“Pros and Cons of Hydraulic Fracturing”

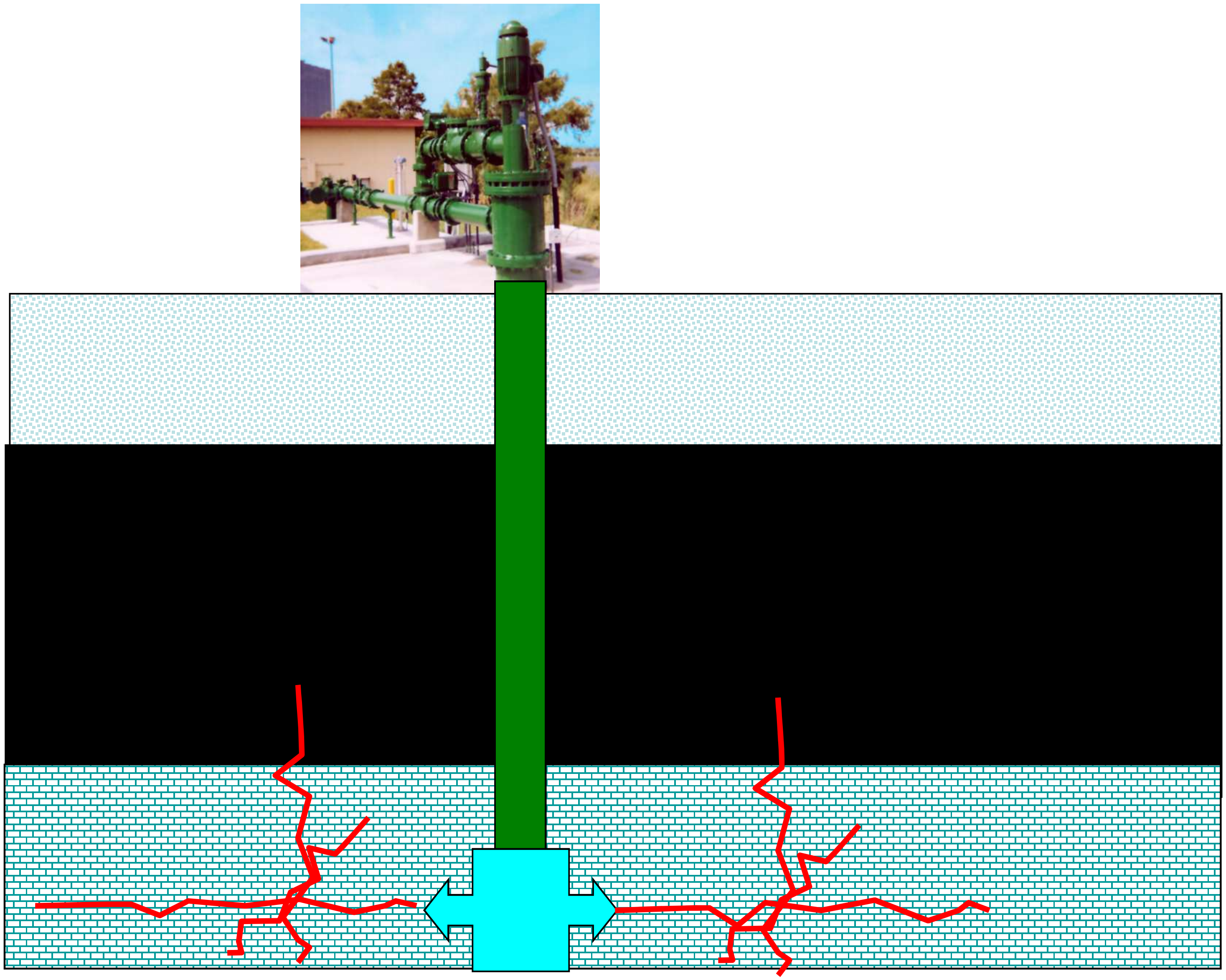
- Hydraulic Fracturing is a reality and is not going away;
- Mostly safe but needs better practices and enhanced regulations;
- Will alter the entire USA energy economy; and,
- Excerpts from Geibel & Brown (2012) – Other things besides oil and gas hydraulic fracturing are possible but probably unlikely.

Presentation by Chris J. Brown, Ph.D., P.E., January 2013

Presentation Outline

- Introduction – What is hydraulic fracturing ?;
- At what water pressures do we see the onset of fracturing ?;
- Where are prospective areas for H. fracturing ?
- What is driving H. fracturing ?
- Pros and Cons;
- What about in Florida ?
- FAS Hydrogeological Setting;
- What is issue with Everglades ASR System?;
- Questions.

What is hydraulic fracturing ?

