Virginia

REASONABLY FORESEEABLE DEVELOPMENT SCENARIO FOR FLUID MINERALS

Prepared for:

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
EASTERN STATES
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May 2008

The Bureau of Land Management is responsible for the stewardship of our public lands. It is committed to manage, protect, and improve these lands in a manner to serve the needs of the American people for all times. Management is based on the principles of multiple use and sustained yield of our nation's resources within a framework of environmental responsibility and scientific technology. These resources include air, fish and wildlife, minerals, paleontological relics, recreation, rangelands, scenic scientific and cultural values, timber; water, and wilderness.

BLM/ES/PL-08/XXX

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ACRONYMS

ACEC	Area of Critical Environmental Concern
APD	Application for Permit to Drill
AU	Assessment Units
BCF	billion cubic feet
BLM	Bureau of Land Management
BOPD	barrels of oil per day
CBNG	Coal Bed Natural Gas
DMME	Department of Mines, Minerals, and Energy
EIA	Energy Information Agency
EIS	Environmental Impact Statement
EOR	Enhanced Oil Recovery
ESA	Endangered Species Act
EIS	Environmental Impact Statement
JFO	Jackson Field Office
MMBO	million barrels of oil
mya	million years ago
RFDS	Reasonable Foreseeable Development Scenario
ROD	Record of Decision
RMP	Resource Management Plan
SMA	Surface Management Agency
TCF	trillion cubic feet
TPS	Total Petroleum Systems
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	U.S. Geological Survey

Summary

1.0 INTRODUCTION

The Bureau of Land Management's Jackson Field Office is located in Jackson, Mississippi, and is responsible for 11 southern states: Alabama, Arkansas, Virginia, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia. The Jackson Field Office manages approximately 34.25 million acres of federal mineral estate in the eastern portion of the United State. Of this approximately 1.19 million mineral estate acres are located in Virginia with oil and leasing present at the George Washington National Forest and the Flannagan Dam.

The Reasonable Foreseeable Development Scenario (RFDS) forecasts fluid mineral exploration, development, and production for the planning area for the next 10 years. The RFDS assumes a baseline scenario in which no new policies are introduced and all areas not currently closed to leasing and development are opened for oil and gas activity.

Interagency Reference Guide - Reasonably Foreseeable Development Scenarios and Cumulative Effects Analysis for Oil and Gas Activities on Federal Lands in the Greater Rocky Mountain Region" (USDI 2002), "Policy for Reasonably Foreseeable Development Scenario (RFD) for Oil and Gas (BLM WO IM No. 2004-089) and Planning for Fluid Minerals Supplemental Program Guidance (BLM Handbook H-1624-1) guided the criteria and analyses methods used in this RFD.

1.1 Discussion of Determining Oil and Gas Resource Potential

Potential accumulations of oil and gas are described in Section 2. Non-BLM land within the state may be included in this section when it provides a better understanding of resource potential on BLM property. These determinations were made using the geologic criteria provided by reference in Section 2. Also contained in Section 2 are descriptions of stratigraphy, structure, historic oil and gas activities, as well as relevant studies done in the area. Potential reservoir rocks, source rocks, and existing stratigraphic and structural traps are discussed in detail.

1.2 Methodology for Predicting Future Oil and Gas Exploration and Development Activity

Section 7 predicts the type and intensity of future oil and gas exploration and development activities. These forecasts are determined by an area's geology, and historical and present activity, as well as factors such as economics, technological advances, access to oil and gas areas, transportation, and access to processing facilities. Economics, technology, and other factors may be hard to predict because of their complex nature and rapid rate of change. Projections of oil and gas activities are based upon present knowledge. Future changes in global oil and gas markets, infrastructure and transportation, or technological advancements, may affect future oil and gas exploration and development activities within the state.

1.3 Relating the Potential for Resource Occurrence to Potential for Activity

Predicted oil and gas activity does not necessarily correlate with geologic potential for the presence of hydrocarbons. Although the geology of an area may suggest the possibility of oil and gas resources, actual exploration and development may be restricted by high exploration costs, low oil and gas prices, or difficulty accessing the area due to lease stipulations. Thus a small area may have a high resource potential, yet have a low exploration and development potential due to severe restrictions on access. Conversely, technological advancements or an increase in oil and gas prices could result in oil and gas activities in areas regarded as having low potential for occurrence.

2.0 DESCRIPTION OF THE GEOLOGY OF VIRGINIA

Virginia sits directly over the junction between the Atlantic Coastal Plain and the Appalachian Mountains. As shown in the generalized geologic map in Figure 1, the Allegheny Plateau, Valley and Ridge, Blue Ridge, Triassic Basin, Piedmont, and Coastal Plain are all represented in Virginia. Each of these provinces more or less extends up and down the east coast from Georgia to New York with Virginia more or less in the middle.

Each province is distinct in a number of ways. They have physiographical distinct features, from one province to another the landforms change and the countryside has a different appearance. The types of rocks differ; they may be igneous, sedimentary, and/or metamorphic. The structure of the rocks differ; they may be flat lying, or folded and faulted. Additionally, the geologic ages of the rocks differ. The combination of these features is unique for each province, and gives each its special character.

2.1 Regional Geology

2.1.1 Allegheny Plateau

This province is located in the southwest part of Virginia, although much of West Virginia is composed of the plateau. The rocks here are sedimentary, flat lying, and topographically high above sea level relative to the rest of the state. They develop a characteristic dendritic drainage pattern (the stream valleys keep splitting and splitting in a random pattern). That is to say that although some drainages appear organized, in many places they follow no particular pattern, especially in the southwest.

The exposed rocks are late Paleozoic in age (Devonian, Mississippian, Pennsylvanian) and in parts of West Virginia, Permian (Figure 2 Geology of Virginia). These rocks were deposited at a time when most of Virginia to the east contained major mountain ranges (Taconic, Acadian, and Alleghenian orogenies). Underneath the Devonian rocks are additional flat lying sedimentary rocks of Cambrian, Ordovician and Silurian age. Finally at the bottom of the pile are igneous and metamorphic Grenville basement rocks (1.1 billion years and older) (Fichter & Baedke, 1999).

2.1.2 Valley and Ridge

This province lies east of the Allegheny Plateau and west of the Blue Ridge; its western boundary is known as the *Allegheny Front* and marks an abrupt change from the flat lying rocks of the plateau to the folded/faulted rocks in the valley and ridge. On the ground these ridges can be easily seen looking west and appear as row after row of parallel mountains and valleys (beginning with the Shenandoah Valley) gives the province its name. The underlying structures formed during the Alleghenian orogeny.

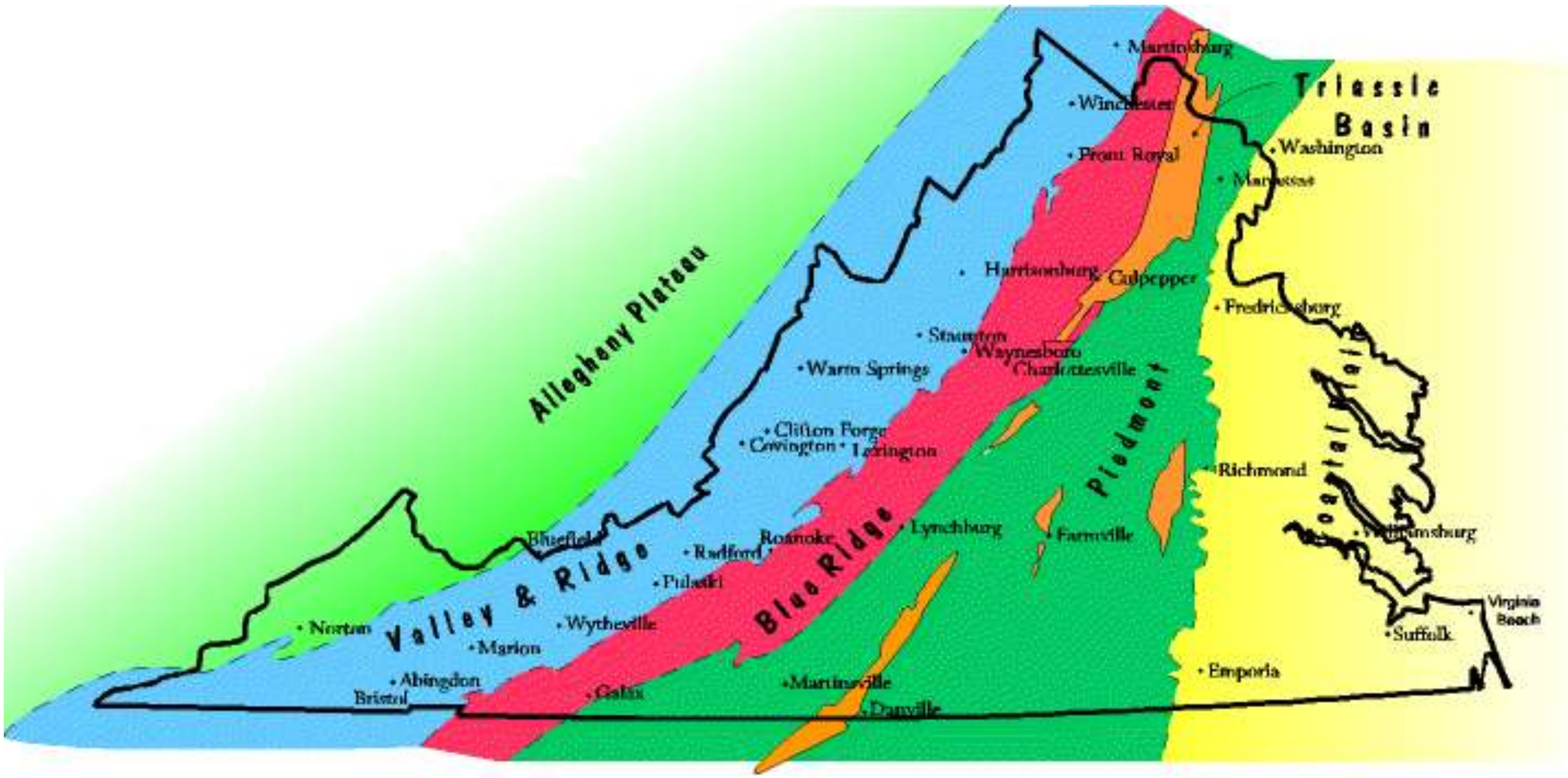
The rocks here are sedimentary, thrust faulted and folded into anticlines and synclines, lower and middle Paleozoic in age (Cambrian through lower Mississippian), and have a trellis drainage pattern. A trellis drainage is when rivers are forced to run parallel to long ridges. The ridges exist because they are underlain by hard rock that erodes less easily than the softer rock in the valleys.

The lowest part of the stratigraphic section is mostly Cambrian and lower Ordovician carbonates (limestones and dolomites) deposited in tidal flat and coastal environments. Today these are best exposed in the Shenandoah and Page valleys. Most of the rest of the sedimentary rocks are sandstones and shales deposited in deep marine basins during times when the Piedmont region was a large mountain rather than its present flatness.

