

Unconventional Resource Development – A Look Ahead



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Overview

- ▶ Objective: Provide a high level view of emerging operational and environmental technology trends for unconventional oil and gas development operations.
- ▶ Key topic areas
 - Workplace Safety
 - Wellbore Integrity
 - Water and Chemical Use
 - Air Emissions
 - Waste Management
 - Footprint Management
 - Public Interface

Workplace Safety

- ▶ Is Safety a core corporate value?
- ▶ Is there unequivocal management commitment to safety?
- ▶ Is there a clear safety based management system?
- ▶ Is a change in the regulatory paradigm possible?
- ▶ Good progress seen 2012-13.
- ▶ A year from now...



Wellbore Integrity



- ▶ A well has two primary functions:
 - Protect groundwater
 - Contain fluids
- ▶ Broader implementation of performance based design and installation standards.
 - Tubulars (casing and tubing) and connections
 - Cementing materials and procedures
- ▶ Continued improvement in verification and diagnostic tools.
 - Pressure
 - Temperature
 - Acoustic
- ▶ Methane migration (stray gas)

Water and Chemical Use

- ▶ Water reuse will increasingly become SOP in most regions. Drivers vary regionally;
 - Disposal costs
 - Scarcity, access, and competing uses
 - Induced seismicity concerns with disposal
 - Public support
- ▶ Water treatment technologies generally mature, but implementation/application technologies improving.
 - Mobile or transportable systems improve
 - Economics improve with scale
- ▶ Water alternatives will gain use.
 - Methane, propane, carbon dioxide, nitrogen
 - Technical aspects and cost will limit broad application
 - Re-fracturing may increase opportunities for use

Water and Chemical Use (cont.)

- ▶ Water from non-traditional sources will increase.
 - Industrial or municipal effluents
 - High total dissolved solids (TDS) groundwater
 - Acid mine drainage (AMD) in Appalachia
- ▶ Evolution of chemicals toward lower persistence, bioaccumulation, and toxicity (PBT) characteristics will continue.
 - “Food grade” systems available
 - Trade-off with reuse or non-traditional waters will decrease
 - Diesel use essentially eliminated already

Air Emissions

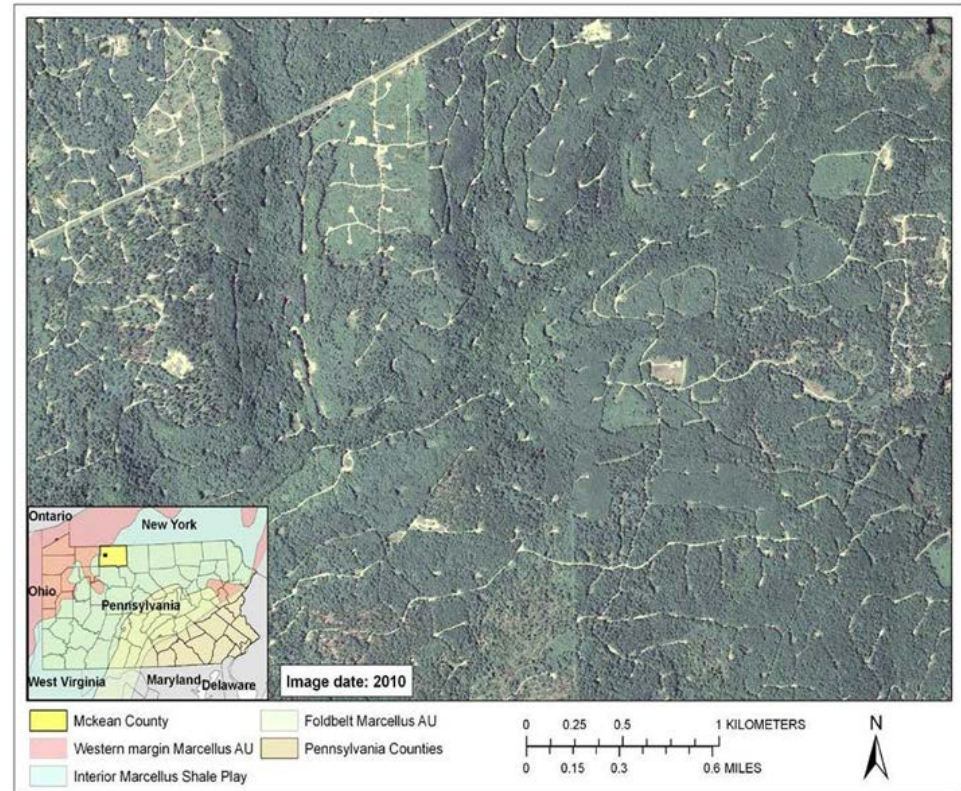
- ▶ Emission reductions driven by EPA Subpart OOOO implementation will continue.
 - Increasingly applied to oil wells in addition to gas wells
 - Controls apply to completion and production operations, methane and VOC's
 - EPA GHG emission data shows strong reductions in emissions 2011-13, which should continue moving forward
 - Challenges remain in Bakken region due to infrastructure constraints.
- ▶ Engine emissions (drilling and HF equipment) will continue to fall.
 - Equipment upgrades to Tier 4 engines
 - Fuel switching; diesel to methane or propane will occur but more limited

