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Technologies Reduce Pad Size, Waste

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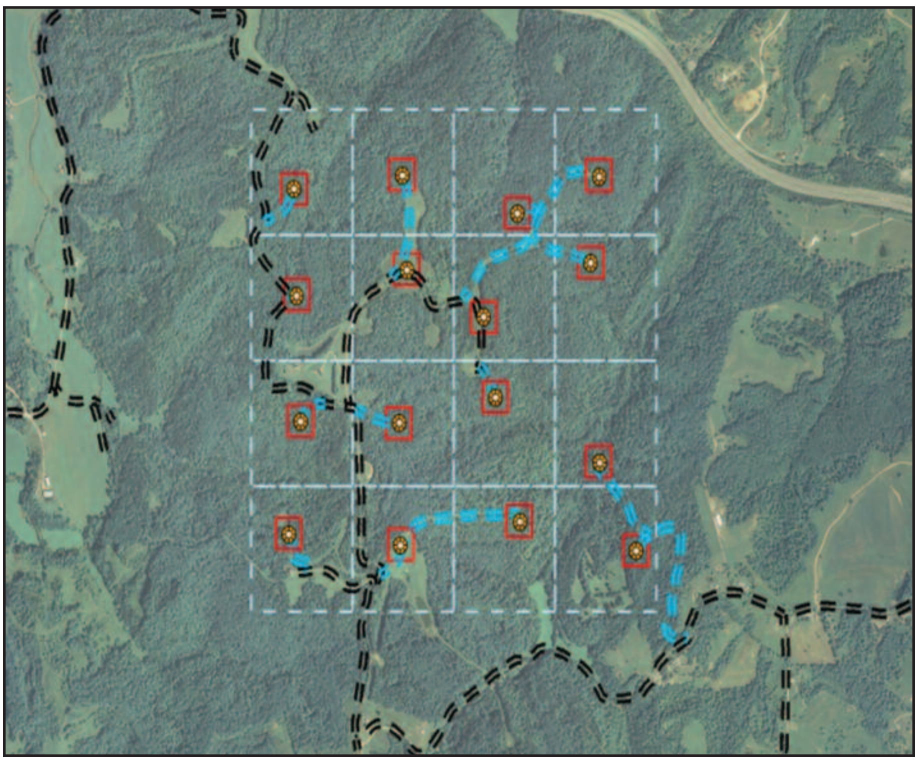
TULSA–Since the turn of the millennium, new onshore oil and gas development has increasingly focused on unconventional reservoirs such as oil from the Bakken Shale of the Williston Basin and natural gas from numerous shale gas plays (e.g., Barnett Shale, Fayetteville Shale, Haynesville Shale, and Marcellus Shale). In some plays, including much of the Marcellus Shale, this involves drilling in areas that have limited experience with oil and gas development. This has resulted in increasing levels of public concern and in some cases outright resistance to resource development.

Two topics of concern frequently expressed by regulators, nongovernmental organizations, and the public are surface disturbance and waste management. Not surprisingly, surface disturbance is one of the most readily apparent consequences of resource development. Waste generation is often greater for unconventional reservoirs than it is for conventional plays, primarily because high volume hydraulic fracturing (HVHF), which is typically necessary to economically develop low-permeability unconventional reservoirs, creates large volumes of waste water. This article will examine a few of the technologies for addressing these public concerns and reducing environmental impacts. The examples discussed will primarily come from shale gas plays, but the basic concepts are applicable to many other unconventional development scenarios.

FIGURE 1

Footprint of Developing 640 Acres with Vertical Wells



Modern shale gas development includes both vertical and horizontal wells. The emerging shale gas basins are expected to follow a trend similar to the Barnett Shale, with horizontal wells becoming increasingly common as the plays mature. The growing popularity of horizontal wells stems from improvements in technology and the economic benefits of greater reservoir exposure. For example, in the Marcellus Shale, a vertical well may be exposed to as little as 50 feet of the reservoir while a horizontal well may have a lateral well bore extending in length from 2,000 to 6,000 feet within the target formation.