2.1.3 Blue Ridge

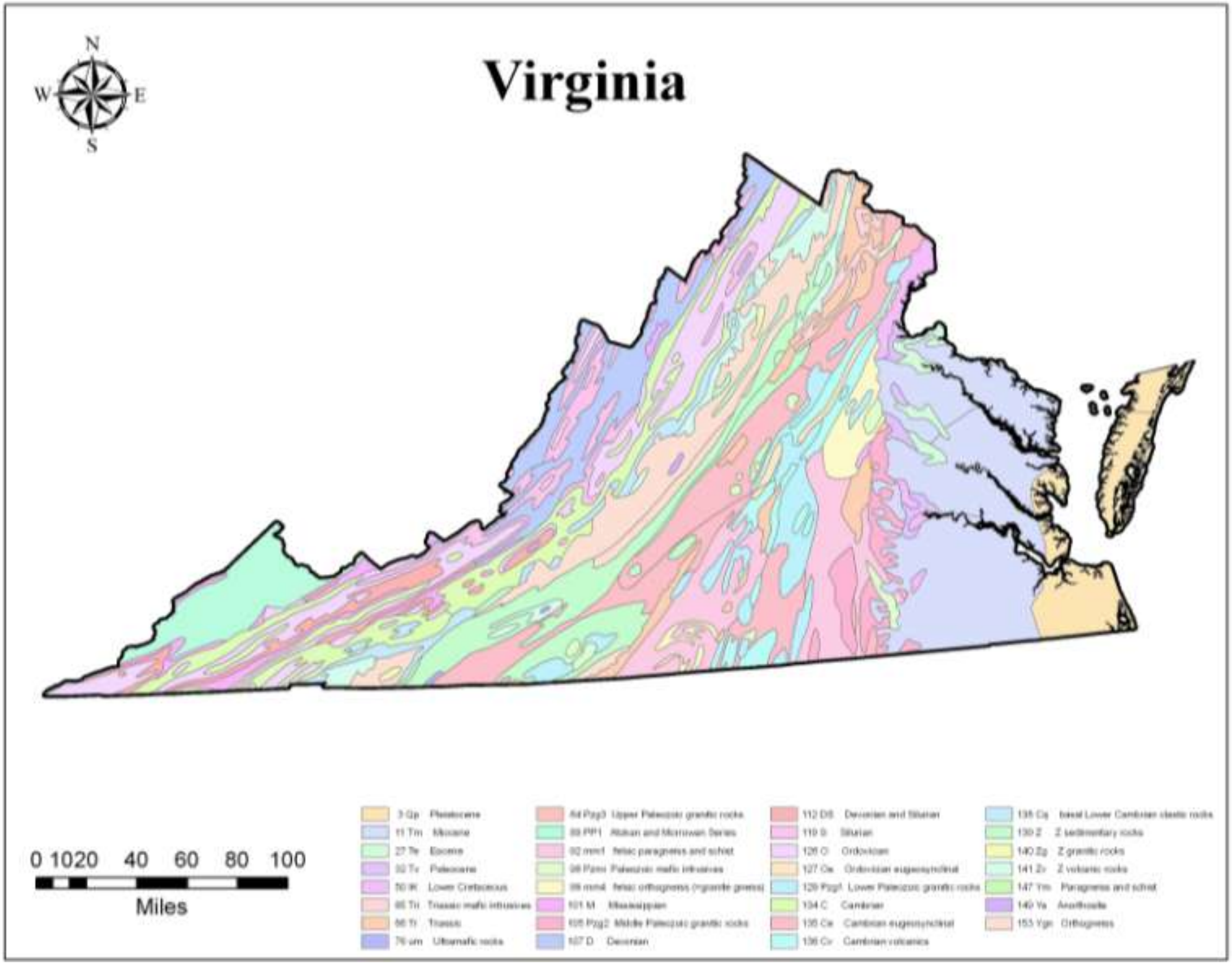
The Blue Ridge province includes both the Blue Ridge mountains and the land to the

Figure 1: Geological Provinces of Virginia



Source: Virginia Department of Mines, Minerals and Energy, 2008

Figure 2: Geologic Map of Virginia



east running through Galax, Charlottesville, Culpepper, and Warrenton. This is an instance where the physiographic features and the geology do not exactly correspond. The geologic province is defined primarily by the rocks underlying it, (coarse grained igneous and metamorphic Grenville basement rocks) than its topography (the eastern part of the geologic province blends in topographically with the piedmont in many places, and appears distinct from the Blue Ridge Mountains). In northern Virginia the Blue Ridge province extends from about five miles east of Front Royal to Bull Run mountain just west of Manassas where it is about 20 miles wide.

Structurally the Blue Ridge province is a large, eroded anticline overturned to the west. The core of the anticline is composed of igneous and metamorphic rocks collectively known as the Grenville, although there are also late Proterozoic intrusives and sediments present too. They are some of the oldest rocks in the state at 1.1 billion back to 1.8 billion.

The east and west flanks of the anticline are much younger volcanics (Crossnore event) and clastic sediments. The clastic sediments fill rift grabens on the northwest and southeast flanks of the anticline (Lynchburg, Ocoee, Grandfather Mtn., Mt. Rogers Groups). Stratigraphic thicknesses range from about 3000 meters to 7000 meters. The final filling of the graben and creation of a divergent continental margin is preserved in the metamorphosed lava flows (Catoctin formation) and sedimentary rocks (Chilhowee Group and Evington formation) about 570-600 million years old.

The Crossnore igneous suite includes a volcanic pile (Mt Rogers in the south) and granite batholiths (Robertson River) intruding into Grenville plutons.

2.1.4 Piedmont

The Piedmont, is relatively flat and topographically featureless, but it contains some of the most fascinating rocks in Virginia. There are two distinct divisions to the piedmont rocks, one a set of Late Proterozoic and Paleozoic igneous and metamorphic rocks, and a second of lower Mesozoic (Triassic) sedimentary rocks deposited in graben basins faulted into the igneous and metamorphic rocks.

The Late Proterozoic and Paleozoic igneous and metamorphic rocks include three main components. First, the roots of several volcanic island chains such as in the Charlotte/Chopawamsic belt, and Carolina slate and Eastern slate belts; second; several small continental fragments that are possibly Grenville in age (Sauratown Mountain in the south and Raleigh/Goochland belt running west of Richmond); and third, the Inner piedmont belt running just east of the Blue Ridge Province.

The volcanic arcs in their day were comparable to volcanic islands like Japan, Borneo and Sumatra, and the Aleutian Islands. Many, more likely all, of these formed somewhere else and were brought to Virginia by later events. They are said to be *allochthonous*; rocks still in the place they formed are *autochthonous*.

The Grenville age rocks may be microcontinental fragments torn loose and left behind during the Proto-Atlantic rifting, or continental fragments brought in from elsewhere. They contain high grade metamorphic rocks and igneous intrusions.

The Inner piedmont belt contains rocks on the southeast flank of the Blue Ridge anticline. They are sediments (metamorphosed to greenschist and amphibolite) represented by the Evington/Alligator Back formations, and mafic-ultramafic igneous bodies scattered along the whole length that represent old oceanic lithosphere. This is most likely a fragment of the Proto-Atlantic divergent continental margin.

In addition, numerous late Paleozoic granite intrusions cut through the region, mostly in the eastern half. These were generated in the Taconic orogeny (e.g. Petersburg granite dated at 320 mya), and the Alleghenian orogeny. These rocks have been deformed and metamorphosed, often several times, therefore they are very complex. They also contain many economically important mineral deposits, including gold, talc, kyanite, and feldspar.

2.1.5 Triassic Basins

The lower Mesozoic sediments deposited in fault basins are usually referred to as Triassic basin deposits, although they are now known to also contain lower Jurassic rocks. These basins formed when Africa separated from North America to create the Atlantic ocean. The Culpepper basin in the western piedmont near the Blue Ridge province is the largest, but numerous smaller basins including the Richmond, Farmville, and Danville are scattered throughout the piedmont.

Structurally these are half-graben with a main fault only on the western side. These basins can be easily recognized because the rocks turn red, or there are coal beds, but often the evidence is subtler.

The sediments filling the basins are ancient alluvial fan conglomerates along the western borders, but the deep red sediments to the east, often with fish fossils or crisscrossed with dinosaur tracks, indicate the tropical lakes and mudflats which existed at the time.

Cutting into the Triassic-Jurassic sediments are numerous igneous dikes, stocks (small bodies of igneous rock), and lava flows that accompanied the volcanic activity accompanying the opening of the Atlantic ocean.

2.1.6 Costal Plain

The Costal Plain is made-up of mostly unconsolidated or partially consolidated sediments deposited along a coastline not significantly different from that which exists on the coast of Virginia today. The deposition on the present continental margin is a continuation of the coastal plain deposition which has been going on since the Triassic. The coastal plain sediments are laid down like a wedge, thick to the east and thinning to a feather edge on the west. The Triassic basins found in the piedmont extend under the coastal plain.

2.2 Subsurface Stratigraphy and Structure

The apparent distinctness of the surface geology described for each province is a superficial mask hiding the subsurface geology. Virtually the entire geology of Virginia has been compressed, folded, thrust faulted, and telescoped so that most of the rocks have been moved from their site of origin and stacked. The exceptions are the Allegheny Plateau and the Coastal Plain.

For example, the Grenville igneous and metamorphic rocks now found exposed in the Blue Ridge also underlie most of eastern North America, buried under the sedimentary rocks. On the other hand, the Grenville rocks in the Blue Ridge are not now located where they originally formed. Their original location was somewhere to the east, perhaps as far as Richmond, and they were transported to their present location during the Alleghenian orogeny along a major thrust fault. Indeed most of the rocks in the Blue Ridge and Piedmont have been transported from their original locations. Furthermore, most of the piedmont rocks are not originally part of North America in the first place but have been added in pieces during the Paleozoic, and each of these pieces has its own tectonic history that may or may not correspond with the timing of the events in the rest of Virginia, see figure 3.

On the other hand, the lower and middle Paleozoic sedimentary rocks of the Valley and Ridge do not stop at the Blue Ridge. They extend far to the east under the Blue Ridge and Piedmont. Or to put it another way, the piedmont and Blue Ridge have been thrust faulted over the Cambrian-Ordovician DCM sediments.

Of interest to oil and gas development are the Devonian Shale present in southwestern Virginia where it is referred to in the aggregate as the Chattanooga Shale (see stratigraphic chart in Figure 3). This thick, highly organic shale extends over most of the Eastern US as shown in Figure 4, including the Appalachian Plateau of Virginia.

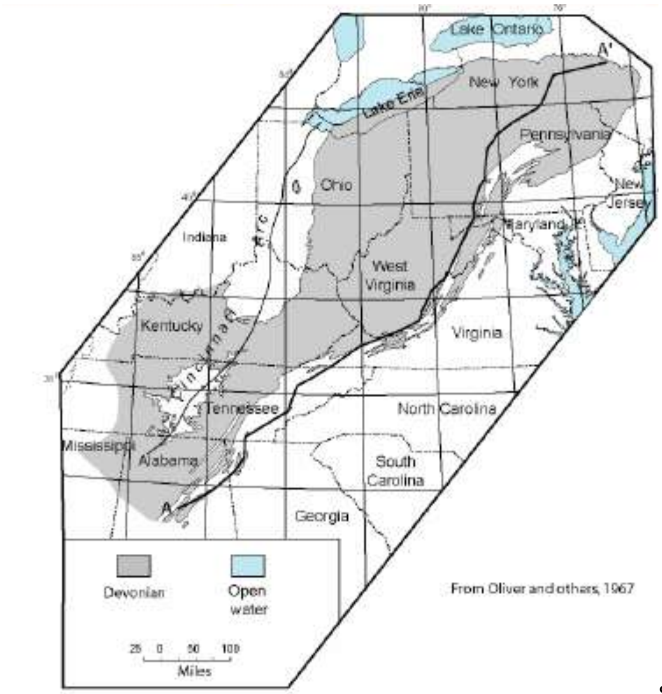
In Virginia the Devonian Shale consists only of the Marcellus, the basal member of the Chattanooga as shown in Figure 5. The Marcellus is less than 50 feet thick in Virginia as shown in the isopach map in Figure 6, this thickness may not attract a great deal of drilling in Virginia. The Marcellus produces natural gas from wells that are co-mingled with conventional gas reservoirs (Enomoto, 2008). It is unknown at the present time how many wells are perforated in the Marcellus and how much gas they produce from that zone. As an estimate, of the 1,487 active gas wells in the state, 420 were drilled deep enough to fully penetrate the Marcellus (Enomoto, 2008). While the Marcellus is an attractive gas reservoir farther north in West Virginia and Pennsylvania, the shale may be too thin to constitute an important gas target in Virginia (Durham, 2008). On the other hand, the shale appears to be present in the Valley and Ridge Province (see Figure 6) where it might be folded and squeezed into greater thicknesses. As shown in Figure 7, the Valley and Ridge Province has not been exploited for the Marcellus.

