NATIONAL ENERGY TECHNOLOGY LABORATORY

Design and Rationale for a Field Experiment using Tracers in Hydraulic Fracture Fluid

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Morgantown, WV

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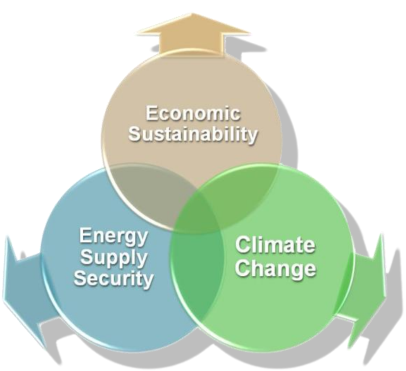
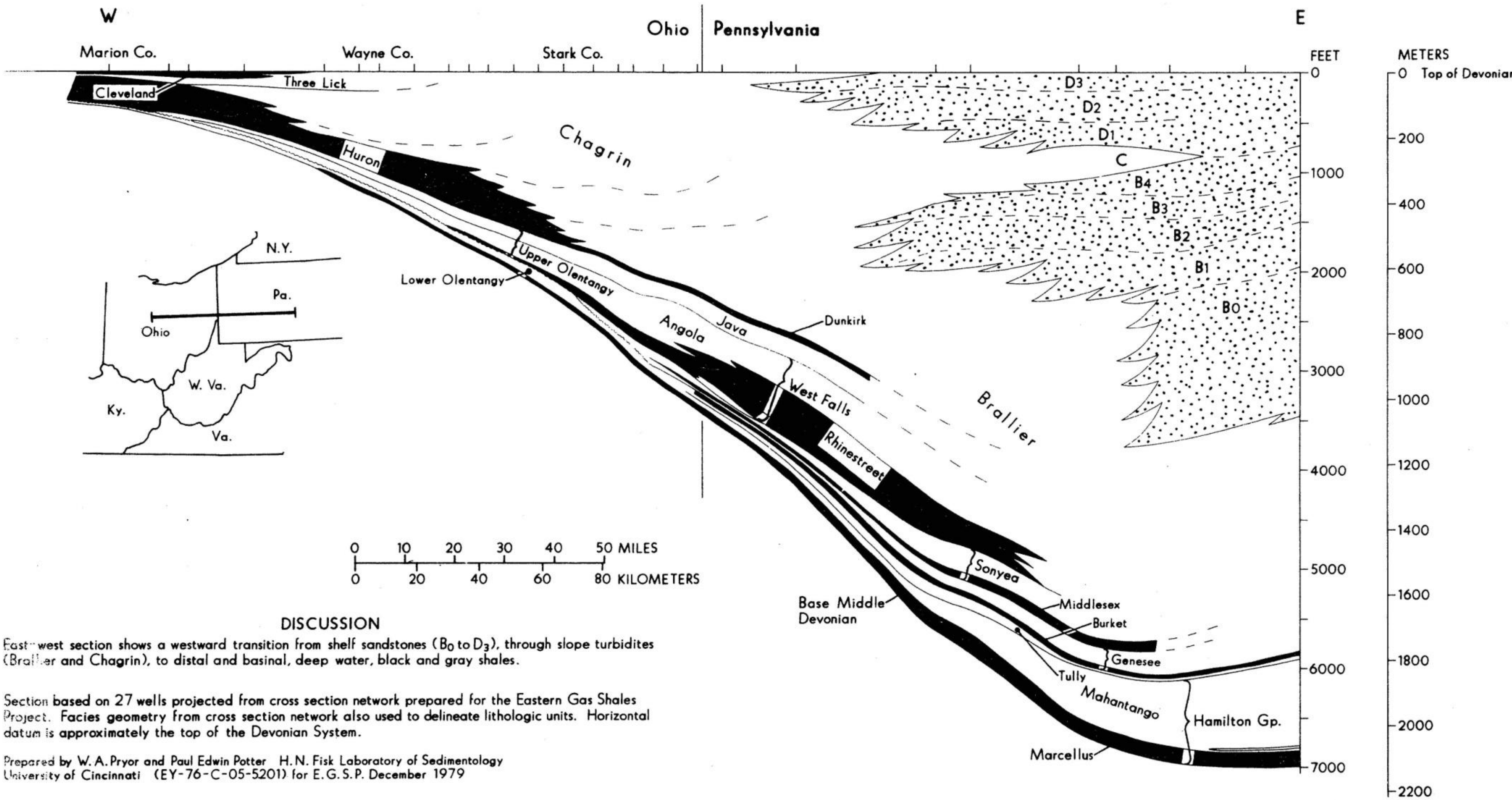
Well Construction and Operations




