NYC Environmental Protection

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By Electronic Transmission

Joseph Martens
Commissioner
New York State Department of Environmental Conservation
625 Broadway
Albany, NY 12233-6500

Re: Comments on the Revised Draft Supplemental Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program (September 7, 2011)

Dear Commissioner Martens:

The City of New York (City or NYC) submits the following comments on the Revised Draft Supplemental Generic Environmental Impact Statement (RDSGEIS) on the Oil, Gas and Solution Mining Regulatory Program - Well Permit Issuance for Horizontal Drilling and High-Volume Hydraulic Fracturing in the Marcellus Shale and Other Low- Permeability Gas Reservoirs (September 7, 2011).[1] We appreciate the tremendous effort by the New York State Department of Environmental Conservation (DEC) to develop the RDSGEIS with the goal of balancing much-needed energy supplies and economic development with the proper avoidance or minimization of long-term risks to natural resources. In that same spirit, we offer these comments on this important issue, informed by the best available information and technical analysis.

As you know, the New York City water supply provides high quality drinking water to nearly half the population of the State of New York – the over eight million residents of the City and the millions more commuters and tourists who visit every year, as well as the one million people in upstate counties who tap into our system. Currently, the City provides more than one billion gallons a

[1] The City previously understood this environmental review to apply to all horizontal drilling and all high-volume fracking, but based on recent conversations with DEC staff we now understand it to be limited to high-volume hydraulic fracturing (both horizontal and vertical) and not to cover low volume hydraulic fracturing (LVHF), whether horizontal or vertical. As discussed below, we respectfully request confirmation in the final SGEIS of the scope of that environmental review as well as of DEC's intentions with respect to further supplemental environmental review, if necessary, of the impacts of LVHF (both horizontal and vertical) in the watershed of New York City's water supply system. In the event that such confirmation is not provided, however, the City reserves all rights to challenge the final SGEIS on these bases.

day of high quality drinking water from surface water supplies, primarily from the Catskill and Delaware watersheds, which do not have to be filtered. The Marcellus shale underlies the entire Catskill/Delaware watershed and the tunnels that transport water from the Cannonsville, Pepacton, Neversink, and Schoharie reservoirs to our West of Hudson terminal reservoirs (Rondout and Ashokan), and also underlies portions of the aqueducts that transport water from those terminal reservoirs to the City. The East Delaware Tunnel, West Delaware Tunnel, Neversink Tunnel, Delaware Aqueduct, and Catskill Aqueduct all run outside of the watershed boundaries, in whole or in part; only the Shandaken Tunnel is wholly within the watershed. The Catskill/Delaware system provides a significant portion of the City's water; currently, it is providing 100% of daily demand.

We support DEC's proposed ban on high-volume hydrofracking (HVHF) in the Catskill/Delaware watershed and a 4,000 foot buffer around the watershed. With regard to our tunnels and aqueducts that are outside of the watershed, in 2009 the City proposed a seven-mile zone around all of our tunnels where HVHF would be banned. We have carefully reviewed the RDSGEIS and have commissioned an independent study, focused on geologic risks. Based on that independent expert review of the risks of HVHF and the City's analysis of the potential serious consequences to our infrastructure, we modify our 2009 comments and request that the RDSGEIS be amended to include the following elements in order to mitigate the significant adverse consequences that could arise from HVHF near deep rock tunnels and other infrastructure:

- A seven mile Infrastructure Exclusion Zone, where no HVHF would be permitted, around the Delaware and Catskill Aqueducts from our terminal reservoirs. If we needed to take these aqueducts off line for repairs, the City would lose the ability to reliably supply water to both upstate and City consumers. (See enclosed map of the proposed exclusion zone.)

- A two mile Infrastructure Exclusion Zone around all other tunnels plus an Infrastructure Enhanced Protection Zone from two to seven miles around these tunnels. This hybrid protection regime accounts for the risks to the system in the context of the Department of Environmental Protection's (DEP) flexibility to operate the water supply system to withstand an outage of one of these tunnels for repair. (See enclosed map of the proposed exclusion and enhanced protection zones.)

- All HVHF applications within the Infrastructure Enhanced Protection Zone should require site specific review of proposed HVHF wells and the City's approval; DEC would not issue a permit for drilling if the City identified specific reasons not to approve the site.

- Both the Infrastructure Exclusion Zone and the Infrastructure Enhanced Protection Zone should be measured from the tunnel to the tip of the lateral well bore rather than to the well pad.