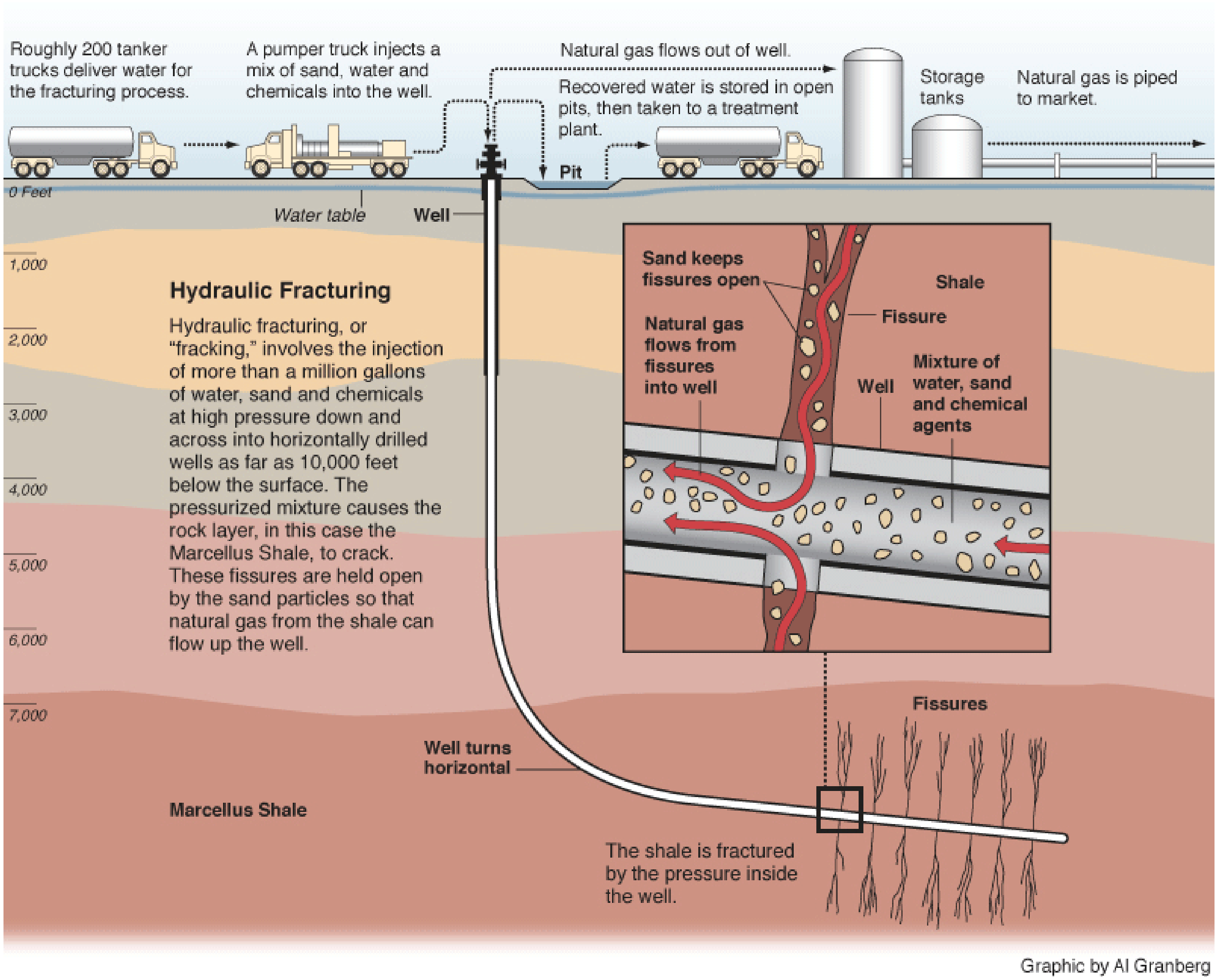


Unconfined Aquifer

Confining Unit

Confined Zone

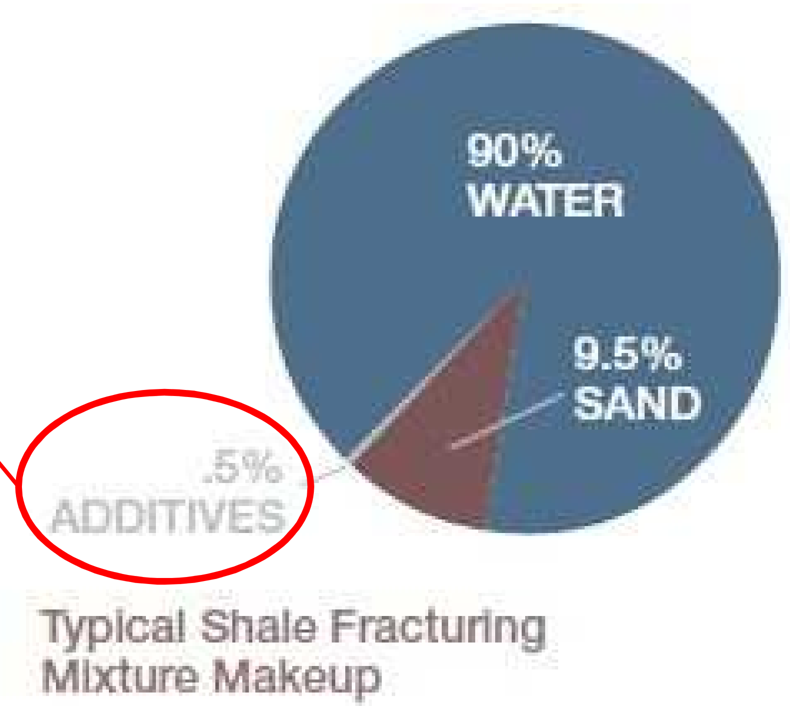
What is hydraulic fracturing ?



Source: Propublica

Typical Makeup of Fracturing Fluids

Methanol;
Isopropanol;
Ethylene Glycol;
Benzene;
Lead;
Diesel Fuel;
Starch;
Guar Gum;



Source: API, Congressional Reports

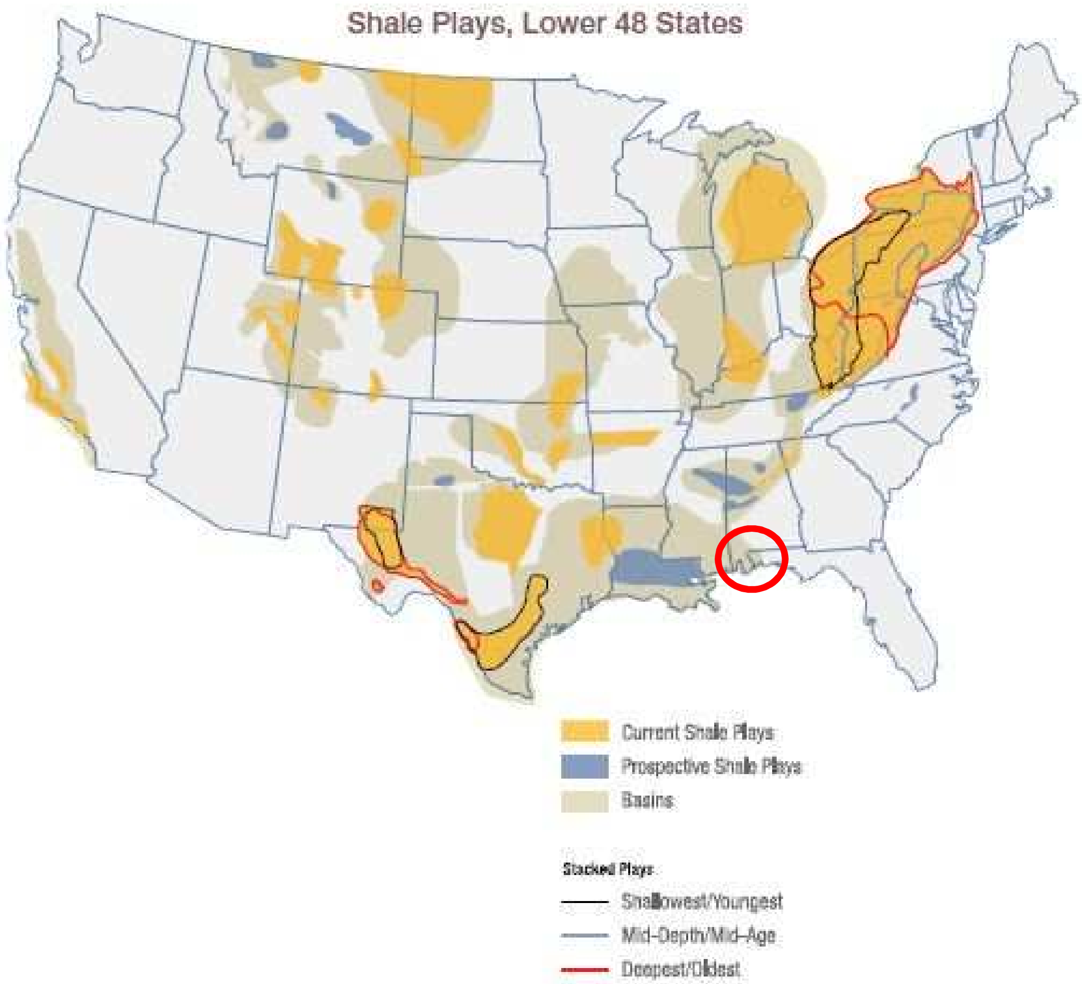
Typical Well Site

Source: NRDC

At what pressures do we expect onset of fracturing ?

