January 11, 2012

To: Commissioner Joe Martens
NYS Dept of Environmental Conservation
625 Broadway
Albany, NY 12233-1011

Re: Revised Draft SGEIS 2011

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My comments focus on migration of fluids and gases through natural faults and fractures in the NYS geology that will be precipitated by high volume, slick-water hydraulic fracturing. This issue is of critical importance because it will have a profound detrimental and potentially catastrophic impact on ground and surface water. There is no way to control migration of fluids and gases caused by fracking. The most recent draft SGEIS however dismisses the fact that migration of fluids and resultant contamination is a probability, although there is overwhelming scientific evidence to the contrary. Attached is a selection of reports, studies and scientific papers documenting migration of fluids and gases through faults, fractures and fissures in the naturally fractured bedrock geology of New York State.

In response to the previous draft SGEIS there was a significant body of reputable, scientific work submitted by geologists, hydro-geologists, petrochemical engineers, many environmental engineering firms and various governmental agencies that addressed the migration/contamination link. However there is no indication, based upon the attention given this subject in the draft SGEIS 2011, that this material was reviewed or considered. The following is the greater part of any reference in the draft SGEIS made on the *migration* issue. On page 11 of the Executive Summary, the following is stated;

> "Chapters 5 and 6 contain analysis that demonstrate that no significant adverse impact to water resources is likely to occur due to underground vertical migration of fracturing fluids through the shale formation. The developable shale formations are vertically separated from potential freshwater aquifers by at least 1000 feet of sandstone and shales of moderate to low permeability…That shales must be hydraulically fractured to produce fluids is evidence that these types of rock formations do not readily transmit fluids. The high salinity of native water in the Marcellus is evidence that fluid has been trapped in the pore spaces for hundreds of millions of years, implying that there is no mechanism for discharge of fluids to other formations. Hydraulic fracturing is engineered to target the prospective hydrocarbon-producing zone. The induced fractures create a pathway to the intended wellbore, but do not create a discharge mechanism or

> pathway beyond the fractured zone where none existed before. Accordingly, there is no likelihood of significant adverse impacts from migration of fracturing fluids."

It is in response to the above statement that I submit the attached compilation of reports that contradict the above statement in its entirety. But in terms of "no likelihood…from migration of fracturing fluids" (stated above), I submit an excerpt from the following USGS paper; *A Regional Perspective of the Devonian Shale and Ordovician Utica Shale Total Petroleum Systems of the Appalachian Basin* (September 2011) Robert T. Ryder, et al. 1U.S. Geological Survey, Reston, VA 20192, rryder@usgs.gov

> "….For example, oil and gas generated and expelled from the Marcellus Shale in N.Y., Ohio, Pa., and W.Va. probably migrated vertically through about 1,500 to 4,000 ft of overlying shale and siltstone into Upper Devonian and Mississippian sandstone. In addition, a short time after vertical migration, large volumes of Marcellus Shale gas (from cracked oil or kerogen conversion) were expelled a short distance into underlying Lower Devonian sandstone and migrated either into adjoining anticlines or updip as far as 50 miles. Furthermore, oil and gas generated and expelled from the Utica Shale in Ohio and Pa. suggest the following migration patterns: 1) westward across-dip migration for 30 to 80 miles through about 1,000 ft of underlying Ordovician carbonate rocks before entrapment in Cambrian reservoirs, and 2) vertical migration through about 1,500 ft of overlying Ordovician shale followed by updip migration as far as 50 miles before entrapment in Lower Silurian sandstone."[i]

In addition, the NYCDEP commissioned Hazen and Sawyer Report documents migration of gases that were recorded during the construction of the NYC water tunnels – up to 7 miles through natural faults. The EPA recently documented migration of fluids containing fracking chemicals in water wells and an aquifer in Pavillion, WY. The same problems were documented in Dimmock, PA.

There are numerous detailed scientific studies on rock fracture mechanics, that prove that fluids and gases can and will predictably migrate via faults, joints and fissures, known as migration pathways in an unpredictable variety of ways, and can find their way to ground and surface fresh water resources including aquifers. The hydraulic fracturing process will (as it is designed to) stimulate movement and release of gases and fluids through existing and fracking induced pathways through the naturally fractured geology. These fluids and gases are toxic; both naturally occurring (heavy metals, deep-seated saline waters, radioactive materials and gases) and introduced toxic fracking fluids (aka slick-water).

