Geosynthetic lining systems for shale gas drilling activities

Usage, regulations, concerns, and challenges

By Theresa Andrejack Loux and Archie Filshill

1. Introduction

Natural gas has long been used to heat buildings and, more recently, to fuel internal combustion engines and power plants. With natural gas providing an alternative to oil, gasoline, and coal in these applications, it promises a marked decrease in the dependence of the U.S. on foreign oil.

It is often seen as a "cleaner" fossil fuel and has been easier to harvest with the advancement of drilling techniques including horizontal drilling and hydraulic fracturing (also known as "fracking"). In 2008, studies were published citing the recoverable gas potential of the Marcellus Shale to be around 363 trillion cubic feet as a low estimate. It is not surprising this information set off a large prospecting rush throughout the Northeast (Wilber 2012). Gas has been extracted from shale basins worldwide (**Figure 1** shows identified shale gas plays within the continental United States). Marcellus Shale extends from Virginia to New York, with the distribution of Marcellus Shale presented in **Table 1.**

Fresh on the heels of the Marcellus Shale speculation is new information hypothesizing that the Utica Shale formation, covering a more extensive footprint in the Appalachian Basin and several thousand feet deeper, will rival the resource potential of the Marcellus play (Wilber 2012).

A large source of potential contamination during shale gas drilling activities is from the mixture of water, sand, and chemicals used during fracking operations. This mixture is forced under high pressure though the vertical and horizontal bore to split the rock and free the trapped gas (Wilber 2012). Without these additional pathways for gas to flow out, the shale rock would not be permeable enough to extract large quantities of gas. Chemicals added during fracking serve roles such as reducing friction or killing bacteria (Galbraith 2012). Additionally, the recovered water from fracking, also known as flowback or produced water, will contain these added chemicals as well as naturally occurring contaminants that exist within the subsurface profile. Thus, the contaminant profile of the flowback water is very site-specific. Commonly found contaminants in flowback water include mineral salts, heavy metals, organic compounds, and naturally-occurring radioactive elements (U.S. Environmental Protection Agency, 2000).

A complication to environmental protection during shale gas drilling is that some—but not all— U.S. states have disclosure laws requiring oil and gas companies to provide information on the chemical makeup of the fracking fluid additives they are using. Even in states where disclosure laws exist, there is often a "trade secrets" clause that enables companies to prevent this information from ever entering the public sphere (Galbraith 2012).

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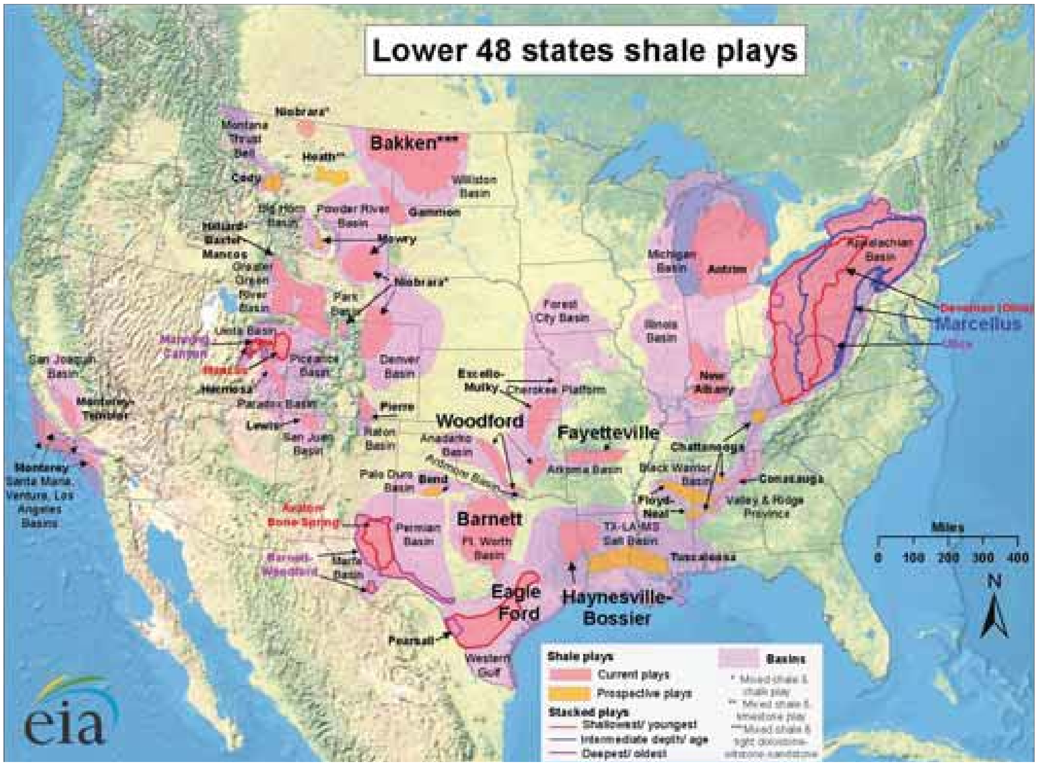

