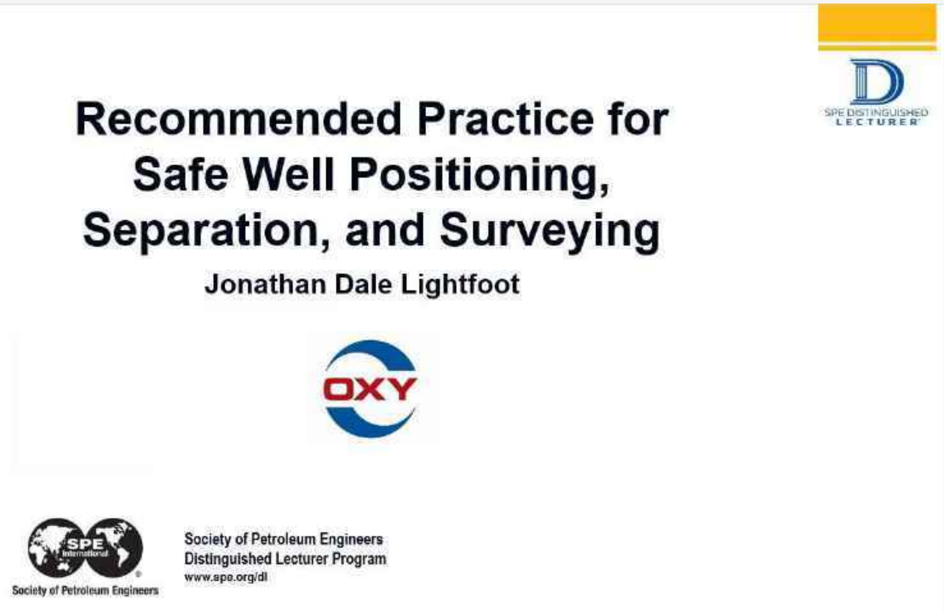
SAFE SEPARATION

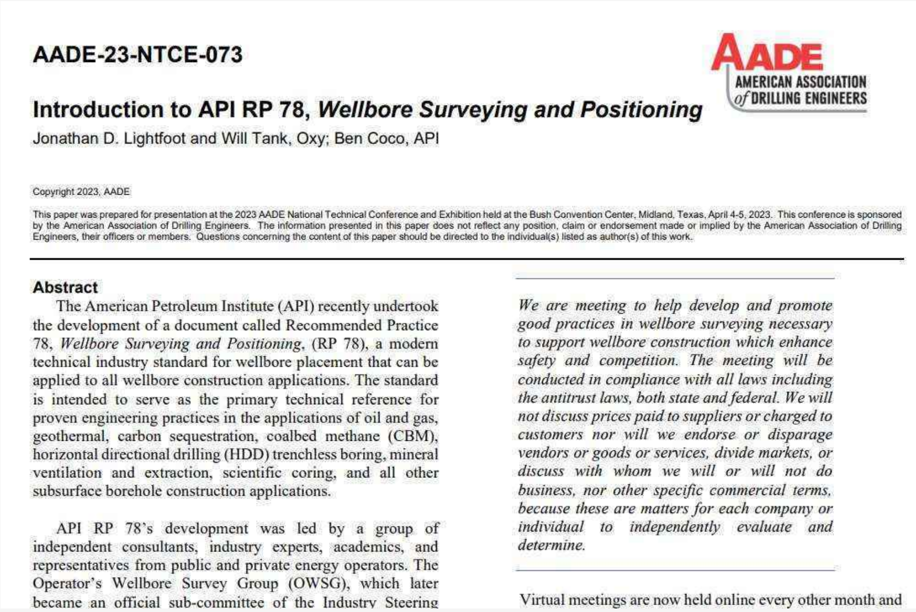
Recommended Practice for Safe Wellbore Positioning, Separation & Surveying

2026 MARCH 05 – AADE HOUSTON MEETING

AADE
AMERICAN ASSOCIATION *of* DRILLING ENGINEERS

Presentation Background





AADE-23-NTCE-073

AADE AMERICAN ASSOCIATION of DRILLING ENGINEERS

Introduction to API RP 78, *Wellbore Surveying and Positioning*

Jonathan D. Lightfoot and Will Tank, Oxy; Ben Coco, API

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Abstract

The American Petroleum Institute (API) recently undertook the development of a document called Recommended Practice 78, *Wellbore Surveying and Positioning*, (RP 78), a modern technical industry standard for wellbore placement that can be applied to all wellbore construction applications. The standard is intended to serve as the primary technical reference for proven engineering practices in the applications of oil and gas, geothermal, carbon sequestration, coalbed methane (CBM), horizontal directional drilling (HDD) trenchless boring, mineral ventilation and extraction, scientific coring, and all other subsurface borehole construction applications.

API RP 78's development was led by a group of independent consultants, industry experts, academics, and representatives from public and private energy operators. The Operator's Wellbore Survey Group (OWSG), which later became an official sub-committee of the Industry Steering

We are meeting to help develop and promote good practices in wellbore surveying necessary to support wellbore construction which enhance safety and competition. The meeting will be conducted in compliance with all laws including the antitrust laws, both state and federal. We will not discuss prices paid to suppliers or charged to customers nor will we endorse or disparage vendors or goods or services, divide markets, or discuss with whom we will or will not do business, nor other specific commercial terms, because these are matters for each company or individual to independently evaluate and determine.

Virtual meetings are now held online every other month and

SPE 2024-2025 Distinguished Lecturer Program Technical Presentation

AADE-23-NTCE-073: Technical Paper

Presentation Outline

Safe Separation

Applications

Industry Collaboration

Management Principles

Position Uncertainty Models (PUMs)

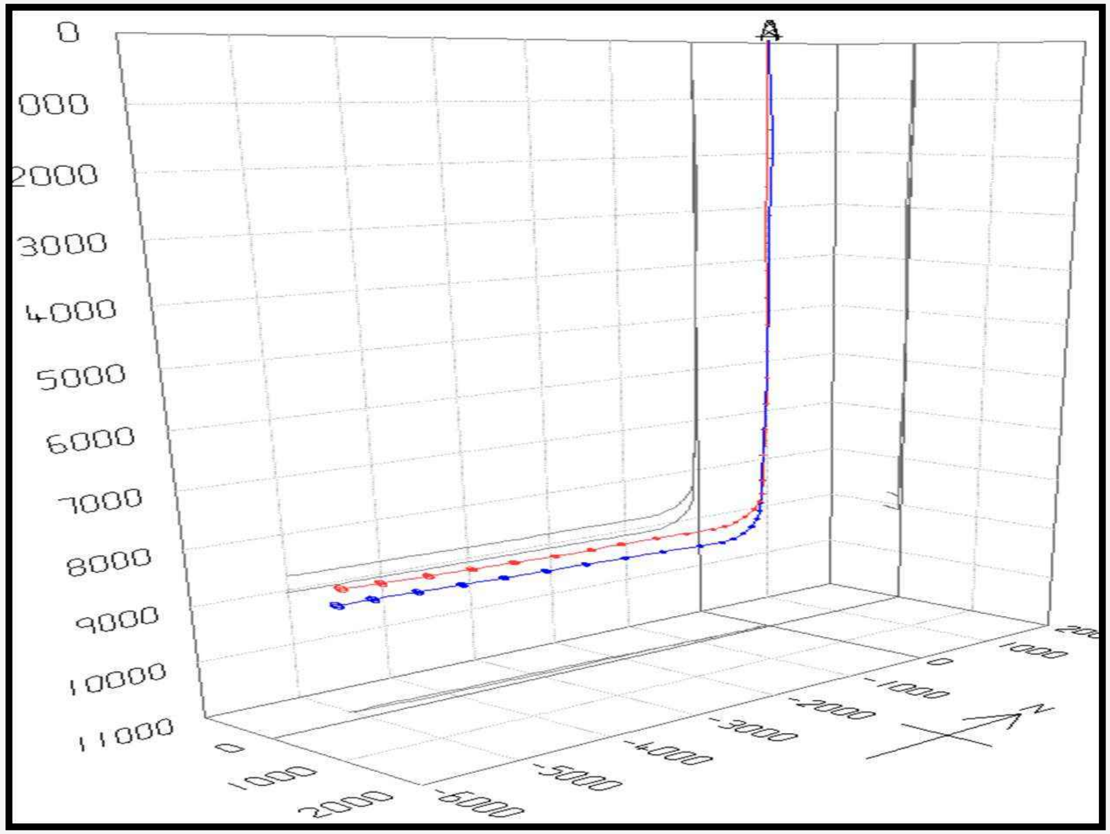
Offset Well Environment

Case Studies

- **Offset Operator Close Approach**
- **Lateral Undulations**
- **Key Performance Indicators**
- **Steerable Motor Curve**
- **Lateral Tortuosity**
- **Texas Long Lateral Example**

