This paper provides a summary of my work experience with Equitable Resources (EQT) in Pittsburgh Pa, from June 2007 through December 2007. Throughout my initial 6 months of employment at Equitable Resources I worked in the capacity of a Geologist. I focused mainly on learning the oil and natural gas business, well planning and design, geologic mapping, and gas play development. The purpose of this report is to provide a summary of my day-to-day responsibilities, projects I have contributed to, and opportunities I have been given while working at Equitable Resources.
INTERNSHIP WITH EQUITABLE RESOURCES PRODUCTION COMPANY. – GEOLOGIST

An Internship Report

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Institute of Environmental Sciences

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# Table of Contents

Table of Contents........................................................................................................................... ii  
Introduction.......................................................................................................................................... 1  
   Equitable Resources Background .................................................................................................. 1  
The Basics of the Natural Gas Production Process............................................................................ 3  
   Well Preparation Process ............................................................................................................. 3  
   Staking Requests........................................................................................................................... 4  
   Well Prognoses .............................................................................................................................. 5  
   Perforation Recommendations ...................................................................................................... 5  
Additional Day-to-Day Responsibilities............................................................................................... 6  
   Drilling Rig Locations .................................................................................................................... 6  
   Backup Information and Data Collection ....................................................................................... 6  
   Downhole Geophysical Logging and Interpretation ........................................................................ 7  
   Video Logs...................................................................................................................................... 12  
Projects................................................................................................................................................... 13  
   Coal Thickness Mapping ............................................................................................................... 13  
   Gas Content Determination .......................................................................................................... 14  
   Gas in Place.................................................................................................................................... 15  
   Treated Inches of Coal and Recovery Factor Mapping ............................................................... 17  
   Recompletions ............................................................................................................................... 18  
   Reserve Audit with Ryder Scott ..................................................................................................... 20  
Additional Work Activities..................................................................................................................... 21  
   Testifying before the Virginia Gas and Oil Board ......................................................................... 21  
   Horizontal Drilling......................................................................................................................... 21  
Training Opportunities.......................................................................................................................... 21  
   Other Responsibilities: .................................................................................................................... 23
List of Figures:

Figure 1: Approximate area of operation.
Figure 2: Virginia drilling plan broken down by month for 2007.
Figure 3: Typical front page print out of Conventional welllog.
Figure 4: Typical readings taken by logging tools.
Figure 5: Producible area in Conventional well, Ravencliff Formation.
Figure 6: Producible area in CBM well, Middle Seaboard coal seam.
Figure 7: Typical log response in Lower Huron Devonian shale.
Figure 8: Typical coal seam thickness map.
Figure 9: Map showing total inches of treatable coal.
Figure 10: Recovery factor map.
Figure 11: Map showing possible recompletion project area.
Figure 12: Photo of Pound Gap outcrop in Virginia.
List of Acronyms:
AAPG: American Association of Petroleum Geologist
BSG: Big Stone Gap (Virginia drilling district)
CBM: Coalbed Methane (Methane found in coal seams)
GIS: Geographic Information System
GPS: Global Positional System
EUR: Estimated Ultimate Recovery, usually given in MMCF of gas
IES: Institute of Environmental Sciences
MCF: Thousand Cubic Feet
MMCF: Million Cubic Feet
PAPG: Pittsburgh Association of Petroleum Geologist
SCF: Standard Cubic Feet
TD: Total Depth (measured from the surface to the bottom of the well)
Conventional Wells: In this case wells that produce gas from formations other than coal seams

List of Definitions:
E-Log: Electron Log. Contains data readings such as gamma ray, density, temperature, audio, porosity, and caliper (washout indicator).
Feet of pay: Amount of a formation that has parameters typical of a producible zone, porosity is the most common parameter used to calculate this.
Frac-Job: Process used by engineers to create fractures in a rock formation to allow for production of oil or natural gas
Gas Content: Amount of gas present in a formation, usually given in standard cubic feet of gas per ton of rock (scf/ton).
Gas in Place: Total amount of gas present in a formation or production field.
Isomap: Map that shows distance from one point in the rock formations to another, such as the distance between the top of one formation to the top of another.
Net sand: Amount of sand (total ft) present in a formation or well.
Perforation: Hole shot into a formation to allow for fracturing of that formation
Plat. Diagram showing surveyed well location.
Recovery Factor: Percentage of total Gas in Place that is being recovered by production.
Roustabout: General Oil or Natural Gas field worker
Well Prognosis: Write-up that provides geologic information about a proposed well location
Introduction