Waste Management

- ▶ Use of centralized treatment and holding facilities for reusable waste water likely to increase.
 - Use of tanks vs lined impoundments will vary regionally. General trend toward more tanks.
 - Treatment residuals management challenges likely to increase.
 - Solid waste management controls to increase (Naturally occurring radioactive material (NORM) limits for drill cuttings).
 - Operator due diligence improvements needed.
 - Inspections and audits

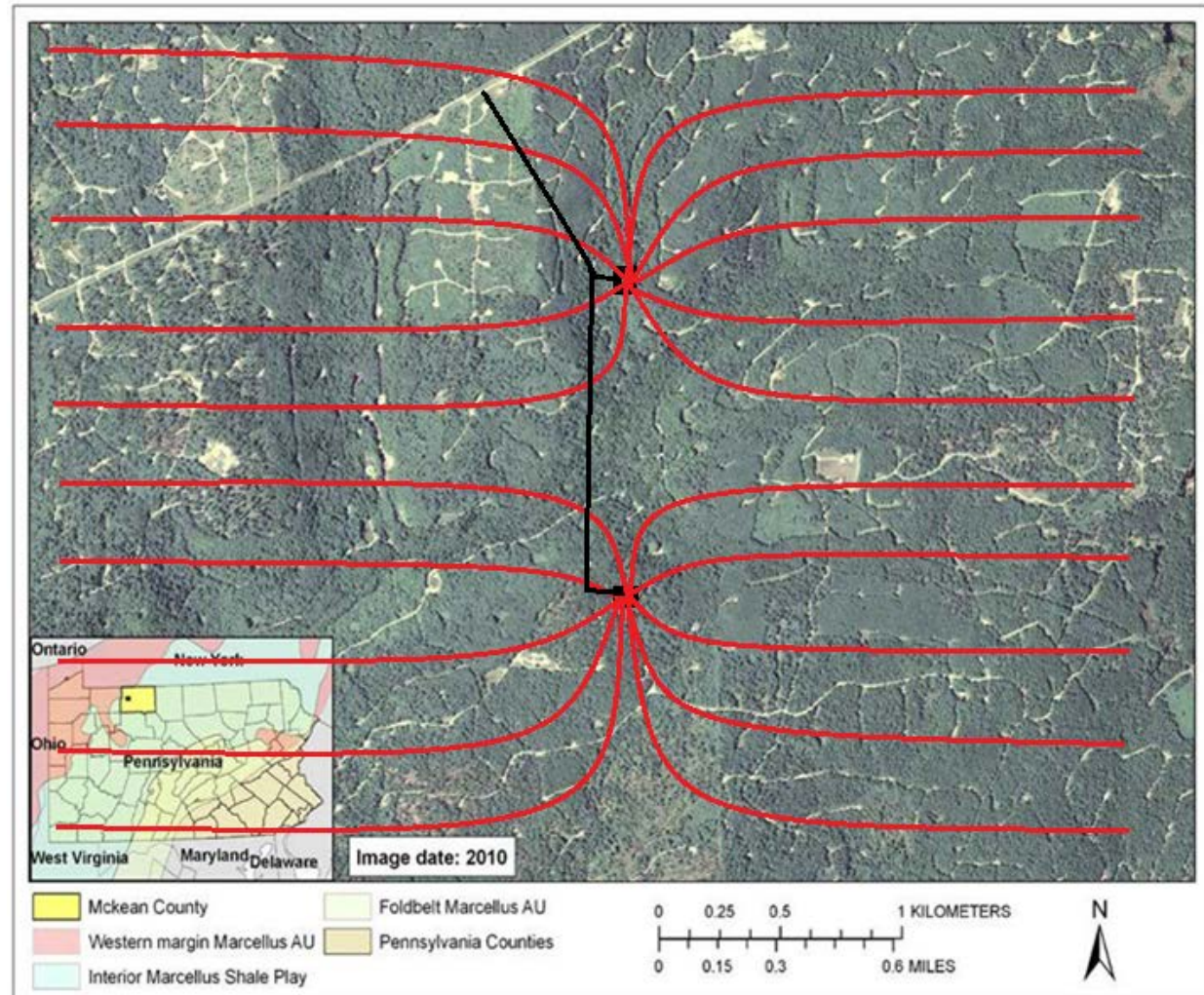
Footprint Management

- ▶ Continuing move to multi-well pad operations.
 - Trade-offs need to be understood by all and communicated.
 - Overall, unconventional development density lower than conventional development density.



Footprint Management

- Existing conventional production area developed with vertical wells.
 - >200 wells/pads
 - >50 miles of roads
- Equivalent unconventional development.
 - 20 wells, 2 pads
 - <2 miles of road
- Trade-off is the areal extent of development.



Public Interface

- ▶ Infrastructure demands; short term vs long term expectations.
 - Continuing development will stabilize and improve demand structure.
 - Health care, housing, support facilities
 - Road maintenance
- ▶ Traffic and route planning.
 - Continued emphasis on driver quality and training.
 - Expanded use of “no activity” times and zones.
- ▶ Setback limits will tend to increase
 - Beware of unintended consequences.
 - Allow flexibility in implementation.
- ▶ Operator public outreach and engagement will improve.
 - More transparency and regular discussion.
 - Industry integration into fabric of communities.

Conclusions

- ▶ Unequivocal commitment to safety.
 - One is too many.
 - A year from now....
- ▶ Environmental aspects will continue to benefit from continuing technology and regulatory improvements.
- ▶ Public engagement processes improving.
 - More transparency = more trust

Questions



"This just isn't doing it for me. Could we go back to using the crystal ball?"