Webinars

ISCWSA
Well Intercept Subcommittee

Wellbore Ranging Technologies, Intercept Application and Best Practice

Presented by; Roger B. Goobie, Benny Poedjono, Chad Hanak, Pete Schiermeier

SPE Wellbore Positioning Technical Section

Webinars

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Roger Goobie

Mr. Goobie currently works for BP GWO as an SME and is the Well Placement Technical Specialist for their western hemisphere operations. He has been a member of the SPE for the last 17 years and have authored and presented over a dozen technical papers on a wide variety of Drilling Optimization topics. In 2014 Roger received the SPE North America Gulf Coast Regional Drilling Engineering Award which recognizes and rewards him for aligning himself with the SPE's vision and goals of technology dissemination.

Dr. Hanak spent the first decade of his career at NASA's Johnson Space Center, where he designed guidance and navigation systems for both manned and unmanned spacecraft. Some of his design work includes aerocapture guidance at Titan and Neptune, low thrust trajectory optimization to Mars and Jupiter, crater-based lunar navigation, and autonomous navigation flight software for the Orion manned spacecraft. Chad left NASA in 2011 to go work for Baker Hughes. His work at Baker Hughes and elsewhere includes both active and passive magnetic ranging system developments, among other technologies.

Dr. Chad Hanak

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Mr. Schiermeier is a Global Technical Advisor for Survey Management/Survey/Ranging services with Halliburton. His introduction to the oilfield started in 2007 where he has spent the last 11 years within Sperry Drilling management and operational roles specializing in advanced wellbore placement, magnetic referencing, ranging technology, product development/management and global technical services for engineering solutions.

Mr. Poedjono is a Schlumberger Petro-Technical Expert, an Advisor in Wellbore Positioning, Interception and Relief Well Operations. He started his career with Schlumberger in 1982 as field engineer and has held various positions and has worked in more than 29 countries. His recent areas of expertise are in Geomagnetic Referencing, Advanced Wellbore Positioning, Acoustic Ranging, Collision Avoidance Management, Wellbore Interception, Relief Well Operation, Platform and Pad Design and Robotics for Oil and Gas. He has published more than 50 technical papers and holds many various patents.

Benny Poedjono

Well Intercept eBook (WISC)

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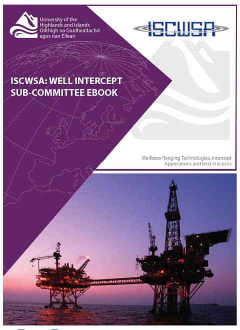

- Completed
  - Wellbore Ranging Technologies Intercept Application and Best Practices
- Ready for Download
  - http://www.iscwsa.net/docs-and-publications
- Current eBook
  - Eight Main Chapters
- Lexicon
  - Updated end 2017
- Bibliography
  - Added publications

Acknowledgements

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Acknowledgements

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This book was compiled by members of the Industry Steering Committee on Wellbore Survey Accuracy (ISCWSA), a Society of Petroleum Engineers (SPE) Technical Section on Wellbore Positioning. The acknowledgement table captures main authors; some who have contributed to more than one chapter and we sincerely thank them for their commitment, contribution and for sharing their knowledge. We also thank Halliburton for allowing us to use their "Customer Guide to Relief Well Ranging" without any copyright violation.

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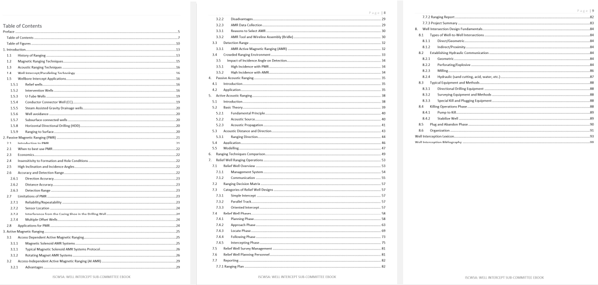