- 1930s and 1940s – P > 1 psi/ft of overburden depth;
- Bouwer (1978) – P > 67% overburden pressure;
- Driscoll (1986) – P > 0.50 psi/ft of overburden depth for coastal plain sediments/soft rock;
- Driscoll (1986) – P > 1.2 psi/ft of overburden depth for crystalline rock;
- Sterret (2007) – P > 1.0 psi/ft of overburden plus 1,500 psi – *Intentional Fracture*;
- Ehlig-Economides & Economides (2010) – P > 0.82 psi/ft of overburden depth;

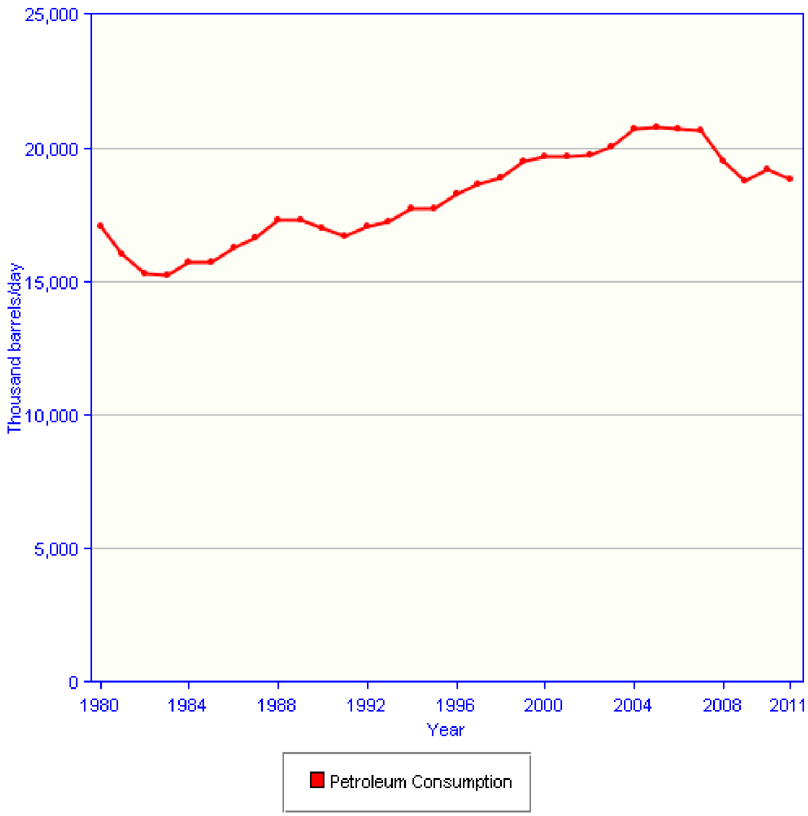
Location of Shale Gas/Oil Resources in USA



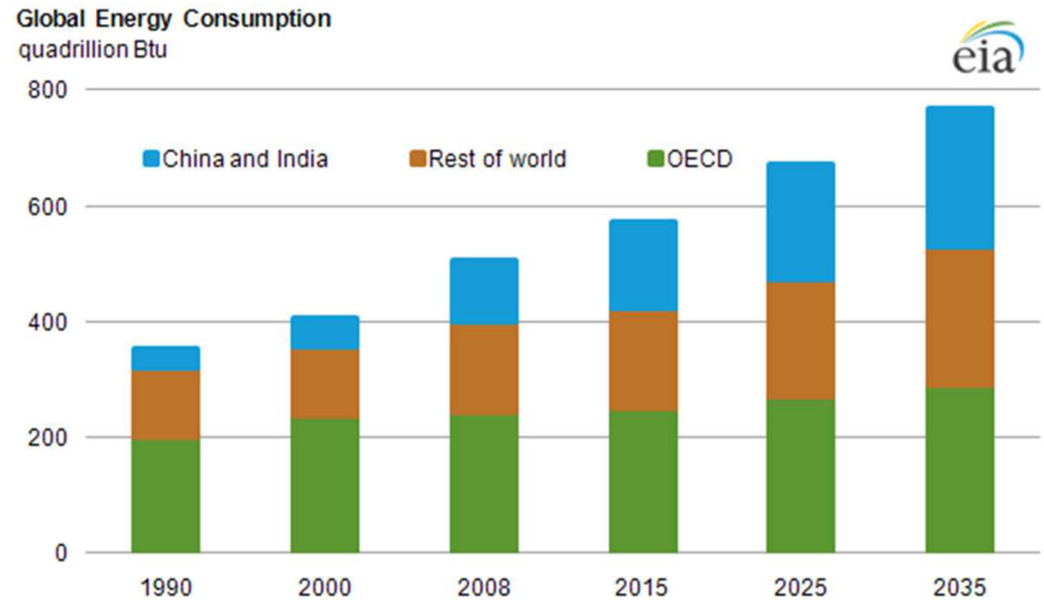
Source: EPA

EIA 2013 Annual Energy Outlook

So what is driving the boom in hydraulic fracturing ?



