

Appendix J

Glossary

Appendix J. Glossary

J.1. Glossary Terms and Definitions

- 1 **Acid mine drainage:** Flow of water from areas that have been mined for coal or other mineral ores.
2 The water has a low pH because of its contact with sulfur-bearing material and is harmful to
3 aquatic organisms. ([U.S. EPA, 2013d](#))
- 4 **Additive:** A single chemical or chemical mixture designed to serve a specific purpose in the
5 hydraulic fracturing fluid.¹
- 6 **Adsorption:** Adhesion of molecules of gas, liquid, or dissolved solids to a surface. ([U.S. EPA, 2013d](#))
- 7 **Advection:** A mechanism for moving chemicals in flowing water, where a chemical moves along
8 with the flow of the water itself.
- 9 **Aeration:** A process that promotes biological degradation of organic matter in water. The process
10 may be passive (as when waste is exposed to air) or active (as when a mixing or bubbling device
11 introduces the air). ([U.S. EPA, 2013d](#))
- 12 **Aerobic mesophiles:** Microorganisms that use oxygen for energy production and are tolerant of
13 moderate temperatures.
- 14 **Analyte:** The element, ion, or compound that an analysis seeks to identify; the compound of
15 interest. ([U.S. EPA, 2013d](#))
- 16 **Annulus:** Refers to either the space between the casing of a well and the wellbore or the space
17 between any two strings of tubing or casing. ([U.S. EPA, 2013d](#))
- 18 **API number:** A unique identifying number for all oil and gas wells drilled in the United States. The
19 system was developed by the American Petroleum Institute. ([Oil and Gas Mineral Services, 2010](#))
- 20 **Aquifer:** An underground geological formation, or group of formations, containing water. A source
21 of ground water for wells and springs. ([U.S. EPA, 2013d](#))
- 22 **Base fluid:** The fluid into which additives and proppants are mixed to formulate a hydraulic
23 fracturing fluid.
- 24 **Basin:** A depression in the crust of the earth, caused by plate tectonic activity and subsidence, in
25 which sediments accumulate. Sedimentary basins vary from bowl-shaped to elongated troughs.
26 Basins can be bounded by faults. Rift basins are commonly symmetrical; basins along continental
27 margins tend to be asymmetrical. If rich hydrocarbon source rocks occur in combination with
28 appropriate depth and duration of burial, then a petroleum system can develop within the basin.

¹ Definitions that have no associated citation in this glossary were developed for this assessment.

- 1 Most basins contain some amount of shale, thus providing opportunities for shale gas exploration
2 and production. ([Schlumberger, 2014](#))
- 3 **Biogenic:** Methane that is produced in shallower formations by bacterial activity in anaerobic
4 conditions. It is the ultimate dissimilation product of microbially mediated reactions of organic
5 molecules.
- 6 **Blowout preventer (BOP):** Casinghead equipment that prevents the uncontrolled flow of oil, gas,
7 and mud from the well by closing around the drill pipe or sealing the hole. ([Oil and Gas Mineral
8 Services, 2010](#))
- 9 **Brackish water:** Mixed fresh and salt waters. Used here to qualitatively refer to water that contains
10 higher total dissolved solids (TDS) than that typically used for fresh drinking water.
- 11 **BTEX:** An acronym for benzene, toluene, ethylbenzene, and xylenes. These chemicals are a group of
12 single ringed aromatic hydrocarbon based on the benzene structure. These compounds are found in
13 petroleum and are of specific importance because of their health effects.
- 14 **Caliper log:** A log that is used to check for any wellbore irregularities. It is run prior to primary
15 cementing as a means of calculating the amount of cement needed. Also run in conjunction with
16 other open hole logs for log corrections or run on cased holes to evaluate metal loss. ([NYSDEC,
17 2011](#))
- 18 **Capillarity:** The action by which the surface of a liquid where it is in contact with a solid is elevated
19 or depressed depending on the relative attraction of the molecules of the liquid for each other and
20 for those of the solid. Capillary forces arise from the differential attraction between immiscible
21 fluids and solid surfaces; these are the forces responsible for capillary rise in small-diameter tubes
22 and porous materials. ([Adapted from Dake, 1978](#))
- 23 **Casing:** Steel pipe that is lowered into a wellbore. Casing extends from the bottom of the hole to the
24 surface. ([Schlumberger, 2014](#))
- 25 **Casing inspection logs:** An in situ record of casing thickness and integrity, to determine whether
26 and to what extent the casing has undergone corrosion. The term refers to an individual
27 measurement, or a combination of measurements using acoustic, electrical, and mechanical
28 techniques, to evaluate the casing thickness and other parameters. The log is usually presented
29 with the basic measurements and an estimate of metal loss. It was first introduced in the early
30 1960s. Today the terms casing-evaluation log and pipe-inspection log are used synonymously.
31 ([Schlumberger, 2014](#))
- 32 **Cation exchange capacity:** The total amount of cations (positively charged ions) that a soil can
33 hold.

- 1 **Cement:** Material used to support and seal the well casing to the rock formations exposed in the
2 borehole. Cement also protects the casing from corrosion and prevents movement of injectate up
3 the borehole. ([U.S. EPA, 2013d](#))
- 4 **Cement squeeze:** A remedial cementing operation designed to force cement into leak paths in
5 wellbore tubulars. The required squeeze pressure is achieved by carefully controlling pump
6 pressure. Squeeze cementing operations may be performed to repair poor primary cement jobs,
7 isolate perforations, or repair damaged casing or liner. ([Schlumberger, 2014](#))
- 8 **Centralized waste treatment facility (CWT):** any facility that treats (for disposal, recycling or
9 recovery of material) any hazardous or non-hazardous industrial wastes, hazardous or non-
10 hazardous industrial wastewater, and/or used material received from off-site. ([U.S. EPA, 2012b](#))
- 11 **Coalbed methane:** Methane contained in coal seams. A coal seam is a layer or stratum of coal
12 parallel to the rock stratification. ([U.S. EPA, 2013d](#))
- 13 **Collapse pressure:** The pressure at which a tube, or vessel, will catastrophically deform as a result
14 of differential pressure acting from outside to inside of the vessel or tube. ([Schlumberger, 2014](#))
- 15 **Collar:** A threaded coupling used to join two lengths of pipe such as production tubing, casing, or
16 liner. The type of thread and style of collar varies with the specifications and manufacturer of the
17 tubing. ([Schlumberger, 2014](#))
- 18 **Combination truck:** A truck tractor or a truck tractor pulling any number of trailers. ([U.S.](#)
19 [Department of Transportation, 2012](#))
- 20 **Community water systems:** Public water systems that supply water to the same population year-
21 round. ([U.S. EPA, 2013c](#))
- 22 **Completion:** A term used to describe the assembly of equipment at the bottom of the well that is
23 needed to enable production from an oil or gas well. It can also refer to the activities and methods
24 (including hydraulic fracturing) used to prepare a well for production following drilling.
- 25 **Complexation:** A reaction between two chemicals that form a new complex, either through
26 covalent bonding or ionic forces. This often results in one chemical solubilizing the other.
- 27 **Compressive strength:** Measure of the ability of a substance to withstand compression. ([NYSDEC,](#)
28 [2011](#))
- 29 **Conductor casing:** This large diameter casing is usually the first string of casing in a well. It is set
30 or driven into the unconsolidated material where the well will be drilled to keep the loose material
31 from caving in. ([NYSDEC, 2011](#))
- 32 **Confidential business information (CBI):** Information that contains trade secrets, commercial or
33 financial information, or other information that has been claimed as confidential by the submitter.
34 The EPA has special procedures for handling such information. ([U.S. EPA, 2013d](#))

