Critical Issues Forum

America's Increasing Reliance on Natural Gas: Benefits and Risks of a Methane Economy

Wifi network: FWC Wireless
Password: (no password needed)

american geosciences institute
connecting earth, science, and people

Session 3:
Environmental, health, and safety impacts

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Alan Krupnick

Resources for the Future





The health and environmental impacts of shale gas development: What we know and don't

Alan Krupnick
Director, Center for Energy and Climate Economics

RESOURCES FOR THE FUTURE

Environmental, Health and Safety Issues
American Geosciences Institute
Dallas, TX, November 19, 2014

Damage function chain

Activity→
burden→
toxicity→
probability in environment →
probability of exposure→
impact→
value

RFF

This talk

Comprehensive risk matrix

Risks from liquid wastes: produced water, ponds and tanks, surface water, seismic

Ecological

Health (truck accidents, low birth weight)

Quality of life (property values)

Valuation

Research priorities

Activity➔burden➔toxicity➔probability in environment➔ probability of exposure➔impact➔ value

Risk Matrix

Site Development and Drilling Preparation
After locating a site for shale gas development, the area must be excavated and prepared for drilling. Preparation activity also often includes leveling of the site.

Activity	Intermediate Impacts					
	Groundwater	Surface Water	Soil Quality	Air Quality	Habitat Disruption	Community Disruption
Clearing of land/construction of roads, well pads, pipelines, other infrastructure		Stormwater flows Invasive species	Stormwater flows	Conventional air pollutants and CO_2	Habitat fragmentation Invasive species	Industrial landscape Light pollution Noise pollution
On-road vehicle activity		Stormwater flows		Conventional air pollutants and CO_2	Other	Noise pollution Road congestion/accidents
Off-road vehicle activity		Stormwater flows		Conventional air pollutants and CO_2	Other	Noise pollution

Return to Top

Drilling Activities
Drilling begins by boring a single well shaft vertically into the desired formation. One or more lateral wells are then drilled from the end of the vertical wellbore, angling to run horizontally through the shale formation.

Activity	Intermediate Impacts					
	Groundwater	Surface Water	Soil Quality	Air Quality	Habitat Disruption	Community Disruption
Drilling equipment operation at surface	Drilling fluids/cuttings	Drilling fluids/cuttings	Drilling fluids/cuttings	Conventional air pollutants and CO_2		Industrial landscape Light pollution Noise pollution
Drilling of vertical and lateral wellbore	Methane Drilling fluids/cuttings Intrusion of saline-formation water into fresh groundwater	Drilling fluids/cuttings		Methane		

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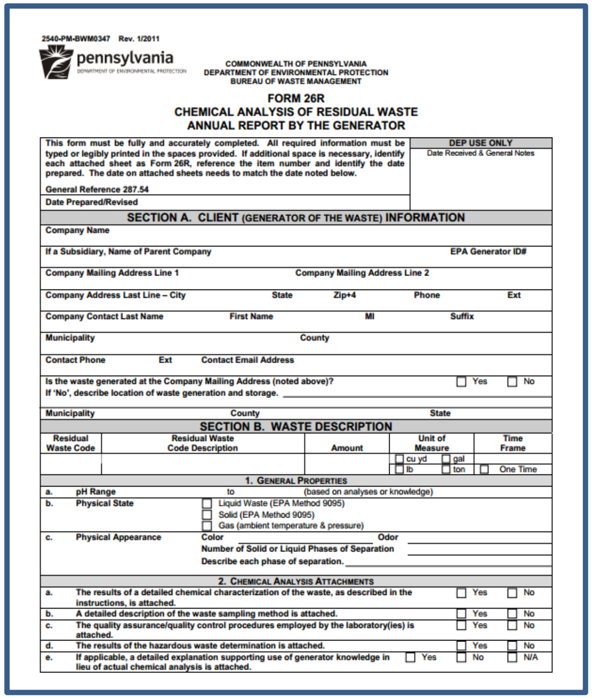
Wastewater characteristics from Marcellus shale gas development in PA

- Researchers: J. Shih, S. Olmstead (UT Austin), J. Chu, L. Muehlenbachs (U. Calgary), J. Saiers (Yale), S. Anisfeld (Yale).
- Statistically analyzes characteristics of flowback, produced water, and drilling fluid waste sent to wastewater treatment facilities in PA, 2008-2011.
- Data Source: Form 26R, submitted to PADEP by “residual waste” generators.
- 432 different analytes were identified in the data, in the following categories:
    1. General chemicals
    2. Organics
    3. Pesticides
    4. Metals
    5. Radioactive Materials



2540-PM-BWM0347 Rev. 1/2011

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF WASTE MANAGEMENT

FORM 26R
CHEMICAL ANALYSIS OF RESIDUAL WASTE
ANNUAL REPORT BY THE GENERATOR

This form must be fully and accurately completed. All required information must be typed or legibly printed in the spaces provided. If additional space is necessary, identify each attached sheet as Form 26R, reference the item number and identify the date prepared. The date on attached sheets needs to match the date noted below.

General Reference 287.54

Date Prepared/Revised

DEP USE ONLY
Date Received & General Notes

SECTION A. CLIENT (GENERATOR OF THE WASTE) INFORMATION

Company Name

If a Subsidiary, Name of Parent Company | EPA Generator ID#

Company Mailing Address Line 1 | Company Mailing Address Line 2

Company Address Last Line – City | State | Zip+4 | Phone | Ext

Company Contact Last Name | First Name | MI | Suffix

Municipality | County

Contact Phone | Ext | Contact Email Address

Is the waste generated at the Company Mailing Address (noted above)? ☐ Yes ☐ No
If ‘No’, describe location of waste generation and storage.

Municipality | County | State

SECTION B. WASTE DESCRIPTION

Residual Waste Code	Residual Waste Code Description	Amount	Unit of Measure	Time Frame
			☐ cu yd ☐ gal	
			☐ lb ☐ ton	☐ One Time

1. GENERAL PROPERTIES

a. pH Range to (based on analyses or knowledge)

b. Physical State ☐ Liquid Waste (EPA Method 9095) ☐ Solid (EPA Method 9095) ☐ Gas (ambient temperature & pressure)

c. Physical Appearance Color Odor
Number of Solid or Liquid Phases of Separation
Describe each phase of separation.

2. CHEMICAL ANALYSIS ATTACHMENTS

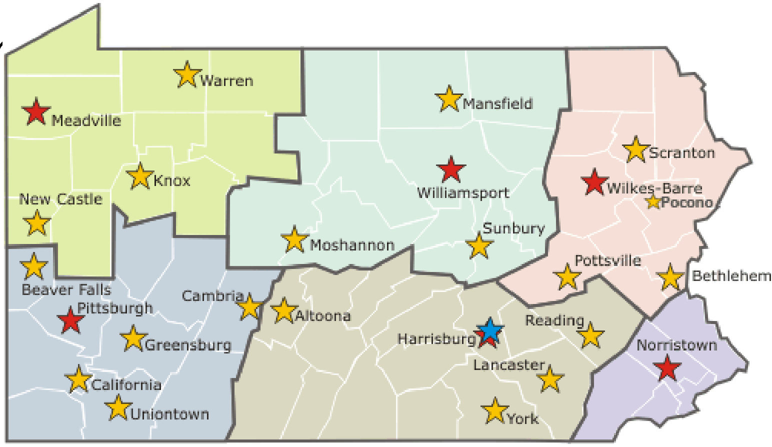
a. The results of a detailed chemical characterization of the waste, as described in the instructions, is attached. ☐ Yes ☐ No

b. A detailed description of the waste sampling method is attached. ☐ Yes ☐ No

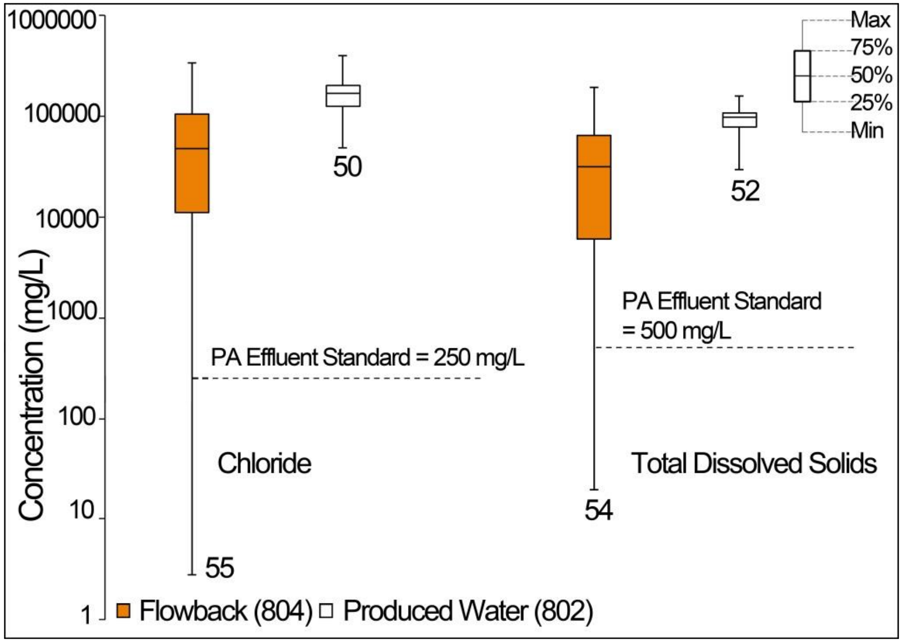
c. The quality assurance/quality control procedures employed by the laboratory(ies) is attached. ☐ Yes ☐ No

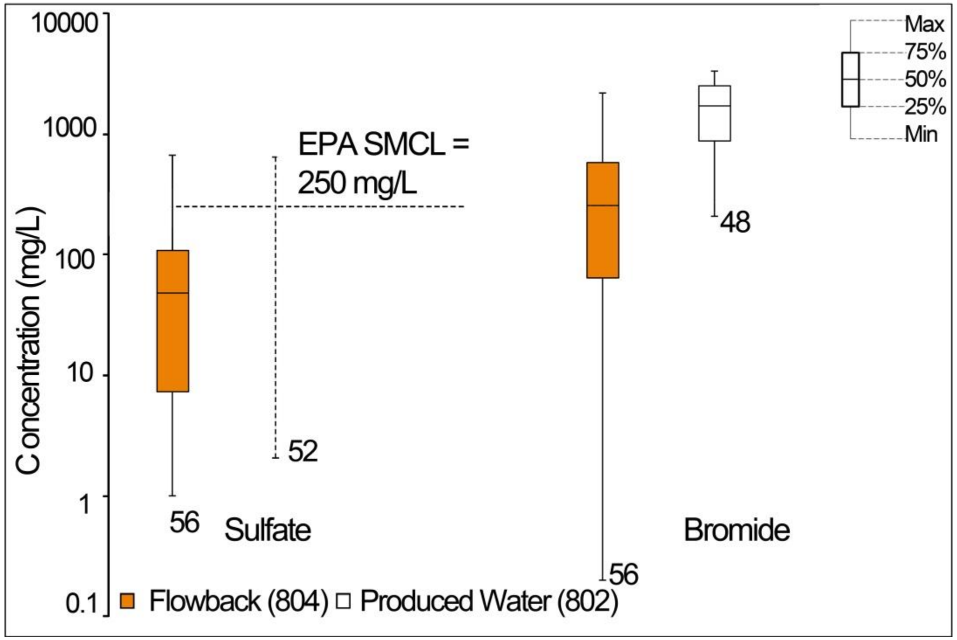
d. The results of the hazardous waste determination is attached. ☐ Yes ☐ No

e. If applicable, a detailed explanation supporting use of generator knowledge in lieu of actual chemical analysis is attached. ☐ Yes ☐ No ☐ N/A



