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## Comments on the Scope of the EPA's Proposed Study of Hydraulic Fracturing

To whom it may concern:

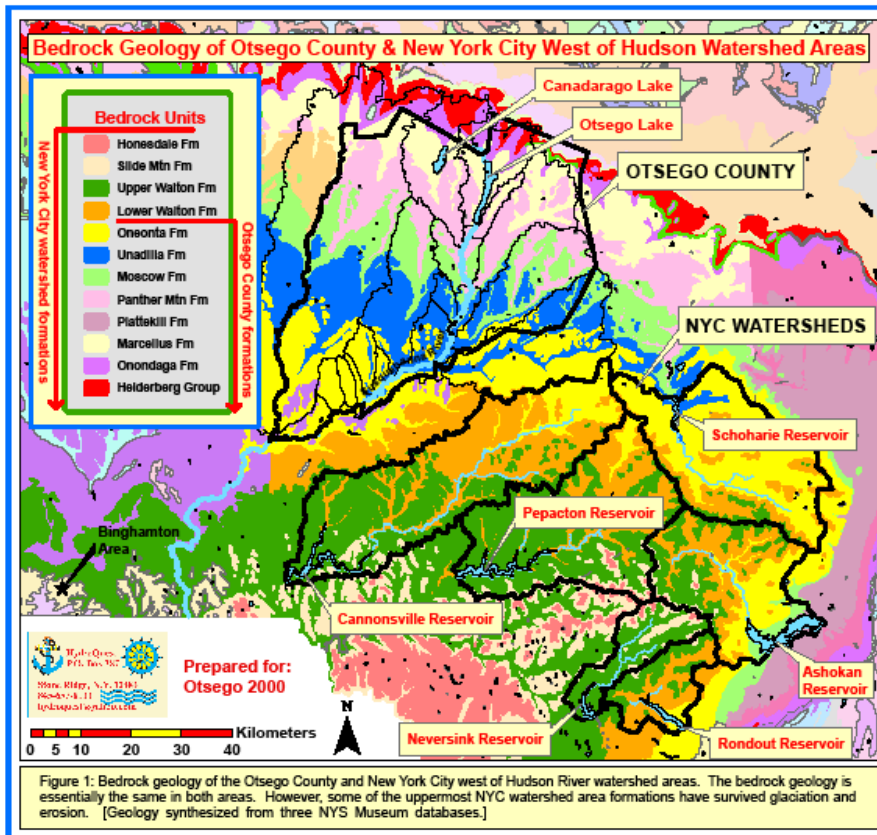
Hydraulic fracturing of shale formations and related surface activities has the potential to permanently and irreparably harm ground and surface water resources in New York State. Extensive existing fracture and fault networks throughout the Appalachian Basin may provide upward pathways for contaminant and gas migration through geologic zones believed to be physically isolated, based on incomplete data. As a result, there are significant health and environmental risks associated with advancing horizontal gas drilling in Otsego County, New York and elsewhere in the Appalachian Basin.

Herein, HydroQuest provides a comparison between Otsego County ground and surface water resources and those in New York City's West of Hudson River watershed, demonstrating that they are virtually indistinguishable and require similar water quality protection. I offer this conclusion based on my training as a geologist, hydrogeologist, and hydrologist with more than twenty-nine years of professional environmental experience which includes work conducted for the New York State Attorney General's Office (Environmental Protection Bureau), Oak Ridge National Laboratory (Environmental Sciences Division), the New York City Department of Environmental Protection, and as an independent environmental consultant as President of HydroQuest. Within the broad field of hydrology, I have specialized expertise in both ground and surface water hydrology.

The notion has been recently advanced that some Appalachian basin watersheds (i.e., New York City West of Hudson River and Syracuse) are more vulnerable to contaminant excursions and therefore, should be afforded greater protection through a more stringent permitting process. The decision to exclude New York City and Syracuse from the "generic" review process must stem from the respectively larger populations supplied by these water resources. It appears to be strictly a political decision, without defensible scientific, geological or hydrologic basis.

The potential environmental threats to Otsego County ground and surface water resources from hydraulic fracturing-related contaminant excursions are not significantly different than those present in New York City's West of Hudson River or Syracuse watersheds. **The following set of seven colored GIS map figures provide the scientific rational in support of considering Otsego County and New York City watershed areas equally.** These figures may also be viewed at: <http://hydroquest.com/OtsegoConfidential/>

**Figure 1: The bedrock geology of the Otsego County and New York City West of Hudson River watershed areas is essentially the same.**



As depicted in Figure 1, many of the upper bedrock units present in Otsego County are the same as those present in New York City's West of Hudson watersheds. Geologically, these units are comprised of a series of sedimentary shales, siltstones, sandstones, and some conglomerates layered from the Honesdale Formation downward through and below the Marcellus Formation. These rock units were deposited under the same hydrologic conditions through the widespread area now recognized by geologists as the Catskill Delta. Before the sediments of these rock units were lithified into bedrock, they were shed northwesterly from the ancestral Acadian Mountains.

