MARCELLUS SHALE ENERGY AND ENVIRONMENT LABORATORY (MSEEL)

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Project Objectives

MARCELLUS SHALE ENERGY AND ENVIRONMENT LABORATORY

MSEEL

The objective of the Marcellus Shale Energy and Environment Laboratory (MSEEL) is to provide a long-term collaborative field site to develop and validate new knowledge and technology to improve recovery efficiency and minimize environmental implications of unconventional resource development

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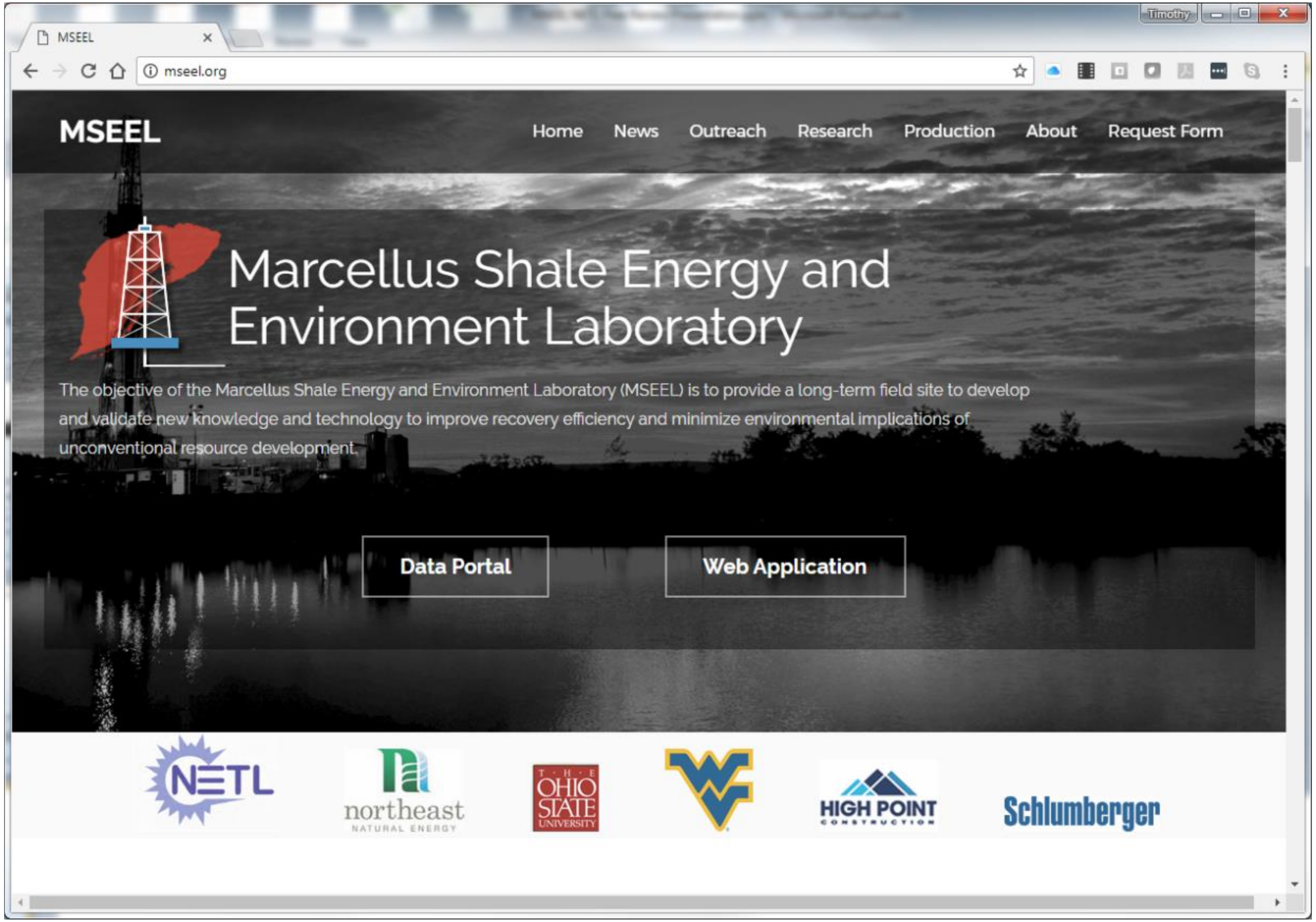
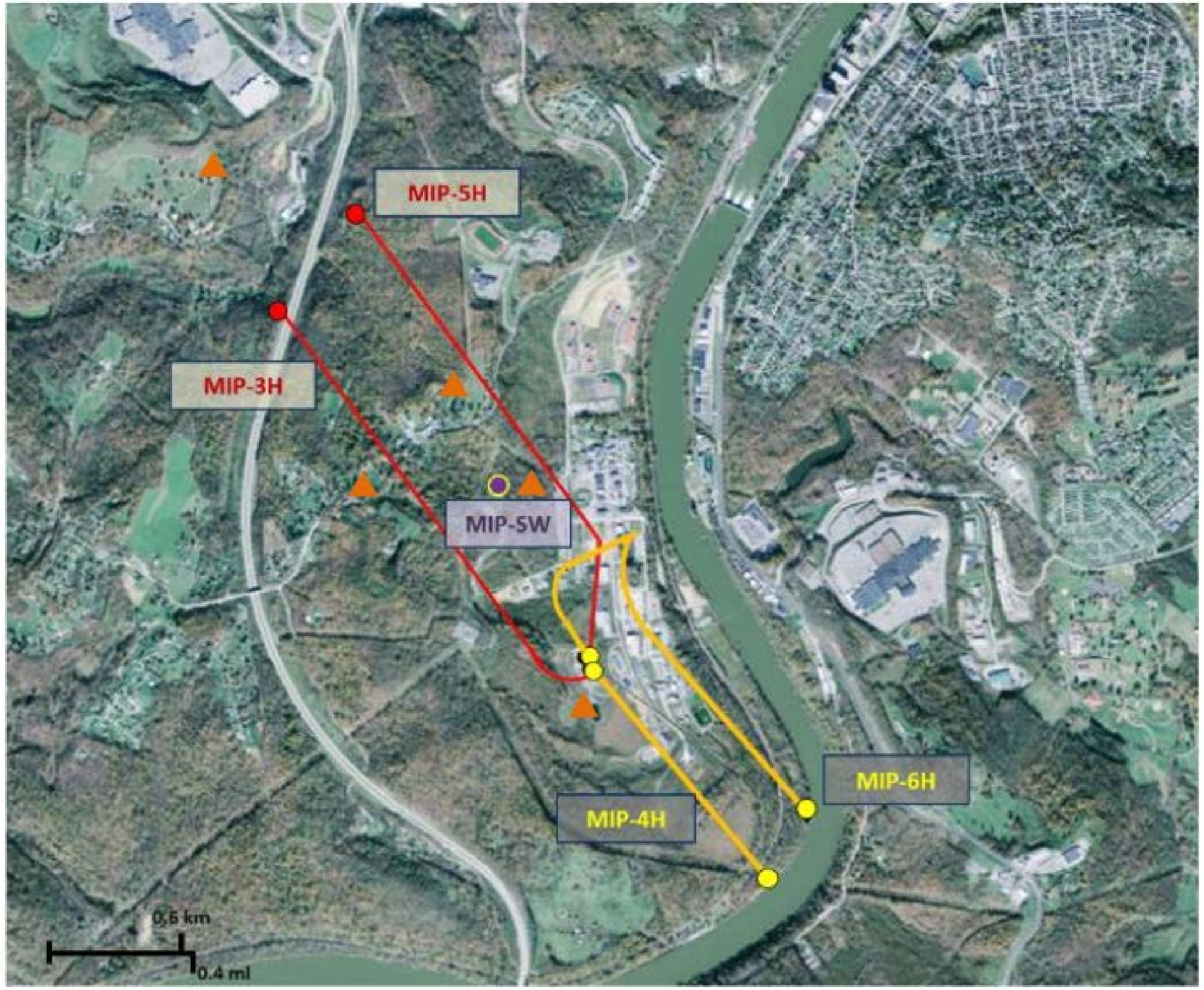
Marcellus Shale
Energy & Environment
Laboratory
Northeast Natural Energy

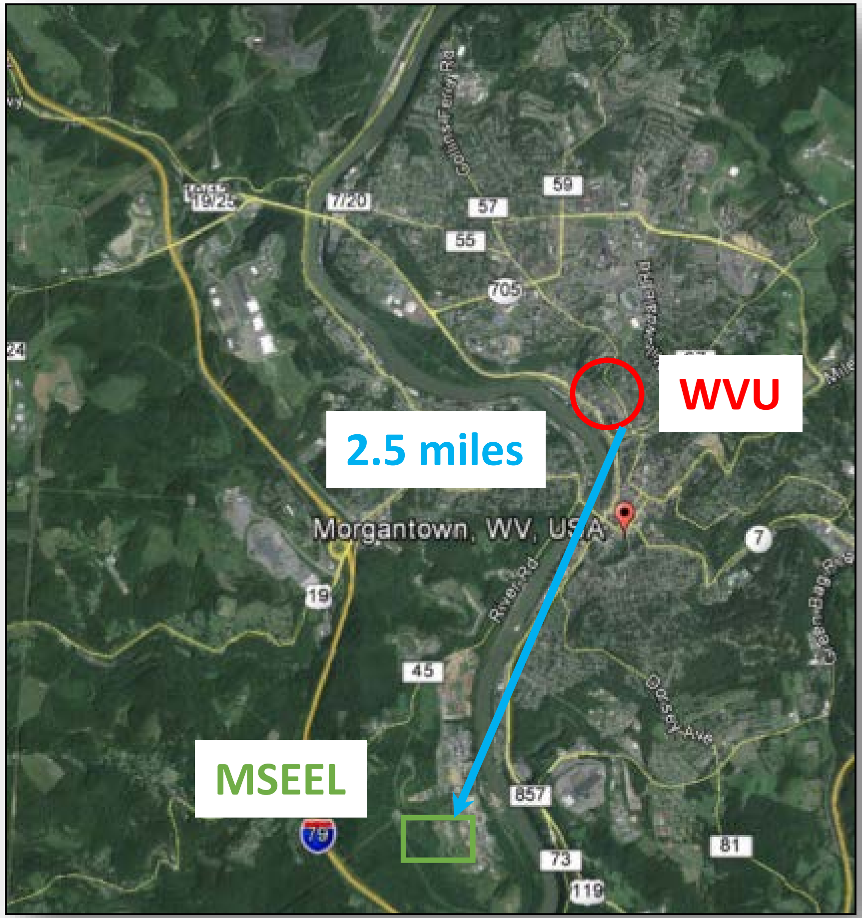
MSEEL.ORG



Creating Interactivity on MSEEL.ORG

MSEEL Site





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MSEEL Publications & Presentations
Well Over 70

- American Association of Petroleum Geologists
- Society Of Petroleum Engineers
- Society of Exploration Geophysicists
- Geological Society of America
- American Society of Civil Engineers
- American Chemical Society
- American Petroleum Institute
- US Department of State
- US Energy Information Agency
- US Gas Power Conference
- Marcellus Shale Coalition
- Gas Technology Institute
- North American Coalbed Methane Forum

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Core Distribution - Institutions

- Oklahoma State Univ.
- Univ. Texas at Austin
- Stanford Univ.
- Cornell Univ.
- Texas A&M
- University of Virginia
- Colorado School of Mines (currently arranging shipment)
- Ohio State
- West Virginia University
- LBNL
- LANL (2 projects)
- SLAC
- Sandia
- NETL (3 groups)

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Task Objectives - Liquid & Solid Wastes

- Characterize liquid and solid wastes
  - Makeup water
    - Inorganics, organics, radiochemistry
  - Hydraulic fracturing fluid
    - Injected volume
    - Chemistry
      - Inorganics, organics, radiochemistry
  - Produced water
    - Time series changes in produced water generation
    - Time series changes in produced water chemistry
      - Inorganics, organics, radiochemistry
  - Solid wastes
    - Drill cuttings
      - TCLP inorganics and organics
      - Radiochemistry
      - Effect of drilling fluid

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Core Distribution - Research Topics

- Core characterization and pore isolation
  - FIB-SEM
  - Bulk CT
  - Core logging with XRF
- Geochemical analysis of fracturing fluid alteration of shale matrix
  - Small scale synchrotron
  - Core scale fracture flow
- Geochemical leaching studies
- Evolutional diagenesis studies
- Brine/CO_2 contact angle measurements
- Proppant embedment studies

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Progress to Date - Drill Cuttings

- Drill cutting radioactivity levels were within West Virginia DEP standards of 5 pCi/g above background. This was true of both vertical and horizontal (Marcellus) sections.

- Using the green drilling fluid Bio-Base 365, all drill cutting samples, vertical and horizontal, passed the USEPA's method 1311 (Toxicity Characteristics Leaching Procedure or TCLP) for inorganic and organic contaminants. This indicates that under Federal and West Virginia solid waste rules, these solid wastes would not be considered hazardous.

