NEW YORK STATE OF OPPORTUNITY

Department of Environmental Conservation

Chapter 5

Natural Gas Development Activities & High-Volume Hydraulic Fracturing

Final

Supplemental Generic Environmental Impact Statement

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Chapter 5 - Natural Gas Development Activities & High-Volume Hydraulic Fracturing

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Chapter 5 NATURAL GAS DEVELOPMENT ACTIVITIES & HIGH-VOLUME HYDRAULIC FRACTURING

As noted in the 1992 GEIS, New York has a long history of natural gas production. The first gas well was drilled in 1821 in Fredonia, and the 40 Bcf of gas produced in 1938 remained the production peak until 2004 when 46.90 Bcf were produced. Annual production exceeded 50 Bcf from 2005 through 2008, dropping to 44.86 Bcf in 2009 and 35.67 Bcf in 2010. Chapters 9 and 10 of the 1992 GEIS comprehensively discuss well drilling, completion and production operations, including potential environmental impacts and mitigation measures. The history of hydrocarbon development in New York through 1988 is also covered in the 1992 GEIS.

New York counties with actively producing gas wells reported in 2010 were: Allegany, Cattaraugus, Cayuga, Chautauqua, Chemung, Chenango, Erie, Genesee, Livingston, Madison, Niagara, Ontario, Oswego, Schuyler, Seneca, Steuben, Tioga, Wayne, Wyoming and Yates.

Hydraulic fracturing is a well stimulation technique which consists of pumping a fluid and a proppant such as sand down the wellbore under high pressure to create fractures in the hydrocarbon-bearing rock. No blast or explosion is created by the hydraulic fracturing process. The proppant holds the fractures open, allowing hydrocarbons to flow into the wellbore after injected fluids are recovered. Hydraulic fracturing technology was first developed in the late 1940s and, accordingly, it was addressed in the 1992 GEIS. It is estimated that as many as 90% of wells drilled in New York are hydraulically fractured. ICF International provides the following history:[121]

Hydraulic Fracturing Technological Milestones [122]	
Early 1900s	Natural gas extracted from shale wells. Vertical wells fractured with foam.
1983	First gas well drilled in Barnett Shale in Texas
1980-1990s	Cross-linked gel fracturing fluids developed and used in vertical wells
1991	First horizontal well drilled in Barnett Shale
1991	Orientation of induced fractures identified
1996	Slickwater fracturing fluids introduced
1996	Microseismic post-fracturing mapping developed
1998	Slickwater refracturing of originally gel-fractured wells
2002	Multi-stage slickwater fracturing of horizontal wells
2003	First hydraulic fracturing of Marcellus Shale[123]
2005	Increased emphasis on improving the recovery factor
2007	Use of multi-well pads and cluster drilling

[121] ICF Task 1, 2009, p. 3.

[122] Matthews, 2008, as cited by ICF Task 1, 2009, p. 3.

[123] Harper, 2008, as cited by ICF Task 1, 2009, p. 3.

5.1 Land Disturbance

Land disturbance directly associated with high-volume hydraulic fracturing will consist primarily of constructed gravel access roads, well pads and utility corridors. According to the most recent industry estimates, the average total disturbance associated with a multi-well pad, including incremental portions of access roads and utility corridors, during the drilling and fracturing stage is estimated at 7.4 acres and the average total disturbance associated with a well pad for a single vertical well during the drilling and fracturing stage is estimated at 4.8 acres. As a result of required partial reclamation, this would generally be reduced to averages of about 5.5 acres and 4.5 acres, respectively, during the production phase. These estimates include access roads to the well pads and incremental portions of utility corridors including gathering lines and compressor facilities, and the access roads associated with compressor facilities. These associated roads and facilities are projected to account for, on average, about 3.95 acres of the land area associated with each pad for the life of the wells. During the long-term production phase, a multi-well pad itself would occupy about 1.5 acres, while a well pad for a single vertical well would occupy about 0.5 acre.[124,125]

5.1.1 Access Roads

The first step in developing a natural gas well site is to construct the access road and well pad. For environmental review and permitting purposes, the acreage and disturbance associated with the access road is considered part of the project as described by Topical Response #4 in the 1992 GEIS. However, instead of one well per access road as was typically the case when the GEIS was prepared, most shale gas development will consist of several wells on a multi-well pad serviced by a single access road. Therefore, in areas developed by horizontal drilling using multi-well pads, fewer access roads as a function of the number of wells will be needed. Industry estimates that 90% of the wells used to develop the Marcellus Shale will be horizontal wells located on multi-well pads.[126]

Access road construction involves clearing the route and preparing the surface for movement of heavy equipment, or reconstruction or improvement of existing roads if present on the property

[124] ALL Consulting, 2010, pp. 14 – 15.

[125] Cornue, 2011.

[126] ALL Consulting, 2010, pp. 7 – 15.

being developed. Ground surface preparation for new roads typically involves staking, grading, stripping and stockpiling of topsoil reserves, then placing a layer of crushed stone, gravel, or cobbles over geotextile fabric. Sedimentation and erosion control features are also constructed as needed along the access roads and culverts may be placed across ditches at the entrance from the main highway or in low spots along the road.

The size of the access road is dictated by the size of equipment to be transported to the well site, distance of the well pad from an existing road and the route dictated by property access rights and environmental concerns. The route selected may not be the shortest distance to the nearest main road. Routes for access roads may be selected to make use of existing roads on a property and to avoid disturbing environmentally sensitive areas such as protected streams, wetlands, or steep slopes. Property access rights and agreements and traffic restrictions on local roads may also limit the location of access routes.

Access road widths would generally range from 20 to 40 feet during the drilling and fracturing phase and from 10 to 20 feet during the production phase. During the construction and drilling phase, additional access road width is necessary to accommodate stockpiled topsoil and excavated material along the roadway and to construct sedimentation and erosion control features such as berms, ditches, sediment traps or sumps, or silt fencing along the length of the access road.

Each 150 feet of a 30-foot wide access road adds about one-tenth of an acre to the total surface acreage disturbance attributed to the well site. Industry estimates an average access road size of 0.27 acre,[127] which would imply an average length of about 400 feet for a 30-foot wide road. Permit applications for horizontal Marcellus wells received by the Department prior to publication of the 2009 draft SGEIS indicated road lengths ranging from 130 feet to approximately 3,000 feet.

Photo 5.1, Photo 5.2, Photo 5.3, and Photo 5.4 depict typical wellsite access roads.

[127] Cornue, 2011.

Photo 5.1 Access road and erosion/sedimentation controls, Salo 1, Barton, Tioga County NY. Photo taken during drilling phase. This access road is approximately 1,400 feet long. Road width averages 22 feet wide, 28 feet wide at creek crossing (foreground). Width including drainage ditches is approximately 27 feet.
Source: NYS DEC 2007.

Photo 5.2 Nornew, Smyrna Hillbillies #2H, access road, Smyrna, Madison County NY. Photo taken during drilling phase of improved existing private dirt road (approximately 0.8 miles long). Not visible in photo is an additional 0.6 mile of new access road construction. Operator added ditches, drainage, gravel & silt fence to existing dirt road.
The traveled part of the road surface in the picture is 12.5' wide; width including drainage ditches is approximately 27 feet. Portion of the road crossing a protected stream is approximately 20 feet wide. Source: NYS DEC 2008.

Photo 5.3 In-service access road to horizontal Marcellus well in Bradford County, PA. Source: Chesapeake Energy

Photo 5.4 Access road and sedimentation controls, Moss 1, Corning, Steuben County NY. Photo taken during post-drilling phase. Access road at the curb is approximately 50 feet wide, narrowing to 33 feet wide between curb and access gate. The traveled part of the access road ranges between 13 and 19 feet wide. Access road length is approximately 1,100 feet long.
Source: NYS DEC 2004.

5.1.2 Well Pads

Pad size is determined by site topography, number of wells and pattern layout, with consideration given to the ability to stage, move and locate needed drilling and hydraulic fracturing equipment. Location and design of pits, impoundments, tanks, hydraulic fracturing equipment, reduced emission completion equipment, dehydrators and production equipment such as separators, brine tanks and associated control monitoring, as well as office and vehicle parking requirements, can increase square footage. Mandated surface restrictions and setbacks may also impose additional acreage requirements. On the other hand, availability and access to offsite, centralized dehydrators, compressor stations and centralized water storage or handling facilities may reduce acreage requirements for individual well pads.[128]

The activities associated with the preparation of a well pad are similar for both vertical wells and multi-well pads where horizontal drilling and high volume hydraulic fracturing will be used.[129] Site preparation activities consist primarily of clearing and leveling an area of adequate size and preparing the surface to support movement of heavy equipment. As with access road construction, ground surface preparation typically involves staking, grading, stripping and stockpiling of topsoil reserves, then placing a layer of crushed stone, gravel, or cobbles over geotextile fabric. Site preparation also includes establishing erosion and sediment control structures around the site, and constructing pits for retention of drilling fluid and, possibly, fresh water.

Depending on site topography, part of a slope may be excavated and the excavated material may be used as fill (cut and fill) to extend the well pad, providing for a level working area and more room for equipment and onsite storage. The fill banks must be stabilized using appropriate sedimentation and control measures.

The primary difference in well pad preparation for a well where high-volume hydraulic fracturing will be employed versus a well described by the 1992 GEIS is that more land is disturbed on a per-pad basis, though fewer pads should be needed overall.[130] A larger well pad

[128] ICF Task 2, 2009, pp. 4-5.

[129] Alpha, 2009, p. 6-6.

[130] Alpha, 2009, p. 6-2.

is required to accommodate fluid storage and equipment needs associated with the high-volume fracturing operations. In addition, some of the equipment associated with horizontal drilling has a larger surface footprint than the equipment described by the 1992 GEIS.

Industry estimates the average size of a multi-well pad for the drilling and fracturing phase of operations at 3.5 acres.[131] Average production pad size, after partial reclamation, is estimated at 1.5 acres for a multi-well pad.[132] Permit applications for horizontal wells received by the Department prior to publication of the 2009 draft SGEIS indicated multi-well pads ranging in size from 2.2 acres to 5.5 acres during the drilling and fracturing phase of operations, and from 0.5 to 2 acres after partial reclamation during the production phase.

The well pad sizes discussed above are consistent with published information regarding drilling operations in other shale formations, as researched by ICF International for NYSERDA.[133] For example, in an Environmental Assessment published for the Hornbuckle Field Horizontal Drilling Program (Wyoming), the well pad size required for drilling and completion operations is estimated at approximately 460 feet by 340 feet, or about 3.6 acres. This estimate does not include areas disturbed due to access road construction. A study of horizontal gas well sites constructed by SEECO, Inc. in the Fayetteville Shale reports that the operator generally clears 300 feet by 250 feet, or 1.72 acres, for its pad and reserve pits. Fayetteville Shale sites may be as large as 500 feet by 500 feet, or 5.7 acres.

Photo 5.5, Photo 5.6, and Photo 5.7 depict typical Marcellus well pads, and Figure 5.1 is a schematic representation of a typical drilling site.

[131] Cornue, 2011.

[132] ALL Consulting, 2010, p. 15.

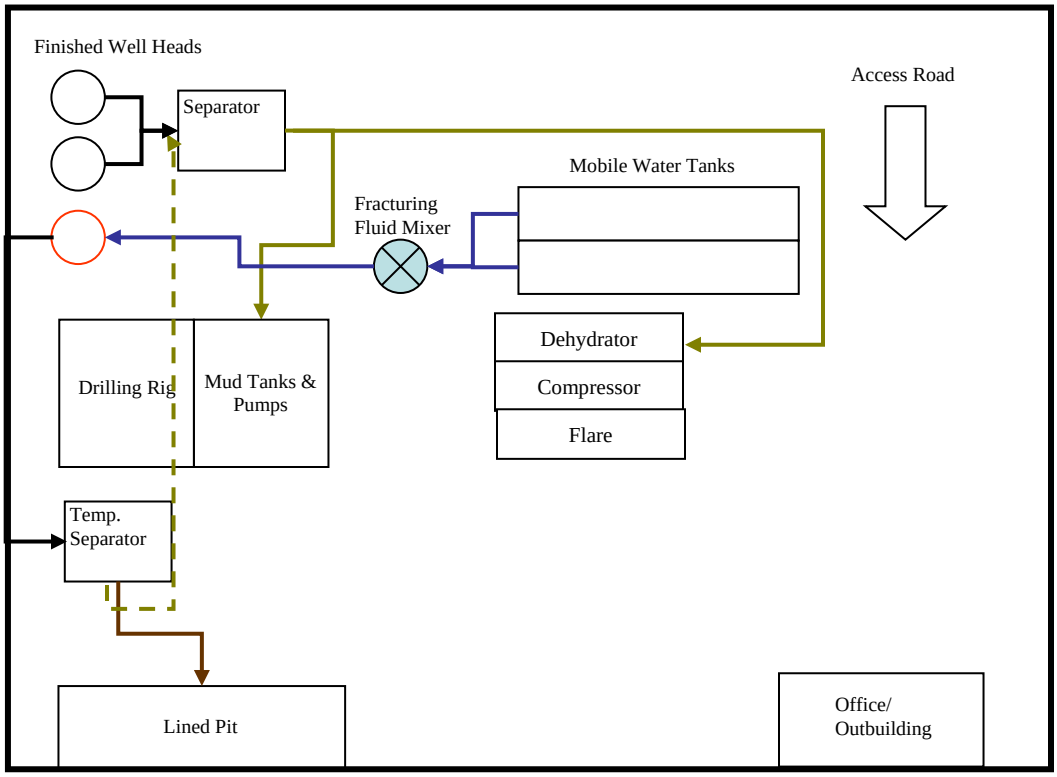
[133] ICF Task 2, 2009, p. 4.

Photo 5.5 Chesapeake Energy Marcellus well drilling, Bradford County, PA
Source: Chesapeake Energy

Photo 5.6 Hydraulic fracturing operation, horizontal Marcellus well, Upshur County, WV
Source: Chesapeake Energy, 2008

Photo 5.7 Hydraulic fracturing operation, horizontal Marcellus well, Bradford County, PA
Source: Chesapeake Energy, 2008

Figure 5.1 - Well Pad Schematic



Not to scale (As reported to NYSERDA by ICF International, derived from Argonne National Laboratory: EVS-Trip Report for Field Visit to Fayetteville Shale Gas Wells, plus expert judgment)

5.1.3 Utility Corridors

Utility corridors associated with high-volume hydraulic fracturing will include acreage used for potential water lines, above ground or underground electrical lines, gas gathering lines and compressor facilities, with average per-well pad acreage estimates as follows:

- 1.35 acres for water and electrical lines;
- 1.66 acres for gas gathering lines; and

- 0.67 acre for compression (because a compressor facility will service more than one well pad, this estimate is for an *incremental* portion assigned to a single well pad of a compressor facility and its associated sales line and access roads).[134]

Gathering lines may follow the access road associated with the well pad, so clearing and disturbance for the gathering line may be conducted during the initial site construction phase, thereby adding to the access road width. For example, some proposals include a 20-foot access road to the well pad with an additional 10-foot right-of-way for the gathering line.

Activities associated with constructing compressor facility pads are similar to those described above for well pads.

5.1.4 Well Pad Density

5.1.4.1 Historic Well Density

Well operators reported 6,732 producing natural gas wells in New York in 2010, approximately half of which (3,358) are in Chautauqua County. With 1,056 square miles of land in Chautauqua County, 3,358 reported producing wells equates to at least three producing wells per square mile. For the most part, these wells are at separate surface locations. Actual drilled density where the resource has been developed is somewhat greater than that, because not every well drilled is currently producing and some areas are not drilled. The Department issued 5,490 permits to drill in Chautauqua County between 1962 and June 30, 2011, or five permits per square mile. Of those permits, 62% (3,396) were issued during a 10-year period between 1975 and 1984, for an average rate of 340 permits per year in a single county. Again, most of these wells were drilled at separate surface locations, each with its own access road and attendant disturbance. Although the number of wells is lower, parts of Seneca and Cayuga County have also been densely drilled. Many areas in all three counties – Chautauqua, Seneca and Cayuga – have been developed with "conventional" gas wells on 40-acre spacing (i.e., 16 wells per square mile, at separate surface locations). Therefore, while recognizing that some aspects of shale development activity will be different from what is described in the 1992 GEIS, it is worthwhile to note that this pre-1992 drilling rate and site density were part of the experience upon which the 1992 GEIS and its findings are based.

[134] Cornue, 2011.

Photo 5.8, Photo 5.9, Photo 5.10, and Photo 5.11 are photos and aerial views of existing well sites in Chautauqua County, provided for informational purposes. As discussed above, well pads where high-volume hydraulic fracturing will be employed will necessarily be larger in order to accommodate the associated equipment. In areas developed by horizontal drilling, well pads will be less densely spaced, reducing the number of access roads and gathering lines needed.

5.1.4.2 Anticipated Well Pad Density

The number of wells and well sites that may exist per square mile is dictated by gas reservoir geology and productivity, mineral rights distribution, and statutory well spacing requirements set forth in ECL Article 23, Title 5, as amended in 2008. The statute provides three statewide spacing options for shale wells, which are described below. Although the options include vertical drilling and single-well pad horizontal drilling, the Department anticipates that multi-well pad horizontal drilling (which results in the lowest density and least land disturbance) will be the predominant approach, for the following reasons:

- Industry estimates that 90% of the wells drilled to develop the Marcellus Shale will be horizontal wells on multi-well pads;[135]

- The addition to the ECL of provisions to address multi-well pad drilling was one of the primary objectives of the 2008 amendments, and was supported by the Department because of the reduced environmental impact;

- Multi-well pad drilling reduces operators' costs, by reducing the number of access roads and gathering lines that must be constructed as well as potentially reducing the number of equipment mobilizations; and

- Multi-well pad drilling reduces the number of regulatory hurdles for operators, because each well pad location would only need to be reviewed once for environmental concerns, stormwater permitting purposes and to determine conformance to SEQRA requirements, including the 1992 GEIS and the Final SGEIS.

[135] ALL Consulting, 2010, p. 7.

