# An Overview of the Process of Unconventional Gas Development from Shale Formations: Potential Impacts on the Environment and Human Health

**Table 2**

Estimated Ultimate Recovery from Marcellus after a 50-year decline.
*Power-law model assuming that 70% of the sections in each county are accessible and a well spacing of 80-acres.*

| | Counties | Sections | Total Risked Potential | Total Risked Potential | Total Risked Potential |
|---|---|---|---|---|---|
| | | | **P90** | **P50** | **P10** |
| | | | **Bcf** | **Bcf** | **Bcf** |
| Maryland | 1 | 656 | 3,123 | 6,980 | 11,756 |
| New York | 17 | 13,906 | 30,955 | 71,859 | 126,176 |
| Pennsylvania | 42 | 32,622 | 133,240 | 291,648 | 521,406 |
| Ohio | 18 | 9,298 | 18,361 | 41,166 | 71,010 |
| West Virginia | 39 | 16,851 | 35,022 | 77,588 | 136,814 |
| **Totals** | **117** | **73,333** | **220,701** | **489,241** | **867,162** |

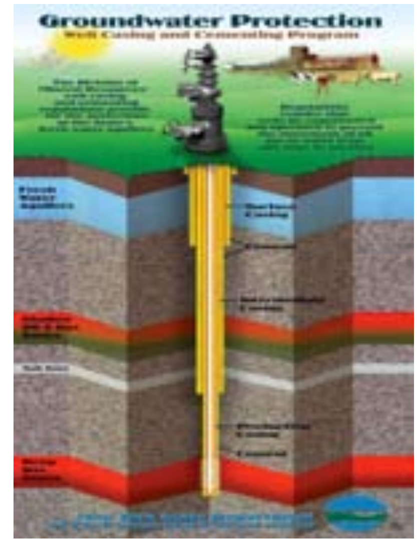
The Health Implications of
**HYDROFRACKING**
UPSTATE MEDICAL UNIVERSITY PUBLIC HEALTH SYMPOSIUM
April 13, 2011

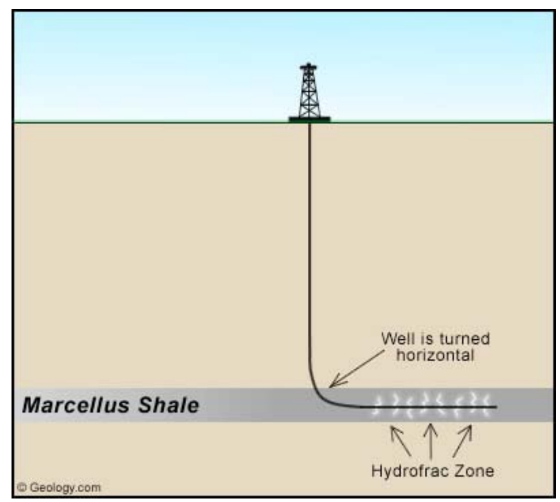

**Prof. Tony Ingraffea**
***Physicians, Scientists, and Engineers for Sustainable and Healthy Energy***

# Why Is Unconventional Shale Gas Different from Conventional Gas?

## The Wells Are "Bigger"

- Total Length
  - More and heavier drilling equipment
  - Longer drilling time
  - Higher probability of drilling problems
  - More venting during drilling, "making gas"
- Frac design and number of stages
  - More and heavier fracing equipment
  - More stages and volume per stage
  - More plugs and longer drill-out period
- Flowback waste, produced "water"
  - Higher volume, longer period
  - More venting and/or flaring of gas



# Gas Wells In NYS: Past and Future

For a **conventional** NYS gas well:

A pad = 1 well < 80,000 gallons of frac fluid < 80,000 gallons of waste fluid

For an average **unconventional shale gas** site in PA today:

A pad = 8+ wells > 80+ frac stages > 44,000,000 gallons of frac fluid > millions of gallons of waste fluid

Prof. Engelder's (Penn State) estimate for number of Marcellus wells alone in NYS:

36,000 to 78,000

This would mean **360,000 to 780,000 frac stages at ~500,000 gallons per stage**

**The first 1,000 shale gas wells would use more frac fluid, and produce more waste, than all previous ~50,000 gas wells in NYS.**

# Why Is Unconventional Shale Gas Different from Conventional Gas?

Because the Gas Is Everywhere, There Will Be Wells Almost Everywhere

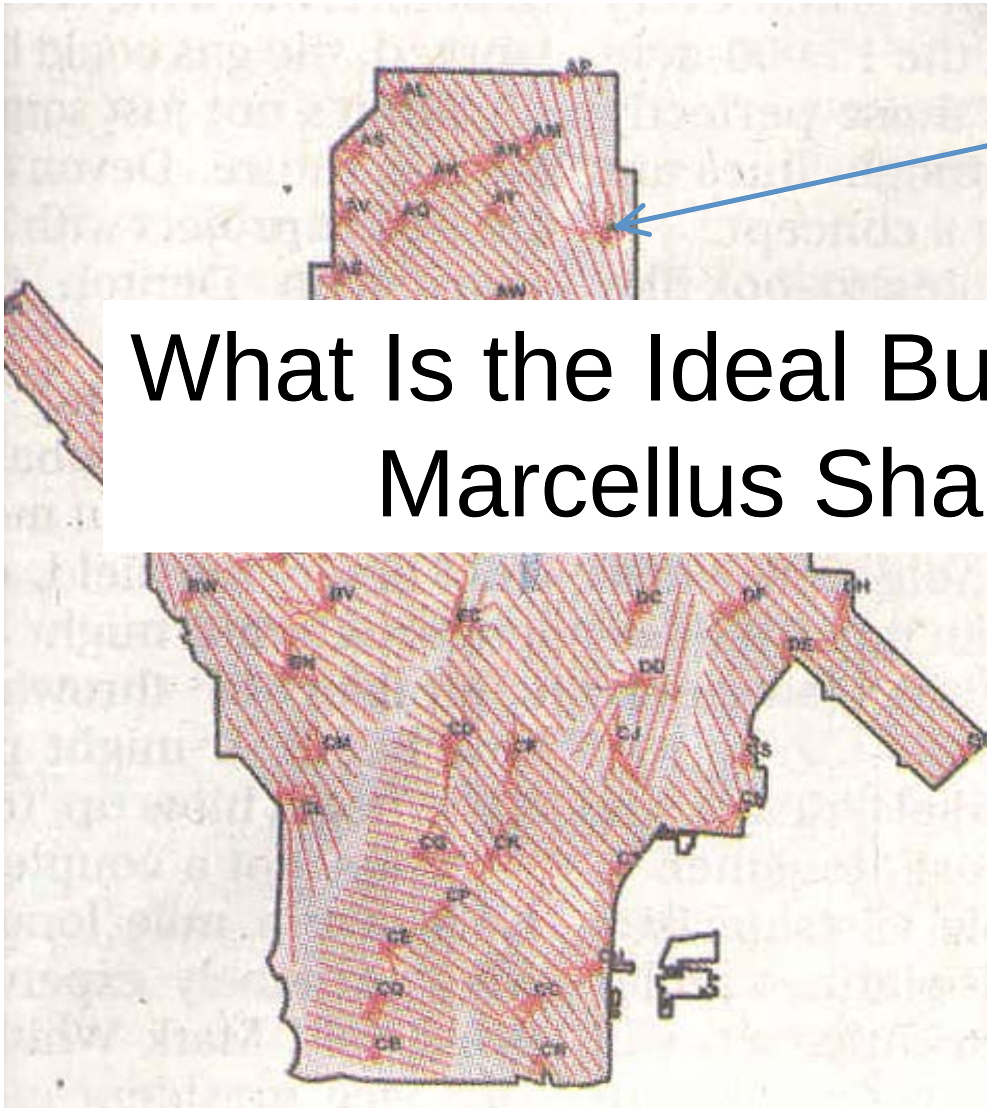
**Table 2**

Estimated Ultimate Recovery from Marcellus after a 50-year decline.
*Power-law model assuming that 70% of the sections in each county are accessible and a well spacing of 80-acres.*

