Ecological Considerations in Shale Gas Development

Zachary H. Bowen[1] and Aida Farag[2]

U.S. Geological Survey [1] Fort Collins Science Center and [2] Columbia Environmental Research Center

Domestic energy production is a national priority and unconventional gas resources are an important and growing source of energy for the Nation. Development of shale gas resources is an increasingly important driver of landscape change in different regions across the United States. Multiple decisions regarding policy, planning, permitting, siting, mitigation, and reclamation or restoration of shale gas development include consideration of the potential effects of development on other natural resources. Ecological considerations associated with shale gas development include potential effects of development on terrestrial and aquatic ecosystems. The potential effects of shale gas development on terrestrial ecosystems are dependent on the type of ecosystem and the particular landform, climate, soils, vegetation, and fauna present. Direct effects of shale gas development on terrestrial ecosystems are similar to those associated with other types of oil and gas development and are associated primarily with well pad construction, road construction, and development of other required infrastructure to support gas production in a project area. Direct effects include removal of vegetation, decreased area of habitat, potential introduction of invasive plant species, and potential mortality for wildlife species. Indirect effects on terrestrial systems include fragmentation of habitat, changes in wildlife habitat use, and potential consequences to survival and reproduction. Additional potential direct and indirect effects on terrestrial ecosystems are related to human activity, noise, light, and dust generated during construction or operation of shale gas production areas.

Assessment of direct effects typically involves estimation or measurement of the surface area disturbed during development. Based on the vegetation community present, this estimate or measure of surface disturbance can be translated into estimates of primary production, carbon storage, or habitat altered as a result of development activities. In planning documents for energy development, the assessment of direct effects is often focused on areal measure or estimation of surface disturbance and habitat alteration. Indirect effects of energy development on terrestrial ecosystems are usually assessed based on species-specific behavioral responses to habitat alteration and measures of habitat fragmentation. Improved technologies associated with tracking wildlife, increased availability of high-resolution remotely sensed data, and wide availability of advanced computing capability provide improved capacity to assess wildlife behavioral responses to energy development. New approaches combining advanced habitat selection modeling and conservation genetics are being employed to assess potential consequences of habitat alteration for connectivity of habitat and populations over large geographic areas. These species-focused analyses are useful for informing land use planning and management by identifying important habitats, such as movement corridors. Vulnerability assessments overlay existing or potential energy development with habitat, communities, or ecosystems to help identify areas of exposure and also use information on sensitivity of species or habitats to development to estimate potential vulnerability. Vulnerability assessments are a major component of ecoregional assessments, which are currently being conducted by a number of land and resource management agencies. Such large-scale assessments consider multiple natural resources and are intended to better quantify and understand the potential cumulative effects of different land use alternatives and to help identify potential areas for conservation, restoration, or development.

Activities associated with energy development also affect aquatic systems during the cycle of industrial water use which includes acquisition, extraction (produced water), treatment, and disposal. Produced water may be discharged into watersheds, increasing stream flows and converting ephemeral watercourses to perennial streams; injected into deep wells, discharged to drip irrigation systems, maintained in evaporation ponds, or treated before discharge to a surface water body. As a result, multiple opportunities exist to alter the aquatic health and the resulting ecology of waterways. Studies of potential effects of energy development include direct effects of surface disturbance (erosion and habitat loss) and water quality (beneficial use versus toxicity of trace organics, salts, and trace metals) as well as examination of effects of water acquisition on aquatic ecosystems. Approaches that define the potential effects for both individuals and populations can assist in better understanding the overall potential for unconventional oil and gas development to adversely affect aquatic resources. It is the intersection of information from research on individual organisms and populations in both the laboratory and field that provides an improved capacity to predict effects of oil and gas development in real-world conditions.

To establish toxicity thresholds of the various constituents of concern, acute and chronic experiments are performed in the laboratory. These data are generally widely applicable and provide pertinent information to maintain the health of aquatic ecosystems. Defining mechanisms of toxicity is important as investigations from the laboratory are applied in the field. Mechanistic information (for example, histological, physiological, biochemical, and genomic metrics) is used to assess the health of resident individuals of a population, and provide plausible explanations about the pathway of exposure and manifestation of effects at the population level. Population and community level assessments are necessary at field sites to complete the scientific data base of information about potential effects of development on aquatic ecosystems. Initial field studies usually have a limited focus, for example, following a spill, and then may expand to assessments at larger spatial scales. The combination of individual, population, laboratory, and field investigations along with long-term water quality monitoring is critical for understanding the potential effects of unconventional oil and gas development at large spatial scales. Large-scale investigations would benefit from a national database that documents the movement and use of water during unconventional oil and gas development activities.

Scientific tools are available to assess the potential responses of both terrestrial and aquatic ecosystems to unconventional oil and gas development. Though toxicity threshold data for some of the trace organics used in new technologies may be lacking and additional research on species-specific responses to development is needed, many of the tools used in studies of conventional oil and gas are applicable to shale gas development. The size, scope, and level of integration of studies and assessments are expanding based on the need for information on potential cumulative effects of shale gas energy and other development over large geographic areas. Focusing effort and technical assistance to help managers make better use of existing high-quality science while developing better data resources on the distribution and abundance of shale gas, water, vegetation, and fauna will improve the information foundation for assessing potential ecological effects of shale gas development.