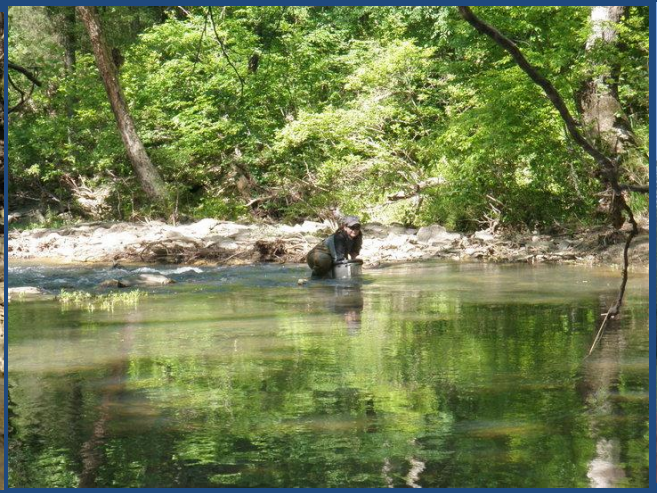
Past experience in Arkansas

Sally Entrekin

University of Central Arkansas



Collaborators

Funding through Arkansas Game and Fish Commission
State Wildlife Grant # 223017 & 223023

University of Central Arkansas, Biology
Sediment dynamics and invertebrates: S. Entrekin, N. Jensen, J. Kelso, A. Musto

Fish: G. Adams, R. Adams, L. Stearman, J. Green

University of Arkansas, Biology
Nutrients and Metabolism: M. Evans-White, B. Austin

Arkansas Water Resources Center, University of Arkansas
Chemical Analysis: B. Haggard, L. Massey

The Nature Conservancy
GIS support: E. Inlander, C. Gallipeau

US Fish and Wildlife Service
Field support: L. Lewis, C. Davidson

Brent Johnson and Elizabeth Hagenbuch

Presentation Outline

- Natural gas development in Arkansas
  - Extent
  - Pace
  - Proximity to surface waters
- Approach to quantifying natural gas development
  - Cumulative Effects
  - GIS metrics
  - Gradient analysis versus Before-After-Control-Impact
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  - Biological responses to sedimentation
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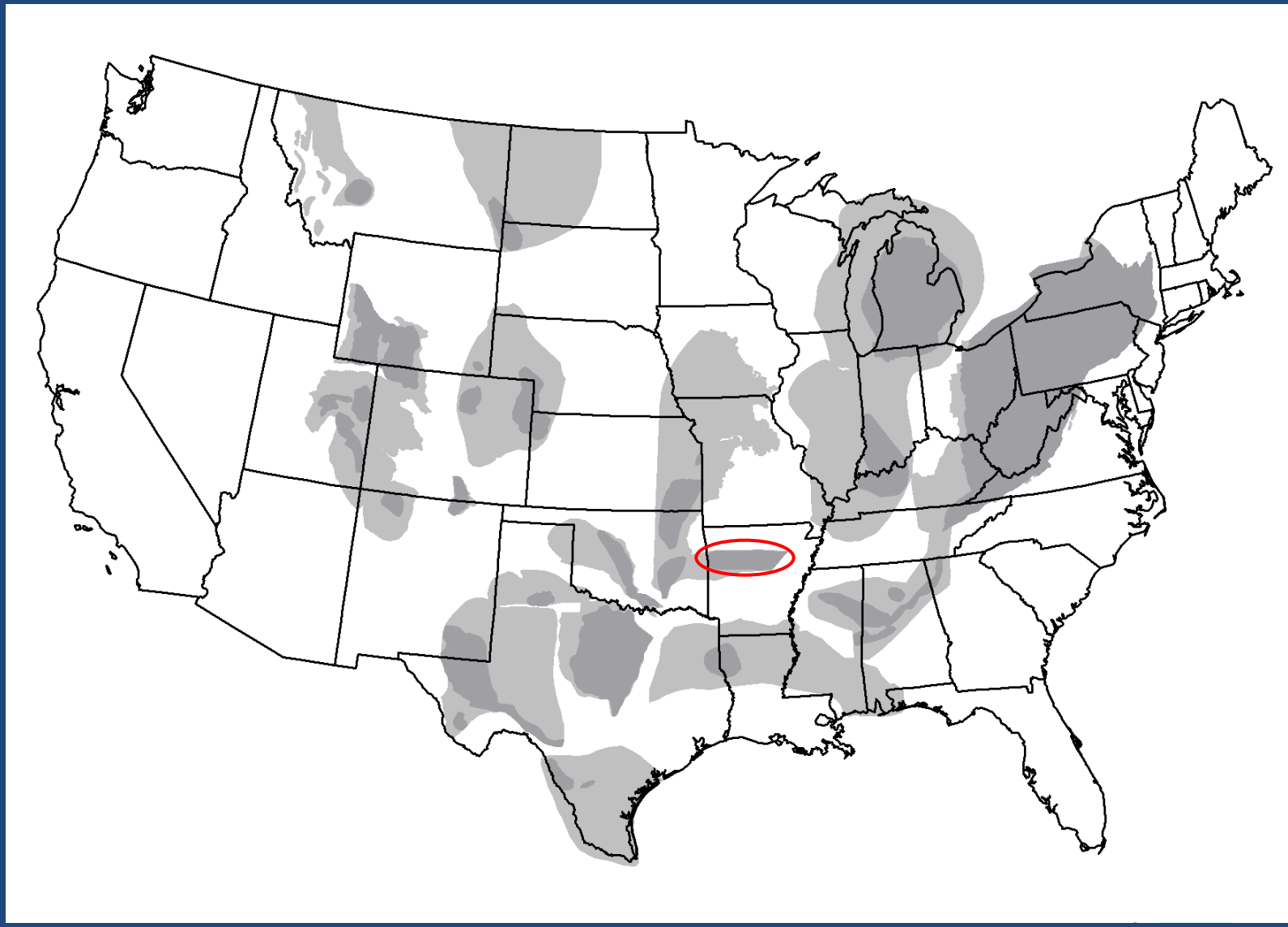
Over 20 shale basins in the U.S.

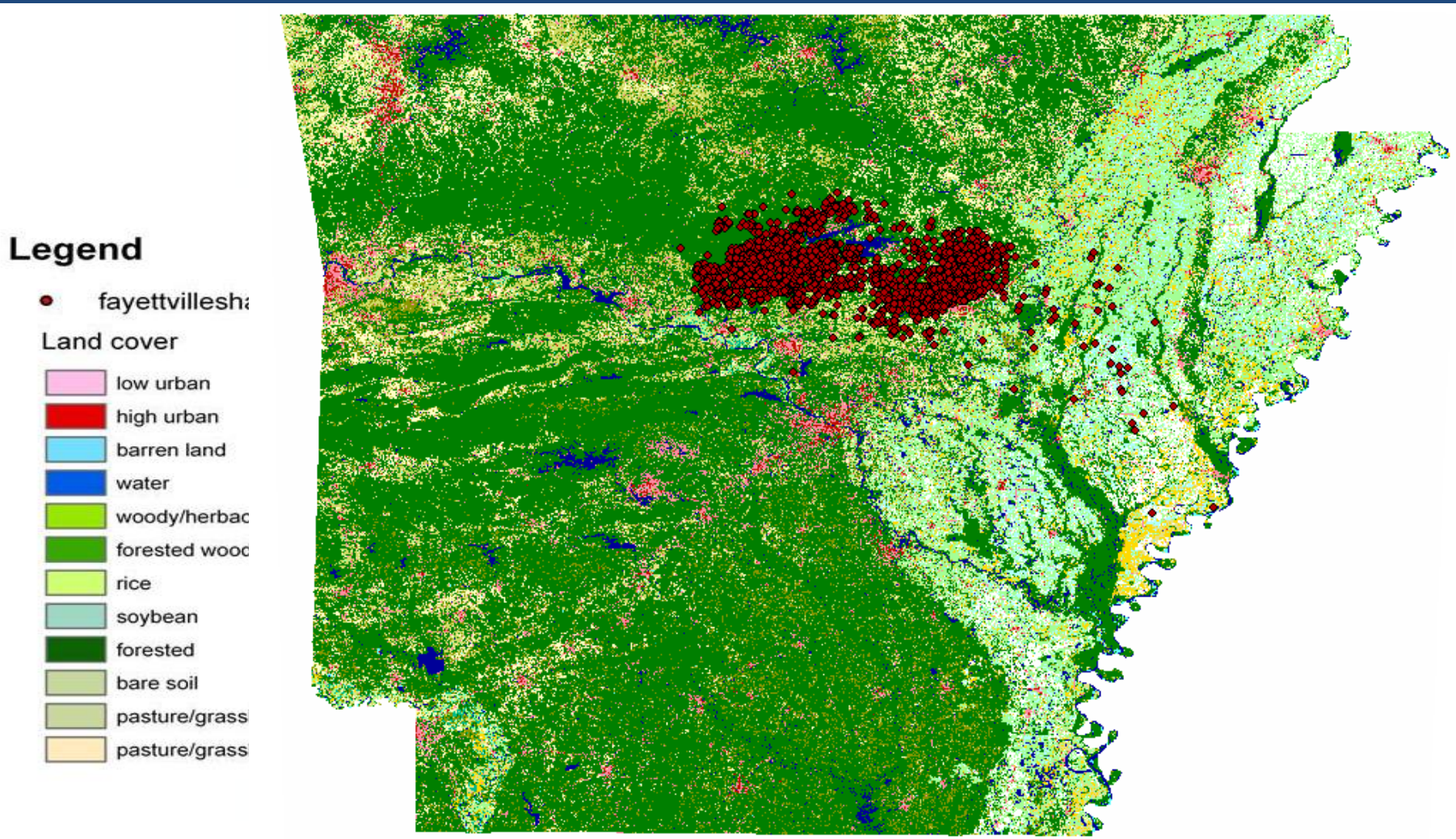


•Identified as one of the top 10 threats to global ecosystems (Sutherland et. al. 2010)

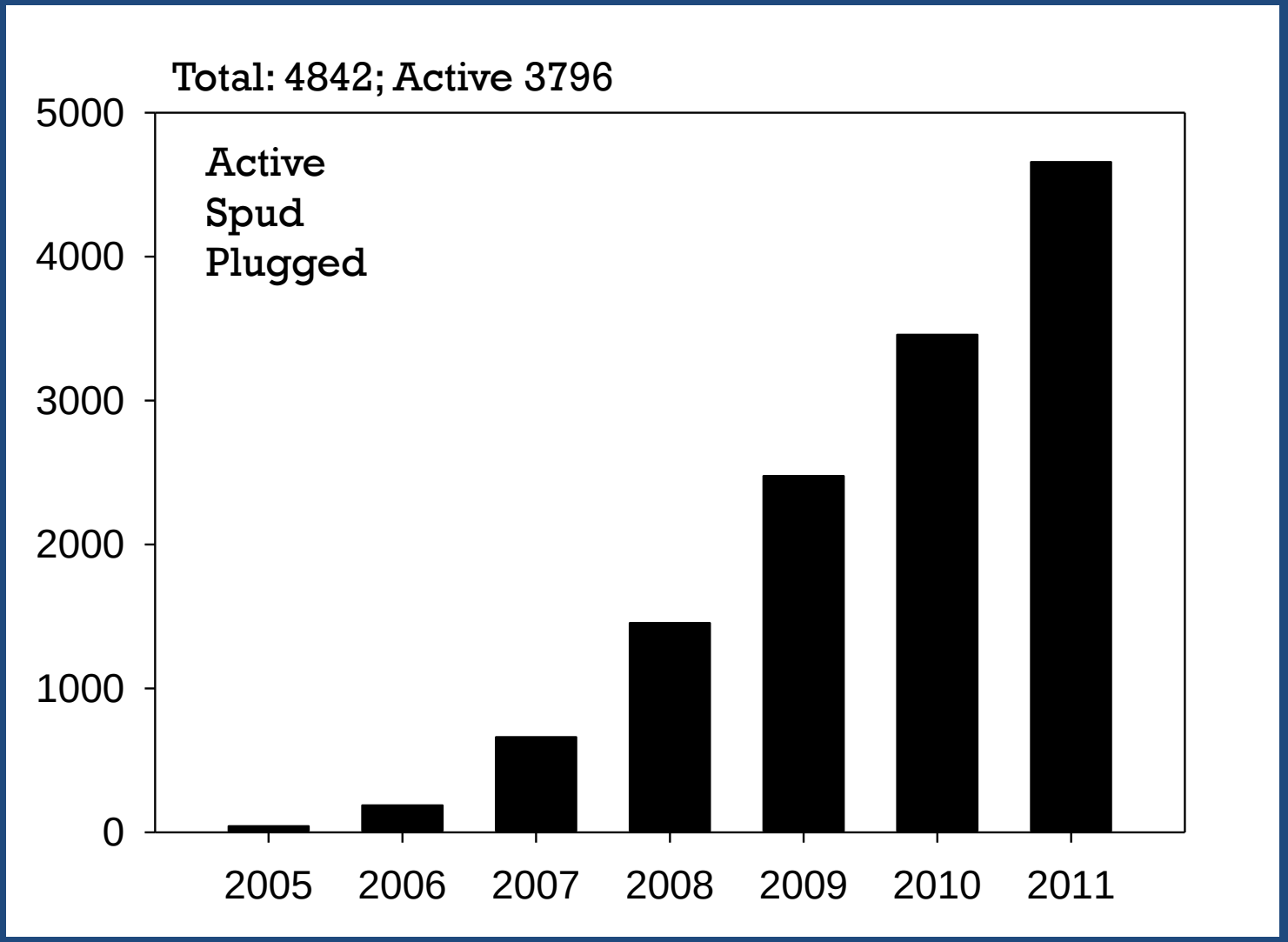
Natural gas wells in the Fayetteville Shale gas play

(data from Oil and Gas Commission)

