Public Health Impacts of Shale Gas Development and Production

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May 30, 2013

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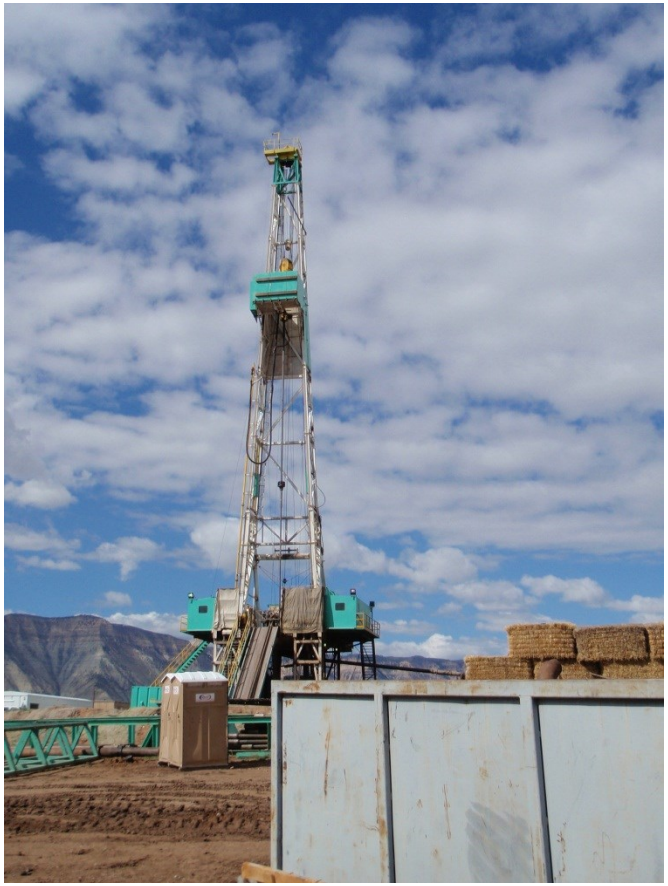
Acknowledgements

- Bernie Goldstein and Lisa McKenzie
- Funding from the Colorado School of Public Health, the National Science Foundation (NSF CBET-1240584), and RPSEA
- CSPH Colleagues: Roxana Witter, Lee Newman, Ken Scott, Kaylan Stinson
- Garfield County Public Health: Jim Rada, Paul Reaser

Roadmap

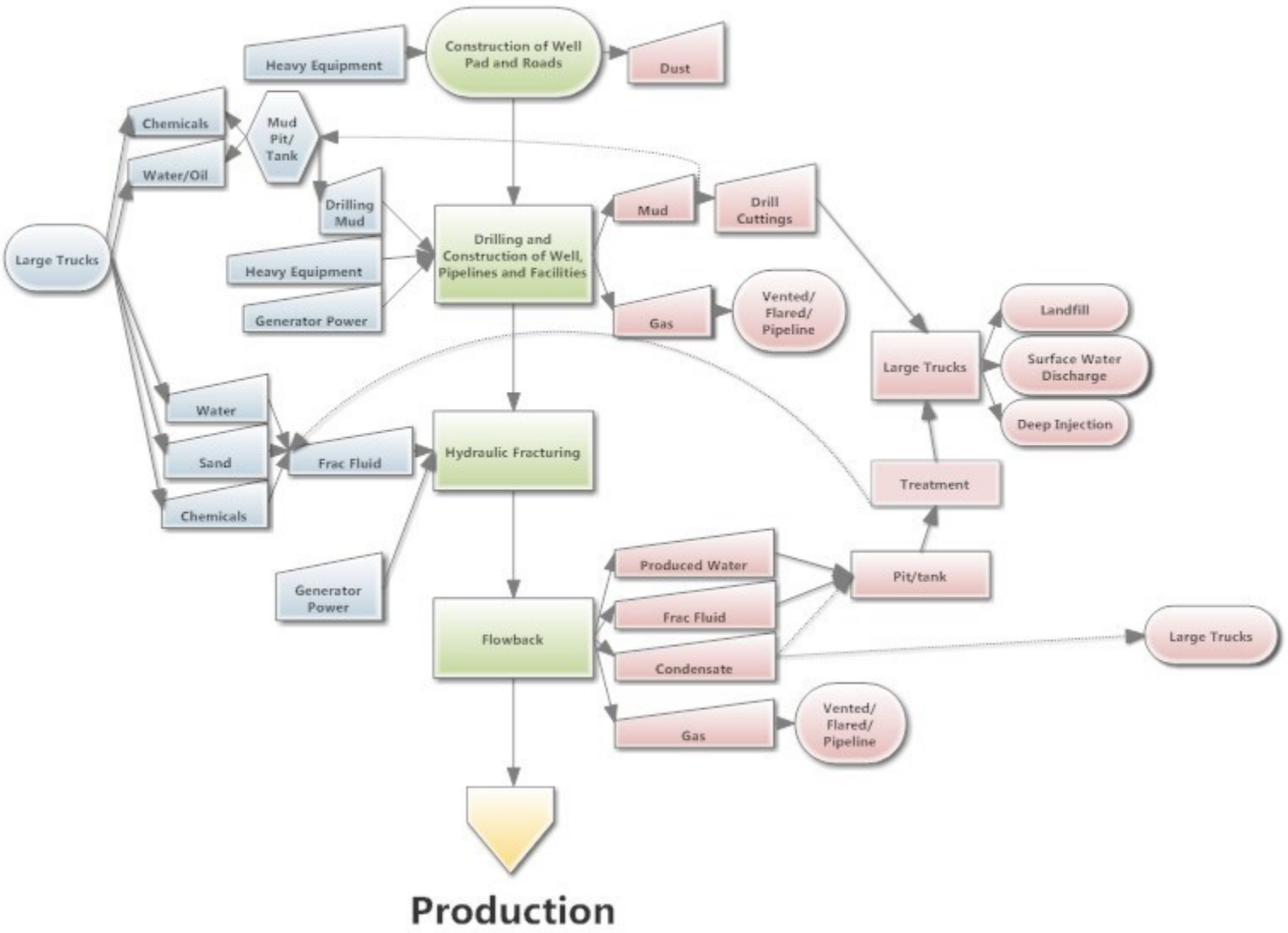
- **What have we learned?**
  - Colorado Example
    - *HIA*
    - *Exposures and Risks*
  - Research on potential air and water exposures
- **What do we need to know?**
  - Uncertainties and Research Needs