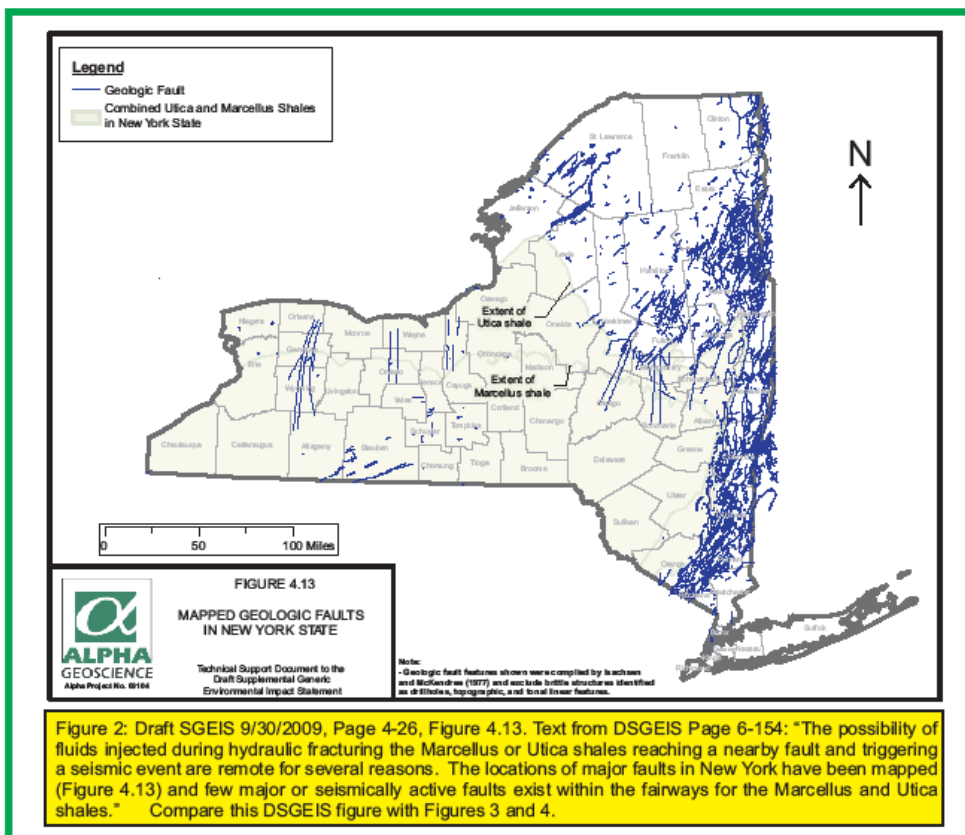
As reflected in Figure 1, it is apparent that erosion has, in places, removed some of the uppermost bedrock units through glaciation and erosion. In places, both Otsego County and New York City watershed areas have the same bedrock units exposed at the ground surface (e.g., Oneonta Formation). Significantly, geologically and hydrologically, ground and surface water flow in both the Otsego County and New York City watershed areas behaves similarly – all potentially being vulnerable to gas field-related contaminants from below and above. Indeed, because some of the Otsego County bedrock formations are stratigraphically closer to the Marcellus Shale than those in New York City watersheds, the risk of contamination is even greater there. Geologically, there is no reason why Otsego County watersheds should not be afforded the same degree of protection as NYC watershed.

Carbonates of the Onondaga Formation and Helderberg group outcrop in the northern portion of Otsego County. These carbonate formations, while stratigraphically lower than the Marcellus shale, overlie other shale beds that may be gas rich (e.g., the Utica shale of the Trenton Group). This is indicated by

gas leases over these formations (see Figure 5). These carbonate formations are recognized among karst hydrologists as being karstic or cave/conduit bearing in nature. An important aspect of karst is its effect on water supply and contaminant transport. Water in solution conduits can travel up to several kilometers per day, and contaminants can move at the same rate. This poses serious problems when monitoring for water quality. Contaminants enter the ground easily through sinkholes and sinking streams, and filtering is virtually non-existent. Even small solution conduits can transmit groundwater and contaminants hundreds of times faster than the typical un-enlarged fracture network. Hydrofracking-related contaminants that may enter karstic solution conduits, from below or above, would quickly degrade groundwater and surface water quality. As a result of the DEC's failure to address this significant environmental concern, it must be studied by the EPA.