> 4000 wells in 8000 km^2



Gas well development continues to increase in the Fayetteville shale

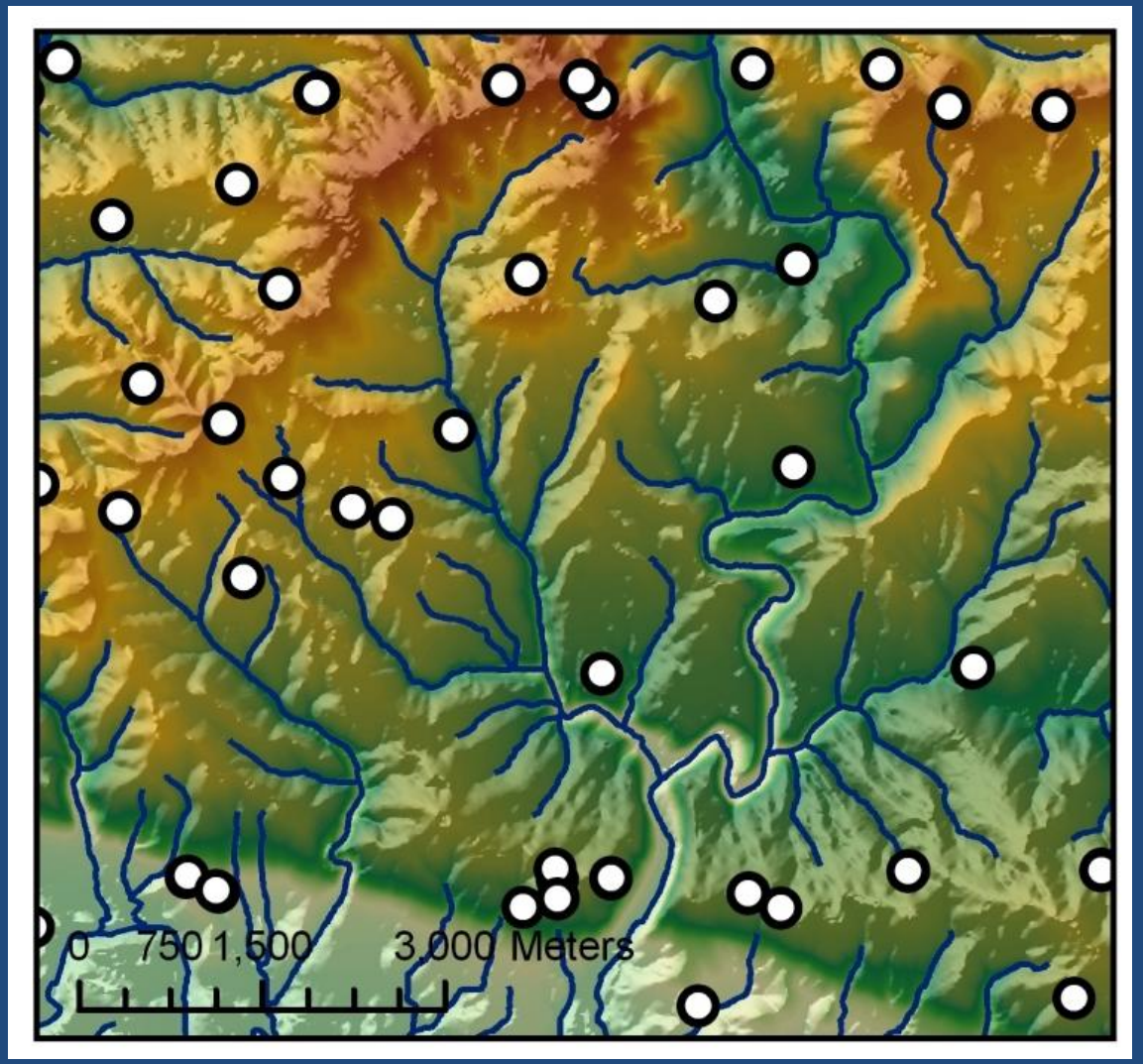


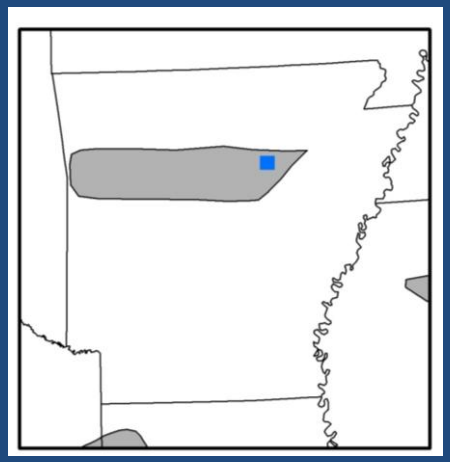
Wells can be close to streams
Fayetteville Shale, AR

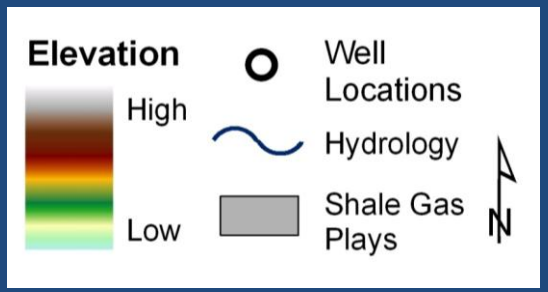
100m
- 12% NHD Flowline

300m
- 61% NHD Flowline

NHD Flow lines





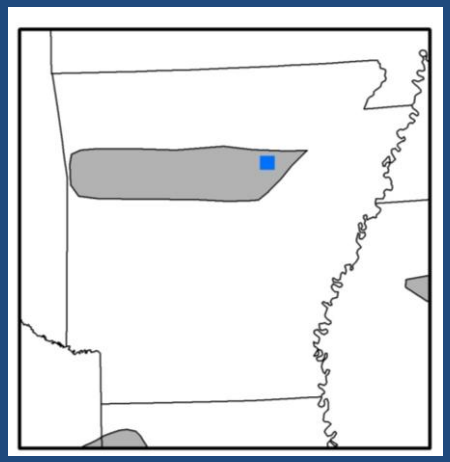


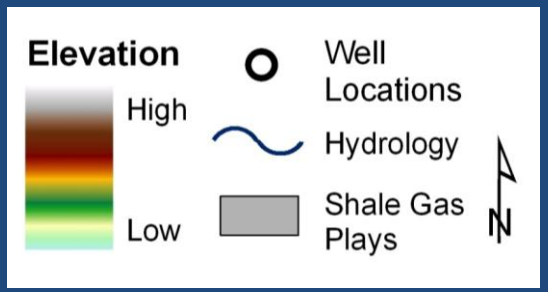
Entrekin, Evans-White, Johnson, Hagenbuch, Frontiers in Ecology and the Environment, 2011

Wells can be close to streams
Fayetteville Shale, AR

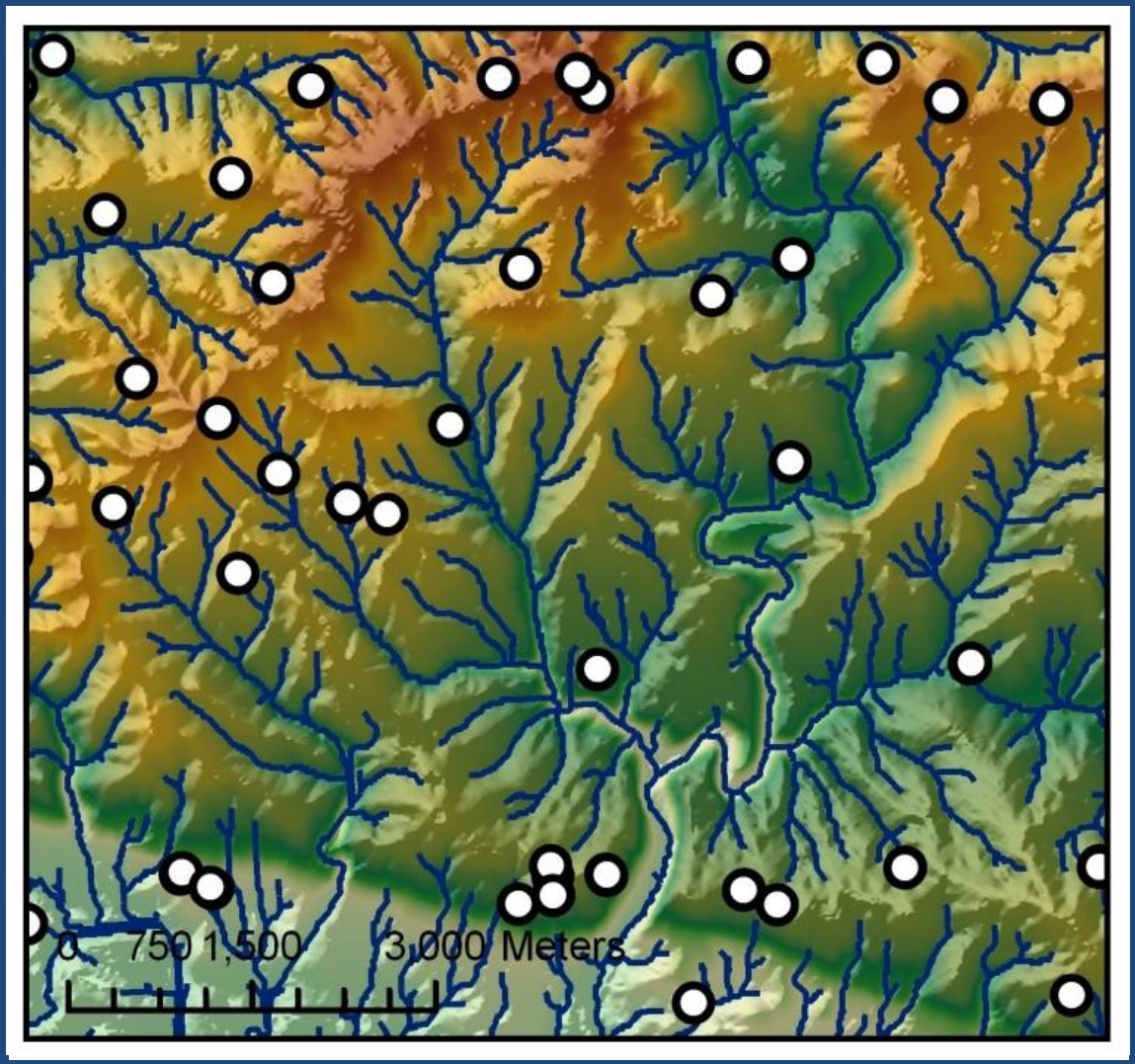
100m
- 12% NHD Flowline
- 32% Drainage Lines

300m
- 61% NHD Flowline
- 82% Drainage Lines





Modeled Flow lines

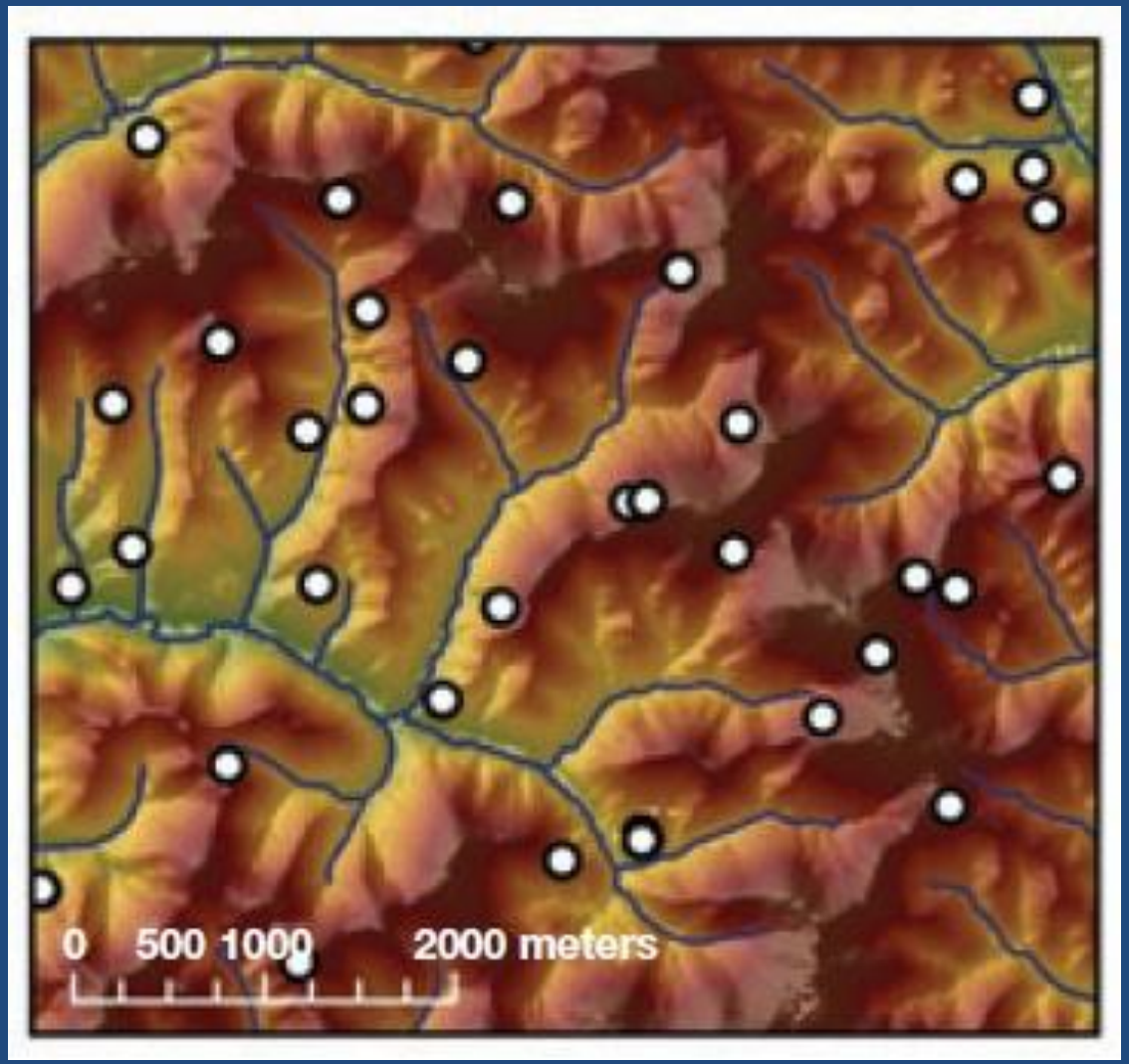


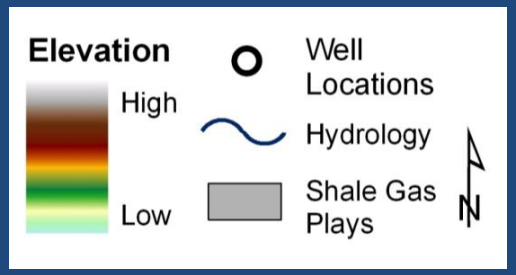
Wells can be close to streams
Marcellus, PA