Lexicon and Bibliography

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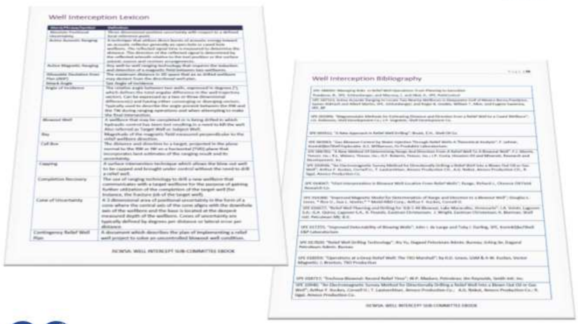

Webcast Outline

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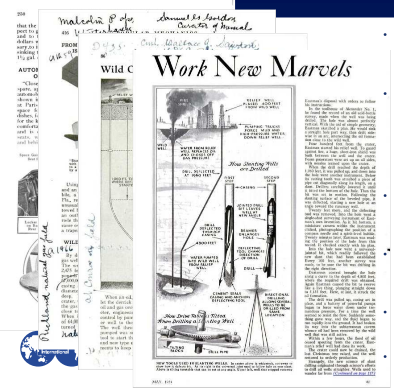
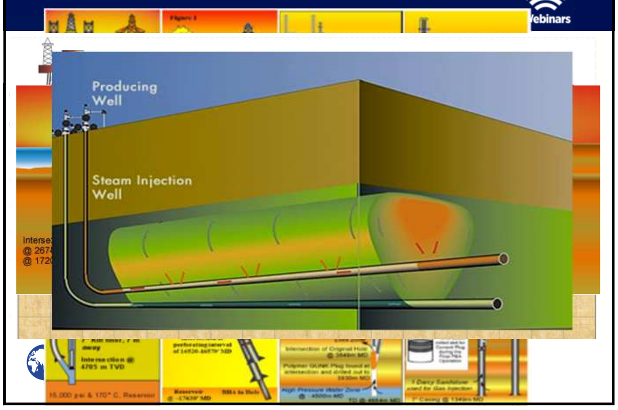
- History
  - Ranging and Wellbore Intercept
- Ranging Technologies
  - Passive Magnetic Ranging
  - Active Magnetic Ranging
  - Active Acoustic Ranging
  - Technology Summary
- Relief Well Operation
  - Workflows
  - Examples
- Conclusions
- Question and Answer

Ranging and Intercept History



- Documents dates back to 1906
  - Blow out well in Louisiana
  - Vertical injector wells
- Directional Relief Well 1933
  - Standard Oil Madely #1 Well
  - Blow out well in Conroe Texas
  - Whipstock Tool
  - Single Shot Tool
  - Did not intercept
- Geometric Intersection 1970
  - Shell Corporation Cox No. 1 Well
  - Passive Magnetic Ranging
- Ranging Tools 1978
  - Houston Oil and Minerals blowout 1975
  - Tensor Inc. MAGRANGE Service
- Electromagnetic Ranging 1980s
  - Currently a mature service
- Acoustic Ranging 2015
  - New, tested and developed

Ranging Applications



Passive Magnetic Ranging (PMR)

- Collision Avoidance
  - When magnetic interference is detected
  - During planned close approaches with relatively similar wellbore trajectories
- Well Twinning
- Passing Over/Under a Perpendicular Well
  - The MWD sensor must pass by the perpendicular well before an accurate range can be obtained
  - Not an anti-collision option for perpendicular wells
- Well Intercept
- Well Re-Entry

Introduction to Passive Magnetic Ranging (PMR)

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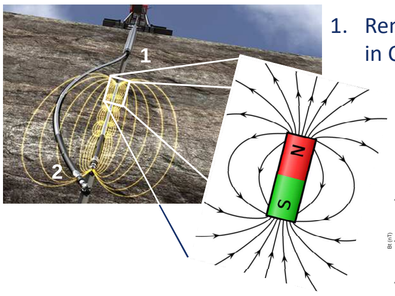

1. Remnant Magnetism in Casing
2. MWD
3. Magnetic Interference

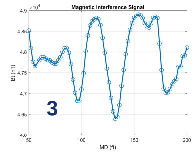

Image Credit: Haliburton and http://www.wikiwand.com

PMR – High Level Processing

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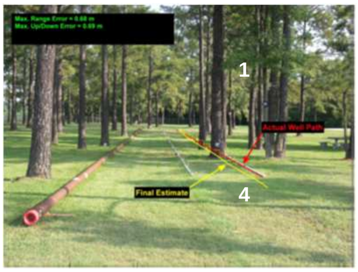