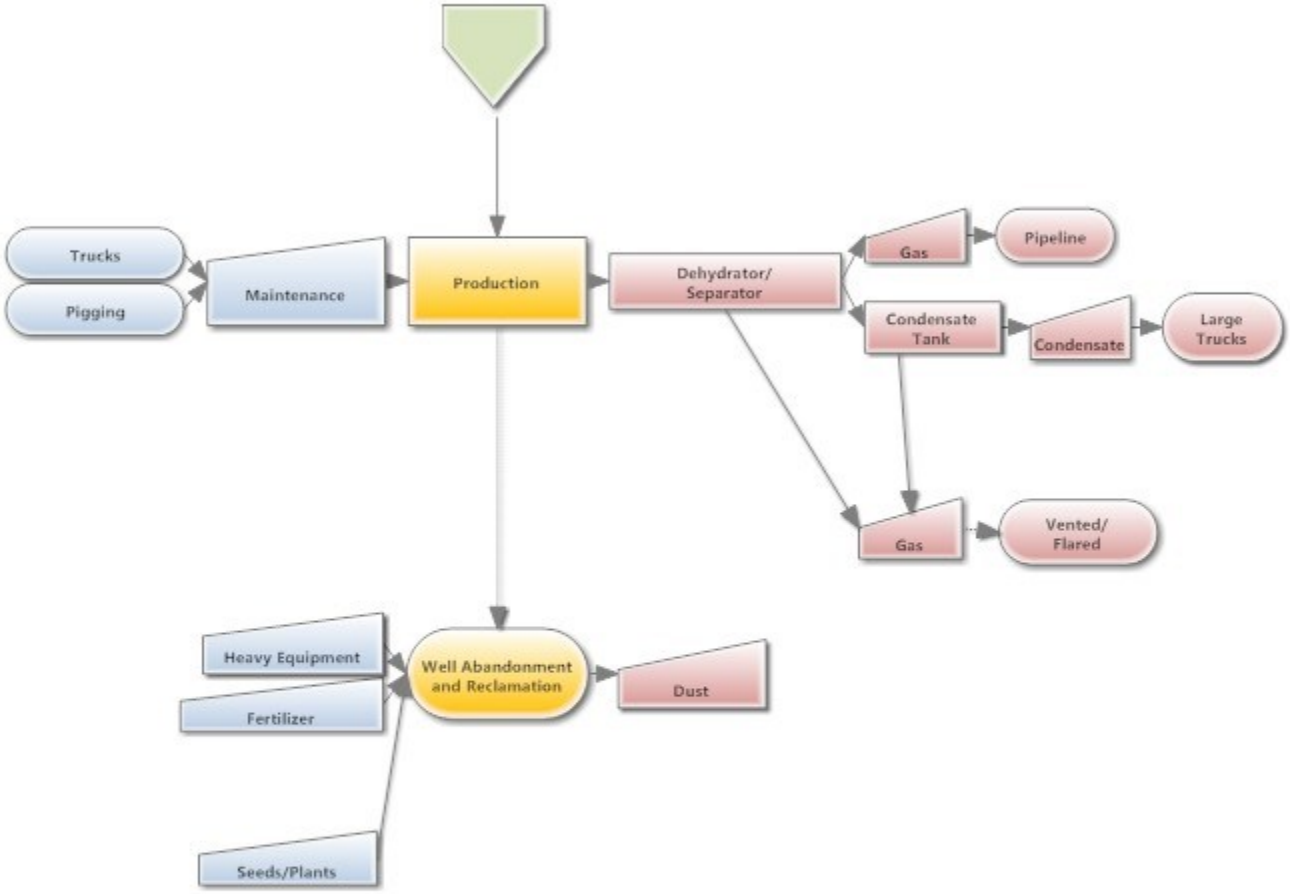
Shale Gas D&P From a Public Health Perspective

- **Systems Approach**
  - Direct and indirect effects, environmental and social processes
- **Well Development**
  - Short term, repeated in many locations
  - Episodic and continuous exposures
  - Short- and long-term risks
- **Well Production**
  - Infrastructure: more continuous, less episodic
  - Accidents, Incidents, and Impacts
  - Long term PH Effects / Trade Offs

NG Development

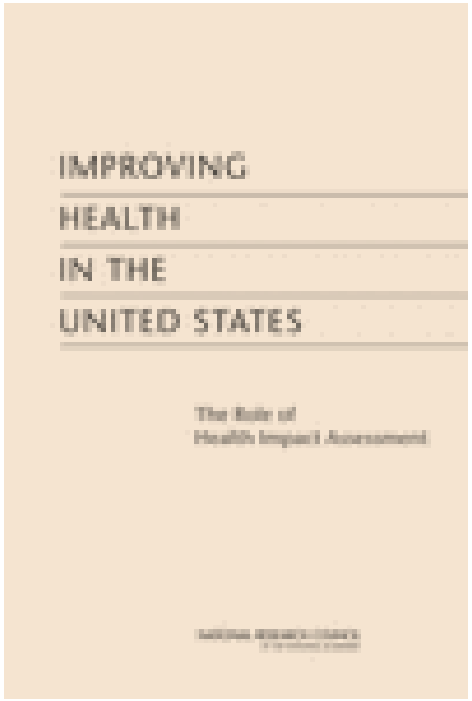


Production



Inputs **Process** **Outputs**

Battlement Mesa Health Impact Assessment



NRC 2011

What effects does natural gas development have on human health?

Issues in B. Mesa:

- Air quality
- Water quality
- Traffic
- Noise
- Economic conditions
- Social conditions
- Health infrastructure
- Accidents/malfunction

GARFIELD COUNTY

how do I? | our towns | business here | for seniors | do it online | SEARCH

Colorado

Departments: Choose

ENVIRONMENTAL HEALTH

public health | preparedness

pages

- Garfield County home
- Environmental Health home
- Public Health home
- Air quality management
- Air emissions study

Battlement Mesa HIA/EHMS

Battlement Mesa Health Impact Assessment (2nd draft)

The Battlement Mesa Health Impact Assessment (HIA) is a document that provides objective information and evidence-based recommendations to increase the potential health benefits of natural gas drilling in the Battlement Mesa PUD, while minimizing potential health risks. On March 1, 2011, the second draft of the HIA became available for stakeholders in the community to review. We invited community stakeholders, including stakeholders in government, citizen groups, academia and the private sector, to submit questions, criticisms and comments that they may have about the HIA.

resources

New! EHMS Final Design December 2011

Health Impact Assessment 2nd draft

http://www.garfield-county.com/environmental-health/battlement-mesa-health-impact-assessment-ehms.aspx

AJPH June 2013

The Use of Health Impact Assessment for a Community Undergoing Natural Gas Development

Roxana Z. Witter, MD, MSPH, Lisa McKenzie, PhD, MPH, Kaylan E. Stinson, MSPH, Kenneth Scott, MPH, Lee S. Newman, MD, MA, and John Adgate, PhD, MSPH

The development of natural gas wells is rapidly increasing, yet little is known about associated exposures and potential public health consequences. We used health impact assessment (HIA) to provide decision-makers with information to promote public health at a time of rapid decision making for natural gas development. We have reported that natural gas development may expose local residents to air and water contamination, industrial noise and traffic, and community changes. We have provided more than 90 recommendations for preventing or decreasing health impacts associated with these exposures. We also have reflected on the lessons learned from conducting an HIA in a politically charged environment. Finally, we have demonstrated that despite the challenges, HIA can successfully enhance public health policymaking. (*Am J Public Health*. Published online ahead of print April 18, 2013: e1–e9. doi:10.2105/AJPH.2012.301017)

Many regions of the United States hold large natural gas reserves.[1] Colorado is one of the states experiencing rapid natural gas development. Applications for permits to drill rose from 1939 in 2003 to 7870 in 2008[2,3] and natural gas wells in the community, some of which would be approximately 500 feet from homes. The well development phase would be 5 years, followed by a 20- to 30-year production phase.

"complete physical, mental, and social well-being"[17] and understanding that living environment is a determinant of health,[18] we addressed a wide range of potential exposures from natural gas development and the subsequent effects these exposures could have on public health. Because we conducted the HIA before the project had begun, site-specific data for exposures were not available; instead we used exposure data from other local sites where natural gas development had occurred and medical literature to describe the known health effects of such exposures. Throughout the HIA process, we worked closely with county public health professionals and received technical guidance and support from experienced HIA practitioners. The full HIA and supporting documents are available on the county Web site.[19]

