

**Fruitland Formation Outcrop**

**Methane Flux Measurements**

**2007 – 2017**

**and**

**Converting Fugitive Methane Gas  
Emissions into a Viable Resource**

**La Plata and Archuleta Counties, Colorado**



**LT Environmental, Inc.**

*COMPLIANCE / ENGINEERING / REMEDIATION*



# OUR TEAM

Methane Seep Monitoring and Capture – La Plata and Archuleta Counties, Colorado



**DEVIN HENCMANN**

Project Manager/Field Staff

Technical lead and project manager in charge of all data collection and operations and maintenance.



**CHRIS SHEPHARD, P.E.**

Senior Design Engineer

Design engineer for coal bed gas mitigation, collection and cogeneration.



**ASHLEY AGER, M.S., P.G.**

Senior Geologist

Environmental consulting in CBM fields including domestic water well sampling, seep monitoring, soil gas surveys, and spill response.



# GEOLOGIC SEEPS

Dead Vegetation, Grayish Colored Soil



# CREEK SEEPAGE



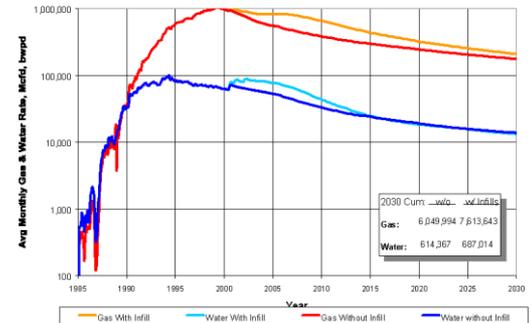
# 4M PROJECT

Mapping, Monitoring, Modeling, and Mitigation

## OPERATORS?



Figure 80: 3M Projections with and without Infill Wells

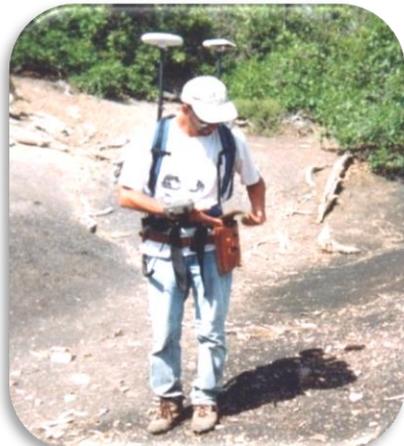


COGCC established the 3M (Mapping, Monitoring, and Modeling) Project to develop a more comprehensive understanding of outcrop seepage.

Expanded to 4M (Mitigation) in 2007

# MAPPING AND MONITORING

Joint Effort



GPS/Geologic Mapping



Vehicle



Probes



Monitoring Wells

Subsurface (reservoir), fixed-point, gas/water pressures

# MAPPING AND MONITORING

Joint Effort



Slide Hammer/LEL Meter



Flux Chambers  
Surface, fixed point, flow



Monitoring Wells  
Flux Meter since 2007

# FRUITLAND OUTCROP MONITORING

## 2007-2017

- La Plata County – COGCC Orders 112-156 and 112-157 (BP, XTO, Chevron)
- Archulta County - USFS and BLM: Decision Point 5 of the Record of Decision (ROD) to obtain approval of an application for permit to drill (Petrox)

IN THE MATTER OF THE PROMULGATION AND ESTABLISHMENT OF FIELD RULES TO GOVERN OPERATIONS IN THE IGNACIO-BLANCO FIELD, LA PLATA AND ARCHULETA COUNTIES, COLORADO Cause No. 112 Order No. 112-157

### REPORT OF THE COMMISSION

This cause came on for hearing before the Commission on April 24, 2000 in the Boettcher Auditorium, Colorado History Museum, 1300 Broadway, Denver, Colorado, on April 25, 2000 in Suite 801, 1120 Lincoln Street, Denver, Colorado, on June 5 and 6, 2000 in the Exhibit Hall, La Plata County Fairgrounds, 2500 Main Avenue, Durango, Colorado and on July 10 and 11, 2000 in Suite 801, 1120 Lincoln Street, Denver, Colorado on the verified application of Amoco Production Company, the Southern Ute Indian Tribe, d/b/a Red Willow Production Company, J.M. Huber Corporation, Hallwood Petroleum, Inc., SG Interests I, Ltd., Four Star Oil & Gas Company, Vastar Resources, Inc., EnerVest San Juan Operating, LLC, Pablo Operating Company, Petrogulf Corporation, Elm Ridge Resources, Maralex Resources, Inc., and Don Gosney for an order from the Commission to allow an optional additional well to be drilled for production of gas from the Fruitland Coal seams for certain 320-acre drilling and spacing units in the Ignacio-Blanco Field.

