

NARUC

Winter Committee Meetings

Staff **Subcommittee** On Gas

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ANADARKO PETROLEUM CORPORATION

PROTECTING DRINKING WATER RESOURCES

NARUC Winter Conference

David McBride, VP Global HSE

Anadarko's Mission & Values

WE LIVE OUR VALUES

- Integrity and Trust: We will act with the highest ethical standards and honor our promises and obligations to work, family, faith and community.
- Servant Leadership: We will place the success of others above our own, as we pledge to exhibit personal humility and professional courage.
- People and Passion: We will recognize and reward strong performance and respect diversity in thought, practice and culture.
- Commercial Focus: We will safeguard the long-term interest of our shareholders and maintain high standards for health, safety and the environment.

 Open Communication: We will listen for understanding, communicate freely and clearly, as well as encourage diverse opinions and constructive debate.

ANADARKO PETROLEUM CORPORATION



ANADARKO Corporate Responsibility

Our Mission: To provide a competitive and sustainable rate of return to shareholders by exploring for, acquiring and developing oil and natural gas resources vital to the world's health and welfare.

What Differentiates Anadarko?

- Proven Successful Track Record
- Deep and Balanced Portfolio
- Best-in-Class Capital Allocation
- Distinct Competitive Advantages
- Active Portfolio Management



Benefits of Domestic Oil Natural Gas

Direct benefits to Americans

- Saved \$700 on average in 2015 from lower gasoline prices (API)
- Average households realized \$1,200 in savings in 2012
- Savings will rise to \$3,500 annually in 2025 as a result of domestic natural gas production (API)
- More than 95% of all products we use on a daily basis are derived from or powered by oil and natural gas

Environmental benefits from US oil and natural gas

- Greenhouse gas emissions from the industry have declined by 374 million metric tons of CO2e from 2008 – 2014 (API)
- While natural gas production has dramatically increased, methane emissions have declined, and today make up only 4% of total U.S. greenhouse gas emissions (API)

Can water use and protection be another benefit?



Source: API (2015), IHS Global Insight

US EPA Final Report: Potential Impacts of Hydraulic Fracturing on Water Resources

- US EPA changed the primary conclusion from:
 - "No systemic widespread impacts from hydraulic fracturing" to
 - "Hydraulic fracturing activities <u>can</u> impact drinking water resources under <u>some</u> circumstances"
- Final report failed to recognize that oil and gas operations are well regulated for all aspects of water management

U.S. EPA Identified Issue	Current State Actions	Examples of Anadarko Practices to Reduce Risk
Focus on quantity of water used in drought areas	States are doing water plans or asking for data	 Participated in Colorado State Water Plan Works to increase water recycling and reduce fresh water use Works with Texas Water Development Board on data Works to enhance research into water treatment technology
Need for greater stringency for water discharge permits	States have strong water discharge permit programs	 Manages water usage to maximize recycling and reuse Conducts internal assessments for beneficial use of produced water Engaging with state and federal regulators on appropriate limits
Attention on seismicity and disposal wells	States have strong programs and U.S. EPA has the UIC program	 Prepare for alternatives to disposal wells Extensively evaluates location of potential new wells to ensure best geologic conditions exist for siting the well Works with state agencies to reduce risk
Continued focus on chemicals used	States require disclosure of chemicals used	 Founded FracFocus and is a top reporter Operates the CARE process Cooperates with states in updating regulations
Greater focus on spills	States have spill reporting and management programs	 Complies with regulations Utilizes data to trends causes and develop mitigation strategies for spills Has a contractor spill awareness and prevention program

Life Cycle of Water in Upstream Operations



ANADARKO PETROLEUM CORPORATION

Working to Reduce Fresh Water Use

- Wells will typically produce energy for 30 years
- Colorado OGCC projected that water usage for oil and natural gas is about 0.08% of total water use in Colorado
- US EPA projected nationwide upstream water use is <1% of total water use</p>



Formation Water as a Use-able Product

Oil was King natural gas was considered a waste product from an oil well

Both Oil & Natural Gas

became a profitable commodity

Produced or Formation Water can it also become a useable by-product?