USA Data



Source: EIA

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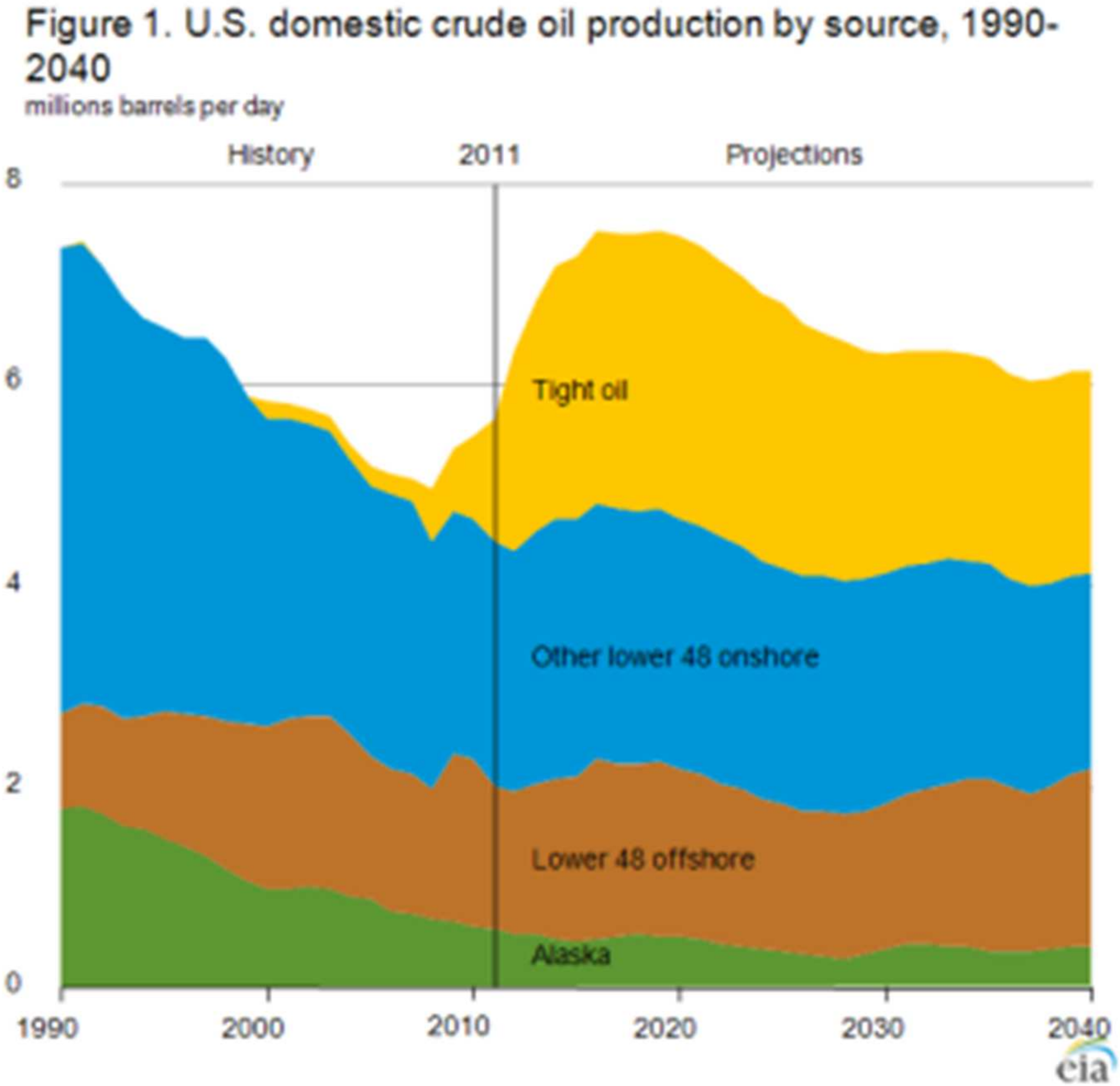
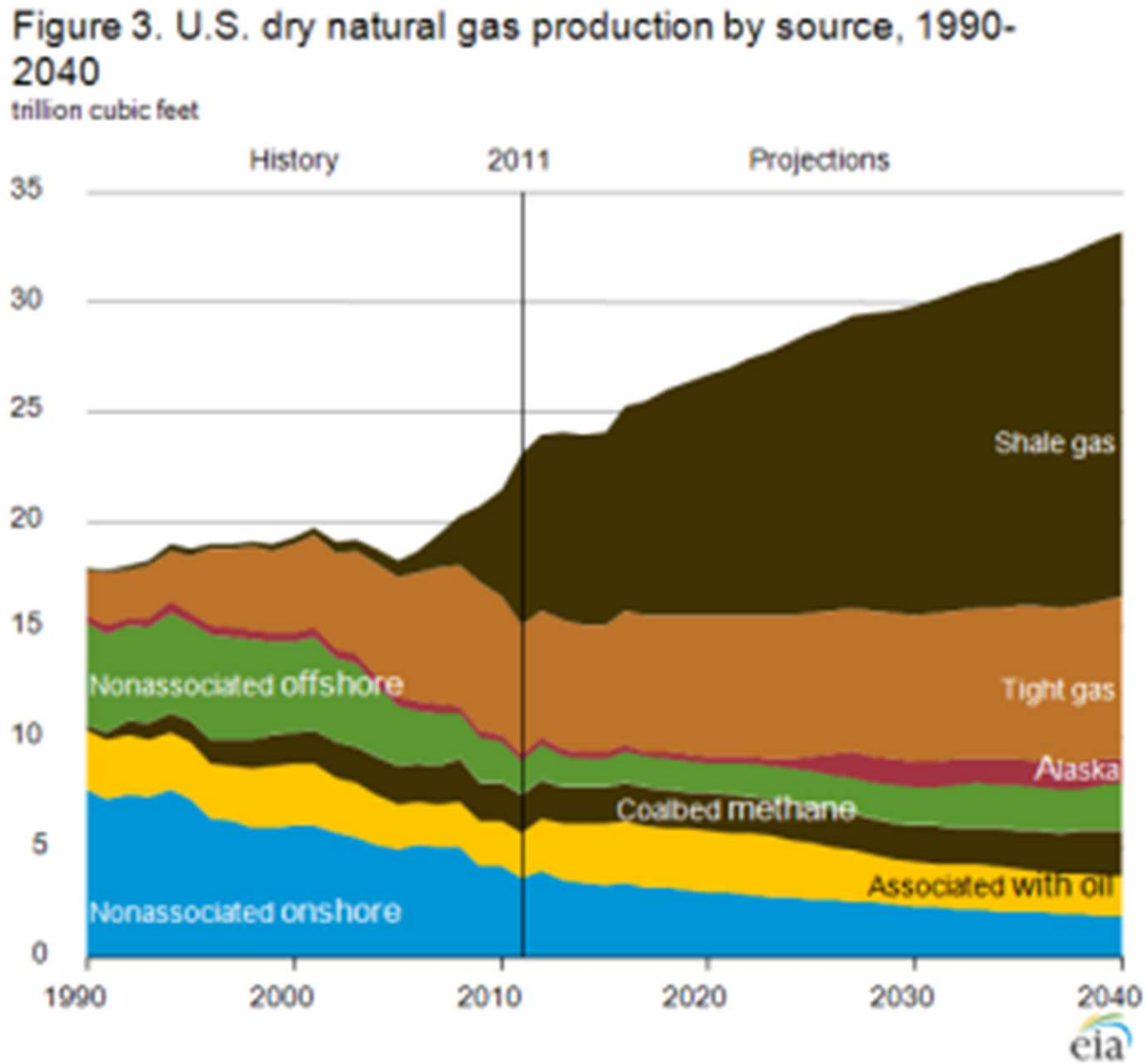
EIA 2013 Annual Energy Outlook