These recommendations are discussed in greater detail below.

Ban on HVHF in the Watershed

The City supports the proposed ban of natural gas drilling using HVHF within the New York City drinking water watershed. We highly commend New York State and DEC for taking a hard look at the potential impacts of HVHF to unfiltered surface water supply systems and taking this critical step toward protecting those irreplaceable resources. Balancing environmental and public health concerns with the need for adequate energy resources and economic development is a complex and challenging issue – not only in New York but throughout the nation. We believe, given the potential negative and irreversible impacts of HVHF on the watershed, as set forth below and in the City's comments[2] on the September 2009 draft Supplemental Generic Environmental Impact Statement (2009 DSGEIS), which are incorporated herein by reference, that the State has made the correct decision in proposing to ban HVHF in unfiltered surface water source areas throughout the state.

The proposed ban of HVHF within the NYC watershed and the designation of a 4,000-foot buffer zone around that watershed address many of the concerns raised by the City's extensive risk analysis,[3] which identified a number of serious risks to the water supply, including the industrialization of the watershed, chemical contamination of surface waters, surface water withdrawals, and damage to our infrastructure. The level of industrial activity and heightened risk of water contamination from the expected number of roads, well pads and impoundments associated with HVHF in the watershed would clearly threaten the City's ability to sustain an unfiltered water supply system.

Even with a robust regulatory program in place, and a diligent HVHF operator, failures due to human error or natural disaster are inevitable. Such failures, should they occur in the watershed of the City's unfiltered water supply, have the potential to impact the millions of New York State residents who rely on the City's reservoirs as their source of drinking water. Given the fact that almost half the population of New York State relies on NYC's unfiltered water supply, nobody, including a drilling company, the State, or other responsible entity, could provide an alternate supply of potable water while the contamination was addressed. If the contamination or infrastructure damage could not be sufficiently remediated, it would take more than a decade for the City to design and build a filtration treatment facility that could protect against the contaminants of concern (if that were even feasible); during these many years, the public health, safety, and welfare of millions of New Yorkers would be at risk. Thus, a ban on HVHF in the City's watershed is absolutely critical to protect this irreplaceable and vital resource.

Based on its technical and economic analysis, we understand that DEC has concluded that low volume hydraulic fracturing (drilling that uses less than 300,000 gallons) is unlikely to occur within the Marcellus or Utica shales in New York State to any significant degree and, therefore, in DEC's view, there is no reason to reconsider the findings of the 1992 environmental review

[2] Letter to DEC from DEP dated 12/21/09. The City remains concerned about several risks to the water supply watershed from activities that are directly related to natural gas production, even if all natural gas drilling is prohibited in the watershed. Some of the City's 2009 comments have not been fully addressed including, but not limited to, radioactivity of waste materials, wastewater disposal in the watershed, solid waste disposal in the watershed, spills and road overuse.

[3] Final Impact Assessment, prepared for DEP by Hazen & Sawyer, Leggette, Brashears and Graham, 2009.

concerning low volume drilling at this time. The lack of LVHF activity to date (there have been no applications seeking permits for hydraulic fracturing of any kind in the watershed) combined with the fact that DEC anticipates that any drilling that is likely to occur would fall within the HVHF ban, support DEC's conclusion that little or no low volume hydraulic fracturing in low permeability reservoirs would take place in the watershed in the foreseeable future.

We remain concerned, however, that the proposed ban on HVHF in the NYC watershed might have the unintended consequence of creating an incentive to pursue low volume hydraulic fracturing in the watershed. That is, LVHF wells could prove economically viable along the edges of the watershed because of their proximity to productive areas outside of the watershed already developed with HVHF horizontal wells. Once support infrastructure is built for the more profitable HVHF horizontal wells (e.g., gas collection pipelines, compressor stations, and centralized water and wastewater facilities), gas companies may find the option of low volume drilling in the watershed preferable to leaving economically valuable natural gas untapped – particularly if those wells can be re-fracked. Similarly, it is possible that companies would find it more cost-effective to pursue drilling of LVHF wells that are not subject to the rigorous requirements proposed to apply only to HVHF wells.