70% of area, 8 wells/square mile: 400,000 wells

| | | | | | |
|---|---|---|---|---|---|
| | | | **P90** | **P50** | **P10** |
| | | | **Bcf** | **Bcf** | **Bcf** |
| Maryland | 1 | 656 | 3,123 | 6,980 | 11,756 |
| New York | 17 | 13,906 | 30,955 | 71,859 | 126,176 |
| Pennsylvania | 42 | 32,622 | 133,240 | 291,648 | 521,406 |
| Ohio | 18 | 9,298 | 18,361 | 41,166 | 71,010 |
| West Virginia | 39 | 16,851 | 35,022 | 77,588 | 136,814 |
| **Totals** | **117** | **73,333** | **220,701** | **489,241** | **867,162** |

# Example: Dallas/Fort Worth Airport Property, Barnett Shale Play


SOURCE: CHESAPEAKE ENERGY

- 53 pads on 18,076 acres
  ~2 pads/sq.mi.

# What Is the Ideal Build-Out of the Marcellus Shale Play?

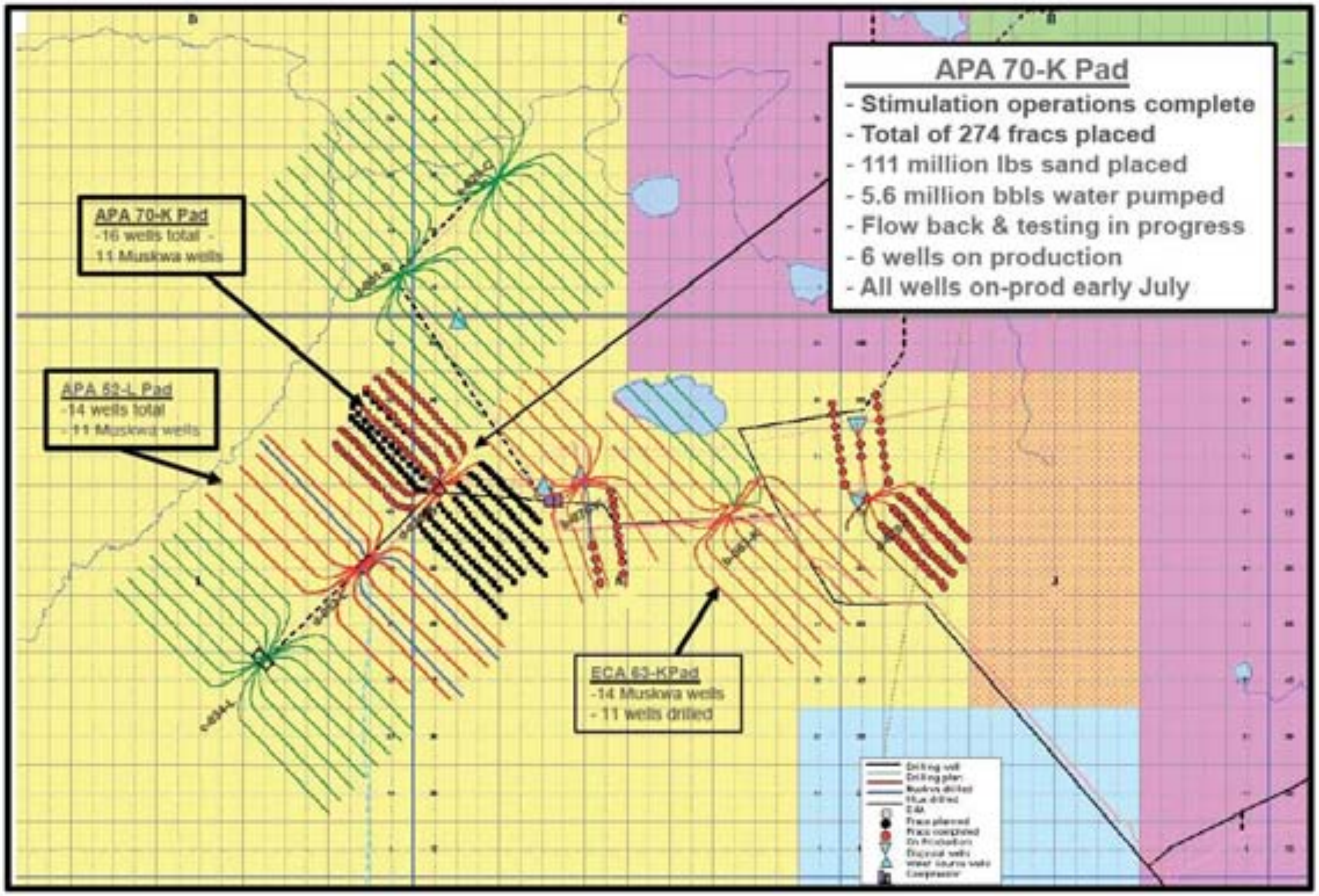
coverage

- Patchwork, mostly ideal units

- One developer

# Horn River Area, NE British Columbia

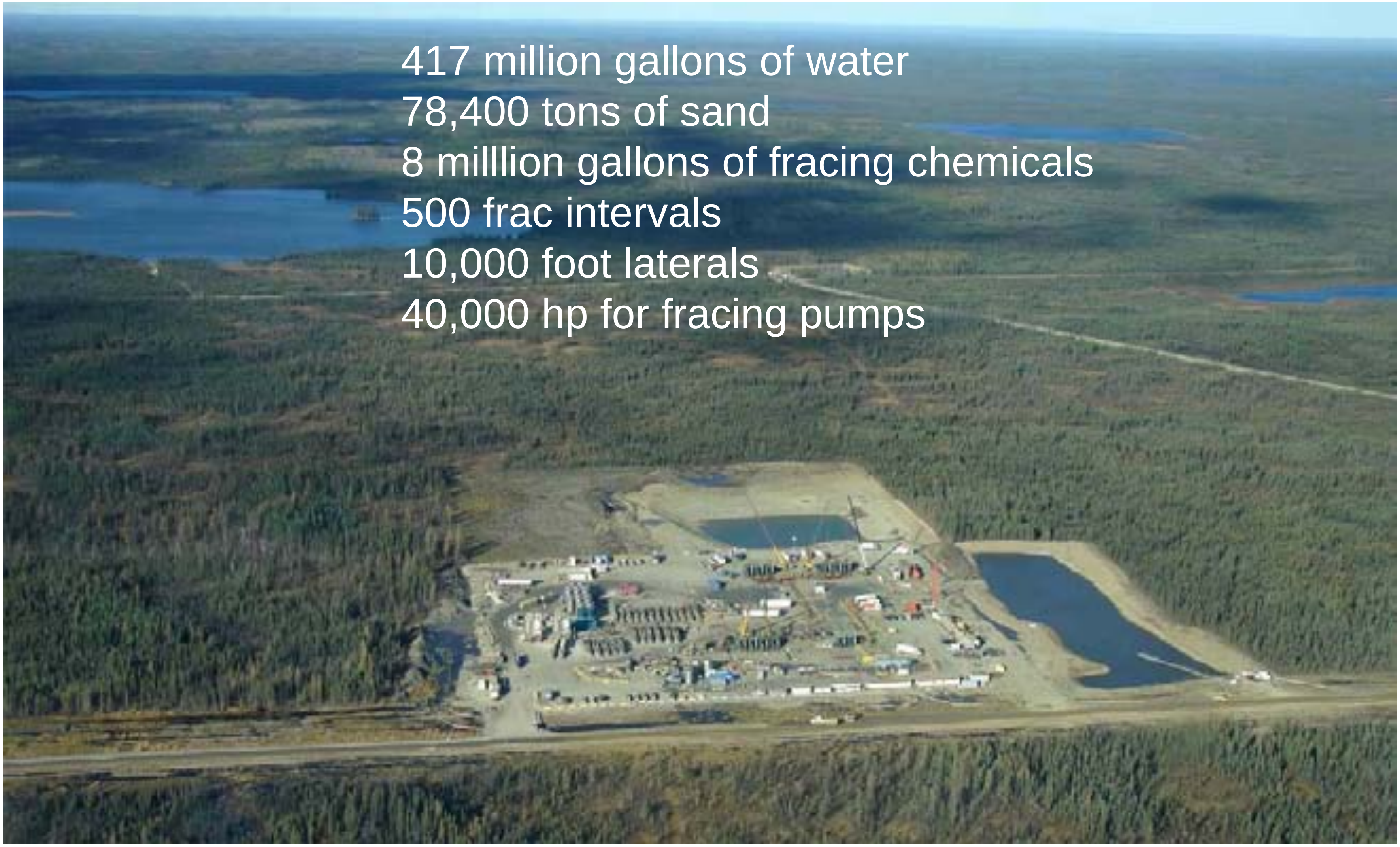
