For help accessing this document, email NEI_Help@epa.gov.

A Monte Carlo Approach to Developing Area Source Oil and Gas Emissions Inventories

Tom Richardson, P.E.

Oklahoma DEQ

Taking stock of some of our previous work on super-emitters

Air & Waste Management Association
108th Annual Conference & Exhibition
June 25, 2015

Fat Tails and Emissions Inventories for Oil & Gas Production Facilities

Extended Abstra

DEQ OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

Tom Richa
Existing So
Air Quality
Oklahoma

The Take-Ho

1. For emissions inventories, **outliers matter**.
2. When scaling up from individual facilities, multiply the number of facilities by the **arithmetic mean** of emissions emitted by a sample of the individual facilities.
3. If you think the outliers are skewing your airshed emissions estimates high, gather more data.

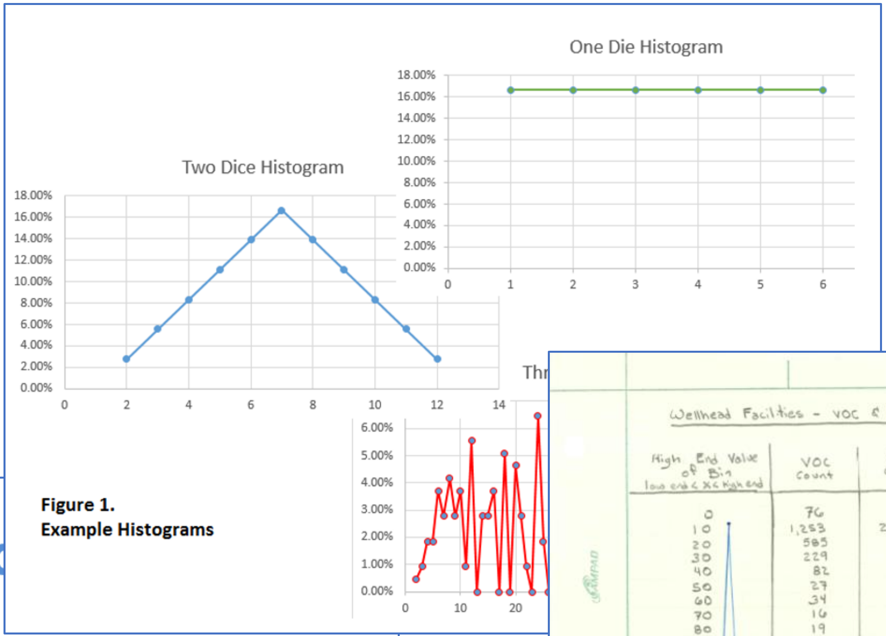
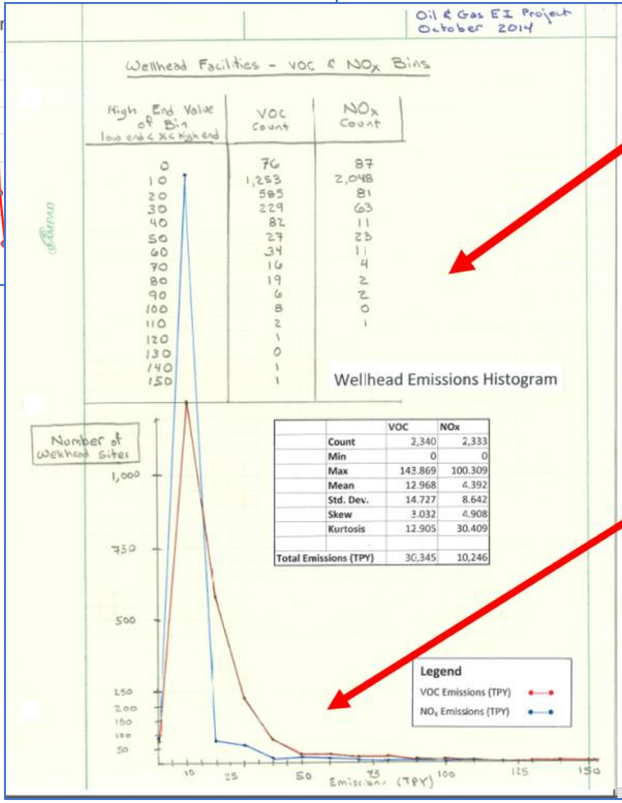


Figure 1.
Example Histograms



	VOC	NOx
Count	2,340	2,333
Min	0	0
Max	143.869	100.309
Mean	12.968	4.392
Std. Dev.	14.727	8.642
Skew	3.032	4.908
Kurtosis	12.905	30.409
Total Emissions (TPY)	30,345	10,246

Before (and, later, After Pictures)

Note the heavy-tailed Distribution.

Recognizing my collaborators

Thanks to My Co-Authors:

Cooper Garbe
Environmental Programs Specialist
Rules and Planning Section

Formerly with the

Mark Gibbs
Environmental Programs Manager
Emissions Inventory Section

OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY

June 25, 2015 36

DEPARTMENT OF ECOLOGY State of Washington

Approach and Caveats

- Data source: The 2020 Nonpoint Oil and Gas Emission Estimation Tool, Version 1.3
- One county only: Kingfisher County, Oklahoma

Parameter	Value
Crude Oil Production	29,350,750 bbl
Crude Oil Wells	1,584
VOC Emissions (Working, Breathing, and Flashing) from Crude Oil Tanks	2,976.4 tons

- This is a proof of concept.
- Not actually a Monte Carlo simulation! A simple data set with all possible combinations rather than sampling.
- Only one source category evaluated and only one pollutant: VOC emissions from Crude Oil Tanks.

