

6.10 Noise ¹³⁸

The noise impacts associated with horizontal drilling and high volume hydraulic fracturing are, in general, similar to those addressed in the 1992 GEIS. The rigs and supporting equipment are somewhat larger than the commonly used equipment described in 1992, but with the exception of specialized downhole tools, horizontal drilling is performed using the same equipment, technology, and procedures as used for many wells that have been drilled in New York. Production-phase well site equipment is very quiet and has negligible impacts.

The greatest difference with respect to noise impacts, however, is in the duration of drilling. A horizontal well takes four to five weeks of drilling at 24 hours per day to complete. The 1992 GEIS anticipated that most wells drilled in New York with rotary rigs would be completed in less than one week, though drilling could extend two weeks or longer.

High-volume hydraulic fracturing is also of a larger scale than the water-gel fracs addressed in 1992. These were described as requiring 20,000 to 80,000 gallons of water pumped into the well at pressures of 2,000 to 3,500 pounds per square inch (psi). High-volume hydraulic fracturing of a typical horizontal well could require, on average, 3.6 million gallons of water and a maximum pumping pressure that may be as high as 10,000 to 11,000 psi. This volume and pressure would result in more pump and fluid handling noise than anticipated in 1992. The proposed process requires three to five days to complete. There was no mention of the time required for hydraulic fracturing in 1992.

There would also be significantly more trucking and associated noise involved with high-volume hydraulic fracturing than was addressed in the 1992 GEIS.

Site preparation, drilling, and hydraulic fracturing activities could result in temporary noise impacts, depending on the distance from the site to the nearest noise-sensitive receptors.

Typically, the following factors are considered when evaluating a construction noise impact:

¹³⁸ Section 6.10, in its entirety, was provided by Ecology and Environment Engineering, P.C., August 2011, and was adapted by the Department.

- Difference between existing noise levels prior to construction startup and expected noise levels during construction;
- Absolute level of expected construction noise;
- Adjacent land uses; and
- The duration of construction activity.

In order to evaluate the potential noise impacts related to the drilling operation phases, a construction noise model was used to estimate noise levels at various distances from the construction site during a typical hour for each phase of construction. The algorithm in the model considered construction equipment noise specification data, usage factors, and distance. The following logarithmic equation was used to compute projected noise levels:

$$Lp1 = Lp2 + 10\log(U.F./10) - 20\log(d2/d1):$$

where:

Lp1 = the average noise level (dBA) at a distance (d2) due to the operation of a unit of equipment throughout the day;

Lp2 = the equipment noise level (dBA) at a reference distance (d1);

U.F. = a usage factor that accounts for a fraction of time an equipment unit is in use throughout the day;

d2 = the distance from the unit of equipment in feet; and

d1 = the distance at which equipment noise level data is known.

Noise levels and usage factor data for construction equipment were obtained from industry sources and government publications. Usage factors were used to account for the fact that construction equipment use is intermittent throughout the course of a normal workday.

Once the average noise level for the individual equipment unit was calculated, the contribution of all major noise-producing equipment on-site was combined to provide a composite noise level at various distances using the following formula:

$$Leq_{total} = 10 \log \left(10^{\frac{Leq_1}{10}} + 10^{\frac{Leq_2}{10}} + 10^{\frac{Leq_3}{10}} \dots etc. \right)$$

Using this approach, the estimated noise levels are conservative in that they do not take into consideration any noise reduction due to ground attenuation, atmospheric absorption, topography, or vegetation.

6.10.1 Access Road Construction

Newly constructed access roads are typically unpaved and are generally 20 to 40 feet wide during the construction phase and 10 to 20 feet wide during the production phase. They are constructed to efficiently provide access to the well pad while minimizing potential environmental impacts.

The estimated sound pressure levels (SPLs) produced by construction equipment that would be used to build or improve access roads are presented in Table 6.54 for various distances. The composite result is derived by assuming that all of the construction equipment listed in the table is operating at the percent utilization time listed and by combining their SPLs logarithmically.

These SPLs might temporarily occur over the course of access road construction. Such levels would not generally be considered acceptable on a permanent basis, but as a temporary, daytime occurrence, construction noise of this magnitude and duration is not likely to result in many complaints in the project area.

Table 6.54 - Estimated Construction Noise Levels at Various Distances for
Access Road Construction (New August 2011)

Construction Equipment	Quantity	Usage Factor %	Lmax SPL @ 50 Feet (dBA)	Distance in Feet/SPL (dBA)					
				50 (adj.)	250	500	1,000	1,500	2,000
Excavator	2	40	81	80	66	60	54	50	48
Grader	2	40	85	84	70	64	58	54	52
Bulldozer	2	40	82	81	67	61	55	51	49
Compactor	2	20	83	79	65	59	53	49	47
Water truck	2	40	76	75	61	55	49	45	43
Dump truck	8	40	76	81	67	61	55	52	49
Loader	2	40	79	78	64	58	52	48	46
Composite Noise Level				89	75	69	63	59	57

Source: FHWA 2006.

Key:

adj = adjusted.

dBA = A-weighted decibels.

L_{max} = maximum noise level.

SPL = Sound Pressure Level.

6.10.2 Well Site Preparation

Prior to the installation of a well, the site must be cleared and graded to make room for the placement of the necessary equipment and materials to be used in drilling and developing the well. The site preparation would generate noise that is associated with a construction site, including noise from bulldozers, backhoes, and other types of construction equipment. The A-weighted SPLs for the construction equipment that typically would be utilized during well pad preparation are presented in Table 6.55 along with the estimated SPLs at various distances from the site. Such levels would not generally be considered acceptable on a permanent basis, but as a temporary, daytime occurrence, construction noise of this magnitude and duration is not likely to result in many complaints in the project area.

Table 6.55 - Estimated Construction Noise Levels at Various Distances for Well Pad Preparation (New August 2011)

Construction Equipment	Quantity	Usage Factor %	Lmax SPL @ 50 Feet (dBA)	Distance in Feet/SPL (dBA)					
				50 (adj.)	250	500	1,000	1,500	2,000
Excavator	1	40	81	77	63	57	51	47	45
Bulldozer	1	40	82	78	64	58	52	48	46
Water truck	1	40	76	72	58	52	46	42	40
Dump truck	2	40	76	75	61	55	49	45	43
Pickup truck	2	40	75	74	60	54	48	44	42
Chain saw	2	20	84	80	66	60	54	50	48
Composite Noise Level				84	70	64	58	55	52

Source: FHWA 2006.

Key:

adj = adjusted.

dBA = A-weighted decibels.

L_{max} = maximum noise level.

SPL = Sound Pressure Level.

6.10.3 High-Volume Hydraulic Fracturing – Drilling

High-volume hydraulic fracturing involves various sources of noise. The primary sources of noise were determined to be as follows:

- Drill Rigs. Drill rigs are typically powered by diesel engines, which generate noise emissions primarily from the air intake, crankcase, and exhaust. These levels fluctuate depending on the engine speed and load.
- Air Compressors. Air compressors are typically powered by diesel engines and generate the highest level of noise over the course of drilling operations. Air compressors would be in operation virtually throughout the drilling of a well, but the actual number of operating compressors would vary. However, more compressed air capacity is required as the drilling advances.
- Tubular Preparation and Cleaning. Tubular preparation and cleaning is an operation that is conducted as drill pipe is placed into the wellbore. As tubulars are raised onto the drill floor, workers physically hammer the outside of the pipe to displace internal debris. This process, when conducted during the evening hours, seems to generate the most concern from adjacent landowners. While the decibel level is comparatively low, the acute nature of the noise is noticeable.

- Elevator Operation. Elevators are used to move drill pipe and casing into and/or out of the wellbore. During drilling, elevators are used to add additional pipe to the drill string as the depth increases. Elevators are used when the operator is removing multiple sections of pipe from the well or placing drill pipe or casing into the wellbore. Elevator operation is not a constant activity and its duration is dependent on the depth of the well bore. The decibel level is low.
- Drill Pipe Connections. As the depth of the well increases, the operator must connect additional pipe to the drill string. Most operators in the Appalachian Basins use a method known as “air-drilling.” As the drill bit penetrates the rock the cuttings must be removed from the wellbore. Cuttings are removed by displacing pressurized air (from the air compressors discussed above) into the well bore. As the air is circulated back to the surface, it carries with it the rock cuttings. To connect additional pipe to the drill string, the operator will release the air pressure. It is the release of pressure that creates a higher frequency noise impact.

Once initiated, the drilling operation often continues 24 hours a day until completion and would therefore generate noise during nighttime hours, when people are generally involved in activities that require lower ambient noise levels. Certain noise-producing equipment is typically operated on a fairly continuous basis during the drilling process. The types and quantities of this equipment are presented in Table 6.56 for rotary air drilling and in Table 6.57 for horizontal drilling (see Photo 6.6), along with the estimated A-weighted individual and composite SPLs that would be experienced at various distances from the operation. An analysis of both types of drilling is included since according to industry sources, in accessing the natural gas formation, rotary air drilling is often used for the vertical section of the well and then horizontal drilling is used for making the turn and completing the horizontal section.

Table 6.56 - Estimated Construction Noise Levels at Various Distances for Rotary Air Well Drilling (New August 2011)

Construction Equipment	Quantity	Sound Power Level (dBA)	Distance in Feet/SPL ¹ (dBA)					
			50 (adj.)	250	500	1,000	1,500	2,000
Drill rig drive engine	1	105	71	57	51	45	41	38
Compressors	4	105	77	63	57	51	47	45
Hurricane booster	3	81	51	37	31	25	22	19
Compressor exhaust	1	85	51	37	31	25	21	18
Composite Noise Level			79	64	58	52	48	45

Source: Confidential Industry Source.

¹ SPL = Sound Pressure Level

Key:

adj = adjusted to quantity.

Table 6.57 - Estimated Construction Noise Levels at Various Distances for Horizontal Drilling (New August 2011)

Construction Equipment	Quantity	Sound Level	Distance	Distance in Feet/SPL (dBA)					
				50 (adj.)	250	500	1000	1500	2000
Rig drive motor	1	105 ²	0	71	57	51	45	41	38
Generator	3	81 ²	0	51	37	31	25	22	19
Top drive	1	85 ¹	5	65	51	45	39	35	33
Draw works	1	74 ¹	10	60	46	40	34	30	28
Triple shaker	1	85 ¹	15	75	61	55	49	45	43
Composite Noise Level				76	62	56	50	47	44

Source: Confidential Industry Source.

¹ SPL = Sound Pressure Level

Key:

adj = adjusted to quantity.

Photo 6.6 - Electric Generators, Active Drilling Site (New August 2011)



Intermittent operations that occur during drilling include tubular preparation and cleaning, elevator operation, and drill pipe connection blowdown. These shorter-duration events may occur at intervals as short as every 20 to 30 minutes during drilling. Noise associated with the drilling activities would be temporary and would end once drilling operations cease.¹³⁹

6.10.4 High-Volume Hydraulic Fracturing – Fracturing

During the hydraulic fracturing process, water, sand, and other additives are pumped under high pressure into the formation to create fractures. To inject the required water volume and achieve the necessary pressure, up to 20 diesel-pumper trucks operating simultaneously are necessary (see Photo 6.7 and Photo 6.8). Typically the operation takes place over two to five days for a single well. Normally, hydraulic fracturing is only performed once in the life of a well. The sound level measured for a diesel- pumper truck under load ranges from 110 to 115 dBA at a distance of 3 feet. Noise from the diesel engine varies according to load and speed, but the main component of the sound spectrum is the fundamental engine rotation speed. The diesel engine

¹³⁹ Page 4, - Notice of Determination of Non-Significance – API# 31-015-22960-00, Permit 08828 (February 13, 2002)

sound spectrum, which peaks in the range of 50 Hz to 250 Hz, contains higher emissions in the lower frequencies.

Table 6.58 presents the estimated noise levels that may be experienced at various distances from a hydraulic fracturing operation, based on 20 pumper trucks operating at a sound power level of 110 dBA and 20 pumper trucks operating at a sound power level of 115 dBA.

