APPENDIX A: SUMMARY OF THE NATURAL GAS DRILLING PROCESS

To transport natural gas that is diffusely embedded in sediment thousands of feet below the earth's surface to a commercial gas pipeline and into a household's gas stove is a complex process involving many different operations. While the description included in this HIA is far from complete, to understand the HIA and its recommendations requires some familiarity with natural gas drilling. For additional reading about the natural gas drilling process, please refer to the following documents:

- *Community Guide to Understanding Natural Gas Development*, written by the Garfield County Energy Advisory Board[101] and
- *Comprehensive Safety Recommendations for Land-Based Oil and Gas Well Drilling*[102]

Natural gas drilling involves the following processes.

Site Selection

A geological survey team collects information on the geology of potential sites to drill. The geological survey team and business managers discuss the benefits and risks of each potential site. Eventually, the business managers and geologists select a site or a group of sites to develop into well pads.

Site Preparation

Before drilling can begin, an operator must prepare the site. The operator typically contracts this task to earth moving companies that create a level surface on which to work. In addition to creating a level platform for drilling activities, site preparation companies often dig and dike any required reservoirs and excavate the cellar. The cellar is, essentially, a pit that collects fluids and accommodates the **blowout preventer** and other equipment. During the site preparation, contractors often transport heavy machinery to the site for earth moving operations and gravel/soil to create a level well pad. Site preparation also may include building roads to access the well pad and installation of pipes to transport natural gas and water.

Drilling

A subcontractor delivers and erects a load-bearing structure to support the weight of the **drill**, the **drill string** and other relevant equipment. Historically, contractors used a structure called a **derrick**. While many contractors still use derricks, contractors also use a different type of structure called a **mast**. Whereas derricks must be constructed on site, masts do not require as much assembly once they are delivered to the site. Masts are simply hoisted and secured into place.

When the load-bearing structure is secure, the drill creates an initial hole by a process commonly called "**spudding in**". As soon as "spudding in" is complete, the contractor inserts a section of metal pipe, called **conductor casing**, into the hole to prevent blowouts and ensure the well's integrity. The contractor secures the conductor casing into place by injecting cement between the sediment and the casing.

Once the conductor casing is securely cemented into place, the drill bores to a depth of approximately 900 feet below ground surface (bgs). This "surface hole" is also lined with casing (called **surface casing**), which like the conductor casing is cemented into place. Surface casing is the barrier between the well bore and groundwater reserves.

After surface casing is securely in place, the contractor continues to drill, meanwhile installing the subsequent layer of casing, called **production casing**. Production casing, like other forms of casing, is manufactured, transported and installed in thirty-foot sections. Eventually, the production casing runs thousands of feet deep to reach the hydrocarbon formations – as much as 10,000 feet bgs but in the Piceance Basin, more likely around 6,000 feet bgs. The production casing, as with the other sections of casing, is cemented into place.

During the drilling process, contractors transport the drill rig, casing, materials for drilling mud, water and other equipment to the well pad. After the production casing is securely in place, the drill rig is disassembled and the well completion process begins.

A couple of additional terms to be aware of include (but are not limited to):

Drilling Mud – Drilling contractors use drilling mud to lubricate the drill bit, carry cuttings (i.e. sediment) to the surface, and provide downward pressure in the well bore. Drilling mud is usually a complex mixture of liquids, reactive solids and inert solids. Mud often includes bentonite, a heavy clay material. The liquid might be comprised of freshwater, diesel oil, crude oil and/or "conditioners." The category of "conditioners" actually includes a wide variety of chemical compounds that serve various purposes in the drilling process[103]. Some conditioners stabilize the geologic formation as the operator drills deeper. Other conditioners lubricate the drill. Some conditioners make the drilling mud thicker. Others make the mud thinner. Characterizing the precise chemical composition of all of the conditioners available for Antero's use is beyond the scope of this HIA.

Directional Drilling – Drilling contractors now have the ability to drill at angles other than directly downward. The angle of the well bore relative to the surface can change during the drilling process. Sometimes, wells are started at an angle and drill practically horizontally. Other times, contractors drill straight down and change the angle of the well bore after the production casing is in place.

Well Stimulation

At the depth of the hydrocarbon formation, the production casing is pierced with explosive charges or bullets. Perforating the production casing itself and the surrounding layer of cement creates channels through which natural gas can pass. Well perforation is not the same as hydraulic fracturing, although it is a necessary precursor.

Natural gas contractors use **well stimulation** methods to increase the rate at which natural gas flows to the surface. One prominent stimulation method is **hydraulic fracturing**, whereby a contractor injects liquids under high pressure to create fissures in the sediment surrounding the well bore. By creating fissures in the sediment, hydraulic fracturing releases natural gas that was embedded in the tightly packed sediment. The gas enters the well bore through the perforated production casing and flows up to the surface. The liquids used in the hydraulic fracturing process are composed of water and various chemicals – some of which may be protected by trade secrets. Hydraulic fracturing fluids also may be called fracking or frac'ing fluid or water.

Well Completion

The pressure of the geologic formation and its heterogeneous contents necessitate the process called **well completion**. After a formation is hydraulically fractured, the natural gas operator must collect water, hydraulic fracturing fluids, sediment, condensate, oil and natural gas that is generated in the process. Well completion is a process by which the channels of the well are cleared so that natural gas can pass freely to the surface. The contents are typically collected into tanks and shipped off-site.

Well Production

After the well has been completed, the well pad shifts into production mode, whereby the recently-drilled well releases natural gas into the commercial line. However, to ensure the safety and the quality of the gas, the well production phase requires additional technologies. For instance, tanks collect water and additional condensate that the well may produce.

Reclamation

After a well is no longer producing gas, it is plugged and abandoned. According to the Colorado Oil and Gas Conservation Commission's regulations pertaining to well reclamation, the land surrounding the wellhead must be restored as closely as possible to its original condition. If the well pad is on cropland, the operator has three months to begin the reclamation process. Operators have 12 months to begin reclamation on non-crop land. To reclaim the well-pad, the operator needs to remove all of the equipment and waste from the site. They need to re-fill the hole in which the wellhead was located. Land needs to be re-graded and re-vegetated to its original condition, as do access roads. Prior to deeming the land "reclaimed" a COGCC inspector must investigate the land to ensure it has been properly re-graded and re-vegetated and that all of the waste and debris have been cleared.