-
- 1 **Contaminant:** A substance that is either present in an environment where it does not belong or is
2 present at levels that might cause harmful (adverse) health effects. ([U.S. EPA, 2013d](#))
- 3 **Conventional reservoir:** A reservoir in which buoyant forces keep hydrocarbons in place below a
4 sealing caprock. Reservoir and fluid characteristics of conventional reservoirs typically permit oil
5 or natural gas to flow readily into wellbores. The term is used to make a distinction from shale and
6 other unconventional reservoirs, in which gas might be distributed throughout the reservoir at the
7 basin scale, and in which buoyant forces or the influence of a water column on the location of
8 hydrocarbons within the reservoir are not significant. ([Schlumberger, 2014](#))
- 9 **Crosslinked gels:** linear gels that are linked together by chemicals called crosslinkers, which may
10 link two or more chains together.
- 11 **Crude oil:** A general term for unrefined petroleum or liquid petroleum. ([Schlumberger, 2014](#))
- 12 **Cumulative effects:** Refers to combined changes in the environment that can take place as a result
13 of multiple activities over time and/or space.
- 14 **Cumulative water use/cumulative water:** Refers to the amount of water used or consumed by all
15 hydraulic fracturing wells in a given area per year.
- 16 **Cyclical stress:** Refers to stress caused by frequent or rapid changes in temperature or pressure.
- 17 **Deviated well:** Any non-horizontal well in which the well bottom is intentionally located at a
18 distance (e.g., hundreds of feet) laterally from the wellhead.
- 19 **Discharge:** Any emission (other than natural seepage), intentional or unintentional. Includes, but is
20 not limited to, spilling, leaking, pumping, pouring, emitting, emptying, or dumping. ([U.S. EPA,](#)
21 [2013d](#))
- 22 **Disinfection byproduct (DBP):** A compound formed by the reaction of a disinfectant such as
23 chlorine with organic material in the water supply. ([U.S. EPA, 2013d](#))
- 24 **Domestic water use:** Includes indoor and outdoor water uses at residences, and includes uses such
25 as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, watering lawns
26 and gardens, and maintaining pools. ([USGS, 2015](#))
- 27 **Drill bit:** The tool used to crush or cut rock. Most bits work by scraping or crushing the rock as part
28 of a rotational motion, while some bits work by pounding the rock vertically. ([Schlumberger, 2014](#))
- 29 **Drill collar:** A component of a drill string that provides weight on the bit for drilling. Drill collars
30 are thick-walled tubular pieces machined from solid bars of steel, usually plain carbon steel but
31 sometimes of nonmagnetic nickel-copper alloy or other nonmagnetic premium alloys.
32 ([Schlumberger, 2014](#))
- 33 **Drill cuttings:** Ground rock produced by the drilling process.
-

-
- 1 **Drill string:** The combination of the drillpipe, the bottomhole assembly, and any other tools used to
2 make the drill bit turn at the bottom of the wellbore. ([Schlumberger, 2014](#))
- 3 **Drilling fluid:** Any of a number of liquid and gaseous fluids and mixtures of fluids and solids used
4 when drilling boreholes. ([Adapted from Schlumberger, 2014](#))
- 5 **Drinking water resource:** Any body of ground water or surface water that now serves, or in the
6 future could serve, as a source of drinking water for public or private use ([U.S. EPA, 2013d](#))
- 7 **Dry gas:** Refers to natural gas that occurs in the absence of liquid hydrocarbons. ([Adapted from](#)
8 [Schlumberger, 2014](#))
- 9 **Effluent:** Waste material being discharged into the environment, either treated or untreated. ([U.S.](#)
10 [EPA, 2013d](#))
- 11 **Facultative anaerobes:** Microorganisms that can use oxygen for energy production if it is present
12 in their environment, but can also use alternatives for energy production if no oxygen is present.
- 13 **Fault:** A fracture or fracture zone along which there has been displacement of the sides relative to
14 each other. ([NYSDEC, 2011](#))
- 15 **Field:** Area of oil and gas production with at least one common reservoir for the entire area. ([Oil](#)
16 [and Gas Mineral Services, 2010](#))
- 17 **Flowback:** The term is defined multiple ways in the literature. In general, it is either fluids
18 predominantly containing hydraulic fracturing fluid that return from a well to the surface or a
19 process used to prepare the well for production.
- 20 **Fluid:** A substance that flows when exposed to an external pressure; fluids include both liquids and
21 gases.
- 22 **Fluid formulation:** The entire suite of chemicals, proppant, and base fluid injected into a well
23 during hydraulic fracturing. ([U.S. EPA, 2013d](#))
- 24 **Formation:** A body of earth material with distinctive and characteristic properties and a degree of
25 homogeneity in its physical properties. ([U.S. EPA, 2013d](#))
- 26 **Formation packer:** A specialized casing part that has the same inner diameter as the casing but
27 whose outer diameter expands to make contact with the formation and seal the annulus between
28 the casing and formation, preventing migration of fluids.
- 29 **Formation fluid:** Fluid that occurs naturally within the pores of rock. These fluids consist primarily
30 of water, with varying concentrations of total dissolved solids, but may also contain oil or gas.
31 Sometimes referred to as native fluids, native brines, or reservoir fluids.
- 32 **FracFocus Registry:** A registry for oil and gas well operators to disclose information about
33 hydraulic fracturing well locations, and water and chemical use during hydraulic fracturing
-