- The absence of hazardous TCLP findings suggest that drilling fluids, not the inherent properties of the Marcellus formation, play the dominant role in determining drill cutting toxicity

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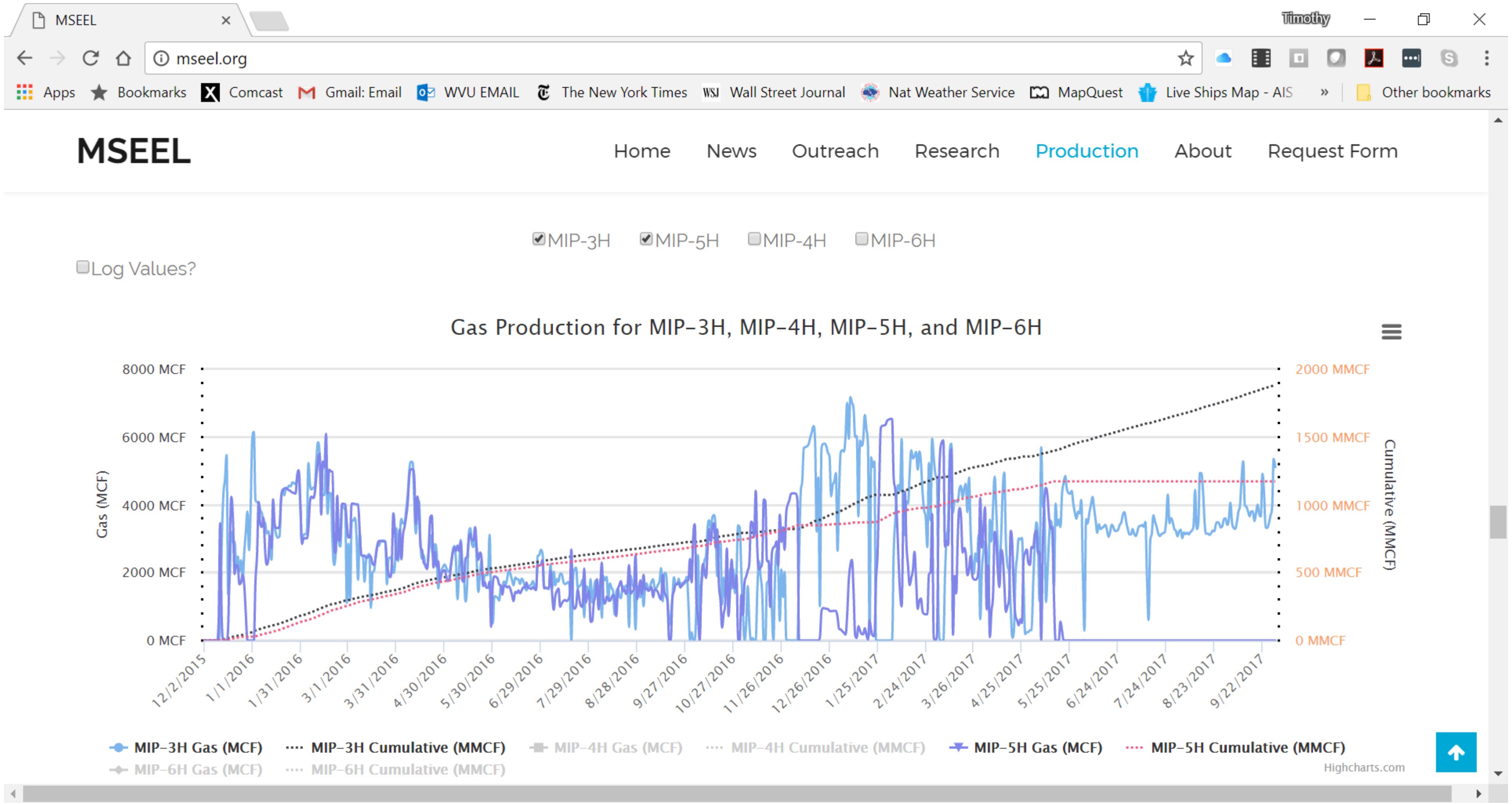
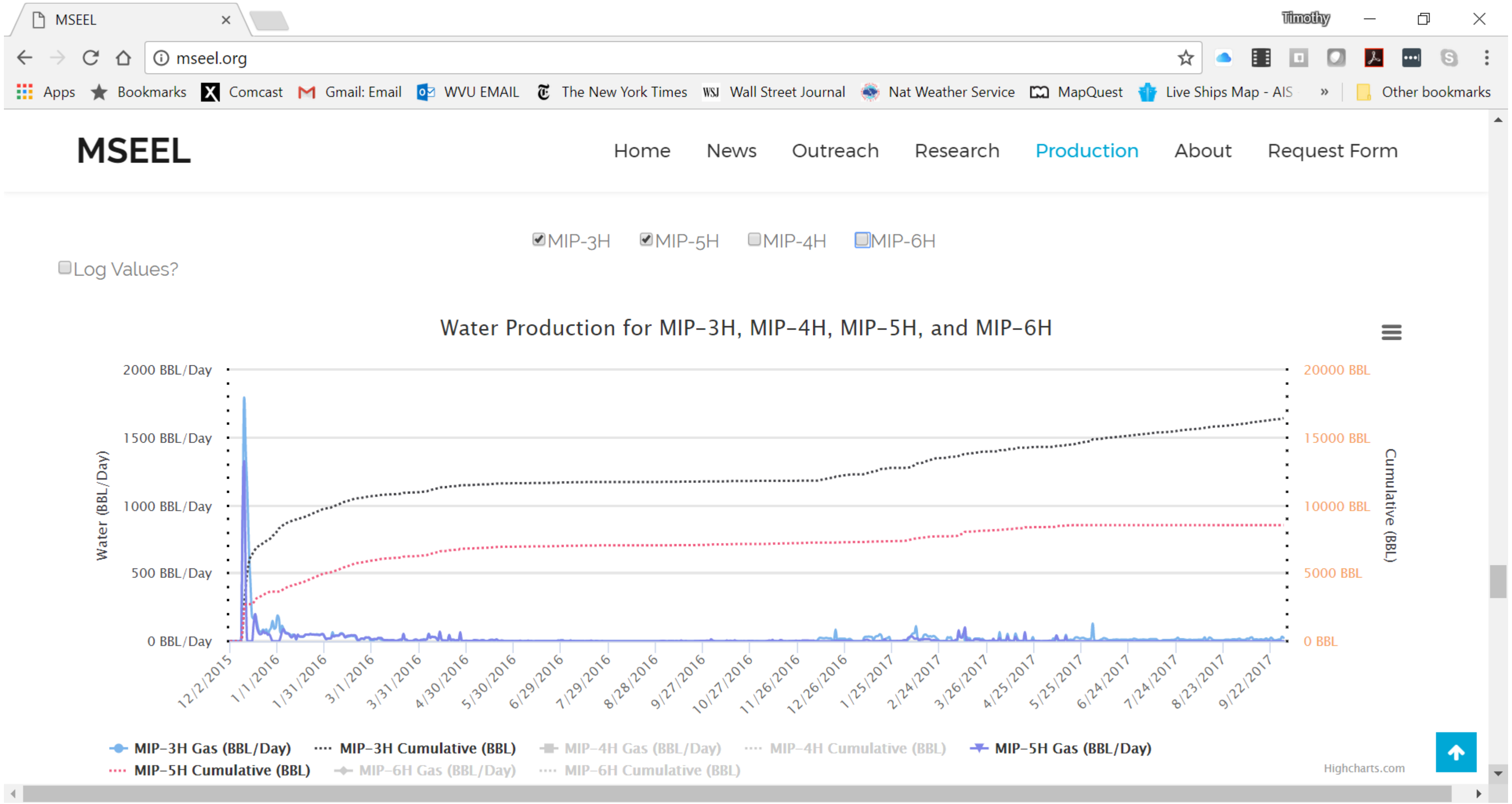
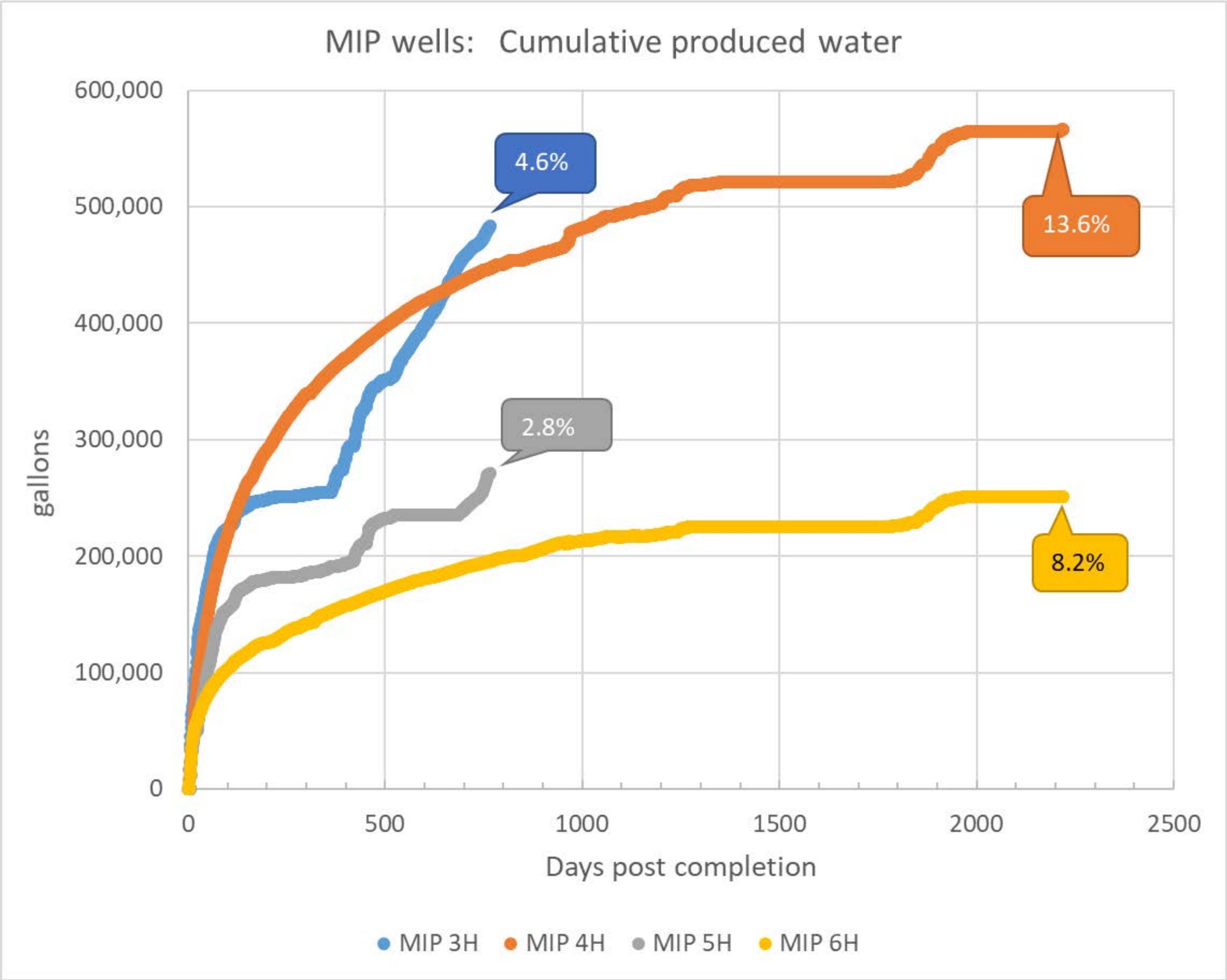
MSEEL – Gas Production



MSEEL Water Production



Cumulative Water Production



Produced water vs. injected HF fluid

	days post	cumulative produced water		HF injected	
	completion	gal	% injected	gal	m^3
MIP 3H	766	482,977	4.6%	10,404,198	39,380
MIP 5H	767	271,985	2.8%	9,687,888	36,669
MIP 4H	2219	540,552	13.0%	4,160,982	15,749
MIP 6H	2219	250,905	8.2%	3,042,396	11,515