Key Takeaways

API RP78 Status Update



Safe Separation

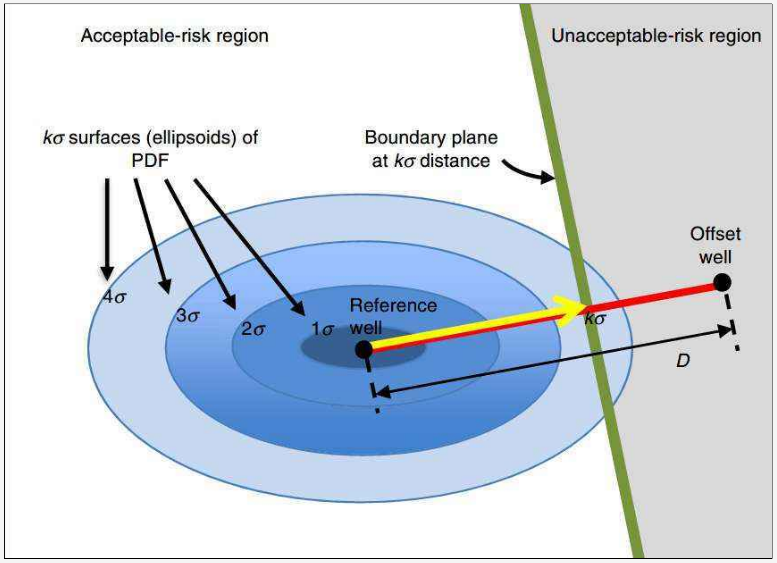
The Wellbore Positioning Technical Section (WPTS) Rule

Separation Factor = Ratio of Separation Distance and Uncertainty

$$\frac{\text{Numerator}}{\text{Denominator}} = \frac{\text{Distance}}{\text{Uncertainty}}$$

$$SF = \frac{D - R_r - R_o - S_m}{k\sqrt{\sigma_s^2 + \sigma_{pa}^2}}$$

$$\sqrt{\sigma_r^2 + \sigma_o^2} \quad k\sqrt{\sigma_s^2 + \sigma_{pa}^2}$$



Industry Collaboration

Industry Steering Committee on Wellbore Survey Accuracy

- **Produces, maintains, and publishes standards for the industry**
- **Promotes a collaborative understanding of issues associated with wellbore surveying**
- **Formed in 1999, ISCWSA has been around for 29 Years [SPE 67616-PA]**
- **63 General Meetings**

SPE Wellbore Positioning Technical Section (WPTS)

ISCWSA

Applications

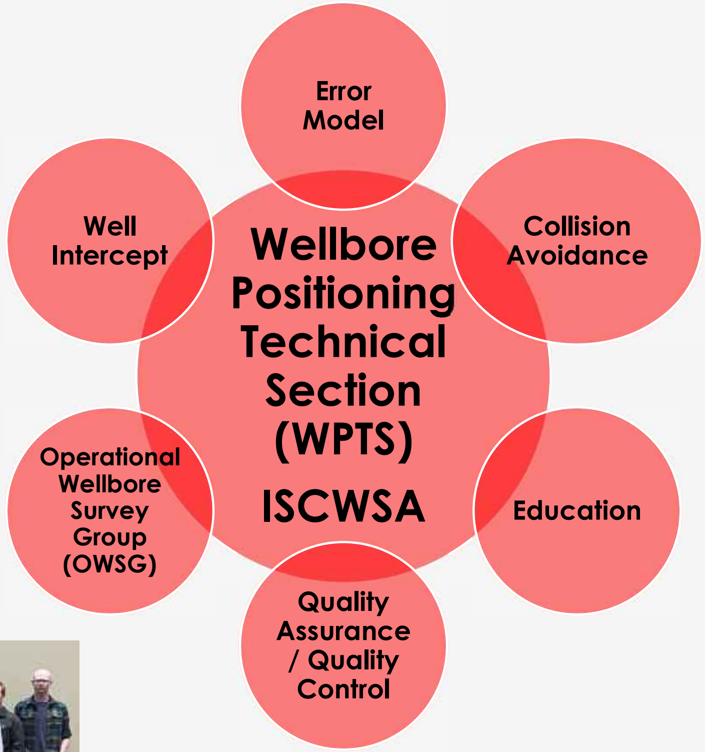
Serves as the primary technical reference for proven engineering practice in the broad wellbore construction application of:

- **Oil and Gas**
- **Geothermal**
- **Carbon Sequestration**
- **Coalbed Methane (CBM)**
- **Horizontal Directional Drilling (HDD), trenchless boring**
- **Mineral Ventilation and Extraction**
- **Scientific Coring**
- **All other subsurface borehole construction applications**

Industry Collaboration

WPTS has Six (6) Primary Sub-Committees

1. Collision Avoidance
2. Error Model Maintenance
3. Well Intercept
4. Operational Wellbore Survey Group
5. Quality Assurance / Quality Control
6. Education

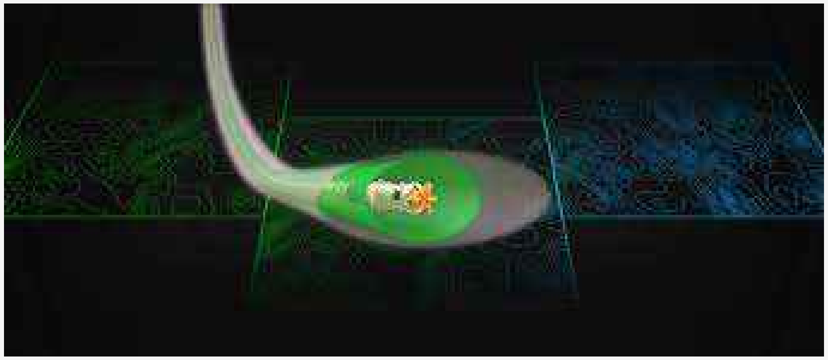


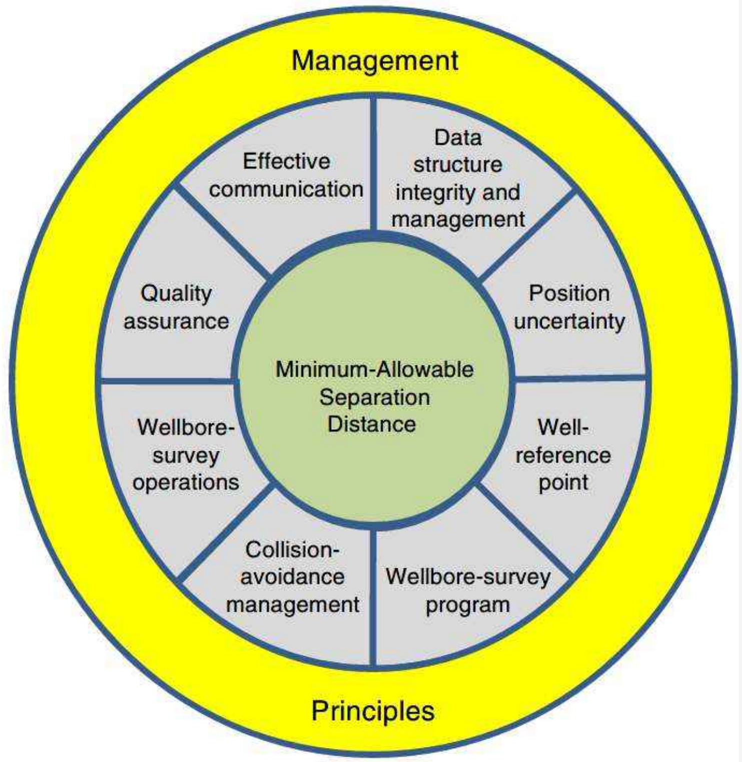
Management Principles

Minimum Allowable Separation Distance (MASD)

Maintain a Safe Separation Distance Between Wells Being Drilled and Subsurface Hazards

8 Core MASD Elements





The eight collision-avoidance elements supporting the MASD

Allowable Deviation from Plan for SF=1

Any given **separation factor** (**SF**) value represents a specific probability of the **reference well** crossing the **offset well**. The distance ***D*** at which a particular **SF** value occurs is **situation-specific**. For any point on a reference well, the critical value **SF = 1** defines a **minimum allowable separation distance (MASD)** from the specified offset well along ***D***.

