TECHNICAL MEMORANDUM

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SUBJECT: Modeling Allocation Factors for the 2011 Nonpoint NEI

1.0 INTRODUCTION

The exploration and production of oil and gas has increased in terms of quantities and locations over the last five years, primarily through the use of new technologies, such as hydraulic fracturing. As part of the 2011 National Emissions Inventory (NEI) cycle, EPA recently prepared county-level emission estimates for the oil and gas sector. This emissions inventory was more comprehensive on a geographic, source category, and pollutant coverage basis when compared to prior NEI base years for this sector.

The purpose of this memorandum is to summarize procedures used to develop spatial and temporal modeling allocation factors for the 2011 Nonpoint NEI using data primarily from the Oil and Gas Estimation Tool and other sources. EPA directed ERG to start with the analysis and files delivered to EPA Office of Compliance on April 11, 2013 (U.S. EPA, 2013a), and to incorporate additional datasets to develop surrogate modeling factors. All work was performed under EPA Contract No. EP-D-09-048, Delivery Order 00-54, entitled “Report Development - Data Characterization.”

2.0 BACKGROUND INFORMATION

EPA recently developed a 2011 Nonpoint NEI for the oil and gas sector (U.S. EPA, 2013d). For the majority of the country, emission estimation methodologies were consistent, in terms of geographic, source category, and pollutant coverage due to the development of EPA's National Oil and Gas Emission Estimation Tool ("Tool") (EPA, 2013c). During the compilation stage, State/Local/Tribal agencies had the opportunity to revise EPA's emission estimates.

EPA uses the NEI for several purposes, including emissions modeling for regulatory activities. For nonpoint sources, emissions are presented in the NEI at the county-level, which may not be suitable for particular types of modeling applications. Thus, county-level emissions may need to be allocated to sub-county levels. For this Delivery Order, ERG developed spatial allocation factors at both the census tract and the 4-km grid scale level. Additionally, EPA asked ERG to develop monthly temporal allocation factors, which can be useful for future air quality modeling.

3.0 DATA SOURCES

The modeling surrogates were developed using multiple data sources described below.

3.1 HPDI

The primary activity data source used for EPA's 2011 Nonpoint NEI for oil and gas was data from Drilling Info (DI) Desktop's HPDI database (Drilling Info, 2012). This database contains well-level location, production, and exploration statistics at the monthly level. Due to a proprietary agreement with DI Desktop, individual well locations and ancillary production cannot be made publicly available, but aggregated statistics are allowed. For the Tool, the individual well-level statistics were summed to the county-level. HPDI data represents approximately 80% of the activity data used in the Tool.

3.2 Oil and Gas Commission Websites

For the remaining 20%, ERG supplemented the HPDI activity data with additional data from Oil and Gas Commission (OGC) websites. In many cases, the correct surrogate parameter was not available (e.g., feet drilled), but an alternative surrogate parameter was available (e.g., number of spudded wells) and downloaded. The types of information retrieved from these websites are presented in Table 1, as well as the corresponding reference listed in Section 8.

Table 1. Information Retrieved from State Websites

State	Information Retrieved	Reference No.
Alabama	Well Depths	1
Alaska	Well Depths	2
Arkansas	Oil and Gas Completions	3
California	Well Locations	4
Illinois	Well Locations	6
Indiana	Well Locations	7
Kansas	Oil and Gas Completions, Well Depths	8
Michigan	Well Locations	9
Missouri	Well Locations	10
Montana	Oil and Gas Completions	11
Nevada	Well Locations	12
New Mexico	Spud Counts	13
Oklahoma	Spud Counts	14
Pennsylvania	Produced Water, Spud Counts	15
Texas	Well Locations	16
Utah	Spud Counts	21
West Virginia	Well Locations, Oil Production	22

3.3 EPA Greenhouse Gas Inventory for Completions

EPA supplemented the completion information from HPDI by implementing the methodology for counting oil and gas well completions developed for the U.S. National Greenhouse Gas Inventory (U.S. EPA, 2013b). Under that methodology, both completion date and date of first production from HPDI were used to identify wells completed during 2011.

4.0 DATA COMPILATION

In total, over 1.08 million unique well locations were compiled from the above data sources. The well locations cover 33 states and 1,193 counties. Each well was uploaded into ArcGIS, and assigned to the associated census tract identifier and 4-km grid identifier. Census tract identifiers were matched to the 2010 census and the 4-km grid was provided by EPA. Well locations are presented in Figure 1. Additionally, census tract coverage is presented in Figure 2 and the 4-km coverage is presented in Figure 3. It is important to note that the 4-km surrogate grid only includes the continental United States. Thus, oil and gas activities for Alaska are not developed.