Marcellus Shale in Hanson Quarry, NY
Oatka Creek Member
Cherry Valley LS
Union Springs Member

Appalachian Basin Stratigraphy



Hydraulic Fracturing

- Hydraulic fracturing is used to create high-permeability pathways into a formation.
- Hydraulic fractures are made by filling the well with fluid and then increasing the pressure until the rock strength is exceeded.
- Fluid and proppant are pumped out into the fractures; the proppant stays behind and keeps the fractures open after pressure is released.

Potential for Aquifer Contamination

- Does the frac fluid get into shallow, freshwater aquifers (USDW) when under pressure creating the fractures?
- Unlikely because of:
  - Low hydraulic conductivity
  - Flow gradients wrong direction
  - Depth of target formation
  - Long groundwater travel times
- What if there are flow conduits to the surface like faults or abandoned wells?
- No definitive evidence of direct water contamination from deep hydraulic fracturing has been documented, but a tracer test would help provide rigorous data.

Formation Water Chemistry

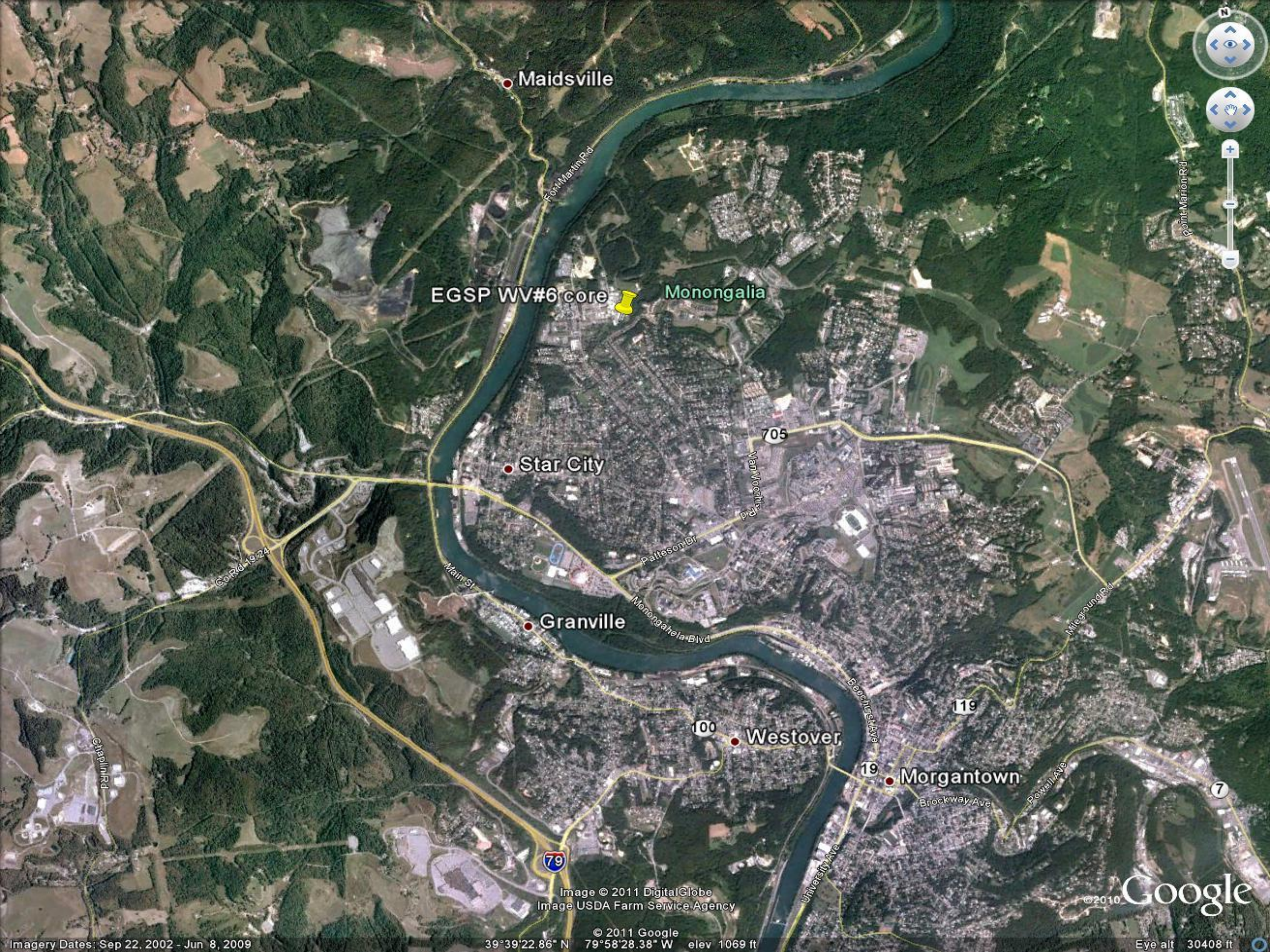
- Fluid recovered from the well after the frac is called flowback.
  - Mix of frac water and formation water – how much of each?
  - Starts fresh, then turns very salty with high TDS and odd chemistry
  - Only about 1/4 - 1/3 of the injected fluid is recovered as flowback
- What happens to the frac fluid that remains downhole?
  - Pools in the bottom of fractures?
  - Evaporates and is transported out with the gas?
  - All of the above?
  - None of the above?
- Source of the TDS, and links between brine chemistry and bulk rock geochemistry of shale are not well understood.
- Relationship of Marcellus water chemistry to other waters in the basin (i.e. Oriskany) is not well understood either.