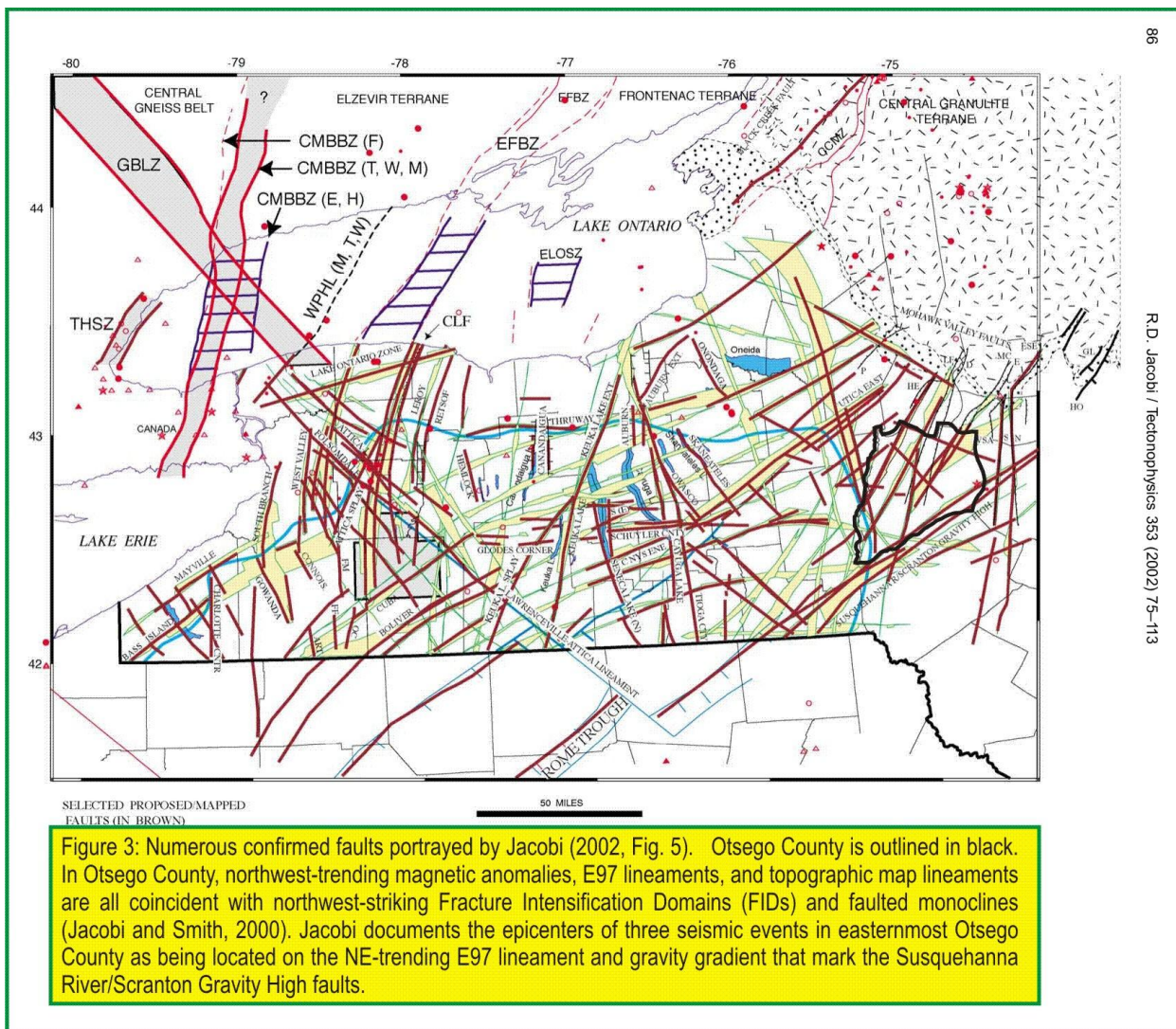
**Figure 2: The Draft SGEIS fails to reference all known fault and fracture information.**

The DSGEIS relies on outdated and limited fault and fracture set locations throughout New York State. Figure 2 is the chart prepared by consultants for inclusion in the DGSEIS. Many more were known at the time of the issuance of the DSGEIS as reflected in Figures 3 and 4, discussed below. As a result of the DEC's failure to analyze more recent fault mapping, the risk of ground and surface water contamination through seismic activity stemming from natural causes or from lubrication and pressurization along dormant faults through fracturing has not been adequately addressed and must be studied by the EPA.



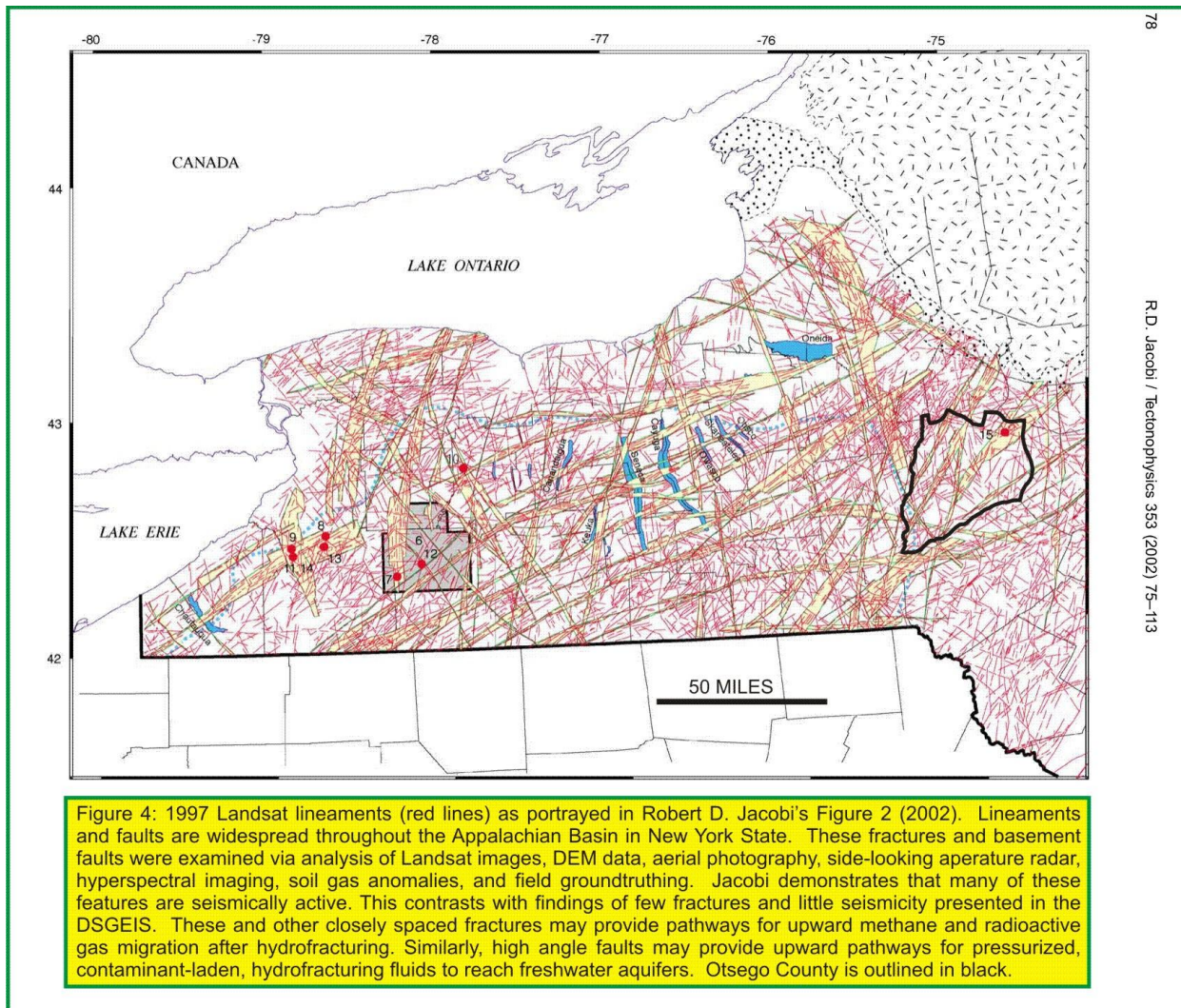
**Figures 3 and 4: Numerous confirmed faults and lineaments known in Otsego County and New York State were not discussed in the DEGEIS. These and other faults may provide pathways for contaminated fracture fluids, deep-seated saline water, radioactivity, and gas migration to migrate to aquifers, reservoirs, lakes, rivers, streams, wells, and even homes.**