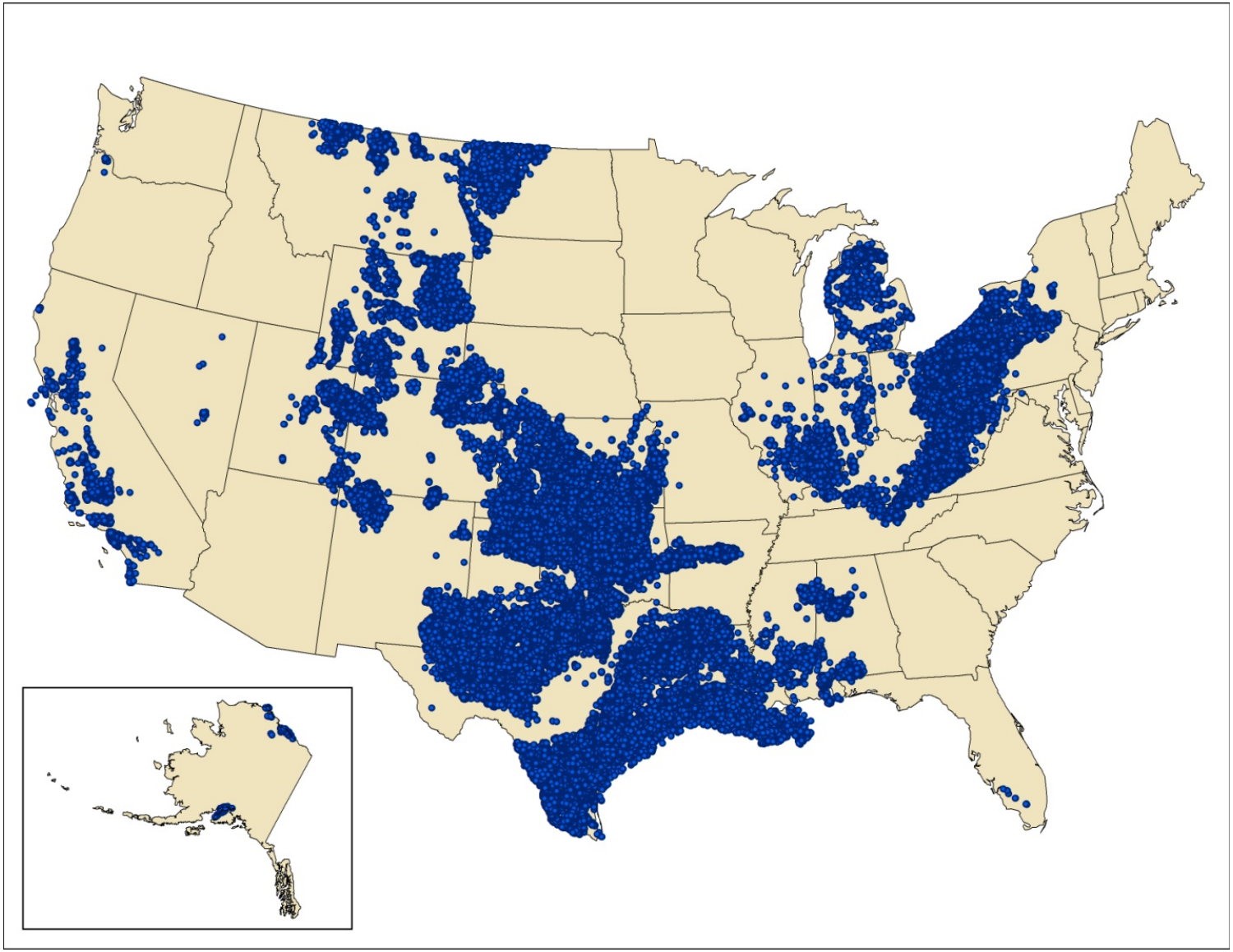

Figure 1. Compiled Well Locations for the U.S.