HIA: Available Data and Information Gaps

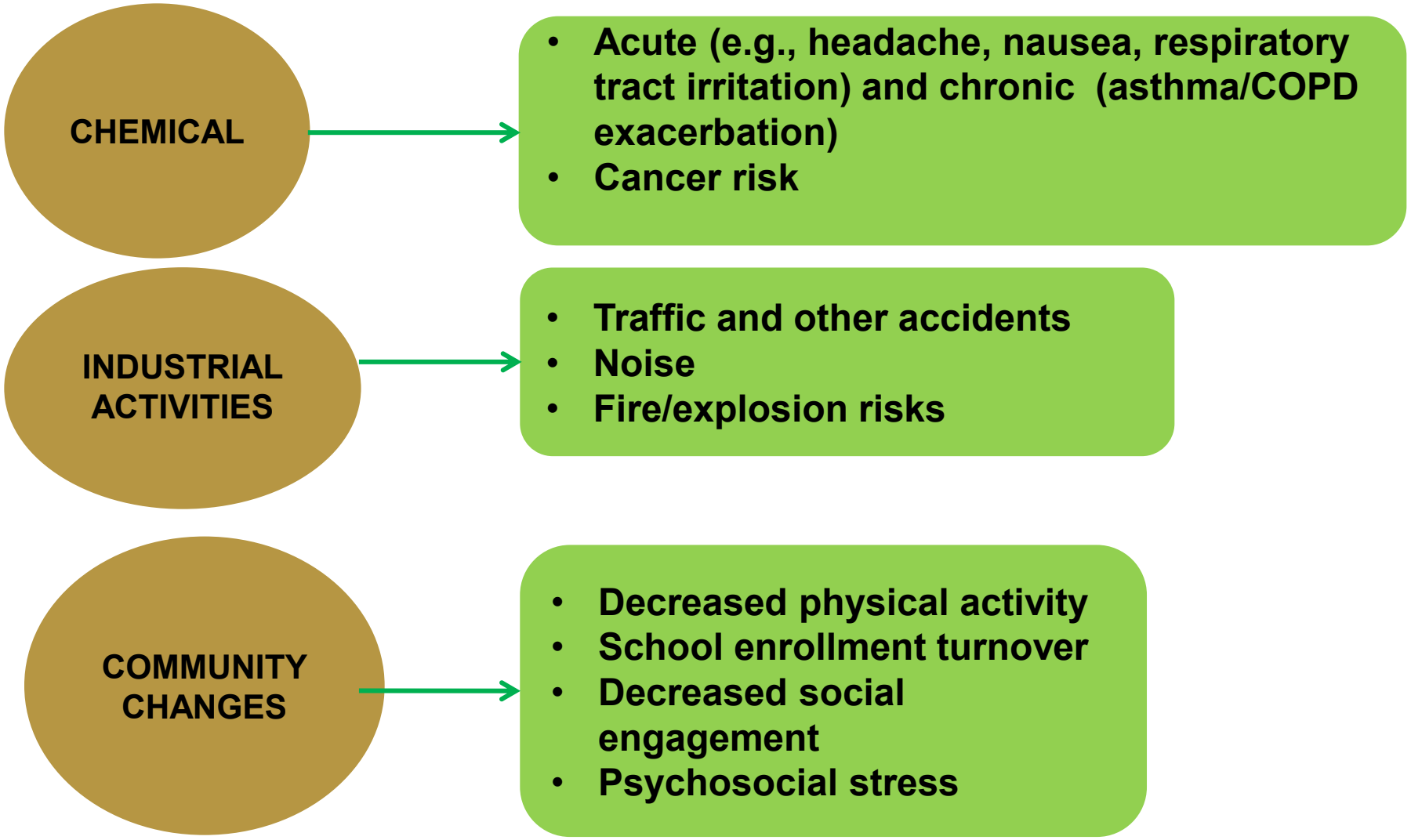
Available

- ✓ Local air monitoring data
- ✓ Traffic and noise estimates
- ✓ Anecdotal reports of exposures and health symptoms
- ✓ Demographic, vital statistics, cancer, birth outcomes, hospital discharge, STI, school, crime data
- ✓ Scientific literature for possible exposures

Didn't have complete exposure information

Didn't have complete health outcomes data

HIA Findings: Potential Adverse Health Impacts



HIA Recommendations

- **Pollution Prevention**
  - reduce the opportunity for residents to be exposed to industrial chemicals
- **Promote Safety**
  - promote safe industry operations in a residential neighborhood
- **Communication**
  - foster constructive interaction between stakeholders

HIA to Quantitative Risk Assessment

- Ambient air data collected over several years was available
- Applied standard EPA methodology for screening level risk assessment
- One of many tools used to evaluate human health

Uncontrolled Emission Estimates from NG Completion Operations (USEPA 2011)

Well Completion Category	Emissions (Mcf/event)	Emissions (tons/event)		
	Methane	Methane	VOCs	HAPs
NG Well Completion w/o Fracturing	38.6	0.80	0.12	0.009
NG Well Completion **with Fracturing**	7,623	158.6	23.1	1.7

~200X more air pollution from uncontrolled NG well completions

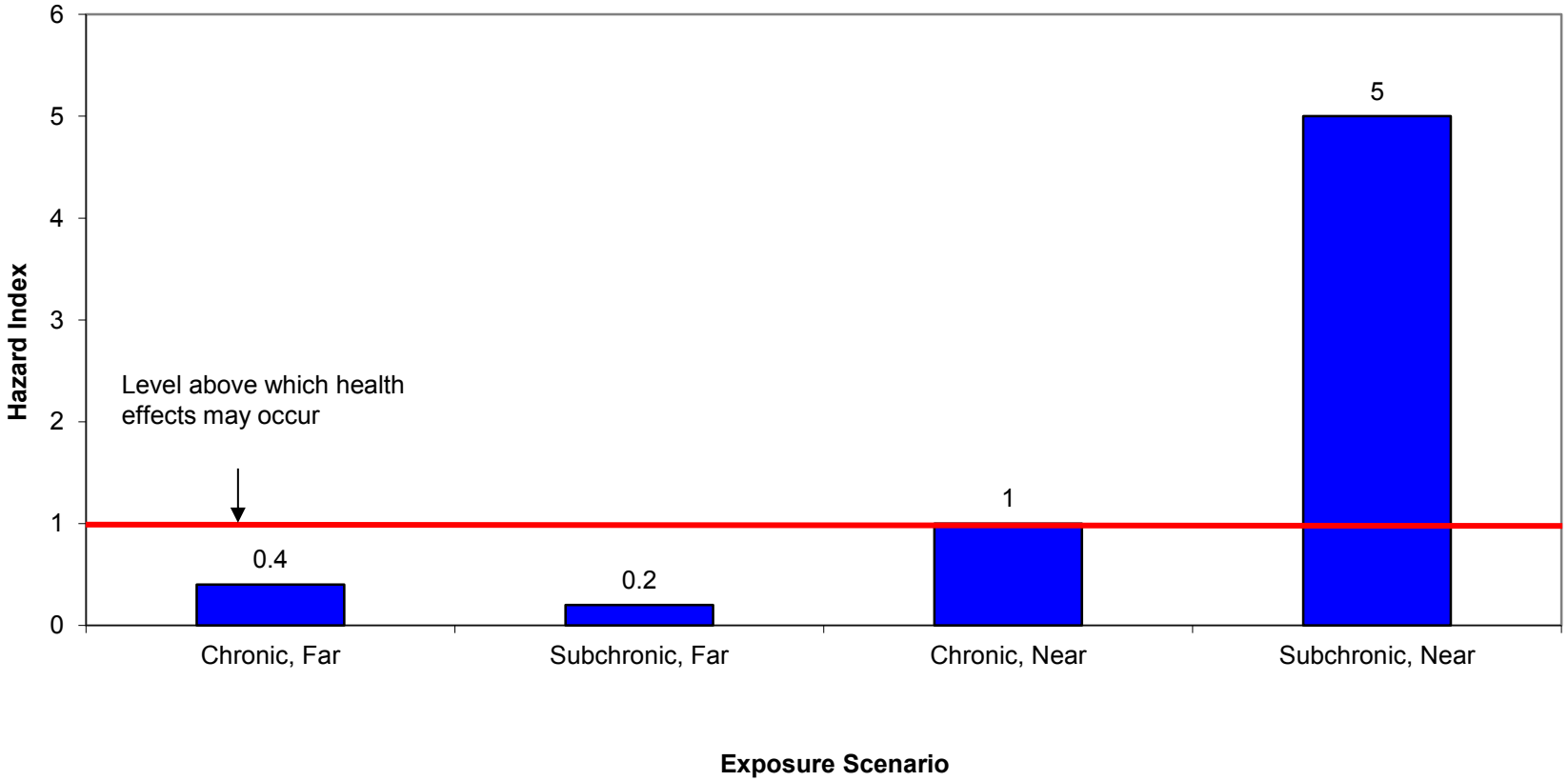
Air Quality During Well Completion

- Mckenzie et al, 2012.
  - Human Health Risk Assessment
  - Limited number of “flowback” samples as well as area samples
  - Risk of sub-chronic and chronic non- cancer health effects and lifetime excess cancer risk