On June 4th, 2007, I began a position as a geologist with Equitable Resources with their main office in Pittsburgh, PA, in part to fulfill the internship requirement for a Master of Environmental Science (M.En.) from Miami University’s Institute of Environmental Sciences (IES). My background in geology includes an undergraduate degree in geology from Marietta College and coursework associated with the IES degree program. Prior to this job I worked several summers for oil and natural gas companies as a roustabout and later doing global positioning system (GPS) field mapping. My educational background, past job experiences and personal references were beneficial in obtaining my current job position.

Equitable Resources Background

Equitable Resources is both a natural gas production company and utility company. The utility side supplies natural gas to over 275,000 homes. The production side consists of citing and completing gas wells in the Appalachian Basin. The production fields have been broken down into four main regions: Kentucky, Northern West Virginia, Southern West Virginia, and Virginia. I have been assigned to the Virginia team (Figure 1).

In 2007, the Virginia team is responsible for drilling more wells than any of the other three regional teams. For 2007 the Virginia team had a target of drilling between 289 and 337 wells (Figure 2).

In the Virginia region there are two different types of wells that are drilled, conventional wells and coalbed methane (CBM) wells. Conventional wells in Virginia are drilled to depths around 6,000ft to obtain natural gas from sandstone, shale, and limestone formations. CBM wells typically consist of drilling between 2,000 ft to 3,000 ft to obtain natural gas from coal seams. In Virginia the number of CBM wells drilled is much higher than the number of conventional wells drilled. The total number of targeted CBM wells for 2007 was 260 and the target for conventional wells was 45. This is due to cost of the wells (CBM wells are much cheaper and have consistent economic rate of
returns), spacing regulations (CBM wells and be closer to each other and Conventional wells), and availability of economic locations.

Figure 1. Approximate area of Virginia operation.
The Basics of the Natural Gas Production Process

Well Preparation Process

The first step in the Equitable Resources process to harvest natural gas from the earth is for the geologist to get a staking request for a well. A staking request is a proposal for the location of a well. The location is selected by looking at the geologic structures of a certain area, the production of near by wells, and by examining topology for the actual location of the well.

If the well location meets certain criteria then landmen in the field determine the surface owners, access routes, and best possible location with advice from the geologists. Once a site is chosen by the landmen, approval is obtained from the site-construction crews, and then the pipeline division determines the best location for a pipeline to connect the new well with existing infrastructure. Surveyors draw up a plat and send it to the coal company for approval (Coal companies have first rights to minerals and must approve of the well location in order for drilling to be allowed). Once this is completed the surveyors complete the plat for the well location.
After all of this has been approved, the geologist completes a well prognosis. This involves using the information from the staking request in conjunction with additional information from surrounding wells to make estimates as to what rock formations will be found and what their potential thickness will be. This prognosis is then submitted to the state for a permit to drill. Title work is conducted to obtain the legal right to drill on the land. When the title and permits have been obtained, the different divisions (i.e. drilling, construction, pipeline, etc.) submit estimated costs for drilling the well. Equitable management then looks at the project well and either approves or denies based on the profit margin and economic rate of return. If the well is approved then a secondary check is conducted to ensure that all steps were properly carried out. The drilling location is then cleared and built, the well is drilled, and pipeline is connected to the wellhead.

Once the well is drilled, various data-gathering tools are lowered down the hole to take measurements about the rock formations around the well. Based on these measurements, the geologist determines where to perforate the pipe and fracture the formations to obtain the highest possible gas yield from the well.

Drilling these wells involves a very long process that includes getting titles to the land approved, permits, approval from the coal companies, building drilling locations, and drilling the wells. As a geologist I have responsibilities before and after the wells are drilled. Before drilling, the well prognosis must be completed and after drilling, the perforation recommendations need to be made.

**Staking Requests**

Over time, I have taken on more responsibilities. One such responsibility is approving well locations. This process starts with the land department suggesting a group of wells that they have determined are likely to be approved by the coal companies for drilling, or when the geologist requests a location in a specific area. My first step is to map the grids suggested by the land department, with the area’s geologic structures, our current wells, and their production information. Using this map we can determine which locations are more likely to be approved for drilling from an economic standpoint. Grid locations are selected based on distance to good producing wells, and their position
relative to geologic structure. Once these grids are chosen, the information is passed on to the data techs to prepare the formal location staking requests.