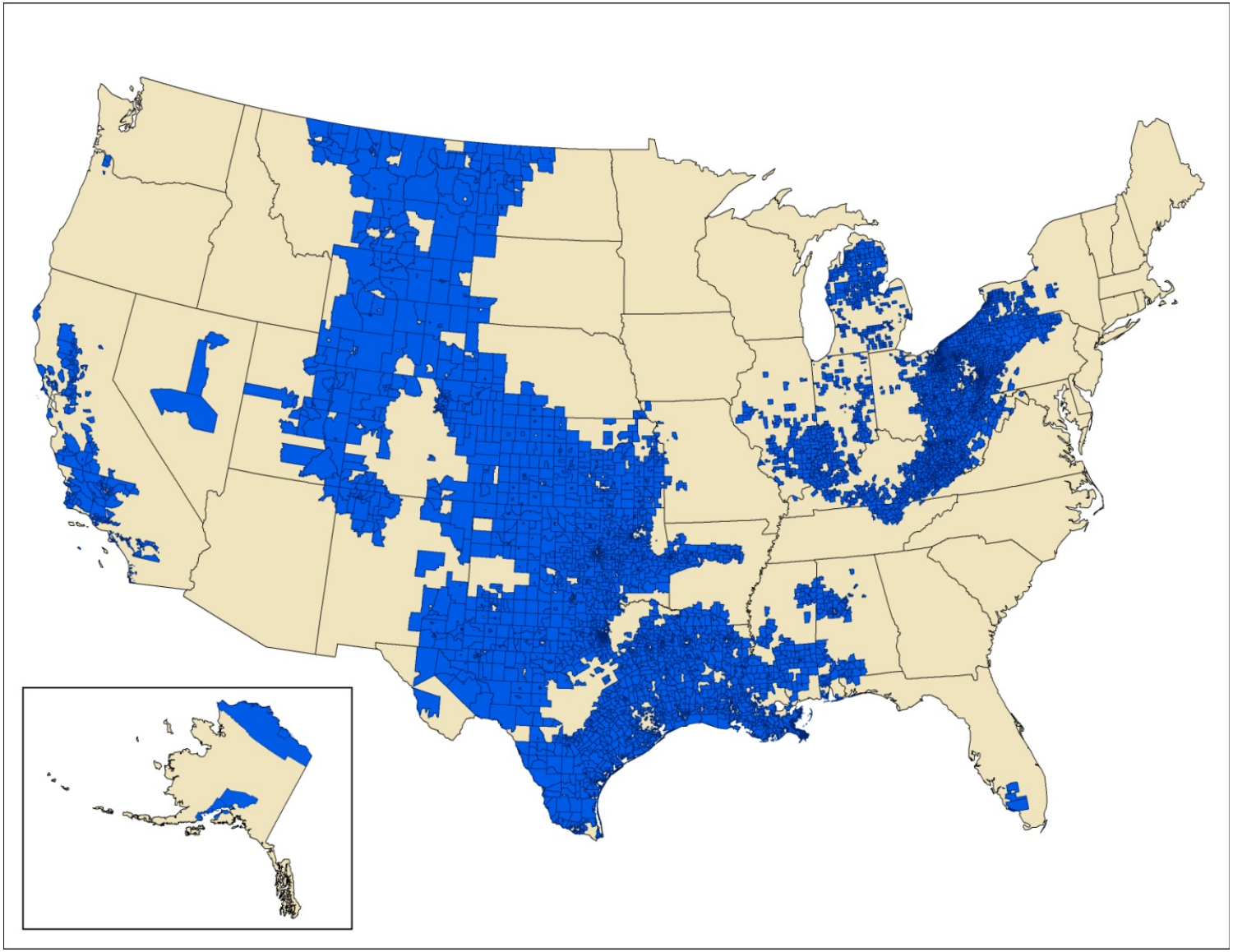

Figure 2. Compiled Well Locations Placed at U.S. Census Tracts

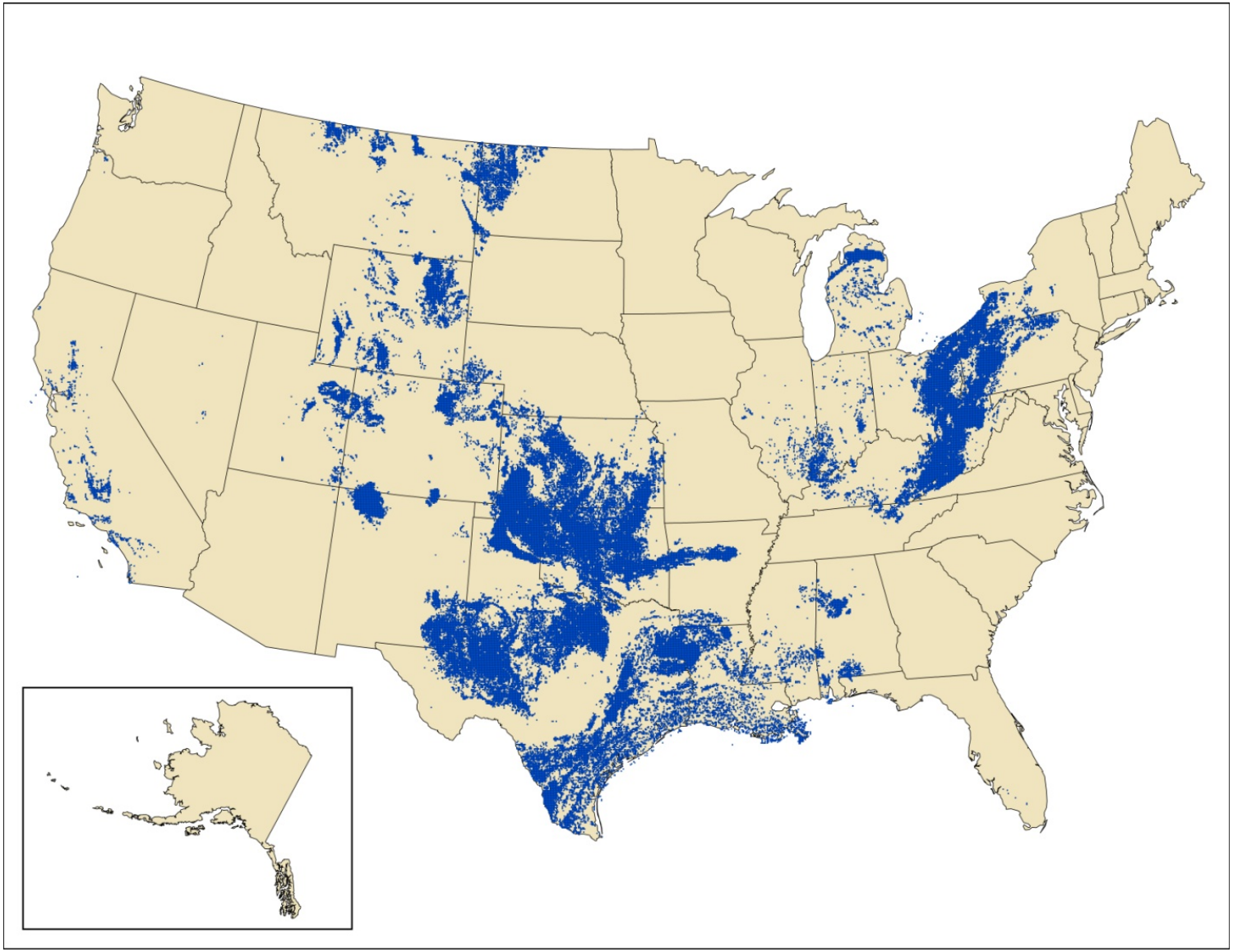

Figure 3. Compiled Well Locations Placed at U.S. 4-km Grids

5.0 OIL AND GAS SURROGATES

The 2011 Nonpoint NEI for oil and gas contains emission estimates for 33 states and 1,161 counties. Additionally, emissions are estimated for 101 oil and gas source classification codes (SCCs), those that begin with 2310xxxxxx. The list of SCCs is presented in Appendix A. Of the 101 SCCs, 34 were directly matched to the SCCs in the Tool. In total, there are 26,196 unique county-SCC pairs with emissions.

Despite the large number of SCCs, emissions were allocated to the census tract and 4-km level with fifteen surrogates. These surrogates are presented in Table 2.

Table 2. Oil and Gas Surrogate Codes

EPA Surrogate Code	EPA Surrogate Description	Surrogate Spatial Allocation Factor Name
681	Spud count - Oil Wells	SPUD_OIL
682	Spud count - Horizontally-drilled wells	SPUD_HORIZONTAL
683	Produced Water at all wells	WATER_PROD
684	Completions at Gas and CBM Wells	GAS_CBM_COMPLETIONS
685	Completions at Oil Wells	OIL_COMPLETIONS
686	Completions at all wells	PULL_COMPLETIONS
687	Feet drilled at all wells	FT_DRILLED
688	Spud count - Gas and CBM Wells	SPUD_GAS_CBM
689	Gas production at all wells	TOTAL_GAS_PROD
692	Spud count - All Wells	SPUD_GAS_CBM_OIL
693	Well count - all wells	TOTAL_WELL_COUNTS
694	Oil production at oil wells	OIL_PROD
695	Well count - oil wells	OIL_COUNTS
697	Oil production at Gas and CBM Wells	CONDENSATE_PROD
698	Well counts - Gas and CBM Wells	GAS_COUNTS

Appendix B presents the county-SCC pairs with the primary surrogate codes. If the primary surrogate was not available, then an alternate surrogate was assigned. Appendix C presents the surrogate assignment progression. In cases where there is no well-level location data for a particular county, then a surrogate code of 400, which is allocation by rural land area, was assigned. This accounted for only eleven of 26,196 county-SCC records. Table 3 summarizes the number of county-SCC pairs by surrogate code.