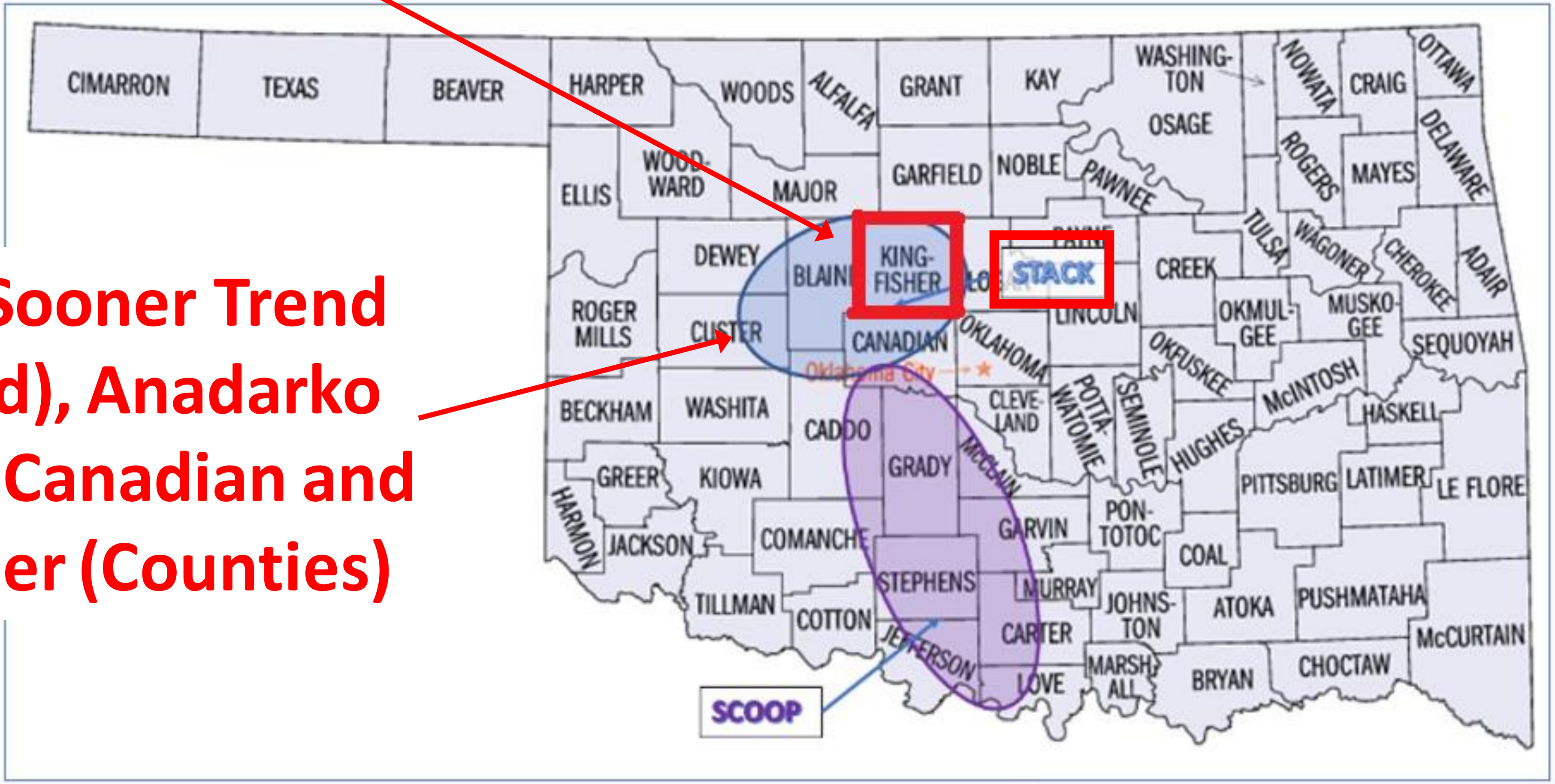
3.5 Crude Oil Tanks

Crude oil tanks are used to store liquid product at a well pad or central tank battery prior to transfer downstream to a refinery. Figure 3-4 shows a central tank battery (circled) in the Permian Basin adjacent to numerous well pads with pump jacks.[2]