FIGURE 1 Shale Gas Plays in the Continental United States [U.S. Energy Information Administration (2011)].

2. Applications of lining systems in shale gas drilling

Geosynthetic lining systems have been vetted by the solid waste industry for the past 50 years to ensure the adequate protection of groundwater sources and the surrounding environment from potential contamination.

Other industries are quick to adopt these systems, including similar material types, configurations, and quality control techniques during construction, when confronted with the same goal. Similarly, the materials used to waterproof ponds for freshwater storage or stormwater control have been in existence for many years, and these lining systems are ubiquitous in modern erosion and sediment (E&S) control plans.

2.1 Drill pads and frack tank storage

Typically, there are three to six vertical well heads at a single well site. Large drill rigs are brought in to complete the vertical and horizontal drilling of each well. These wells are usually concentrated in an area on-site known as the drill pad.

Although the well heads are usually clustered together at a site, because of the existence of horizontal drilling, the "reach" of a single well site can extend radially outward for several miles from the drill pad. The pumps and pipe lines required for fracking are connected at these access points on the drill pad.

Frack tanks are often located in close proximity to the well heads, in many cases utilizing the same underlying lining system to protect against any spills or leaks from the tanks, piping network, or pump system.

2.2 Freshwater impoundments and stormwater control basins

During fracking operations, large quantities of fresh water are consumed. Thus, a

TABLE 1 State distribution of the Marcellus Shale Play [U.S. Energy Information Administration (2011)].

State	Area % of Marcellus
Pennsylvania	35.4
West Virginia	21.3
New York	20.1
Ohio	18.2
Virginia	3.9
Maryland	1.1

reliable method of storing the required water is necessary and is often a geosynthetic-lined impoundment. The inclusion of lined stormwater control basins at shale gas drilling sites may be necessary depending on the best management practices (BMPs) that govern an individual site.

2.3 Frack water surface impoundments and drill cutting disposal

There are sites where frack water is stored in impoundments rather than in on-site, above-ground tanks. These flowback pits can also serve as temporary storage facilities for drill cuttings that reside on-site during drilling operations.

Eventually, these cuttings are normally sent to a nearby solid waste disposal facility for permanent removal.

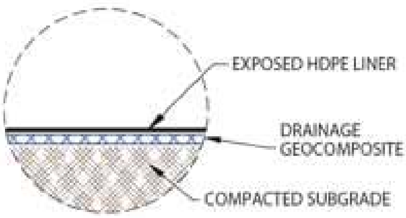

FIGURE 2 Typical liner system cross section.

3. Geosynthetic lining systems overview

All geosynthetic lining systems acting as barriers are designed to be "impermeable"—intended to prevent or restrict the transport of liquid or gas through them.