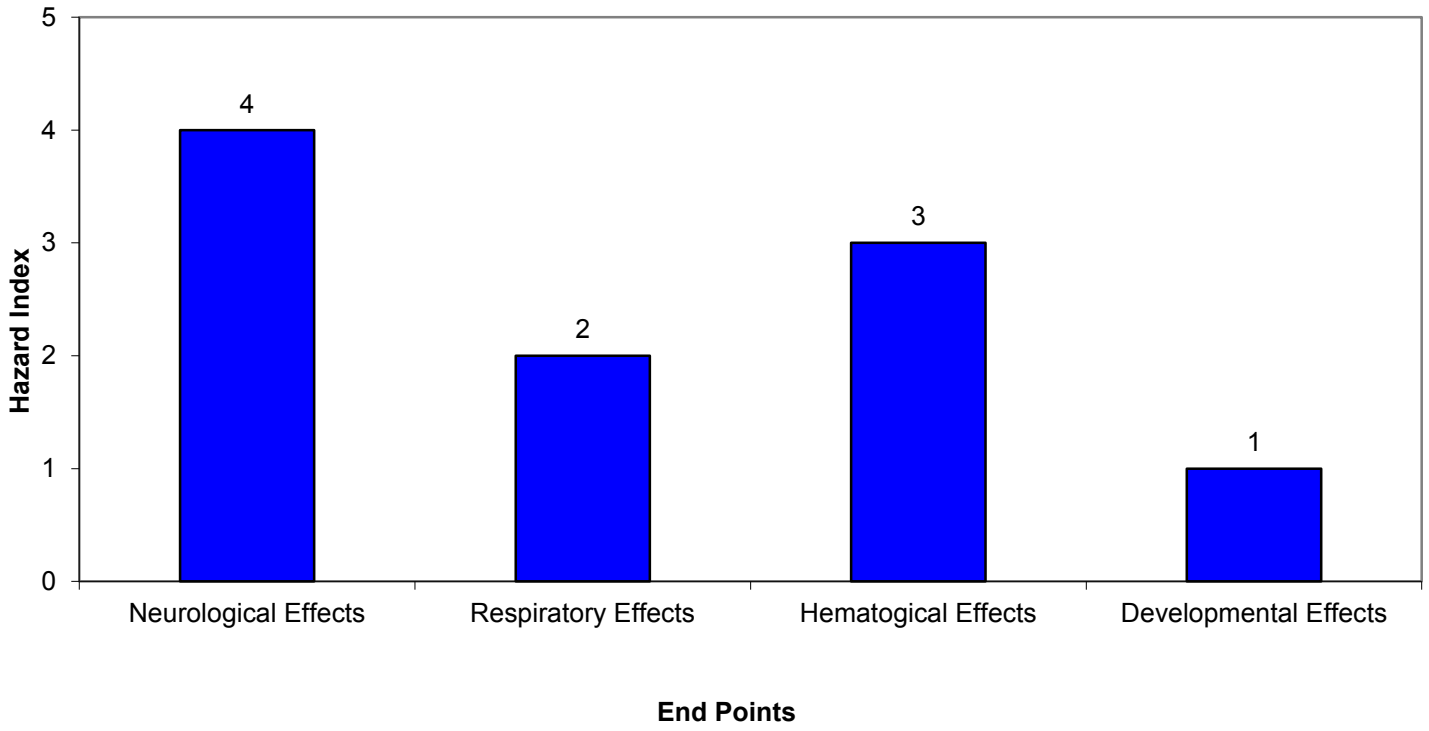
Human Health Risk Assessment

- "Screening" Risk Estimates Using EPA methods
  - EPA Reference Concentrations (RfCs), inhalation unit risks, and other health-based guidelines when RfCs or cancer potency estimates not available
  - Scenario-based chronic and subchronic assessments for nearby residents
- Quantitative Risk Assessment
  - Non Cancer (Systemic): Hazard Index
    - *Ratio of estimated exposure to RfC and/or health-based guidance level*
    - *Index sums potential effects of multiple chemicals*
    - *Are these greater than 1?*
  - Cancer: Lifetime Excess Cancer Risk, multiple chemicals
    - *Are risks greater than 1 in a million ?*
    - *Are risks greater than 1 in 10,000 ?*

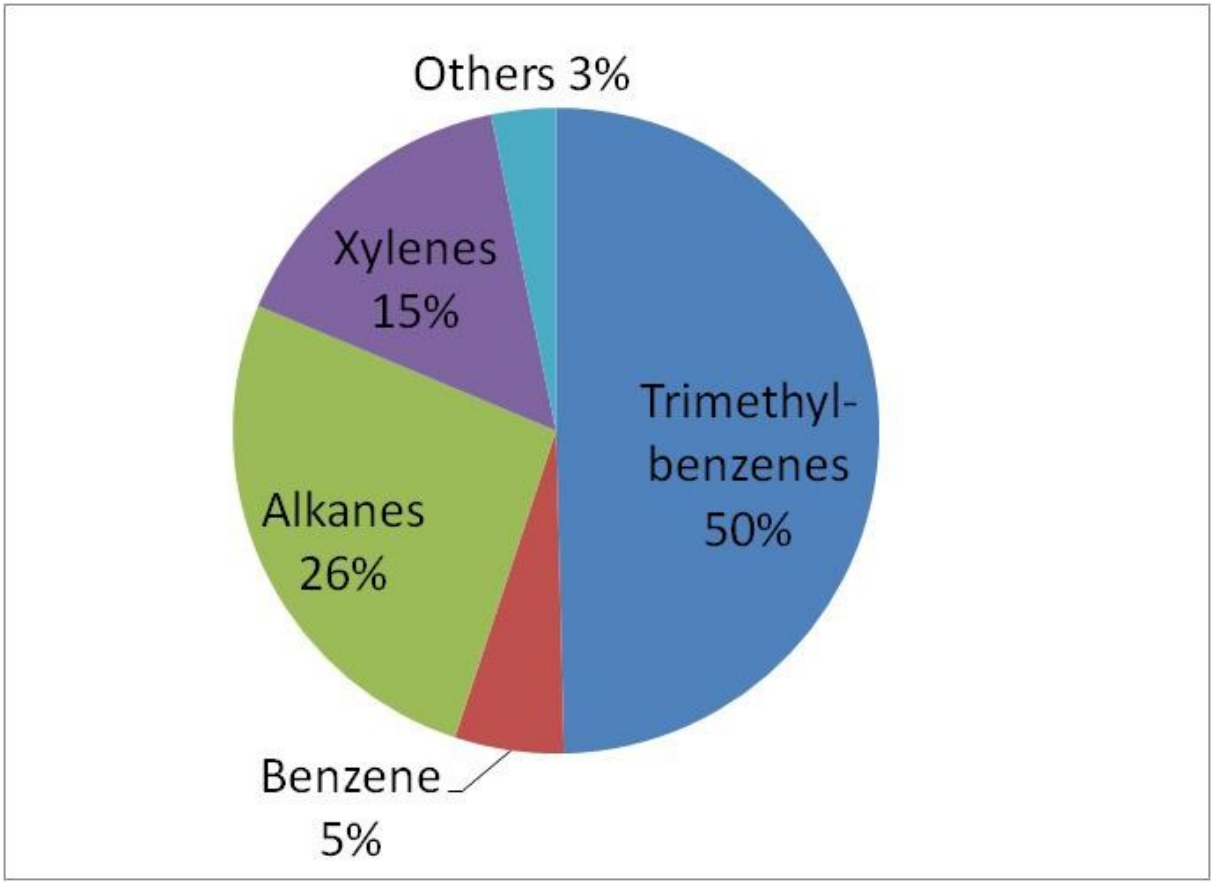
Hazard Indices by Duration of Exposure and Distance from Source