Table 3. Oil and Gas Surrogate Codes

Surrogate Code	# County-SCC Records with Emissions	% of Total
698	9,968	38.05
695	6,698	25.57
693	2,379	9.08
694	2,337	8.92
697	996	3.80
689	937	3.58
686	740	2.82
683	543	2.07
687	537	2.05
684	281	1.07
685	268	1.02
692	223	0.85
688	123	0.47
681	88	0.34
682	67	0.26
400	11	0.04

6.0 SPATIAL SURROGATE CALCULATIONS

Since emissions were at the county-level, the surrogate factors need to be developed for portions within the county.

6.1 Spatial Surrogate Calculations – Census-Tract Level

For the census-tract allocation, the following steps were used:

a. Using GIS software, assign wells to census tract
b. Sum allocation factors to the census tract-level
c. Sum allocation factors to the county-level
d. Divide summed census-tract allocations by the summed county-level allocations to calculate census-tract spatial allocation factors

For example, County A reports 10 tons of VOCs from 4-stroke lean burn Wellhead Compressors. The primary activity data used to generated emissions is the number of natural gas wells. County A has a total of 80 natural gas wells and is subdivided into 4 census tracts with the following information:

1) Census tract 1 has 50 natural gas wells
2) Census tract 2 has 20 natural gas wells
3) Census tract 3 has 0 natural gas wells
4) Census tract 4 has 10 natural gas wells

Thus, VOC emissions within County A are then apportioned, as follows:

Step 1

$$\text{Tract 1 VOC emissions} = \frac{(10\ \text{tpy, County A}) * (50\ \text{natural gas wells, Census tract 1})}{80\ \text{natural gas wells in County A}}$$

Tract 1 VOC emissions = 6.25 tpy

Step 2

$$\text{Tract 2 VOC emissions} = \frac{(10\ \text{tpy, County A}) * (20\ \text{natural gas wells, Census tract 2})}{80\ \text{natural gas wells in County A}}$$

