Operational Risk Issues in Shale Gas Development: Response to "*Understanding and Mitigating Risks Associated with Well Construction and Hydraulic Fracturing*"

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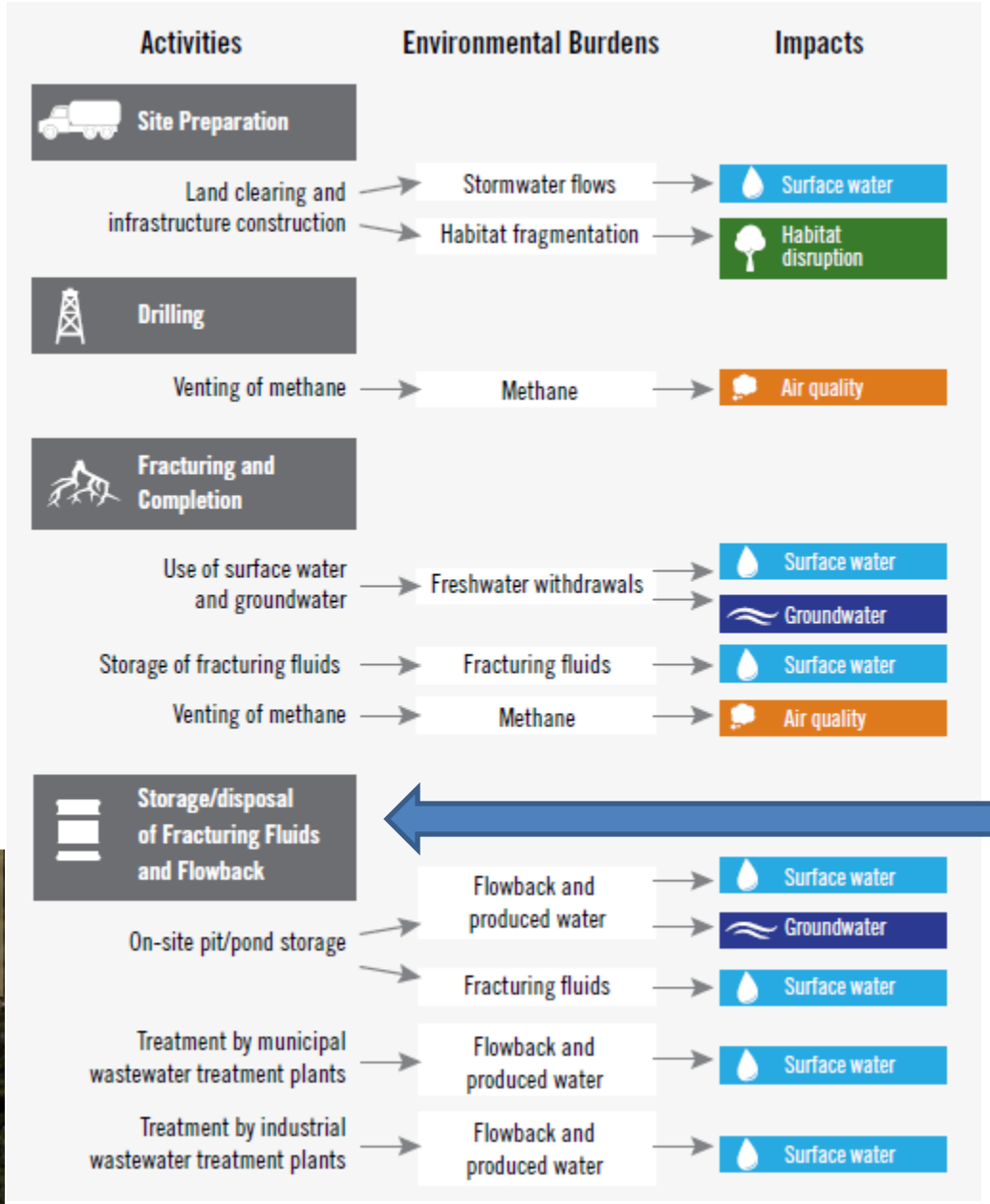
Key Themes

- Unplanned subsurface fluid migration resulting from the well construction process
- Accidental surface release of fracturing fluids and chemicals
- Induced seismicity from wastewater disposal and hydraulic fracturing injection operations

