

**Environmental Protection Agency's Confirmatory Dose Calculations of the
Department of Energy's Use of CAP88-PC for the February 2014 Radiological
Emission Release at the Waste Isolation Pilot Plant**

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Table of Contents

1.0 Executive Summary.....	3
2.0 Accident Description.....	3
3.0 Station B Filter Analysis.....	3
Table 1: DOE’s Station B Filter Data Collected Between February 14 and February 21, 2014.....	4
4.0 Regulatory Requirements.....	4
5.0 DOE Dose Calculations.....	5
6.0 EPA Confirmatory Calculations.....	5
Table 2: DOE and EPA Highest CAP88-PC EDE Results.....	6
References.....	7
Attachment I: Location of Nearby Residences and Communities in the Vicinity of WIPP.....	8
Attachment II: DOE’s CAP88-PC Inputs.....	9
Table II.1: Source Term Used in CAP88-PC.....	9
Table II.2: WIPP Fence Line Where CAP88-PC EDEs Are Calculated.....	9
Table II.3: CAP88-PC Meteorological Inputs.....	10
Attachment III: EPA’s CAP88-PC Results.....	11
Table III.1: CAP88-PC Effective Dose Equivalent Derived by EPA, Version 3 and 4.....	11

1.0 Executive Summary

On February 14, 2014, an event took place in the underground of the Department of Energy (DOE) Waste Isolation Pilot Plant (WIPP) that led to the release of a small but measurable amount of radioactive material to the atmosphere. DOE is responsible for assuring that any radiological emissions from the WIPP do not exceed an effective dose equivalent (EDE) of 10 millirem (mrem)/year to any member of the public. CAP88-PC is the U.S. Environmental Protection Agency's (EPA) computer software system for calculating dose and risk from annual average releases of radionuclides to the air and can be used by DOE to demonstrate compliance with EPA regulations.

DOE performed dose calculations using CAP88-PC Version 3 to assess the location of the highest dose at and outside of the WIPP fence line. DOE's results indicated the highest EDE was 0.67 mrem/year at the fence line location 347 meters (~0.2 miles) northwest of the WIPP Station B exhaust shaft. Using radionuclide release data collected and provided by DOE, EPA staff were able to recreate DOE's results for this location. Additionally, EPA performed CAP88-PC calculations with Version 3 to verify the highest EDE in a populated area outside of the WIPP Land Withdrawal Boundary (LWB) was below the regulatory limits. These calculations found the highest EDE for a populated area outside of the WIPP LWB to be 0.005 mrem/year at the Smith Ranch, which is located 7186 meters (~4.5 miles) northwest of the exhaust shaft.

EPA also performed dose calculations with CAP88-PC Version 4, which uses updated age-specific breathing rates and updated dose conversion and utilization factors. The effective dose equivalents were lower using CAP88-PC Version 4. Thus, both the DOE and EPA dose calculations resulted in a maximum effective dose equivalent below 1 mrem/year, which is less than the regulatory limit of 10 mrem/year.

2.0 Accident Description

On February 14, 2014, at 2314 hours Mountain Standard Time (MST), an underground continuous air monitor at the Waste Isolation Pilot Plant measured elevated levels of alpha-beta airborne activity. This caused the underground mine ventilation system to switch to filtration mode. In filtration mode the aboveground bypass dampers are closed and mine exhaust air is rerouted through the high efficiency particle air (HEPA) filtration system, then exhausted at effluent monitoring Station B. Due to leakage around the dampers, a small amount of mine exhaust bypassed the HEPA filters and was exhausted without being filtered. The aboveground ambient fixed air sampler (FAS) on the WIPP site detected airborne alpha and beta activity levels that were above background levels downstream from the HEPA filter exhaust measured at Station B. The bulk of the radioactive releases to the atmosphere lasted approximately 90 hours. DOE has since sealed the air exhaust duct dampers that allowed a small amount of radioactive particles to escape.