Jacobi and Smith (2002) document the epicenters of three seismic events in eastern Otsego County. These seismic events indicate that earth movement occurs from great depth along faults upward to aquifers and potentially to exposure at the ground surface. The great lateral extent of these faults, and their visually observable connectivity with other faults, confirms that the process of hydraulic fracturing, which may interconnect naturally occurring faults and fractures, has a great and very real potential of causing contaminants to migrate to aquifers and surface water from localized zones across and beyond county and watershed boundaries.



Fracking contaminants, once mobilized vertically along fault planes and fractures, especially under pressurized conditions, can reach freshwater aquifers. Even if all fracking fluids were comprised of

non-toxic chemicals, the risk of interconnecting deep saline-bearing formations (i.e., connate water) and/or radioactive fluids with freshwater aquifers is not warranted. Any commingling of deep-seated waters, with or without hazardous fracking fluids is unacceptable. Documented gas excursions near existing gas fields demonstrate that vertical pathways are open. If gas can migrate to the surface it is highly likely that hydrocarbon and contaminant-rich Light Non-Aqueous Phase Liquids (LNAPLs) will also reach aquifers and surface water resources. These contaminants may then also migrate to down gradient wells, principal aquifers, and waterways.



Importantly, Figures 3 and 4 provide a very conservative approximation of the actual number of fractures and faults present throughout Otsego County and New York State. In establishing a relationship between seismicity and faults, Jacobi (2002) examined Fracture Intensification Domains (FIDs), E97 lineaments (Fig. 3), topographic lineaments, gradients in gravity and magnetic data, seismic reflections profiles, and well logs. Jacobi states:

*“In interbedded shales and thin sandstones in NYS, fractures within the FID that parallel the FID characteristically have a fracture frequency greater than 2/m, and commonly the frequency is an order of magnitude greater than in the region surrounding the FID.”*

Jacobi (2002) portrays an earthquake of magnitude 4.5-4.9 as having occurred in Otsego County (Fig. 3). Jacobi makes a case for repeated reactivation along faults in the Appalachian Basin. Furthermore, and importantly, Jacobi addresses his and Fountain's identification of FIDs based on soil gas anomalies over open fractures:

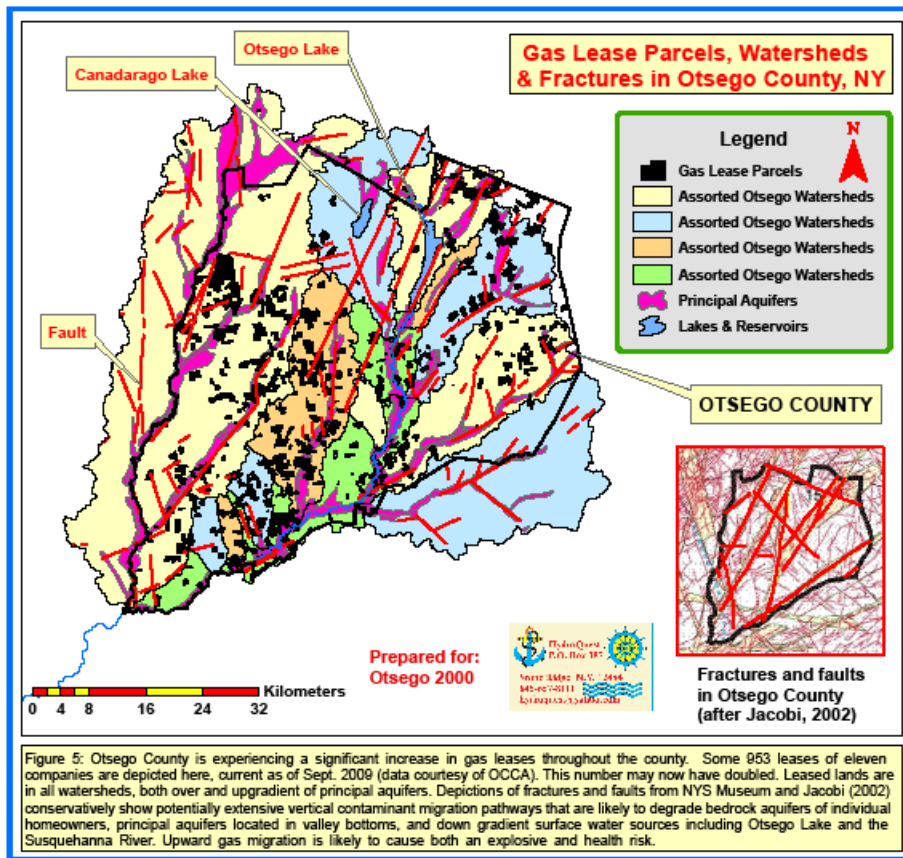
*“Certain sets of FIDs are marked by soil gas anomalies commonly less than 50 m wide (Jacobi and Fountain, 1993, 1996; Fountain and Jacobi, 2000). In NYS, the background methane gas content in soil is on the order of 4 ppm, but over open fractures in NYS, the soil gas content increases to 40-1000+ ppm.”*