$$SF = \frac{D - R_r - R_o - S_m}{k\sqrt{\sigma_s^2 + \sigma_{pa}^2}}$$

$$SF = \frac{D - R_r - R_o - 0.3}{3.5\sqrt{\sigma_s^2 + 0.25}}$$

$k = 3.5$, $S_m = 0.3\text{m}$ and $\sigma_{pa} = 0.5\text{m}$

$$D_{MASD} = k\sqrt{\sigma_s^2 + \sigma_{pa}^2} + R_r + R_o + S_m$$

Allowable Deviation from Plan for SF=1

MASD Management Principles (SPE-187073-PA)

$$D_{MASD} = k\sqrt{\sigma_s^2 + \sigma_{pa}^2} + R_r + R_o + S_m$$

If the distance D falls below D_{MASD}, then $SF < 1$. The difference between the planned distance D_{plan} and the D_{MASD} is the allowable deviation from the plan D_{ADP} :

$$D_{ADP} = D_{plan} - D_{MASD}$$

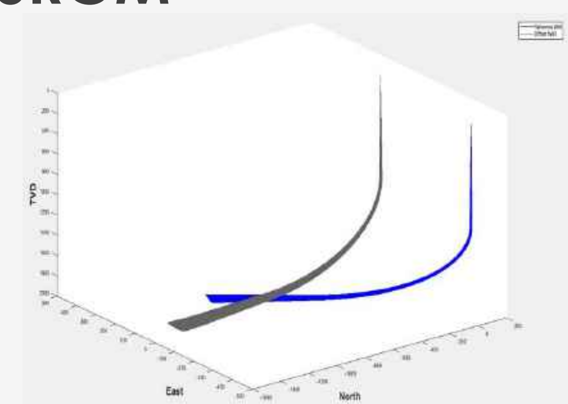
SPE-187073-MS

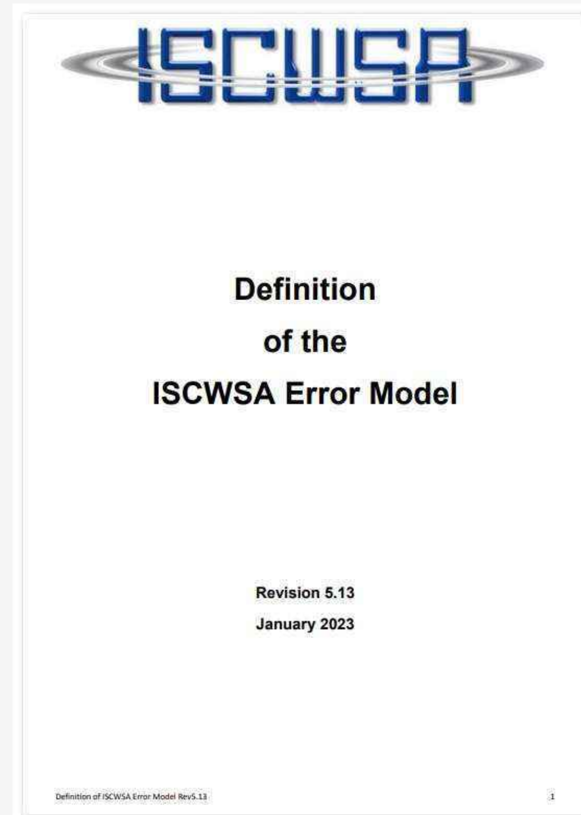
Well Collision Avoidance - Separation Rule

S.J.Sawaryn, Consultant, H. Wilson, Baker Hughes a GE Company, J. Bang, Gyrodata Inc., E. Nyrnes, Statoil ASA, A. Sentance, Dynamic Graphics Inc., B. Poedjono and R. Lowdon, Schlumberger, I. Mitchell and J. Codling, Halliburton, P.J. Clark, Chevron Energy Technology, W.T. Allen, BP

Position Uncertainty Models (PUM)

- ISCWSA & OWSG Revisions
- PUM Categories
- Magnetic Reference Classification
- Generic Models (Set A & B)
- PUM Example: MWD + SRGM
- MWD Corrections




ISCWSA

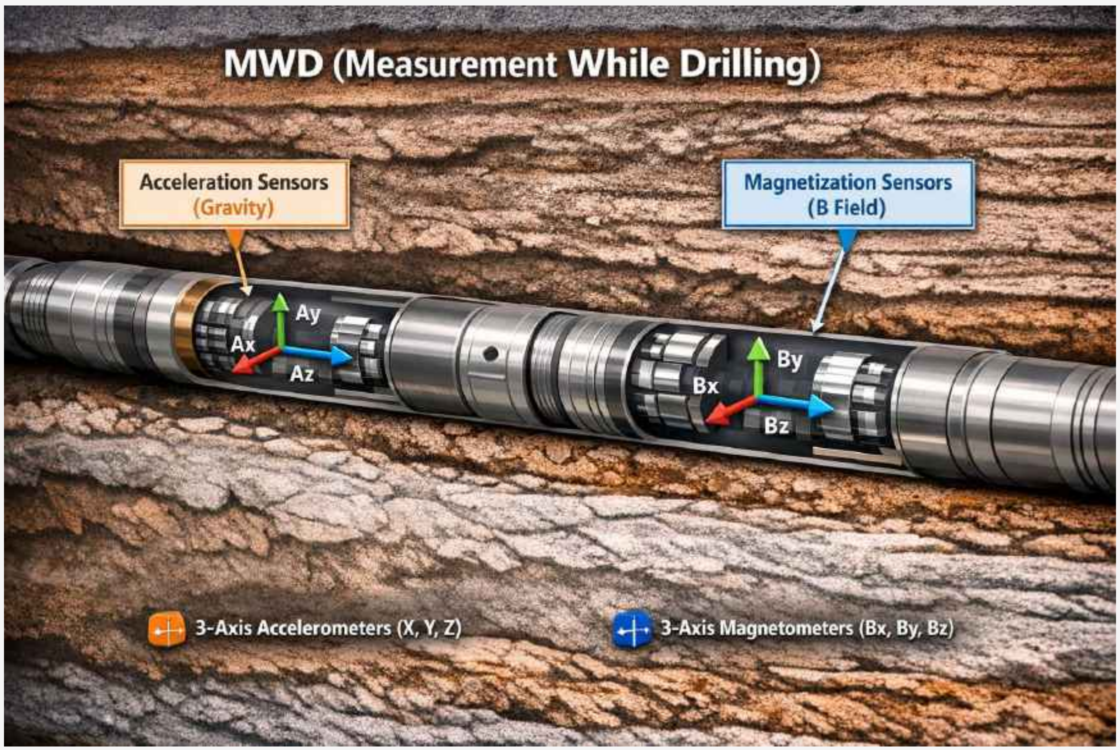
Definition
of the
ISCWSA Error Model

Revision 5.13
January 2023

Definition of ISCWSA Error Model Rev5.13 1

MEASUREMENT WHILE DRILLING (MWD)

What does the MWD Tool Measure?



Sensor Measurements

- Acceleration
- Magnetic Field

We compute Inclination, Magnetic Azimuth, Toolface

Quality Control (Field Acceptance Criteria)

True Azimuth = Magnetic Azimuth + Declination

PUM Sets – Established by OWSG

PUM, often referred to as Error Models or Instrument Performance Models, Revision 5.13 (Current)