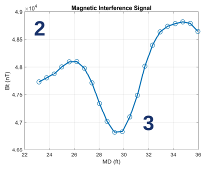

1. Start with survey location
2. Take ranging shots
   - Ranging interval must be greater than length of single casing joint
   - Spacing between shots distance-dependent
   - Example: 20 shots over 45 ft
3. Fit Data
4. Update target surface location to match range and direction at depth

Image Credit: SPE/IADC-173135-MS

PMR – Detection Distance Depends on Pole Strength Difference

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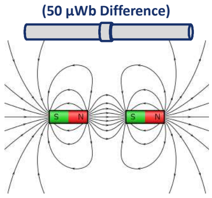
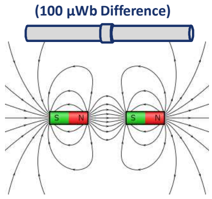
150 µWb North Pole Abutting
200 µWb South Pole
(50 µWb Difference)



200 nT seen at 15 ft from collar

100 µWb North Pole Abutting
200 µWb South Pole
(100 µWb Difference)



200 nT seen at 21 ft from collar

Image Credit: http://www.wikiwand.com

PMR – Detection Distance Depends on Magnetic Orientation

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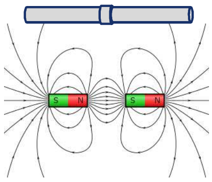
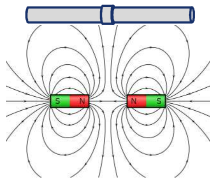
Scenario: 150 µWb pole abutting 200 µWb pole

Repeating Magnetic Orientation



200 nT seen at 15 ft from collar

Opposing Magnetic Orientation



200 nT seen at 39 ft from collar

Image Credit: http://www.wikiwand.com

Impact of Incidence Angle on Detection

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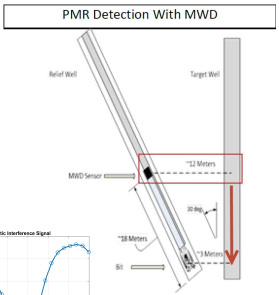
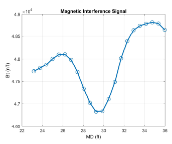
When the magnetometers are located in a conventional BHA, they are usually 50 to 60 feet behind the bit.

Additionally, the center of the ranging data interval will be another 25 feet or so above the deepest possible MWD sensor depth

- The PMR range estimate may correspond to a point 75 to 85 feet above the hole depth
- For every degree of incidence angle, the bit will be 1.5 feet closer to the offset well than the calculated PMR range

PMR Detection With MWD





PMR – Benefits & Limitations

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Benefits

- No specialty hardware
- No need to trip
- No need to access offset wellbore
- Not sensitive to formation
  - e.g. can be used in salt
- Used in all hole inclinations
- Direction to casing is very accurate (±5° at 1-σ)

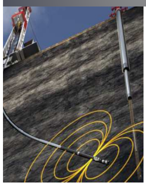
Limitations

- Typical MWD sensor location (50 – 60 ft behind the bit)
- Detection range (20 – 33 ft)
  - Pre-magnetized casing can improve
- Data fit repeatability
- Multiple offset wells
  - Some vendors have approaches
- Interference from drilling well
  - e.g. from a casing shoe
- Time-based variation in the background mag. field
- MWD sensor saturation (@ < 1.5’)
- Range to casing is less accurate (10% of distance at 1-σ, fat tails)

Active Magnetic Ranging (AMR)

Webinars

Wellbore Intersection



- Relief Well
- Plug and Abandon
- Multiple Intersections
- Intersect Verticals with Horizontals
- Connect End to End (River Crossing)
- Open/Cased Hole Re-Entries

Wellbore Avoidance

- Twinning (SAGD, Frac Recovery)
- In-Fills and Re-Drills
- Pad Optimization
- Areas with high density of existing wells
- Anti-Collision

AMR – Magnetic Field Generation

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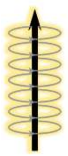
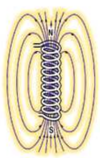
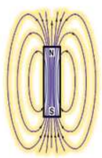