## Two Island Lake Operations Status



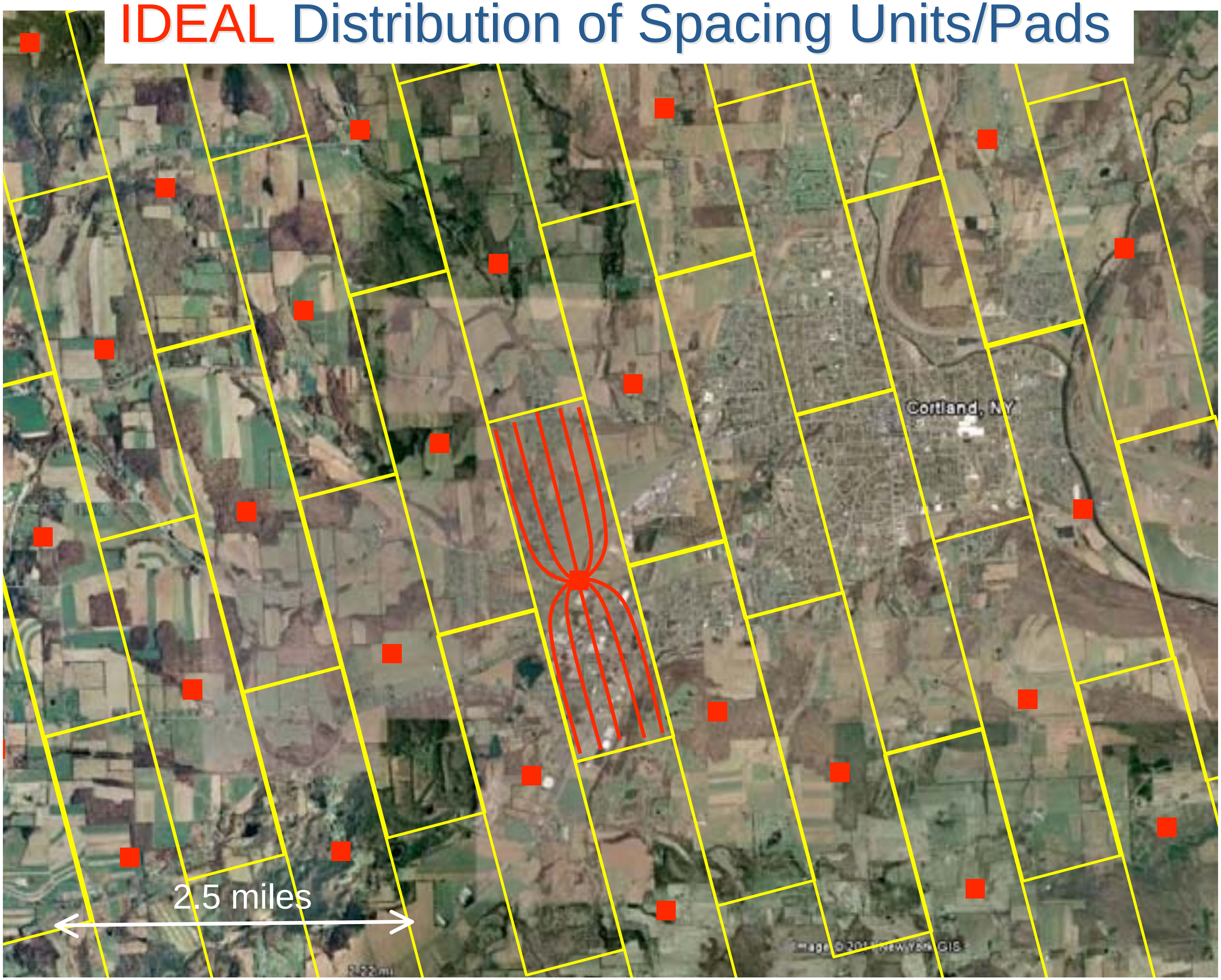
## World's Largest Frac Job

# What Will the Marcellus Pad of the Near Future Look Like?

# Encana Says "No!" This One Is It



# IDEAL Distribution of Spacing Units/Pads



# Follow the Waste Streams: Liquids

"At least 269 million gallons of wastewater went to treatment plants in Pennsylvania for river discharge in the 18 months ending Dec. 31, according to an Associated Press review of reports filed with the state's Department of Environmental Protection. Millions more gallons of wastewater went unaccounted for because of weaknesses in the state's tracking system. DEP records also show some public water utilities downstream from plants treating wastewater have struggled with potentially dangerous levels of trihalomethanes, carcinogens that can be linked indirectly to drilling waste."