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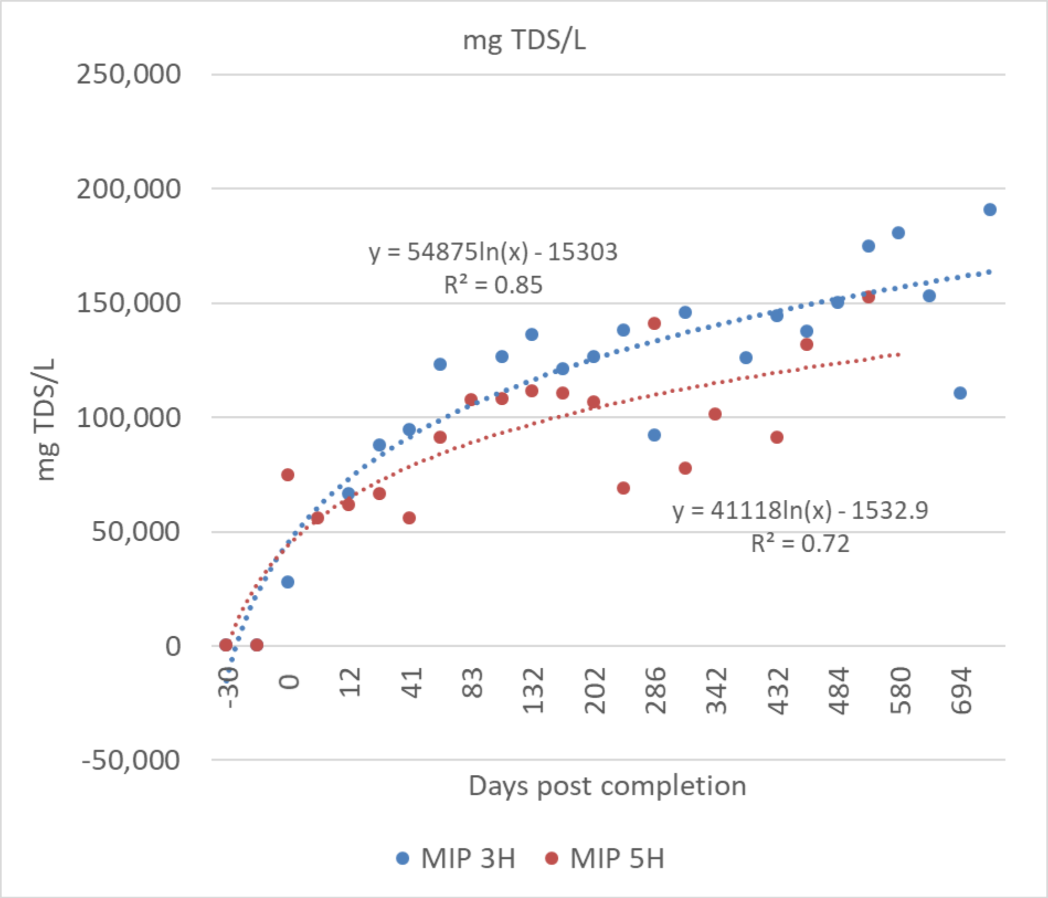
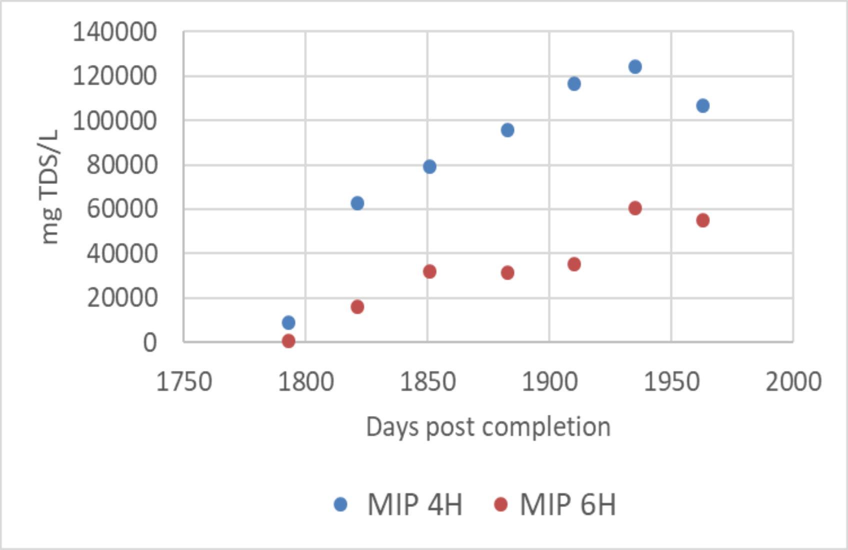
TDS trends

MIP 3,5H: Day -30 to 694



MIP 4,6H: After two year shut-in



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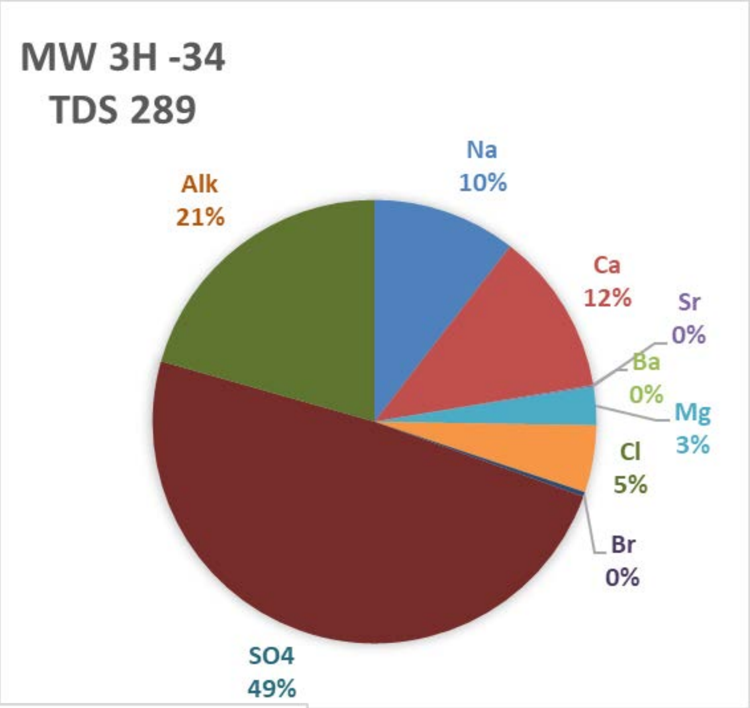
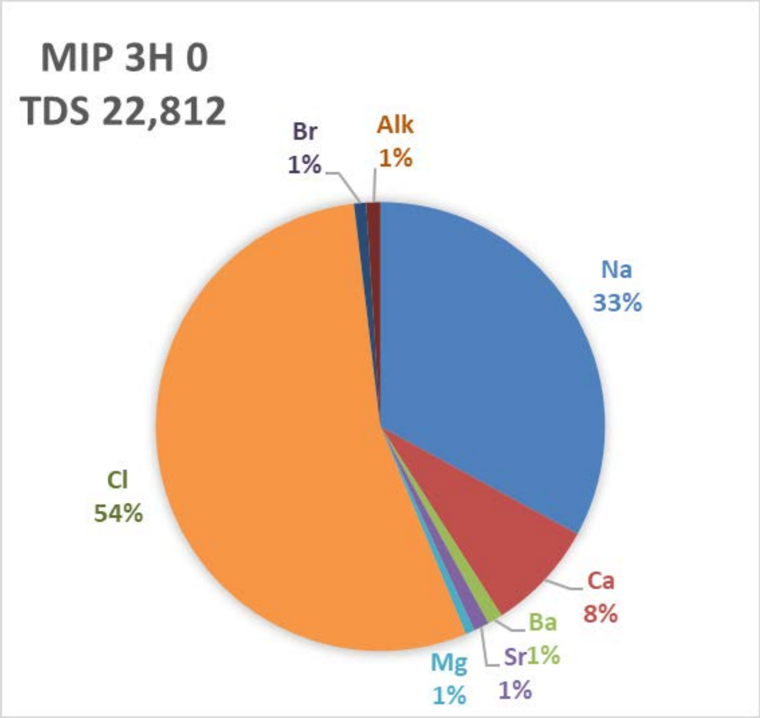
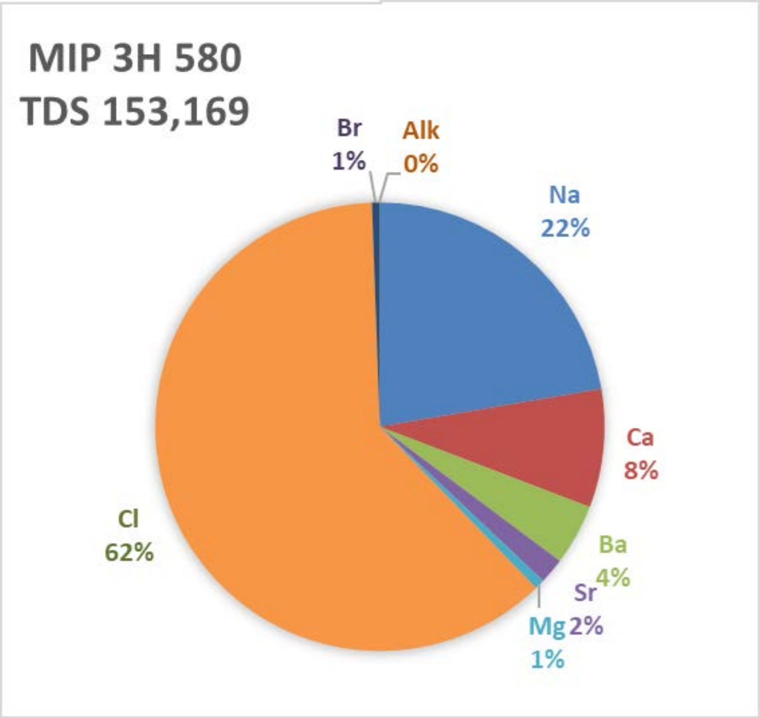
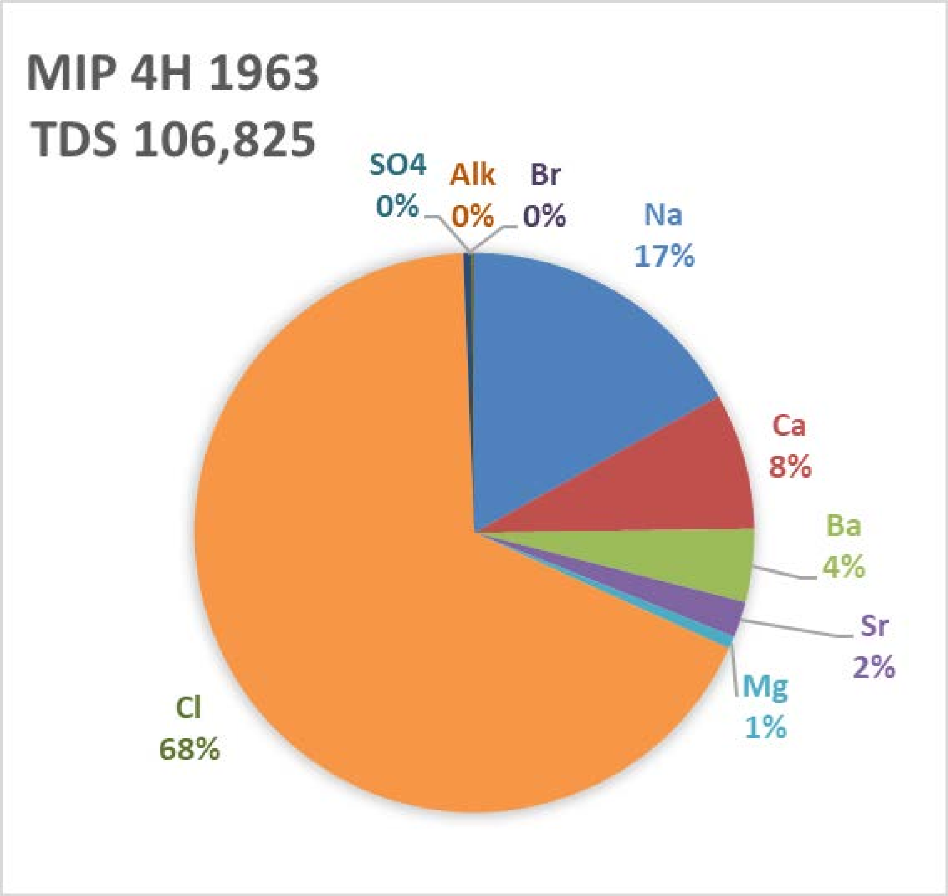
MIP 3H changes in produced water chemistry:

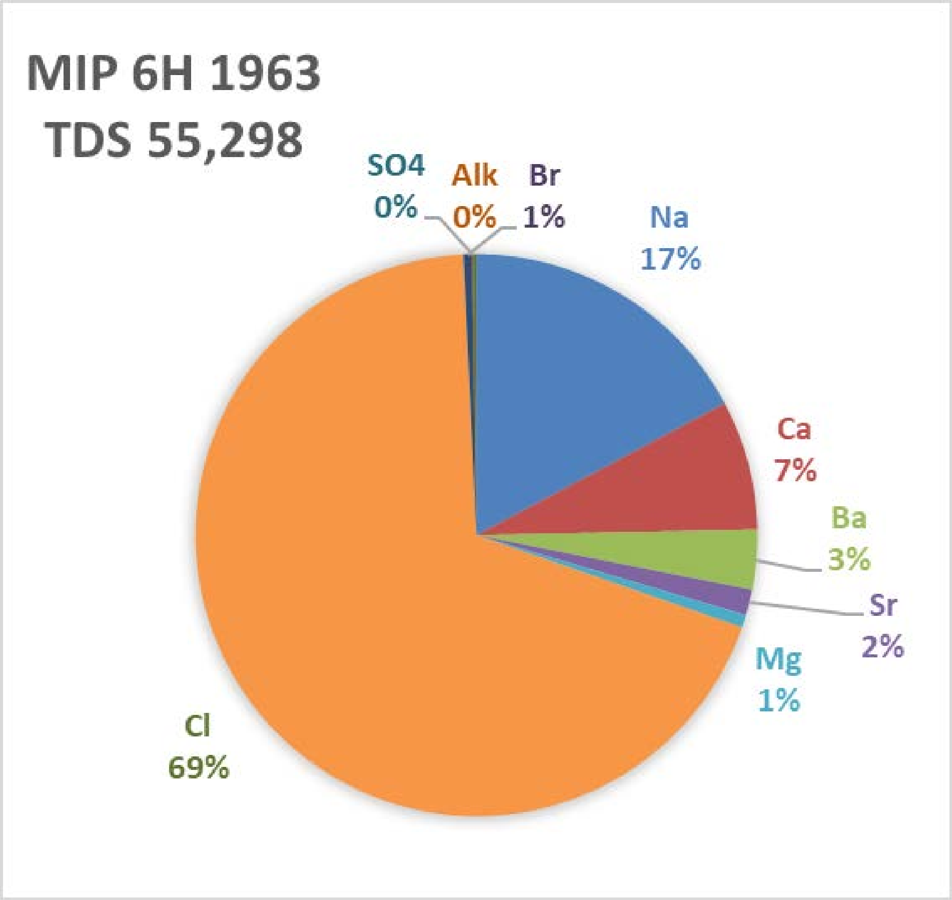






Produced water chemistry @ 1963 days
Declining TDS, same ionic ratios





Progress to Date
Produced Water Quality

- Hydraulic fracturing fluid was nearly identical to makeup (Monongahela River) water. Initial produced water was radically changed in ionic composition and underwent a two order of magnitude increase in total dissolved solids (TDS).
- Produced water is highly saline and total dissolved solids (TDS) rapidly increased to a maximum between 100 and 150 g/L.
- Hower, there was negligible change in ionic composition between the initially produced water and that sampled five years post completion.
- Concentrations of both ^{226}Ra and ^{228}Ra increased rapidly through the produced water cycle to combined maximum concentrations of 20,000 pCi/L in the first year post completion. These radium isotopes are critical regulatory determinants.

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Implications for practice

- Strong evidence that, green drilling fluids can produce non hazardous drill cuttings
- may be neither hazardous (per RCRA) nor radioactive (per WV policy)
- There are standard tests for both
- How to translate into policy?

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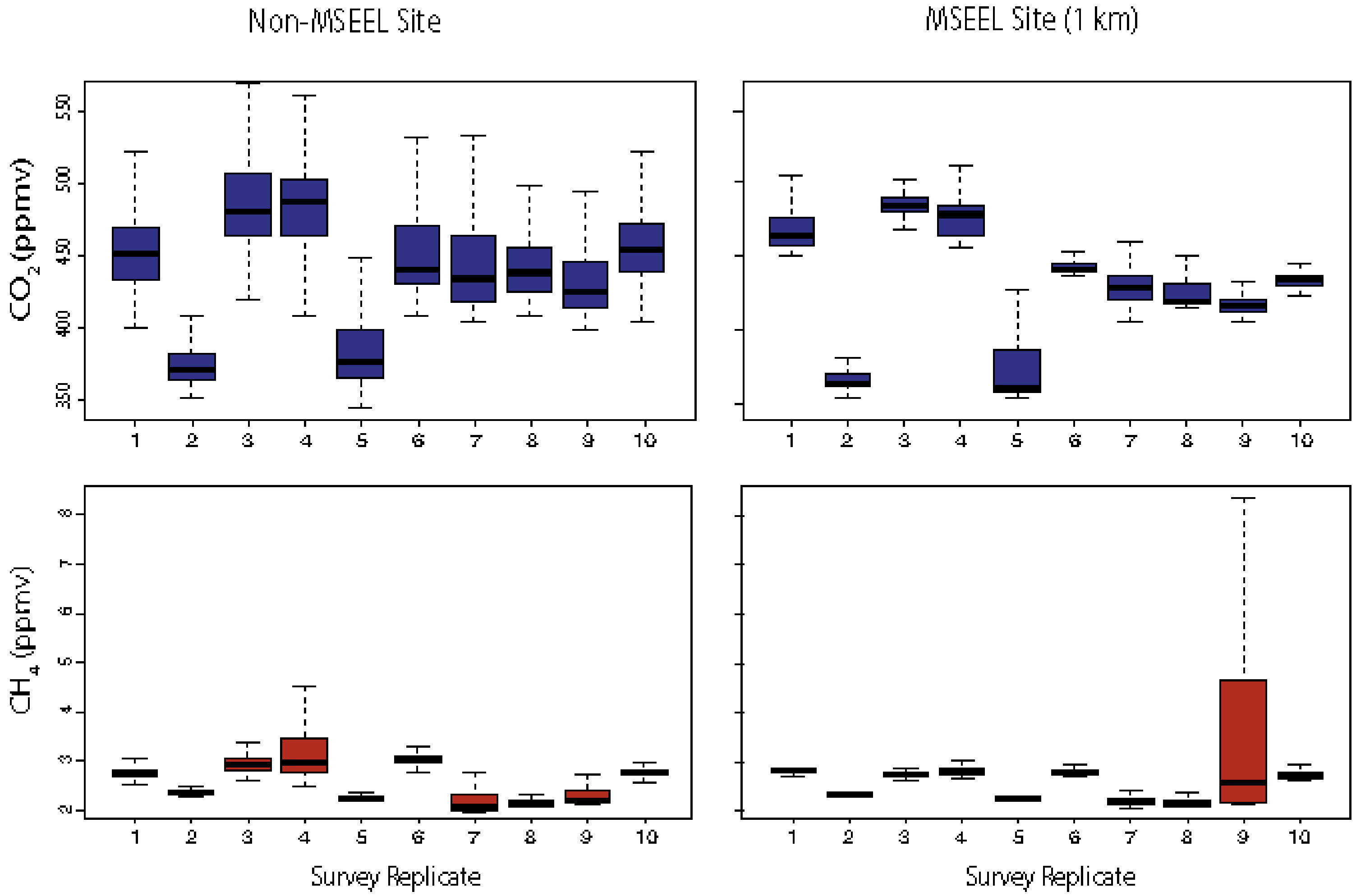
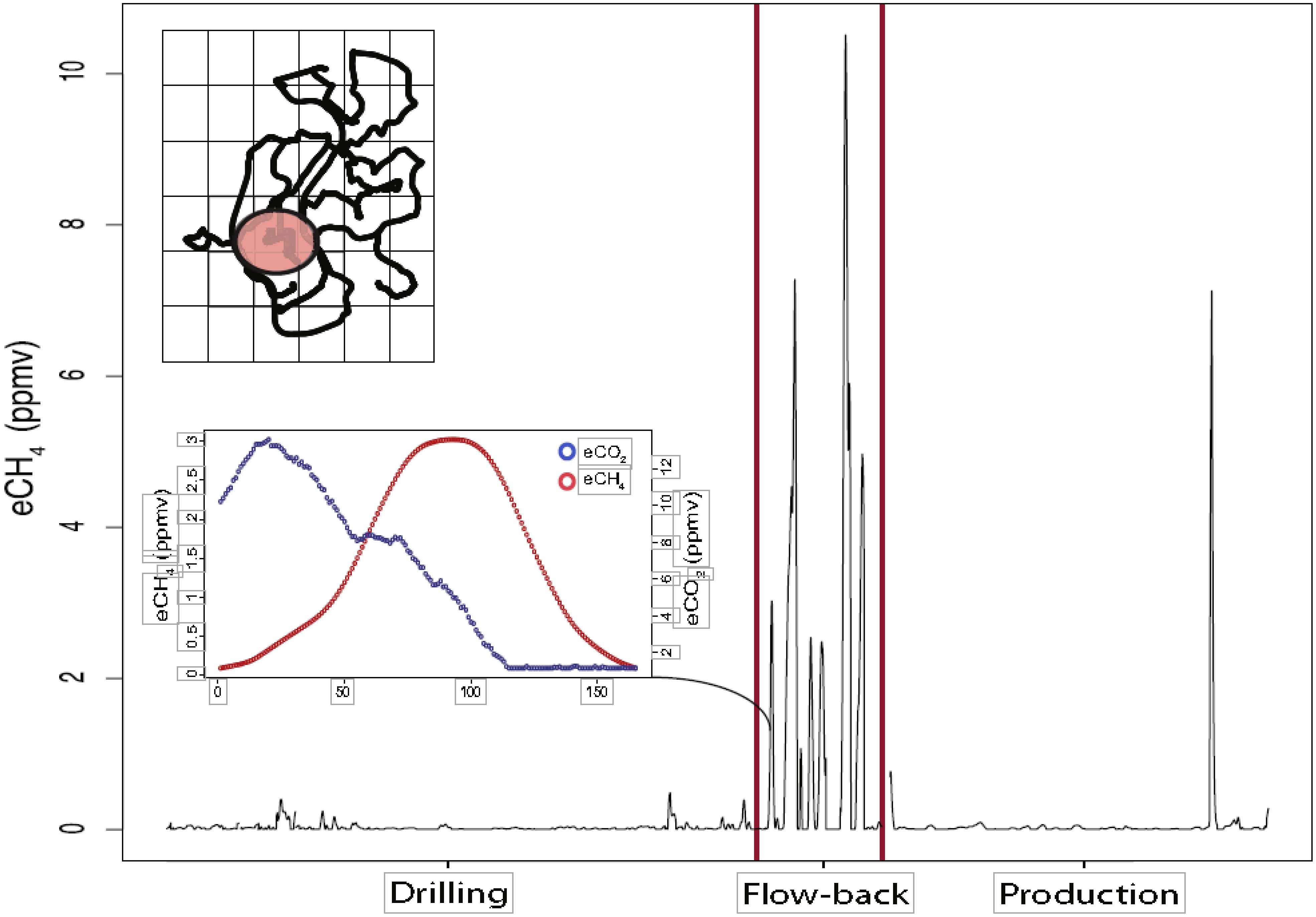
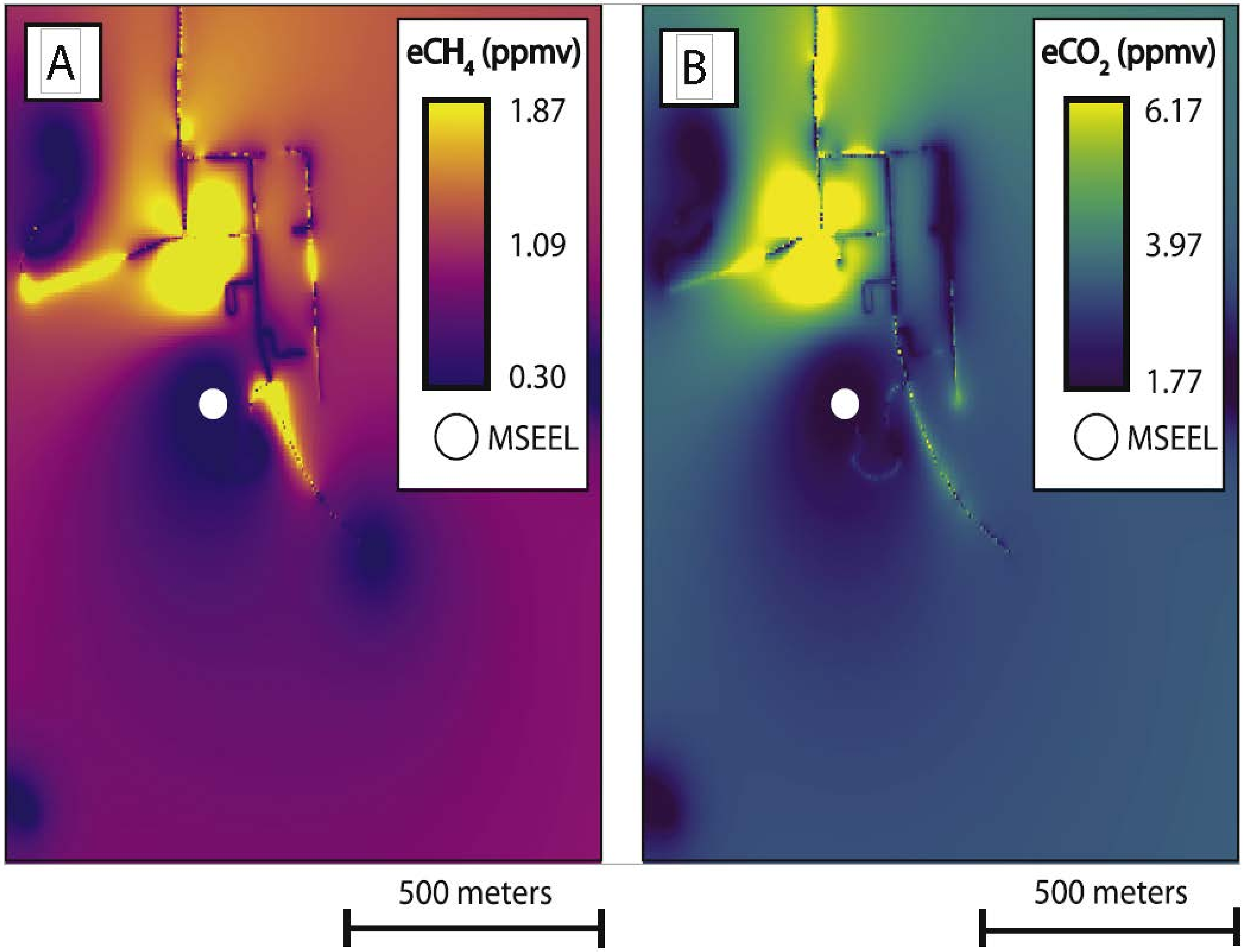