Current through Wire or on Pipe



Current through Coil of Wire



Permanent Magnets

Remnant Magnetic Field of Target Tubulars

AMR – Ranging Technology

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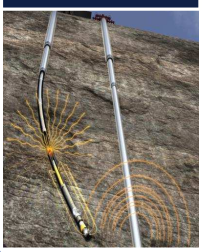
Access Independent



Access Dependent

AMR – Access Dependent

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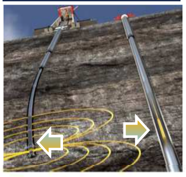
Magnetic Solenoid

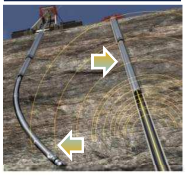
- Coil of Wire in Target Well
- MWD

Rotating Magnet



- Rotating Magnets in BHA
- Sensors in Target

Energized Wire



- Current in Wire
- Sensors in BHA

AMR – Access Independent

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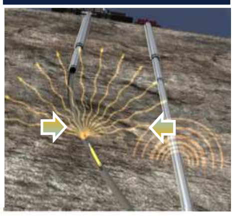
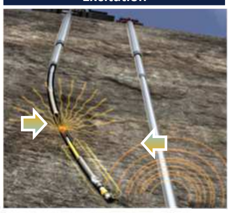
Wireline Deployed Excitation



- Induced Field
- WL Receiver

Wireline/BHA Deployed Excitation



- Induced Field
- BHA Receiver

Incidence angle on Detection

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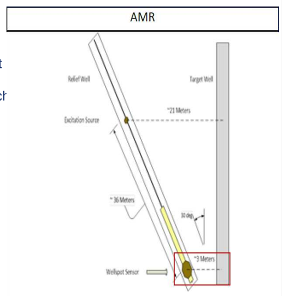
AMR

- excitation source will be farther away from the target well, thus reducing the signal intensity.
- While this may cause some possible detection issues when at greater distances from the target well, in the case illustrated above the ARM tool sensor is only 3 meters from the target well which reduces the signal intensity requirements for a ranging determination.
- Ranging with active magnetic at this well geometry does not pose an unintended collision risk.



AMR – Benefits and Limitations

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Benefits

- Detection based on a signal that is generated by the AMR assembly.
- Planning can be developed around a calculated detection range significantly reducing the likelihood of a side-track.
- Works equally well on steel and non-magnetic tubulars.
- Detection range not significantly impacted by the target well tubular size.
- Industry's only ranging service that can take a direct distance measurement.
- Lowest risk of an accidental collision as the ranging is taken on bottom with the greatest depth of investigation.

Limitations

- While the ability to perform AMR exists in a directional drilling BHA, the service is not appropriate for all applications.
  - On a typical relief well, the majority of ranging runs will require an open hole wireline trip.
- Service may not work when run in ultra-high resistivity (UHR) formations such as pure salt.
- Service requires dedicated kit and personnel onsite which increases the cost.

Active Acoustic Ranging (AAR)

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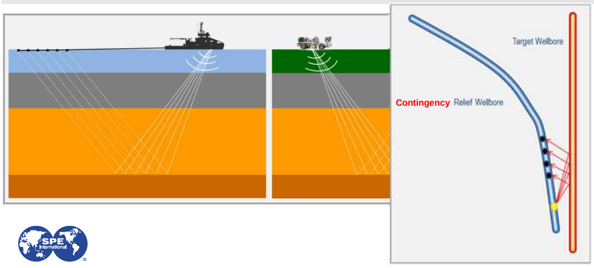
Reflected Signals History: Sonic-waveform data to generate seismic surveys

1980 | First discussed (1984) | 1990 | Revisited (1989) | Image | Borehole Acoustics Reflection Survey (BARS) (2006) | 2000



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Active Acoustic Ranging (AAR)

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AAR – Modelling

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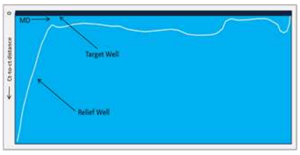
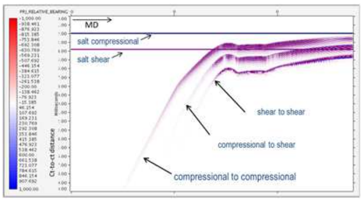
Modelling for ranging scenarios
- Done in advance
- Modelled distance vs. target wellbore
- Detectable amplitude arrivals