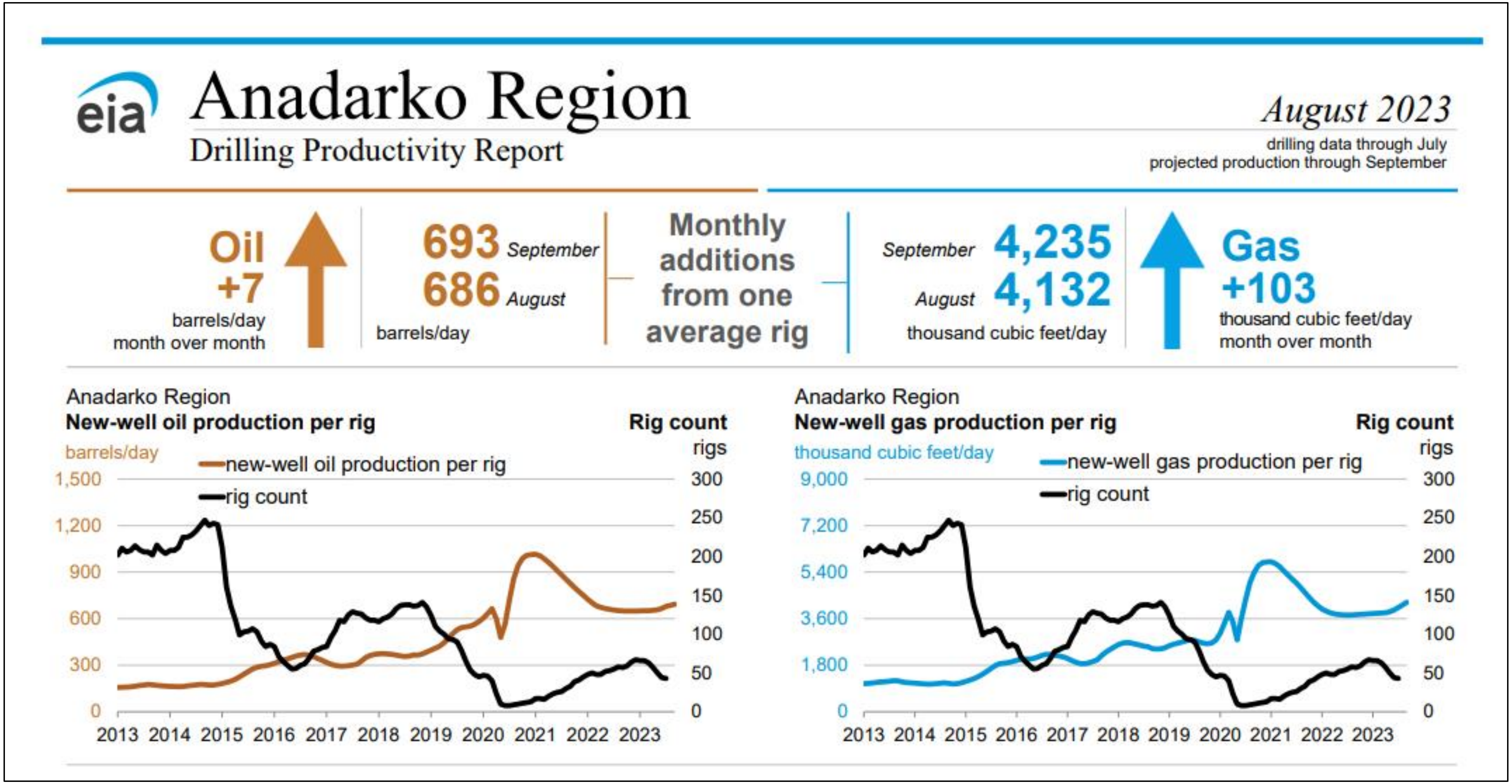
Crude oil tank emissions are generated by working and breathing processes. The methodology for estimating oil tank venting emissions is shown in Equations 11-12. This methodology is based on a combined working and breathing losses VOC emissions factor on a per unit throughput basis (mass emissions per barrel of oil).

Kingfisher County, Oklahoma

STACK: Sooner Trend (Oil Field), Anadarko (Basin), Canadian and Kingfisher (Counties)



In 2020, Kingfisher County was the highest crude oil producing county in Oklahoma



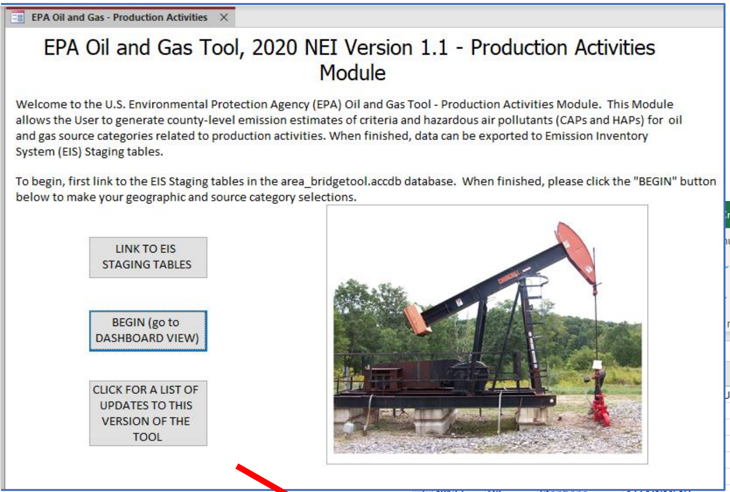
https://www.eia.gov/petroleum/drilling/pdf/anadarko.pdf

