



Well Planning and Construction Haynesville Shale - East Texas

Carolyn S. Debrick, PE
Drilling Engineering Manager - Southern Division

Agenda

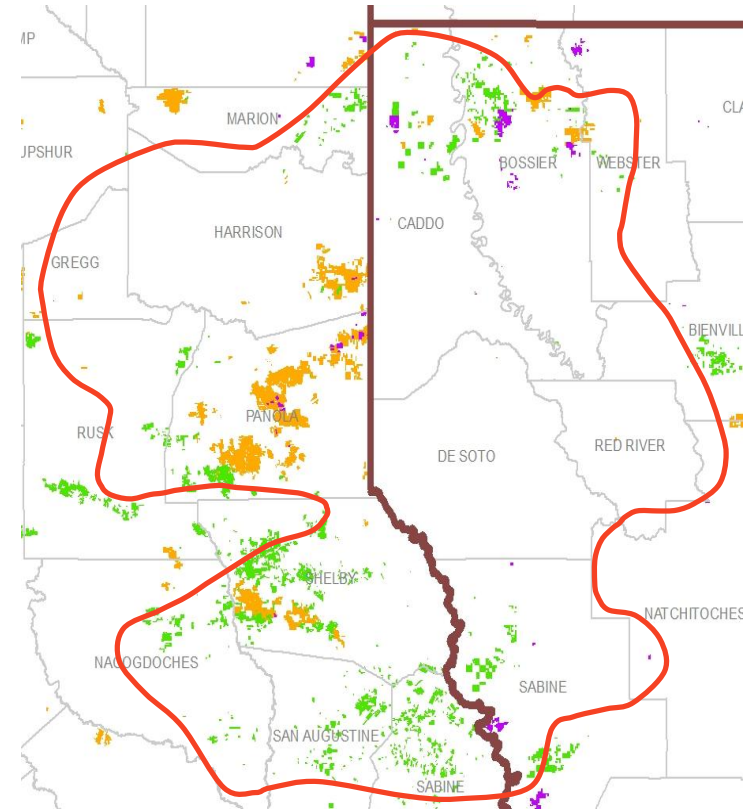
- Haynesville Shale
- Well Planning - Design
- Well Interference
- Surface Casing Setting Depth
- Casing Design Considerations
- Surface Casing Cement Design
- Production Casing Cement Design