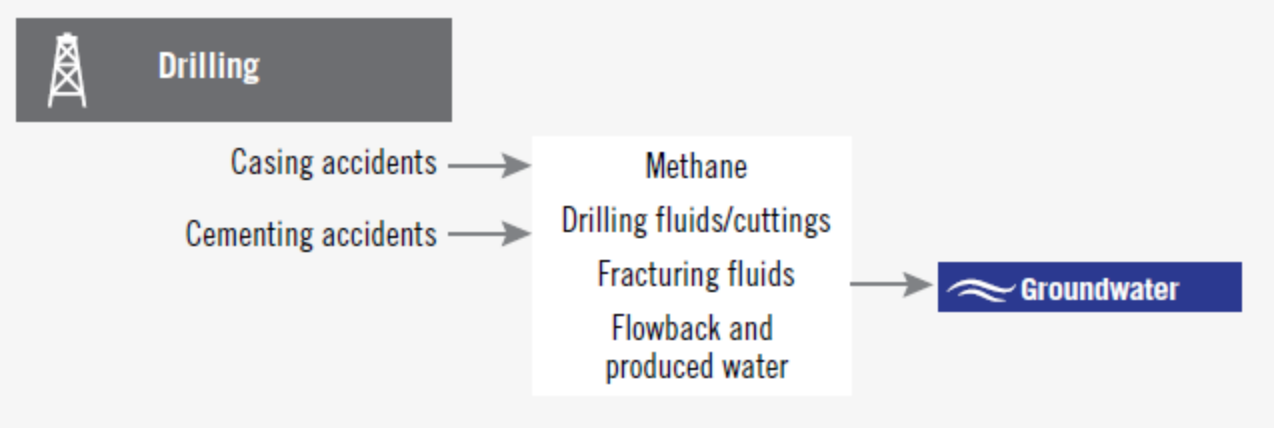
12 Consensus Routine Risk Pathways



Release of HF fluids

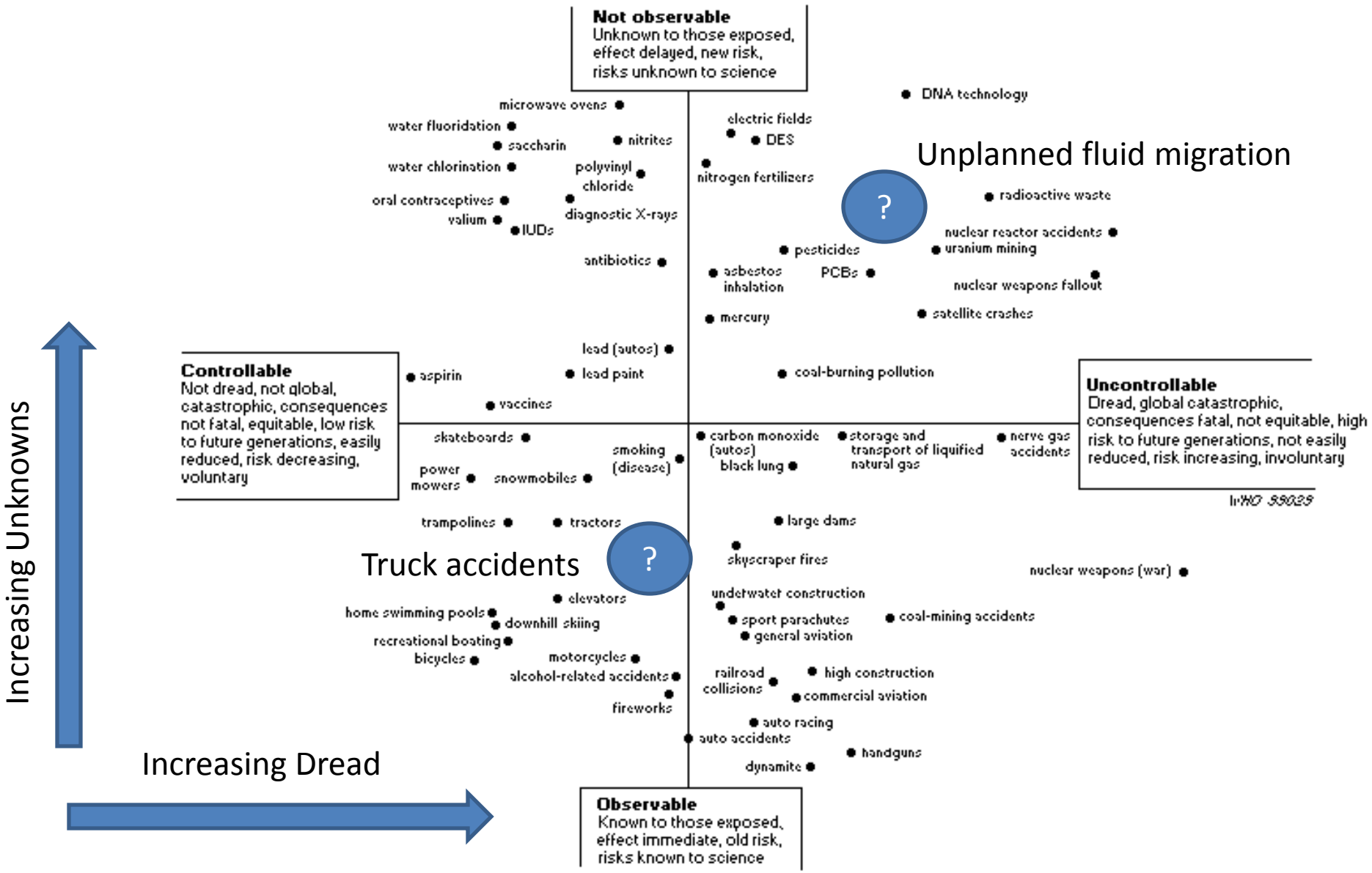
Triggered Seismicity

2 Consensus Accident Pathways



- Other experts selected truck accidents and leakage of wastewater pits and ponds