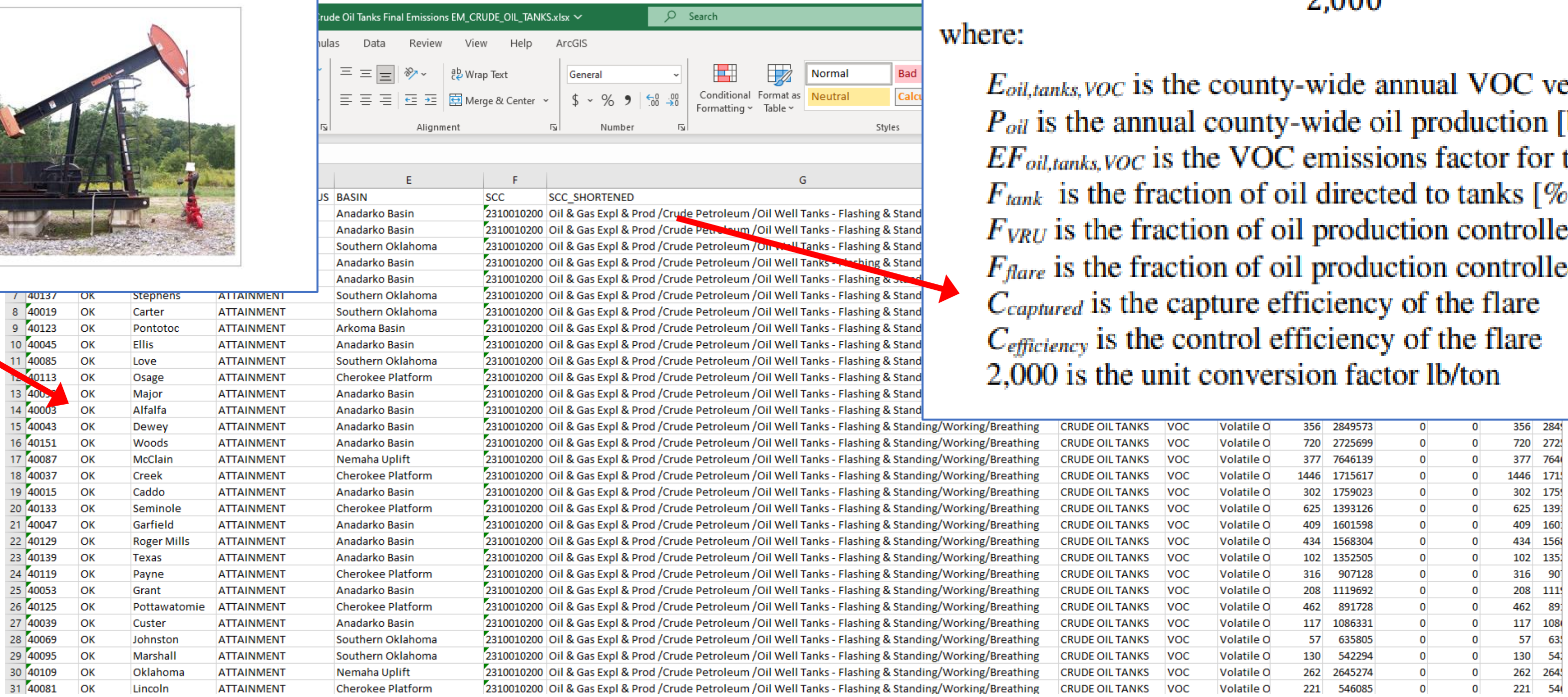
$$E_{oil,tanks,VOC} = P_{oil} \times \frac{EF_{oil,tanks,VOC}}{2,000} \times F_{tank} \times [1 - F_{VRU} - F_{flare} \times C_{captured} \times C_{efficiency}]$$

1. Activity

2. Emission Factor

3. Control





Equation 11)

$$E_{oil,tanks,VOC} = P_{oil} \times \frac{EF_{oil,tanks,VOC}}{2,000} \times F_{tank} \times [1 - F_{VRU} - F_{flare} \times C_{captured} \times C_{efficiency}]$$

where:

$E_{oil,tanks,VOC}$ is the county-wide annual VOC venting losses from oil tanks [tons-VOC/yr]

P_{oil} is the annual county-wide oil production [bbl/yr]

$EF_{oil,tanks,VOC}$ is the VOC emissions factor for total losses from oil tanks [lb-VOC/bbl]

F_{tank} is the fraction of oil directed to tanks [%]

