Summary of Findings:
Understanding Health Impacts from Hydraulic Fracturing

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Scope of Report

- Stephen J. Foster, PhD
- Report timeframe – June 2104 to November 2014
- Report approved by City Council to support as part of Memorandum 2A
- Goals of Report:
  - Aid City of Fort Collins with future decisions regarding hydraulic fracturing
  - Review the adverse health effects of the major hydraulic fracturing-related chemical
  - To focus on direct impacts of hydraulic fracturing and storage of wastes per the moratorium

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What is Hydraulic Fracturing?

- Hydraulic fracturing – “fracking” is:

“Well stimulation process used to extract deposits of oil, gas and other hydrocarbons through the underground injection of large quantities of water, gels, acids or gasses, sand or other proppants, and chemical additives, many of which are known to be toxic.”

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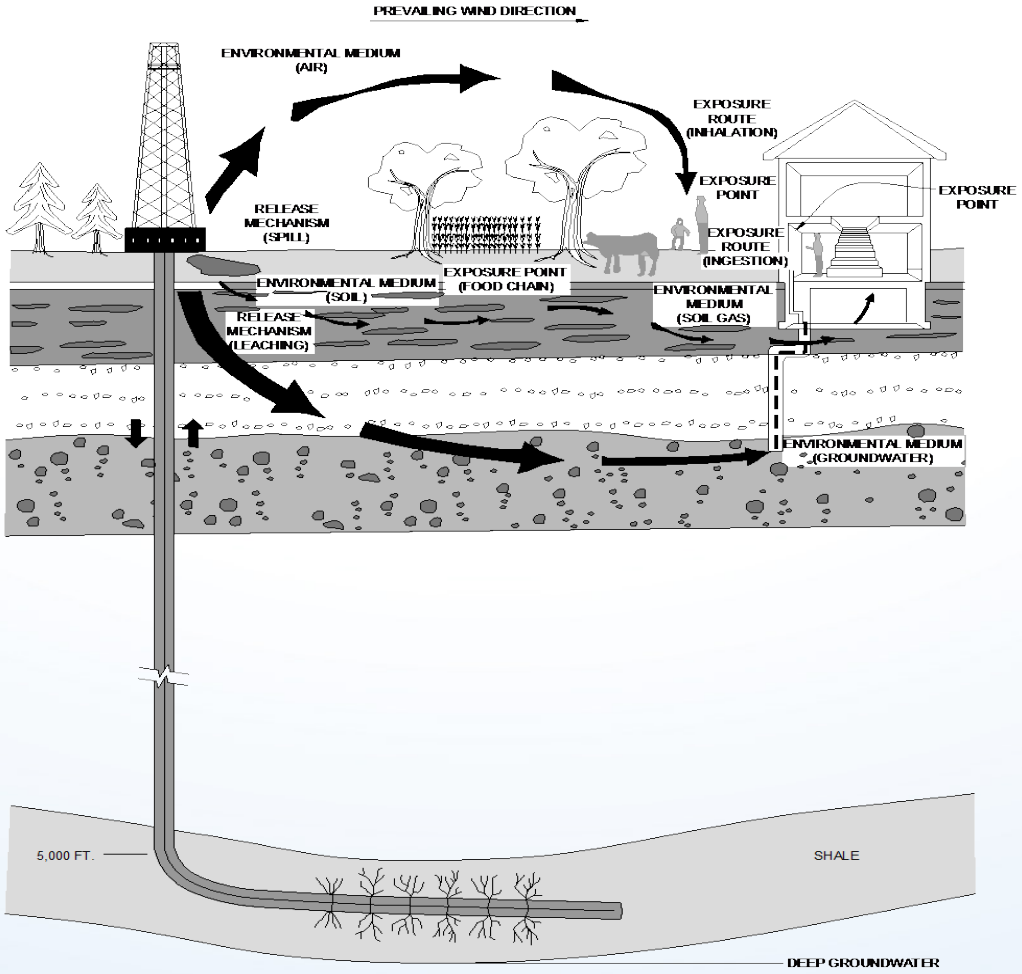
What is Hydraulic Fracturing?