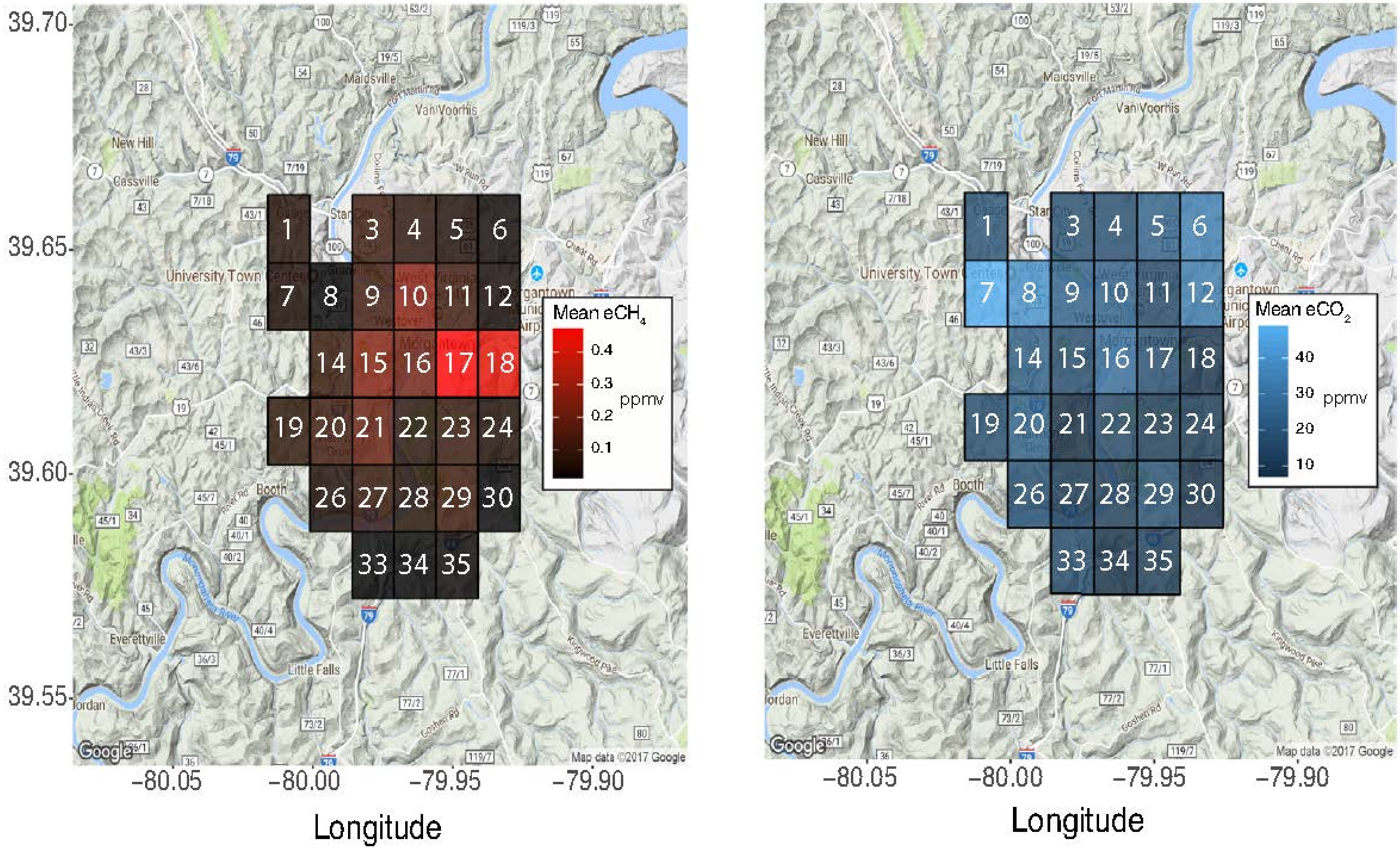
Non-MSEEL Site
MSEEL Site (1 km)
CO2 (ppmv)
350
400
450
500
550
1
2
3
4
5
6
7
8
9
10
CH4 (ppmv)
2
3
4
5
6
7
8
Survey Replicate
Survey Replicate



eCH4 (ppmv)
0
2
4
6
8
10
eCO2
eCH4
eCH4 (ppmv)
eCO2 (ppmv)
0
0.5
1
1.5
2
2.5
3
2
4
6
8
10
12
0
50
100
150
Drilling
Flow-back
Production



A
eCH4 (ppmv)
1.87
1.09
0.30
MSEEL
500 meters
B
eCO2 (ppmv)
6.17
3.97
1.77
MSEEL
500 meters


39.70
39.65
39.60
39.55
-80.05
-80.00
-79.95
-79.90
Longitude
Mean eCH_4
0.4
0.3
0.2
0.1
ppmv
Mean eCO_2
40
30
20
10
ppmv
1
3
4
5
6
7
8
9
10
11
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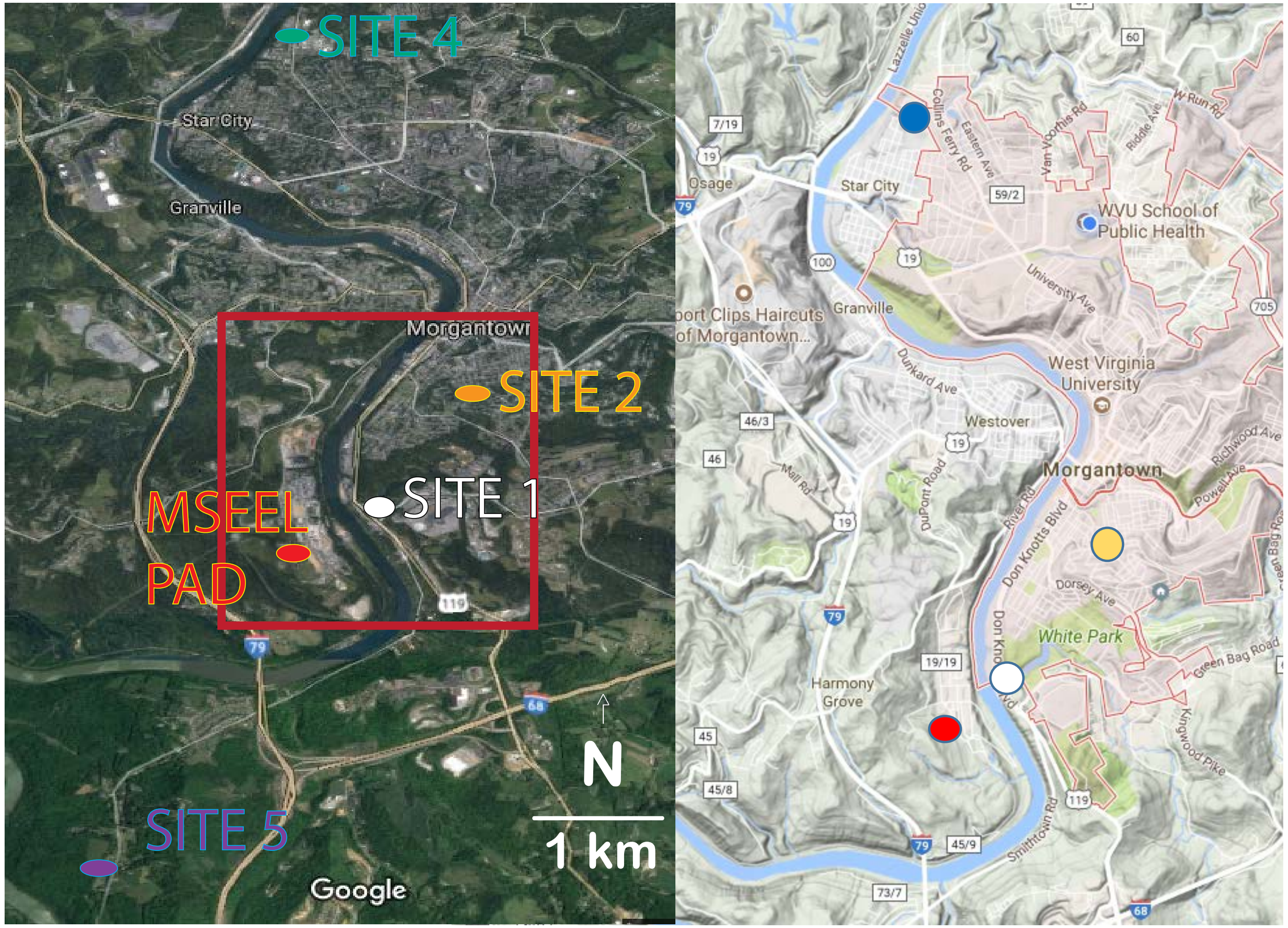
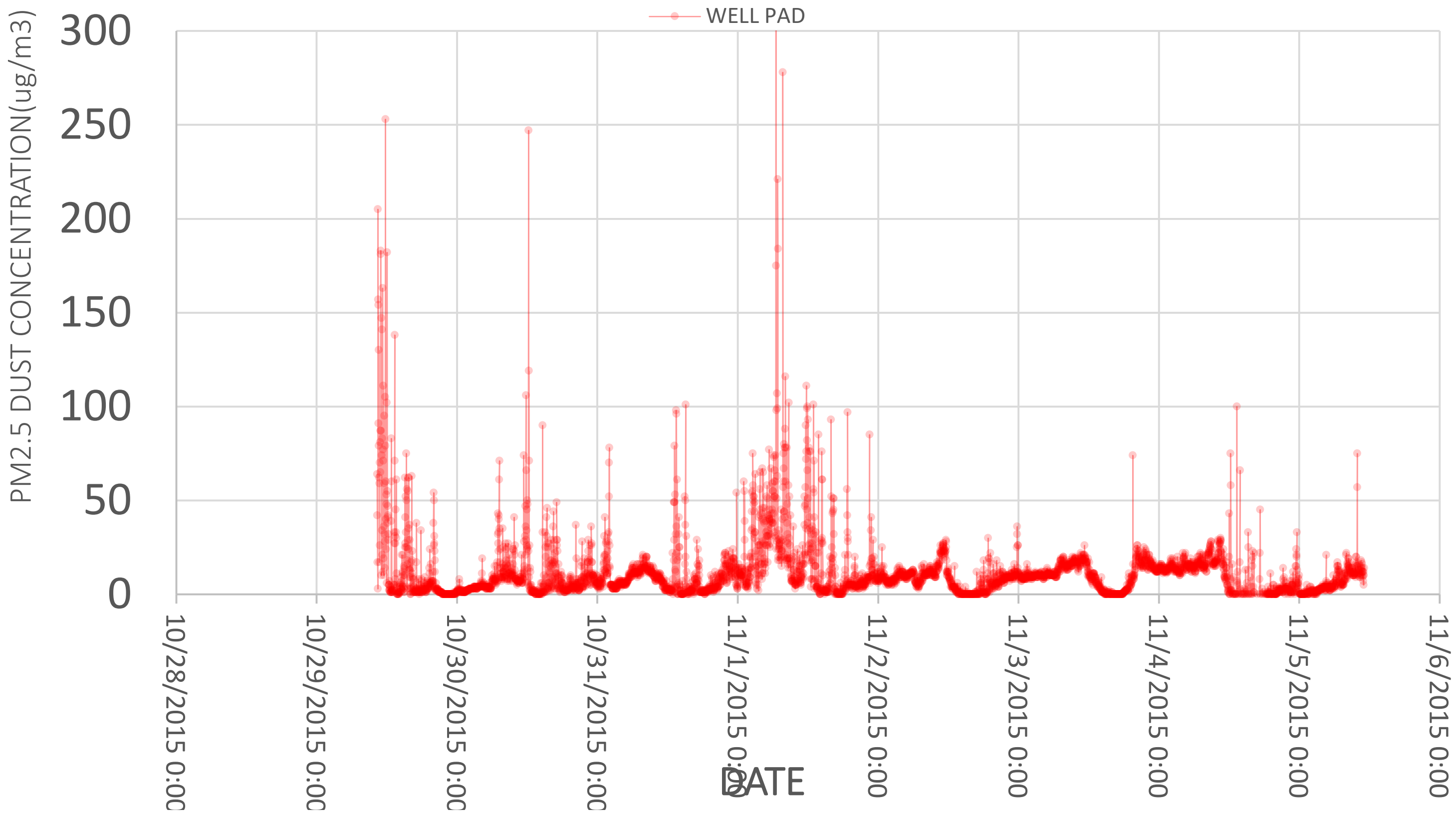
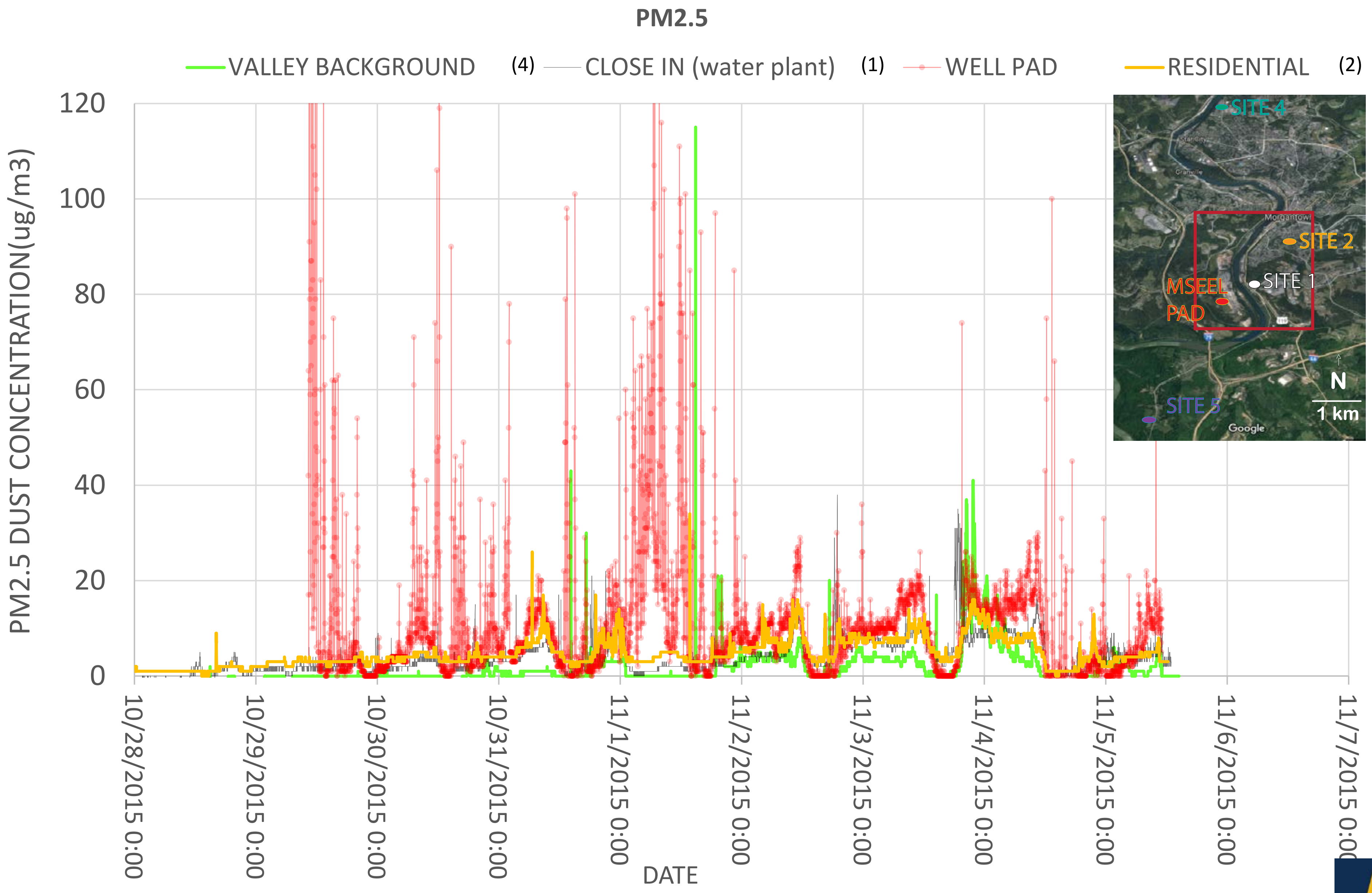
Maidsville
Van Voorhis
New Hill
Cassville
Star City
University Town Centre
Westover
Morgantown
Booth
Everettville
Little Falls
Map data ©2017 Google