Table 6.58 - Estimated Construction Noise Levels at Various Distances for High-Volume Hydraulic Fracturing (New August 2011)

Construction Equipment	Quantity	SPL ¹ (dBA)	Distance (feet)	Quantity Adjusted Sound Level	Distance in Feet/SPL ¹ (dBA)					
					50	250	500	1000	1500	2000
Pumper truck	20	110	3	123	99	85	79	73	69	67
Pumper truck	20	115	3	128	104	90	84	78	74	72

Source: Confidential Industry Source.

¹ SPL = Sound Pressure Level

Photo 6.7 - Truck-mounted Hydraulic Fracturing Pump (New August 2011)



Photo 6.8 - Hydraulic Fracturing of a Marcellus Shale Well Site (New August 2011)



The existing sound level in a quiet rural area at night may be as low as 30 dBA at times. Since the drilling and hydraulic fracturing operations are often conducted on a 24-hour basis, these operations, without additional noise mitigations, may result in an increase in noise of 37 to 42 dB over the quietest background at a distance of 2,000 feet. As indicated previously, according to NYSDEC guidance, sound pressure increases of more than 6 dB may require a closer analysis of impact potential, depending on existing SPLs and the character of surrounding land use and receptors, and an increase of 6 dB(A) may cause complaints. Therefore, mitigation measures would be required if increases of this nature would be experienced at a receptor location.

Table 6.59 presents the estimated duration of the various phases of activity involved in the completion of a typical installation. Multiple well pad installations would increase the drilling and hydraulic fracturing duration in a given area.

Table 6.59 - Assumed Construction and Development Times (New August 2011)

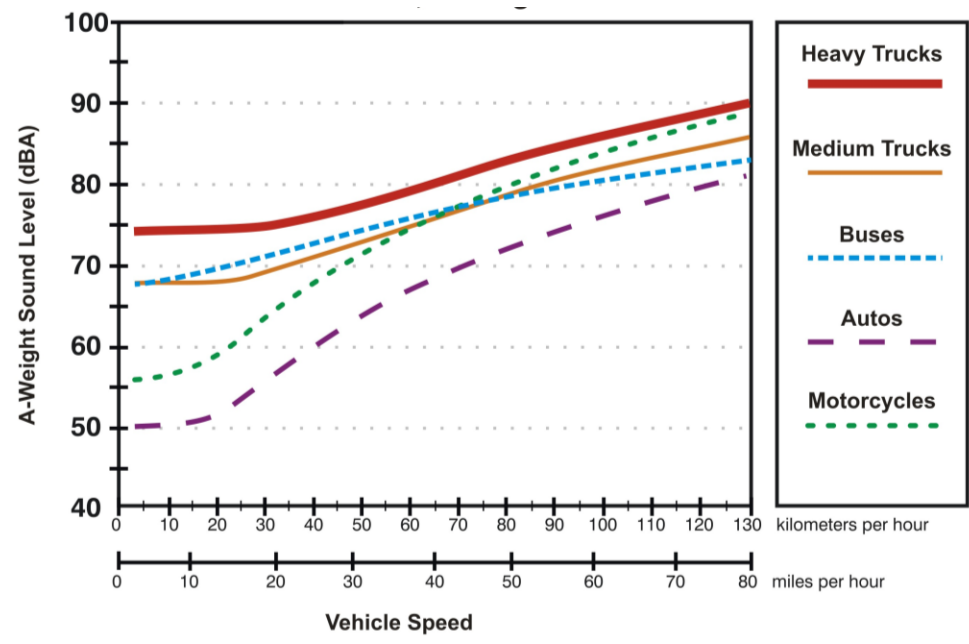
Operation	Estimated Duration (days)
Access roads	3 - 7
Site preparation/well pad	7 - 14
Well drilling	28 - 35
Hydraulic fracturing single well	2 - 5

6.10.5 Transportation

Similar to any construction operation, drill sites require the use of support equipment and vehicles. Specialized cement equipment and vehicles, water trucks, flatbed tractor trailers, and delivery and employee vehicles are the most common forms of support machinery and vehicles. Cement equipment would generate additional noise during operations, but this impact is typically short lived and is at levels below that of the compressors described above.

The noise levels generated by vehicles depend on a number of variable conditions, including vehicle type, load and speed, nature of the roadway surface, road grade, distance from the road to the receptor, topography, ground condition, and atmospheric conditions. Figure 6.20 depicts measured noise emission levels for various vehicles and cruise speeds at a distance of 50 feet on average pavement. As shown in the figure, a heavy truck passing by at 50 miles per hour would contribute a noise level of approximately 83 dBA at 50 feet from the road in comparison to a passing automobile, which would contribute approximately 73 dBA at 50 feet. Although a truck passing by would constitute a short duration noise event, multiple truck trips along a given road could result in higher hourly Leq noise levels and impacts on noise receptors close to main truck travel routes. The noise impact of truck traffic would be greater for travel along roads that do not normally have a large volume of traffic, especially truck traffic.

Figure 6.20 - A-Weighted Noise Emissions: Cruise Throttle, Average Pavement (New August 2011)



FHWA 1998.

In addition to the trucks required to deliver the drill rig and its associated equipment, trucks are used to bring in water for drilling and hydraulic fracturing, sand for hydraulic fracturing additive, and frac tanks. Trucks are also used for the removal of flowback for the site. Estimates of truck trips per well and truck trips over time during the early development phase of a horizontal and a vertical well installation are presented in Section 6.11, Transportation.

Development of multiple wells on a single pad would add substantial additional truck traffic volume in an area, which would be at least partially offset by a reduction in the number of well pads overall.

This level of truck traffic could have negative noise impacts on those living in proximity to the well site and access road. Like other noise associated with drilling, this would be temporary. Current regulations require that all wells on a multi-well pad be drilled within three years of starting the first well. Thus, it is possible that someone living in proximity to the pad would experience adverse noise impacts intermittently for up to three years.

6.10.6 Gas Well Production

Once the well has been completed and the equipment has been demobilized, the pad is partially reclaimed. The remaining wellhead production does not generate a significant level of noise.

Operation and maintenance activities could include a truck visit to empty the condensate collection tanks on an approximately weekly basis, but condensate production from the Marcellus Shale in New York is not typically expected. Mowing of the well pad area occurs approximately two times per year. These activities would result in infrequent, short-term noise events.

6.11 Transportation Impacts¹⁴⁰

While the trucking for site preparation, rig, equipment, materials, and supplies is similar for horizontal drilling to what was anticipated in 1992, the water requirement of high-volume hydraulic fracturing could lead to significantly more truck traffic than was discussed in the GEIS in the regions where natural gas development would occur. This section presents (1) industry

¹⁴⁰ Section 6.11, in its entirety, was provided by Ecology and Environment Engineering, P.C., August 2011, and was adapted by the Department.

estimates on the number of heavy- and light-duty trucks needed for horizontal well drilling as compared to vertical drilling that already takes place, (2) comparisons and reasonable scenarios with which to gauge potential impacts on the existing road system and transportation network, (3) potential impacts on roadways and the transportation network, and (4) potential impacts on rail and air service.

6.11.1 Estimated Truck Traffic

The Department requested information from the Independent Oil & Gas Association of New York (IOGA-NY) to estimate the number of truck trips associated with well construction.

6.11.1.1 Total Number of Trucks per Well

Table 6.60 presents the total estimated number of one-way (i.e., loaded) truck trips per horizontal well during construction, and Table 6.61 presents the total estimated number of one-way truck trips per vertical well during construction. Information is further provided on the distribution of light- and heavy-duty trucks for each activity associated with well construction. Table 6.62 summarizes the total overall light- and heavy-duty truck trips per well for both vertical and horizontal wells. The Department assumed that all truck trips provided in the industry estimates were one-way trips; thus, to obtain the total vehicle trips, the numbers were doubled to obtain the round-trips across the road network (Dutton and Blankenship 2010).

As discussed in 1992 regarding conventional vertical wells, trucking during the long-term production life of a horizontally drilled single or multi-well pad would be insignificant.

IOGA-NY provided estimates of truck trips for two periods of development, as shown in Table 6.60 and Table 6.61: (1) a new well location completed early on in the development life of the field, and (2) a well location completed during the peak development year. During the early well pad development, all water is assumed to be transported to the site by truck. During the peak well pad development, a portion of the wells are assumed to be accessible by pipelines for transport of the water used in the hydraulic fracturing.

As shown in comparing the number of truck trips per well in Table 6.60 and Table 6.61, the truck traffic associated with drilling a horizontal well with high-volume hydraulic fracturing is 2 to 3 times higher than the truck traffic associated with drilling a vertical well.

Table 6.60 - Estimated Number of One-Way (Loaded) Trips Per Well:
Horizontal Well¹ (New August 2011)

Well Pad Activity	Early Well Pad Development (all water transported by truck)		Peak Well Pad Development (pipelines may be used for some water transport)	
	Heavy Truck	Light Truck	Heavy Truck	Light Truck
Drill pad construction	45	90	45	90
Rig mobilization ²	95	140	95	140
Drilling fluids	45		45	
Non-rig drilling equipment	45		45	
Drilling (rig crew, etc.)	50	140	50	140
Completion chemicals	20	326	20	326
Completion equipment	5		5	
Hydraulic fracturing equipment (trucks and tanks)	175		175	
Hydraulic fracturing water hauling ³	500		60	
Hydraulic fracturing sand	23		23	
Produced water disposal	100		17	
Final pad prep	45		50	
Miscellaneous	-	85	-	85
Total One-Way, Loaded Trips Per Well	1,148	831	625	795

Source: All Consulting 2010.

1. Estimates are based on the assumption that a new well pad would be developed for each single horizontal well. However, industry expects to initially drill two wells on each well pad, which would reduce the number of truck trips. The well pad would, over time, be developed into a multi-well pad.
2. Each well would require two rigs, a vertical rig and a directional rig.
3. It was conservatively assumed that each well would use approximately 5 million gallons of water total and that all water would be trucked to the site. This is substantially greater than the likely volume of water that would be trucked to the site.

Table 6.61 - Estimated Number of One-Way (Loaded) Trips Per Well: Vertical Well (New August 2011)

Well Pad Activity	Early Well Pad Development (all water transported by truck)		Peak Well Pad Development (pipelines may be used for some water transport)	
	Heavy Truck	Light Truck	Heavy Truck	Light Truck
Drill pad construction	32	90	25	90
Rig mobilization	50	140	50	140
Drilling fluids	15		15	
Non-rig drilling equipment	10		10	
Drilling (rig crew, etc.)	30	70	30	70
Completion chemicals	10	72	10	72
Completion equipment	5		5	
Hydraulic fracturing equipment (trucks and tanks)	75		75	
Hydraulic fracturing water hauling	90		25	
Hydraulic fracturing sand	5		5	
Produced water disposal	42		26	
Final pad prep	34	50	34	50
Miscellaneous	0	85	0	85
Total One-Way, Loaded Trips Per Well	398	507	310	507

Source: All Consulting 2010.

