Continuation: Year 4 of assessing physical, chemical, and biological effects before, after, and during gas well construction in the main stem and tributaries of South Fork Little Red River on Gulf Mountain Wildlife Management Area.

We propose to continue to quantify potential changes in water quality and aquatic biota of headwater tributaries and the main stem of the river in the Gulf Mountain Wildlife Management Area (GMWMA) from natural gas drilling. Further, we will relate water quality and sediment quantity and composition to aquatic biota in the streams draining catchments with wells in GMWMA (6 catchments) to those with high intensity and questionable best management practices (BMPs) in 3 catchments nearby, and 3 catchments with low intensity gas development and questionable BMPs. We have or will sample streams in Gulf Mountain Autumn and Spring 2009, 2010, 2011 and Autumn and Spring 2010 and 2011 on SFLRR. Three well pads have been placed on Gulf WMA and several more are proposed for 2012 along with installation of a 34,000 foot pipeline. We are requesting funds for 1 additional year of funding to continue to study headwaters for a fourth year and main stem of the SFLRR for a third year in GMWMA as infrastructure placement and fracturing continues.

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35% match Requesting $ 249,136 Project total $ 387,934
50% match Requesting $ 243,736 Project total $ 488,100

Overall Project Statement: Project need: Natural gas development is occurring at an unprecedented rate that could impact over 20 states in the U.S.**.** Our past data indicate cumulative effects of gas development on stream water quality and biota in regions where management practices during well development were uncertain (Appendix 1 and 2). We will continue to address the potential effects of natural gas development to a particularly sensitive watershed with threatened taxa (Appendix 3); the SFLRR main stem in north-central Arkansas' Fayetteville Shale gas play as pipelines, roads, and pads are installed and wells are fractured. If funded, we will be able to complete a 4th year of sampling as well as monitor streams as the gas development proceeds on Gulf Mountain Wildlife Management Area (GMWMA).
Region and study site location - Our study sites are located in the Fayetteville Shale of central Arkansas in intermittent streams spanning the Arkansas Valley and Boston Mountain ecoregions (Appendix 4) and SFLRR on GMWMA (Appendix 5). Study sites off near GMWMA are in the 1st and 2nd congressional districts. Gulf Mountain study areas fall within the 2nd congressional district located in Van Buren County.

Objectives – Sampling will occur from autumn **2012 to autumn 2013**. We will sample variables outlined below twice a year, unless noted otherwise, in spring and in autumn or early winter. In addition, funds will contribute to the continued maintenance of real-time water quality monitoring, discharge gaging and storm sampling of the SFLRR by USGS. Our primary objective is to quantify potential alterations in water quality in the SFLRR main stem and headwater streams in Gulf Mountain WMA. We began sampling these streams in autumn 2009 and have sampled twice a year since. We are also analyzing differences in water quality in catchments with *high intensity and questionable BMP* implementation near Gulf Mountain (Sunnyside, Black Fork, and East Point Remove catchments), *low intensity and questionable BMPs*, and *low intensity developing gas well infrastructure with rigorous BMP implementation*. The biological data from the tributaries will be used as a comparison to parallel data collected on the main stem of the SFLRR in Gulf Mountain WMA.

Headwater approach: We are using before-after-control-impact factorial analysis to detect changes in chosen biological attributes following drilling and fracturing. In addition, a suite of multivariate statistics will be used to further examine potential biological effects from pipe line, road, and reservoir densities. Study sites were chosen based on catchment size, land use land cover, and well density. We will add the collection of stream water level to the tributary sampling to address how changing hydrology relates to species distributions and water quality.

Measured variables

1. Five benthic sediment samples from each of 12 stream reaches at low flow and sampled using a core, collecting a known volume of slurry, and filtered in the laboratory. Sediment content and volume will be quantified. (PI Entrekin) (1 year x 2 sampling dates x 12 stream reaches x 5 cores=100 total samples. Composite sediment samples from each of the 12 streams will be collected, sieved to particles less than 2 or 4.5 mm, extracted using a Mehlich III method, and analyzed on a separate ICP in the Agricultural Diagnostic Lab to detect Al, B, Ca, Cu, Fe, K, Mg, Mn, Na, P, S, and Zn. (1 year x 3 cores x 12 stream=36 samples AWRC)