**Well Prognoses**

Completing well prognoses is another major part of my work at Equitable. Along with well perforation recommendations, it makes up the second part of the development drilling process. The well-prognosis process begins with the staking request to the land department. Once a staked location has been approved, a plat is drawn up and sent to the geologist for determination as to where different coal seams and/or rock formations will be encountered while drilling the well. Because this region of Virginia is heavily mined for coal, a major part of this is letting the drillers know if and at what depth they can expect to encounter old abandoned coal mines. Determining this information involves looking at depth information from offsetting wells, information provided to us from the coal company, and structure maps to see if the rocks are rising or dipping in relation to existing offsetting wells that encountered mines.

The process eventually yields an estimate for existing abandoned mine tops, formations tops, and in the case of CBM wells how many inches of treatable coal we can expect to encounter. This estimate of treatable coal is then used by the reservoir engineers to predict if the well is going to produce enough gas to make it economic to drill. The general rule is the more coal there is in a CBM well, the more gas it will make. This is not always the case though, because different coal seams have varying gas contents, permeabilities, and water contents that all affect the way a well will produce.

**Perforation Recommendations**

Creating perforation recommendations is a significant responsibility of the geologist. After the well is drilled, the log reading are analyzed to determine which formations have economic gas producing capabilities. A recommendation is then set out detailing what depth holes (perforations) are to be shot into the side of the hole. Natural gas enters the well through pipe perforations, and these perforations also allow the well completion/stimulation job (frac job) to fracture the formation or coal seam. The frac job
takes place after the well is drilled but before the completion tubing (the pipe that runs to
the bottom of the hole) is laid. Once the frac job is complete the natural gas is produced
though the completion tubing and then to the pipeline on the surface for market.

**Additional Day-to-Day Responsibilities**

**Drilling Rig Locations**
In my region of Virginia, Equitable operates more than one rig at a time. The
number of rigs depends on the number of locations that are built and ready for drilling.
One of my responsibilities is to keep track of the wells that the various rigs currently are
drilling as well as where they are going in the near future. As I learn more and more I will
be able to direct where the rigs move to in order to maximize our drilling results. The rigs
are spotted daily on a large map so that we can easily see where our drilling activity is
happening. Information is drawn from an internal network database that is updated from
the field with information regarding the location and depth of each well being drilled.
When drilling is completing, all maps and tracking spreadsheet are updating with new
location information. In addition to this, a drilling report is released each week that
allows me to spot the upcoming locations for the different rigs.

**Backup Information and Data Collection**
Another responsibility of my position is ensuring that certain information, such as
wells status, location status, formation data, and completion information, is recorded and
kept up-to-date. Most data can be kept current by the data technician. However, some
information, such as specific formation data, needs to be evaluated and monitored by the
geologist. It is important for us to know the potential of a reservoir. This begins by
calculating several parameters that help to characterize a reservoir rock such as feet-of-
pay and net sand values from a well log. To determine feet-of-pay within a reservoir
various pre-determined limits are established for porosity and density readings, then these
cutoffs are used to calculate the footage in a reservoir that has the potential for containing
gas. Net sand is determined for our sandstone formations by counting the number of feet
in a formation that contains can be classified as sand by looking at a combination of the gamma ray (helps to determine organic content levels, sandstones have very little), the density log (there are typical density log responses that are dependent on lithology), and Photo Electric Log (PE). Other miscellaneous information that is recorded is temperature or audio shows within a formation (determined by looking as temperature and audio readings), completion of that formation in offsetting wells, and the presence or absence of open mines for use in drilling offsetting wells.

**Downhole Geophysical Logging and Interpretation**

A major part of my job involves interpreting the geophysical logs readings to determine zones where natural gas may be present and recoverable. The logging tools measure several rock characteristics including gamma, porosity, density and permeability, all important characteristics for determining a rock’s type potential as a natural gas reservoir. One of the most fundamental and useful measurements is that of gamma radiation. Gamma ray logs are obtained by lowering a radioactive source into the wellbore and then measuring the level of radiation that is returned to sensors located on the tool. This gives an amount of natural radioactivity present in the rock formations. Clean (shale-free) sandstones and carbonates contain very little radioactive material and in turn yield a low gamma ray response. Shales have a higher concentration of radioactive material found in the organics within the shale that usually contain potassium or uranium (Asquith et al, 2004).