Table 6.62 - Estimated Truck Volumes for Horizontal Wells Compared to Vertical Wells (New August 2011)

	Horizontal Well with High-Volume Hydraulic Fracturing		Vertical Well	
	Heavy Truck	Light Truck	Heavy Truck	Light Truck
Light-duty trips	831	795	507	507
Heavy-duty trips	1,148	625	389	310
Combined Total	1,975	1,420	905	817
Total Vehicle Trips	3,950	2,840	1,810	1,634

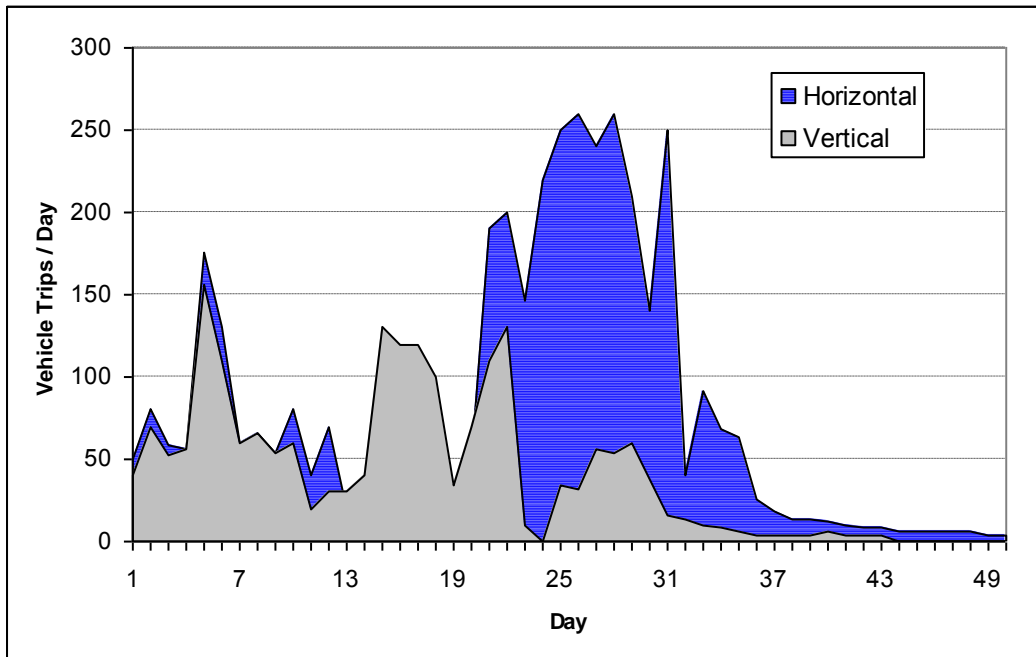
Source: Dutton and Blankenship 2010

Note: The first three rows in this table are round trips; total vehicle trips are one-way trips.

6.11.1.2 *Temporal Distribution of Truck Traffic per Well*

Figure 6.21 shows the daily distribution of the truck traffic over the 50-day period of early well pad development of a horizontal well and a vertical well (Dutton and Blankenship 2010). As seen in the figure, certain phases of well development require heavier truck traffic (peaks in the graph). Initial mobilization and drilling is comparable between horizontal and vertical wells; however, from Day 20 to Day 35, the horizontal well requires significantly more truck transport than the vertical well.

Figure 6.21 - Estimated Round-Trip Daily Heavy and Light Truck Traffic, by Well Type - Single Well (New August 2011)



Source: Dutton and Blankenship 2010.

6.11.1.3 *Temporal Distribution of Truck Traffic for Multi-Well Pads*

The initial exploratory development using horizontal wells and high-volume hydraulic fracturing would likely involve a single well on a pad. However, commercial demand would likely expand development, resulting in multiple wells being drilled on a single pad, with each horizontal well extending into a different sector of shale. Thus, horizontal wells would be able to access a larger sector of the shale from a single pad site than would be possible for traditional development with vertical wells. This means there would be less truck traffic for the development of the pad itself.

There is a tradeoff, however, as each horizontal well utilizing the high-volume hydraulic fracturing method of extraction would require more truck trips per well than vertical wells (Dutton and Blankenship 2010).

Two development scenarios were proposed to estimate the truck traffic for horizontal and vertical well development for multi-well pads (Dutton and Blankenship 2010). The key parameters and assumptions are as follows:

Multi-pad Development Scenario 1: Horizontal Wells with High-Volume Hydraulic Fracturing:

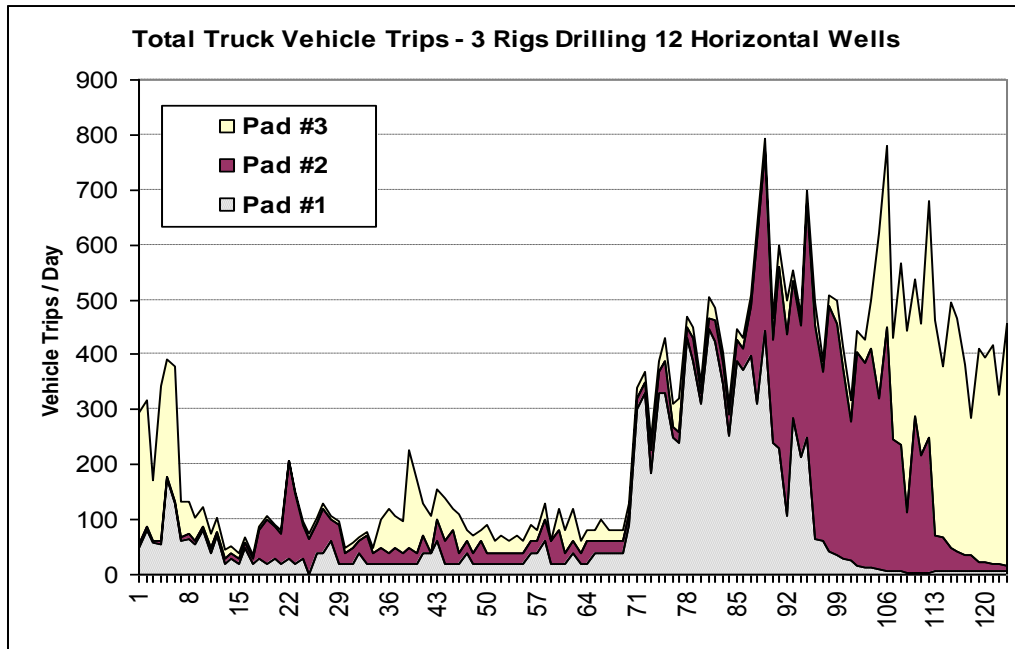
- Three rigs operated over a 120-day period.
- Each rig drills four wells in succession, then moves off to allow for completion.
- All water needed to complete the fracturing is hauled in via truck.
- Fracturing and completion of the four wells occurs sequentially and tanks are brought in once for all four wells.
- At an average of 160 acres per well, the three rigs develop a total of 1,920 acres of land.

Multi-pad Development Scenario 2: Vertical Wells

- Four rigs operated over a 120-day period
- Each rig drills four wells, moving to a new location after drilling of a well is completed.
- All water needed to complete the fracturing is hauled in via truck.
- Fracturing and completion of each well occurs after the rig relocates to a new location.
- At an average of 40 acres per well, the four rigs develop a total of 640 acres of land.

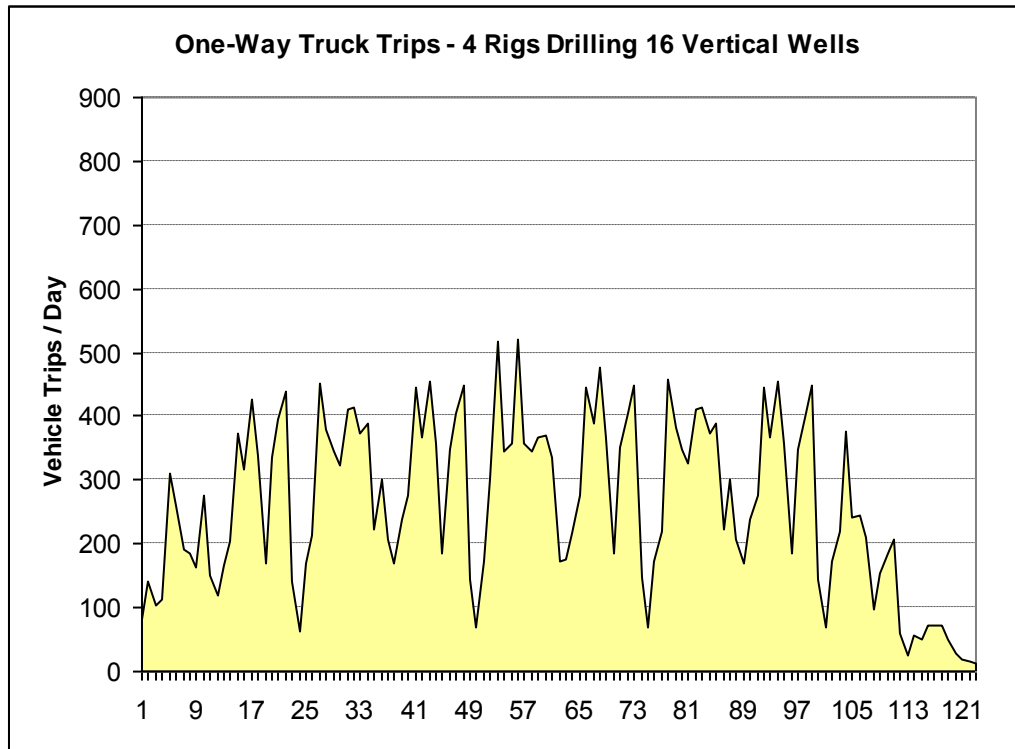
The extra yield of horizontal wells was compensated for by assuming that four vertical rigs were utilized during the same time span as three horizontal rigs. The results of these two development scenarios on a day-by-day basis are depicted in Figure 6.22 and Figure 6.23. As shown, the number of vehicle trips varies depending on the number of wells per pad. Horizontal wells have the highest volume of truck traffic in the last five weeks of well development, when fluid is utilized in high volumes. This is in contrast to the more conventional vertical wells (see Figure 6.23), where the volume of truck traffic is more consistent throughout the period of development.

Figure 6,22 - Estimated Daily Round-Trips of Heavy and Light Truck Traffic - Multi Horizontal Wells (New August 2011)



Source: Dutton and Blankenship 2010.

Figure 6,23 - Estimated Round-Trip Daily Heavy and Light Truck Traffic - Multi Vertical Wells (New August 2011)



Source: Dutton and Blankenship 2010.

The major conclusions to be drawn from this comparison of the truck traffic resulting from the use of horizontal and vertical wells are as follows (Dutton and Blankenship 2010):

- Peak-day traffic volumes given sequential completions with multiple rigs drilling horizontal wells along the same access road could be substantially higher than those for multiple rigs drilling vertical wells.
- The larger the area drained per horizontal well and the drilling of multiple wells from a pad without moving a rig offsets some of the increase in truck traffic associated with the high-volume fracturing.
- Based on industry data and other assumptions applied for these scenarios, the total number of vehicle trips generated by the three rigs drilling 12 horizontal wells is roughly equivalent to the number of vehicle trips associated with four rigs drilling 16 vertical wells. However, the horizontal wells require three-times the amount of land (1,920 acres for horizontal wells versus 640 acres for vertical wells). Thus, developing the same amount of land using vertical wells would either require three times longer, or would require deployment of 12 rigs during the same period, effectively tripling the total number of trips and result in peak daily traffic volumes above the levels associated with horizontal wells.

Based upon the information presented in these two development scenarios, utilizing horizontal wells and high-volume hydraulic fracturing rather than vertical wells to access a section of land would reduce the total amount of truck traffic. However, because vertical well hydraulic fracturing is not as efficient in its extraction of natural gas, it is not always economically feasible for operators to pursue. Currently, it is estimated that 10% of the wells drilled to develop low-permeability reservoirs with high-volume hydraulic fracturing will be vertical. Thus, the number of permits requested by applicants and issued by NYSDEC has not been fully reached. Horizontal drilling with high-volume hydraulic fracturing would be expected to result in a substantial increase in permits, well construction, and truck traffic over what is present in the current environment.

6.11.2 Increased Traffic on Roadways

As described in Section 6.18, Socioeconomics, three possible development scenarios are being assessed in this SGEIS to reflect the uncertainties associated with the future development of natural gas reserves in the Marcellus and Utica Shales – a high, medium and low development scenario. Each development scenario is defined by the number of vertical and horizontal wells drilled annually. (A summary of the development scenarios is provided in Section 6.8). Based on the number of wells estimated in each development scenario and the estimated number of

truck trips per well as discussed above in Section 6.1.1, the total estimated truck trips for all wells developed annually is provided in Table 6.63. Annual trips are projected for Years 1 through 30 in 5-year increments. Estimated truck trips are provided for the three representative regions (Regions A, B, and C), New York State outside of the three regions, and statewide.