Morgantown, WV – Air Sampling Sites



PM 2.5 conc. on Well Pad during Hydraulic Fracturing





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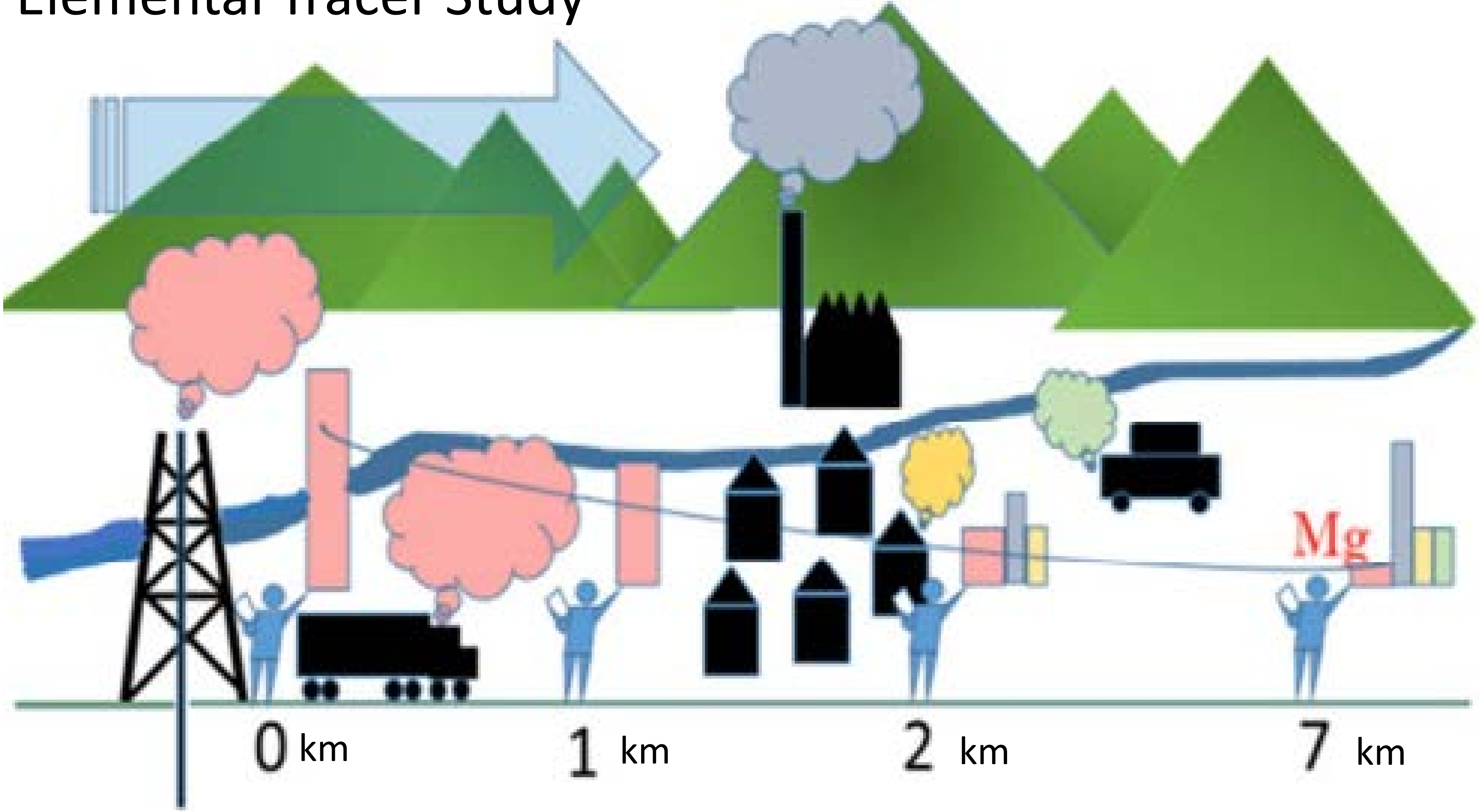
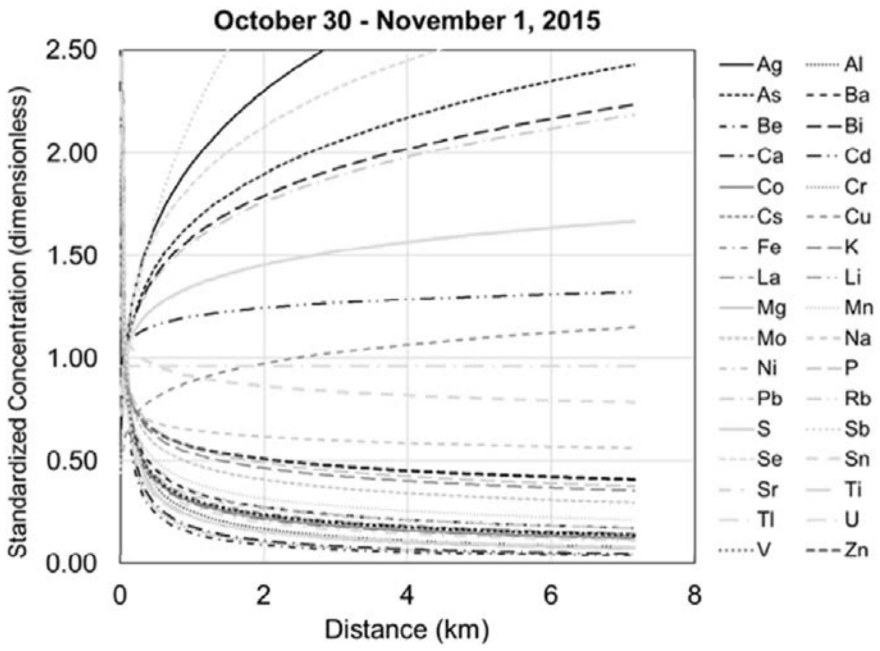
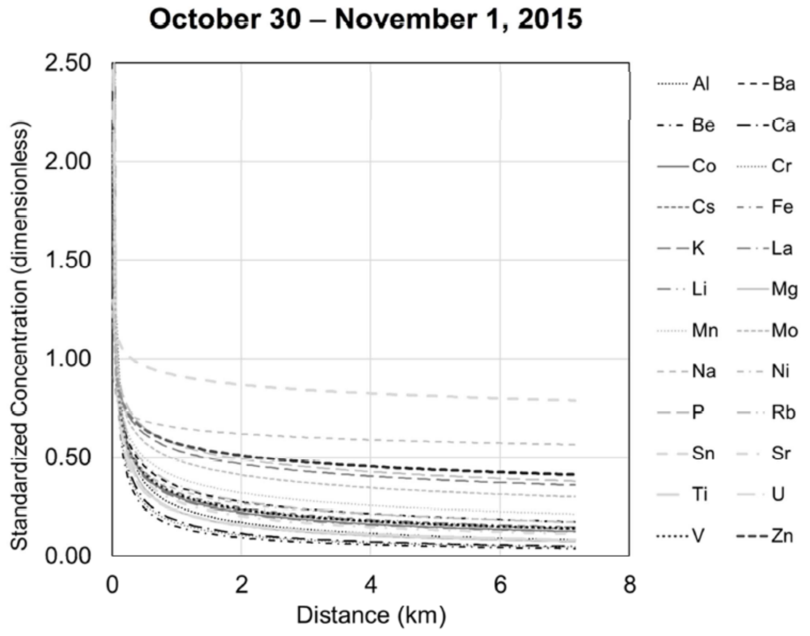
Elemental Tracer Study