### SUMMARY OF PROCEEDINGS

1. Amoco Production Company, the Southern Ute Indian Tribe, d/b/a Red Willow Production Company, J.M. Huber Corporation, Hallwood Petroleum, Inc., SG Interests I, Ltd., Four Star Oil & Gas Company, Vastar Resources, Inc., EnerVest San Juan Operating, LLC, Pablo Operating Company, Petrogulf Corporation, Elm Ridge Resources, Maralex Resources, Inc., and Don Gosney, as applicants herein, are interested parties in the subject matter of the above-referenced hearing.

2. Due notice of the time, place and purpose of the hearing has been given in all respects as required by law.

3. The Commission has jurisdiction over the subject matter embraced in said Notice, and of the parties interested therein, and jurisdiction to promulgate the hereinafter prescribed order pursuant to the Oil and Gas Conservation Act and the terms of the Memorandum of Understanding ("MOU") between the Commission and the Bureau of Land Management ("BLM").

4. On June 15, 1988, the Commission issued Order No. 112-60 which established 320-acre drilling and spacing units for the production of gas from the Fruitland coal seams, underlying certain lands in the Ignacio-Blanco Field, with the units to consist of a governmental half section and the permitted well when north of the north line of Township 32 North to be located in the NW1/4 and the SE1/4 of each section and when south of the north line of Township 32 North to be located in the NE1/4 and SW1/4 of each section, no closer than 990 feet from the boundaries of the quarter section, nor closer than 130 feet to any interior quarter section line. Order Nos. 112-61 and 112-85 were subsequently adopted amending Order No. 112-60 to establish additional field rules for the Fruitland coal seams.

5. On March 6, 2000 Amoco Production Company, the Southern Ute Indian Tribe, d/b/a Red Willow Production Company, J.M. Huber Corporation, Hallwood Petroleum, Inc., SG Interests I, Ltd., Four Star Oil & Gas Company, Vastar Resources, Inc., EnerVest San Juan Operating, LLC, Pablo Operating Company, Petrogulf Corporation, Elm Ridge Resources, Maralex Resources, Inc., and Don Gosney ("Applicants"), by and through their attorneys, filed with the Commission a single application requesting an order from the Commission to allow an optional additional well to be drilled for production of gas from the Fruitland coal seams for certain 320-acre drilling and spacing units in the Ignacio-Blanco Field.

### Northern San Juan Basin Coal Bed Methane Project

### Record of Decision



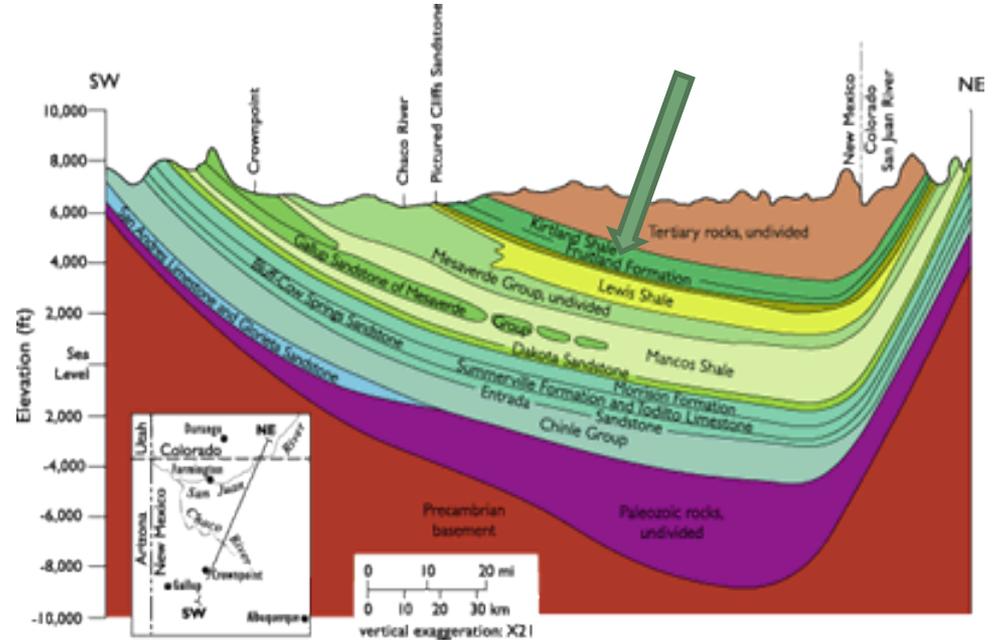
U.S. Department of Interior  
Bureau of Land Management  
San Juan Center