Figure 3: Virginia Stratigraphic Chart

Age	Formations	Production
Pennsylvanian	Wise	Coal
	Norton	CBNG
	Lee	CBNG
	Pocahontas	CBNG
Mississippian	Hinton	Conventional Gas
	Bluefield	
	Greenbrier	
	Price/Pocono	
Devonian	Chattanooga	Shale-Gas
Ordovician	Trenton	Oil

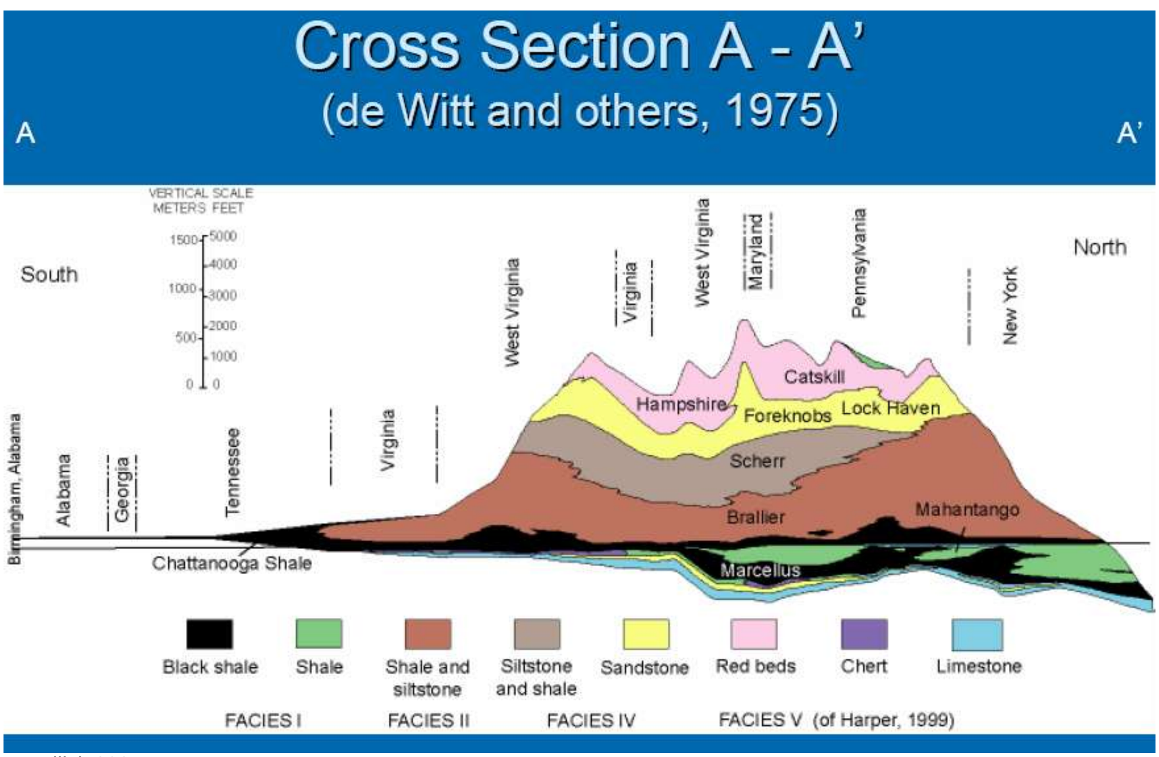
Source: DMME, 2008

Figure 4: Geographical Extent of Devonian Shale with Location of Cross-Section Shown in Figure 5



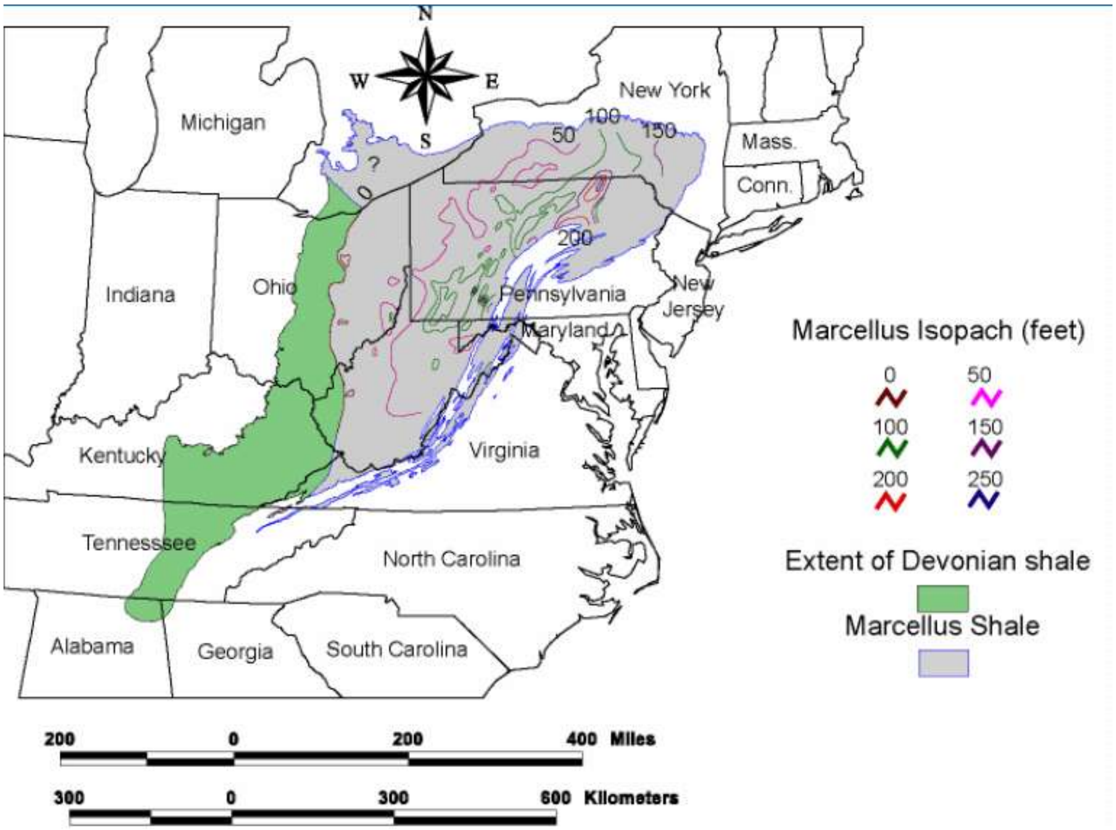
Source: Milici, 2005

Figure 5: Devonian Shale Stratigraphy



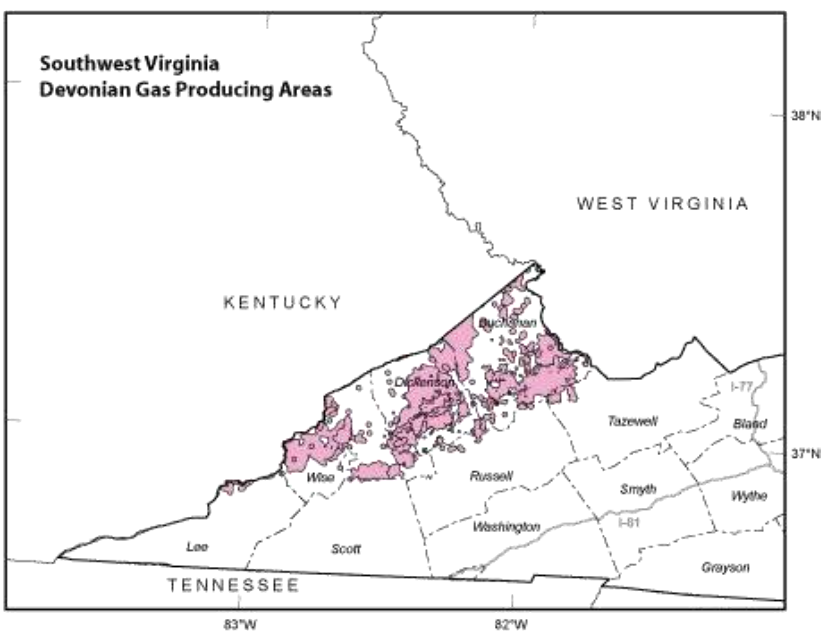
Source: Milici, 2005

Figure 6: Isopach Map of the Marcellus Member



Source: Milici, 2005

Figure 7: Marcellus Gas Producing Area



Source: DMME, 2008

3.0 SUMMARY OF USGS PLAY DESCRIPTIONS FOR THE STATE OF VIRGINIA

A series of oil and gas assessments have been conducted for the provinces that cross Virginia as part of the 1995 USGS National Oil and Gas Assessment (Milici, R.C., 1995 & Ryder, R.T., 1995). The provinces found in Virginia include the Appalachian Basin (067), Blue Ridge Thrust Belt (068), Piedmont (069), Atlantic Coastal Plain (070), Adirondack (071), and New England (072). Except for the Appalachian Basin, these provinces do not produce oil or gas and are not currently viewed as prospective for oil and gas. For each of those province assessments a number of conventional and unconventional oil and gas plays were assessed which might have an impact on oil and gas exploration and production activity in Virginia.

The following is a summary of those province assessments and includes only very general information relative to the plays. The primary source materials for this summary presentation are the geologic reports for each of the province assessments as published by the USGS and are available at the USGS National Oil and Gas Assessment website (http://energy.cr.usgs.gov/oilgas/noga/). Copies of the province reports (067) and 068-072) are included in Appendix B.

3.1 Appalachian Basin Province (067)

The Appalachian Basin contains Paleozoic sedimentary rocks of Early Cambrian through Early Permian age. The basin runs north to south and crosses the western edge of Virginia. The province covers an area of about 185,500 sq mi. The province is 1,075 miles long from northeast to southwest and between 20 to 310 miles wide from northwest to southeast. There are a number of conventional and unconventional plays that have been explored in the basin since the discovery of oil in 1859 at Drake well in Venango County, Pennsylvania. The oil and gas plays in Virginia include the following:

- 6702 – Upper Cambrian, Ordovician, And Lower/Middle Silurian Thrust Belt Play
- 6703 Beekmantown/Knox Carbonate Oil/Gas Play
- 6706 – Trenton/Black River Carbonate Oil/Gas Play
- 6716 – Upper Silurian Sandstone Gas Play
- 6717 – Silurian Carbonate Gas Play
- 6718 – Silurian And Devonian Carbonate Thrust Belt Play
- 6719 – Devonian Carbonate Gas Play
- 6720 – Oriskany Sandstone Gas/Faulted Anticlines Play
- 6721 – Oriskany Sandstone Gas
- 6725. Mississippian And Pennsylvanian Sandstone/Carbonate Play
- 6727 – Tuscarora Sandstone Gas Play
- 6731 – Clinton/Medina Sandstone Gas Low Potential Play
- 6732 - Clinton/Medina Sandstone Oil/Gas Play
- 6735 - Upper Devonian Sandstone Gas Medium-Low Potential Play
- 6740. Devonian Black Shale–Greater Big Sandy Play

3.2 Coalbed Gas Plays

Coalbed gas plays in the Appalachian Basin can be divided into three northeast-southwest trending basins for purposes of coal geology. These include the Northern, Central, and Cahaba (plays 6750 – 6753). With regards to Virginia only the Central

Appalachian Coal Basin is present and contains one coalbed gas play, Central Basin Play (6752) (Rice and Finn 1995).

Based on the total gas in place per section, the play can be divided into two areas, which is the result of coal thickness, depth, and gas content. The central area has thick coal beds and occurs at depths greater than 1,000 ft deep indicating higher gas content. Gas in-place is estimated at as much as five BCF per sq mi. Located in southwest Virginia are the Nora and Oakwood fields which are part of the central area.

The central part is surrounded by other major seams, such as the Pocahontas No. 3 and 4, and War Creek. These other areas are generally thinner and shallower. The gas in-place estimate by volume is less than one BCF per sq mi. A few wells in the Roaring Fork field have been drilled in this play, otherwise it is essentially undeveloped. The undiscovered potential for this play is considered to be good, although the production rates for individual wells will probably be lower than for the central area. The potential for additions to reserves for this entire play is considered to be very good.

3.3 Hypothetical Plays in Virginia

There are two hypothetical plays that have potential development areas within Virginia. These are the Southern Appalachian Sub-Thrust Sheet Play (6801) and the East Coast Mesozoic Basins Play (6901).

The Southern Appalachian Sub-thrust Sheet Play is a hypothetical high-risk play located along the leading edge of the southern Appalachian thrust sheet in the Blue Thrust Belt Province, mainly in southern Virginia and eastern Tennessee. A formal assessment for this play was not conducted because of the lack of evidence for potential source rocks and reservoirs. More information is available in Appendix B.