*MICHAEL RUBINKAM AND DAVID B. CARUSO, Associated Press*
*April 12, 2011*

**DISPOSAL OF FRAC WATER -**

BY MUNICIPAL WASTEWATER TREATMENT PLANTS (POTW)
AND DISCHARGE TO SURFACE WATER

# Follow the Waste Streams: Gases, on the Largest Scale

***Developing Natural Gas in the Marcellus and Other Shale Formations Is Likely to Aggravate Global Warming***

Clima tic Change
DOI 10.1007/s10584-011-0061-5

LETTER

# Methane and the greenhouse-gas footprint of natural gas from shale formations

## A letter

**Robert W. Howarth · Renee Santoro · Anthony Ingraffea**

Received: 12 November 2010 / Accepted: 13 March 2011


**Abstract** We evaluate the greenhouse gas footprint of natural gas obtained by high-volume hydraulic fracturing from shale formations, focusing on methane emissions. Natural gas is composed largely of methane, and 3.6% to 7.9% of the methane from shale-gas production escapes to the atmosphere in venting and leaks over the lifetime of a well. These methane emissions are at least 30% more than and perhaps more than twice as great as those from conventional gas. The higher emissions from shale gas occur at the time wells are hydraulically fractured—as methane escapes from flow-back return fluids—and during drill out following the fracturing. Methane is a powerful greenhouse gas, with a global warming potential that is far greater than that of carbon dioxide, particularly over the time horizon of the first few decades following emission. Methane contributes substantially to the greenhouse gas footprint of shale gas on shorter time scales, dominating it on a 20-year time horizon. The footprint for shale gas is greater than that for conventional gas or oil when viewed on any time horizon, but particularly so over 20 years. Compared to coal, the footprint of shale gas is at least 20% greater and perhaps more than twice as great on the 20-year horizon and is comparable when compared over 100 years.

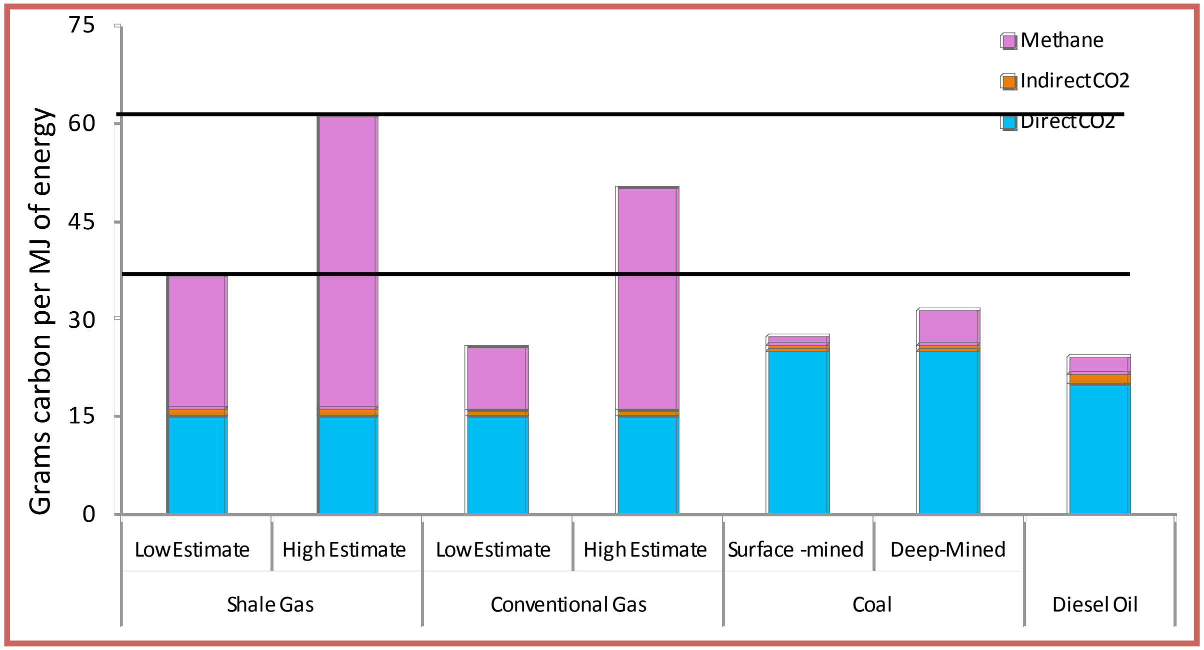
**Keywords** Methane · Greenhouse gases · Global warming · Natural gas · Shale gas · Unconventional gas · Fugitive emissions · Lifecycle analysis · LCA · Bridge fuel · Transitional fuel · Global warming potential · GWP

**Electronic supplementary material** The online version of this article (doi:10.1007/s10584-011-0061-5) contains supplementary material, which is available to authorized users.

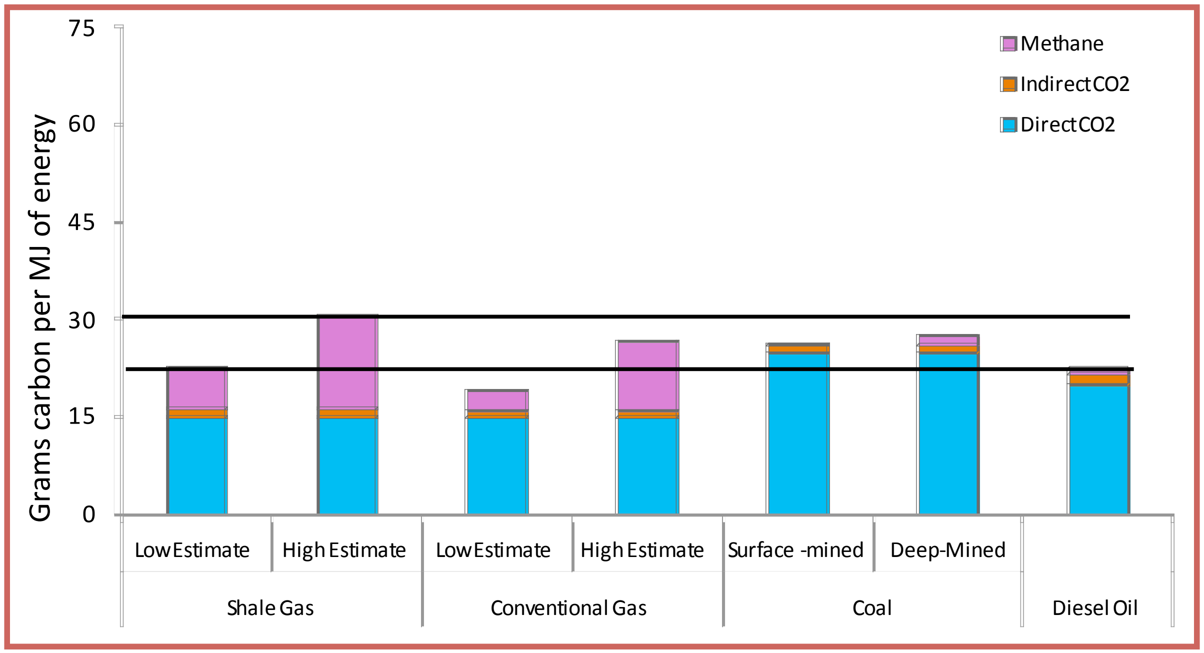
R. W. Howarth (✉) · R. Santoro
Department of Ecology and Evolutionary Biology, Cornell University, Ithaca, NY 14853, USA
e-mail: rwh2@cornell.edu

A. Ingraffea
School of Civil and Environmental Engineering, Cornell University, Ithaca, NY 14853, USA

20 year




100 year




(Howarth et al. 2011)