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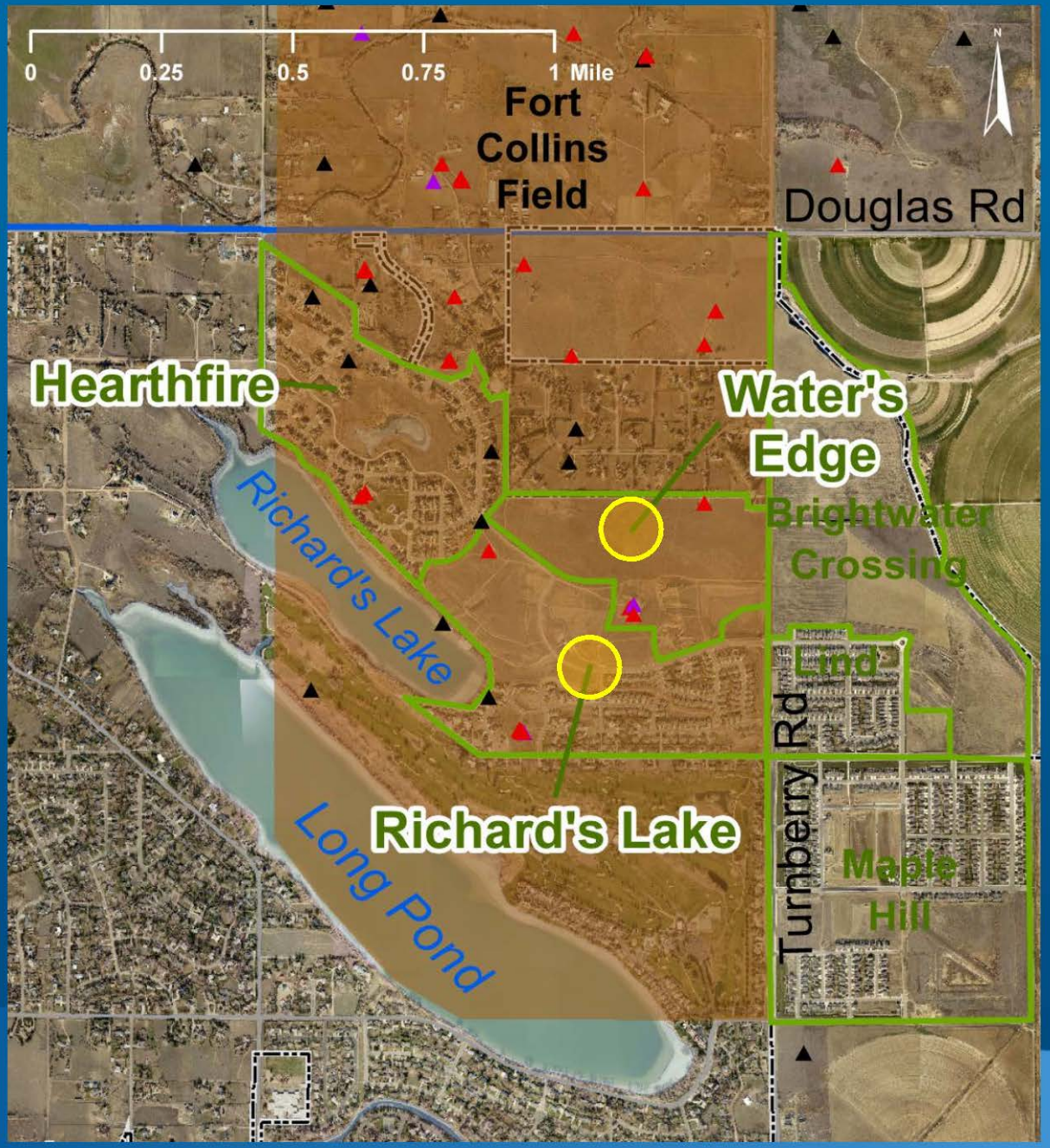
Presentation Overview

- Oil extraction process activities in Fort Collins
- Used Human Health Risk Assessment process as the basis for the report
- Evaluated potential routes of exposure to fracturing-related chemicals
- Discusses the chemicals used and released during Hydraulic fracturing
- Discusses their potential effects on human health
- Discusses current studies

