the ENERGY lab

R&D FACTS

Geological & Environmental Systems

Integrated Assessment Model for Predicting Potential Risks to Groundwater and Surface Water Associated with Shale Gas Development

Background

The EPAct Subtitle J, Section 999A-999H established a research and development (R&D) program for ultra-deepwater and unconventional natural gas and other petroleum resources. This legislation identified three program elements to be administered by a consortium under contract to the U.S. Department of Energy. Complementary research performed by the National Energy Technology Laboratory's (NETL) Office of Research and Development (ORD) is a fourth program element of this cost-shared program. NETL was also tasked with managing the consortium: Research Partnership to Secure Energy for America (RPSEA). Historically, the Complementary R&D Program being carried out by NETL's ORD has focused on improving scientific knowledge in four key areas: drilling under extreme conditions, environmental impacts of oil and natural gas development, enhanced and unconventional oil recovery, and resource assessment.

In response to the April 2010 Macondo Prospect oil well blowout and resulting spill in the Gulf of Mexico, the focus of RPSEA and the Complimentary R&D Program has shifted to emphasize efforts directed toward establishing the technical basis for assessing and mitigating risks of potential impact to the environment and human health, both for deepwater oil exploration and unconventional fossil resource development.

Significant public concern and media attention have arisen in response to rapid industry development of our nation's abundant shale gas resources; shale gas development in the Marcellus Shale formation in the north-eastern United States has generated significant concern for potential impact to surface and subsurface potable groundwater resources, related impacts to human health and the natural environment, and induced seismicity from hydraulic fracturing.

Project Description

Through collaboration with its research partners, NETL is developing the science and engineering base to better understand the attributes and performance of unconventional fossil resource development systems, including investigation of geochemical properties of rock matrix, properties of fluid/rock interaction, characteristics and behavior of natural faults and fractures, mechanisms of fracture propagation and reservoir stimulation efficiency, and potential for unwanted fluid migration through natural and engineered pathways, response of underground sources of drinking water to perturbation by pressure or fluid, impact to regional air quality as a result of site— and regional-scale development, and predicting time dependent volume and composition of flowback water from hydraulic fracturing.

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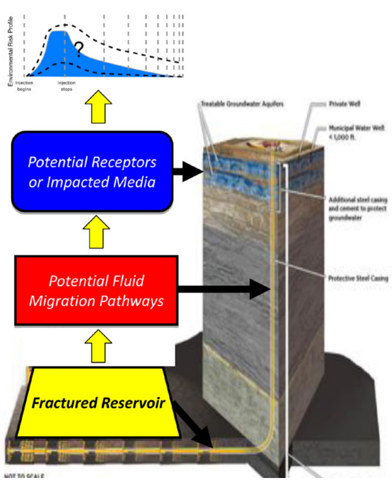
As insights from such investigations develop, they are being disseminated and applied in two primary ways: incorporation into NETL's information sharing and synthesis platform - the Energy Data Exchange, and representation within an integrated assessment modeling (IAM) framework to develop robust characterizations of systems-level performance.

In line with the technical focus of NETL's Complementary Program, integrated assessments are focused toward quantitative characterization of risk that developing of our nation's abundant unconventional fossil resources could have associated environmental impacts. Risks of interest include those resulting from well site activity, such as potential for impacts to surface and groundwater resources, but also those resulting from other life cycle activities that may occur away from the well site, such as potential for induced seismicity as a result of aqueous byproduct injection disposal. The scope of NETL's risk assessment is not be limited to a single site, since some impacts may result from compound effects of many sites at the regional scale.

Developing IAMs requires that characterizations of key system features, events, and processes be drawn from the findings of field investigations, laboratory analyses, numerical simulation, and secondary public and proprietary sources and appropriately linked within an integrating framework. Characterizations of system elements can be complex and require computationally expensive numerical modeling; linking several such numerical models in an IAM would make systems-level simulation cumbersome. It is often necessary to develop computationally efficient reduced order characterizations based on performance of detailed models for application within an integrated assessment framework. Such reduced order characterizations may take the form of correlations, regressions, lookup tables, response surface models, reduced physics models, or surrogate reservoir models.



Simplified illustration of key system elements to be considered in quantitative assessments of risks associated with shale gas resource development.
Image adapted from: *NETL, Shale Gas: Applying technology to solve America's Energy Challenge, January 2011*

Current efforts focus on building characterizations and reduced-order characterizations for key system elements and building the conceptual and computational framework to integrate those reduced-order characterizations. Resulting IAMs will be exercised to probabilistically assess systems-level performance, assess environmental risk for a set of relevant risk proxies, and quantify associated uncertainties. Current efforts are focused toward incorporating characterizations of the geospatial density, depth of penetration, and abandonment state of pre-existing legacy wells in and around shale gas development sites, characterizing the volumes and compositions of flowback water after hydraulic fracturing, characterizing the vertical extent of hydraulic fracturing, and characterizing the potential for fluid migration through overlying low permeability strata. Going forward, more and better characterizations of performance of individual system elements will be incorporated to improve and expand IAM predictive capabilty.

Goals/Objectives

The primary objective of this research is to develop a robust, science-based tool for the unbiased assessment of potential risks associated with development of shale-gas resources, focusing particularly on protecting groundwater and understanding induced seismic effects. This tool will incorporate best-available information to characterize these complex engineered systems, including properties of geologic formations and reservoir fluids, wellbore characteristics, coupled fracture propagation dynamics and fluid flow, and groundwater geochemical responses. Impacts of system variability and uncertainty on quantified risks will be taken into account through formalized uncertainty quantification.

Key Milestones/Deliverables

- Establish systems analysis design basis and representative scenario for assessment (September 2012)
- Build subsystem model elements and subsystem linkages (Dec. 2013)
- First generation risk profiles with sensitivity analysis/ uncertainty quantification (August 2014)

Benefits

With an established framework for integrated modeling of shale gas resource development activities, researchers can perform rapid assessments to quantify potential impacts associated with specific reservoir conditions or development scenarios. Such assessments will provide information useful for policymakers and stakeholders so risk considerations and related uncertainties can be incorporated into decisions about how to develop these important energy resources safely and with minimal environmental impact. This approach will also help researchers to identify parameters and system attributes that contribute most to uncertainty in quantified risks, allowing them to direct subsequent research to resolve those key uncertainties.