Comparison of General Chemicals in Produced Water and Fracking Fluid Waste





* Number at the bottom of the boxplot is the sample size

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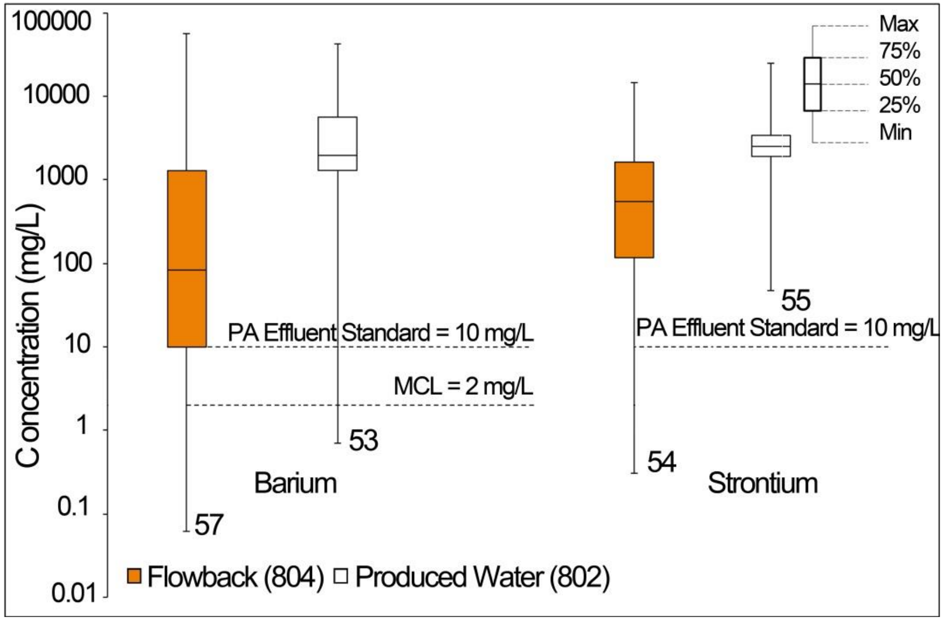
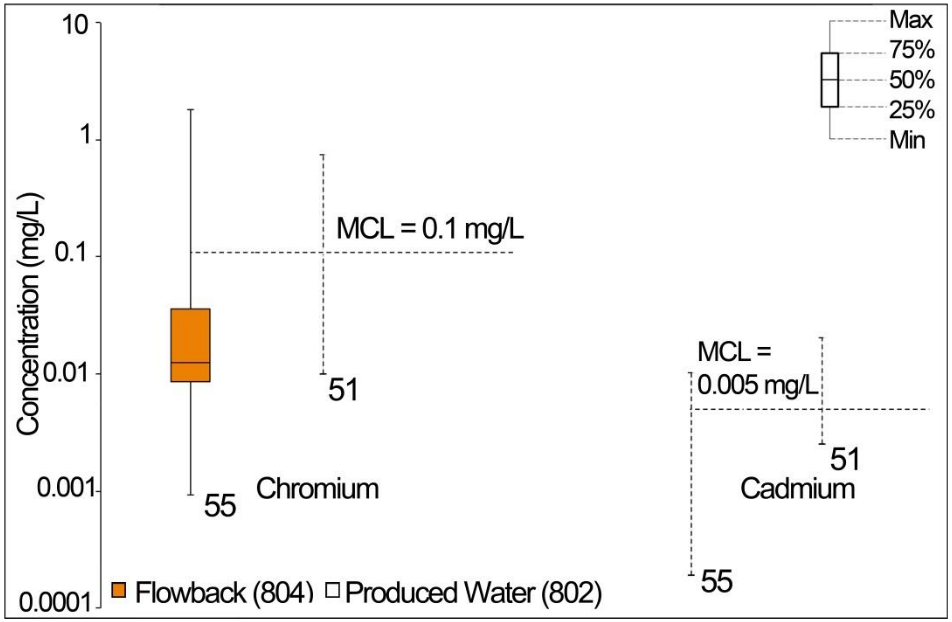
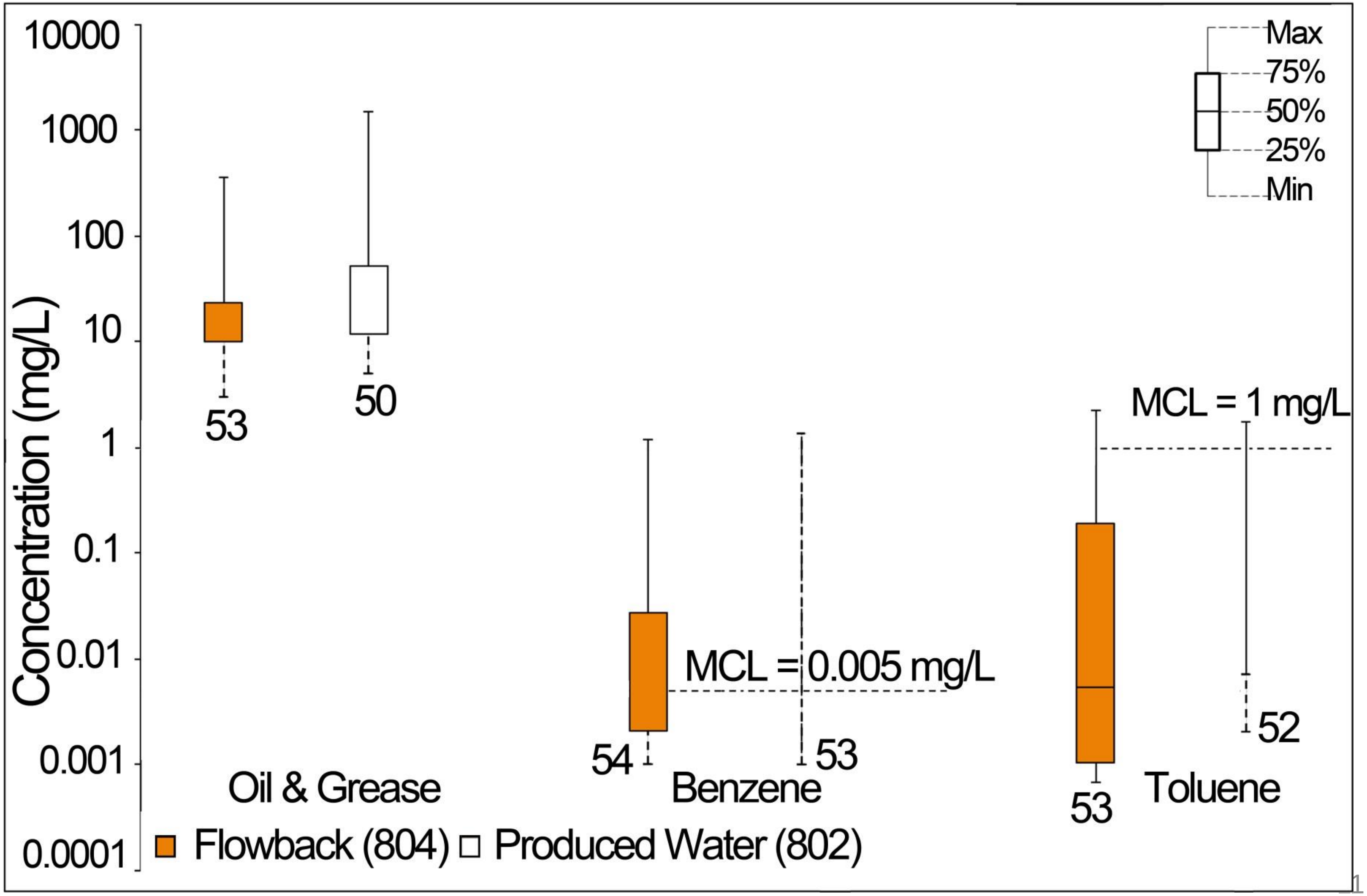
Comparison of Metals in Produced Water and Fracking Fluid Waste





Comparison of Organics in Produced Water and Fracking Fluid Waste



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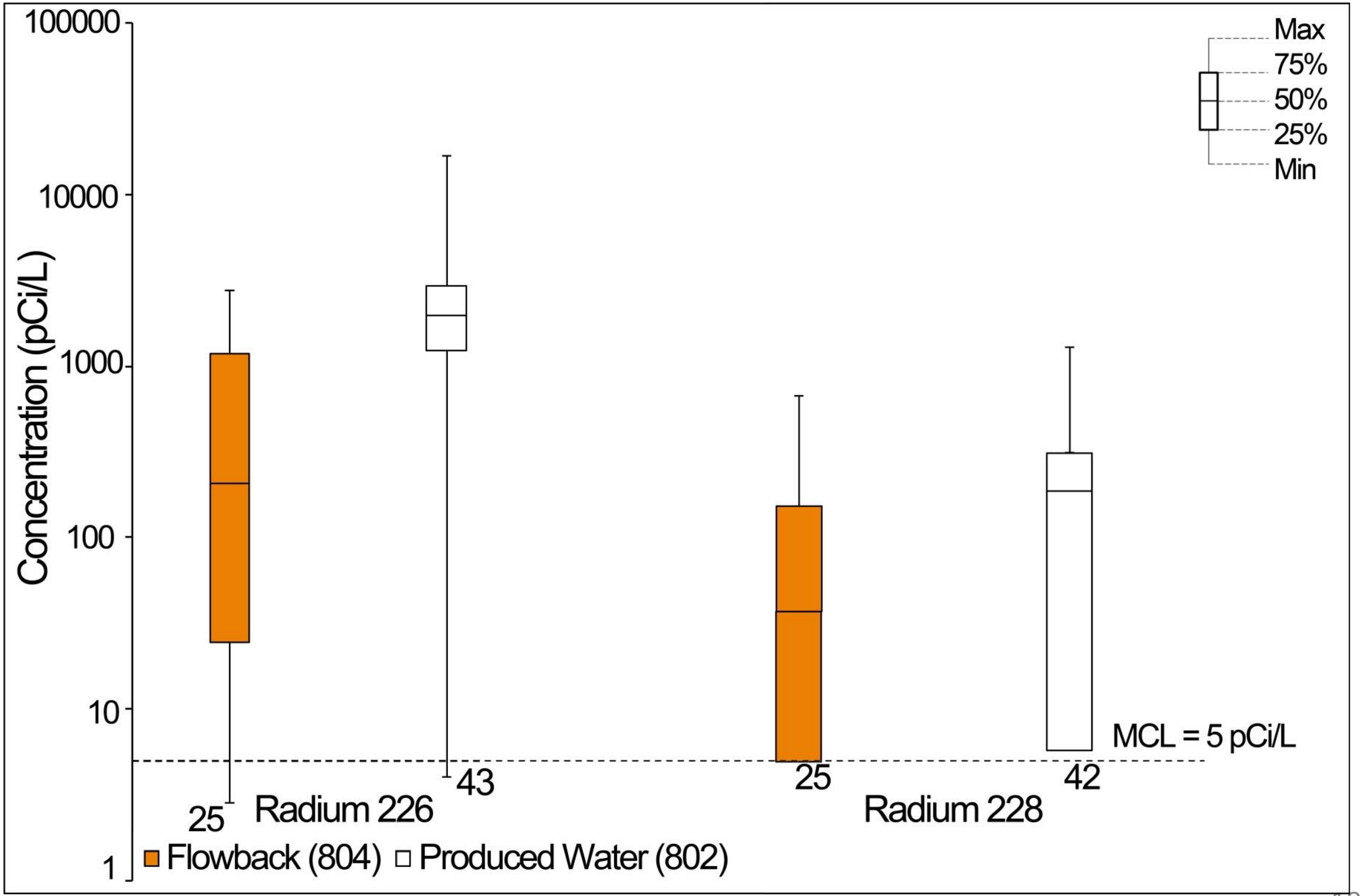
Comparison of Naturally Occurring Radioactive Materials in Produced Water and Fracking Fluid Waste



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Analysis of state databases of spills and releases

- New Mexico, Colorado, and Oklahoma (not comparable)
- Only reported spills/releases
- Materials spilled: Produced water, fracturing fluid, brine, drilling mud/fluid, HCl, KCl, crude oil, fresh water

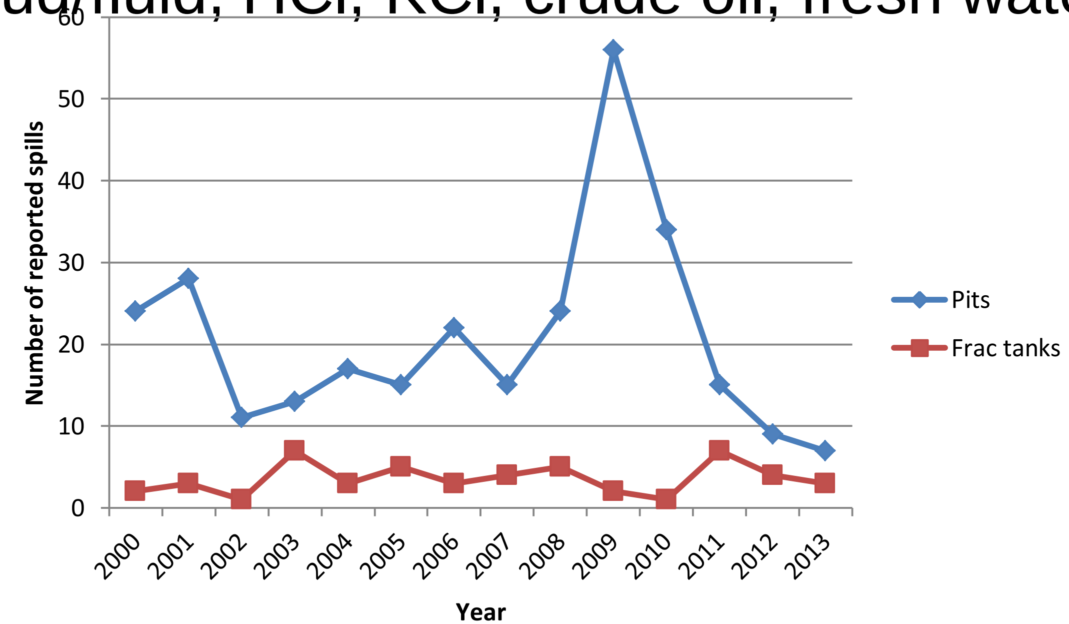

Figure: Spills from pits and frac tanks as reported to New Mexico OCD.

Analysis of state databases of spills and releases

Number of spills in New Mexico by category (2000 – 2013)

Panel A: Pits

Cause of spill	# spills
Overflow	33
Liner malfunction	31
Unidentified or undocumented	19
Discovery of historical spill	8
Blowover	7
Improper closure or reclamation	3
Sinkhole	2
Other	2
TOTAL	**105**

Panel B: Frac Tanks

Cause of spill	# spills
Leak	21
Unidentified or undocumented	13
Overflow	9
Other	3
Collapse	2
Vandalism	2
TOTAL	**50**

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Surface Water Quality Risk Study (PNAS, 2013)

We exploit spatial and temporal variation in the proximity of shale gas wells, waste treatment facilities, and surface water quality monitors in Pennsylvania to estimate:

1. the impact of *shale gas wells* on downstream chloride and TSS concentrations; and

2. the impact of *shale gas waste treatment* and release to surface water on downstream chloride and TSS concentrations.

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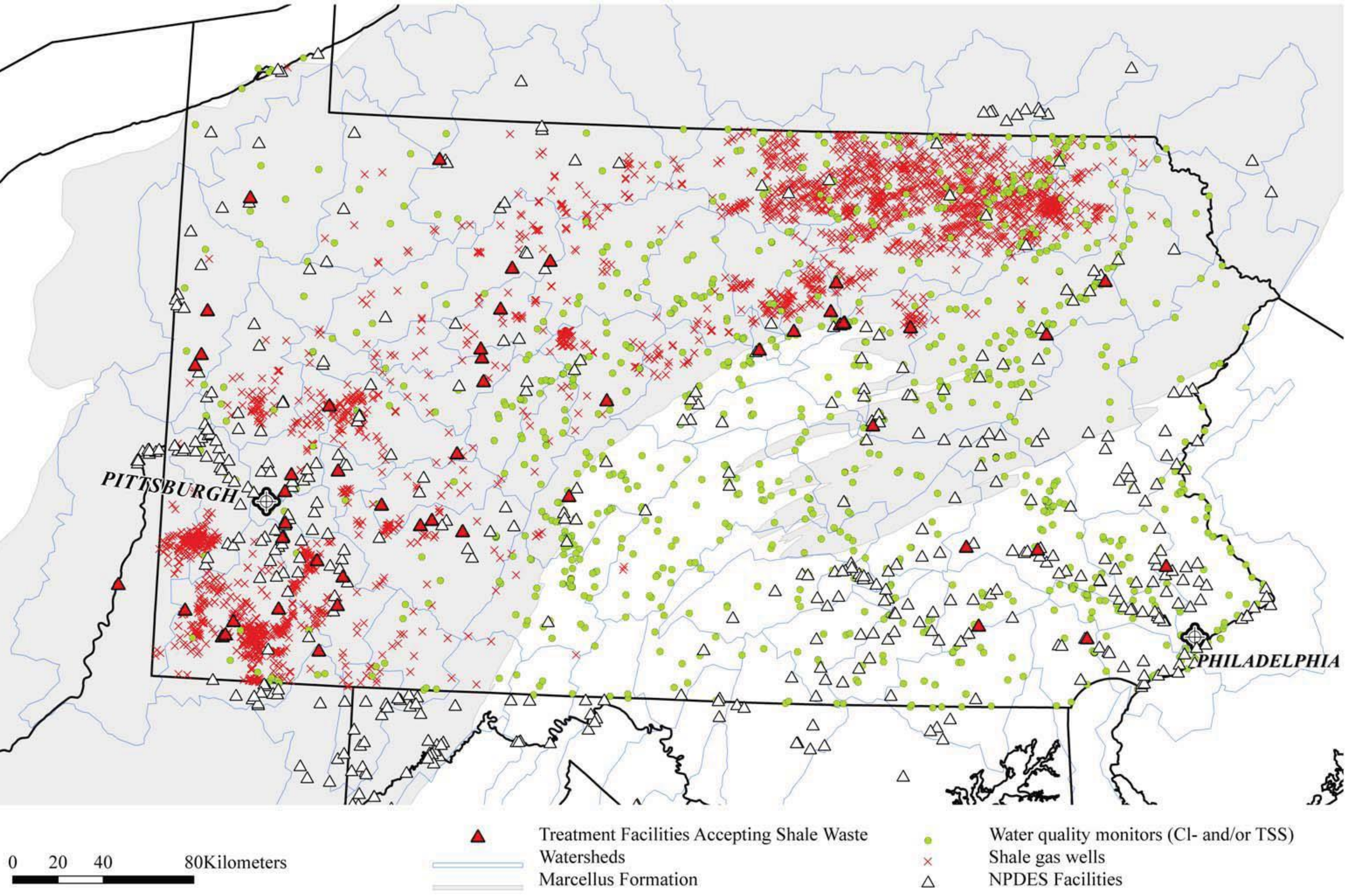
PITTSBURGH
PHILADELPHIA
0 20 40 80Kilometers
Treatment Facilities Accepting Shale Waste
Watersheds
Marcellus Formation
Water quality monitors (Cl- and/or TSS)
Shale gas wells
NPDES Facilities

Conclusions

- No statistically significant impact of shale gas wells on downstream chloride concentrations.
  - A positive result here would have been consistent with contamination problems from spills, dumping, etc.
- Release of treated shale gas waste to surface water by permitted waste facilities appears to increase downstream chloride concentrations.
  - Effect is significant only for POTWs, not CWTs.
- Shale gas wells appear to increase downstream TSS concentrations.