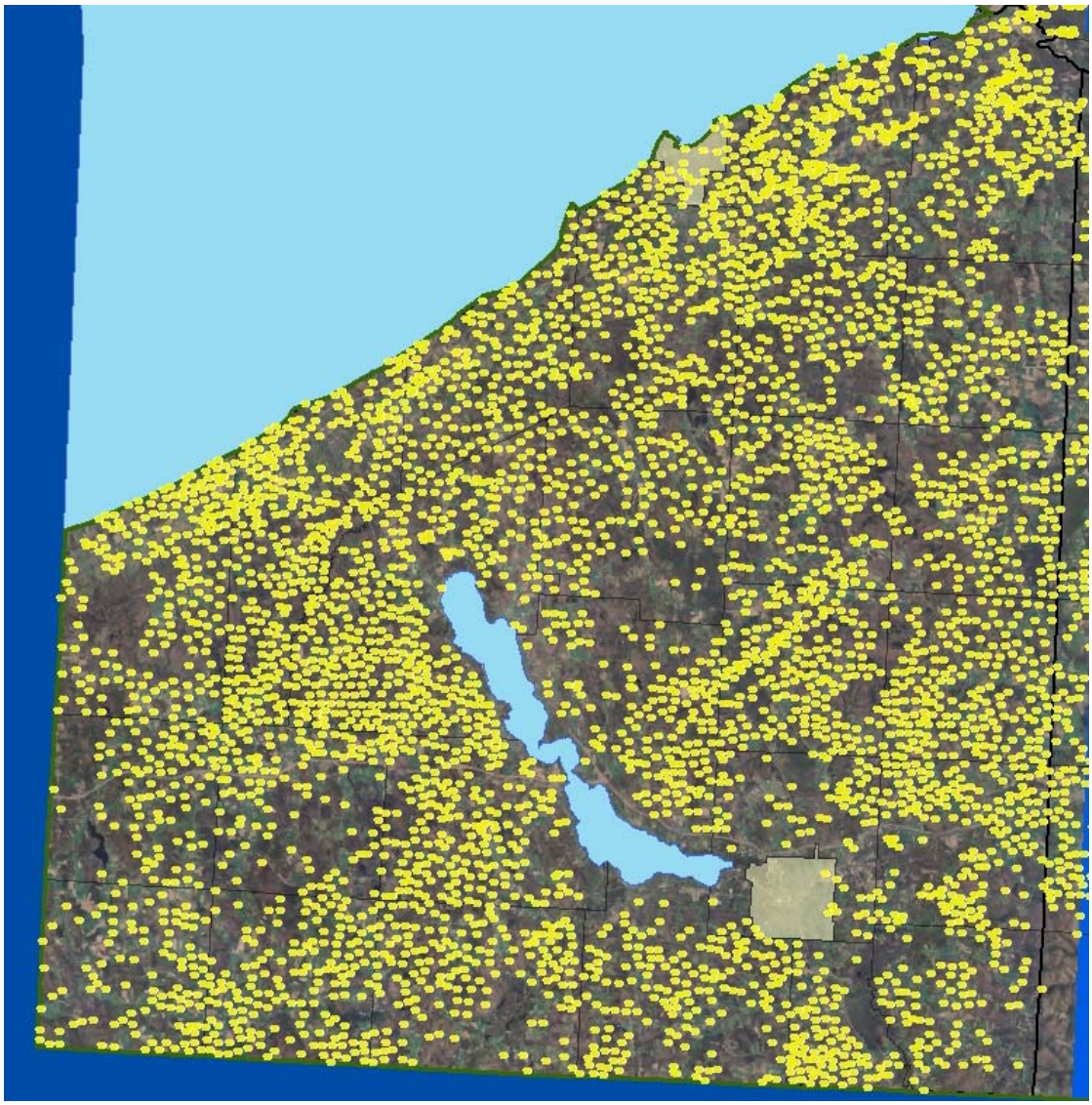


Photo 5.8 This map shows the locations of over 4,400 Medina formation natural gas wells in Chautauqua County from the Mineral Resources database. The wells were typically drilled on 40 to 80 acre well spacing, making the distance between wells at least 1/4 mile.

Readers can re-create this map by using the DEC on-line searchable database using County = Chautauqua and exporting the results to a Google Earth KML file.

Natural Gas Wells in Chautauqua County

Year Permit Issued	Total
Pre-1962 (before permit program)	315
1962-1979	1,440
1980-1989	1,989
1990-1999	233
2000-2009	426
Grand Total	4,403

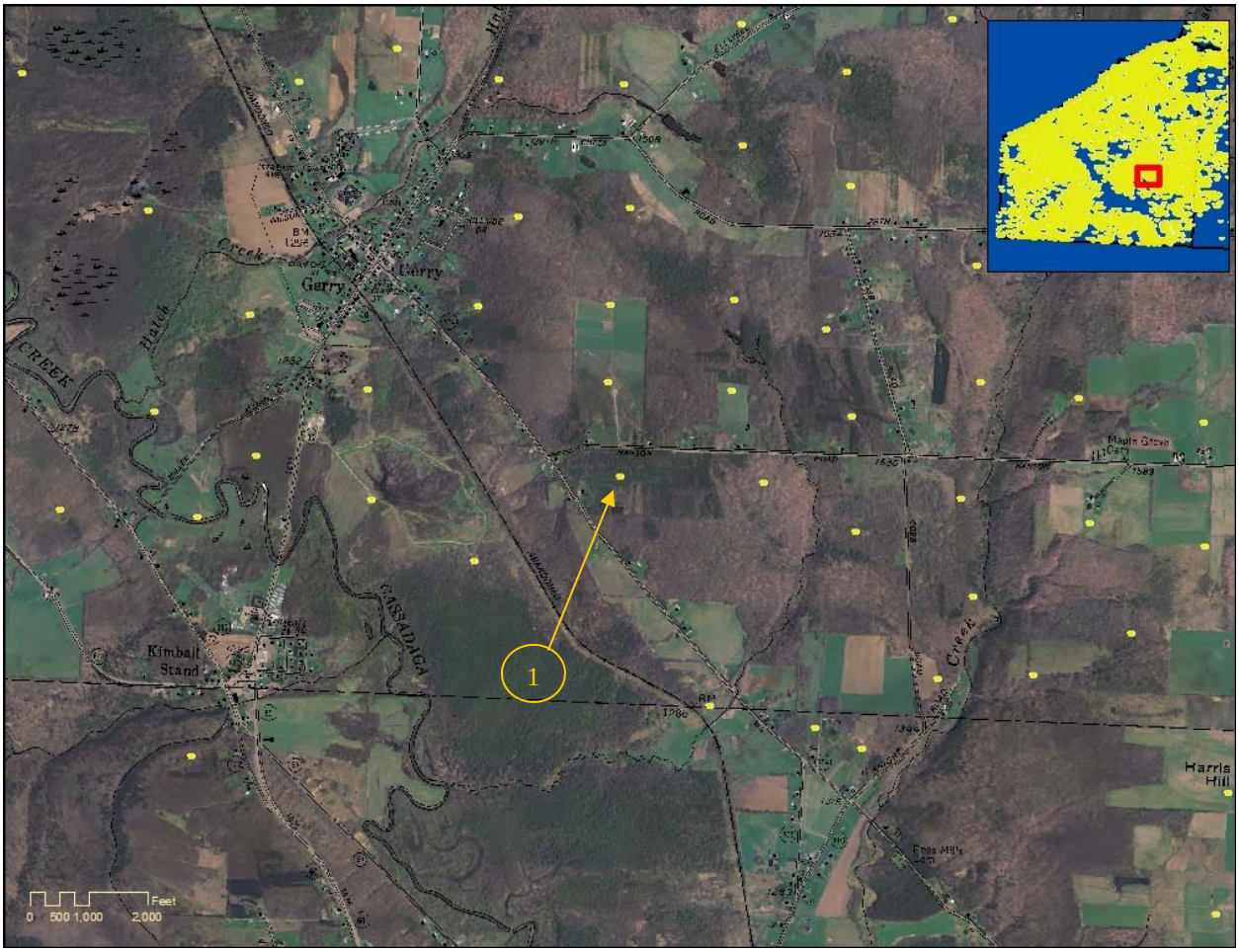


Photo 5.9 a & b The above map shows a portion of the Chautauqua County map, near Gerry. Well #1 (API Hole number 25468) shown in the photo to the right was drilled and completed for production in 2008 to a total depth of 4,095 feet. Of the other 47 Medina gas wells shown above, the nearest is approximately 1,600 feet to the north.

These Medina wells use single well pads. Marcellus multi-well pads will be larger and will have more wellheads and tanks.

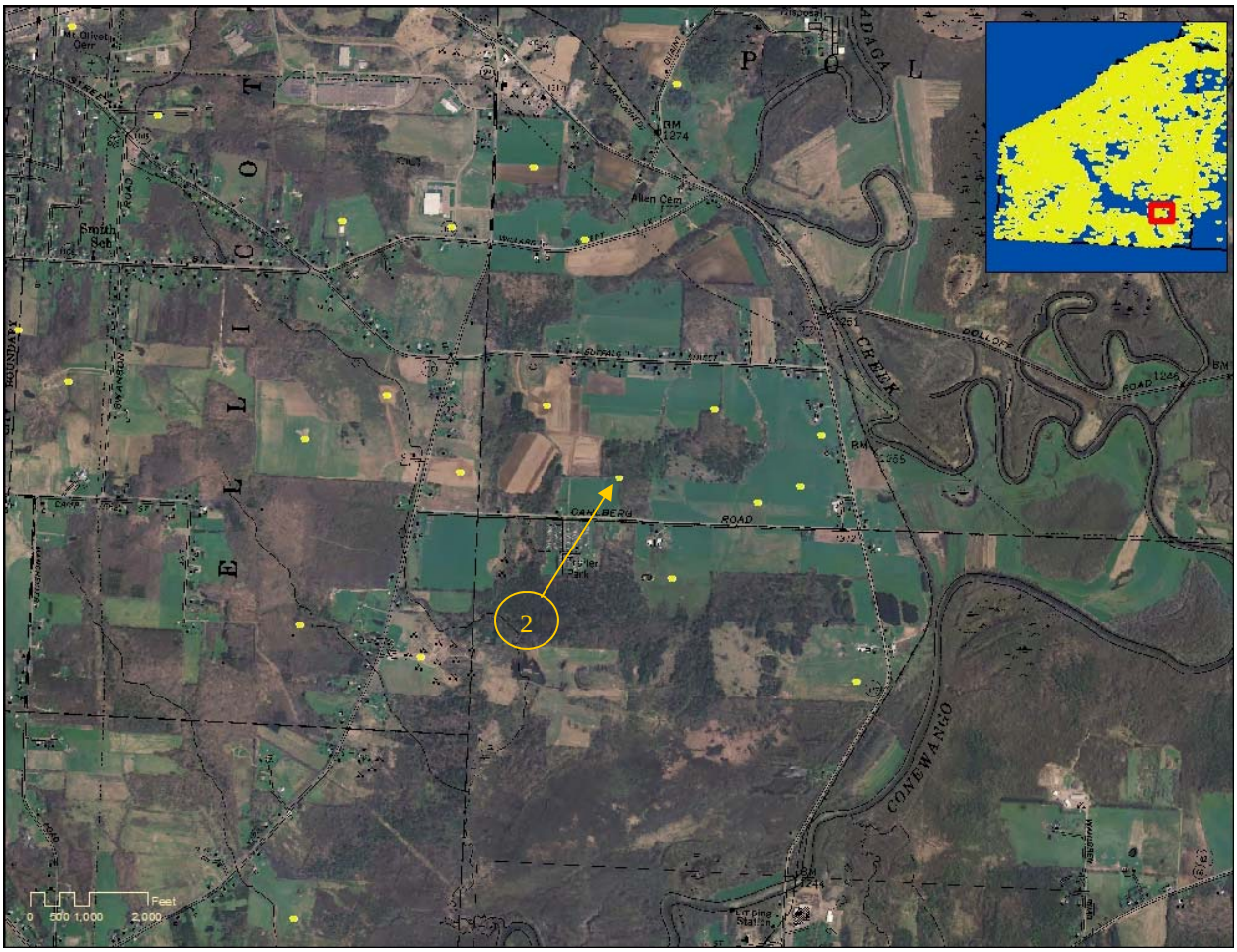


Photo 5.10 a & b This map shows 28 wells in the Town of Poland, Chautauqua County. Well #2 (API Hole number 24422) was drilled in 2006 to a depth of 4,250 feet and completed for production in 2007. The nearest other well is 1,700 feet away.

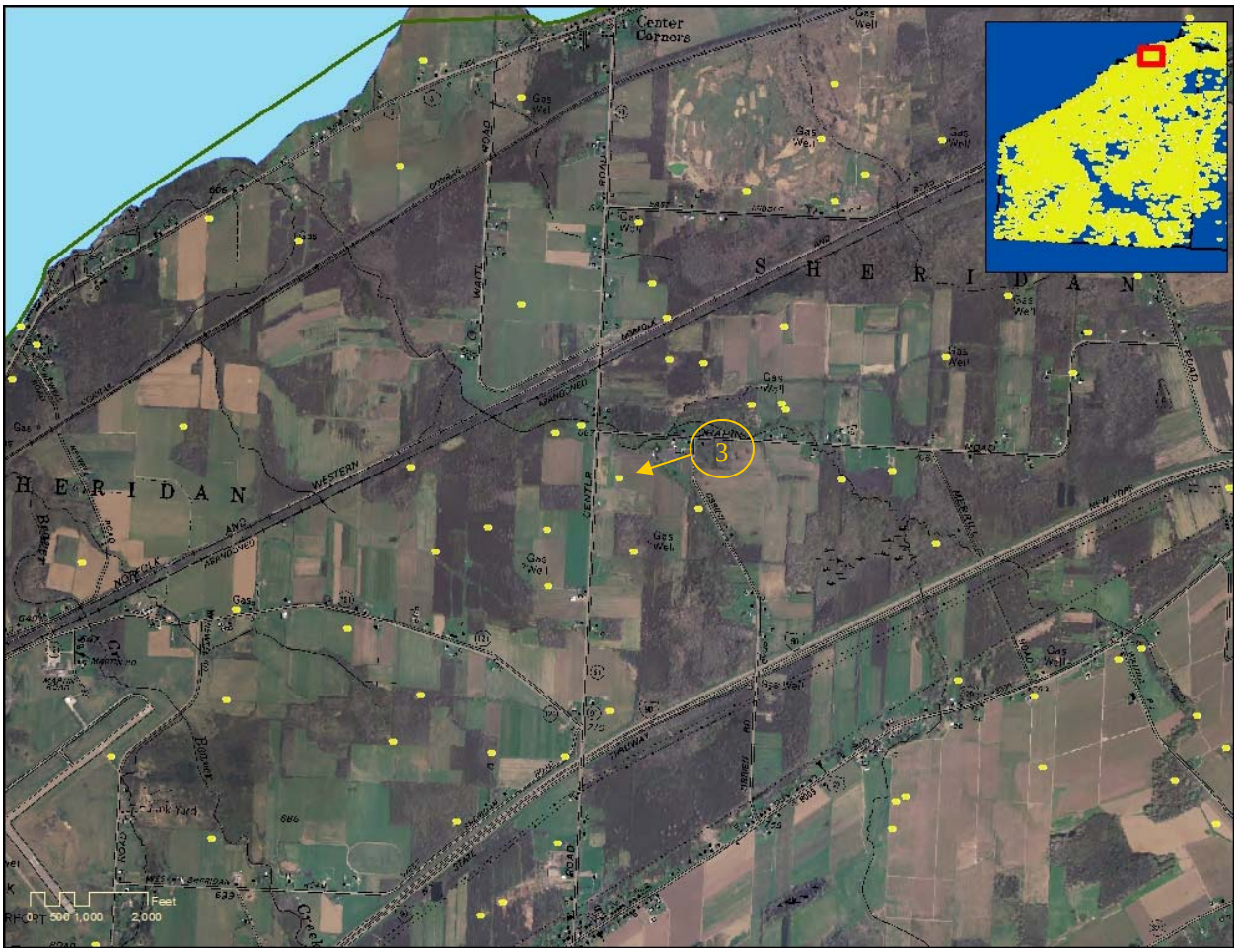


Photo 5.11 a & b The map above shows 77 wells. Well #3 (API Hole number 16427) identified in the map above, and shown in the photo below, was completed in the Town of Sheridan, Chautauqua County in 1981 and was drilled to a depth of 2,012 feet. The map indicates that the nearest producing well to Well #3 is 1/4 mile away.

Vertical Wells

Statewide spacing for vertical shale wells provides for one well per 40-acre spacing unit.[136] This is the spacing requirement that has historically governed most gas well drilling in the State, and as mentioned above, many square miles of Chautauqua, Seneca and Cayuga counties have been developed on this spacing. One well per 40 acres equates to a density of 16 wells per square mile (i.e., 640 acres). Infill wells, resulting in more than one well per 40 acres, may be drilled upon justification to the Department that they are necessary to efficiently recover gas reserves. Gas well development on 40-acre spacing, with the possibility of infill wells, has been the prevalent gas well development method in New York for many decades. However, as reported by the Ground Water Protection Council,[137] economic and technological considerations favor the use of horizontal drilling for shale gas development. As explained below, horizontal drilling necessarily results in larger spacing units and reduced well pad density. Industry estimates that 10% of the wells drilled to develop shale resources by high-volume hydraulic fracturing will be vertical.[138]

Horizontal Wells in Single-Well Spacing Units

Statewide spacing for horizontal wells where only one well will be drilled at the surface site provides for one well per 40 acres plus the necessary and sufficient acreage so that there will be 330 feet between the wellbore in the target formation and the spacing unit boundary. This means that the width of the spacing unit will be at least 660 feet and the distance within the target formation between wellbores will also always be at least 660 feet. Surface locations may be somewhat closer together because of the need to begin building angle in the wellbore about 500 feet above the target formation. However, unless the horizontal length of the wellbores within the target formation is limited to 1,980 feet, the spacing units will exceed 40 acres in size. Although it is possible to drill horizontal wellbores of this length, all information provided to date indicates that, in actual practice, lateral distance drilled will normally exceed 2,000 feet and as an example would most likely be 4,000 feet or more, requiring substantially more than 40

[136] A spacing unit is the geographic area assigned to the well for the purposes of sharing costs and production. ECL §23-0501(2) requires that the applicant control the oil and gas rights for 60% of the acreage in a spacing unit for a permit to be issued. Uncontrolled acreage is addressed through the compulsory integration process set forth in ECL §23-0901(3).

[137] GWPC, April 2009, pp. 46-47.

[138] ALL Consulting, 2010, p. 7.

acres. Therefore, the overall density of surface locations would be less than 16 wells per square mile. For example, with 4,000 feet as the length of a horizontal wellbore in the target shale formation, a spacing unit would be 4,660 feet long by 660 feet wide, or about 71 acres in size. Nine, instead of 16, spacing units would fit within a square mile, necessitating nine instead of 16 access roads and nine instead of 16 gas gathering lines. Longer laterals would further reduce the number of well pads per square mile. The Department anticipates that the vast majority of horizontal wells will be drilled from common pads (i.e., multi-well pads), reducing surface disturbance even more.

Horizontal Wells with Multiple Wells Drilled from Common Pads

The third statewide spacing option for shale wells provides, initially, for spacing units of up to 640 acres with all the horizontal wells in the unit drilled from a common well pad. Industry estimates that 90% of the wells drilled to develop shale resources by high-volume hydraulic fracturing will be horizontal;[139] as stated above, the Department anticipates that the vast majority of them will be drilled from multi-well pads. This method provides the most flexibility to avoid environmentally sensitive locations within the acreage to be developed and significantly reduces the number of needed well pads and associated roads.