-
- 1 operations developed by the Ground Water Protection Council and the Interstate Oil and Gas
2 Compact Commission.
- 3 **Fracture:** A crack or breakage surface within a rock.
- 4 **Fracture geometry:** Refers to characteristics of the fracture such as height and aperture (width).
- 5 **Fresh water:** Qualitatively refers to water with relatively low TDS that is most readily available for
6 drinking water currently.
- 7 **Gelled fluids:** Fracturing fluids that are usually water-based with added gels to increase the fluid
8 viscosity to aid in the transport of proppants. ([Spellman, 2012](#); [Gupta and Valkó, 2007](#))
- 9 **Ground water:** In the broadest sense, all subsurface water; more commonly that part of the
10 subsurface water in the saturated zone. ([Solley et al., 1998](#))
- 11 **Halite:** A soft, soluble evaporate mineral commonly known as salt or rock salt. Can be critical in
12 forming hydrocarbon traps and seals because it tends to flow rather than fracture during
13 deformation, thus preventing hydrocarbons from leaking out of a trap even during and after some
14 types of deformation. ([Schlumberger, 2014](#))
- 15 **Hazard evaluation:** A component of risk assessment that involves gathering and evaluating data
16 on the types of health injuries or diseases (e.g., cancer) that may be produced by a chemical and on
17 the conditions of exposure under which such health effects are produced.
- 18 **Hazard identification:** A process for determining if a chemical or a microbe can cause adverse
19 health effects in humans and what those effects might be. ([U.S. EPA, 2013d](#))
- 20 **Henry's law constant:** Ratio of a chemical's vapor pressure in the atmosphere to its solubility in
21 water. The higher the Henry's law constant, the more volatile the compound will be from water.
22 ([NYSDEC, 2011](#))
- 23 **Horizontal drilling:** Drilling a portion of a well horizontally to expose more of the formation
24 surface area to the wellbore. ([Oil and Gas Mineral Services, 2010](#))
- 25 **Horizontal well:** A well that is drilled vertically up to a point known as the kickoff point, where the
26 well turns toward the horizontal, extending into and parallel with the approximately horizontal
27 targeted producing formation.
- 28 **Hydraulic fracturing:** A stimulation technique used to increase production of oil and gas.
29 Hydraulic fracturing involves the injection of fluids under pressures great enough to fracture the
30 oil- and gas-production formations. ([U.S. EPA, 2011a](#))
- 31 **Hydraulic fracturing fluids:** Engineered fluids, typically consisting of a base fluid, additives, and
32 proppant, that are pumped under high pressure into the well to create and hold open fractures in
33 the formation.
-

- 1 **Hydraulic fracturing wastewater:** Flowback and produced water that is managed using practices
2 that include but are not limited to reuse in subsequent hydraulic fracturing operations, treatment
3 and discharge, and injection into disposal wells.
- 4 **Hydraulic fracturing water cycle:** The cycle of water in the hydraulic fracturing process,
5 encompassing the acquisition of water, chemical mixing of the fracturing fluid, injection of the fluid
6 into the formation, the production and management of flowback and produced water, and the
7 ultimate treatment and disposal of hydraulic fracturing wastewaters.
- 8 **Hydraulic gradient:** Slope of a water table or potentiometric surface. More specifically, change in
9 the hydraulic head per unit of distance in the direction of the maximum rate of decrease. ([U.S. EPA,](#)
10 [2013d](#))
- 11 **Hydrocarbon:** An organic compound containing only hydrogen and carbon, often occurring in
12 petroleum, natural gas, and coal. ([U.S. EPA, 2013d](#))
- 13 **Hydrostatic pressure:** The pressure exerted by a column of fluid at a given depth.
- 14 **Imbibition:** The displacement of a non-wet fluid (i.e., gas) by a wet fluid (typically water). ([Adapted](#)
15 [from Dake, 1978](#))
- 16 **Immiscible:** The chemical property in which two or more liquids or phases are incapable of
17 attaining homogeneity. ([U.S. EPA, 2013d](#))
- 18 **Impact:** Any observed change in the quality or quantity of drinking water resources, regardless of
19 severity, that results from a mechanism.
- 20 **Impact, potential:** Any change in the quality or quantity of drinking water resources that could
21 logically occur, but has not yet been observed, as the result of a mechanism or potential mechanism.
- 22 **Induced fracture:** A fracture created during hydraulic fracturing.
- 23 **Injection well:** A well into which fluids are being injected (40 CFR 144.3).
- 24 **Integrated risk information system (IRIS):** An electronic database that contains the EPA's latest
25 descriptive and quantitative regulatory information about chemical constituents. Files on chemicals
26 maintained in IRIS contain information related to both noncarcinogenic and carcinogenic health
27 effects. ([U.S. EPA, 2013d](#))
- 28 **Intermediate casing:** Casing that seals off intermediate depths and geologic formations that may
29 have considerably different reservoir pressures than deeper zones to be drilled. ([Devereux, 1998;](#)
30 [Baker, 1979](#))
- 31 **Karst:** A type of topography that results from dissolution and collapse of carbonate rocks, such as
32 limestone, dolomite, and gypsum, and that is characterized by closed depressions or sinkholes,
33 caves, and underground drainage. ([Solley et al., 1998](#))