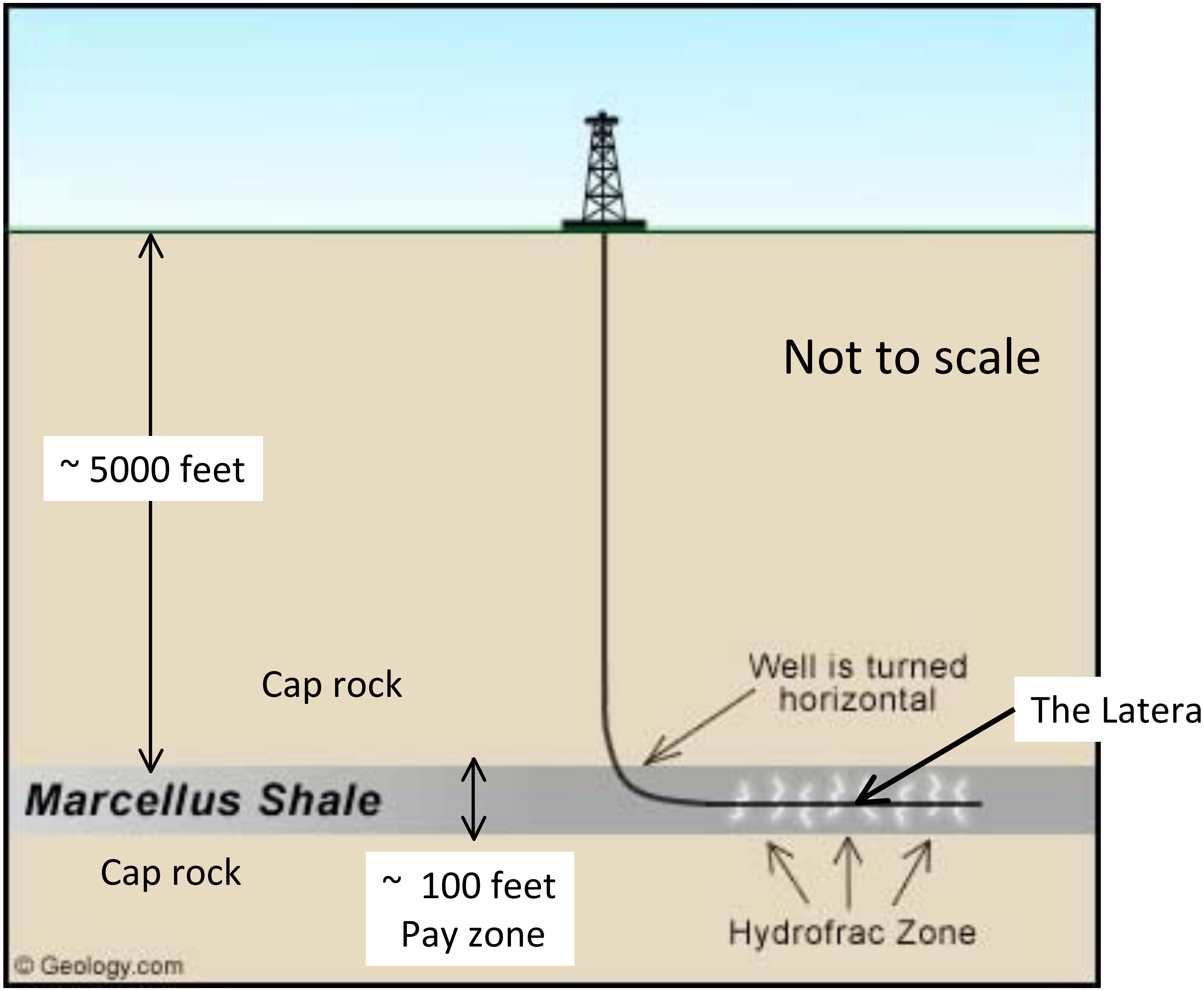
Thank you for your attention.

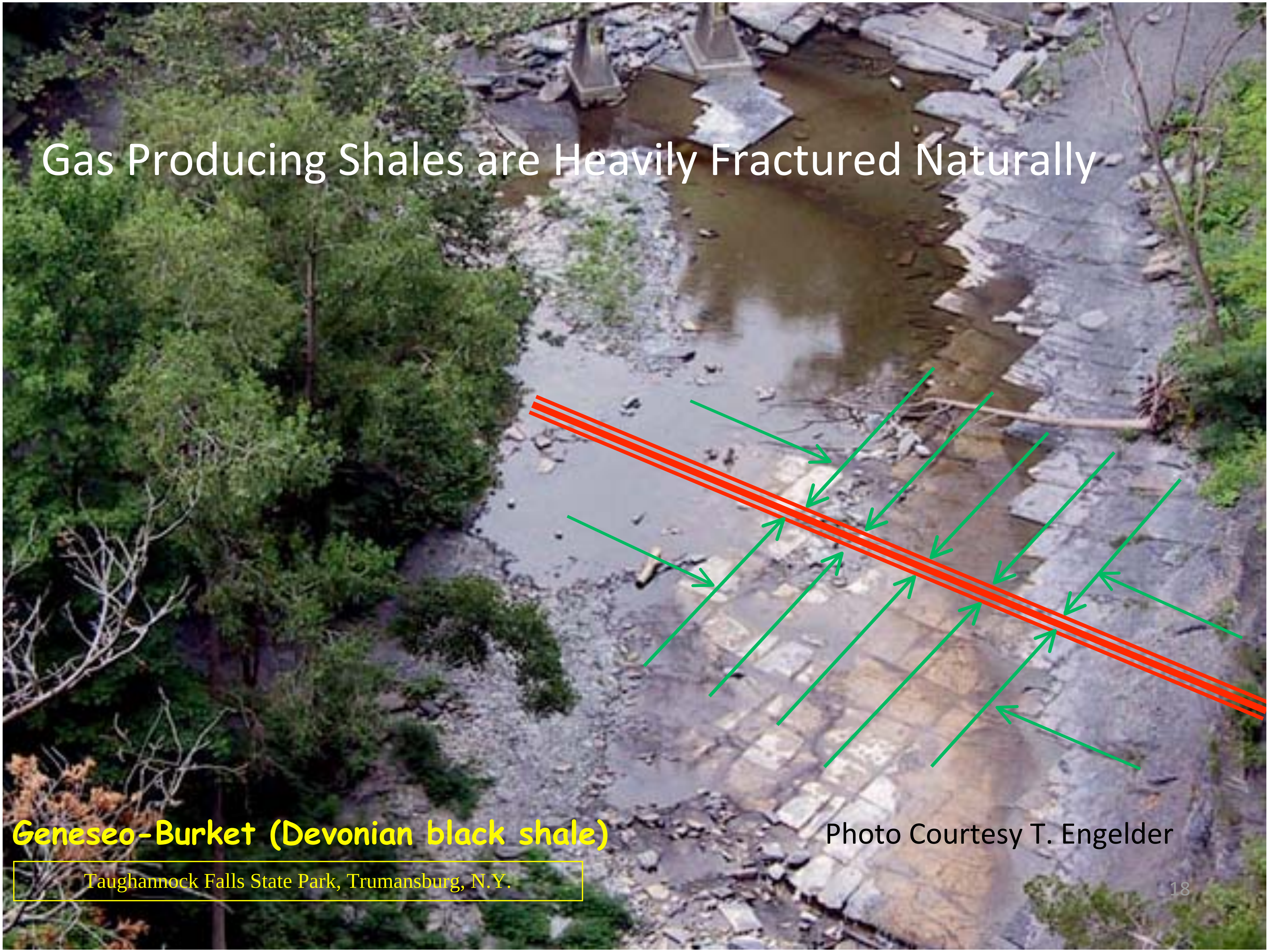
I look forward to a constructive and informative Q&A.