The fact that Jacobi and Fountain have successfully identified and measured methane seepage from fractures that most likely extend downward to gas producing shales shows that open vertical pathways already exist, confirming the risk of increasing gas excursions as a result of hydraulic fracturing. Clearly, Jacobi and Fountain's work suggests that expanding fractures that now naturally release methane from gas-rich shales will provide even greater gas and contaminant migration pathways when interconnected and widened via hydraulic fracturing. Failure to recognize this and to allow expansive interconnection of existing faults and fractures is a recipe for environmental disaster throughout Otsego County and the Appalachian basin.

**Figure 5: Gas leases in Otsego County are increasing throughout all watersheds, thereby potentially jeopardizing the water quality of principal aquifers, wells, reservoirs, and surface waterways.**

Otsego County is experiencing a significant increase in gas leases throughout the county. Some 953 leases of eleven companies are depicted here, current as of September 2009. This number may now have doubled. Leased lands are found in all watersheds, both over and up gradient of principal aquifers. Depictions of fractures and faults from the New York State Museum and Jacobi (2002) conservatively show extensive vertical contaminant migration pathways that are likely to degrade bedrock aquifers of individual homeowners, principal aquifers located in valley bottoms, and down gradient ground and surface water sources, including Otsego Lake and the Susquehanna River.

A 2008 OCCA map of gas leases shows many overlying principal aquifers and others within a 1-mile buffer of major surface water supplies (i.e., Otsego Lake, Wilbur Lake). The risk to aquifers, rivers, streams, lakes, reservoirs, and the Susquehanna River should not be tolerated. Because the density, location, aperture width, and length of all fractures (often present and not visible beneath a soil mantle) are not known, it would not be prudent to risk placement of gas wells and their respective chemical storage or impoundment sites anywhere within watersheds that contain reservoirs used for public water supplies (e.g., Lake Otsego, Wilbur Lake, New York City reservoirs). The contaminant risk, risk to public water quality perception, and potential remedial costs are not warranted by the potential economic and energy gain.



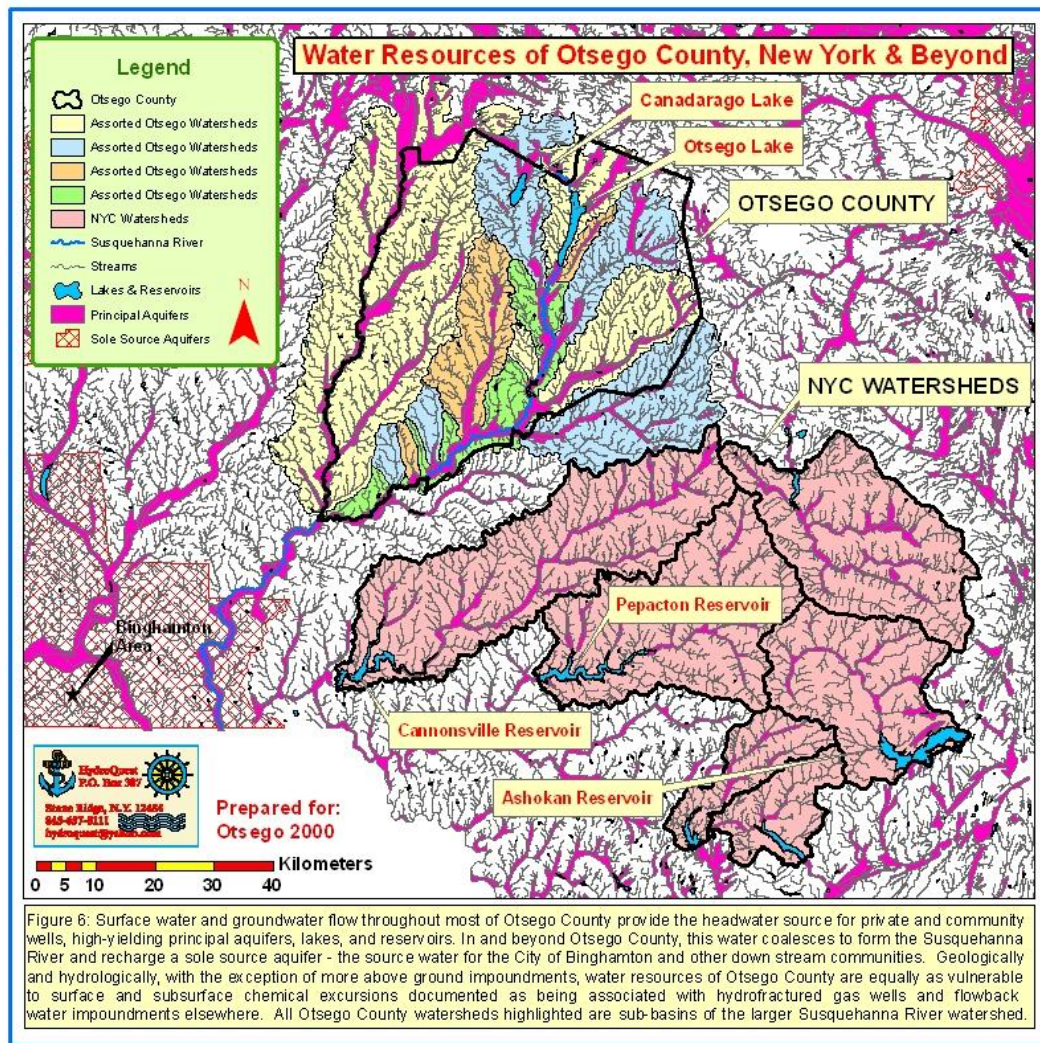
This conclusion is supported by a growing catalog of hydro-fracking related accidents in other gas-field plays (see e.g., Hazen and Sawyer, 2009). Accidental spills of fracking fluids and flow-back water have the potential of contaminating ground and surface water. Similarly, lateral and upward migration of hydro-fracturing chemicals pose a real risk to County aquifers, especially to moderate and high yield unconfined aquifers situated in stream valleys that receive their base flow recharge from up-gradient groundwater aquifers. Approximately 60% of Otsego County listed community and non-community water supplies rely on groundwater.