-
- 1 **Kill fluid:** A weighted fluid with a density that is sufficient to overcome the formation pressure and
2 prevent fluids from flowing up the wellbore.
- 3 **Large truck:** A truck with a gross vehicle weight rating greater than 10,000 pounds. ([U.S.](#)
4 [Department of Transportation, 2012](#))
- 5 **Lateral:** A horizontal section of a well.
- 6 **Leakoff:** The fraction of the injected fluid that infiltrates into the formation (e.g., through an
7 existing natural fissure) and is not recovered during production.
- 8 **Linear gel:** a series of chemicals linked together so that they form a chain.
- 9 **Liner:** A casing string that does not extend to the top of the wellbore, but instead is anchored or
10 suspended from inside the bottom of the previous casing string. ([Schlumberger, 2014](#))
- 11 **Lost cement:** Refers to a failure of the cement to be circulated back to the surface, indicating that
12 the cement has escaped into the formation.
- 13 **Lowest-observable-adverse effect level (LOAEL):** The lowest exposure level at which there are
14 biologically significant increases in frequency or severity of adverse effects between the exposed
15 population and its appropriate control group.
- 16 **Maximum allowable daily level (MADL):** The maximum allowable daily level of a reproductive
17 toxicant at which the chemical would have no observable adverse reproductive effect, assuming
18 exposure at 1,000 times that level.
- 19 **Maximum contaminant level (MCL):** The highest level of a contaminant that is allowed in
20 drinking water. MCLs are enforceable standards. ([U.S. EPA, 2014b](#))
- 21 **Mechanical integrity:** The absence of significant leakage within the injection tubing, casing, or
22 packer (known as internal mechanical integrity), or outside of the casing (known as external
23 mechanical integrity). ([U.S. EPA, 2013d](#))
- 24 **Mechanism:** A means or series of events by which an activity within the hydraulic fracturing water
25 cycle has been observed to change the quality or quantity of drinking water resources.
- 26 **Mechanism, potential:** A means or series of events by which hydraulic fracturing activities could
27 logically or theoretically (for instance, based on modeling) change the quality or quantity of
28 drinking water resources but one that has not yet been observed.
- 29 **Mechanism, suspected:** A means or series of events by which hydraulic fracturing activities could
30 logically have resulted in an observed change in the quality or quantity of drinking water resources.
31 Available evidence may or may not be sufficient to determine if it is the *only* mechanism that caused
32 the observed change.
-

- 1 **Metropolitan combined statistical area:** A core urban area of 50,000 or more people. ([U.S.](#)
2 [Census Bureau, 2013](#))
- 3 **Microaerophiles:** Microorganisms that require small amounts of oxygen for energy production.
- 4 **Microannuli:** Very small channels that form in the cement and that may serve as pathways for fluid
5 migration to drinking water resources.
- 6 **Micropolitan combined statistical area:** An urban core of at least 10,000, but less than 50,000,
7 people. ([U.S. Census Bureau, 2013](#))
- 8 **Microseismic monitoring:** A technique to track the propagation of a hydraulic fracture as it
9 advances through a formation. ([Schlumberger, 2014](#))
- 10 **Minimum risk level (MRL):** An estimate of daily human exposure to a hazardous substance at or
11 below which the substance is unlikely to pose a measurable risk of harmful (adverse),
12 noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a
13 specified time period (acute, intermediate, or chronic).
- 14 **Mobility:** The ratio of effective permeability to phase viscosity. The overall mobility is a sum of the
15 individual phase viscosities. Well productivity is directly proportional to the product of the mobility
16 and the layer thickness product. ([Schlumberger, 2014](#))
- 17 **National Pollution Discharge Elimination System (NPDES):** A national program under
18 Section 402 of the Clean Water Act for regulation of discharges of pollutants from point sources to
19 waters of the United States. Discharges are illegal unless authorized by an NPDES permit. ([U.S. EPA,](#)
20 [2013d](#))
- 21 **National Secondary Drinking Water Regulations (NSDWR):** Non-enforceable guidelines
22 regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or
23 aesthetic effects (such as taste, odor, or color) in drinking water (also referred to as secondary
24 standards). ([U.S. EPA, 2014b](#))
- 25 **Natural gas:** A naturally occurring mixture of hydrocarbon and nonhydrocarbon gases in porous
26 formations beneath the earth's surface, often in association with petroleum. The principal
27 constituent of natural gas is methane. ([Schlumberger, 2014](#))
- 28 **Natural organic matter (NOM):** Complex organic compounds that are formed from decomposing
29 plant animal and microbial material in soil and water. ([U.S. EPA, 2013d](#))
- 30 **Non-community water systems:** Water systems that supply water to at least 25 of the same
31 people at least six months per year, but not year-round. ([U.S. EPA, 2013c](#))
- 32 **Octanol-water partition coefficient (K_{ow}):** A coefficient representing the ratio of the solubility of a
33 compound in octanol (a nonpolar solvent) to its solubility in water (a polar solvent). The higher the
34 K_{ow} , the more nonpolar the compound. Log K_{ow} is generally used as a relative indicator of the

- 1 tendency of an organic compound to adsorb to soil. Log K_{ow} values are generally inversely related to
2 aqueous solubility and directly proportional to molecular weight. ([U.S. EPA, 2013d](#))
- 3 **Offset well:** An existing wellbore close to a proposed well that provides information for planning
4 the proposed well. ([Schlumberger, 2014](#))
- 5 **Open hole completion:** A well completion that has no casing or liner set across the reservoir
6 formation, allowing the produced fluids to flow directly into the wellbore. ([Schlumberger, 2014](#))
- 7 **Oral slope factor (OSF):** An upper-bound, approximating a 95% confidence limit, on the increased
8 cancer risk from a lifetime oral exposure to an agent. This estimate, usually expressed in units of
9 proportion (of a population) affected per mg/kg day, is generally reserved for use in the low dose
10 region of the dose response relationship, that is, for exposures corresponding to risks less than 1 in
11 100.
- 12 **Organic carbon-water partition coefficient (K_{oc}):** A coefficient representing the amount of a
13 compound that is adsorbed to soil to the amount of a compound that is dissolved in water,
14 normalized to the total organic carbon content of the soil. The higher the K_{oc} , the more likely a
15 compound is to adsorb to soils and sediments, and the less likely it is to migrate with water. Along
16 with log K_{ow} , log K_{oc} is used as a relative indicator of the tendency of an organic compound to adsorb
17 to soil.
- 18 **Orphaned well:** An inactive oil or gas well with no known (or financially solvent) owner.
- 19 **Overburden:** Material of any nature, consolidated or unconsolidated, that overlies a deposit of
20 useful minerals or ores. ([U.S. EPA, 2013d](#))
- 21 **Packer:** A device that can be run into a wellbore with a smaller initial outside diameter that then
22 expands externally to seal the wellbore. ([Schlumberger, 2014](#))
- 23 **Pad fluid:** a mixture of base fluid, typically water and additives designed to create, elongate, and
24 enlarge fractures along the natural channels of the formation when injected under high pressure.
- 25 **Partial cementing:** Cementing a casing string along only a portion of its length.
- 26 **Passby flow:** A prescribed, low-streamflow threshold below which withdrawals are not allowed.
27 ([U.S. EPA, 2015d](#))
- 28 **Peer review:** A documented critical review of a specific major scientific and/or technical work
29 product. Peer review is intended to uncover any technical problems or unresolved issues in a
30 preliminary or draft work product through the use of independent experts. This information is then
31 used to revise the draft so that the final work product will reflect sound technical information and
32 analyses. The process of peer review enhances the scientific or technical work product so that the
33 decision or position taken by the EPA, based on that product, has a sound and credible basis. ([U.S.](#)
34 [EPA, 2013d](#))