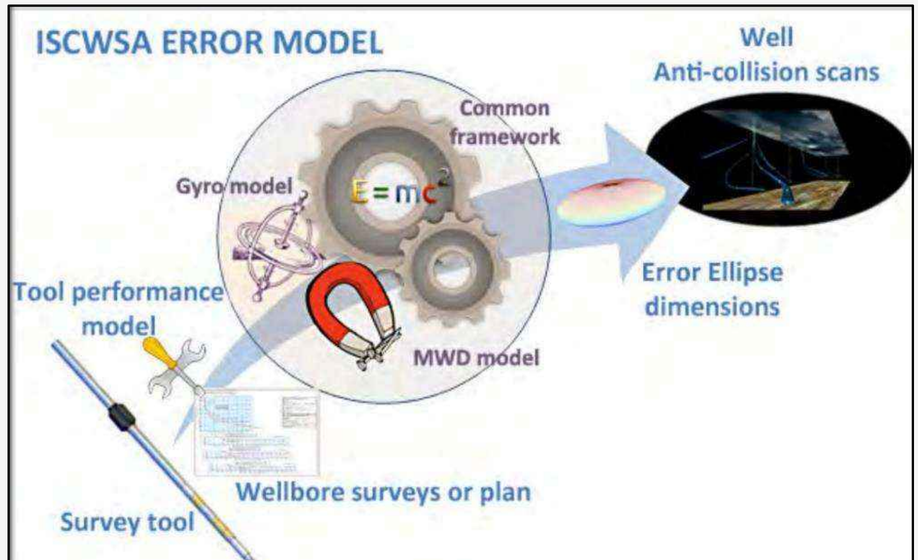
Set A: Standard

Set B: Extended

Set C: Vendor-supplied

Set D: Gyro software validation

Set E: Prototypes in development

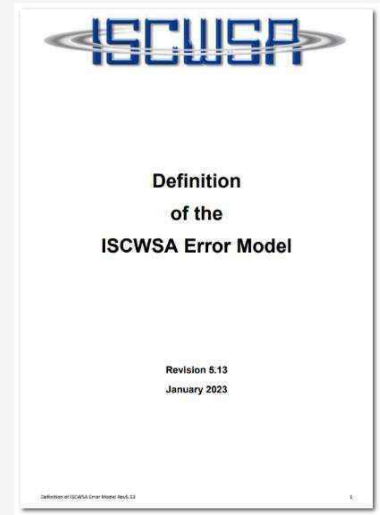


Ref: ISCWSA Introduction to Wellbore Positioning eBOOK

Grindrod, S. J., Clark, P. J., Lightfoot, J. D., Bergstrom, N.. , and L. S. Grant. "**OWSG Standard Survey Tool Error Model Set for Improved Quality and Implementation in Directional Survey Management**." Paper presented at the IADC/SPE Drilling Conference and Exhibition, Fort Worth, Texas, USA, March 2016.
doi: https://doi.org/10.2118/178843-MS

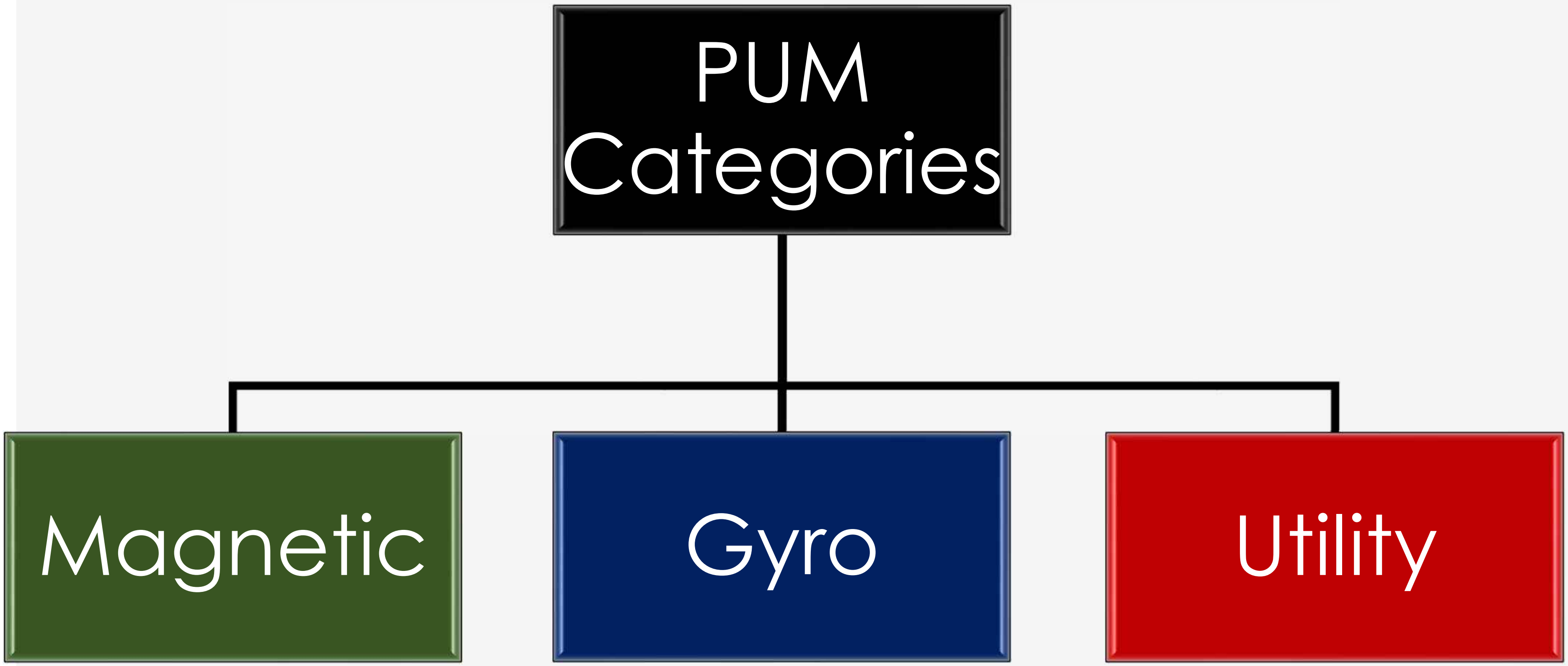
Position Uncertainty Models (PUM)

Revision	Date	Description
Rev 0	**Dec 2000**	As per SPE 67616 together with various typographical corrections [1]
Rev 1	**March 2005**	Changed to the gyro style misalignment with 4 terms and calculation options [2]
Rev 2	**Feb 2007**	Changes to the parameter values for the depth scale and stretch terms [2]
Rev 3	**Oct 2009**	Replacement of all toolface dependent terms
Rev 4 & OWSG Rev 2	**Mar 2019**	Introduction of AMIL term and changes to misalignment magnitudes. Random magnetic reference values introduced to the main MWD model. OWSG includes Conventional, Gyro and Utility PUMs. Included Low Resolution and High Resolution Magnetic Reference Models for MWD and EMS. [3]
Rev 5 (Beta)	**Oct 2020**	Introduction of the XCL term, changes to misalignments and sag, breakout of magnetic reference terms and clarification of the surface tie-on. [4]
Rev 5.13	**Jan 2023**	**Minor updates to Rev 5 [4] – Latest Official Revision Five**