Haynesville Shale

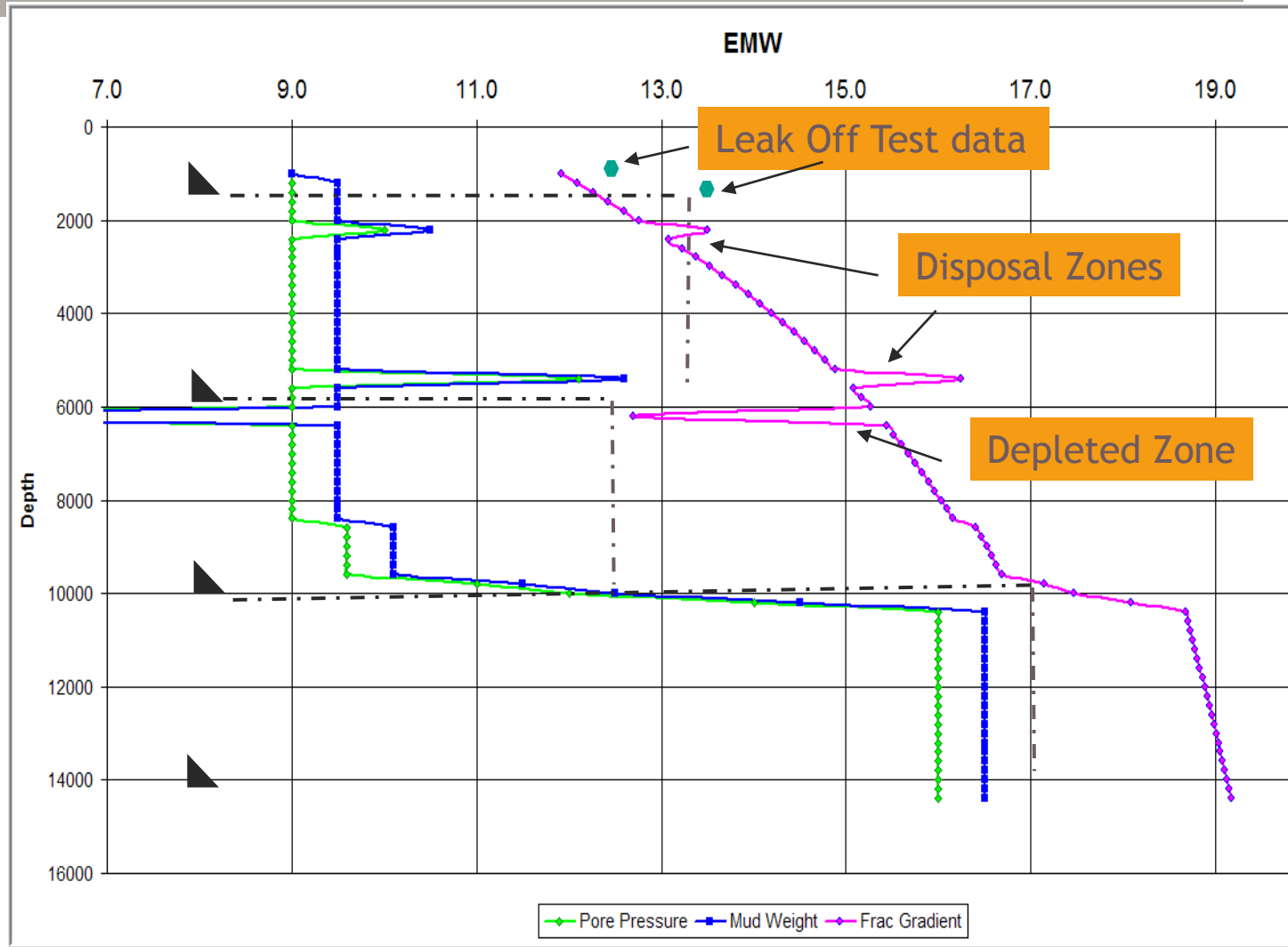
East Texas

- Located in East Texas, Six Counties
- Total Vertical Depth: 10,500' to 13,600'
- Measured Depth: 15,500' to 20,000'
- Pore Pressure: 15 ppg to 18 ppg
- Shale Frac Gradient: ≥ 1.0 psi/ft
- Treatment Pressure > 10,000 psi
- Bottom Hole Temperature: 270 to 350 F



Well Planning - Design

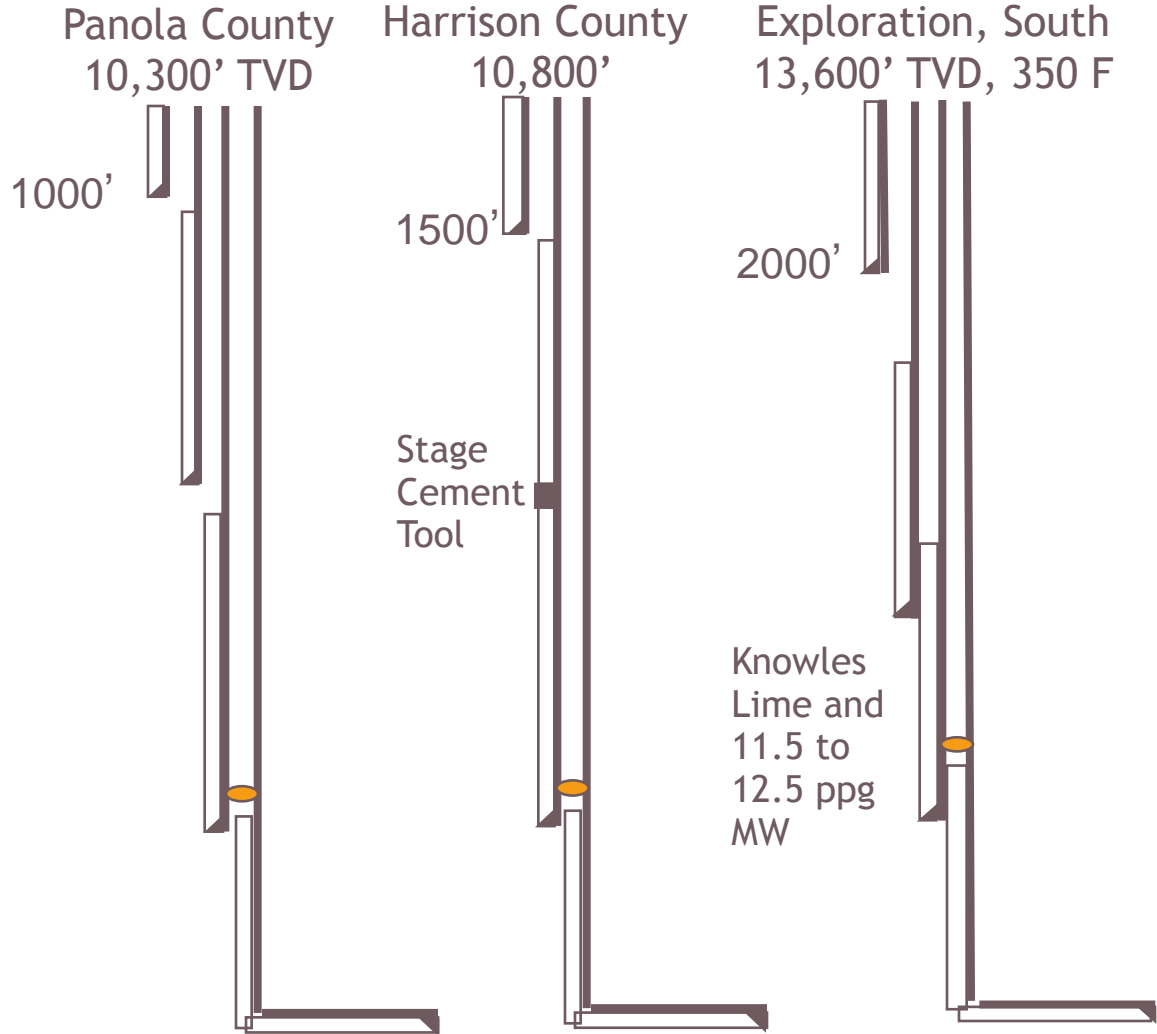
Pore Pressure, Frac Gradient, & Casing Seat Selections