With respect to overall land disturbance, the larger surface area of an individual multi-well pad will be more than offset by the fewer total number of well pads within a given area and the need for only a single access road and gas gathering system to service multiple wells on a single pad. Overall, there clearly is a smaller total area of land disturbance associated with horizontal wells for shale gas development than that for vertical wells.[140] For example, a spacing of 40 acres per well for vertical shale gas wells would result in, on average, of 70 – 80 acres of disturbance for the well pads, access roads and utility corridors (4.8 acres per well[141]) to develop an area of 640 acres. By contrast, a single well pad with 6 to 8 horizontal shale gas wells could access all 640 acres with an average of 7.4 acres of total land disturbance. Table 5.1 below provides another comparison between the well pad acreage disturbed within a 10-square mile

[139] ALL Consulting, 2010, p. 7.

[140] Alpha, 2009, p. 6-2.

[141] ALL Consulting, 2010, p. 14.

area completely developed by multi-well pad horizontal drilling versus single-well pad vertical drilling.[142]

Table 5.1 - Ten square mile area (i.e., 6,400 acres), completely drilled with horizontal wells in multi-well units or vertical wells in single-well units (Updated July 2011)

Spacing Option	Multi-Well 640 Acre	Single-Well 40 Acre
Number of Pads	10	160
Total Disturbance - Drilling Phase	74 Acres (7.4 acres per pad)	768 Acres (4.8 ac. per pad)
% Disturbance - Drilling Phase	1.2%	12%
Total Disturbance - Production Phase	15 Acres (1.5 ac. per pad)	80 Acres (0.5 ac. per pad)
% Disturbance - Production Phase	0.23%	1.25%

It is possible that a single well-pad could be positioned to site wells to reach adjacent units, thereby developing 1,280 acres or more without increasing the land disturbance described above for multi-well pads. Use of longer lateral wellbores is another potential method for developing larger areas with less land disturbance.[143]

Variances or Non-Conforming Spacing Units

The ECL has always provided for variances from statewide spacing or non-conforming spacing units, with justification, which could result in a greater well density for any of the above options. A variance from statewide spacing or a non-conforming spacing unit requires the Department to issue a well-specific spacing order following public comment and, if necessary, an adjudicatory hearing. Environmental impacts associated with any well to be drilled under a particular spacing order will continue to be reviewed separately from the spacing variance upon receipt of a specific well permit application.

5.2 Horizontal Drilling

The first horizontal well in New York was drilled in 1989, and in 2008 approximately 10% of the well permit applications received by the Department were for directional or horizontal wells. The predominant use of horizontal drilling associated with natural gas development in New York

[142] NTC, 2009, p. 29, updated with information from ALL Consulting, 2010.

[143] ALL Consulting, 2010, p. 87.

has been for production from the Black River and Herkimer Formations during the past several years. The combination of horizontal drilling and hydraulic fracturing is widely used in other areas of the United States as a means of recovering gas from tight shale formations.

Except for the use of specialized downhole tools, horizontal drilling is performed using similar equipment and technology as vertical drilling, with the same protocols in place for aquifer protection, fluid containment and waste handling. As described below, there are four primary differences between horizontal drilling for shale gas development and the drilling described in the 1992 GEIS. One is that larger rigs may be used for all or part of the drilling, with longer per-well drilling times than were described in the 1992 GEIS. The second is that multiple wells are likely to be drilled from each well site (or well pad). The third is that drilling mud rather than air may be used while drilling the horizontal portion of the wellbore to lubricate and cool the drill bit and to clean the wellbore. Fourth and finally, the volume of rock cuttings returned to the surface from the target formation will be greater for a horizontal well than for a vertical well.

Vertical drilling depth will vary based on target formation and location within the state. Chapter 5 of the 1992 GEIS discusses New York State's geology with respect to oil and gas production. Chapter 4 of this SGEIS expands upon that discussion, with emphasis on the Marcellus and Utica Shales. Chapter 4 includes maps which show depths and thicknesses related to these two shales.

In general, wells will be drilled vertically to a depth of about 500 feet above the top of a target interval, such as the Union Springs Member of the Marcellus Shale. Drilling may continue with the same rig, or a larger drill rig may be brought onto the location to build angle and drill the horizontal portion of the wellbore. A downhole motor behind the drill bit at the end of the drill pipe is used to accomplish the angled or directional drilling deep within the earth. The drill pipe is also equipped with inclination and azimuth sensors located about 60 feet behind the drill bit to continuously record and report the drill bit's location.

Current drilling technology for onshore consolidated strata results in maximum lateral lengths that do not greatly exceed the depth of the well. For example, a 5,000-foot deep well would generally not have a lateral length of significantly greater than 5,000 feet.[144] This may change,

[144] ALL Consulting, 2010, pp. 87-88.

however, as drilling technology continues to evolve. The length of the horizontal wellbore can also be affected by the operator's lease position or compulsory integration status within the spacing unit, the configuration of the approved spacing unit and wellbore paths, and other factors which influence well design.

5.2.1 Drilling Rigs

Wells for shale gas development using high-volume hydraulic fracturing will be drilled with rotary rigs. Rotary rigs are described in the 1992 GEIS, with the typical rotary rigs used in New York at the time characterized as either 40 to 45-foot high "singles" or 70 to 80-foot high "doubles." These rigs can, respectively, hold upright one joint of drill pipe or two connected joints. "Triples," which hold three connected joints of drill pipe upright and are over 100 feet high, were not commonly used in New York State when the 1992 GEIS was prepared. However, triples have been more common in New York since 1992 for natural gas storage field drilling and to drill some Trenton-Black River wells, and may be used for drilling wells in the Marcellus Shale and other low-permeability reservoirs.

Operators may use one large rig to drill an entire wellbore from the surface to toe of the horizontal bore, or may use two or three different rigs in sequence. For each well, only one rig is over the hole at a time. At a multi-well site, two rigs may be present on the pad at once, but more than two are unlikely because of logistical and space considerations as described below.

When two rigs are used (in sequence) to drill a well, a smaller rig of similar dimensions to the typical rotary rigs described in the 1992 GEIS would first drill the vertical portion of the well. Only the rig used to drill the horizontal portion of the well is likely to be significantly larger than what is described in the 1992 GEIS. This rig may be a triple, with a substructure height of about 20 feet, a mast height of about 150 feet, and a surface footprint with its auxiliary equipment of about 14,000 square feet. Auxiliary equipment includes various tanks (for water, fuel and drilling mud), generators, compressors, solids control equipment (shale shaker, de-silter, de-sander), choke manifold, accumulator, pipe racks and the crew's office space (dog house). Initial work with the smaller rig would typically take up to two weeks, followed by another up to two weeks of work with the larger rig. These estimates include time for casing and cementing the

well, and may be extended if drilling is slower than anticipated because of properties of the rock, or if other problems or unexpected delays occur.

When three rigs are used to drill a well, the first rig is used to drill, case, and cement the surface hole. This event generally takes about 8 to12 hours. The dimensions of this rig would be consistent with what is described in the 1992 GEIS. The second rig for drilling the remainder of the vertical hole would also be consistent with 1992 GEIS descriptions and would again typically be working for up to 14 days, or longer if drilling is slow or problems occur. The third rig, equipped to drill horizontally, would, as noted above, be the only one that might exceed 1992 GEIS dimensions, with a substructure height of about 20 feet, a mast height of about 150 feet, and a surface footprint with its auxiliary equipment of about 14,000 square feet. Work with this rig would take up to 14 days, or longer if drilling is slow or other problems or delays occur.

An important component of the drilling rig is the blow-out prevention (BOP) system. This system is discussed in the 1992 GEIS. In summary, BOP system on a rotary drilling rig is a pressure control system designed specifically to contain and control a “kick” (i.e., unexpected pressure resulting in the flow of formation fluids into the wellbore during drilling operations). Other than the well itself, the BOP system basically consists of four parts: 1) the blow-out preventer stack, 2) the accumulator unit, 3) the choke manifold, and 4) the kill line. Blow-out preventers are manually or hydraulically operated devices installed at the top of the surface casing. Within the blow-out preventer there may be a combination of different types of devices to seal off the well. Pipe rams contain two metal blocks with semi-circular notches that fit together around the outside of the drill pipe when it is in the hole to block movement of fluids around the pipe. Blind rams contain two rubber faced metal blocks that can completely seal off the hole when there is no drill pipe in it. Annular or "bag" type blowout preventers contain a resilient packing element which expands inward to seal off the hole with or without drill pipe. In accordance with 6 NYCRR §554.4, the BOP system must be maintained and in proper working order during operations. A BOP test program is employed to ensure the BOP system is functioning properly if and when needed.

Appendix 7 includes sample rig specifications provided by Chesapeake Energy. As noted on the specs, fuel storage tanks associated with the larger rigs would hold volumes of 10,000 to 12,000 gallons.

In summary, the rig work for a single horizontal well – including drilling, casing and cementing – would generally last about four to five weeks, subject to extension for slow drilling or other unexpected problems or delays. A 150-foot tall, large-footprint rotary rig may be used for the entire duration or only for the actual horizontal drilling. In the latter case, smaller, 1992 GEIS-consistent rigs would be used to drill the vertical portion of the wellbore. The rig and its associated auxiliary equipment would typically move off the well before fracturing operations commence.

Photo 5.12, Photo 5.13, Photo 5.14, and Photo 5.15 are photographs of drilling rigs.

5.2.2 Multi-Well Pad Development

Horizontal drilling from multi-well pads is the common development method employed to develop Marcellus Shale reserves in the northern tier of Pennsylvania and is expected to be common in New York as well. In New York, ECL 23 requires that all horizontal wells in a multi-well shale unit be drilled within three years of the date the first well in the unit commences drilling, to prevent operators from holding acreage within large spacing units without fully developing the acreage.[145]

As described above, the space required for hydraulic fracturing operations for a multi-well pad is dictated by a number of factors but is expected to most commonly be about 3.5 acres.[146] The well pad is often centered in the spacing unit.

[145] ECL §23-0501.

[146] Cornue, 2011.

Photo 5.12 Double. Union Drilling Rig 54, Olsen 1B, Town of Fenton, Broome County NY. Credit: NYS DEC 2005.

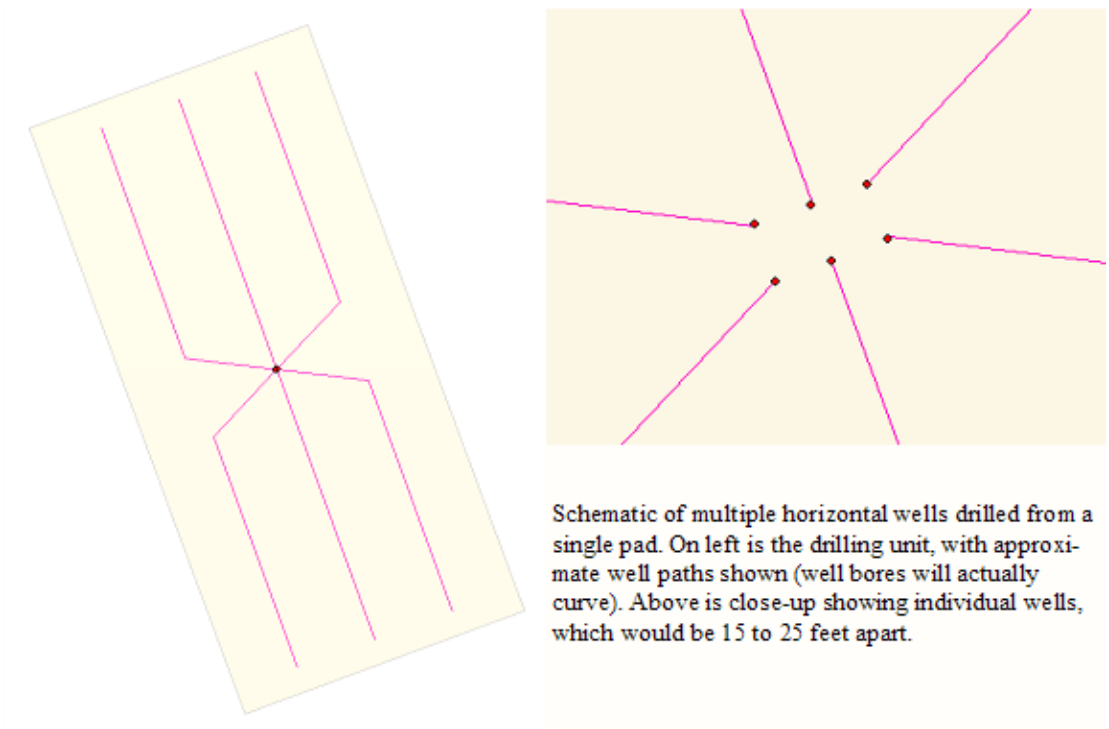
Photo 5.13 Double. Union Drilling Rig 48. Trenton-Black River well, Salo 1, Town of Barton, Tioga County NY. Source: NYS DEC 2008.

Photo 5.14 Triple. Precision Drilling Rig 26. Ruger 1 well, Horseheads, Chemung County. Credit: NYS DEC 2009.

Photo 5.15 Top Drive Single. Barber and DeLine rig, Sheckells 1, Town of Cherry Valley, Otsego County. Credit: NYS DEC 2007.

Several factors determine the optimal drilling pattern within the target formation. These include geologic controls such as formation depth and thickness, mechanical and physical factors associated with the well construction program, production experience in the area, lease position and topography or surface restrictions that affect the size or placement of pads.[147] Often, evenly spaced parallel horizontal bores are drilled in opposite directions from surface locations arranged in two parallel rows. When fully developed, the resultant horizontal well pattern underground could resemble two back-to-back pitchforks [Figure 5.2]. Other, more complex patterns may also be proposed.

Figure 5.2 - Possible well spacing unit configurations and wellbore paths



Because of the close well spacing at the surface, most operators have indicated that only one drilling rig at a time would be operating on any given well pad. One operator has stated that on a well pad where six or more wells are needed, it is possible that two triple-style rigs may operate concurrently. Efficiency and the economics of mobilizing equipment and crews would dictate that all wells on a pad be drilled sequentially, during a single mobilization. However, this may

[147] ALL Consulting, 2010, p. 88.

be affected by the timing of compulsory integration proceedings if wellbores are proposed to intersect unleased acreage.[148] Other considerations may result in gaps between well drilling episodes at a well pad. For instance, early development in a given area may consist of initially drilling and stimulating one to three wells on a pad to test productivity, followed by additional wells later, but within the required 3-year time frame. As development in a given area matures and the results become more predictable, the frequency of drilling and completing all the wells on each pad with continuous activity in a single mobilization would be expected to increase.

5.2.3 Drilling Mud

The vertical portion of each well, including the portion that is drilled through any fresh water aquifers, will typically be drilled using either compressed air or freshwater mud as the drilling fluid. Operators who provided responses to the Department's information requests stated that the horizontal portion, drilled after any fresh water aquifers have been sealed behind cemented surface casing, and typically cemented intermediate casing, may be drilled with a mud that may be (i) water-based, (ii) potassium chloride/polymer-based with a mineral oil lubricant, or (iii) synthetic oil-based. Synthetic oil-based muds are described as "food-grade" or "environmentally friendly." When drilling horizontally, mud is needed for (1) powering and cooling the downhole motor and bit used for directional drilling, (2) using navigational tools which require mud to transmit sensor readings, (3) providing stability to the horizontal borehole while drilling and (4) efficiently removing cuttings from the horizontal hole. Other operators may drill the horizontal bore "on air," (i.e., with compressed air) using special equipment to control fluids and gases that enter the wellbore. Historically, most wells in New York are drilled on air and air drilling is addressed by the 1992 GEIS.

Drilling mud is contained and managed on-site through the rig's mud system which is comprised of a series of piping, separation equipment, and tanks. Photo 5.16 depicts some typical mud-system components. During drilling or circulating mud is pumped from the mud holding tanks at the surface down hole through the drill string and out the drill bit, and returns to the surface through the annular space between the drill string and the walls of the bore hole, where it enters the flowline and is directed to the separation equipment. Typical separation equipment includes

[148] ECL §23-0501 2.b. prohibits the wellbore from crossing unleased acreage prior to issuance of a compulsory integration order.

shale shakers, desanders, desilters and centrifuges which separate the mud from the rock cuttings. The mud is then re-circulated back into the mud tanks where it is withdrawn by the mud pump for continued use in the well. As described in the 1992 GEIS, used drilling mud is typically reconditioned for use at a subsequent well. The subsequent well may be located on the same well pad or at another location.

Photo 5.16 - Drilling rig mud system (blue tanks)

5.2.4 Cuttings

The rock chips and very fine-grained rock fragments removed by the drilling process and returned to the surface in the drilling fluid are known as "cuttings" and are contained and managed either in a lined on-site reserve pit or in a closed-loop tank system.[149] As described in Section 5.13.1, the proper disposal method for cuttings is determined by the composition of the fluid or fluids used during drilling. The proper disposal method will also dictate how the cuttings must be contained on-site prior to disposal, as described by Section 7.1.9.

[149] Adapted from Alpha, 2009, p. 133.

5.2.4.1 Cuttings Volume

Horizontal drilling penetrates a greater linear distance of rock and therefore produces a larger volume of drill cuttings than does a well drilled vertically to the same depth below the ground surface. For example, a vertical well with surface, intermediate and production casing drilled to a total depth of 7,000 feet produces approximately 154 cubic yards of cuttings, while a horizontally drilled well with the same casing program to the same target depth with an example 4,000-foot lateral section produces a total volume of approximately 217 cubic yards of cuttings (i.e., about 40% more). A multi-well site would produce approximately that volume of cuttings from each well.

5.2.4.2 NORM in Marcellus Cuttings

To determine NORM concentrations and the potential for exposure to NORM contamination in Marcellus rock cuttings and cores (i.e., continuous rock samples, typically cylindrical, recovered during specialized drilling operations), the Department conducted field and sample surveys using portable Geiger counter and gamma ray spectroscopy methods. Gamma ray spectroscopy analyses were performed on composited Marcellus samples collected from two vertical wells drilled through the Marcellus, one in Lebanon (Madison County), and one in Bath (Steuben County). The results of these analyses are presented in Table 5.2a. Department staff also used a Geiger counter to screen three types of Marcellus samples: cores from the New York State Museum's collection in Albany; regional outcrops of the unit; and various Marcellus well sites from the west-central part of the state, where most of the vertical Marcellus wells in NYS are currently located. These screening data are presented in Table 5.2b. Additional radiological analytical data for Marcellus Shale drill cuttings has been reported from Marcellus wells in Pennsylvania. Samples were collected from loads of drill cuttings being transported for disposal, as well as directly from the drilling rigs during drilling of the horizontal legs of the wells. The materials sampled were screened in-situ with a micro R meter, and analyzed by gamma ray spectroscopy. These data are provided in Table 5.3. As discussed further in Chapter 6, the results, which indicate levels of radioactivity that are essentially equal to background values, do not indicate an exposure concern for workers or the general public associated with Marcellus cuttings.

