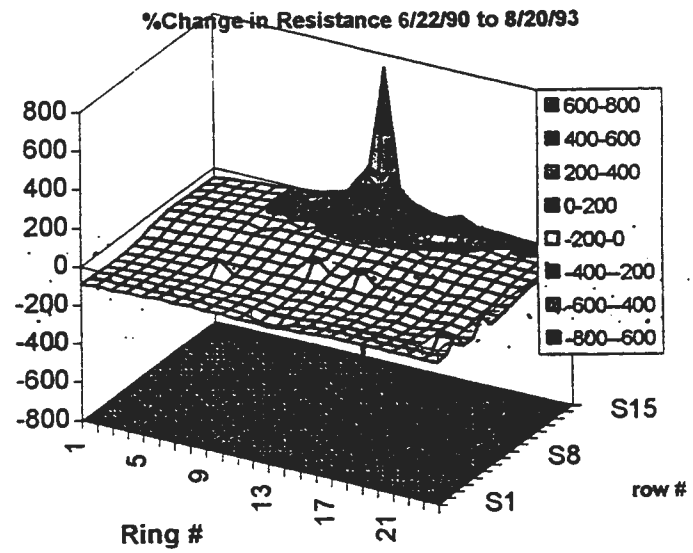


Figure 4d: Change in resistance (resistance decreasing with resaturation of DRZ; zone of higher resistance may reflect the opening of a secondary fracture[s] in the floor)



Self Potential Surveys in Room Q

We measure electrical self potential regularly as a background check for electrical surveys in Room Q and elsewhere in the underground. The self potential measures the background current flow when our induced sources are turned-off. This self potential is commonly induced by ionic flow accompanying fluid flow in rocks. As such, the self potential is used to detect zones of fluid flow (e.g., leaks in man made structures). In the WIPP underground, the self potential may not be totally natural and may reflect perturbations in the electrical field due to the shafts and underground mine operations. However, the observed self potentials show that the ionic flow occurs in the pore network of the Salado. Figure 3 shows the self potentials measured in the electrical arrays of Room Q.

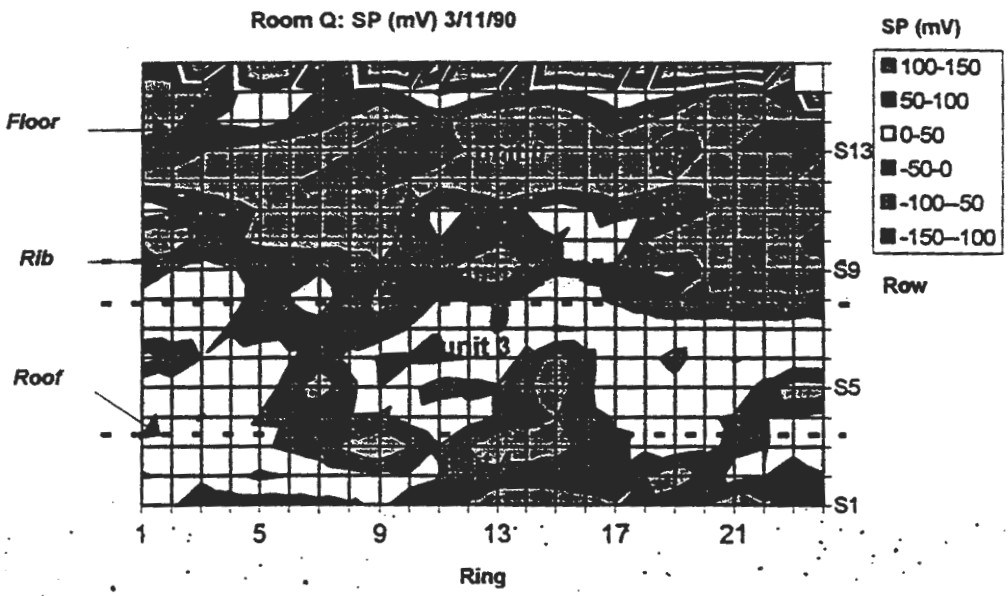


Figure 4: Self Potential (SP) measured in Room Q on 3/11/90. Figure represents the cylindrical surface of room projected onto a planar surface. The intersection of the excavation with the map units is marked by the dotted lines. The relative positions of the floor, rib and roof are marked by arrows.