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Induced Seismicity

- Seismicity from fracking NOT a problem
- Deep well injection
  - #3 in anthropogenic earthquakes):
  - 40,000 wells taking oil and gas liquid wastes.
  - Growth in earthquakes > 3.0 since 2009, “coincident with” oil and gas waste injections.”
  - In CO, TX, OH, ARK, OK. a few “caused by.”

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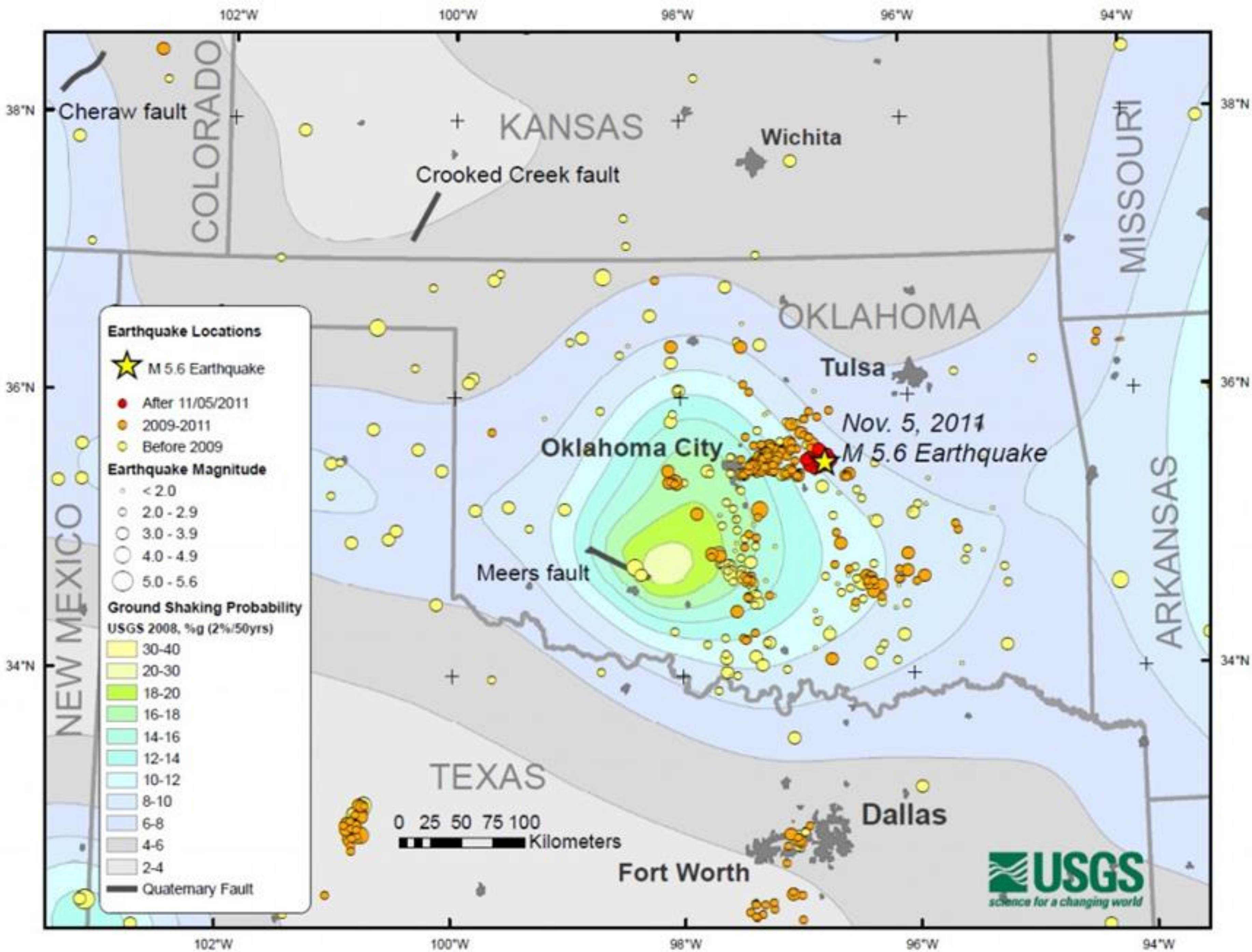
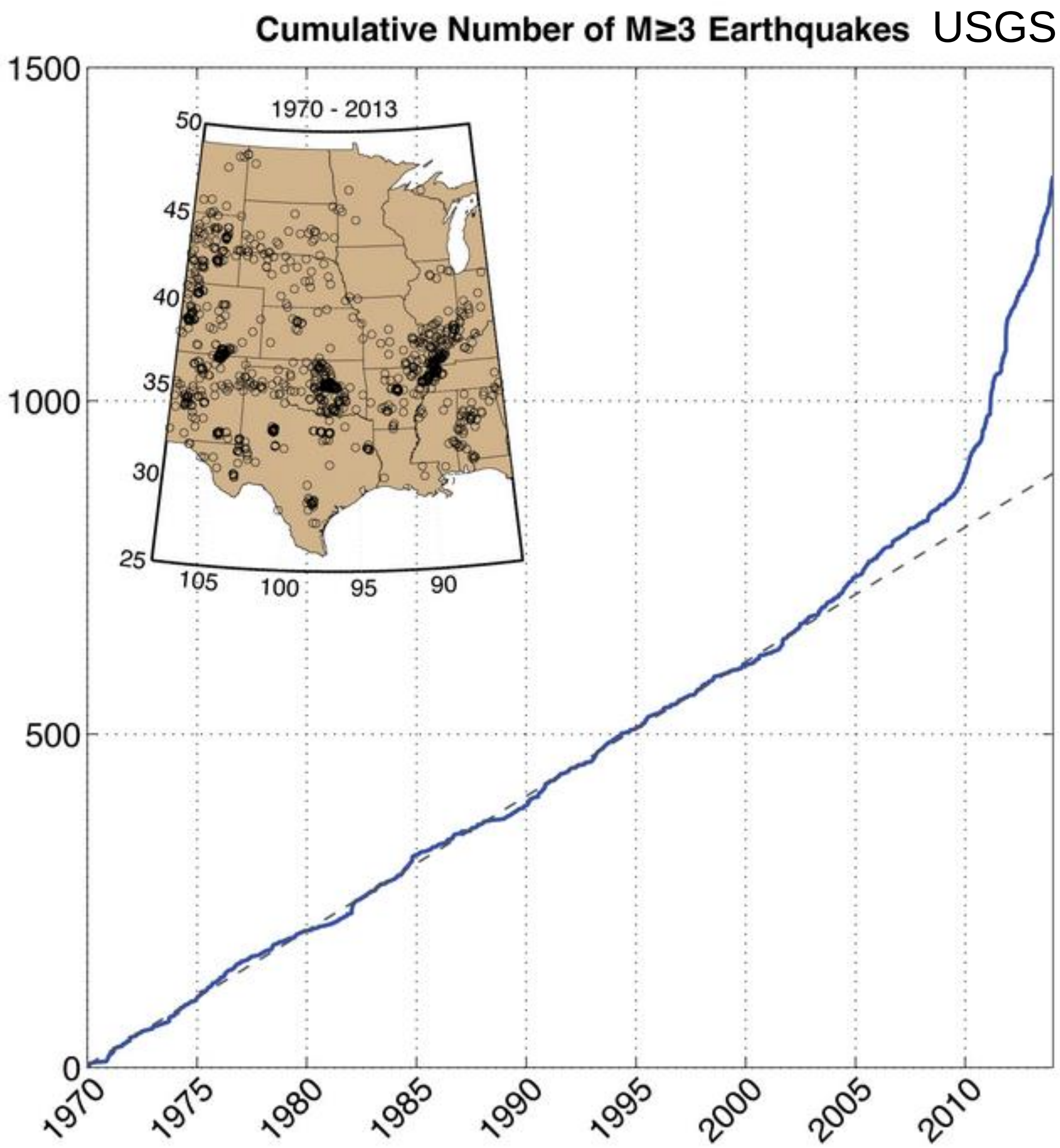


102°W
100°W
98°W
96°W
94°W
38°N
36°N
34°N
Cheraw fault
COLORADO
KANSAS
Wichita
Crooked Creek fault
MISSOURI
OKLAHOMA
Tulsa
Oklahoma City
Nov. 5, 2011
M 5.6 Earthquake
Meers fault
NEW MEXICO
ARKANSAS
TEXAS
Dallas
Fort Worth
0 25 50 75 100
Kilometers
Earthquake Locations
M 5.6 Earthquake
After 11/05/2011
2009-2011
Before 2009
Earthquake Magnitude
< 2.0
2.0 - 2.9
3.0 - 3.9
4.0 - 4.9
5.0 - 5.6
Ground Shaking Probability
USGS 2008, %g (2%/50yrs)
30-40
20-30
18-20
16-18
14-16
12-14
10-12
8-10
6-8
4-6
2-4
Quaternary Fault
USGS
science for a changing world



Cumulative number of earthquakes with a magnitude of 3.0 or larger in the central and eastern United States, 1970–2013. The dashed line corresponds to the long-term rate of 20.2 earthquakes per year, with an increase in the rate of earthquakes starting around 2009.

Induced Seismicity, cont.

- DWI better than pits, which leak; better than CWTs which can’t treat some elements of produced water
- Can it be managed?
  - Industry cutting water flows through reuse/recycling, using less liquids

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Sawyer, Hall, and Ryan Nielson. 2010. Mule Deer Monitoring in the Pinedale Anticline Project Area: 2010 Report. Cheyenne, WY: Western Ecosystems Technology.

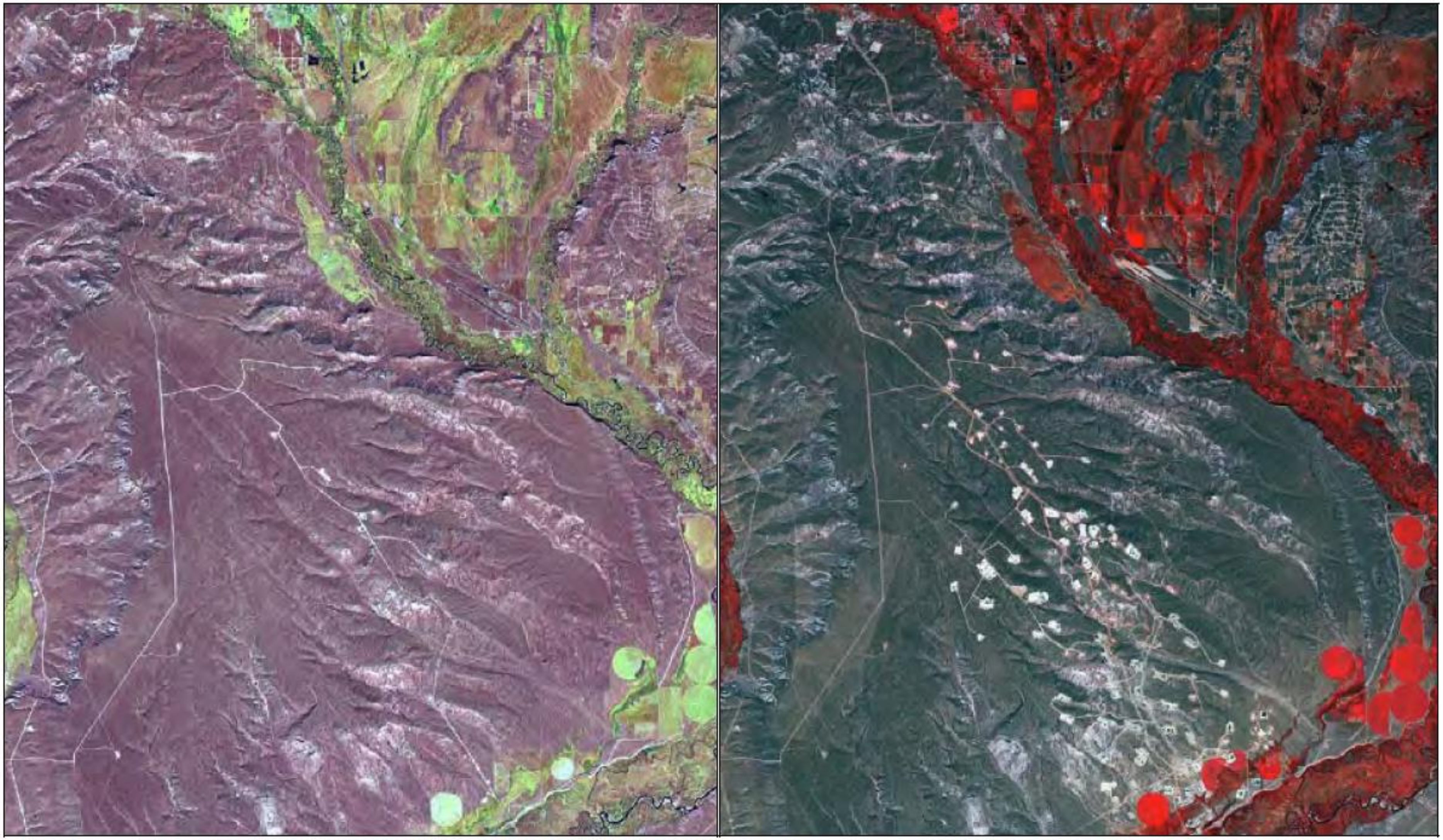


Figure 3. Satellite image of Mesa in 1999 (left) compared to 2009 (right).