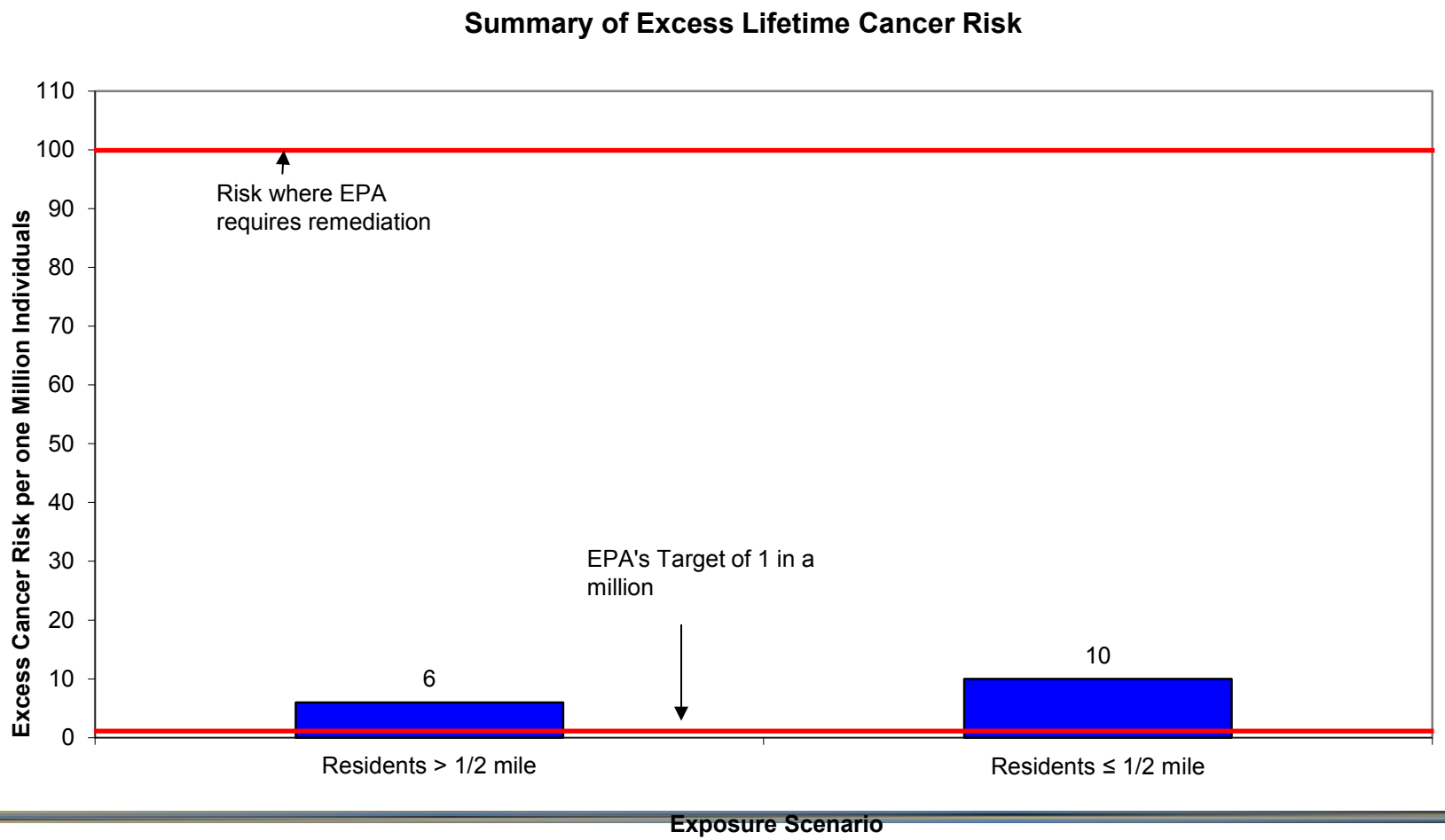
Hazard Indices by Health Endpoint: Near Wells, 20 Month Exposure Scenario



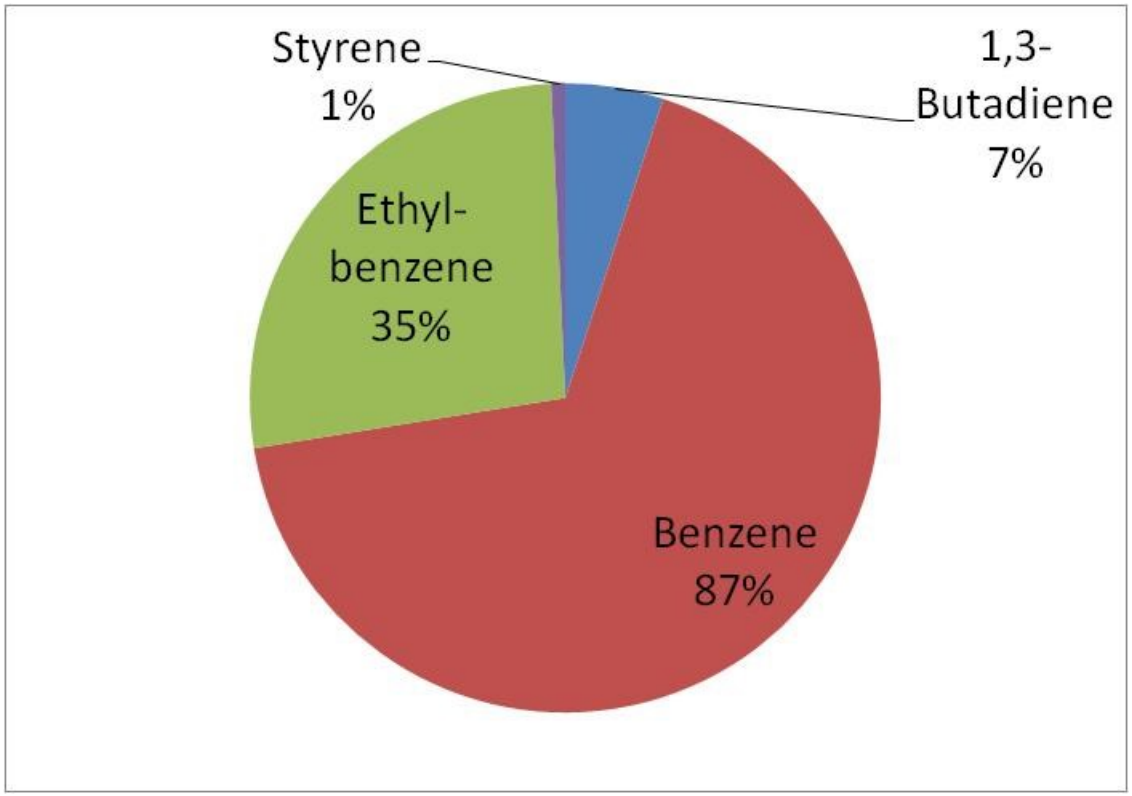
Non-Cancer Risk Drivers



Excess Lifetime Cancer Risks



Excess Lifetime Cancer Risk Drivers



Risk Assessment Summary

- Residents living near well completion activities potentially exposed to substantial levels of air toxics
- Estimated cancer risks and chronic non-cancer hazard indices are greater for residents living nearest the well pads, but are within generally acceptable range.
- **Subchronic non-cancer cumulative and endpoint specific hazard indices are greater than one for residents living near well pads**.