U.S. Department of Agriculture  
Forest Service  
San Juan National Forest

April 2007

# FRUITLAND OUTCROP

ERA PER	EPOCH	DEPOSITION TIMES IN MILLIONS OF YEARS AGO	SOUTHEASTERN SAN JUAN BASIN		
			FORMATION / MEMBER	DESCRIPTION	
GENOZOIC	HOLOCENE	54 - 38	Terrace and piedmont deposits		
	PLEISTOCENE		Volcanics		
	PLIOCENE		Santa Fe Group		
	MIOCENE				
	OLIGOCENE				
	EOCENE				
	PALEOGENE		64 - 60	NACIMIENTO	
			65 - 64	OJO ALAMO	
	MESOZOIC		LATE CRETACEOUS	73 - 70	KIRTLAND
75 - 73		FRUITLAND		←	
		Pictured Cliffs Sandstone			
		Lewis Shale			
		Cliff House Sh.			
		Mesaverde Group			
		Point Lookout Sh.			
		Saban Tongue			
		Hosta Tongue			
		Cravens Tongue			
		Mulatto Tongue			
		Cravens Canyon Fm.			
		Gallup Sandstone			
		Unnamed Shale			
		Juana Lopez Mbr.			
	Semilla Sh. Mbr.				
	Rio Salado Tongue				
	Twowells Sh. Tongue				
	Whitehall Arroyo Sh. Mbr.				
	Pisquale Tongue				
	City Mesa Tongue				
	Cyprus Tongue				
	Oak Canyon Mbr.				
	Special Johnson Mbr.				
EARLY CRETACEOUS	94 - 80	MORRISON			
	97 - 94	MORRISON			
	150 - 144	MORRISON			
JURASSIC	LATE				
	MIDDLE	Summerville Formation			
	EARLY	Toddlr Formation			
TRIASSIC	LATE	230 - 213			
	MIDDLE	Chinle Group			
	EARLY	Chinle Group			





# DETAILED MAPPING METHODS

WestSystems, LLC

## Portable Flux Meter

Measures flux of  $\text{CH}_4$ ,  $\text{H}_2\text{S}$ , and  $\text{CO}_2$  at the ground surface