Well Planning - Designs (cont.)

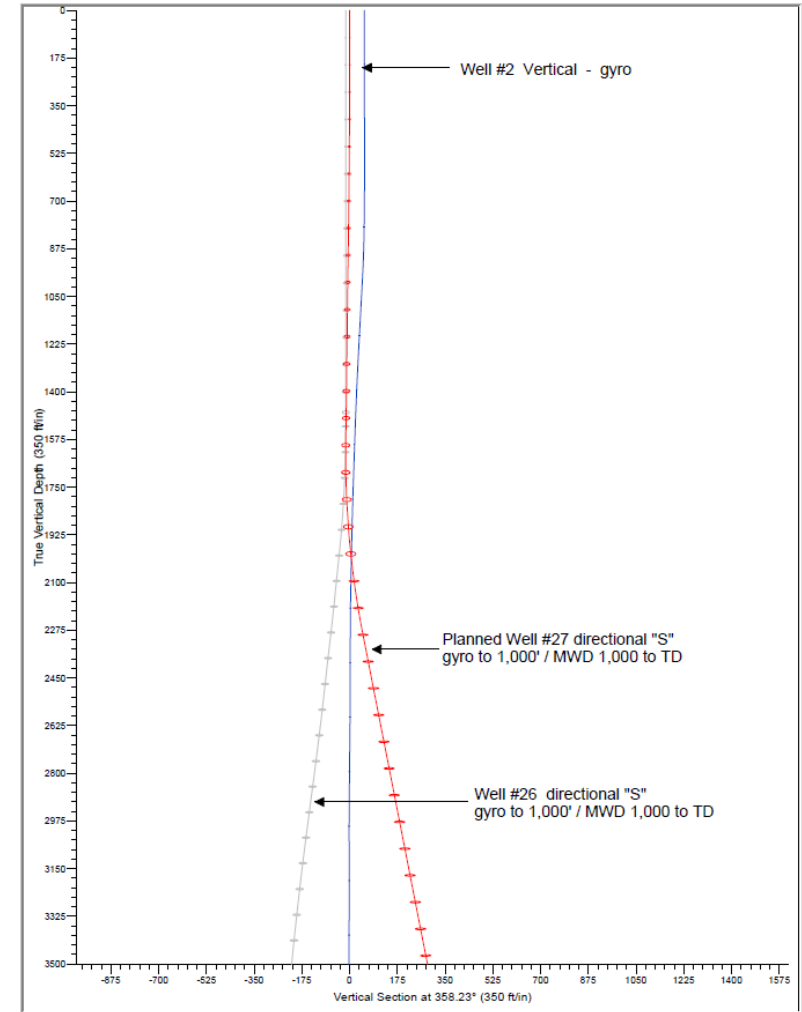
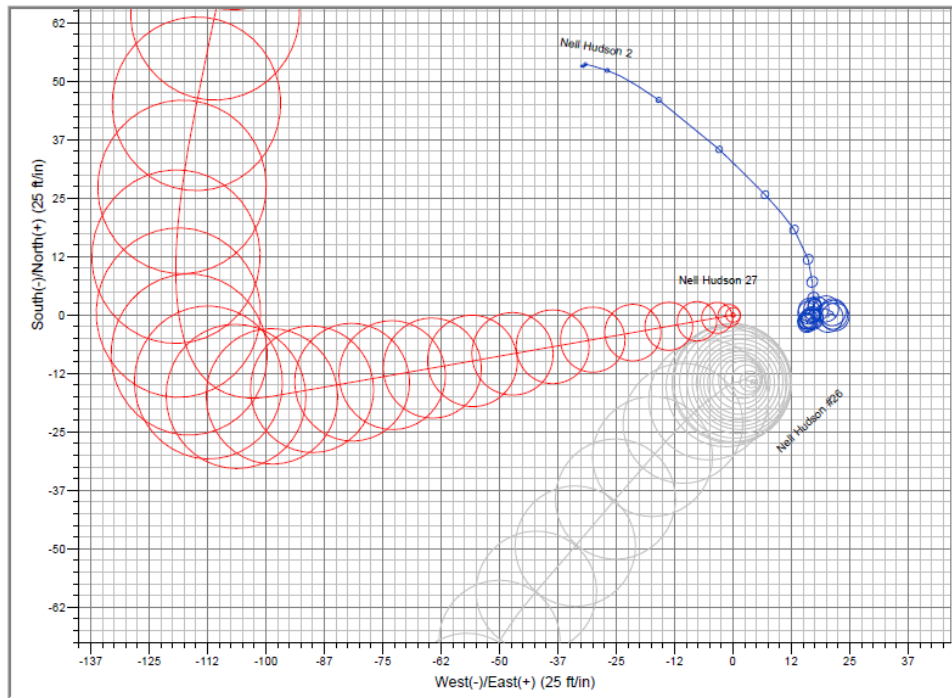
Geologic Cross Section