Tract 2 VOC emissions = 2.50 tpy

Step 3

$$\text{Tract 3 VOC emissions} = \frac{(10\ \text{tpy, County A}) * (0\ \text{natural gas wells, Census tract 3})}{80\ \text{natural gas wells in County A}}$$

Tract 3 VOC emissions = 0 tpy

Step 4

$$\text{Tract 4 VOC emissions} = \frac{(10\ \text{tpy, County A}) * (10\ \text{natural gas wells, Census tract 4})}{80\ \text{natural gas wells in County A}}$$

Tract 4 VOC emissions = 1.25 tpy

Nearly 35,000 Surrogate Code-FIPS-census tract surrogates were developed, and are presented in Appendix C.

6.2 Spatial Surrogate Calculations – 4-km Grid Scale

For the 4-km allocation, the following steps were used:

a. Using GIS software, assign wells to 4-km grid cell
b. Sum allocation factors to the county- and 4-km grid cell-level

c. Sum allocation factors to the county-level
d. Divide summed county- and 4-km grid cell allocations by the summed county-level allocations to calculate 4-km spatial allocation factors

For example, County B reports 25 tons of CO from 4-stroke rich burn Wellhead Compressors from 1,000 natural gas wells. In an adjacent county, County C reports 15 tons of CO from 100 natural gas wells for the same source category. The two counties share one similar 4-km grid cell (55) on the border. The primary activity data used to generated emissions is the number of natural gas wells. County B has a total of 100 natural gas wells in grid cell 55 and County C a total of 50 natural gas wells in grid cell 55.

Thus, VOC emissions for grid cell 55 within County B are then apportioned, as follows:

Step 1

$$\text{County B, grid cell 55 CO emissions} = \frac{(25\ \text{tpy, County A}) * (100\ \text{natural gas wells, Count B, grid cell 55})}{1{,}000\ \text{natural gas wells in County B}}$$

County B, grid cell 55 CO emissions = 2.5 tpy

Step 2

$$\text{County C, grid cell 55 CO emissions} = \frac{(15\ \text{tpy, County A}) * (50\ \text{natural gas wells, Count C, grid cell 55})}{100\ \text{natural gas wells in County B}}$$

County C, grid cell 55 CO emissions = 7.5 tpy

Step 3

Grid cell 55 CO emissions=2.5 tpy+7.5 tpy=10.0 tpy

Over 306,000 Surrogate Code-County-Grid Cell IDs were developed, and are presented in Appendix D.

6.2 Temporal Surrogate Calculations

Monthly surrogates were prepared for county-SCC combinations which overlap with data extracted from HPDI. The following steps were used to generate the monthly surrogates:

a. Sum allocation factors to the monthly timeframe
b. Sum allocation factors to annual timeframe

c. Divide summed monthly allocations by the summed annual allocations to calculate monthly spatial allocation factors

For county-SCC combinations that were not extracted from HPDI, the surrogate parameter was evenly distributed by month. Appendix E presents the temporal factors by the county-SCC combinations.

7.0 FINAL DATA PRODUCTS

For the census-tract and 4-km spatial allocation factors, ERG prepared SMOKE-ready files for each surrogate code.

The census-tract spatial allocation factor files contain the following data fields:

a. Surrogate Code
b. State and County FIPS Code
c. Census Tract identifier
d. Spatial Allocation Factor
e. Fractionated census-level total value
f. County-level total

The 4-km spatial allocation factor files contain the following data fields:

a. Surrogate Code
b. State and County FIPS Code
c. Grid-Scale Column Value
d. Grid-Scale Row Value
e. Spatial Allocation Factor
f. Fractionated grid-level total value
g. County-level total

The temporal allocation factors were in one-record per line (ORL) format with the following data fields:

a. FIPS
b. SCC
c. JANFRAC
d. FEBFRAC

e. MARFRAC
f. APRFRAC
g. MAYFRAC
h. JUNFRAC
i. JULFRAC
j. AUGFRAC
k. SEPFRAC
l. OCTFRAC
m. NOVFRAC
n. DECFRAC

Finally, ERG prepared GIS shapefiles of the 4-km grid and these are presented in Appendix F.

8.0 REFERENCES

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Appendix A – 2011 Nonpoint NEI Oil and Gas SCCs

