Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy (DOE) Office of Environmental Management (EM).

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SRNL-STI-2011-00217

Date: March 12, 2018

To: EDG File

From: L. D. Koffman, 773-42A
K. L. Dixon, 773–42A

G. T. Jannik, Technical Reviewer

Population Distribution within a 50-mile Radius of SRS based on the 2010 U.S. Census Population

A database of the population within 50 miles of the Savannah River Site (SRS) is needed to estimate radiation doses to a collective group of individuals. The offsite population data was last updated with the 2000 census data (Simpkins 2002; Koffman 2001) and has been once again updated with the 2010 census data. The data acquisition process for the 2010 census data was the same as for the 2000 census data. Koffman (2001) provides complete details of the process and is provided in Appendix A.

Both AXAIRQ (Dixon and Abbott, 2016) and POPDOSE-SR (Jannik and Trimor, 2017) utilize these data in the form provided to estimate population dose. Both codes convert the grid to a pie grid centered on the release location. This pie grid is divided into the 16 compass sectors and ten radial rings. CAP88 (Rosnick, 2013) uses the pie grid as determined by POPDOSE-SR for the center of the site as input to estimate population doses.

Tables 1 through 3 show the 2010, 2000, and 1990 50-mile SRS population by sector and radial arc as shown as output to POPDOSE-SR (referenced to the center of site). Table 4 shows the ratio of the 2010 to 2000 data. While comparisons of populations are informative, resulting doses associated with these data give a better idea of the impact on the dose calculations. Table 5 shows the resulting doses using 2000 versus 2010 population data for POPDOSE-SR test cases (Dixon, 2018)

Table 1. 2010 Population Data

	Radial Ring (miles)					
Sector	5-10	10-20	20-30	30-40	40-50	Total
N	65	9000	13000	5280	12900	40300
NNE	4	3540	2740	7380	33800	47500
NE	0	4710	2760	6230	19100	32800
ENE	39	1920	4560	5930	47500	59900
E	101	7920	7040	7540	4330	26900
ESE	32	2350	1280	1740	3150	8560
SE	14	523	6560	6520	9820	23400
SSE	6	114	306	404	4870	5700
S	1	316	1290	7950	4020	13600
SSW	1	1170	2090	5410	3610	12300
SW	11	1060	1690	1030	1880	5670
WSW	53	1340	9860	1260	5910	18400
W	1	3280	10200	4730	7400	25600
WNW	617	2360	118000	88500	16900	226000
NW	263	8410	91500	52900	3000	156000
NNW	489	29400	30300	11600	6750	78500
Total	1700	77400	303000	214000	185000	781000

Table 2. 2000 Population Data

	Radial Ring (miles)					
Sector	5-10	10-20	20-30	30-40	40-50	Total
N	43	6630	11800	4540	12900	35913
NNE	4	3090	2240	6430	23500	35264
NE	0	4740	2900	6070	16000	29710
ENE	38	1920	5120	5660	46200	58938
E	98	8050	7360	7770	4580	27858
ESE	32	2420	1420	1940	3310	9122
SE	18	606	6060	7390	9890	23964
SSE	14	202	301	350	5230	6097
S	4	413	1480	8560	4000	14457
SSW	1	1000	2250	5950	3300	12501
SW	9	883	1680	1010	2170	5752
WSW	37	1270	9130	1520	6340	18297
W	0	3560	9560	4290	7170	24580
WNW	581	2430	117000	62300	14600	196911
NW	260	8220	90800	41100	2780	143160
NNW	485	25100	28300	10200	6910	70995
Total	1624	70534	297401	175080	168880	713519

Table 3. 1990 Population Data

	Radial Ring (miles)					
Sector	5-10	10-20	20-30	30-40	40-50	Total
N	26	5321	10020	5067	12210	32644
NNE	6	1320	2066	4445	14370	22207
NE	1	2945	2928	5269	10200	21343
ENE	27	3126	4483	5337	40770	53743
E	155	6743	5305	8812	4334	25349
ESE	36	1556	1931	2711	3253	9487
SE	26	547	6511	6685	8577	22346
SSE	40	391	769	1356	2539	5095
S	1	558	1332	7251	3335	12477
SSW	2	897	2008	4181	2944	10032
SW	17	944	2240	2606	2660	8467
WSW	60	1103	7112	2285	5818	16378
W	55	3314	7941	7994	6780	26084
WNW	449	3342	106900	50310	11550	172551
NW	271	5899	87930	26570	3025	123695
NNW	363	18030	27160	6665	6079	58297
Total	1535	56036	276636	147544	138444	620195

