Web Conference Summary of April 16-17 and June 3, 2013 Technical Workshops on Well Construction/Operation and Subsurface Modeling

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Workshop Structure

Day 1:	**Well Construction/Operation**	**(April 16)**
Session 1:	Well Design and Construction to Protect Drinking Water	
Session 2:	Well Operation and Monitoring to Protect Drinking Water	
Day 2:	**Subsurface Modeling**	**(April 17)**
Session 3:	Subsurface Modeling of Fluid Migration to Identify and Understand Potential Impact on Aquifers	
Technical Follow-up Discussion		**(June 3)**
Session 1:	Subsurface Scenarios: What are we trying to model?	
Session 2:	Modeling Subsurface Scenarios: How do we do this?	

EPA Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources

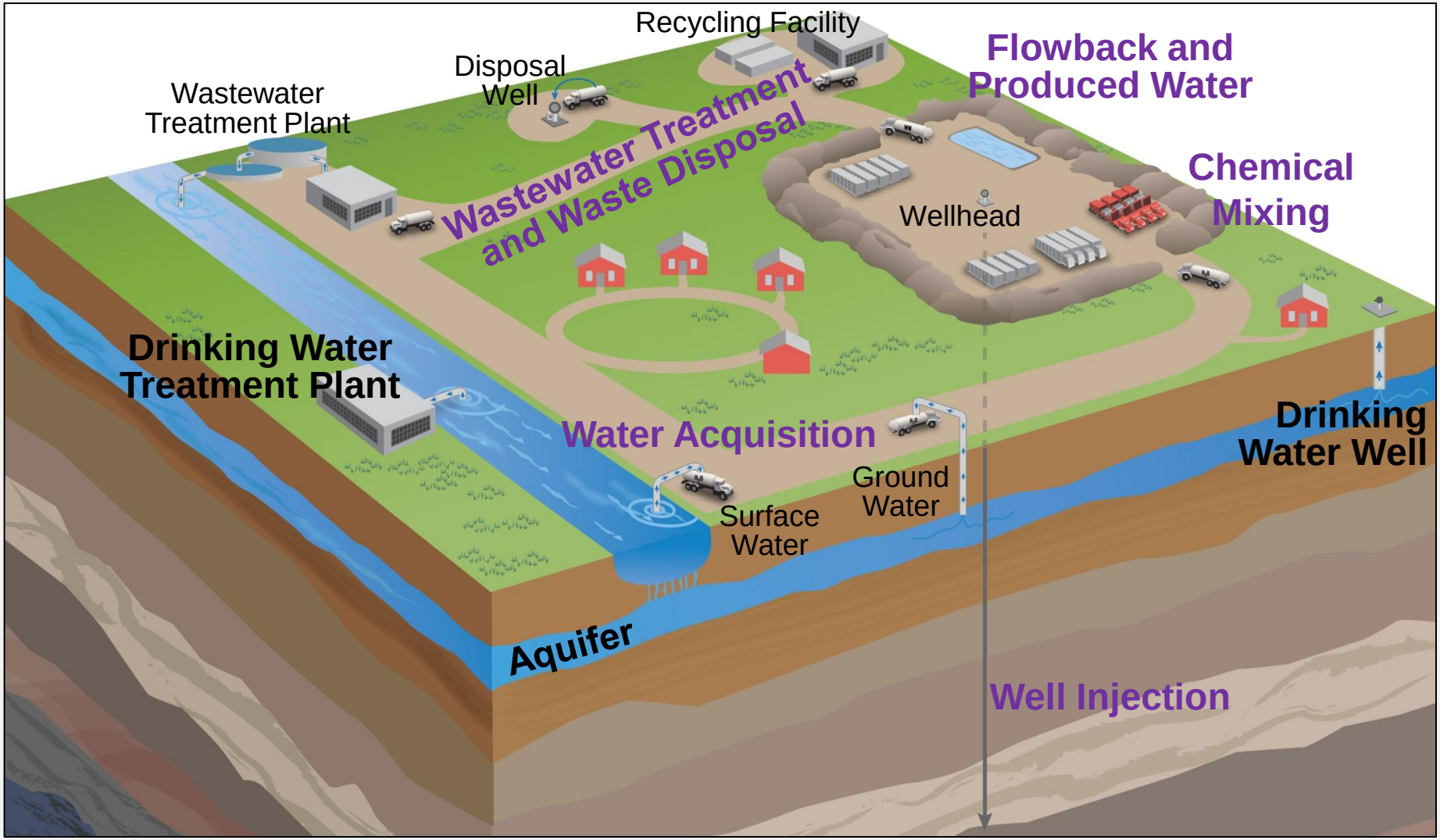
Study Goals:

- Assess whether hydraulic fracturing may impact drinking water resources

- Identify driving factors that may affect the severity and frequency of impacts

For more information:
http://www.epa.gov/hfstudy

Hydraulic Fracturing Water Cycle



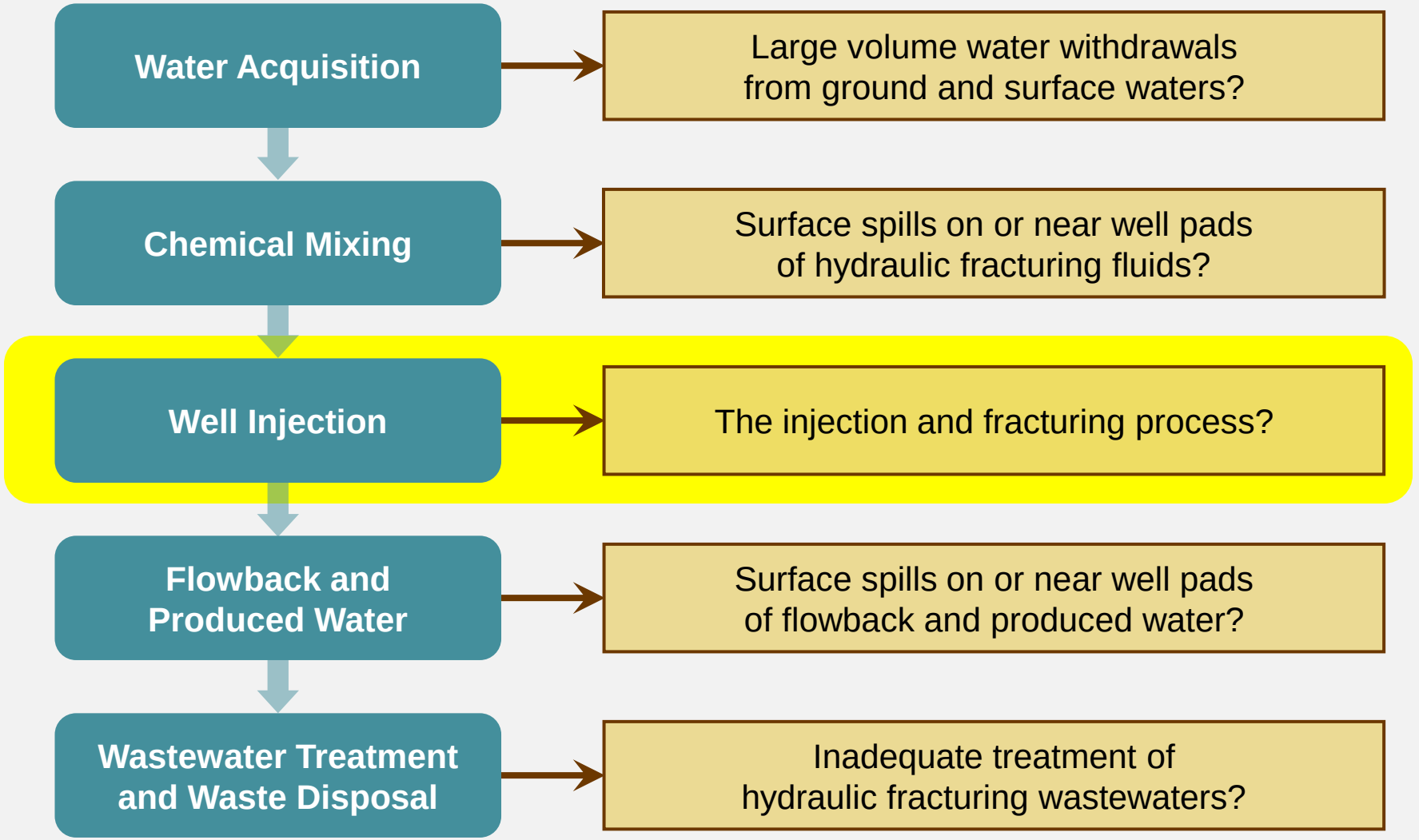
WATER CYCLE STAGES

Water Acquisition → Chemical Mixing → Well Injection →
Flowback and Produced Water → Wastewater Treatment and Waste Disposal

EPA United States Environmental Protection Agency

Primary Research Questions

What are the potential impacts on drinking water resources of:



EPA United States Environmental Protection Agency

Well Injection

Secondary Research Questions

- How effective are current well construction practices at containing gases and fluids before, during, and after fracturing?
- Can subsurface migration of fluids or gases to drinking water resources occur, and what local geologic or man-made features might allow this?