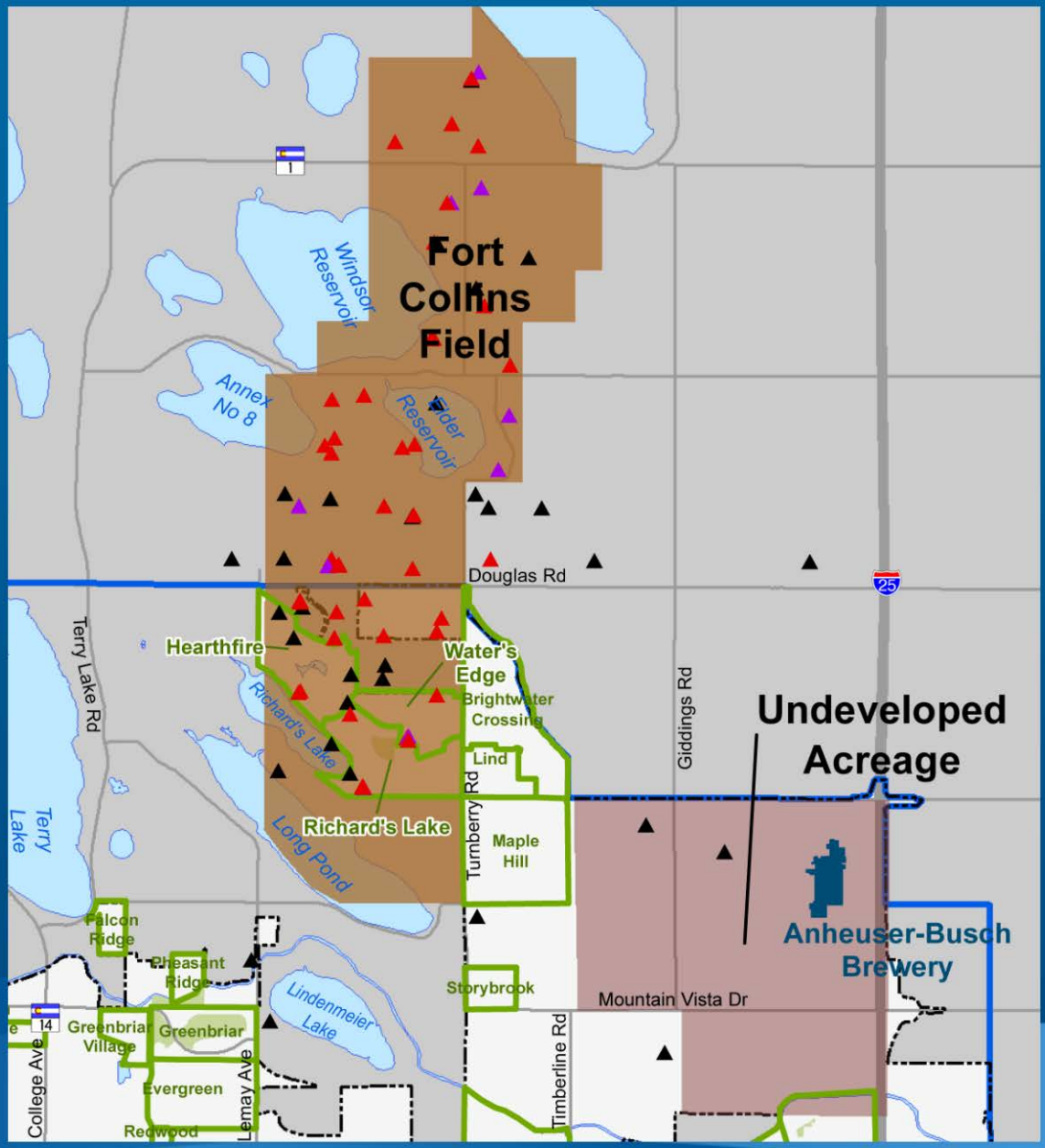
Current Oil and Gas Activity

- Oil extraction only
  - Oil wells established some time ago
  - Community built near the wells
  - Petroleum-related chemicals
  - No hydraulic fracturing currently occurring within City limits