Appendix A. 2011 Oil and Gas Nonpoint NEI SCCs

SCC	SCC DESCRIPTION SHORTENED	TOOL OVERLAP FLAG
2310000000	Oil & Gas Expl & Prod /All Processes /Total: All Processes	
2310000220	Oil And Gas Exploration Drill Rigs	X
2310000230	Oil & Gas Expl & Prod /All Processes /Workover Rigs	
2310000330	Oil & Gas Expl & Prod /All Processes /Artificial Lift	X
2310000550	PRODUCED WATER	X
2310000660	Oil & Gas Expl & Prod /All Processes /Hydraulic Fracturing Engines	X
2310002000	Off-Shore Oil And Gas Production /Total: All Processes	
2310002301	Off-Shore Oil And Gas Production /Flares: Continuous Pilot Light	
2310002305	Off-Shore Oil And Gas Production /Flares: Flaring Operations	
2310002401	Off-Shore Oil And Gas Production /Pneumatic Pumps: Gas And Oil Wells	
2310002411	Off-Shore Oil And Gas Production /Pressure/Level Controllers	
2310002421	Off-Shore Oil And Gas Production /Cold Vents	
2310010000	Oil & Gas Expl & Prod /Crude Petroleum /Total: All Processes	
2310010100	On-Shore Oil Production /Heater Treater	X
2310010200	Oil & Gas Expl & Prod /Crude Petroleum /Oil Well Tanks - Flashing & Standing/Working/Breathing	X
2310010300	Oil Production Pneumatic Devices	X
2310010700	Oil & Gas Expl & Prod /Crude Petroleum /Oil Well Fugitives	
2310010800	Oil & Gas Expl & Prod /Crude Petroleum /Oil Well Truck Loading	
2310011000	On Shore Crude Oil Production All Processes	X
2310011020	On-Shore Oil Production /Storage Tanks: Crude Oil	
2310011100	On-Shore Oil Production /Heater Treater	
2310011201	On-Shore Oil Production /Tank Truck/Railcar Loading: Crude Oil	X
2310011450	On-Shore Oil Production /Wellhead	
2310011500	On-Shore Oil Production /Fugitives: All Processes	
2310011501	On-Shore Oil Production /Fugitives: Connectors	X
2310011502	On-Shore Oil Production /Fugitives: Flanges	X
2310011503	On-Shore Oil Production /Fugitives: Open Ended Lines	X
2310011504	On-Shore Oil Production /Fugitives: Pumps	
2310011505	On-Shore Oil Production /Fugitives: Valves	X
2310011506	On-Shore Oil Production /Fugitives: Other	
2310012000	Off-Shore Oil Production /Total: All Processes	
2310012020	Off-Shore Oil Production /Storage Tanks: Crude Oil	
2310012511	Off-Shore Oil Production /Fugitives, Connectors: Oil Streams	
2310012512	Off-Shore Oil Production /Fugitives, Flanges: Oil	

SCC	SCC DESCRIPTION SHORTENED	TOOL OVERLAP FLAG
2310012515	Off-Shore Oil Production /Fugitives, Valves: Oil	
2310012516	Off-Shore Oil Production /Fugitives, Other: Oil	
2310012521	Off-Shore Oil Production /Fugitives, Connectors: Oil/Water Streams	
2310012522	Off-Shore Oil Production /Fugitives, Flanges: Oil/Water	
2310012526	Off-Shore Oil Production /Fugitives, Other: Oil/Water	
2310020000	Oil & Gas Expl & Prod /Natural Gas /Total: All Processes	
2310020600	Oil & Gas Expl & Prod /Natural Gas /Compressor Engines	
2310020800	Oil & Gas Expl & Prod /Natural Gas /Gas Well Truck Loading	
2310021010	On-Shore Gas Production /Storage Tanks: Condensate	X
2310021011	On-Shore Gas Production / Condensate Tank Flaring	
2310021030	On-Shore Gas Production /Tank Truck/Railcar Loading: Condensate	X
2310021100	On-Shore Gas Production /Gas Well Heaters	X
2310021101	On-Shore Gas Production /Natural Gas Fired 2Cycle Lean Burn Compressor Engines < 50 HP	
2310021102	On-Shore Gas Production /Natural Gas Fired 2Cycle Lean Burn Compressor Engines 50 To 499 HP	
2310021103	On-Shore Gas Production /Natural Gas Fired 2Cycle Lean Burn Compressor Engines 500+ HP	
2310021201	On-Shore Gas Production /Natural Gas Fired 4Cycle Lean Burn Compressor Engines <50 HP	
2310021202	On-Shore Gas Production /Natural Gas Fired 4Cycle Lean Burn Compressor Engines 50 To 499 HP	X
2310021203	On-Shore Gas Production /Natural Gas Fired 4Cycle Lean Burn Compressor Engines 500+ HP	
2310021251	On-Shore Gas Production/Lateral Compressors 4 Cycle Lean Burn	X
2310021300	On-Shore Gas Production Pneumatic Devices	X
2310021301	On-Shore Gas Production /Natural Gas Fired 4Cycle Rich Burn Compressor Engines <50 HP	
2310021302	On-Shore Gas Production /Natural Gas Fired 4Cycle Rich Burn Compressor Engines 50 To 499 HP	X
2310021303	On-Shore Gas Production /Natural Gas Fired 4Cycle Rich Burn Compressor Engines 500+ HP	
2310021310	On-Shore Gas Production / Gas Well Pneumatic Pumps	
2310021351	On-Shore Gas Production/Lateral Compressors 4 Cycle Rich Burn	X
2310021400	On-Shore Gas Production Dehydrators	X
2310021402	On-Shore Gas Production /Nat Gas Fired 4Cycle Rich Burn Compressor Engines 50 To 499 HP w/NSCR	
2310021403	On-Shore Gas Production /Nat Gas Fired 4Cycle Rich Burn Compressor Engines 500+ HP w/NSCR	
2310021411	On-Shore Gas Production / Gas Well Dehydrators - Flaring	
2310021500	On-Shore Gas Production /Gas Well Completion - Flaring	
2310021501	On-Shore Gas Production /Fugitives: Connectors	X
2310021502	On-Shore Gas Production /Fugitives: Flanges	X
2310021503	On-Shore Gas Production /Fugitives: Open Ended Lines	X
2310021504	On-Shore Gas Production /Fugitives: Pumps	