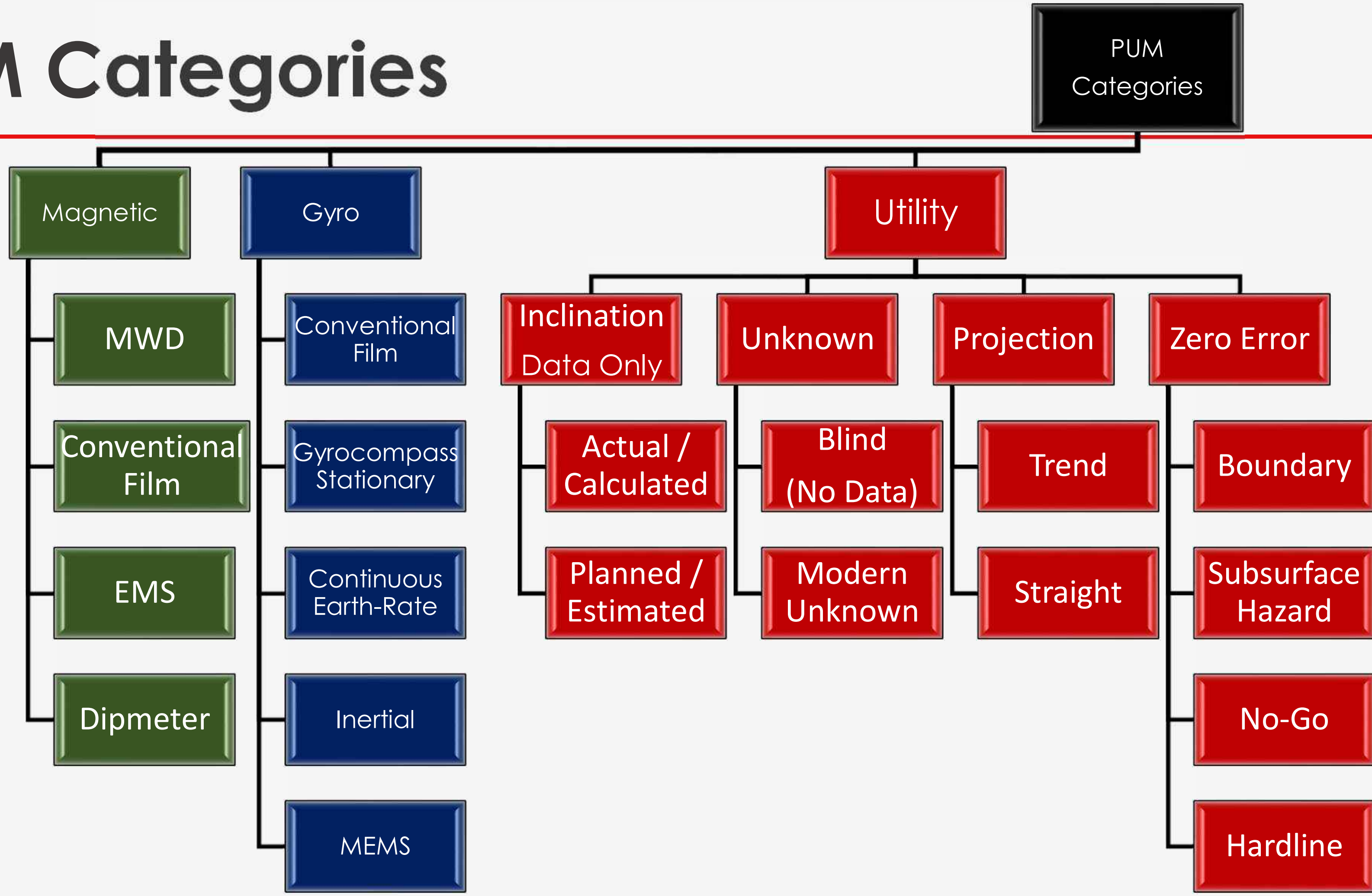


1. https://doi.org/10.2118/67616-PA
2. https://doi.org/10.2118/105558-MS
3. https://doi.org/10.2118/178843-MS
4. https://www.iscwsa.net/media/files/files/64bd61c2/definition-of-iscwsa-error-model-v5-13.pdf

PUM Primary Categories



PUM Categories



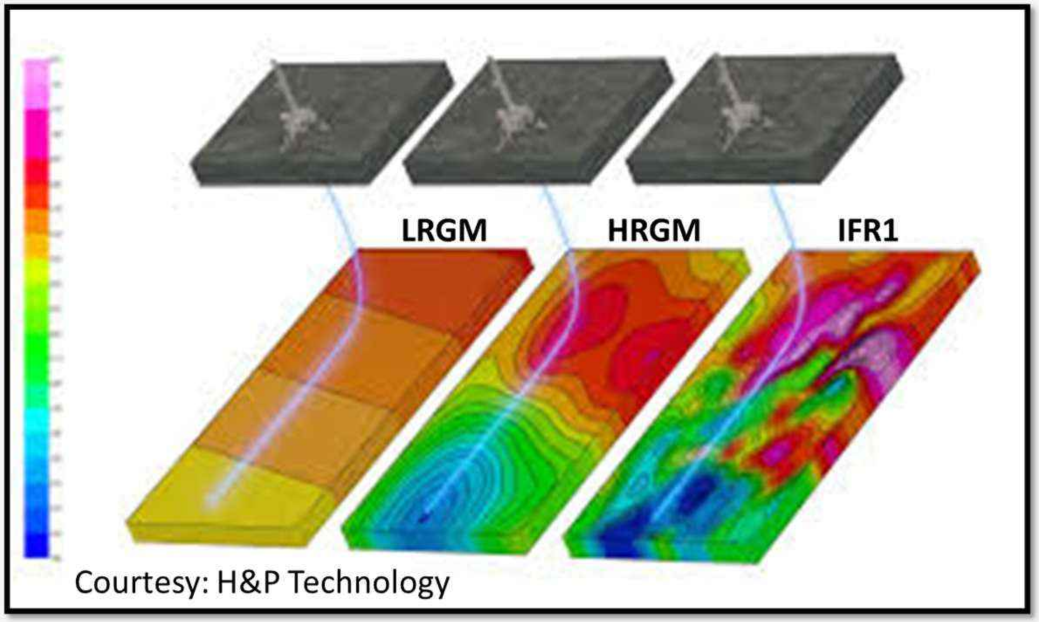
Magnetic Reference PUM Classification

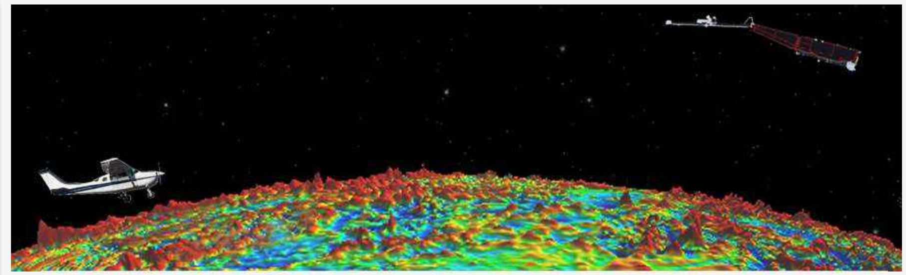
AADE AMERICAN ASSOCIATION of DRILLING ENGINEERS

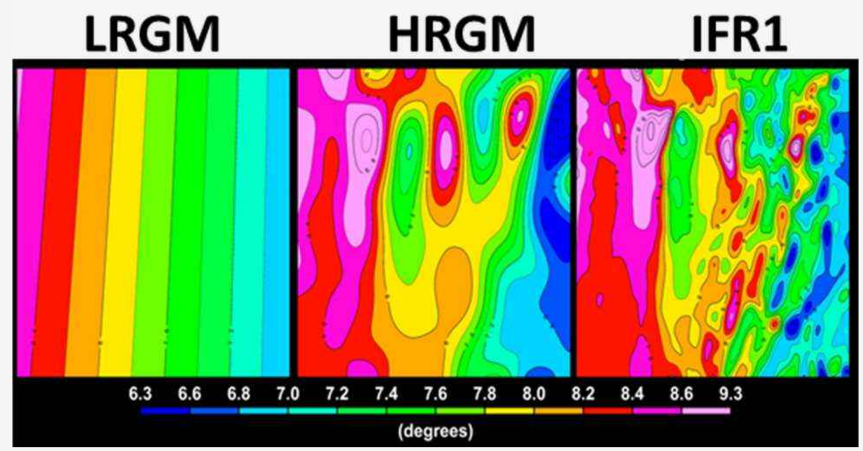
Category	Abbreviation	Example Geomagnetic Models	Wavelength from 40,000 km Coverage	Update Frequency
Low Resolution	LRGM	GRF, WMM, CGRF	≤ 4000 km	Less than Annual
Standard Resolution	SRGM	MVSD, Pre-BGGM2019	≤ 300 km	Annual
High Resolution	HRGM	HDGM, MVHD, BGGM2019+, HDGM-RT	≤ 55 km	Annual
In-Field Referencing	IFR1	IFR, IFR1, Ground shot plus secular variation correction	≤ 2 km	Annual
In-Field Referencing with Realtime Disturbance Field Correction	IFR2	IFR2, IIFR	≤ 2 km plus local realtime (≤ 1 min) sampling	Annual