observed in Room Q related to the map units. These map units represent the sedimentary layering of the Salado as marked by variations in texture and clay content. **Map Unit 0** has a distinct self potential, which is 100 mV greater than **Map Unit 3**. The boundary between these two units is horizontal and corresponds to the relatively thinner **Map Units 1 and 2**. *The distribution of self potentials suggests that layer stratified ionic flow is occurring around the Room Q excavation.*

References:

Borns, D. J., H. T. Andersen, and D. I. Neuman, 1994, Electrical Resistance Measurements of Boreholes: E3X23, E3X24, E3X25, E3X26, E3X27, and E3X28 in Alcove E300N90:Field Test Portion of the Core Damage Assessment Study for the Salado Two-Phase Flow Laboratory Program, Sandia Report, SAND94-1200, Sandia National Laboratories, Albuqerque, New Mexico

Brace, W. F., 1977, Permeability and Resistance and Pore Shape, Journal of Geophysical Research, 82, 3343-3349

Howarth, S., 1993, Conceptual Plan: Two Phase Flow Laboratory Program for the Waste Isolation Pilot Plant, Sandia Report, SAND93-1197, Sandia National Laboratories, Albuquerque, New Mexico

Jensen, A. L., R. L. Jones, E. N. Lorusso, and C. L. Howard, 1991, Large-scale brine inflow data report for Room Q prior to November 25, 1991, Sandia Report, SAND92-1173, Sandia National Laboratories, Albuqerque, New Mexico

Pfeifer, M. C., D. J. Bornsm C. K. Skokan, H. T. Andersen, and J. Starrett, 1989, Geophysical methods to monitor development of the disturbed rock zone around underground excavation in bedded salt, Procedding of the Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP), Golden, CO, March 1989, SAND89-7055A

Truskowski, M. G., 1994, Detecting material proerty changes and fluid flow using a stationary DC resistance grid, M.S. Thesis, Colorado School of Mines, Golden, CO.

Parameter(s): Log of the Intrinsic Permeability of the Disturbed Rock Zone

References: (continued)

Pfeifer, M.C., D.J. Borns, C.K. Skokan, H.T. Anderson, and J.M. Starrett. 1989. *Geophysical Methods to Monitor Development of the Disturbed Rock Zone Around Underground Excavations in Bedded Salt*. SAND89-7055A. Albuquerque, NM: Sandia National Laboratories.

Saulnier, G.J. Jr., and J.D. Avis. 1988. *Interpretation of Hydraulic Tests Conducted in the Waste-Handling Shaft at the Waste Isolation Pilot Plant (WIPP) Site*. SAND88-7001. Albuquerque, NM: Sandia National Laboratories.

Stormont, J.C. 1990. *Summary of 1988 WIPP Facility Horizon Gas Flow Measurements*. SAND89-2497. Albuquerque, NM: Sandia National Laboratories.

Stormont, J.C., and C.L. Howard. 1987. *Development, Implementation and Early Results: Test Series C of the Small-Scale Seal Performance Tests*. SAND87-2203. Albuquerque, NM: Sandia National Laboratories.

Parameter(s): Effective Porosity - Disturbed Rock Zone

Parameter Description:

Effective porosity of the Disturbed Rock Zone (DRZ) from time t = -5 yrs to 10,000 yrs.

Material and Parameter Name(s):

DRZ_0 POROSITY (#178)
DRZ_1 POROSITY (#195)

Parameter Value: 1.29×10^{-2}

mean	median	minimum	maximum	units
1.565×10^{-2}	1.29×10^{-2}	3.90×10^{-3}	3.29×10^{-2}	m^3/m^3

Distribution Type: Cumulative

Data: Investigator Judgment

Discussion:

Parameter values for the DRZ are defined for two time periods: 1) the 'waste emplacement' time associated with a fresh panel (-5 to 0 years), and 2) the sealed repository time period from 0 to 10,000 years. The effective porosity for both time periods is the same and is equal to 0.0029 plus the Salado halite effective porosity.

References:

Vaughn, Palmer. 1996. E-mail from Palmer Vaughn to Margaret Chu, Re: Revision to DRZ and TZ Properties to be used in the BRAGFLO CCA Calculations. January 24, 1996.