Ongoing Research Projects

Literature Review

Service Company Analysis

Well File Review

Subsurface Migration Modeling

Retrospective Case Studies

Well File Review

GOAL

Identify practices or factors that may impact drinking water resources

Identify Hydraulically Fractured Wells

- Provided by nine hydraulic fracturing service companies
- Fractured between Sept. 2009 and Sept. 2010

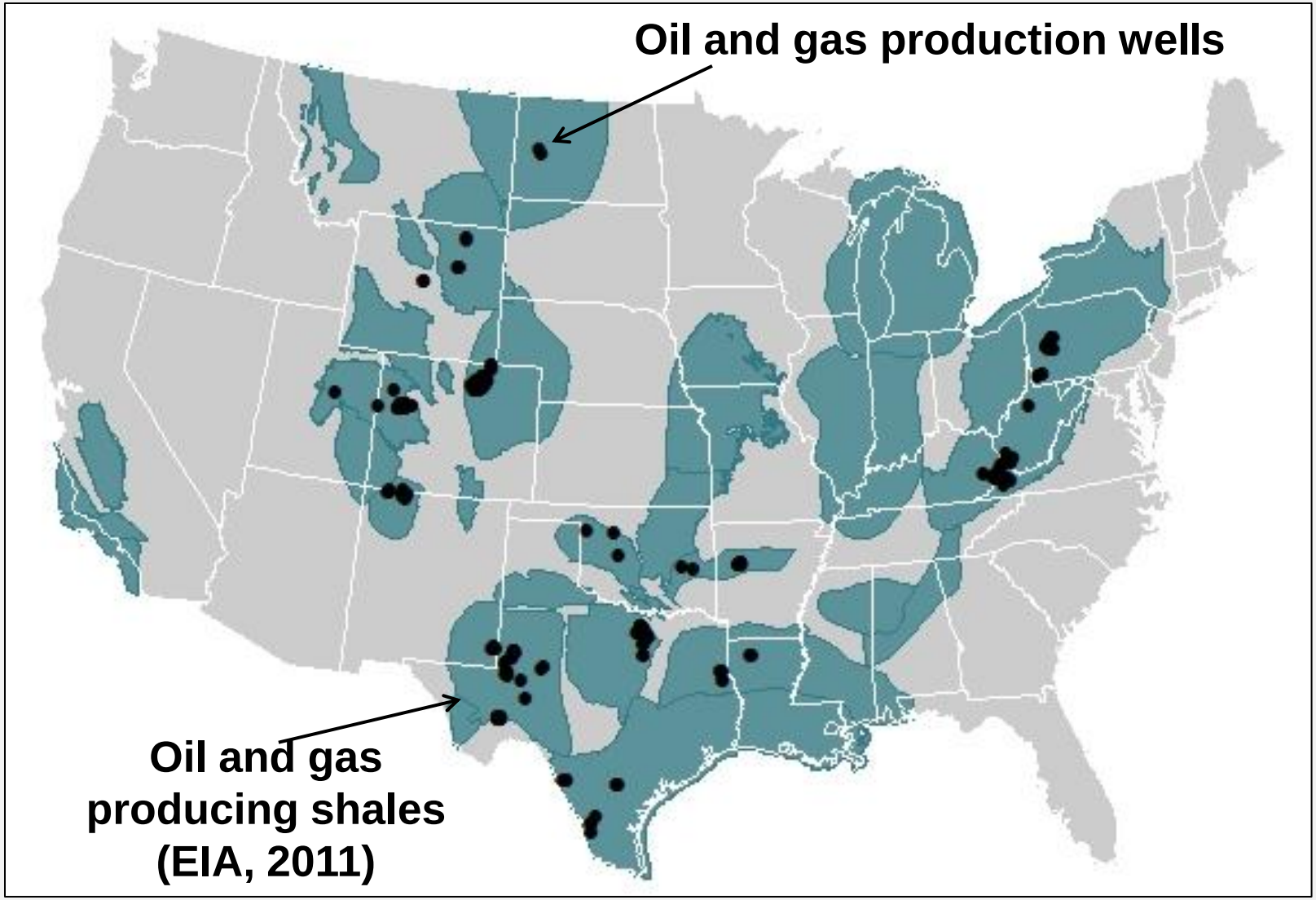
Select Wells for Well File Review

- Select statistically representative sample of wells from nine oil and gas operators of various sizes
- Wells include different geographic areas and completion types