Aquifer contamination may retard residential growth and may degrade principal and primary aquifers. Similarly, many high yielding unconfined aquifers may flow into and recharge the Clinton Street - Ballpark Valley Aquifer System that is a sole source of drinking water for approx. 127,555 residents of Vestal, Johnson City, Endicott, Nichols, Waverly, and Owego. Beyond this, the City of Binghamton and other downstream communities' primary water source is the Susquehanna River - a water supply system analogous to that of NYC's, except without impounded reservoirs.

**Figure 6: Watersheds throughout Otsego County and the New York City west of Hudson River basins are physically located atop similar bedrock types which recharge geologically similar underlying aquifers.**

Ground and surface water flow throughout most of Otsego County provide the drinking water source for

private and community wells, high-yielding principal aquifers, lakes, and reservoirs. In and beyond Otsego County, this water coalesces to form the Susquehanna River and recharge a sole source aquifer – the source water for the City of Binghamton and other downstream communities. Geologically and hydrologically, with the exception of more above ground impoundments, water resources of Otsego County are equally vulnerable to surface and subsurface chemical excursions documented as being associated with hydro-fractured gas wells and flow-back water impoundments elsewhere.



**Figure 7: Repeated Fracturing Cycles Seriously Exacerbate Risks Of Contaminant Migration.**

The goal of hydraulic fracturing is to interconnect joints, faults, bedding planes, and other partings (i.e., fractures collectively) through horizontal boreholes, thereby increasing gas extraction productivity. Naturally occurring excursion of methane gas via faults and fractures has long been recognized. Hydraulic fracturing will create new fractures as well as open and enlarge existing natural fracture aperture widths, causing aquifer and ground water contamination risk. Recent studies are now beginning to confirm that both methane and hydro-fracking chemicals are migrating upward along hydro-fractured fracture pathways to freshwater aquifers and homeowner water supplies. For example, Lustgarten

(ProPublica, 2009) references scientific work conducted on methane gas excursions in Garfield County, Colorado where a three-year study used sophisticated scientific techniques to match methane from water to a deep gas-rich bedrock layer stating:

*“The Garfield County report is significant because it is among the first to broadly analyze the ability of methane and other contaminants to migrate underground in drilling areas, and to find that such contamination was in fact occurring. It examined more than 700 methane samples from 292 locations and found that methane, as well as wastewater from the drilling, was making its way into drinking water not as a result of a single accident but on a broader basis. As the number of gas wells in the area increased from 200 to 1,300 in this decade, methane levels in nearby water wells increased too. The study found that natural faults and fractures exist in underground formations in Colorado, and that it may be possible for contaminants to travel through them. Conditions that could be responsible include vertical upward flow along natural open-fracture pathways or pathways such as well-bores or hydraulically-opened fractures ...”*

What we are just beginning to understand is the fact that repeated fracturing at each well will further amplify all of these risks. Reaping maximum gas production from horizontal gas wells commonly requires repeated hydro-fracturing of wells (see discussion by James Northrop, 2010). With each successive hydro-fracturing event, more toxic contaminants are introduced into subsurface formations, including those already aggravated and potentially opened in the first fracturing cycle. In addition, as gas companies expand their operations, they may turn to the new, more effective, multilateral drilling technology to selectively tap multiple target zones in adjacent areas. This will necessarily result in multiple wellheads and multiple fracturing operations in close proximity. Through these processes, it is highly likely that new, previously unconnected, fractures will be integrated into the area influenced by each production well.