Fort Collins Field Potential Areas for Additional Wells



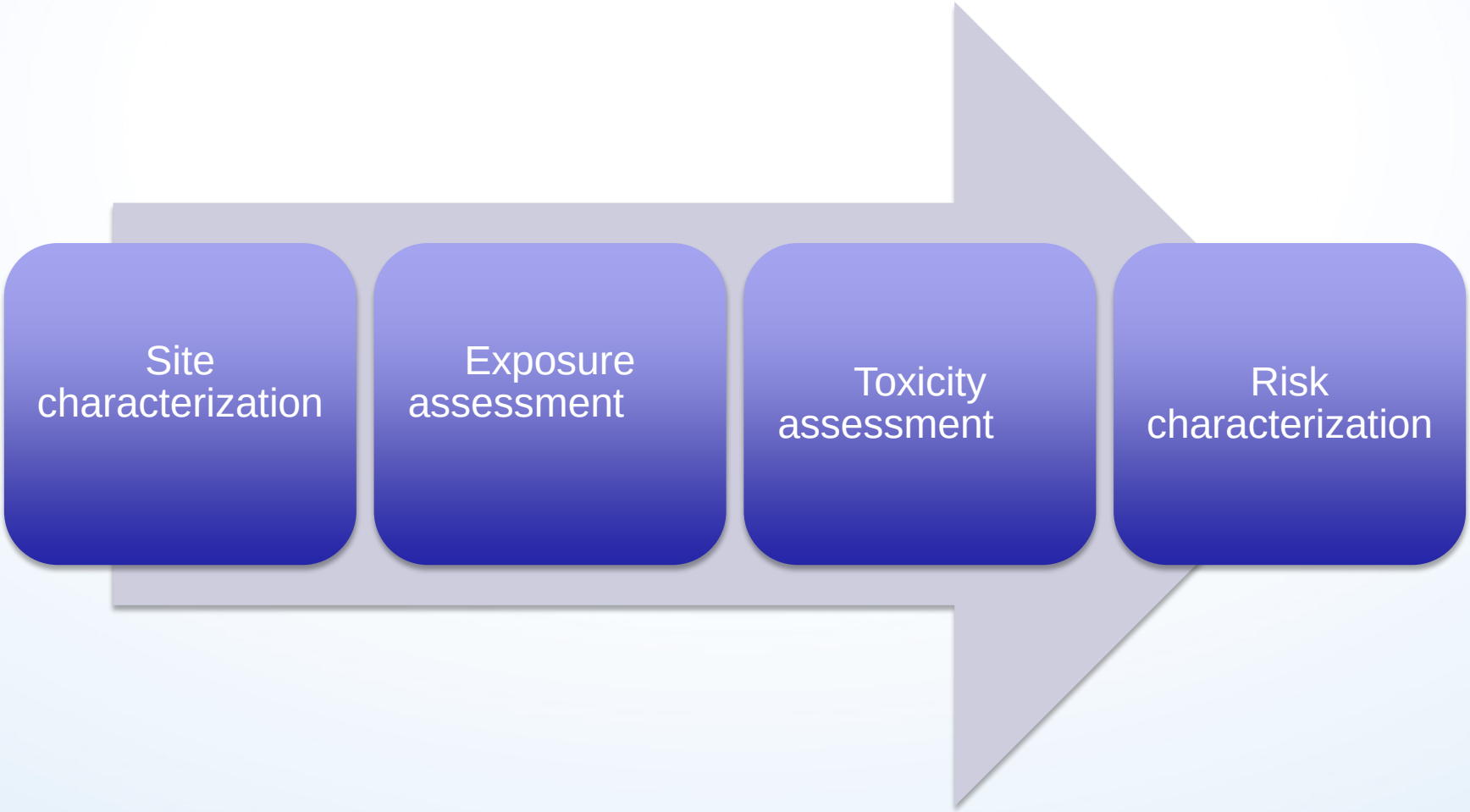
Fort Collins Field & Neighborhoods



Potential Exposure

- How could people be exposed to fracking-related chemicals?
  - Does drinking water comes in contact with fracking-related chemicals?
  - Does soil comes in contact with fracking-related chemicals?
  - Do the chemicals contact surface water (streams, lakes, rivers)?
  - Are fracking-related chemicals in the air we breathe?