![Figure 3: Typical log response in Lower Huron Devonian shale.](image)

Figure 3: Typical log response in Lower Huron Devonian shale.

Other very useful curves on the well log for conventional wells are the temperature, density, and audio curves. As natural gas enters the wellbore there is a cooling effect as the gas expands while going from the relative high pressure of the
formation to the lower pressure of the wellbore, so if we see a temperature drop it can be an indicator of gas presence. The audio probe detects the sound of gas entering the borehole, so a spike in the audio log is a good sign of gas presence. The density reading is also very useful and gives an indication of lithology and porosity. The density tool consists of a radioactive source and gamma count detector. As a formation is exposed to radioactivity the density tool reads the number of gamma rays that are returned to the detector. This number will depend on the electron density of the formation. The gamma ray count will be low when formation density is high. The electron density derived from the tool is proportional to bulk density, which in turn can be used to calculate density porosity (Smith, 2009). To effectively determine producible areas the density, audio, and temperature readings must be examined in unison. During my internship, I have become more skilled at quickly assessing these readings.

The logging tools are usually lowered to the bottom of the hole and then take measurements as they are raised to the surface. Once these readings are taken in the field, an engineer decides where to place baffles in the pipe, essentially sectioning off the hole so that several different fracture stages can be created. The down-hole log is either emailed or loaded onto the web so the geologist and engineers that need use this information are able to access it (Figure 3-6).
### PHOTO DENSITY COMPENSATED NEUTRON ARRAY INDUCTION

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Permit Number: 7786  
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Log Measured From DRILL TABLE 6 FT above Permanent Datum  
Drilling Measured From TABLE  
Elevations:  
KBS:  
DF:  
GL: 1035.47

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| Depth Logger | 5706.00 feet |
| First Reading| 5765.00 feet |
| Last Reading | 0.00 feet   |
| Casing Driller | 2165.00 feet |
| Casing Logger | 2185.00 feet |
| Bit Size    | 6.50 inches |
| Hole Fluid Type | NONE       |

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Rmf @ Measured Temp  
Rmc @ Measured Temp

Source Rmt / Rmo  
Rm @ BHT  
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Equipment Name: COMPACT  
Equipment Base: 13045 NORTON

Recorded By: MIKE JARRETT  
Witnessed By: MR. FURBY, MR. KOSE

FIELD TICKET: 36279  
Last Line:                

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Figure 3: Typical front page print out of conventional well log.
Figure 4: Typical readings taken by logging tools
When dealing with a CBM well the most important factor is being able to determine where the coal seams are to produce gas. Coal seams are characterized by a lower gamma ray count and a density of less than 2 grams/cc (Figure 6). Occasional coal seams will be accompanied by temperature or audio gas shows, but due to the nature of CBM production, a coal seam with no gas shows may still yield significant production after completion.
Video Logs

Another aspect of examining wells is reviewing video logs. These are performed right after the regular electric log (E-Log, usually consisting of density, gamma ray, temperature, audio, and caliper readings) is run, typically on coalbed methane wells. It consists of lowering a video camera with lights on it down the wellbore. This tool has a depth recorder on it to monitor the cameras location relative to the E-Log. The video log is used to look for the presence of natural fracturing within a formation, and check for the presence of gas being emitted from a formation in the form of gas bubbles escaping along the wellbore. Prior to a video log being run, the hole is cleaned with soap. Not only does this clean out the hole of any left over drilling debris, but it also allows for the detection of gas shows from the soap bubbling where gas in comes out of the formation. We may discover that coal seams we normally wouldn’t complete because they are too thin have nice gas shows, and therefore warrant completion. This process is particularly useful in areas of the field that do not currently have a lot of production. It allows the geologist to see which of the coal seams appear to be gassy before the well is completed (method of creating fractures to enhance gas recovery in a well). Using this information the geologist can then make more informed decisions when writing up the perforation recommendation.
Projects