The proposed action would also have an impact on traffic on federal, state, county, regional local roadways. Given the generic nature of this analysis, and the lack of specific well pad locations to permit the identification of specific road-segment impacts, the projected increase in average annual daily traffic (AADT) and the associated impact on the level of service on specific roadway segments, interchanges, and intersections cannot be determined. The AADT on roadways can vary significantly, depending largely on functional class, and particularly whether the count was taken in heavily populated communities or in proximity to heavily traveled intersections/interchanges. Trucks traveling on higher level roadways along arterials and major collectors are not anticipated to have a significant impact on traffic patterns and traffic flow, as these roads are designed for a high level of vehicle traffic, and the anticipated increase in the level of traffic associated with this action would only represent a small, incremental change in existing conditions. However, certain local roads and minor collectors would likely experience congestion during certain times of the day or during certain periods of well development.

Table 6.64 illustrates this variation by providing the highest and lowest AADT on three functional class roads in three counties, one in each of the representative regions. The counts presented are the lowest and highest counts on the identified road in the designated functional class in the county.

On some roads, truck traffic generated by high-volume hydraulic fracturing operations may be small compared to total AADT, as would be the case on I-17 in Binghamton, where AADT was approximately 77,000 vehicles. In other cases, and particularly on collectors and minor arterials, traffic from high-volume hydraulic fracturing could be a large share of AADT. Truck traffic from high-volume hydraulic fracturing operations could also be a large share of total daily truck traffic on specific stretches of certain interstates and be much larger than existing truck volumes on lower functional class roads that serve natural gas wells or link the wells to major truck heads such as water supply, rail trans-loading, and staging areas.

Table 6.63 - Estimated Annual Heavy Truck Trips (in thousands) (New August 2011)

	Region A			Region B			Region C			Rest of New York State			State-Wide Totals		
Counties	Broome, Chemung, Tioga,			Delaware, Otsego, Sullivan			Cattaraugus, Chautauqua			Rest of New York State			State-Wide Totals		
Low Development Scenario															
Year	Horizontal	Vertical	Total	Horizontal	Vertical	Total	Horizontal	Vertical	Total	Horizontal	Vertical	Total	Horizontal	Vertical	Total
1	4,334	226	4,561	2,053	113	2,166	456	0	456	1,597	113	1,710	8,441	453	8,893
5	21,216	1,245	22,460	9,809	566	10,375	2,053	113	2,166	9,353	453	9,806	42,431	2,376	44,807
10	42,431	2,376	44,807	19,391	1,132	20,522	4,334	226	4,561	18,478	1,018	19,496	84,634	4,752	89,387
15	42,431	2,376	44,807	19,391	1,132	20,522	4,334	226	4,561	18,478	1,018	19,496	84,634	4,752	89,387
20	42,431	2,376	44,807	19,391	1,132	20,522	4,334	226	4,561	18,478	1,018	19,496	84,634	4,752	89,387
25	42,431	2,376	44,807	19,391	1,132	20,522	4,334	226	4,561	18,478	1,018	19,496	84,634	4,752	89,387
30	42,431	2,376	44,807	19,391	1,132	20,522	4,334	226	4,561	18,478	1,018	19,496	84,634	4,752	89,387
Average Development Scenario															
Year	Horizontal	Vertical	Total	Horizontal	Vertical	Total	Horizontal	Vertical	Total	Horizontal	Vertical	Total	Horizontal	Vertical	Total
1	16,881	1,018	17,900	7,756	453	8,209	1,597	113	1,710	7,528	339	7,868	33,763	1,924	35,686
5	84,634	4,752	89,387	39,009	2,150	41,159	8,441	453	8,893	37,184	2,150	39,334	169,269	9,505	178,773
10	169,269	9,505	178,773	77,791	4,413	82,203	16,881	905	17,786	74,597	4,187	78,783	338,538	19,009	357,547
15	169,269	9,505	178,773	77,791	4,413	82,203	16,881	905	17,786	74,597	4,187	78,783	338,538	19,009	357,547
20	169,269	9,505	178,773	77,791	4,413	82,203	16,881	905	17,786	74,597	4,187	78,783	338,538	19,009	357,547
25	169,269	9,505	178,773	77,791	4,413	82,203	16,881	905	17,786	74,597	4,187	78,783	338,538	19,009	357,547
30	169,269	9,505	178,773	77,791	4,413	82,203	16,881	905	17,786	74,597	4,187	78,783	338,538	19,009	357,547
High Development Scenario															
Year	Horizontal	Vertical	Total	Horizontal	Vertical	Total	Horizontal	Vertical	Total	Horizontal	Vertical	Total	Horizontal	Vertical	Total
1	25,322	1,471	26,793	11,634	679	12,313	2,509	113	2,623	11,178	566	11,744	50,644	2,829	53,473
5	126,381	7,015	133,397	58,172	3,168	61,340	12,547	679	13,226	55,663	3,055	58,718	252,763	13,917	266,680
10	252,763	13,917	266,680	116,344	6,450	122,793	25,322	1,358	26,680	111,097	6,110	117,207	505,525	27,835	533,360
15	252,763	13,917	266,680	116,344	6,450	122,793	25,322	1,358	26,680	111,097	6,110	117,207	505,525	27,835	533,360
20	252,763	13,917	266,680	116,344	6,450	122,793	25,322	1,358	26,680	111,097	6,110	117,207	505,525	27,835	533,360
25	252,763	13,917	266,680	116,344	6,450	122,793	25,322	1,358	26,680	111,097	6,110	117,207	505,525	27,835	533,360
30	252,763	13,917	266,680	116,344	6,450	122,793	25,322	1,358	26,680	111,097	6,110	117,207	505,525	27,835	533,360

Table 6.64 - Illustrative AADT Range for State Roads (New August 2011)

Functional Class	County	Route	AADT Range, (1,000s)	Estimated Average Truck Volume (1,000s)
Interstate	Delaware	88	11 - 12	2.40
Arterial	Delaware	28	1 - 6	0.30
Collector	Delaware	357	2 - 4	0.02
Interstate	Broome	17	7 - 77	7.00
Arterial	Broome	26	2 - 33	1.00
Collector	Broome	41	1	0.01
Interstate	Cattaraugus	86	8 - 13	2.00
Arterial	Cattaraugus	219	6 - 11	1.00
Collector	Cattaraugus	353	1 - 6	0.20

AADT and Trucks rounded to the nearest 1,000.

Source: NYSDOT 2011

Although truck traffic is expected to significantly increase in certain locations, most of the projected trips would be short. The largest component of the truck traffic for horizontal drilling would be for water deliveries, and these would involve very short trips between the water procurement area and the well pad. Since the largest category of truck trips involve water trucks (600 of 1,148 heavy truck trips; see Table 6.60), it is anticipated that the largest impacts from truck traffic would be near the wells under construction or on local roadways.

Development of the high-volume hydraulic fracturing gas resource would also result in direct and indirect employment and population impacts, which would increase traffic on area roadways. The Department, in consultation with NYSDOT, will undertake traffic monitoring in the regions where well permit applications are most concentrated. These traffic studies and monitoring efforts will be conducted and reviewed by NYSDOT and used to inform the development of road use agreements by local governments, road repairs supported by development taxes, and other mitigation strategies described in Chapter 7.13.

6.11.3 Damage to Local Roads, Bridges, and other Infrastructure

As a result of the anticipated increase in heavy- and light-duty truck traffic, local roads in the vicinity of the well pads are expected to be damaged. Road damage could range from minor

fatigue cracking (i.e., alligator cracking) to significant potholes, rutting, and complete failure of the road structure. Extra truck traffic would also result in extra required maintenance for other local road structures, such as bridges, traffic devices, and storm water runoff structures. Damage could occur as normal wear and tear, particularly from heavy trucks, as well as from trucks that may be on the margin of the road and directly running over culverts and other infrastructure that is not intended to handle such loads.

As discussed in Section 2.4.14, the different classifications of roads are constructed to accommodate different levels of service, defined by vehicle trips or vehicle class. Typically, the higher the road classification, the more stringent the design standards and the higher the grade of materials used to construct the road. The design of roads and bridges is based on the weight of vehicles that use the infrastructure. Local roads are not typically designed to sustain a high level of vehicle trips or loads and thus oftentimes have weight restrictions.

Maintenance and repair of the road infrastructure in New York currently strains the limited budgets of the New York State Department of Transportation (NYSDOT) as well as the county and local agencies responsible for local roads. Heavy trucks generally cause more damage to roads and bridges than cars or light trucks due to the weight of the vehicle. A general “rule of thumb” is that a single large truck is equivalent to the passing of 9,000 automobiles (Alaska Department of Transportation and Public Facilities 2004). The higher functional classes of roads, such as the interstate highways, generally receive better and more frequent maintenance than the local roads that are likely to receive the bulk of the heavy truck traffic from the development of shale gas.

Some wells would be located in rural areas where the existing roads are not capable of accommodating the type of truck or number of truck trips that would occur during well development. In addition, intersections, bridge capacities, bridge clearances, or other roadway features may prohibit access to a well development site under current conditions. Applicants would need to improve the roadway to accommodate the anticipated type and amount of truck traffic, which would be implemented through a road use agreement with the local municipality. This road use agreement may include an excess maintenance agreement to provide compensation for impacts. These criteria are discussed further in Section 7.13, Mitigating Transportation and

Road Use Impacts. Section 7.13 also discusses additional ways that compensatory mitigation may be applied to pay for damages.

Actual costs associated with local roads and bridges cannot be determined because these costs are a factor of (1) the number, location, and density of wells; (2) the actual truck routes and truck volumes; (3) the existing condition of the roadway; (4) the specific characteristics of the road or bridge (e.g., the number of lanes, width, pavement type, drainage type, appurtenances, etc.); and (5) the type of treatment warranted. However, based on a sample of 147 local bridges with a condition rating of 6 (i.e., Fair to Poor) in Broome, Chemung, and Tioga counties, estimates of replacement costs could range from \$100,000 to \$24 million per bridge, and averaged \$1.5 million per bridge. The NYSDOT estimates that bridges with a condition rating of 6 or below would be impacted by the projected increase in truck traffic, resulting in accelerated deterioration, and warrant replacement. Because these routes were often built to lower standards, heavy trucks would have a much greater impact than other types of traffic.

According to the NYSDOT, the costs of repair to damaged pavement on local roads also varies widely depending on the type of work necessary and the characteristics of the road. Low-level maintenance treatments such as a single course overlay, would range from \$70,000 to \$150,000 per lane mile. Higher-level maintenance such as rubberizing and crack and seat rehabilitation would range from \$400,000 to \$530,000 per lane mile. Full-depth reconstruction can range from \$490,000 to \$1.9 million per lane mile.

6.11.4 Damage to State Roads, Bridges, and other Infrastructure

For roads of higher classification in the arterial or major collector categories, the general construction of the roads would be adequate to sustain the projected travel of heavy- and light-trucks associated with horizontal drilling and high-volume hydraulic fracturing. However, there would be an incremental deterioration of the expected life of these roads due to the estimated thousands of vehicle trips that would occur because of the increase in drilling activity. These larger roads are part of the public road network and have been built to service the areas of the state for passenger, commercial, and industrial traffic; however, the loads and numbers of heavy trucks proposed by this action could effectively reduce the lifespan of several roads, requiring

unanticipated and early repairs or reconstruction, which would burden of the State and its taxpayers.

When the cumulative and induced impacts of the total high-volume hydraulic fracturing gas development are considered, the resulting traffic impacts can be considerable. The principal cumulative traffic impacts would occur during drilling and well development. Impacts on the road, bridge, and other infrastructure would be primarily from the cumulative impact of heavy trucking.