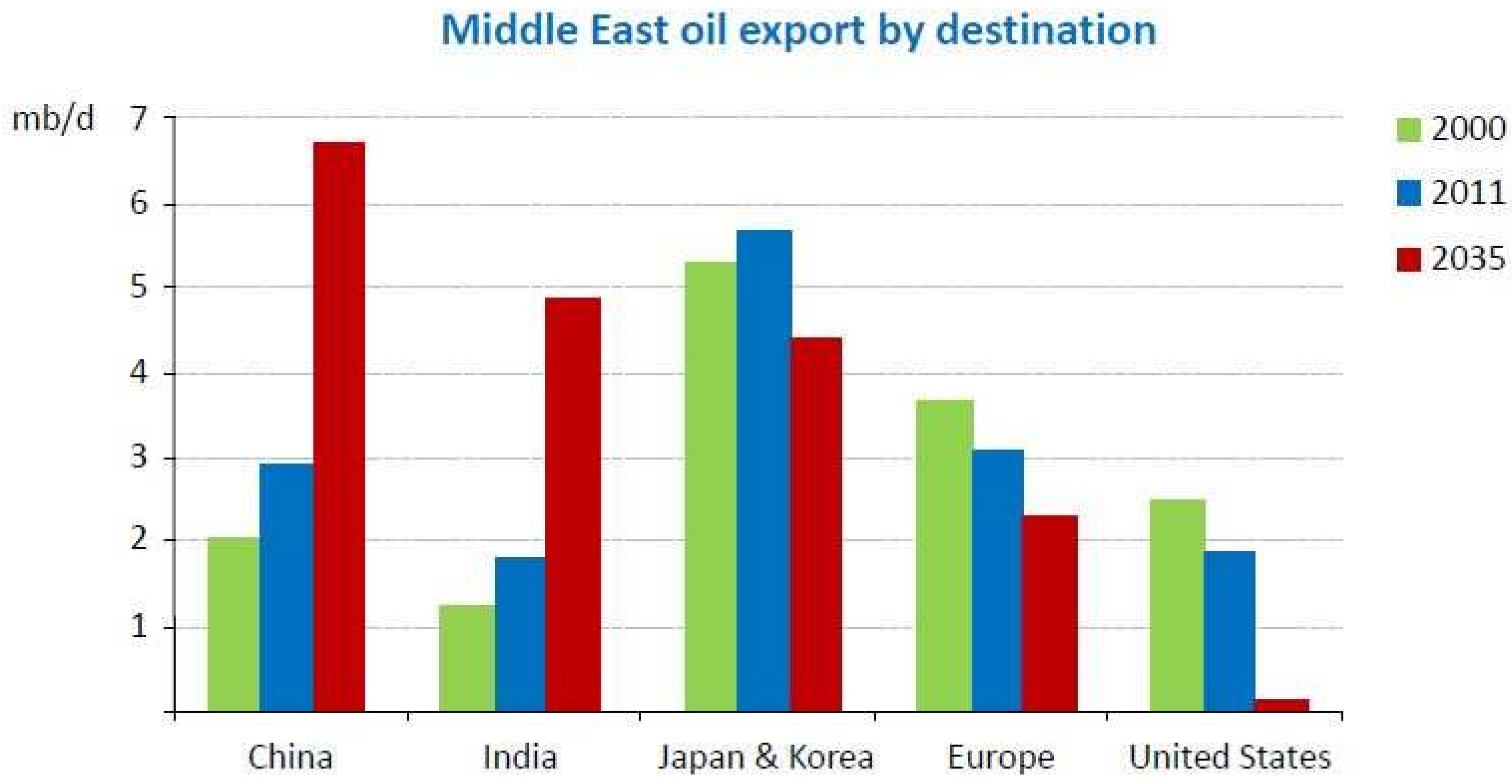
Source: EIA

EIA 2013 Annual Energy Outlook



Source: EIA

EIA 2013 Annual Energy Outlook



Source: World Energy Outlook 2012

What are the “Pros” ?

- Reduce energy dependence on Middle East;
- New development supported 600,000 jobs in 2011;
- Cheap natural gas = more manufacturing in USA;
- Future exporter of energy ??
- Reduced generation of greenhouse gas due to replacement of coal with natural gas.
  - In 2000 16% of power generated with nat gas;
  - In 2030, 30% use predicted.

What are the “Cons” ?

- Huge water demand;
- Huge amount of wastewater generated;
- Poor or limited regulation – Energy Policy Act of 2005 excludes most hydraulic fracturing from being regulated under SDWA, UIC program;
- Potential for cross-contamination of drinking water aquifers with fracturing chemicals or more likely, methane;
  - See cases in Wyoming, Colorado, and PA;
- Induced seismic activity from deep injection wells; and,
- Extend our reliance on fossil fuels.

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Geology of Shale Gas Areas

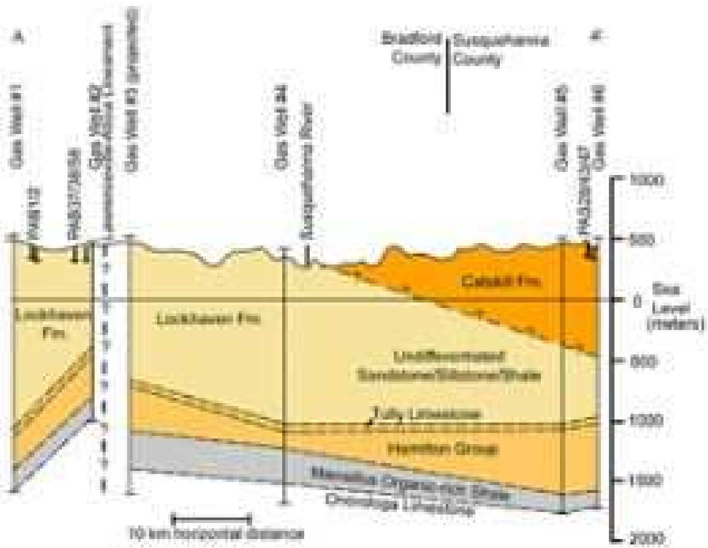


Fig. 2. Geologic cross-section of Bradford and western Susquehanna Counties created from gas-well log data provided by the Pennsylvania Department of Conservation and Natural Resources. The approximate location of the Lawrenceville-Attica Lineament is taken from Alexander et al. (34). The Ordovician Utica organic-rich shale (not depicted in the figure) underlies the Middle Devonian Marcellus at approximately 3,500 m below the ground surface.

