Chapter 5

# HORIZONTAL DRILLING

# Chapter 5

How much money am I about to put on the table for a horizontal well?

Did I do sufficient planning?

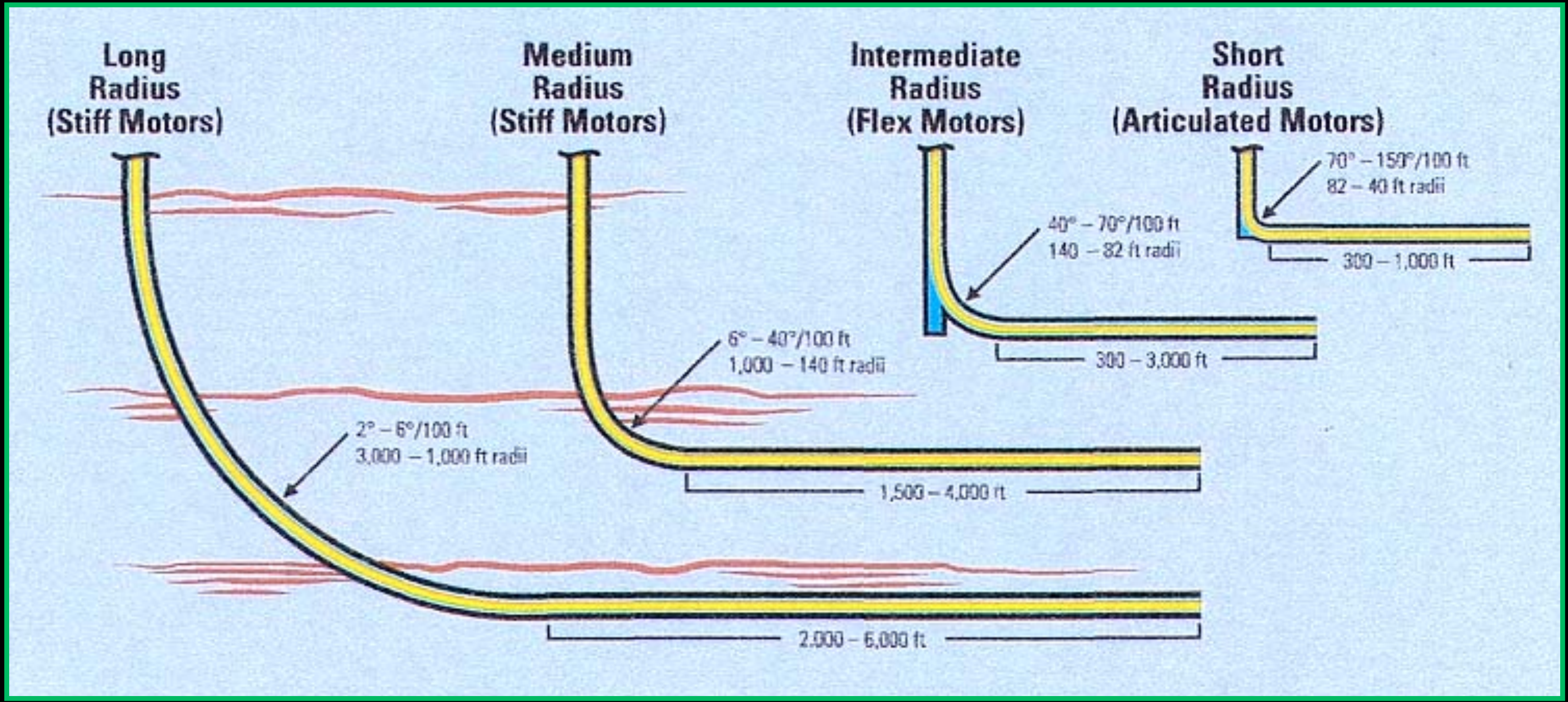
# Keys to Successful Horizontal Wells

- Multi-disciplined teams working together from the beginning of a project
- Open, honest communication between team members
- Build and develop confidence in simulation models
- Always weigh cost/benefit for each considered scenario

# Determining Build Rates

- Short Radius
- Intermediate Radius
- Medium Radius
- Long Radius

# Build Rates

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# Build Rate Definitions

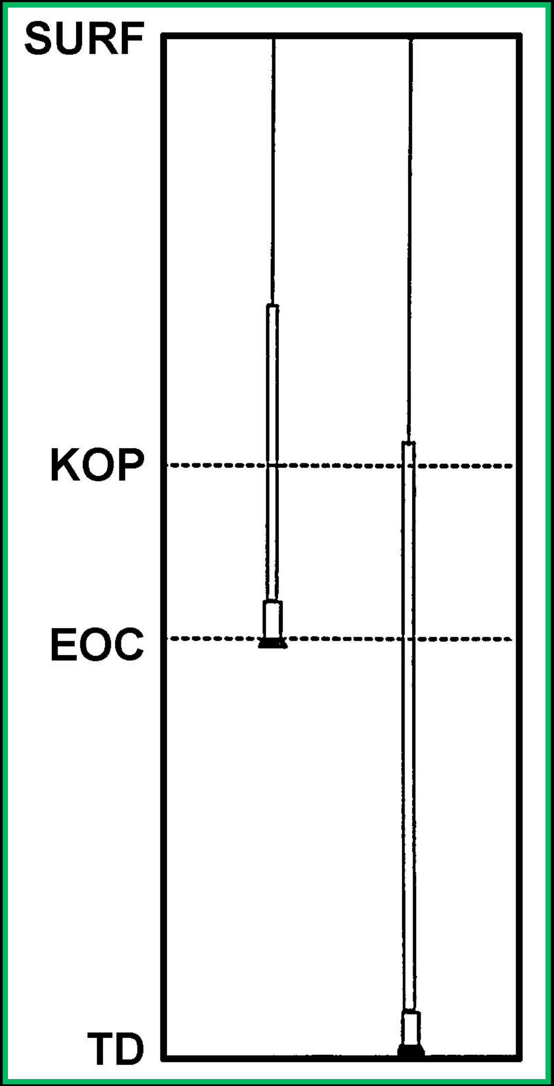
| | Build Rate /100′ | Radius | Lateral Length |
|---|---|---|---|
| Short Radius | 80-350° | 20-80′ | 200-1000′ |
| Intermediate Radius | 25-80° | 80-225′ | 500-2000′ |
| Medium Radius | 8-25° | 225-700′ | 2000-4000′ |
| Long Radius | 2-8° | 700-3000′ | 3000-5000′ |

# Common Questions

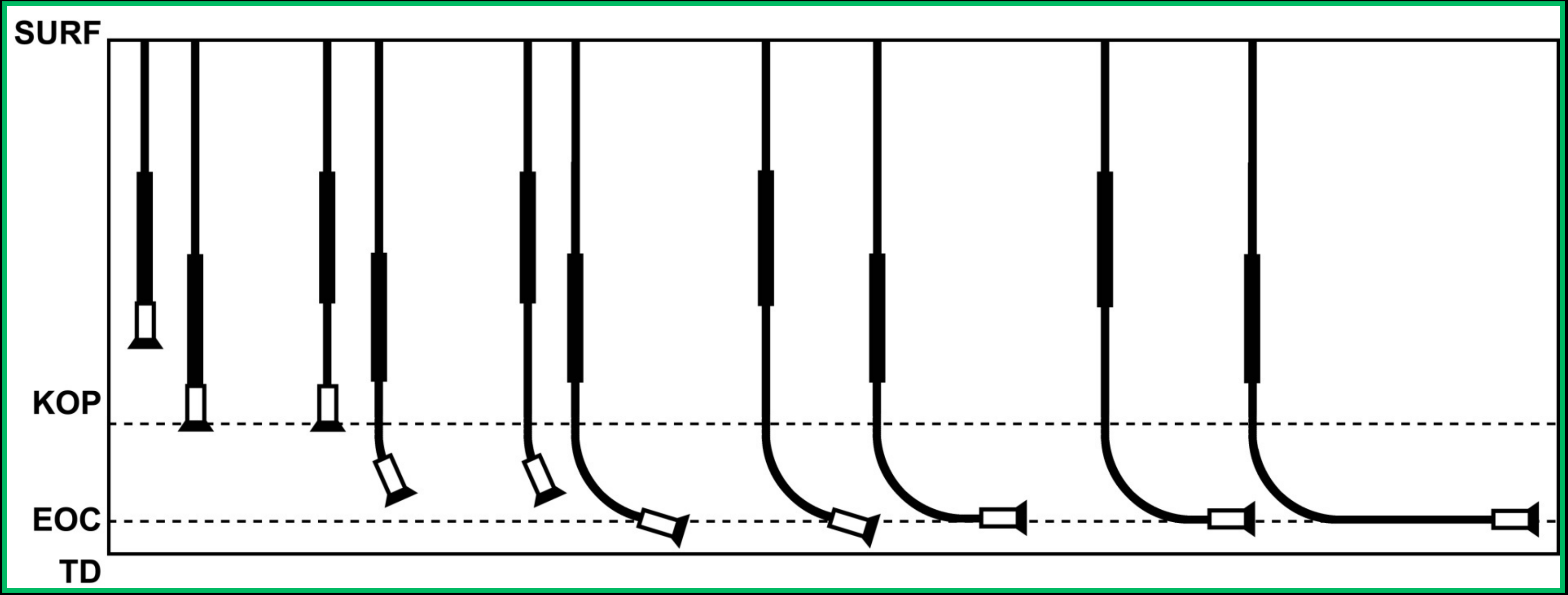
How do you get weight on the bit?

How do you bend the pipe to drill the curve?