Actual costs to roads of higher functional classification cannot be determined because these costs are a factor of (1) the number, location and density of wells; (2) the actual truck routes and truck volumes; (3) the existing condition of the roadway; (4) the specific characteristics of the road or bridge (e.g., the number of lanes, width, pavement type, drainage type, appurtenances, etc.); and (5) the type of treatment warranted, similar to the local roads discussed above.

However, based on a sample of 166 state bridges with a condition rating of 6 (i.e., Fair to Poor) in Broome, Chemung, and Tioga counties, estimates of replacement costs could range from \$100,000 to \$31 million per bridge, and averaged \$3.3 million per bridge. The NYSDOT estimates that bridges with a condition rating of 6 or below would be impacted by the projected increase in truck traffic, resulting in accelerated deterioration, and warrant replacement.

According to the NYSDOT, the costs of repair to damaged pavement on state roads also varies widely depending on the type of work necessary and the characteristics of the road. Low-level maintenance treatments such as a single-course overlay, would range from \$90,000 to \$180,000 per lane mile. Higher-level maintenance such as rubberizing and crack and seat rehabilitation would range from \$540,000 to \$790,000 per lane mile. Full depth reconstruction can range from \$910,000 to \$2.1 million per lane mile.

Depending on the volume and location of high-volume hydraulic fracturing, there is a possibility that a number of bridges and certain segments of state roads would require higher levels of maintenance and possibly replacement. The extent of such road work that would be attributable to high-volume hydraulic fracturing cannot be calculated because the proportion of truck and vehicular traffic attributable to such operations compared to truck and vehicular traffic

attributable to other industries on any particular road would vary significantly. On collectors and minor arterials, there is a potential for greater impacts from this activity because these routes were often built to lower standards, and thus, heavy trucks would have a much greater impact than other types of traffic. As a result, actual contribution of heavy trucks to road and bridge deterioration would be greater than suggested by their proportion to total traffic. Conversely, any additional traffic on higher functional class roads, and especially interstates and major arterials, would result in little impact because these roads were built to higher construction and pavement standards.

6.11.5 Operational and Safety Impacts on Road Systems

An increase in the amount of truck traffic, and vehicular traffic in general, traveling on both higher and lower level local roads would most likely increase the number of accidents and breakdowns in areas experiencing well development. These potential breakdowns and accidents would require the response of public safety and other transportation-related services (e.g., tow trucks). Local road commissions and the NYSDOT would also likely incur costs associated with operational and safety improvements.

The costs of implementing operational and safety improvements on local roads would vary widely depending on the type of treatment required. Improvements on turn lanes could cost from \$17,000 to \$34,000, and the provision of signals and intersection could cost from approximately \$35,000 for the installation of flashing red/yellow signals and from \$100,000 to \$150,000 for the installation of three-color signals.

The costs of addressing operational and safety impacts on state roads also would vary widely depending on the type of treatment required. The most common treatments include constructing turn lanes, with costs ranging from \$20,000 to \$40,000 on state roads, and installing signals and intersections, where costs range from approximately \$35,000 for the installation of flashing red/yellow signals and from \$100,000 to \$150,000 for the installation of three-color signals.

The cost of addressing capacity and flow constraints stemming from high levels of truck traffic or direct and indirect employment and population traffic volumes are much greater, however,

and might approach \$1 million per lane per mile (roughly the cost of full reconstruction), not including the costs of acquiring rights-of-way.

6.11.6 Transportation of Hazardous Materials

Vertical wells do not require the volumes of chemicals that would require consideration of hazardous chemicals beyond the use of diesel fuel for the equipment on the surface. The truck traffic supporting the development of the horizontal wells involving high-volume hydraulic fracturing would be transporting a variety of equipment, supplies, and potentially hazardous materials.

As described in Section 5.4 of the SGEIS, fracturing fluid is 98% freshwater and sand and 2% or less chemical additives. There are 12 classes of chemical additives that could be in the hazardous waste water being trucked to or from a location. Additive classes include: proppant, acid, breaker, bactericide/biocide, clay stabilizer/control, corrosion inhibitor, cross linker, friction reducer, gelling agent, iron control, scale inhibitor, and surfactant. These classes are described in full detail in Section 5.4, Table 5.6. Although the composition of fracturing fluid varies from one geologic basin or formation to another, the range of additive types available for potential use remains the same. The selection may be driven by the formation and potential interactions between additives, and not all additive types would be utilized in every fracturing job (see Section 5.4). Table 5.7 (Section 5.4) shows the constituents of all hydraulic fracturing-related chemicals submitted to NYSDEC to date for potential use at shale wells within New York. Only a handful of these chemicals would be utilized at a single well. Data provided to NYSDEC to date indicates that similar fracturing fluids are needed for vertical and horizontal drilling methods.

Trucks transporting hazardous materials to the various well locations would be governed by USDOT regulations, as discussed in Section 5.5 and Chapter 8. Transportation of any hazardous materials always carries some risks from spills or accidents. Hazardous materials are moved daily across the state without incident, but the additional transport resulting from horizontal drilling poses an additional risk, which could be an adverse impact if spills occur.

6.11.7 Impacts on Rail and Air Travel

The development of high-volume hydraulic fracturing natural gas would require the movement of large quantities of pipe, drilling equipment, and other large items from other locations and from manufacturing sites that are likely far away from the well sites. Rail provides an inexpensive and efficient means of moving such material. The final movement, from rail depots to the well sites, would be accomplished with large trucks. The extent of rail and the choice of unloading locations depends on the well sites and cannot be predicted at this time. However, the use of rail to transport materials would have several predictable results:

- Total truck traffic would decrease;
- Truck traffic near the rail terminals would increase,
- Truck traffic on the arterials between the terminals and well fields would increase.

These positive and negative impacts would likely alleviate some impacts but might exacerbate impacts in neighborhoods along the routes to and from the rail centers. These impacts would require examination as part of road use agreements.

The heavy, bulky, equipment utilized for horizontal drilling would not likely be transported by air. However, the large numbers of temporary workers that the industry would employ would likely utilize the network of small airports and commuter airlines that service New York State. This would increase the traffic to and from these airports. None of the regional airports in New York State are at capacity, so the air travel is not expected to be a significant impact. In fact, the extra economic activity would be positive. However, residents that are along approach and departure corridors would experience more noise from increased service by airplanes.

6.12 Community Character Impacts¹⁴¹

High-volume hydraulic fracturing operations could potentially have a significant impact on the character of communities where drilling and production activities would occur. Both short-term and long-term, impacts could result if this potentially large-scale industry were to start operations. Experiences in Pennsylvania and West Virginia show that wholesale development of

¹⁴¹ Section 6.12, in its entirety, was provided by Ecology and Environment Engineering, P.C., August 2011, and was adapted by the Department.

the low-permeable shale reserves could lead to changes in the economic, demographic, and social characteristics of the affected communities.

While some of these impacts are expected to be significant, the determination of whether these impacts are positive or negative cannot be made. Change would occur in the affected communities, but how this change is viewed is subjective and would vary from individual to individual. This section, therefore, seeks to identify expected changes that could occur to the economic and social makeup of the impacted communities, but it does not attempt to make a judgment on whether such change is beneficial or harmful to the local community character.

The amount of the change in community character that is expected to occur would be impacted by several factors. However, the most important factors would be the speed at which high-volume hydraulic fracturing activities would occur and the overall level of the natural gas activities. Slow, moderate growth of the industry, if it were spread over several years, would generate much less acute impacts than rapid expansion over a limited time. Community character is constantly in a state of flux; a community's sense of place is constantly revised and adapts as social, demographic, and economic conditions change. When these changes are gradual, residents are given time to adapt and accommodate to the new conditions and typically do not view them as negative. When these changes are abrupt and dramatic, residents typically find them more adverse.

If the high-volume hydraulic fracturing operations reach some of the more optimistic development levels described in previous sections, the size and structure of the regional economies could be influenced by this new industry. Local communities that have experienced declining employment and population levels for decades could quickly become some of the fastest growing communities in the state. Traditional employment sectors could decline in importance while new employment sectors, such as the natural gas extraction industry and its suppliers, could expand in importance. Employment opportunities would increase in the communities and the types of jobs offered would change.

Total population would increase in the communities and the demographic makeup of these populations would change. In-migration resulting from the high-volume hydraulic fracturing

operations would bring a racially and ethnically diverse workforce into the area. Most of the new population would be working age or their dependents. In addition, most of the employment opportunities created would be for skilled blue collar jobs.

In addition to employment and demographic impacts, the proposed high-volume hydraulic fracturing would greatly increase income and earnings throughout affected communities. Royalty payments to local landowners, increased payroll earnings from the natural gas industry, added profits to firms that supply the natural gas industry, and added earnings from all of the induced economic activity that would occur in the communities would all add to the affluence of the region. While total income in the communities would increase, this added income and wealth would not be evenly distributed. Landowners that lease out their subsurface mineral rights would benefit financially from the high-volume hydraulic fracturing operations; however, those residents that do not own the subsurface mineral rights or chose not to exploit these rights would not see the same financial benefits. Some entrepreneurs and property owners would see large financial gains from the increase in economic activity, other residents may experience a rise in living expenses without enjoying any corresponding financial gains.

In some areas, the housing market would experience an increase in value and price if there is not sufficient outstanding supply to meet the increased demand. Existing property owners would most likely benefit; residents not already property owners could experience price rises and difficulties entering the market. Additional housing would most likely be constructed in response to increased demand, and in certain instances such development could occur on currently undeveloped land. Activities that achieve lower financial returns on property, such as agriculture, may be considered less desirable compared to housing developments. While at the same time, farmers who own large tracts of land could also benefit greatly from the royalty payments on the new natural gas wells.

Local governments would see a rapid expansion in the amount of sales tax and property tax generated by gas drilling and would now have the funding to complete a wide range of community projects. At the same time, the large influx of population would demand additional community services and facilities. Existing facilities would likely become overcrowded, and additional new facilities would have to be built to accommodate this new population.

Commuting patterns in the affected communities would also change. An increase in traffic both from the added truck transportation and from the additional population would likely increase traffic on certain areas roadways and, as further explained in the Transportation subchapter, would likely lead to the need for road improvements, reconstruction and repairs.

Ambient noise levels in the communities would likely increase as a direct result of drilling and additional traffic at the well pads, and as a result of increased development in the region (see Section 2.4.13). Aesthetic resources and viewsheds could be at least temporarily impacted and changed during well pad construction and development (see Section 2.4.12).

6.13 Seismicity¹⁴²

Economic development of natural gas from low permeability formations requires the target formation to be hydraulically fractured to increase the rock permeability and expose more rock surface to release the gas trapped within the rock. The hydraulic fracturing process fractures the rock by controlled application of hydraulic pressure in the wellbore. The direction and length of the fractures are managed by carefully controlling the applied pressure during the hydraulic fracturing process.

The release of energy during hydraulic fracturing produces seismic pressure waves in the subsurface. Microseismic monitoring commonly is performed to evaluate the progress of hydraulic fracturing and adjust the process, if necessary, to limit the direction and length of the induced fractures. Chapter 4 of this SGEIS presents background seismic information for New York. Concerns associated with the seismic events produced during hydraulic fracturing are discussed below.

6.13.1 Hydraulic Fracturing-Induced Seismicity

Seismic events that occur as a result of injecting fluids into the ground are termed “induced.” There are two types of induced seismic events that may be triggered as a result of hydraulic fracturing. The first is energy released by the physical process of fracturing the rock which creates microseismic events that are detectable only with very sensitive monitoring equipment.

¹⁴² Alpha, 2009, Section 7; discussion was provided for NYSERDA by Alpha Environmental, Inc., and Alpha’s references are included for informational purposes.

Information collected during the microseismic events is used to evaluate the extent of fracturing and to guide the hydraulic fracturing process. This type of microseismic event is a normal part of the hydraulic fracturing process used in the development of both horizontal and vertical oil and gas wells, and by the water well industry.