The impacts of LVHF in the watershed, if it were in fact to occur other than in an occasional and isolated manner, could have significant adverse impacts that were not considered in the 1992 environmental review. The general impacts from LVHF – such as possible increased likelihood of accidents and surface spills, issues associated with produced water management, the construction of well pads and roads and the possible conduct of other large scale industrial activity – raise the potential that such activities could result in significant adverse impacts to the New York City water supply system. For these reasons, we request that DEC state its commitment in the Final SGEIS to consider whether further environmental review is necessary in the event that there is any indication that LVHF may take place, beyond an occasional isolated instance, in the watershed of New York City's water supply system.

Risk to Water Supply Infrastructure

The most significant remaining issue, given the proposed prohibition of HVHF in the watershed itself, is the protection of the NYC water supply infrastructure. Protection of the dams and tunnels that store and deliver the City's drinking water is just as critical as protection of the watershed – and the need to protect these critical assets is paramount to protecting the City's water supply. Damage to the City's dams and tunnels could put nearby residents in danger and could also seriously impair the ability of the City to deliver water to consumers.

We are unaware of any deep rock tunnels in other areas of the country (or world) where HVHF is occurring. Therefore, we must exercise our best engineering judgment using observations from such areas, our knowledge of the underlying geology, and the designs of the infrastructure at issue to estimate the risks involved. In 2008, the City retained Hazen & Sawyer/Leggette, Brashears & Graham (Joint Venture) to conduct a balanced, objective assessment of the potential impacts to water quality, water quantity, and water supply infrastructure. The City recently added Hager-Richter Geosciences to the Joint Venture project team to assess potential impacts to

the water supply infrastructure. Hager-Richter (H-R) was specifically asked to review orthoimagery,[4] LIDAR[5] and other geophysical data to identify previously unrecognized faults and fractures, to review and evaluate previously identified areas of risk to the infrastructure and the applicable RDSGEIS sections, and to evaluate the potential impacts from microseismicity and reactivation of faults. The results are summarized below and in the Hager-Richter Technical Memorandum (H-R Tech Memo) that is enclosed with this letter and is incorporated into our comments in full.[6]

The RDSGEIS proposed a 4,000 foot no-drill buffer, measured from a well pad, around the NYC watershed boundary and, therefore, around the dams that are on that boundary. In terms of potential risks to the dams from seismic activity, under prior contracts, DEP completed an assessment of the ability of the City's dams to withstand seismic events. The potential magnitude of seismic events known to be triggered by HVHF (i.e., magnitude of one to three (1-3) on the Richter scale) is well within the ranges that our dams can safely withstand.[7] Nevertheless, the City remains concerned about potential structural impacts to the dams in the situation where the drill pad is outside of the buffer but the horizontal section of the well extends closer to or even underneath a dam. These concerns include the possibility of migration of high volumes of fluids near our dams, from directions not anticipated in the design of the dams, as well as other changes to the hydraulic regime. The City therefore recommends that a site-specific review be conducted when the horizontal section of the well comes within the 4,000 foot buffer proposed by DEC around any part of the dam. Additional permit conditions within this area should include the completion of enhanced subsurface geophysical surveys prior to drilling and City review and approval of permits. We look forward to working with DEC on the specifics of implementing this process.

It is our understanding that the U.S. Army Corps of Engineers (Fort Worth, Texas District) is also concerned about the risk hydraulic fracturing may pose to dams and a technical report on this issue is expected in May 2012. Any findings from that report should be considered in the SGEIS.

The risks to the tunnels from HVHF include damage from direct penetration, differential pressures, seismic activity, and impacts from migration of fluids and/or gas, as discussed below and in the attached H-R Tech Memo. The RDSGEIS proposes to mitigate these risks by simply requiring coordination with the City for any drilling application that proposes a well pad within a buffer of 1,000 feet from a tunnel. This proposed mitigation is inadequate to address potential

[4] Digital orthoimagery is vertical aerial imagery that has had all distortions caused by ground elevation changes and camera distortions removed through digital processing and formatted for use with computer applications. A digital orthoimage combines the rich information content of an aerial photo with the accuracy and spatial registration of a map. http://www.nysgis.state.ny.us/gateway/orthoprogram/ortho_options.htm

[5] LIDAR stands for Light Detection And Ranging and is an optical remote sensing technology.

[6] Technical Memorandum: Geophysical Evaluation of Infrastructure Risks of Natural Gas Production On New York City Water Supply Infrastructure, prepared by Hager-Richter Geosciences, Inc, for Hazen & Sawyer, Leggette, Brashears and Graham, and DEP, December 2011.