Flux = Measure change in concentration in known area

Convert to  $\text{mol}/\text{m}^2 \cdot \text{day}$

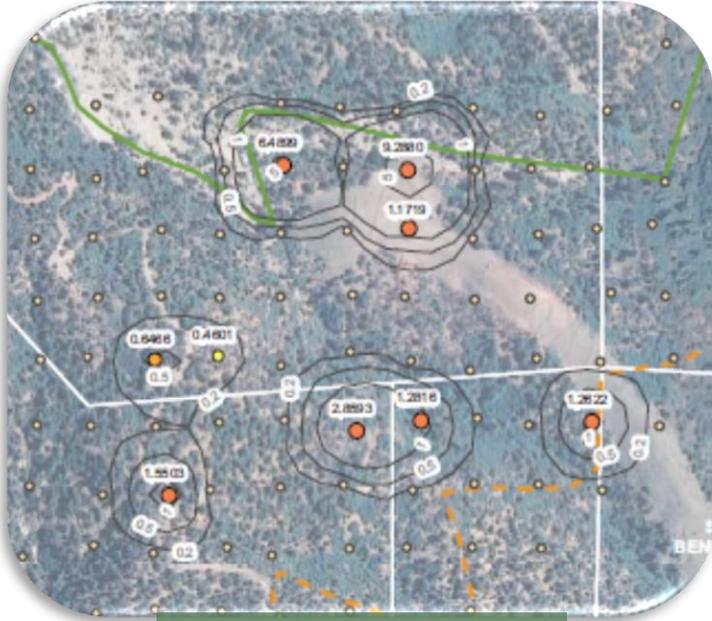


GPS

Backpack with  
detectors

Kettle/chamber

# DETAILED MAPPING METHODS

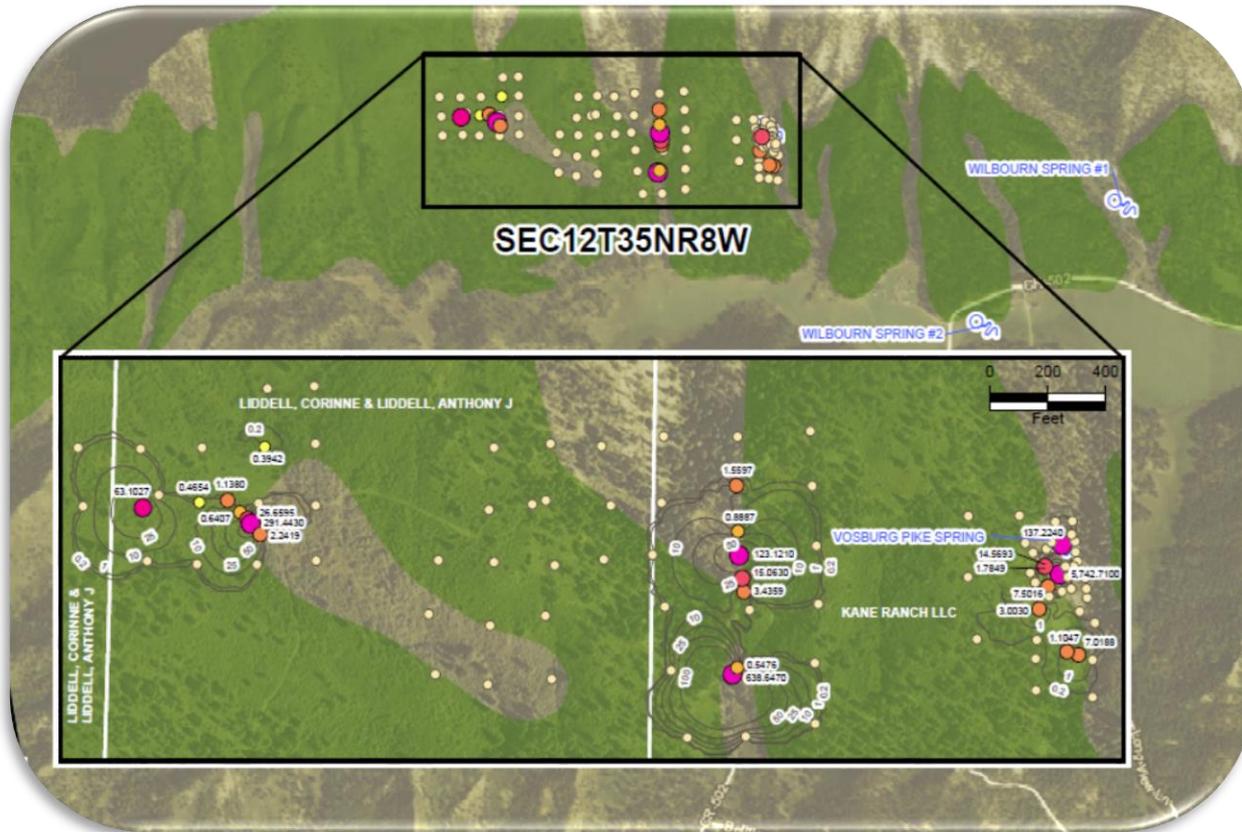


Grid Mapping System

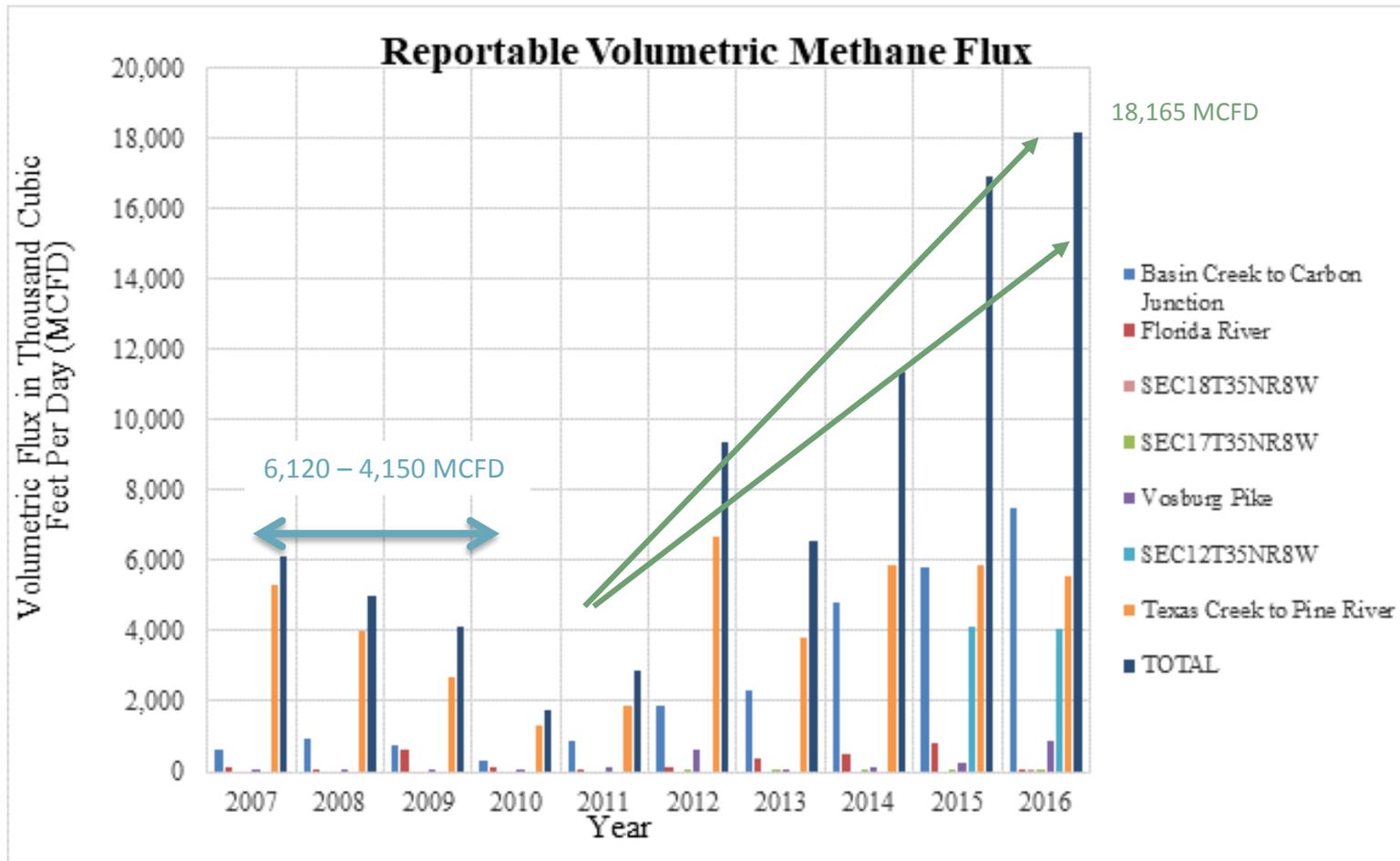


Aerial Infrared Survey

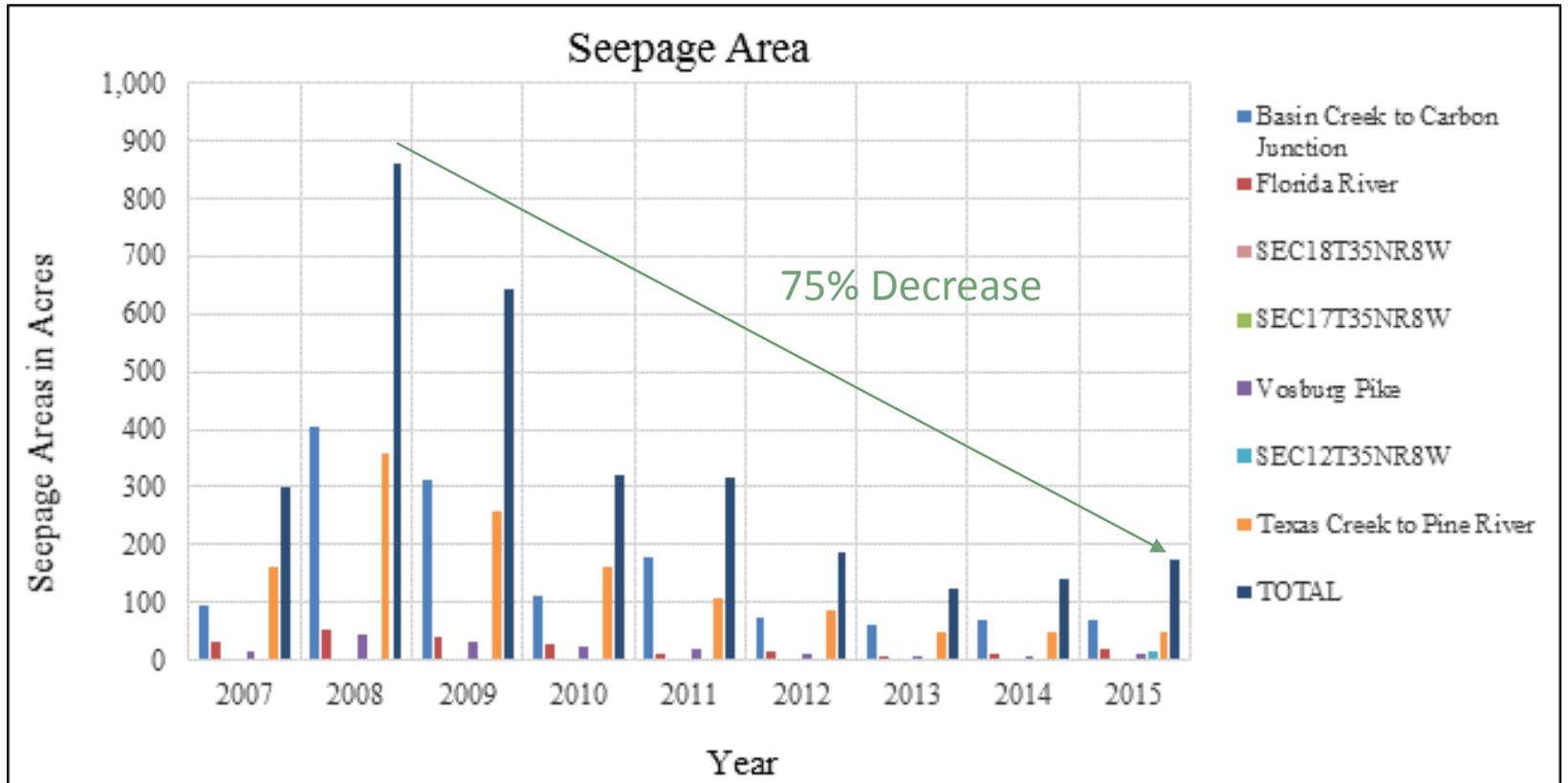
# RESULTS



# RESULTS



# RESULTS



# CONVERSIONS AND ASSUMPTIONS

$$18,165 \text{ MCFD} = 18,165,000 \text{ CFD}$$

$$18,165,000 \frac{\text{ft}^3}{\text{day}} \times 0.0417 \frac{\text{lbs}}{\text{ft}^3} = 757,480.5 \frac{\text{lbs}}{\text{day}}$$

$$\frac{757,480.5 \frac{\text{lbs}}{\text{day}}}{2,000 \frac{\text{lbs}}{\text{ton}}} = 378.74 \frac{\text{tons}}{\text{day}}$$

$$378.74 \frac{\text{tons}}{\text{day}} \times 365 \text{ days} = \mathbf{138,240 \frac{\text{tons}}{\text{year}}}$$