Wellbore Integrity: Protecting Groundwater

We protect groundwater by:

- Determining where fresh groundwater sources reside (between 100 and 500 feet beneath the surface)
- Designing wells with multiple layers of steel and cement
- Testing pipe and cement during drilling to ensure integrity
- Equipping wells with monitoring equipment for 24-hour observation throughout its production life
- Sampling nearby fresh water sources within 2,500 feet of our drilling locations (many areas)



Source: Adapted with Permission from Texas Oil & Natural Gas Association (© 2010)

Plug and Abandonment of Producing Well: Protecting Groundwater

- Primary goal is to permanently shut in and isolate a well at its end of life
- Regulations require operators to ensure that strata (i.e., freshwater aquifers) are adequately isolated
- In most cases, a series of cement plugs is set in the wellbore with an inflow or integrity test made at each stage to confirm hydraulic isolation



Final

Collaboration to Drive Technology: Energy Water Initiative (EWI)

- EWI is a collaborative effort to study, communicate and improve lifecycle water use and management in onshore oil and natural gas exploration and production
 - Technology and knowledge-sharing
 - Recommended management practices and technologies
 - Fact-based information to stakeholders
 - Follows API's anti-trust provisions during all meetings and discussions

Anadarko Petroleum Corp.	Devon Energy	QEP Resources, Inc.
Apache Corporation	Hess Corporation	Repsol, S.A.
BG Group	Marathon Oil Corporation	Royal Dutch Shell Plc
BP PIc	Newfield Exploration Co.	Southwestern Energy
Chesapeake Energy	Noble Energy	XTO Energy, Inc.
Chevron Corporation	Pioneer Natural Resources Co.	
ConocoPhillips Co.	Occidental Petroleum Corporation	

Questions





EVALUATING THE EFFECTS OF HYDRAULIC FRACTURING ON GROUNDWATER QUALITY:

THE PAVILLION GAS FIELD, WYOMING









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Contents of Presentation







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- **Overview of Controversy**
- **USEPA Study and Responses**





HISTORY OF PAVILLION, WYOMING GAS FIELD

Pavillion Gas Field, Wyoming





- First commercial gas wells completed in 1960. Expanded production in past decade.
- Today, over 200 active gas wells, 50 inactive or plugged wells, 30 former surface pits.
- Numerous irrigation wells and domestic wells in field; 90% are < 620 feet deep.
 - Principal gas production zone > 1500 feet, but some gas well perforations as shallow as 700 feet. Hydraulic fracturing commonly > 1500 feet but as shallow as 1060 feet.

SOURCES: Wyoming Breeze, 2011:, Stephens et al, 2014; WDEQ, 2015; WDEQ, 2016

USEPA STUDY OF POTENTIAL IMPACTS OF HYDRAULIC FRACTURING: 2008 - 2011



Residents complain of taste and odor issues in domestic wells.

USEPA initiates study in 2008. Sample/test:

- 57 soil and vapor sampling locations
- **47 domestic wells + 3 other water wells**
- 11 pit monitoring wells

2 deep monitoring wells (screened /drilled depth: 765 to 785/ 984 ft and 970 to 990 /997 ft deep)

FINDINGS

WHY

WHAT

USEPA Draft Report (Dec 2011) indicates that hydraulic fracturing has impacted the groundwater aquifer used for drinking water.



KEY POINT: First regulatory agency study in US to indicate that hydraulic fracturing had caused regional groundwater impacts resulting in immediate national and global press coverage.

RESPONSE TO USEPA DRAFT REPORT: MEDIA AND TECHNICAL FIRESTORM



PRESS	reporting suspected impacts of "fracking"			
USGS	Sept 2012 report finds USEPA monitoring wells and data unreliable.			
ΑΡΙ	2012 evaluation finds "fatal flaws" due to poor field and lab work. Determines that data is unreliable and that the wells should be abandoned!			
USEPA	2013 - declines to finalize draft report & stands by data??? Almost no press.			
Stephens	2014 peer-reviewed paper reaches similar conclusions as USGS, API, etc.			
DiGiulio et al.	2016 peer-reviewed paper from former USEPA study leader, now at Stanford, supports original USEPA report.			
GSI	2016 peer-reviewed response to Stanford paper finds that geochemistry shows no impact by fracking.			
WDEQ	Wyoming state regulator finds negligible likelihood of groundwater impact by fracking, recommends further study to address odor and taste issues.			