# Why Is Shale Gas Development "Unconventional"

- Because it requires 4 technologies only recently combined to make gas production from shales technically and economically feasible.
- Directional drilling: needed to access a thin layer of shale with long laterals.
- High frac fluid volumes: needed to stimulate gas release from many existing fractures.
- Slickwater: needed to control the amount of power needed to pump large volumes of frac fluids, at high pressures, quickly, over long distances, through small diameter casing.
- Multi-well Pads: needed to access as much of the gas inventory as possible, under constraints of leasing and capital.

# High Volume, Slickwater Fracing from Long Laterals: The Concept

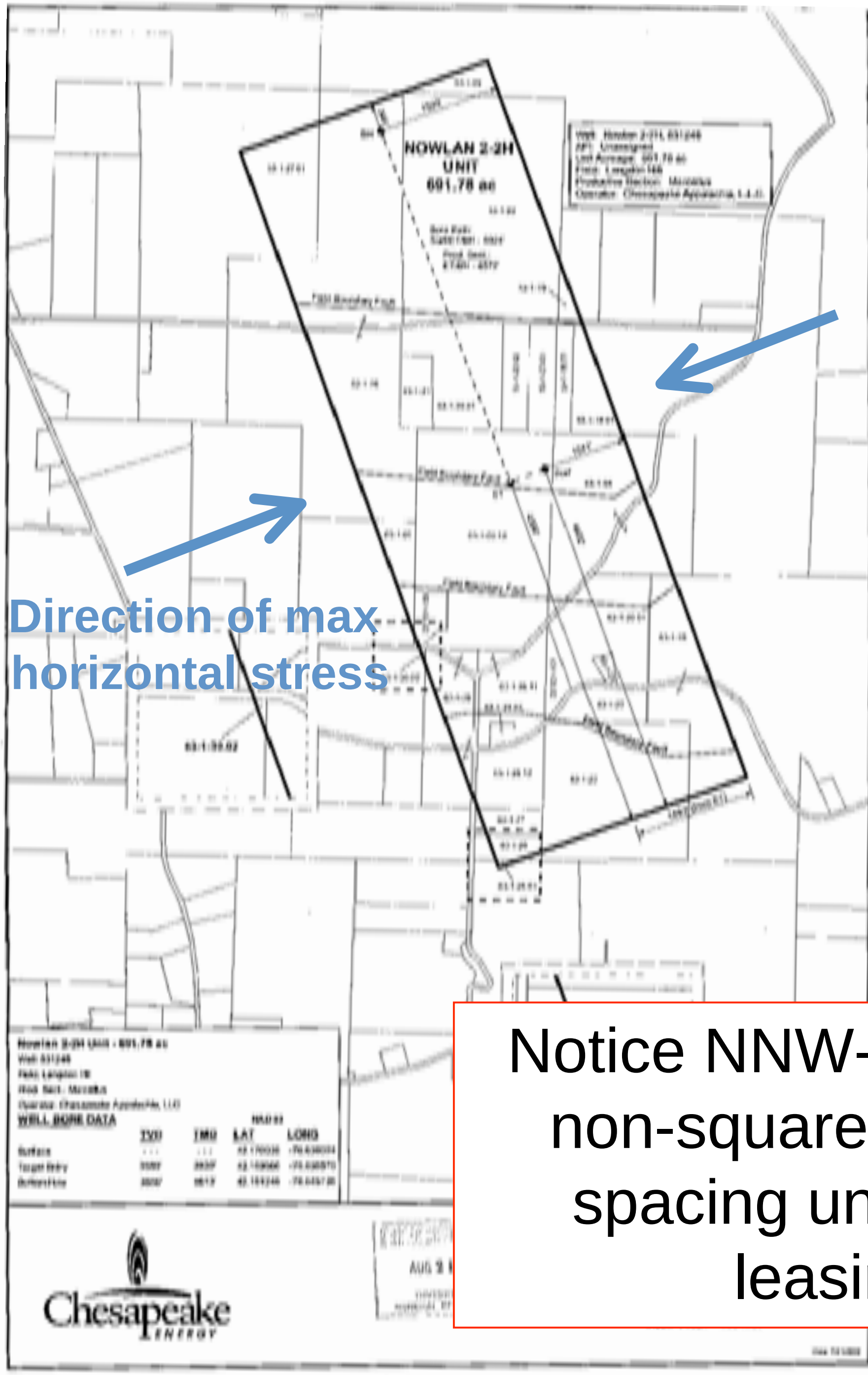


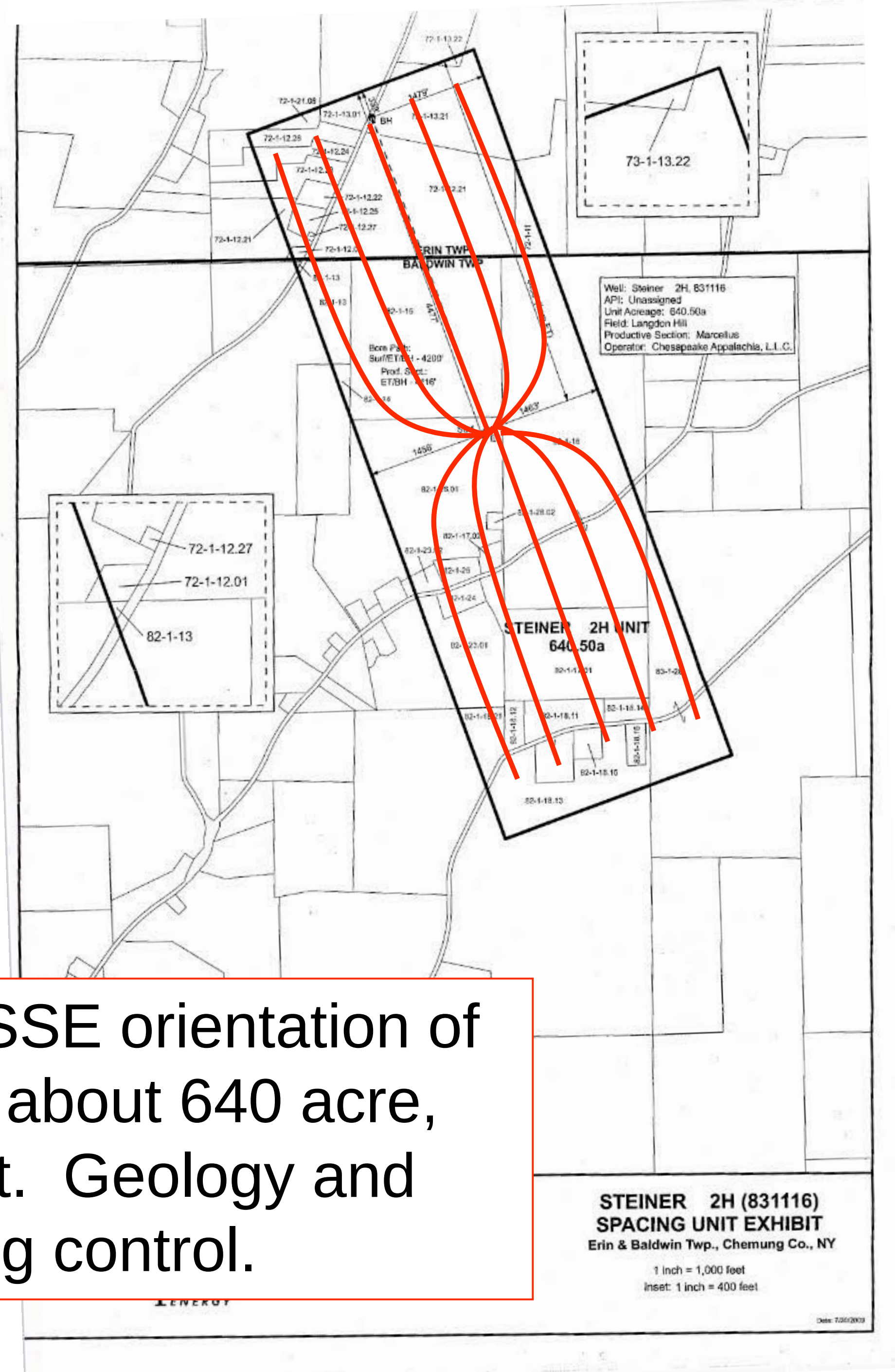

Gas Producing Shales are Heavily Fractured Naturally
Geneseo-Burket (Devonian black shale)
Taughannock Falls State Park, Trumansburg, N.Y.
Photo Courtesy T. Engelder

# Summary of the Technology: HVSFLL Is a Recent Process -- It Has NEVER Been Used In NYS

| Hydraulic Fracturing Technological Milestones [14] | |