Sawyer, Hall, and Ryan Nielson. 2010. Mule Deer Monitoring in the Pinedale Anticline Project Area: 2010 Report. Cheyenne, WY: Western Ecosystems Technology.

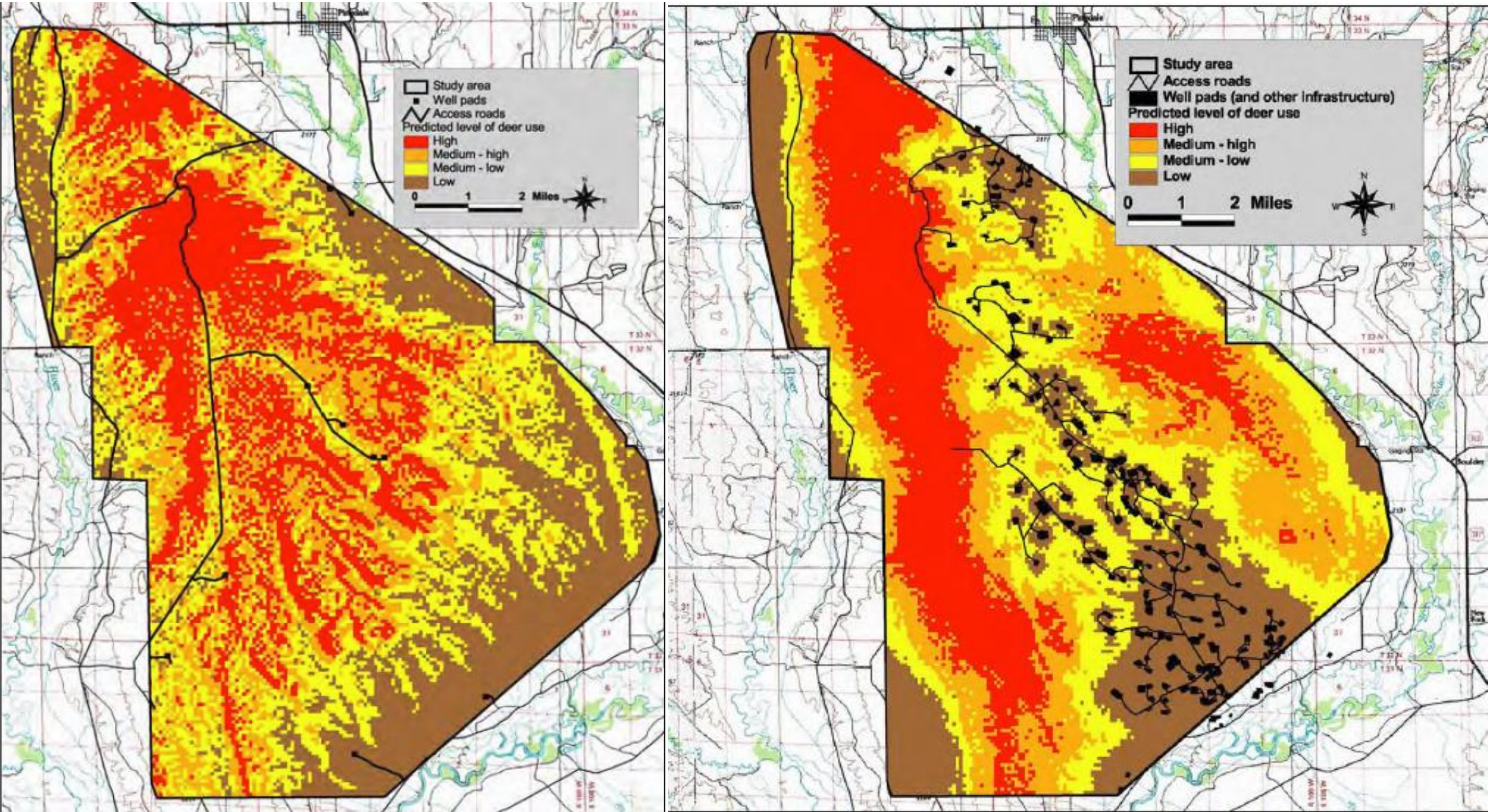
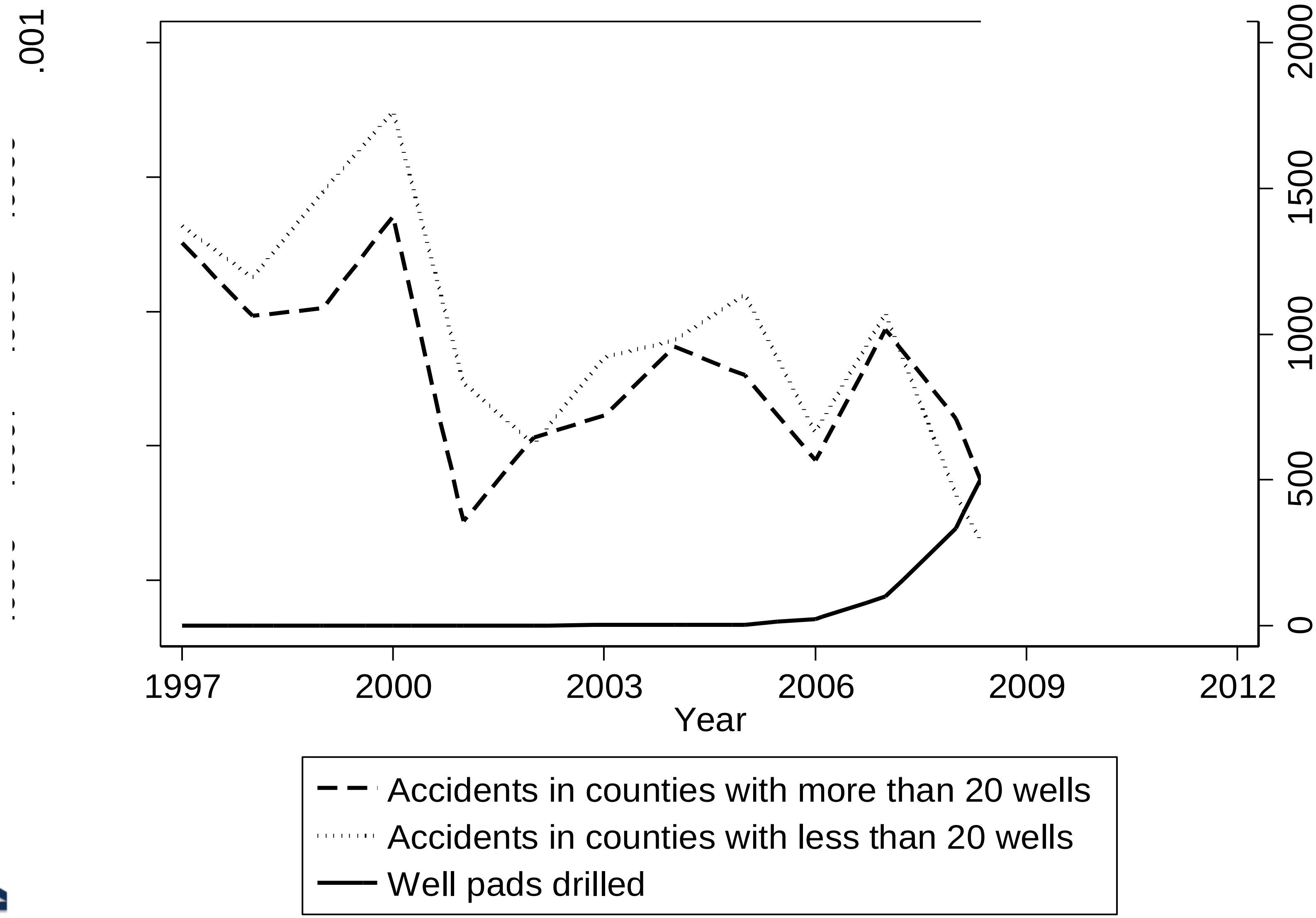


Figure 6. Predicted level of mule deer habitat use during Year 10 (winter of 2009-10) of natura gas development on the Mesa.

Truck Traffic Accidents in Pennsylvania by Well Activity



Property Values

- Great aggregator of local perceived risks – with **real** effects
- Effects of proximity and intensity
- Proximity Matters
  - Within 1.5 km and on groundwater: $33,000 decrease versus homes further away and on public water
- Intensity Matters a little

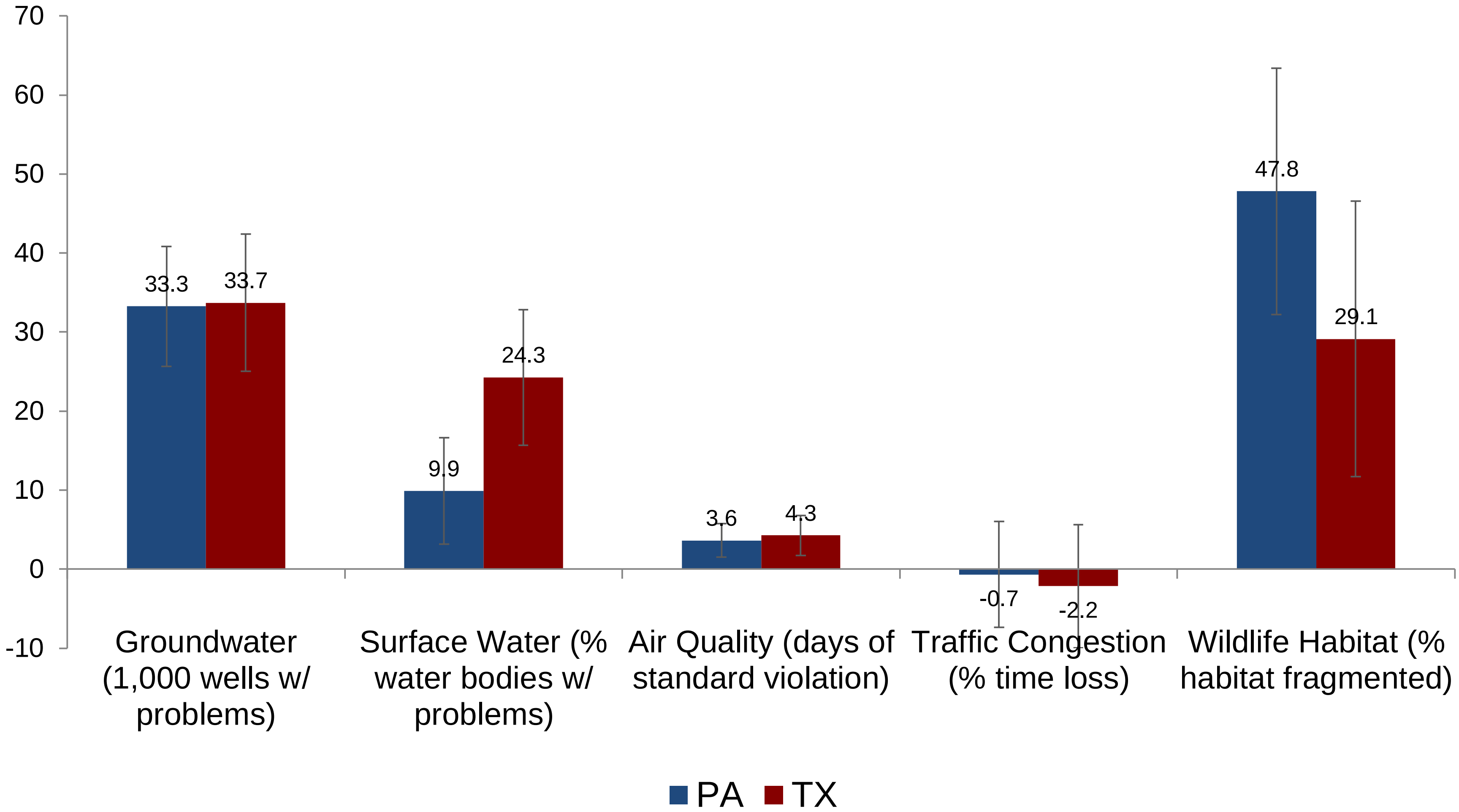


Figure 2. Estimated WTP (\$ household^{-1} year^{-1}), on average, for the reduction of risks associated with shale gas development

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Research priorities for the future

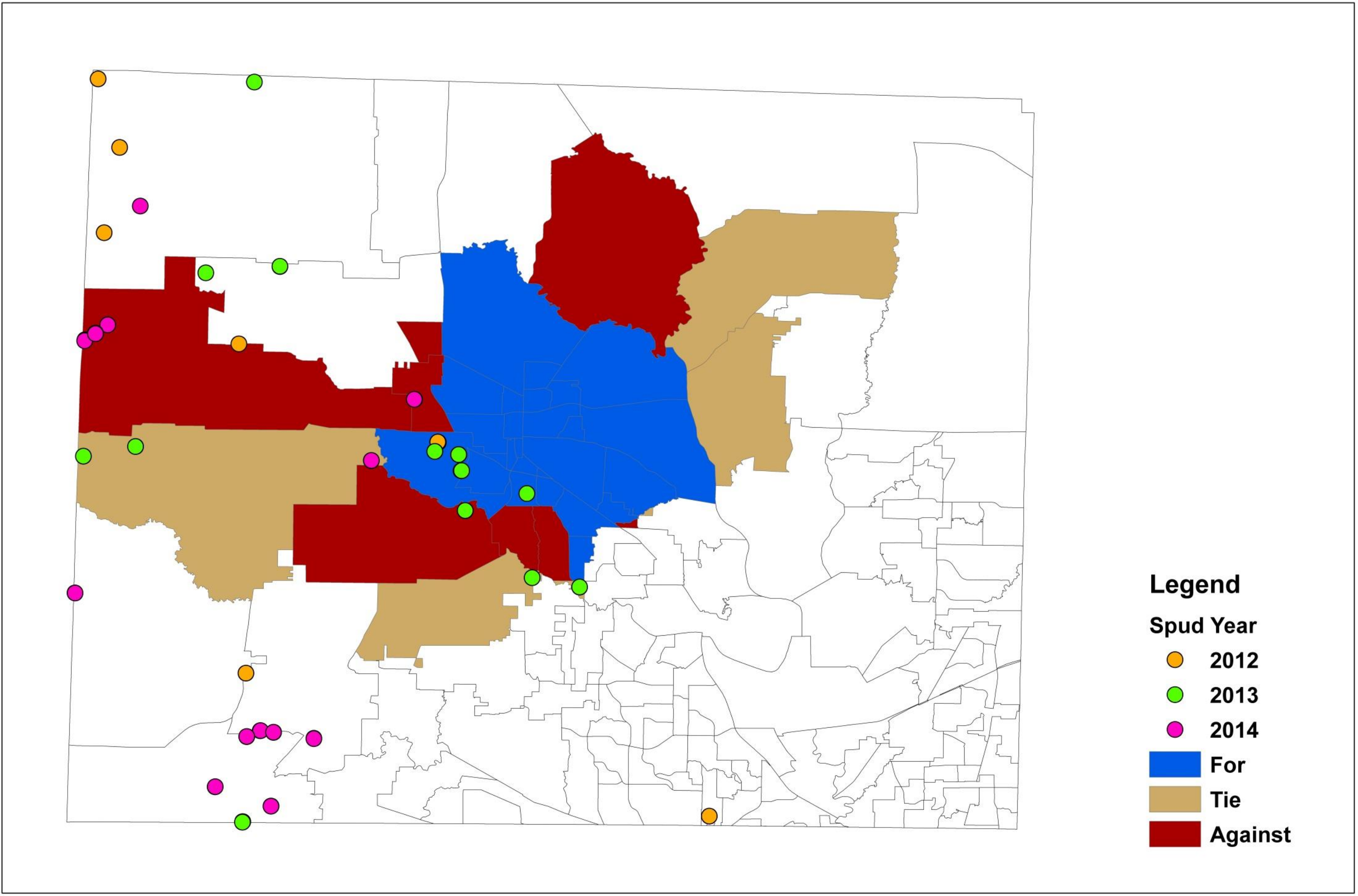
- Remainder of the water cycle
- Net benefits to communities of SGD
- Approaches for internalizing externalities and compensating locals.
  - Act 13.   Turned down by PA Supreme Court.
- Mental health effects of SGD? Low Birth Weight effect?
- Legacy