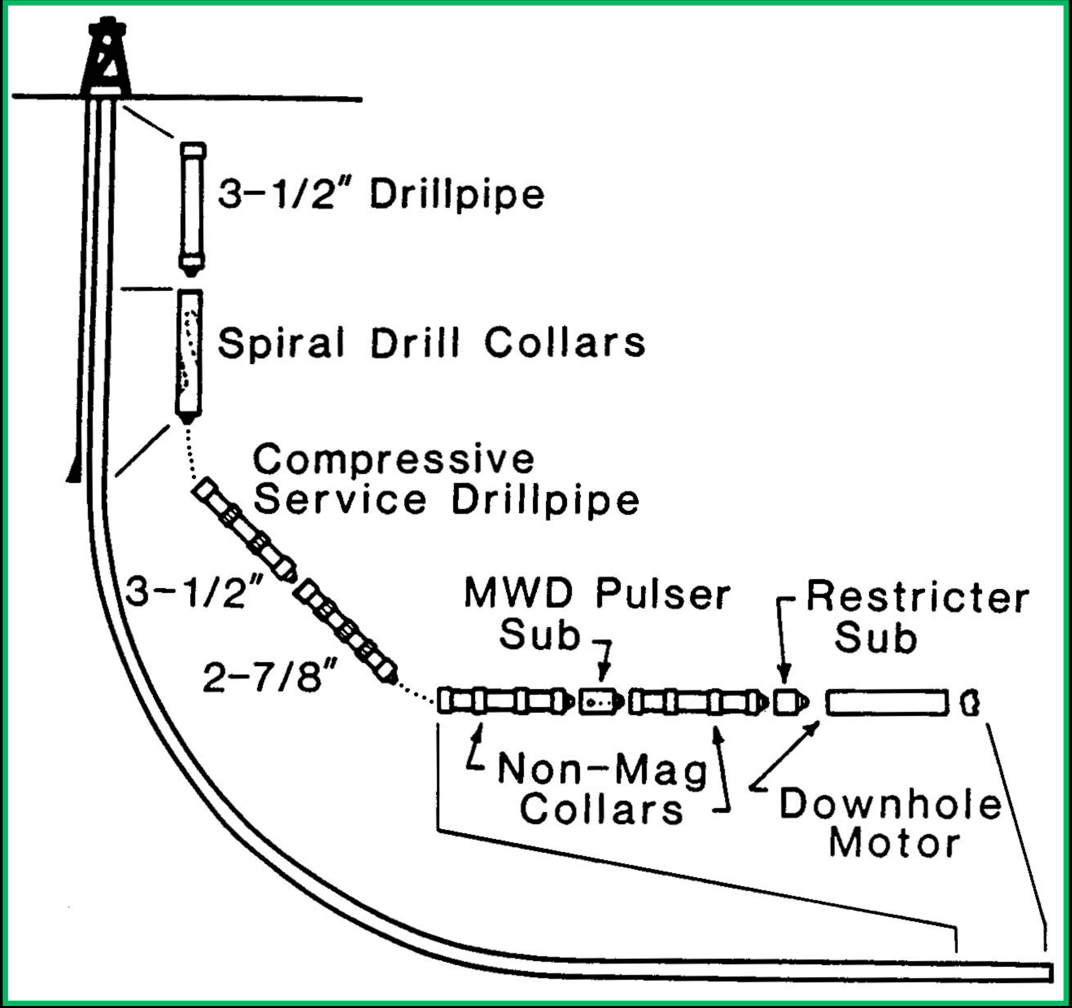
# Vertical Drillstring Strategy



# Horizontal Drillstring Strategy



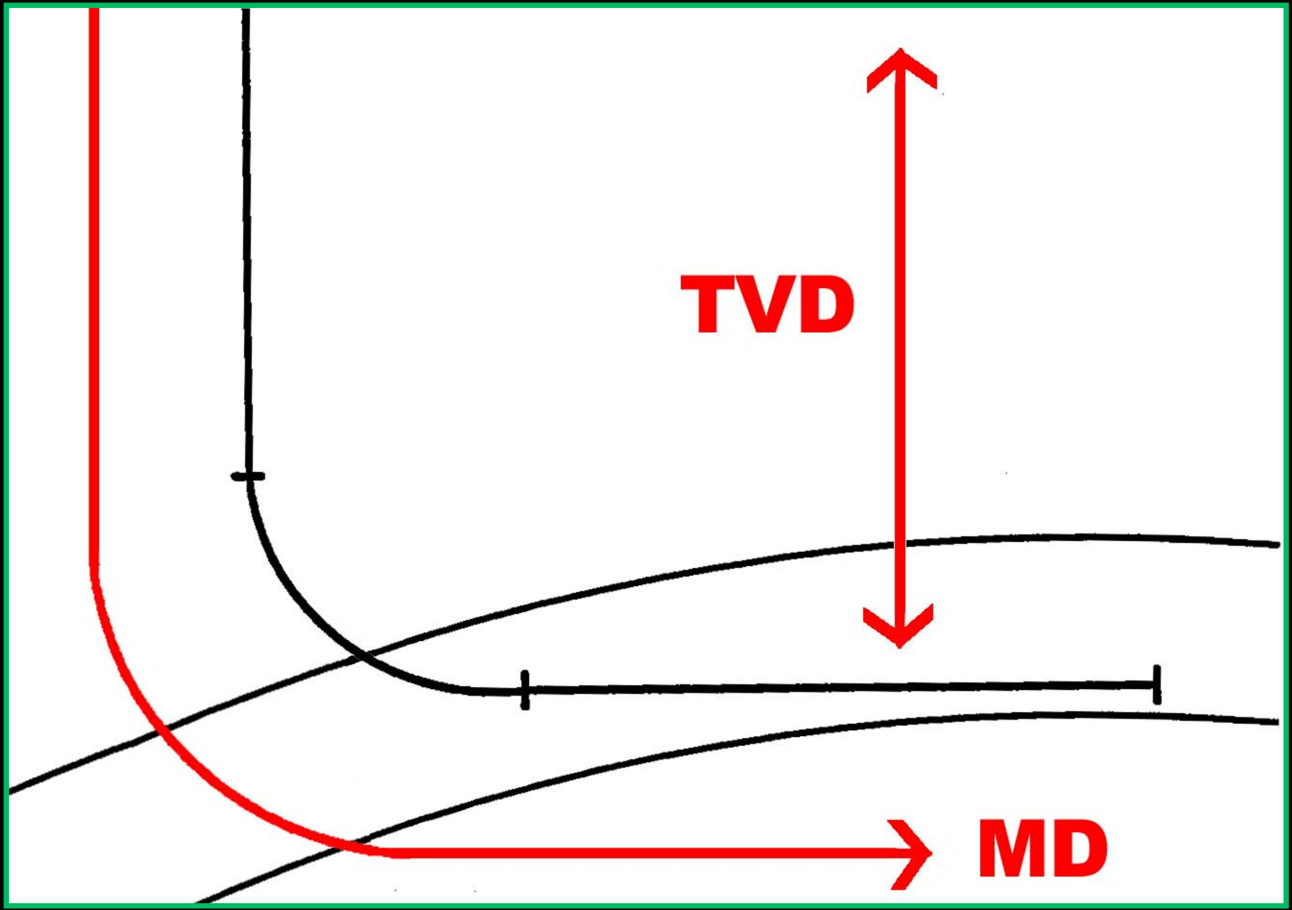
# Drillstring Configuration



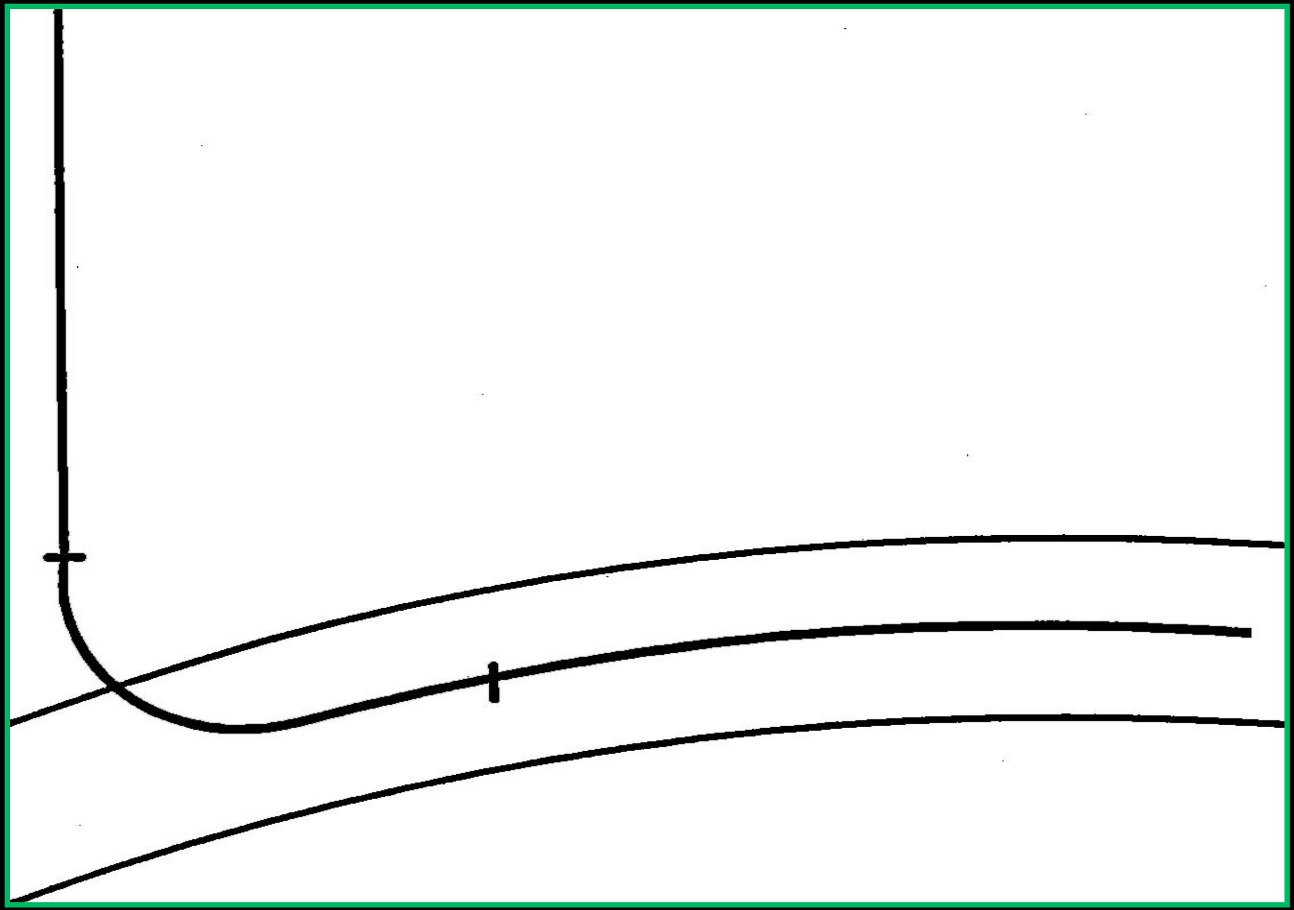
# Horizontal Targets

- Defined True Vertical Depth (TVD)
- Defined Structural Position
- Slant Hole
- Geo-Steering (Snake)