Appendix A. 2011 Oil and Gas Nonpoint NEI SCCs

SCC	SCC DESCRIPTION SHORTENED	TOOL OVERLAP FLAG
2310021505	On-Shore Gas Production /Fugitives: Valves	X
2310021506	On-Shore Gas Production /Fugitives: Other	X
2310021509	On-Shore Gas Production /Fugitives: All Processes	
2310021600	On-Shore Gas Production /Gas Well Venting	
2310021601	On-Shore Gas Production / Gas Well Venting - Initial Completions	
2310021602	On-Shore Gas Production / Gas Well Venting - Recompletions	
2310021603	On-Shore Gas Production / Gas Well Venting - Blowdowns	X
2310021604	On-Shore Gas Production / Gas Well Venting - Compressor Startups	
2310021605	On-Shore Gas Production / Gas Well Venting - Compressor Shutdowns	
2310021700	On-Shore Gas Production / Miscellaneous Engines	
2310022000	Off-Shore Gas Production /Total: All Processes	
2310022010	Off-Shore Gas Production /Storage Tanks: Condensate	
2310022051	Off-Shore Gas Production /Turbines: Natural Gas	
2310022090	Off-Shore Gas Production /Boilers/Heaters: Natural Gas	
2310022105	Off-Shore Gas Production /Diesel Engines	
2310022410	Off-Shore Gas Production /Amine Unit	
2310022420	Off-Shore Gas Production /Dehydrator	
2310022501	Off-Shore Gas Production /Fugitives, Connectors: Gas Streams	
2310022502	Off-Shore Gas Production /Fugitives, Flanges: Gas Streams	
2310022505	Off-Shore Gas Production /Fugitives, Valves: Gas	
2310022506	Off-Shore Gas Production /Fugitives, Other: Gas	
2310030000	Oil & Gas Expl & Prod /Natural Gas Liquids /Total: All Processes	
2310030210	Oil & Gas Expl & Prod /Natural Gas Liquids /Gas Well Tanks - Flashing & Standing/Working/Breathing, Uncontrolled	
2310030300	Natural Gas Liquids / Gas Well Water Tank Losses	
2310030401	Natural Gas Liquids / Gas Plant Truck Loading	
2310111100	On-Shore Oil Exploration /Mud Degassing	X
2310111401	On-Shore Oil Exploration /Oil Well Pneumatic Pumps	X
2310111700	On-Shore Oil Exploration: Oil Well Completion: All Processes	X
2310112401	Off-Shore Oil Exploration /Oil Well Pneumatic Pumps	
2310121100	On-Shore Gas Exploration /Mud Degassing	X
2310121401	On-Shore Gas Exploration: Gas Well Pneumatic Pumps	X
2310121700	On-Shore Gas Exploration: Gas Well Completion: All Processes	X
2310122100	Off-Shore Gas Exploration /Mud Degassing	

Appendix B – 2011 Nonpoint NEI Oil and Gas County FIPS, SCCs, and Surrogate

(see AppendixB-2011Nonpoint_NEI_County_SCC_Surrogate.xlsx)

Appendix C – Surrogate Priority

Appendix C. Priority of Primary and Alternate Surrogates

CONDENSATE_PROD
↓
TOTAL_GAS_PROD
↓
TOTAL_WELL_COUNTS
↓
SPUD_GAS_CBM_OIL
↓
COMPLETIONS (PULL, OIL, or GAS/CBM)
↓
FT_DRILLED
↓
RURAL_LAND_AREA