Multiplier	Category
1.21	LRGM
1.00	SRGM
0.82	HRGM

Magnetic Reference PUM Classification

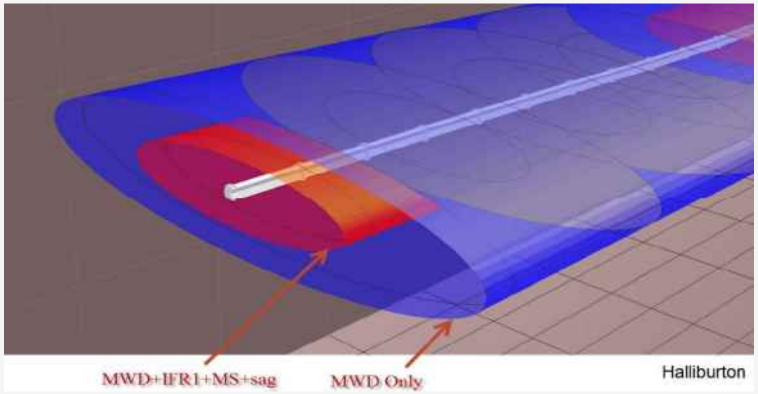






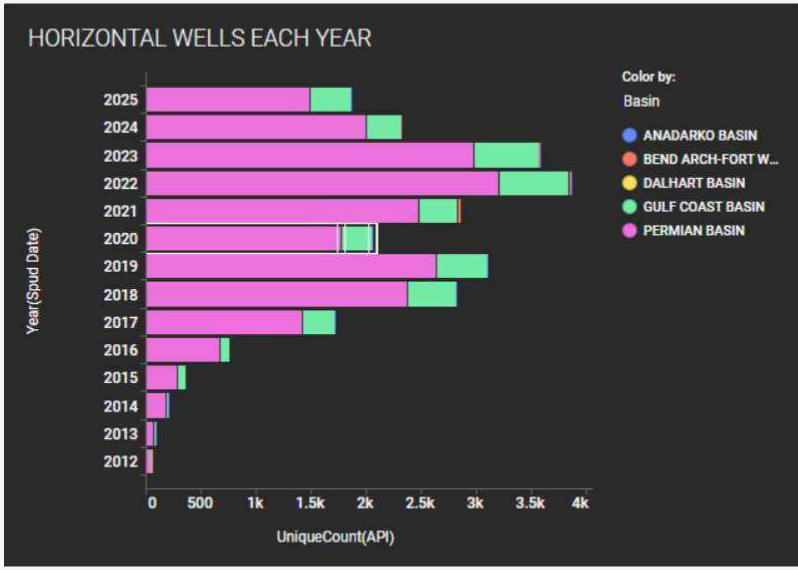
Ultra Long Laterals - Case Study

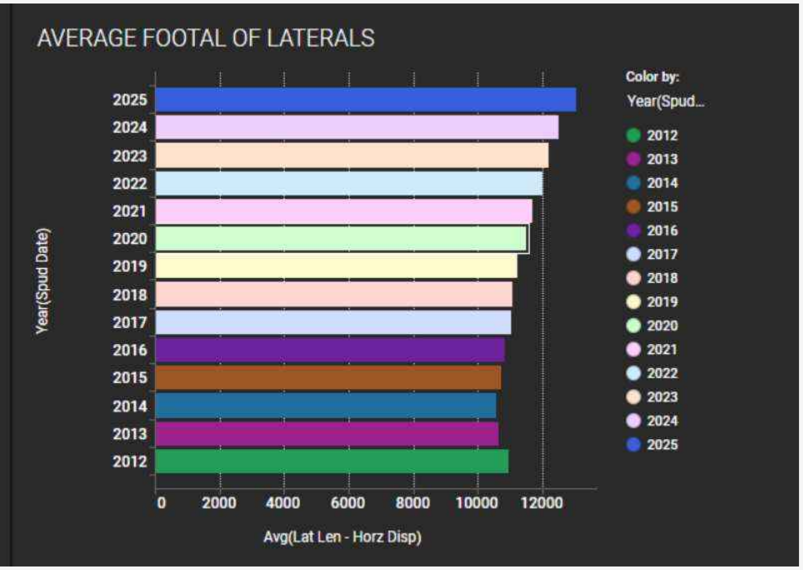
Texas: 155,759 Horizontal Wells

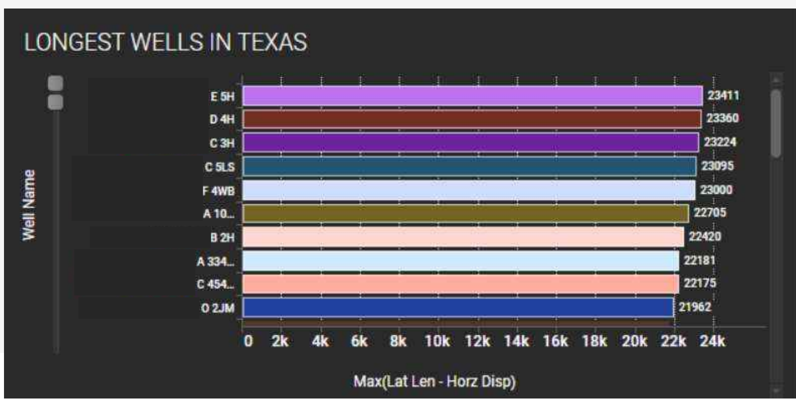


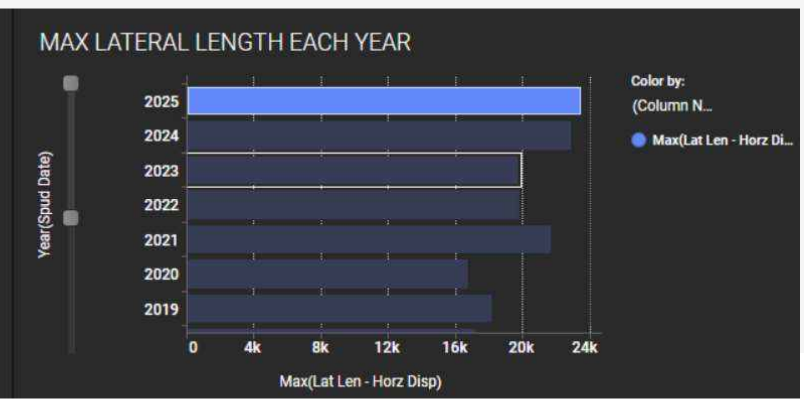
- 25,730 Laterals > 10K ft Departure
- 2216 Laterals > 15K ft Departure
- 45 Laterals > 20K ft Departure
- 5 Laterals > 23,000 ft Departure
- Longest in TX: 33,913 ft MD April 19 – June 9, 2025
  - Eagle Ford – La Salle County (API# 4229337753) – 23,411 ft Displacement

EXAMPLE – TEXAS COMPLEX WELLS

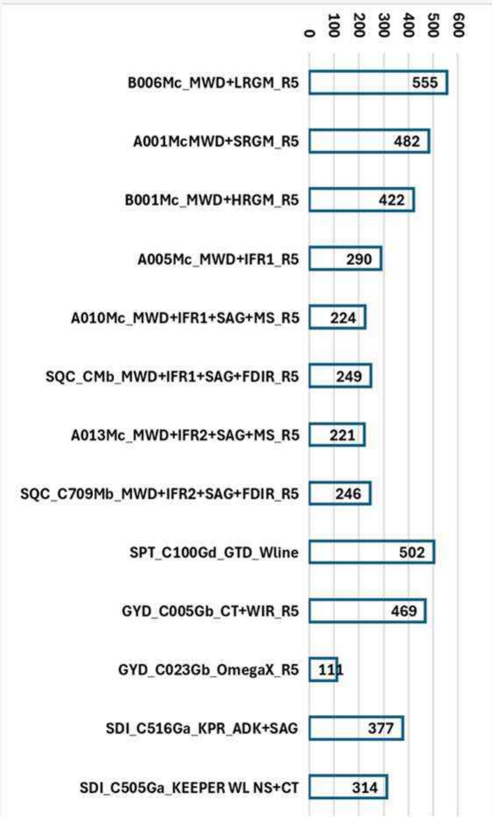




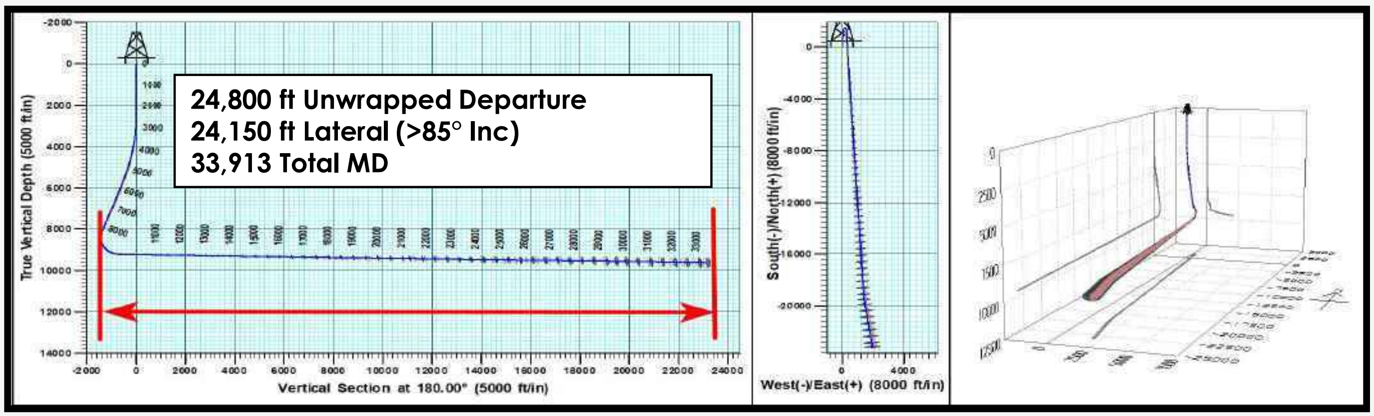




TX EXAMPLE – PUM COMPARISON



GEOMAGNETIC REFERENCE	PUM ISCWSA CODE	LATERAL UNCERTAINTY (Radius ft)	VERTICAL UNCERTAINTY (Radius ft)	LATERAL IMPROVEMENT	VERTICAL IMPROVEMENT
LRGM	B006Mc_MWD+LRGM_R5	555	253	-15%	-
SRGM	A001McMWD+SRGM_R5	482	253	REFERENCE	REFERENCE
HRGM	B001Mc_MWD+HRGM_R5	422	253	12%	-
IFR1	A005Mc_MWD+IFR1_R5	290	253	40%	-
IFR1	A010Mc_MWD+IFR1+SAG+MS_R5	224	146	53%	42%
IFR1	SQC_CMb_MWD+IFR1+SAG+FDIR_R5	249	146	48%	42%
IFR2	A013Mc_MWD+IFR2+SAG+MS_R5	221	146	54%	42%
IFR2	SQC_C709Mb_MWD+IFR2+SAG+FDIR_R5	246	146	49%	42%
WIRELINE GYRO	SPT_C100Gd_GTD_Wline	502	108	-4%	57%
WIRELINE GYRO	GYD_C005Gb_CT+WIR_R5	469	99	3%	61%
DROP GYRO	GYD_C023Gb_OmegaX_R5	111	106	77%	58%
DROP GYRO	SDI_C516Ga_KPR_ADK+SAG	377	154	22%	39%
WIRELINE GYRO	SDI_C505Ga_KEEPER WL NS+CT	314	162	35%	36%



PUM Toolcodes Rev 5-1

AADE AMERICAN ASSOCIATION of DRILLING ENGINEERS

A default set of conservative PUM tool-codes for use when tool specific models are not available.