Geosynthetic materials that function as barriers include geomembranes and geosynthetic clay liners. There are many types of geomembranes that vary with resin type (LLDPE, HDPE, PVC, etc.) and additives, texture, and thickness. The resin type and additives will be most critical when determining compatibility of the contaminants with the geomembrane. Geosynthetic clay liners are more expensive than most geomembranes and should be analyzed for compatibility issues if utilized to contain flowback water.

The design for a liner system includes specified items: geometry of the liner, cross section including underlying and overlying materials, geosynthetic type and thickness, and runout and anchor trench details (Koerner 2005).

The design lifetime for the lining systems at shale gas drilling sites can vary greatly. Some of the freshwater impoundments are required only for the initial vertical and horizontal drilling at these sites which may take around one year to

FIGURE 3 Installation of an exposed, 1.5 mm (60 mil) HDPE liner underlain by a draintube geocomposite.

complete. Other applications, such as the liner system under the well pad itself will be in use for the lifetime of the wells (as long as 40 years). The applications detailed above can be divided into two categories: the first must prevent the migration of generally fresh water while the second must prevent the migration of contaminants.

3.1 Containment of freshwater

It is imperative to include an underdrain system in these freshwater impoundments to prevent gas "whales." These whales are pockets of gas that get trapped beneath a geomembrane liner and have no pathway to escape.

Common underdrain systems include: sand bedding layers, thick needle-punched nonwoven geotextiles, drainage geocomposites, and geotextiles outfitted with small perforated pipes within its cross section. A typical cross section and installation photograph are shown in **Figures 2** and **3.**

While the freshwater impoundments described above are generally designed to balance cut-to-fill earthwork quantities, certain circumstances, such as a high water table or permitting issues, lead to mobile impoundment construction. These mobile impoundments consist of fabricated steel trusses with a geomembrane liner overlying them **(Figure 4).** While generally more expensive than the in-ground impoundments, the only site requirement for these systems is a flat, competent subgrade. These systems also have the benefit of being able to be deconstructed and reused, giving them an economic advantage in cases where the impoundment will be in service for a relatively short period of time.

3.2 Containment of contaminated water and waste

A more robust lining system would include both a primary and a secondary liner, with a collection system between the two liners and a detection system beyond the secondary liner. While this type of system is common in landfills where leachate will be generated over hundreds of years, the containment of flowback water will be necessary only for the design life of the well pad (likely 20 to 30 years).

The authors have has seen the gamut of well pad designs. The minimum requirement is generally a single geomembrane or geosynthetic clay liner. Other designs combine the two materials to form a composite liner. Yet other systems include a geomembrane liner overlaid by a cushion geotextile and then topped with geocells or other specialty mat or cushioning product **(Figure 5).**

FIGURE 4 Above-ground impoundment for water storage.

4. Regulations regarding lining systems in shale gas drilling

Attempting to summarize all of the regulations regarding shale gas drilling in the U.S. would be an onerous task because there is a fair amount of variation state to state.

Koerner and Koerner (2012) compiled survey results of 35 U.S. state environmental departments to determine how many departments were involved with the shale gas drilling permitting process. Alarmingly, 18 states responded to the survey indicating that two to four departments were involved in the permitting process. Many of these states are relatively new to shale gas drilling activities. It should also be noted that New Jersey has a ban on all fracking within the state and New York has had a moratorium on shale gas drilling for the past four years while the environmental impacts of hydraulic fracturing are evaluated.

As an example, a review of the Pennsylvania regulation (PA § 78.56) for pits and tanks required for the temporary containment of pollutional substances and wastes during and produced from drilling, the following requirements are set forth:

- Two feet of freeboard should be maintained at all times.
- The synthetic liner should have a coefficient of permeability of less than 1×10^{-7}cm/s.
- The synthetic liner thickness should be greater than 0.75mm (30mils).
- The protective subbase should be greater than 150mm (6in.) thick.
- The bottom of the pit should be at least 20in. higher than the seasonal high groundwater table.
- The pit or tank should be protected from third parties at all times.