100m
- 5% NHD Flowline

300m
- 70% NHD Flowline

NHD Flow lines

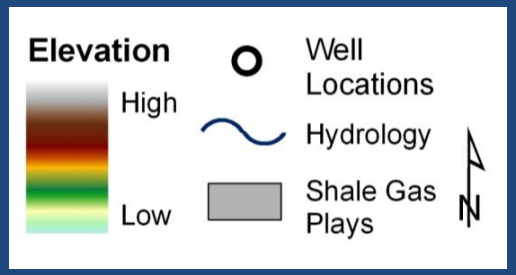




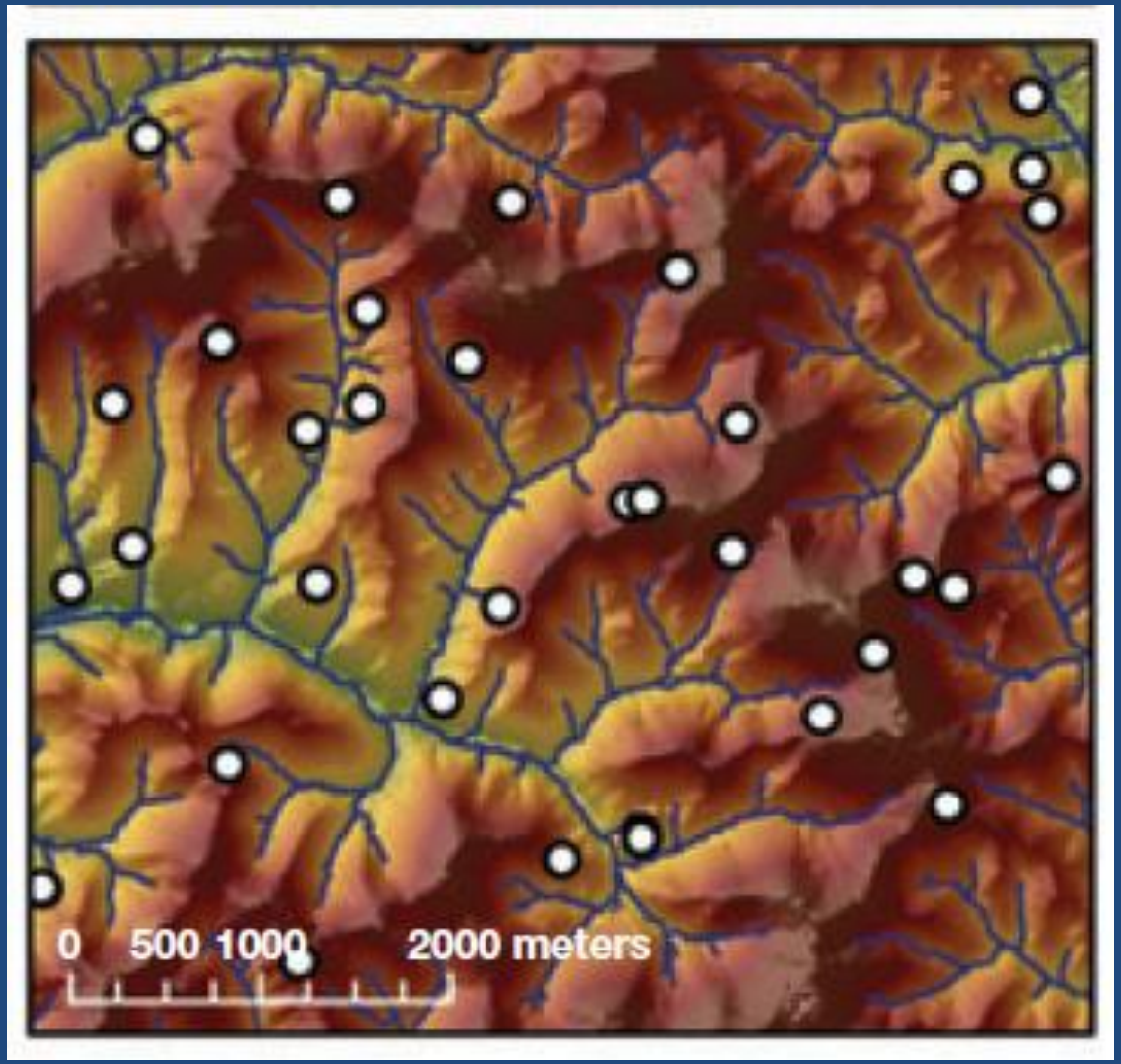
Wells can be close to streams
Marcellus, PA

100m
- 5% NHD Flowline
- 70% NHD Flowline

300m
- 70% NHD Flowline
- 100% NHD Flowline



Modeled Flow lines



Potential threats to surface water

- Water withdrawal
- Contamination
- Sediment

Type of violation	Number of violations	Percent of all violations
Erosion from well site	121	22.2%
Inadequate liner, trash, or other violations in the reserve pit	89	16.4%
Unauthorized discharge into waters of the state	56	10.3%
Oil/fluid spill or staining	54	9.9%

Arkansas Public Policy Panel
September 2011

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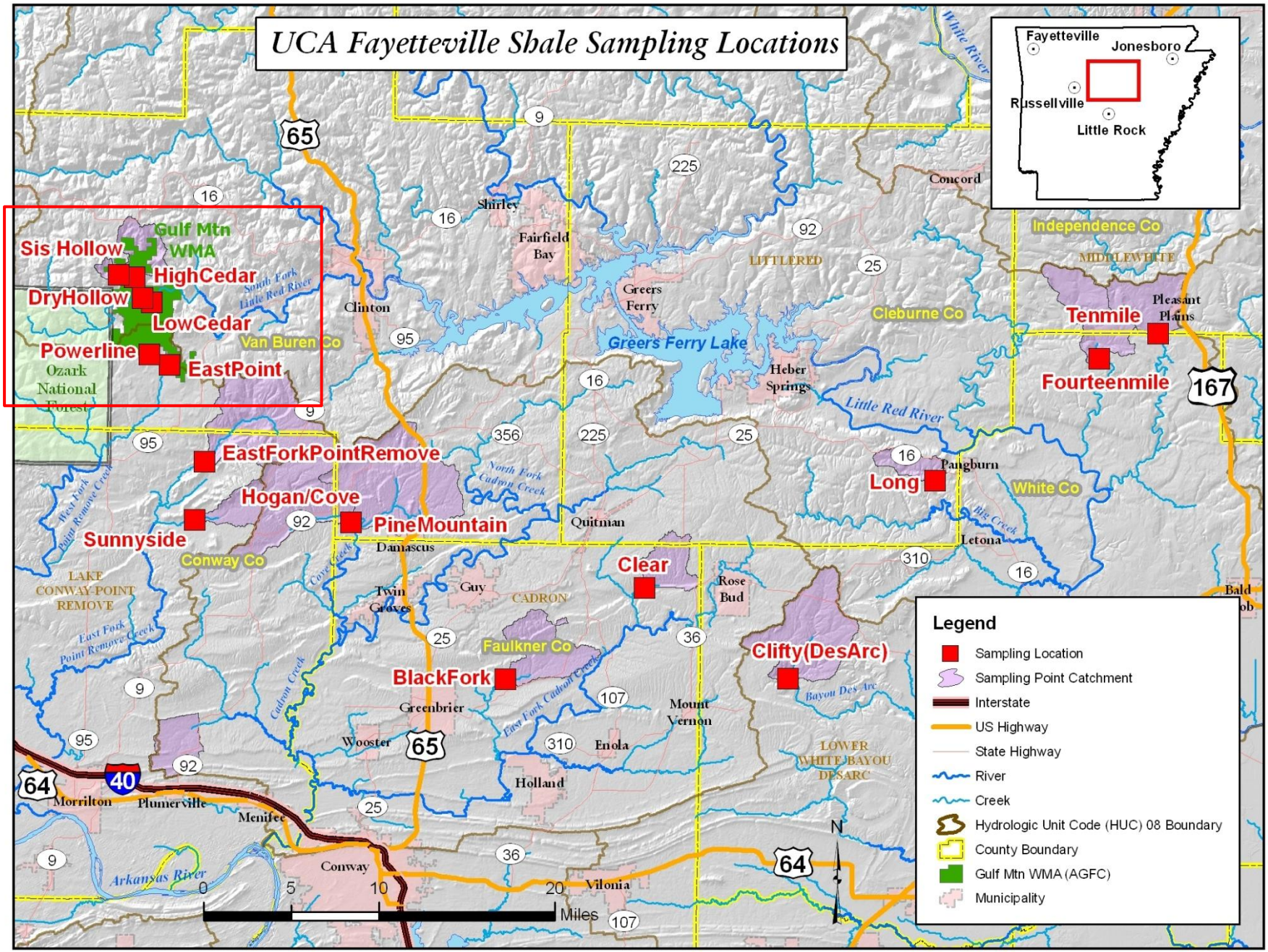
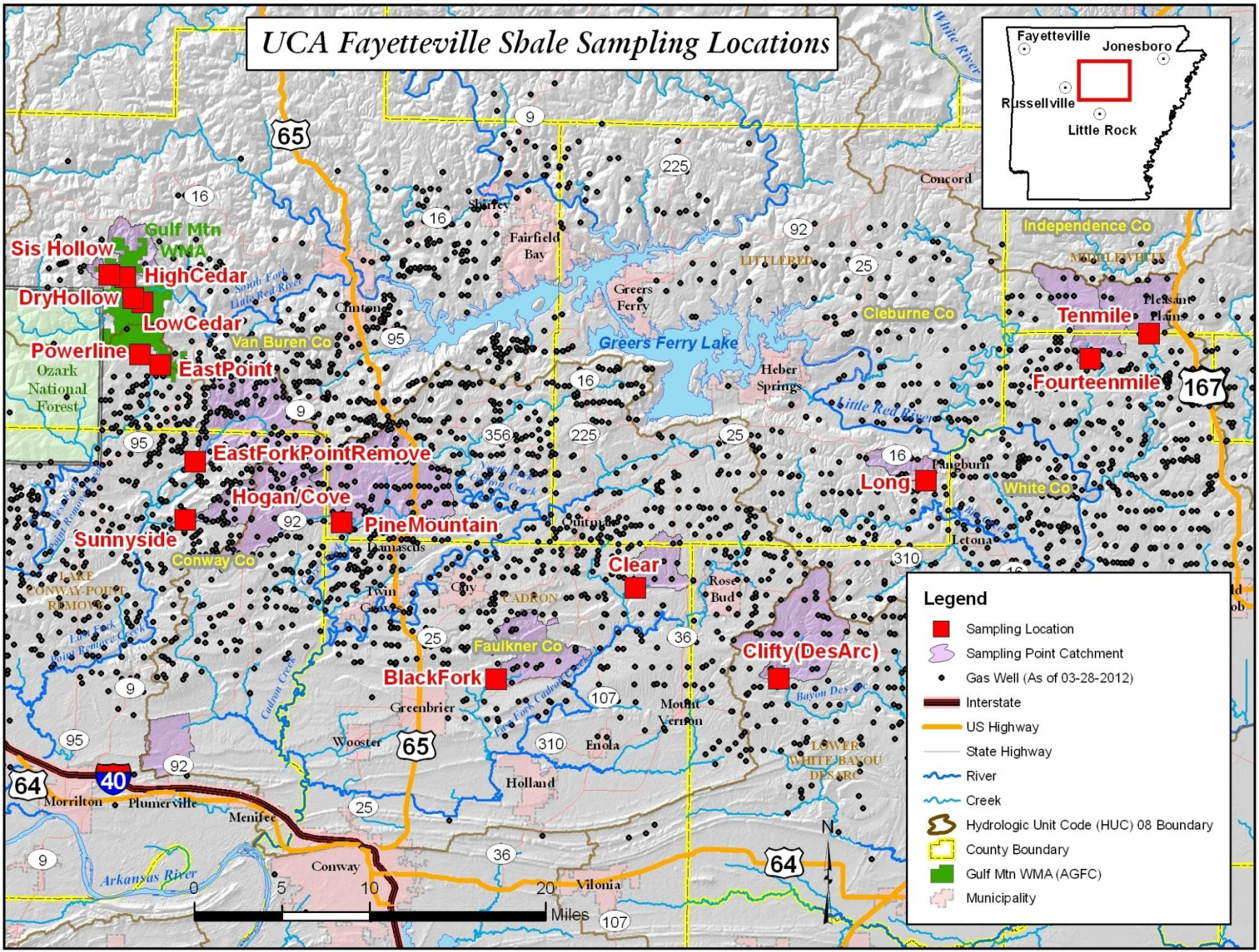
Goal: To assess potential cumulative effects of gas wells on surrounding stream drainages.

Approach:

- Relate turbidity and suspended sediment concentration to surrounding land use in north-central Arkansas.

- Gradient analysis with gas well activity as independent variables and turbidity, suspended sediments, metabolism, macroinvertebrate community metrics as dependent variables.


UCA Fayetteville Shale Sampling Locations
Fayetteville
Jonesboro
Russellville
Little Rock
Sis Hollow
Gulf Mtn WMA
HighCedar
DryHollow
LowCedar
Powerline
EastPoint
Ozark National Forest
Van Buren Co
EastForkPointRemove
Hogan/Cove
PineMountain
Sunnyside
Conway Co
LAKE CONWAY-POINT REMOVE
Clear
BlackFork
Faulkner Co
Clifty(DesArc)
Tenmile
Fourteenmile
Long
Cleburne Co
Independence Co
White Co
Greers Ferry Lake
Little Red River
Legend
Sampling Location
Sampling Point Catchment
Interstate
US Highway
State Highway
River
Creek
Hydrologic Unit Code (HUC) 08 Boundary
County Boundary
Gulf Mtn WMA (AGFC)
Municipality
Miles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Sunnyside
Conway Co
Van Buren Co
Faulkner Co
Cleburne Co
Independence Co
White Co
Tenmile
Fourteenmile
Long
Clear
BlackFork
Clifty(DesArc)
Greers Ferry Lake
Fairfield Bay
Heber Springs
Clinton
Shirley
Concord
Pleasant Plain
Pangburn
Letona
Damascus
Twin Groves
Gley
Rose Bud
Greenbrier
Mount Vernon
Wooster
Enola
Holland
Morrilton
Plumerville
Menifee
Conway
Vilonia
Arkansas River
Cadron Creek
South Fork Little Red River
Little Red River
White River
Bayou Des Arc
0 5 10 20 Miles
N
Legend
Sampling Location
Sampling Point Catchment
Gas Well (As of 03-28-2012)
Interstate
US Highway
State Highway
River
Creek
Hydrologic Unit Code (HUC) 08 Boundary
County Boundary
Gulf Mtn WMA (AGFC)
Municipality

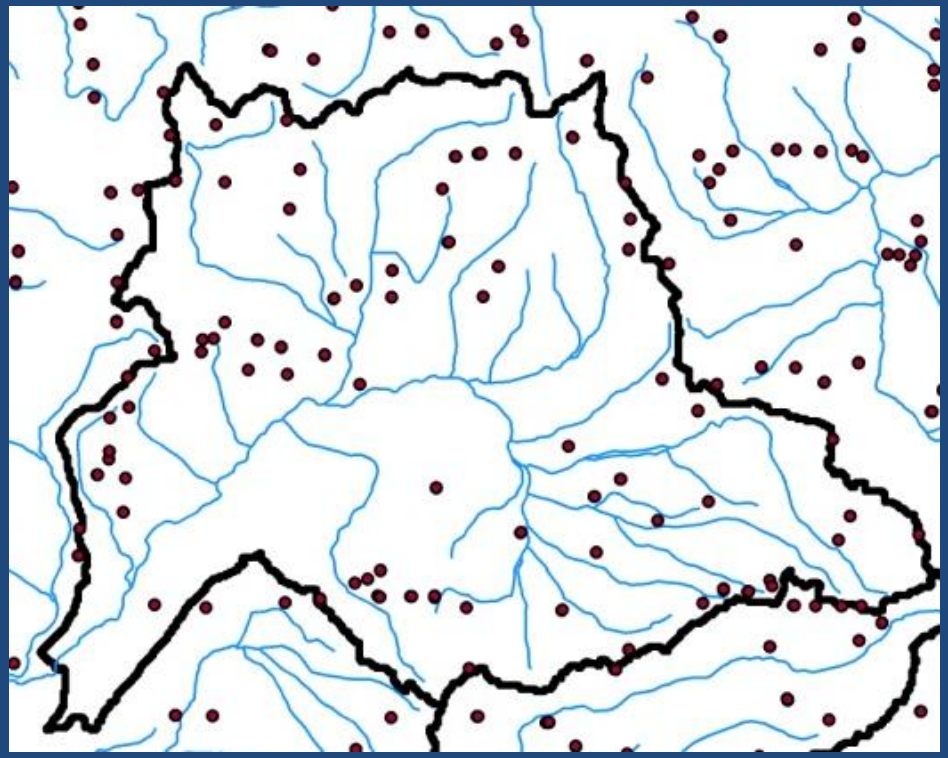
Metrics used to characterize landscape in stream catchments