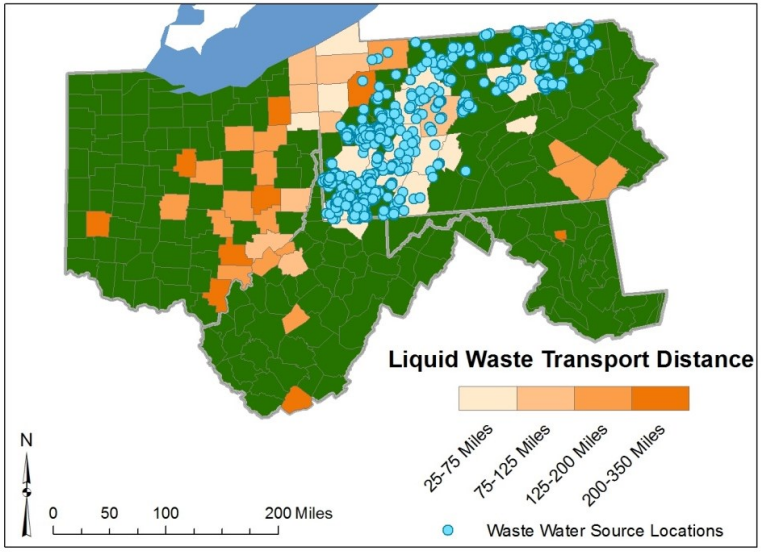
Characterizing Perceived Risk

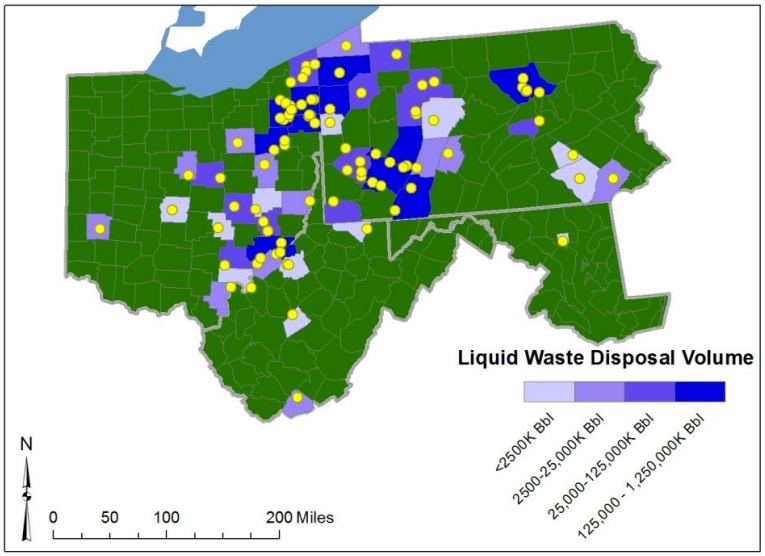


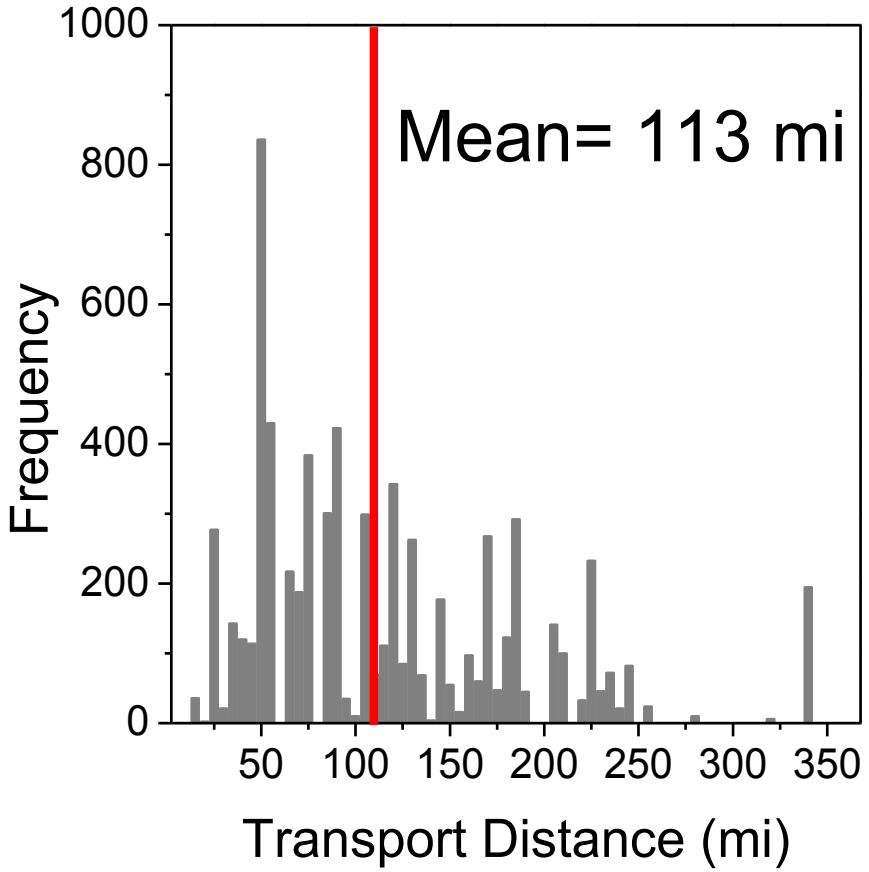
Discussion Questions

- How should risk evaluation be prioritized? Are routine shale gas development risks and impacts sufficiently well characterized?
- To what extent are the risks and impacts of unconventional natural gas development intrinsic to the process itself, and to what extent are they preventable?
  - Through better management practices?
  - Through improved technology?