Table 5.2 - 2009 Marcellus Radiological Data

Table 5.2a Marcellus Radiological Data from Gamma Ray Spectroscopy Analyses					
Well (Depth)	**API #**	**Date Collected**	**Town (County)**	**Parameter**	**Result +/- Uncertainty**
Crouch C 4H (1040 feet - 1115 feet)	31-053-26305-00-00	3/17/09	Lebanon (Madison)	K-40	14.438 +/- 1.727 pCi/g
				Tl-208	0.197 +/- 0.069 pCi/g
				Pb-210	2.358 +/- 1.062 pCi/g
				Bi-212	0.853 +/- 0.114 pCi/g
				Bi-214	1.743 +/- 0.208 pCi/g
				Pb-214	1.879 +/- 0.170 pCi/g
				Ra-226	1.843 +/- 0.573 pCi/g
				Ac-228	0.850 +/- 0.169 pCi/g
				Th-234	1.021 +/- 0.412 pCi/g
				U-235	0.185 +/- 0.083 pCi/g
Blair 2A (2550' - 2610')	31-101-02698-01-00	3/26/09	Bath (Steuben)	K-40	22.845 +/- 2.248 pCi/g
				Tl-208	0.381 +/- 0.065 pCi/g
				Pb-210	0.535 +/- 0.712 pCi/g
				Bi-212	1.174 +/- 0.130 pCi/g
				Bi-214	0.779 +/- 0.120 pCi/g
				Pb-214	0.868 +/- 0.114 pCi/g
				Ra-226	0.872 +/- 0.330 pCi/g
				Ac-228	1.087 +/- 0.161 pCi/g
				Th-234	0.567 +/- 0.316 pCi/g
				U-235	0.079 +/- 0.058 pCi/g

Table 5.2b Marcellus Radiological Data from Geiger Counter Screening				
Media Screened	**Well**	**Date**	**Location (County)**	**Results**
Cores	Beaver Meadow 1	3/12/09	NYS Museum (Albany)	0.005 - 0.080 mR/hr
	Oxford 1	3/12/09	NYS Museum (Albany)	0.005 - 0.065 mR/hr
	75 NY-14	3/12/09	NYS Museum (Albany)	0.015 - 0.065 mR/hr
	EGSP #4	3/12/09	NYS Museum (Albany)	0.005 - 0.045 mR/hr
	Jim Tiede	3/12/09	NYS Museum (Albany)	0.005 - 0.025 mR/hr
	75 NY-18	3/12/09	NYS Museum (Albany)	0.005 - 0.045 mR/hr
	75 NY-12	3/12/09	NYS Museum (Albany)	0.015 - 0.045 mR/hr
	75 NY-21	3/12/09	NYS Museum (Albany)	0.005 - 0.040 mR/hr
	75 NY-15	3/12/09	NYS Museum (Albany)	0.005 - 0.045 mR/hr
	Matejka	3/12/09	NYS Museum (Albany)	0.005 - 0.090 mR/hr
Outcrops	N/A	3/24/2009	Onesquethaw Creek (Albany)	0.02 - 0.04 mR/hr
	N/A	3/24/2009	DOT Garage, CR 2 (Albany)	0.01 - 0.04 mR/hr
	N/A	3/24/2009	SR 20, near SR 166 (Otsego)	0.01 - 0.04 mR/hr
	N/A	3/24/2009	Richfield Springs (Otsego)	0.01 - 0.06 mR/hr
	N/A	3/24/2009	SR 20 (Otsego)	0.01 - 0.03 mR/hr
	N/A	3/24/2009	Gulf Rd (Herkimer)	0.01 - 0.04 mR/hr
Well Sites	Beagell 2B	4/7/2009	Kirkwood (Broome)	0.04 mR/hr *
	Hulsebosch 1	4/2/2009	Elmira City (Chemung)	0.03 mR/hr *
	Bush S1	4/2/2009	Elmira (Chemung)	0.03 mR/hr *

	Parker 1	4/7/2009	Oxford (Chenango)	0.05 mR/hr *
Well Sites	Donovan Farms 2	3/30/2009	West Sparta (Livingston)	0.03 mR/hr *
	Fee 1	3/30/2009	Sparta (Livingston)	0.02 mR/hr *
	Meter 1	3/30/2009	West Sparta (Livingston)	0.03 mR/hr *
	Schiavone 2	4/6/2009	Reading (Schuyler)	0.05 mR/hr *
	WGI 10	4/6/2009	Dix (Schuyler)	0.07 mR/hr *
	WGI 11	4/6/2009	Dix (Schuyler)	0.07 mR/hr *
	Calabro T1	3/26/2009	Orange (Schuyler)	0.03 mR/hr *
	Calabro T2	3/26/2009	Orange (Schuyler)	0.05 mR/hr *
	Frost 2A	3/26/2009	Orange (Schuyler)	0.05 mR/hr *
	Webster T1	3/26/2009	Orange (Schuyler)	0.05 mR/hr *
	Haines 1	4/1/2009	Avoca (Steuben)	0.03 mR/hr *
	Haines 2	4/1/2009	Avoca (Steuben)	0.03 mR/hr *
	McDaniels 1A	4/1/2009	Urbana (Steuben)	0.03 mR/hr *
	Drumm G2	4/1/2009	Bradford (Steuben)	0.07 mR/hr *
	Hemley G2	3/26/2009	Hornby (Steuben)	0.03 mR/hr *
	Lancaster M1	3/26/2009	Hornby (Steuben)	0.03 mR/hr *
	Maxwell 1C	4/2/2009	Caton (Steuben)	0.07 mR/hr *
	Scudder 1	3/26/2009	Bath (Steuben)	0.03 mR/hr *
	Blair 2A	3/26/2009	Bath (Steuben)	0.03 mR/hr *
	Retherford 1	4/1/2009	Troupsburg (Steuben)	0.05 mR/hr *
	Carpenter 1	4/1/2009	Troupsburg (Steuben)	0.05 mR/hr *
	Cook 1	4/1/2009	Troupsburg (Steuben)	0.05 mR/hr *
	Zinck 1	4/1/2009	Woodhull (Steuben)	0.07 mR/hr *
	Tiffany 1	4/7/2009	Owego (Tioga)	0.03 mR/hr *
*maximum values detected				

Table 5.3 - Gamma Ray Spectroscopy

							Radionuclide Concentration (per wet mass)								
LAB	Sample#	Date	Sample Location	Material Type	Depth	Gamma*	Radium-226			Thorium-232			Potassium-40		
ID#		Collected			(feet)	(uR/hr)	(pCi/g)			(pCi/g)			(pCi/g)		
Gas Drill Rig Cuttings															
738-1	31110A	3/11/2010	Bradford Co., Pa.	Marcellus shale	5942	8 / 10	2.4	±	0.2	0.5	±	0.1	12.9	±	1.0
738-2	31110B	3/11/2010	Bradford Co., Pa.	Hamilton Limestone	6562	5 / 5 **	1.1	±	0.1	0.9	±	0.1	17.8	±	1.0
738-3	31110C	3/11/2010	Bradford Co., Pa.	Marcellus shale	6687	11 / 8	4.3	±	0.2	0.9	±	0.1	15.8	±	0.9
738-5	31910A	3/19/2010	Tioga County, Pa.	Marcellus shale	6101	5 / 10	2.8	±	0.2	0.9	±	0.1	17.4	±	1.0
738-6	31910B	3/19/2010	Tioga County, Pa.	Marc. shale with Bayrite	6101	5 / 10	0.6	±	0.1	0.2	±	0.0	3.4	±	0.2
738-13	1-M1	3/2/2010	Landfill, Lowman, NY	transported gas rig cuttings	unk.	12	2.3	±	0.1	0.7	±	0.1	17.2	±	1.1
738-11	2-M2	3/2/2010	Landfill, Painted Post, NY	transported gas rig cuttings	unk.	12	0.9	±	0.1	1.2	±	0.1	16.7	±	1.1
738-12	3-M1	3/2/2010	Landfill, Angelica, NY	transported gas rig cuttings	unk.	12	2.7	±	0.2	0.8	±	0.1	12.6	±	0.8
						AVERAGE	**2.1**	±	**1.2**	**0.7**	±	**0.3**	**14.2**	±	**4.8**

5.2.5 Management of Drilling Fluids and Cuttings

The 1992 GEIS discusses the use of reserve pits and tanks, either alone or in conjunction with one another, to contain the cuttings and fluids associated with the drilling process. Both systems result in complete capture of the fluids and cuttings; however the use of tanks in closed-loop tank systems facilitates off-site disposal of wastes while more efficiently utilizing drilling fluid and providing additional insurance against environmental releases.

5.2.5.1 Reserve Pits on Multi-Well Pads

The 1992 GEIS describes the construction, use and reclamation of lined reserve pits, (also called "drilling pits" or "mud pits") to contain cuttings and fluids associated with the drilling process. Rather than using a separate pit for each well on a multi-well pad, operators may propose to maintain a single pit on the well pad until all wells are drilled and completed. The pit would need to be adequately sized to hold cuttings from all the wells, unless the cuttings are removed intermittently as needed to ensure adequate room for drilling-associated fluids and precipitation. Under existing regulations, fluid associated with each well would have to be removed within 45 days of the cessation of drilling operations, unless the operator has submitted a plan to use the fluids in subsequent operations and the Department has inspected and approved the pit.[150] Chapter 7 discusses restrictions related to the use of reserve pits for managing drilling fluids and cuttings for high-volume hydraulic fracturing.

5.2.5.2 Closed-Loop Tank Systems

The design and configuration of closed-loop tank systems will vary from operator to operator, but all such systems contain drilling fluids and cuttings in a series of containers, thereby eliminating the need for a reserve pit. The containers may include tanks or bins that may have closed tops, open tops or open tops in combination with open sides. They may be stationary or truck-, trailer-, or skid-mounted. Regardless of the specific design of the containers, the objective is to fully contain the cuttings and fluids in such a manner as to prevent direct contact with the ground surface or the need to construct a lined reserve pit.

Depending on the drilling fluid utilized, a variety of types of separation equipment may be employed within a closed-loop tank system to separate the liquids from the cuttings prior to

[150] 6 NYCRR §554.1(c)(3).

capture within the system's containers. For air drilling employing a closed-loop tank system, shale shakers or other gravity-based equipment would likely be utilized to separate any formation fluids from the cuttings whereas mud drilling would employ equipment which is virtually identical to that of the drilling mud systems described previously in Section 5.2.3.

In addition to the equipment typically employed in a drilling mud system, operators may elect to utilize additional solids control equipment within the closed-loop system when drilling on mud, in an effort to further separate liquids from the cuttings. Such equipment could include but is not limited to drying shakers, vertical or horizontal rotary cuttings dryers, squeeze presses, or centrifuges[151] and when oil-based drilling muds are utilized the separation process may also include treatment to reduce surface tension between the mud and the cuttings.[152,153] The additional separation results in greater recovery of the drilling mud for re-circulation and produces dryer cuttings for off-site disposal.

Depending on the moisture-content of the cuttings, operators may drain or vacuum free-liquids from the cuttings container, or they may mix absorbent agents such as lime, saw dust or wood chips into the cuttings in order to absorb any free-liquids prior to hauling off-site for disposal. This mixing may take place in the primary capture container where the cuttings are initially collected following separation or in a secondary container located on the well pad.

Operators may simply employ primary capture containers which are suitable for capturing and transporting cuttings from the well site, or they may transfer cuttings from the primary capture container to a secondary capture container for transport purposes. If cuttings will be transferred between containers, front end loaders, vacuum trucks or other equipment would be utilized and all transfers will be required to occur in a designated transfer area on the well pad, which will be required to be lined.

[151] ANL, 2011(a).

[152] The American Oil & Gas Reporter, August 2010, p. 92-93.

[153] Dugan, April 2008.

Depending on the configuration and design of a closed-loop tank system use of such a system can offer the following advantages:

- Eliminates the time and expense associated with reserve pit construction and reclamation;
- Reduces the surface disturbance associated with the well pad;
- Reduces the amount of water and mud additives required as a result of re-circulation of drilling mud;
- Lowers mud replacement costs by capturing and re-circulating drilling mud;
- Reduces the wastes associated with drilling by separating additional drilling mud from the cuttings; and
- Reduces expenses and truck traffic associated with transporting drilling waste due to the reduced volume of the waste.

5.3 Hydraulic Fracturing

The 1992 GEIS discusses, in Chapter 9, hydraulic fracturing operations using water-based gel and foam, and describes the use of water, hydrochloric acid and additives including surfactants, bactericides,[154] clay and iron inhibitors and nitrogen. The fracturing fluid is an engineered product; service providers vary the design of the fluid based on the characteristics of the reservoir formation and the well operator's objectives. In the late 1990s, operators and service companies in other states developed a technology known as "slickwater fracturing" to develop shale formations, primarily by increasing the amount and proportion of water used, reducing the use of gelling agents and adding friction reducers. Any fracturing fluid may also contain scale and corrosion inhibitors.

ICF International, which reviewed the current state of practice of hydraulic fracturing under contract with NYSERDA, states that the development of water fracturing technologies has reduced the quantity of chemicals required to hydraulically fracture target reservoirs and that

[154] Bactericides must be registered for use in New York in accordance with ECL §33-0701. Well operators, service companies, and chemical supply companies were reminded of this requirement in an October 28, 2008 letter from the Division of Mineral Resources formulated in consultation with the former Division of Solid and Hazardous Materials, now Materials Management. This correspondence also reminded industry of the corresponding requirement that all bactericides be properly labeled and that the labels for such products be kept on-site during application and storage.

slickwater treatments have yielded better results than gel treatments in the Barnett Shale.[155] Poor proppant suspension and transport characteristics of water versus gel are overcome by the low permeability of shale formations which allow the use of finer-grained proppants and lower proppant concentrations.[156] The use of friction reducers in slickwater fracturing procedures reduce the required pumping pressure at the surface, thereby reducing the number and power of pumping trucks needed.[157] In addition, according to ICF, slickwater fracturing causes less formation damage than other techniques such as gel fracturing.[158]

Both slickwater fracturing and foam fracturing have been proposed for Marcellus Shale development. As foam fracturing is already addressed by the 1992 GEIS, this document focuses on slickwater fracturing. This type of hydraulic fracturing is referred to herein as "high-volume hydraulic fracturing" because of the large water volumes required.

5.4 Fracturing Fluid

The fluid used for slickwater fracturing is typically comprised of more than 98% fresh water and sand, with chemical additives comprising 2% or less of the fluid.[159] The Department has collected compositional information on many of the additives proposed for use in fracturing shale formations in New York directly from chemical suppliers and service companies. This information has been evaluated by the Department's Division of Air Resources (DAR) and DOW as well as the NYSDOH's Bureaus of Water Supply Protection and Toxic Substances Assessment. It has also been reviewed by technical consultants contracted by NYSERDA[160] to conduct research related to the preparation of this document. Discussion of potential environmental impacts and mitigation measures in Chapters 6 and 7 of this SGEIS reflect analysis and input by all of the foregoing entities.

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[155] ICF Task 1, 2009. pp. 10, 19.

[156] ICF Task 1, 2009. pp. 10, 19.

[157] ICF Task 1, 2009. P. 12.

[158] ICF Task 1, 2009. P. 19.

[159] GWPC, April 2009, pp. 61-62.

[160] Alpha Environmental Consultants, Inc., ICF International, URS Corporation.

Six service companies[161] and 15 chemical suppliers[162] have provided additive product compositional information to the Department in the form of product Material Safety Data Sheets (MSDSs)[163] and product composition disclosures consisting of chemical constituent names and their associated Chemical Abstract Service (CAS) Numbers,[164] as well as chemical constituent percent by weight information. Altogether, some compositional information is on file with the Department for 235 products, with complete[165] product composition disclosures and MSDSs on file for 167 of those products. Within these products are 322 unique chemicals whose CAS Numbers have been disclosed to the Department and at least 21 additional compounds whose CAS Numbers have not been disclosed due to the fact that many are mixtures. Table 5.4 is an alphabetical list of all products for which complete chemical information, including complete product composition disclosures and MSDSs, has been provided to the Department. Table 5.5 is an alphabetical list of products for which only partial chemical composition information has been provided to the Department, either in the form of product MSDSs or product composition disclosures which appear to be lacking information. Any product whose name does not appear within Table 5.4 or Table 5.5 was not evaluated in this SGEIS either because no chemical information was submitted to the Department or because the product has not been proposed for use in high-volume hydraulic fracturing operations in New York to date. These tables are included for informational purposes only and are not intended to restrict the proposal of additional additive products. See Chapter 8, Section 8.2.1.1 for a description of the permitting requirements related to fracturing additive information.

[161] BJ Services, Frac Tech Services, Halliburton, Superior Well Services, Universal Well Services, Schlumberger.

[162] Baker Petrolite, CESI/Floteck, Champion Technologies/Special Products, Chem EOR, Cortec, Fleurin Fragrances, Industrial Compounding, Kemira, Nalco, PfP Technologies, SNF Inc., Stepan Company, TBC-Brinadd/Texas United Chemical, Weatherford/Clearwater, and WSP Chemicals & Technology.

[163] MSDSs are regulated by the Occupational Safety and Health Administration (OSHA)'s Hazard Communication Standard, 29 CFR 1910.1200(g) and are described in Chapter 8.

[164] Chemical Abstracts Service (CAS) is a division of the American Chemical Society. CAS assigns unique numerical identifiers to every chemical described in the literature. The intention is to make database searches more convenient, as chemicals often have many names.

[165] The Department defines a complete product composition disclosure to include the chemical names and associated CAS Numbers of every constituent within a product, as well as the percent by weight information associated with each constituent of a product.