Land use (%, Gorham and Tullis 2007)
- Pasture
- Forest
- Urban
- Crop

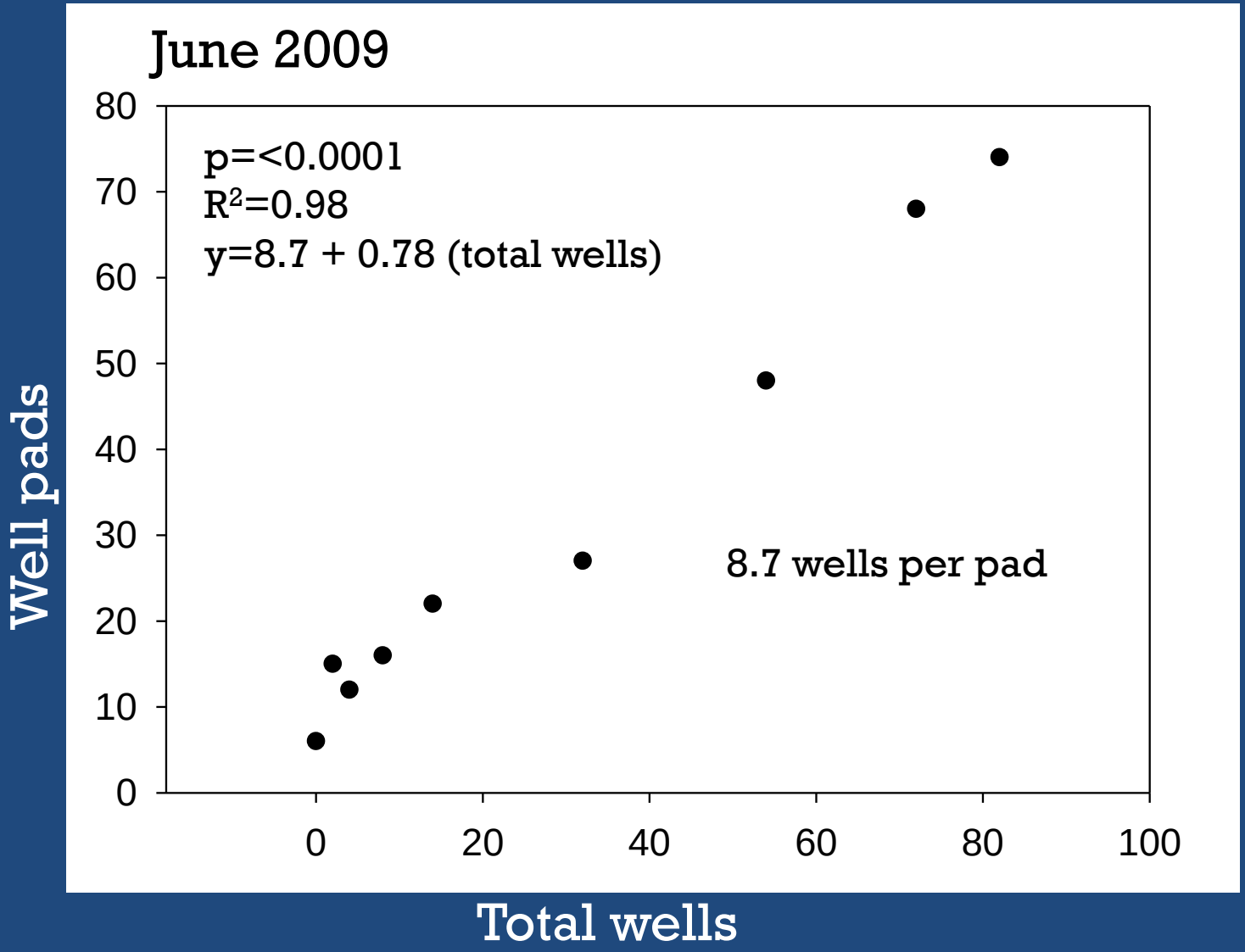
Catchment geomorphology
- Size
- Slope

Gas activity in each catchment
- Total gas wells
- Well density
- Pad density
- Well density prior to one year of sampling
- Rate of gas well activity
- Total flow length from pads

Other features
- Road density
  - Paved and unpaved



Total wells can predict number of gas pads



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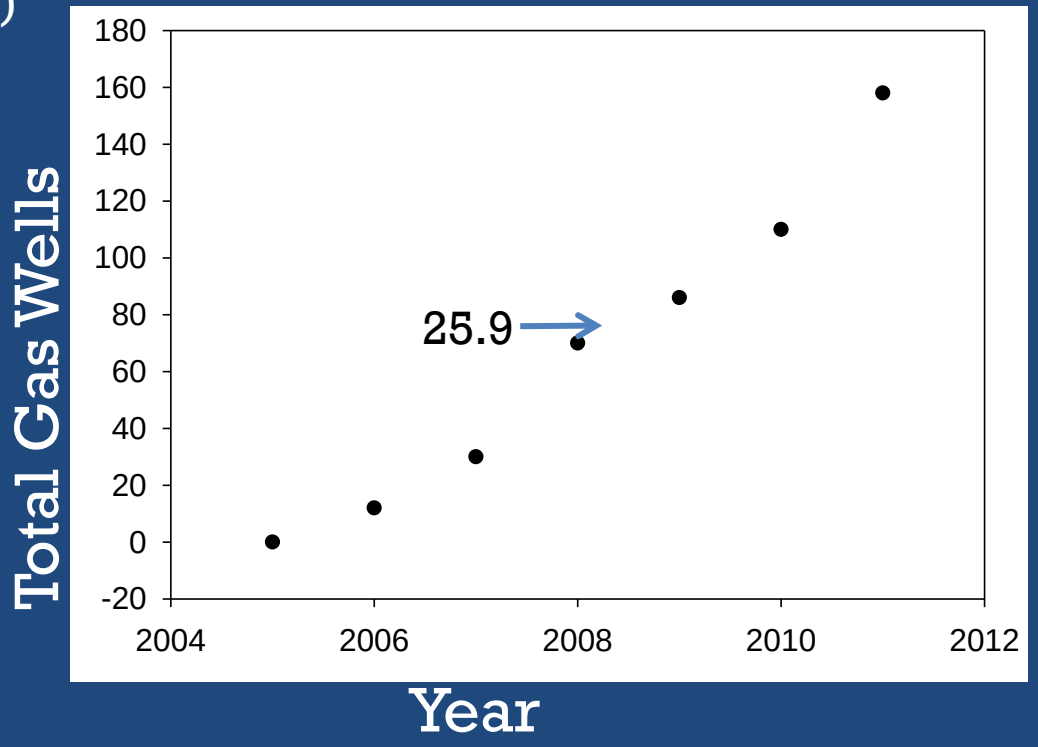
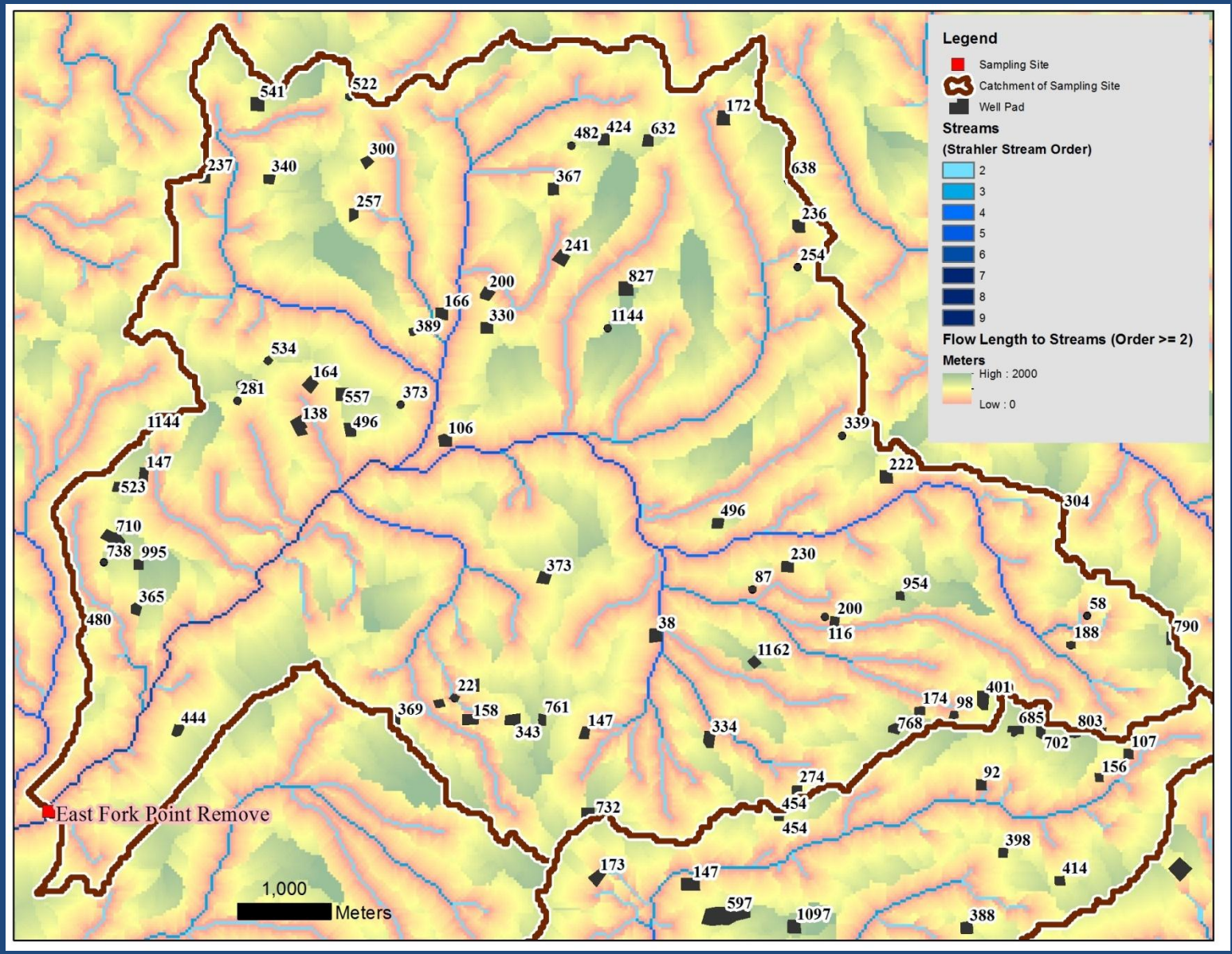


Calculating Flow Length



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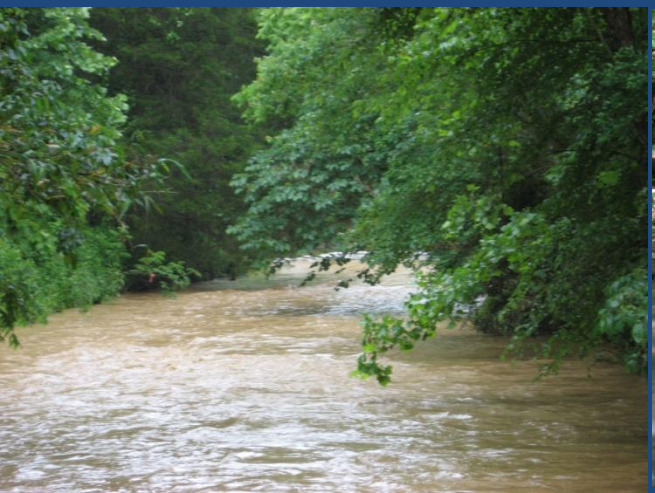
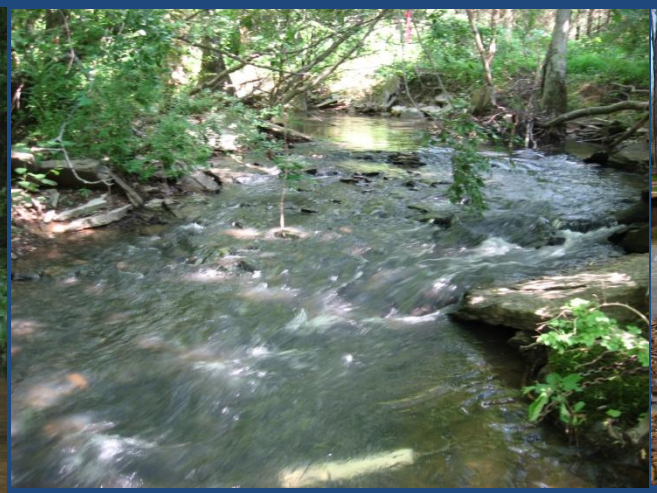
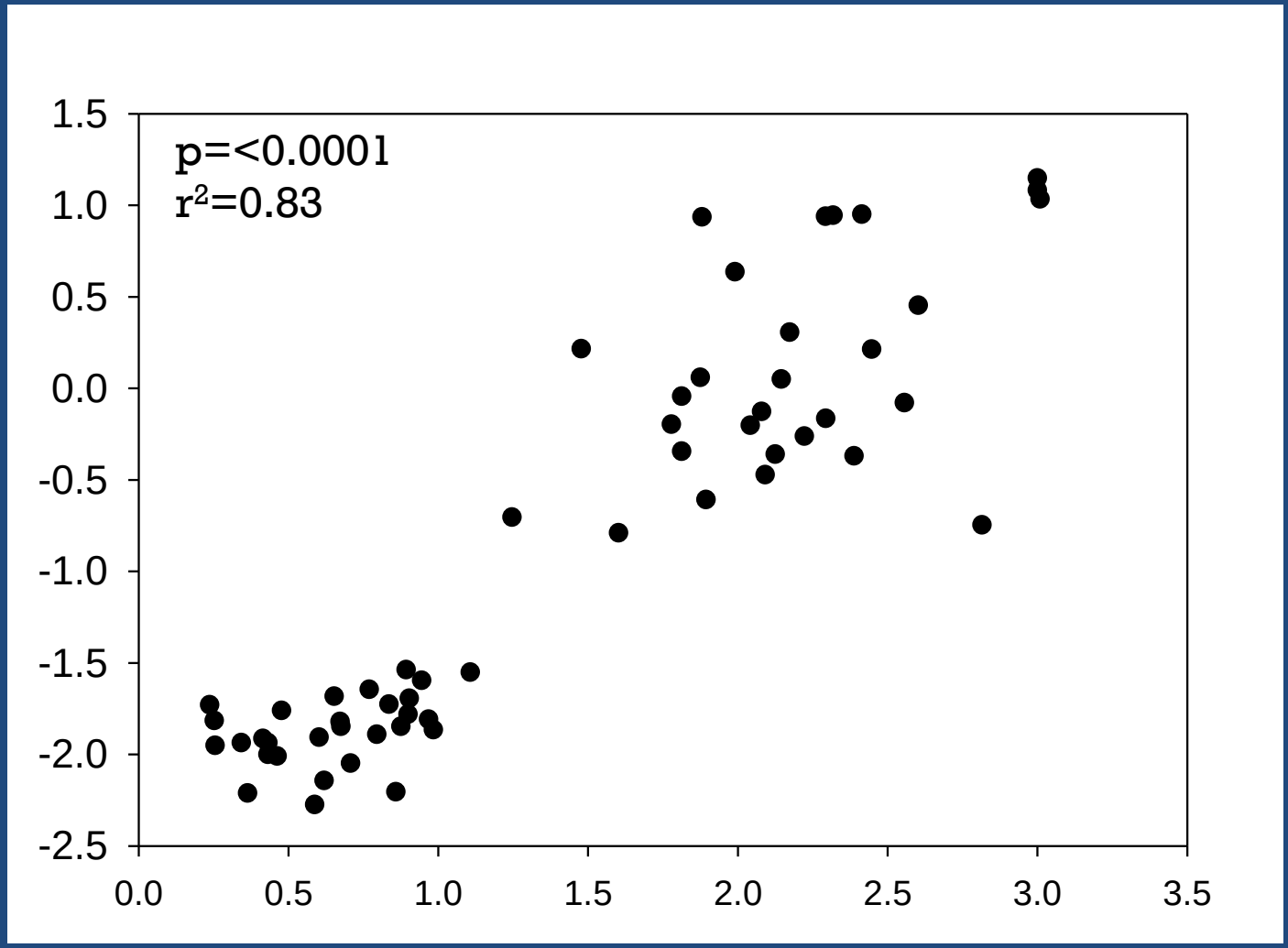
Study site descriptions