Human Health Risk Assessment Process



Drinking Water

- Fracking/oil and gas not affecting Fort Collins' drinking water
- Safe—supplied by the City of Fort Collins
- Sources—West of the City and away from potential oil and gas development

Normal Operating Conditions (No spills or ruptures)

- Soil—not affected
  - Impacts (if any) are on-site
  - No known public exposure
- Surface Water—not affected
  - No surface water on-site (excluded by agreement)
  - Run off is managed by operator

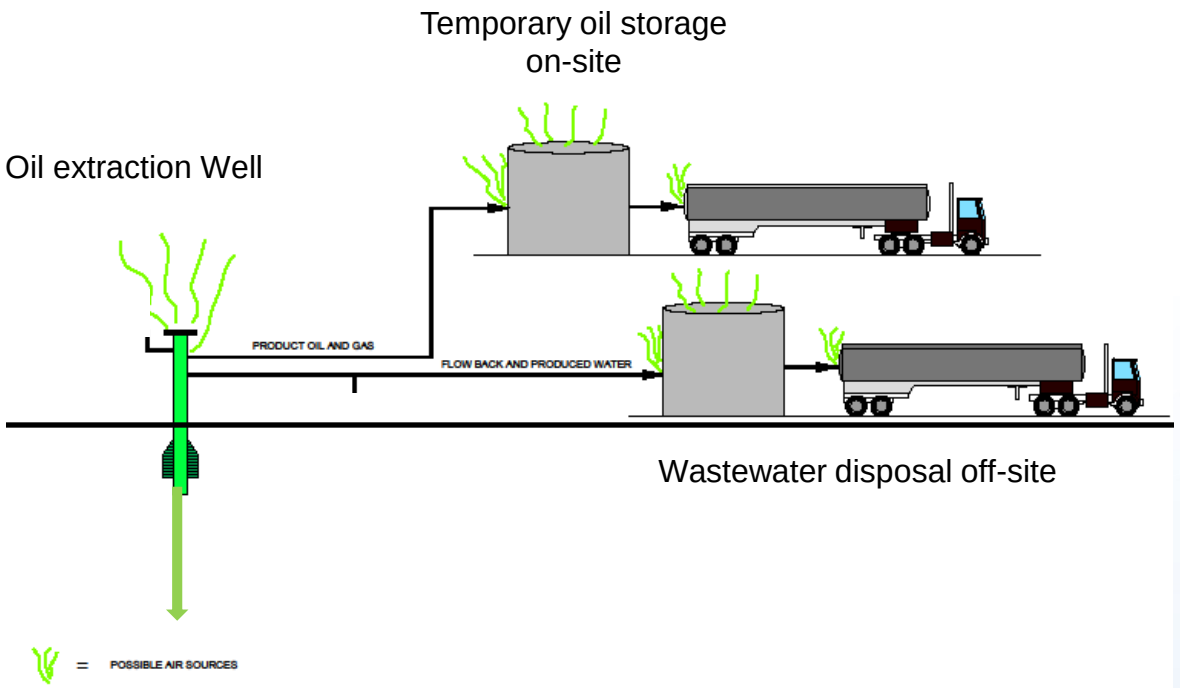
Normal Operating Conditions

- Groundwater-not affected
  - Shallow groundwater 1000s feet above fracking horizon
  - Shallow and deep groundwater do not mix
  - Impact would require leak or rupture in the well casing
  - No public exposure
    - No known human groundwater consumption
    - No known impact to groundwater
    - Private livestock wells are untested, no impacts suspected

Normal Operating Conditions

- Air
  - Primary way people could be exposed is by breathing chemicals released to air
  - During:
    - Well development
    - Oil and gas extraction
    - Routine operations
    - Oil and gas storage

Chemicals in Air



Oil and Gas Chemicals

- Methane
  - Gas, easily evaporates, low toxicity, flammable and potentially explosive
- Petroleum
  - Easily evaporates (benzene, toluene, butadiene)
  - Potentially toxic. Toxicity varies by chemical
- Fracturing chemicals
  - Majority not easily evaporative (not an air concern)

Oil and Gas Chemicals (cont.)

- Wastewater
  - Wastewater storage lagoons from Fracturing process
  - Mixtures of gases and chemicals
  - Toxicity varies by chemical
- Hydrogen sulfide
  - A highly evaporative gas
  - Generated by bacteria, or found at certain gas wells
  - Noxious gas with an unpleasant odor

Chemicals of Primary Health Concern

- Petroleum
  - The same chemicals used by your car
  - Benzene, ethyl benzene, formaldehyde, butadiene (known/suspected to cause cancer in humans)
  - Toluene, xylene, other hydrocarbons (known to cause other health effects)
- Hydrogen sulfide
  - Not known to cause cancer
  - Health effects at low levels (well above levels where it can be smelled)