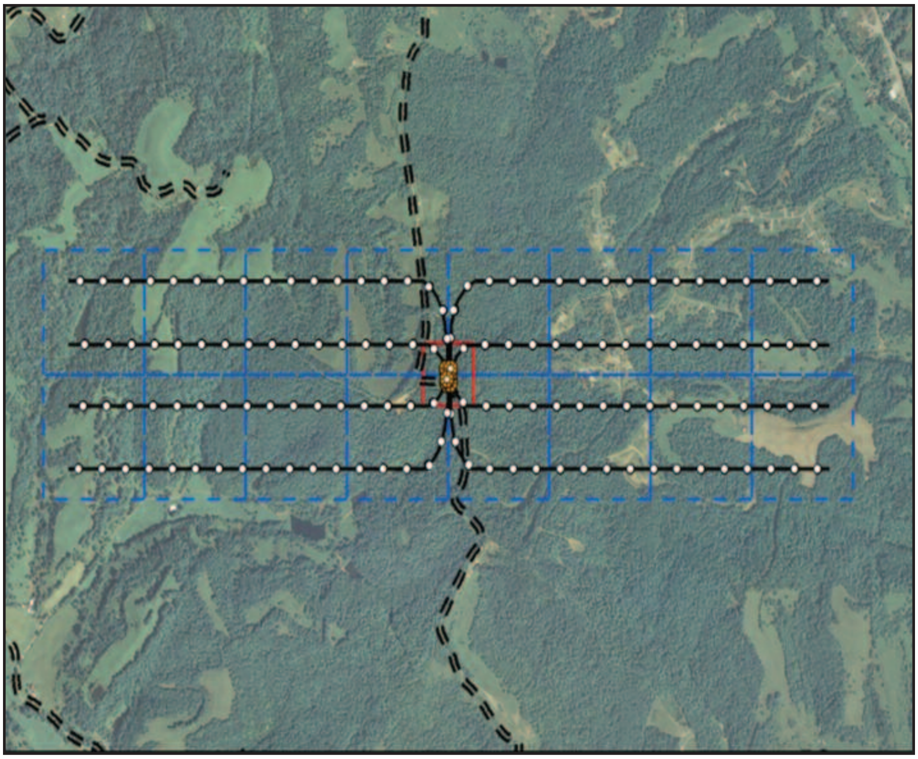
Using horizontal drilling and HVHF on the one hand is a contributor to a key environmental benefit (minimizing surface disturbance) and on the other hand is the source of one of shale development's environmental concerns (waste generation).

Reducing Surface Impacts

Surface disturbances are part of oil and gas development. The magnitude of the disturbance may vary according to the region or physiographic setting, but some disturbance is necessary to allow access to the resource (e.g., roads and well pads) and resource transportation

FIGURE 2

Footprint of Developing 640 Acres with Horizontal Wells



(e.g., pipelines and compressors). To address this inevitability, oil and gas companies have adopted a mantra of avoiding environmental impacts when possible, minimizing the impacts that cannot be avoided, and mitigating the impacts that remain.

For example, the companies could develop an area of one square mile (640 acres) using 16 vertical wells (at 40-acre spacing), each located on a separate well pad (Figure 1). However, the industry prefers a different approach: using four to eight horizontal wells drilled from a single well pad (Figure 2). Using horizontal wells in the Barnett Shale has allowed three or four vertical wells to be replaced with a single horizontal well.

At full-field development scale, this reduction in the overall number of well pads significantly reduces the total environmental disturbance. The number of production facilities required and total mileage of access roads and utility corridors are reduced, thus minimizing wildlife habitat fragmentation, impacts on the public and overall environmental footprint. Furthermore, horizontal drilling also can make it possible to develop areas where surface occupancy is impractical or undesirable.

Analysis performed in 2008 for the U.S. Department of the Interior, using the Fayetteville Shale as an example, estimated that a shallow vertical gas well typically would have a 2.1-acre well pad plus 2.7 incremental acres for associated process areas, access roads, utility corridors, etc., resulting in a total construction disturbance of 4.8 acres for each well. In contrast, a well pad for four or more horizontal wells in the same play would occupy only four acres plus incremental acres for associated process areas, access roads, utility corridors, etc., resulting in a total of 7.4 acres disturbed. Thus, sixteen vertical wells with individual pads and roads would disturb 77 acres, more than 10 times the area of horizontal wells capable of producing the same natural gas. This difference in development footprint is significant in rural and urban settings.

Other technologies and approaches also can limit surface disturbance associated with drilling. Advances in drilling technology, such as directional drilling, closed-loop drilling, coiled tubing drilling, modular rigs, pneumatic drilling, slim-hole drilling, and automated rigs, allow smaller well pads. In urban settings, steel storage tanks can be used to hold drilling fluids as well as to store water and fluids for use during hydraulic fracturing. Tanks used in closed-loop drilling systems decrease the amount of drilling fluids required by facilitating reuse. This in turn generates less waste and allows the use of smaller well pads.

Fit-for-purpose rigs also can reduce drilling pad size. These specialized rigs can drill multiple horizontal wells efficiently from a relatively small well pad. The rigs are mounted on a rail system, enabling them to drill one well, then be moved on the rails several feet to drill the next. The rig can drill a row of directional wells from one setup, then the rig and rails can be repositioned to drill a second row of directional wells. In fact, some of these rigs have rails in two directions to allow drilling two rows of wells without

This low-profile, fit-for-purpose drilling rig is drilling Barnett Shale wells at the Dallas-Fort Worth airport.

breaking down the rig. In this manner, eight or more wells can be drilled from one small well pad, shrinking the drilling operation's footprint while reducing rig moves and therefore downtime. Such specialized rigs are limited in number and may not be available in all areas.