David Kargho et al. (2010), U.S. EPA Region III, recently cautioned about the particular challenges still unresolved about drilling in tight shale formations:

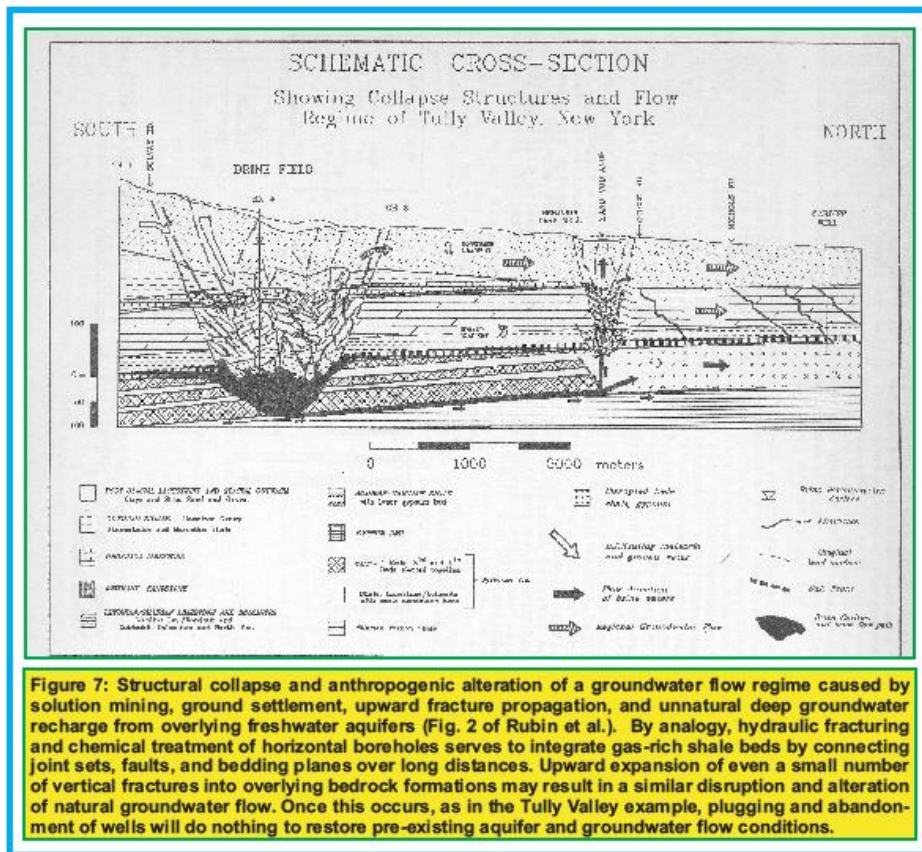
*“The control of well bore trajectory and placement of casing become increasingly difficult with depth...At the Marcellus Shale, temperatures of 35-51°C (120-150°F) can be encountered at depth and formation fluid pressures can reach 410 bar (6000 psi) (8). This can accelerate the impact of saturated brines and acid gases on drilling at greater depths. In addition, the effect of higher temperature on cement setting behavior, poor mud displacement and lost circulation with depth makes cementing the deep exploration and production wells in the Marcellus Shale quite challenging. For example following a recent report by residents of Dimock, PA, of natural gas in their water supplies, inspectors from the Pennsylvania Department of Environment Protection (PADEP) discovered that the casings on some gas wells drilled by Cabot Oil & Gas were improperly cemented, potentially allowing contamination to occur....During drilling into the tight Marcellus Shale, there is a slight risk of hitting permeable gas reservoirs at all levels. This may cause shallow gas blowouts and underground blowouts between subsurface intervals. Other geo-hazards that may pose challenges to drillers in the Marcellus Shale include: (1) disruption and alteration of subsurface hydrological conditions including the disturbance and destruction of aquifers, (2) severe ground subsidence because of extraction, drilling, and unexpected subterranean conditions, and (3) triggering of small scale earthquakes.”*

With each repeated fracturing cycle, all of the “challenges” noted by Kargho, Wilhelm, and Campbell of necessity multiply and increase. See also the BP internal report released September 9, 2010, attributing fault for the 2010 Deepwater Horizon oil rig explosion to unexpected cementing problems at pressures less than those of the average shale gas frack. Studies have not yet been done regarding the effect of depth and pressure on casing failure rates in tight shale formations, nor on the repeated fracturing re-pressurization under such temperature and depth conditions on cement casings and joints. Nor have studies or plans been developed for remedial action should the casings and joints fail at extreme depth.

These risks of casing failure are further compounded by the frequency (or spacing) of casing couplings which may be on the order of every 100 feet or less. Zhou et al. (2010) assessed casing pipes in oil well construction and the risk that they may suddenly buckle inward as their inside and outside hydrostatic pressure difference increases. They point out the importance of measuring the stress state of casing pipe, complete with real-time monitoring and state-of-the-art warning system installations. EPA should consider evaluating cost-effective and reliable sensing technologies and installation techniques for long-term monitoring and evaluation of casing pipe. Most deeply buried casings are difficult to repair or replace and, as such, can lead to aquifer contamination. Even a small percent casing or grout failure can be effectively irreparable at deep depths and irreparably harm ground and surface water sources.

Finally the EPA must study the risk of ground collapse as a result of repeated fracturing cycles. “*Severe ground subsidence*” may occur “*because of extraction, drilling, and unexpected subterranean conditions*”, as may “*disruption and alteration of subsurface hydrological conditions including the disturbance and destruction of aquifers*” (Kargbo et al., 2010).

Deep solution mining of salt beds in Tully Valley, conducted under NYSDEC mining permits, regulation, and oversight has resulted in slow and catastrophic collapse of portions of Tully Valley from depths of 1,700 feet (518 m) to the ground surface. Rubin et al. (1992) document the structural failure of portions of the valley overlying and adjacent to brine cavities where salt was removed. The resulting settlement area is in excess of 550 hectares (~1,360 acres; 2.1 mi<sup>2</sup>). It continues to expand outward. Upward fracture propagation eventually resulted in open permeable pathways where fresh aquifer and infiltrating meteoric water began to recharge formerly isolated groundwater flow regimes, thereby establishing new deep flow routes that now result in connate, saline, and turbid water discharge to the ground surface, and Onondaga Creek (see Figure 7).