- 1 **Perforation:** The communication tunnel created from the casing or liner into the reservoir
2 formation through which injected fluids and oil or gas flows. Also refers to the process of creating
3 communication channels, e.g., via the use of a jet perforating gun.
- 4 **Permeability:** The ability of a material (e.g., rock or soil) to transmit fluid to move through pore
5 spaces.
- 6 **Persistence:** The length of time a compound stays in the environment, once introduced. A
7 compound may persist for less than a second or indefinitely.
- 8 **Physicochemical properties:** The inherent physical and chemical properties of a molecule such as
9 boiling point, density, physical state, molecular weight, vapor pressure, etc. These properties define
10 how a chemical interacts with its environment. ([U.S. EPA, 2013d](#))
- 11 **Play:** A set of oil or gas accumulations sharing similar geologic, geographic properties, such as
12 source rock, hydrocarbon type, and migration pathways. ([Oil and Gas Mineral Services, 2010](#))
- 13 **Poisson's ratio:** A ratio of transverse-to-axial (or latitudinal-to-longitudinal) strain; characterizes
14 how a material is deformed under pressure.
- 15 **Polar molecule:** A molecule with a slightly positive charge at one part of the molecule and a
16 slightly negative charge on another. The water molecule, H₂O, is an example of a polar molecule,
17 where the molecule is slightly positive around the hydrogen atoms and negative around the oxygen
18 atom.
- 19 **Porosity:** A measure of pore space, or the percentage of the material (e.g., rock or soil) volume that
20 can be occupied by oil, gas, or water.
- 21 **Produced water:** Water that flows from oil and gas wells.
- 22 **Production casing:** The deepest casing set and serves primarily as the conduit for producing fluids,
23 although when cemented to the wellbore, this casing can also serve to seal off other subsurface
24 zones including ground water resources. ([Devereux, 1998](#); [Baker, 1979](#))
- 25 **Production well:** A well that is used to bring fluids (such as oil or gas) to the surface.
- 26 **Production zone:** Refers to the portion of a subsurface rock zone that contains oil or gas to be
27 extracted (sometimes using hydraulic fracturing). The production zone is sometimes referred to as
28 the target zone.
- 29 **Proppant/propping agent:** A granular substance (sand grains, aluminum pellets, or other
30 material) that is carried in suspension by the fracturing fluid and that serves to keep the cracks
31 open when fracturing fluid is withdrawn after a fracture treatment. ([U.S. EPA, 2013d](#))
- 32 **Protected ground water resource:** The deepest aquifer that the state or other regulatory agency
33 requires to be protected from fluid migration through or along wellbores.

- 1 **Public water system source:** The source of the surface or ground water used by a public water
2 system, including source wells, intakes, reservoirs, infiltration galleries, and springs.
- 3 **Public water systems:** Water systems that provide water for human consumption from surface or
4 ground water through pipes or other infrastructure to at least 15 service connections or serve an
5 average of at least 25 people for at least 60 days a year. ([Safe Drinking Water Act, 2002](#))
- 6 **Publicly owned treatment works (POTW):** Any device or system used in the treatment (including
7 recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is
8 owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only
9 if they convey wastewater to a POTW providing treatment. ([U.S. EPA, 2013d](#))
- 10 **Quality assurance (QA):** An integrated system of management activities involving planning,
11 implementation, documentation, assessment, reporting, and quality improvement to ensure that a
12 process, item, or service is of the type and quality needed and expected by the customer. ([U.S. EPA,](#)
13 [2013d](#))
- 14 **Quality assurance project plan (QAPP):** A formal document describing in comprehensive detail
15 the necessary quality assurance procedures, quality control activities, and other technical activities
16 that need to be implemented to ensure that the results of the work performed will satisfy the stated
17 performance or acceptance criteria. ([U.S. EPA, 2013d](#))
- 18 **Quality management plan:** A document that describes a quality system in terms of the
19 organizational structure, policy and procedures, functional responsibilities of management and
20 staff, lines of authority, and required interfaces for those planning, implementing, documenting, and
21 assessing all activities conducted. ([U.S. EPA, 2013d](#))
- 22 **Radioactive tracer log:** A record of the presence of tracer material placed in or around the
23 borehole to measure fluid movement in injection wells. ([Schlumberger, 2014](#))
- 24 **Radionuclide:** Radioactive particle, man-made or natural, with a distinct atomic weight number.
25 Emits radiation in the form of alpha or beta particles, or as gamma rays. Can have a long life as soil
26 or water pollutant. Prolonged exposure to radionuclides increases the risk of cancer. ([U.S. EPA,](#)
27 [2013d](#))
- 28 **Reference dose (RfD):** An estimate (with uncertainty spanning perhaps an order of magnitude) of
29 a daily oral exposure to the human population (including sensitive subgroups) that is likely to be
30 without an appreciable risk of deleterious effects during a lifetime.
- 31 **Reference value (RfV):** An estimate of an exposure for a given duration to the human population
32 (including susceptible subgroups) that is likely to be without an appreciable risk of adverse health
33 effects over a lifetime. Reference value is a generic term not specific to a given route of exposure.
- 34 **Relative permeability:** A dimensionless property allowing for comparison of the different abilities
35 of fluids to flow in multiphase settings. If a single fluid is present, its relative permeability is equal