Table 5.4 - Fracturing Additive Products – Complete Composition
Disclosure Made to the Department (Updated July 2011)

Product Name
ABF
Acetic Acid 0.1-10%
Acid Pensurf / Pensurf
Activator W
AGA 150 / Super Acid Gell 150
AI-2
Aldacide G
Alpha 125
Ammonium Persulfate/OB Breaker
APB-1, Ammonium Persulfate Breaker
AQF-2
ASP-820
B315 / Friction Reducer B315
B317 / Scale Inhibitor B317
B859 / EZEFLO Surfactant B859 / EZEFLO F103 Surfactant
B867 / Breaker B867 / Breaker J218
B868 / EB-CLEAN B868 LT Encapsulated Breaker / EB-Clean J479 LT Encapsulated Breaker
B875 / Borate Crosslinker B875 / Borate Crosslinker J532
B880 / EB-CLEAN B880 Breaker / EB-CLEAN J475 Breaker
B890 / EZEFLO Surfactant B890 / EZEFLO F100 Surfactant
B900 / EZEFLO Surfactant B900/ EZEFLO F108 Surfactant
B910 / Corrosion Inhibitor B910 / Corrosion Inhibitor A264
B916 / Gelling Agent ClearFRAC XT B916 / Gelling Agent ClearFRAC XT J590
BA-2
BA-20
BA-40L
BA-40LM
BC-140
BC-140 X2
BE-3S
BE-6
BE-7
BE-9
BF-1
BF-7 / BF-7L
BioClear 1000 / Unicide 1000
Bio-Clear 200 / Unicide 2000

Product Name
Breaker FR
BXL-2, Crosslinker/ Buffer
BXL-STD / XL-300MB
Carbon Dioxide
CC-302T
CI-14
CL-31
CLA-CHEK LP
Claproteck CF
CLA-STA XP
Clay Treat PP
Clay Treat TS
Clay Treat-3C
Clayfix II
Clayfix II plus
CPF-X Plus
Cronox 245 ES
CS-250 SI
CS-650 OS, Oxygen Scavenger
CS-Polybreak 210
CS-Polybreak 210 Winterized
CT-ARMOR
EB-4L
Enzyme G-NE
FAC-1W / Petrostep FAC-1W
FAC-3W / Petrostop FAC-3W
FE-1A
FE-2
FE-2A
FE-5A
Ferchek
Ferchek A
Ferrotrol 300L
Flomax 50
Flomax 70 / VX9173
FLOPAM DR-6000 / DR-6000
FLOPAM DR-7000 / DR-7000
Formic Acid
FR-46
FR-48W

Product Name
FR-56
FRP-121
FRW-14
GasPerm 1000
GBL-8X / LEB-10X / GB-L / En-breaker
GBW-30 Breaker
Green-Cide 25G / B244 / B244A
H015 / Hydrochloric Acid 15% H15
HAI-OS Acid Inhibitor
HC-2
High Perm SW-LB
HPH Breaker
HPH foamer
Hydrochloric Acid
Hydrochloric Acid (HCl)
Hydrochloric Acid 10.1-15%
HYG-3
IC 100L
ICA-720 / IC-250
ICA-8 / IC-200
ICI-3240
Inflo-250
InFlo-250W / InFlo-250 Winterized
Iron Check / Iron Chek
Iron Sta IIC / Iron Sta II
Isopropyl Alcohol
J313 / Water Friction-Reducing Agent J313
J534 / Urea Ammonium Nitrate Solution J534
J580 / Water GellingAgent J580
K-34
K-35
KCI
L058 / Iron Stabilizer L58
L064 / Temporary Clay Stabilizer L64
LGC-35 CBM
LGC-36 UC
LGC-VI UC
Losurf 300M
M003 / Soda Ash M3
MA-844W

Product Name
Methanol
MO-67
Morflo III
MSA-II
Muriatic Acid 36%
Musol A
N002 / Nitrogen N_2
NCL-100
Nitrogen
Nitrogen, Liquid N_2
OptiKleen-WF
Para Clear D290 / ParaClean II
Paragon 100 E+
Parasperse
Parasperse Cleaner
PSI-720
PSI-7208
Salt
SAS-2
Scalechek LP-55
Scalechek LP-65
Scalechek SCP-2 / SCP-2
Scalehib 100 / Super Scale Inhibitor / Scale Clear SI-112
SGA II
Shale Surf 1000
Shale Surf 1000 Winterized
SI 103
Sodium Citrate
SP Breaker
STIM-50 / LT-32
Super OW 3
Super Pen 2000
SuperGel 15
U042 / Chelating Agent U42
U066 / Mutual Solvent U66
Unicide 100 / EC6116A
Unifoam
Unigel 5F
UniHibA / SP-43X
UnihibG / S-11

Product Name
Unislik ST 50 / Stim Lube
Vicon NF
WG-11
WG-17
WG-18
WG-35
WG-36
WLC-6
XL-1
XL-8
XLW-32
Xylene

Table 5.5 - Fracturing Additive Products – Partial Composition Disclosure to the Department (Updated July 2011)

Product Name
20 Degree Baume Muriatic Acid
AcTivator / 78-ACTW
AMB-100
B869 / Corrosion Inhibitor B869 / Corrosion Inhibitor A262
B885 / ClearFRAC LT B885 / ClearFRAC LT J551A
B892 / EZEFLO B892 / EZEFLO F110 Surfactant
CL-22UC
CL-28M
Clay Master 5C
Corrosion Inhibitor A261
FAW- 5
FDP-S798-05
FDP-S819-05
FE ACID
FR-48
FRW-16
FRW-18
Fracsal FR-143
Fracsal III
Fracsal NE-137
Fracsal Ultra
Fracsal Ultra-FM1
Fracsal Ultra-FM2
Fracsal Ultra-FM3
Fracsal Waterbase
Fracsal Waterbase-M1
FRW-25M
GA 8713
GBW-15L
GW-3LDF
HVG-1, Fast Hydrating Guar Slurry
ICA 400
ICP-1000
Inflo-102
Inhibisal Ultra CS-135
Inhibisal Ultra SI-141
J134L / Enzyme Breaker J134L
KCLS-2, KCL Substitute

Product Name
L065 / Scale Inhibitor L065
LP-65
Magnacide 575 Microbiocide
MSA ACID
Multifunctional Surfactant F105
Nitrogen, Refrigerated Liquid
Product 239
PS 550
S-150
SandWedge WF
SilkWater FR-A
Super TSC / Super Scale Control TSC
Super Sol 10/20/30
Ultra Breake-C
Ultra Breake-CG
Ultra Breake-M
Ultra-Breake-MG
Unislick 30 / Cyanaflo 105L
WC-5584
WCS 5177 Corrosion Scale Inhibitor
WCW219 Combination Inhibitor
WF-12B Foamer
WF-12B Salt Inhibitor Stix
WF-12B SI Foamer/Salt Inhibitor
WF12BH Foamer
WRR-5
WFR-C
XLBHT-1
XLBHT-2

Information in sections 5.4.1-3 below was compiled primarily by URS Corporation,[166] under contract to NYSERDA.

5.4.1 Properties of Fracturing Fluids

Additives are used in hydraulic fracturing operations to elicit certain properties and characteristics that would aide and enhance the operation. The desired properties and characteristics include:

- Non-reactive;
- Non-flammable;
- Minimal residuals;
- Minimal potential for scale or corrosion;
- Low entrained solids;
- Neutral pH (pH 6.5 – 7.5) for maximum polymer hydration;
- Limited formation damage;
- Appropriately modify properties of water to carry proppant deep into the shale;
- Economical to modify fluid properties; and
- Minimal environmental effects.

5.4.2 Classes of Additives

Table 5.6 lists the types, purposes and examples of additives that have been proposed to date for use in hydraulic fracturing of gas wells in New York State.

[166] URS, 2011, p. 2-1 & 2009, p. 2-1.

Table 5.6 - Types and Purposes of Additives Proposed for Use in New York State (Updated July 2011)

Additive Type	Description of Purpose	Examples of Chemicals[167]
Proppant	"Props" open fractures and allows gas / fluids to flow more freely to the well bore.	Sand [Sintered bauxite; zirconium oxide; ceramic beads]
Acid	Removes cement and drilling mud from casing perforations prior to fracturing fluid injection, and provides accessible path to formation.	Hydrochloric acid (HCl, 3% to 28%) or muriatic acid
Breaker	Reduces the viscosity of the fluid in order to release proppant into fractures and enhance the recovery of the fracturing fluid.	Peroxydisulfates
Bactericide / Biocide / Antibacterial Agent	Inhibits growth of organisms that could produce gases (particularly hydrogen sulfide) that could contaminate methane gas. Also prevents the growth of bacteria which can reduce the ability of the fluid to carry proppant into the fractures.	Gluteraldehyde; 2,2-dibromo-3-nitrilopropionamide
Buffer / pH Adjusting Agent	Adjusts and controls the pH of the fluid in order to maximize the effectiveness of other additives such as crosslinkers	Sodium or potassium carbonate; acetic acid
Clay Stabilizer / Control /KCl	Prevents swelling and migration of formation clays which could block pore spaces thereby reducing permeability.	Salts (e.g., tetramethyl ammonium chloride Potassium chloride (KCl)
Corrosion Inhibitor (including Oxygen Scavengers)	Reduces rust formation on steel tubing, well casings, tools, and tanks (used only in fracturing fluids that contain acid).	Methanol; ammonium bisulfate for Oxygen Scavengers
Crosslinker	Increases fluid viscosity using phosphate esters combined with metals. The metals are referred to as crosslinking agents. The increased fracturing fluid viscosity allows the fluid to carry more proppant into the fractures.	Potassium hydroxide; borate salts
Friction Reducer	Allows fracture fluids to be injected at optimum rates and pressures by minimizing friction.	Sodium acrylate-acrylamide copolymer; polyacrylamide (PAM); petroleum distillates
Gelling Agent	Increases fracturing fluid viscosity, allowing the fluid to carry more proppant into the fractures.	Guar gum; petroleum distillates
Iron Control	Prevents the precipitation of metal oxides which could plug off the formation.	Citric acid;
Scale Inhibitor	Prevents the precipitation of carbonates and sulfates (calcium carbonate, calcium sulfate, barium sulfate) which could plug off the formation.	Ammonium chloride; ethylene glycol;
Solvent	Additive which is soluble in oil, water & acid-based treatment fluids which is used to control the wettability of contact surfaces or to prevent or break emulsions	Various aromatic hydrocarbons
Surfactant	Reduces fracturing fluid surface tension thereby aiding fluid recovery.	Methanol; isopropanol; ethoxylated alcohol

[167] Chemicals in brackets [ ] have not been proposed for use in the State of New York to date, but are known to be used in other states or shale formations.

5.4.3 Composition of Fracturing Fluids

The composition of the fracturing fluid used may vary from one geologic basin or formation to another or from one area to another in order to meet the specific needs of each operation; but the range of additive types available for potential use remains the same. There are a number of different products for each additive type; however, only one product of each type is typically utilized in any given hydraulic fracturing job. The selection may be driven by the formation and potential interactions between additives. Additionally not all additive types will be utilized in every fracturing job.

Sample compositions, by weight, of fracturing fluid are provided in Figure 5.3, Figure 5.4 and Figure 5.5. The composition depicted in Figure 5.3 is based on data from the Fayetteville Shale[168]while those depicted in Figure 5.4 and Figure 5.5 are based on data from Marcellus Shale development in Pennsylvania. Based on this data, between approximately 84 and 90 percent of the fracturing fluid is water; between approximately 8 and 15 % is proppant (Photo 5.17); the remainder, typically less than 1 % consists of chemical additives listed above.

Barnett Shale is considered to be the first instance of extensive high-volume hydraulic fracturing technology use; the technology has since been applied in other areas such as the Fayetteville Shale and the Haynesville Shale. URS notes that data collected from applications to drill Marcellus Shale wells in New York indicate that the typical fracture fluid composition for operations in the Marcellus Shale is similar to the provided composition in the Fayetteville Shale. Even though no horizontal wells have been drilled in the Marcellus Shale in New York, applications filed to date as well as information provided by the industry[169] indicate that it is realistic to expect that the composition of fracture fluids used in the Marcellus Shale in New York would be similar to the fluids used in the Fayetteville Shale and the Marcellus Shale in Pennsylvania.

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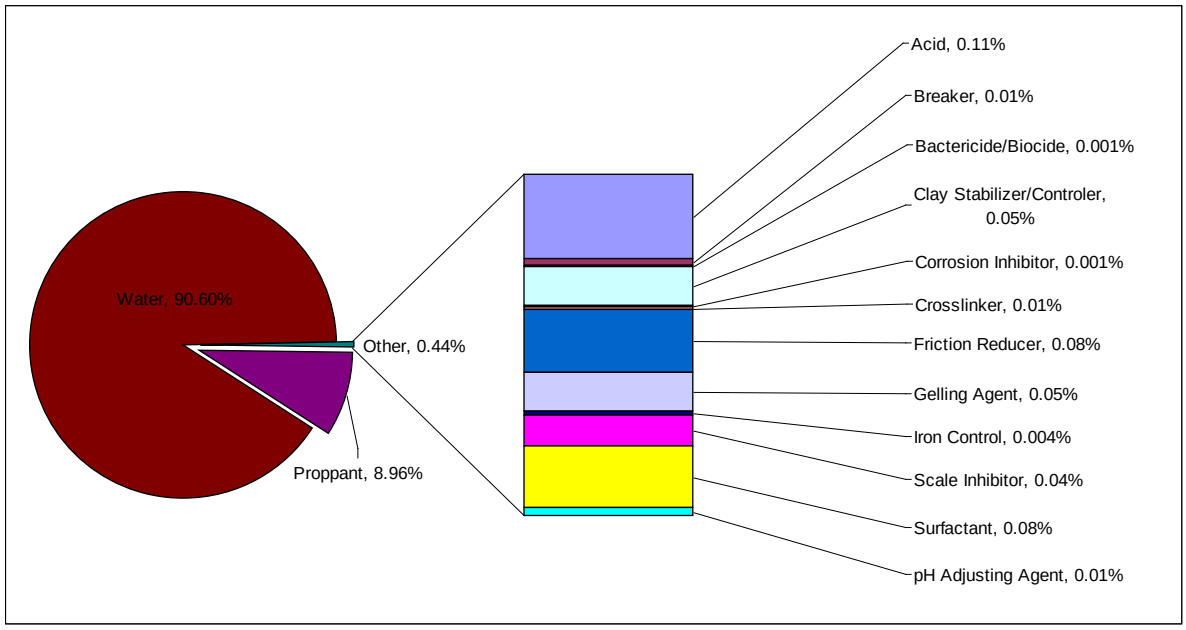
[168] Similar to the Marcellus Shale, the Fayetteville Shale is a marine shale rich in unoxidized carbon (i.e. a black shale). The two shales are at similar depths, and vertical and horizontal wells have been drilled/fractured at both shales.

[169] ALL Consulting, 2010, p. 80.

Photo 5.17 - Sand used as proppant in hydraulic fracturing operation in Bradford County, PA

Figure 5.3 - Sample Fracturing Fluid Composition (12 Additives), by Weight, from Fayetteville Shale[170]



[170] URS, 2009, p. 2-4.

Figure 5.4 - Sample Fracturing Fluid Composition (9 Additives), by Weight, from Marcellus Shale[171] (New July 2011)

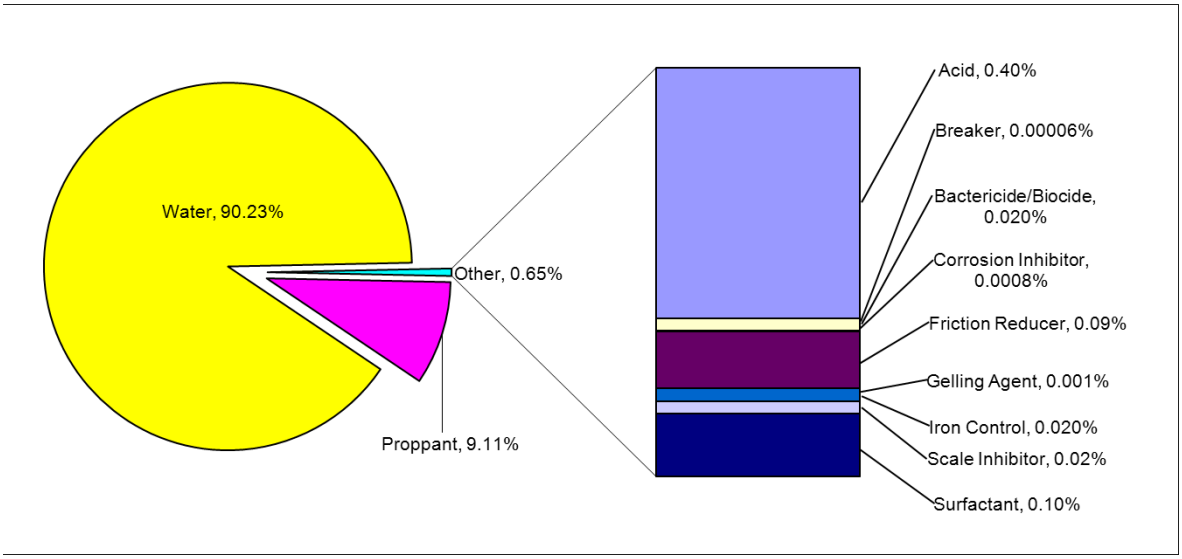
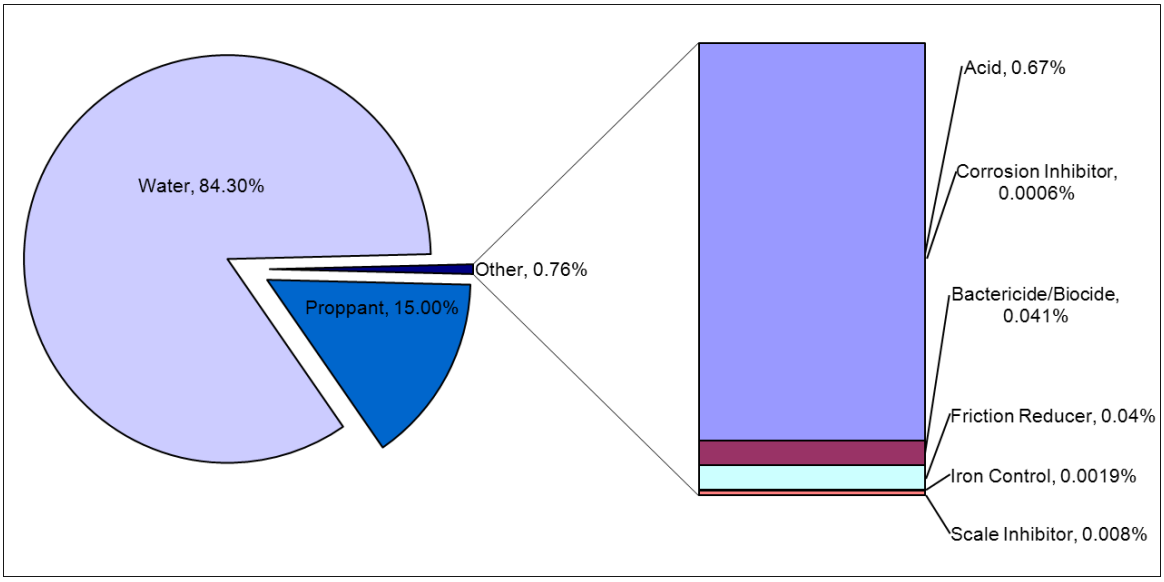


Figure 5.5 - Sample Fracturing Fluid Composition (6 Additives), by Weight, from Marcellus Shale[172] (New July 2011)



[171] URS, 2011, p. 2-4, adapted from ALL Consulting, 2010, p.81.

[172] URS, 2011, p.2-5, adapted from ALL Consulting, 2010, p. 81.

Each product within the 13 classes of additives may be made up of one or more chemical constituents. Table 5.7 is a list of chemical constituents and their CAS numbers, that have been extracted from product composition disclosures and MSDSs submitted to the Department for 235 products used or proposed for use in hydraulic fracturing operations in the Marcellus Shale in New York. It is important to note that several manufacturers/suppliers provide similar products (i.e., chemicals that would serve the same purpose) for any class of additive, and that not all types of additives are used in a single well.

Data provided to the Department to date indicates similar fracturing fluid compositions for vertically and horizontally drilled wells.