What is a Tracer?

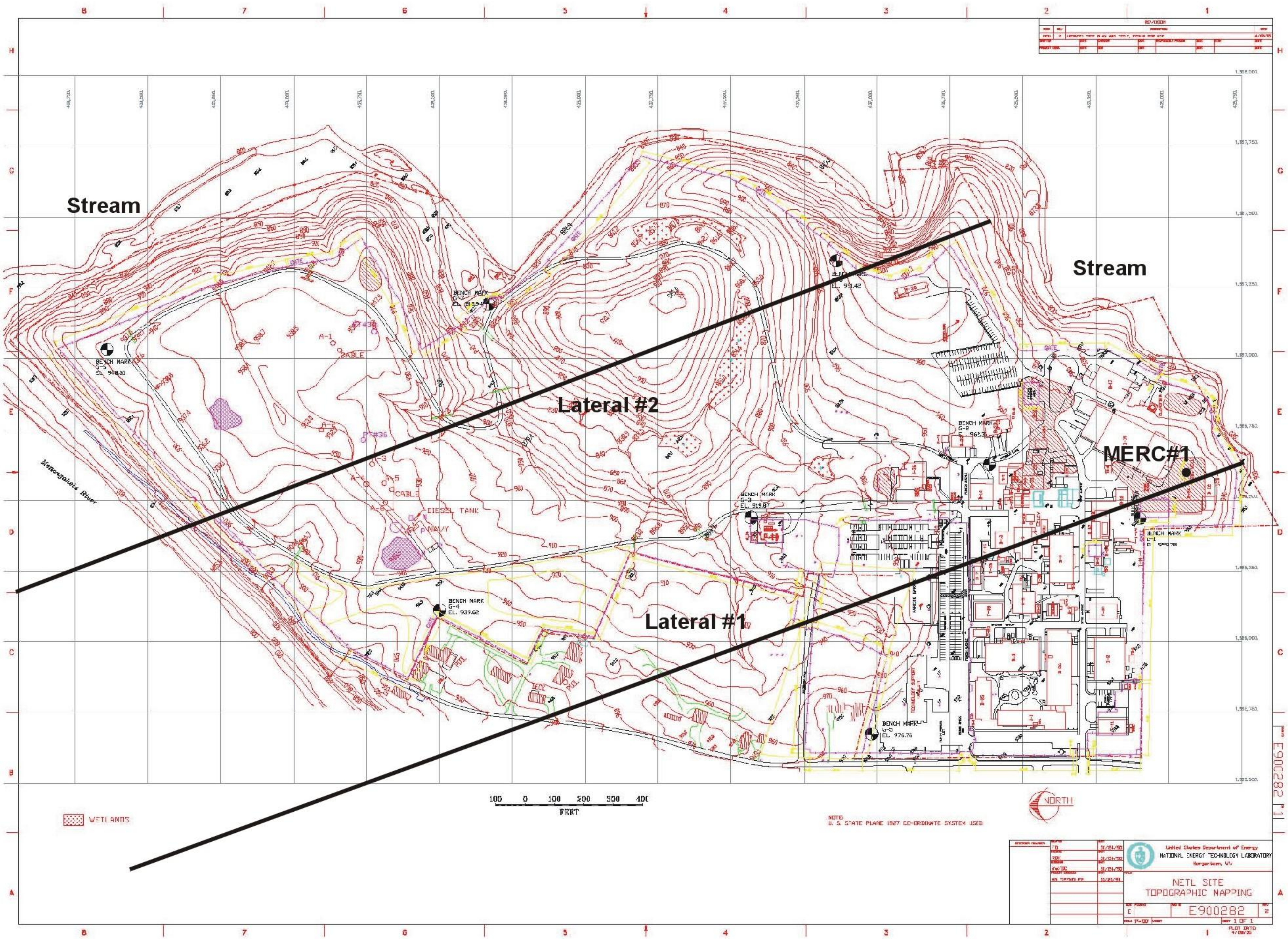
- **Tracers are elements, compounds, or isotopes that can be used to delineate groundwater flow paths and estimate time-of-travel (USGS).**
- **Environmental tracers: anthropogenic compounds that entered into the hydrologic cycle at a known time and concentration**
  - CFCs, sulfur hexafluoride (SF_6) from atmosphere
  - Tritium/helium-3, chlorine-36, other radionuclides from above-ground weapons testing in the 1950’s (spikes)
- **Introduced tracers: dyes, chemicals, or isotopes added for a test**
  - Conservative tracers travel with the plume; non-conservative tracers may diffuse or disperse out ahead of it.
  - An ideal tracer is easily detectable, obvious, moves with the water flow, does not chemically react with passing substrates, and does not alter the properties of the water.