FT_DRILLED
↓
SPUD_GAS_CBM_OIL
↓
COMPLETIONS (PULL, OIL, or GAS/CBM)
↓
TOTAL_WELL_COUNTS
↓
RURAL_LAND_AREA

GAS_CBM_COMPLETIONS
↓
COMPLETIONS (PULL or OIL)
↓
SPUD_GAS_CBM_OIL
↓
FT_DRILLED
↓
TOTAL_WELL_COUNTS
↓
RURAL_LAND_AREA

GAS_CBM_COUNTS
↓
TOTAL_GAS_PROD
↓
TOTAL_WELL_COUNTS
↓
COMPLETIONS (PULL, OIL, or GAS/CBM)
↓
RURAL_LAND_AREA

GAS_CBM_PROD
↓
GAS_CBM_COUNTS
↓
TOTAL_WELL_COUNTS
↓
RURAL_LAND_AREA

OIL_COMPLETIONS
↓
COMPLETIONS (PULL or GAS/CBM)
↓
OIL_COUNTS
↓
TOTAL_WELL_COUNTS
↓
RURAL_LAND_AREA

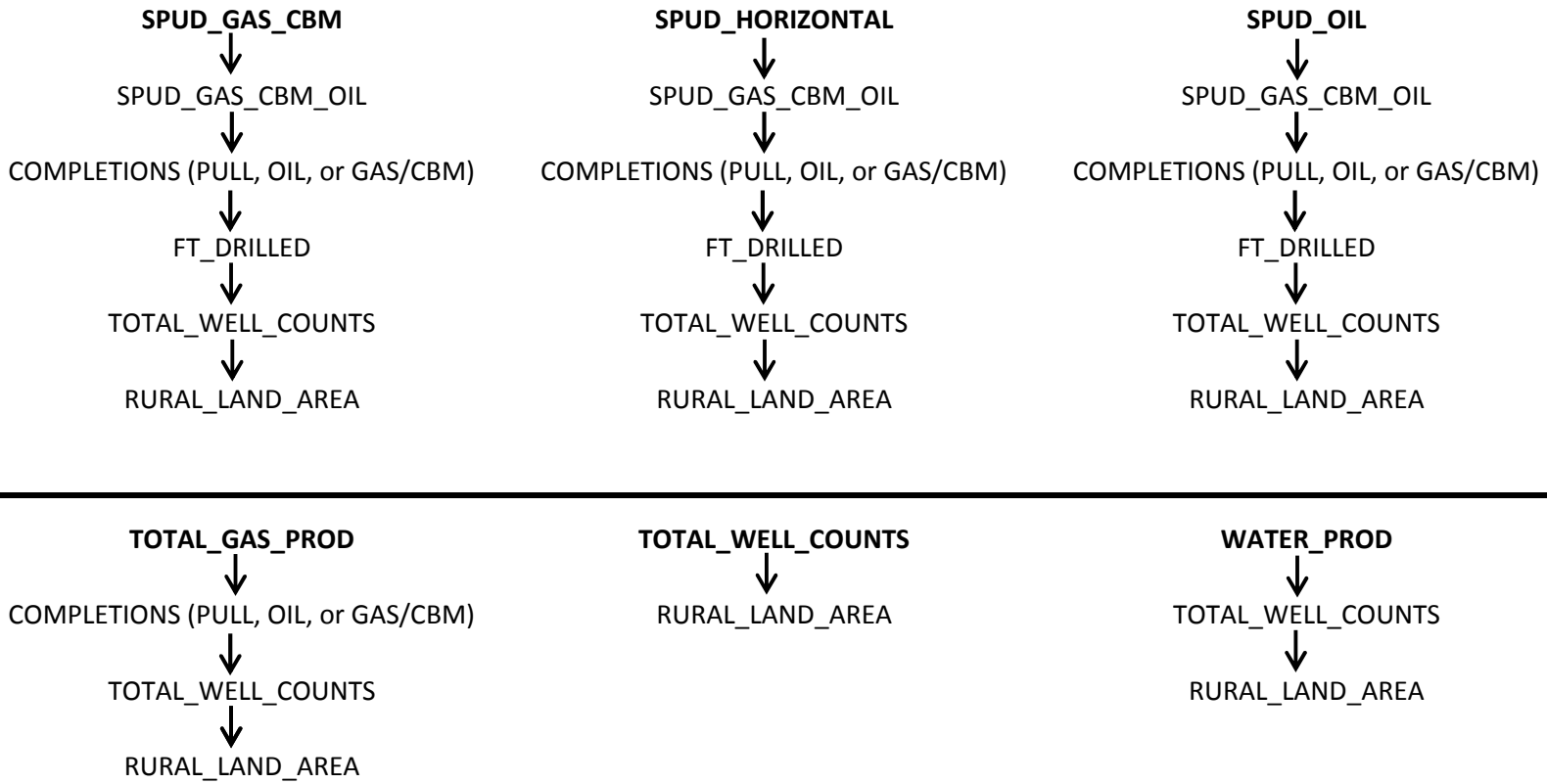
OIL_COUNTS
↓
OIL_PROD
↓
GAS_CBM_COUNTS
↓
TOTAL_WELL_COUNTS
↓
RURAL_LAND_AREA

OIL_PROD
↓
CONDENSATE_PROD
↓
TOTAL_WELL_COUNTS
↓
RURAL_LAND_AREA

SPUD_GAS_CBM_OIL
↓
COMPLETIONS (PULL, OIL, or GAS/CBM)
↓
FT_DRILLED
↓
TOTAL_WELL_COUNTS
↓
RURAL_LAND_AREA

BOLD: Primary Surrogate
Non-BOLD: Alternate Surrogate

Appendix C. Priority of Primary and Alternate Surrogates



BOLD: Primary Surrogate
Non-BOLD: Alternate Surrogate

Appendix D – Surrogate, County FIPs, and 4-km Grid Cells

(see AppendixD-Surrogate_County_Grid.xlsx)

Appendix E – Monthly Temporal Factors

(see AppendixE-MonthlyTemporalFactors.xlsx)

Appendix F – 4-km GIS ShapeFile

(see AppendixF-Wells_Surrogates.zip)