The second type of induced seismicity is fluid injection of any kind, including hydraulic fracturing, which can trigger seismic events ranging from imperceptible microseismic, to small-scale, “felt” events, if the injected fluid reaches an existing geologic fault. A “felt” seismic event is when earth movement associated with the event is discernable by humans at the ground surface. Hydraulic fracturing produces microseismic events, but different injection processes, such as waste disposal injection or long term injection for enhanced geothermal, may induce events that can be felt, as discussed in the following section. Induced seismic events can be reduced by engineering design and by avoiding existing fault zones.

6.13.1.1 *Background*

Hydraulic fracturing consists of injecting fluid into a wellbore at a pressure sufficient to fracture the rock within a designed distance from the wellbore. Other processes where fluid is injected into the ground include deep well fluid disposal, fracturing for enhanced geothermal wells, solution mining and hydraulic fracturing to improve the yield of a water supply well. The similar aspect of these methods is that fluid is injected into the ground to fracture the rock; however, each method also has distinct and important differences.

There are ongoing and past studies that have investigated small, felt, seismic events that may have been induced by injection of fluids in deep disposal wells. These small seismic events are not the same as the microseismic events triggered by hydraulic fracturing that can only be detected with the most sensitive monitoring equipment. The processes that induce seismicity in both cases are very different.

Deep well injection is a disposal technology which involves liquid waste being pumped under moderate to high pressure, several thousand feet into the subsurface, into highly saline, permeable injection zones that are confined by more shallow, impermeable strata (FRTR, August

12, 2009). The goal of deep well injection is to store the liquids in the confined formation(s) permanently.

Carbon sequestration is also a type of deep well injection, but the carbon dioxide emissions from a large source are compressed to a near liquid state. Both carbon sequestration and liquid waste injection can induce seismic activity. Induced seismic events caused by deep well fluid injection are typically less than a magnitude 3.0 and are too small to be felt or to cause damage. Rarely, fluid injection induces seismic events with moderate magnitudes, between 3.5 and 5.5, that can be felt and may cause damage. Most of these events have been investigated in detail and have been shown to be connected to circumstances that can be avoided through proper site selection (avoiding fault zones) and injection design (Foxall and Friedmann, 2008).

Hydraulic fracturing also has been used in association with enhanced geothermal wells to increase the permeability of the host rock. Enhanced geothermal wells are drilled to depths of many thousands of feet where water is injected and heated naturally by the earth. The rock at the target depth is fractured to allow a greater volume of water to be re-circulated and heated. Recent geothermal drilling for commercial energy-producing geothermal projects have focused on hot, dry, rocks as the source of geothermal energy (Duffield, 2003). The geologic conditions and rock types for these geothermal projects are in contrast to the shallower sedimentary rocks targeted for natural gas development. The methods used to fracture the igneous rock for geothermal projects involve high pressure applied over a period of many days or weeks (Florentin 2007 and Geoscience Australia, 2009). These methods differ substantially from the lower pressures and short durations used for natural gas well hydraulic fracturing.

Hydraulic fracturing is a different process that involves injecting fluid under higher pressure for shorter periods than the pressure level maintained in a fluid disposal well. A horizontal well is fractured in stages so that the pressure is repeatedly increased and released over a short period of time necessary to fracture the rock. The subsurface pressures for hydraulic fracturing are sustained typically for one or two days to stimulate a single well, or for approximately two weeks at a multi-well pad. The seismic activity induced by hydraulic fracturing is only detectable at the surface by very sensitive equipment.

Avoiding pre-existing fault zones minimizes the possibility of triggering movement along a fault through hydraulic fracturing. It is important to avoid injecting fluids into known, significant, mapped faults when hydraulic fracturing. Generally, operators would avoid faults because they disrupt the pressure and stress field and the hydraulic fracturing process. The presence of faults also potentially reduces the optimal recovery of gas and the economic viability of a well or wells.

Injecting fluid into the subsurface can trigger shear slip on bedding planes or natural fractures resulting in microseismic events. Fluid injection can temporarily increase the stress and pore pressure within a geologic formation. Tensile stresses are formed at each fracture tip, creating shear stress (Pinnacle; “FracSeis;” August 11, 2009). The increases in pressure and stress reduce the normal effective stress acting on existing fault, bedding, or fracture planes. Shear stress then overcomes frictional resistance along the planes, causing the slippage (Bou-Rabee and Nur, 2002). The way in which these microseismic events are generated is different than the way in which microseisms occur from the energy release when rock is fractured during hydraulic fracturing.

The amount of displacement along a plane that is caused by hydraulic fracturing determines the resultant microseism’s amplitude. The energy of one of these events is several orders of magnitude less than that of the smallest earthquake that a human can feel (Pinnacle; “Microseismic;” August 11, 2009). The smallest measurable seismic events are typically between 1.0 and 2.0 magnitude. In contrast, seismic events with magnitude 3.0 are typically large enough to be felt by people. Many induced microseisms have a negative value on the MMS. Pinnacle Technologies, Inc. has determined that the characteristic frequencies of microseisms are between 200 and 2,000 Hertz; these are high-frequency events relative to typical seismic data. These small magnitude events are monitored using extremely sensitive instruments that are positioned at the fracture depth in an offset wellbore or in the treatment well (Pinnacle; “Microseismic;” August 11, 2009). The microseisms from hydraulic fracturing can barely be measured at ground surface by the most sensitive instruments (Sharma, personal communication, August 7, 2009).

There are no seismic monitoring protocols or criteria established by regulatory agencies that are specific to high volume hydraulic fracturing. Nonetheless, operators monitor the hydraulic

fracturing process to optimize the results for successful gas recovery. It is in the operator's best interest to closely control the hydraulic fracturing process to ensure that fractures are propagated in the desired direction and distance and to minimize the materials and costs associated with the process.

The routine microseismic monitoring that is performed during hydraulic fracturing serves to evaluate, guide, and control the process and is important in optimizing well treatments. Multiple receivers on a wireline array are placed in one or more offset borings (new, unperforated well(s) or older well(s) with production isolated) or in the treatment well to detect microseisms and to monitor the hydraulic fracturing process. The microseism locations are triangulated using the arrival times of the various p- and s-waves with the receivers in several wells, and using the formation velocities to determine the location of the microseisms. A multi-level vertical array of receivers is used if only one offset observation well is available. The induced fracture is interpreted to lie within the envelope of mapped microseisms (Pinnacle; "FracSeis;" August 11, 2009).

Data requirements for seismic monitoring of a hydraulic fracturing treatment include formation velocities (from a dipole sonic log or cross-well tomogram), well surface and deviation surveys, and a source shot in the treatment well to check receiver orientations, formation velocities and test capabilities. Receiver spacing is selected so that the total aperture of the array is about half the distance between the two wells. At least one receiver should be in the treatment zone, with another located above and one below this zone. Maximum observation distances for microseisms should be within approximately 2,500 feet of the treatment well; the distance is dependent upon formation properties and background noise level (Pinnacle; "FracSeis;" August 11, 2009).

6.13.1.2 *Recent Investigations and Studies*

Hydraulic fracturing has been used by oil and gas companies to stimulate production of vertical wells in New York State since the 1950s. Despite this long history, there are no records of induced seismicity caused by hydraulic fracturing in New York State. The only induced seismicity studies that have taken place in New York State are related to seismicity suspected to have been caused by waste fluid disposal by injection and a mine collapse, as identified in

Section 4.5.4. The seismic events induced at the Dale Brine Field (Section 4.5.4) were the result of the injection of fluids for extended periods of time at high pressure for the purpose of salt solution mining. This process is significantly different from the hydraulic fracturing process that would be undertaken for developing the Marcellus and other low-permeability shales in New York.

Gas producers in Texas have been using horizontal drilling and high-volume hydraulic fracturing to stimulate gas production in the Barnett Shale for the last decade. The Barnett is geologically similar to the Marcellus, but is found at a greater depth; it is a deep shale with gas stored in unconnected pore spaces and adsorbed to the shale matrix. High-volume hydraulic fracturing allows recovery of the gas from the Barnett to be economically feasible. The horizontal drilling and high-volume hydraulic fracturing methods used for the Barnett Shale play are similar to those that would be used in New York State to develop the Marcellus, Utica, and other gas bearing shales.

Alpha contacted several researchers and geologists who are knowledgeable about seismic activity in New York and Texas, including:

- Mr. John Armbruster, Staff Associate, Lamont-Doherty Earth Observatory, Columbia University;
- Dr. Cliff Frohlich, Associate Director of the Texas Institute for Geophysics, The University of Texas at Austin;
- Dr. Won-Young Kim, Doherty Senior Research Scientist, Lamont-Doherty Earth Observatory, Columbia University;
- Mr. Eric Potter, Associate Director of the Texas Bureau of Economic Geology, The University of Texas at Austin;
- Mr. Leonardo Seeber, Doherty Senior Research Scientist, Lamont-Doherty Earth Observatory, Columbia University;
- Dr. Mukul Sharma, Professor of Petroleum and Geosystems Engineering, The University of Texas at Austin; and
- Dr. Brian Stump, Albritton Professor, Southern Methodist University.

None of these researchers have knowledge of any seismic events that could be explicitly related to hydraulic fracturing in a shale gas well. Mr. Eric Potter stated that approximately 12,500 wells in the Barnett play and several thousand wells in the East Texas Basin (which target tight gas sands) have been stimulated using hydraulic fracturing in the last decade, and there have been no documented connections between wells being fractured hydraulically and felt quakes (personal communication, August 9, 2009). Dr. Mukul Sharma confirmed that microseismic events associated with hydraulic fracturing can only be detected using very sensitive instruments (personal communication, August 7, 2009).

The Bureau of Geology, the University of Texas' Institute of Geophysics, and Southern Methodist University (SMU) are planning to study earthquakes measured in the vicinity of the Dallas - Fort Worth (DFW) area, and Cleburne, Texas, that appear to be associated with salt water disposal wells, and oil and gas wells. The largest quakes in both areas were magnitudes of 3.3, and more than 100 earthquakes with magnitudes greater than 1.5 have been recorded in the DFW area in 2008 and 2009. There is considerable oil and gas drilling and deep brine disposal wells in the area and a small fault extends beneath the DFW area. Dr. Frohlich recently stated that "[i]t's always hard to attribute a cause to an earthquake with absolute certainty." Dr. Frohlich has two manuscripts in preparation with SMU describing the analysis of the DFW activity and the relationship with gas production activities (personal communication, August 4 and 10, 2009). Neither of these manuscripts was available before this document was completed. Nonetheless, information posted online by SMU (2009) states that the research suggests that the earthquakes seem to have been caused by injections associated with a deep production brine disposal well, and not with hydraulic fracturing operations.

6.13.1.3 Correlations between New York and Texas

The gas plays of interest, the Marcellus and Utica Shales in New York and the Barnett Shale in Texas, are relatively deep, low-permeability, gas shales deposited during the Paleozoic Era. Horizontal drilling and high-volume hydraulic fracturing methods are required for successful, economical gas production. The Marcellus Shale was deposited during the early Devonian, and the slightly younger Barnett was deposited during the late Mississippian. The depth of the Marcellus in New York ranges from exposure at the ground surface in some locations in the northern Finger Lakes area to 7,000 feet or more below the ground surface at the Pennsylvania

border in the Delaware River valley. The depth of the Utica Shale in New York ranges from exposure at the ground surface along the southern Adirondacks to more than 10,000 feet along the New York Pennsylvania border.

Conditions for economic gas recovery likely are present only in portions of the Marcellus and Utica members, as described in Chapter 4. The thickness of the Marcellus and Utica in New York ranges from less than 50 feet in the southwestern portion of the state to approximately 250 feet at the south-central border. The Barnett Shale is 5,000 to 8,000 feet below the ground surface and 100 to 500 feet thick (Halliburton; August 12, 2009). It has been estimated that the entire Marcellus Shale may hold between 168 and 516 trillion cubic feet of gas; in contrast, the Barnett has in-place gas reserves of approximately 26.2 trillion cubic feet (USGS, 2009A) and covers approximately 4 million acres.