Reducing Waste

Waste is generated throughout the development process, but is perhaps most prominent during two phases: the drilling phase and the stimulation/completion phase, during which HVHF generates large volumes of produced water. Properly managing these activities can minimize waste, reduce costs, and provide ancillary environmental benefits.

Drilling wastes in the form of cuttings and used drilling mud have long been a ubiquitous waste associated with oil and gas development. However, closed-loop drilling systems offer a means to minimize those wastes.

Closed-loop drilling systems utilizing shale shakers, sand and silt removal, dewatering equipment and integral mud tanks can effectively manage the drilling mud system, limiting waste and minimizing or eliminating the need for earth-disturbing reserve/mud pits. In these systems, drilling mud is commonly recycled after processing to remove fines and solids.

By separating the cuttings and recycling the mud, the volume of waste, as well as any surface disturbance associated with disposal of the waste, is minimized. Closed-loop systems also can provide for a smaller well pad footprint because the mud is kept in tanks rather than earthen constructions. Solids control and drilling mud maintenance can have numerous other benefits, including lower mud volumes, increased penetration rates, and longer bit life. Furthermore, the self-contained nature of closed-loop systems reduces the chance of spills.

Waste can be reduced even more by using alternative drilling systems where practical. For example, some operators in the Marcellus Shale are drilling the vertical portion of the well bore using smaller air-rotary drilling rigs, completely eliminating the need for drilling mud and limiting the waste generated to drill cuttings for that portion of the well bore.

During the completion stage of well construction, unconventional reservoirs generally require HVHF stimulations. Typically, the largest volume of waste generated during the shortest period is the return flow of spent fracturing fluids following reservoir stimulation.

Fracturing a typical horizontal shale gas well may require 2 million-5 million gallons of water on average. In most cases, water produced during flow back will contain residual spent chemicals from the fracturing fluids as well as dissolved ionic constituents that are naturally present in the formation water or minerals naturally present in the shale formation.

Volumes of water produced during flowback vary from play to play and even from well to well within a play, but in the first few weeks or months the volume for horizontal wells can range from 15 percent to 35 percent of the original fracture fluid volume. Vertical wells may have higher percentage rates of recovery during flow back.

This waste has raised a number of public concerns. In addition, some areas of the country have few commercial disposal facilities or old, played out oil or gas fields that may be suitable for underground injection of waste brine. This has resulted in operators transporting the waste water long distances to commercial disposal facilities, which is costly and creates additional risk of spills.

A new trend is emerging in some shale gas plays, including the Marcellus: reusing produced water as make-up water for subsequent HVHF stimulation jobs. Once the water produced during flow back has returned to the surface, service companies and operators evaluate its quality to determine how much treatment, if any, is needed to reuse the water. In many cases it is more practical to treat the water to a quality appropriate for reuse than to treat it to the level necessary for more sensitive uses (e.g., industrial or municipal), or for permitted discharge to surface water bodies.

In reuse, the produced water typically is blended with fresh make-up water to achieve the volumes necessary for the subsequent HVHF stimulation job. The produced water often receives limited treatment before blending, such as the addition of treatment chemicals to flocculate and precipitate out select metallic ions that might cause scaling.

In addition to this treatment, the produced water is mixed with a larger volume of freshwater to dilute the chlorides and other salts present in the produced water. These blends are often 20 percent produced water to 80 percent fresh water, but the ratio will depend on site-specific conditions, including the quality and the volume of produced water being used. In this manner, as much as 100 percent of the water that flows back can be reused.

The benefits of produced water recycling extend well beyond minimizing waste. Reuse also reduces the volume of freshwater that must be sourced for subsequent HVHF stimulation jobs. In general, this reduces transportation impacts on the community by requiring less truck-

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ing of fresh water from a withdrawal site to the well. It also reduces transportation and freshwater procurement costs, and reduces or eliminates waste disposal costs.

There are multiple opportunities to approach unconventional oil and gas development activities in an environmentally friendly manner throughout the full life cycle, from initial drilling and development through production and final abandonment. Although this article has discussed only a few, new technologies and practices are being developed continually to meet the challenges of unconventional reservoir development while reducing environmental impact and public concern.

Technologies that once were regarded as novel or "unconventional" are rapidly becoming the conventional approach. Many already have become industry standard practices; some have become best management practices with regional applicability; and still others are emerging technologies. While some of these technologies initially were developed and implemented to reduce costs and improve profits, they are yielding significant environmental benefits by reducing surface disturbance and minimizing waste disposal. ❐