PROBLEMS WITH USEPA STUDY: MONITORING WELL CONSTRUCTION AND SAMPLING



FINDINGS OF API, STEPHENS, ETC

- USEPA findings rely principally on 2 flawed, deep monitoring wells.
- Fatal flaws with monitoring well locations, construction, sampling, well materials, etc.
- Contaminants in 2 deep monitoring wells likely associated with poor installation (spills of diesel, glycol; poor decontamination, etc.)
- No evidence of impact to actual water wells. No response to odor, taste complaints.
- Pavillion field not representative of typical hydraulic fracturing operations.

"Fatal flaws in study design, implementation, and interpretation resulted in biased and unreliable results."



- Monitoring wells are deeper than nearly all water wells, potentially extending into non-commercial gas zones.
- Water wells show no increased impacts with proximity to gas wells.
- Monitoring wells contain many organic chemicals not found in either water wells or produced water from gas wells.
- The inorganic signature of the two monitoring wells is different. Therefore, cannot be related to a single source, *i.e.*, fracking fluid.



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Comparison of Organic Chemicals in Well Fluids



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- The inorganic signature of the two monitoring wells is different. Therefore, cannot be related to a single source, i.e., fracking fluid.
- Monitoring wells contain many organic chemicals not found in either water wells or produced water from gas wells.
 - Data suggest an irregularity in these 2 monitoring wells, rather than impact by hydraulic fracturing.

WDEQ PALATABILITY STUDY, 2016

DEQ

SAMPLING PROGRAM

- 14 water supply wells (domestic, irrigation, stock)
- 52 gas wells with hydraulic fracturing (of 169 in gas field), within 1420 feet of a water well
- 25 oilfield pits

KEY FINDINGS

Water Wells Sampled by WDEQ in Pavillion Field



- Unlikely that hydraulic fracturing fluids have risen to depths used by water wells.
- Water wells not impacted. Salinity at natural levels; no indication of organic chemical contamination. Poor water palatability due to natural conditions.
- More study recommended to address odor and taste issues.

WRAP-UP: NEED FOR GOOD SCIENCE

FACTS

- Environmental practices in the oilfield are designed to prevent impacts and will continue to evolve and improve.
- Groundwater impacts from oil and gas operations are very rare (< 0.04% of wells sites).
- No known cases of groundwater impacts by fracking fluids. Isolated cases of methane issues.



WHAT WE NEED

- R&D along with associated studies are needed and should be developed to address key unknowns for protecting water resources.
- Proper studies need subject matter experts, good design, transparency, proper implementation, objective interpretation, adequate peer review, etc.



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HYDRAULIC FRACTURING EFFECTS ON GROUNDWATER: OTHER HIGHLY PUBLICIZED CASES

GSI: Molofsky et al, 2011, 2013.



DIMOCK, PENNSYLVANIA

CASE: Cluster of water wells with elevated methane. Receives intense press attention.

FACTS: At many wells, methane is naturallyoccurring, assoc. with low valleys, water type, etc.

OUTCOME: PADEP and USEPA conclude impacts not due to gas wells

KEY Natural methane is ubiquitous; correlates with topography, *POINT:* water type, redox conditions, and other factors

HYDRAULIC FRACTURING EFFECTS ON GROUNDWATER: OTHER HIGHLY PUBLICIZED CASES

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PARKER COUNTY, TEXAS

CASE: Household well with high gas flow, "flamethrower" garden hose. Gas well in Barnett formation is blamed.

FACTS: Gas in household well related to natural seepage from non-commercial gas zone (Strawn formation). Garden hose flame was fraud.

OUTCOME: Texas RRC and USEPA conclude impacts not due to gas wells. METHANE LEAK DETECTION/MEASUREMENT Pipelines, Compressors, and Underground Storage Sites





PROBLEM: Potential methane leaks pose safety hazard, product loss, GHG concerns.