northeast Pennsylvania (Catskill and Lockhaven formations) and

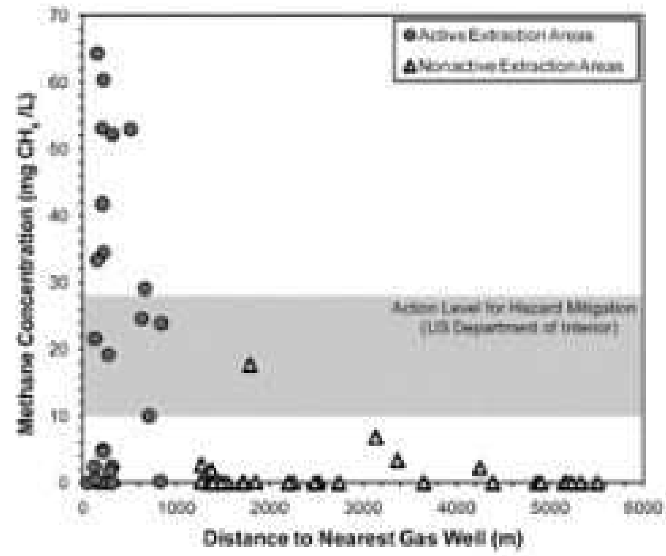
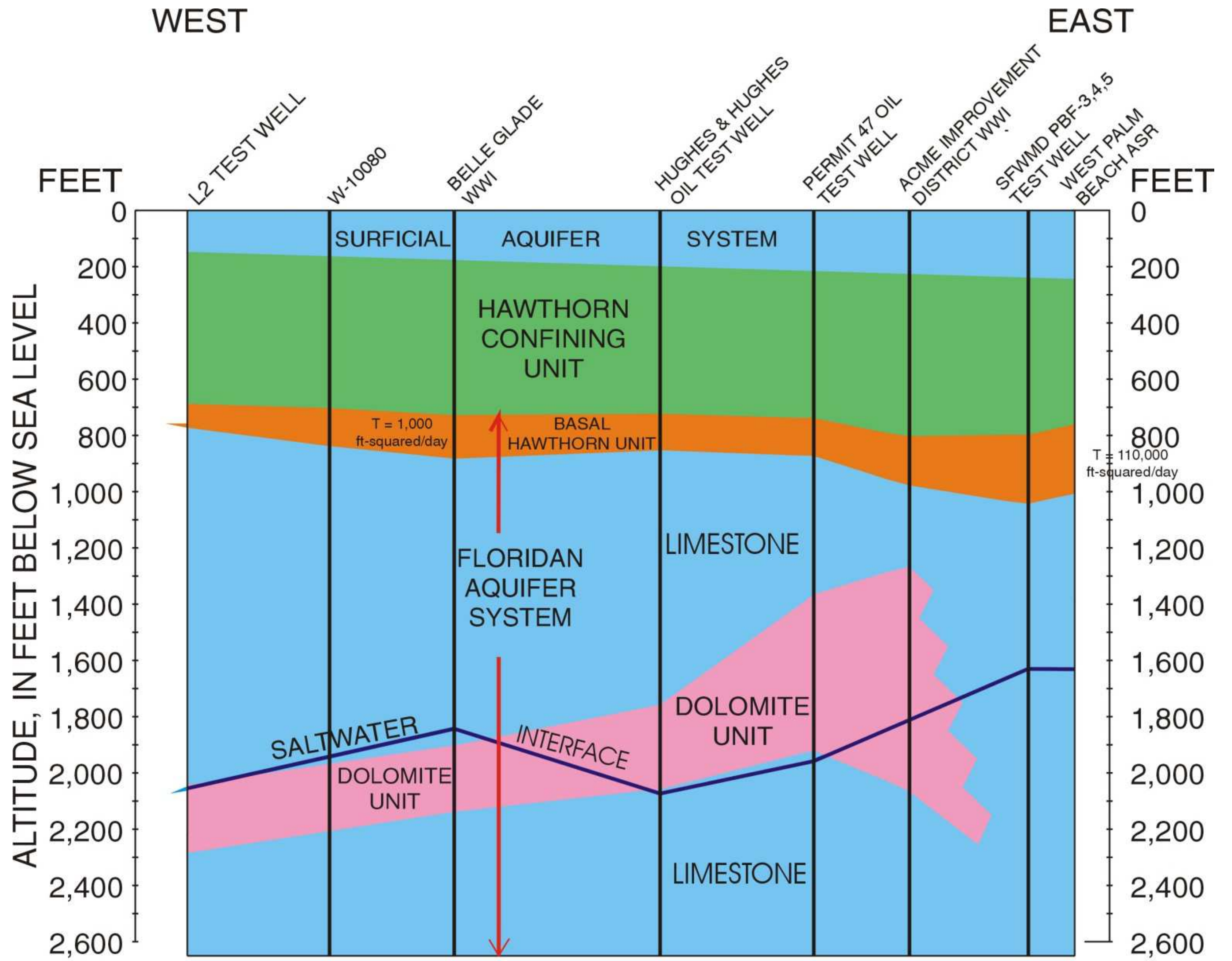


Fig. 3. Methane concentrations (milligrams of CH_4 L^{-1}) as a function of distance to the nearest gas well from active (closed circles) and nonactive (open triangles) drilling areas. Note that the distance estimate is an upper limit and does not take into account the direction or extent of horizontal drilling underground, which would decrease the estimated distances to some extraction activities. The precise locations of natural-gas wells were obtained from the Pennsylvania Department of Environmental Protection and Pennsylvania Spatial Data Access databases (ref. 35; accessed Sept. 24, 2010).