|---|---|
| Early 1900s | Natural gas extracted from shale wells. Vertical wells fracked with foam. |
| 1983 | First gas well drilled in Barnett Shale in Texas |
| 1980-1990s | Cross-linked gel fracturing fluids developed and used in vertical wells |
| 1991 | First horizontal well drilled in Barnett Shale |
| 1991 | Orientation of induced fractures identified |
| 1996 | Slickwater fracturing fluids introduced |
| 1996 | Microseismic post-fracturing mapping developed |
| 1998 | Slickwater refracturing of originally gel-fracked wells |
| 2002 | Multi-stage slickwater fracturing of horizontal wells |
| 2003 | First hydraulic fracturing of Marcellus shale[15] |
| 2005 | Increased emphasis on improving the recovery factor |
| 2007 | Use of multi-well pads and cluster drilling |

From NYS SGEIS draft, page 5-32, 2009



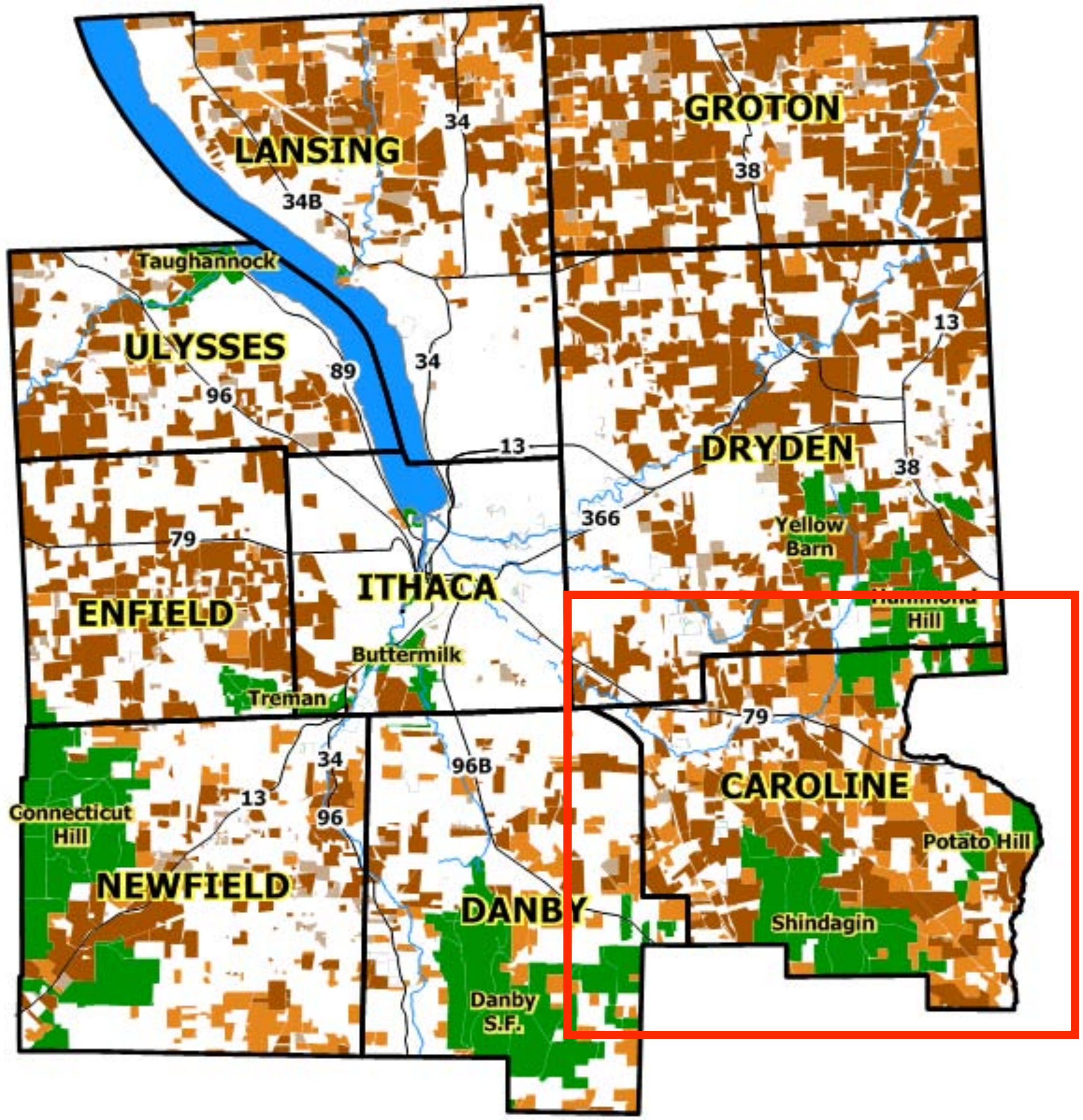




Notice NNW-SSE orientation of non-square, about 640 acre, spacing unit. Geology and leasing control.