F_{VRU} is the fraction of oil production controlled by vapor recovery units

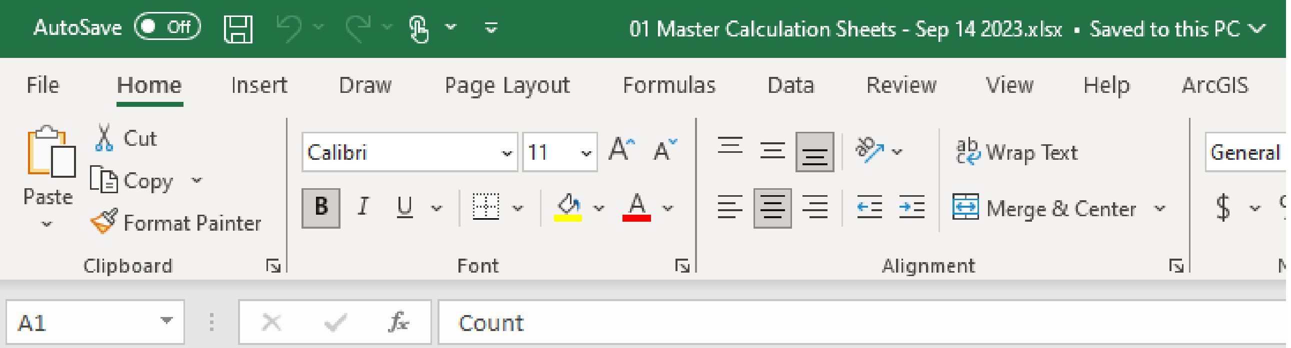
F_{flare} is the fraction of oil production controlled by flares