[7] Weston Geophysical Corporation, 2002. Final Report, Probabilistic Seismic Hazard Analysis of the Dams of the Catskill and Delaware Watersheds, New York City Water Supply System, prepared for GZA GeoEnvironmental of New York, Contract CAT-146.

damage by direct penetration of the tunnel and fails to address the other risks that HVHF poses to these critical assets.

Differential Pressure

Our technical assessment identified a risk from the subsurface transmittal of elevated pressures due to HVHF operations. HVHF operations are anticipated to involve pressures in the range of 5,000 psi to 10,000 psi. As part of the City's 2009 technical assessment, Jenny Engineering conducted a structural analysis using the original design specifications of the tunnels and concluded that differential pressures as low as 20 psi could have a detrimental impact on the unreinforced concrete liners of the Delaware tunnels. These tunnels were designed and built to accommodate fluctuating water levels. They were not designed to withstand this type of subsurface activity (and indeed, portions of the Delaware Aqueduct have already demonstrated a susceptibility to cracks under certain conditions). The risk from elevated pressures increases as more wells are drilled and stimulated in close proximity to the tunnels. Differential pressures on the tunnel liners could be caused by movement of the surrounding rocks, slip along a fault or from earthquake waves, or movement of fluids or gas.

While there is a risk of cracks or greater damage to tunnel liners from differential pressure, the consequence of such impacts is likely to be a loss of efficiency in water transmission and a reduction in capacity from leaks, plus any damage from surface expressions of water. Repairs of such damage can be expensive but also can take place over a number of years without catastrophic harm to the City. Unlike the case of a catastrophic tunnel loss, the risks to the liners can be managed by adopting protections proportional to the distance from the tunnel.

Induced Seismic Activity

In addition to differential pressures, which do not result in earth movement, the City has evaluated risks from seismic activity, which does result in the motion of the earth. The RDSGEIS concludes that the magnitude of seismic events induced by HVHF is too small to be an issue.[8] This may be true with respect to impacts to surface structures like houses; however, the City's infrastructure is located deep underground and therefore closer to the origin of these seismic events.

DEP initially identified induced seismicity as a potential impact based on knowledge of induced seismicity from underground injection wells. The underlying geologic mechanisms of induced seismic activity from underground injection wells and from HVHF are the same – fluid injected underground migrates to a fault and triggers a seismic event. While injection well-related earthquakes are typically small, a recent event in Youngstown Ohio was estimated at a magnitude four (4.0) on the Richter scale.[9]

Given the similar geological mechanisms, the City has further investigated the risk that seismic activity from shale gas drilling poses to our tunnels and, based on that investigation, has

[8] RDSGEIS p. 6-328.
[9] http://www.nytimes.com/2012/01/02/science/earth/youngstown-injection-well-stays-shut-after-earthquake.html?_r=3.

concluded that the proposed protections do not go far enough to protect the integrity of the tunnels. Seismic activity from natural gas drilling can be divided into two categories: hydraulic fracturing microseismicity and small induced earthquakes. Microseismicity typically refers to events with a magnitude of less than negative one (-1) on the Richter scale that are created by hydraulic fracturing of the rock. These microseisms are used by the industry to map and monitor the subsurface fracture locations and guide subsequent HVHF. Small induced earthquakes are events with a magnitude greater than these microseisms but less than or equal to magnitude three (3) on the Richter scale. These induced earthquakes are believed to occur when drilling activities allow fluids to "lubricate" a fault zone, resulting in a small earthquake.

The H-R Tech Memo evaluated the risk from HFHV microseismicity. It considered (1) the measured amplitudes of microseisms reported in relevant scientific literature, and (2) H-R's direct experience with vibration effects in the blast and construction vibration discipline. Even though some potentially relevant information, such as the current condition of the concrete liners, is unavailable, Hager-Richter concluded that microseisms due to HVHF are unlikely to damage the tunnels either as single events or as multiple repeated events.

In contrast, however, Hager-Richter identified significant risks associated with HVHF-induced earthquakes. These significant risks are not disclosed or analyzed in the RDSGEIS and are, in turn, dependent on faults, fractures, and brittle zones, many of which are not included in the maps that were published in the RDSGEIS. The risk of induced seismicity associated with wastewater disposal wells has been known and well documented for many years. The RDSGEIS does discuss, and dismiss, this risk but only on the grounds that underground injection is permitted separately and is not part of the action under review.[10] The H-R Tech Memo evaluates the risk from small magnitude earthquakes specifically induced from hydraulic fracturing including: recent evidence of induced earthquakes from the Preese Hall Well near Blackpool, England and the Eola Gas Field, in Oklahoma; documented tunnel failures from earthquakes; and additional data on fractures, faults and earthquakes in the vicinity of the water supply tunnels. The H-R Tech Memo's findings regarding these risks, which our experts have concluded are significant, are summarized below. We note that the link between HVHF and induced earthquakes is only recently confirmed and the research is in its early stages. The City believes it is prudent to take a cautious approach to the risks and monitor further evidence as it emerges.