3.0 Station B Filter Analysis

During the February 14 radiological event, data was collected from the FAS located downstream from the Station B exhaust duct. The Station B FAS filter records the global activity as total alpha/beta disintegrations per minute (dpm). Filters were removed and replaced with new filters on an eight hour cycle immediately after the release. The FAS filter that collected the initial high dpm values during the February 14 release was removed from the Station B FAS on February 15 at 0820 hours MST. This

filter was sent to WIPP Laboratories for analysis to determine the individual radiological and isotopic components that contributed to the global activity. The isotopic components of subsequent filters collected at Station B were estimated based on laboratory analysis conducted on the first post-incident filter. Table 1 lists DOE's calculated radiological components and activities from the Station B filters collected between February 14 and February 21. DOE provided this data to EPA in an EXCEL file.¹

Table 1: DOE's Station B Filter Data Collected Between February 14 and February 21, 2014

Station B Filter Isotopic Activity	
Total Curies (Ci) over the 7.334 day (10566 minutes) peak release period.	
Radionuclide	Activity (Ci)
Am-241	1.69 E-03
Pu-238	4.82 E-06
Pu 239/240	9.35 E-05
Sr-90	5.38 E-08
Cs-137	2.42 E-07
U-233	3.53 E-08
U-238	5.14 E-09

4.0 Regulatory Requirements

Pertinent to the WIPP and as a requirement in EPA's Code of Federal Regulations (CFR) Title 40 Part 191, Subpart A, "Environmental Standards for Management and Storage," DOE is to assure annual doses to the public from a nuclear repository are limited. More specifically, in 191.03(b), the DOE is to

...provide a reasonable assurance that the combined annual dose equivalent to any member of the public in the general environment resulting from discharges of radioactive material and direct radiation from such management and storage shall not exceed 25 millirems to the whole body and 75 millirems to any critical organ.

Furthermore, the EPA has authority to regulate air emissions (through the Clean Air Act) to the environment from DOE facilities, per 40 CFR Part 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities". However, in Section 90, "Designation of Facilities", it states that DOE disposal facilities are explicitly excluded. In order to implement and facilitate the Part 191 Subpart A requirements, the DOE and EPA agreed—via a 1995 Memorandum of Understanding²—that the WIPP will comply with Part 61, Subpart H until repository closure. The specifics in 40 CFR Part 61 satisfy the air emission component for periodic confirmatory measurements. Title 40 CFR 61.92 gives DOE responsibility for assuring that radiological emissions from the facility do not exceed an effective dose of 10 mrem per year to any member of the

¹ Vincent, Oba of the Department of Energy, email message to Tom Peake, U.S. EPA, March 12, 2014. Subject: CAP88 Special Input/Output files.

² Department of Energy and Environmental Protection Agency. "Memorandum of Understanding Between the U.S. EPA and the U.S. DOE Concerning the Clean Air Act Emission Standards for Radionuclides 40 CFR § 61, Including Subparts H, I, Q & T." Signed by Mary D. Nichols, EPA Assistant Administrator for Air and Radiation: September 29, 1994. Signed by Tara O'Toole, DOE Assistant Secretary for Environment, Safety, and Health, April 5, 1995. See http://www.epa.gov/radiation/docs/neshaps/epa_doe_caa_mou.pdf.

public.³ Title 40 CFR 61.93 requires periodic sampling at release points which could cause an effective dose equivalent (EDE) in excess of 1% of the 10 mrem/year limit.

CAP88-PC calculates EDE and risk from annual average releases of radionuclides to the air. The software is developed and maintained by EPA and is one of several that can be used to demonstrate compliance with EPA regulations at 40 CFR Part 61, Subpart H.

5.0 DOE Dose Calculations

DOE performed dose calculations using CAP88-PC Version 3 to assess the location of the highest EDE outside of the WIPP's fence line. In a March 12, 2014 email transmission⁴, DOE sent EPA the calculated high EDE, at a specific location along the fence line and the calculated radionuclide concentrations in the environment within an 80 km (~50 mile) radius of the air exhaust shaft. DOE's radionuclide inputs (i.e., the source term) are provided in Table 1. It is presumed in the model that these are the only radionuclides released to the atmosphere in the WIPP vicinity during the entire year that would cause an exposure to a target individual.