ISCWSA_Generic_Toolcodes SetA Rev5-1
(updated Sept 23, 2022)

ISCWSA_Generic_Toolcodes SetB Rev5-1
(updated Sept 23, 2022)

- **Header / Reference Info**
- **Weighting Functions**
- **Technical Reference / Source**
- **Code & Term Description**
- **Type, Magnitude & Units**
- **Correlation Coefficients & Comments**
- **Formulas (Inclination & Azimuth)**

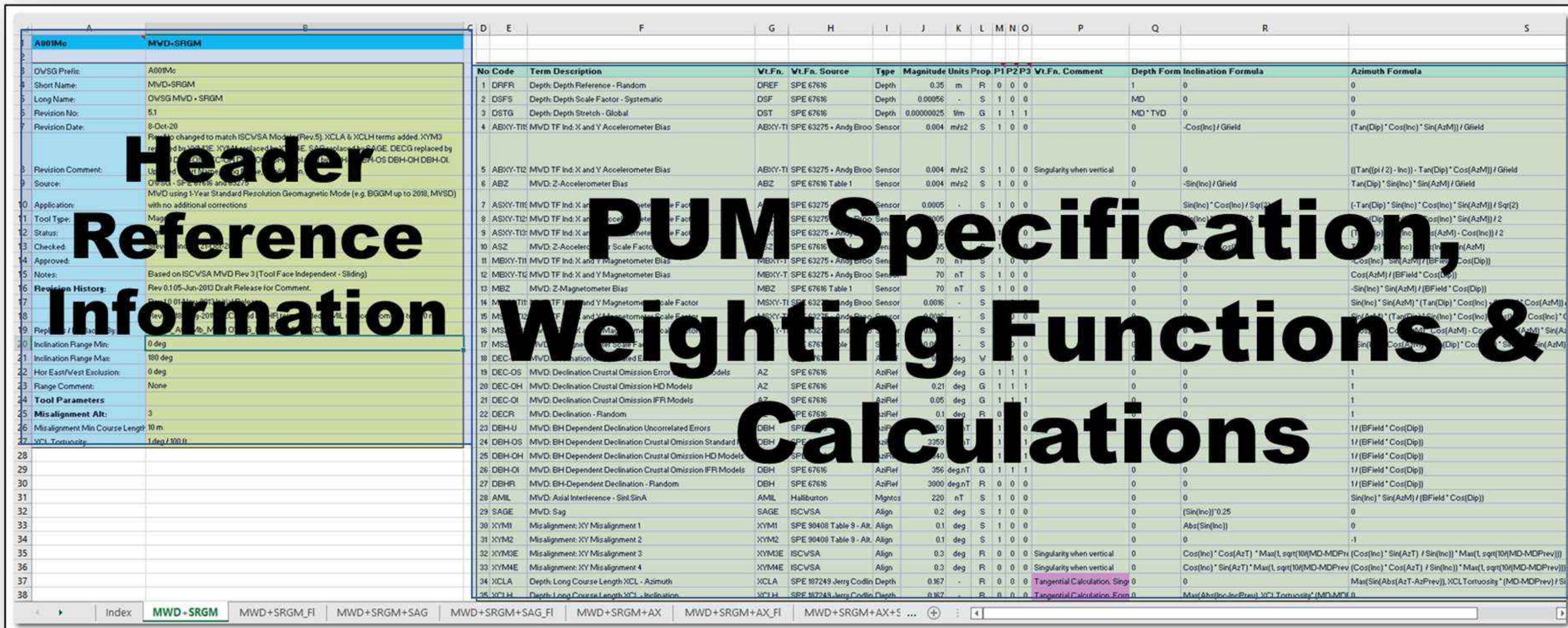
	OWSG Prefix	Short Name	Long Name
1	A001Mc	MWD+SRGM	OWSG MWD + SRGM
3	A002Mc	MWD+SRGM+SAG	OWSG MWD + SRGM + Sag Correction
5	A003Mc	MWD+SRGM+AX	OWSG MWD + SRGM + Axial Correction
7	A004Mc	MWD+SRGM+AX+SAG	OWSG MWD + SRGM + Axial Correction + Sag Correction
9	A005Mc	MWD+IFR1	OWSG MWD + IFR1
11	A006Mc	MWD+IFR1+AX	OWSG MWD + IFR1 + Axial Corr
13	A007Mc	MWD+IFR1+AX+SAG	OWSG MWD + IFR1 + Axial Corr + Sag Correction
15	A008Mc		
17	A009Mc		
19	A010Mc		
21	A011Mc		
23	A012Mc		
25	A013Mc		
27	A014Mc		
29	A015Mc		
31	A016Mc		
33	A017Mc		
35	A018Mb		
37	A019Gb		
39	A020Gb		
41	A021Gc		
43	A022Gb		
45	A023Gb		
47	A024Mb		
49	A025Mb		
51	A026Ua		
53	A027Ub		
55	A028Ub		
57	A029Ub		
59	A030Ua		

	OWSG Prefix	Short Name	Long Name
1	B001Mc	MWD+HRGM	OWSG MWD + HRGM
3	B002Mc	MWD+HRGM+AX	OWSG MWD + HRGM + Axial Correction
5	B003Mc	MWD+HRGM+AX+SAG	OWSG MWD + HRGM + Axial Correction + Sag Correction
7	B004Mc	MWD+HRGM+SAG	OWSG MWD + HRGM + Sag Correction
9	B005Mc	MWD+HRGM+SAG+MS	OWSG MWD + HRGM + Sag + Multi-Station Correction
11	B006Mc	MWD+LRGM	OWSG MWD + LRGM
13	B007Mc	MWD+LRGM+AX	OWSG MWD + LRGM + Axial Correction
15	B008Mc	MWD+LRGM+AX+SAG	OWSG MWD + LRGM + Axial Correction + Sag Correction
17	B009Mc	MWD+LRGM+SAG	OWSG MWD + LRGM + Sag Correction
19	B010Mc	EMS+IFR1+AX+SAG	OWSG EMS + IFR1 + Axial Corr + Sag Correction
21	B011Mc	EMS+IFR1+SAG	OWSG EMS + IFR1 + Sag Correction
23	B012Mc	EMS+IFR1+SAG+MS	OWSG EMS + IFR1 + Sag + Multi-Station Correction
25	B013Mc	EMS+HRGM	OWSG EMS + HRGM
27	B014Mc	EMS+HRGM+AX	OWSG EMS + HRGM + Axial Correction
29	B015Mc	EMS+HRGM+AX+SAG	OWSG EMS + HRGM + Axial Correction + Sag Correction
31	B016Mc	EMS+HRGM+SAG	OWSG EMS + HRGM + Sag Correction
33	B017Mc	EMS+LRGM	OWSG EMS + LRGM
35	B018Md	EMS+LRGM+AX	OWSG EMS + LRGM + Axial Correction
37	B019Md	EMS+LRGM+AX+SAG	OWSG EMS + LRGM + Axial Correction + Sag Correction
39	B020Mc	EMS+LRGM+SAG	OWSG EMS + LRGM + Sag Correction
41	B021Ga	FINDS	OWSG BHI Ferranti FINDS
42	B022Ua	BLIND+TREND	OWSG BLIND+TREND

https://www.iscwsa.net/error-model-documentation/

Example: A001Mc MWD+SRGM

https://www.iscwsa.net/error-model-documentation/
ISCWSA_Generic_Toolcodes SetA Rev5-1 (updated 23/9/22)
Excel Workbook Tab: MWD+SRGM