Reflected signal strength is affected by:
- Geometric spreading
- Reflector shape
- Formation attenuation





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AAR Modelling

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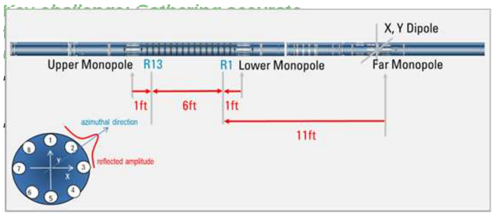
Key challenge: Gathering accurate



Early detection is necessary to:
- Prevent unintentional early interception.
- Determine forward trajectory of relief well.

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AAR – Case Study

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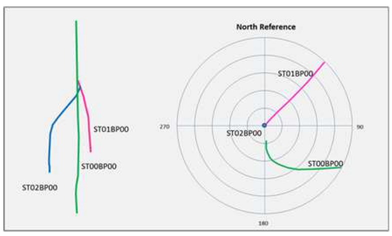
Operator identified Candidate well with three wellbores.

Parent wellbore with two sidetracks.

Team agreed to test AAR, using wireline ASL already established in existing wellbore logging program.

Demonstrated system availability and resulted in a low impact to overall planned logging operations.



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AAR – Case Study Results

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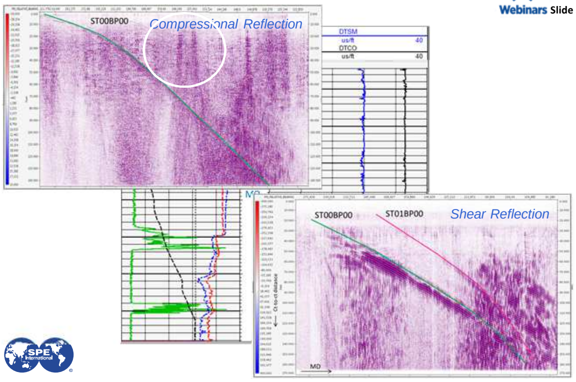

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AAR – Case Study Results

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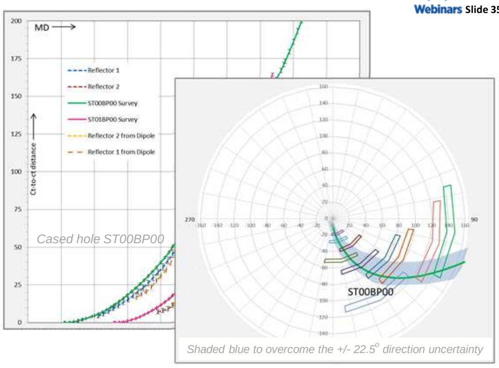

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AAR – Conclusions

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Ranging Case Study: Successful collaboration to test viability of AAR solutions in **salt**.

Maximum effective distance: ~160 ft. (49 m), slowness values, +/- 11.75° of direction.

Use **monopole and dipole sources** to record compression and shear waves.

- **Compressional signals:** Better to detect Cased Hole.
- **Shear signals:** Better to detect Open Hole.