DOE performed dose calculations along the perimeter of the WIPP fence line because it is a location where a member of the public can approach the WIPP site unfettered and, hypothetically, would result in maximum exposure if residing there. The fence line outlines the perimeter of the WIPP facility buildings and is within the LWB. DOE's CAP88-PC results indicated that the highest concentration of radionuclides was at the northwest fence line location 347 meters (~0.2 miles) from the WIPP Station B exhaust shaft, with the EDE at this location calculated at 0.67 mrem/year.

The EDE at the fence line was well below the 10 mrem/year regulatory dose limit specified in 40 CFR 61.92. DOE's results indicated that radionuclide concentrations outside of the Land Withdrawal Boundary were significantly lower than those at the fence line. EPA presumed the calculated EDE further from the fence line would be lower but performed additional confirmatory calculations using CAP88-PC Versions 3 and 4 to verify this assumption.

See Attachment II for a list of DOE input files.

See Attachment III for a table of EPA's CAP88-PC results.

6.0 EPA Confirmatory Calculations

CAP88-PC calculations are performed on a radial computational grid divided in concentric sectors with the source point at the center. The sectors are divided in compass directional subsectors. The EDE for a location of interest is determined by the directional sector it lies in. Calculated EDE are limited to an 80 km (50 mile) radius. (See Attachment I)

With Version 3 of CAP88-PC, EPA was able to replicate DOE's EDE of 0.67 mrem/year along the northwest fence line. The Agency's confirmatory CAP88-PC Version 3 calculations used the same radial grid and source term as DOE to assure DOE's results were reproducible. EPA also replicated the

³ As defined in 40 CFR 191.02, a member of the public is *any individual except during the time when that individual is a worker engaged in any activity, operation, or process that is covered by the Atomic Energy Act of 1954, as amended.*

⁴ Vincent, Oba of the Department of Energy, email message to Tom Peake, U.S. EPA, March 12, 2014. Subject: CAP88 Special Input/Output files.

same radionuclide concentrations within the 80 km radius of the exhaust shaft. (Note, these concentrations are used to generate EDEs within each radial sector and are additional output of CAP88-PC.) The EPA wanted to assure the EDEs in populated areas within an 80 km radius of the WIPP's exhaust shaft were below the 10 mrem/year regulatory limit. EPA's confirmatory calculations produced the highest EDE in a populated area outside of the LWB of 0.005 mrem/year at Smith Ranch. Smith Ranch is 7186 meters (~4.5 miles) northwest of the exhaust shaft.

EPA also performed dose calculations with CAP88-PC Version 4⁵, which includes updated age-specific inhalation and ingestion rates, incorporates more refined radionuclide build-up and removal rates and includes more isotopes due to ingrowth and decay. For these calculations, EPA identified the maximally exposed individual as an adult, thus allowing for a comparison to the "effective target individual" in Version 3. The intention in performing calculations with CAP88-PC Version 4 was to compare results with those derived from Version 3 and assure the calculated EDE estimates did not exceed the 10 mrem/year regulatory limit.

Results from CAP88-PC Version 4 were lower than the results from Version 3. The highest calculated EDE, 0.42 mrem/year, was at the fence line 347 meters northwest of the WIPP exhaust shaft, which was the same location calculated using Version 3. The highest EDE for the nearest population center outside of the WIPP Land Withdrawal Boundary was at the Smith Ranch, as was produced with Version 3, with an EDE of less than 0.005 mrem/year. Table 2 lists the DOE and EPA EDE results at the WIPP fence line and Smith Ranch.