The draft SGEIS Executive Summary Statement (above) summarily dismisses the large body of accepted scientific work on this subject or has based its conclusions on some other scientific study(s) or body of knowledge. In either case it would be valuable to the public and the scientific community if the draft SGEIS provided information or evidence that specifies what scientific research their position is based upon. This issue is so evidently a singular crucial aspect of the ultimate safety of hydro-fracking technology that appears to be without remedy. It certainly deserves proper attention and analysis.

Attached are reports from (including but not limited to) several experts and environmental engineering firms that substantiate this position. The group includes Robert D. Jacobi (whose work on mapping faults and fractures with the Geology Dept - Rock Fracture Group at The Univ of Buffalo is some of the most extensive on the subject); Hazen & Sawyer for NYCDEP, Arcadis US for the NY Watershed Inspector General, Paul Rubin, Geologist/Hydrogeologist - HydroQuest; Jeffrey Thyne, Geologist and author of the Garfield Co Hydrogeological Study; Marc Durand, geological engineering professor (Université du Québec à Montréal) whose specialty is rock mechanics and hydrogeology, among others.

This compilation of reports confirms the extensive pattern of faults and fissures in NYS (Appalachian Basin). Yet the draft SGEIS fails to reference relatively well known fault and fracture information, including the existence of up to date mapping. The draft SGEIS includes an outdated map (figure A; pg 9) that shows only a small fraction of the known actual faults in NYS (compare with Jacobi's map; figure B; pg 9). This lack of relevant and accurate documentation is incomprehensible and worthy of invalidating the study.

Some of the most extensive studies on mapping of faults and fissures in NYS have been done by Robert Jacobi. This work has been endorsed and widely accepted by the scientific community (including the Society of Petroleum Engineers – SPE, NYSERTA, and the NYSDEC) and has not been challenged by any scientific organization, and is often referred to as the most extensive, documented mapping of NYS geology. It's unacceptable that the DEC is not better informed; there is too much at stake.

The Jacobi report; *Basement Faults and Seismicity in the Appalachian Basin of NYS; Jacobi 2009*, states;

> "seismic activity is most active along the myriad pattern of faults in NYS, …thus, it is not surprising that almost all of the seismic events in the Appalachian Basin portion of NYS can be correlated with the known and suspected faults. It appears that more faults are seismically active in NYS than previously supposed. It may be that most of the basement faults that extend to the surface rocks are seismically capable, even those that do not have historical seismicity ascribed to them. Further work will undoubtedly modify the specific locations of fault traces and their seismic capability. However, the conclusion is inescapable that a large number of faults do exist in NYS, and that several of them have been seismically active."[ii]
>
> Gas shales are often the origin of hydrocarbon stored in conventional reservoirs. These hydrocarbons have been expelled, migrating upward into a trap of reservoir quality rock below a sealing unit (often shale). In gas shale systems, the shale is all three: hydrocarbons are generated, stored and held in place. The preserved organic matter is "consumed" through biogenic or thermogenic processes to generate smaller chain hydrocarbons (gas or liquid). The remaining carbon that cannot be converted (dead carbon) and clay minerals form a storage mechanism through adsorption, which increases tremendously the potential storage volume. The relationship between temperature, pressure, available volume and the general attractiveness of methane (partial pressure) will define ultimate adsorbed storage capacity. Even after a great amount of generated gas is expelled out of the shale (as source rock), there can remain an enormous quantity as adsorbed gas. Gas will also reside in rock matrix pore space and fractures if there is a "seal" to keep the gas in these spaces.[iii]

I will not elaborate on seismic activity in this comment but do so for two reasons. One is that the Jacobi studies have so much to do with seismic activity, and second because of the recent reporting of earthquakes/seismic activity related to fracking (and/or injection wells) in Ohio and before that in

Arkansas, Texas, England and elsewhere. The Ohio State geologist investigating the recent earthquake said that, “this could be avoided if more analysis (although costly) was performed so that wells intersecting with faults could be avoided” (Scientific American; Jan 3, 2012).

This of course is likely impossible in NYS where the faults are so densely populated with literally a matrix of criss-crossing fractures (as described by Jacobi) that it would be quite difficult – if not impossible to avoid.

Also taken from Jacobi’s report: ...Part of the multidisciplinary approach developed (by Jacobi and Fountain 1996) was the identification of fracture intensification domains (FIDs; e.g., Jacobi and Xu, 1998; Jacobi and Fountain, 2001, 2002). The FIDs are characterized by closely spaced fractures, the strike of which defines the trend of the FID. The closely spaced fractures are also commonly the master fractures, even though they may characteristically abut other fracture sets in regions outside the FID. 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 goes on to say;

An important observation is that these seismically active faults crisscross a large portion of NYS. The high number of faults means that most cultural facilities (e.g., waste disposal sites, bridges, pipelines) are not far from a potentially seismically active fault. For example, the West Valley faults extend south to the West Valley Demonstration Project, a high- and low- level radioactive waste storage site. Similarly, the Attica – Lockport Fault passes fairly close to the Darien Lakes theme park, where some of the highest amusement rides in the Northeast are located. And one final example: in the Mohawk Valley region, the south end of the Hinckley Reservoir dam is adjacent to the Prospect Fault. Thus, it is vitally important to assess the maximum credible seismic event that can be expected along these faults.