Proposed Hydraulic Fracture Tracer Test

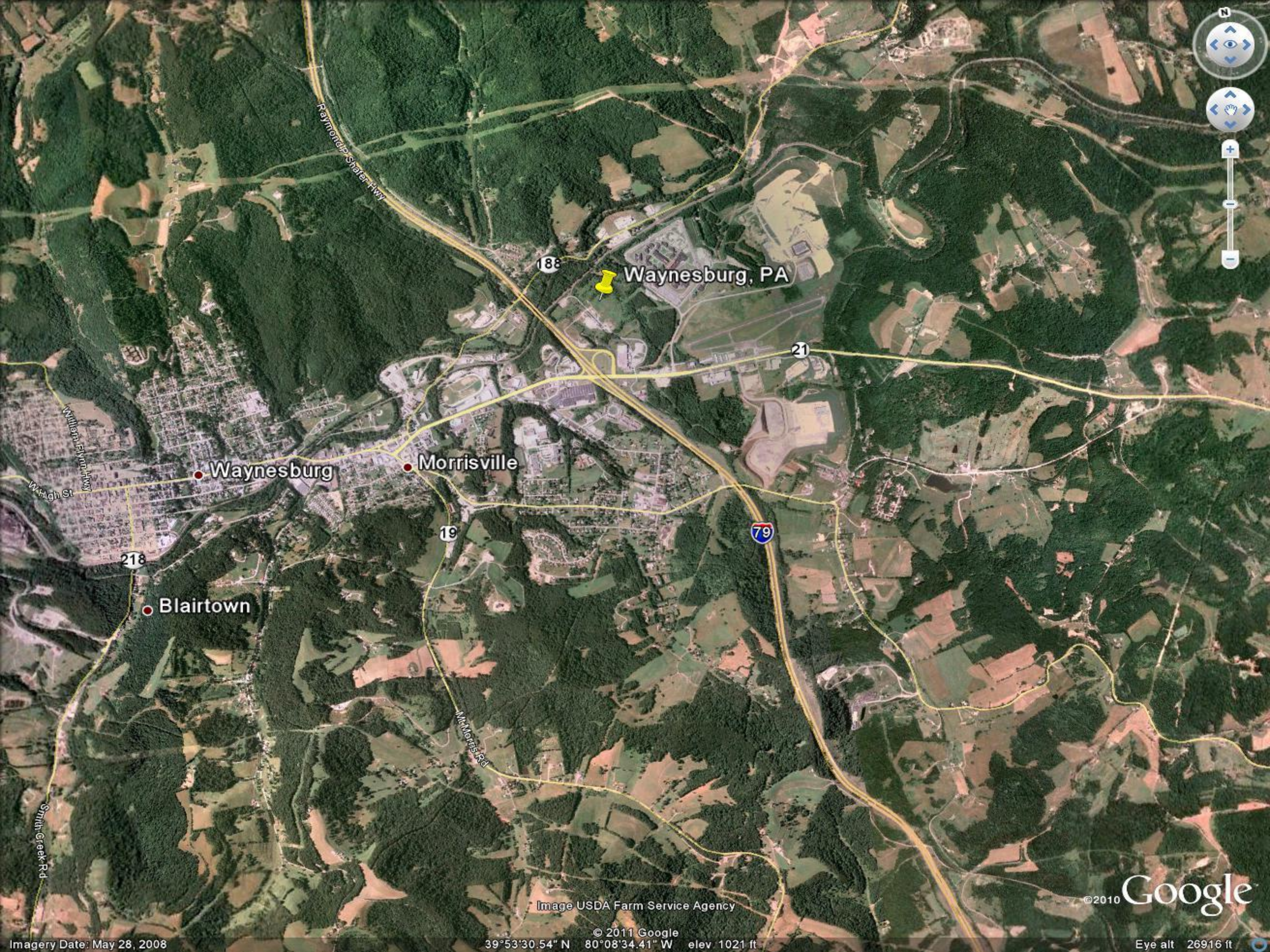
- Collect baseline data on site groundwater, structure and geology.
- Drill parallel laterals at site and prepare for frac.
- Add a conservative tracer in the frac fluid mix; place instruments on-site
- Hydraulically fracture the wells in the normal manner.
- Monitor frac physics and sample groundwater for tracer.
- Drill a vertical well to the Oriskany some time after frac.
- Sample formation water all the way down to and including the Oriskany Sandstone.
- Run lab analyses of groundwater and formation water to determine fate of frac fluid from detection of tracer.
- Government control of design, sampling, analysis and data, with other selected participants (industry, university, etc.) following same QA.
- Security is required to protect sample sites and data integrity (more QA).
- Status: site and alternate sites identified, driller agreeable but service company not approached, interagency collaborators identified (USGS, EPA)
- Sites: NETL-Morgantown, locations near Waynesburg, PA, possible central WV locations.