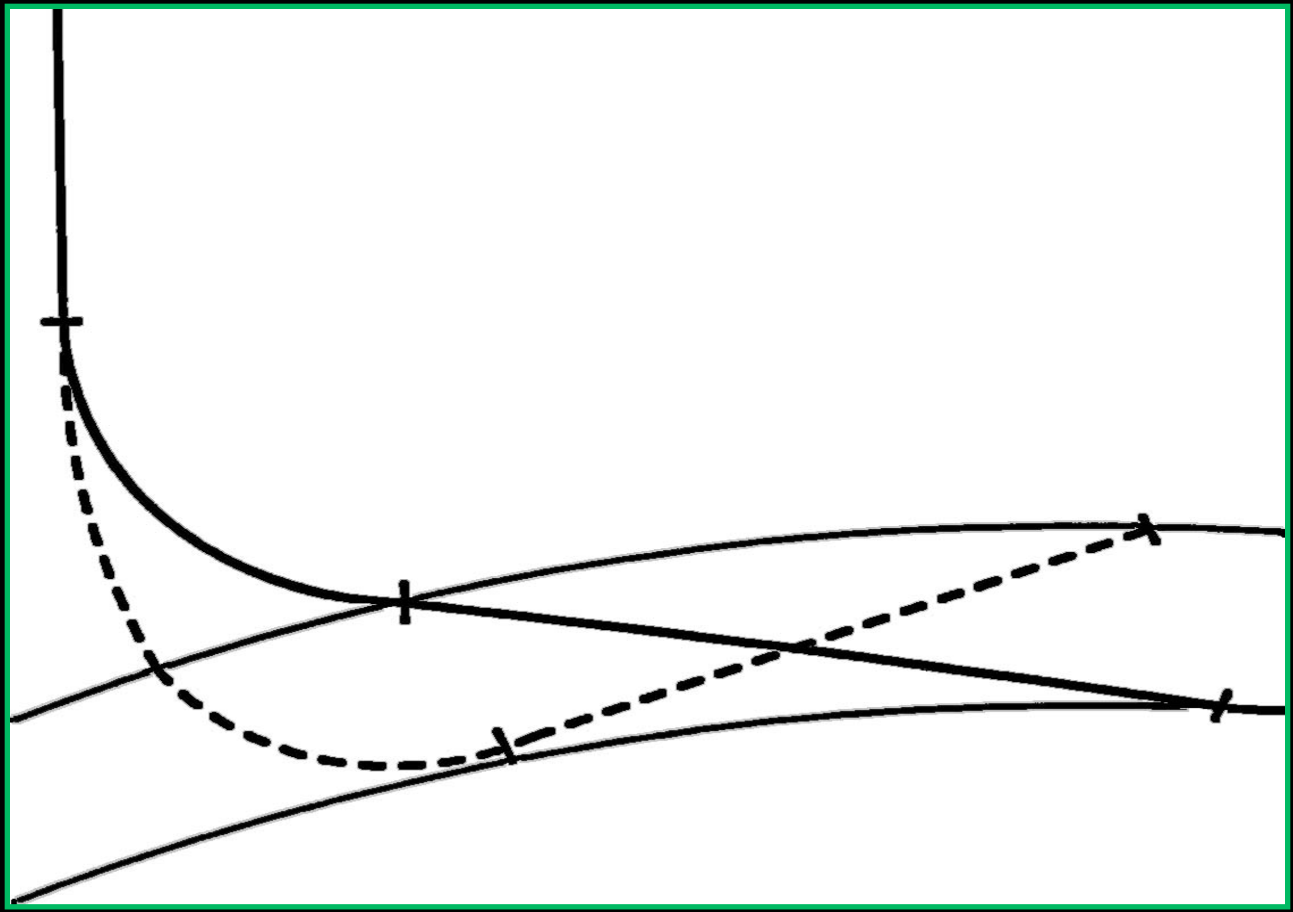
# Defined True Vertical Depth



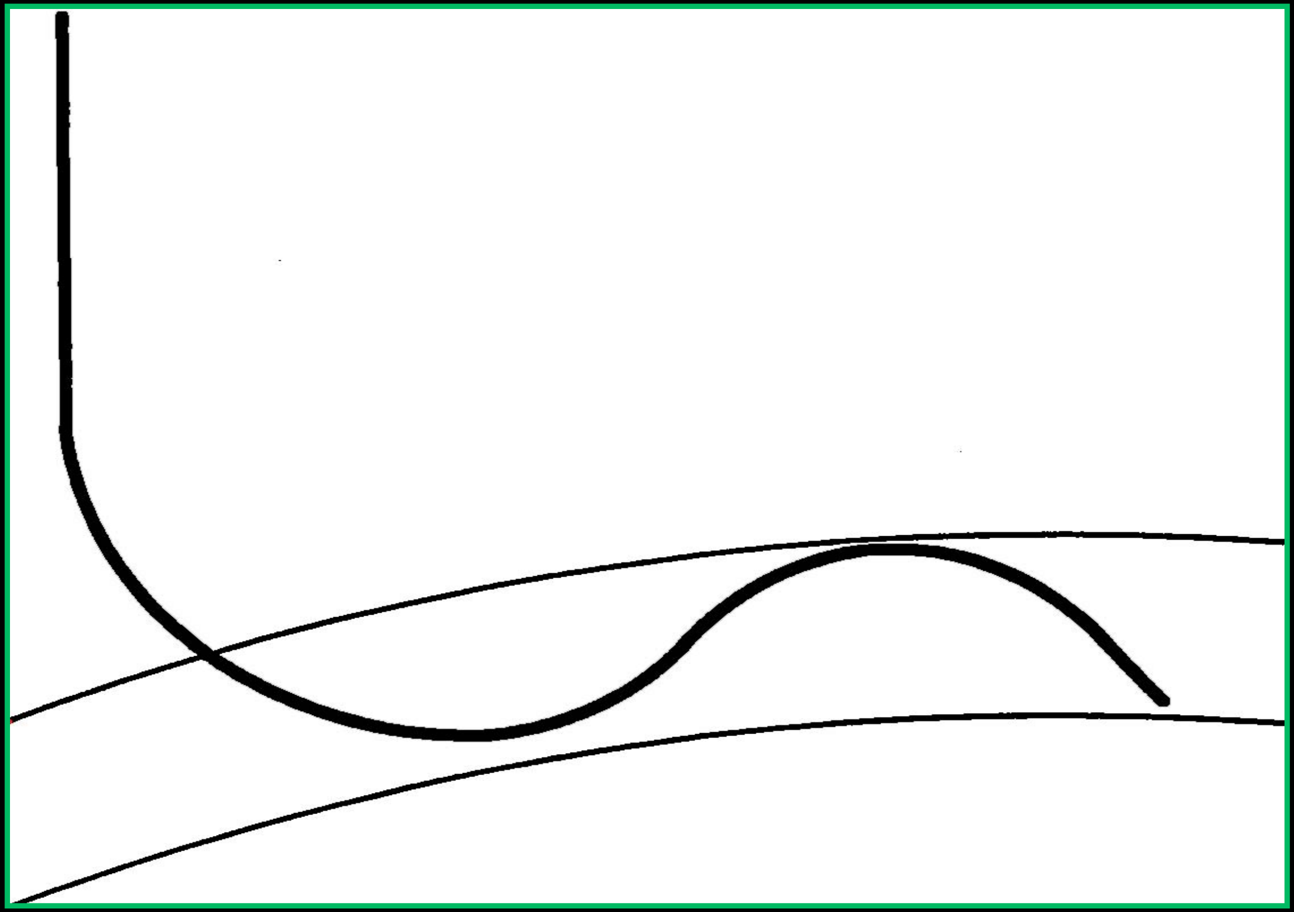
# Defined Structural Position



# Slant Hole



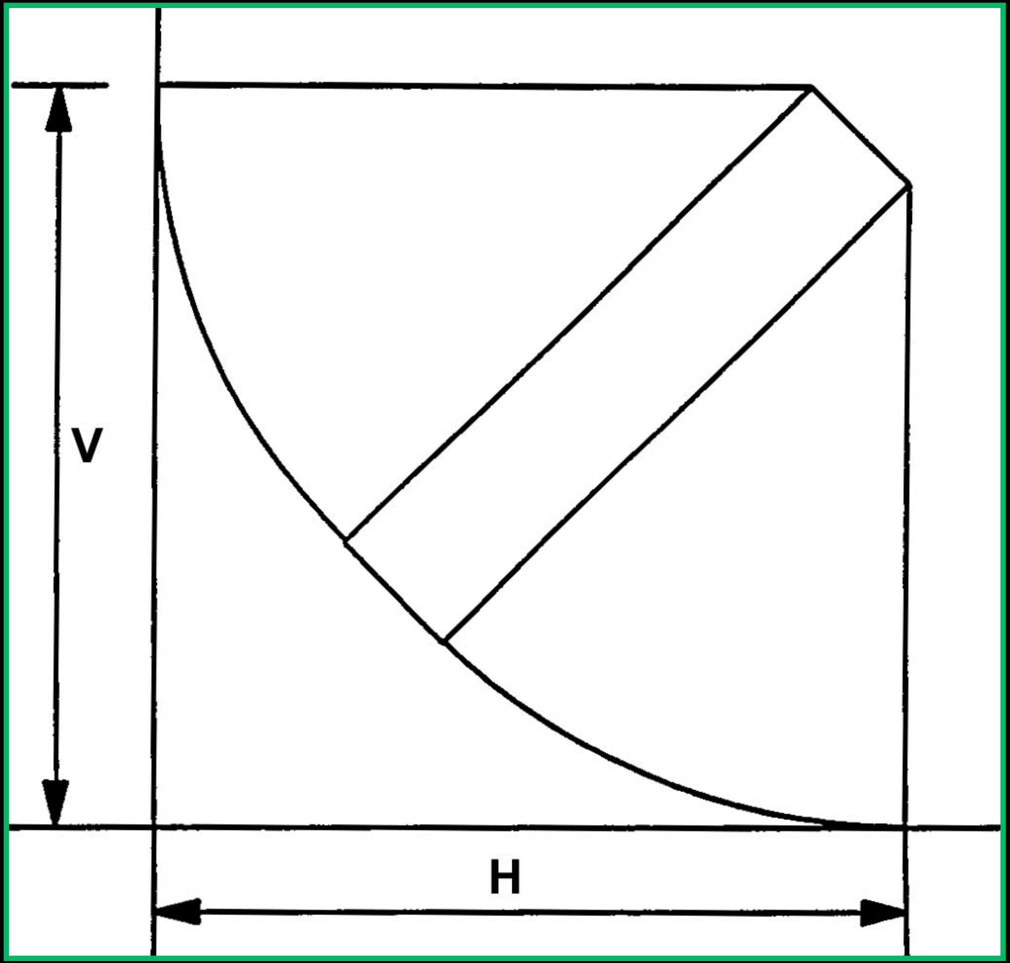
# Geo-Steering (Snake)