RFF

Thank you!

krupnick@rff.org

RESOURCES FOR THE FUTURE



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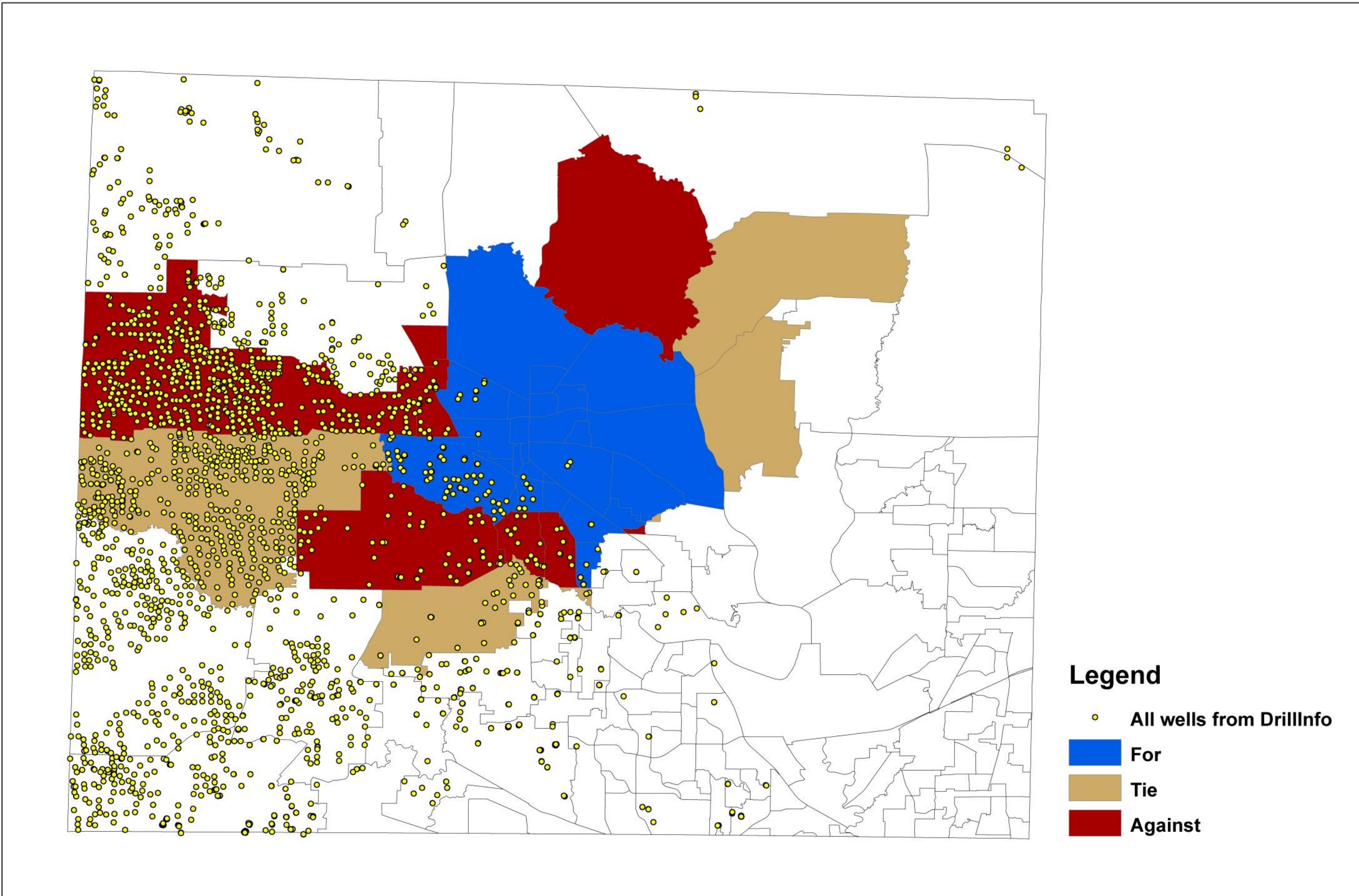