Table 2: DOE and EPA Highest CAP88-PC EDE Results

Highest Results From DOE and EPA Calculations Using CAP88-PC Versions 3 and 4 Effective Dose Equivalent (mrem/year)			
Location	DOE Results CAP88-PC Version 3	EPA Results CAP88-PC Version 3	EPA Results CAP88-PC Version 4
Fence Line - 347-m NW of Exhaust Shaft	0.678	0.678	0.42
Smith Ranch	Not Given to EPA	0.005	0.003

For both Version 3 and 4 simulations, the main contributors to dose were americium-241, plutonium-238 and plutonium-239. Consistently, both DOE and EPA dose calculations resulted in a maximum EDE below 1 mrem/year, well below the regulatory limit of 10 mrem/year. The effective dose equivalent calculated by EPA using both CAP88-PC Version 3 and 4 at all the population centers can be found in Attachment III.

⁵ CAP88-PC Version 4 is still undergoing testing and is not yet approved by EPA for regulatory compliance demonstrations.

References

Department of Energy and Environmental Protection Agency. "Memorandum of Understanding Between the U.S. EPA and the U.S. DOE Concerning the Clean Air Act Emission Standards for Radionuclides 40 CFR § 61, Including Subparts H, I, Q & T." Signed by Mary D. Nichols, EPA Assistant Administrator for Air and Radiation: September 29, 1994. Signed by Tara O'Toole, DOE Assistant Secretary for Environment, Safety, and Health, April 5, 1995. See http://www.epa.gov/radiation/docs/neshaps/epa_doe_caa_mou.pdf.

Environmental Protection Agency (EPA). "40 CFR Part 191, Subpart A, Environmental Standards for Management and Storage." 58 *Federal Register* 66398 (20 December 1993).

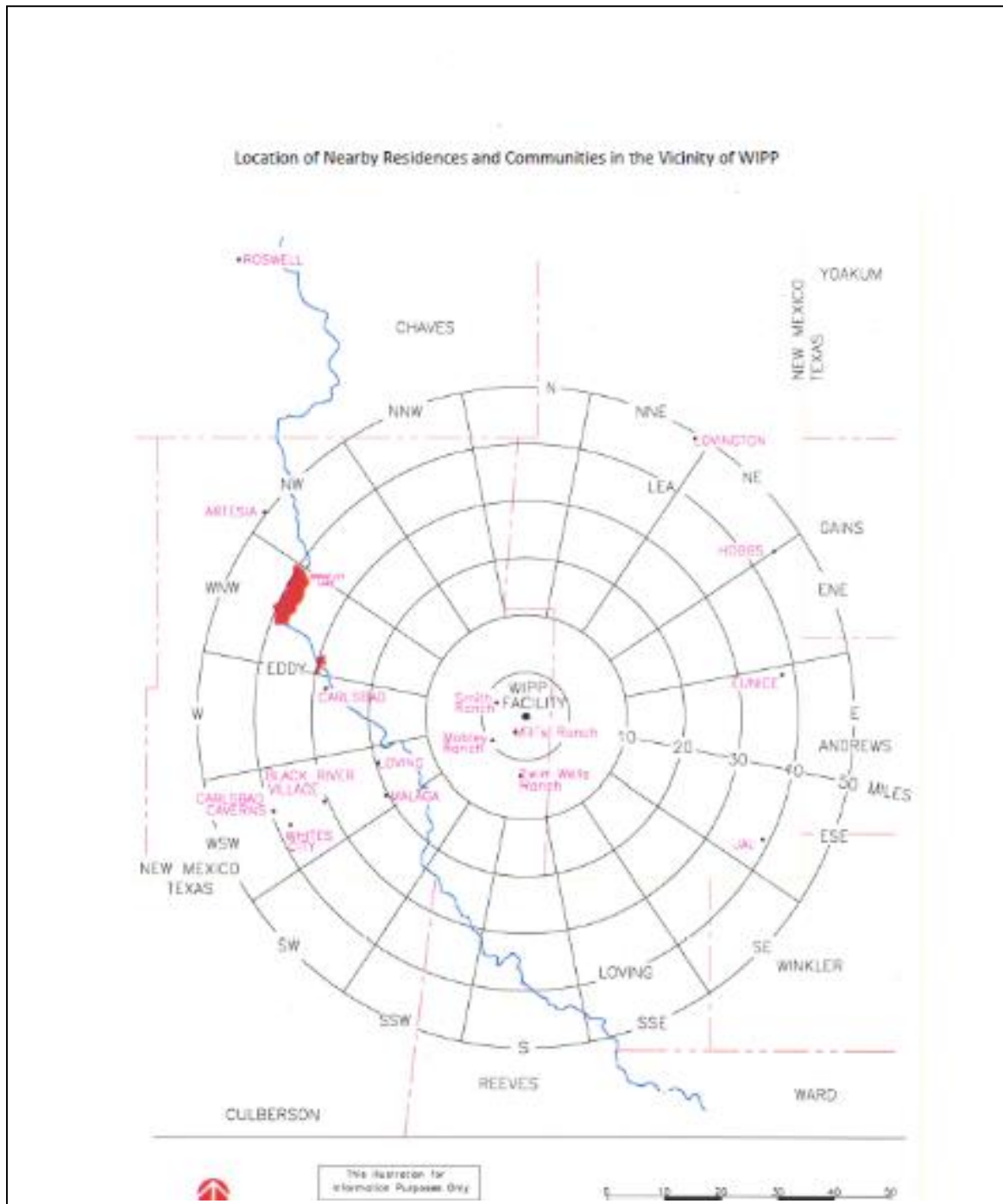
Environmental Protection Agency (EPA). "40 CFR Part 194, Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations: Final Rule." 61 *Federal Register* 5224 (9 February 1996).