2. Storm sampling using two siphon samplers placed at each of the 12 study sites to capture suspended sediments will be collected twice a season. One set of samplers is set 10 cm above base flow and the other is set 30 cm above base flow. We aim to sample 1 year x 2 storms x 4 seasons x 2 samplers per stream reach x 12 stream reaches=192 total samples Entrekin PI). In addition, composite sediment samples from each of the 12 streams will be collected and analyzed from storm samples. Sediments will be extracted using a Mehlich III method described above (1 year x 12 stream=12 samples AWRC)

3. Ten benthic invertebrate samples will be collected in each stream reach within each representative habitat using a 250 µm mesh Hess sampler. Invertebrates will be collected, preserved in ethanol, enumerated, identified, and biomass will be estimated. (PI Entrekin) (1 year x 2 sampling dates x 12 stream reaches x 10 cores=240 total samples).

4. Fish will be sampled at base flow with triple pass electro-fishing. Fish taxa richness, density, and biomass will be quantified. Fish that cannot be identified in the field will be preserved in 10% formalin and taken to the laboratory. Individual fish will be identified and weight and length measurements recorded. (PI G and R Adams).

5. Periphyton chlorophyll *a* and ash-free dry mass will be collected at each site twice (2 seasons x 12 reaches x 10 cobbles = 240 total samples). Whole-stream metabolism will also be measured in each stream twice (24 estimates). Two water grab and siphon storm samples will be taken for dissolved N and P at each site (4 samples x 12 reaches = 44). (PI Evans-White).

6. Grab water (N=10) and siphon storm samples (N=2) will be taken from each site and will be analyzed for conductivity, turbidity, dissolved trace elements (e.g., arsenic, copper, cadmium, calcium, chromium, iron, magnesium, manganese, zinc) using inductively coupled plasma optical emissions spectrometry (ICP–OES ; 12 samples x 12 reaches; PI Haggard).

7. Each catchment will have a characterization of the land cover, well densities, and unpaved roads identifying total length, density, and hydrologic proximity to streams. Gas infrastructure will be quantified in each catchment as total length of gas pipelines, their proximity to streams, the number of well pads, and their proximity to the stream. Spatial data will need to be updated seasonally (TNC).

SFLRR approach:

1. The USGS currently maintains continuous water–quality monitors that measures turbidity, specific conductance, temperature, dissolved oxygen, and pH; collects rise, peak and fall water samples from three storm events; and operates discharge monitoring stations (http://ar.water.usgs.gov). Funds from this proposal will be used to help support these activities which are not funded by other sources.

2a. Collect water samples at four established sites along the South Fork of the Little Red River. The AWRC will collect grab water samples at each of the four sites monthly. The total number of samples collected will be at least 12 grab samples per year during base flow conditions. The USGS will collect rise, peak and fall water samples during three separate storm events, where the USGS will collect equal-width-increment (EWI) samples following standard protocols. All water samples collected will be delivered to the AWRC Water Quality Lab.

2b. Analyze water samples from the South Fork of the Little Red River. The collected water samples will be stored on ice, in the dark and then delivered to the AWRC Water Quality Lab within required holding time. Water samples will be analyzed for conductivity, turbidity, anions, total suspended solids, and total organic carbon. Select water samples will be analyzed for dissolved trace elements using ICP–OES.

3. Collect macroinvertebrate samples and identify organisms to the lowest practical taxonomic level at the four established stream locations seasonally (i.e., twice a year). Macroinvertebrates will be quantified in spring and autumn for one year in each reach by the University of Central Arkansas. Five benthic invertebrate samples will be collected [during base flow conditions only] in riffles. Invertebrates will be collected with a modified Hess, preserved in ethanol, enumerated, identified to lowest practical taxonomic level, and biomass will be estimated.

4. Determine benthic sediment composition at the four sites along the South Fork of the Little Red River. Fine benthic sediments will be sampled twice in each reach (2 seasons x 4 reaches x 5 cores= 200). Fine sediments will also be collected once for Mehlich III extractions and analyzed for trace elements on an ICP-OES (4 reaches x 3 samples = 12). Periphyton samples will be taken twice (2 seasons x 4 reaches x 10 cobbles = 80). Metabolism will be estimated from USGS continuous dissolved oxygen data (2 sites x 10 days = 20). (PI Evans-White)

Expected benefits and results: The combination of SFLRR main stem and tributary parallel data collection will provide a long term quantitative analysis of potential natural gas development to surface waters in the Fayetteville shale. We will continue to use these data to inform resource managers and concerned citizens of potential threats from gas well development. In addition to addressing a pressing emerging issue, data collected on water levels, species distributions, and abundance over multiple years with varying hydrologic regimes at several sites will contribute to our understanding of the critical flow needs of species of concern (Appendix 3).