Many companies with drilling operations in Pennsylvania have chosen to exceed the requirements listed above, most notably with an increase in the thickness of the synthetic liner. Also in Pennsylvania, recommendations exist to provide a secondary containment system with a leak detection layer between the secondary and primary liner system for flowback pits and drill pits.

5. Concerns

5.1 Engineering perspective

In many cases, the state where a given site is located will dictate the minimum lining system requirements in a freshwater or containment liner system. While the culture of the oil and gas company often contributes to the assent of increasing the robustness of the system that is designed and installed, many engineering firms should also be commended for the expert guidance they have provided.

Those local engineering firms that are active in the solid waste sector and already experienced with all aspects of designing long-term containment solutions likely had an easier transition to providing oil and gas companies with lining system design and oversight services. Additionally, these companies would be familiar with the geology in the areas where drilling operations commenced. In some states, it might be an advantage to be familiar with the solid-waste regulators if shale gas drilling impoundments also fall under their jurisdiction. In other states, Pennsylvania included, many engineering firms deal with an entirely different department for shale gas impoundments and liner systems than they do for solid waste.

BMPs influencing liner system design and selection include, but are not limited to: material strength (its resistance to tear and puncture), liner material compatibility with the contained medium, installation methods, quality control and inspection, and maintenance and repair procedures. The underlying geotextile or geocomposite should be designed to serve two primary roles: to provide drainage to prevent the formation of whales under the liner system and to provide puncture protection to the geomembrane liner from the subbase material. In any liner system design, the subgrade soil stability

FIGURE 5 A well pad system that consists of, from the bottom up: a 1.5mm (60mil) HDPE textured geomembrane, a 340 g/m2 (10 oz./yd2) cushion geotextile, a 50mm (2in.) recycled foam product, and a durable, reusable specialty mat product.

FIGURE 6 Aerial photograph of a remote drilling site in central Pennsylvania.

and cover soil stability should always be evaluated and may affect the selection of the liner. Common geomembrane liner materials are 40- or 60-mil textured LLDPE or HDPE geomembranes.

Also, with regard to the regulatory hurdles, those states with a single department that acts as the point of contact for all shale gas permitting has a more transparent and easier to navigate permitting process than those that do not.

5.2 Contractor perspective

Some of the biggest challenges for geosynthetic and earthwork contractors working at Marcellus Shale sites are the locations themselves. The sites are generally rural, mountainous, and out of cell phone reception **(Figure 6).**

Combined with the capricious weather in the Northeast U.S., contractors must be organized and prepared for adverse conditions, as well as somewhat flexible in their installation schedules. The pace of construction has slowed somewhat in the past year as natural gas prices reached all-time lows, but there are still many wells being permitted and drilled.

Quality control is of utmost importance during the installation of the liner system itself. A fusion weld or extrusion weld is utilized to seam LLDPE or HDPE geomembranes. Conscientious owners and engineers will insist that the field crew completing these welds should have sufficient training, experience, and qualifications. The geosynthetic contractor may be required to complete nondestructive field testing of every seam and weld in the liner system and document these and the panel locations in field as-built drawings.

Additionally, destructive tests are completed at given intervals to ensure proper seam strength. There is usually a third-party construction quality assurance (CQA) consultant present at all times during liner installation to ensure proper installation conditions and procedures. Once the liner system installation is complete, a leak-detection survey may be done before the pit is put into service.

6. Conclusions

The regulations and governing agencies that influence lining system design at shale gas drilling sites varies by state within the U.S. Within a single U.S. state, the lining system requirements may differ for pits or tanks that will contain potentially polluted sediments or liquid compared to those that are constructed to hold freshwater reserves or stormwater runoff. Geosynthetics offer versatile and cost-effective solutions in lining systems to minimize the impact of shale gas drilling activities on the surrounding environment.

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