Uncertainties, Limitations & Unanswered Questions

- Limited data exists on emissions on primary, secondary, and engine-related air pollutants at well completion sites
  - Understanding spatial and temporal variability in exposures is key
- Non-methane pollutant emissions vary by field type, number of well heads, completion process used and controls in place
- **These data do not tell us how far is far enough nor how close is too close to well development sites**

Water

Concerns About Water

- Quantity
  - 1-2 million gallons/drill
  - 2-5 million gallons/hydraulic fracture
- Quality
  - Chemicals
    - *Hydraulic fracturing, drilling muds and additives, naturally occurring*
  - Contamination of ground and surface water
- Disposal
  - Salts, metals, hydrocarbons, radioactivity (NORM)
  - Earthquakes
- **Mixtures**

Additive	Example Chemical	Purpose
Acid	Hydrochloric acid or muriatic acid	Helps dissolve minerals and initiate cracks in the rock
Antibacterial agent	Glutaraldehyde	Eliminates bacteria in the water that produces corrosive by-products
Iron control	Citric acid	Prevents precipitation of metal oxides
Breaker	Ammonium persulfate	Allows a delayed break down of the frac gel
Corrosion inhibitor	n,n-dimethyl formamide	Prevents corrosion of pipe
Crosslinker	Borate salts	Maintains fluid viscosity
Surfactant	Isopropanol	Increases viscosity of the frac fluid
Friction reducer	Petroleum distillate	Minimizes friction
Gel Guar gum	Hydroxyethyl cellulose	Helps suspend the sand in water
Clay stabilizer	Potassium chloride	Brine carrier fluid
pH adjusting agent	Sodium or potassium carbonate	Adjusts and controls pH of the fluid
Scale Inhibitor	Ethylene glycol	Reduces scale deposits in pipe

Hazard Identification & Exposure Modeling

Rozell, 2012 Risk Analysis

- Probability bounds analysis
- Modeled 5 possible water contamination pathways
  - Casing failure, fracture migrations, surface contamination, transportation, disposal
- Wastewater disposal poses highest risk -- by several orders of magnitude

Industrial Activities

Silica

(NIOSH; Esswein et al 2013)

- OSHA-NIOSH HAZARD ALERT
- 11 sites in AR, CO, ND, PA, TX
- 116 Personal breathing zone, full shift samples
- Exceeded OSHA PEL, NIOSH REL, ACGIH TLV
- 31% w/ levels above what respirator could handle

Centers for Disease Control

http://www.osha.gov/dts/hazardalerts/hydraulic_frac_hazard_alert.html

Hazards Associated with Truck Traffic

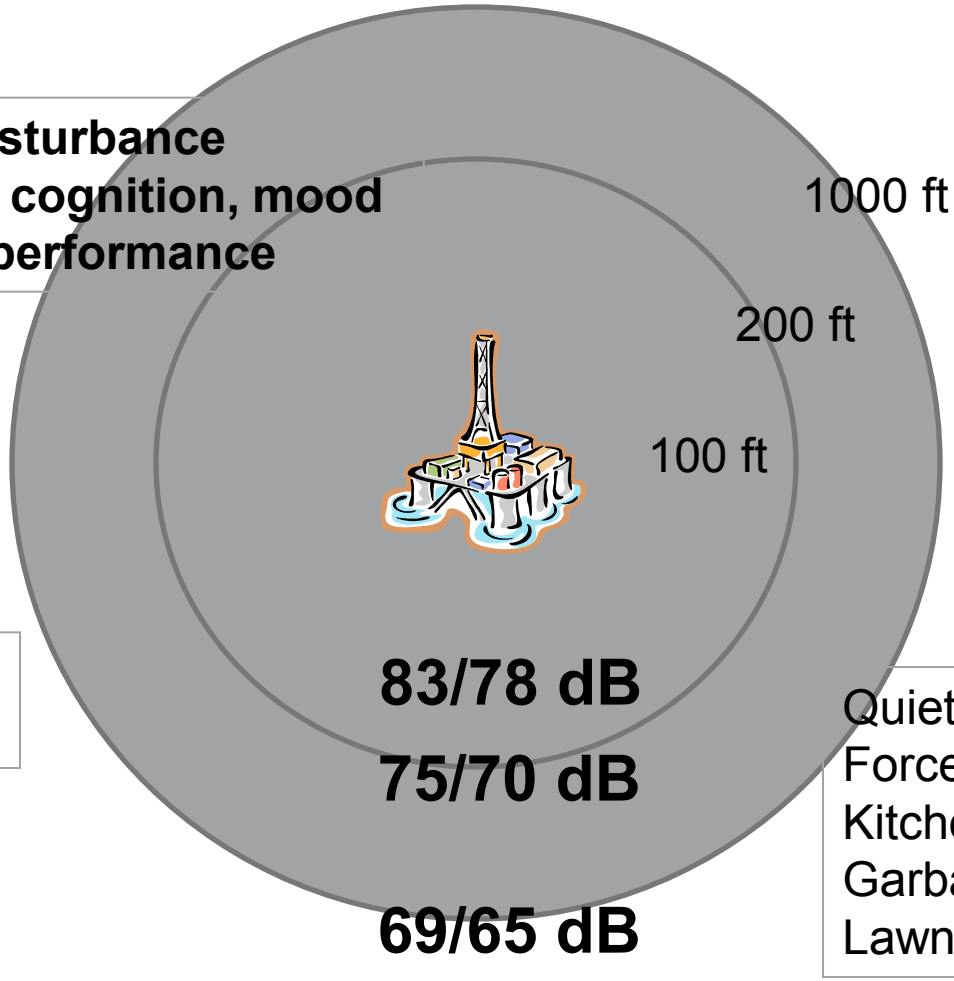
- NY State/GAO estimates: 1,000+ truck trips per well
  - Multiply on multi-well pads
- Dispersed and well pad impacts
  - Living along haul routes
  - Round the clock operations
- Variety of hazards
  - Diesel exhaust
  - Dust
  - Noise, vibration
    - *Engine braking*
    - *Grinding gears*
  - Safety risks
    - *School routes*

Occupational Fatalities: Wyoming
(Ryan 2011)

- Wyoming 2001-10 occupational fatality rate per 100,000 ranged from 2-3X the US rate
  - Oil/Gas: from 2001-8 there were 62 fatalities
    - *32 (52%) occurred on a drill rig*
    - *25 (40%) were transportation-related*
    - *5 (8%) related to distribution and off-site repair*
- Overriding theme: "lack of a culture of safety"

Hazards Associated with Noise

30 dB: Sleep disturbance
55 dB: Fatigue, cognition, mood
70 dB: School performance