Maidsville
EGSP WV#6 core
Monongalia
Fort Martin Rd
Point Marion Rd
705
Star City
Van Voorhis Rd
Patteson Dr
Co Rd 19/24
Main St
Granville
Monongahela Blvd
Mileground Rd
Beechurst Ave
119
100
Westover
19
Morgantown
Powell Ave
Brockway Ave
7
Chaplin Rd
79
University Ave
Image © 2011 DigitalGlobe
Image USDA Farm Service Agency
© 2011 Google
©2010 Google
Imagery Dates: Sep 22, 2002 - Jun 8, 2009
39°39'22.86" N 79°58'28.38" W elev 1069 ft
Eye alt 30408 ft


Stream
Stream
Lateral #2
Lateral #1
MERC#1
Monongahela River
DIESEL TANK
BENCH MARK
WETLANDS
FEET
NORTH
NOTE:
U. S. STATE PLANE 1927 CO-ORDINATE SYSTEM USED
United States Department of Energy
NATIONAL ENERGY TECHNOLOGY LABORATORY
Morgantown, WV
NETL SITE
TOPOGRAPHIC MAPPING
E900282

EGSP WV-6 Well and Core (MERC#1)


Waynesburg, PA
Raymond P. Shafer Hwy
188
21
Waynesburg
Morrisville
William Flynn Hwy
W High St
218
19
79
Blairtown
Mt Morris Rd
Smith Creek Rd
Image USDA Farm Service Agency
©2010 Google
© 2011 Google
Imagery Date: May 28, 2008
39°53'30.54" N 80°08'34.41" W elev 1021 ft
Eye alt 26916 ft

Site Issues

- NETL: Management has not confirmed support; not sure how facilities/safety people will react, may be difficulties with pipeline capacity to take gas.
- NETL: One landowner has control of land, site is secured with fence and guards, oriented properly, old Marcellus well for stratigraphic control.