The maximum credible seismic event is extremely difficult to determine, partly because the historical recurrence rates of all earthquake magnitudes are relatively low in NYS (especially the moderate magnitude events) and because there may be a disconnect on Gutenberg – Richter curves between small events and maximum credible seismic events.

And most relevant with respect to migration from Jacobi;
Certain sets of fracture intensification domains are marked by soil gas anomalies commonly less than 50m 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. (R.D. Jacobi / Tectonophysics 353 (2002) 75–113 p79).

“The high concentration of gas in the faults is consistent with why drillers seek out the faults, because this is where hydrocarbons exist in greatest concentrations because the faults provide both a pathway and collection zone.” (Marc Durand)

The Executive Summary also states “Hydraulic fracturing is engineered to target the prospective hydrocarbon-producing zone. The induced fractures create a pathway to the intended wellbore, but do not create a discharge mechanism or pathway beyond the fractured zone where none existed before. Accordingly, there is no likelihood of significant adverse impacts from migration of fracturing fluids."[iv]

This statement is not accurate and cannot be scientifically supported. Some of the released gas (with luck possibly most) will migrate up the wellbore as desired. But there is no doubt that some (also possibly most – if not lucky) will find other pathways. As per Marc Durand (below), fracking recovers only 20% of the gas in a reservoir until the well is capped due to productivity decline. The rest of the gas will migrate naturally - through the network of natural faults and fissues, including additional pathways opened up by fracking that were previously naturally sealed.

Marc Durand, geological engineering professor (Université du Québec à Montréal) whose discipline is rock mechanics and hydrogeology states (Shale Gas Info March 12, 2011); "Hydraulic fracturing artificially creates a network of interconnected fractures towards which the gas begins to migrate. The technique initiates the flow of gas in the deposit as happened in the classic natural gas deposits over hundreds of thousands of years, but the (fracking) technique cannot speed up the geologic process. The construction of a well and it's fracturing are completed in a few weeks; the flow begins and continues on a geologic time scale. The amount of time before the well is closed (once the rate is no longer commercially viable) represents no more than an infinitesimal portion of the geologic time. Fracking gets out only 20 per cent of the gas (in a reservoir), a figure confirmed by Canada's National Energy Board.

"After maybe eight years of production, the gas companies will seal – and forget – the wells, Durand said. That means that the remaining gas (80%), will continue to release itself from the shale (post fracking). The rock formations shattered by fracking will be thousands of times more permeable, allowing the remaining 80 per cent of shale gas and underground toxic water, 10 times more salty than sea water, to continue circulating, bubbling to the surface through disused (abandoned) gas wells. Over time, methane could leak into the groundwater and gas leaks could gush, uncontrolled, into the air. Because this happens deep below, it is not visible on the surface," Durand wrote in a paper raising questions about shale gas.

Paul Rubin of Hydro-Quest makes the same case in this report (Scope of EPA Study on Hydraulic Fracturing, August 10, 2010).

"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 depths along faults upwards 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 a 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 and/or radioactive fluids 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 (LNAPL's) will also reach aquifers and surface water resources. These contaminants may then also migrate to down gradient wells, principal aquifers and waterways."[v]

So, what will be the legacy of shale gas hydraulic fracturing for NYS? Concerns regarding the aftermath are not addressed in the draft SGEIS except an oblivious assumption that the "sites" will be restored and look nice and grassy. That is the image that industry provides. Marc Durand provides the following analysis;