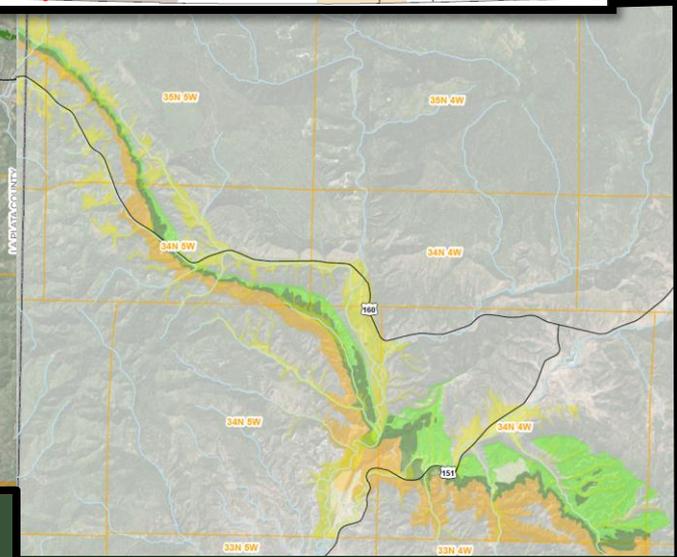
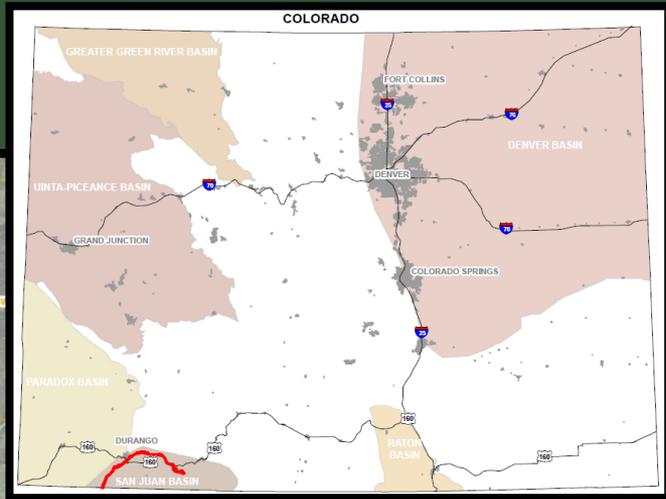
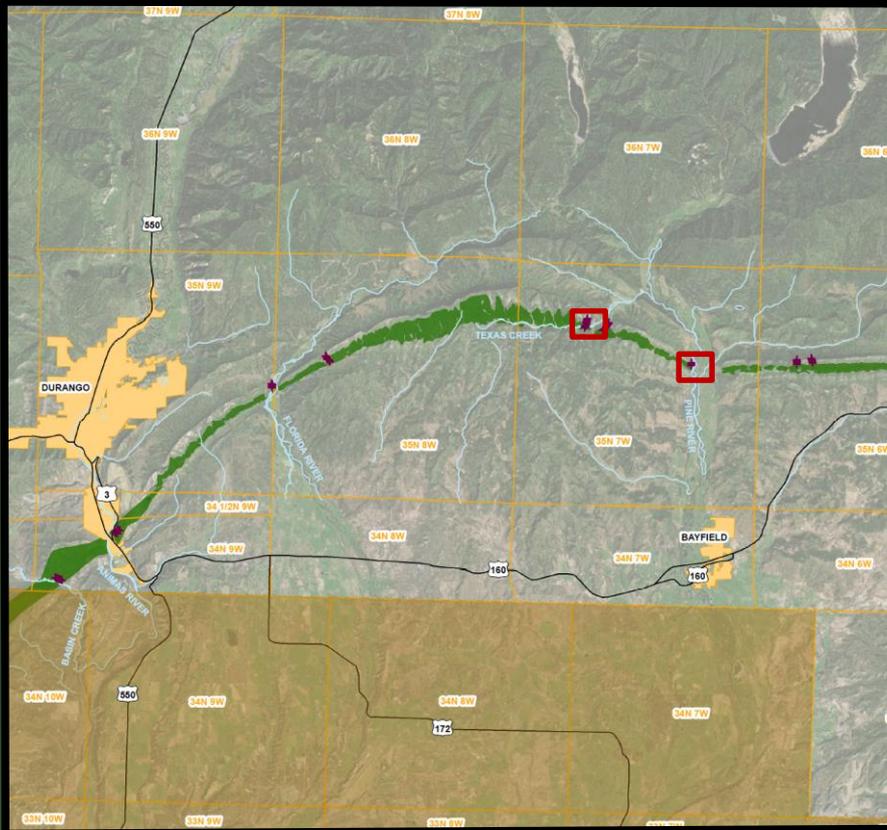
$$\rho = 0.0417 \text{ lb/ft}^3, 68 \text{ }^\circ\text{F and 1 atm}$$