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Ranging Technology Summary

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DESCRIPTION	PASSIVE RANGING	ACTIVE RANGING	ACTIVE ACOUSTIC RANGING
Technique	Depends on target well casing magnetization / Earth magnetic field variations / Magnetic noise. Take multiple surveys from MWD Tool	Inject Current into formation from electrode. Receptor at bottom. Multiple shots along the MD	Based on Sonic Waves propagation. Analyze the reflected sonic Waves. Transmitters and receivers are on the same logging tool.
Best Case Performance	Wells are parallel	Wells are parallel	Wells are at the same plane
Worst Case Performance	Wells are perpendicular	Pure Salt Formation Wells are perpendicular	Wells are perpendicular at large c-c distance
Detection Range Estimate	Selected from a chart representing the possible max magnetic field	Calculated using geometry and magnetic model	Calculated using geometry and actual sonic wave propagation property as measured during the run
Definitive Detection Range	5 – 15m	20 – 60m 40 – 100m with Direct Excitation on TW	1 – 55m
Detection Along Body of The Target Well	Detection range up to 5m (1/2 joint length), 6m on 12m casing	Up to 60m	Up to 55m
Detection Near Break or End of Pipe	Detection Range Up to 15m	Limited range within 1m of top and bottom of pipe ends	Up to 55m. Can detect Open Hole
Deployment - Wireline Required	No. However WL can be required for high density or for on bottom data collection	Yes. However, It can also now be deployed in Non Mag BHA behind MWD	Yes. It is a logging tool
Data Acquisition Time	6 to 30 hours For MWD Logging	30 hours (8 hours in TPR BHA) (assuming 4500m well)	6 to 15 hours depending on the logging intervals (assuming 4500m well)
Distance Accuracy	10% of detection Range. To be considered 1 standard deviation.	Non Gradient Tool : 5-20% Depends on High Side to Target variation	~0.3m at 1 standard deviation

Ranging Technology Summary

DESCRIPTION	PASSIVE RANGING	ACTIVE RANGING	ACTIVE ACOUSTIC RANGING
	Depends on the quality of the Target Well Magnetization strength and Signal/Noise ratio level.	Gradient Tool: Depends on distance. Less than 5%	
Direction Accuracy	~5° at 1 standard deviation	~5° at 1 standard deviation	~ 22.5° at 2 Standard deviation
Target Well detection	Casing, Fish, Packer, completion, all steel equipment	Casing, Fish, Packer, completion, all steel equipment	Casing, Fish, Packer, completion, all steel equipment and Open hole
Case Histories	Widely used in the industry Mainly used for P&A and collision avoidance Very Few Successful Relief Well Intercept	Widely used in the industry Relief Well & Re-Entry Wells	New technology recently developed Only few case histories are available
Sensor Measurement Point	15m – 20m from Bottom hole On Bottom if WL Deployed.	On Bottom 25 – 35m from Bottom Hole if deployed in BHA	On Bottom
Non Magnetic Target Pipe	Detection not possible	No Effect same as steel pipe	No Effect same as steel pipe
Target Casing Corrosion	Detection may not be possible	Minimal impact on detection range	Minimal impact on detection range
Presence Of Breaks Or Discontinuities In Target Pipe	Potential to increase detection range from the magnetic signature	Detection range reduced for short sections (~1m) of the target well	Minimal impact on detection range
Effects of Different Casing Sizes and Weight	Casing weight has a direct impact in range: 20 Lbs./Ft has an expected max range of 2m along the body	Negligible Effect	Negligible Effect

Ranging Technology Summary

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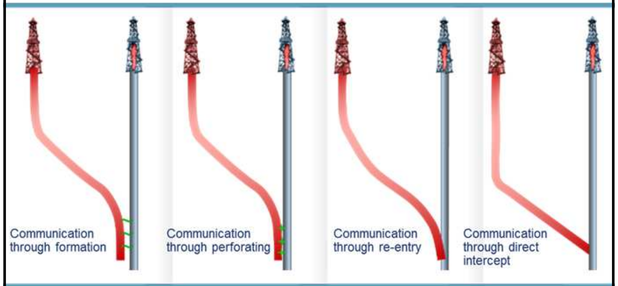
DESCRIPTION	PASSIVE RANGING	ACTIVE RANGING	ACTIVE ACOUSTIC RANGING
Effects of Different Casing Sizes and Weight	Casing weight has a direct impact in range: 20 Lbs./Ft has an expected max range of 2m along the body 40 Lbs./Ft has an expected max range of 3m along the body	Negligible Effect	Negligible Effect
Effects of Other Nearby Wellbores	Eliminates possibility of using service	Direct excitation of OW method removes impact. If direct excitation not possible vector subtraction mitigates effect	Under special process, can detect multiple wells from different azimuthal positions
Effects of Highly Insulating Formation	No Effect	Minimal impact up to 300m MD into the formation. Beyond 300m detection range is largely reduced	Negligible Effect
Effects of High Incidence Angle Between Target And Drilling Well	High incidence angle increases sensor to target thus greatly reducing the effective detection range	AMR signal reduced by increasing distance between excitation source and target well	Increases the quality of the wave propagation signal analysis
Is The System Effected By Poor Hole Conditions in Drilling Well	No Effect	Potential to add additional ranging run time for open ended drill pipe runs	Negligible Effect
Effects of Different Mud Types	No Effect	OBM may slightly reduce the detection range	Negligible Effect