Marc Durand, from *Shale Gas – A Business Plan Very Much in the Red:*

> In 20 or 30 years how much will 20,000 depleted wells, which will simply have been concealed before being bequeathed to the geographic locale, cost us per year? There is total silence on this question, because the mining and oil sector has never been concerned for what happens to the drill holes afterwards. The industry has never allocated funds for that. The newest legislation requires only the rehabilitation of the site at the end of its exploitation. Companies must restore the surface of the site but there is almost nothing for what is underneath.
>
> There are thousands of well sites at the end of their life span, hidden in the surface vegetation which have become all the more dangerous because their location has been forgotten. In the United States, there are more and more reports of victims of explosions from gas which resurfaces from old wells. In the majority of cases, it is old exploration wells dating from the beginning of the last century (Appalachia, Colorado). The problem will take on a whole new dimension shortly with the end of life of the gas wells situated in layers, which have undergone intense modification by hydraulic fracturing. The technique, newly applied on a large scale, will leave thousands of abandoned wells under inhabited zones, without anything being known of the impacts which will arise at the end of the work.
>
> Lets be clear about what we understand by the end of the life-span of a shale gas well. A working well has a life of 3-5 years. It is an optimal plan for extracting the gas as quickly as possible at the lowest cost. The output the fractured shale delivers is very high at first, then it diminishes logarithmically or exponentially. The wells are abandoned when the rate of gas is deemed unprofitable; at which point about 20% of the gas in place has been captured.
>
> In classic gas reservoirs, up to 95% of the natural gas can be captured. For shales, recoveries are expected to be around 20% because of low permeabilities, despite high- density horizontal drilling and extensive hydraulic fracturing . (National Energy Board, A Primer for Understanding Canadian Shale Gas).
>
> At the end of this period the extraction well is summarily transformed for another job or task whose sole purpose is to stop the flow of gas in the well. By means of blocking down hole plugs, cement plugs in the tubing, etc., the temporary extraction site must be turned into something permanent, the function of which is very different. In reality, practically nothing changes in the structure and composition of the well but the addition of a permanent plug. Whatever the design of the plug, the new work cannot have a drastically modified life-span. Nevertheless, these plugged wells must resist in perpetuity the pressure of the methane, which will continue to seep from the fractured shale. And let's not forget that 80% of the gas remains in the shale at the end of extraction.

Underneath the inhabited plain, the Utica will have become an extremely permeable reservoir, still containing the left over methane after the skimming of the 20%. This enormous volume, 100 metres thick times 10,000 Km squared will be directly connected to the surface by 20,000 slowly corroding wells .The steel pipes and the sealing grout in an extremely saline environment will erode. This will possibly vary in speed from one well to another according to the quality of the sealing work done. The life duration of each of these wells, is the time before the deterioration is so advanced that major leaks force the authorities to intervene. From then on there will necessarily be a cost . This cost may appear very early in the process for certain wells, as has happened in Québec with some wells whose exploitation phase hasn't even begun; but for now, the industry is still the owner of the wells and so pays the cost. This demonstrates though, that leaks occur even with brand new wells.

Figure 1 shows various routes the gas can take to reach the surface and drinking water wells. (P) The light blue letters (A,B,C) show the gas flow in the case where the drilling intersects a flaw or a long fracture. It is difficult to estimate in what proportion of wells this could occur because a detailed geological map is not readily available for the rock under the soft deposits of the St. Lawrence Valley.

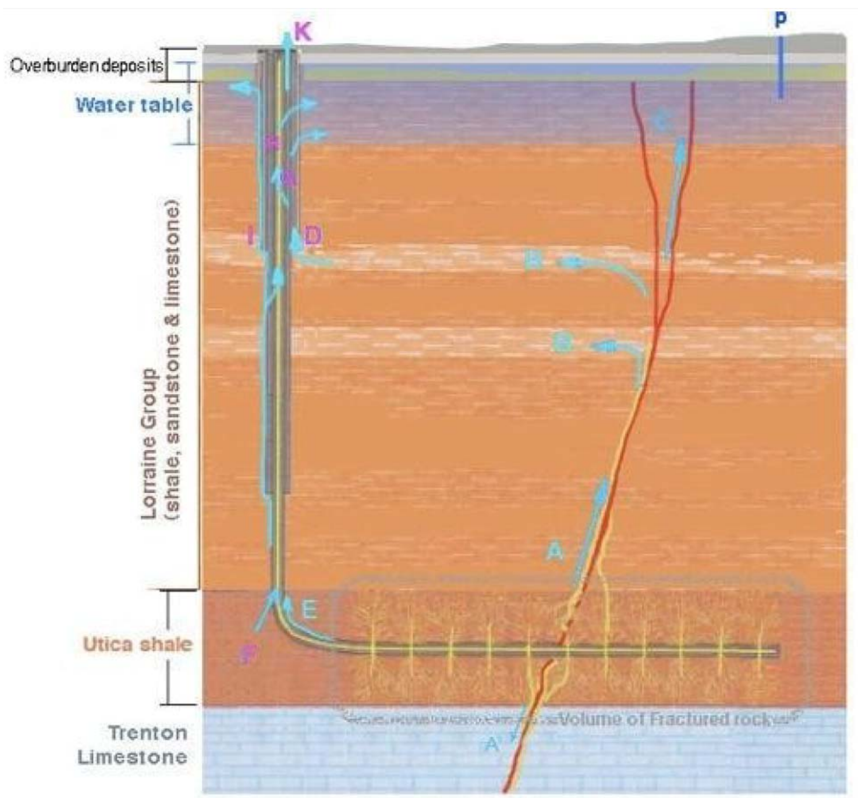

Figure 1 : possible leaks for an extraction well – capped well.