The only known induced seismicity associated with the stimulation of the Barnett wells are microseisms that are monitored with downhole transducers. These small-magnitude events triggered by the fluid pressure provide data to the operators to monitor and improve the fracturing operation and maximize gas production. The hydraulic fracturing and monitoring operations in the Barnett have provided operators with considerable experience with conditions similar to those that would be encountered in New York State. Based on the similarity of conditions, similar results are anticipated for New York State; that is, the microseismic events would be unfelt at the surface and no damage would result from the induced microseisms. Operators are likely to monitor the seismic activity in New York, as in Texas, to optimize the hydraulic fracturing methods and results.

6.13.1.4 Affects of Seismicity on Wellbore Integrity

Wells are designed to withstand deformation from seismic activity. The steel casings used in modern wells are flexible and are designed to deform to prevent rupture. The casings can withstand distortions much larger than those caused by earthquakes, except for those very close to an earthquake epicenter. The magnitude 6.8 earthquake event in 1983 that occurred in Coalinga, California, damaged only 14 of the 1,725 nearby active oilfield wells, and the energy released by this event was thousands of times greater than the microseismic events resulting from hydraulic fracturing. Earthquake-damaged wells can often be re-completed. Wells that cannot

be repaired are plugged and abandoned (Foxall and Friedmann, 2008). Induced seismicity from hydraulic fracturing is of such small magnitude that it is not expected to have any effect on wellbore integrity.

6.13.2 Summary of Potential Seismicity Impacts

The issues associated with seismicity related to hydraulic fracturing addressed herein include seismic events generated from the physical fracturing of the rock, and possible seismic events produced when fluids are injected into existing faults.

The possibility of fluids injected during hydraulic fracturing the Marcellus or Utica Shales reaching a nearby fault and triggering a seismic event are remote for several reasons. The locations of major faults in New York have been mapped (Figure 4.13) and few major or seismically active faults exist within the fairways for the Marcellus and Utica Shales. Similarly, the paucity of historic seismic events and the low seismic risk level in the fairways for these shales indicates that geologic conditions generally are stable in these areas. By definition, faults are planes or zones of broken or fractured rock in the subsurface. The geologic conditions associated with a fault generally are unfavorable for hydraulic fracturing and economical production of natural gas. As a result, operators typically endeavor to avoid faults for both practical and economic considerations. It is prudent for an applicant for a drilling permit to evaluate and identify known, significant, mapped, faults within the area of effect of hydraulic fracturing and to present such information in the drilling permit application. It is Alpha's opinion that an independent pre-drilling seismic survey probably is unnecessary in most cases because of the relatively low level of seismic risk in the fairways of the Marcellus and Utica Shales. Additional evaluation or monitoring may be necessary if hydraulic fracturing fluids might reach a known, significant, mapped fault, such as the Clarendon-Linden fault system.

Recent research has been performed to investigate induced seismicity in an area of active hydraulic fracturing for natural gas development near Fort Worth, Texas. Studies also were performed to evaluate the cause of the earthquakes associated with the solution mining activity near the Clarendon-Linden fault system near Dale, NY in 1971. The studies indicated that the likely cause of the earthquakes was the injection of fluid for production brine disposal for the incidents in Texas, and the injection of fluid for solution mining for the incidents in Dale, NY

The studies in Texas also indicate that hydraulic fracturing is not likely the source of the earthquakes.

The hydraulic fracturing methods used for enhanced geothermal energy projects are appreciably different than those used for natural gas hydraulic fracturing. Induced seismicity associated with geothermal energy projects occurs because the hydraulic fracturing is performed at greater depths, within different geologic conditions, at higher pressures, and for substantially longer durations compared with the methods used for natural gas hydraulic fracturing.

There is a reasonable base of knowledge and experience related to seismicity induced by hydraulic fracturing. Information reviewed in preparing this discussion indicates that there is essentially no increased risk to the public, infrastructure, or natural resources from induced seismicity related to hydraulic fracturing. The microseisms created by hydraulic fracturing are too small to be felt, or to cause damage at the ground surface or to nearby wells.

Seismic monitoring by the operators is performed to evaluate, adjust, and optimize the hydraulic fracturing process. Monitoring beyond that which is typical for hydraulic fracturing does not appear to be warranted, based on the negligible risk posed by the process and very low seismic magnitude. The existing and well-established seismic monitoring network in New York is sufficient to document the locations of larger-scale seismic events and would continue to provide additional data to monitor and evaluate the likely sources of seismic events that are felt.

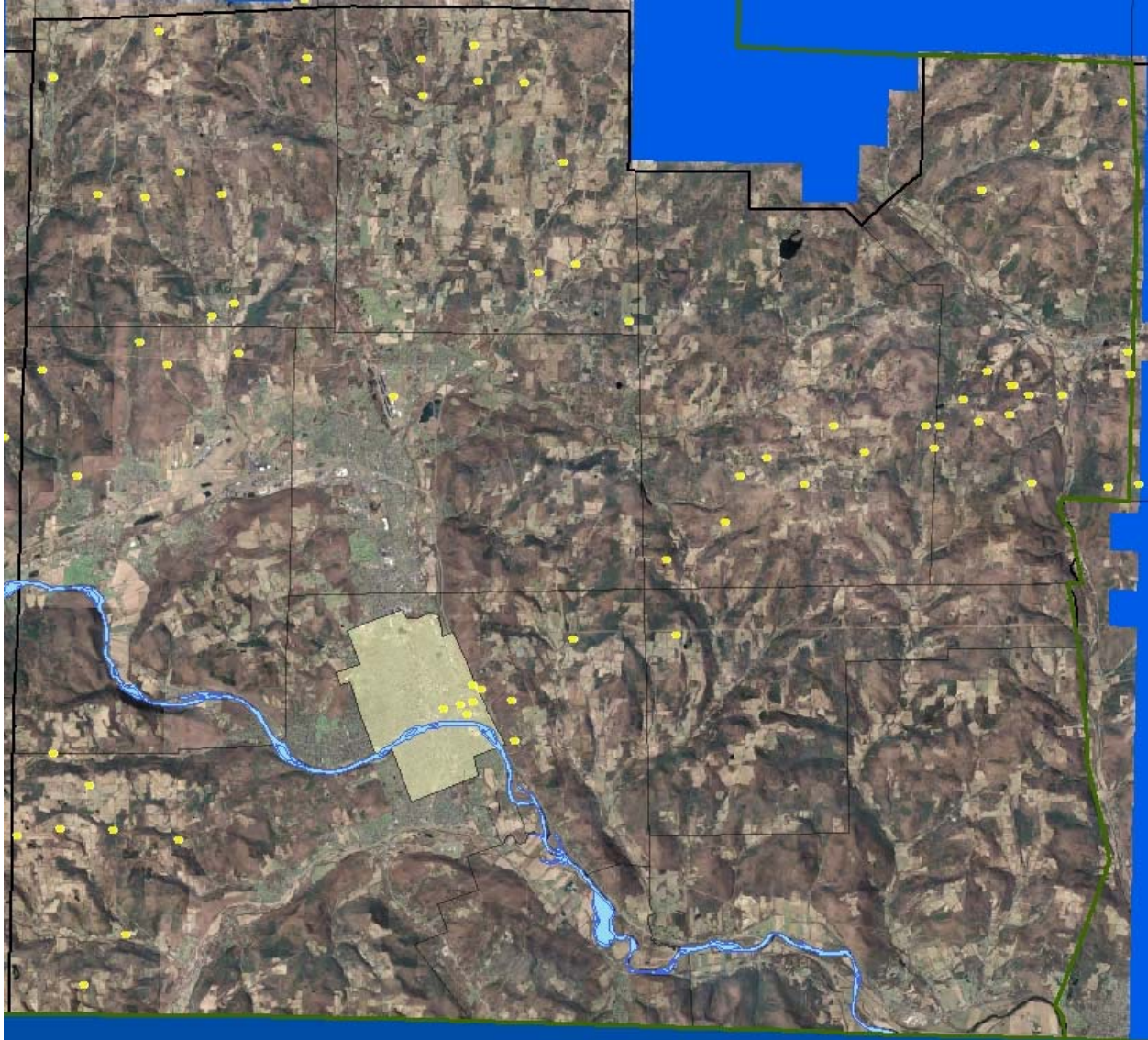
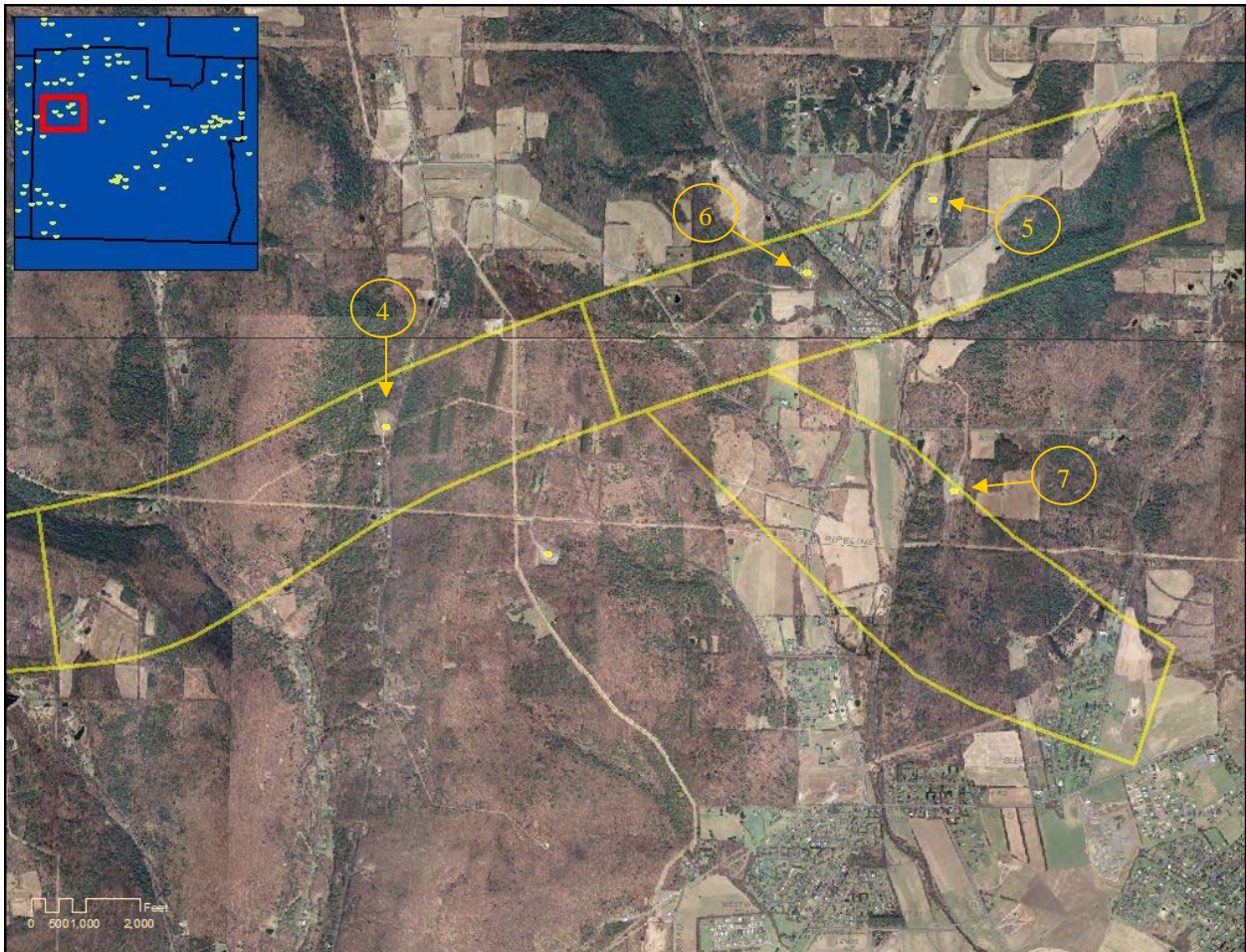


Photo 6.9 The following series of photos shows Trenton-Black River wells in Chemung County. These wells are substantially deeper than Medina wells, and are typically drilled on 640 acre units. Although the units and well pads typically contain one well, the size of the well units and pads is closer to that expected for multi-well Marcellus pads. Unlike expected Marcellus wells, Trenton-Black River wells target geologic features that are typically narrow and long. Nevertheless, photos of sections of Trenton-Black River fields provide an idea of the area of well pads within producing units.