SPE International

Relief Well Project Concept

Webinars



SPE International

Relief Well Drilling Team

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- Successful relief well drilling is dependent on teamwork between **oil company, service company, drilling contractor, and third party contractors.**
- Oil company: Responsible party to make decisions based on recommendations or conclusions of relief well team experts.

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Relief Well Project Context

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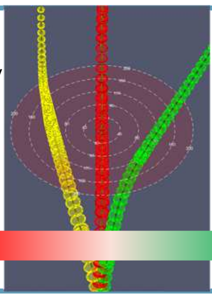
Challenges	Requirements
Technical Complexity	Technology and Expertise
Multidisciplinary Interactions	Communication Protocols and Workflows
HSE Risks	Hazard and Risk Control
Emergency and Pressure Control	Leadership, Experience and Commitments



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Relief Well Activity

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At the **core of the relief well process is the workflow,** which consists of **seven phases.**

All actions described

- Who
- What
- When
- How
- Deliverable
- Risk Analysis
- Assessment

Activities

1. Planning
2. Approach
3. Locate
4. Following
5. Intercepting
6. Killing operations
7. Plug and abandon

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Relief Well Management System

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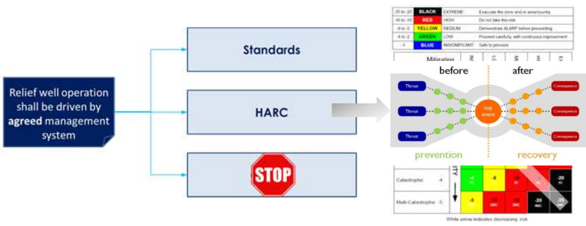
Example of components needed for relief well drilling and how they relate to other activities.



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Relief Well Activity

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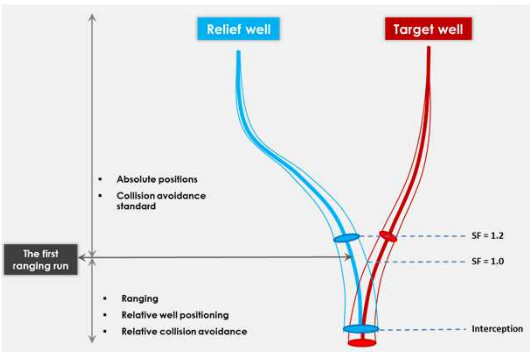