Budget

35% match					50% Match			
Category	**SWG funds**	**Match**	**Total**		**Category**	**SWG funds**	**Match**	**Total**
Salaries	$142,541	$53,419	$195,960		Salaries	$139,270	$127,526	$266,796
Contract	$54,526		$54,526		Contract	$54,526		$54,526
Supplies	$16,750		$16,750		Supplies	$15,750		$15,750
Travel	$14,950		$14,950		Travel	$14,050	$3,500	$17,550
Indirect Cost	$20,369	$85,379	$105,748		Indirect	$20,140	$113,338	$133,478
Total	$249,136	$139,798	$387,934			$243,736	$244,364	$488,100

Qualifications of assembled research group:

Sally Entrekin is an aquatic ecologist often studying headwater streams on which she has published. Her responsibilities on this project will include project organization, mentoring of an undergraduate and graduate student to investigate organic matter dynamics and invertebrate community structure.

Ginny Adams research has focused on the conservation of sensitive and endangered species in relation to anthropogenic disturbance. She is an expert in morphology, physiology, life history, genetics, and ecology of invertebrates and fishes on which she has published.

Reid Adams research has focused on physiology and ecology of freshwater fishes and invertebrates in large river systems and has several papers relevant papers on these subjects. He will contribute his broad experience on the ecology of streams and rivers in this region.

Michelle Evans-White research and scientific publications have focused on roles of animals in organic matter and nutrient dynamics in stream ecosystems and how anthropogenic factors may alter species functional roles.

Chris Davidson is an endangered species biologist with the United States Fish and Wildlife Service. He has national lead on recovery of the federally endangered speckled pocketbook and monitors the activity of natural gas activities in the Little Red River watershed, including authorizing BMPs.

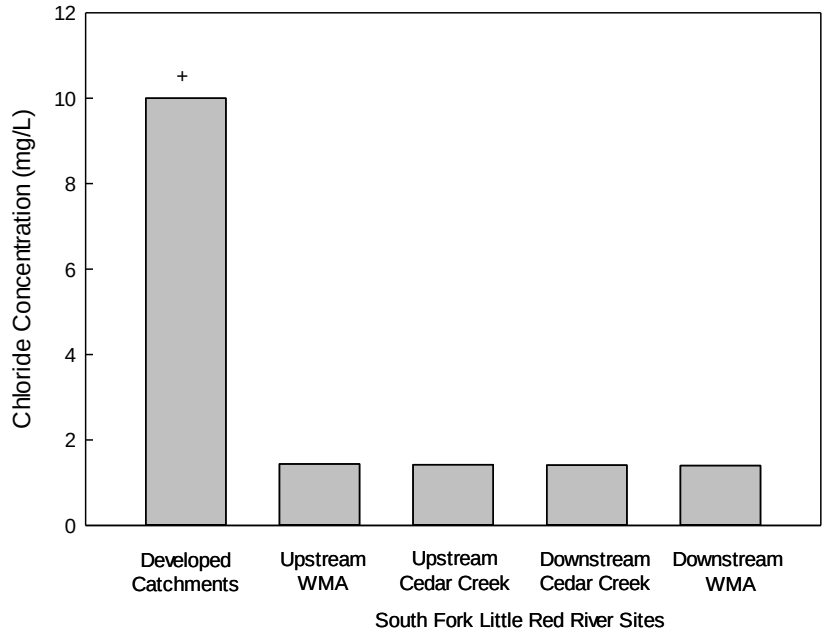
Lindsey Lewis is a biologist with the United States Fish and Wildlife Service. Among his many duties, he monitors the activity of well drillers in the state of Arkansas. He will act in an advisory role to help us find study locations, gain access to private lands, and help disseminate our research results.

Brian Haggard is a professor and the director of the Arkansas Water Resources Center and has many years of experience analyzing sediments and water for contaminants. He will manage the analysis of water and sediment samples, and help disseminate our results.

Ethan Inlander is a professional geographer and project manager with over 15 years experience applying geospatial technologies and analyses to land management and conservation issues. His emphases include watershed modeling, riparian mapping and conservation prioritization.