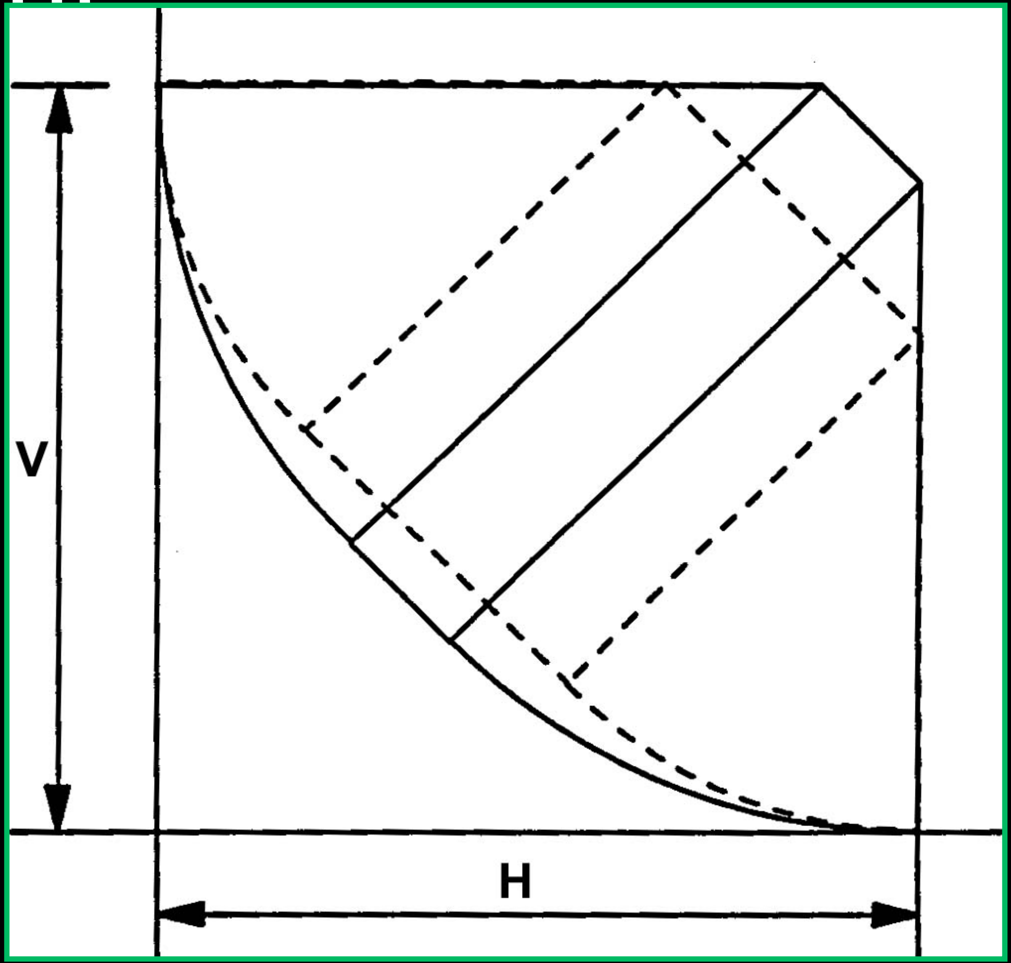
# Adjusting TVD and Target Entry

- Simple Tangent
- Tangent Adjustment – 45º Tangent
- 70º Tangent
- Tangent Adjustment – 70º Tangent