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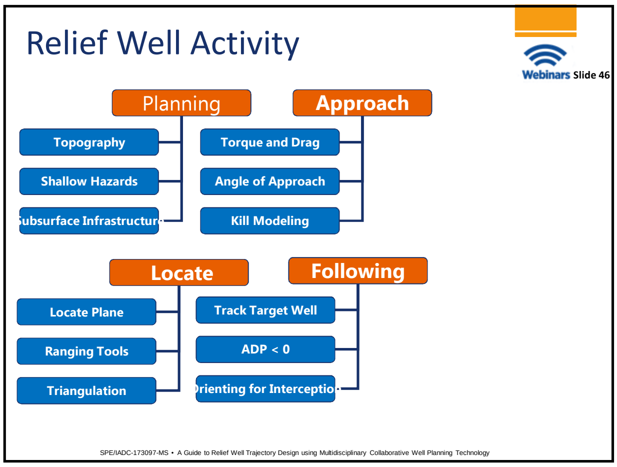
Relief Well Activity
Webinars Slide 46
Planning
Approach
Topography
Shallow Hazards
Subsurface Infrastructure
Torque and Drag
Angle of Approach
Kill Modeling
Locate
Following
Locate Plane
Ranging Tools
Triangulation
Track Target Well
ADP < 0
Orienting for Interception
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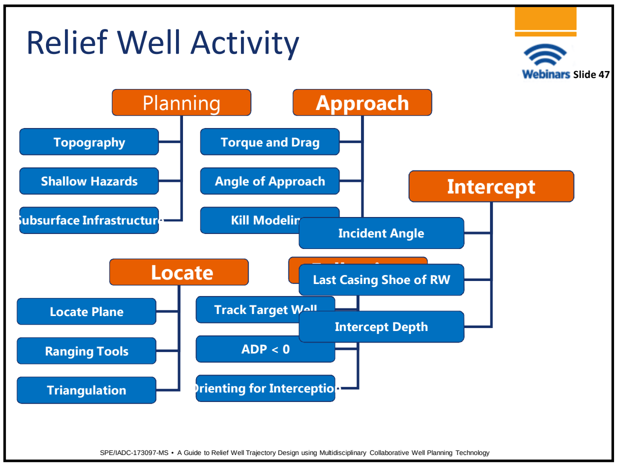
Relief Well Activity
Webinars Slide 47
Planning
Approach
Topography
Shallow Hazards
Subsurface Infrastructure
Torque and Drag
Angle of Approach
Kill Modelin
Intercept
Incident Angle
Last Casing Shoe of RW
Intercept Depth
Locate
Locate Plane
Ranging Tools
Triangulation
Track Target Well
ADP < 0
Orienting for Interception
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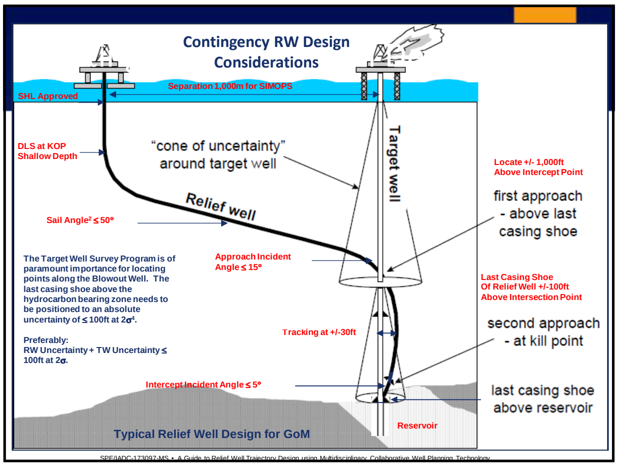
Contingency RW Design Considerations
Separation 1,000m for SIMOPS
SHL Approved
DLS at KOP Shallow Depth
"cone of uncertainty" around target well
Relief well
Target well
Sail Angle² ≤ 50°
The Target Well Survey Program is of paramount importance for locating points along the Blowout Well. The last casing shoe above the hydrocarbon bearing zone needs to be positioned to an absolute uncertainty of ≤ 100ft at 2σ⁴.
Preferably: RW Uncertainty + TW Uncertainty ≤ 100ft at 2σ.
Approach Incident Angle ≤ 15°
Tracking at +/-30ft
Intercept Incident Angle ≤ 5°
Locate +/- 1,000ft Above Intercept Point
first approach - above last casing shoe
Last Casing Shoe Of Relief Well +/-100ft Above Intersection Point
second approach - at kill point
last casing shoe above reservoir
Reservoir
Typical Relief Well Design for GoM
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QA/QC Ladder Plot

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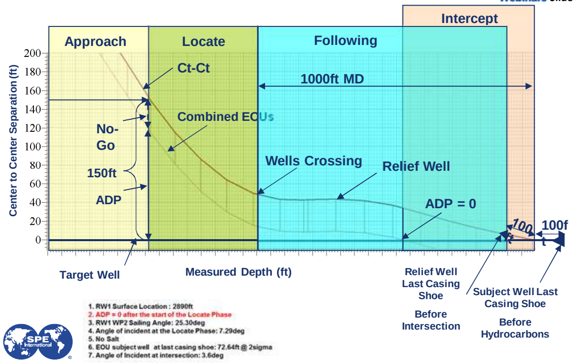

1. RW1 Surface Location : 2890ft
2. ADP = 0 after the start of the Locate Phase
3. RW1 WP2 Sailing Angle: 25.30deg
4. Angle of incident at the Locate Phase: 7.29deg
5. No Salt
6. EOU subject well at last casing shoe: 72.64ft @ 2sigma
7. Angle of Incident at intersection: 3.6deg

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