Where there is the presence of such a fracture, the injected liquid opens this route and pushes very far (A) into the Lorraine strata. The flow path is opened permanently to continue into the sandstone and other more permeable layers.

Gas leaks show up in the artesian wells and the dwellings in proximity to the fault. Note that the fracturing fluid also penetrates a great deal further than the fault in the limestone (A) The Trenton is more permeable than shale and it contains very salty water. Thus a route is opened for saline contamination. Some analyses of fracking water indicate that this type of problem has already been encountered in the first wells.

Between the pipes and the drilled rock, and between the producing pipes and the protective sheath, the quality of the placement of the grout can leave spaces : annular fractures may also form during the intensive use of the wells. So that it is a possible origin of gas leaks coming from the wells themselves (E and K).

As well as these possibilities of leaks, at the end of the well's life, probably between 2 and 5 decades after the end of operations, more generalized leaks will begin progressively, in growing proportion to the abandoned wells. The first reasons will be : 1) the disintegration of the steels and cements of the seal. 2) the pressure of the gas which builds slowly and surely on the capping. 3) the readjustment of the pressure (more precisely, the state of the constraints) in the fractured rock will slowly readjust, shearing off or deforming locally sections of the pipes.

The Utica strata tend to inflate when exposed; the same property in the depths will tend to flow and close up the opened fractures a bit over time. The fractured shale will thus tend to lose some of its permeability; but this will not be sufficient to return it to its initial impermeability. On the contrary, these micro ruptures will contribute to the liberation of yet more methane over time.

We are dealing here with structures which will disintegrate in extremely salty environments underground far from all possibility of inspection and maintenance, in rock transformed by the operations of hydraulic fracturing. The flow of fluids, saline water and methane will become modified. All the structures linking the surface of the transformed Utica will sooner or later attain an advanced degree of decomposition. The wells will reach a state where their function as sealing devices will no longer be operational. That means what exactly? : mega-problems at each of the wells, means of mitigation to be put in place , complex studies to be undertaken to try to find a solution, BAPE commissions for each site? (see my analysis of the Mercier case in my preceding text) There will be many of the 20,000 , maybe between 250 and 500 new cases per decade in one generation. Billions to plan for in the budget of Québec.

If the heads of the wells are kept accessible for perpetuity, rather than restore the surface, one would have a less complex task, because one could sound the ground and know when catastrophe threatens. Yet no one anywhere is proposing that. It is said that the site must be restored at the conclusion of the extraction. All that means is burying and forgetting the problem until it hits us in the face. Finding a solution at that point will be an impossible task, as it is impossible to obliterate a well . The hole remains there, even if one tries to plug it with something else, that other material will never have the same properties as the shale that has been drilled and fractured. This Utica Shale has contained the gas for 400,000,000 years.
All our technology, present and future will never manage to do that well.[vi]

Regulations cannot make fracking safe. No amount of regulation can control migration of fluids released by hydraulic fracturing. It’s actually based upon very simple physics.

Joe Levine
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[i] RYDER, T. ROBERT, et al. *A regional Perspective of the Denovian Shale and Ordovician Utica Shale Total Petroleum Systems of the Appalachian Basin.* AAPG Search and Discovery Article#90131, 25-27 September 2011.

[ii] JACOBI, ROBERT D., PhD, Geology, Columbia University. *Basement Faults and Seismicity in the Appalachian Basin of New York State*. November 2001, April 26, 2002.

[iii] MARTIN, JOHN P., et al. A Primer on New York's Gas Shales
http://offices.colgate.edu/bselleck/AppBasin/GasshaleMartin.pdf

[iv] JACOBI, ROBERT D., PhD, Geology, Columbia University. *Basement Faults and Seismicity in the Appalachian Basin of New York State*. November 2001, April 26, 2002.

[v] RUBIN, PAUL A., Hydroquest. *Comments on the EPA's Proposed Study of Hydraulic Fracturing*. August 10, 2010.
http://63.134.196.109/documents/10aug19_HydroQuestEPAComments.pdf

[vi] DURAND, MARC. *Shale Gas—A Business Plan Very Much in the Red.*
http://www.damascuscitizens.org/Durand_shale_gas_faults.html