The above photo of Chemung County shows Trenton-Black River wells and also historical wells that targeted other formations. Most of the clearings visible in this photo are agricultural fields.

Photo 6.10 The Quackenbush Hill Field is a Trenton-Black River field that runs from eastern Steuben County to north-west Chemung County. The discovery well for the field was drilled in 2000. The map below shows wells in the eastern end of the field. Note the relative proportion of well pads to area of entire well units. The unit sizes shown are approximately 640 acres, similar to expected Marcellus Shale multi-well pad units.



Photos 6.11 Well #4 (Hole number 22853) was a vertical completed in February 2001 at a true vertical depth of 9,682 feet. The drill site disturbed area was approximately 3.5 acres. The site was subsequently reclaimed to a fenced area of approximately 0.35 acres for production equipment. Because this is a single-well unit, it contains fewer tanks and other equipment than a Marcellus multi-well pad. The surface within a Trenton-Black River well fenced area is typically covered with gravel.



Rhodes 1322 11/13/2001



Rhodes 1322 5/6/2009

Photos 6.12 Well #5 (Hole number 22916) was completed as a directional well in 2002. Unit size is 636 acres. Total drill pad disturbed area was approximately 3 acres, which has been reclaimed to a fenced area of approximately 0.4 acres.



Gregory #1446A 12/27/2001



Gregory #1446A 5/6/2009

Photo 6.13 Well #6 (Hole number 23820) was drilled as a horizontal infill well in 2006 in the same unit as Well #6. Total drill pad disturbed area was approximately 3.1 acres, which has been reclaimed to a fenced area of approximately 0.4 acres.



Schwengel #2 5/6/2009

Photos 6.14 Well #7 (Hole number 23134) was completed as a horizontal well in 2004 to a true vertical depth of 9,695 and a true measured depth of 12,050 feet Well unit size is 624 acres. The drill pad disturbed area was approximately 4.2 acres which has been reclaimed to a gravel pad of approximately 1.3 acres of which approximately 0.5 acres is fenced for equipment.



Soderblom #1 8/19/2004



Soderblom #1 8/19/2004



Soderblom #1 5/6/2009

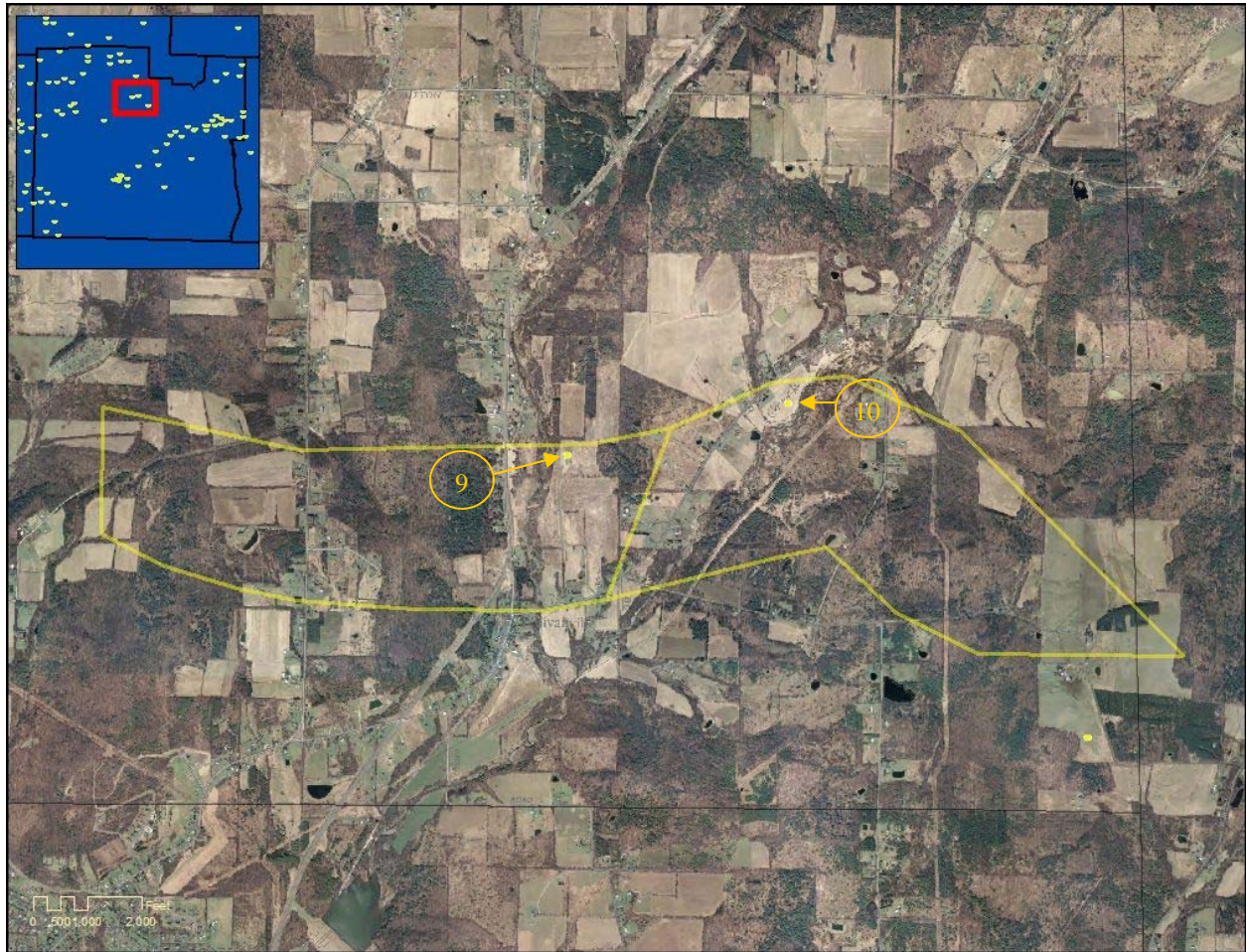


Soderblom #1 5/6/2009



Soderblom #1 5/6/2009

Photo 6.15 This photo shows two Trenton-Black River wells in north-central Chemung County. The two units were established as separate natural gas fields, the Veteran Hill Field and the Brick House Field.



Photos 6.16 Well #9 (Hole number 23228) was drilled as a horizontal Trenton-Black River well and completed in 2006. The well was drilled to a true vertical depth of 9,461 and a true measured depth of 12,550 feet. The well unit is approximately 622 acres.



Little 1 10/6/2005



Little 1 11/3/2005

Photos 6.17 Well #10 (Hole number 23827) was drilled as a horizontal Trenton-Black River well and completed in 2006. The well was drilled to a true vertical depth of 9,062 and a true measured depth of 13,360 feet. The production unit is approximately 650 acres.

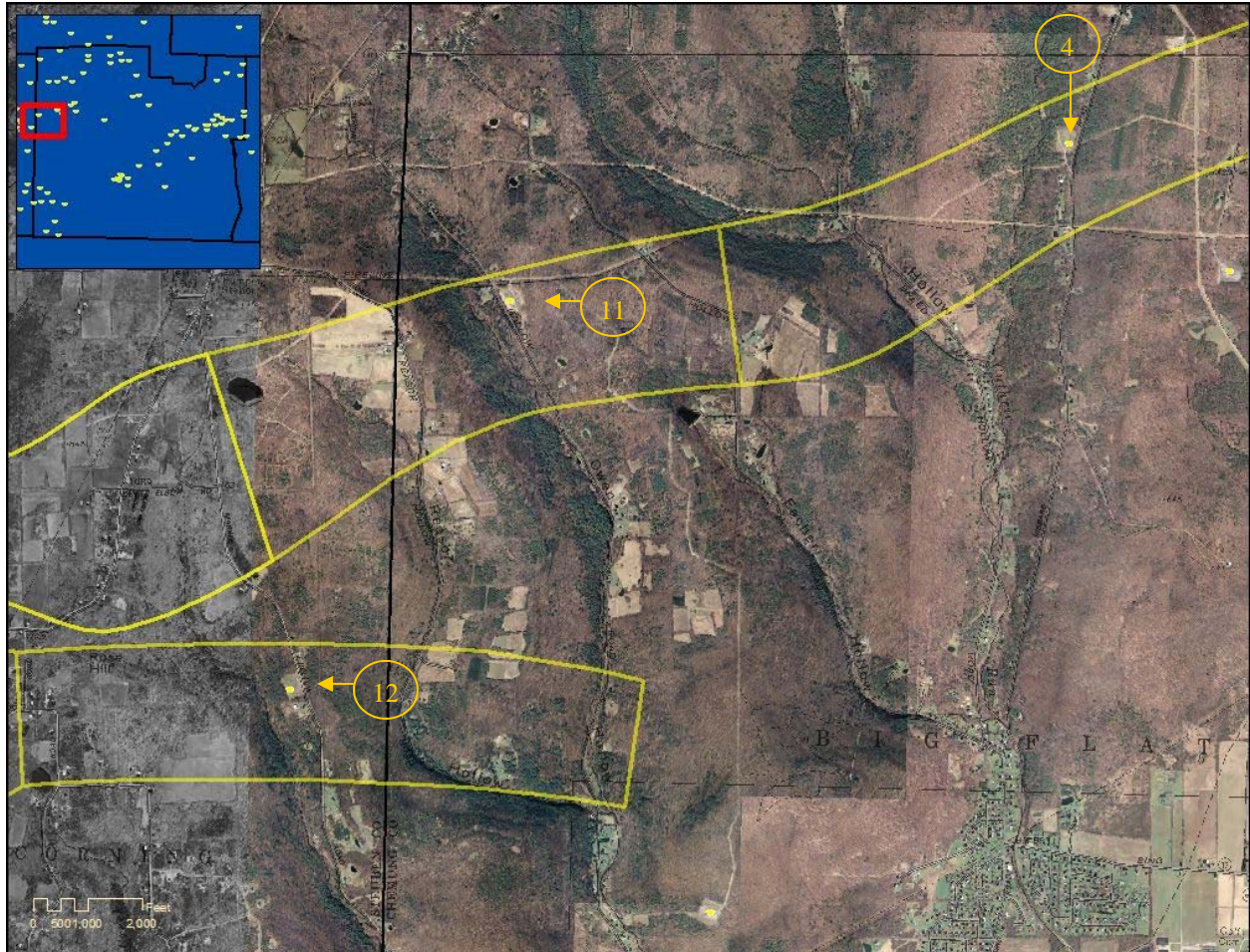


Hulett #1 10/5/2006



Hulett #1 5/6/2009

Photo 6.18 This photo shows another portion of the Quackenbush Hill Field in western Chemung County and eastern Steuben County. As with other portions of Quackenbush Hill Field, production unit sizes are approximately 640 acres each.



Photos 6.19 Well #11 (Hole number 22831) was completed in 2000 as a directional well to a total vertical depth of 9,824 feet. The drill site disturbed area was approximately 3.6 acres which has been reclaimed to a fenced area of 0.5 acres.



Lovell 11/13/2001



Lovell 5/6/2009

Photos 6.20 Well #12 (Hole number 22871) was completed in 2002 as a horizontal well to a true vertical depth of 9,955 feet and a true measured depth of 12,325 feet. The drill site disturbed area was approximately 3.2 acres which has been reclaimed to a fenced area of 0.45 acres.



Henkel 10/22/2002



Henkel 5/6/2009