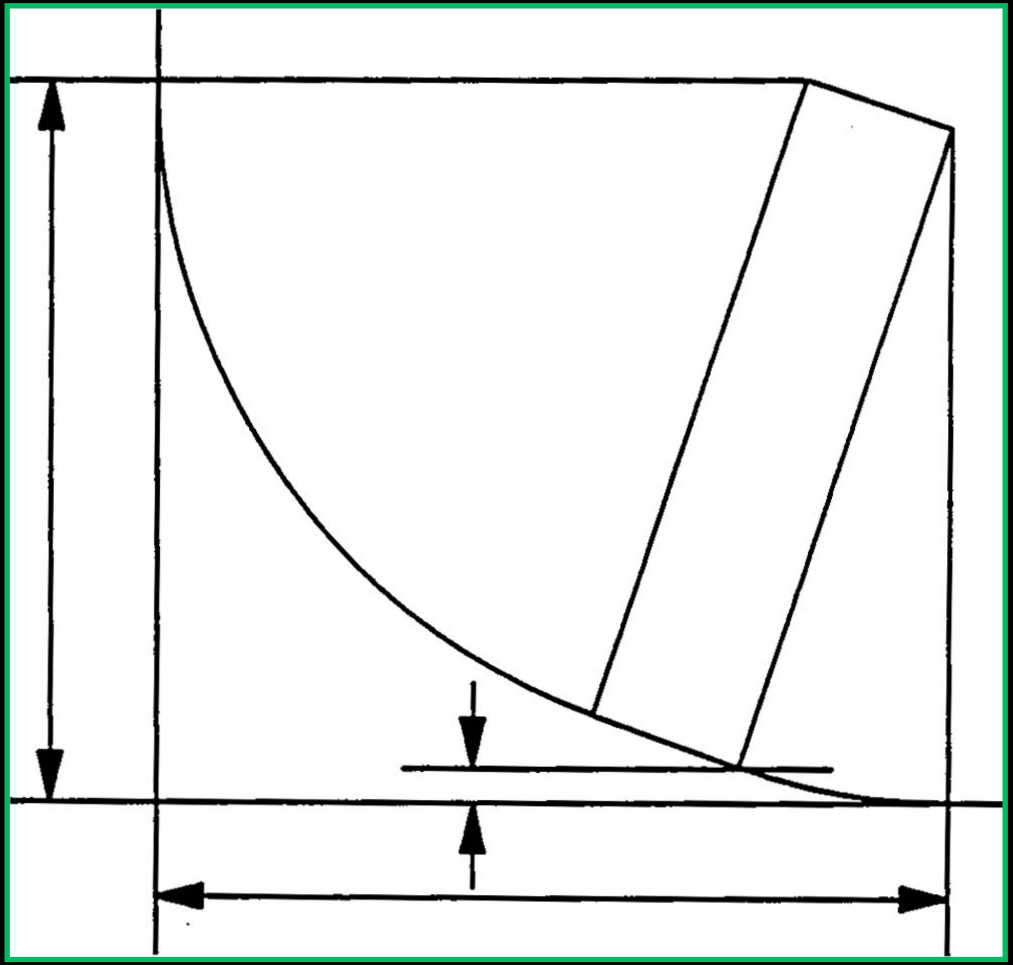
# Simple Tangent



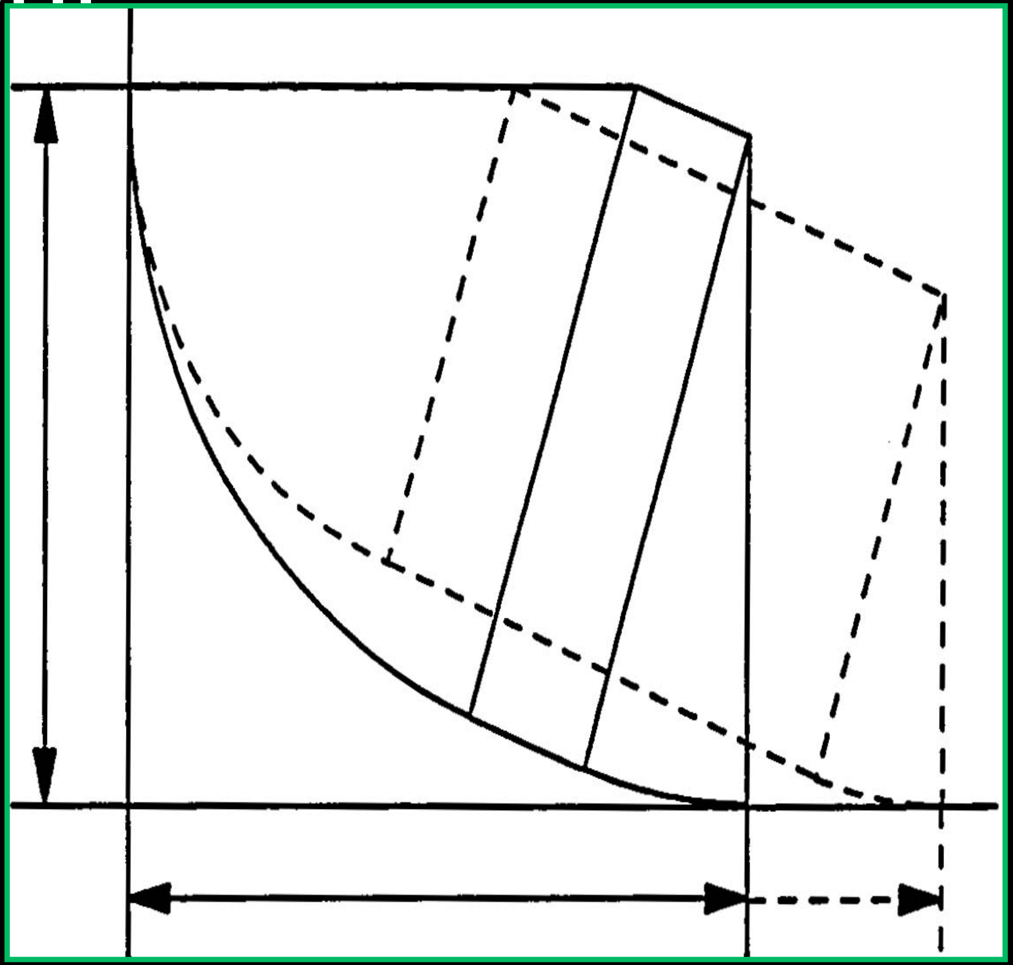
# Tangent Adjustment /45º Tangent



# 70º Tangent



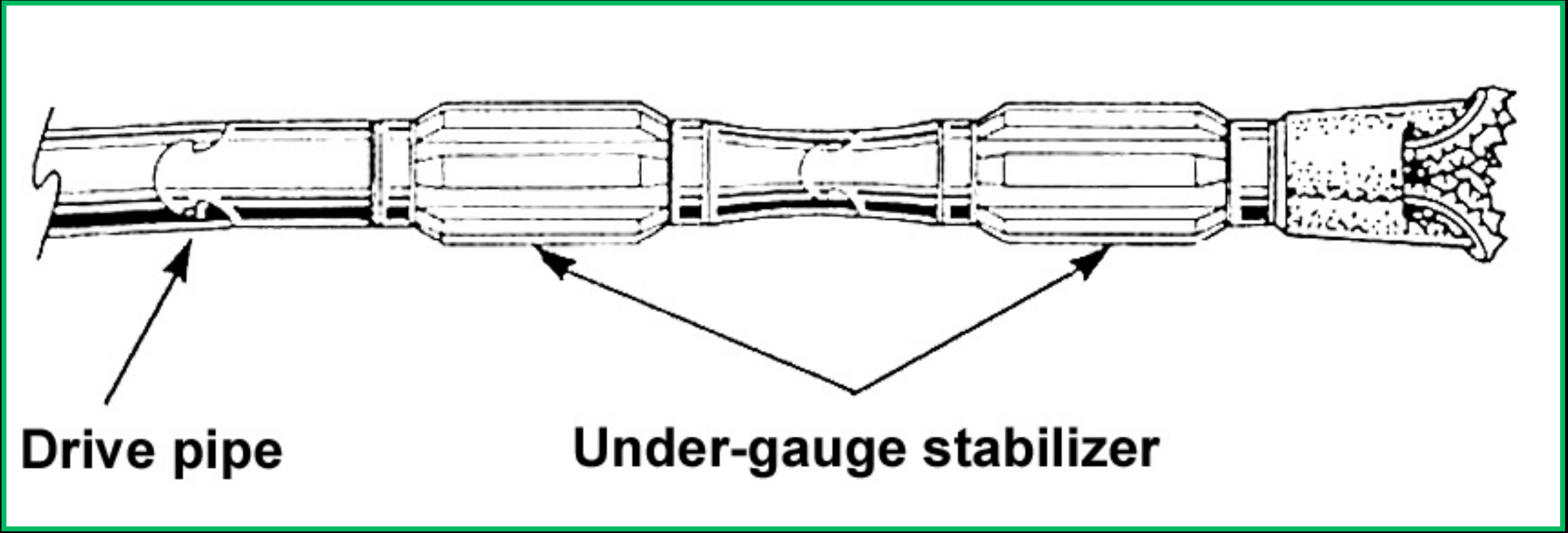
# Tangent Adjustment - 70º Tangent



# Short Radius

- Uses specialized equipment
- Mechanical and motor systems available
- Typically used in sidetracking existing wells
- Bending stress and fatigue can be a problem
- 200’ to 1000’ horizontal section lengths depending upon equipment used

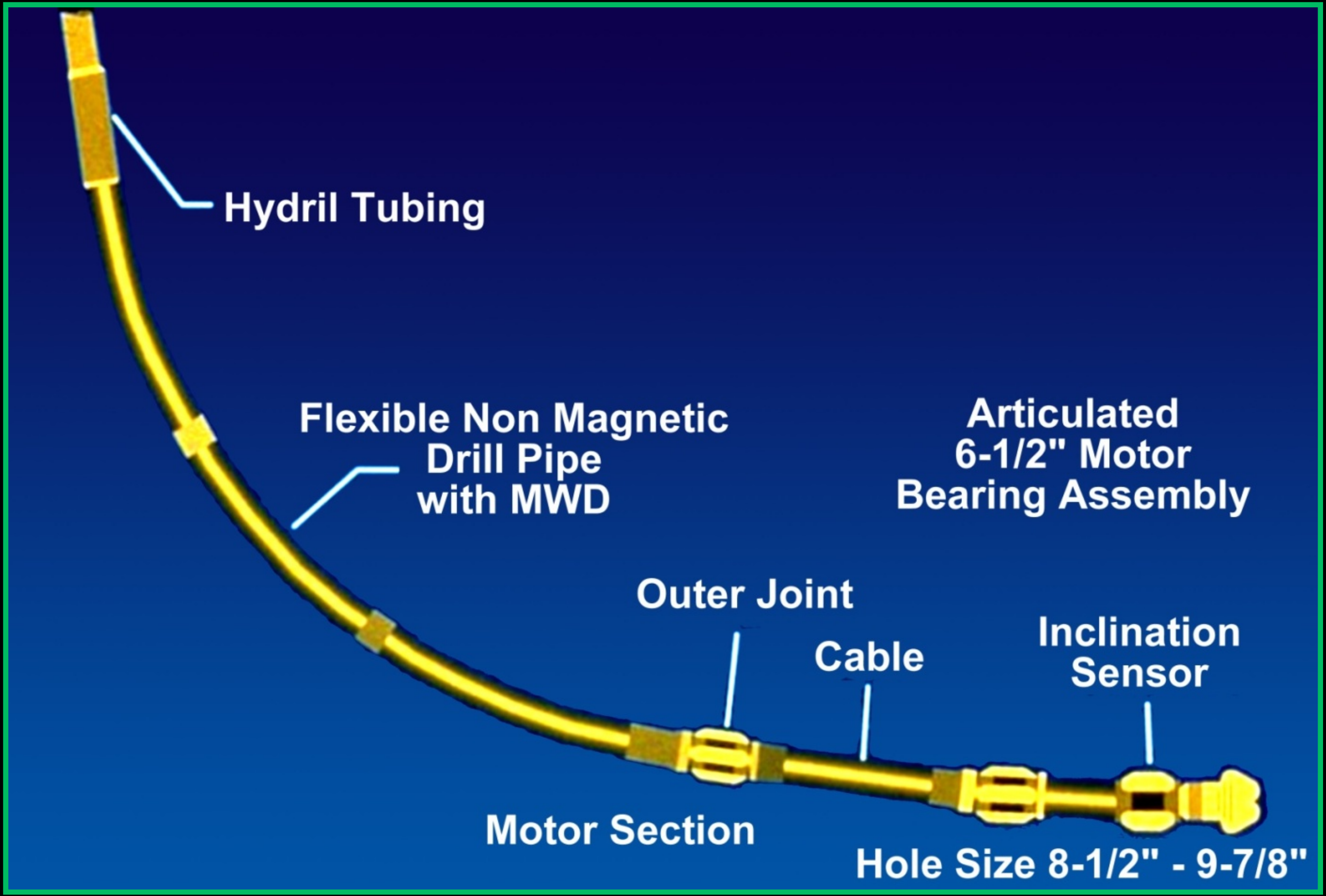
# Short Radius



# Short Radius

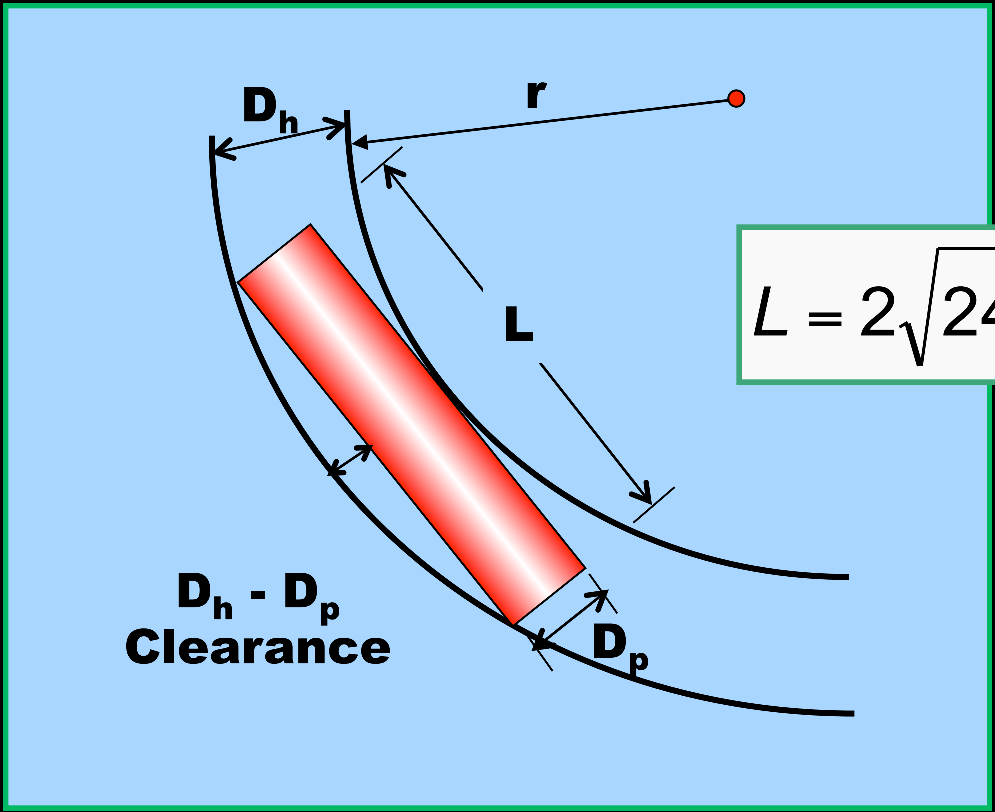
# Short Radius

## Short Radius Articulated Motor



# Short Radius

Not all tools will go through the build curve in short radius drilling




$$L = 2\sqrt{24r\left(D_h - D_p\right) + \left(D_h - D_p\right)^2}$$

# Intermediate Radius

- Uses specialized equipment
- Typically used in sidetracking existing wells
- Bending stress and fatigue can be a problem at higher build rates
- 500’ to 2000’ horizontal lengths depending upon build rates

# Intermediate Radius

In the build section, the pipe cannot be rotated

At the lower end of intermediate radius, the pipe can be rotated while drilling the lateral without causing significant fatigue damage

Smaller diameter pipe can be rotated at higher build rates

# Intermediate Radius

- At the higher end of intermediate radius, pipe rotation should be very limited with smaller diameter tubulars only
- Since the pipe is fatigued, the cost of the pipe is considered as part of the cost of drilling the well
- When the pipe can be rotated in the lateral, the amount of lateral that can be drilled is increased

# Intermediate Radius

Getting completion equipment into the hole may be a problem at the higher build rates but is not a problem at the lower build rates