<i>Formation</i>	<i>Depth, ft</i>	<i>MW, ppg</i>
Duck Creek	2200	9 - 14
Anhydrite	5000	9
Rodessa	5400	9 - 13.8
Pettit	5900	2 - 9
Travis Peak	6300	4 to 9.8
Cotton Valley	8000	4 to 9.8
Bossier	9900 -12500	14 - 17
Haynesville	10500 -13600	14- 17



Well Interference: Anti-Collision

- Directional planning off a pad
- Different survey tools
- Separation Factor



Surface Casing Setting Depth & MASP

- Base of Wilcox, Panola County: 250 ft to 350 ft
 - Requirement is 200 ft or less below the base
 - Maximum Anticipated Surface Pressure - MASP
 - Devon sets surface casing at depth greater than prescribed by regulator to protect the USDW, the rig, and personnel
- *MASP = Fracture Gradient - maximum Mud Weight planned for next hole section*

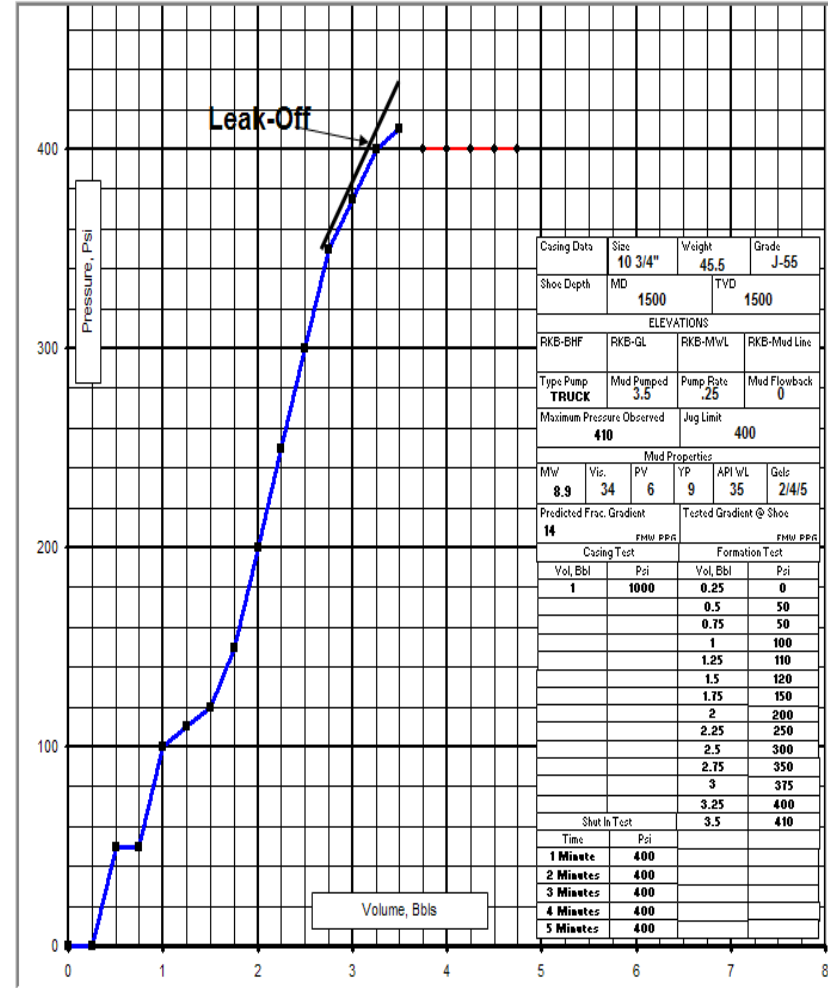
Surface Casing Depth	Fracture EMW	Planned Mud Weight	MASP
600 ft	11.5 ppg	10 ppg	47 psi
1,000 ft	12.5 ppg	10 ppg	130 psi
1,500 ft	13.5 ppg	10 ppg	234 psi