The East Coast Mesozoic Basins Play is located beneath the Atlantic Coastal Plain in northern Florida, Georgia and Alabama and extends northeastward along the Atlantic coastal margin to southern New England. The East Coast Mesozoic Basins are assessed collectively as a single play that occurs in parts of four distinct provinces, the Atlantic Coastal Plain, Blue Ridge, New England and Piedmont provinces. The play also extends eastward onto the outer continental shelf. The play contains about 113,000 sq mi, and is approximately 900 miles long and 100–140 miles wide. The East Coast Mesozoic Basins that have portion in Virginia including the Culpeper, Dan River-Danville, Richmond, and Taylorsville basins however none have shown any promise for large scale oil or gas development. See appendix B for a more detailed discussion regarding these plays.

3.4 Unconventional Plays

There are no unconventional plays described in the Province Reports.

4.0 PAST AND PRESENT OIL AND GAS EXPLORATION ACTIVITY

4.1 Geophysical and Geochemical Surveys

No extensive geophysical or geochemical surveys have been undertaken in Virginia in recent years other than individual seismic operations targeted at specific exploration targets generated off of surface or subsurface geologic studies.

4.2 Exploratory Drilling and Success Rates

At the present time and for the foreseeable future, hydrocarbons are confined to the

Plateau Province as illustrated in Figure 8, map of oil and gas fields in the state. As shown in Figure 8, oil and gas is largely confined to the Appalachian Plateau except the abandoned Bergton gas field. The Richmond and Taylorsville basins are also shown in Figure 8; these basins have had shows of oil and gas but have never produced. Figure 9 plots the distribution of Federal lands across the state.

The success rates are difficult to statistically confirm because there are not good records

4.2.1 Mesozoic Basins

During the Triassic, extensive rifting along the Atlantic Margin of North America gave rise to a number of small to medium-sized, fault-bounded rift basins that are seen from Florida to Nova Scotia both onshore and offshore. Scattered bore-holes have been drilled in these basins although no oil or gas has been produced; the most thoroughly explored of the Mesozoic basins are the Richmond and Taylorsville basins, both in Virginia (USGS, 1995b). Most of the sedimentary section in these basins is terrestrial in nature although some lacustrine strata are also present including organic shales and coals, which could function as source rocks under the right conditions.

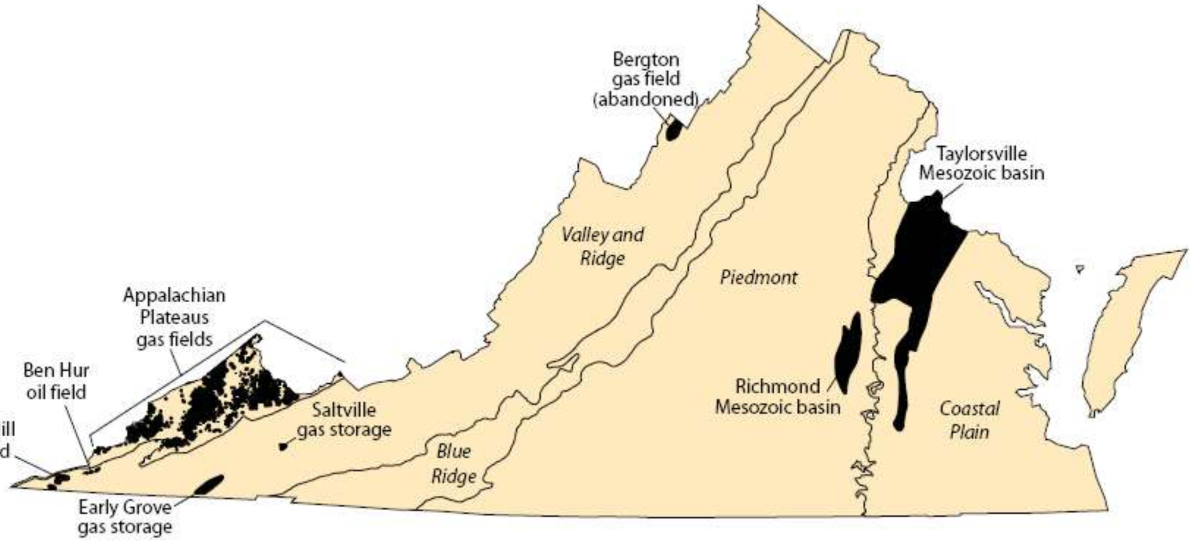
The Richmond Basin, Virginia, has been drilled extensively for coal, oil, and gas. Between 1897 and 1985, 38 exploratory holes were drilled in the basin. Of the 38 holes, 22 were drilled to depths of 1,000 feet or more. The deepest hole, Cornell Oil Company No. 1 Bailey, encountered granite basement at 7110 feet and was drilled to a total depth of 7,438 feet. The hole drilled several coal beds, but saw no oil or gas. Of the remaining deep holes, 6 had shows of liquid and/or gaseous hydrocarbons. Subsequently, industry has conducted at least two core-drilling campaigns for coal along the margins of the basin. The holes apparently were abandoned because of excessive disruption of the coal beds by faulting. Extensive drilling in this relatively small basin indicates that the chances of finding significant amounts oil or gas there are likely minimal.

The Taylorsville Basin, Virginia, has also been the subject of limited industry interest and exploration. In 1986, Texaco, Inc. drilled 5 diamond core holes in the basin each to a depth of 5,500 feet, apparently the limit of the drilling rig. A sixth hole encountered crystalline basement at about 3,533 feet. The core holes were followed in 1989 by a deep test, the Texaco W. B. Wilkins et ux No. 1, which was drilled into basement at a total depth of 10,135 feet. Three of the core holes and the deep test had indications of oil and gas (USGS, 1995b).

4.3 New Field and Reservoirs

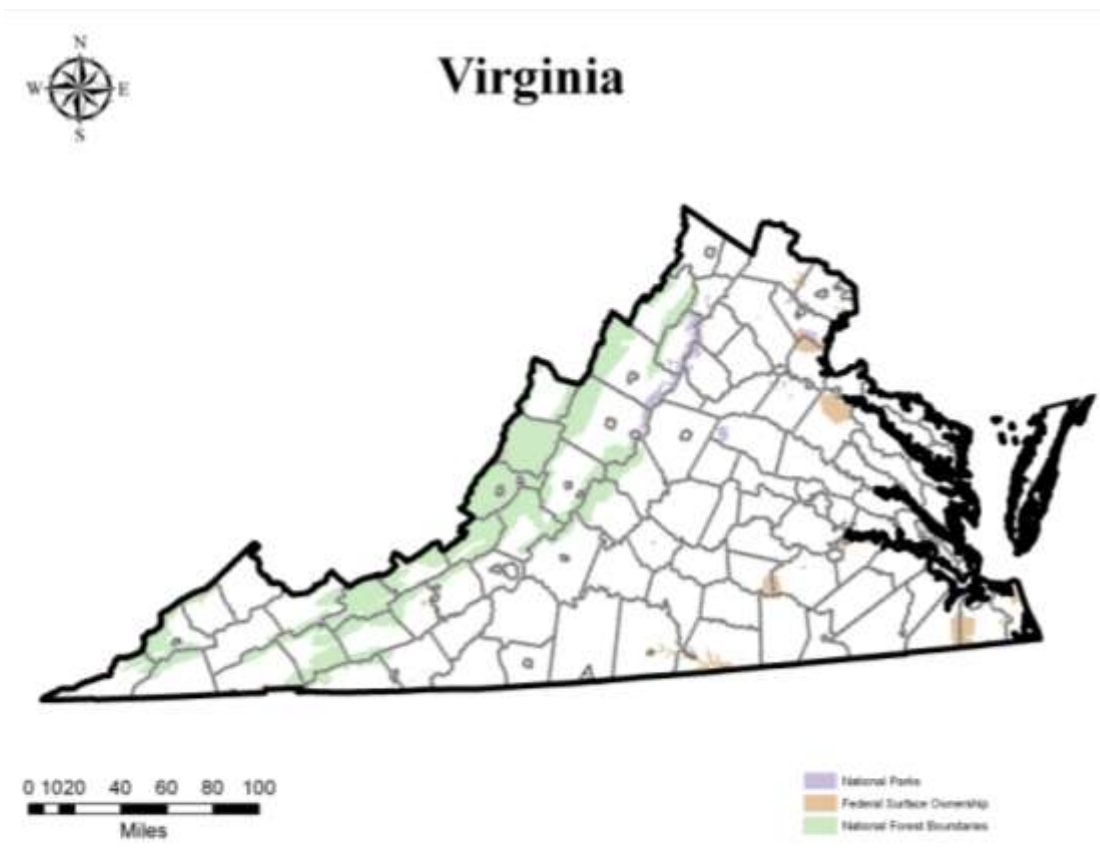
There have been no new fields or reservoirs discovered in Virginia in the past decade.

Figure 8: Gas and Oil Fields of Virginia



Source: DMME, 2007

Figure 9: Federal Acreage in Virginia



5.0 OIL AND GAS ACTIVITY IN VIRGINIA

This section deals with the current status of oil and gas activity in Virginia based on information provided by both public and private sources. Information includes; leasing activity, well spacing requirements, drilling permits by county, drilling practices, production statistics, oil and gas characteristics, oil and gas prices, operational costs (drilling and completion), conflicts with other mineral development, and gas storage fields.

5.1 Leasing Activity

Leasing activity in Virginia has been slight over the past decade (Wilson, 2008).There are few minor tracts available, most trend acreage has been leased.

5.2 Well Spacing Requirements

Well spacing requirements for oil and gas wells drilled in Virginia are subject to the rules and regulations of the Virginia Gas and Oil Act, Title 45.1 Mines and Mining. Spacing requirements fall under those set by specific regulation under 45.1-361.17. Generally spacing for oil wells is set at 1,250 feet from any well completed in the same pool and 625 feet from the property boundary. General gas well spacing is 2,500 feet from any well completed in the same pool and 1,250 feet from the property boundary. CBNG wells can be placed 1,000 feet from any other CBNG well and 500 feet from the property boundary. Field rules issued by the Virginia Department of Mines Minerals and Energy can be modified under Chapter 160 Virginia Gas and Oil Board Regulations following the procedure outlined in 4 VAC 24-160-60 *Applications for exception to minimum well spacing requirements.*

5.3 Drilling and Completion Statistics

5.3.1 Drilling Practices

The DMME reports that only a very few horizontal or directionally drilled holes have been done in the state. As of 2006 (the latest year with complete records) there were four active horizontal wells. During 2006 four horizontal wells were permitted, one was completed as a gas well, one was dry and abandoned, the other two are unknown (DMME, 2008). As a comparison, over 25% of CBNG wells drilled in West Virginia have been horizontals (Avery, 2008). Drilling depth to CBNG, Big Lime, Berea, and Marcellus targets are shown in Table 1 for the more promising counties in the Appalachian Plateau. Although the depths are variable, it appears that CBNG wells are usually less than 3,000 feet in depth while shale gas wells are drilled to depths approaching 7,000 feet.

Table 1: Drilling Depths for Conventional, CBNG, and Shale Gas in Virginia

County	Coal Top	Big Lime Top	Berea Sand Top	Marcellus Shale Top
Wise		4,700’	5,400’	6100’
Buchanan	2,500 to 5,000	3,500’	4,100’	5,900’
Dickenson		3,300’	4,200’	5,800’
Russell	1,300 to 2,500’	5,300’	6,500’	
Tazewell	600 to 2,100’		3,200’	

Source: DMME, 2008

5.3.2 Drilling and Completion Costs

Drilling costs and well completion costs vary by depth, reservoir, and completion practice for the specific reservoir to be produced. Very generalized costs associated with oil production areas in the state suggest that well costs for deep (>6,000 fbs) are in the order of approximately $300,000 to 500,000 for drilling costs and $50,000 to $100,000 for completion costs (Hall, 2008). CBNG wells are drilled to relatively shallow depths of <1,800 to 2,200 feet and typically run about $150.00/foot to drill and complete or $350,000 per well.(Penn Virginia Corporation, 2005).

5.4 Production Statistics

5.4.1 Crude Oil

Oil production is minor in Virginia, with few active wells and declining production as shown in Figure 10. Active oil wells in the state are down to only three (not including those approximately 41 gas wells that also produce small amounts of liquid hydrocarbons). As shown in Figure 11, oil is found in the same southwestern part of the state as natural gas. Oil is currently being produced in Buchanan, Lee, Russell, and Wise Counties; more than two-thirds of the oil production is from Lee County. Oil is largely produced from fractured carbonates of the Trenton Formation where it is bent into structural traps (DMME, 2008).