# Medium Radius

- Uses what is now considered conventional equipment
- Horizontal section lengths have been drilled over 7000' but typically 2000' to 4000'
- No problem with bending stress or completion equipment

# Medium Radius

- Build rate depends upon hole size
- Higher build rates: Smaller hole diameter

**Sperry Sun build rates for medium radius**

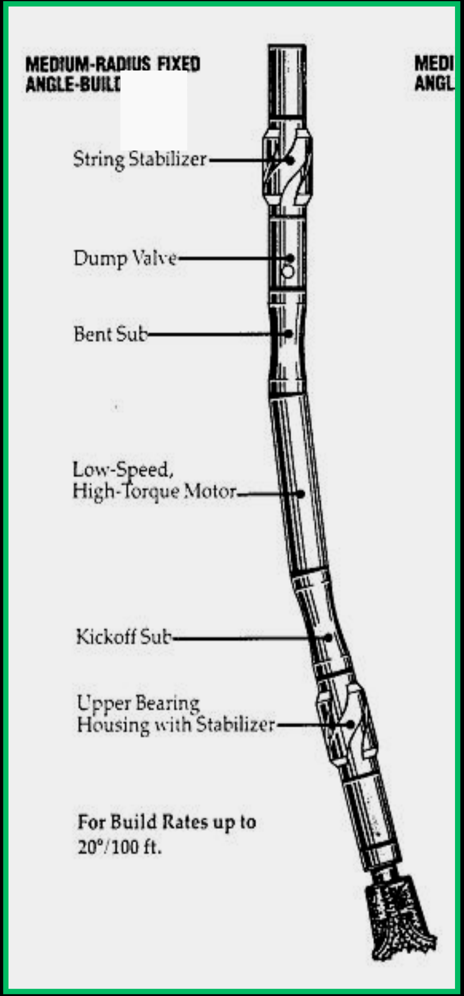
| Hole size (in.) | Build Rate (°/100ft) | Radius (ft) |
|---|---|---|
| 6 to 6 3/4 | 12 to 25 | 478 to 229 |
| 8 1/2 | 10 to 18 | 573 to 318 |
| 12 1/4 | 8 to 14 | 716 to 409 |

# Medium Radius

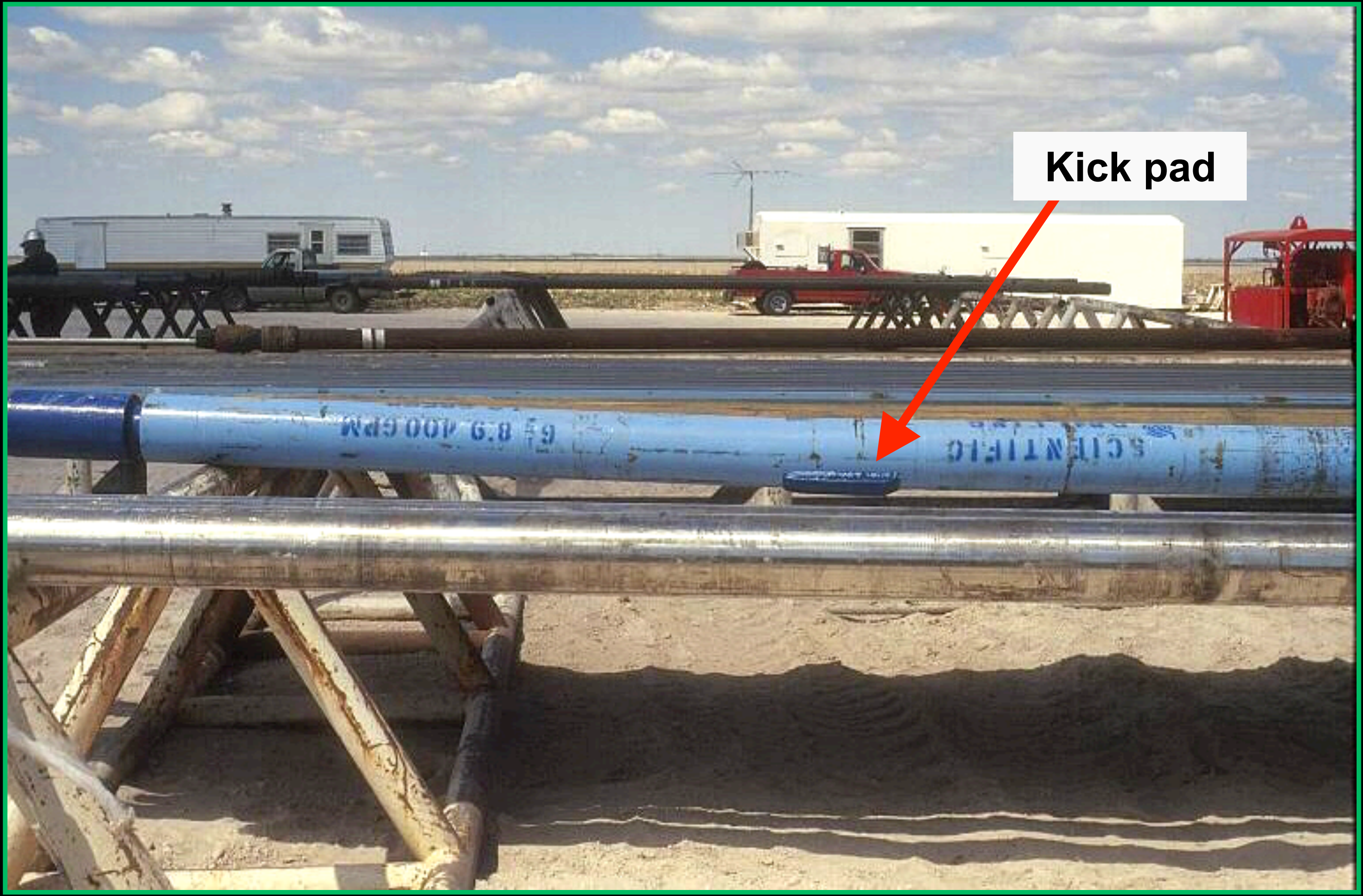
- Minimum pipe rotation in the build section
- Pipe rotation in the lateral section
- Fatigue is a minimal problem

# Medium Radius

- Conventional motor with bent housing
- At the higher build rates, a double bent motor

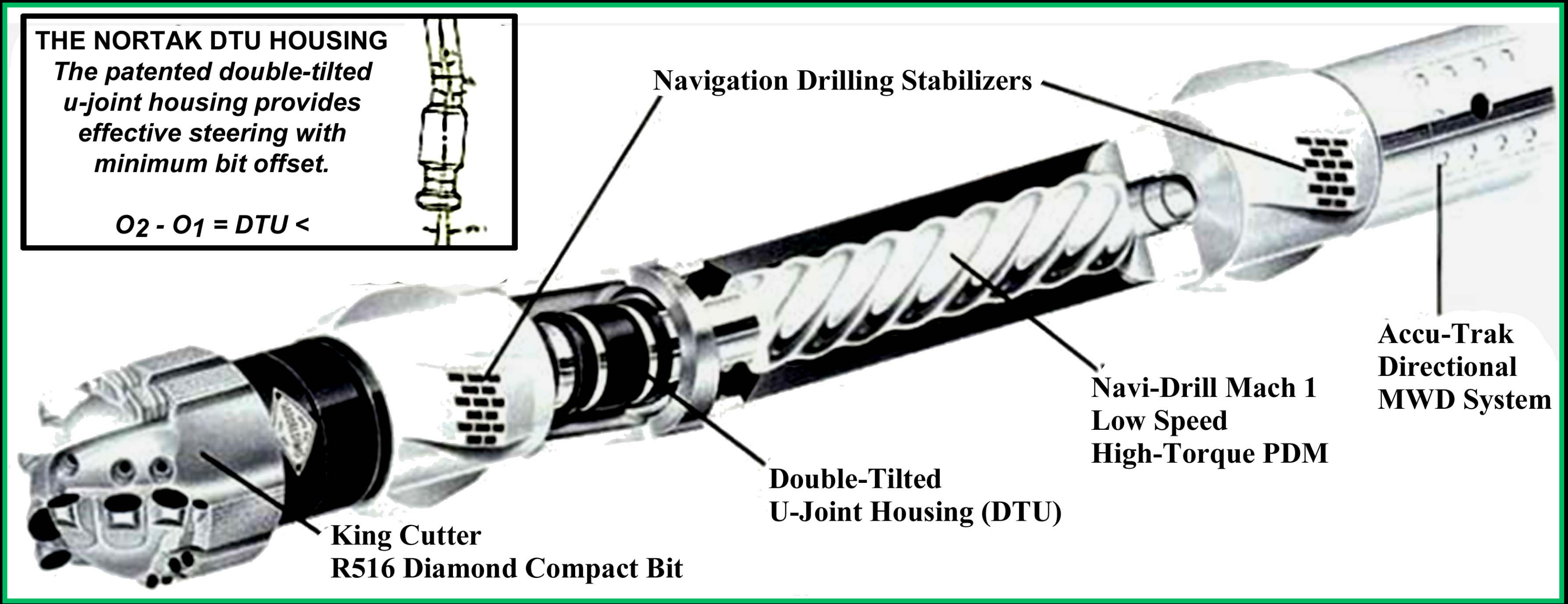


# Medium Radius



# Medium Radius

## Double Bent Motor



# Drilling Techniques

Short Radius

vs.

Medium Radius

# Hole Size

Short Radius

- 3 7/8” to 6 ¼”

Medium Radius

- 4 ½” to 8 ½”

# Tools

Short Radius

- Curve drilling assemblies
- Articulated mud motors

Medium Radius

- Conventional mud motors
- Articulated mud motors
- Smart rotary steerable systems

# Lateral Length

Short Radius
- Up to 1000’

Medium Radius
- Up to 4000’

Both are limited by ability to overcome friction to get weight on bit.