# MITIGATION



# MITIGATION



# DESIGN

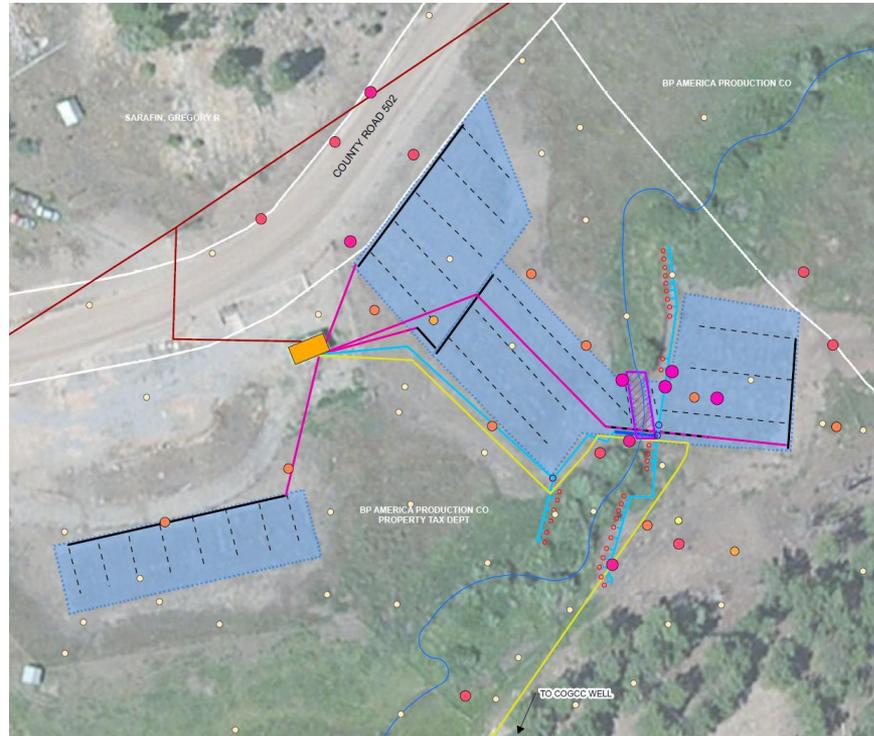
Installed in 2008-2009



4 collection areas initially



Best methane recovery observed near the creek



Subsequently added collection beneath creek with Corps of Engineers approval



0.8 acre collection area



In 2012, BP took over O&M costs



# CAPTURE

Captured Gas Routed to a Combustion Chamber

Capture of methane through collection system and manifold

Capture then compress methane to allow for operation of a turbine generator.

Compression

Oilfield gas compression equipment with low vacuum/suction to optimize recovery and minimize oxygen collection.

Microturbine

Microturbine generator used for electrical generation. Spins at 30,000 to 40,000 RPM and requires limited maintenance.