Environmental Protection Agency (EPA). "40 CFR Part 61, Subpart H, National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities." 67 *Federal Register* 57166 (9 September 2002).

Vincent, Oba of the Department of Energy, email message to Tom Peake, U.S. EPA, March 12, 2014. Subject: CAP88 Special Input/Output files.

Attachment I: Location of Nearby Residences and Communities in the Vicinity of WIPP

Depiction of CAP88-PC computational radial grid centered at the WIPP exhaust shaft and overlain by nearby populated areas.



Attachment II: DOE's CAP88-PC Inputs

The source term used in EPA's CAP-88 PC Version 4 calculations was the same as in DOE's Version 3 runs. DOE transmitted this data to EPA in an EXCEL file.¹ Version 4 of CAP88-PC calculates more radionuclide ingrowth and decay activity, which includes the radionuclide Barium (Ba). Therefore, a non-zero value for the isotope Ba-137 was needed in the input file that was not required for the Version 3 runs.

Table II.1: Source Term Used in CAP88-PC

Station B Filter Isotopic Activity				
Description				
Total Curies (Ci) per the 7.337 day (10566 minutes) peak release period.				
Radionuclide	Chemical Form	Particle Type	Size	Activity (Ci)
Am-241	P	M	1	1.69 E-03
Pu-238-P	P	M	1	4.82 E-06
Pu 239/240-P	P	M	1	9.35 E-05
Sr-90-P	P	M	1	5.38 E-08
Cs-137-P	P	F	1	2.42 E-07
U-233-P	P	M	1	3.53 E-08
U-238-P	P	M	1	5.14 E-09
Ba-137	N/A	0	N/A	1.0 E-25
The letter 'P' denotes the nuclide's chemical form is a particle. The choices for particle type, as specified in EPA's Federal Guidance Report 13, "Cancer Risk Coefficients for Environmental Exposure to Radionuclides," are fast (F), medium (M) or slow (S).				

Table II.2: WIPP Fence Line Where CAP88-PC EDEs Are Calculated

Distance From Exhaust Shaft to Fence Line Boundary of the WIPP Exclusive Use Area			
Direction From Exhaust Shaft	Distance (m)	Distance (km)	Distance (mi)
NW, S	347	0.347	0.22
SSE	376	0.376	0.23
N, SE	490	0.490	0.30
NNW, NNE	530	0.530	0.33
W, SSW, E	592	0.592	0.37
WNW, WSW, ESE, E	646	0.646	0.40
NW, NE	691	0.691	0.43
SW	778	0.778	0.48

¹ Vincent, Oba of the Department of Energy, email message to Tom Peake, U.S. EPA, March 12, 2014. Subject: CAP88 Special Input/Output files.