- Waynesburg: Multiple landowners, may be denied access, unsecured sites near interstate highway, schedule moving rapidly.
- Waynesburg: more timely, leases and permits in place and gas lines in area, existing water wells, multiple landowners might be a good thing for options.

Cost (Guess)timates

- Drill the vertical wells to kickoff, drill the laterals, case, perf, zipper frac, complete: ~$4 million; industry cooperator will cover these costs in return for the gas.
- Install groundwater monitoring wells and surface or downhole geophysical instrumentation: $300K
- Construct a vertical well from surface to Oriskany Sandstone, including ~100 ft of Marcellus core: $800K
- Interagency funds for selecting tracer, monitoring frac, collecting samples: $250K
- EPA, USGS laboratory analysis of water samples: $300K
- Analysis of other data (geophysics, soil gas, etc.): $250K
- Assessing results and writing/publishing report: $100K
- Total estimated government cost for one field experiment: $2 mill

DOE Marcellus Tracer Test

Goals

Assess environmental impacts to aquifers.

Address scientific issues related to hydrology and geochemistry

Outcomes

Rigorous study with well-documented data, solid QA pedigree, no question about data integrity.

Applications

Provide public information to help regulators, and create a more informed environmental debate.

Benefits

Improve understanding of hydraulic fracture injection and downhole movement.

Document formation water chemistry and links to Marcellus brine.

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The statements made during the workshop do not represent the views or opinions of EPA. The claims made by participants have not been verified or endorsed by EPA.

The economic recovery of natural gas from organic-rich shales requires the use of horizontal boreholes and staged hydraulic fracturing. Many questions have been raised about the potential threat this production method may pose to groundwater. Field-based measurements to gather hydrologic and geophysical data from a representative hydraulic fracture treatment in the shale could help ascertain the movement of hydraulic fracture fluid in the ground, and determine how close it might come to contaminating drinking water supply aquifers.

Geophysical field data collected by microseismic methods show the extent and dimensions of hydraulic fractures created in lateral boreholes as a stimulation technique for shale gas production. The data indicate that hydraulic fractures do not approach closer than several thousand feet below the freshwater aquifers above the Barnett Shale of the Fort Worth Basin, and the Marcellus Shale of the Appalachian Basin, the two major shale gas production areas in the U.S. (Fisher, 2010). Nevertheless, there is still a degree of uncertainty concerning the potential effects that such fracturing treatments might have on groundwater. In particular, the possible migration of fracturing fluids from the target production formation into drinking water supply aquifers remains a hotly-debated topic. The absence of rigorous data to support either side in this argument has left the general public confused, concerned, and in some cases frightened.

The proposed field experiment would begin by collecting representative groundwater samples for baseline analysis along the planned trajectory of the horizontal borehole prior to drilling. Structural features will be located by a seismic survey during site characterization, and additional groundwater sampling points will be installed over structures such as faults, which might provide conduits for hydraulic fracture fluids to move out of the stimulation zone and into aquifers. Soil gas samples will also be collected from locations above the laterals and analyzed for any traces of natural methane or radon gas potentially released by the fracture treatment. Prior to hydraulic fracturing, a conservative tracer will be placed in the fracturing fluid. Microseismic and other advanced geophysics will be run above the laterals during the hydraulic fracturing process to map the length and orientation of the induced fractures. A series of groundwater samples will be collected before, during and after the drilling and hydraulic fracturing operations, and analyzed for the tracer. Groundwater sampling will be carried out at regular intervals for a few weeks to months after the hydraulic fracturing to determine if there is any upward movement of fluids over time.

After completion of the hydraulic fracturing, a vertical borehole will be drilled down to the Marcellus Shale, and continue through it to the underlying Oriskany Sandstone. The drilling will be paused at water-bearing formations, such as sandstones and limestones, to collect formation water samples. The samples will be analyzed for the tracer, to determine if it has contaminated any of the deeper saltwater aquifers. Water samples will also provide data on the chemistry of natural formation brines in the basin, and determine if the brines in the Marcellus are chemically related to other formation waters. Data collected from this experiment should provide insights into the location of hydraulic fractures in relation to aquifers, the potential for the upward movement of hydraulic fracturing fluid to contaminate groundwater, and the geochemistry of Appalachian Basin formation waters in comparison to the Marcellus Shale.

Reference: Fisher, Kevin, 2010: Data Confirm Safety of Well Fracturing, The American Oil & Gas Reporter, July 2010