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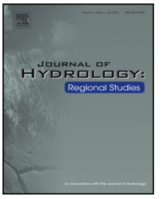

Quantifying the potential effects of high-volume water extractions on water resources during natural gas development: Marcellus Shale, NY

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ABSTRACT

Study region: The Marcellus Shale, New York State, USA.

Study focus: Development of natural gas resources within the Marcellus Shale will require large volumes of water if high-volume hydraulic fracturing expands into New York State. Although this region has ample fresh water resources, it is necessary to explore the response of hydraulically connected groundwater and surface water systems to large withdrawals. Because such effects would not be apparent from a typical water budget approach, this study applied groundwater flow modelling under scenarios of high-volume water withdrawals. Emphasis on water quantity, in contrast with other lines of research concerning water quality, introduced an important perspective to this controversial topic.

New hydrological insights for the region: The potential effects of the withdrawal scenarios on both the water table and stream discharge were quantified. Based on these impact results, locations in the aquifer and stream networks were identified, which demonstrate particular vulnerability to increased withdrawals and their distribution. These are the locations of importance for planners and regulators who oversee water permitting, to reach a sustainable management of the water resources under changing conditions of energy and corresponding water demand.

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1. Introduction

Unconventional natural gas production from shale formations provides a significant domestic energy source in the United States (U.S. Energy Information Administration, 2011). Natural gas extraction from tight geologic formations has increased due to technological advancements of horizontal drilling, leading to economic viability of previously untapped reserves (U.S. Department of Energy, 2009). The potential expansion of high-volume hydraulic fracturing (HVHF) of the Marcellus and Utica Shale into New York State to extract natural gas resources is a controversial issue for policy makers, industry stakeholders, and community members. Issues surrounding this debate range from socioeconomic to logistic to environmental, with emphasis on water quality dictating the direction of scientific research and media attention.

Recently, other environmental concerns associated with HVHF in New York have come to the forefront of discussion. This includes a water quantity perspective, which is traditionally less critical in regions that have ample freshwater supplies in humid climates and/or large, proximate freshwater bodies (Rahm and Riha, 2012). HVHF requires large volumes of water which will ultimately increase water demand from the regions that will experience development. Increased water demand will prompt regulators to determine from where, and at what rate, this water should be extracted to protect sustainable use for drinking water, agriculture, and other industry demands. Altered stream geochemistry and consequences to stream ecosystems, as a result of decreased stream discharge, are factors beyond the anthropogenic freshwater demands mentioned above that may merit consideration. Although water budgets from the New York State Department of Environmental Conservation (NYSDEC) demonstrate that increased water demands from HVHF in New York would make up a minor fraction of total water use (NYSDEC, 2011), it is unclear how hydraulically linked groundwater–surface water systems might respond to such a development. Water budgets alone may not be sufficient in predicting the spatially variable response of these systems, particularly in identifying areas which present heightened sensitivity to withdrawals. For example, the response of aquifers and streams to increased withdrawals of water might vary as a function of valley width, thickness and depth of aquifers within the valley fill. Additionally, smaller streams might be vulnerable to induced changes in groundwater discharge during drought.

The projected path of HVHF development of the Marcellus Shale in New York will most likely focus on the Southern Tier of the state, including Broome and Tioga counties (Fig. 1). The major valleys within these counties overlie an unconsolidated glacial valley-fill aquifer network which has been classified as a sole source aquifer since 1985 (U.S. Environmental Protection Agency, 2010). Such a designation emphasizes the importance of this groundwater source to the overlying municipalities, which receive more than half of their drinking water from the aquifer. In this region there is a high degree of hydraulic connectivity between streams and underlying unconsolidated glacial deposits (Randall, 1977; Wolcott and Coon, 2001; Yager, 1993). High-volume withdrawals of water from groundwater may elicit a response from surface water, or vice versa, due to their physical connectivity (Winter et al., 1998). It is therefore necessary to investigate how different development scenarios might affect both the water table and stream flow.

This research focuses on the use of groundwater flow modeling to determine if increased water demand associated with HVHF is enough to cause significant change to groundwater levels and stream flow within the study area. The objective of this research is to identify scenarios and locations that are particularly vulnerable to high-volume withdrawals of water and may require further evaluation should water permits be requested. A simulated range of development scenarios demonstrate how varying well pad density, water source, and water volume might affect the groundwater–surface water systems in the Southern Tier of New York. The importance of this research lies in its application to all stakeholders in the HVHF controversy currently underway in New York. Not only will policy makers and regulators benefit from the predictive capacity of computer modeling, but industry, community members and interest groups can better understand how a water quantity perspective is valuable for sustainable energy development.