Casing Design Considerations

- Loads
 - Drilling
 - Casing running loads
 - Stimulation
 - Production
- Connection Selection
 - Pressure application, API or premium
 - Bending strength
 - Need to rotate
 - Compression and tension efficiency
 - Surface casing connection - Wellhead load structural requirements

Surface Casing Cement

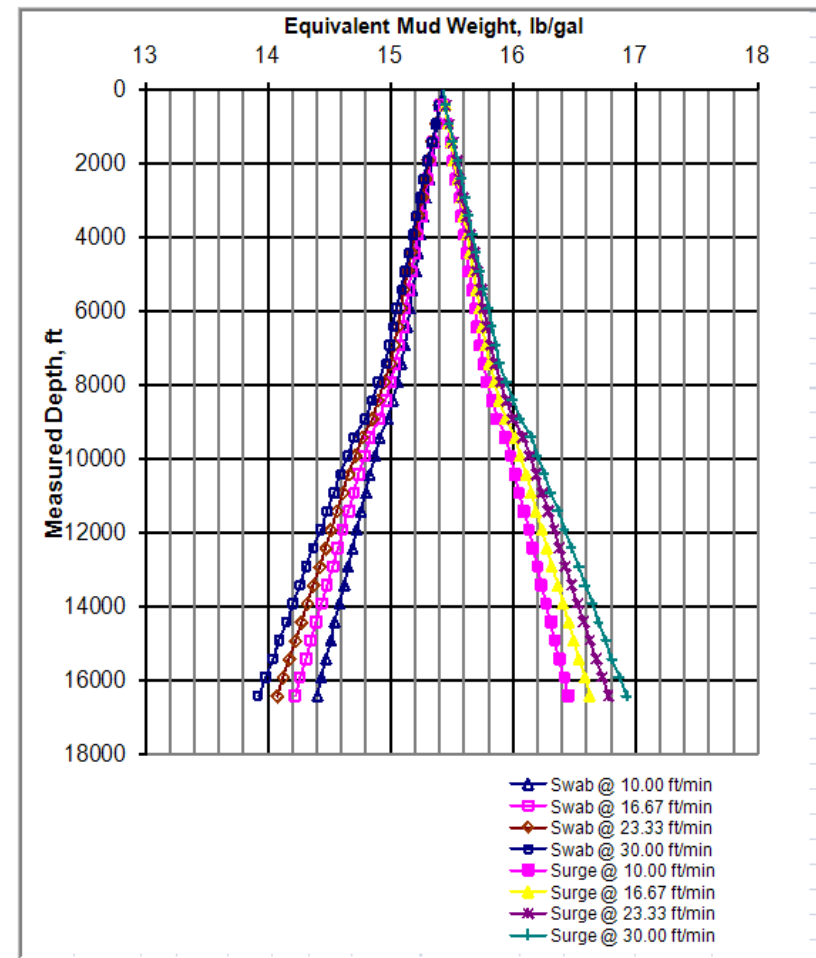
- Class A Cement
 - 15 ppg tail, 30% annular height
 - Extenders & accelerators added to lead
 - Cement returns to surface
- Haynesville Field Practices
 - Condition mud
 - Keep ECD below fracture strength
 - Pump spacers
 - Run centralizers
 - Reciprocate casing
 - Test casing shoe after drilling out
- Cement Design on Next String
 - Top of cement (TOC) into shoe of surface casing
 - Or, Run cement bond log (CBL) to determine if TOC is sufficiently above any zone to be stimulated