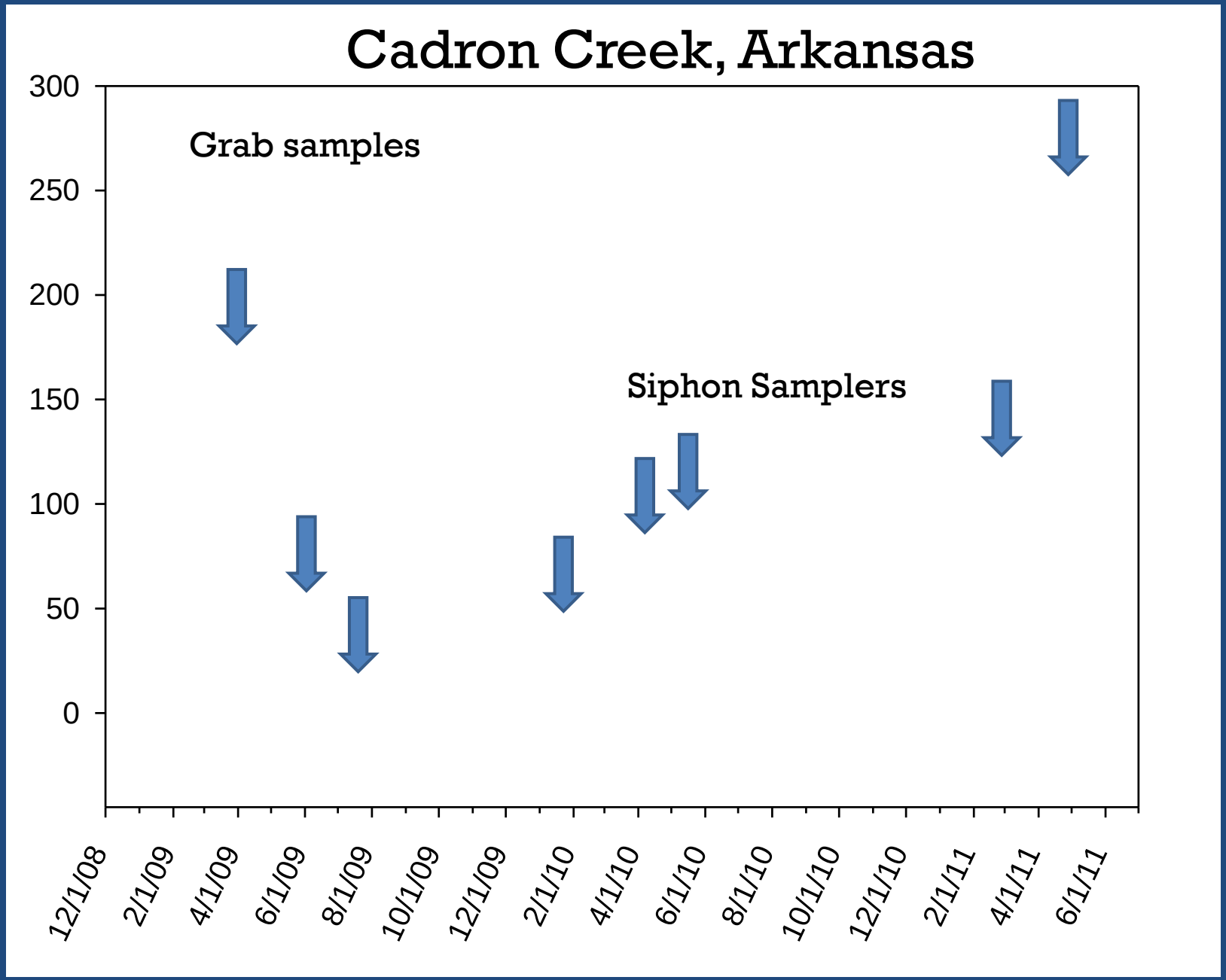
- Well densities: 0.3 to 2.3 wells/km^2
- Catchment size: 12 to 84 km^2
- Land use: 39 to 72% forest
  13 to 50% pasture
- Stream width: ~3 to 6 meters


Turbidity generally predict total suspended sediment during storms

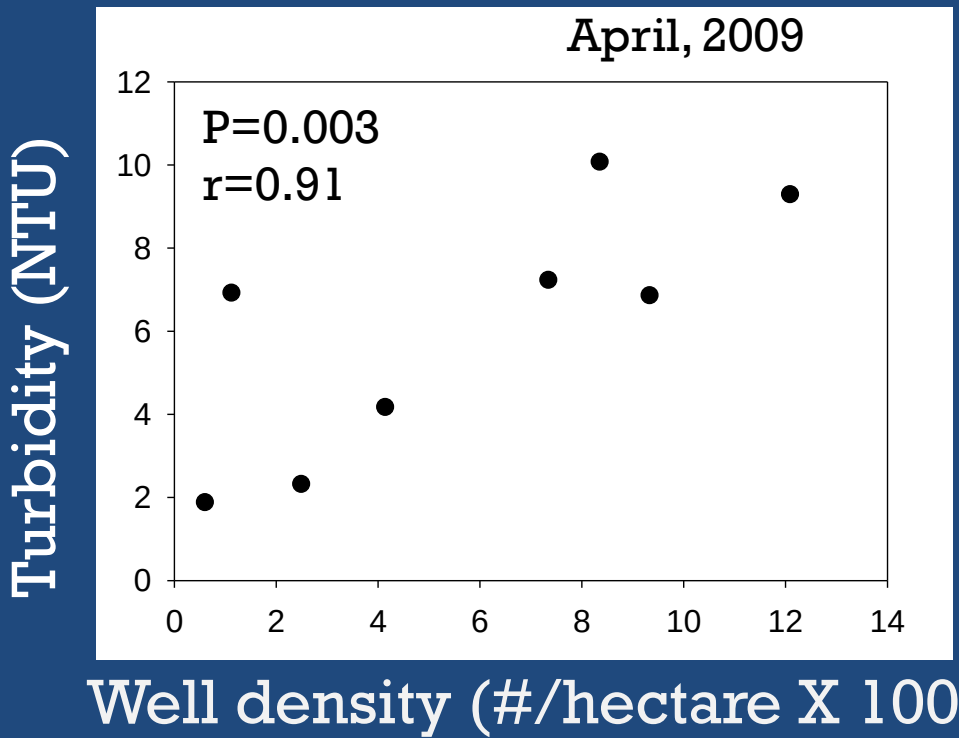


Sample dates



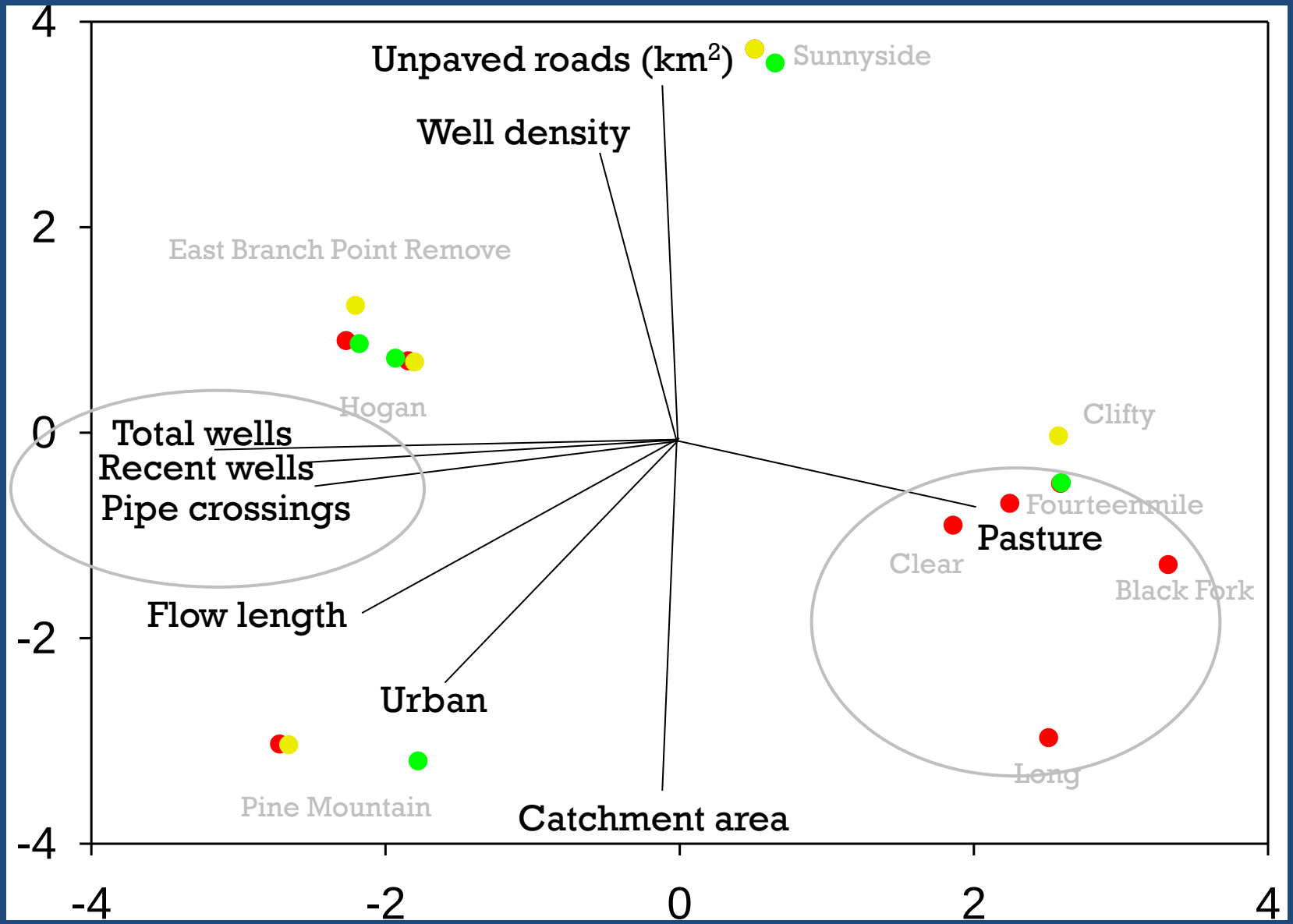
Turbidity increased with increasing well density

- All flow values 40 NTU (ADEQ Reg 2, 2011)
- Biological effects at 5 NTUs (Evans-White et al. 2010)

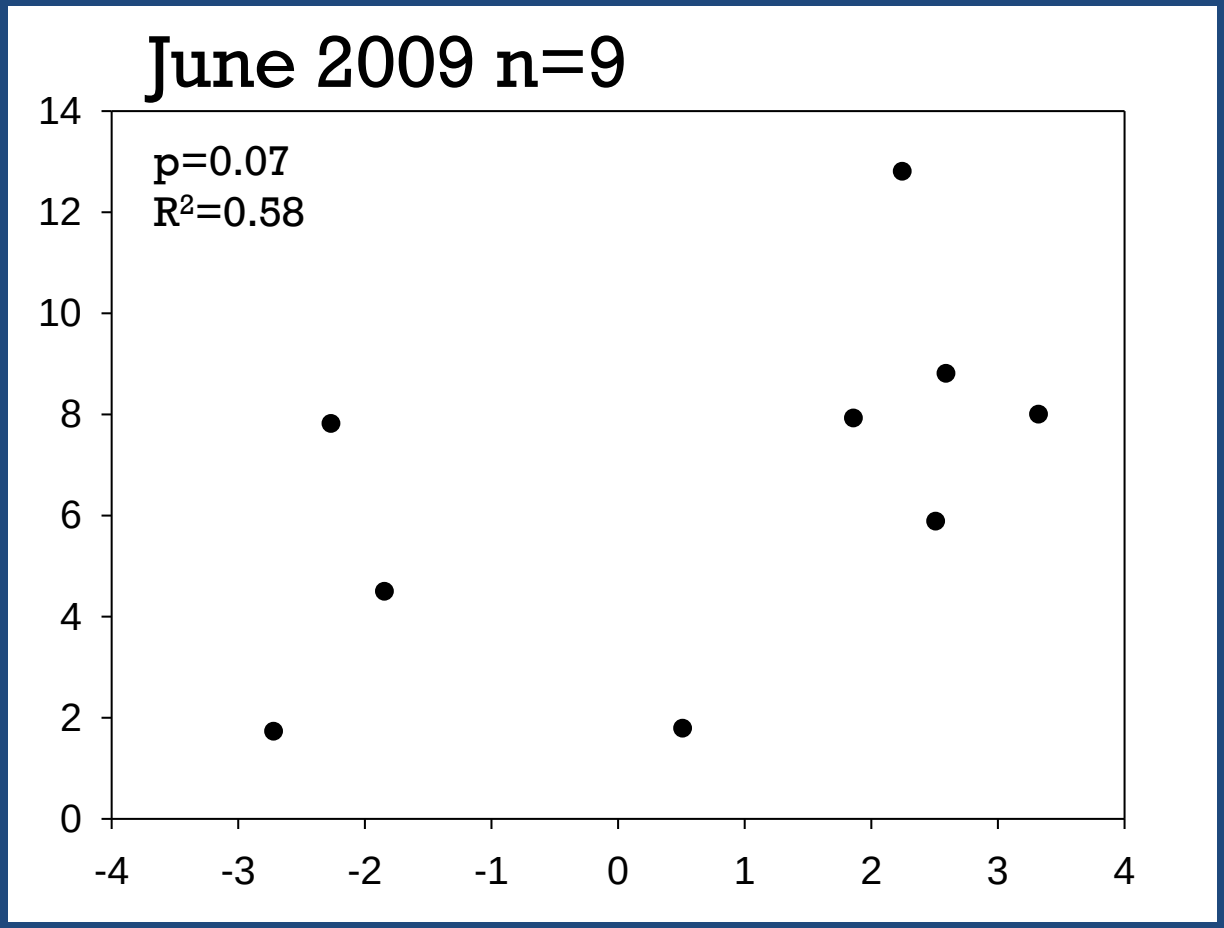


Entrekin, Evans-White, Johnson, Hagenbuch, Frontiers in Ecology and the Environment, 2011