Legend
All wells from DrillInfo
For
Tie
Against

Mark Brownstein

Environmental Defense Fund

Natural Gas in a Low Carbon Future

Environmental Opportunities & Challenges

Mark Brownstein

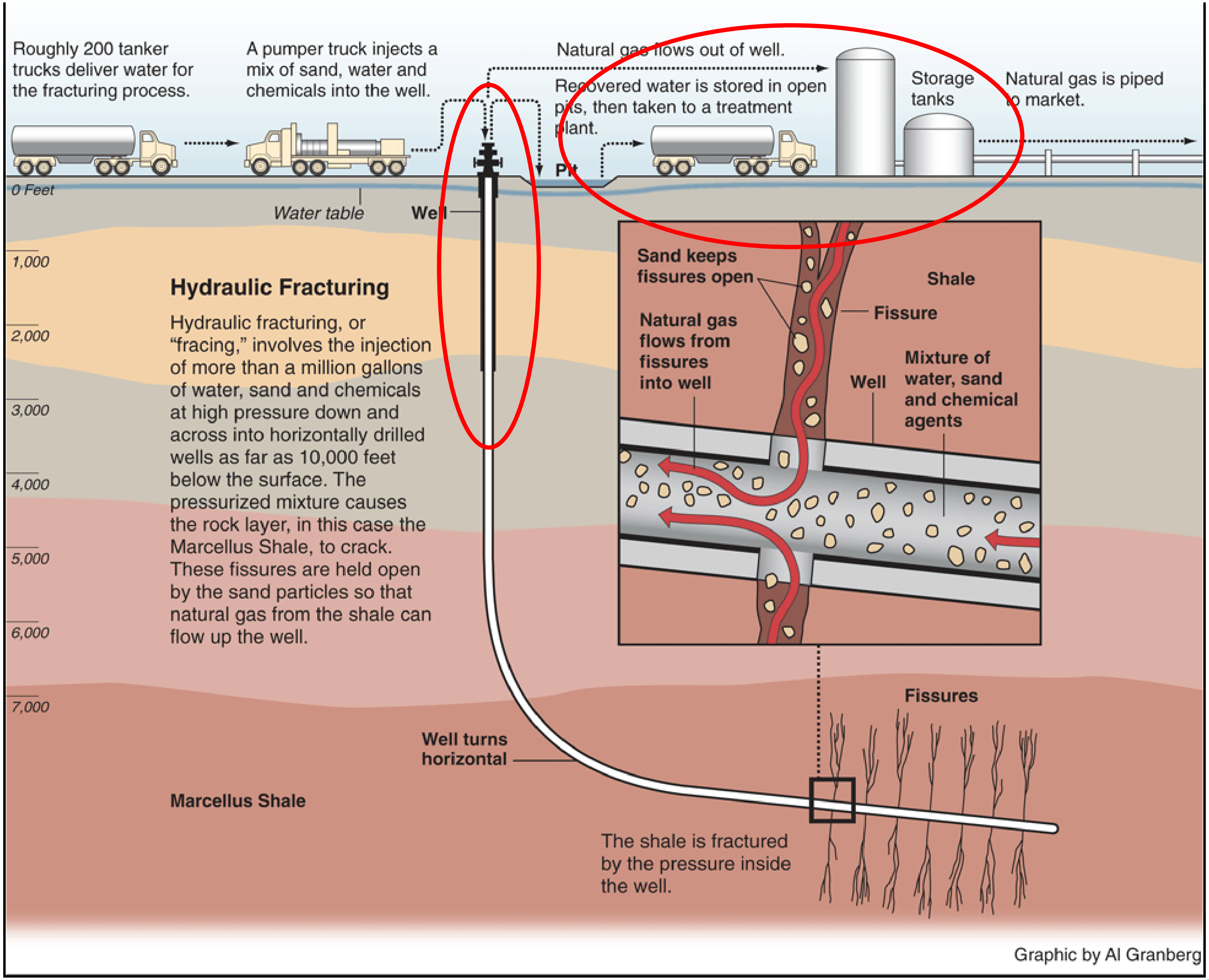
Associate Vice President

U.S. Climate & Energy Program

EDF ENVIRONMENTAL DEFENSE FUND™

Finding the ways that work

Must address the ‘fracking’ issues



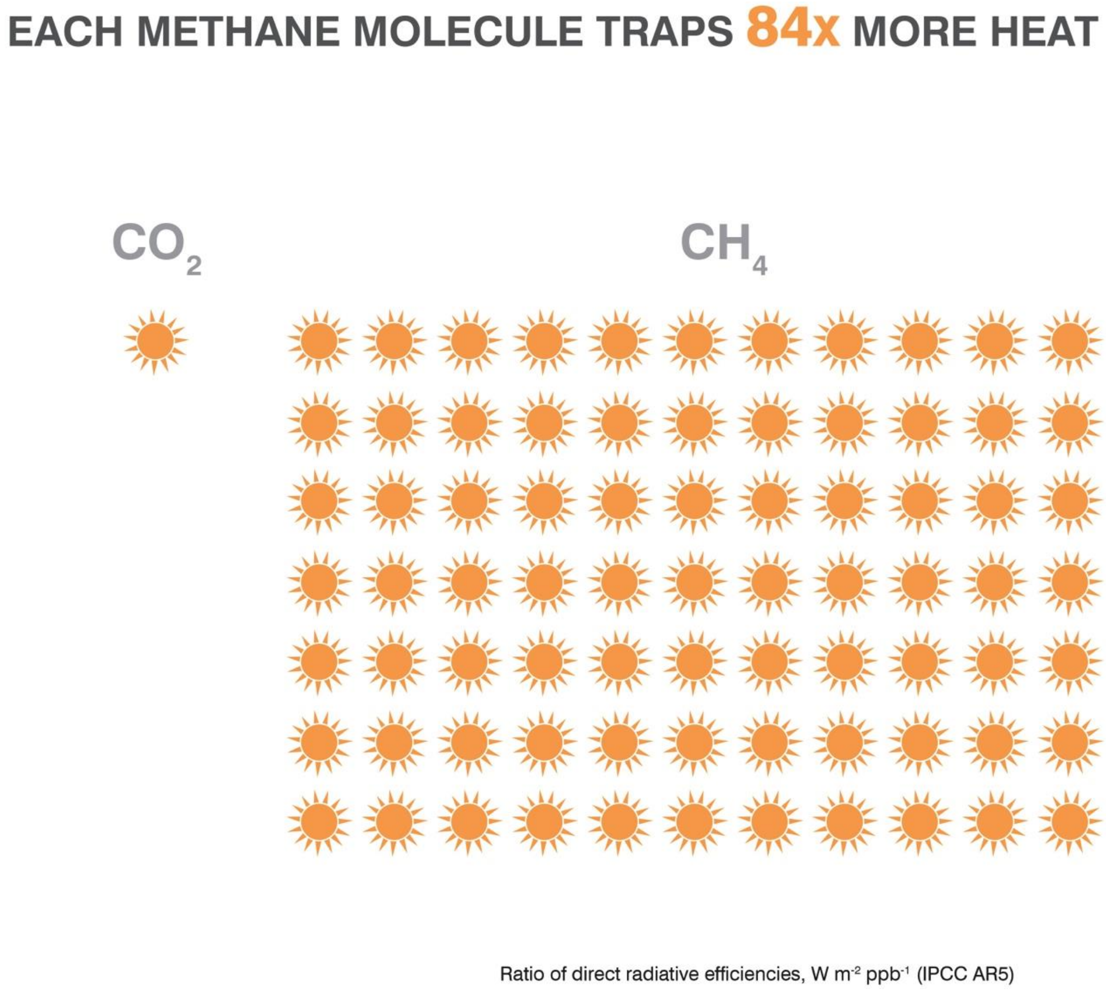
And then, there's methane…

Gas storage tank

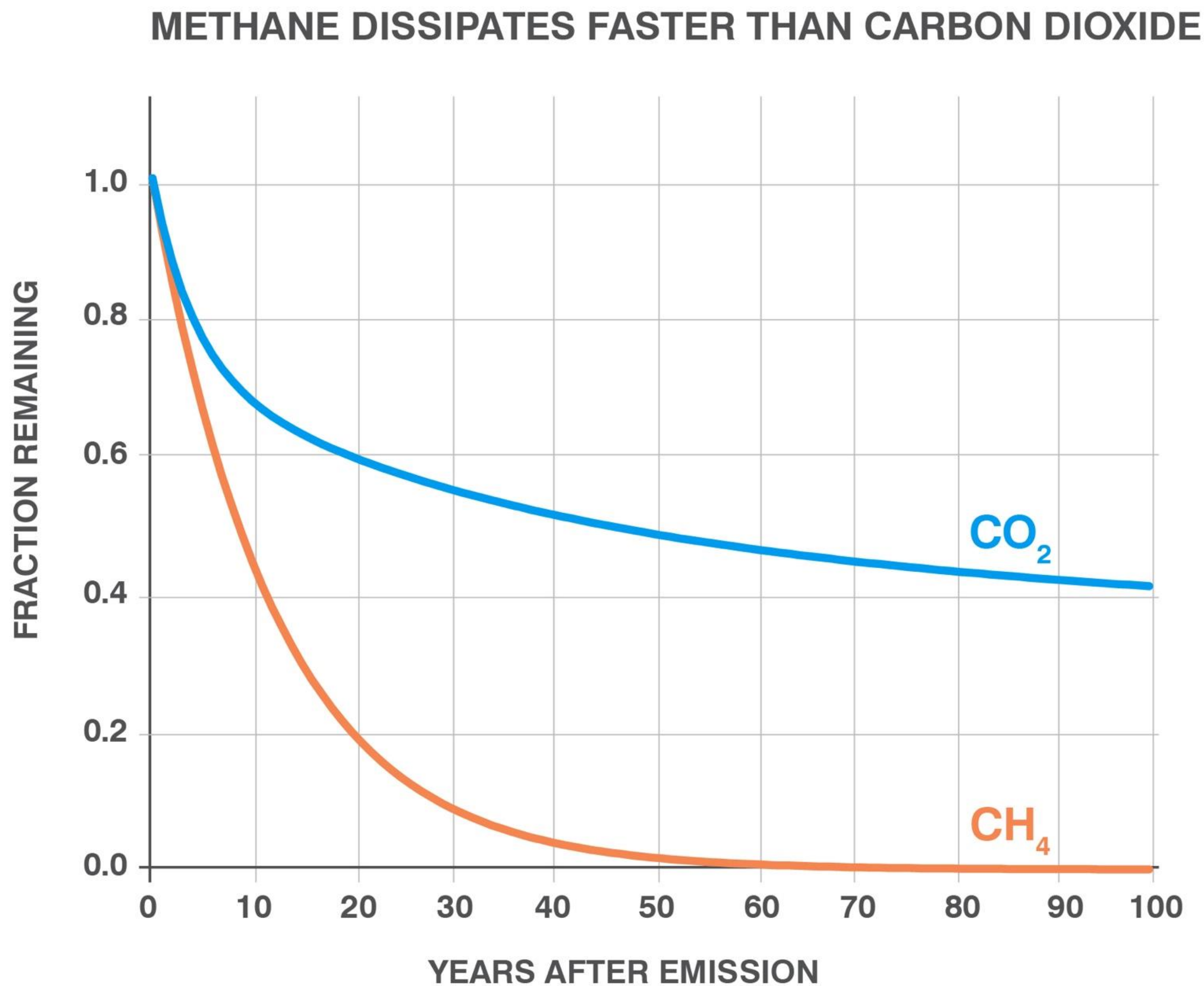
Same tank, same time, infrared camera view

…an increasingly 'visible' problem

CH_4 traps more heat than CO_2…

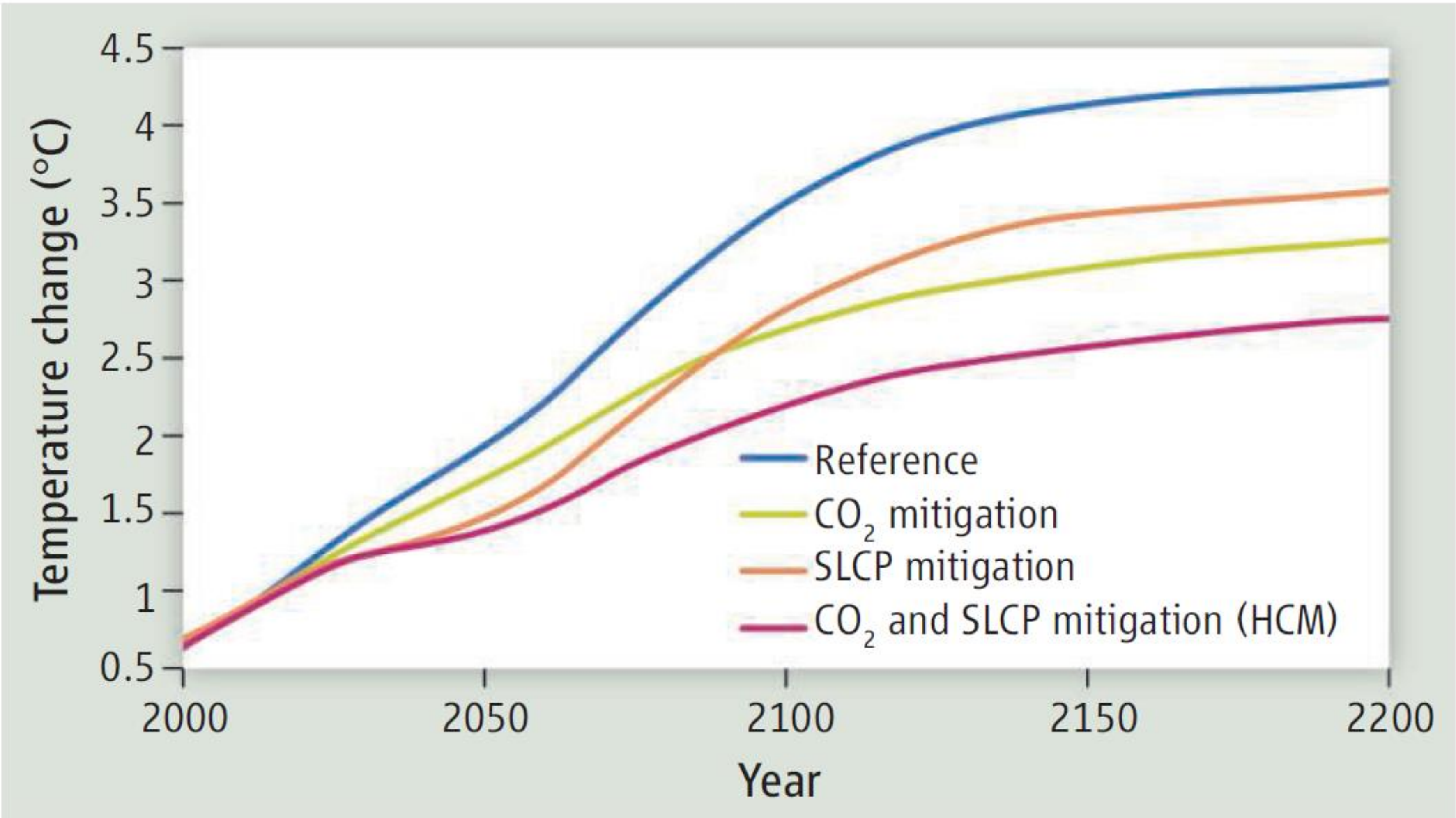


…but breaks down faster than CO_2



- CH_4 produces tropospheric ozone and stratospheric water vapor as it decays
- Increases the direct warming effect by 65% (IPCC AR5)

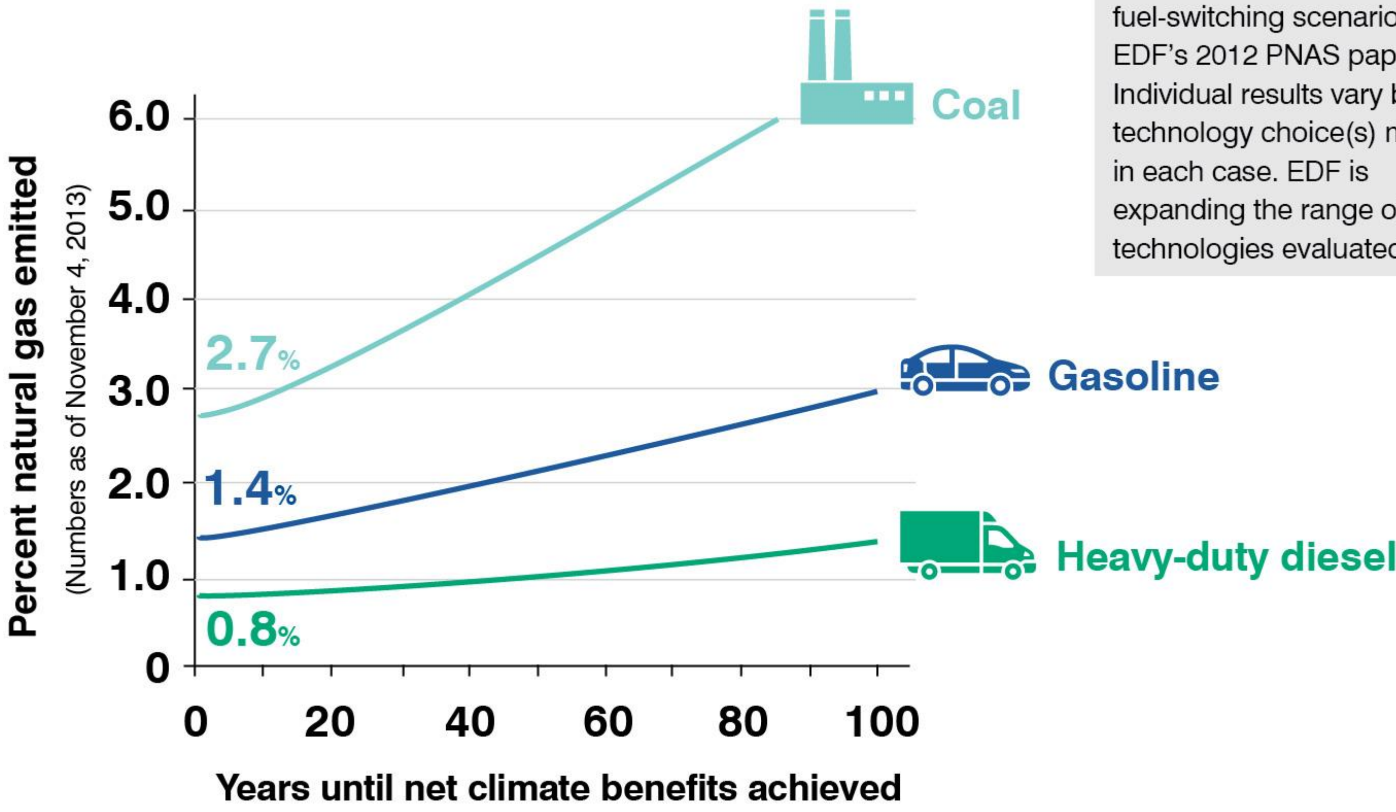
Methane *and* CO_2 reductions required



Shoemaker, et. al., **What Role for Short-Lived Climate Pollutants in Mitigation Policy?,** Science, December 19, 2013

Gas can be worse than alternatives

Depending on emission rate and timeframe

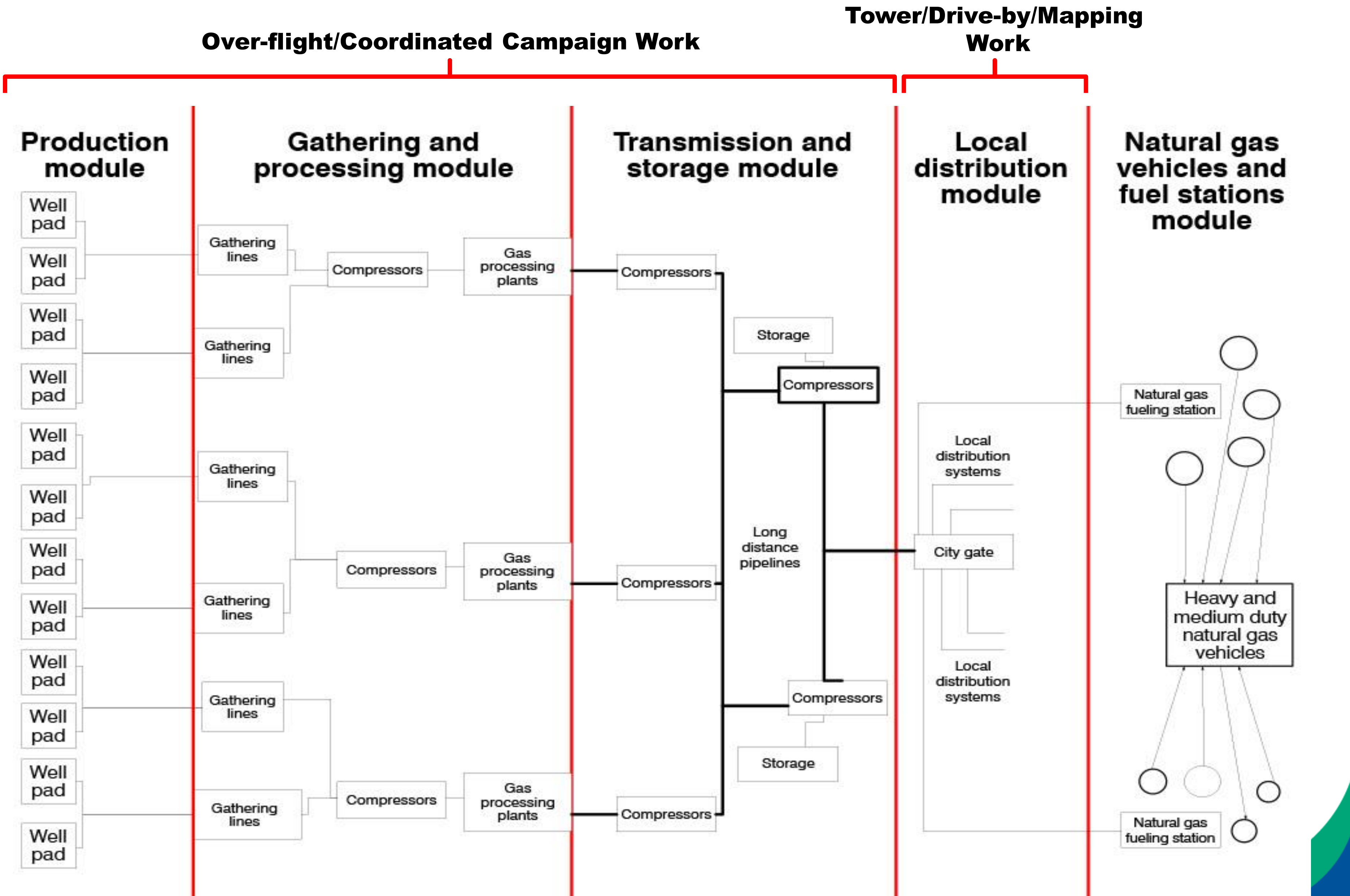


Updated calculations of fuel-switching scenarios in EDF's 2012 PNAS paper.* Individual results vary by the technology choice(s) made in each case. EDF is expanding the range of technologies evaluated.