$C_{captured}$ is the capture efficiency of the flare

$C_{efficiency}$ is the control efficiency of the flare

2,000 is the unit conversion factor lb/ton

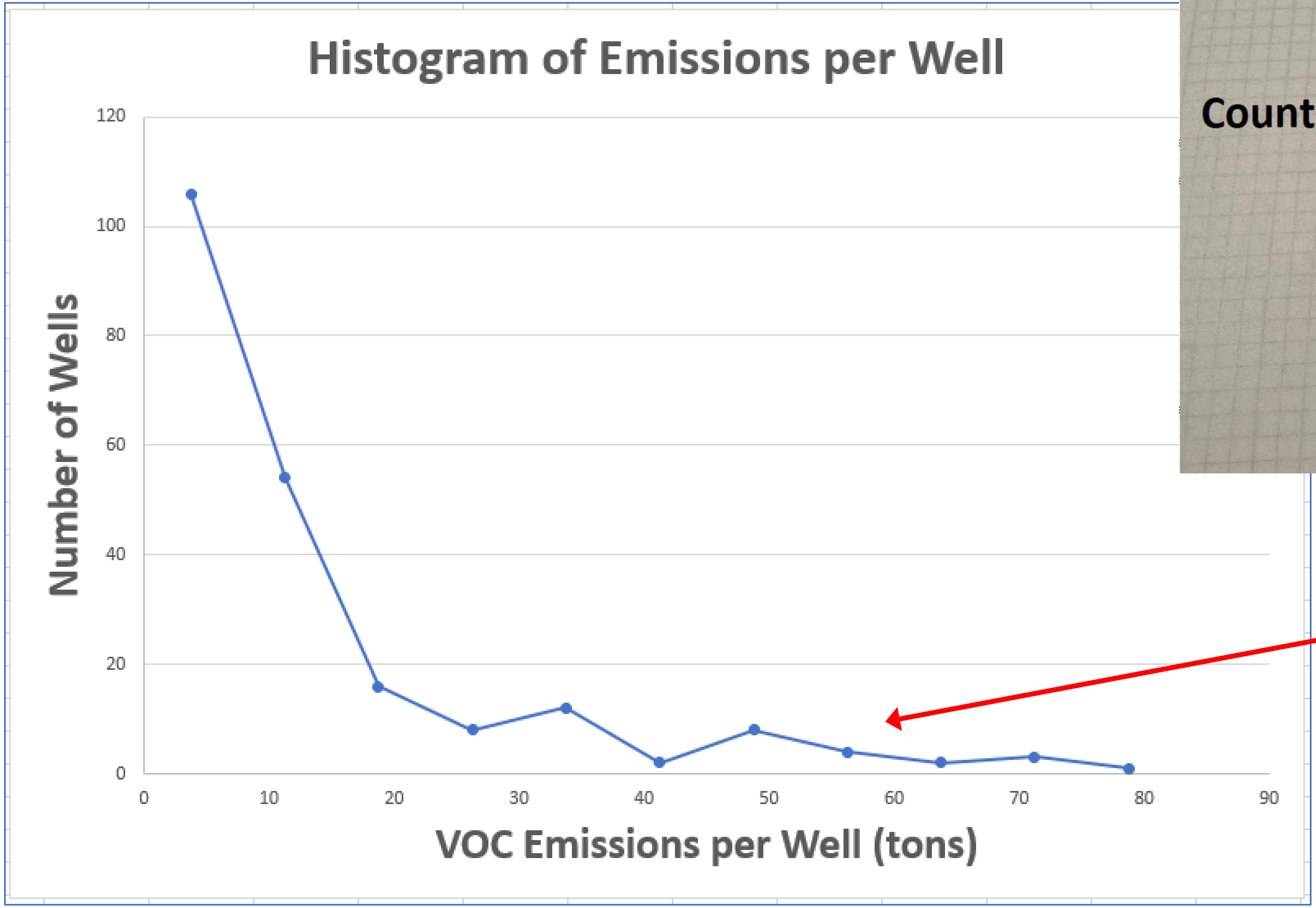
Data Analysis

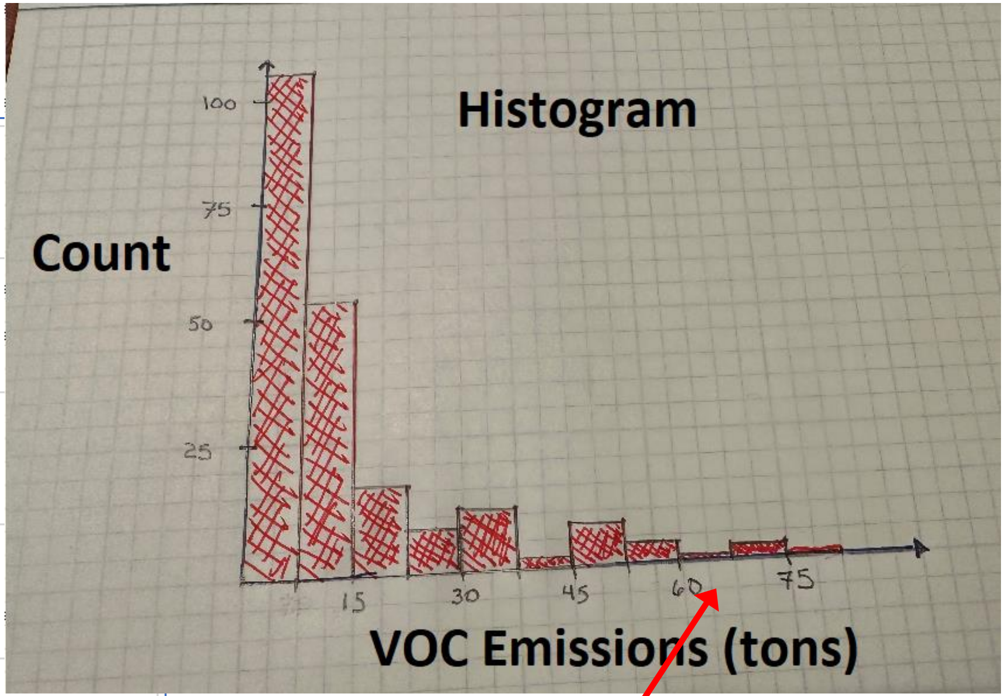


	A	B	C	D	E	F	G
1	Count	Activity	Emission Factor	Conversion Factor	Control Factor		E_oil_tanks_VOC
2	1	305,737.0	1.552078	2000	0.316285403		75.04
3	2	220,810.0	1.552078	2000	0.316285403		54.20
4	3	135,883.1	1.552078	2000	0.316285403		33.35
5	4	67,941.6	1.552078	2000	0.316285403		16.68
6	5	50,956.2	1.552078	2000	0.316285403		12.51
7	6	33,970.8	1.552078	2000	0.316285403		8.34
8	7	305,737.0	1.120946	2000	0.316285403		54.20
9	8	220,810.0	1.120946	2000	0.316285403		39.14
10	9	135,883.1	1.120946	2000	0.316285403		24.09
11	10	67,941.6	1.120946	2000	0.316285403		12.04
12	11	50,956.2	1.120946	2000	0.316285403		9.03
13	12	33,970.8	1.120946	2000	0.316285403		6.02
14	13	305,737.0	0.689813	2000	0.316285403		33.35
15	14	220,810.0	0.689813	2000	0.316285403		24.09
16	15	135,883.1	0.689813	2000	0.316285403		14.82
17	16	67,941.6	0.689813	2000	0.316285403		7.41
18	17	50,956.2	0.689813	2000	0.316285403		5.56
19	18	33,970.8	0.689813	2000	0.316285403		3.71
20	19	305,737.0	0.344906	2000	0.316285403		16.68
21	20	220,810.0	0.344906	2000	0.316285403		12.04
22	21	135,883.1	0.344906	2000	0.316285403		7.41
23	22	67,941.6	0.344906	2000	0.316285403		3.71
24	23	50,956.2	0.344906	2000	0.316285403		2.78
25	24	33,970.8	0.344906	2000	0.316285403		1.85
26	25	305,737.0	0.258680	2000	0.316285403		12.51
27	26	220,810.0	0.258680	2000	0.316285403		9.03
28	27	135,883.1	0.258680	2000	0.316285403		5.56
29	28	67,941.6	0.258680	2000	0.316285403		2.78
30	29	50,956.2	0.258680	2000	0.316285403		2.08

	A	B	C	D
1	E_oil_tanks_VOC		Statistics	
2	75.04			
3	73.28		Mean	13.78
4	69.76		Median	7.75
5	69.76		Mode	3.44
6	66.24		Maximum	75.04
7	64.48		Minimum	0.80
8	54.20			
9	54.20			
10	52.93			
11	52.93			
12	50.38			