Recent Evidence of Earthquakes Triggered by HVHF

While HVHF is a relatively new technology, two recently released technical reports now directly link shale gas HVHF to induced seismicity. The first report, commissioned by a gas production company, investigates earthquakes from a vertical shale well near Blackpool, UK.[11] Hydraulic fracturing of the Preese Hall Well was shown to have caused earthquakes of magnitude 2.3 and 1.5, as well as 48 earthquakes of smaller magnitudes. In those cases, earthquakes were induced when HVHF fluids migrated into a previously unmapped fault that does not extend to the surface and was therefore undiscovered by surficial mapping.

[10] RDSGEIS p. 6-64, 6-320.

[11] De Pater, C.J. and Baisch, S., 2011, Geomechanical Study of Bowland Shale Seismicity, published by Cuadrilla Resources, Ltd., available at http://www.cuadrillaresources.com/cms/wp-content/uploads/2011/11/Final_Report_Bowland_Seismicity_02-11-11.pdf.

The second report concerns the Eola Field of Garvin County, Oklahoma, and was conducted by the Oklahoma Geological Survey.[12] There, forty-three earthquakes ranging in magnitude from 1.0 to 2.8 on the Richter scale occurred within approximately 2.2 miles of the vertical well soon after HVHF commenced. This area is naturally seismically active, which complicates the analysis. However, the timing, location and frequency of earthquakes can provide a convincing technical connection, and in fact the Oklahoma Geological Survey found that the temporal correlation of HVHF and the earthquakes, as well as modeling conducted using a simple pore pressure diffusion model, indicated that the earthquakes were likely induced by HVHF. Now that a direct link has been made between HVHF and induced earthquakes, other past instances of possible HVHF induced earthquakes will likely be examined.

The H-R Tech Memo states:

> *The Blackpool earthquakes and probably the Oklahoma earthquakes demonstrate that hydraulic fracturing fluids can reach a nearby fault and can trigger a seismic event. (p. 28)*

It should be noted that the natural gas wells in both of these cases were vertical, not horizontal, and neither well directly intercepted a fault. Nevertheless, the earthquakes generated were several miles away from the well. Horizontal wells, in contrast, have an even greater chance of directly intercepting a fault and, the distance from a well pad in which HVHF could reactivate a fault is therefore greater. These factors support a minimum buffer distance for horizontal wells.

Seismic Data in or near the Watershed

The H-R Tech Memo evaluates three small seismic events recorded in the vicinity of the Delaware water supply tunnels. The location and depths have a fair amount of uncertainty because of their small magnitude and the locations of the regional seismic network. However, a magnitude 2.0 earthquake occurred in 2001, approximately 2 miles north of the Pepacton Reservoir. The H-R Tech Memo concludes:

> *Although the WOH watershed infrastructure is located in a region of low seismicity, low seismicity does not necessarily mean that induced seismicity will not occur. (p. 30)*

These small events indicate active faults are likely present in the region and could be reactivated by HVHF. At the same time, these events indicate that our infrastructure can withstand limited occurrences of small scale seismic events. Our concern is the unknown impacts of repeated events, larger scale events, or the combination of the two, caused by widespread HVHF.

[12] Holland, A., 2011, Examination of Possibly Induced Seismicity from Hydraulic Fracturing in the Eola Field, Garvin County, Oklahoma, Oklahoma Geological Survey Open-File Report OF1-2011.