Extract and Analyze Well File Data

- Well construction practices
- Hydraulic fracturing practices, including water acquisition and wastewater disposal

Well Locations



EPA United States Environmental Protection Agency

Information Requested

- Geologic maps and cross sections
- Daily drilling and completion records
- Mud logs
- Open hole logs, such as porosity and resistivity logs
- Description of well casings installed
- Cased hole logs, such as cement evaluation logs
- Pressure testing results of installed casing
- Up-to-date wellbore diagram
- Pre- and post-hydraulic fracturing reports, including volumes/additives used
- Source(s) of water used
- Chemical analyses of fluids (used in treatment, water zones, offset locations, flowback)
- Microseismic monitoring results
- Spill/incident reports

Session 1: Well Design and Construction to Protect Drinking Water

Participants considered three questions:

1. What current techniques are designed to prevent leaks through production well tubulars and fluid movement along the wellbore?
2. What factors are typically used to ensure adequate confinement of fluids that can move?

3a. How are ground water resources identified and documented prior to and during production well installation?

3b. What is the breadth of approaches?

Session 1: Well Design and Construction to Protect Drinking Water

Key Themes

Pressure monitoring

- Knowledge of well conditions important to interpret pressure monitoring
- Conditions that can cause annular pressure
  - Tubular expansion
  - Stray gas migration
- Pressure changes due to significant problems during hydraulic fracturing are usually immediate and noticeable
- Are there more subtle, sub-catastrophic signals that could indicate a need to modify operations?
- Is another monitoring method needed?
- Corrosion monitoring may be useful over the course of the well's life

Session 1: Well Design and Construction to Protect Drinking Water

Key Themes

Diagnostics to assess well integrity

- Regulations vary and companies use different tools, such as:
  - Mechanical inspection logs, caliper logs, sonic and/or magnetic flux, and pressure-testing the casing
- Important to understand current condition of older wells before hydraulic fracturing

Well life cycle

- Wells are often subjected to multiple pressure changes throughout lifespan and operators need to plan for this when designing the well

Session 1: Well Design and Construction to Protect Drinking Water

Key Themes

Cementing

- Different criteria for each well
- Cementing of annular spaces can be a means to enhance barrier functioning
- Cement displaced to the surface eliminates the potential to monitor annular pressure

Session 1: Well Design and Construction to Protect Drinking Water

Key Themes

Cementing, *cont.*

- When refracturing in a new zone, examine the initial completion and work to ensure zonal isolation
- Cement bond log evaluations have potentially subjective interpretations
- Foamed cement formulations are difficult to evaluate using cement bond logs

Alternative technologies

- Emerging and future technologies
  - High-strength resin used for small fractures are not affected by water, acids, or bases

Session 1: Well Design and Construction to Protect Drinking Water

Key Themes

Definition of protected water

- Definition of “protected” or “useable” groundwater varies by state

Options for identifying ground water resources

- Petrophysical evaluation
- Talk with local geologists or water well drillers and verify with samples and logging
- Water resource board data
- Resistivity logs

Session 1: Well Design and Construction to Protect Drinking Water

Key Themes

Variability of water quality and need for better data

- Local water quality can vary significantly between locations
- Data on water quality often limited
  - Well drilling records may contain information on physical location, depth, and some lithology

Session 2: Well Operation and Monitoring to Protect Drinking Water

Questions for Consideration

Participants considered two questions:

1. What testing is conducted to verify issues do not exist prior to, during and after hydraulic fracturing?

2a. What testing or monitoring techniques ensure adequate confinement?

2b. What is the breadth of approaches?