Production Casing & Cement

Haynesville Horizontal Well

- Design concerns
 - Close tolerance between hole & casing size
 - High mud & cement weights; therefore more circulating friction
- Haynesville Field Practices
 - Run surge & swab to determine casing running speed
 - Reduce mud yield point before tripping to run casing
 - Design low rheology cement
 - Run cement job ECD's to determine cement displacement rates & ensure below fracture
 - Run swell packer if job ECD & fracture strength close
- If flow after cementing is a concern:
 - Shut in annular
 - Hold pressure & wait until cement sets
 - Run a CBL before perforating

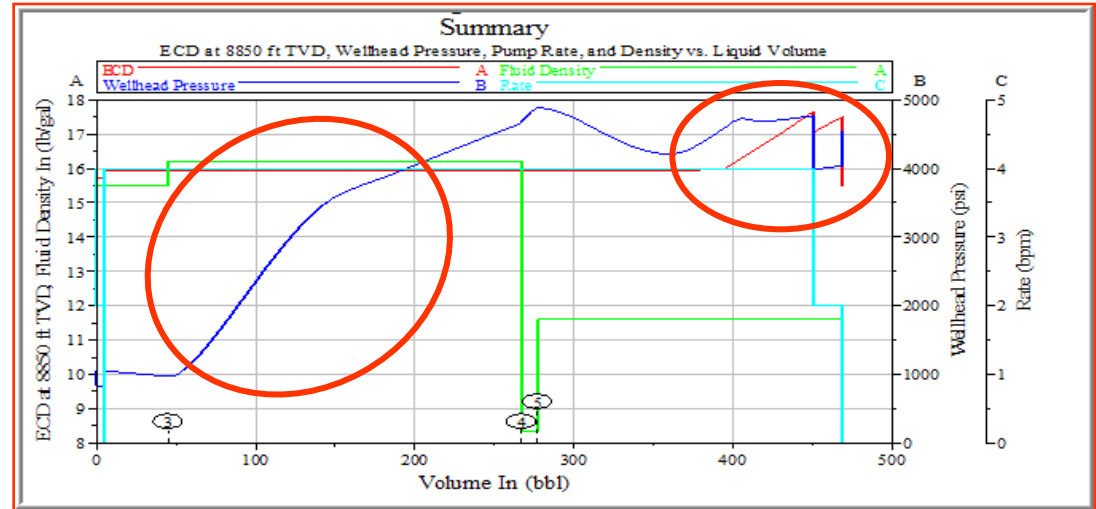


Production Casing & Cement (cont.)

Haynesville Horizontal Well

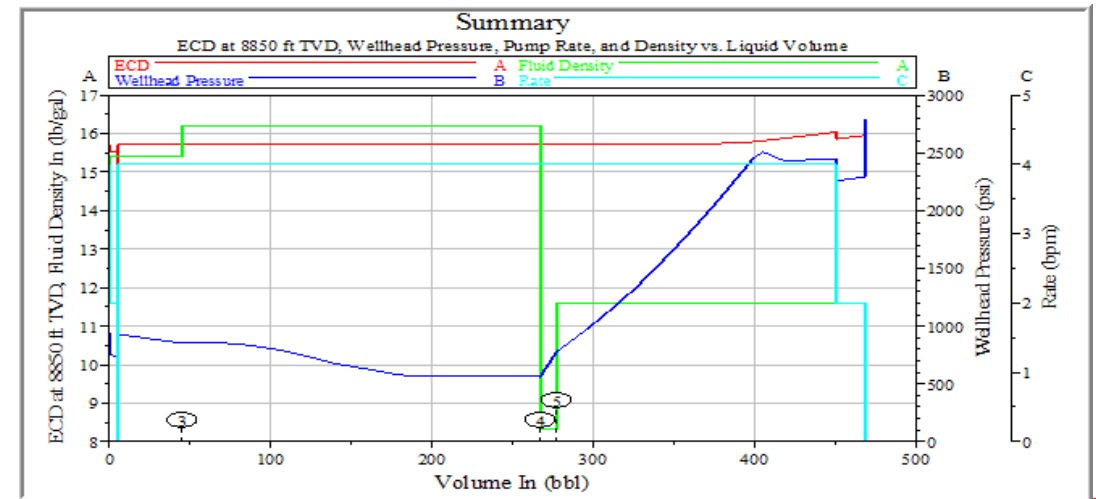
Design Considerations:

- Zero free water
- Fluid loss below 150 cc
- Adequate turbulent spacer
- Expander
- Gas Stop



Example Tests:

- Lab tests are performed on new slurry design to ensure they perform as designed - Example test.