Parameter(s): Log of the Intrinsic Permeability (T = 0 to 10,000 yrs) - Disturbed Rock Zone

Parameter Description:

The log of the intrinsic permeability of the Disturbed Rock Zone (DRZ) from 0 to 10,000 years.

Material and Parameter Name(s):

DRZ_1	PRMX_LOG (#198)
DRZ_1	PRMY_LOG (#199)
DRZ_1	PRMZ_LOG (#200)

Parameter Value: -15.0

Units: $\log(m^2)$

Distribution Type: Constant

Data: Site-Specific Experimental Data

A significant number of laboratory, field, and modeling studies have been performed to determine the mechanics of DRZ development. DRZ development has been documented in almost all horizontal rectangular excavations of the WIPP underground facility by gas permeability testing (Stormont and Howard, 1987; Stormont 1990), visual observations (Borns and Stormont, 1988), and by other methodologies (Holcomb, 1988; Pfeifer et al., 1989). Laboratory testing of salt cores has also provided significant insight into DRZ development. Hansen and Mellegard (1979) found that dilatency is favored by conditions of low-confining stress and high deviatoric stress which characterizes the region near an excavation. Laboratory testing has shown that a halite DRZ is self-healing given the proper stress conditions (Brodsky, 1990). Brodsky (1990) showed that artificially damaged cores could be healed with certain confining pressures and time.

Although a sizeable body of laboratory and field evidence of DRZ development exists, there have been no definitive studies conducted in vertical excavations at the WIPP until recently. Two hydraulic testing programs have been conducted within WIPP shafts. The earliest hydraulic testing program was conducted in the Waste Handling Shaft (WHS) (Saulnier and Avis, 1988). More recently, hydraulic testing was performed to determine the extent of the DRZ in the Air Intake Shaft (AIS). Six boreholes, three at each of two levels, were used to determine gas and brine permeabilities.

Parameter(s): Log of the Intrinsic Permeability (T = 0 to 10,000 yrs) - Disturbed Rock Zone

Discussion:

The intrinsic permeability value for the DRZ for the time period from 0 to 10,000 years is the same as mode of the value for the shaft seal DRZ which is described in the "Data" section above. Parameter values for the DRZ are defined for two time periods: 1) the 'waste emplacement' time associated with a fresh panel (-5 to 0 years), and 2) the sealed repository time period from 0 to 10,000 years. For t = 0 to 10,000 yrs., the DRZ is assumed to be a well developed region characterized by vertical fractures. Because of gas generation and the resulting pressures in the repository the DRZ above and below the repository is assumed not to heal. These fractures are a result of both the presence of the excavation and the pressurization of the repository due to gas generation. Consequently, the DRZ is assumed to provide a relatively permeable connection between the repository and the adjacent anhydrite layers. Because this enhanced permeability is associated with vertical fracturing there is little further increase in porosity. Many of the parameter values are selected to reduce the possibility of the numerical model result of over pressurization (pressures in excess of lithostatic for extend periods of time) of the repository due to gas generation. The surrounding formation will respond by providing pathways to relieve this pressure so that pressures of this magnitude are not realistic. The Salado FEP issue S-6 examined modeling of the DRZ and is documented in the FEPs record package. This analysis shows that use of a time invariant elevated permeability is an acceptable alternative to using a time varying permeability.

References:

Borns, D.J., and J.C. Stormont. 1988. *An Interim Report on Excavation Effects Studies at the Waste Isolation Pilot Plant: Delineation of the Disturbed Rock Zone*. SAND87-1375. Albuquerque, NM: Sandia National Laboratories.

Brodsky, N.S. 1990. *Crack Closure and Healing Studies in WIPP Salt Using Compressional Wave Velocity and Attenuation Measurements*. SAND90-7076. Albuquerque, NM: Sandia National Laboratories.

Hansen, F.D., and K.D. Mellegard. 1979. *Creep Behavior of Bedded Salt From Southeastern New Mexico at Elevated Temperature*. SAND79-7030. Albuquerque, NM: Sandia National Laboratories.

Holcomb, D.J. 1988. "Crosshole Measurements of Velocity and Attenuation to Detect a Disturbed Rock Zone in Salt at the Waste Isolation Pilot Plant." *Proceedings of the 29th U.S. Symposium on Rock Mechanics, University of Minnesota, Minneapolis, MN, June 1988*, p. 23-25.