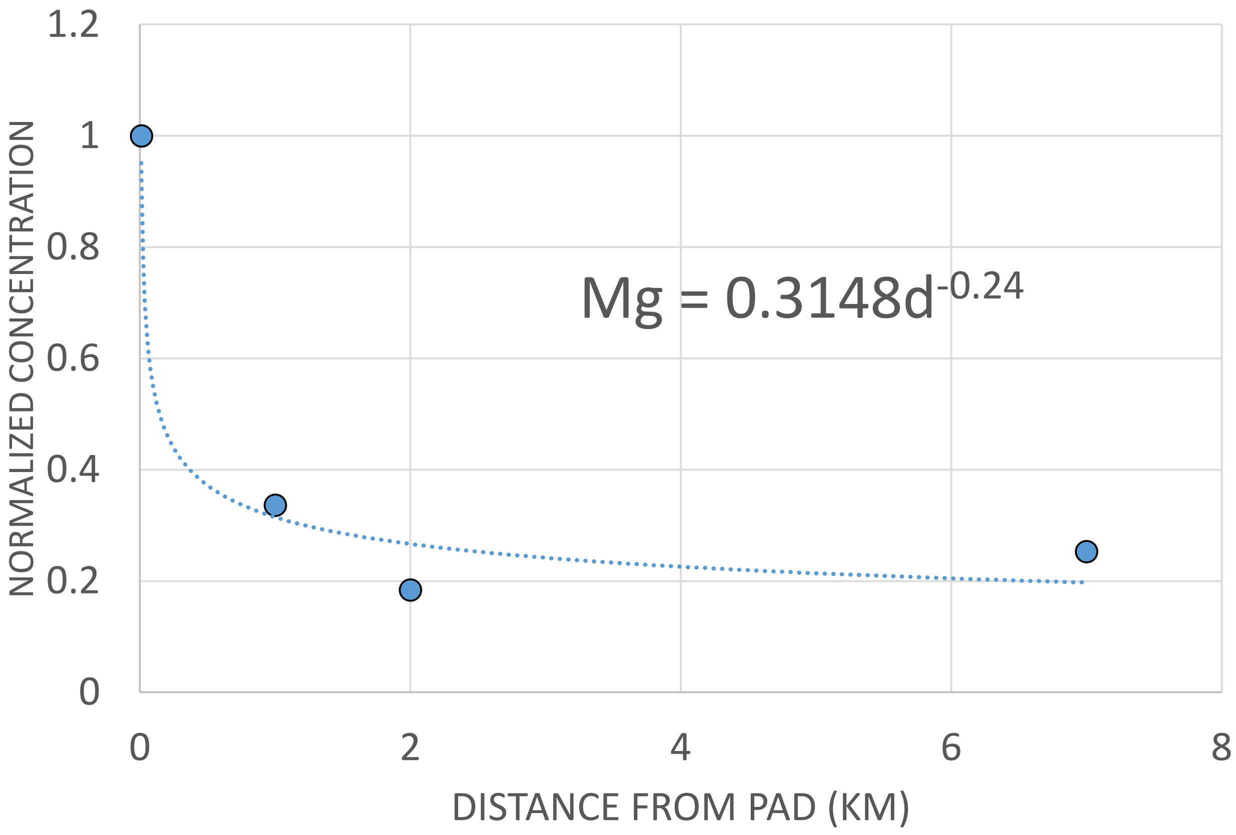




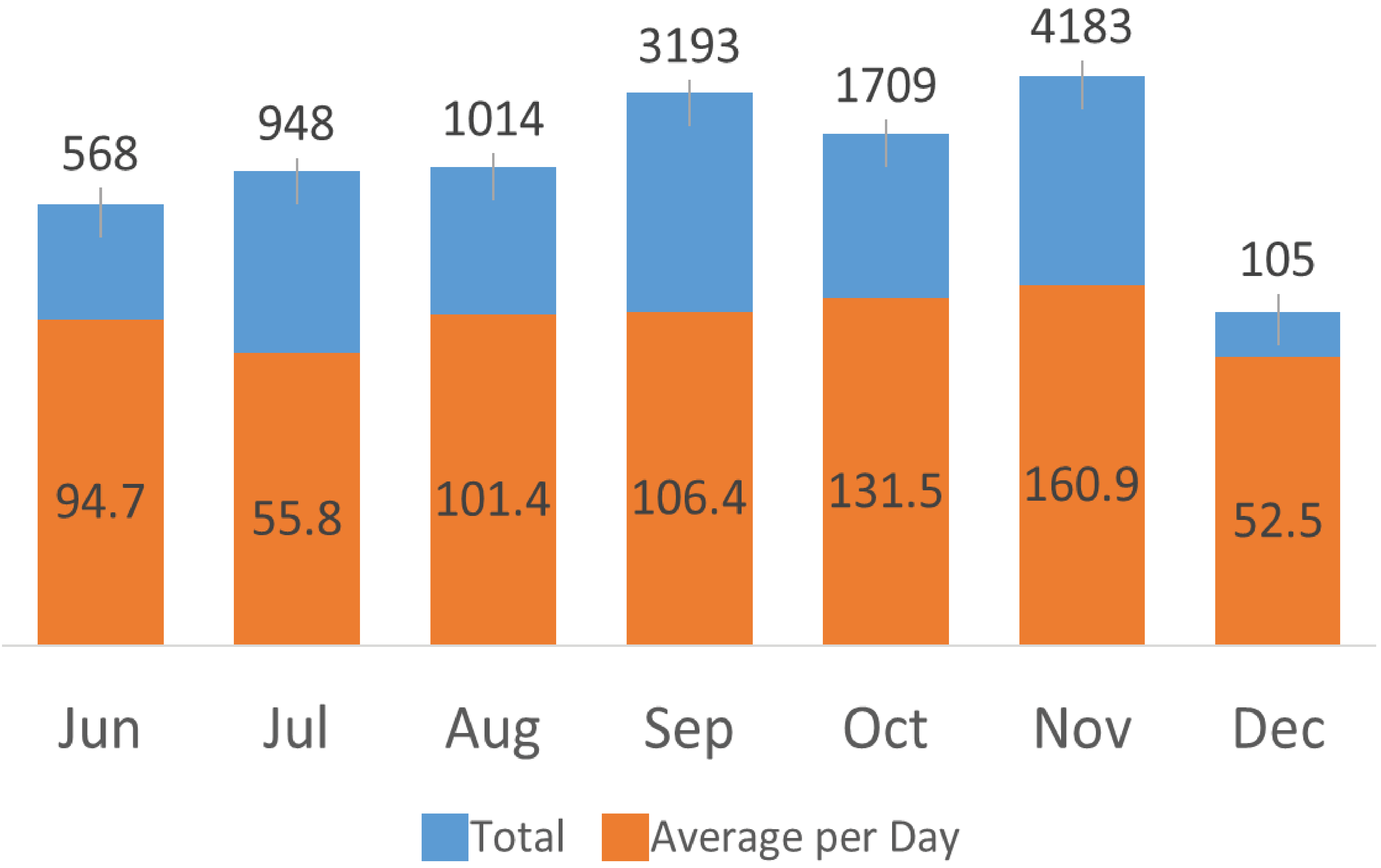
Elimination Criteria

1. Detectable Mass
2. Decreased with distance from source
3. Power fit of decrease (r2 > 0.6)
4. Proportional over distance to at least 3 of the other elements (r2 > 0.6)
5. Wind speed >1 mph, in northerly direction >5% of time.
6. Must be consistent over all 3 sampling periods





2015 Estimated Vehicle Trips*



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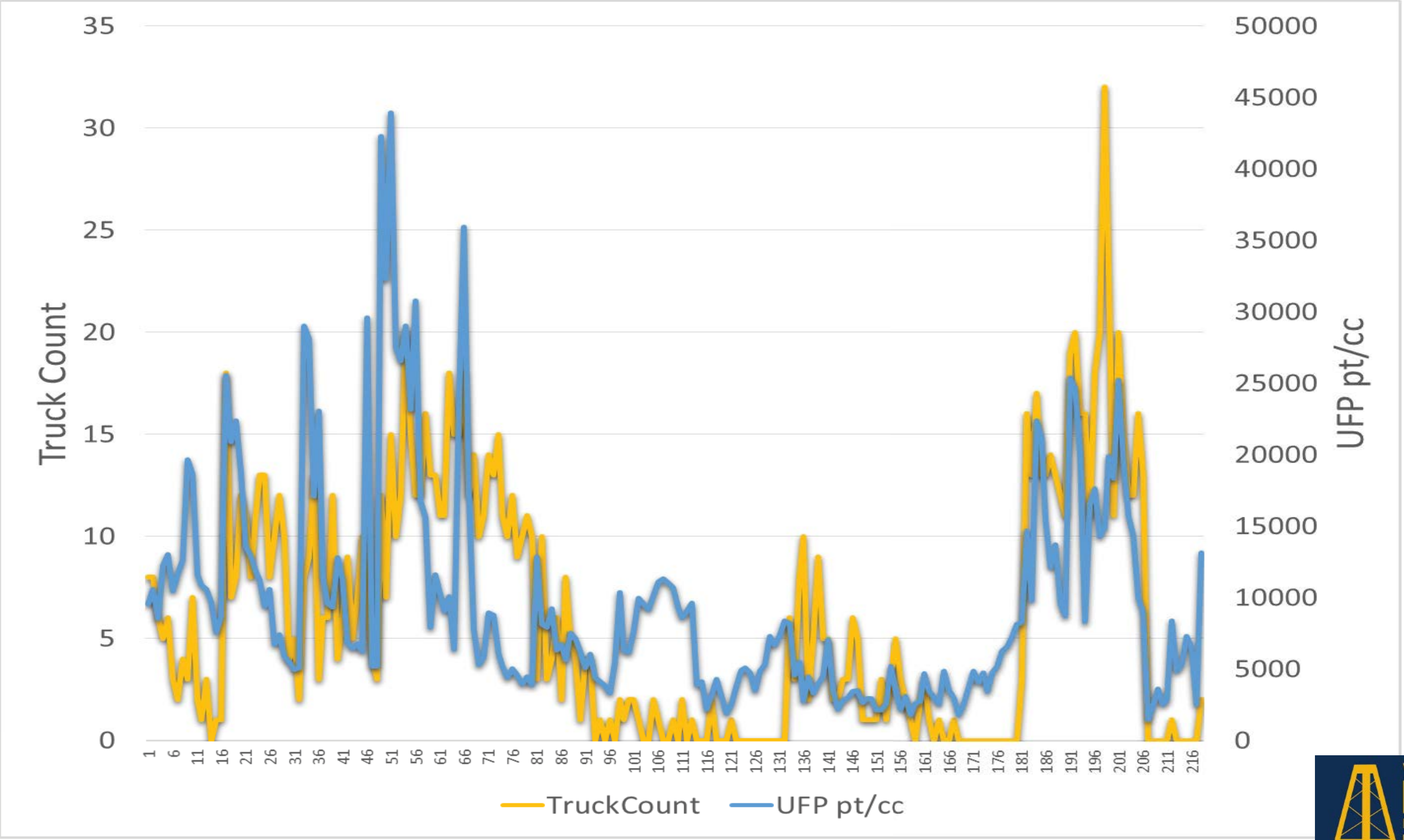