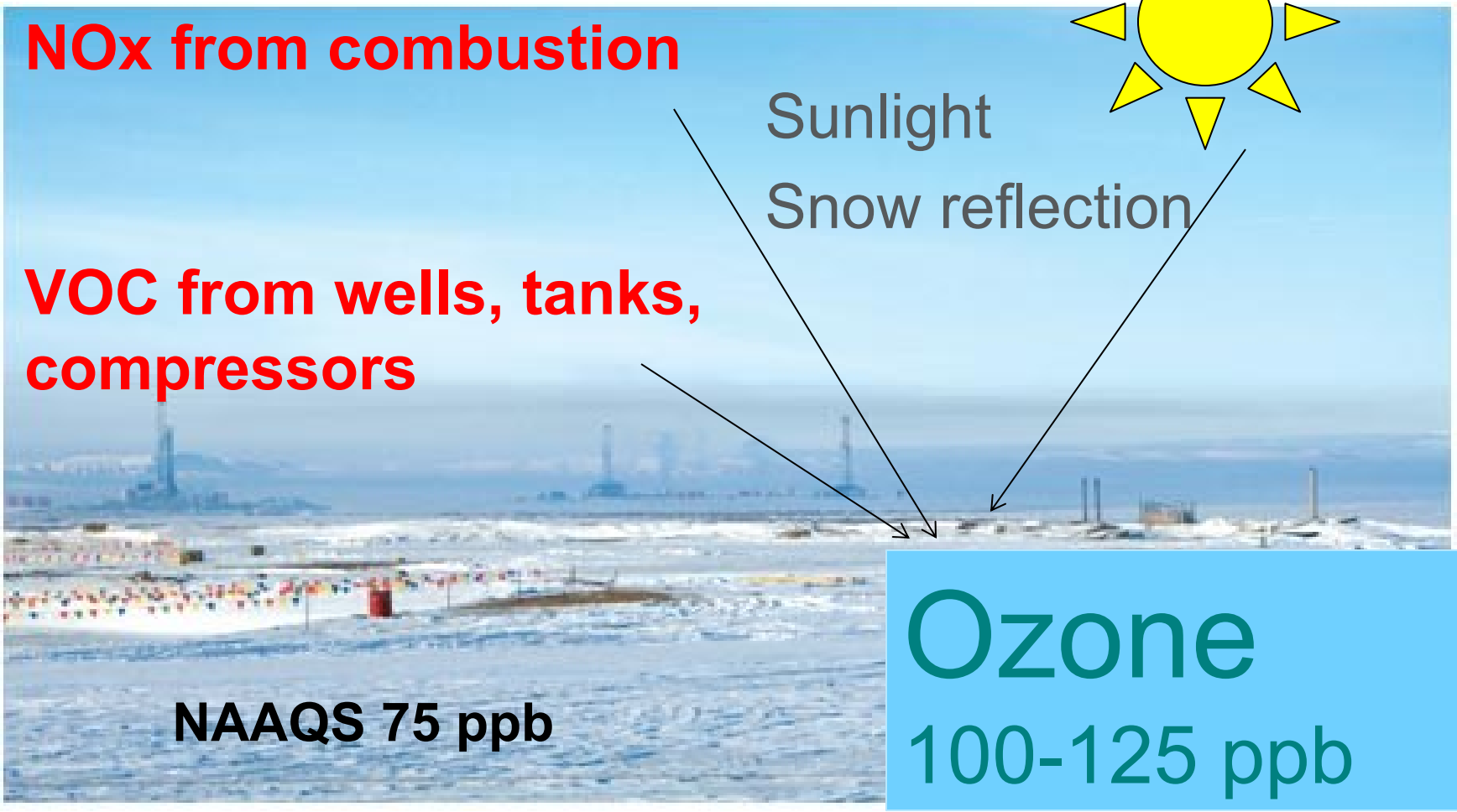
Hypertension
Cardiac disease

Quiet room	28-33 dB
Forced air heat	42-52 dB
Kitchen exhaust fan	69-71 dB
Garbage disposal	76-83 dB
Lawn mower	88-94 dB

Regions and Communities

Regional Wintertime Ozone

Wyoming, Utah



http://deq.state.wy.us/aqd/Ozone%20Main.asp
http://www.denverpost.com/business/ci_20042330

Predicted regional ozone impacts in TX and LA

- **Ozone Impacts of Natural Gas Development in the Haynesville Shale**
  - Increases of 5 ppm from increased precursors 2° to NG

Kembal-Cook, 2010 Enviro Sci Technology

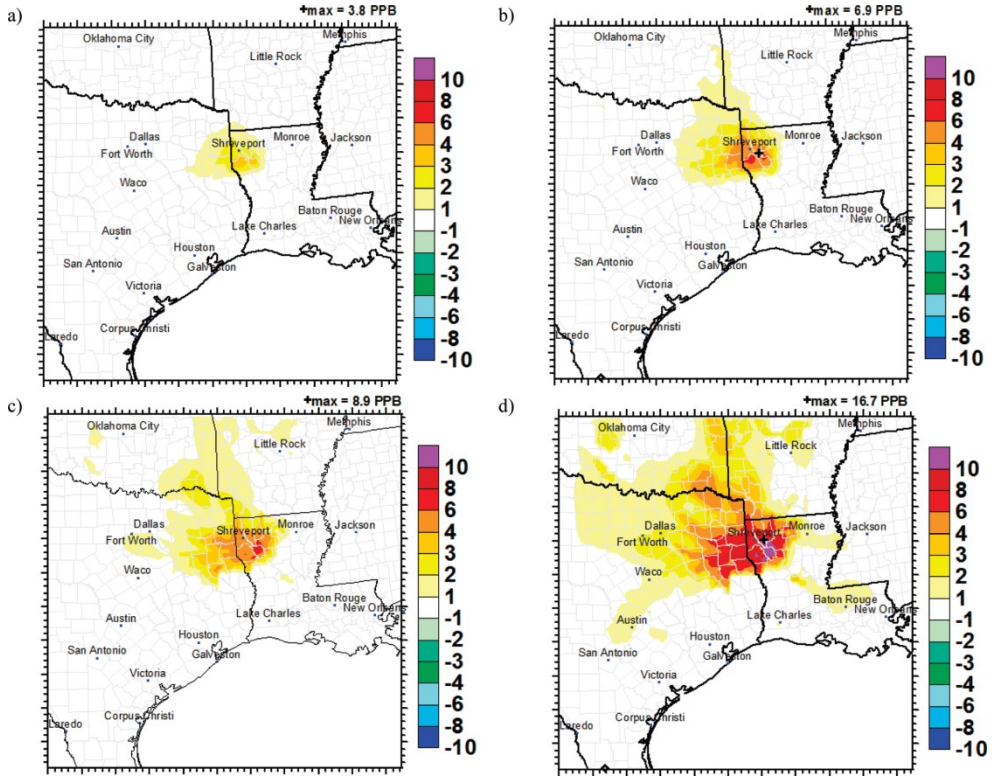
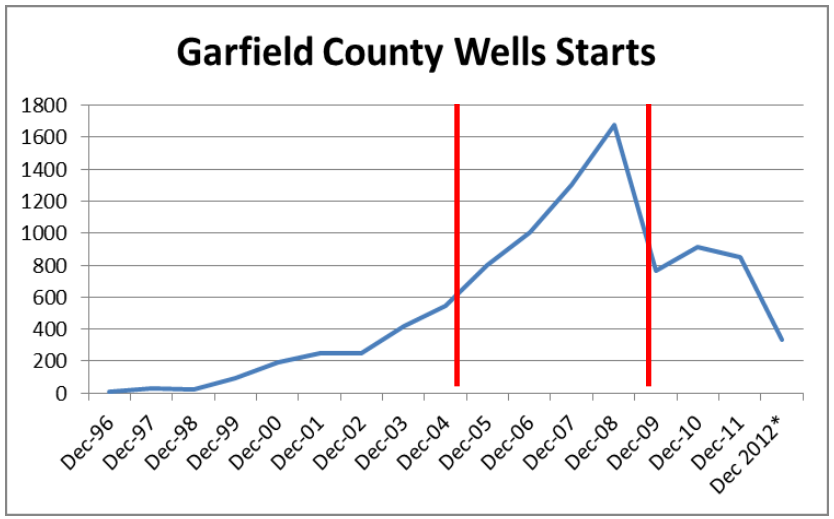


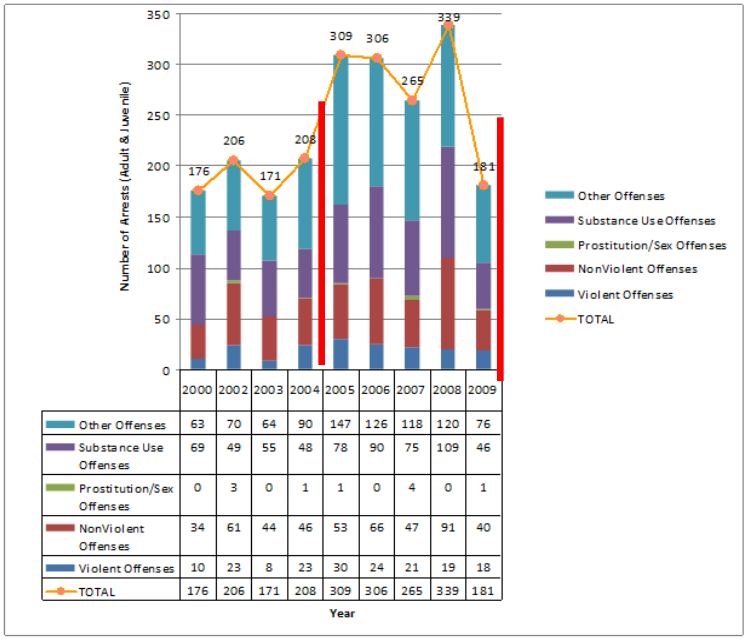
FIGURE 4. Twelve km grid ozone modeling results: a) Episode average difference in daily maximum 8-h ozone (ppb): Haynesville Low Secenario-2012 Baseline and b) Episode average difference in daily maximum 8-h ozone (ppb): Haynesville High Scenario-2012 Baseline and c) Episode maximum difference in daily maximum 8-h ozone (ppb): Haynesville Low Scenario-2012 Baseline and d) Episode maximum difference in daily maximum 8-h ozone (ppb): Haynesville High Scenario-2012 Baseline.