Nat'l Gas Storage Facility

Gas Compressor Station



Gas Storage Wells

GSI/ DOE: NEW LEAK DETECTION/ MEASUREMENT TECHNOLOGIES

PIPELINES/ COMPRESSORS

- Optical imaging.
- High-flow samplers for fugitive emissions
- Open-Path FTIR air monitoring

GAS STORAGE FACILITIES

- All of the above, plus:
- Ground surface gas flux chambers
- Remote-sensing thermal monitoring probes

TECHNICAL ADVISORY STEERING COMMITTEES

 INDUSTRY: Over 20 natural gas-related companies (production, processing, transmission, storage, marketing)
 REGULATOR/NGOS: DOE, EPA, BLM, state environmental agencies, AGA, INGAA, API, academia, and others

NARUC winter meeting 2017



Walt Hufford – Director – US Government and Regulatory Affairs



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Trust

American public attitude to industries Overall opinion*, %





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Staff **Subcommittee** On Gas

Prudent Development of U.S. Oil and Natural Gas Resources: Focus on Hydraulic Fracturing and Water

NARUC Winter Committee Meetings February 12, 2017 Washington, DC

Nancy Johnson DOE Senior Advisor Environmental Science and Policy Analysis





LARGE PORTION OF U.S. ENERGY DEMAND FUELED BY NATURAL GAS

Energy consumption (Reference case) quadrillion British thermal units



Source: EIA, Annual Energy Outlook 2017



U.S. NATURAL GAS PRODUCTION IS DRIVEN BY CONTINUED DEVELOPMENT OF SHALE GAS AND TIGHT OIL PLAYS



Source: EIA, Annual Energy Outlook 2017



- Technology advancements have unlocked vast quantities of oil and gas in low-permeability shale formations.
- DOE R&D from 1978-1992 played a key role to enable today's shale gas revolution -- for example, by developing and demonstrating new and improved techniques for recovering gas from tight reservoirs that at the time could not be economically produced.

HYDRAULIC FRACTURING: ENABLER OF GROWING U.S. OIL AND GAS SUPPLY



- Combined with horizontal drilling, hydraulic fracturing has made the U.S. the world's leading producer of oil and gas.
- Up to 95% of new wells drilled today are hydraulically fractured, accounting for more than 43% of total U.S. oil production and 67% of natural gas production.
- The full potential of U.S. resources has yet to be
 realized, given current recovery efficiencies of about 10% for oil and 30% for natural gas.

Sources: EIA Drilling Productivity Report and Baker Hughes



CONSERVING AND PROTECTING WATER RESOURCES

- Dialogue across the nation and around the globe has increased understanding of the nexus between water and energy.
- Water is an essential element of economic and sustainable U.S. oil and gas development, including:
 - Cost and logistics
 - Wellbore integrity
 - Regulatory compliance
 - Environmental stewardship.
- DOE's R&D has addressed many facets of these issues, targeted to both increasing production efficiency and reducing environmental risk.
- Options for water management are usually site and region specific.



- Injection tends to be the least cost option for disposing of formation and other water produced during oil and gas production.
- While over 9 billion barrels are injected annually for enhanced recovery, another 8 billion barrels are injected for disposal which provides a potential opportunity for increased reuse both within and beyond the oil and gas sector.

U.S. Produced Water Volumes and Management Practices in 2012, J. Veil, 2015.

DOE'S OIL & NATURAL GAS PROGRAMS

Mission: Maximize the value of U.S. oil and gas resources to the public and ensure their responsible development and delivery through policy, research, innovation, and outreach

Water and Hydraulic Fracturing Research Highlights

Water Treatment Technologies and Management Decision Tools

Region and Basin-Specific Studies

Field Observatories

Fundamental Science

Collaboration with States



DOE OIL AND GAS PRODUCED WATER TREATMENT AND MANAGEMENT PROJECTS

Major focus of DOE's water program from 2008-2016 included water treatment technologies, accounting for about 40% of projects and a third of funding.

- Projects managed by DOE's National Energy Technology Laboratory (NETL), have included state institutions, other federal agencies, national laboratories, and the private sector.
- Addressing a broad range of water-related issues (e.g., improved wellbore cementing technology to protect aquifers).
- NETL-ORD in-house research focused on risk assessment and basic science surrounding a host of water issues.

Category	Number of Projects	Total Value* (MM\$)
Water treatment technology development	25	33.4
Basic science and risk assessment (NETL ORD in-house research)	8	na
Water management tool development	6	8.4
Improved annular isolation	5	19.2
Environmental impact reduction	3	14.3
Alternatives to water as fracturing fluid	3	7.6
Enhanced water disposal options	2	2.1
Other (e.g., beneficial use, water chemistry, induced seismicity, volume reduction)	7	19.4
	59	104.4

* Average partner cost share of about 30%, DOE funding about 70%. NETL and RPSEA (EPACT Sec. 999) and other.