Table 5.7 - Chemical Constituents in Additives[173,174,175] (Updated July 2011)

CAS Number[176]	**Chemical Constituent**
106-24-1	(2E)-3,7-dimethylocta-2,6-dien-1-ol
67701-10-4	(C8-C18) and (C18) Unsaturated Alkylcarboxylic Acid Sodium Salt
2634-33-5	1,2 Benzisothiazolin-2-one / 1,2-benzisothiazolin-3-one
95-63-6	1,2,4 trimethylbenzene
93858-78-7	1,2,4-Butanetricarboxylicacid, 2-phosphono-, potassium salt
123-91-1	1,4 Dioxane
3452-07-1	1-eicosene
629-73-2	1-hexadecene
104-46-1	1-Methoxy-4-propenylbenzene
124-28-7	1-Octadecanamine, N, N-dimethyl- / N,N-Dimthyloctadecylamine
112-03-8	1-Octadecanaminium, N,N,N-Trimethyl-, Chloride /Trimethyloctadecylammonium chloride
112-88-9	1-octadecene
40623-73-2	1-Propanesulfonic acid
1120-36-1	1-tetradecene
95077-68-2	2- Propenoic acid, homopolymer sodium salt

[173] Table 5.7, is a list of chemical constituents and their CAS numbers that have been extracted from product composition disclosures and MSDSs submitted to the Department. It was compiled by URS Corporation (2011) and was adapted by the Department to ensure that it accurately reflects the data submitted.

[174] These are the chemical constituents of all chemical additives proposed to be used in New York for hydraulic fracturing operations at shale wells. Only a few chemicals would be used in a single well; the list of chemical constituents used in an individual well would be correspondingly smaller.

[175] This list does not include chemicals that are exclusively used for drilling.

[176] Chemical Abstracts Service (CAS) is a division of the American Chemical Society. CAS assigns unique numerical identifiers to every chemical described in the literature. The intention is to make database searches more convenient, as chemicals often have many names. Almost all molecule databases today allow searching by CAS number.

CAS Number[176]	Chemical Constituent
98-55-5	2-(4-methyl-1-cyclohex-3-enyl)propan-2-ol
10222-01-2	2,2 Dibromo-3-nitrilopropionamide
27776-21-2	2,2'-azobis-{2-(imidazlin-2-yl)propane}-dihydrochloride
73003-80-2	2,2-Dobromomalonamide
15214-89-8	2-Acrylamido-2-methylpropanesulphonic acid sodium salt polymer
46830-22-2	2-acryloyloxyethyl(benzyl)dimethylammonium chloride
52-51-7	2-Bromo-2-nitro-1,3-propanediol
111-76-2	2-Butoxy ethanol / Ethylene glycol monobutyl ether / Butyl Cellusolve
1113-55-9	2-Dibromo-3-Nitriloprionamide /2-Monobromo-3-nitriilopropionamide
104-76-7	2-Ethyl Hexanol
67-63-0	2-Propanol / Isopropyl Alcohol / Isopropanol / Propan-2-ol
26062-79-3	2-Propen-1-aminium, N,N-dimethyl-N-2-propenyl-chloride, homopolymer
9003-03-6	2-propenoic acid, homopolymer, ammonium salt
25987-30-8	2-Propenoic acid, polymer with 2 p-propenamide, sodium salt / Copolymer of acrylamide and sodium acrylate
71050-62-9	2-Propenoic acid, polymer with sodium phosphinate (1:1)
66019-18-9	2-propenoic acid, telomer with sodium hydrogen sulfite
107-19-7	2-Propyn-1-ol / Progargyl Alcohol
51229-78-8	3,5,7-Triaza-1-azoniatricyclo[3.3.1.13,7]decane, 1-(3-chloro-2-propenyl)-chloride,
106-22-9	3,7 - dimethyl-6-octen-1-ol
5392-40-5	3,7- dimethyl-2,6-octadienal
115-19-5	3-methyl-1-butyn-3-ol
104-55-2	3-phenyl-2-propenal
127-41-3	4-(2,6,6-trimethyl-1-cyclohex-2-enyl)-3-buten-2-one
121-33-5	4-hydroxy-3-methoxybenzaldehyde
127087-87-0	4-Nonylphenol Polyethylene Glycol Ether Branched / Nonylphenol ethoxylated / Oxyalkylated Phenol
64-19-7	Acetic acid
68442-62-6	Acetic acid, hydroxy-, reaction products with triethanolamine
108-24-7	Acetic Anhydride
67-64-1	Acetone
79-06-1	Acrylamide
38193-60-1	Acrylamide - sodium 2-acrylamido-2-methylpropane sulfonate copolymer
25085-02-3	Acrylamide - Sodium Acrylate Copolymer / Anionic Polyacrylamide / 2-Propanoic Acid
69418-26-4	Acrylamide polymer with N,N,N-trimethyl-2[1-oxo-2-propenyl]oxy Ethanaminium chloride / Ethanaminium, N, N, N-trimethyl-2-[(1-oxo-2-propenyl)oxy]-, chloride, polymer with 2-propenamide (9Cl)
68891-29-2	Alcohols C8-10, ethoxylated, monoether with sulfuric acid, ammonium salt
68526-86-3	Alcohols, C11-14-iso, C13-rich
68551-12-2	Alcohols, C12-C16, Ethoxylated / Ethoxylated alcohol
64742-47-8	Aliphatic Hydrocarbon / Hydrotreated light distillate / Petroleum Distillates / Isoparaffinic Solvent / Paraffin Solvent / Napthenic Solvent
64743-02-8	Alkenes

CAS Number[176]	Chemical Constituent
68439-57-6	Alkyl (C14-C16) olefin sulfonate, sodium salt
9016-45-9	Alkylphenol ethoxylate surfactants
1327-41-9	Aluminum chloride
68155-07-7	Amides, C8-18 and C19-Unsatd., N,N-Bis(hydroxyethyl)
73138-27-9	Amines, C12-14-tert-alkyl, ethoxylated
71011-04-6	Amines, Ditallow alkyl, ethoxylated
68551-33-7	Amines, tallow alkyl, ethoxylated, acetates
1336-21-6	Ammonia
631-61-8	Ammonium acetate
68037-05-8	Ammonium Alcohol Ether Sulfate
7783-20-2	Ammonium bisulfate
10192-30-0	Ammonium Bisulphite
12125-02-9	Ammonium Chloride
7632-50-0	Ammonium citrate
37475-88-0	Ammonium Cumene Sulfonate
1341-49-7	Ammonium hydrogen-difluoride
6484-52-2	Ammonium nitrate
7727-54-0	Ammonium Persulfate / Diammonium peroxidisulphate
1762-95-4	Ammonium Thiocyanate
12174-11-7	Attapulgite Clay
121888-68-4	Bentonite, benzyl(hydrogenated tallow alkyl) dimethylammonium stearate complex / organophilic clay
71-43-2	Benzene
119345-04-9	Benzene, 1,1'-oxybis, tetratpropylene derivatives, sulfonated, sodium salts
74153-51-8	Benzenemethanaminium, N,N-dimethyl-N-[2-[(1-oxo-2-propenyl)oxy]ethyl]-, chloride, polymer with 2-propenamide
122-91-8	Benzenemethanol,4-methoxy-, 1-formate
1300-72-7	Benzenesulfonic acid, Dimethyl-, Sodium salt /Sodium xylene sulfonate
140-11-4	Benzyl acetate
76-22-2	Bicyclo (2.2.1) heptan-2-one, 1,7,7-trimethyl-
68153-72-0	Blown lard oil amine
68876-82-4	Blown rapeseed amine
1319-33-1	Borate Salt
10043-35-3	Boric acid
1303-86-2	Boric oxide / Boric Anhydride
71-36-3	Butan-1-ol
68002-97-1	C10 - C16 Ethoxylated Alcohol
68131-39-5	C12-15 Alcohol, Ethoxylated
1317-65-3	Calcium Carbonate
10043-52-4	Calcium chloride
1305-62-0	Calcium Hydroxide
1305-79-9	Calcium Peroxide
124-38-9	Carbon Dioxide
68130-15-4	Carboxymethylhydroxypropyl guar

CAS Number[176]	Chemical Constituent
9012-54-8	Cellulase / Hemicellulase Enzyme
9004-34-6	Cellulose
10049-04-4	Chlorine Dioxide
78-73-9	Choline Bicarbonate
67-48-1	Choline Chloride
91-64-5	Chromen-2-one
77-92-9	Citric Acid
94266-47-4	Citrus Terpenes
61789-40-0	Cocamidopropyl Betaine
68155-09-9	Cocamidopropylamine Oxide
68424-94-2	Coco-betaine
7758-98-7	Copper (II) Sulfate
14808-60-7	Crystalline Silica (Quartz)
7447-39-4	Cupric chloride dihydrate
1490-04-6	Cyclohexanol,5-methyl-2-(1-methylethyl)
8007-02-1	Cymbopogon citratus leaf oil
8000-29-1	Cymbopogon winterianus jowitt oil
1120-24-7	Decyldimethyl Amine
2605-79-0	Decyl-dimethyl Amine Oxide
3252-43-5	Dibromoacetonitrile
25340-17-4	Diethylbenzene
111-46-6	Diethylene Glycol
22042-96-2	Diethylenetriamine penta (methylenephonic acid) sodium salt
28757-00-8	Diisopropyl naphthalenesulfonic acid
68607-28-3	Dimethylcocoamine, bis(chloroethyl) ether, diquaternary ammonium salt
7398-69-8	Dimethyldiallylammonium chloride
25265-71-8	Dipropylene glycol
34590-94-8	Dipropylene Glycol Methyl Ether
139-33-3	Disodium Ethylene Diamine Tetra Acetate
64741-77-1	Distillates, petroleum, light hydrocracked
5989-27-5	D-Limonene
123-01-3	Dodecylbenzene
27176-87-0	Dodecylbenzene sulfonic acid
42504-46-1	Dodecylbenzenesulfonate isopropanolamine
50-70-4	D-Sorbitol / Sorbitol
37288-54-3	Endo-1,4-beta-mannanase, or Hemicellulase
149879-98-1	Erucic Amidopropyl Dimethyl Betaine
89-65-6	Erythorbic acid, anhydrous
54076-97-0	Ethanaminium, N,N,N-trimethyl-2-[(1-oxo-2-propenyl)oxy]-, chloride, homopolymer
107-21-1	Ethane-1,2-diol / Ethylene Glycol
111-42-2	Ethanol, 2,2-iminobis-
26027-38-3	Ethoxylated 4-nonylphenol
9002-93-1	Ethoxylated 4-tert-octylphenol

CAS Number[176]	Chemical Constituent
68439-50-9	Ethoxylated alcohol
126950-60-5	Ethoxylated alcohol
67254-71-1	Ethoxylated alcohol (C10-12)
68951-67-7	Ethoxylated alcohol (C14-15)
68439-46-3	Ethoxylated alcohol (C9-11)
66455-15-0	Ethoxylated Alcohols
84133-50-6	Ethoxylated Alcohols (C12-14 Secondary)
68439-51-0	Ethoxylated Alcohols (C12-14)
78330-21-9	Ethoxylated branch alcohol
34398-01-1	Ethoxylated C11 alcohol
78330-21-8	Ethoxylated C11-14-iso, C13-rich alcohols
61791-12-6	Ethoxylated Castor Oil
61791-29-5	Ethoxylated fatty acid, coco
61791-08-0	Ethoxylated fatty acid, coco, reaction product with ethanolamine
68439-45-2	Ethoxylated hexanol
9036-19-5	Ethoxylated octylphenol
9005-67-8	Ethoxylated Sorbitan Monostearate
9005-70-3	Ethoxylated Sorbitan Trioleate
64-17-5	Ethyl alcohol / ethanol
100-41-4	Ethyl Benzene
93-89-0	Ethyl benzoate
97-64-3	Ethyl Lactate
9003-11-6	Ethylene Glycol-Propylene Glycol Copolymer (Oxirane, methyl-, polymer with oxirane)
75-21-8	Ethylene oxide
5877-42-9	Ethyloctynol
8000-48-4	Eucalyptus globulus leaf oil
61790-12-3	Fatty Acids
68604-35-3	Fatty acids, C 8-18 and C18-unsaturated compounds with diethanolamine
68188-40-9	Fatty acids, tall oil reaction products w/ acetophenone, formaldehyde & thiourea
9043-30-5	Fatty alcohol polyglycol ether surfactant
7705-08-0	Ferric chloride
7782-63-0	Ferrous sulfate, heptahydrate
50-00-0	Formaldehyde
29316-47-0	Formaldehyde polymer with 4,1,1-dimethylethyl phenolmethyl oxirane
153795-76-7	Formaldehyde, polymers with branched 4-nonylphenol, ethylene oxide and propylene oxide
75-12-7	Formamide
64-18-6	Formic acid
110-17-8	Fumaric acid
111-30-8	Glutaraldehyde
56-81-5	Glycerol / glycerine
9000-30-0	Guar Gum

CAS Number[176]	Chemical Constituent
64742-94-5	Heavy aromatic petroleum naphtha
9025-56-3	Hemicellulase
7647-01-0	Hydrochloric Acid / Hydrogen Chloride / muriatic acid
7722-84-1	Hydrogen Peroxide
64742-52-5	Hydrotreated heavy napthenic (petroleum) distillate
79-14-1	Hydroxy acetic acid
35249-89-9	Hydroxyacetic acid ammonium salt
9004-62-0	Hydroxyethyl cellulose
5470-11-1	Hydroxylamine hydrochloride
39421-75-5	Hydroxypropyl guar
35674-56-7	Isomeric Aromatic Ammonium Salt
64742-88-7	Isoparaffinic Petroleum Hydrocarbons, Synthetic
64-63-0	Isopropanol
98-82-8	Isopropylbenzene (cumene)
68909-80-8	Isoquinoline, reaction products with benzyl chloride and quinoline
8008-20-6	Kerosene
64742-81-0	Kerosine, hydrodesulfurized
63-42-3	Lactose
8022-15-9	Lavandula hybrida abrial herb oil
64742-95-6	Light aromatic solvent naphtha
1120-21-4	Light Paraffin Oil
546-93-0	Magnesium Carbonate
1309-48-4	Magnesium Oxide
1335-26-8	Magnesium Peroxide
14807-96-6	Magnesium Silicate Hydrate (Talc)
1184-78-7	methanamine, N,N-dimethyl-, N-oxide
67-56-1	Methanol
119-36-8	Methyl 2-hydroxybenzoate
68891-11-2	Methyloxirane polymer with oxirane, mono (nonylphenol) ether, branched
8052-41-3	Mineral spirits / Stoddard Solvent
64742-46-7	Mixture of severely hydrotreated and hydrocracked base oil
141-43-5	Monoethanolamine
44992-01-0	N,N,N-trimethyl-2[1-oxo-2-propenyl]oxy Ethanaminium chloride
64742-48-9	Naphtha (petroleum), hydrotreated heavy
91-20-3	Naphthalene
38640-62-9	Naphthalene bis(1-methylethyl)
93-18-5	Naphthalene, 2-ethoxy-
68909-18-2	N-benzyl-alkyl-pyridinium chloride
68139-30-0	N-Cocoamidopropyl-N,N-dimethyl-N-2-hydroxypropylsulfobetaine
68424-94-2	N-Cocoamidopropyl-N,N-dimethyl-N-2-hydroxypropylsulfobetaine
7727-37-9	Nitrogen, Liquid form
68412-54-4	Nonylphenol Polyethoxylate
8000-27-9	Oils, cedarwood

CAS Number[176]	Chemical Constituent
121888-66-2	Organophilic Clays
628-63-7	Pentyl acetate
540-18-1	Pentyl butanoate
8009-03-8	Petrolatum
64742-65-0	Petroleum Base Oil
64741-68-0	Petroleum naphtha
101-84-8	Phenoxybenzene
70714-66-8	Phosphonic acid, [[(phosphonomethyl)imino]bis[2,1-ethanediylnitrilobis(methylene)]]tetrakis-, ammonium salt
8000-41-7	Pine Oil
8002-09-3	Pine Oils
60828-78-6	Poly(oxy-1,2-ethanediyl), a-[3,5-dimethyl-1-(2-methylpropyl)hexyl]-w-hydroxy-
25322-68-3	Poly(oxy-1,2-ethanediyl), a-hydro-w-hydroxy / Polyethylene Glycol
31726-34-8	Poly(oxy-1,2-ethanediyl), alpha-hexyl-omega-hydroxy
24938-91-8	Poly(oxy-1,2-ethanediyl), α-tridecyl-ω-hydroxy-
9004-32-4	Polyanionic Cellulose
51838-31-4	Polyepichlorohydrin, trimethylamine quaternized
56449-46-8	Polyethlene glycol oleate ester
9046-01-9	Polyethoxylated tridecyl ether phosphate
63428-86-4	Polyethylene glycol hexyl ether sulfate, ammonium salt
62649-23-4	Polymer with 2-propenoic acid and sodium 2-propenoate
9005-65-6	Polyoxyethylene Sorbitan Monooleate
61791-26-2	Polyoxylated fatty amine salt
65997-18-4	Polyphosphate
127-08-2	Potassium acetate
12712-38-8	Potassium borate
1332-77-0	Potassium borate
20786-60-1	Potassium Borate
584-08-7	Potassium carbonate
7447-40-7	Potassium chloride
590-29-4	Potassium formate
1310-58-3	Potassium Hydroxide
13709-94-9	Potassium metaborate
24634-61-5	Potassium Sorbate
112926-00-8	Precipitated silica / silica gel
57-55-6	Propane-1,2-diol, /Propylene glycol
107-98-2	Propylene glycol monomethyl ether
68953-58-2	Quaternary Ammonium Compounds
62763-89-7	Quinoline,2-methyl-, hydrochloride
62763-89-7	Quinoline,2-methyl-, hydrochloride
15619-48-4	Quinolinium, 1-(phenylmethl),chloride
8000-25-7	Rosmarinus officinalis l. leaf oil
7631-86-9	Silica, Dissolved

CAS Number[176]	Chemical Constituent
5324-84-5	Sodium 1-octanesulfonate
127-09-3	Sodium acetate
95371-16-7	Sodium Alpha-olefin Sulfonate
532-32-1	Sodium Benzoate
144-55-8	Sodium bicarbonate
7631-90-5	Sodium bisulfate
7647-15-6	Sodium Bromide
497-19-8	Sodium carbonate
7647-14-5	Sodium Chloride
7758-19-2	Sodium chlorite
3926-62-3	Sodium Chloroacetate
68-04-2	Sodium citrate
6381-77-7	Sodium erythorbate / isoascorbic acid, sodium salt
2836-32-0	Sodium Glycolate
1310-73-2	Sodium Hydroxide
7681-52-9	Sodium hypochlorite
7775-19-1	Sodium Metaborate .8H_2O
10486-00-7	Sodium perborate tetrahydrate
7775-27-1	Sodium persulphate
68608-26-4	Sodium petroleum sulfonate
9003-04-7	Sodium polyacrylate
7757-82-6	Sodium sulfate
1303-96-4	Sodium tetraborate decahydrate
7772-98-7	Sodium Thiosulfate
1338-43-8	Sorbitan Monooleate
57-50-1	Sucrose
5329-14-6	Sulfamic acid
68442-77-3	Surfactant: Modified Amine
112945-52-5	Syntthetic Amorphous / Pyrogenic Silica / Amorphous Silica
68155-20-4	Tall Oil Fatty Acid Diethanolamine
8052-48-0	Tallow fatty acids sodium salt
72480-70-7	Tar bases, quinoline derivs., benzyl chloride-quaternized
68647-72-3	Terpene and terpenoids
68956-56-9	Terpene hydrocarbon byproducts
533-74-4	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione (a.k.a. Dazomet)
55566-30-8	Tetrakis(hydroxymethyl)phosphonium sulfate (THPS)
75-57-0	Tetramethyl ammonium chloride
64-02-8	Tetrasodium Ethylenediaminetetraacetate
68-11-1	Thioglycolic acid
62-56-6	Thiourea
68527-49-1	Thiourea, polymer with formaldehyde and 1-phenylethanone
68917-35-1	Thuja plicata donn ex. D. don leaf oil
108-88-3	Toluene

CAS Number[176]	Chemical Constituent
81741-28-8	Tributyl tetradecyl phosphonium chloride
68299-02-5	Triethanolamine hydroxyacetate
68442-62-6	Triethanolamine hydroxyacetate
112-27-6	Triethylene Glycol
52624-57-4	Trimethylolpropane, Ethoxylated, Propoxylated
150-38-9	Trisodium Ethylenediaminetetraacetate
5064-31-3	Trisodium Nitrilotriacetate
7601-54-9	Trisodium ortho phosphate
57-13-6	Urea
25038-72-6	Vinylidene Chloride/Methylacrylate Copolymer
7732-18-5	Water
8042-47-5	White Mineral Oil
11138-66-2	Xanthan gum
1330-20-7	Xylene
13601-19-9	Yellow Sodium of Prussiate

Chemical Constituent
Aliphatic acids
Aliphatic alcohol glycol ether
Alkyl Aryl Polyethoxy Ethanol
Alkylaryl Sulfonate
Anionic copolymer
Aromatic hydrocarbons
Aromatic ketones
Citric acid base formula
Ethoxylated alcohol blend/mixture
Hydroxy acetic acid
Oxyalkylated alkylphenol
Petroleum distillate blend
Polyethoxylated alkanol
Polymeric Hydrocarbons
Quaternary amine
Quaternary ammonium compound
Salt of amine-carbonyl condensate
Salt of fatty acid/polyamine reaction product
Sugar
Surfactant blend
Triethanolamine

The chemical constituents listed in Table 5.7 are not linked to the product names listed in Table 5.4 and Table 5.5 because a significant number of product compositions have been properly justified as trade secrets within the coverage of disclosure exceptions of the Freedom of

Information Law [Public Officers Law §87.2(d)] and the Department's implementing regulation, 6 NYCRR § 616.7. The Department however, considers MSDSs to be public information ineligible for exception from disclosure as trade secrets or confidential business information.