Coal Thickness Mapping

Coal seams that can be fracture to produce gas at economic levels are referred to as treatable. The thicknesses of treatable coal seams are mapped. This allows us to visually display the thickness of each seam in different areas, determine how deep to drill a well, and to help identify possible target seams for horizontal drilling. This mapping and updating of maps is process that needs to be completed every few months as more data is gathered. When we drill a CBM well each of the coal seems we hit has a name associated with it. We are not interested in the shallow coals (first 500 ft or so of the well), except to insure that these seams were not mined so that our drillers can know when to expect to hit a void when drilling the well. Completing of these shallow seams could lead to fracturing into the water table, which could cause the well to water out (make to much water to effectively produce the gas). With each of the coal seams below depths that are typically mined by coal companies (this depth varies from area to area) we record the depth and thickness. This information is then imported into the geographic information system (GIS) software, GeoGraphix®. We create a separate layer for each of the seams, and each layer must be updated separately with the addition of more information. The result is a set of maps that shows the various thicknesses of different coal seams (Figure 8).
Gas Content Determination

To determine the gas content of treatable coal seams, we first had to define the edges of our Nora CBM production field, based on geologic boundaries (faults) and economically producible areas (coal presence). Once this was done, a treatable coal thickness map was created using the recorded thickness for each well. A gas-content map was also created using data collected from some 18 cores taken throughout the production field. The core data gives us gas content by coal seam in standard cubic feet of gas per ton of coal (scf/ton). These gas-content data are averaged and are used and extrapolated throughout the field area. Each of the 60-acre grids is assigned a value for coal thickness and for gas content by assigning these extrapolated values to each of our
well location points (one per 60-acre grid). The equation below outlines the equation and values that were used to determine this
Field area * volume of treatable coal * average gas content of the coal = Gas in place

The gas content project was done both to estimate the total gas in place for the production field, and to determine whether or not the current infill program is justified economically for the increases in production versus the cost of drilling the well.

Gas in Place

Once the gas content was determined for the treatable coal, the next step was to determine the gas in place for the Nora CBM field. My part in this process was primarily mapping data. Two variable map layers need to be created: a gas content map and a map showing the total inches of treatable coal. The Nora field is already broken into a 60 acre-grid system, originally defined by the Virginia Division of Gas and Oil board. To calculate the gas in place we needed to assign a value for each of the 60 acre grids. Using well-control data, the map of total inches of treatable coal was created (Figure 9). The next step was taking data from cores of 18 wells throughout the field area. The cores indicate gas content for each individual coal seam in that location. The seams that were not within our producible range were eliminated and the average gas content of treatable coal only was determined for each core. These averages were then mapped with a isomap (a parameter contour map) using the follow equation,
Gas in place in million cubic feet of gas (mmcf) per 60 acre grid =

\[(a*b/12)*1900/1000000*60\]

Where grid a = gas content isovalue map in scf/ton (using previously created gas content map) and b = total treatable inches of coal. Assuming that there are 1,900 tons of coal per every acre-ft of volume.
Figure 9: Map of total inches of treatable coal. Red areas are the thickest; blue areas are the thinnest.

The gas in place was calculated, and a value for each of the 60-acre grids was exported for further analysis by our reservoir engineers. One of the underlying purposes of this study was to determine the effectiveness of our infill program. The regulations originally set up by the Virginia Gas and Oil Board allow operators to drill one CBM well per 60-acre grid. However, past studies conducted by both Equitable and other companies indicated that one well cannot effectively drain the gas from an entire 60 acre grid. So we have gone back to the State Gas and Oil Board and received location exceptions to drill two wells in a single 60-acre grid in a number of locations. If both the
infill well and the original well prove to be economic, then the infill program can be considered a success and hopefully applied to a larger area of the CBM field. In previous studies it was found that the amount of gas produced from a 60 acre grid that contained both an original CBM well and an infill well exceeded the gas in place for that 60 acre grid. However, new values obtained from this exercise support the theory that in some areas this is ample gas in place to support two wells per 60 acre grid.