Table 4. Ratio of 2010 Population Data to 2000 Population Data

	Radial Ring (miles)					
Sector	5-10	10-20	20-30	30-40	40-50	Total
N	1.51	1.36	1.10	1.16	1.00	1.12
NNE	1.00	1.15	1.22	1.15	1.44	1.35
NE	-[a]	0.99	0.95	1.03	1.19	1.10
ENE	1.03	1.00	0.89	1.05	1.03	1.02
E	1.03	0.98	0.96	0.97	0.95	0.97
ESE	1.00	0.97	0.90	0.90	0.95	0.94
SE	0.78	0.86	1.08	0.88	0.99	0.98
SSE	0.43	0.56	1.02	1.15	0.93	0.93
S	0.25	0.77	0.87	0.93	1.01	0.94
SSW	1.00	1.17	0.93	0.91	1.09	0.98
SW	1.22	1.20	1.01	1.02	0.87	0.99
WSW	1.43	1.06	1.08	0.83	0.93	1.01
W	-[a]	0.92	1.07	1.10	1.03	1.04
WNW	1.06	0.97	1.01	1.42	1.16	1.15
NW	1.01	1.02	1.01	1.29	1.08	1.09
NNW	1.01	1.17	1.07	1.14	0.98	1.11
Total	1.05	1.10	1.02	1.22	1.10	1.09

[a]There were no residents in this sector in 2000.

Table 5. Changes in Estimated Dose Using 2010 Population Data for POPDOSE-SR

Test Case	Release Area	Dose for 2000 Population (person-rem)	Dose for 2010 Population (person-rem)	% Change
1	F	1.26E+01	1.36E+01	8%
2	Center of Site	1.29E+01	1.40E+01	8%
3	H	1.73E+01	1.87E+01	7%
4	P	1.67E+01	1.79E+01	7%
5	Center of Site	1.51E+01	1.64E+01	8%
6	K	1.82E+01	1.97E+01	7%
7	A	8.86E+00	9.64E+00	8%
8	D	2.00E+01	2.14E+01	7%
AER 2016	Center of Site	1.26E+00	1.37E+00	8%

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Distribution:

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Appendix A

Koffman Memo on 2000 Census Data Acquisition

SRS savannah river site

WESTINGHOUSE SAVANNAH RIVER COMPANY
INTEROFFICE MEMORANDUM

December 19, 2001 SRT-EMS-2001-00024

TO: A. A. Simpkins, 773-42A

C: G. T. Jannik, 773-42A
C: C. P. Holding-Smith, 773-42A

FROM: L. D. Koffman, 773-42A LDK

Conversion of Census2000 Population Data for Use with SRS Dose Assessment Codes

Ali Simpkins and Tim Jannik of the Environmental Analysis Group of SRTC perform offsite dose assessment calculations using various computer codes, some of which require population input data based on Census data. The current population input data is based on the 1990 Census and it is desired to update this population input data to be based on the 2000 Census. Thus, the objective of this task is to acquire Census2000 data for the region surrounding SRS and to convert this population data into the input format required by the dose assessment codes.

The required population input data format is a 120x120 matrix of population values that represent the population for one minute by one minute grid cells that extend over a two degree by two degree geographic extent that is centered near the center of SRS. The population for each grid cell is to be determined from the geographic distribution of Census2000 data and apportioned on an area weighted basis from the most detailed Census2000 data available. Such spatial calculations are easily done with Geographic Information Systems (GIS) software. The GIS software used for this task is ArcView 3.2.

Acquistion of Census Data

Census data contains population demographic information based on various geographic entities. Counties are subdivided into census tracts, census tracts are subdivided into census block groups, and block groups are subdivided into census blocks. The census block is the finest level of geographic detail available. The population demographic information is provided in tabular form with a unique identifier that corresponds to the specific geographic entity. The geographic entity boundaries are provided as TIGER files (Topologically Integrated Geographic Encoding and Referencing system). Both the tabular files and the TIGER files are available for download via the Internet at www.census.gov. However, these data are in a raw form and generally require conversion into some other format to be used by tabular

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processing software (database) or geoprocessing software (GIS). Conversion of this data can be a formidable task and has been very time intensive in past efforts.