The meteorological input file was the data collected at the DOE meteorological tower during the week spanning the event. The tower is located approximately 600 m (1,970 ft) northeast of the Station B. This station measures precipitation as well as wind speed, wind direction, relative humidity and temperature at 2, 10, and 50 m above ground (6.5, 33, and 165 ft).

Table II.3: CAP88-PC Meteorological Inputs

Meteorological Parameter	Description and Notes	
Temperature	Temperature value was rounded up to 15.4 degrees C in DOE's summary file	
Average Temperature (Celsius)	15.39	
Precipitation	Total precipitation during the event that spanned 7.34 days. This value was input into CAP88 Version 3. Version 4 requires a non-zero value for precipitation. EPA input a very low value precipitation.	
	Precipitation Unit	Value
	mm	0.0 (Version 3) 0.01 (Version 4)
Humidity	Absolute Humidity	
	Unit	Value
	g/meter ³	8

Attachment III: EPA's CAP88-PC Results

Table III.1: CAP88-PC Effective Dose Equivalents Derived by EPA, Version 3 and 4.

Population Centers and Populated Areas Within 80 km of the WIPP Exhaust						
Population Center	Pop #	Compass Direction from Shaft	Distance³		CAP88 Results¹ (mrem/year)	
			m	km	Version 3	Version 4
Mills (James) Ranch	5	SSW	5240	5.24	< 3.4E-03	< 2.1E-03
Smith [Crawford] Ranch	1	WNW	7186	7.19	< 4.9E-03	< 3.10E-03
Mobley Ranch	0	SW	9580	9.58	< 2.3E-03	< 8.2E-04
Pue Ranch	5	WNW	15495	15.5	< 2.0E-03	< 1.20E-03
Malaga CDP	147	WSW	32187	32.19	~ 2.2E-04	< 1.4E-04
Loving CCD	2179	WSW	32187	32.19	~ 2.2E-04	~1.4E-4
Loco @ 20 mi NW	150	NW	32187	32.19	< 1.2E-03	< 7.5.0E-04
Livingston Wheeler	609	W	45062	45.06	< 5.8 E-05	< 3.6E-05
Carlsbad city	26138	W	48280	48.28	< 5.8 E-05	< 3.6E-05
Loco Hills	149	NNW	48280	48.28	~ 4.30E-04	< 2.7E-04
Loving Co (Red Bluff & Orla)	74	SSE	51499	51.5	< 9.0 E-05	< 3.4E-04
Happy Valley (CDP)	519	W	56327	56.33	< 5.80E-05	< 2.2E-05
White City (DP)	7	WSW	61155	61.16	< 9.20E-04	< 5.8E-05
Monument CDP	206	NE	64374	64.37	< 1.40E-04	< 9.0E-05
Eunice CCD	1610	E	64374	64.37	< 8.70E-05	< 5.5E-05
Kermit City ²	5708	SE	67593	67.59	< 6.20E-05	< 3.9E-05
JAL CCD ²	3220	ESE	72421	72.42	< 1.10E-04	< 7.0E-05
Atoka CDP ²	1077	NW	72421	72.42	< 5.10E-04	< 3.2E-04
Lovington ²	5505	NNE	80467	80.47	< 1.30E-04	< 8.2E-05
Nadine CDP ²	376	NE	80467	80.47	< 1.30E-04	< 9.0E-05
Hobbs ² CCD	21653	ENE	80467	80.47	< 7.6E-05	< 9.0E-05

1. EDE – Effective Dose Equivalent
2. The CAP88-PC code limits the predicted dose to within an 80 km radius. Because Lovington, Nadine, and Hobbs are slightly over 80 km from the WIPP release point, their dose calculations will be considered as 'qualified' estimates.
3. Calculations are on a radial grid divided in concentric sectors and further divided in smaller compass directional subsectors. The source point is at the center. The EDE for a population center is within the boundaries of a specific sector.