Marcellus Liquid Waste Transport, 2011



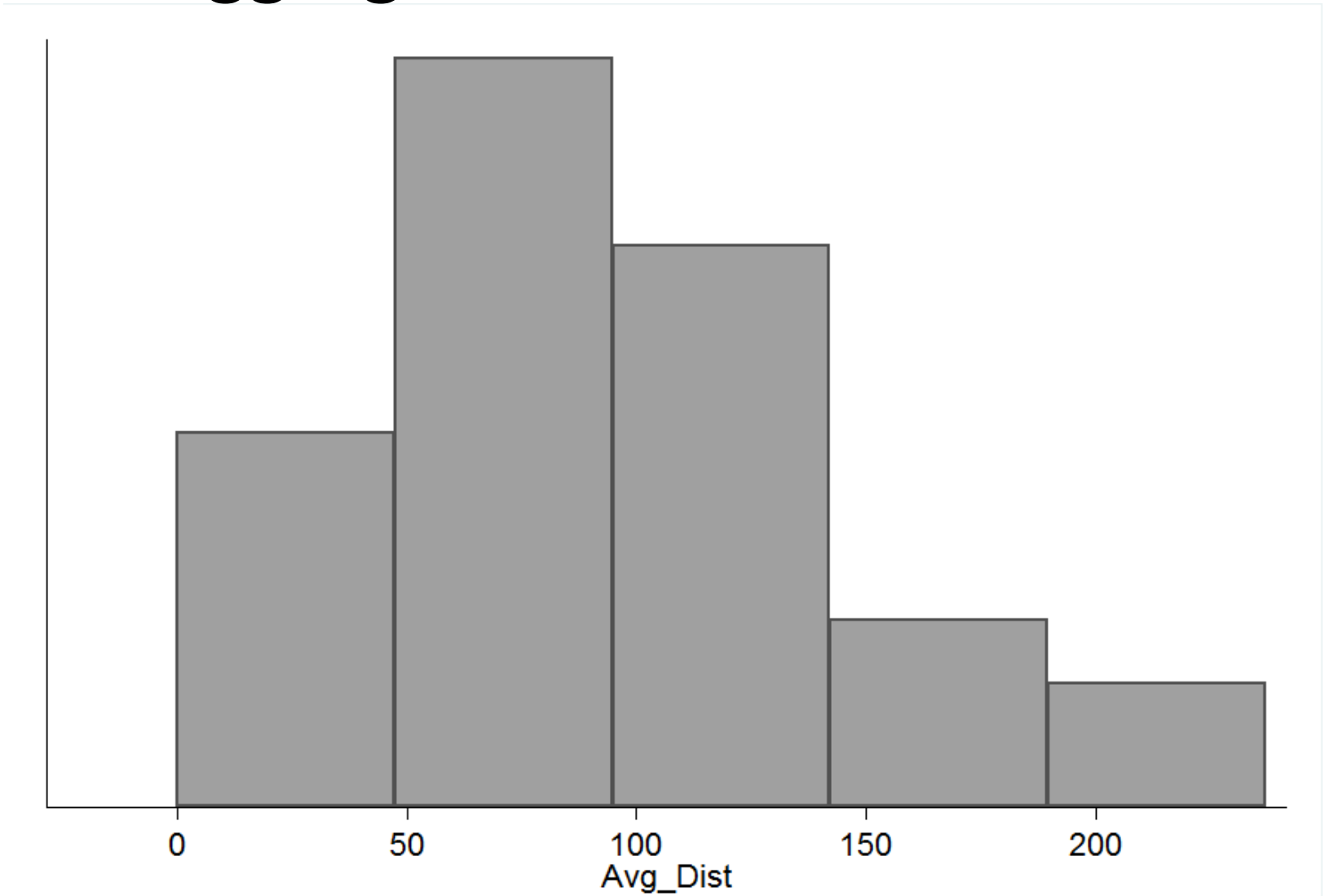




Liquid (Excluding 56% Direct Reuse) Waste Transport

26 million miles of waste transport in 2011 (0.1% of total truck traffic in PA)