Fortunately, the Census TIGER files have been converted into ArcView shapefile format by ESRI and are available for free download from the Geography Network (www.geographynetwork.com). The geographic entities can be downloaded by county and we have downloaded the census tract, block group, and block shapefiles for all the Georgia and South Carolina counties in the required geographic region around SRS. Figure 1a shows the census block groups and Figure 1b shows the census blocks, each with the 2 degree by 2 degree grid extent. It is evident that the census blocks are much more detailed than the block groups (actually about 50 times more). The SRS boundary is evident in the census blocks since there is no permanent population within the SRS boundary. Likewise, Fort Gordon outside Augusta and Fort Jackson outside Columbia are evident in the census block figure.

There is a census tract shapefile for each of the 46 counties in the geographic region around SRS. These shapefiles were merged into a single tract shapefile for the region. Likewise, the block group shapefiles were merged into a single block group shapefile and the block shapefiles were merged into a single block shapefile. These shapefiles contain the unique identifier for each entity that can be related to the tabular population data.

Early in this task the tabular data was not available in a compiled form, so the raw Summary File 1 (SF1) data files were downloaded from the Census web site. The SF1 data is downloaded by state and there are 40 separate files that make up the complete SF1 demographic data. Since we are only interested in total population, we only needed the geography file and the first of the 39 data files. Thus, we downloaded the files gageo.uf1 and ga00001.uf1 for Georgia and the files scgeo.uf1 and sc00001.uf1 for South Carolina. The Census web site also provides a Microsoft Access template, Sf1.mdb, that imports the data files into a Microsoft Access database. An Access database was built for each state. The two tables in each database were related by a unique ID field. We then needed to export the data associated with each of the geographic entities. The geographic entity is identified by the SUMLEV field where census tract = 080, block group = 091, and block = 101. A query was set up in Access to show just SUMLEV = 080 and this data was exported as a dbf file (dBASE IV format), which can be read directly by ArcView. Likewise, queries were set up for each of the geographic entities in each of the state Access databases, and the data was exported. The exported data contains a unique identifier, STFID, that relates to the geographic entities in the TIGER files. However, there were multiple records for some common STFID identifiers. In order to get total population for a geographic entity, we need to sum all of the like STFID records. This is easily done in ArcView using the summarize function. Thus, we constructed six dbf files that have unique STFID identifiers: one each for tracts, block groups, and blocks for each of the two states. These data files for population can be related to the TIGER shapefiles through the STFID identifier.

Later in this task we discovered that the SF1 data had been compiled by ESRI and was available for download as dbf files from the Geography Network. We downloaded the dbf files for Georgia and South Carolina for each of tracts, block groups, and blocks. We compared the total population in the files from Geography Network with those that we compiled from the raw Census data. The results for total population were identical. Since the Geography Network files contain other demographic data than total population, we used those files to join to the TIGER shapefiles for the final Census data.

The last step in preparing the census data shapefiles is projecting the geographic data into a coordinate system where accurate area calculations can be made. The TIGER shapefiles are provided in geographic coordinates (lat/lon) based on the datum NAD83. GIS data used at SRS is projected into UTM coordinates based on the datum NAD27. We used the projection wizard that comes with ArcView 3.2 to project the TIGER shapefiles into UTM NAD27, which is an appropriate coordinate system for area calculations.

Grid of Study Area

The required grid to be generated is composed of 1minute by 1 minute cells with 120 cells in each direction, resulting in a grid extent of 2 degrees by 2 degrees in geographic coordinates (lat/lon). The lower left corner of the grid is specified as located at 82.625W, 32.251N. ArcView was used to created a polygon shapefile composed of these 14,400 cells in geographic coordinates. The cells were named by their xy cell number, where x goes left to right and y goes from top to bottom. The shapefile was then projected to UTM coordinates so that accurate areas can be calculated. Note that the areas of the cells vary from southernmost to northernmost by 4% due to the projection of geographic cells to UTM. This should not be a problem as long as the code calculations are accounting for this variation.