Benzene Health Concerns

- Benzene
  - Toxicology states: "The dose makes the poison"
  - Health risk = amount x duration of exposure x toxicity
  - People living close to a source of benzene potentially have higher risks. Sources include:
    - Gas stations
    - Oil and gas extraction (wells)
    - Oil and gas storage, and handling facilities

Other Chemical of Concerns

- Petroleum Chemicals
  - Concerns about ethyl benzene are similar to benzene
  - Concerns about toluene and other chemicals are less because they are typically less toxic than benzene
- Hydrogen sulfide (H_2S)
  - Controlling the bacteria that form H_2S will prevent exposure
  - If the gas comes from the well it must be cleaned up at the well head

Benzene Health Concerns

- Benzene
  - Known to cause cancer with high exposure in workers
  - Exposure shows causal relationship with adult leukemia
  - Suspected of causing childhood leukemia
  - EPA assumes no safe levels
  - However: EPA assumes an acceptable level at very low risk of developing cancer

Fort Collins Air Monitoring Project

- Short-term air monitoring project:
  - Conducted for 90 days Nov. 2013 – Feb. 2014
  - Establish existing conditions
  - Determine if concentrations of air pollutants are of concern for further study
  - Measured hydrogen sulfide and volatile organic compounds
  - Results discussed in next presentation

Overall Findings

- Direct contact with fracking chemicals is unlikely
- Breathing chemicals is the most likely way a person could be exposed
- Drinking water not affected and unlikely to be affected
- Possibility of surface water contamination is low
- Air data are limited
- Current data indicate residential exposure is low from oil wells in Fort Collins

Current Limited Data Sets

- Air
  - Air data vary over time
  - Monitoring requires more frequent sampling
  - Monitoring requires multiple locations
  - Monitoring requires multiple chemicals
- Ozone
  - Oil and gas emissions increase ozone
  - More rigorous research would be needed to quantify the relationship between oil and gas development and Ft. Collins air quality

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Studies Underway

- Front Range Air Pollution and Photochemistry Experiment
  - A joint study with NCAR, CDPHE, CU-Boulder, NOAA, CSU and other agencies
  - Study 2014, data published 2015 and 2016
- CSU—North Front Range Air Emissions and Dispersion
  - CDPHE funded study, mobile air quality laboratory study
  - Expected completion 2016
- University of Colorado - National Science Foundation (NSF)—Routes to Sustainability for Natural Gas Development
  - CU Boulder Coordinates on-going studies
  - Expected completion 2018

Studies Underway

- Environmental Defense Fund (EDF)—Sixteen methane studies (6 in Colorado)
  - Will use data up stream and down stream of wells
  - Expected completion 2015
- EPA, National Drinking Water Study
  - Studies the potential impact of hydraulic fracturing on drinking water
  - Expected completion 2014 to 2015, publications 2015
- Others

Current Limited Data Sets

- Groundwater and Surface Water
  - No background data available
  - Monitoring requires up- and down-gradient sampling, on an annual basis
  - Monitoring can use limited “marker” analyses
  - Monitoring could be limited to location near oil and gas activity

Current Limited Information

- Naturally Occurring Radioactive Materials (NORMS)
- Limited/No data available on NORMS on Colorado
  - Data needed on NORMS in wastewater, sludges, equipment and other residuals
  - Requires collaborative study

Information Gaps

- Earthquakes
  - Limited/no data on the relationship between Fracturing/deep injection and quakes in this area
  - Although other studies have shown relationships between wastewater injection and low/moderate earthquake activity

What we do with the studies?

Conclusions

- Currently, within Fort Collins City Limits
  - No potential impacts to groundwater, soil or surface water
  - Impact to air most likely route of exposure
  - Current air data indicate benzene levels are consistent with background
  - Development of land use regulations and decisions
  - Identify fracking best management practices including operator agreements
- Future work will depend on the law suit and other factors

Fort Collins Specific Study

If a Human Health Risk Assessment were required the level of effort could be:

- Baseline/background air quality
- Air quality in the vicinity of old and new wells
- Study of naturally occurring radioactive materials
- HHRA when suitable environmental and health data are available
- Toxicological studies to evaluate human health impacts from hydraulic fracturing (benzene effect on the children)
- Estimated Cost: Depends on time, locations, toxicology, etc
  - $1.1 million to $5.6 million to conduct

QUESTIONS