- 1 to 1, but the presence of multiple fluids generally inhibits flow and decreases the relative
2 permeability.
- 3 **Reservoir:** A porous and permeable geologic formation where hydrocarbons collect under
4 pressure over geological time.
- 5 **Residuals:** The solids generated or retained during the treatment of wastewater. ([U.S. EPA, 2013d](#))
- 6 **Safe Drinking Water Act (SDWA):** The act designed to protect the nation's drinking water supply
7 by establishing national drinking water standards (maximum contaminant levels or specific
8 treatment techniques) and by regulating underground injection control wells. ([U.S. EPA, 2013d](#))
- 9 **Sandstone:** A clastic sedimentary rock whose grains are predominantly sand sized. The term is
10 commonly used to imply consolidated sand or a rock made of predominantly quartz sand, although
11 sandstones often contain feldspar, rock fragments, mica, and numerous additional mineral grains
12 held together with silica or another type of cement. The relatively high porosity and permeability of
13 sandstones make them good reservoir rocks. ([Schlumberger, 2014](#))
- 14 **Science Advisory Board (SAB):** A federal advisory committee that provides a balanced, expert
15 assessment of scientific matters relevant to the EPA. An important function of the Science Advisory
16 Board is to review EPA's technical programs and research plans. ([U.S. EPA, 2013d](#))
- 17 **Service company:** A company that assists well operators by providing specialty services, including
18 hydraulic fracturing. ([U.S. EPA, 2013d](#))
- 19 **Shale:** A fine-grained, fissile, detrital sedimentary rock formed by consolidation of clay- and silt-
20 sized particles into thin, relatively impermeable layers. ([Schlumberger, 2014](#))
- 21 **Shale gas:** Natural gas generated and stored in shale.
- 22 **Shale oil:** Oil present in unconventional oil reservoirs that are made up of shale.
- 23 **Shut-in:** The process of sealing off a well by either closing the valves at the wellhead, a downhole
24 safety valve, or a blowout preventer.
- 25 **Slickwater:** A type of fracturing fluid that consists mainly of water with a very low portion of
26 additives like polymers that serve as friction reducers to reduce friction loss when pumping the
27 fracturing fluid downhole. ([Barati and Liang, 2014](#))
- 28 **Solubility:** The amount of mass of a compound that will dissolve in a unit volume of solution. ([U.S.](#)
29 [EPA, 2013d](#))
- 30 **Sorption:** The general term used to describe the partitioning of a chemical between soil and water
31 and depends on the nature of the solids and the properties of the chemical.
- 32 **Source water:** Surface or ground water, or reused wastewater, acquired for use in hydraulic
33 fracturing. ([U.S. EPA, 2013d](#))

-
- 1 **Spacer fluid:** A fluid pumped before the cement to clean drilling mud out of the wellbore.
- 2 **Spud (spud a well):** To start the well drilling process by removing rock, dirt, and other
3 sedimentary material with the drill bit. ([U.S. EPA, 2013d](#))
- 4 **Stages (frac stages):** A single reservoir interval that is hydraulically stimulated in succession with
5 other intervals.
- 6 **Stimulation:** Refers to (1) injecting fluids to clear the well or pore spaces near the well of drilling
7 mud or other materials that create blockage and inhibit optimal production (i.e., matrix treatment)
8 and (2) injecting fluid to fracture the rock to optimize the production of oil or gas.
- 9 **Stray gas:** Refers to the phenomenon of natural gas (primarily methane) migrating into shallow
10 drinking water resources or to the surface.
- 11 **Strings:** An assembled length of steel pipe configured to suit a specific wellbore.
- 12 **Subsurface formation:** A mappable body of rock of distinctive rock type(s), including the rock's
13 pore volume (i.e., the void space within a formation that fluid flow can occur, as opposed to the bulk
14 volume which includes both pore and solid phase volume), with a unique stratigraphic position.
- 15 **Surface casing:** The shallowest cemented casing, with the widest diameter. Cemented surface
16 casing generally serves as an anchor for blowout protection equipment and to seal off drinking
17 water resources. ([Baker, 1979](#))
- 18 **Surface water:** All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds,
19 streams, impoundments, seas, estuaries, etc.). ([U.S. EPA, 2013d](#))
- 20 **Surfactant:** Used during the hydraulic fracturing process to decrease liquid surface tension and
21 improve fluid passage through the pipes. ([U.S. EPA, 2013d](#))
- 22 **Sustained casing pressure:** Refers to cases when the pressure in any well annulus that is
23 measurable at the wellhead rebuilds after it is bled down, not caused solely by temperature
24 fluctuations or imposed by the operator. If the pressure is relieved by venting natural gas from the
25 annulus to the atmosphere, it will build up again once the annulus is closed (i.e., the pressure is
26 sustained). ([Skjerven et al., 2011](#))
- 27 **Technically recoverable resources:** The volumes of oil and natural gas that could be produced
28 with current technology, regardless of oil and natural gas prices and production costs. ([EIA, 2013](#))
- 29 **Temperature log:** A log of the temperature of the fluids in the borehole; a differential temperature
30 log records the rate of change in temperature with depth and is sensitive to very small changes.
31 ([U.S. EPA, 2013d](#))
- 32 **Tensile strength:** The force per unit cross-sectional area required to pull a substance apart.
33 ([Schlumberger, 2014](#))
-

- 1 **Thermogenic:** Methane that is produced by high temperatures and pressures in deep formations
2 over geologic timescales. Thermogenic methane is formed by the thermal breakdown, or cracking,
3 of organic material that occurs during deep burial of sediment.
- 4 **Tight oil:** Oil found in relatively impermeable reservoir rock. ([Schlumberger, 2014](#))
- 5 **Total dissolved solids (TDS):** The quantity of dissolved material in a given volume of water. Total
6 dissolved solids can include salts (e.g., sodium chloride), dissolved metals, radionuclides, and
7 dissolved organics. ([U.S. EPA, 2013d](#))
- 8 **Toxicity:** The degree to which a substance or mixture of substances can harm humans or animals.
9 Acute toxicity involves harmful effects in an organism through a single or short-term exposure.
10 Chronic toxicity is the ability of a substance or mixture of substances to cause harmful effects over
11 an extended period, usually upon repeated or continuous exposure, sometimes lasting for the entire
12 life of the exposed organism. Subchronic toxicity is the ability of the substance to cause effects for
13 more than 1 year but less than the lifetime of the exposed organism. ([U.S. EPA, 2013d](#))
- 14 **Tubing:** The narrowest casing set within a completed well, either hung directly from the wellhead
15 or secured at its bottom using a packer. Tubing is not typically cemented in the well.
- 16 **Unconventional reservoir:** A reservoir characterized by lower permeability than conventional
17 reservoirs. It can be the same formation where hydrocarbons are formed and also serve as the
18 source for hydrocarbons that migrate and accumulate in conventional reservoirs. Unconventional
19 reservoirs can include methane-rich coalbeds and oil- and/or gas-bearing shales and tight sands.
- 20 **Unconventional resource:** An umbrella term for oil and natural gas that is produced by means
21 that do not meet the criteria for conventional production. What has qualified as unconventional at
22 any particular time is a complex function of resource characteristics, the available exploration and
23 production technologies, the economic environment, and the scale, frequency, and duration of
24 production from the resource. Perceptions of these factors inevitably change over time and often
25 differ among users of the term. At present, the term is used in reference to oil and gas resources
26 whose porosity, permeability, fluid trapping mechanism, or other characteristics differ from
27 conventional sandstone and carbonate reservoirs. Coalbed methane, gas hydrates, shale gas,
28 fractured reservoirs, and tight gas sands are considered unconventional resources. ([Schlumberger,
29 2014](#))
- 30 **Underground Injection Control (UIC):** The program under the Safe Drinking Water Act that
31 regulates the use of wells to pump fluids into the ground. ([U.S. EPA, 2013d](#))
- 32 **Unsaturated zone:** The soil zone above the water table that is only partially filled by water; also
33 referred to as the “vadose zone.”
- 34 **Vapor pressure:** The force per unit area exerted by a vapor in an equilibrium state with its pure
35 solid, liquid, or solution at a given temperature. Vapor pressure is a measure of a substance's