Session 2: Well Operation and Monitoring to Protect Drinking Water

Key Themes

Options for testing to verify that issues do not exist

- Pressure testing of casing
- Collection of subsurface data
- Diagnostic fracture injection tests (DFIT) to determine reservoir pressure and formation permeability
- Nearby water wells, accounting for representativeness and variability
- Research locations of preexisting water wells at county court house

Session 2: Well Operation and Monitoring to Protect Drinking Water

Key Themes

Options for testing/monitoring to ensure adequate confinement

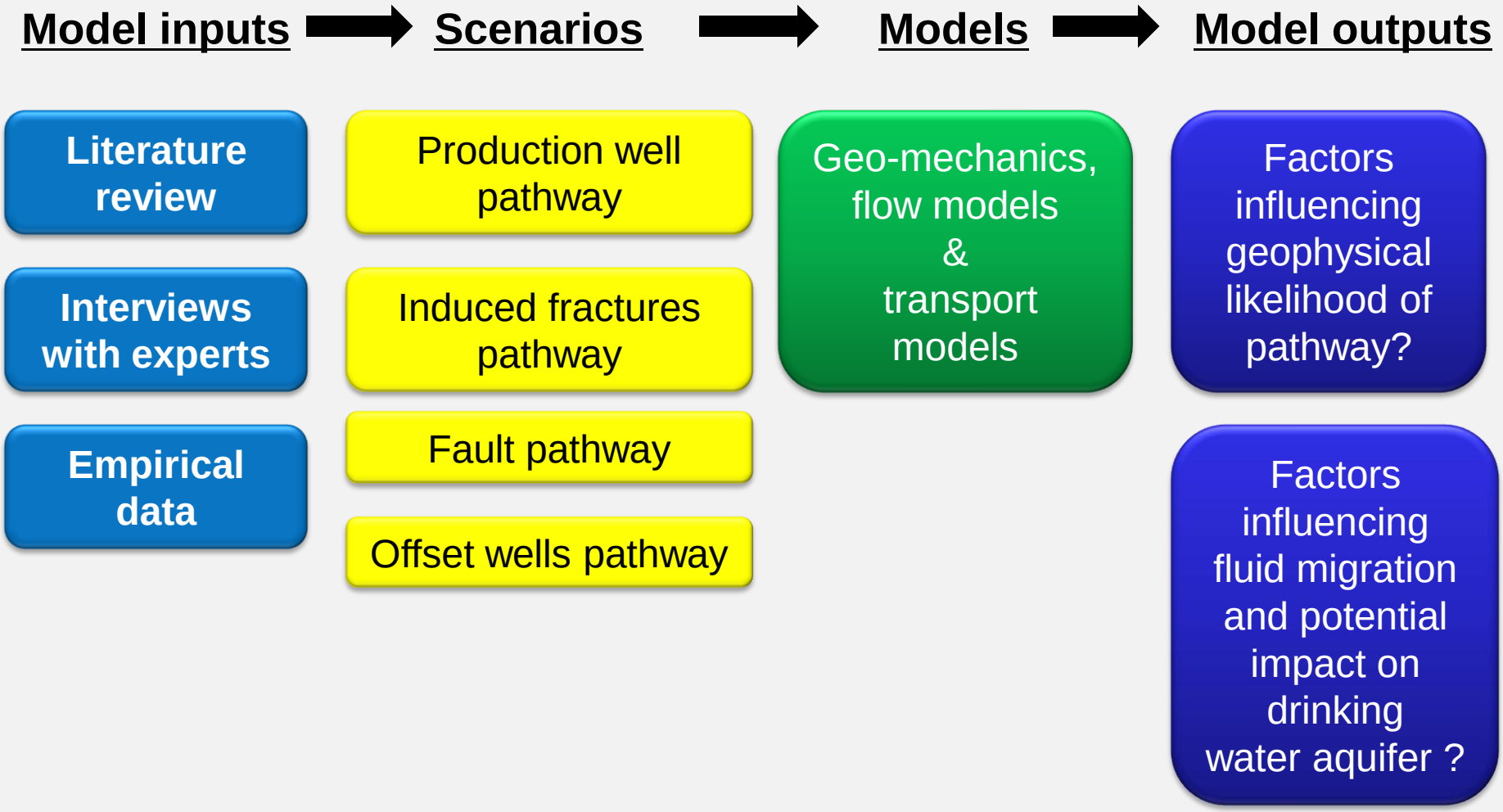
- Collect cores samples to access permeability
- Test rock mechanics
- Model geology of each play
- Use radioactive tracers to identify vertical fracture growth
- Collect baseline ground water quality data
- Install pressure monitors above fractures
- Conduct microseismic monitoring
- Quality control/quality assurance