Source: Osborn et al. 2011

Hydrogeologic Setting

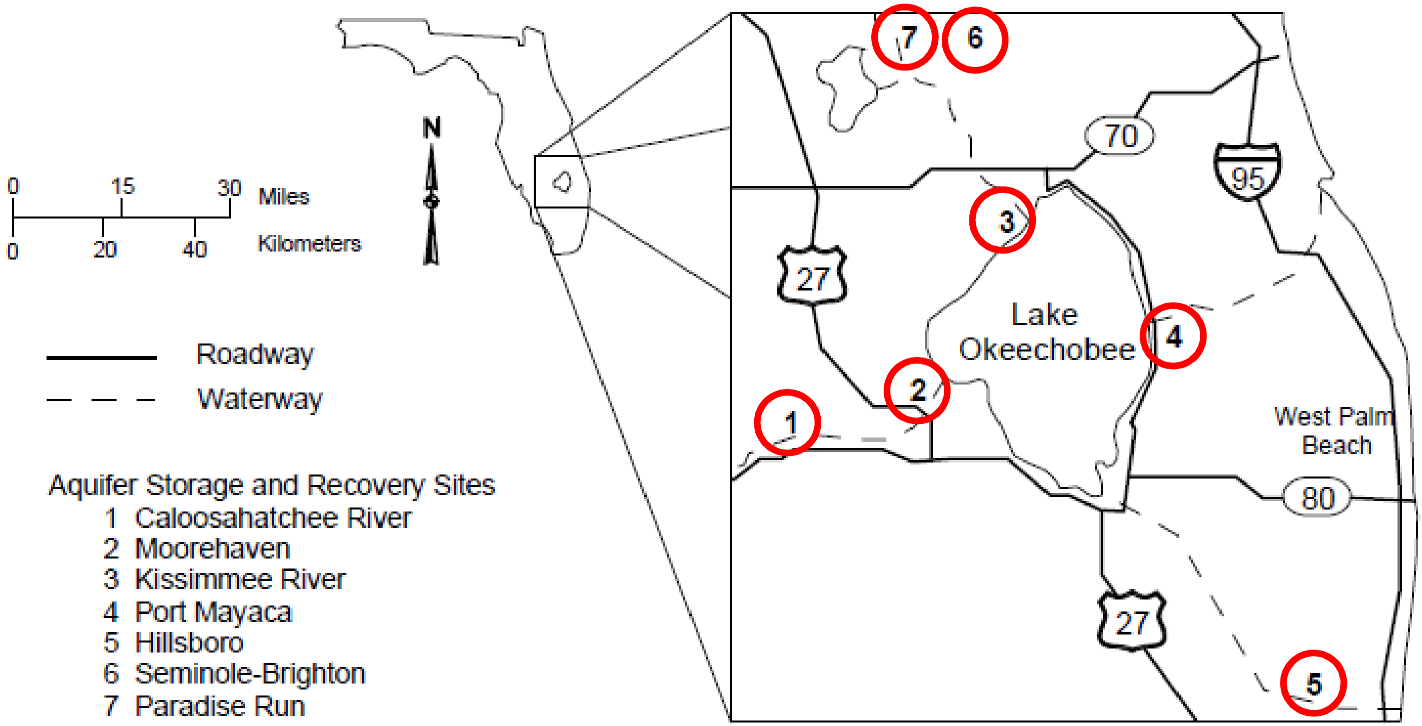


WEST TO EAST CROSS-SECTION THROUGH CENTRAL PALM BEACH COUNTY

Source: USGS

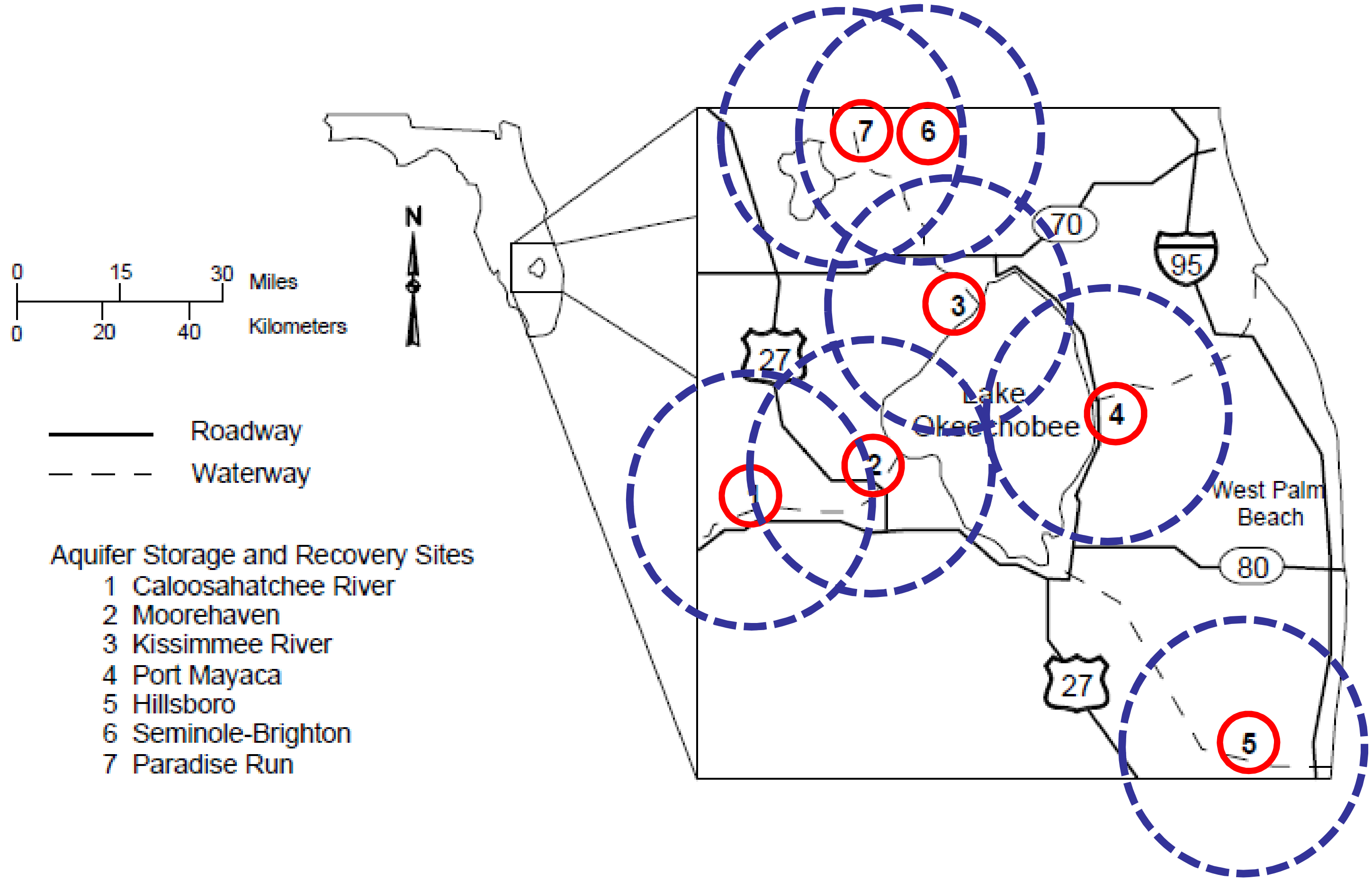
What is the concern with ASR operations ?

- Proposed Everglades ASR Program includes up to 333 wells in southern Florida;



What is the concern with ASR operations ?