Calculation of Area Weighted Population within a Grid Cell

With the census block shapefile and the grid cell shapefile both in UTM coordinates, we are set up to intersect the two and determine the population contribution from each census block to each grid cell. Figure 2a shows the census blocks around Jackson, SC to give an idea of the level of geographic detail. Figure 2b shows the census blocks with the grid cells overlaid. In general, we see that the census blocks are at a finer level of detail than the grid cells. One census block is highlighted and we see in Figure 2b that this block is split among three grid cells. Since we only know the total population within a block and no further information about distribution, our only recourse is to split the population of the block among the three cells on an area weighted basis. That is, the area fraction of the census block is determined within each grid cell and that area fraction is multiplied times the block population to give the portion of population assigned to each grid cell. We do this for every block that has a portion within a grid cell and then we sum the area weighted populations of all the block parts within a grid cell to give the total grid cell population. This grid cell population may have a fraction, so we round the final grid cell population to give a whole number that is appropriate for the input format required by the dose calculation codes.

The above calculations are conceptually straightforward but involve a large number of calculations since there are 14,400 grid cells and 86,230 census blocks that are to be intersected. These are the kinds of spatial calculations for which GIS software (ArcView) is designed. Following is an outline of the steps used with ArcView to perform the calculations.

1. Use the sample ArcView script calcapl.ave to calculate the area for each census block in the block shapefile. Then add a field to the block shapefile for population density and use the calculate function to evaluate population density as population divided by area.

2. Load the Geoprocessing extension and use the Geoprocessing Wizard to intersect the block shapefile with the grid cell shapefile. The resulting intersection shapefile contains the fractions of blocks that are split by the grid cells.

3. Recalculate the areas of the intersection shapefile using the script calcapl.ave.

4. Calculate the fractional population within each piece in the intersection shapefile. Add a field for population named Pop and use the calculate function to evaluate Pop as population density times area.

5. We now want to add all the population pieces within a grid cell. Each piece has the associated grid cell name so we use the summarize function for grid cell names. Within the summarize function we specify that we want the sum of the field Pop. The resulting dbf file contains the total population (with fractional part).

6. Add a field called Pop_round and use the calculate function to round the population within each grid cell to a whole number.

The resulting dbf file contains the desired information for this task. That is, each of the 120x120 grid cells has a whole number population that is derived from the most detailed Census2000 data. The final step is to write the results in the required text format for input to the dose calculation codes. An ArcView script was written to write the results as a text file in the required format. This text file is the final deliverable for this task and was supplied in electronic form.

Supplemental Calculations for Verification of Population Calculations

The dose assessment codes use the population grid cells to determine populations within ring/sector (polar) grids. ArcView can be used to perform two calculations that are useful in determining the accuracy of the population calculations done with the dose assessment codes: (1) an analogous calculation to that performed with the dose assessment codes for direct comparison, and (2) an accurate calculation using census blocks that can be compared directly to the grid cell calculation.

Figure 3 shows a ring/sector grid centered at the SRS center with rings spaced 10 miles apart. This ring/sector grid is overlaid on the cell grid used by the dose assessment codes. Presumably the dose assessment codes are using an area weighted calculation similar to that described above in which the contributions from grid cells are determined for each ring/sector cell. This same calculation can be performed with ArcView to give an accurate GIS calculation that can serve as a benchmark for comparison with the dose assessment code calculations. Table 1 gives the population results for each ring/sector cell as determined with ArcView using the grid cell population distribution.

Figure 4 shows the ring/sector grid overlaid on the census blocks. ArcView was used to compute the ring/sector cell populations based directly on census block population. Table 2 gives the population results for each ring/sector cell based on census block population. This table should be regarded as the most accurate calculation available for the ring/sector population distribution.

We can assess the accuracy of using grid cells rather than census blocks by taking the ratio of Table 2 to Table 1. Table 3 shows the results of this ratio. A ratio greater than one means that the grid cell approach underpredicts population within the ring/sector cell whereas a ratio less than one means that the grid cell approach overpredicts population within the ring/sector cell. For the outermost cells we see that the grid cell approach is within 5%. For the cells closer to SRS, we see a greater difference. This is due to areas within SRS having zero population but areas just outside, such as Jackson, having a significant jump in population. The grid cell contains population that is averaged over the cell, so that the grid cell attributes population to area inside the first ring when in most cases there is no actual population since the first ring of 10 miles almost coincides with the SRS boundary. Thus, we see population overpredicted in the first ring. Likewise, in the second ring in the WNW sector, the population is underpredicted by 11%. This is the sector containing Jackson and the difference is due to the significant population jump across the SRS boundary into Jackson.