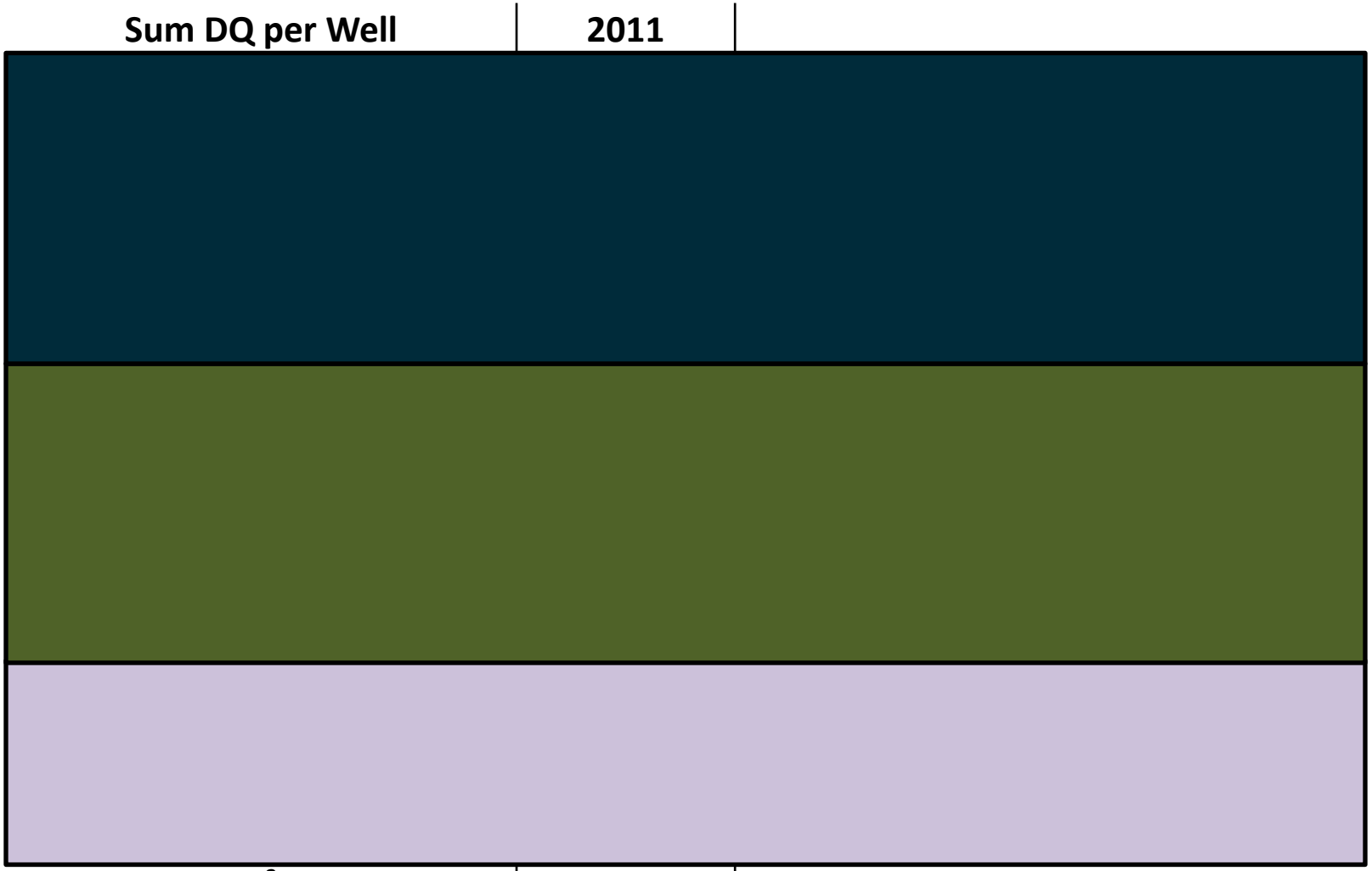
Average Waste Transport Distance, Aggregated to the Firm Level



Explaining Variance in Waste Transport Intensity

Sum DQ per Well	2011	
Percent of Waste Reused	-1.291 (0.512)**	Waste Disposal Method
Percent of Waste Injected	3.408 (1.110)***	
Percent of Waste Recycled	1.939 (0.649)***	
Percent of Waste Discharged	-0.293 (0.859)	
Years in Marcellus	-0.003 (0.021)	Company Attributes
Publically Traded Company	0.009 (0.302)	
Percent Wells Southwest	-0.722 (0.360)*	Spatial Determinants
Percent Wells Northeast	0.325 (0.520)	
Total Waste per Well	0.00001 (0.0000)***	*Standard errors in parentheses*
R^2	0.83	$^{*}p < 0.100$, $^{**}p < 0.01$, $^{***}p < 0.001$
N	34	

Explaining Variance in Percent Waste Reused



	Sum DQ per Well	2011
	R^2	0.77
	N	24

Standard errors in parentheses

$^{*}p < 0.100$, $^{**}p < 0.01$, $^{***}p < 0.001$

Explaining Variance in Violations

Average Violations per Well	**2011**	
Company Size	-0.00072 (0.00032)*	Company Attributes
Publically Traded Company	-1.274 (4.264)	
Wells Drilled in 2011	0.037 (0.022)*	
Total Marcellus Wells Drilled	-0.018 (0.010)*	
R^2	0.053	
N	0	

Standard errors in parentheses

$^{*}p < 0.100$, $^{**}p < 0.01$, $^{***}p < 0.001$

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Spatial Temporal Clustering Improves Opportunities for Reuse