Hazards Associated with Community Changes



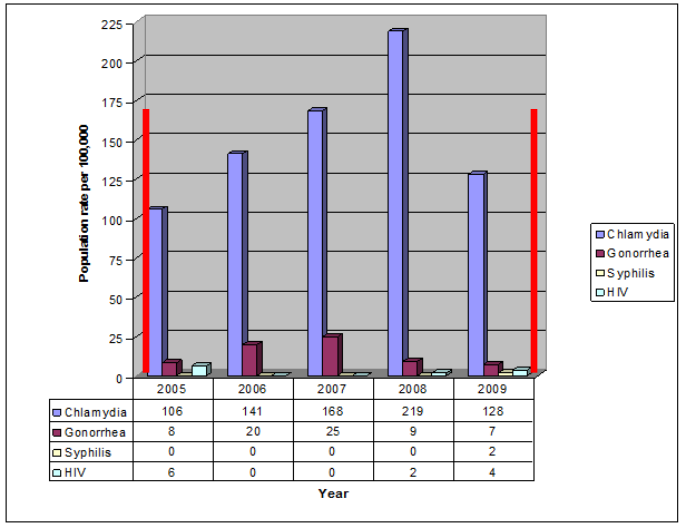
Garfield County population
2000-09: ↑28%
2005-2009: ↑ 14%

Police Arrests



	2000	2002	2003	2004	2005	2006	2007	2008	2009
Other Offenses	63	70	64	90	147	126	118	120	76
Substance Use Offenses	69	49	55	48	78	90	75	109	46
Prostitution/Sex Offenses	0	3	0	1	1	0	4	0	1
NonViolent Offenses	34	61	44	46	53	66	47	91	40
Violent Offenses	10	23	8	23	30	24	21	19	18
TOTAL	176	206	171	208	309	306	265	339	181

Sexually Transmitted Infections



	2005	2006	2007	2008	2009
Chlamydia	106	141	168	219	128
Gonorrhea	8	20	25	9	7
Syphilis	0	0	0	0	2
HIV	6	0	0	2	4

Stress Exposure Public Health: Battlement Mesa HIA Quotes

"I feel angry…impending events weigh on my mind… stress, anger, anxiety, feelings of helplessness and (worry about) possible health problems…"

"There has been be personal distress… including depression, anxiety and insomnia…we don't know what will happen or when…"

Reasons given by those not in favor of UGD

(Goldstein et al, Env Hlth Persp 120:483-486, 2012)

Washington, PA public meeting with Natural Gas Subcommittee of the Secretary of Energy Advisory Board, June, 2011 (N=59)

Reason	Percent (%)
Environmental Concerns	**76.3**
Negative Effects on Water	**66.1**
Negative Effects on Air	**42.4**
Chemicals in Water	**30.5**
General Health Concerns	**61.0**
Health Problem in Family member attributed to drilling	**20.3**
Personal legal rights have been infringed upon by companies	**11.9**
Concerns about safety of drilling operations	**33.9**
Concerns about lack of regulation of industry	**42.4**
Bias, conflict of interest, or lack of expertise in desired subject area by members of the committee	**18.6**
Export of domestic natural gas resources	**10.2**
Depreciation in property values	**3.4**

Stressors Volunteered by Subjects Who Believe Their Health has been Affected by Marcellus Shale Activities (n=33) (Ferrar et al 2013)

Top 6 Stressors	% of group
Denied or provided false information	79%
Corruption	61%
Concerns/complaints ignored	58%
Being taken advantage of	52%
Financial damages	45%
Noise pollution	45%

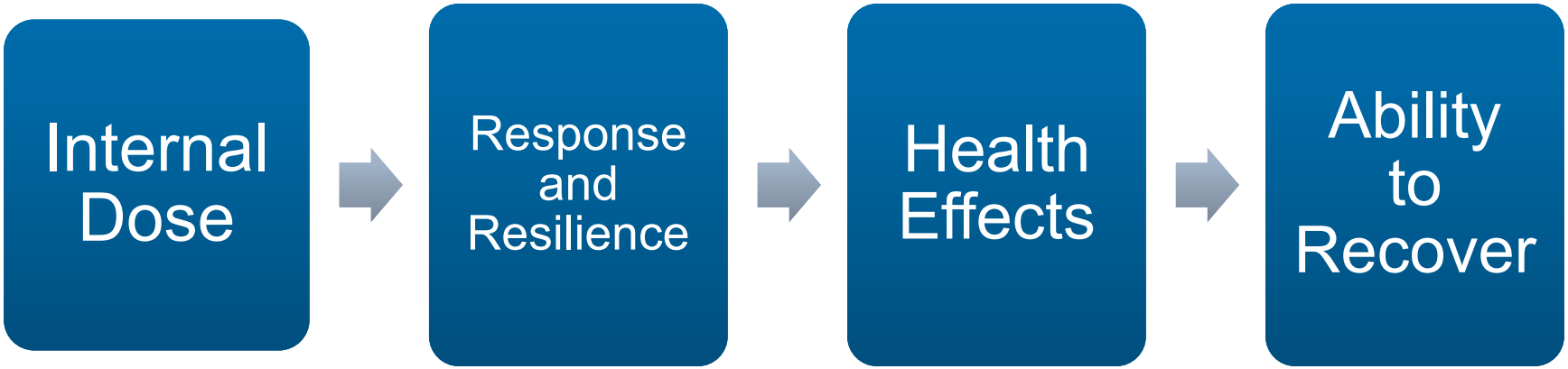
Stress and the Environment

(Morello-Frosche and Shenessa 2006; Clougherty and Kubzansky 2009)

- Allostatic load
  - Chemical and Non-Chemical Stressors
  - Stress affects immune function, susceptibility
- Community Level Effects
- Individual Level Effects

Community Level Effects

Individual Level Effects



Public Health Research

Needed Public Health Research

- Environmental concentrations
- Exposures
- Health outcomes tracking
- Community impacts
  - Noise, Traffic, etc.
  - Psycho-Social effects

Colorado Well Setback Rules

- Old Rules: 150/350 ft for rural/urban areas
- New Rules (Feb 2013): 500 ft, with mitigations for noise, traffic etc. up to 1000 ft
- Industry: too far
- Some Front Range Communities: not far enough
  - Bans of HVHF in Longmont, Erie, Fort Collins, Boulder
  - Litigation!

Photo credit: Denver Post, Hyoung Chang

What Do We Need to Know?

- Characterize the range of activities and environmental factors needed to develop smart setback policies
  - Descriptions of the variability in emissions, air levels, & human exposures
- Develop toxicity factors
- Understand the effects of **chemical mixtures** and noise/traffic/accidents on health & quality of life
- Incorporate stress in the individual and community level assessments

Final Thoughts

- Systematic **before**, **during**, and **after** data collection continues to be needed on exposure and health
- Chemical mixtures and non chemical stressors likely affect both workers and communities
- Public health prevention strategies should be directed at minimizing exposures during completion activities