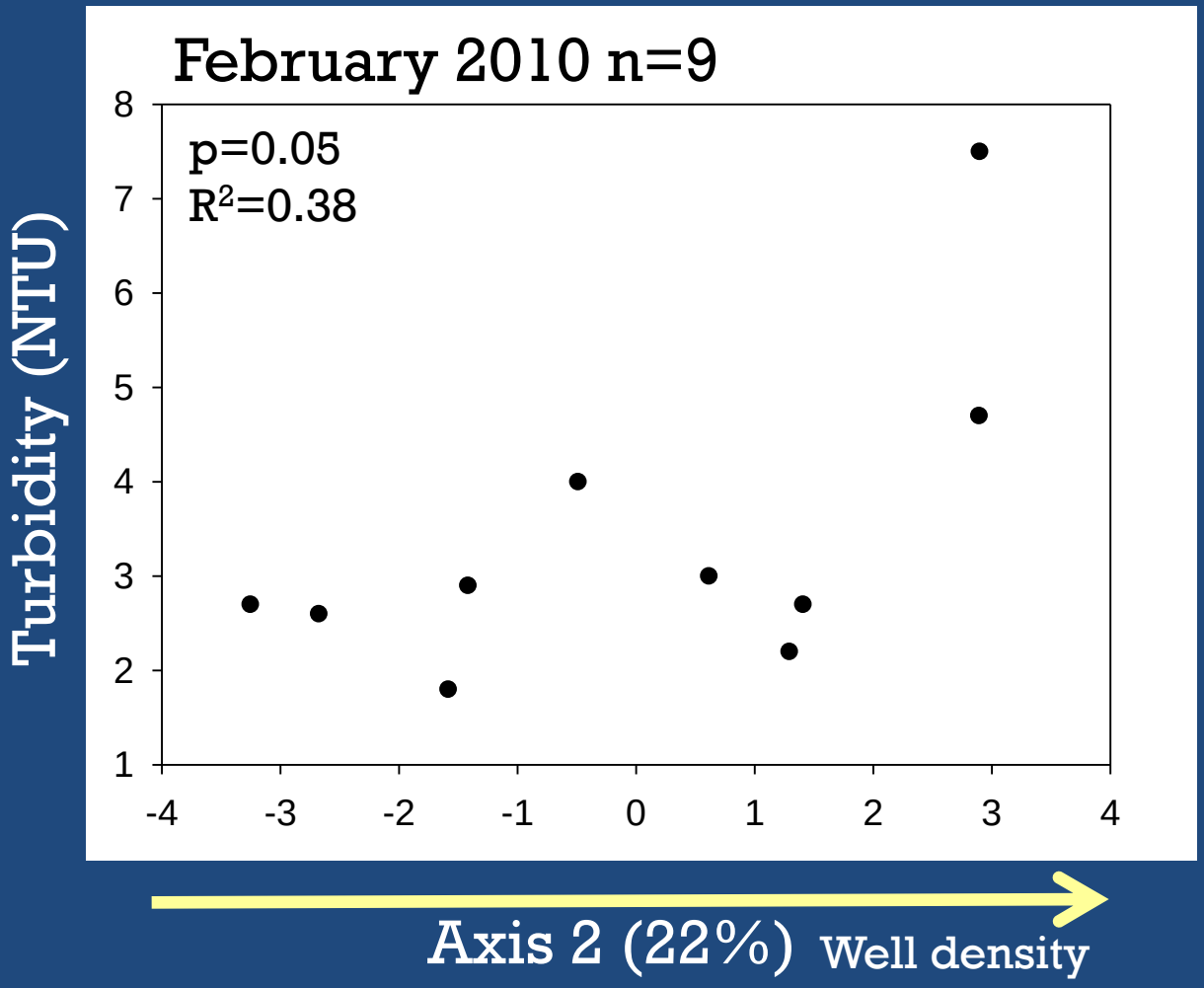
PCA Illustrates catchment-level land uses across study sites in 2009



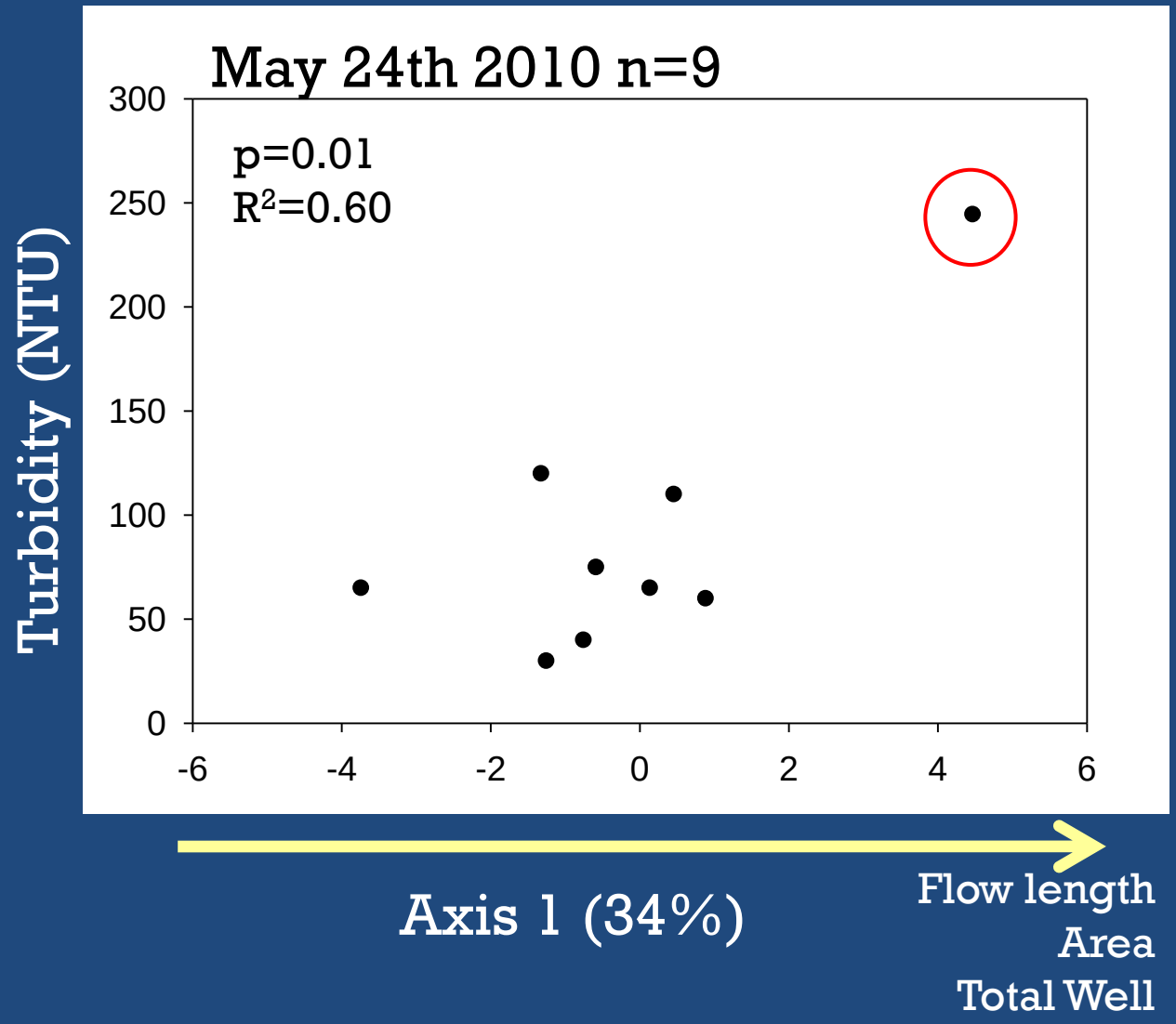
Turbidity was related to pasture and forest



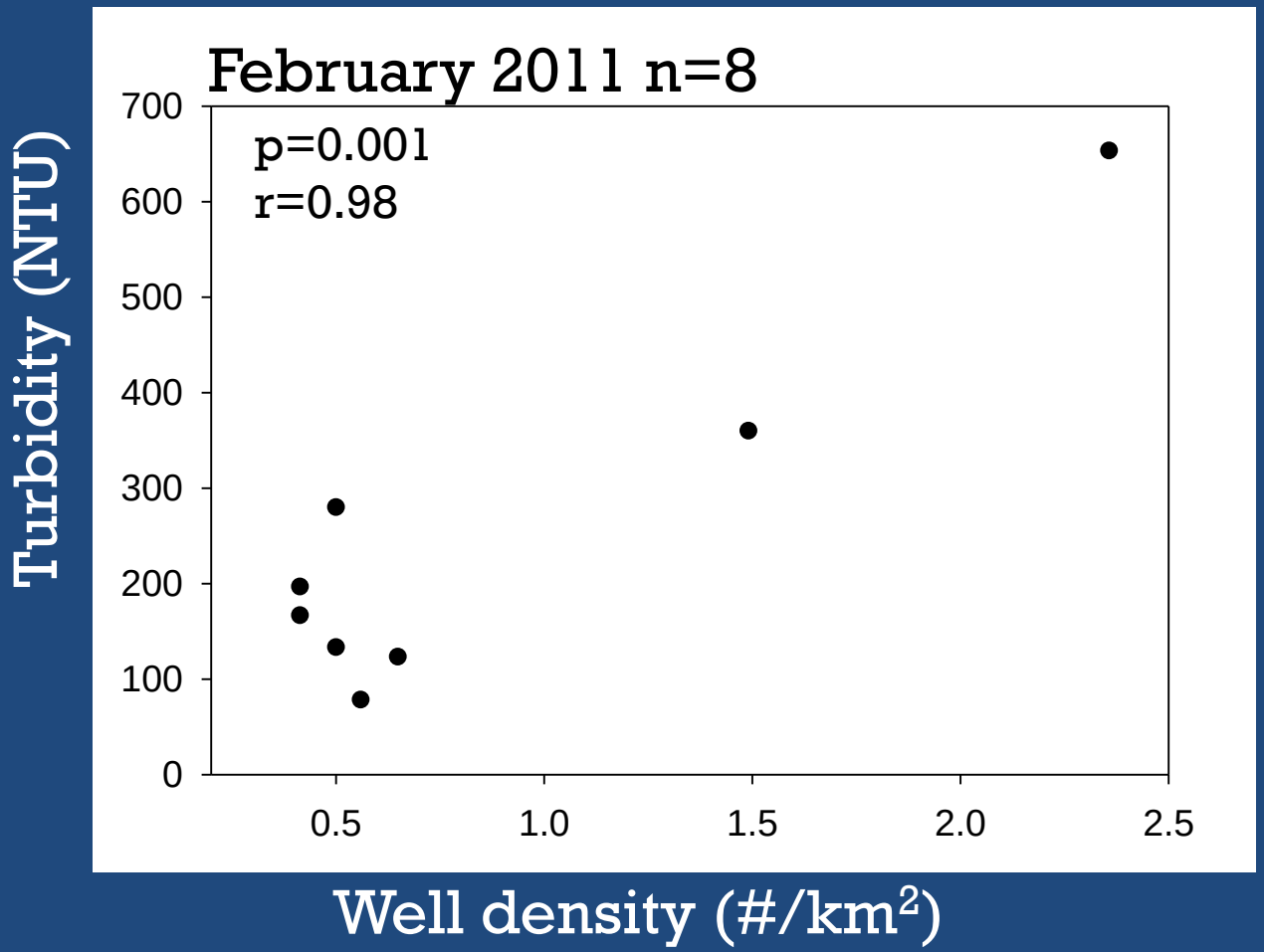
Turbidity was greater in catchments with higher well density