Subsurface Migration Modeling

- Technical workshop included informational presentations, the posing of workshop questions to participants, and open discussions

- Modeling work done by Lawrence Berkeley National Laboratory (LBNL) in consultation with the EPA

Critical Path for Subsurface Migration Modeling



Session 3: Subsurface Modeling

Questions for Consideration

Participants considered four questions:

1. What additional potential failure scenarios not covered in the EPA study progress report should be investigated?
2. What are the most important parameters and appropriate level of complexity for a model that studies the severity of the potential impact of hydraulic fracturing on drinking water resources?
3. What are the advantages and disadvantages of different modeling approaches?
4. What well performance data (e.g., microseismic testing, pressure, tracer or other) are available to EPA that would be useful to build and evaluate the model?

Session 3: Subsurface Modeling
Key Themes

Additional potential failure scenarios

- Consider the tight sandstone and or coal bed methane conceptual model
- Consider the “no failure” scenario to provide confidence in the computational model

Session 3: Subsurface Modeling
Key Themes

Appropriate level of complexity and important model parameters

- Include appropriate level of complexity in models to represent essence of geophysical processes and geological heterogeneities (e.g., discrete vs. continuum approaches for representing fractures)
- Include industry experience and data to help define the range and uncertainty of parameters

Session 3: Subsurface Modeling
Key Themes

Appropriate level of complexity and important model parameters

Examples

- Detailed description of fault deformations and permeability changes
- Conductivity value of debonded or delaminated concrete
- Realistic parameters for reservoirs including layering, K_v/K_h, natural fracturing and stress numbers
- Regional variations
- Spatial and temporal resolution
- Distance from adjacent wells
- Heterogeneity of mechanical properties
- Fluid system and proppant transport
- Attenuation of fracturing fluid constituents

Session 3: Subsurface Modeling
Key Themes

Advantages and disadvantages of the different modeling approaches

- Quantify uncertainty of inputs and the impacts on the results --- conduct sensitivity analysis
- Test the LBNL modeling approach with appropriate and available datasets and models

Session 3: Subsurface Modeling
Key Themes

Available well performance data

- Texas A&M study on the permeability of the Barnett Shale
- DOE Multiwell (MWX) study for data on well performance
- Anadarko study on fault properties

At the end of the workshop, participants expressed interest in a follow-up conversation with more detail about the Subsurface Modeling

Technical Follow-up Discussion on Subsurface Modeling

Session 1 Presentation by EPA*: "Subsurface Scenarios: What are we trying to model?"*

- How and why EPA selected current modeling scenarios, including the level of model complexity
- The important parameters and ranges of values were presented for each scenario.
- The LBNL publication plan was reviewed.

Technical Follow-up Discussion on Subsurface Modeling

Session 2 Presentation by Lawrence Berkeley National Lab*:*
"Modeling Subsurface Scenarios: How Do We Do This?"

- Description of fundamental equations and capabilities of TOUGH+ codes, including new equation-of-state (EOS) modules, and dynamic linking to geomechanics codes
- Mesh generation process for complex 3D geometries
- Verification and application examples were presented.

Technical Follow-up Discussion on Subsurface Modeling

Questions for Consideration

Participants considered five questions:

1. What pros and cons of the scenarios do the participants see?
2. What other, different scenarios would participants recommend we consider?
3. What scenarios does industry typically model?
4. Are there different models/approaches EPA should consider?
5. How does industry conduct modeling to address subsurface scenarios?

Technical Follow-up Discussion on Subsurface Modeling

Key Themes

Revisited the issue of model complexity

- In addition to exploring physical possibility of pathways, should consider evidence from geology
- We should consider the representation of geological heterogeneities in the models

Definition of protected water

- The separation distance between reservoir and aquifer is dependant on the definition of drinking water, which varies by state

Revisited the issue of additional scenarios

- Tight sands and coal bed methanes

Technical Follow-up Discussion on Subsurface Modeling

Key Themes

Description for Public

- Accurately portray scenarios for non-technical audiences, especially graphics

Units of Measurement

- Report results in common oilfield units (barrels/day, psi) in addition to international units

Next Steps

- Case Studies Workshop July 30, 2013
- Technical Roundtables will reconvene in late Summer 2013
- Information on technical workshop series:
  http://www.epa.gov/hfstudy/techwork13.html
- Federal register request for information:
  https://federalregister.gov/a/2013-10154