EDF ENVIRONMENTAL DEFENSE FUND® Finding the ways that work

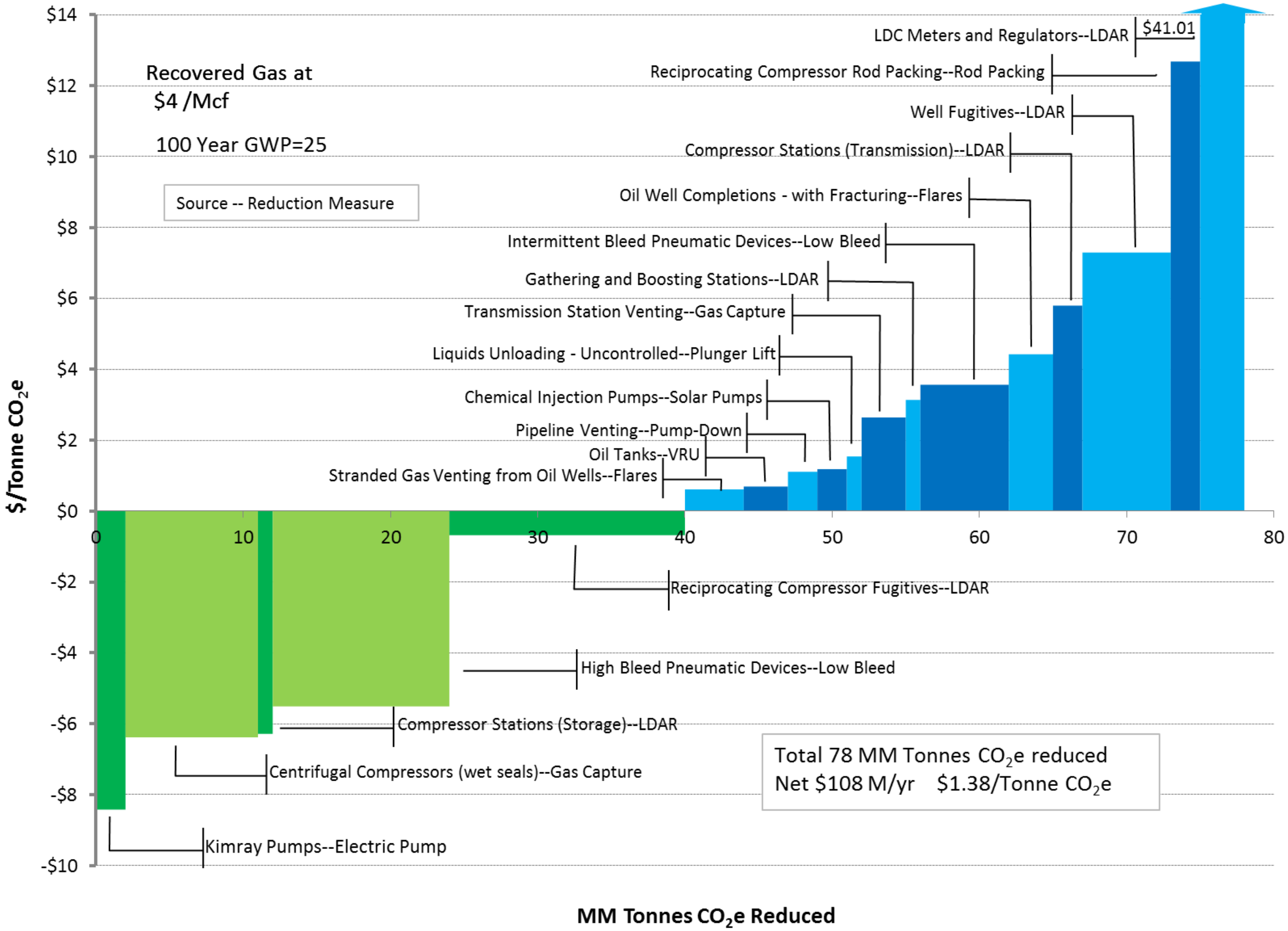
*Adapted from Alvarez et al. (2012) PNAS, **109**: 6435–6440, reflecting new IPCC AR5 & 2013 EPA GHG data. IPCC updates: (1) direct/indirect radiative forcing of CH_4 and CO_2, (2) CH_4 lifetime, (3) CO_2 impulse response function. Additional effects due to climate-carbon feedbacks and CO_2 from the oxidation of CH_4 not included (AR5 lacks data to support time-dependent analysis but EDF believes these effects to be small). Emissions updates include factors in Table 1 and corresponding L_{REF} values in Table S1 of PNAS paper; an L_{REF} value specific to heavy-duty CNG vehicles is now used.

Comprehensive emission study effort



Highly cost-effective reductions

http://www.edf.org/icf-methane-cost-curve-report



Economic Analysis of Methane Emission Reduction Opportunities in the U.S. Onshore Oil and Natural Gas Industries
ICF International, March 2014,

Doug Jordan

Southwestern Energy Company

american geosciences institute

connecting earth, science, and people

SWN
Southwestern Energy®

Health, Safety, and Environmental – Building Collaboration and Culture

AGI Critical Issues Forum

Fort Worth, TX

November 19 – 20, 2014

Doug Jordan

Director, Corporate Environmental Programs

Development Solutions
Balancing Environment, Community & Economy
a division of Southwestern Energy

Forward-Looking Statements

All statements, other than historical facts and financial information, may be deemed to be forward-looking statements within the meaning of Section 27A of the Securities Act of 1933, as amended, and Section 21E of the Securities Exchange Act of 1934, as amended. All statements that address activities, outcomes and other matters that should or may occur in the future, including, without limitation, statements regarding the financial position, business strategy, production and reserve growth and other plans and objectives for the company's future operations, are forward-looking statements. Although the company believes the expectations expressed in such forward-looking statements are based on reasonable assumptions, such statements are not guarantees of future performance and actual results or developments may differ materially from those in the forward-looking statements. The company has no obligation and makes no undertaking to publicly update or revise any forward-looking statements. You should not place undue reliance on forward-looking statements. They are subject to known and unknown risks, uncertainties and other factors that may affect the company's operations, markets, products, services and prices and cause its actual results, performance or achievements to be materially different from any future results, performance or achievements expressed or implied by the forward-looking statements. In addition to any assumptions and other factors referred to specifically in connection with forward-looking statements, risks, uncertainties and factors that could cause the company's actual results to differ materially from those indicated in any forward-looking statement include, but are not limited to: the timing and extent of changes in market conditions and prices for natural gas and oil (including regional basis differentials); the company's ability to fund the company's planned capital investments; the company's ability to transport its production to the most favorable markets or at all; the timing and extent of the company's success in discovering, developing, producing and estimating reserves; the economic viability of, and the company's success in drilling, the company's large acreage position in the Fayetteville Shale play overall as well as relative to other productive shale gas plays; the impact of government regulation, including any increase in severance or similar taxes, legislation relating to hydraulic fracturing, the climate and over the counter derivatives; the costs and availability of oilfield personnel, services and drilling supplies, raw materials, and equipment, including pressure pumping equipment and crews; the company's ability to determine the most effective and economic fracture stimulation for the Fayetteville Shale formation; the company's future property acquisition or divestiture activities; the impact of the adverse outcome of any material litigation against the company; the effects of weather; increased competition and regulation; the financial impact of accounting regulations and critical accounting policies; the comparative cost of alternative fuels; conditions in capital markets, changes in interest rates and the ability of the company's lenders to provide it with funds as agreed; credit risk relating to the risk of loss as a result of non-performance by the company's counterparties and any other factors listed in the reports the company has filed and may file with the Securities and Exchange Commission (SEC). For additional information with respect to certain of these and other factors, see the reports filed by the company with the SEC. The company disclaims any intention or obligation to update or revise any forward-looking statements, whether as a result of new information, future events or otherwise.

The SEC has generally permitted oil and gas companies, in their filings with the SEC, to disclose only proved reserves that a company has demonstrated by actual production or conclusive formation tests to be economically and legally producible under existing economic and operating conditions. We use the terms "estimated ultimate recovery," "EUR," "probable," "possible," and "non-proven" reserves, reserve "potential" or "upside" or other descriptions of volumes of reserves potentially recoverable through additional drilling or recovery techniques that the SEC's guidelines may prohibit us from including in filings with the SEC. These estimates are by their nature more speculative than estimates of proved reserves and accordingly are subject to substantially greater risk of being actually realized by the company.

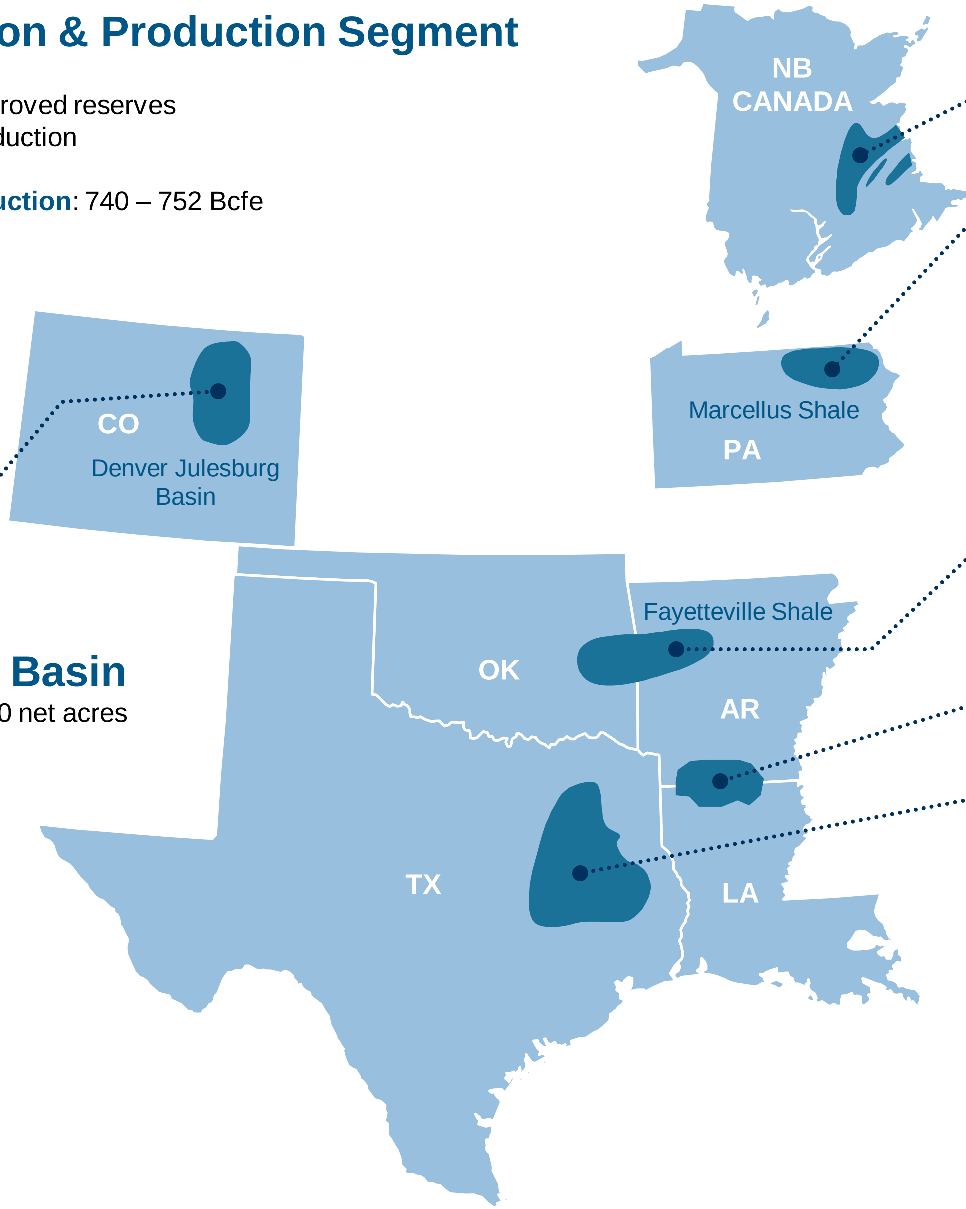
The contents of this presentation are current as of August 1, 2013.

Areas of operation

Exploration & Production Segment

2013
6,976 Bcfe* of proved reserves
657 Bcfe of production

2014 est. production: 740 – 752 Bcfe



Denver Julesburg Basin
Acreage: 302,000 net acres

New Brunswick
Acreage: 2.5 million net acres

Marcellus Shale
Acreage: 292,446 net acres (at 12/31/13)
2013 Reserves: 1,963 Bcfe (28% of total)
2013 Production: 151 Bcfe (23% of total)

Fayetteville Shale
Acreage: 905,684 net acres (at 12/31/13)
2013 Reserves: 4,795 Bcfe (69% of total)
2013 Production: 486 Bcfe (74% of total)

Brown Dense Project
Acreage: 459,000 net acres (at 12/31/13)

Ark-La-Tex
Acreage: 152,937 net acres (at 12/31/13)
2013 Reserves: 215 Bcfe (3% of total)
2013 Production: 18 Bcfe (3% of total)

- Bcfe is an equivalent measurement of one billion cubic feet of mixed oil and gas reserves
- ** Arkoma acreage excludes 124,653 net acres in the conventional Arkoma Basin operating area that are also within the company's Fayetteville Shale focus area.

HS&E Culture

Values + Behaviors = Culture

A true HSE culture exists when:

- HSE becomes part of everyday business.
- One has pride in HSE just like having pride in being excellent in production, footage drilled, and customer satisfaction.
- HSE is not an afterthought, but a way of doing business.

Culture is a key to continued HSE excellence!

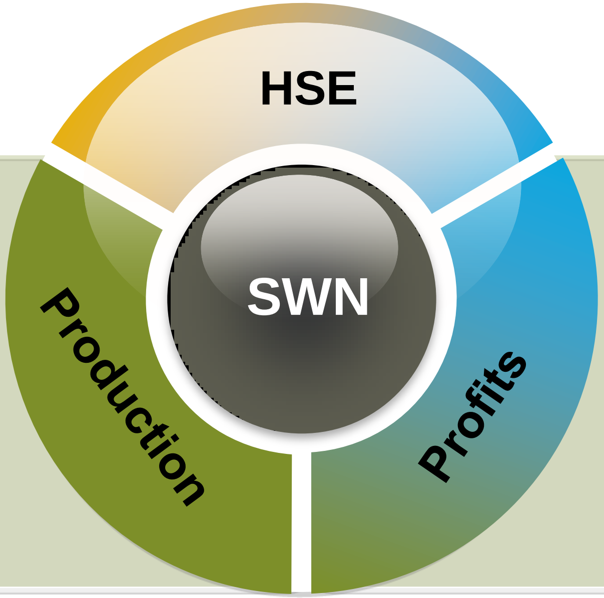
Key Steps in Developing an HSE Culture

Embrace HSE as a value integral to the organization

SWN Management Philosophy

SWN Values Safety

SWN makes HSE equal to production/operations and profits/expenses.



HSE Compliance is Key

If it can't be done within HSE compliance, it will not be done at SWN.

SWN HS&E

"HS&E is My Responsibility"

- A SWN priority is to ensure that health, safety and environmental management is integrated into all of our business activities.