5.4.3.1 Chemical Categories and Health Information

The Department requested assistance from NYSDOH in identifying potential exposure pathways and constituents of concern associated with high-volume hydraulic fracturing for low-permeability gas reservoir development. The Department provided DOH with fracturing additive product constituents based on MSDSs and product-composition disclosures for hydraulic fracturing additive products that were provided by well-service companies and the chemical supply companies that manufacture the products.

Compound-specific toxicity data are very limited for many chemical additives to fracturing fluids, so chemicals potentially present in fracturing fluids were grouped together into categories according to their chemical structure (or function in the case of microbiocides) in Table 5.8, compiled by NYSDOH. As explained above, any given individual fracturing job will only involve a handful of chemicals and may not include every category of chemicals.

Table 5.8 - Categories based on chemical structure of potential fracturing fluid constituents.[177] (Updated July 2011)

Chemical	CAS Number
Amides	
Formamide	75-12-7
acrylamide	79-06-1
Amides, C8-18 and C19-Unsatd., N,N-Bis(hydroxyethyl)	68155-07-7
Amines	
urea	57-13-6
thiourea	62-56-6
Choline chloride	67-48-1
tetramethyl ammonium chloride	75-57-0
Choline Bicarbonate	78-73-9
Ethanol, 2,2-Iminobis-	111-42-2
1-Octadecanaminium, N,N,N, Trimethyl-, Chloride (aka Trimethyloctadecylammonium choride)	112-03-8
1-Octadecanamine, N,N-Dimethyl- (aka N,N-Dimethyloctadecylamine)	124-28-7
monoethanolamine	141-43-5

[177] The chemicals listed in this table are organized in order of ascending CAS Number by category.

Chemical	CAS Number
Decyldimethyl Amine	1120-24-7
methanamine, N,N-dimethyl-, N-oxide	1184-78-7
Decyl-dimethyl Amine Oxide	2605-79-0
dimethyldiallylammonium chloride	7398-69-8
polydimethyl dially ammonium chloride	26062-79-3
dodecylbenzenesulfonate isopropanolamine	42504-46-1
N,N,N-trimethyl-2[1-oxo-2-propenyl]oxy ethanaminium chloride	44992-01-0
2-acryloyloxyethyl(benzyl)dimethylammonium chloride	46830-22-2
ethanaminium, N,N,N-trimethyl-2-[(1-oxo-2-propenyl)oxy]-, chloride, homopolymer	54076-97-0
Cocamidopropyl Betaine	61789-40-0
Quaternary Ammonium Chloride	61789-71-7
polyoxylated fatty amine salt	61791-26-2
quinoline, 2-methyl, hydrochloride	62763-89-7
N-cocoamidopropyl-N,N-dimethyl-N-2-hydroxypropylsulfobetaine	68139-30-0
tall oil fatty acid diethanolamine	68155-20-4
N-cocoamidopropyl-N,N-dimethyl-N-2-hydroxypropylsulfobetaine	68424-94-2
amines, tallow alkyl, ethoxylated, acetates	68551-33-7
quaternary ammonium compounds, bis(hydrogenated tallow alkyl) dimethyl, salts with bentonite	68953-58-2
amines, ditallow alkyl, ethoxylated	71011-04-6
amines, C-12-14-tert-alkyl, ethoxylated	73138-27-9
benzenemethanaminium, N,N-dimethyl-N-[2-[(1-oxo-2-propenyl)oxy]ethyl]-, chloride, polymer with 2-propenamide	74153-51-8
Erucic Amidopropyl Dimethyl Betaine	149879-98-1
Petroleum Distillates	
light paraffin oil	1120-21-4
kerosene	8008-20-6
Petrolatum	8009-03-8
White Mineral Oil	8042-47-5
stoddard solvent	8052-41-3
Distillates, petroleum, light hydrocracked	64741-77-1
petroleum naphtha	64741-68-0
Mixture of severely hydrotreated and hydrocracked base oil	64742-46-7
<u>Multiple names listed under same CAS#:</u> LVP aliphatic hydrocarbon, hydrotreated light distillate, low odor paraffin solvent, paraffin solvent, paraffinic napthenic solvent, isoparaffinic solvent, distillates (petroleum) hydrotreated light, petroleum light distillate, aliphatic hydrocarbon, petroleum distillates, mixture of severely hydrotreated and hydrocracked base oil	64742-47-8
naphtha, hydrotreated heavy	64742-48-9

Chemical	CAS Number
Multiple names listed under same CAS#: hydrotreated heavy napthenic distillate, Petroleum distillates	64742-52-5
petroleum base oil	64742-65-0
kerosine (petroleum, hydrodesulfurized)	64742-81-0
kerosine (petroleum, hydrodesulfurized)	64742-88-7
Multiple names listed under same CAS#: heavy aromatic petroleum naphtha, light aromatic solvent naphtha	64742-94-5
light aromatic solvent naphtha	64742-95-6
alkenes, C> 10 α-	64743-02-8
Aromatic Hydrocarbons	
benzene	71-43-2
naphthalene	91-20-3
naphthalene, 2-ethoxy	93-18-5
1,2,4-trimethylbenzene	95-63-6
cumene	98-82-8
ethyl benzene	100-41-4
toluene	108-88-3
dodecylbenzene	123-01-3
xylene	1330-20-7
diethylbenzene	25340-17-4
naphthalene bis(1-methylethyl)	38640-62-9
Alcohols & Aldehydes	
formaldehyde	50-00-0
sorbitol (or) D-sorbitol	50-70-4
Glycerol	56-81-5
propylene glycol	57-55-6
ethanol	64-17-5
isopropyl alcohol	67-63-0
methanol	67-56-1
isopropyl alcohol	67-63-0
butanol	71-36-3
2-(4-methyl-1-cyclohex-3-enyl)propan-2-ol	98-55-5
3-phenylprop-2-enal	104-55-2
2-ethyl-1-hexanol	104-76-7
3,7 - dimethyloct-6-en-1-ol	106-22-9
(2E)-3,7-dimethylocta-2,6-dien-1-ol	106-24-1
propargyl alcohol	107-19-7
ethylene glycol	107-21-1
Diethylene Glycol	111-46-6
3-methyl-1-butyn-3-ol	115-19-5
4-hydroxy-3-methyoxybenzaldehyde	121-33-5
5-methyl-2-propan-2-ylcyclohexan-1-ol	1490-04-6
3,7-dimethylocta-2,6-dienal	5392-40-5
Ethyloctynol	5877-42-9

Chemical	CAS Number
Glycol Ethers, Ethoxylated Alcohols & Other Ethers	
phenoxybenzene	101-84-8
1-methyoxy-4-prop-1-enylbenzene	104-46-1
propylene glycol monomethyl ether	107-98-2
ethylene glycol monobutyl ether	111-76-2
triethylene glycol	112-27-6
ethoxylated 4-tert-octylphenol	9002-93-1
ethoxylated sorbitan trioleate	9005-70-3
Polysorbate 80	9005-65-6
ethoxylated sorbitan monostearate	9005-67-8
Polyethylene glycol-(phenol) ethers	9016-45-9
Polyethylene glycol-(phenol) ethers	9036-19-5
fatty alcohol polyglycol ether surfactant	9043-30-5
Poly(oxy-1,2-ethanediyl), α-tridecyl-ω-hydroxy-	24938-91-8
Dipropylene glycol	25265-71-8
Nonylphenol Ethoxylate	26027-38-3
crissanol A-55	31726-34-8
Polyethylene glycol-(alcohol) ethers	34398-01-1
dipropylene glycol methyl ether	34590-94-8
Trimethylolpropane, Ethoxylated, Propoxylated	52624-57-4
Polyethylene glycol-(alcohol) ethers	60828-78-6
Ethoxylated castor oil [PEG-10 Castor oil]	61791-12-6
ethoxylated alcohols	66455-15-0
ethoxylated alcohol	67254-71-1
Ethoxylated alcohols (9 – 16 carbon atoms)	68002-97-1
ammonium alcohol ether sulfate	68037-05-8
Polyethylene glycol-(alcohol) ethers	68131-39-5
Polyethylene glycol-(phenol) ethers	68412-54-4
ethoxylated hexanol	68439-45-2
Polyethylene glycol-(alcohol) ethers	68439-46-3
Ethoxylated alcohols (9 – 16 carbon atoms)	68439-50-9
C12-C14 ethoxylated alcohols	68439-51-0
Exxal 13	68526-86-3
Ethoxylated alcohols (9 – 16 carbon atoms)	68551-12-2
alcohols, C-14-15, ethoxylated	68951-67-7
Ethoxylated C11-14-iso, C13-rich alcohols	78330-21-8
Ethoxylated Branched C11-14, C-13-rich Alcohols	78330-21-9
Ethoxylated alcohols (9 – 16 carbon atoms)	84133-5-6
alcohol ethoxylated	126950-60-5
Polyethylene glycol-(phenol) ethers	127087-87-0
Microbiocides	
bronopol	52-51-7
glutaraldehyde	111-30-8
2-monobromo-3-nitrilopropionamide	1113-55-9
1,2-benzisothiazolin-3-one	2634-33-5
dibromoacetonitrile	3252-43-5
dazomet	533-74-4

Chemical	CAS Number
Hydrogen Peroxide	7722-84-1
2,2-dibromo-3-nitrilopropionamide	10222-01-2
tetrakis	55566-30-8
2,2-dibromo-malonamide	73003-80-2
Organic Acids, Salts, Esters and Related Chemicals	
tetrasodium EDTA	64-02-8
formic acid	64-18-6
acetic acid	64-19-7
sodium citrate	68-04-2
thioglycolic acid	68-11-1
hydroxyacetic acid	79-14-1
erythorbic acid, anhydrous	89-65-6
ethyl benzoate	93-89-0
ethyl lactate	97-64-3
acetic anhydride	108-24-7
fumaric acid	110-17-8
ethyl 2-hydroxybenzoate	118-61-6
methyl 2-hydroxybenzoate	119-36-8
(4-methoxyphenyl) methyl formate	122-91-8
potassium acetate	127-08-2
sodium acetate	127-09-3
Disodium Ethylene Diamine Tetra Acetate	139-33-3
benzyl acetate	140-11-4
Trisodium Ethylenediamine tetraacetate	150-38-9
sodium benzoate	532-32-1
pentyl butanoate	540-18-1
potassium formate	590-29-4
pentyl acetate	628-63-7
ammonium acetate	631-61-8
Benzenesulfonic acid, Dimethyl-, Sodium salt (aka Sodium xylene sulfonate)	1300-72-7
Sodium Glycolate	2836-32-0
Sodium Chloroacetate	3926-62-3
trisodium nitrilotriacetate	5064-31-3
sodium 1-octanesulfonate	5324-84-5
Sodium Erythorbate	6381-77-7
ammonium citrate	7632-50-0
tallow fatty acids sodium salt	8052-48-0
Polyethoxylated tridecyl ether phosphate	9046-01-9
quinolinium, 1-(phenylmethyl), chloride	15619-48-4
diethylenetriamine penta (methylenephonic acid) sodium salt	22042-96-2
potassium sorbate	24634-61-5
dodecylbenzene sulfonic acid	27176-87-0
diisopropyl naphthalenesulfonic acid	28757-00-8
hydroxyacetic acid ammonium salt	35249-89-9
isomeric aromatic ammonium salt	35674-56-7
ammonium cumene sulfonate	37475-88-0
Fatty Acids	61790-12-3

Chemical	CAS Number
Fatty acids, coco, reaction products with ethanolamine, ethoxylated	61791-08-0
fatty acid, coco, ethoxylated	61791-29-5
2-propenoic acid, telomer with sodium hydrogen sulfite	66019-18-9
fatty acides, c8-18 and c18-unsatd., sodium salts	67701-10-4
carboxymethylhydroxypropyl guar	68130-15-4
Blown lard oil amine	68153-72-0
Tall oil Fatty Acid Diethanolamine	68155-20-8
fatty acids, tall oil reaction products w/ acetophenone, formaldehyde & thiourea	68188-40-9
triethanolamine hydroxyacetate	68299-02-5
alkyl (C14-C16) olefin sulfonate, sodium salt	68439-57-6
triethanolamine hydroxyacetate	68442-62-6
Modified Amine	68442-77-3
fatty acids, c-18-18 and c18-unsatd., compds with diethanolamine	68604-35-3
Sodium petroleum sulfonate	68608-26-4
Blown rapeseed amine	68876-82-4
Poly(oxy-1,2-ethanediyl), α-sulfo-ω-hydroxy-, c8-10-alkyl ethers, ammonium salts	68891-29-2
N-benzyl-alkyl-pyridinium chloride	68909-18-2
phosphonic acid, [[(phosphonomethyl)imino]bis[2,1-ethanediylnitrilobis (methylene)]]tetrakis-ammonium salt	70714-66-8
tributyl tetradecyl phosphonium chloride	81741-28-8
2-Phosphonobutane-1,2,4-tricarboxylic acid, potassium salt	93858-78-7
sodium alpha-olefin sulfonate	95371-16-7
benzene, 1,1'-oxybis, tetratpropylene derivatives, sulfonated, sodium salts	119345-04-9
Polymers	
guar gum	9000-30-0
guar gum	9000-30-01
2-propenoic acid, homopolymer, ammonium salt	9003-03-6
low mol wt polyacrylate	9003-04-7
Low Mol. Wt. Polyacrylate	9003-04-7
Multiple names listed under same CAS#: oxirane, methyl-, polymer with oxirane, Ethylene Glycol-Propylene Glycol Copolymer	9003-11-6
Polyanionic Cellulose	9004-32-4
cellulose	9004-34-6
hydroxyethyl cellulose	9004-62-0
cellulase/hemicellulase enzyme	9012-54-8
hemicellulase	9025-56-3
xanthan gum	11138-66-2
acrylamide-sodium acrylate copolymer	25085-02-3
Vinylidene Chloride/Methylacrylate Copolymer	25038-72-6
polyethylene glycol	25322-68-3
copolymer of acrylamide and sodium acrylate	25987-30-8
formaldehyde polymer with 4,1,1-dimethylethyl phenolmethyl oxirane	29316-47-0
hemicellulase	37288-54-3
acrylamide - sodium 2-acrylamido-2-methylpropane sulfonate copolymer	38193-60-1
TerPoly (Acrylamide-AMPS Acrylic Acid)	40623-73-2

Chemical	CAS Number
oxiranemthanaminium, N,N,N-trimethyl-, chloride, homopolymer (aka: polyepichlorohydrin, trimethylamine quaternized)	51838-31-4
polyethlene glycol oleate ester	56449-46-8
polymer with 2-propenoic acid and sodium 2-propenoate	62649-23-4
modified thiourea polymer	68527-49-1
methyloxirane polymer with oxirane, mono (nonylphenol) ether, branched	68891-11-2
acrylamide polymer with N,N,N-trimethyl-2[1-oxo-2-propenyl]oxy ethanaminium chloride	69418-26-4
2-propenoic acid, polymer with sodium phosphinate (1:1)	71050-62-9
2- Propenoic acid, homopolymer sodium salt	95077-68-2
formaldehyde, polymers with branched 4-nonylphenol, ethylene oxide and propylene oxide	153795-76-7
Minerals, Metals and other Inorganics	
carbon dioxide	124-38-9
sodium bicarbonate	144-55-8
Sodium Carbonate	497-19-8
Magnesium Carbonate	546-93-0
Potassium Carbonate	584-08-7
Boric Anhydride (a.k.a. Boric Oxide)	1303-86-2
sodium tetraborate decahydrate	1303-96-4
Calcium Hydroxide	1305-62-0
Calcium Peroxide	1305-79-9
Magnesium Oxide	1309-48-4
Potassium Hydroxide	1310-58-3
sodium hydroxide	1310-73-2
Calcium Carbonate	1317-65-3
Borate Salt	1319-33-1
aluminum chloride, basic	1327-41-9
Magnesium Peroxide	1335-26-8
sodium tetraborate decahydrate	1332-77-0
aqua ammonia 29.4%	1336-21-6
ammonium hydrogen-difluoride	1341-49-7
ammonium thiocyanate	1762-95-4
sulfamic acid	5329-14-6
hydroxylamine hydrochloride	5470-11-1
ammonium nitrate	6484-52-2
cupric chloride dihydrate	7447-39-4
potassium chloride	7447-40-7
Trisodium ortho phosphate	7601-54-9
Non-Crystaline Silica	7631-86-9
sodium bisulfate	7631-90-5
hydrochloric acid	7647-01-0
sodium chloride	7647-14-5
sodium bromide	7647-15-6
aqueous ammonia	7664-41-7
sodium hypochlorite	7681-52-9
ferric chloride	7705-08-0