Thank You.

Well Planning and Construction Techniques

Carolyn S. Debrick, PE

Devon Energy

The statements made during the workshop do not represent the views or opinions of EPA. The claims made by participants have not been verified or endorsed by EPA.

This paper will focus on the well planning and construction techniques Devon uses in the Haynesville Shale. It will briefly cover issues that are related to designing and drilling the well safely and protecting subsurface drinking water sources. The goal as a Devon drilling engineer is to design the well for the maximum volume of fluids and pressure to be encountered while drilling as well as for the entire life of the well, and to do so in an environmentally safe manner.

Background

The Haynesville Shale is located in East Texas and North Louisiana. This paper will focus on Devon's well design and construction in the East Texas Haynesville Shale. This paper discusses an area covering six counties in East Texas. The depth of the shale varies from 10,500 ft to 13,500 ft. Pore pressure varies from an equivalent mud weight (EMW) of 15 pounds per gallon (ppg) to 18 ppg. Bottom hole temperatures range from 270 degrees F to 350 degrees F. Measured well depths range from 15,000 ft to 20,000 ft.

General Data Gathering

Before the well can be designed various data needs to be gathered and interpreted. The data gathered is as follows: pore pressure, fracture pressure, fresh water zones, temperature gradients, squeezing or unstable formations, depleted zones, disposal zones, sensitive shales, shallow gas hazards, presence of H₂S or CO₂, geologic targets, well interference data, minimum hole size required, production casing size required, completion design and fluids, topographic surface restrictions, and regulatory requirements.

General Well Design

The pore pressure and fracture gradient chart with the geological data is the basis for the entire well design. This determines how many casing seats will be required and consequently what diameter casing size is set at surface. The information is displayed in terms of EMW. The geological cross section is also included as some formations have higher or lower shoe strengths. There are empirical methods of determining pore pressure from logs and seismic data but the best information is from offset wells. Information on reservoir depletion due to production is also gathered and an estimated bottom hole pressure due to hydrocarbon withdrawal is determined. In East Texas, disposal wells that inject fluids may have higher than normal pore pressures. Information from the disposal well operators is gathered, and subsequently, a fracture gradient chart is created. Fracture gradient is a function of overburden and pore pressure but varies depending on the age of the rock and the in-situ stresses.

Equations generated over the years by industry experts can be used but actual offset leak off test data from the surrounding area is best.

For the Texas Haynesville Shale, Devon Energy uses more than three different well designs depending on where geographically the well is drilled. In Panola County, there is a high density of producing wells and some formations are depleted to an EMW of 2 ppg. In addition there are disposal zones that are charged above normal pressures. These factors impact the number of casing strings required to drill the well and the surface casing setting depth.

Directional Plan: Anti-Collision

Part of the early well planning process is to assess possible hazards such as potential collisions with existing well bores. Devon Energy looks at all offset wells including producing wells, abandoned wells, disposal wells, and any water wells.

Often Devon drills multiple wells off an existing pad or platform. In this case, survey data from each existing well to compare to the well that is being planned.

There are various surveying tools used to measure and determine the path of a well bore. Each of these tools has a degree of inaccuracy. This inaccuracy varies depending on the type of tool, (i.e. gyro vs single shot or magnetic). This uncertainty is translated into an ellipse referred to as “the ellipse of uncertainty”. It is assumed that the actual well bore can lie anywhere within the ellipse. The size of the ellipse of uncertainty depends on the type of tool run. Each type of tool has been assigned an “error factor” by experts that help determine the size of the ellipse. The anti-collision calculations take into account this “error” and adjust the ellipses accordingly. We can then examine the survey data combined with ellipses of uncertainty to assess any possible risk of collision.

Vertical wells can be legally surveyed using rudimentary angle only devices. While these basic surveys satisfy the legal requirements for surveying, they do not provide adequate information to track the well bore for anti collision purposes. If a well does not have adequate survey data we will survey the well bore in question to gather the necessary data to run anti collision calculations.

Drinking Water Source Identification and Surface Casing Setting Depth

In Texas, the Texas Commission for Environmental Quality (TCEQ) maintains data on drinking water protection zones and water wells. TCEQ defines the location of the base of underground source of drinking water (USDW) and identify water source wells within one-quarter mile. The USDW in East Texas is typically at the base of the Wilcox formation. This depth can be as shallow as 250 ft or as deep as 1650 ft or more. Surface casing is to be set within 200 ft below these zones.