**Treated Inches of Coal and Recovery Factor Mapping**

To determine the percent of gas that was being recovered out of the total gas in place through the field a recovery factor map was created. First a map was created by the geologist that showed the average treated thickness of coal for different parts of the field overlaid with the percentage of gas that has been recovered or is predicted to be recovered by current wells (used average of 225 mmcf). Many wells have above 100% recovery factor because average gas-in-place used was a conservative estimate. (Figure 10).
Recompletions

The total output of natural gas from a well is estimated using EURs (Estimated Ultimate Recovery). This value is determined by the engineers based on the current production, reservoir properties, and offset well data. Occasionally wells do not perform as expected. Often times this occurs in older wells, or wells that didn’t treat all productive formations or coals. For this project I created structure maps of two commonly produced formation, Big Lime and Weir sandstone (Figure 11), and overlaid our well production data. From analyzing a wells EUR with its position on geologic structure and comparing this with offsetting wells in similar situations I was able to spot wells that were not
yielding expected levels of return and wells that were nearing the end of their production life in the formations that were completed.

Some of the old wells that I examined were not uneconomic wells, but when they were drilled they were too far from existing pipeline infrastructure to be economically connected. However as our production field has grown, pipeline infrastructure has also grown, and wells that previously were not economic to turn-in-line (connect to production line), now are.

Specifically I looked at possible recompletion of well A (Figure 11). This was a matter of production communication between well A and one of its offsetting wells. Well A started out producing very well (over 150 mcf a day), then after a couple of years it began to drop rapidly over a 10 month period before regaining a normal decline curve. After investigation it was found that at the time well A began losing production an offset
well was drilled and completed. Looking around in this area it was found that this had occurred in several other pairs of wells. There are spacing regulations between wells that are set up to prevent communication from one well to the next, however the area in question is heavily faulted which allows for a long conduit for the gas to flow through.

The difference between well A and the other wells in the area that this happened to, was that the new offset well that was completed was not very productive. Usually if one well is producing gas from the same reservoir of another you would expect the new well to produce at least as much gas as the older well. One possibility is that when the newer well was treated the fractures generated could have shut off the gas flow to the older well. However if this were the case we would have expected the gas level in the older well to immediate drop instead of the increased gradual decline that we saw in well A. The end result of this study was that the field operators are going to pull the tubing from inside the well and see if there is a build up of sand at the bottom of the hole, or see if water if an increase in water production is slowing down the gas. If not, then a possible recompletion may be done on this well, where the original formations are completed again to attempt to re-fracture the gas producing zones.

**Reserve Audit with Ryder Scott**

Every year Equitable and other resource companies have to give forecasts of the amount total reserves (natural gas or oil) they have left in the ground on acreage they already have leased. A detailed inventory of reserves is created and used by upper management to place a value on the company for investors. Before this information can be used by management it must be audited by a third party, in our case we use Ryder Scott (this is a professional company that performs oil and gas reserve audits). To prepare for this the reserves for each individual well is determined and then estimated reserves are predicted for locations offsetting that well. The farther a location is away from an existing well the more risk there is associated with that location. We are only allowed to book proved reserves for locations that are immediate offsets to an existing producing well. Many maps are created for the different areas displaying the estimated reserves for each location. The maps are then reviewed by the Ryder Scott representative who then either approves our reserve estimates or changes as warranted.
Additional Work Activities

Testifying before the Virginia Gas and Oil Board

In Virginia, a separate drilling unit needs to be set up for horizontal wells to establish well parameters and allocate royalty payments for that well. Every month there is a meeting of the Virginia Gas and Oil board to approve and establish these units. As the geologist I have to first determine where we want to drill a horizontal well. Then get the land department to stake and get coal approval for the location just like a vertical well. Once that is done maps are created that show the proposed unit. These are submitted to the Board along with surveyed plats of the well location and unit. At the board hearings I have to testify to the size, location, and economic justification for the proposed unit. The Board usually then approves the unit and we can proceed with permitting and drilling the well.

Horizontal Drilling

Horizontal drilling has become one of the most successful and economic methods to effectively drain a natural gas reservoir. Equitable has been one of the leaders in the industry at drilling horizontal wells on air instead of filling the wellbore with fluid to facilitate drilling. As a geologist not only do I select location for horizontal drilling, but I also write up well prognosis for the well, and monitor the well while drilling. Every day that a horizontal well in my area is being drilled, I receive calls and reports as to the progress and any problems that are going on with the well. Once the drilling is complete, I set up the completion recommendations and pass these along to the engineers to design the well completion procedure. The cost of horizontal wells is much higher than vertical wells, but the economic returns are higher and the gas is recovered faster.