Chemical	CAS Number
nitrogen	7727-37-9
ammonium persulfate	7727-54-0
water	7732-18-5
sodium sulfate	7757-82-6
sodium chlorite	7758-19-2
sodium thiosulfate	7772-98-7
Sodium Metaborate.8H2O	7775-19-01
Sodium Persulphate	7775-27-1
ferrous sulfate, heptahydrate	7782-63-0
ammonium bisulfate	7783-20-2
boric acid	10043-35-3
Calcium Chloride	10043-52-4
Chlorine Dioxide	10049-04-4
ammonium bisulphite	10192-30-0
sodium perborate tetrahydrate	10486-00-7
ammonium chloride	12125-02-9
Attapulgite Clay	12174-11-7
potassium borate	12714-38-8
Yellow Sodium of Prussiate	13601-19-9
potassium metaborate	13709-94-9
Magnesium Silicate Hydrate (Talc)	14807-96-6
crystalline silica (quartz)	14808-60-7
glassy calcium magnesium phosphate	65997-17-3
Polyphosphate	65997-18-4
silica gel	112926-00-8
synthetic amorphous, pyrogenic silica	112945-52-5
synthetic amorphous, pyrogenic silica	121888-66-2
Miscellaneous	
Sucrose	57-50-1
lactose	63-42-3
acetone	67-64-1
ethylene oxide	75-21-8
1,7,7-trimethylbicyclo[2.2.1]heptan-2one	76-22-2
chromen-2-one	91-64-5
1-octadecene	112-88-9
1,4-dioxane	123-91-1
(E)-4-(2,6,6-trimethyl-1-cyclohex-2-enyl)but-3-en-2-one	127-41-3
1-hexadecene	629-73-2
1-tetradecene	1120-36-1
sorbitan monooleate	1338-43-8
1-eicosene	3452-07-1
D-Limonene	5989-27-5
rosmarinus officinalis l. leaf oil	8000-25-7
oils, cedarwood	8000-27-9
cymbopogan winterianus jowitt oil	8000-29-1
Pine Oil	8000-41-7
eucalyptus globulus leaf oil	8000-48-4

Chemical	CAS Number
oils, pine	8002-09-3
cymbopogon citratus leaf oil	8007-02-1
lavandula hydrida abrial herb oil	8022-15-9
2,2'-azobis-{2-(imidazlin-2-yl)propane}-dihydrochloride	27776-21-2
3,5,7-triaza-1-azoniatricyclo[3.3.1.13,7]decane, 1-(3-chloro-2-propenyl)-chloride	51229-78-8
alkenes	64743-02-8
Cocamidopropyl Oxide	68155-09-9
terpene and terpenoids	68647-72-3
thuja plicata donn ex. D. don leaf oil	68917-35-1
terpene hydrocarbon byproducts	68956-56-9
tar bases, quinoline derivs., benzyl chloride-quaternized	72780-70-7
citrus terpenes	94266-47-4
organophilic clays	121888-68-4
Listed without CAS Number[178]	
belongs with amines	
proprietary quaternary ammonium compounds	NA
quaternary ammonium compound	NA
triethanolamine (tea) 85%, drum	NA
Quaternary amine	NA
Fatty amidoalkyl betaine	NA
belongs with petroleum distillates	
petroleum distillate blend	NA
belongs with aromatic hydrocarbons	
aromatic hydrocarbon	NA
aromatic ketones	NA
belongs with glycol ethers, ethoxylated alcohols & other ethers	
Acetylenic Alcohol	NA
Aliphatic Alcohols, ethoxylated	NA
Aliphatic Alcohol glycol ether	NA
Ethoxylated alcohol linear	NA
Ethoxylated alcohols	NA
aliphatic alcohol polyglycol ether	NA
alkyl aryl polyethoxy ethanol	NA
mixture of ethoxylated alcohols	NA
nonylphenol ethoxylate	NA
oxyalkylated alkylphenol	NA
polyethoxylated alkanol	NA
Oxyalkylated alcohol	NA
belongs with organic acids, salts, esters and related chemicals	
Aliphatic acids derivative	NA
Aliphatic Acids	NA

[178] Constituents listed without CAS #'s were tentatively placed in chemical categories based on the name listed on the MSDS or within confidential product composition disclosures. Many of the constituents reported without CAS #s, are mixtures which require further disclosure to the Department.

Chemical	CAS Number
hydroxy acetic acid	NA
citric acid 50%, base formula	NA
Alkylaryl Sulfonate	NA
belongs with polymers	
hydroxypropyl guar	NA
2-acrylamido-2-methylpropanesulphonic acid sodium salt polymer	NA
Anionic copolymer	NA
Anionic polymer	NA
belongs with minerals, metals and other inorganics	
precipitated silica	NA
sodium hydroxide	NA
belongs with miscellaneous	
epa inert ingredient	NA
non-hazardous ingredients	NA
proprietary surfactant	NA
salt of fatty acid/polyamine reaction product	NA
salt of amine-carbonyl condensate	NA
surfactant blend	NA
sugar	NA
polymeric hydrocarbon mixture	NA
water and inert ingredients	NA

Although exposure to fracturing additives would not occur absent a failure of operational controls such as an accident, a spill or other non-routine incident, the health concerns noted by NYSDOH for each chemical category are discussed below. The discussion is based on available qualitative hazard information for chemicals from each category. Qualitative descriptions of potential health concerns discussed below generally apply to all exposure routes (i.e., ingestion, inhalation or skin contact) unless a specific exposure route is mentioned. For most chemical categories, health information is available for only some of the chemicals in the category. Toxicity testing data is quite limited for some chemicals, and less is known about their potential adverse effects. In particular, there is little meaningful information one way or the other about the potential impact on human health of chronic low level exposures to many of these chemicals, as could occur if an aquifer were to be contaminated as the result of a spill or release that is undetected and/or unremediated.

The overall risk of human health impacts occurring from hydraulic fracturing would depend on whether any human exposure occurs, such as, for example, in the event of a spill. If an actual contamination event such as a spill were to occur, more specific assessment of health risks would

require obtaining detailed information specific to the event such as the specific additives being used and site-specific information about exposure pathways and environmental contaminant levels. Potential human health risks of a specific event would be assessed by comparison of case-specific data with existing drinking water standards or ambient air guidelines.[179] If needed, other chemical-specific health comparison values would be developed, based on a case-specific review of toxicity literature for the chemicals involved. A case-specific assessment would include information on how potential health effects might differ (both qualitatively and quantitatively) depending on the route of exposure.

Petroleum Distillate Products

Petroleum-based constituents are included in some fracturing fluid additive products. They are listed in MSDSs as various petroleum distillate fractions including kerosene, petroleum naphtha, aliphatic hydrocarbon, petroleum base oil, heavy aromatic petroleum naphtha, mineral spirits, hydrotreated light petroleum distillates, stoddard solvent or aromatic hydrocarbon. These can be found in a variety of additive products including corrosion inhibitors, friction reducers and solvents. Petroleum distillate products are mixtures that vary in their composition, but they have similar adverse health effects. Accidental ingestion that results in exposure to large amounts of petroleum distillates is associated with adverse effects on the gastrointestinal system and central nervous system. Skin contact with kerosene for short periods can cause skin irritation, blistering or peeling. Breathing petroleum distillate vapors can adversely affect the central nervous system.

Aromatic Hydrocarbons

Some fracturing additive products contain specific aromatic hydrocarbon compounds that can also occur in petroleum distillates (benzene, toluene, ethylbenzene and xylenes or BTEX; naphthalene and related derivatives, trimethylbenzene, diethylbenzene, dodecylbenzene, cumene). BTEX compounds are associated with adverse effects on the nervous system, liver, kidneys and blood-cell-forming tissues. Benzene has been associated with an increased risk of leukemia in industrial workers who breathed elevated levels of the chemical over long periods of time in workplace air. Exposure to high levels of xylene has damaged the unborn offspring of laboratory animals exposed during pregnancy. Naphthalene is associated with adverse effects on

[179] 10 NYCRR Part 5: Drinking Water Supplies; Subpart 5-1: Public Water Systems, Maximum Contaminant Levels; Department Policy DAR-1: Guidelines for the Control of Toxic Ambient Air Contaminants.

red blood cells when people consumed naphthalene mothballs or when infants wore cloth diapers stored in mothballs. Laboratory animals breathing naphthalene vapors for their lifetimes had damage to their respiratory tracts and increased risk of nasal and lung tumors.

Glycols

Glycols occur in several fracturing fluid additives including crosslinkers, breakers, clay and iron controllers, friction reducers and scale inhibitors. Propylene glycol has low inherent toxicity and is used as an additive in food, cosmetic and drug products. However, high exposure levels of ethylene glycol adversely affect the kidneys and reproduction in laboratory animals.

Glycol Ethers

Glycol ethers and related ethoxylated alcohols and phenols are present in fracturing fluid additives, including corrosion inhibitors, surfactants and friction reducers. Some glycol ethers [e.g., monomethoxyethanol, monoethoxyethanol, propylene glycol monomethyl ether, ethylene glycol monobutyl ether (also known as 2-butoxyethanol)] can affect the male reproductive system and red blood cell formation in laboratory animals at high exposure levels.

Alcohols and Aldehydes

Alcohols are present in some fracturing fluid additive products, including corrosion inhibitors, foaming agents, iron and scale inhibitors and surfactants. Exposure to high levels of some alcohols (e.g., ethanol, methanol) affects the central nervous system.

Aldehydes are present in some fracturing fluid additive products, including corrosion inhibitors, scale inhibitors, surfactants and foaming agents. Aldehydes can be irritating to tissues when coming into direct contact with them. The most common symptoms include irritation of the skin, eyes, nose and throat, along with increased tearing. Formaldehyde is present in several additive products, although in most cases the concentration listed in the product is relatively low (< 1%) and is listed alongside a formaldehyde-based polymer constituent. Severe pain, vomiting, coma and possibly death can occur after drinking large amounts of formaldehyde. Several studies of laboratory rats exposed for life to high amounts of formaldehyde in air found that the rats developed nose cancer. Some studies of humans exposed to lower amounts of formaldehyde in workplace air found more cases of cancer of the nose and throat

(nasopharyngeal cancer) than expected, but other studies have not found nasopharyngeal cancer in other groups of workers exposed to formaldehyde in air.

Amides

Acrylamide is used in some fracturing fluid additives to create polymers during the stimulation process. These polymers are part of some friction reducers and scale inhibitors. Although the reacted polymers that form during fracturing are of low inherent toxicity, unreacted acrylamide may be present in the fracturing fluid, or breakdown of the polymers could release acrylamide back into the flowback water. High levels of acrylamide damage the nervous system and reproductive system in laboratory animals and also cause cancer in laboratory animals.

Formamide may be used in some corrosion inhibitors products. Ingesting high levels of formamide adversely affects the female reproductive system in laboratory animals.

Amines

Amines are constituents of fracturing fluid products including corrosion inhibitors, cross-linkers, friction reducers, iron and clay controllers and surfactants. Chronic ingestion of mono-, di- or tri-ethanolamine adversely affects the liver and kidneys of laboratory animals.

Some quaternary ammonium compounds, such as dimethyldiallyl ammonium chloride, can react with chemicals used in some systems for drinking water disinfection to form nitrosamines. Nitrosamines cause genetic damage and cancer when ingested by laboratory animals.

Organic Acids, Salts, Esters and Related Chemicals

Organic acids and related chemicals are constituents of fracturing fluid products including acids, buffers, corrosion and scale inhibitors, friction reducers, iron and clay controllers, solvents and surfactants. Some short-chain organic acids such as formic, acetic and citric acids can be corrosive or irritating to skin and mucous membranes at high concentrations. However, acetic and citric acids are regularly consumed in foods (such as vinegar and citrus fruits) where they occur naturally at lower levels that are not harmful.

Some foaming agents and surfactant products contain organic chemicals included in this category that contain a sulfonic acid group (sulfonates). Exposure to elevated levels of sulfonates is irritating to the skin and mucous membranes.

Microbiocides

Microbiocides are antimicrobial pesticide products intended to inhibit the growth of various types of bacteria in the well. A variety of different chemicals are used in different microbiocide products that are proposed for Marcellus wells. Toxicity information is limited for several of the microbiocide chemicals. However, for some, high exposure has caused effects in the respiratory and gastrointestinal tracts, the kidneys, the liver and the nervous system in laboratory animals.

Other Constituents

The remaining chemicals listed in MSDSs and confidential product composition disclosures provided to the Department are included in Table 5.8 under the following categories: polymers, miscellaneous chemicals that did not fit another chemical category and product constituents that were not identified by a CAS number. Readily available health effects information is lacking for many of these constituents, but one that is relatively well studied is discussed here. In the event of environmental contamination involving chemicals lacking readily available health effects information, the toxicology literature would have to be researched for chemical-specific toxicity data or toxicity data for closely- related chemicals.

1,4-dioxane may be used in some surfactant products. 1,4-Dioxane is irritating to the eyes and nose when vapors are breathed. Exposure to very high levels may cause severe kidney and liver effects and possibly death. Studies in animals have shown that breathing vapors of 1,4-dioxane, swallowing liquid 1,4-dioxane or contaminated drinking water, or having skin contact with liquid 1,4-dioxane affects mainly the liver and kidneys. Laboratory rats and mice that drank water containing 1,4-dioxane during most of their lives developed liver cancer; the rats also developed cancer inside the nose.

Conclusions

The hydraulic fracturing product additives proposed for use in NYS and used for fracturing horizontal Marcellus Shale wells in other states contain similar types of chemical constituents as

the products that have been used for many years for hydraulic fracturing of traditional vertical wells in NYS. Some of the same products are used in both well types. Chemicals in products proposed for use in high-volume hydraulic fracturing include some that, based mainly on occupational studies or high-level exposures in laboratory animals, have been shown to cause effects such as carcinogenicity, mutagenicity, reproductive toxicity, neurotoxicity or organ damage. This information only indicates the types of toxic effects these chemicals can cause under certain circumstances but does not mean that use of these chemicals would cause exposure in every case or that exposure would cause those effects in every case. Whether or not people actually experience a toxic effect from a chemical depends on whether or not they experience any exposure to the chemical along with many other factors including, among others, the amount, timing, duration and route of exposure and individual characteristics that can contribute to differences in susceptibility.

The total amount of fracturing additives and water used in hydraulic fracturing of horizontal wells is considerably larger than for traditional vertical wells. This suggests the potential environmental consequences of an upset condition could be proportionally larger for horizontal well drilling and fracturing operations. As mentioned earlier, the 1992 GEIS addressed hydraulic fracturing in Chapter 9, and NYSDOH's review did not identify any potential exposure scenarios associated with horizontal drilling and high-volume hydraulic fracturing that are qualitatively different from those addressed in the 1992 GEIS.

5.5 Transport of Hydraulic Fracturing Additives

Fracturing additives are transported in "DOT-approved" trucks or containers. The trucks are typically flat-bed trucks that carry a number of strapped-on plastic totes which contain the liquid additive products. (Totes are further described in Section 5.6.). Liquid products used in smaller quantities are transported in one-gallon sealed jugs carried in the side boxes of the flat-bed. Some liquid constituents, such as hydrochloric acid, are transferred in tank trucks.

Dry additives are transported on flat-beds in 50- or 55-pound bags which are set on pallets containing 40 bags each and shrink-wrapped, or in five-gallon sealed plastic buckets. When smaller quantities of some dry products such as powdered biocides are used, they are contained

in a double-bag system and may be transported in the side boxes of the truck that constitutes the blender unit.

Regulations that reference "DOT-approved" trucks or containers that are applicable to the transportation and storage of hazardous fracturing additives refer to federal (USDOT) regulations for registering and permitting commercial motor carriers and drivers, and established standards for hazardous containers. The United Nations (UN) also has established standards and criteria for containers. New York is one of many states where the state agency (NYSDOT) has adopted the federal regulations for transporting hazardous materials interstate. The NYSDOT has its own requirements for intrastate transportation.[180] For informational purposes, Chapter 8 contains descriptions of applicable NYSDOT and USDOT regulations.

Transporting fracturing additives that are hazardous is comprehensively regulated under existing regulations. The regulated materials include the hazardous additives and mixtures containing threshold levels of hazardous materials. These transported materials are maintained in the USDOT or UN-approved storage containers until the materials are consumed at the drill sites.[181]

5.6 On-Site Storage and Handling of Hydraulic Fracturing Additives

Prior to use, additives remain at the wellsite in the containers and on the trucks in which they are transported and delivered. Storage time is generally less than a week for economic and logistical reasons, materials are not delivered until fracturing operations are set to commence, and only the amount needed for scheduled continuous fracturing operations is delivered at any one time.

As detailed in Section 5.4.3, there are 13 classes of additives, based on their purpose or use; not all classes would be used at every well; and only one product in each class would typically be used per job. Therefore, although the chemical lists in Table 5.7 and Table 5.8 reflect the constituents of 235 products, typically no more than 12 products consisting of far fewer chemicals than listed would be present at one time at any given site.

[180] Alpha 2009, p. 31.

[181] Alpha 2009, p. 31.

When the hydraulic fracturing procedure commences, hoses are used to transfer liquid additives from storage containers to a truck-mounted blending unit. The flat-bed trucks that deliver liquid totes to the site may be equipped with their own pumping systems for transferring the liquid additive to the blending unit when fracturing operations are in progress. Flat-beds that do not have their own pumps rely on pumps attached to the blending unit. Additives delivered in tank trucks are pumped to the blending unit or the well directly from the tank truck. Dry additives are poured by hand into a feeder system on the blending unit. The blended fracturing solution is not stored, but is immediately mixed with proppant and pumped into the cased and cemented wellbore. This process is conducted and monitored by qualified personnel, and devices such as manual valves provide additional controls when liquids are transferred. Common observed practices during visits to drill sites in the northern tier of Pennsylvania included lined containments and protective barriers where chemicals were stored and blending took place.[182]

5.6.1 Summary of Additive Container Types

The most common containers are 220-gallon to 375-gallon high-density polyethylene (HDPE) totes, which are generally cube-shaped and encased in a metal cage. These totes have a bottom release port to transfer the chemicals, which is closed and capped during transport, and a top fill port with a screw-on cap and temporary lock mechanism. Photo 5.18 depicts a transport truck with totes.

[182] Alpha, 2009, p. 35.

Photo 5.18 - Transport trucks with totes

To summarize, the storage containers at any given site during the short period of time between delivery and completion of continuous fracturing operations will consist of all or some of the following:

- Plastic totes encased in metal cages, ranging in volume from 220 gallons to 375 gallons, which are strapped on to flat bed trucks pursuant to USDOT and NYSDOT regulations;
- Tank trucks;
- Palletized 50-55 gallon bags, made of coated paper or plastic (40 bags per pallet, shrink-wrapped as a unit and then wrapped again in plastic);
- One-gallon jugs with perforated sealed twist lids stored inside boxes on the flat-bed; and
- Smaller double-bag systems stored inside boxes on the blending unit.