Devon not only considers the depth of drinkable water when determining surface casing setting depth but also considers what maximum pressure that can be held at the surface in a well control event and not break down the shoe. This pressure is referred to as maximum

anticipated surface pressure (MASP). With shallow shoe depths this pressure is very low (see Table 1 below).

Table 1.

Shoe Depth (feet below surface)	Fracture Equivalent Mud Weight (lb/gal, or ppg)	Planned Mud Weight (lb/gal, or ppg)	Maximum Anticipated Surface Pressure (lb/in ² or psi)
600	11.5	10	47
1000	12.5	10	130
1500	13.5	10	234

In Panola County, the depth of the base of the Wilcox is between 250 ft to 350 ft. Based on these depths and TCEQ requirements the surface casing would be set 450 to 550 ft below ground surface respectively. Devon requests an exception to set surface casing deeper for safety considerations. Devon sets surface casing shoes in East Texas deeper than prescribed by the regulator for two reasons: 1) to provide additional USDW's protection; and 2) to provide sufficient kick tolerance for drilling ahead.

Casing Design Considerations

The goal of the casing design is to provide a safe and reliable design. The design depends on the loads that may occur. Major design considerations are drilling loads, casing running loads, fracture stimulation loads, connection selection, buckling, corrosion issues, temperature related issues, and compressive loads on surface. Any part of the casing that is not cemented is subjected to dynamic well conditions and casing movement due to temperature, pressure, and fluid gradient changes. The selection of the top of cement is based on these considerations.

Connection selection is critical. Most casing failures occur in the connection. Bending, compression, tensile, and fatigue life when rotated are considered.

For surface casing the connection needs to also be able to support the weight of all the casing strings and the applied loads associated with the well life. If the compressive loads exceed the safe rating of the connection, a base plate is installed on the surface casing head.

Cementing Surface Casing

Obtaining a good primary cement job is critical to Devon. Remedial cement jobs are costly and typically do not provide the same level of isolation. In East Texas we utilize Class A cement for surface casing. This cement can develop compressive strengths at lower temperatures. Typically 300 ft of 15.0 ppg neat cement with no fillers is placed on bottom and followed by a lighter weight 12.6 ppg cement with extenders and accelerators to achieve minimum compressive strength before drill out. The hydrostatic density of the cement column when the cement is in its fluid state must not exceed the formation fracture strength. Casing is centralized with bow type centralizers -- one every joint for first 4 joints and one every third to surface. Haynesville field practices to ensure a good cement job include: conditioning mud

before tripping to run casing, running a spacer before the cement, and moving pipe while cementing. Cement is circulated to surface on all these jobs or a top out job is conducted.

Once the cement is set and the shoe is drilled out, a formation leak off test or integrity test is conducted. This is to ensure that a good cement job was accomplished and that the shoe and formation at the shoe has sufficient strength to drill to the next casing seat.

In addition, due to the current and potential for future disposal wells in East Texas, we bring cement on the next casing string into the surface casing shoe if the formations in the open hole can hold the hydrostatic column of cement.

Casing and Cementing Horizontal Production Casing

Additional design and planning is required for the Haynesville due to the long measured depth of the well, the close tolerances of casing to hole diameter, and the high mud weights. Devon runs a tapered 5.5" by 4.5" casing string in 6-3/4" hole and the typical mud weight at total depth is 15 to 16 ppg. In terms of cementing, the same field practices apply here as with surface casing. However, mud and cement rheology are critical in this situation. Prior to pulling out of the hole to run casing a good practice is to condition the mud to as low plastic viscosity and yield point as possible. Surge and swab is run to determine the casing running speed. Calculations are also made on the cement job with the cement and mud rheologies to determine the maximum pump rate which is usually low. We add rheology improving products in the cement as well as expander and strength retrogression products. However we still can lose returns while running casing in the hole or cementing. If there is risk that cement will not reach inside the intermediate we run a swell packer just above the intermediate casing shoe. This packer will swell to the casing internal diameter in a maximum of 2 weeks.

This swell packer provides isolation between the two casings. The fracture treatment pressures for the Haynesville Shale can be as high as 13,000 psi. Back pressure is held on the casing when possible for safety reasons during the fracture treatment job. In addition the swell packer provides isolation from any gas in the open hole.

Cementing Intermediate Casing

Typically the intermediate casing string has pay zones behind pipe. When possible we bring cement inside the surface casing shoe. If this is not possible we run a cement bond log prior to perforating and stimulating any zone in this casing string.