Training Opportunities

The opportunities for trying at Equitable have been numerous. Shortly after I began work, Equitable sent me on a two-week trip to the field in Big Stone Gap, Virginia.
This is the town that our Virginia operations are based out of. This was a great learning experience for me. I spent two weeks going along with field engineers, surveyors, contractors, and consultants learning what the guys in the field actually do. I was able to observe drilling, cement jobs, frac jobs, setting pipe, staking and constructing locations, and many other field operations. The most beneficial part of the trip however was probably getting to meet and talk with the people that I often deal with over the telephone. Being able to put a face to a name or voice makes my job a lot easier in Pittsburgh. Just north of Big Stone Gap there is also a road cut called Pound Gap that exposes most of the formations that we produce in a conventional well. It is also a good location to view geologic folding (Figure 12).

Figure 12: Photo of Pound Gap outcrop in Virginia.

Other training opportunities as an employee at Equitable have been great. In addition to the two-week field training, I have been able to attend multiple training and information sessions. Including a seminar sponsored by Halliburton focused on directional drilling. I was also able to attend a several week long training session on the mapping software we use, Geographix.
Equitable has also paid for my membership to AAPG (American Association of Petroleum Geologists) and PAPG (Pittsburgh Association of Petroleum Geologists). I attended the AAPG yearly region meeting in September of 2007, and presented a paper at the AAPG Eastern Regional Meeting in 2008. Being a part of professional groups such as the AAPG will only help further my career in the future with both the knowledge I am able to gain at seminars as well as contacts with other members.

**Other Responsibilities:**

Other responsibilities include managing the production field: keeping track of well status, number of locations in field, infill drilling program, adding and naming new production clusters, and many others tasks. This is crucial for keeping up with how the field is producing and determining where to concentrate new well production. At Equitable the geologists not only performs a geologic function for the company but also a development field management role.

**Conclusion:**

Overall my experience at Equitable Resources has been a very positive one. Both the people that I work with and the general atmosphere are very professional, but also enjoyable. I have been placed into a position of responsibility very early in my career which I have found challenging and rewarding. I have been able to use my educational background from both Marietta College and Miami University to help further my career. The leadership and teamwork skills I gained while in the Institute of Environmental Sciences have been very valuable to my current position. My entire job at Equitable involves being able to work with others to get projects completed.
References


Smith, Milton III, Feb 2009, Weatherford Open Hole Logging Seminar
APPENDIX A

Well Prognosis Example

Drilling Prognosis Data Sheet

Coalbed Methane

Well Information:

Well No: VCE
Lease Name: Unknown
Lease/Feo No: Unknown
Quadrangle: Cary Ridge
County, ST: Dickenson, VA
PUD #: D-21
Wells #: 46051
Carte Coord: 37.
Latitude: -02
Longitude:
Waters:
A.F.E #: Dad Branch

Projected Depths:

Gas Test: At all casing points, open mines and/or voids. Notify EQT personnel of any show.
Gas: Resable LB and LB at approx 577 and 477 MD
Heat Balance: Drilling engineers will pick up the heat balance previously discussed with the geologist.
Fresh Water:
Salt Water:
Elevation at Surface Location (ft): 2328.47
Total Depth (ft): 2635

Offset Wells:
751, 52, 59

Estimated Formation Tops:

<table>
<thead>
<tr>
<th>Formation Name</th>
<th>Top Depth</th>
<th>Base Depth</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Javeline</td>
<td>102</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greaty Creek</td>
<td>1501</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-Swan</td>
<td>1840</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warneck</td>
<td>1075</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upright C</td>
<td>1111</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Ninemem</td>
<td>2612</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X-Swan</td>
<td>2073</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foa a #7</td>
<td>2240</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foa a #6</td>
<td>2129</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foa a #2</td>
<td>2490</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foa a #1</td>
<td>2510</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Depth</td>
<td>2635</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Driving Directions:
From 53rd Street, take RT. #23 toward Norton. Turn onto RT. #58 and go toward Burien. Take RT. #72 toward Clintwood. Trip.

Geology Remark:
According to logs, the well will penetrate existing deep mine workings in the Upper Banner and Lower Banner at approx 377' M.D. and 477' M.D. respectively.
Shallow coal-bitting is not needed for the well.
Shallow coal to complete in approx 90' M.D.
The well will encounter approx. 270' inches of treatable coal that will be completed with a four-stage frac.
The estimated TD includes 125' below Project.
The closest, most recent well is VC-75003 (1954).
"Depth of the surface casing should be verified once the water well information is available showing depths and elevations of all water wells within 1000' of this location."