Large watershed with a lot of gas wells drives relationship

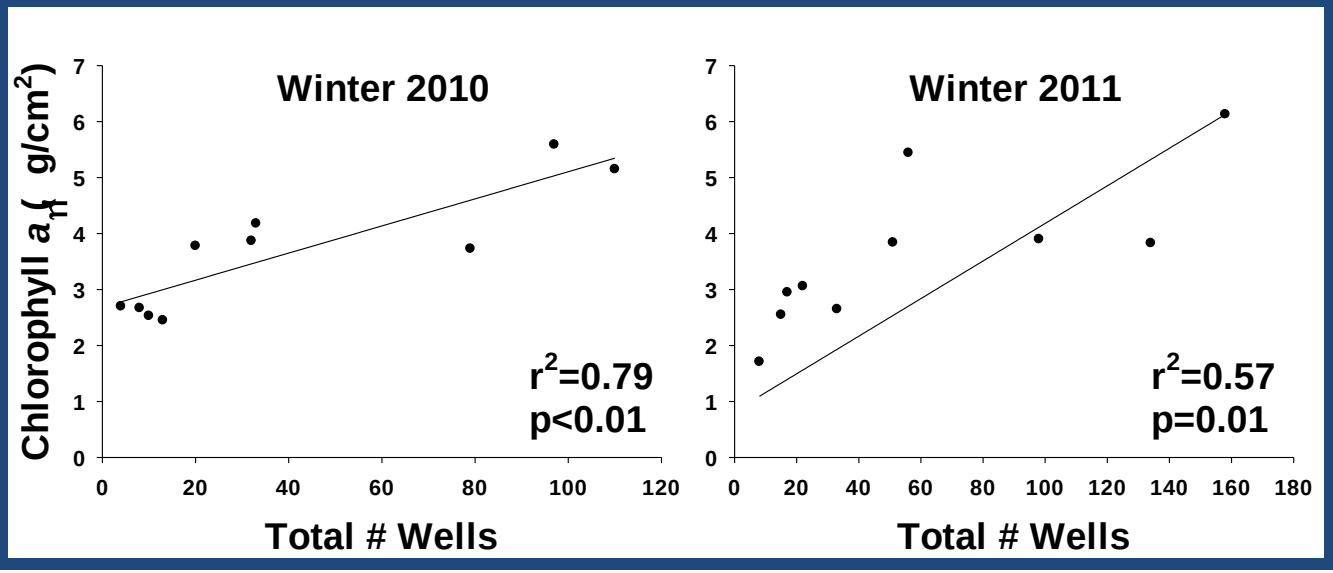


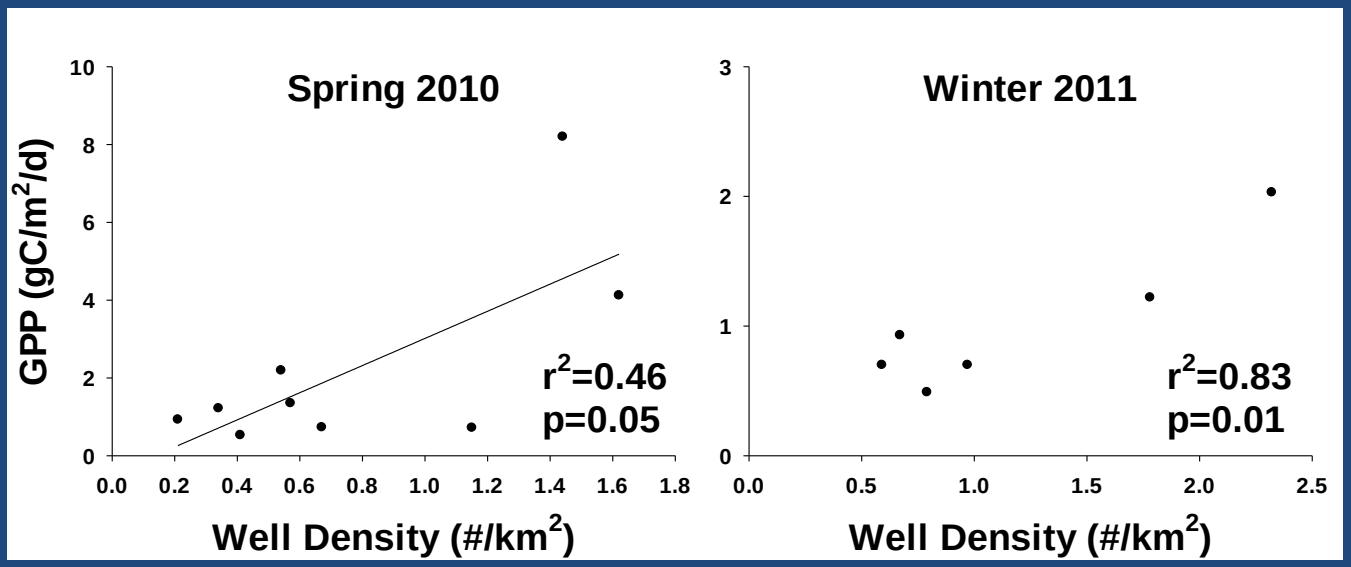
Well density was the only variable related to turbidity



*No relationship with PCA axes

Autotrophic Responses Across A Well Gradient

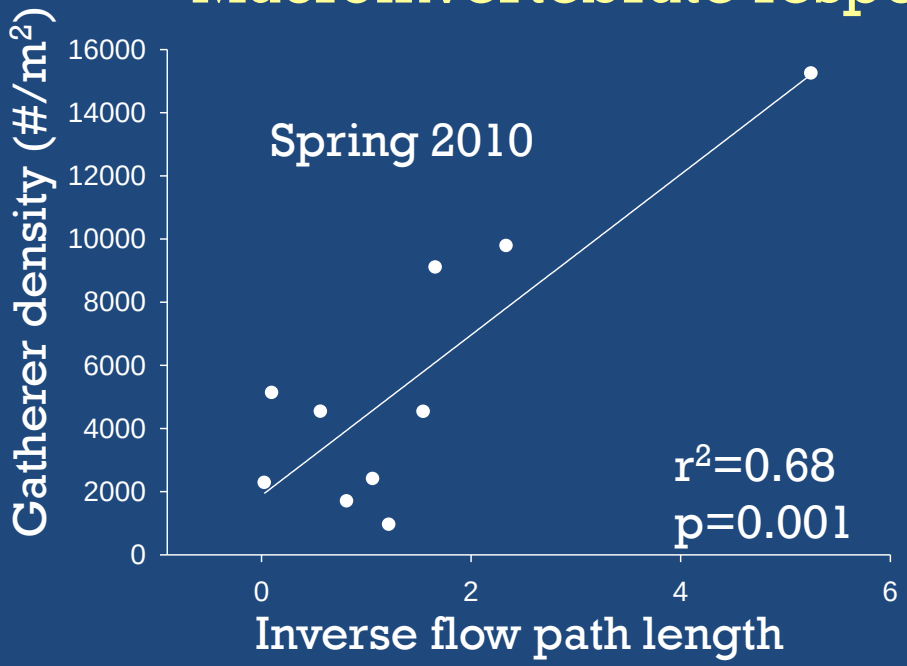


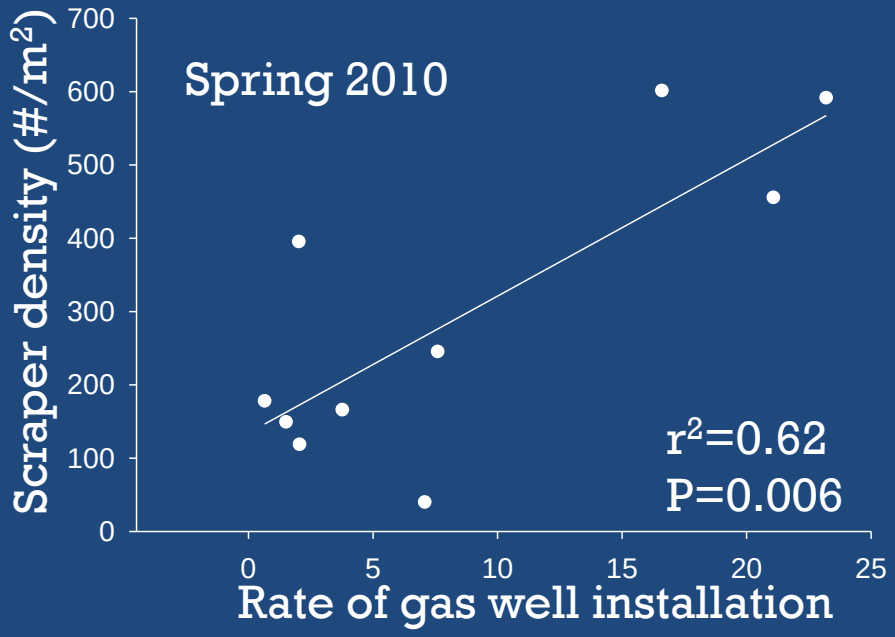


- Chl *a* responded positively or not at all (Spring 2010 & 2011).
- GPP responded positively or not at all (Winter 2010 & Spring 2011).
- No other land use or watershed characteristics explained variation
- Hypothesis: Positive responses due to nutrient or grazer patterns.

Austin and Evans-White, unpublished

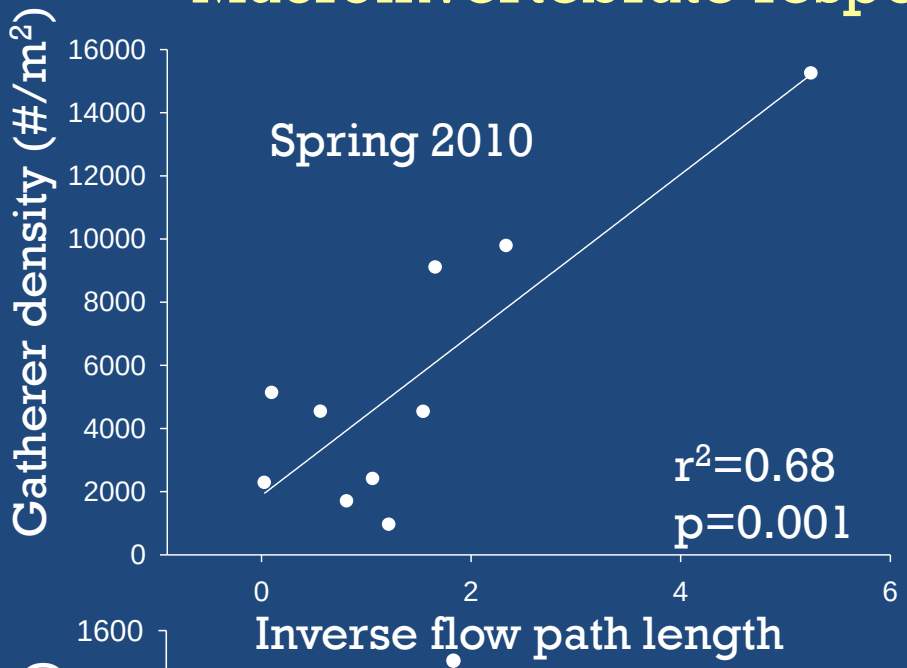
Macroinvertebrate response to gas well development