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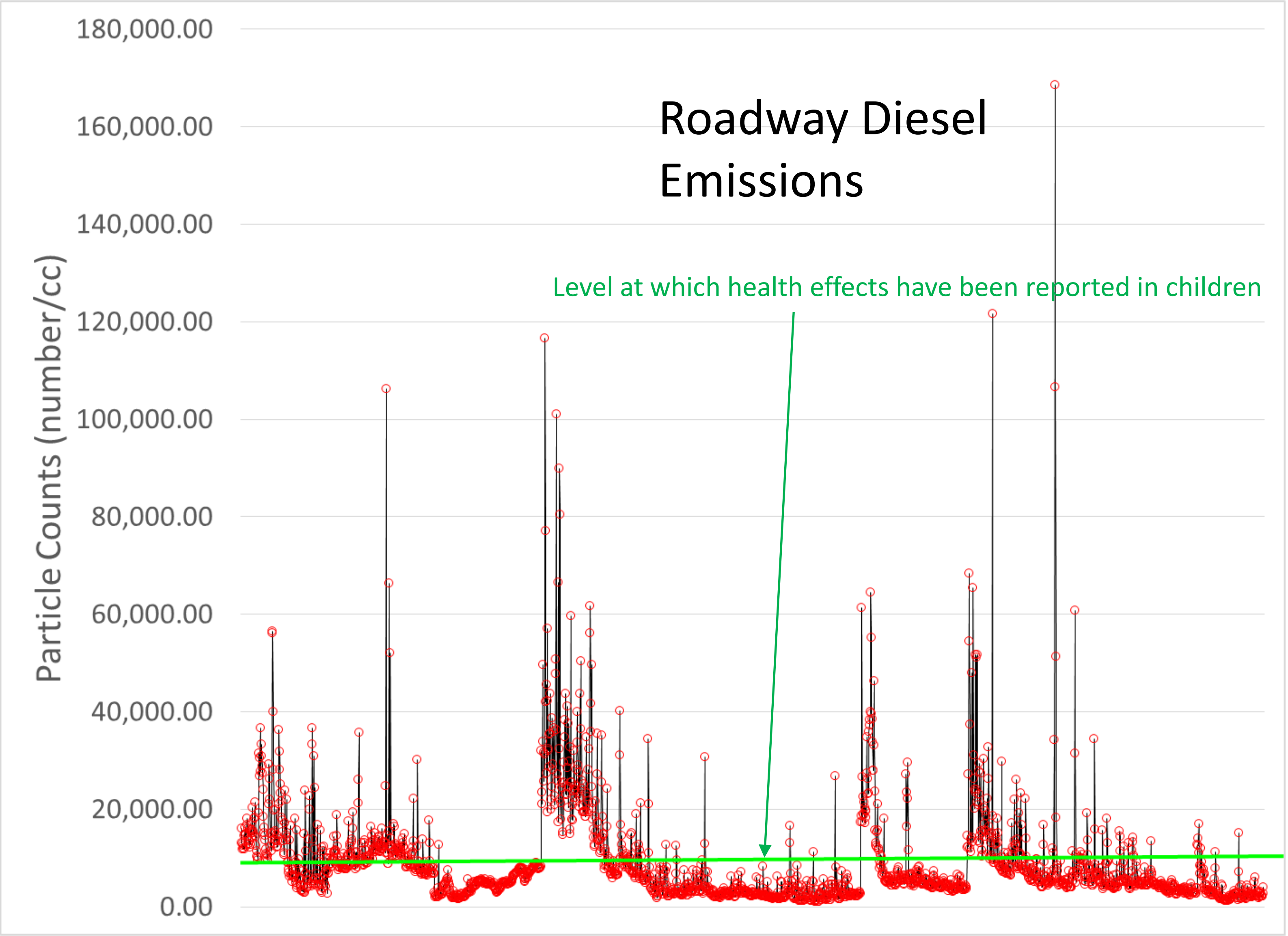

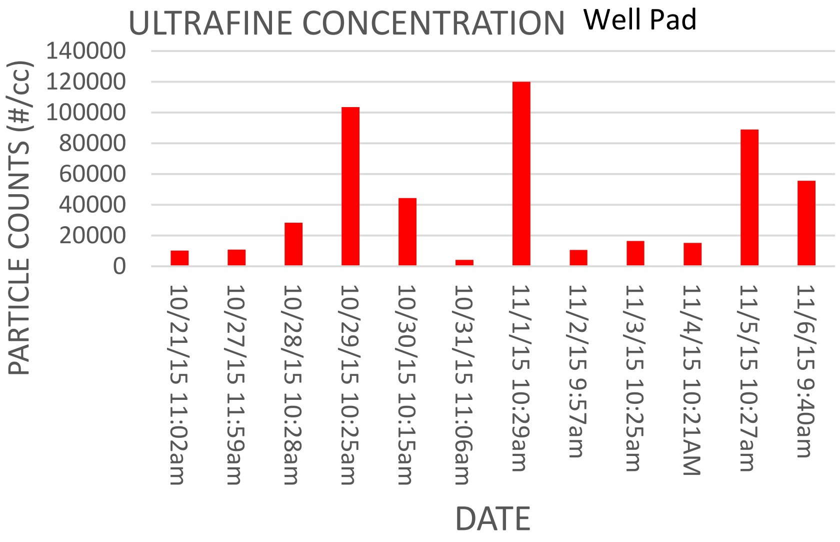

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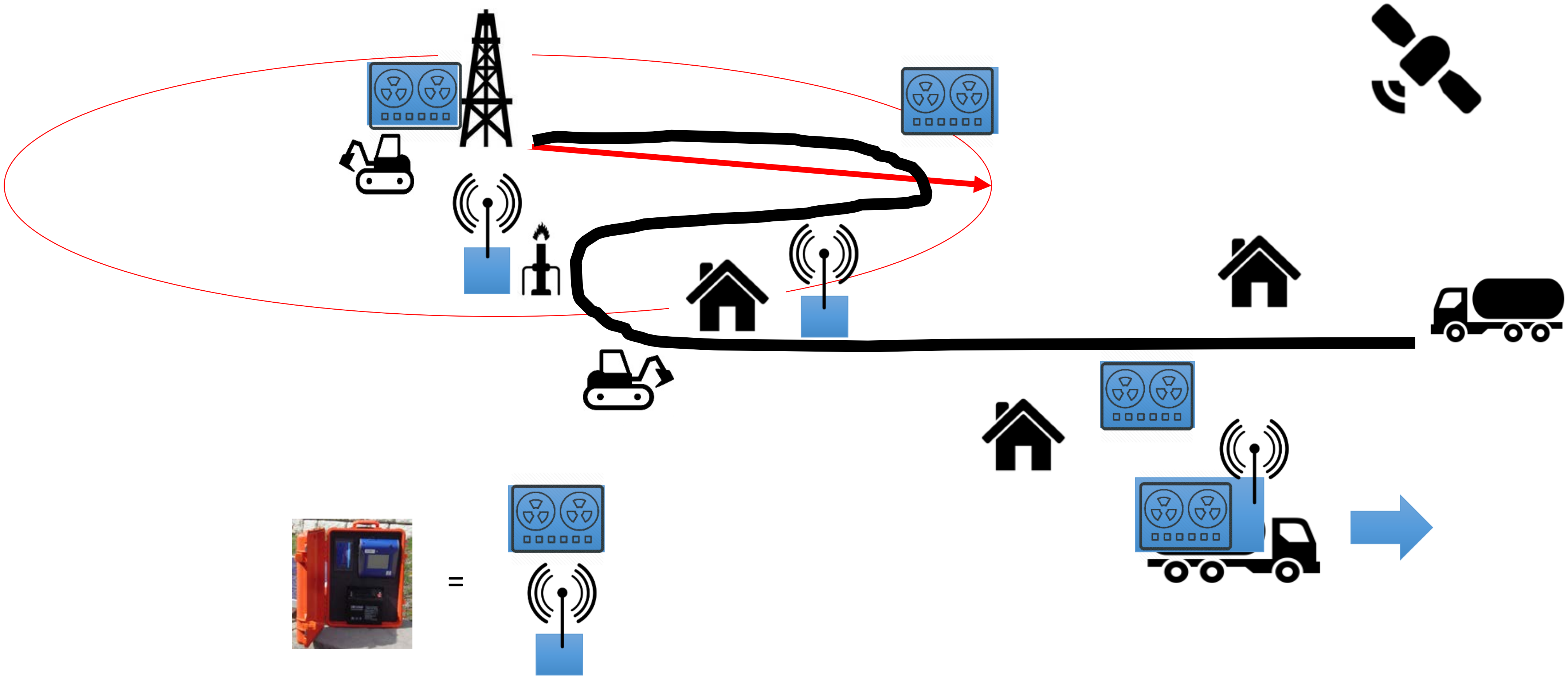
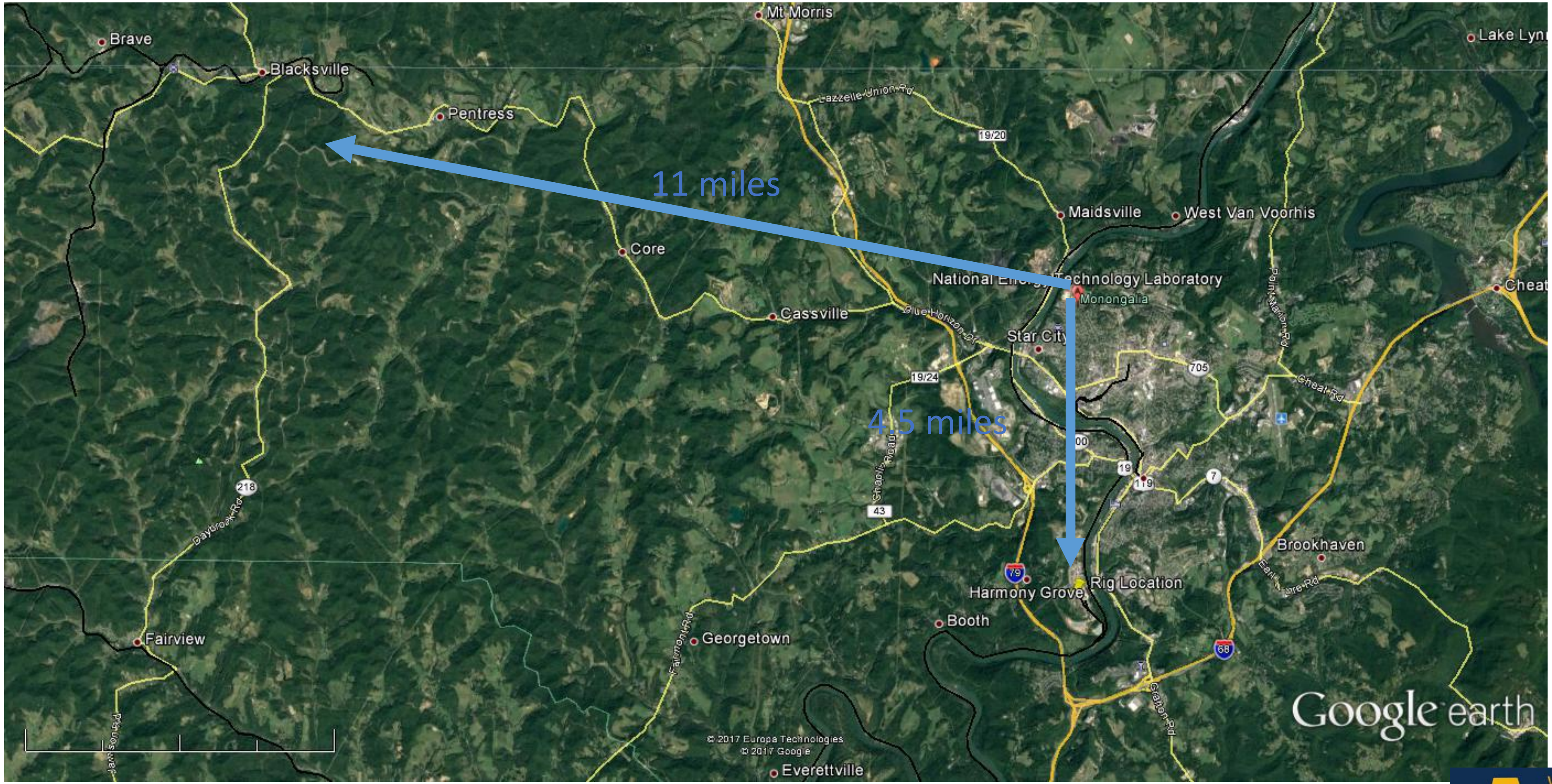
Air Sampling Site Locations



Proposed MSEEL Phase 3 Site



Ample opportunities and interest by NNE to drill and complete another well in association with the MSEEL project

Potential Next Phase Technologies

- Full wellbore and sidewall cores
  - Will be "ground truth" for geomechanical data and logs listed below
- Fracture ID
  - Drillbit geomechanics to determine "fracability" of every few inches along wellbore
  - Eliminates need for some costly horizontal open hole logging – need to correlate to core
- PetroMar FracView
  - Behind bit borehole imaging tool
  - Provides similar picture of natural fracture network intersecting wellbore
  - Will add data points for locating perfs and aid in understanding natural fracture network for modeling drainage patterns, frac efficiency, etc.
- Full Vertical Pilot Logging Suite (SLB)
  - Will tie remainder of field and region to detailed, well specific information
- Surface microseismic
  - Better surface conditions here to obtain data
  - Will be used for multiple wells and frac jobs to look at well to well influence and dependency
- Full well cuttings analysis
  - XRD/XRF to tie to drillbit geomechanics and core analysis
- Tracer technology
  - Used to compare stage to stage communication via proppant and fluid
  - Can be tied to microseismic data and fiber
- Sliding sleeve Frac
  - Can control fluid/sand each cluster received to make sure they are all being fractured effectively
  - Should be great tie in with fiber
- Fiber Optics DAS
  - Not only used for frac efficiency tie, but also possibly for microseismic during drilling/frac of offset wells
  - Continued improvement to analysis software through Academic consortium

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MSEEL Plans for Phase 3

- "How can one leverage this improved understanding gained through MSEEL to drill better wells?"
  - More gas extracted, minimal disturbance, similar/lower costs
- Evolutions over the past two years to allow us to move from test well projects to being able to employ these or similar technologies in a development scenario
  - More cost-effective techniques to better leverage technologies
- Test next generation technologies in an area with previous drilling to determine feasibility of applying lessons learned on an "every well" basis to determine if we can get more gas from each well
  - Allow for models to be created from different (cheaper) data sets that can be deployed in development scenario
  - Some questions – Are there as many fractures and similar orientation? How do rock properties compare to MIP? Why is production better?

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QUESTIONS?

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