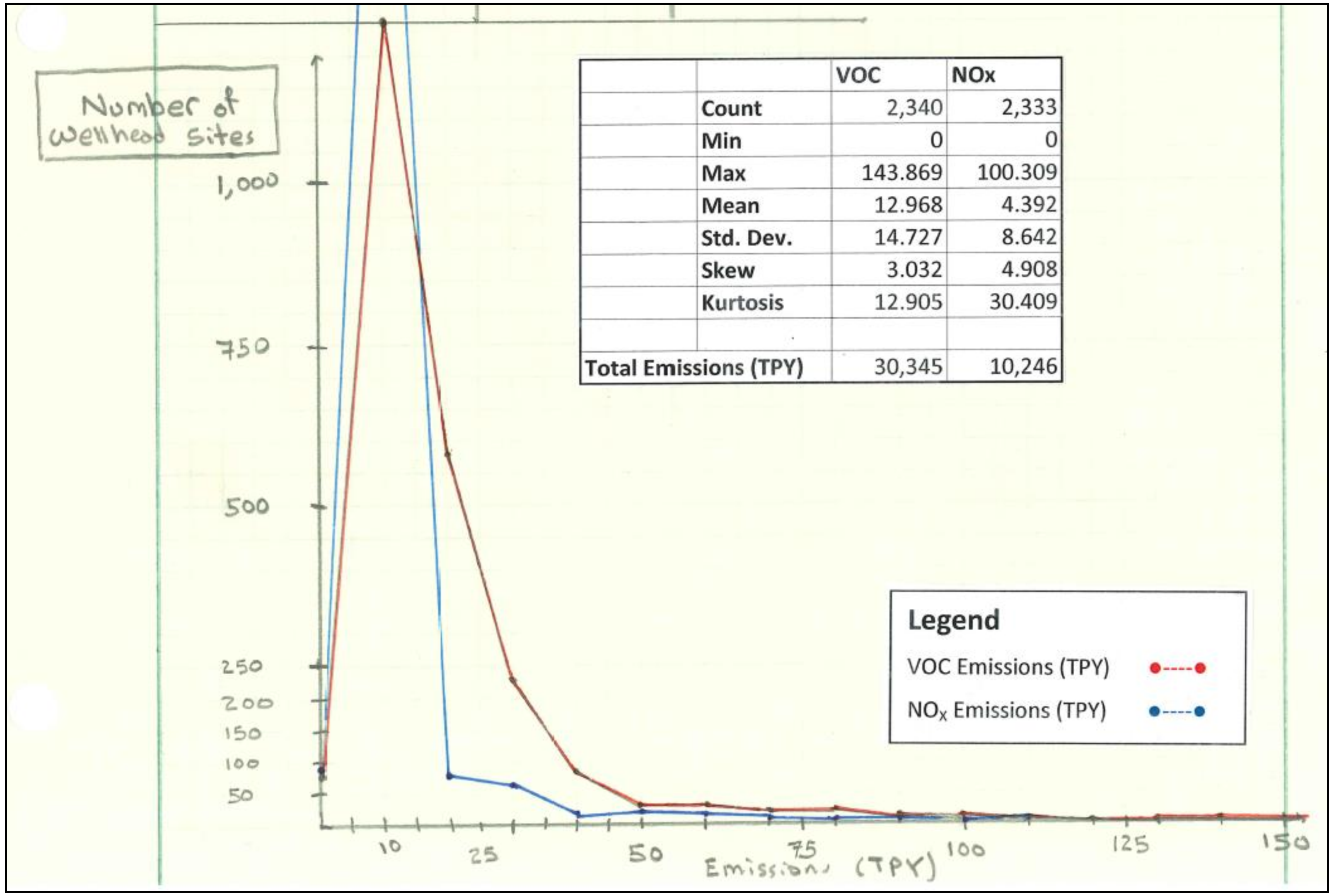
Mid Point of Bin Range	Count
78.75	1
71.25	3
63.75	2
56.25	4
48.75	8
41.25	2
33.75	12
26.25	8
18.75	16
11.25	54
3.75	106





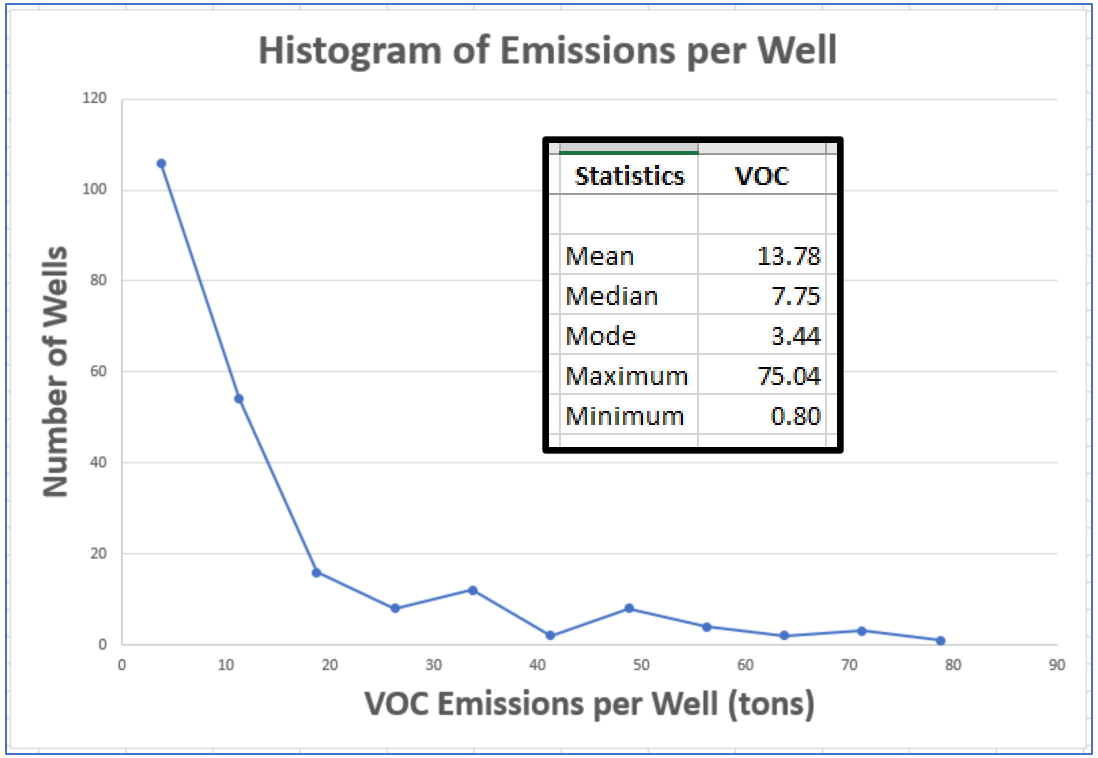
Note the heavy tail of the data distribution