Table 1. Population within Ring/Sector Grid Based on Grid Cells

	0-10	10-20	20-30	30-40	40-50	TOTAL
N	51	6936	12865	4328	12901	37081
NNE	3	3113	2231	6110	22658	34115
NE	0	4748	2944	5855	15750	29297
ENE	27	1954	5078	5403	45408	57870
E	92	8095	7403	7706	4608	27904
ESE	29	2479	1486	1918	3222	9134
SE	16	612	6038	6999	9821	23486
SSE	13	209	311	324	5628	6485
S	3	407	1419	8422	3936	14187
SSW	1	977	2318	5841	3143	12280
SW	7	876	1620	1041	2204	5748
WSW	37	1245	9338	1465	6176	18261
W	0	3454	9325	4361	6934	24074
WNW	522	2397	114849	61259	14745	193772
NW	257	8195	92899	44582	2948	148881
NNW	450	24250	28912	9514	7657	70783
TOTAL	1508	69947	299036	175128	167739	713358

Table 2. Population within Ring/Sector Grid Based on Census Blocks

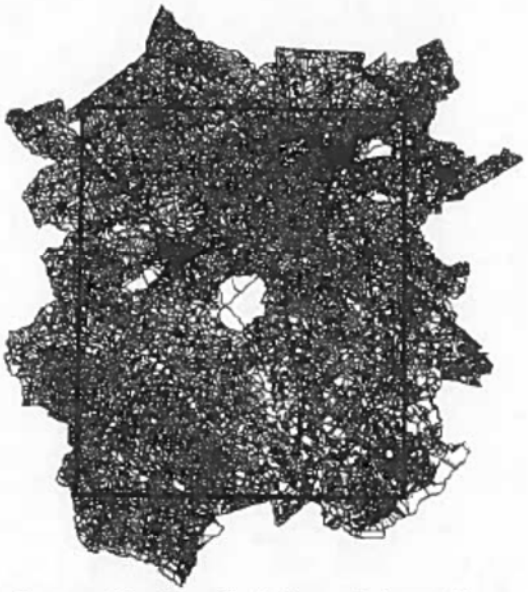
	0-10	10-20	20-30	30-40	40-50	TOTAL
N	12	7062	12745	4132	12988	36939
NNE	0	3122	2226	6010	22568	33926
NE	0	4802	2981	6043	15519	29345
ENE	17	1933	5099	5264	46084	58397
E	60	8143	7440	7625	4618	27886
ESE	24	2435	1510	1916	3206	9091
SE	13	620	5842	7289	9566	23330
SSE	11	209	312	319	5748	6599
S	5	402	1421	8498	3873	14199
SSW	0	955	2337	5893	3162	12347
SW	3	892	1609	1005	2180	5689
WSW	37	1218	9339	1467	6187	18248
W	0	3461	9127	4362	6968	23918
WNW	314	2667	114847	60409	14711	192948
NW	240	8128	93779	44541	2973	149661
NNW	470	24560	28887	9302	7927	71146
TOTAL	1206	70609	299501	174075	168278	713669

Table 3. Ratio of Table 2 to Table 1

	0-10	10-20	20-30	30-40	40-50	TOTAL
N	0.24	1.02	0.99	0.95	1.01	1.00
NNE	0.00	1.00	1.00	0.98	1.00	0.99
NE		1.01	1.01	1.03	0.99	1.00
ENE	0.63	0.99	1.00	0.97	1.01	1.01
E	0.65	1.01	1.00	0.99	1.00	1.00
ESE	0.83	0.98	1.02	1.00	1.00	1.00
SE	0.81	1.01	0.97	1.04	0.97	0.99
SSE	0.85	1.00	1.00	0.98	1.02	1.02
S	1.67	0.99	1.00	1.01	0.98	1.00
SSW	0.00	0.98	1.01	1.01	1.01	1.01
SW	0.43	1.02	0.99	0.97	0.99	0.99
WSW	1.00	0.98	1.00	1.00	1.00	1.00
W		1.00	0.98	1.00	1.00	0.99
WNW	0.60	1.11	1.00	0.99	1.00	1.00
NW	0.93	0.99	1.01	1.00	1.01	1.01
NNW	1.04	1.01	1.00	0.98	1.04	1.01
TOTAL	0.80	1.01	1.00	0.99	1.00	1.00