5.4.2 Natural Gas

In 2006, 21 companies produced gas from 1,487 conventional wells, 3,677 coal bed natural gas wells, and 15 dual completion wells (producing from both conventional gas reservoirs and CBNG reservoirs). Figure 12 shows the number of natural gas producing wells verses the dry gas production in MCF. The estimated value of natural gas produced during 2006 is $660.3 million. Natural gas is produced in Buchanan, Dickenson, Lee, Russell, Scott, Tazewell, and Wise counties, with over 55 percent of the gas production coming from Buchanan County. CBNG accounted for 90 percent of the gas produced in Buchanan County, and nearly 80 percent of the gas produced in Virginia. Figure 13 graphically depicts the natural gas production by type from 1993 through 2006.

Figure 10:

Virginia Annual Oil Production

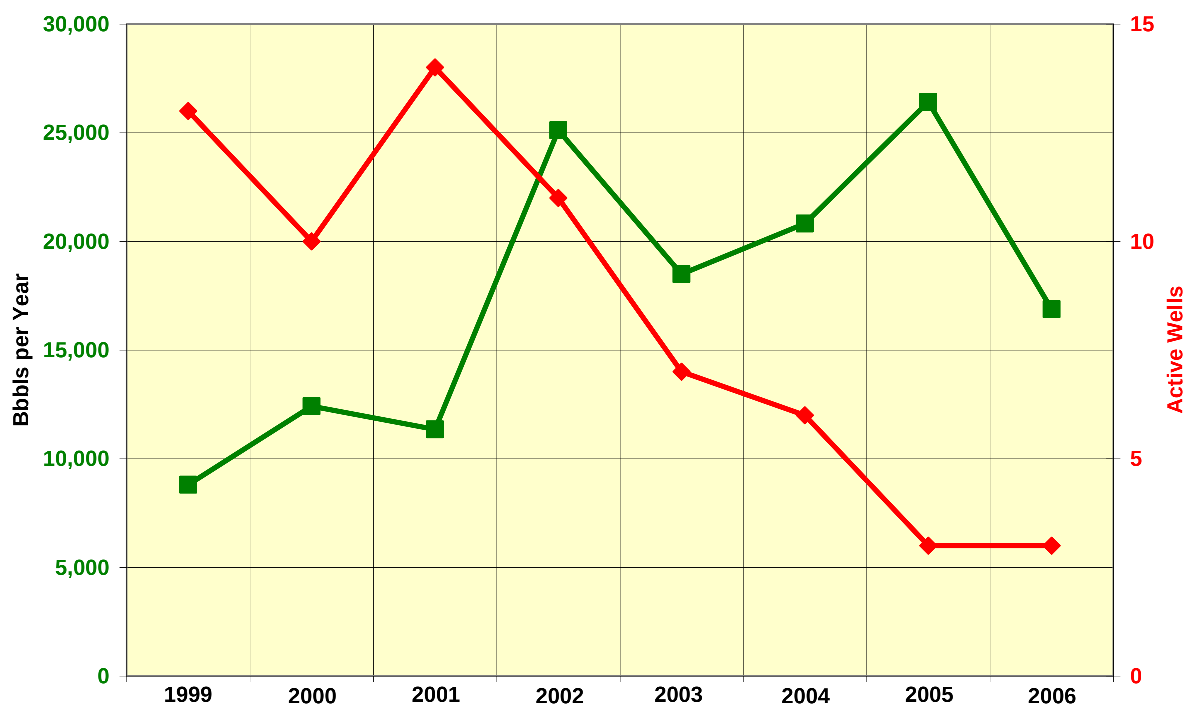
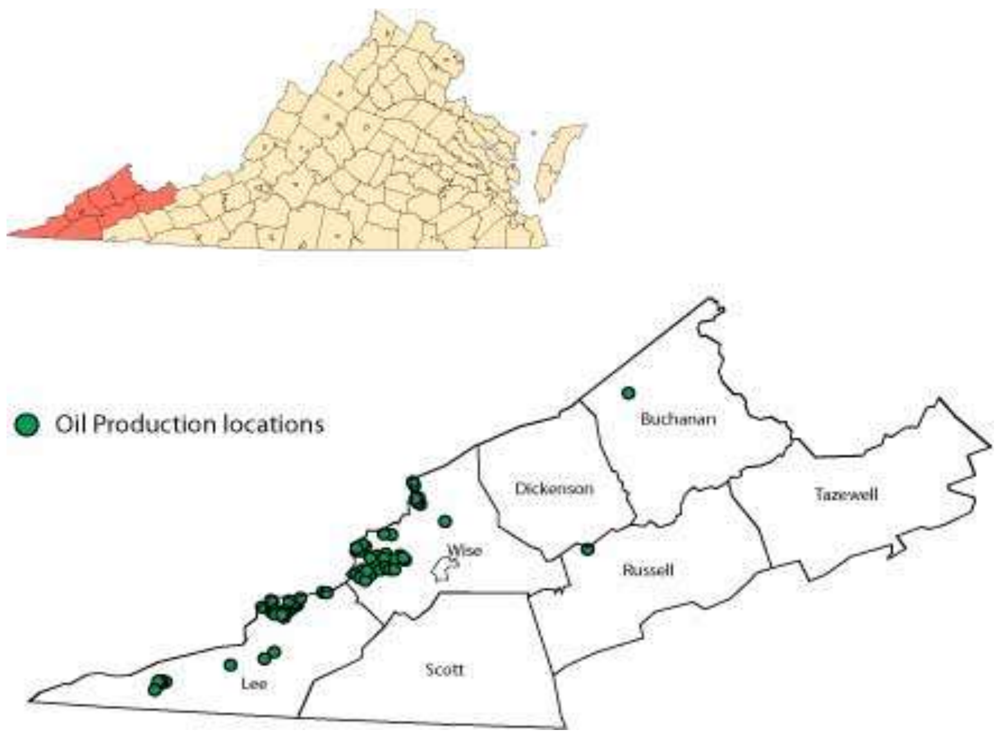
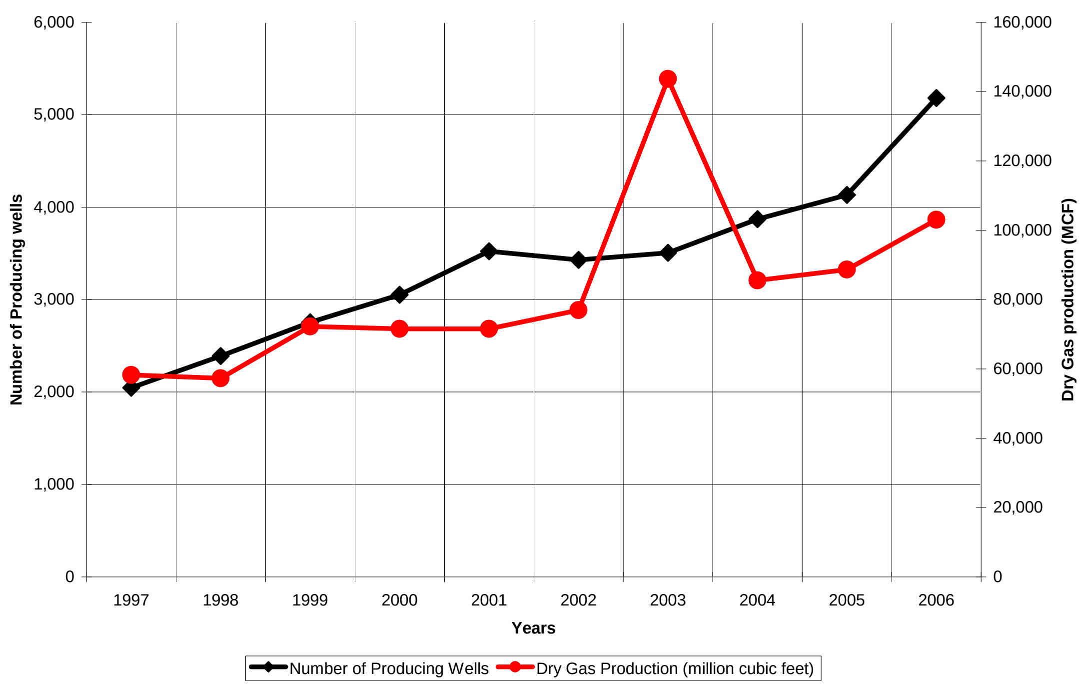


Figure 11: Oil Production in Virginia



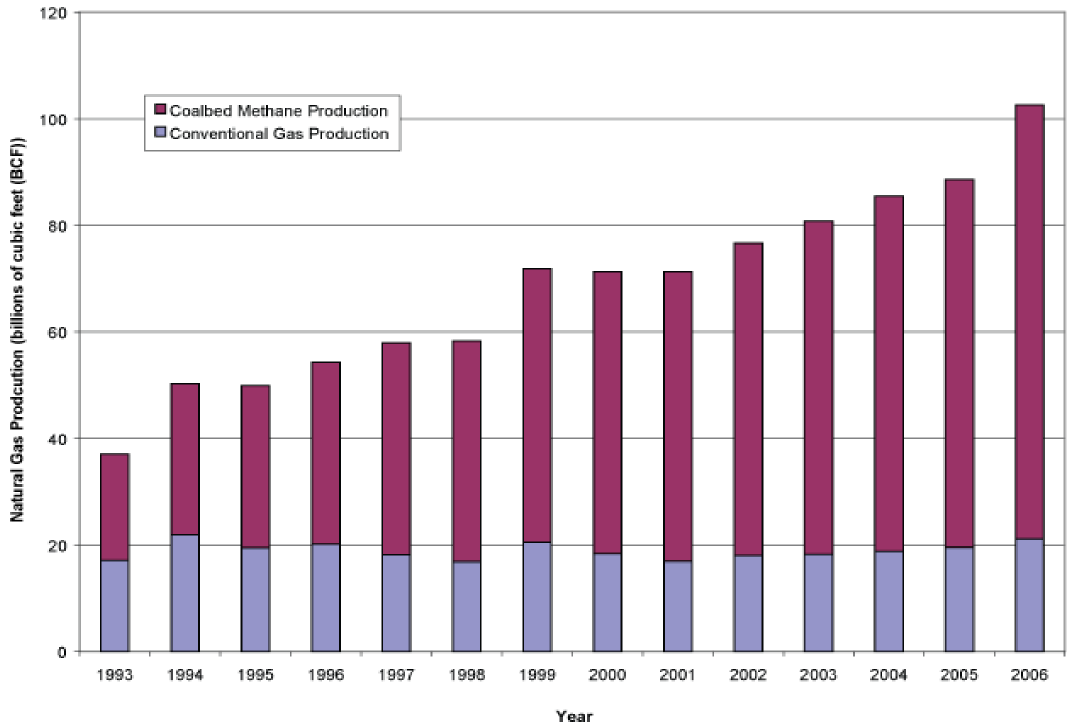
Source: Virginia Department of Mines, Minerals and Energy

Figure 12: Virginia Natural Gas Production & Number of Producing Wells (1997-2006)



Source: DMME 2008

Figure 13: Virginia Gas Production by Type, 1993-2006



Source: DMME, 2008

5.5 Oil and Natural Gas Characteristics

5.5.1 Natural Gas

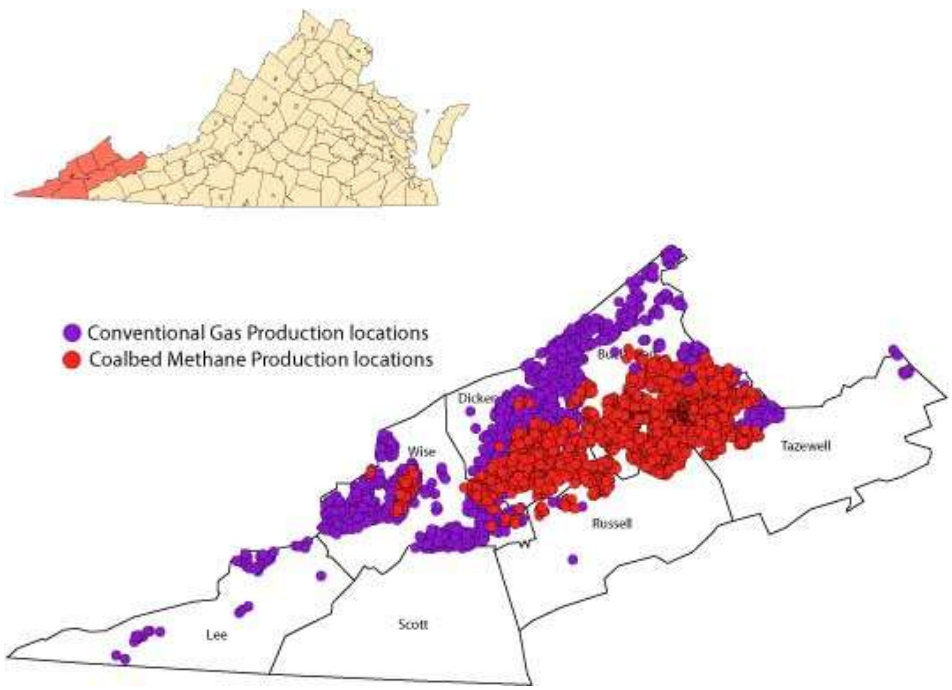
Natural gas is a mixture of methane (CH_4), ethane (C_2H_6), propane (C_3H_8), and carbon dioxide (CO_2). The major markets for natural gas are residential and commercial uses such as space heating, water heating and cooking, and industrial uses such as process heating and chemical feedstock, transportation, and electric power generation. The three types of natural gas produced in Virginia are: conventional gas, which has migrated from an organic source rock to a porous or fractured reservoir rock; shale gas, and coal bed natural gas. Figure 14 identifies the natural gas production areas in Virginia by type.