# Logging

Short Radius

- Conveyed open-hole logging suite
- Tool limitations due to bending concerns

Medium Radius

- Possible logging while drilling
- Conveyed open-hole logging suite

# Casing / Liner Size

Short Radius

- Check bending forces with tubular design
- Open hole to 4 ½”

Medium Radius

- Check bending forces with tubular design
- Open hole to 7”

# Cementing Casing / Liner Size

Short Radius
- Need to be specifically designed
- Up to 4 ½”

Medium Radius
- Need to be specifically designed
- Up to 7”

# Limitations

Short Radius

- Drill pipe rotation in open hole limited
- Severe limitations due to bending (fatigue) concerns

Medium Radius

- Drill pipe rotation in open needs monitoring
- Some limitations due to bending (fatigue) concerns

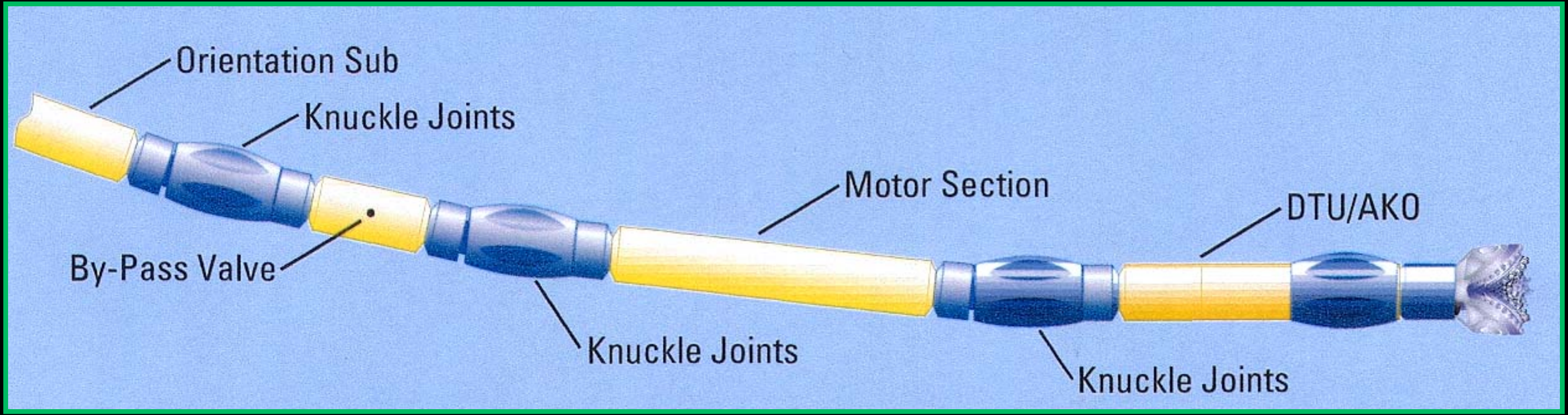
# Short Radius Technique Advantages

- Use existing wells
- Use new wells
- Use smaller rigs
- Reduce environmental impact of rig "footprint"
- Minimizes exposure to problem zones

# Short Radius Technique Advantages

- Minimize casing strings
- Pump in the vertical with low back pressure on reservoir
- Minimize geological surprises
- Multi-lateral possibilities

# Short Radius Drilling Motor

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# Short Radius Curve Drilling Assembly

# Medium Radius Technique Advantages

- Better zone isolation
- Better cementing possibilities
- Longer laterals
- Lower torque requirements

# Rig

- A drilling rig is not required
- Hook loads not very high
- Adequate pumps are important

# Rig Selection Tips

- Crew needs open hole experience
- Adequate hoisting capacity and mast height
- Good mud pumps and mud cleaning system
- Handling tools for all tools and tubulars

# Rig Selection Tips

- Kelly or adequate power swivel
- Good working area on rig floor
- Appropriate well control equipment
- Working daylight or ‘round the clock
- Sufficient lighting for safe working

# Logistics

- Adequate location size
- Reasonable roads for all-weather access
- The more remote the location, the more back up inventory & lead time you will need

# Orientation

Gyros are needed when working in close proximity to steel casing.

# Tubular Requirements

General:

- High strength N/L-80 or P-105
- Shouldered connections
- Connection to hole clearance for fishing
- Sufficient ID for logging/survey tools

# Tubular Requirements

Grand Directions:

- Composite drill pipe
- Lateral section:
  2 $^{3}/_{8}$" PH-6 N/L 80 work string
- Vertical section:
  2 $^{7}/_{8}$" PH-6 N/L 80 work string

# Drill Bits

- Obtain offset vertical well bit records to determine response in target depth and reservoir
- Vertical and horizontal drill bit performance is different

# Drill Bits

- Solid body bits
- Gauge hole very important for correct curve drilling
- Large nozzle design for minimal pressure drop at bit and good bit cleaning

# Drill Bits

- Cutting size effecting mud logging interpretation
- Generating drilling fines could lead to formation damage
- Direction control and ROP could be affected by fractures

# Drilling Fluid

- Simple
- Good filter cake quality
- Minimize formation damage
- Good clean-up qualities

# Drilling Fluid

Use one mud to drill curve and another fluid to drill lateral to minimize formation damage

- Fresh or salt water based polymers
- Natural to synthetic oil based muds
- Underbalanced
  - Pressure drilling
  - Air/foam
  - Nitrogen/foam

# Where should I use Under Balanced Drilling?

# Reservoir Evaluation Tools

Weatherford created a group to assist for reservoir evaluation related to UBD

**SURE** =

**S**uitable **U**nderbalanced **R**eservoir **E**valuation

# Reservoir Evaluation Tools

Answers questions for operators:

1. Where should I use UBD?
   → screening process
   Reservoir Screening Tool

2. How much will it produce?
   → production forecasting process
   Reservoir Damage Assessment

# UBD Screening Data Inputs

- Reservoir pressure
- Porosity
- Permeability + kv/kh
- Water saturation
- Fluid viscosity
- Depth
- Thickness
- Clay content %
- Fractured – yes/no
- Borehole instability
- Primary producing phase
- Lithology
- Drive mechanism

How much will the well produce?

# RDA – Reservoir Damage Assessment

- Usually operator is comparing conventional well to UBD well
- Need production forecasts to run economics

# RDA – Reservoir Damage Assessment

- Weatherford created the RDA – Reservoir Damage Assessment - process to predict formation damage *before drilling*
- From the estimate of formation damage, can create production forecast for economics

# How much will it cost?

# UBD Additional Costs

Increased day rate according to equipment and personnel

Equipment costs (depending on well):

- Rotating control device
- Air or Nitrogen
- Compression
- Fluids, e.g. foam
- Separation or skimming tank

May need to change casing depths

# UBD Avoided Costs

- Lost circulation
- Stuck pipe
- Drilling days – may get higher ROP
- Stimulation to clean up damage – acid or maybe frac
- Killing well

# UBD Costs

- Usually UBD day rate is more
- Drilling days may be less
- Trouble time may be less
- Added benefit of reservoir characterization
  - May find new zones

But the big prize is acceleration & possibly improved recovery.

# Kick Off Options – Short Radius

New Wells

- Cement Plug Kick Off
- Off Bottom Kick Off

# Cement Plug Kick Off

- Drill vertical through target reservoir
- Perform formation evaluation operations
- Run and cement casing above KOP
- Drill out casing shoe
- Spot balanced cement plug
- Dress off plug to KOP

# Off Bottom Kick Off

- Set and cement casing just above KOP
- Drill out shoe
- Drill to KOP

# Exiting the Casing

Casing Exit Options

- Option 1: Section the Casing

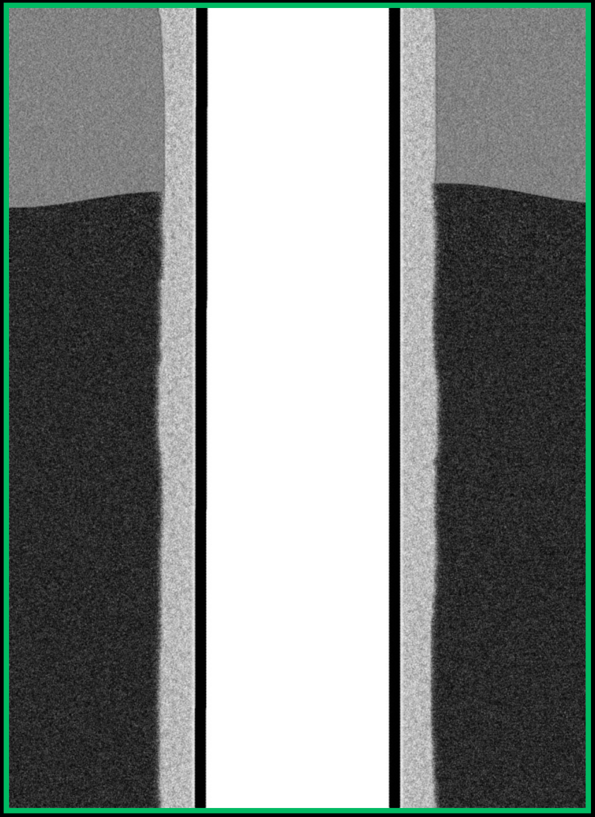
- Option 2: Cut a Window

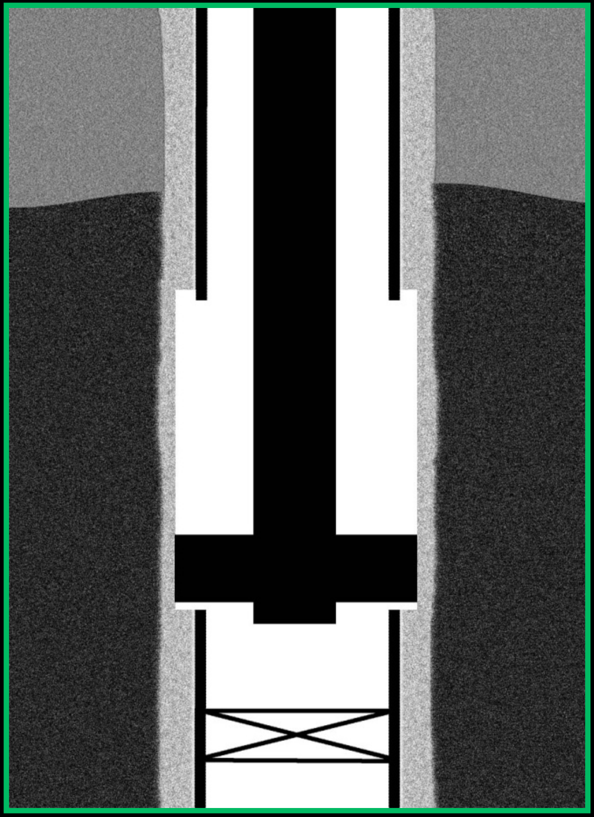
# Casing Exit Option 1

- Mill a section of casing at KOP depth
- Set balanced cement plug across open section
- Dress off plug to KOP
- Drill curve with curve drilling assembly
- Optional:
  - Use whipstock