Additional Fracture and Fault Data in the NYC Water Supply Region

Like the 2009 DSGEIS, the RDSGEIS relies on a subset of the Isachsen and McKendree dataset[13] to provide background as part of the discussion of seismicity in New York. In commenting on the 2009 DSGEIS, the City criticized this data as incomplete.[14] The City asked Hager-Richter Geosciences to identify faults and fractures based on all readily available geophysical data, not just a portion of the Isachsen and McKendree dataset. The H-R Tech Memo includes faults and fractures from more recent data: EarthSat in 1997,[15] a study by Jacobi in 2002,[16] as well as new mapping based on orthoimagery analysis conducted by Hager-Richter.[17] Hager-Richter also considered the full Isachsen and McKendree dataset and notes made during the constructions of the Delaware tunnels, including observations of faults and brittle features. Salient conclusions from the compilation and comparison of these data include:

> *Some of the lineaments detected by the EarthSat survey correspond to lineaments detected by Isachsen and McKendree, but additional previously unidentified lineaments were also detected. Several such previously undetected lineaments cross the Water Supply Tunnel alignments. (p. 51)*
>
> *Jacobi mapped faults in New York State based on Landsat data, geophysical, and earthquake data. Two N-S trending faults that extend south from the previously mapped Sprakers and Noses Faults through Delaware County into the northern portions of Sullivan and Ulster Counties were proposed. The proposed western fault that extends southward from Sprakers Fault crosses the East and West Delaware Tunnels. Jacobi's proposed extension of the Noses Fault nearly crosses the tunnel alignments. (p. 38)*
>
> *Previously unknown projected possible faults that cross the tunnel alignments were interpreted [from the orthoimagery]... The interpreted faults show good correspondence with faults and brittle features encountered during tunnel construction. (p. 38)*

In addition to faults and fractures, the H-R Tech Memo discusses regional rock jointing patterns which are not disclosed or considered in the RDSGEIS. Joints are systematic sets of natural fractures that are structural discontinuities in bedrock which can provide a pathway for fluids or gas migration to faults. There are two pervasive joint sets in the Marcellus Shale, commonly designated as J1 and J2. Engelder et al. interpret both joint sets as natural hydraulic fractures

[13] Isachsen, Y.W., and McKendree, W.G., 1977, Preliminary Brittle Structures Map of New York and Generalized Map of Recorded Joint Systems in New York, New York State Museum, Map and Chart Series, No. 31G.; RDSGEIS p. 4-25.
[14] Letter to NYSDEC from DEP dated 12/21/09.
[15] EarthSat, 1997, Remote Sensing and Fracture Analysis for Petroleum Exploration of Ordovician to Devonian Fractured Reservoirs in New York State, NYSERDA Agreement No. 4358-ERTER-ER-97.
[16] Jacobi, R.D., 2002, Basement Faults and Seismicity in the Appalachian Basin of New York State, Tectonophysics, V., 353, p. 75-113.
[17] See Plate 1 in H-R Tech Memo.

induced by fluid pressures when the shale was deeply buried.[18] Dr. Engelder is quoted in an October 2011 AAPG Explorer article by Durham[19]:

> *The J2 set appears to break out of the gas shales and populate the rock above those gas shales. This second joint set may appear about 1,000 feet or even as much as 4,000 feet above the gas shale…. There appears to be a strong correlation between fracturing above the gas shales by NHF [natural hydraulic fracturing] and the productivity of the source rock. The correlation indicates a gas column above the gas shale that could have extended maybe 3,000 to 4,000 feet above the Marcellus – although it's usually not that much. This is what we call the gas halo.*

The H-R Tech Memo goes on to state:

> *Joint mapping by Geiser and Engelder indicates the widespread presence of joints in Delaware and Sullivan Counties with orientations similar to or somewhat more easterly than the J2 jointing, and may indicate that J2 jointing is widely present in the sedimentary units above the Marcellus Shale near the WOH Watershed Infrastructure. (p. 10)*

This new information on fractures and potential faults as well as the existing information on joint patterns supports the conclusion that the area around the City's water supply infrastructure is more fractured and faulted than the RDSGEIS discloses or analyzes.

<u>Tunnel Damage From Earthquakes</u>

The H-R Tech Memo explored reports of damage to tunnels due to naturally occurring earthquakes of all magnitudes. The Sharma and Judd compilation[20] concludes that tunnels can be damaged by small to moderate earthquakes located miles away. While unlined tunnels suffered the greatest damage, tunnels lined with unreinforced concrete, like the Delaware tunnels, had the second highest risk of damage.

It should be noted that the Sharma and Judd compilations of tunnel damage did not consider minor cracking to be "damage." In the West of Hudson tunnels, however, minor cracking can have significant consequences. For example, the leaks that are currently allowing millions of gallons of water per day to escape the Delaware Aqueduct derive from minor cracking. Given the anticipated magnitude of induced earthquakes, less than magnitude three (3) on the Richter scale, tunnel collapse is not likely an issue, but cracking and/or damage to the concrete liners are a possibility.