- Conventional gas is produced from Mississippian (323 to 354 million years old) limestones and sandstones of the Appalachian Basin, in the Appalachian Plateau Province.
- Shale gas is sourced and reservoired in the thick Devonian (354 to 417 million years old) shales of the Appalachian Plateau.
- Coal Bed Natural Gas (CBNG) is produced from the coal seams in the Norton, Lee (New River), and Pocahontas Formations of Pennsylvanian age (290 to 323 million years old) in the same physiographic region.

5.5.2 Crude Oil

Crude oil produced in Virginia varies in color and in odor by area and by individual reservoir; however the overall quality of the oil does not appreciably vary across geographic regions or reservoirs and is considered to be consistent Pennsylvanian. Crude oils consistent with “Pennsylvania grade crude” oil are thermally stable and

Figure 14: Natural Gas Production Locations in 2006.



Source: DMME, 2008

generally have a high viscosity index. Only very limited specific information as to the gravity of Virginia produced crude oil is available. The crude oil produced from Trenton Limestone is amber in color and volatile, with a gravity of 43-48 degrees API (Nolde, 1992).

5.6 Oil and Gas Prices

Figure 15 plots the domestic price of oil over the past 60 years. Increases have been dramatic, especially during the past ten years; this rise in price has fueled the increases in exploration and production. Current price of oil and gas and the resultant economics are certainly attractive to operators but no new Virginia production has been brought on line in over 20 years.

Both crude oil and natural gas prices are generally expected to remain strong for the foreseeable future.

5.7 Conflicts with Other Mineral Development

Mineral development in Virginia is extensive and involves in addition to oil and gas a number of different mineral resources. These industries are important to Virginia's economy and contribute to an annual combined total value of mineral and fossil fuel production ranging from $1.77 billion in 1999 to $2.09 billion in 2003. Of this, coal accounted for 46 percent of total production, aggregate (crushed stone, construction sand, and gravel) for 24 percent, natural gas and oil for 19 percent, and industrial minerals for 11 percent. Virginia's mineral industries have national significance as they are the only state to produce kyanite and ranked second nationally in feldspar, ilmenite, zirconium, and vermiculite production.

Mineral resources produced in Virginia besides liquid fossil fuels include: Clay Materials, Coal, Crusted Stone, Dimension Stone, Feldspar, Gemstones, Gypsum, Heavy Mineral Sands, Industrial Sand, Iron-Oxide Pigments, Kyanite, Lime, Salt, Sand and Gravel, and Vermiculite. Information contain in this mineral summary is from the

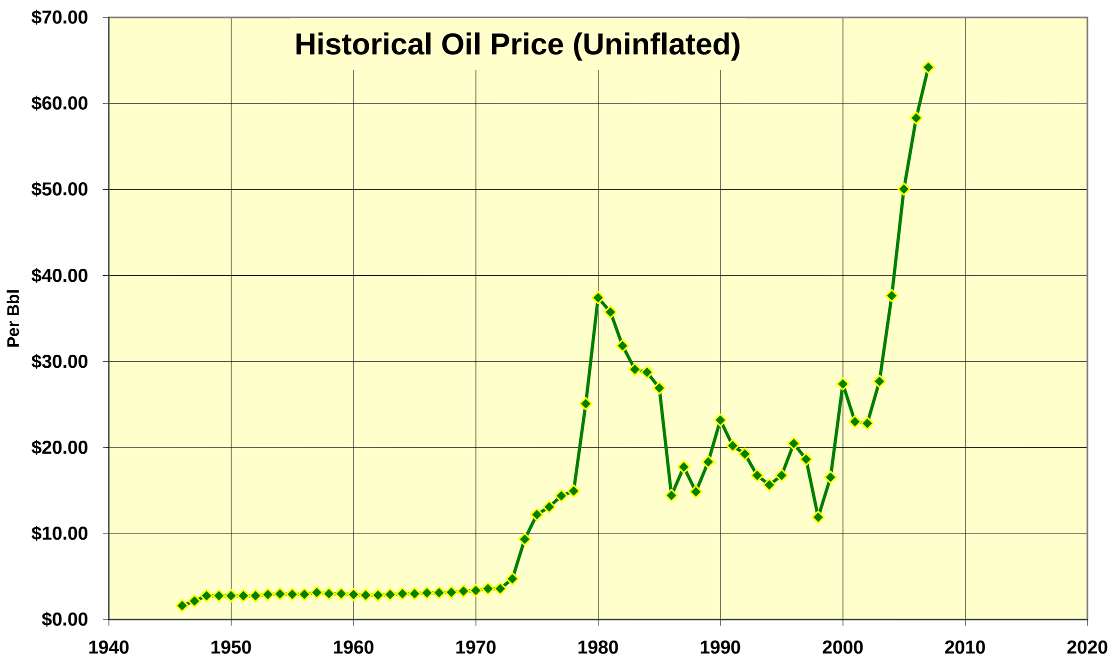
USGS 2004 Mineral Yearbook and from the Virginia Division of Mineral Resources (Open File Report 05-04) see appendix A for a copy of this report.

Coal is the dominate estate and can block the development of CBNG gas wells. A CBNG operator must have permission from the coal mine to fracture a well within 750 feet of the mine boundary. These competing resources are often found in proximity to one another in Virginia however the operators have learned to work together and even benefit one another in some circumstances. Benefits include removal of water and gas prior to mining of the coal reducing the burden for the mining operation, and the disposal of produced water to the mine operator for dust control.

5.8 Gas Storage Fields

EIA gas storage data for 2006 indicates that there are three active gas storage fields operating in the State of Virginia (EIA website, Natural Gas Storage, Form EIA-191 Data, 2007). These storage fields consist of two salt caverns and one depleted field. The salt caverns have have a capacity of 6,275 mcf, while the depleted field holds 3,417 mcf.

Figure 15: Increasing Domestic Oil Price



Source: IOGA, 2008

6.0 OIL AND GAS OCCURRENCE POTENTIAL

6.1 Existing oil and gas production

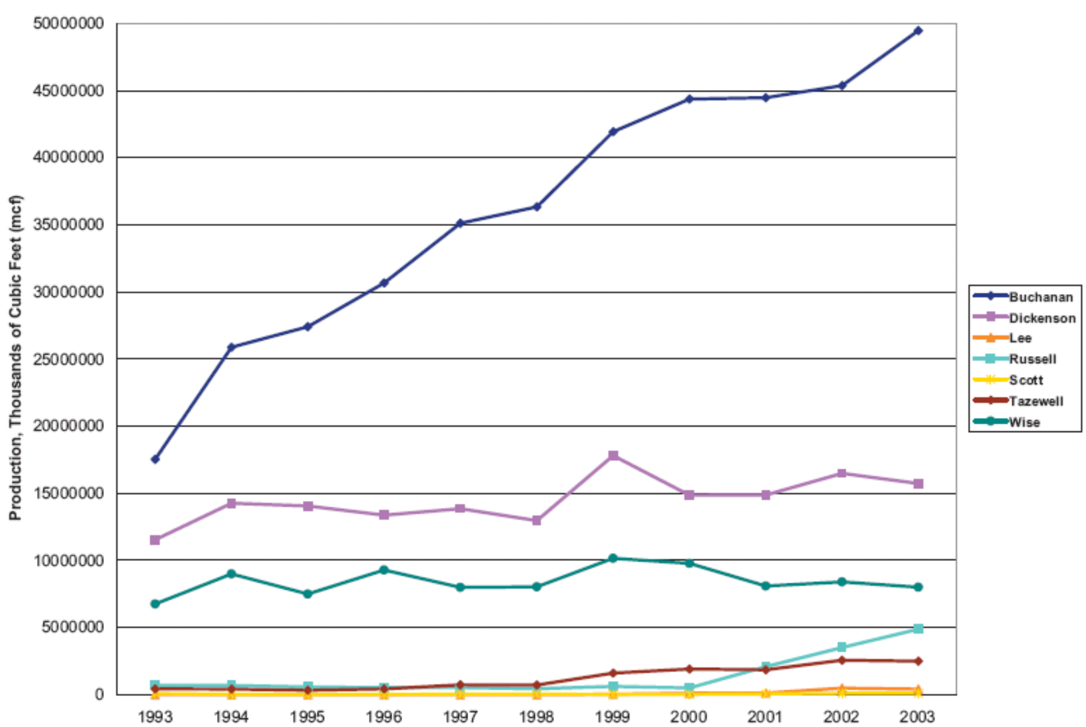
6.1.1 Natural Gas Production

According to the EIA, Virginia ranked 20th among the states for natural gas production, and provided less than 1 percent of U.S. gas production in 2003 (EIA, Quick Stats, Top Natural Gas Producing States, 2003). A record total of 102.8 billion cubic feet (bcf) of natural gas was produced in Virginia in 2006. Gas production has experienced an upward trend since 1980, and has increased 277 percent from 1993 to 2006. The increase was related to growth in CBNG production, which reached a record yearly total of 81.4 bcf in 2006. Most of the growth took place in Buchanan County, where gas production increased from 17.5 bcf in 1993 to 57.2 bcf in 2006. Conventional gas production rate has remained relatively flat in the past eleven years. As shown in Figure 4, the productive areas of conventional and CBNG overlap in the Appalachian Plateau Province of the state.

CBNG has been produced in significant amounts in Virginia since 1990 when the state adopted a version of "force-pooling" to eliminate the uncertainties of CBNG gas ownership. Prior to that time, it was often unclear who owned the natural gas within coal seams. Since then, CBNG has been exploited to depths in excess of 5,000 feet with aggregate coal thicknesses as high as 19 feet (USGS, 1995a). Figure 16 graphs the CBNG production by county from 1993 to 2006.

There has been only one occurrence of hydrocarbons outside of the Appalachian Plateau, the Bergton gas field in Rockingham County was discovered in 1935 when the operator drilled three wells into Devonian "Oriskany" sands. By 1965, five gas tests had been completed and shut-in. Five more gas wells were later

Figure 16: CBNG Production by County, 1993 to 2003



Source: Gilmer et al, 2005

completed and connected to a pipeline by 1982. Approximately 196,160 mcf were produced in 1982 and the field shut-in until 1984. A new operator produced the field from 1984 until 1986, when 4,503 mcf of gas were produced. There has been no reported production from Bergton Field or Rockingham County since 1986 (Milici, 1990). The history of this field suggests that little natural gas will be produced outside the Appalachian Plateau in Virginia.

6.2 Oil Production

In 2006, Virginia ranked last in crude oil production with less than 1 percent of U.S. production and has less than 1 percent of U.S. crude oil proved reserves. There were approximately 18,500 barrels of crude oil produced in Virginia, with an estimated value of just over a million dollars (EIA's U.S. average nominal first purchase price for crude oil in 2006). Annual oil production in Virginia peaked in 1983 at 65,400 barrels. It has since declined reaching a low of 8,804 barrels in 1999. Between 1999 and 2002, annual production increased 185 percent, to a high of 25,110 barrels. The increase in production in 2002 was related to production completions in several gas wells that were also capable of producing oil, but were classified as gas wells because of their high gas to oil production ratio.