- 1 propensity to evaporate. Vapor pressure increases exponentially with an increase in temperature.
2 ([U.S. EPA, 2013d](#))
- 3 **Vertical well:** A well in which the wellbore is vertical throughout its entire length, from the
4 wellhead at the surface to the production zone.
- 5 **Viscosity:** A measure of the internal friction of a fluid that provides resistance to shear within the
6 fluid, informally referred to as how "thick" a fluid is.
- 7 **Volatile:** Readily vaporizable at a relatively low temperature. ([U.S. EPA, 2013d](#))
- 8 **Volatilization:** The process in which a chemical leaves the liquid phase and enters the gas phase.
- 9 **Wastewater treatment:** Chemical, biological, and mechanical procedures applied to an industrial
10 or municipal discharge or to any other sources of contaminated water in order to remove, reduce,
11 or neutralize contaminants. ([U.S. EPA, 2013d](#))
- 12 **Water availability:** There is no standard definition for water availability, and it has not been
13 assessed recently at the national scale ([U.S. GAO, 2014](#)). Instead, a number of water availability
14 indicators have been suggested (e.g., [Roy et al., 2005](#)). Here, availability is most often used to
15 qualitatively refer to the amount of a location's water that could, currently or in the future, serve as
16 a source of drinking water ([U.S. GAO, 2014](#)), which is a function of water inputs to a hydrologic
17 system (e.g., rain, snowmelt, groundwater recharge) and water outputs from that system occurring
18 either naturally or through competing demands of users.
- 19 **Water consumption:** Water that is removed from the local hydrologic cycle following its use (e.g.,
20 via evaporation, transpiration, incorporation into products or crops, consumption by humans or
21 livestock), and is therefore unavailable to other water users ([Maupin et al., 2014](#)).
- 22 **Water intensity:** The amount of water used per unit of energy obtained. ([Nicot et al., 2014](#);
23 [Laurenzi and Jersey, 2013](#))
- 24 **Water reuse:** Any hydraulic fracturing wastewater that is used to offset total fresh water
25 withdrawals for hydraulic fracturing, regardless of the level of treatment required.
- 26 **Water use:** Water withdrawn for a specific purpose, part or all of which may be returned to the
27 local hydrologic cycle.
- 28 **Water withdrawal:** Water removed from the ground or diverted from a surface-water source for
29 use. ([Nicot et al., 2014](#); [Laurenzi and Jersey, 2013](#))
- 30 **Well blowout:** The uncontrolled flow of fluids out of a well.
- 31 **Well communication:** Refers to fractures intersecting abandoned or active (producing) offset
32 wells near the well that is being stimulated.

- 1 **Well logging:** A continuous measurement of physical properties in or around the well with
2 electrically powered instruments to infer formation properties. Measurements may include
3 electrical properties (resistivity and conductivity), sonic properties, active and passive nuclear
4 measurements, measurements of the wellbore, pressure measurement, formation fluid sampling,
5 sidewall coring tools, and others. Measurements may be taken via a wireline, which is a wire or
6 cable that is used to deploy tools and instruments downhole and that transmits data to the surface.
7 ([Adapted from Schlumberger, 2014](#))
- 8 **Well operator:** A company that controls and operates oil and gas wells. ([U.S. EPA, 2013d](#))
- 9 **Well pad:** A temporary drilling site, usually constructed of local materials such as sand and gravel.
10 After the drilling operation is over, most of the pad is usually removed or plowed back into the
11 ground. ([NYSDEC, 2011](#))
- 12 **Wellbore:** The drilled hole or borehole, including the open hole or uncased portion of the well.
- 13 **Wet gas:** Refers to natural gas that typically contains less than 85% methane along with ethane and
14 more complex hydrocarbons.
- 15 **Wetting/nonwetting:** The preferential attraction of a fluid to the surface. In typical reservoirs,
16 water preferentially wets the surface, and gas is nonwetting. ([Adapted from Dake, 1978](#))
- 17 **Workover:** Refers to any maintenance activity performed on a well that involves ceasing
18 operations and removing the wellhead.
- 19 **Young's modulus:** A ratio of stress to strain that is a measure of the rigidity of a material.