Thus, the RDSGEIS conclusion that induced seismic activity is not a significant impact is not supported by the evidence. First, DEC relied on outdated and inadequate data about the

[18] Engelder, T., Lash, G.G., and Uzcategui, R., 2009, Joint Sets That Enhance Production from Middle and Upper Devonian Gas Shales of the Appalachian Basin, AAPG Bulletin, 93, p. 857-889.
[19] Durham, L.S., 2011, With Marcellus, It's All About the Fractures – AAPG Explorer, October 2011, p. 24 and 30.
[20] Sharma, S. and Judd, W.R., 1991, Underground Opening Damage from Earthquakes. Eng. Geol. V30, p. 263-276.

prevalence of faulting and fracturing in the region. Second, DEC failed to consider potential impacts on tunnels from natural earthquakes in assessing the potential for impacts to NYC's water supply tunnels from induced earthquakes. Third, the fact that the region generally has few natural earthquakes is not sufficient to conclude that there is no risk to the subsurface water supply infrastructure. The recent evidence linking HVHF to induced earthquakes, as well as the data linking lubrication from underground injection wells to induced earthquakes, adds a compelling argument that the seismic risk is real and needs to be more fully evaluated for the environmental review to be valid.

Revised Infrastructure Buffer Recommendation

Given the identified risks to the NYC water supply infrastructure, the 1,000 foot zone proposed in the RDSGEIS for enhanced coordination with the City is inadequate to protect the water supply. The H-R Tech Memo evaluated this proposal and states:

> *Based on the evidence of faulting, the possible reactivation of faulting due to HVHF, and the unprecedented nature of HVHF activity under critical water supply tunnels for a large population, Hager-Richter agrees with the assessment of the JV that a much greater protection than the 1,000-foot buffer afforded in the RDSGEIS is required to protect the WOH Watershed Infrastructure. (p. vi)*

In 2009, the City recommended a seven mile, no-drill buffer around the water supply infrastructure to reduce the risk to acceptable levels, based on a statistical analysis of the lengths of known faults and brittle structures (i.e., 90% of the faults were seven miles or smaller). The H-R Tech Memo found this analysis, given the available information, to be a reasonable statistical model[21].

As noted above, the City recently requested that its consultants conduct a more in-depth geophysical analysis of the risk to the water supply infrastructure which reaffirmed many of the previously identified risks. Hager-Richter's analysis does not identify a single, specific buffer distance that would simultaneously provide adequate protection of the infrastructure and also maximize the potential for drilling in its vicinity. Rather, the analysis supports the City's earlier conclusion that determining the appropriate buffer should be informed by the science and research detailed above, as well as by policy determinations about the acceptable level of risk of damage to the critical assets of a public water supply serving nearly half the State's population, and the resulting recovery time and other aspects of remediation.

After considering the more recent and precise geophysical analysis of faults and impacts (i.e., possible tunnel liner failure but not tunnel collapse) against the backdrop of the new requirements proposed in the RDSGEIS, the City is recommending a hybrid approach in lieu of an absolute prohibition within seven miles of all infrastructure, as was previously proposed. Given the lack of detailed subsurface information and research on the potential impacts on this type of infrastructure, adoption of a uniform width buffer would be a reasonable approach but other approaches may provide similar levels of protection and DEP is willing to discuss such

[21] Hager-Richter Report, page 45.

possibilities. Based upon the additional analysis in the H-R Tech Memo, the City believes the following approach, delineating two infrastructure buffer zones, represents a prudent balancing of relevant considerations:

- *Infrastructure Exclusion Zone.* We propose that all HVHF be banned for seven miles around the Delaware and Catskill Aqueducts, which carry water from terminal reservoirs.[22] These two aqueducts currently carry 100% of the water to NYC. Even non-catastrophic leaks or liner collapse would have significant consequences on DEP's ability to meet in-city and upstate water demand. For perspective, DEP is currently budgeting $2.1 billion dollars for repairs to the Delaware Aqueduct, and planning for a shutdown of six to 24 months, to address leaks of 5-35 million gallons a day, a small portion of the tunnel's overall capacity. Obviously, the consequences of damage from HVHF to the single tunnel that provides 50% of the City's water warrant the highest degree of protection: under any repair scenario that would require a tunnel shutdown, the City would lose access to water from Rondout Reservoir and the three upstream Delaware Reservoirs.