7.0 OIL AND GAS DEVELOPMENT POTENTIAL

7.1 Relative Oil and Gas Development Potential

Six counties in Virginia hold all the oil and gas activity currently underway. Newly completed wells are graphed in Figure 17. These wells may not have been drilled in each year but were completed and saw first production in that year. Clearly CBNG activity is still accelerating but conventional gas (including shale gas) is rather quiet. The lion's share of the activity in the next ten years will come from CBNG. Table 2 lists the CBNG activity in the six counties of SW Virginia in terms of total gas wells and new CBNG wells. Forecast activity is generated by extending 2006 activity for all ten years except for Lee County that has minimal activity and is expected to continue to do so in the next ten years.

New drilling forecast for the next ten years are summarized on Table 3. The table emphasizes that the largest proportion of federal land is in Wise County but few overall wells are forecast for Wise County. The largest number of new wells is forecast for Buchanan County but this county contains few federal lands. Most of the forecast drilling should occur in Dickenson County and most of these wells will be shallow CBNG wells.

Figure 17: New Wells Completed by Year

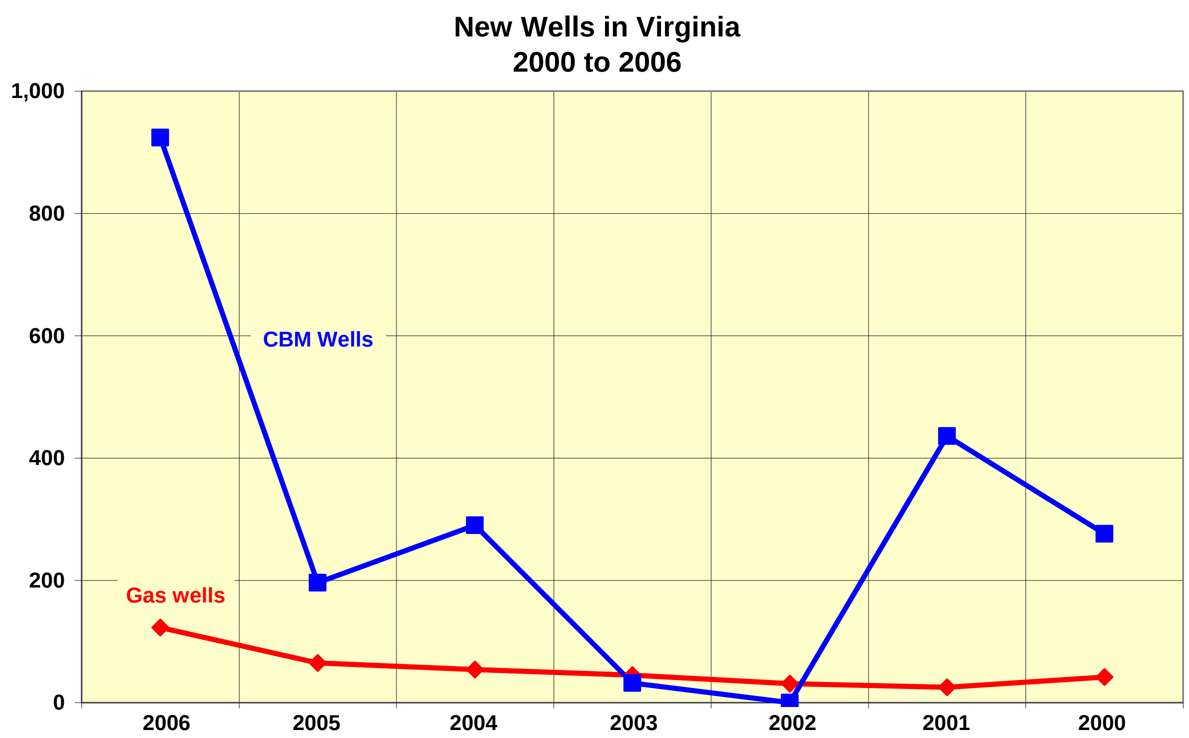


Table 2: New CBNG Drilling in 2006 by County

County	Total Active Gas Wells in 2006	Total Active CBNG Wells	New CBNG Wells Added in 2006	Projected New Wells in the Next Ten Years
Lee	37	0	0	10
Wise	590	107	8	80
Tazewell	329	282	33	330
Russell	376	368	38	380
Dickenson	1,528	993	94	940
Buchanan	2,311	1,927	131	1,310
State Total	***5,171***	***3,677***	***304***	***3,050***

Table 3: 10-Year Forecast Federal Drilling Per County

County	Total Acres	Total Forecast Wells	USFS Acres	Other Federal Acres	USFS Percentage	Other Federal Percentage	Forecast USFS Wells	Forecast Other Federal Wells
Lee	279,743	10	38,020	7,479	13.59	2.67	1	0
Wise	259,120	80	133,699	696	51.60	0.27	41	0
Tazewell	332,468	330	69,572	-	20.93	0.00	69	0
Russell	304,902	380	8,035	-	2.64	0.00	10	0
Dickenson	213,390	940	31,420	4,081	14.72	1.91	138	18
Buchanan	322,232	1,310	156	-	0.05	0.00	1	0
State Total	**1,711,854**	**3,050**	**280,902**	**12,256**	**16.41**	**0.72**	**261**	**18**

8.0 Reasonable Foreseeable Development Baseline Scenario Assumptions and Discussion

This RFD scenario assumes that all potentially productive areas are open under the standard lease terms and conditions except those areas designated as closed to leasing by law, regulation, or executive order. The areas closed to leasing typically include Areas of Critical Environmental Concern (ACECs), Wilderness Study Areas (WSAs) and USFWS Wildlife Refuges. The RFD scenario contains projections for the number or wells and acres disturbed for these counties. This in no way is intended to imply that the BLM are making decisions about the Forest Service lands or the USFWS lands. The predictions are intended to provide the information necessary so that all potential cumulative impacts can be analyzed. The disturbance for each well is based on the typical depth of wells for an area; generally, shallow gas wells disturb fewer acres than deeper oil wells. The assumptions for conventional oil and gas are as follows:

The number of wells was calculated based on historical statistics and data trends as follows:

- Wells drilled to date were taken from the Virginia Bureau of Mines and Mineral Regulation annual reports.
- The number of wells drilled to date was statistically analyzed to calculate a median per year wells drilled per county.
- The data trends associated with the last 9 years (1999-2007) represents a more accurate estimate of future development trends than historical data, thus, it is weighted more heavily.
- The data trends from 1992 to present data set are a more accurate estimate of future trends than the complete historical record and were weighted more heavily than the historical record.
- The data trends for the complete historical record represent the least accurate estimate of future development trends and, thus, it was weighted the lightest.
- For each geographic/geologic boundary region and sub region, the calculated estimates for future development were summed to obtain a per year well count.
- Wellhead oil and gas prices are a driving force for well drilling and completion; current prices are historically high and have resulted in increased activity throughout most states. An estimate of activity for the future well development to into consideration this influence. The forecast assumes wellhead oil and gas prices will remain high and development over the next 10 years will continue at an elevated rate.
- Estimates of well counts for the different mineral ownership entities are based on spatial analysis of the percent of mineral ownership within each county times the total number of producing wells anticipated to be developed in that boundary area.
- The average acreage figure (acres per well) for the resource area was used to estimate federal disturbed acres.
- The RFD projections have a 10-year life.
- The number of dry holes was determined based on historic analysis of dry holes in the geologic boundary areas.

The assumptions were used to calculate the number of wells to be drilled, the number of in-field compressors, and the number of sales compressors required.

9.0 SURFACE DISTURBANCE DUE TO OIL AND GAS ACTIVITY ON ALL LANDS

9.1 Surface Disturbances

Estimates of the surface disturbances associated with the development of oil and gas on federal minerals within the State of Virginia were determined from a variety of resources, including previous oil and gas environmental assessments, discussions with BLM and state oil and gas personnel, discussions with various operators, and document review.

The level of disturbance associated with conventional oil and gas development varies depending on the depth of the well and type of well drilled (horizontal vs. vertical). A shallow oil and gas well (<2,000 feet deep) typically includes a well pad of 2.0 acres, 0.10 miles of gravel road and 0.55 miles of utility lines for a total construction disturbance area of approximately 4.8 acres. Deeper oil and gas wells (5,000 to 12,000 feet below surface) require a greater disturbance area to accommodate the larger amount of equipment necessary to complete drilling. Usually a 3.25 acre well pad, 0.075 miles of gravel road, and 0.475 miles of utility lines for a total of 6.7 disturbed acres during the construction phase. Tables 4 and 5 present surface disturbance estimates for conventional shallow and deep oil and gas wells along with their associated support facilities.

Coalbed Natural Gas (CBNG) can be developed with smaller rigs and therefore the surface disturbances are typically less than those of conventional gas or oil developments. In Virginia, however the CBNG is found in topographically rough surface areas and the disturbances associated with each well are generally more than in other CBNG fields in the U.S. To account for the large disturbances associated with drilling in this mountainous area construction disturbances have been increased based on discussion with the DMME. Table 6 presents the typical disturbances for developing CBNG wells in Virginia.

The surface disturbances are scaled to a per well disturbance level so that calculation of the total disturbance can be generated at the project, field, or county level by multiplying the number of wells for analysis by the numbers provided in the table. Existing surface disturbances are commensurate with the estimates provided in Table 4, 5 and 6.

9.2 Site Construction

The shortest feasible route is chosen to minimize haulage distances and construction costs while considering environmental factors and the surface owner's wishes. The access roads are typically constructed using bulldozers and graders to connect the existing road or trail and the drill site. In some cases improvements such as cattle guards and culvert crossings are installed because of the terrain.

In the planning area the kind of drill rig and drilling depth varies and is determined by the geologic province and expected product from the well. The extent of surface disturbance necessary for construction depends on the terrain, depth of the well, drill rig size, circulating system, and safety standards. The depth of the drill test determines the size of the work area necessary, the need for all-weather roads, water requirements, and other needs. The terrain influences the construction problems and the amount of surface area to be disturbed. Reserve pit size may vary because of well depth, drill rig size, or circulating system.

Access roads to well sites usually consist of running surfaces 14 to 18 feet wide that are ditched on one or both sides. Many of the roads constructed will follow existing roads or trails. New roads might be necessary because existing roads are not at an acceptable standard. For example, a road

Table 4

Level of Disturbance for Conventional Shallow Oil and Gas Wells and Associated Production Facilities

FACILITIES		Exploratory Well Disturbance (acres/well)	Construction Disturbance (acres/well)	Operation/ Production Disturbance (acres/well)
Well Pad (300-foot by 300-foot pad during drilling and construction, 175-foot by 175-foot pad during operation)		2.07	2.07	0.70
Access Roads to Well Sites	Two-track (12-foot wide by 0.25 miles long)	0.36	N/A	N/A
	Graveled (20-foot wide by 0.10 miles long for construction and operation)	N/A	N/A	0.24
	Bladed (20-foot wide by 0.10 miles for construction and operation)	N/A	0.24	0.0
Utility Lines	Water lines (15-foot by 0.20 miles)	N/A	0.18	0.0
	Overhead Elec. (10-foot by 0.15 miles)	N/A	0.12	0.03
	Underground Elec. (15-foot by 0.20 miles)	N/A	0.36	0.0
Transportation Lines	Intermediate Press. Gas line to and from field compressor (15-foot by 0.1 miles)	N/A	0.18	0.045
	High Press. Gas or Crude Oil Gathering Line (20-foot by 0.25 miles)	NA	0.61	0.15
Processing Areas	Tank Battery (one 0.50-ac tank battery per 20 wells)	N/A	0.025	0.025
	Access Roads (25-foot by 0.05 miles)	N/A	0.15	0.15
	Field Compressor (0.5-acre pad per 20 wells)	N/A	0.025	0.025
	Sales Compressor (2-ac pad for 150 wells)	N/A	0.01	0.01
	Sales Line (20-foot by 5 miles per 200 wells)	N/A	0.061	0.015
Produced Water Management	Produced Water pipeline (15-foot by 0.25 miles)	N/A	0.45	0.11
	Water plant/ Inj well (6 ac site per 20 wells)	N/A	0.3	0.3
Total Disturbance per Conventional Oil or Gas Well (acres)		**2.43**	**4.79**	**1.81**

1. The operation disturbance for utilities assumes all utilities will be completed underground, and the land surface will be reclaimed so that no disturbance should remain except where noted.
2. It is assumed that each conventional oil and gas well will need product pipeline and produced water line from the well. In addition, some wells will need intermediate pipeline run from the field compressor to sales line.