As illustrated in the Tully Valley example, once even a few significant fracture interconnections (i.e., planar, laterally extensive, and potentially interconnected with Fracture Intensification Domains) are established between target shale beds and the ground surface, naturally isolated groundwater flow systems then become accessible for commingling of formation waters, for transmission of contaminants, for the unnatural and increased recharge of deeper formations, and for the establishment of new groundwater flow routes. Much as methane can be released upward to lower pressure formations, so will Light Non-Aqueous Phase Liquids (LNAPLs) rise upwards along fault and fracture pathways, thereby broadly contaminating freshwater aquifers. Then, as new groundwater circulation pathways develop in response to repeated hydro-fracturing and newly available freshwater hydraulic/pressure heads, more and more commingling of freshwater and contaminant-laden, saline, water is likely.

With time, hydro-fracturing chemicals will move with groundwater flow, down valley, toward zones of lower hydraulic head, particularly valley bottoms, major streams, and principal aquifers. Areas with higher groundwater flow velocities are likely to develop groundwater circulation patterns along Fracture Intensification Domains (i.e., high permeability pathways), especially where hydro-fracturing has opened elongate fracture pathways that have high hydraulic gradients between watershed uplands and valleys. To a large degree, these new circulation pathways will resemble those illustrated in the Figure 7 Tully Valley example – albeit fracture aperture width may be narrower and associated catastrophic collapse less likely.

While fracture aperture may be narrower than the Tully Valley example, it is important to recognize that the hydraulic transmissivity of fractures increases by the cube of the effective fracture width, thereby pointing out the likely increased risk associated with repeated hydro-fracturing. The combination of excessive pressure associated with hydro-fracturing and lubricated fault planes may lead to increased faulting and seismicity, followed by increased groundwater circulation between formerly isolated hydrologic horizons. Northrup (2010), for example, references a hydro-fracturing induced earthquake in Cleburne, Texas – the likely tip of the iceberg. Once these new groundwater circulation pathways are established, it will be impossible to restore the integrity of adversely impacted freshwater groundwater flow systems, contaminant migration and dispersal will expand, and plugging and abandonment procedures of gas production wells will have little impact on retarding water quality degradation throughout irreparably compromised aquifer systems.

## **Conclusion**

The characterization of vertical fractures, faults, and methane soil gas in Otsego County and elsewhere in the Appalachian Basin in the DSGEIS is inadequate and, as such, does not sufficiently address pre-existing contaminant (i.e., gas and fluid) pathways that extend from the Marcellus shale to aquifers and the ground surface. Drilling, hydro-fracturing and enhancement of gas-bearing fractures may significantly increase gas excursions to formerly isolated geologic formations. Review of reports and news articles indicate that significant environmental contamination has occurred in geologically similar settings, including explosive hazards and groundwater and surface water contamination.

Documentation by Jacobi of Fracture Intensification Domains based on methane soil gas anomalies over open fractures reveals evidence that naturally occurring fractures and faults provide upward gaseous migration pathways, even in the absence of deep hydro-fracturing in the Marcellus shale. If fracture and fault networks are integrated and enlarged via hydro-fracturing processes, it is likely that methane, LNAPL, and radioactive gas excursions will increase.

The reality is that methane gas extraction from tight shale formations, including the Marcellus and similar formations throughout the country, have in fact contaminated ground and surface waters. Reasons for this include poor containment of fracturing fluids, spills of flow-back water, intentional illegal disposal, mixing of different formation waters (e.g., brine and fresh water), inadequately grouted casing, spills, and various forms of operator error. Gas production in Otsego County and elsewhere in the Appalachian Basin would almost certainly result in contaminant excursions, even under the best planned conditions. The presence of confirmed fractures and faults that extend from gas-rich geologic beds to the ground surface, some of which extend laterally for miles and are closely linked with others formed under similar structural conditions, pose potential contaminant pathways to surface waterways, reservoirs, and freshwater aquifers.

Because the density, location, aperture width, and length of all fractures (often present and not visible beneath a soil mantle) are not known, it would not be prudent to risk placement of numerous gas wells within watersheds that contain lakes and reservoirs used for public water supplies (e.g., Lake Otsego, Wilbur Lake, New York City reservoirs). From a water quality standpoint four facts stand out: 1) there is a point at which the actual total number of toxic contaminants introduced into a groundwater flow system no longer matters because the water is unlikely to ever be potable again no matter how much money is spent attempting to remediate it, 2) new groundwater circulation pathways are likely to

develop in response to repeated hydro-fracturing and newly available freshwater hydraulic/pressure heads, resulting in commingling of freshwater and contaminant-laden waters, 3) eventually, even deep groundwater flow systems discharge to surface water, albeit it may take many years to occur (i.e., analogous to a slowly ticking time bomb), and 4) it makes little sense to jeopardize the quality of surface and groundwater by intentionally introducing vast quantities of toxic contaminants into the environment, especially where gas-conducting fractures and faults are known to extend from gas-bearing formations to the ground surface.

It is important to recognize that once our natural resources have been compromised as a result of an operator error, a major contaminant excursion, or an unforeseen breaching of geologic beds, that it is often impossible to remediate and restore them to their pre-existing conditions. Failed confining beds and contaminated natural resources often represent an irrevocable commitment of our lands. Our decision to risk New York State resources and properties must weigh all the health and environmental risks against exploitation of short-lived gas reserves and financial gain.

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