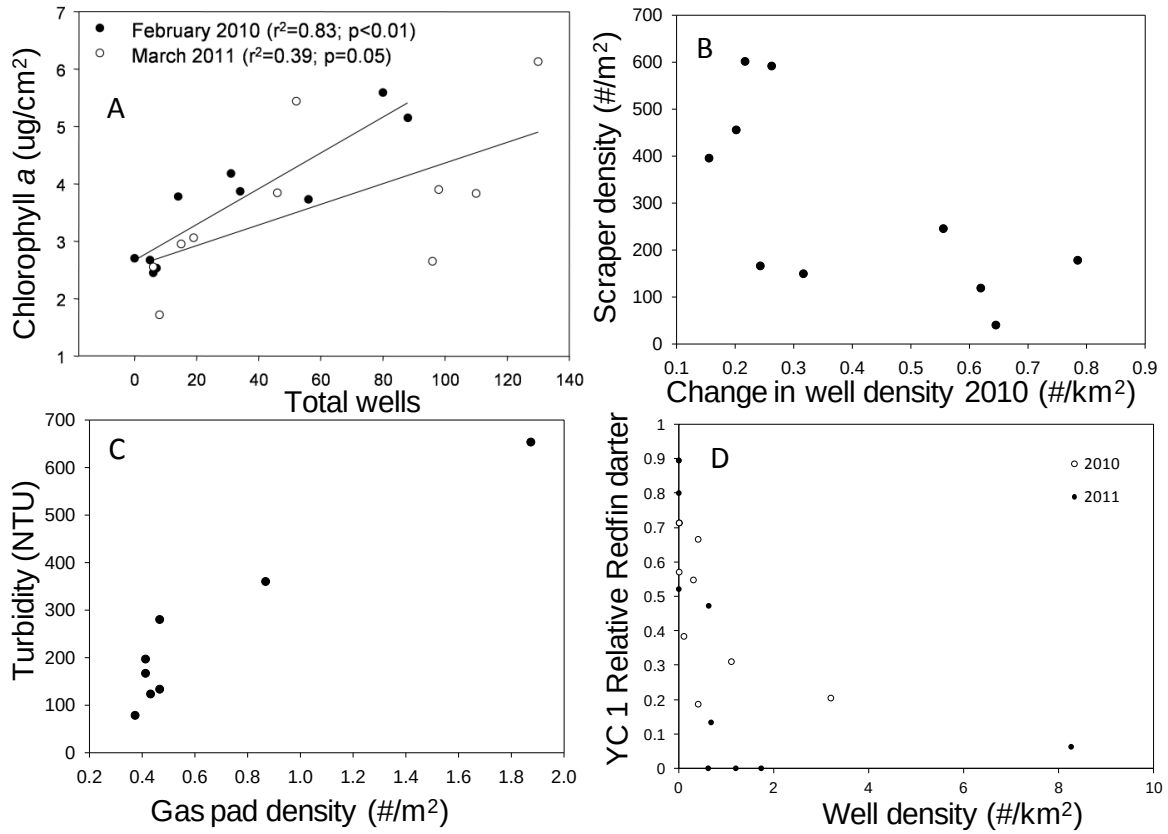
Cory Gallipeau is a GIS Specialist with The Nature Conservancy. He has over 12 years experience using and applying GIS technologies.

Appendix 1. Streams in the GMWMA currently have low chloride and other trace element concentrations compared to similar-sized streams in developed areas in north-central Arkansas.



The streams draining the Gulf Mountain Wildlife Management Areas (WMA) have low chemical concentrations, especially the South Fork of the Little Red River (SFLRR) where chloride concentrations are minimal relative to that observed in developed streams. We need to continue measuring chemical concentrations at these headwater streams and the SFLRR, because this information will establish the chemical baseline. The chemical baseline will allow us to track changes over time and see if hydraulic fracturing and natural gas production in the Fayetteville Shale has an effect on chemical concentrations. Chloride is just one example constituent, which is present in high concentration in fracturing fluids, but we analyze for a suite of elements which have been linked to these fluids.

Appendix 2: Preliminary results indicate potential effects of gas development on streams in the Fayetteville Shale.