Table 5
Level of Disturbance for Conventional Deep Oil and Gas Wells and Associated Production Facilities

FACILITIES		Exploratory Well Disturbance (acres/well)	Construction Disturbance (acres/well)	Operation/ Production Disturbance (acres/well)
Well Pad (375-foot by 375-foot pad during drilling and construction, 200-foot by 200-foot pad during operation)		3.23	3.23	0.92
Access Roads to Well Sites	Two-track (12-foot wide by 0.5 miles long)	0.73	N/A	N/A
	Graveled (20-foot wide by 0.075 miles long for construction and operation)	N/A	N/A	0.18
	Bladed (20-foot wide by 0.075 miles for construction and operation)	N/A	0.18	N/A
Utility Lines	Water lines (12-foot by 0.20 miles)	N/A	0.29	0.0
	Overhead Elec. (10-foot by 0.075 miles)	N/A	0.09	0.023
	Underground Elec. (15-foot by 0.20 miles)	N/A	0.36	0.0
Transportation Lines	Intermediate Press. Gas line to and from field compressor (15-foot by 0.075 miles)	N/A	0.14	0.034
	High Press. Gas or Crude Oil Gathering Line (25-foot by 0.5 miles)	NA	1.21	0.30
Processing Areas	Tank Battery (one 0.50-ac tank battery per 15 wells)	N/A	0.03	0.03
	Access Roads (25-foot by 0.05 miles)	N/A	0.15	0.15
	Field Compressor (0.5-acre pad per 15 wells)	N/A	0.03	0.03
	Sales Compressor (2-ac pad for 150 wells)	N/A	0.01	0.01
	Sales Line (25-foot by 6 miles per 150 wells)	N/A	0.12	0.12
Produced Water Management	Produced Water pipeline (15-foot by 0.25 miles)	N/A	0.45	0.11
	Water plant/ Inj well (6 ac site per 15 wells)	N/A	0.40	0.40
Total Disturbance per Conventional Oil or Gas Well (acres)		**3.96**	**6.71**	**2.24**

1. The operation disturbance for utilities assumes all utilities will be completed underground, and the land surface will be reclaimed so that no disturbance should remain except where noted.
2. It is assumed that each conventional oil and gas well will need product pipeline and produced water line from the well. In addition, some wells will need intermediate pipeline run from the field compressor to sales line.

Table 6
Level of Disturbance for CBNG Wells and Associated Production Facilities

FACILITIES		Exploratory Well Disturbance (acres/well)	Construction Disturbance (acres/well)	Operation/ Production Disturbance (acres/well)
Well Pad (250-foot by 250-foot pad during drilling and construction, 175-foot by 175-foot pad during operation)		1.43	1.43	0.70
Access Roads/ Routes to Well Sites	Two-track	N/A	0.45	0.45
	Graveled	N/A	0.60	0.60
	Bladed	0.75	0.0	0.27
Utility Lines	Water	N/A	0.35	----[1]
	Overhead Elec.	N/A	0.20	0.20
	Underground Elec.	N/A	0.35	----
Transportation Lines	Low Pressure Gas	N/A	0.90	----
	Intermediate Pres. Gas	N/A	0.25	----
Processing Area	Battery Site	N/A	0.020	0.020
	Access Roads	N/A	0.15	0.15
	Field Compressor	N/A	----	0.02 (0.5 acres / 24 producing wells)
	Sales Compressor	N/A	----	0.005 (1.0 acres / 240 producing wells)
	Plastic Line	N/A	----	0.5[2]
	Gathering Line	N/A	----	0.25
	Sales Line	N/A	----	0.075
Produced Water Management	Discharge Point	N/A	0.01	0.002
	Storage Impoundment	N/A	0.3	0.25
Total Disturbance		2.18	5.01	3.22

1. The operation disturbance for utilities assumes all utilities will be completed underground, and the land surface will be reclaimed so that no disturbance should remain except where noted.

2. Plastic lines within the processing area are assumed to disturb an average corridor with of 25 feet.

may be too steep so that realignment is necessary.

Roads can be permanent or temporary, depending on the success of the well. The initial construction can be for a temporary road; however, it is designed so that it can become permanent if the well produces. Not all temporary roads constructed are rehabilitated when the drilling stops. A temporary road is often used as access to other drill sites. The main roads and temporary roads, require graveling to be maintained as all-weather roads. This is especially important in the spring. Access roads may be required to cross public lands to a well site located on private or state lands. The portion of the access road on public land would require a BLM right-of-way.

Most conventional wells are drilled from a fixed platform while the majority of CBNG wells are drilled using a truck-mounted rig. Site preparation generally takes about a week before the drill rig is assembled. For moderate depth oil wells drilling generally takes 2 to 4 weeks, although deeper wells may require longer drilling time because of the geologic formations encountered. Wells drilled from a platform require more surface preparation and cause disturbance to a larger area for the ancillary facilities. CBNG wells are usually drilled in under a week and site preparation is typically less than for conventional wells.

Approximately 1 to 4 acres are impacted by well site construction. The area is cleared of large vegetation, boulders, or debris. Then the topsoil is removed and saved for reclamation. A level area from 1 to 4 acres is then constructed for the well site, which includes the reserve pit.

The well pad is constructed by bulldozers and motor scrapers. The well pad is flat (to accommodate the drill rig and support equipment) and large enough to store all the equipment and supplies without restricting safe work areas. The drill rig must be placed on “cut” material rather than on “fill” material to provide a stable foundation for the rig. The degree of cutting and filling depends on terrain; that is, the flatter the site, the less dirt work is required.

Hillside locations are common, and the amount of dirt work varies with the steepness. A typical well pad will require a cut 10 feet deep against the hill and a fill 8 feet high on the outside. It is normal to have more cut than fill to allow for compaction, and any excess material is then stockpiled. Eventually, when the well is plugged and abandoned, excavated material is put back in its original place.

Reserve pits are normally constructed on the well pad. Usually the reserve pit is excavated in “cut” material on the well pad. The reserve pit is designed to hold drill cuttings and used drilling fluids. The size and number of pits depends on the depth of the well, circulating system and anticipated down hole problems, such as excess water flows.

Reserve pits are generally square or oblong, but may be irregular in shape to conform to terrain. The size of reserve pits for deeper wells can be reduced by the use of steel mud tanks. For truck-mounted drill rigs used in shallow gas fields, a small pit (called the blooie pit) is used. Most or all of the reserve pit is located in the cut location of the drillsite for stability. When the drillsite is completed, the rig and ancillary equipment are moved on location and drilling begins.

The reserve pit can be lined with a synthetic liner to contain pit contents and reduce pit seepage. Not all reserve pits are lined; however, BLM often requires a synthetic liner depending upon factors such as soils, pit locations, ground water and drilling mud constituents. The operator can elect to line the reserve pit without that requirement.

An adequate supply of water is required for drilling operations and other uses. The sources of water can be a well at the drill site or remote sources such as streams, ponds, or wells. The water is transported to the site by truck or pipeline. Pipelines are normally small diameter surface lines. The operator must file for and obtain all necessary permits for water from the state. On public lands an operator must have the BLM’s permission before surface water can be used.

9.3 Mitigation Measures

Mitigation measures are restrictions on lease operations, which are intended to minimize or avoid adverse impacts to resources or land uses from oil and gas activities. The mitigation measures would be applied to permits, leases or approvals granted by the land management agency. Mitigation measures would be included as appropriate to address site-specific concerns during all phases of oil, gas and CBNG development.

9.4 Conditions of Approval

An approved application for permit to drill (APD) includes conditions of approval (COA), and Informational Notices which cite the regulatory requirements from the Code of Federal Regulations, Onshore Operating Orders and other guidance. Conditions of approval are mitigation measures which implement lease restrictions to site specific conditions. General guidance for COA are found in the BLM and U.S. Forest Service brochure entitled “Surface Operating Standards for Oil and Gas Exploration and Development” (USDI, BLM 1989) and BLM Manual 9113 entitled “Roads”.

9.5 Lease Stipulations

Certain Resources in the planning area require protection from impacts associated with oil and gas development. The specific resources and methods of protection are contained in lease stipulations. Lease stipulations usually consist of no surface occupancy, controlled surface use, or timing limitations. A notice may be included with a leased to provide guidance regarding resources or land use. While actual wording of stipulations may be adjusted at the time of leasing, the protection standard described will be maintained.

9.6 Total Disturbances

The disturbances for the RFD scenario over the next 10 years have been calculated and are displayed in Tables 7 and 8. Table 7 address the disturbances from exploration and construction activities for types of gas and oil wells anticipated to be developed. Estimates for deep gas and oil wells from a single pad have been extrapolated. The total disturbances for all predicted wells are estimated at 14,415 acres. Disturbance from federal mineral development would be 1,257 acres of which 1,177 acres would be on USFS lands. The remaining federal disturbance (80 acres) would be on military sites, and national park lands. The disturbance to state and fee lands would be 12,493 acres.

Table 8 depicts the residual disturbance by well type remaining after appropriate mitigation measures and site restoration or rehabilitation activities have taken place. The total residual disturbance from anticipated development activities is 8,826 acres of which 807 would be from federal mineral development. The federal disturbances would affect 755 USFS acres and 52 acres of various surface agencies. State and fee residual disturbance would be 8,019 acres.

The mitigation of initial exploration and construction disturbances would equal nearly 5,590 acres. Mitigation measures would account for remediation of 450 federal acres, and 4,474 state and fee acres.

Table 7: Predicted Development and Surface Disturbance (Exploration and Construction) for Gas and Oil Wells

Well Type	Total Wells Drilled	Dry Holes	Disturbance per Dry Hole	Total Dry Hole Disturbance	Federal Producing Wells	Disturbance per Federal Well	Total Federal Disturbance	State/Fee Producing Wells	Disturbance per State/Fee Well	Total State/Fee Disturbance	USFS Producing Wells	Disturbance per USFS Well	Total USFS Disturbance	Total Producing wells	Total Disturbance
Gas - Shallow	10	1	2.43	2.43	0	4.79	0	8	4.79	38.32	1	4.79	4.79	9	45.54
CBNG	3,040	304	2.18	662.72	16	5.01	0	2,486	5.01	12,454.86	234	5.01	1,172.34	2,736	14,370.08
Total	3,050	305		665.15	16			2,494		12,493.18	235		1,177.13	2,745	14,415.62

Assumptions:

Disturbance per well includes the well pad plus incremental roads, utility lines, transportation lines, processing equipment areas, and produced water management as outlined in Tables 4 and 6 for exploration.

Table 8: Predicted Development and Residual Surface Disturbance (Production) for Gas and Oil Wells

Well Type	Total Wells Drilled	Federal Producing Wells	Disturbance per Federal Well	Total Federal Disturbance	State/Fee Producing Wells	Disturbance per State/Fee Well	Total State/Fee Disturbance	USFS Producing Wells	Disturbance per USFS Well	Total USFS Disturbance	Total Producing wells	Total Disturbance
Gas – Shallow	10	0	1.81	0	8	1.81	14.48	1	1.81	1.81	9	16.29
CBNG	3,040	16	3.22	51.52	2,486	3.22	8,004.92	234	3.22	753.48	2,736	8,809.92
Total	3,050	16		51.52	2,494		8,019.40	235		755.29	2,745	8,826.21

Assumptions:

Disturbance per well is the residual disturbance remaining after the mitigation measures have been implemented.

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Appendix A

VIRGINIA DIVISION OF MINERAL RESOURCES

OPEN-FILE REPORT 05-04

Appendix B

USGS PLAY DESCRIPTIONS

- APPALACHIAN BASIN PROVINCE (067)
- BLUE RIDGE THRUST BELT (068), PEIDMONT PROVINCE (069), ATLANTIC COASTAL PLAIN PROVINCE (070), ADIRONDACK PROVINCE (071) AND NEW ENGLAND PROVINCE (072)
- USGS OPEN-FILE REPORT 2004-1271