Logging Program:
Intermediate:

Drilling Sample Requirement: No

Tentative Casing Schedule:

<table>
<thead>
<tr>
<th>Casing</th>
<th>Casing OD</th>
<th>Casing Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductor</td>
<td>13 3/8&quot;</td>
<td>40 ft.</td>
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<tr>
<td>Conductor 2</td>
<td>9 5/8&quot;</td>
<td>R.</td>
</tr>
<tr>
<td>Surface</td>
<td>7&quot;</td>
<td>427' R.</td>
</tr>
<tr>
<td>Intermediate</td>
<td>9 1/2&quot;</td>
<td>527' R.</td>
</tr>
<tr>
<td>Production</td>
<td>4 1/2&quot;</td>
<td>2635' R.</td>
</tr>
</tbody>
</table>

Drilling Remarks:
Solids. No top hole water in Richard Massey 4-4 Move 8/18/06 and price updated. Build 2nd in a series.

Contacts:
Geologist: Luke Schuilen 412
Backup Geologist: Taylor 412
Engineer: Jim (412)
Landman: George 278
Drilling Superintendent: Cory 278
APPENDIX B:

Perforation Recommendation Example

Drilling engineer: XXX

RECOMMENDATION TO PERFORATE WELL V-55XXXX

Prater Quad
Dickenson Co., VA
Conventional Well

<table>
<thead>
<tr>
<th>FM NAME</th>
<th>TOP</th>
<th>BASE</th>
<th>PERFS:</th>
<th>See Column to right:</th>
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</thead>
<tbody>
<tr>
<td>Base LEE</td>
<td>1927</td>
<td>2750</td>
<td>Stage 4</td>
<td>2725-2742 2 SPF</td>
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<tr>
<td>RVCF</td>
<td>2583</td>
<td>2750</td>
<td>Stage 4</td>
<td>3440-3446 4 SPF</td>
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<tr>
<td>AVIS</td>
<td>2750</td>
<td>2785</td>
<td>Stage 4</td>
<td>35 25</td>
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<tr>
<td>MXTN</td>
<td>3035</td>
<td>3560</td>
<td>Stage 3</td>
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</tr>
<tr>
<td>LLIM</td>
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<td>3634</td>
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<tr>
<td>BGIM</td>
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<td>WEIR</td>
<td>4224</td>
<td>4415</td>
<td>Stage 2</td>
<td></td>
</tr>
<tr>
<td>WEIR Sh</td>
<td>4415</td>
<td>4814</td>
<td>Stage 2</td>
<td></td>
</tr>
<tr>
<td>SNBY</td>
<td>4814</td>
<td>4890</td>
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</tr>
<tr>
<td>BERA</td>
<td>4900</td>
<td>4980</td>
<td>Stage 1</td>
<td></td>
</tr>
<tr>
<td>CLEV</td>
<td>4988</td>
<td></td>
<td>Stage 1</td>
<td></td>
</tr>
<tr>
<td>TLB</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>UHRN</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>MHRN</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>LHRN</td>
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</tr>
<tr>
<td>CNG</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TD</td>
<td>5083</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: MXTN is tight, recommended to use tag gun for perforations.

133 Holes

SPUD DATE:

- #5 3013 8/13/2007
- #4 3733 Perf recom date:
- #6 4817 9/11/2007
- #2 N/A Completion Date:

DTD: 5080

LTD: 5083

NATURAL OPENFLOW: 126
APPENDIX C

Abstract for AAPG paper presentation

Recent Improvements in Production Methods in Nora Coalbed Methane Field, Southwestern Virginia

Luke Schanken, Michael J. Kovarik, Taylor Vactor, Craig A. Eckert

Since the first well was drilled in 1988, coalbed methane production in the Nora field has steadily increased to a current rate of 70 MMcfpd. Many factors are responsible for this increase such as multi-stage completions, infill drilling, efficient field operations, and rapid development and dewatering of new parts of the field. In addition, aggressive pipeline and compression planning and installation have allowed for maximum production benefit of the completed coal seams. Most recently, larger fracs and horizontal drilling may take production rates to levels not attainable through recent practices.