  We propose a two mile buffer on either side of other, non-terminal tunnels such as the West Delaware Tunnel, because damage to one of those tunnels would affect the City's ability to access water from only a single reservoir. DEP's water supply system has the flexibility to withstand an outage of these tunnels.

- *Infrastructure Enhanced Protection Zone.* This is the area between the Infrastructure Exclusion Zone and seven miles on either side of a tunnel from a non-terminal reservoir. (Given that the Infrastructure Exclusion Zone would be seven miles around terminal aqueducts, there would be no enhanced protection zone in their vicinity.) In the Infrastructure Enhanced Protection Zone, drilling would be permitted with stringent conditions to provide the City and DEC the ability to make informed site-specific determinations about the safety of allowing a particular well to be drilled within this distance, rather than relying on a blanket prohibition.

The additional permit conditions in the Infrastructure Enhanced Protection Zone should include, at a minimum: enhanced subsurface geophysical surveys conducted prior to drilling; review and approval by the City[23]; timely notification directly to the City of unexpected subsurface conditions during drilling, casing or hydraulic fracturing; requirement of an intermediate well casing; and enhanced well logs to confirm proper cementing. Seismic sensors, in-tunnel investigations, and a damage fund may also be appropriate mitigation strategies. The H-R report

[22] A terminal reservoir is one from which the City can provide water directly to the distribution system, such as Rondout and Ashokan Reservoirs.

[23] DEC is authorized to delegate such authority to the City pursuant to ECL Section 3-0301(2)(p). In addition, given the RDSGEIS' projection of the development of hundreds of wells annually in the Enhanced Protection Zone, it is imperative that a portion of the permit applicant's fee be provided to the City to pay for the costs of the City's review of such data (in addition to bonding and other requirements discussed in the City's initial comments). The City does not have the expertise or staffing to review the tremendous quantities of technical data that will be included annually in potentially hundreds of well applications and will need to hire or contract for the work. New York City and upstate water ratepayers should not be required to bear the expense associated with review of this activity.

recommends banning drilling near identified faults and fractures that cross the tunnels in addition to a fixed width buffer to limit the risk of induced earthquakes.[24] Proximity to known faults is an important factor that DEC and DEP should evaluate in review of proposed wells in the Infrastructure Enhanced Protection Zone. Identification of known faults cannot be the exclusive method of mitigating of risk, as the two cases of induced seismic activity investigated so far (Blackpool, U.K., and Eola Field, Oklahoma) involved faults that were not known prior to the events and were not visible at the surface.

A critical component of this recommendation is the ability to require applicants for permits within the Infrastructure Enhanced Protection Zone to provide all relevant documentation concerning the proposed activity including geophysical data and seismic surveys. HVHF has only been in widespread use for about ten years. As more data is collected and additional studies are completed, such as the current EPA study on the impacts to drinking water supplies and the U.S. Army Corps of Engineers study on dams, we will refine our understanding of the potential impacts of this technique. We look forward to working with DEC on the specifics of implementing this process.

In both zones, the buffer distance must be measured from the end of the well lateral, rather than from the edge of the surface well pad, to ensure that no drilling is allowed from outside the zone into areas beneath these zones.

The proposed Infrastructure Exclusion Zone would put an additional 327 square miles off limits to drilling in the Marcellus Shale; however 15% of this area (50 sq. mi.) would already be protected by other proposed prohibitions (that is, the area is within State parks or other State land, or is within a primary aquifer), meaning that the net impact is 277 square miles, or 1.5% of the shale deposits in New York State. If we add up the total proposed no-drill area – including otherwise unprotected lands in the watershed, the 4,000 ft. buffer zone around dams and the two mile buffer zone from tunnels and seven mile buffer zone from major aqueducts – only 1,511 square miles of otherwise unprotected land would be taken out of production at this time. This is only 8.1% of the Marcellus shale footprint in New York State. Given the significant risks to the water supply from damage to the City's infrastructure, this relatively small Infrastructure Exclusion Zone is a reasonable and prudent measure to mitigate the impact of this risk.

[24] H-R Report page 47.

In closing, we again thank DEC for the critically vital protection that a ban on HVHF in the watershed provides to the nine million consumers of the NYC water supply. We look forward to discussing these remaining issues in the future as partners in our efforts to protect this invaluable resource.

Very truly yours,

Carter H. Strickland, Jr.

Carter H. Strickland, Jr.

Enclosures: Map of exclusion and enhanced protection zones, H-R Tech Memo

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