Figure 1. Study Area with Block Groups and Blocks

a. Census block groups with 2 deg x 2 deg grid extent



b. Census blocks with 2 deg x 2 deg grid extent

50 0 50 100 Miles

Figure 2. Census Blocks Overlaid by Grid Cells

a. Census blocks around Jackson, SC with one block highlighted

b. One minute by one minute grid cells overlaid on Census blocks

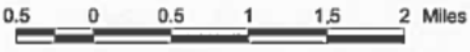


Figure 3. Ring/Sector Grid overlaid on Cell Grid

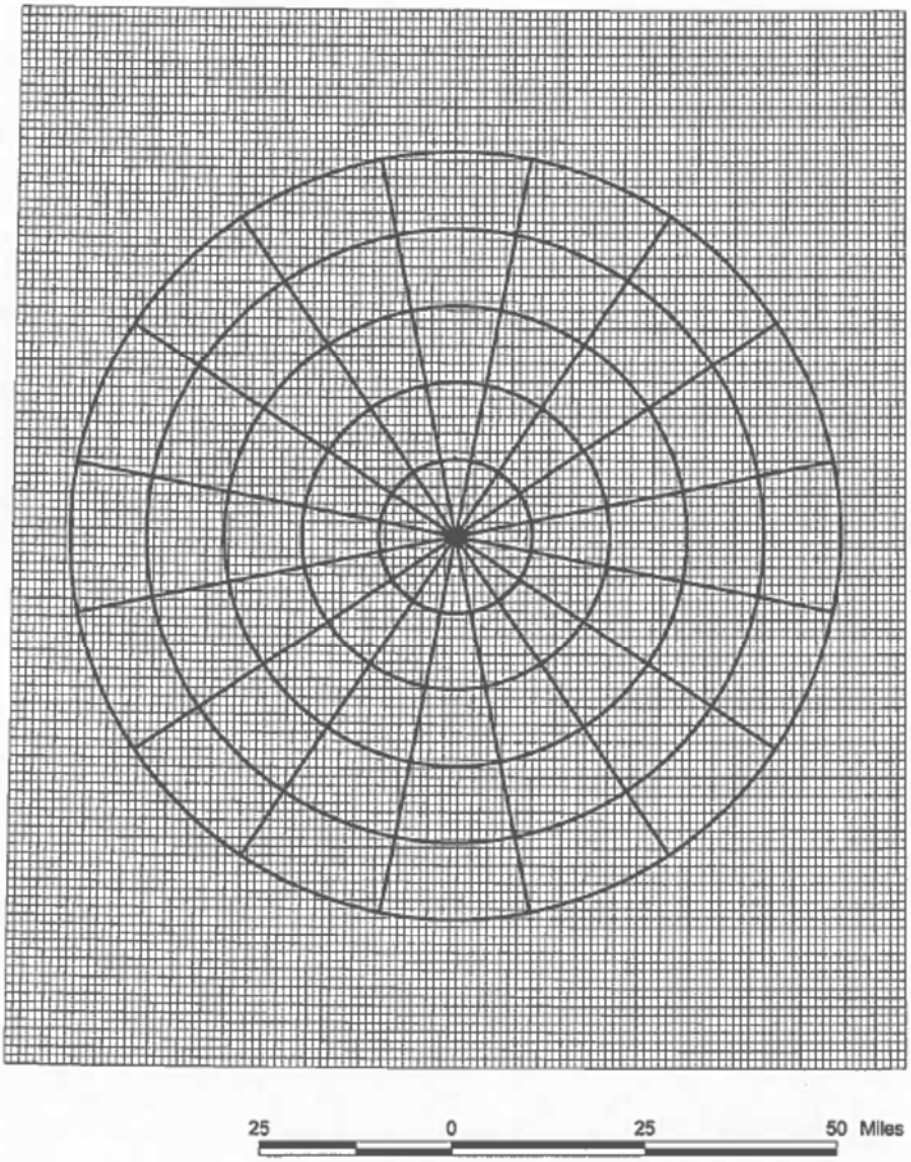


Figure 4. Ring/Sector Grid overlaid on Blocks