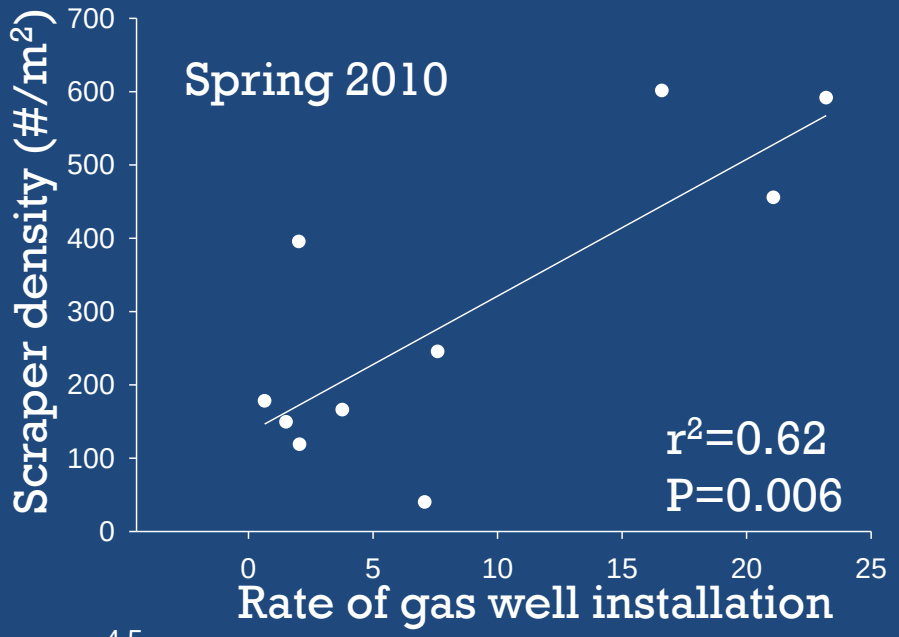


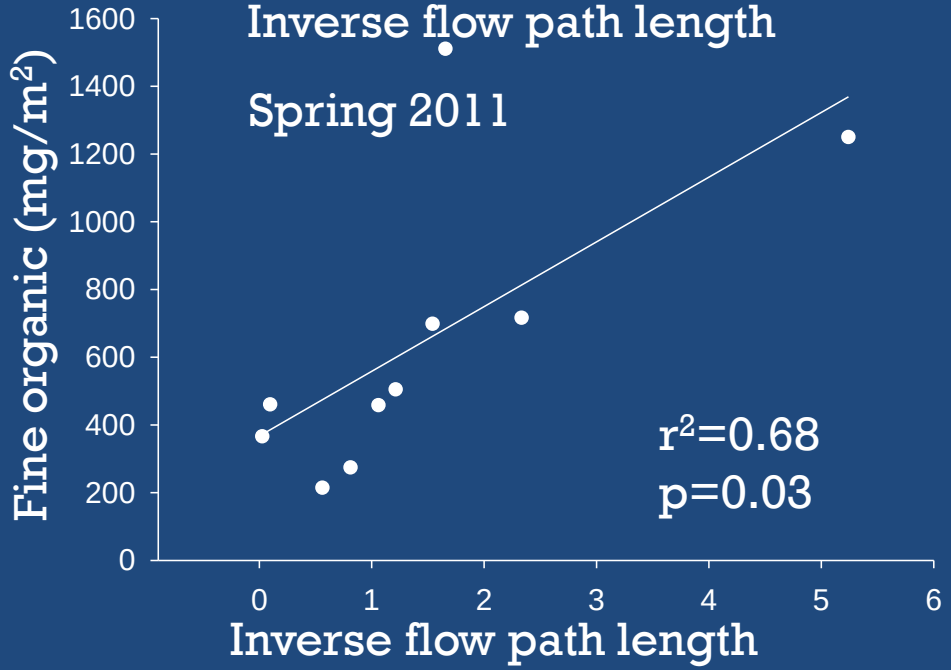


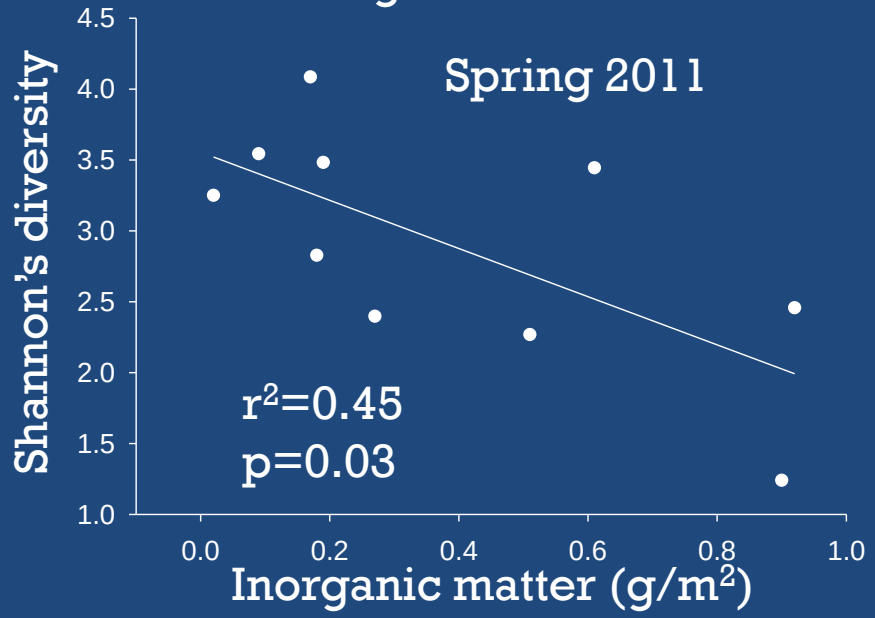
Jensen and Entrekin, unpublished

Macroinvertebrate response to gas well development









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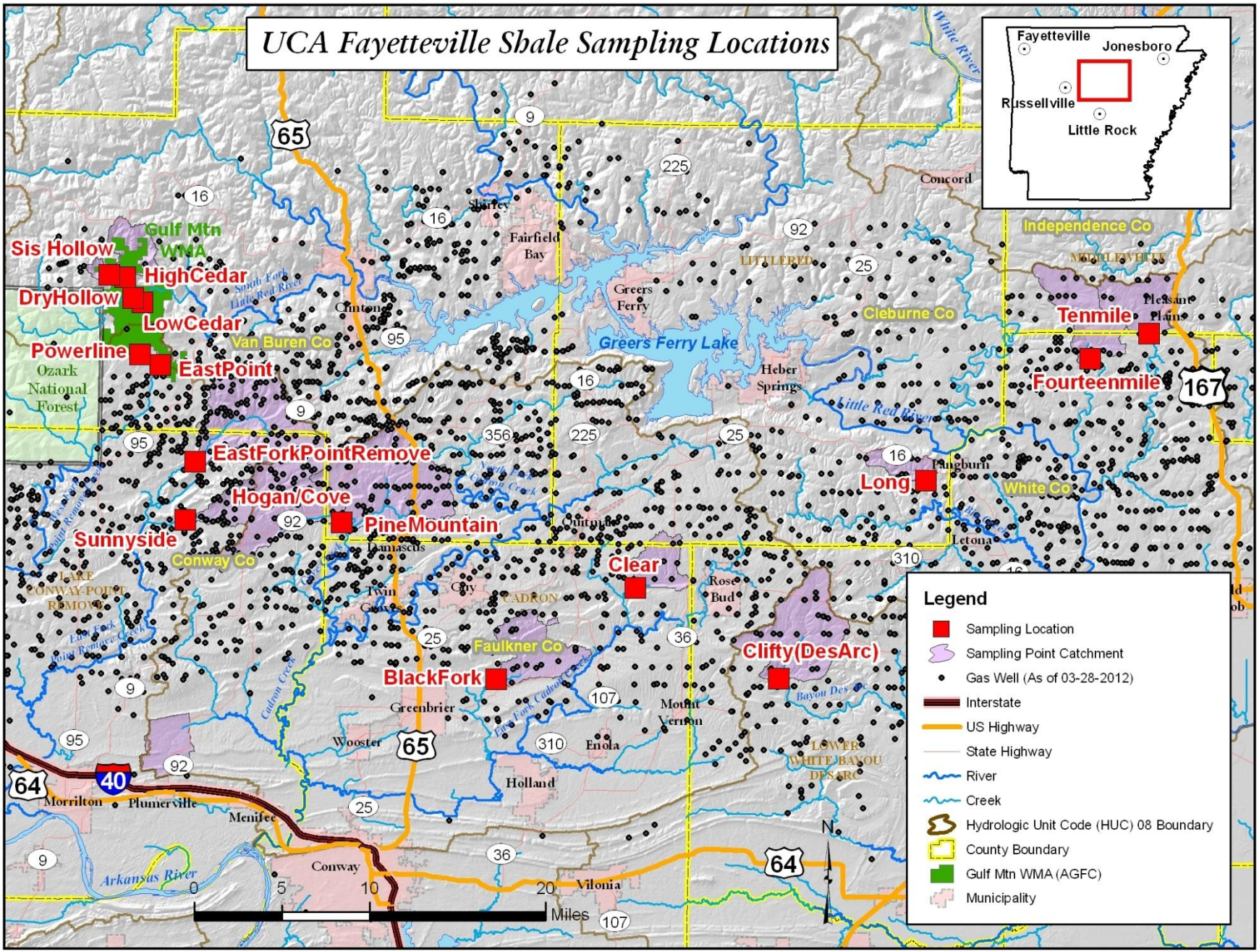
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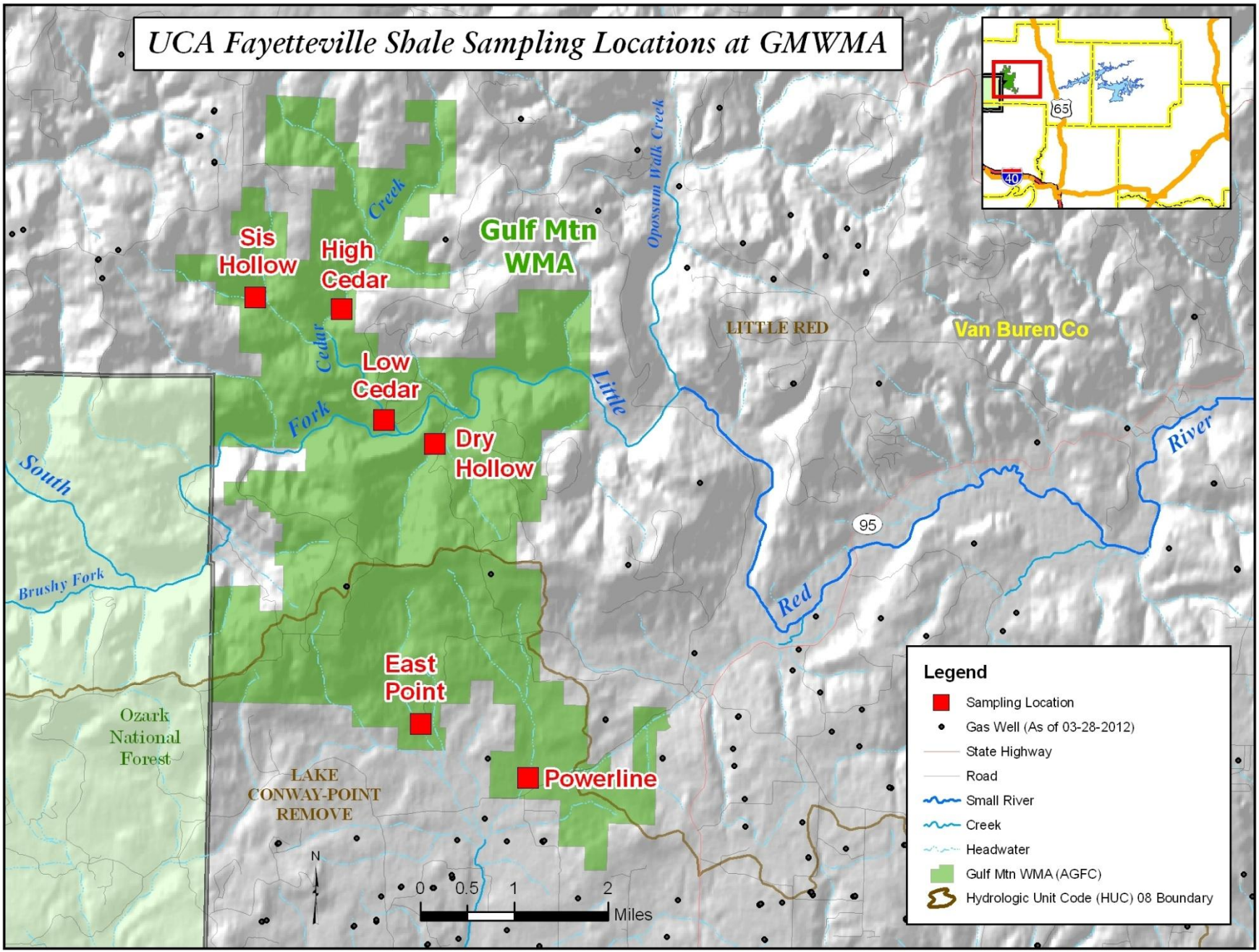
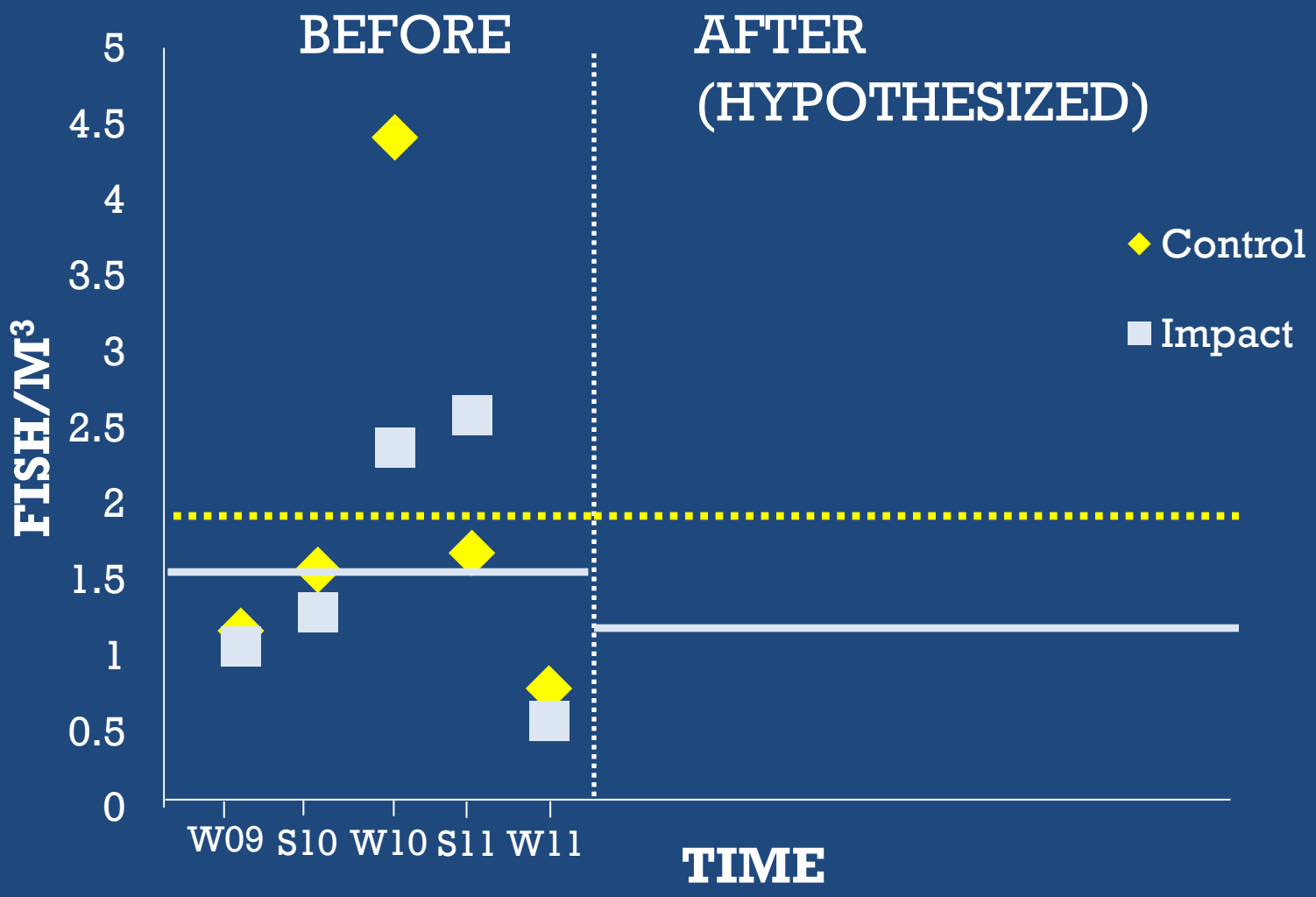
LowCedar
Powerline
EastPoint
Ozark National Forest
EastForkPointRemove
Hogan/Cove
PineMountain
Sunnyside
Conway Co
Van Buren Co
Faulkner Co
Cleburne Co
Independence Co
White Co
Tenmile
Fourteenmile
Long
Clear
BlackFork
Clifty(DesArc)
Greers Ferry Lake
Fairfield Bay
Heber Springs
Clinton
Shirley
Concord
Pleasant Plain
Pangburn
Letona
Damascus
Twin Groves
Gley
Rose Bud
Greenbrier
Mount Vernon
Wooster
Enola
Holland
Morrilton
Plumerville
Menifee
Conway
Vilonia
Arkansas River
Cadron Creek
South Fork Little Red River
Little Red River
White River
Bayou Des Arc
0 5 10 20 Miles
N
Legend
Sampling Location
Sampling Point Catchment
Gas Well (As of 03-28-2012)
Interstate
US Highway
State Highway
River
Creek
Hydrologic Unit Code (HUC) 08 Boundary
County Boundary
Gulf Mtn WMA (AGFC)
Municipality


UCA Fayetteville Shale Sampling Locations at GMWMA
Sis Hollow
High Cedar
Low Cedar
Dry Hollow
East Point
Powerline
Gulf Mtn WMA
Creek
Cedar
Fork
Opossum Walk Creek
Little
River
Red
LITTLE RED
Van Buren Co
95
65
40
South
Brushy Fork
Ozark National Forest
LAKE CONWAY-POINT REMOVE
N
0
0.5
1
2
Miles
Legend
Sampling Location
Gas Well (As of 03-28-2012)
State Highway
Road
Small River
Creek
Headwater
Gulf Mtn WMA (AGFC)
Hydrologic Unit Code (HUC) 08 Boundary

BACI Design
Fish



Green, Stearman, G. Adams, R. Adams, unpublished

Presentation Outline

- Natural gas development in Arkansas
  - Extent
  - Pace
  - Proximity to surface waters
- Approach to quantifying natural gas development
  - Cumulative Effects
  - GIS metrics
  - Gradient analysis versus Before-After-Control-Impact
- Results from gradient analysis study
  - Turbidity and sediment transport during storms
  - Whole stream metabolism at baseflow
  - Benthic macroinvertebrates at baseflow
  - Trace elements and macroinvertebrates
- Results from Before-After-Control-Impact study
  - Macroinvertebrates
  - Fish community structure
- Summary
  - Sedimentation
  - Biological responses to sedimentation
  - Challenges

Take home points

- Episodic increases in turbidity and suspended sediment were related to gas activity at a landscape level

- Quantifiable catchment-scale effects on sediment and biota
  - Winter and Spring
  - Low intensity storms

- Effective metrics for summarizing gas activity
  - Well density
  - Flow path length of gas wells
  - Rate of gas well activity
  - Recent well density

- Biological response
  - More chlorophyll a and faster GPP in streams with more wells and greater density
  - Higher macroinvertebrate density in streams with greater well density
  - Lower macroinvertebrate diversity in streams with more inorganic sediment

On-going research

- Best Management Practices comparison
  - Gulf Mountain Wildlife Management Area
  - Off –Gulf Mountain high intensity development
  - Off-Gulf Mountain low intensity development
- Long –term data in high intensity gas well catchments
- South Fork Little River supports 2 endangered species
  - Water quality
  - Biological communities
  - Ecosystem functions

Challenges

- Accessing updated landscape data
- Experimental design as activity is unpredictable
- Information on implemented Best Management Practices
- Accessing violations to inform data interpretation
- Lack of sophisticated monitoring stations
  - Discharge
  - Water quality

Investigator contacts

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