2013 Permitted Oklahoma Wellhead Point Inventory Facility Emissions



	VOC	NOx
Count	2,340	2,333
Min	0	0
Max	143.869	100.309
Mean	12.968	4.392
Std. Dev.	14.727	8.642
Skew	3.032	4.908
Kurtosis	12.905	30.409
Total Emissions (TPY)	30,345	10,246

2020 Nonpoint Tool Monte Carlo Simulation



Statistics	VOC
Mean	13.78
Median	7.75
Mode	3.44
Maximum	75.04
Minimum	0.80

Additional Element

- Field inspections have shown a tendency for high production wells to overwhelm their vapor collection systems.
- Reduce capture efficiency for the 9% of wells with emissions 171 tons (per year) or more.

Simulated Super-Emitters:

Baseline emissions: **2,976 tons**

Emissions with simulated super-emitters: **3,385 tons**

Percent increase: **13.7%**

	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Conversion Factor	Emissions Prior to Control	Alternative Control Factor	Alternative Emissions		Control Factor		E_oil_tanks_VOC						
2	2000	237	0.430112283	102.1		0.316285403		75.04		Previous		Alt	Super-Emitter	
3	2000	237	0.42392604	100.6		0.308861911		73.28		Control Factor		C_capture	Control Factor	
4	2000	237	0.411553553	97.6		0.294014927		69.76		0.316285		70	0.430112	
5	2000	237	0.411553553	97.6		0.294014927		69.76		0.308862		70	0.423926	
6	2000	237	0.399181066	94.7		0.279167942		66.24		0.294015		70	0.411554	
7	2000	237	0.392994822	93.2		0.27174445		64.48		0.294015		70	0.411554	
8	2000	171	0.430112283	73.7		0.316285403		54.20		0.279168		70	0.399181	
9	2000	171	0.430112283	73.7		0.316285403		54.20		0.271744		70	0.392995	
10	2000	171	0.42392604	72.6		0.308861911		52.93						
11	2000	171	0.42392604	72.6		0.308861911		52.93						
12	2000	171	0.411553553	70.5		0.294014927								
13	2000	171	0.411553553	70.5		0.294014927								
14	2000	171	0.411553553	70.5		0.294014927								
15	2000	171	0.411553553	70.5		0.294014927								
16	2000	171	0.399181066	68.4		0.279167942								
17	2000	171	0.399181066	68.4		0.279167942								
18	2000	171	0.392994822	67.3		0.27174445								
19	2000	171	0.392994822	67.3		0.27174445								
20	2000	124	0.316285403	39.1		0.316285403								
21	2000	124	0.308861911	38.2		0.308861911								
22	2000	124	0.294014927	36.4		0.294014927								
23	2000	124	0.294014927	36.4		0.294014927								
24	2000	124	0.279167942	34.5		0.279167942								
25	2000	124	0.27174445	33.6		0.27174445								
26	2000	105	0.316285403	33.4		0.316285403								

0.294014927	0.9	0.294014927	0.86
0.294014927	0.9	0.294014927	0.86
0.279167942	0.8	0.279167942	0.82
0.27174445	0.8	0.27174445	0.80
	3,385.4		2,976.4
Percent Increase	13.7%		

Check work space | Distribution | Plot Data | Extra Super Emitters | Crude Oil Production by County

Conclusions

- Applying a Monte Carlo approach to existing emissions inventory data can convert a simple, completely flat data distribution into a heavy-tailed distribution.
- With no additional computational changes, the total emissions will remain the same.
- Simple computational changes (e.g., increasing the risk of control system failure for high emission sources) will allow simulation of higher emissions from the heavy tail of the data distribution.

Future Applications

- Incorporate gas composition data into the Monte Carlo analysis to generate benzene concentrations. Add distance-to-population data and demographics to generate probabilistic risk assessments.
- Generate temporal profiles. Use this approach to design measurement site inspections to refine the data, identify super-emitters, and ground truth this approach.

OKLAHOMA Environmental Quality

OKLAHOMA Environmental Quality

Thanks!

QUESTION Time

Tom Richardson, P.E.
Rules & Planning Section
Air Quality Division
Oklahoma DEQ
tom.richardson@deq.ok.gov