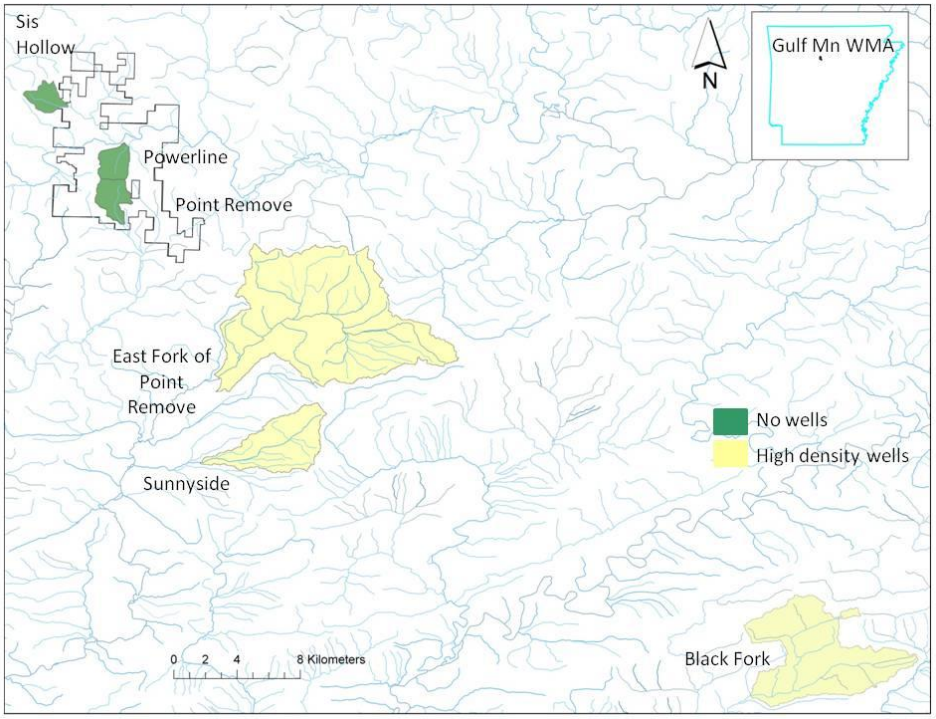


Preliminary data collected from past state wildlife funding addressing the relationship between sediment and biological metrics to gas well density across north-central Arkansas. A. Linear regression depicting the relationship between algal biomass in the form of chlorophyll *a* and total number of wells in each catchment, with solid circles (●) representing the winter 2010 sample period and open circles (○) representing the winter 2011 sample period. B. The density of macroinvertebrate scrapers, those that can scrape epilithic algae,in May 2010 declined with an increase in the number of gas wells installed within the catchment of each site from 2009 to 2010. C. Turbidity increased with increasing gas pad density (digitized by TNC) in February 2010. D. Proportion of population of redfin darters composed of Year Class 1 individuals against gas well density for both 2010 (filled circles) and 2011 (empty circles). High proportion indicates high spawning success and larval survival, low proportion indicates either low spawning success or low larval survival. We observed a correlation between well density and relative strength of Year Class 1 with a decline at high well density.

Appendix 3. Species of greatest conservation need in the South Fork Little Red River and tributaries.

Priority Score	**Common Name**	**Scientific name**
80	Speckled Pocketbook Mussel	*Lampsilis streckeri*
100	Yellowcheek Darter	*Etheostoma moorei*
Some invertebrates of conservation concern may be present in the intermittent streams, such as *Allocapnia* ssp., *Paucicalcaria*, and *Leuctra*.		

Appendix 4: Study site locations on Gulf Mountain Wildlife Management Area in north-central Arkansas.



GPS coordinates for tributary sampling on Gulf Mountain and streams off-gulf within the Fayetteville Shale.

GMWMA	Latitude	Longitude
High Cedar	35.5860	-92.6820
Powerline	35.5134	-92.6471
Dry Hollow	35.5651	-92.6645
East Point	35.5219	-92.6673
Low Cedar	35.5688	-92.6740
Sis Hollow	35.5878	-92.6983
Point Remove	35.5219	-92.6673
High density gas wells		
Black Fork	35.2522	-92.3095
East Fork Point Remove	35.4332	-92.6124
Sunnyside	35.3853	-92.6225
Low density gas wells		
Rock	35.4448	-92.8052
Driver	35.4646	-92.7307
South Fork Little Red River	35.5529	-92.7028

Appendix 5: Sampling locations on the South Fork of the Little Red River on Gulf Mountain Wildlife Management Area, Arkansas.