# Casing Exit Option 1

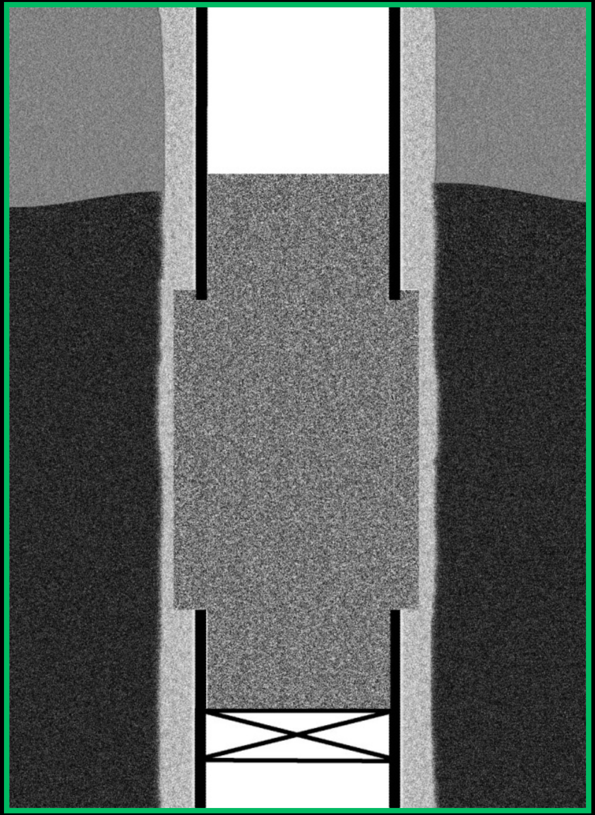
- Mill a section of casing at KOP depth





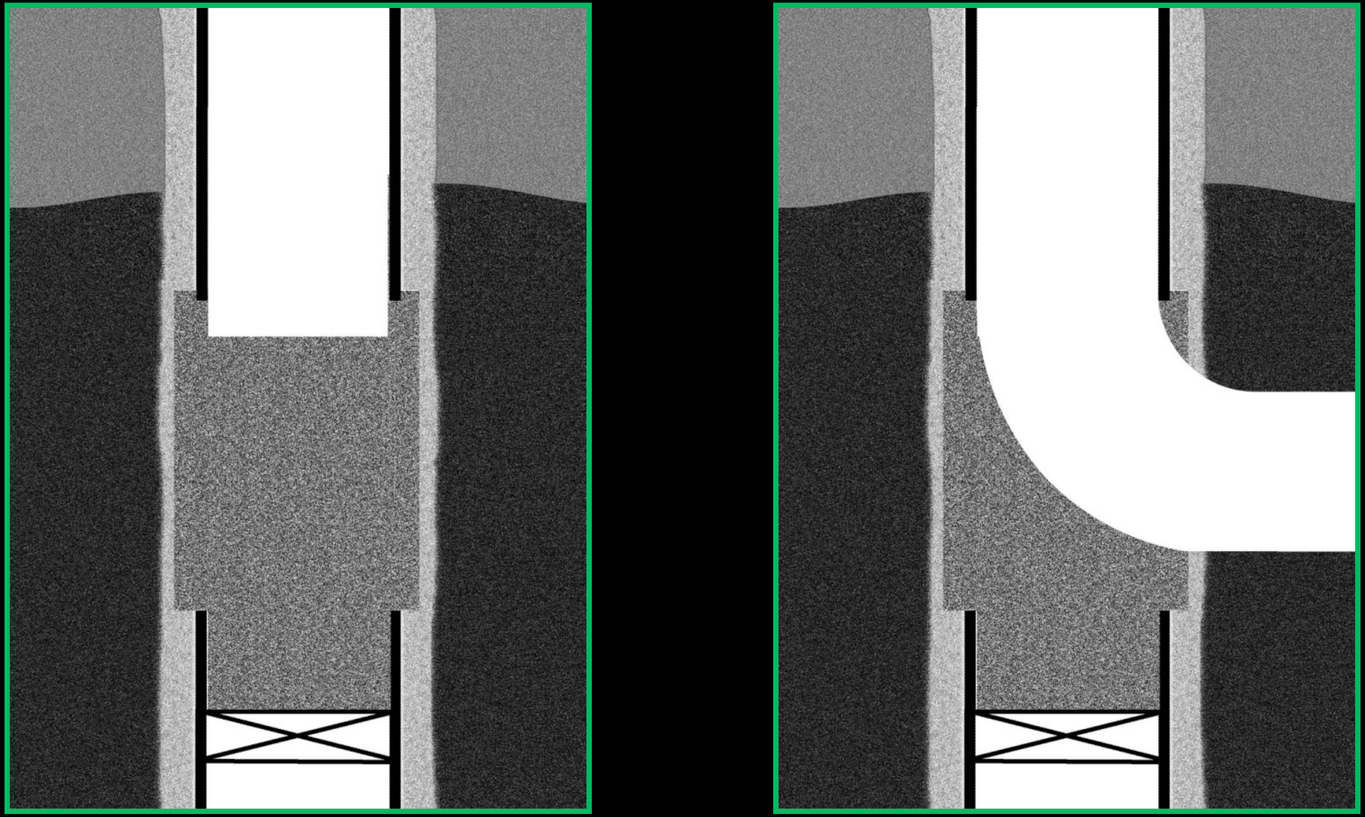
# Casing Exit Option 1

- Set balanced cement plug across open section

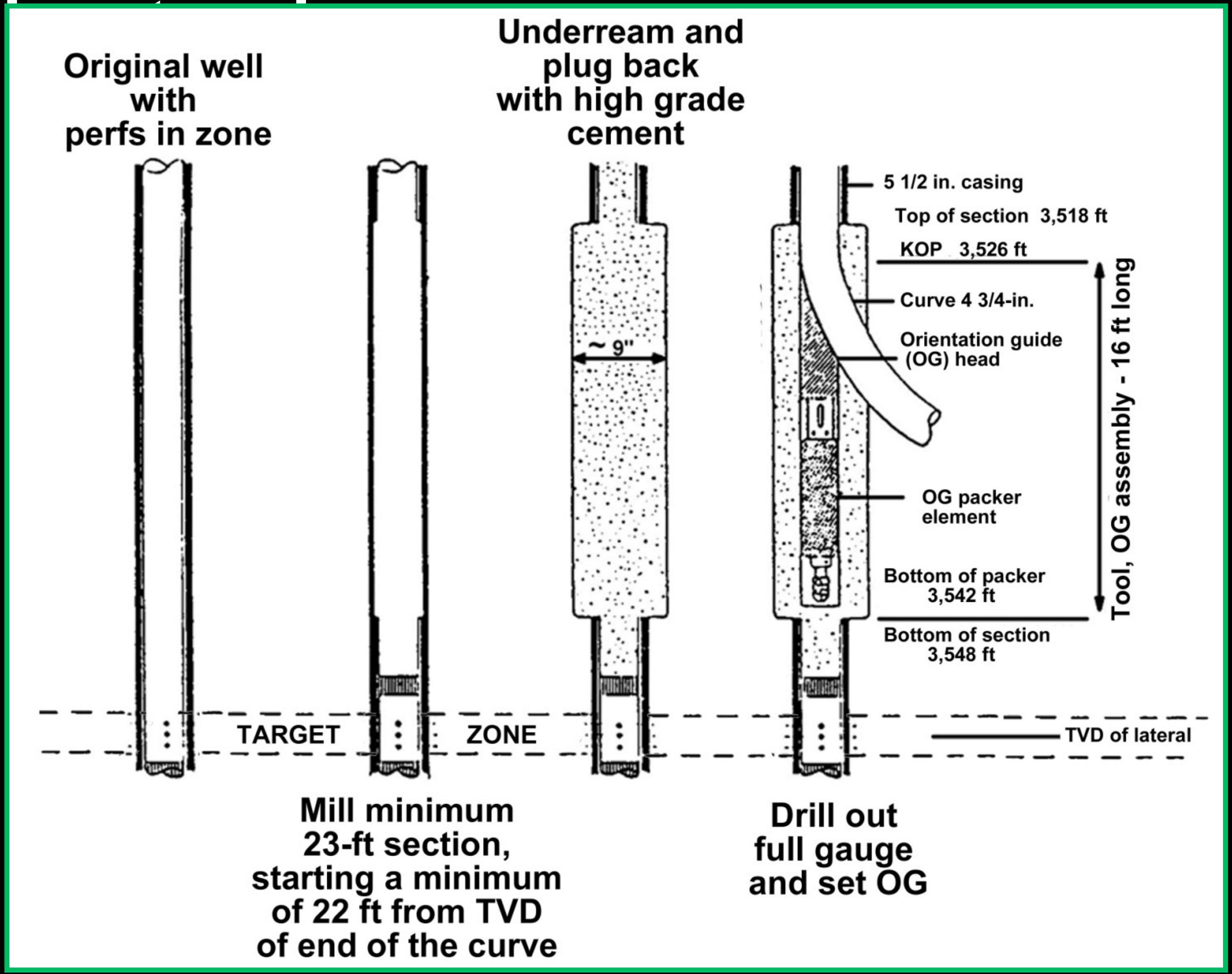


# Casing Exit Option 1

- Dress off plug to KOP
- Drill curve with curve drilling assembly



# Casing Exit Option 1 with Wh




Eastman-Christensen Kickoff Procedure (Mall et al., 1986)

# Casing Exit Option 2

- Use a retrievable or permanent whipstock
- Cut a window out of casing
- Drill curve with curve drilling assembly

# Trackmaster Plus

- Mill the window & drill the lateral in one trip
- Drill several hundred feet of lateral
- PDC cutters deliver durability & performance
- Fully retrievable system

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# Survey Techniques

Real-time directional data

- Wireline with surface readout steering tools
- Side entry subs for sliding, bent subs & mud motors
- Wet-connect tools minimize survey time
- Measure While Drilling (mud pulse)
- Electro-magnetic steering system

Drill and survey (point-and-shoot)

# Potential Problems

- Lost circulation
- Sloughing shales
- Stuck pipe
- Tool parting failure
- Risk of losing hole

# Contingencies

- Plug back & sidetrack curve or lateral
- Plug back to KOP and start over
- Plug back to higher KOP & drill larger radius

# Horizontal Drilling Conclusion

- Know & design for completion requirements
- Choose type of curve
  - Short or medium
- Pay attention to formation damage
  - Mitigation or stimulation
- Pre-spud meeting with team & contractors
- Plan contingencies