J.2. References for Appendix J

- [Baker, R.](#) (1979). A primer of oilwell drilling (4th ed.). Austin, TX: Petroleum Extension Service (PETEX).
- [Barati, R; Liang, J.T.](#) (2014). A review of fracturing fluid systems used for hydraulic fracturing of oil and gas wells. J Appl Polymer Sci Online pub. <http://dx.doi.org/10.1002/app.40735>
- [Dake, L.P.](#) (1978). Fundamentals of reservoir engineering. Boston, MA: Elsevier.
<http://www.ing.unp.edu.ar/asignaturas/reservorios/Fundamentals%20of%20Reservoir%20Engineering%20%28L.P.%20Dake%29.pdf>
- [Devereux, S.](#) (1998). Practical well planning and drilling manual. Tulsa, OK: PennWell Publishing Company.
<http://www.pennwellbooks.com/practical-well-planning-and-drilling-manual/>
- [EIA](#) (Energy Information Administration). (2013). Technically recoverable shale oil and shale gas resources: an assessment of 137 shale formations in 41 countries outside the United States (pp. 730). Washington, D.C.: Energy Information Administration, U.S. Department of Energy.
<http://www.eia.gov/analysis/studies/worldshalegas/>
- [Gupta, DVS; Valkó, P.](#) (2007). Fracturing fluids and formation damage. In M Economides; T Martin (Eds.), Modern fracturing: enhancing natural gas production (pp. 227-279). Houston, TX: Energy Tribune Publishing Inc.
- [Laurenzi, JI; Jersey, GR.](#) (2013). Life cycle greenhouse gas emissions and freshwater consumption of Marcellus shale gas. Environ Sci Technol 47: 4896-4903. <http://dx.doi.org/10.1021/es305162w>

- [Maupin, MA; Kenny, JF; Hutson, SS; Lovelace, JK; Barber, NL; Linsey, KS.](#) (2014). Estimated use of water in the United States in 2010. (USGS Circular 1405). Reston, VA: U.S. Geological Survey. <http://dx.doi.org/10.3133/cir1405>
- [Nicot, JP; Scanlon, BR; Reedy, RC; Costley, RA.](#) (2014). Source and fate of hydraulic fracturing water in the Barnett Shale: a historical perspective. *Environ Sci Technol* 48: 2464-2471. <http://dx.doi.org/10.1021/es404050r>
- [NYSDEC](#) (New York State Department of Environmental Conservation). (2011). Revised draft supplemental generic environmental impact statement (SGEIS) on the oil, gas and solution mining regulatory program: Well permit issuance for horizontal drilling and high-volume hydraulic fracturing to develop the Marcellus shale and other low-permeability gas reservoirs. Albany, NY: NY SDEC. <http://www.dec.ny.gov/energy/75370.html>
- [Oil and Gas Mineral Services.](#) (2010). MineralWise: Oil and gas terminology. Available online at <http://www.mineralweb.com/library/oil-and-gas-terms/>
- [Roy, SB; Ricci, PF; Summers, KV; Chung, CF; Goldstein, RA.](#) (2005). Evaluation of the sustainability of water withdrawals in the United States, 1995 to 2025. *J Am Water Resour Assoc* 41: 1091-1108.
- [Safe Drinking Water Act. Title XIV of the Public Health Service Act Safety of Public Water Systems](#) (Safe Drinking Water Act) as amended through P.L. 107-377, (2002). <http://www.epw.senate.gov/sdwa.pdf>
- [Schlumberger](#) (Schlumberger Limited). (2014). Schlumberger oilfield glossary. Available online at <http://www.glossary.oilfield.slb.com/>
- [Skjerven, T; Lunde, Ø; Perander, M; Williams, B; Farquhar, R; Sinet, I; Sæby, J; Haga, HB; Finnseth, Ø; Johnsen, S.](#) (2011). Norwegian Oil and Gas Association recommended guidelines for well integrity. (117, Revision 4). Norway: Norwegian Oil and Gas Association. <http://www.norskoljeoggass.no/Global/Retningslinjer/Boring/117%20-%20Recommended%20guidelines%20Well%20integrity%20rev4%2006.06.%2011.pdf>
- [Solley, WB; Pierce, RR; Perlman, HA.](#) (1998). Estimated use of water in the United States in 1995. (USGS Circular: 1200). U.S. Geological Survey. <http://pubs.er.usgs.gov/publication/cir1200>
- [Spellman, FR.](#) (2012). Environmental impacts of hydraulic fracturing. In *Environmental impacts of hydraulic fracturing*. Boca Raton, Florida: CRC Press.
- [U.S. Census Bureau.](#) (2013). Metropolitan and micropolitan statistical areas main. Available online at <http://www.census.gov/population/metro/> (accessed January 12, 2015).
- [U.S. Department of Transportation.](#) (2012). Large truck and bus crash facts 2012. Washington, D.C.: Federal Motor Carrier Safety Administration, U.S. Department of Transportation. <http://ai.fmcsa.dot.gov/CarrierResearchResults/PDFs/LargeTruckandBusCrashFacts2012.pdf>
- [U.S. EPA](#) (U.S. Environmental Protection Agency). (2011a). Plan to study the potential impacts of hydraulic fracturing on drinking water resources [EPA Report]. (EPA/600/R-11/122). Washington, DC: U.S. Environmental Protection Agency, Office of Research and Development. <http://www2.epa.gov/hfstudy/plan-study-potential-impacts-hydraulic-fracturing-drinking-water-resources-epa600r-11122>
- [U.S. EPA. General definitions, 40 CFR § 437.2](#) (2012b). <http://www.gpo.gov/fdsys/pkg/CFR-2012-title40-vol31/pdf/CFR-2012-title40-vol31-sec437-2.pdf>
- [U.S. EPA](#) (U.S. Environmental Protection Agency). (2013c). Drinking water and ground water statistics, fiscal year 2011. Washington, DC: U.S. Environmental Protection Agency, Office of Water. <http://water.epa.gov/scitech/datait/databases/drink/sdwisfed/upload/epa816r13003.pdf>

- [U.S. EPA](#) (U.S. Environmental Protection Agency). (2013d). Terminology services (TS): Terms and acronyms. Available online at http://iaspub.epa.gov/sor_internet/registry/termreg/searchandretrieve/termsandacronyms/search.do
- [U.S. EPA](#) (U.S. Environmental Protection Agency). (2014b). Drinking water contaminants. Available online at <http://water.epa.gov/drink/contaminants/>
- [U.S. EPA](#) (U.S. Environmental Protection Agency). (2015d). Case study analysis of the impacts of water acquisition for hydraulic fracturing on local water availability [EPA Report]. (EPA/600/R-14/179). Washington, D.C.
- [U.S. GAO](#) (U.S. Government Accountability Office). (2014). Freshwater: Supply concerns continue, and uncertainties complicate planning. Report to Congressional requesters. (GAO-14-430). Washington, DC: U.S. Government Accountability Office (GAO). <http://www.gao.gov/assets/670/663343.pdf>
- [USGS](#) (U.S. Geological Survey). (2015). Water use in the United States. Available online at <http://water.usgs.gov/watuse/>