FIELD STUDIES AND DECISION TOOLS: TWO EXAMPLES

NETL Field Experiment: Fracturing Does Not Reach Water Aquifers

- Greene County, PA natural gas well pad field site, Marcellus Shale fractured at 8000+ foot depth
- Monitored sands at 2000 to 4500 foot depths; aquifers <1000 feet
- Combined microseismic, pressure/production, water and natural gas isotopes, and perflourocarbon tracer analyses
- No indication of communication via fractures or faults



DOE NETL, 2014. Partners: Weatherford, Univ. of Pittsburgh, Virginia Tech, West Virginia University, ProTechnics, Isotech



Integrated Produced Water Management Framework

- Produced Water Treatment and Beneficial Use Screening Tool which offers industry with tailored suggestions for water treatment and management options
- Takes site-specific data provided by operators and generates a range of available produced water and management options



Available at: http://aqwatec.mines.edu/produced_water/

DOE FIELD OBSERVATORIES



- Baseline and Real-time Air, Water, Land impact Monitoring
- Vertical Science/Observation Wells
- Instrumented Production Wells



- Technology Testing/Demonstration Sites
- Broad Collaborative Opportunities
- Public & International Outreach/Training

DOE FIELD OBSERVATORIES: SHALE OIL AND SHALE GAS

Marcellus	Permian	Utica	
Cost: \$14 million Total;	Cost: \$18 million Total;	Cost: \$9 million Total;	
\$9 million DOE	\$8 million DOE	\$7 million DOE	
Project Start: October 1, 2014	Project Start: October 1, 2014	Project Duration: ~ 5 years	
Project End: September 30, 2019	Project End: December 31, 2017	Site characteristics: deep dry gas	
Site characteristics: dry gas; active site; long history of environmental monitoring Location: Morgantown, WV	Site characteristics: liquid rich Active site; extensive existing data set brought by partners Location: East of Midland, TX	Location: Greene County, PA (14,000 ft depth) Principal Performer: Ohio State University	
 Principal Performer: West Virginia University Objectives: Long-term collaborative field site to develop and validated new knowledge and advanced technologies 	 Principal Performer: Gas Technology Institute Objectives: Determine optimum well spacing based on fracture efficiency 	Objectives: Long-term field research platform for environmental and geotechnical studies before, during and after unconventional oil and gas development	



DOE FIELD OBSERVATORY HYDRAULIC FRACTURING TEST SITE - PERMIAN BASIN

- Field-based hydraulic fracturing research program in West Texas, Permian Basin
- \$21 million joint project between DOE, industry, and academia leveraging 11 new horizontal wells and over 400 fracture treatments -- over \$100 million in industry investment
- Advanced diagnostics including coring through hydraulically fractured reservoirs
 - 600 feet of whole core from Upper & Middle Wolfcamp
- Insights expected to increase resource recovery, spur new technology development, and improve fracture models





Image Courtesy: Laredo Petroleum



FUNDAMENTAL SHALE SCIENCE AT NANOPORE SCALE

Leveraging the capabilities of DOE national labs to increase knowledge of subsurface geophysical and geochemical dynamics in unconventional oil and natural gas resource development



OFFICE OF OIL & NATURAL GA

WATER CROSSCUTS DOE'S COLLABORATION WITH STATES

States sharing information and lessons learned

OFFICE OF OIL

& NATURAL

ECOS. The Environmental Council of the States (ECOS) Shale Gas Caucus (SGC) promotes coordination on such matters as data sharing, best practices, community outreach, and lessons learned.

Data management tools for informed regulatory decision making and increased transparency

Risk Based Data Management System. 24 states and the Osage Nation use the Ground Water Protection Council's Risk Based Data Management System (RBDMS) -- an integrated suite of data management tools -- for managing oil and gas regulatory data. Launched in 1992 with DOE support.

FracFocus.org. Jointly sponsored by the Ground Water Protection Council and Interstate Oil and Gas Compact Commission. 23 states require or allow operators to use this national registry for the public disclosure of chemicals used in hydraulic fracturing. Variations are also used in Europe and Canada. Over 117,600 disclosures submitted in 32 states since 2011. New features facilitate data downloads and analysis by any interested stakeholder.







For more information

DOE Office of Oil and Natural Gas | energy.gov/fe/science-innovation/oil-gas-research **National Energy Technology Laboratory** | https://www.netl.doe.gov/research/oil-and-gas





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