Electrical Output

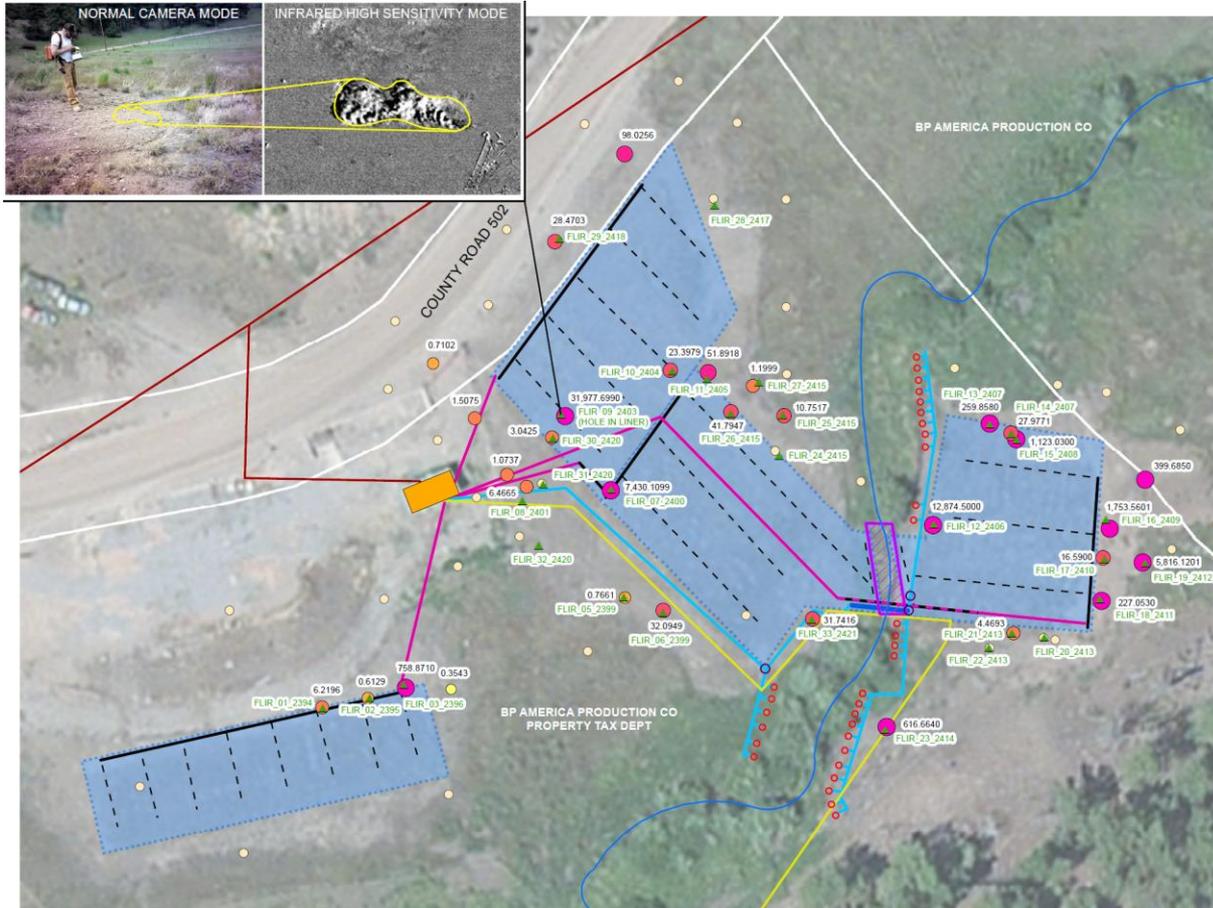
Electrical output is tied to the grid



**15,200 MCF recovered**

**Excess is equal to demand for 4 to 5 homes  
Proven sustainable use of an unconventional resource**

# FLIR SURVEY



Forward-looking  
Infrared (FLIR)  
GF320 OGI camera



Identify leaks and  
quantify with flux  
meter



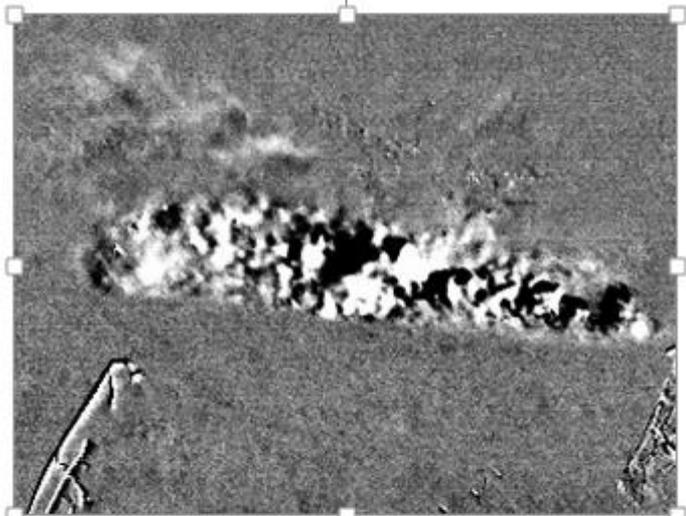
Valuable evaluation  
to more accurately  
measure flux



Areas of seepage  
on the edge of the  
liner = higher flux.



EXAMPLE



EXAMPLE



# CONCLUSIONS



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## SOURCE OF METHANE EMISSIONS

Coalbed methane seepage has been observed historically and measured quantitatively since 2007.

SUIT data are not published and NM data have not been measured.



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## FUTURE WORK

Share data and compare to more detailed source data gathered by NOAA and NASA when published.

Continue to monitor according to COGCC requirements



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## TECHNOLOGY

Proven sustainable use of an unconventional resource.

Incorporating FLIR camera into seep investigations can be used to better quantify seepage along the outcrop.

THANK YOU!



# CONVERSIONS AND ASSUMPTIONS

$$\text{SCFD} = \frac{\text{kg}}{\text{hr}} \times 2.204 \frac{\text{lbs}}{\text{kg}} \times \frac{1 \text{ lb} \cdot \text{mol}}{16.04} \times 379.3 \frac{\text{SCF}}{1 \text{ lb} \cdot \text{mol}} \times 24 \frac{\text{hrs}}{\text{day}}$$

$$\text{SCFD} = \frac{\text{kg}}{\text{hr}} \times 1,251.43$$

$$\text{MCFD} = \frac{\text{kg}}{\text{hr}} \times 1.25143$$

$$18,165 \text{ MCFD} = \frac{\text{kg}}{\text{hr}} \times 1.25143$$

$$\frac{18,165 \text{ MCFD}}{1.25143} = \frac{\text{kg}}{\text{hr}}$$

$$18,165 \text{ MCFD} = 14,515.4 \frac{\text{kg}}{\text{hr}} = 140,124 \text{ ton/year}$$

Molecular weight of methane = 16.04