- Pore pressures within the FAS would get elevated;

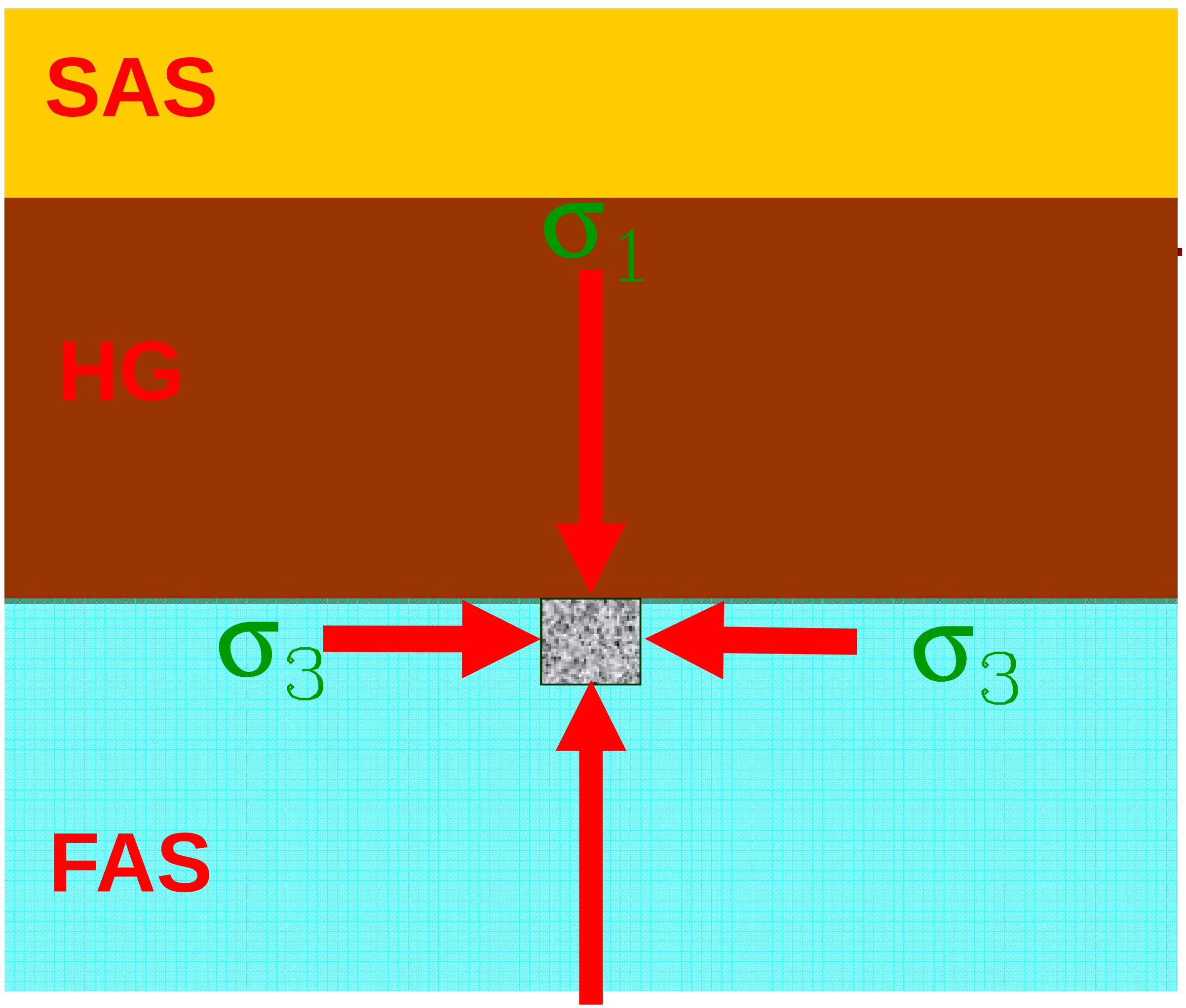


Predicted State of Stress During Injection

32 to
210 feet

396 to
735 feet

Element
At top of
FAS



Methodology

- Use 3 primary evaluation methods and 2 “check” methods;
- Primary Methods included:
  - Shear Failure;
  - Tensile Failure; and,
  - Microfracture Development.
- Check Methods included:
  - Goodman (1980) – Modified Mohr-Coulomb Failure Envelope; and,
  - Bouwer (1978) – P > 50 to 67% of Overburden pressure.

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Summary of Laboratory Rock Testing Data

- Both UU and Triaxial tests with confining pressure were completed;
- Also 1 sample was subjected to splitting tensile strength test;
- UCS ranged from 330 to 1,980 psi;
- UCS arithmetic mean was 998 psi;
- Phi Angle arithmetic mean was 28.9 degrees; and,
- Cohesion arithmetic mean was 332 psi.

Results

- Using the 3 methods presented earlier:
  - Shear Failure – Unlikely given the well head pressures would have to exceed rock shear strength of about 500 psi;
  - Tensile Failure – Onset estimated at well head pressures of 139 to 237 psi or total head of 343 to 559 feet; and,
  - Microfracture Development – Onset estimated at well head pressure of 95 to 166 psi or total head of 233 to 395 feet.

Results

- Using the 3 methods and fracture gradients:
  - Shear Failure – Equates to about 0.73 psi/ft;
  - Tensile Failure – Equates to about 0.69 psi/ft; and,
  - Microfracture Development – 0.61 psi/ft.

Results Seem Reasonable When Compared To Literature Values…..

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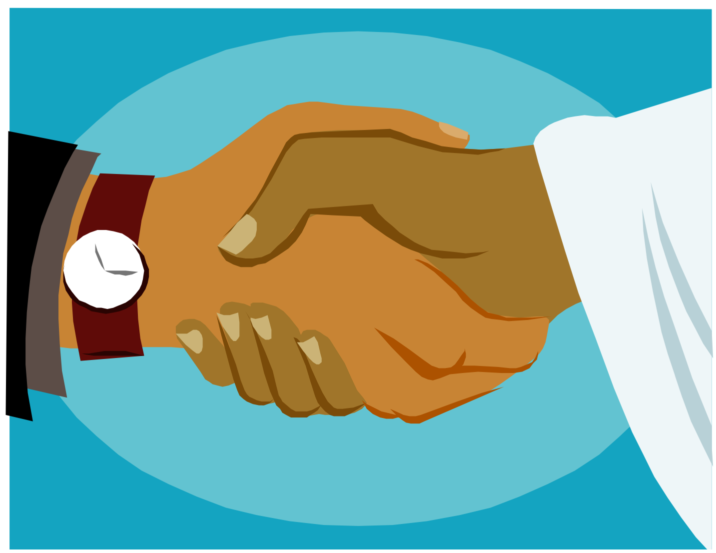
Questions ?

- **Thank you for the opportunity to provide this presentation.**
- **Further information can be found at Geibel, N.M. & Brown, C.J. (2012)** Hydraulic Fracturing of the Floridan Aquifer from Aquifer Storage and Recovery Operations**, *Environmental and Engineering Geoscience*, 18(2): 175-189.**



Christopher.j.brown@unf.edu