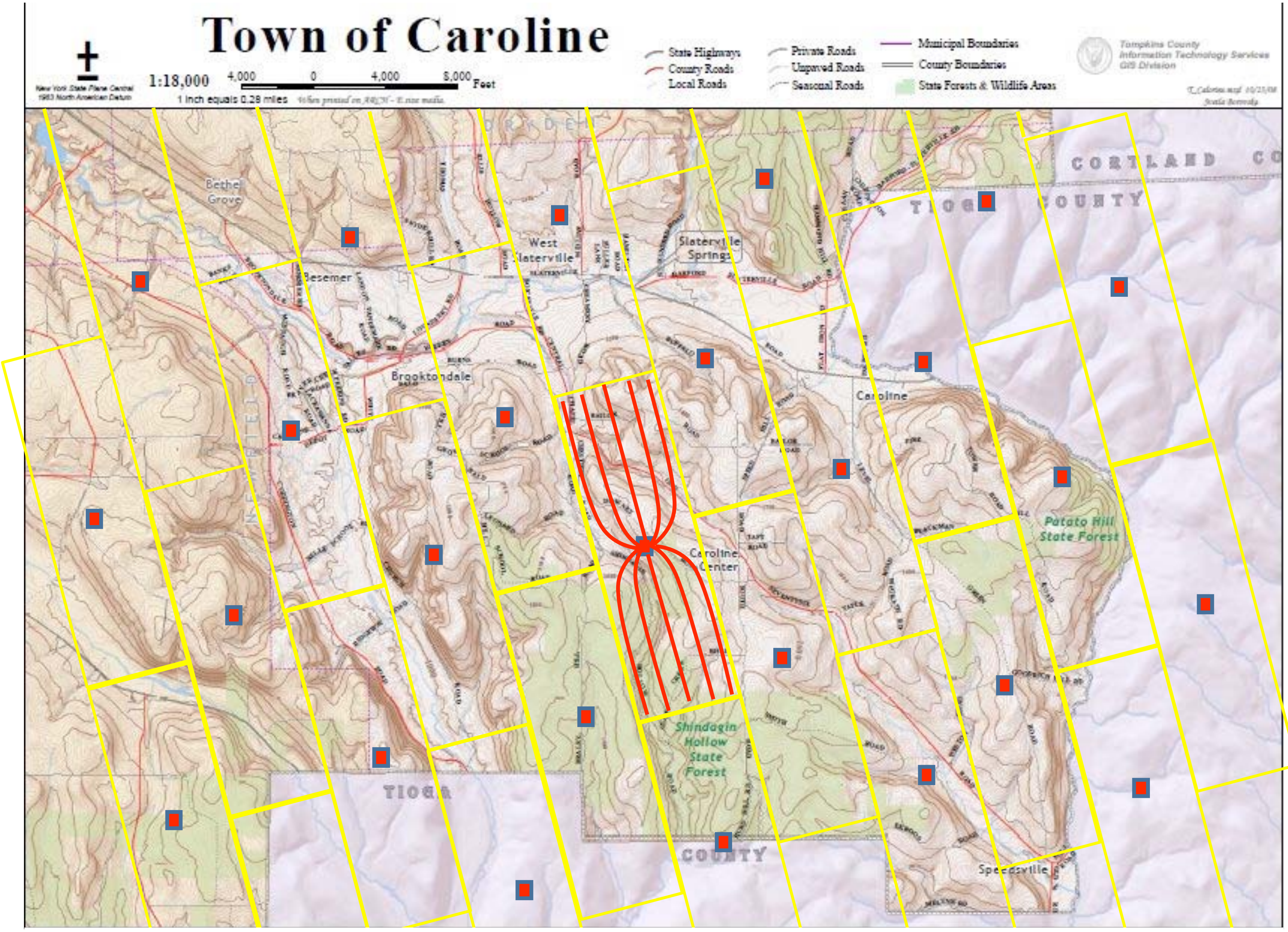
# Hydrocarbon Leases in Tompkins County, October, 2010

http://tcgasmap.org

Brown and Tan mean "leased"



# *Ideal* Arrangement of Spacing Units



# The Shale Gas Debate: A Pattern from Other Environment/Health Debates?

“One key political tactic involves manufacturing a fake debate to undercut emerging scientific consensus. This tactic has been used against the consensus that sulfur and nitrogen emissions cause acid rain, the consensus that chlorofluorcarbons cause the hole in the ozone layer, the consensus that cigarette smoking causes cancer, the consensus on endocrine disruptors, and particularly the growing consensus on global warning. These efforts follow a similar pattern. ***First, deniers argue that the science is uncertain. Then they argue that the scientific concerns are exaggerated and the true risks are small, particularly compared to natural risks already existing in the environment. Finally, they state that technology will solve the problem, eliminating the need for government interference.”***

***p61, "Toxic bodies - hormone disruptors and the legacy of DES"
Nancy Langston, 2010, Yale University Press***

# American Ingenuity Starting to Address The Problem

AQUA PURE

Wastewater Solutions | In-House Capabilities | Investor Center | Downloads | Contacts

Industrial Wastewater SOLUTIONS

Municipal Wastewater SOLUTIONS


Wastewater Solutions

> Industrial Solutions

> Case Studies

- Mobile Wastewater Recycling - NOMAD 2000
- Frac Flowback Recycling
- SAGD Produced Water Recycling
- LPG Storage Cavern – Brine Pond Concentrator

> Municipal Solutions

## Wastewater Solutions [↓]

### Frac Flowback Water Recycling

Natural gas wells often require large volumes of fresh water to frac or stimulate production. While underground, the water dissolves a range of contaminants and a number of chemical additives making the flowback water unsuitable for environmental discharge. Producers currently pay a great deal of money to purchase fresh water, haul the fresh water to site, haul contaminated water to a disposal well, and pay for disposal. Installing an Aqua-Pure evaporator in areas where high levels of well fraccing take place reduces fresh water supply volumes, water hauling volume and produced water disposal by up to 90%. This drastically reduces the cost of natural gas production, especially in areas where fresh water is scarce and/or disposal costs are high.

DOWNLOAD

**Recent Article**
Mobile Evaporators - Clean Water To Go In Texas.

**Cost Comparison**


Wegmans
Wastefluid Recycling
Facility
220
Image PA Department of Conservation and Natural Resources-PAMAP/USGS
©2010 Google
©2009 Google

# Oil, Gas and Solution Mining Law Declaration of Policy - ECL Article 23

**§ 23-0301. Declaration of policy**
It is hereby declared to be in the public interest:

• *to regulate the development, production and utilization of natural resources of oil and gas in this state in such a manner as will prevent waste;*

• *to authorize and to provide for the operation and development of oil and gas properties in such a manner that*

  • *a greater ultimate recovery of oil and gas may be had, and*

  • *that the correlative rights of all owners and the rights of all persons including landowners and the general public may be fully protected, and*

• to provide in similar fashion for the underground storage of gas, the solution mining of salt and geothermal, stratigraphic and brine disposal wells.

(*Italics* mine)

# Compulsory integration in New York is governed by Titles 5 and 9 of the **Oil, Gas and Solution Mining Law**. These titles were significantly amended on August 2, 2005

**§ 23-0901. Compulsory integration and unitization in oil and natural gas pools and fields.**

.

.

.

3. In the absence of voluntary integration as permitted by section 23-0701 of this article and after finding as required by subdivision 2 of this section, the department shall make an order integrating all tracts or interests in the spacing unit for development and operation. Each such integration order shall be upon terms and conditions that are just and reasonable and subject to the following:

(1)"Integrated non-participating owner"…

(2) "Integrated participating owner"…

(3) "Integrated royalty owner"…

# Compulsory integration in New York is governed by Titles 5 and 9 of the **Oil, Gas and Solution Mining Law**. These titles were significantly amended on August 2, 2005

**§ 23-0501. Well permits.**

.

.

.

2. Every person who applies for a permit to drill an oil or gas well or deepen or plug back a well to a different pool after the effective date of this section, notwithstanding prior orders, ***shall control through fee ownership, voluntary agreement, or integration pursuant to section*** 23-0701 or ***23-0901 of this article no less than sixty percent of the acreage within the proposed spacing unit for such*** **well and shall provide the department with: a. A map** in a format specified by the department depicting the proposed spacing unit for the well, the surface and bottom hole locations of the well, the location of the wellbore in the target formation, the location of any field-bounding faults within the proposed spacing unit, the acreage of the proposed spacing unit, and the boundaries of each tract wholly or partially within the proposed spacing unit as may be evidenced by tax identification numbers;