SWN HSE Culture "Tools"

- HSE "Training"
  - New Hire Orientation
  - HS&E Leadership Training
  - "R2 Training"
- HSE Handbook
- HSE Programs
- HSE Goals
  - Balanced Scorecard
  - Industry Peer Group Comparisons
- HSE Steering Committees
- HSE Awards/Recognition

Midstream Balanced Scorecard-2014

PROACTIVE INDICATORS: DRIVING IMPROVEMENT

LEADERSHIP ENGAGEMENT INITIATIVES - (Weight Factor - TBD)		
Develop a plan or set of actions wherein management, at all levels, displays its commitment and overall HSE performance.	% Complete	Target
% of Managers (two or more levels of direct reports) visit field operation sites outside of their BU; observe HSE processes for improvement opportunities and communicate findings back to the site owner	25%	100%
% of Leaders receiving and conducting BBS Training	Not Started	100%
% of all Team Meetings that begin with a HSE Message/Topic	100%	100%

HSE IMPROVEMENT PLAN - (Weight Factor - TBD)		
Develop specific plans to either improve areas of weakness or share lessons across the enterprise to highlight things done to accomplish a high level of achievement and performance.	% Complete	Target
Using 2013 HSE performance gaps, develop and implement two plans to achieve measurable improvement in those identified performance gaps	150%	2
1. Ensure all employees are current with initial and refresher training	70%	100%
2. Implement Southwestern BBS system per corporate plan/schedule	Not Started	100%

CONTRACTOR HSE MANAGEMENT - (Weight Factor - TBD)		
Develop an action plan to improve contractor HSE performance, insure their compliance with SWN HSE standards and continue to screen and select high quality vendors.	% Complete	Target
Using data from team site audits, obtain 100% contractor compliance with TAP and SSE expectations	100%	100%
Identify the 5 highest risk Contractors and work with same for risk reduction	Started	5
Initiate and participate in Contractor HSE Audits/Reviews	20%	3

LEARNING AND SHARING LESSONS - (Weight Factor - TBD)		
Build an inter and intra business process with HSE that leverages the value of lessons learned throughout the SWN enterprise.	% Complete	Target
Write/develop summaries and implement corrective actions on all high potential incidents (injuries, vehicular and environmental incidents) within 30 days. Communicate these enterprise-wide via the HSE portal under "Shared Lessons Learned" and discuss at monthly business unit safety meetings	Not Started	100%
Develop and publish HSE Alerts for Midstream specific concerns or incidents	20%	8
Publish "Lessons of the Quarter" to all Midstream staff and contractors	25%	4

REACTIVE INDICATORS: MEASURING PERFORMANCE

SAFE WORK - (Weight Factor - TBD)		
Traditional 3-tiered system	Actual	Target
TRIR (Total Recordable Incident Rate) monthly, quarterly and annual actual vs. target	0.49	1.25
TSCR (Total Safety Citation Rate) monthly, quarterly and annual vs. target	0	0

SAFE DRIVING - (Weight Factor - TBD)		
Three tiered system implemented in 2014....all incidents count	Actual	Target
PVIR (Preventable Vehicle Incident Rate) monthly, quarterly and annual actual vs. target	1.13	0.78
Recognize all safe drivers of 100,000 miles or greater.	100%	100%

ENVIRONMENTAL COMPLIANCE - (Weight Factor - TBD)		
Traditional 3-tiered system	Actual	Target
TRER (Total Recordable Environmental Rate), monthly, quarterly and annual actual vs. target	0	0.54
NOV's resulting from OSHA/MSHA violations	0	0

INCIDENT RESPONSE - (Weight Factor - TBD)		
Respond in compliance with legal, regulatory or internal requirements.	Actual	Target
Annual Crisis Management Exercise action items completed within 30 days	Not Started	100%
Update, train and drill on all elements of Single Integrated Emergency Plan	Not Started	100%

Not Started
On Track
Completed
At or Below Target Rate
At Risk
Above Target Rate

The Path Forward – "HSE Next Generation"

2014 | 2015 | 2016

Phase 1

- Assess current state
- Evaluate and benchmark safety culture and systems

Action

- Safety Perception Survey completed Q1, 2014

Phase 2

We Are Here

- Envision future state
- Gain management alignment and commitment

Action

- Develop near-term plan with senior leadership using Safety Perception Survey results
- Begin company-wide <u>management and supervisor</u> training

Phase 3

- Plan Transition
- Design corporate & local change management plans

Action

- Develop and implement local change management plans (2015 Balanced Scorecards)
- Begin development of observation and intervention data collection and processing tools
- Organize and develop enterprise-wide HSE governance

Phase 4

- Implement Change
- Build foundation & instill changes in organization

Action

- Begin company-wide <u>employee</u> training
- Begin comprehensive observation and intervention training and implementation
- Develop all encompassing HSE Management System

Phase 5

- Sustain & Improve
- Monitor, measure and continuously improve

Action

- Using Scorecard results, observation findings and lessons learned from incident investigations, develop long term plans to continuous improvement

Complete Safety Perception Survey again in 2017

BEHAVIOR BASED SAFETY IMPLEMENTATION TEAM

SWN Health & Safety Collaboration

- SWN's commitment to the health and safety of our employees, contractors and to our neighbors begins with collaboration – **A ONE Team Approach**

- Agency Engagement
  – NIOSH Flowback and Silica Studies
  – OSHA STEPS Program

- Contractor Engagement

- Community Benefits

SWN Health & Safety Collaborative Programs

SSE	Short Service Employee program.
TAP	Continuous development of the TAP initiative (business unit specific modules).
ISN. Collect. Verify. Connect.	ISNetworld company wide re-launch.
	Contractor Assessment process which includes desktop reviews, onsite visits, and field observations.
StreetSmart Southwestern Energy	Continuation of Street Smart, TEAMworks, eLearning, vendor forums, and SWNlink communications.

SWN Methane Emission Reduction Activities

- EPA Natural Gas Star – member since 2005
  - Cumulative reductions = 37 BCF
  - 2011 Production Partner of the Year
- SWN SMART LDAR Program – voluntary program to survey and repair emission leaks from facilities.
  - Midstream initiated program in 2012
  - Production initiated program in 4th Quarter, 2013.
- SWN Dual fuel drilling rigs – replacing fleet (2014 / 2015)
- Fuel cell field test
  - Pnuematic controller conversion from gas to air

Environmental Collaboration

- Collaborative effort with industry, academia and environmental community to solve issues such as air emissions, water protection and community impact.

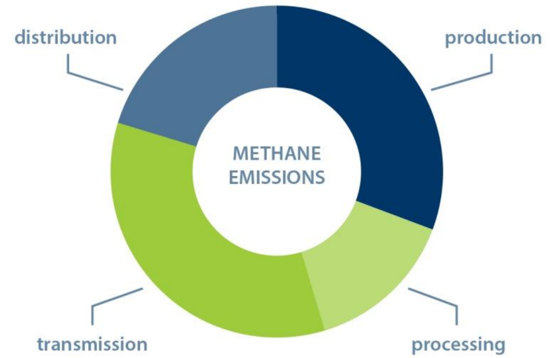
Air Collaboration

ONE
OUR NATION'S ENERGY
FUTURE

AIR

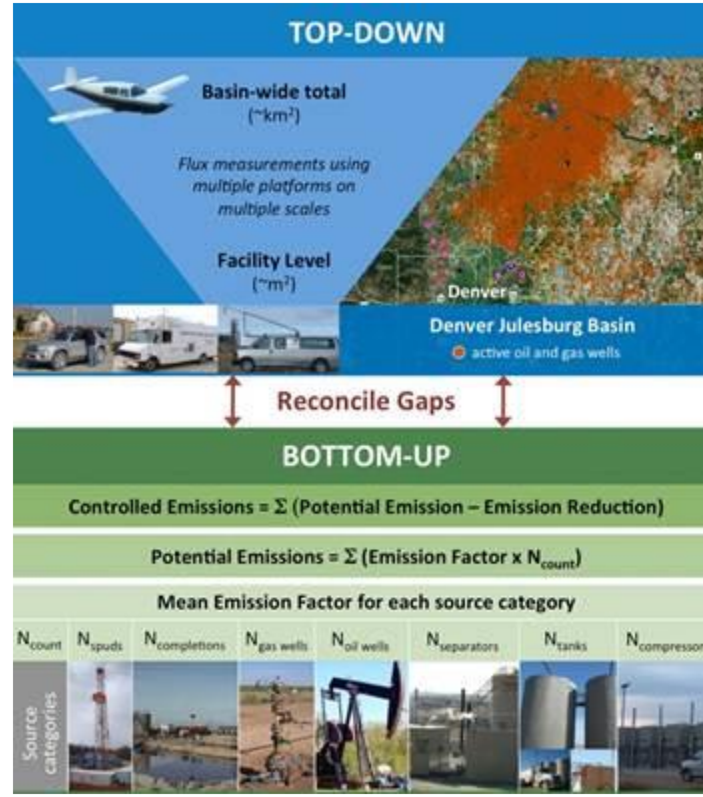
OUR GOAL

Enhance the energy delivery efficiency of the natural gas supply chain by limiting energy waste and by achieving a methane "leak/loss rate" of no more than one percent.



SWN Methane Research - Collaboration

- Top-Down Methane Emissions Studies
  - DOE/Penn State Marcellus Study
    - SWN's participation includes funding additional tower and study participation
- "Bottom-Up" Methane Emissions Studies
  - Production Sector Phase 1 and Phase 2
    - University of Texas
      - URS
      - Aerodyne
    - EDF and 9 Industry Participants
  - Gathering & Processing Sector
    - Colorado State University
      - Carnegie Mellon University
      - Aerodyne
    - EDF and 4 Industry Participants
- "Top-down" and "bottom-up" methane measurements
  - D-J Basin Reconciliation Study
    - Research Partnership to Secure Energy for America
- New Measurement Technology Partnerships
  - EDF "Methane Detectors Challenge"
  - Picarro "Surveyor" field trial
  - Rebellion Photonics "gas cloud imaging camera" field trial



Water Collaboration

ECH2O
energy conserving water

Offset 100% of the volume of fresh water used in SWN operations by 2016:

PROTECTION

REDUCTION

INNOVATION

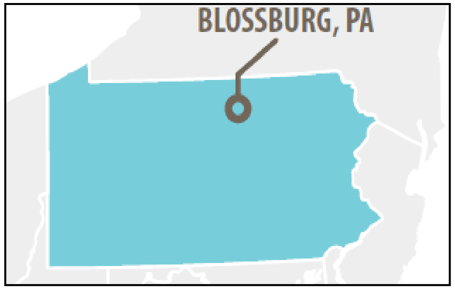
CONSERVATION

ECH2O

- Protection
  - Protection of existing water sources
    - Model Regulatory Framework – Environmental Defense Fund
    - Marcellus Water Well Monitoring - Install monitoring wells before SWN pad activity. One year of monitoring prior to development activity – Yale University
    - Streamsmart – Erosion/sediment control project - Nature Conservancy
- Reduction
  - Minimize the total quantity of water needed
  - Recycle produced water for future completions
  - Replace fresh water with alternate sources
  - Minimize the use of potable water
- Innovation
  - Develop compact, low cost water treatment technologies
  - Research / Develop approaches to economic low water stimulation.
- Conservation
  - Increase water availability or improve water quality.

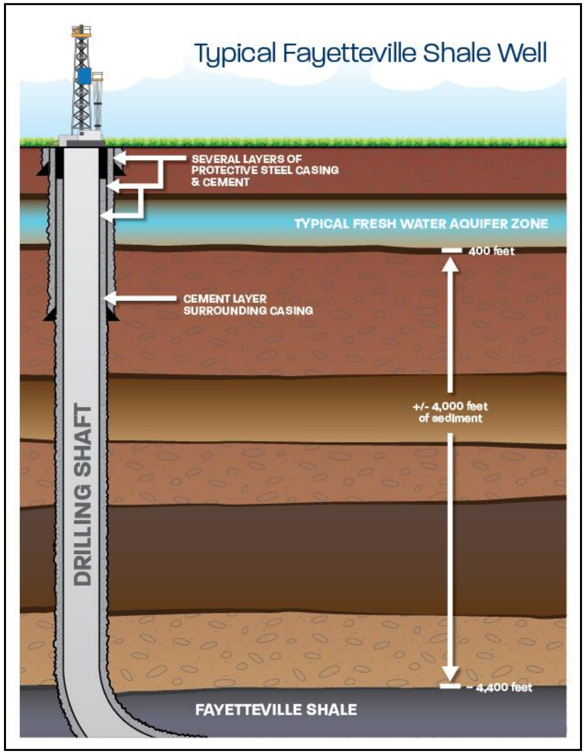
Fall Brook Acid Mine Drainage
Completion - 2016

- **Location:** Tioga River Watershed, Tioga Co, PA
- **Description:** AMD Remediation Project
- **Conservation Type:** Stream and River Restoration
- **Benefits:**
  - Place 325 million gallons (10.7 million barrels) a year of clean water into Susquehanna River for PA and NY
  - Increase recreational and aesthetic value of river
  - Decrease bridge maintenance cost
- **Partners:**
  - PA Fish and Boat Commission
  - PA Dept. of Env. Protection
  - SRBC
  - Trout Unlimited
  - Tioga Co. Concerned Citizens Committee
  - Tioga Co. Conservation District
  - Tioga Co. Commissioners
- **Timeline:**
  - 2014 – Survey and Design
  - 2015 – Construction

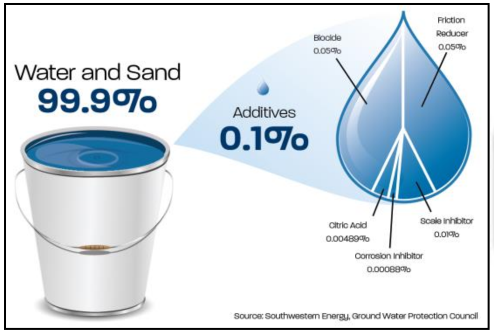


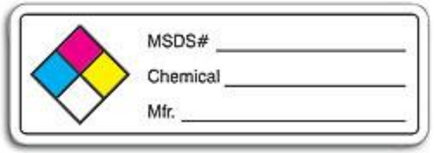
Environmental Protection Collaboration

Well Bore Integrity



Right Products Program





Systematic approach to evaluating chemicals that SWN may use in its operations.

Stream Smart

Erosion Control Training

SWN Formula

The Right People Doing The Right Thing

$$\frac{R^2}{A} \rightarrow V^+ \text{®}$$

Will create Value+

Wisely investing the cash flow from the underlying assets

Session 3:
Environmental, health, and safety impacts

Critical Issues Forum

America's Increasing Reliance on Natural Gas: Benefits and Risks of a Methane Economy

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Password: (no password needed)

american geosciences institute
connecting earth, science, and people