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MWD PUM Survey Corrections

Axial (AX)

Sag

Multi-Station Analysis (MSA or MS)

Axial + Sag

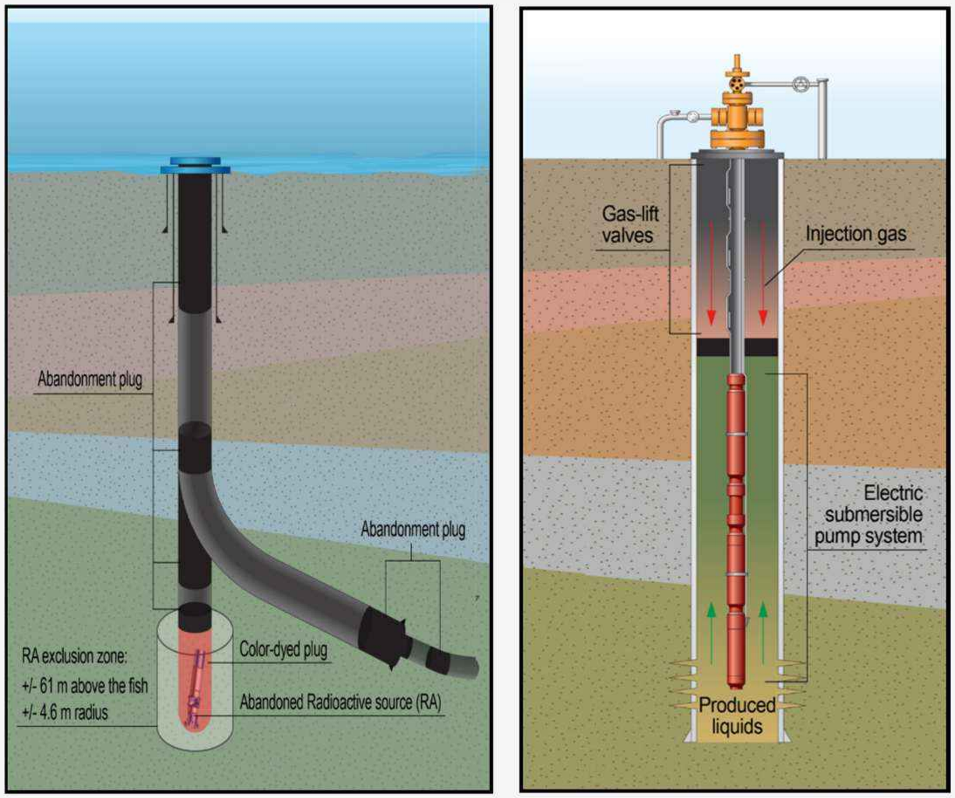
Multi-Station + Sag

Depth Corrections

Advanced MWD Corrections

- Ground Shot (GS) IFR
- Advanced Multi-Station (AMSA)
  - All BHA's for a Wellbore
  - All BHA's for all wellbores on a well (Includes Sidetracks / By-Pass Wellbores)
  - All BHA's for all wellbores on a Site/Location/Pad

Offset Well Environment



MASD Management Principles (SPE-187073-PA)

Offset Well Environment

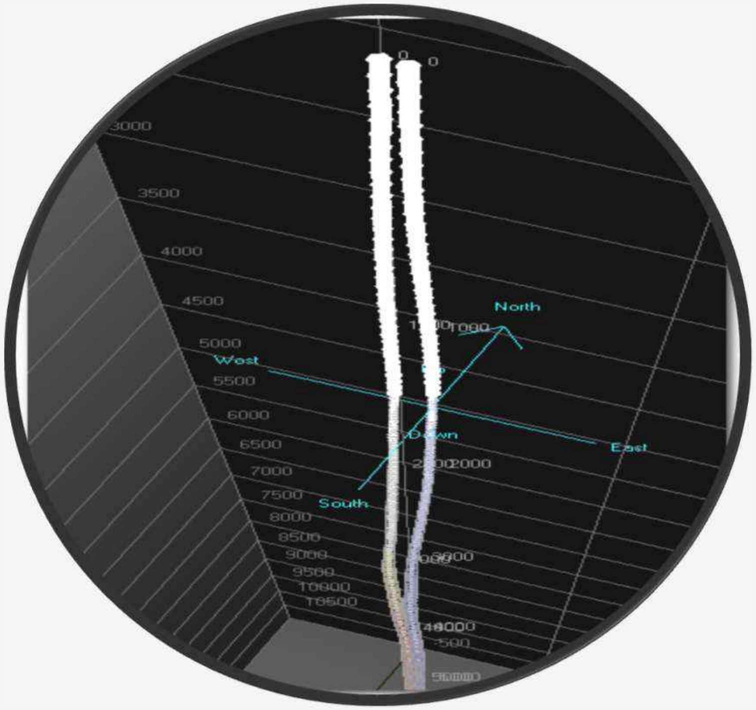
- Status
- Completion Type
- Wellbore Fluids
- Lifting Mechanism

Artificial Lift

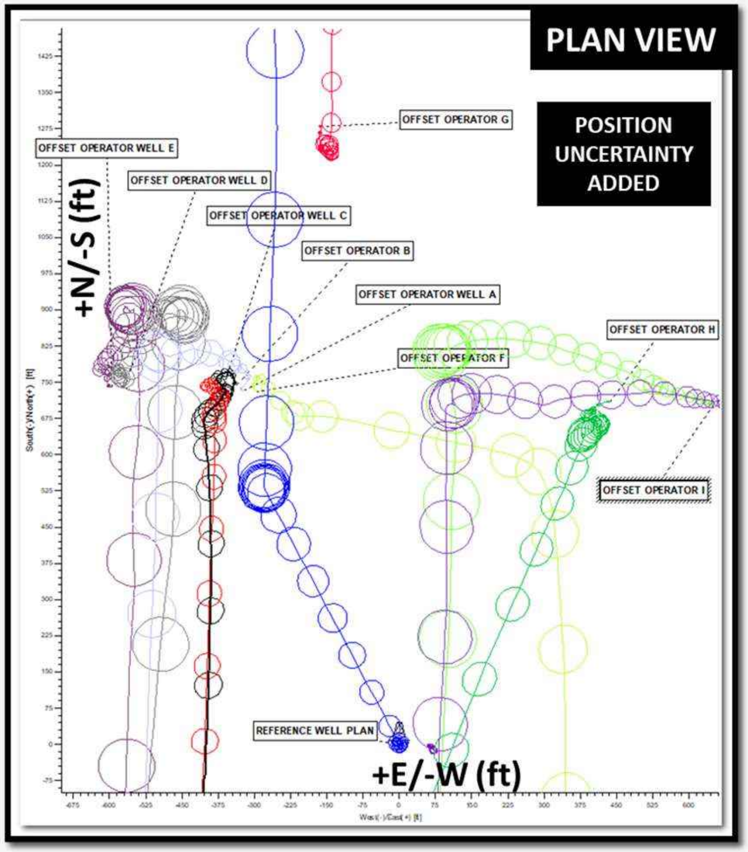
- Rod Pump
- Progressive Cavity
- Hydraulic Pump
- Gas Lift (GL)
- Electric Submersible Pump (ESP)
- Hybrid Lift System
  - GL & ESP
  - ESP & Natural Flow

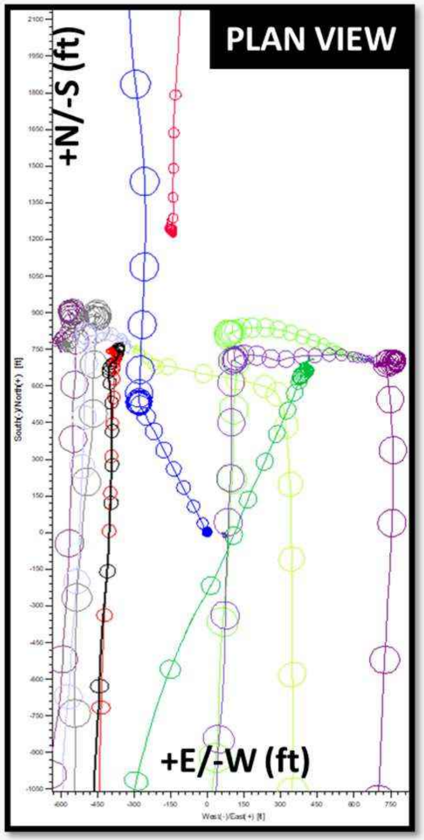
Case Study

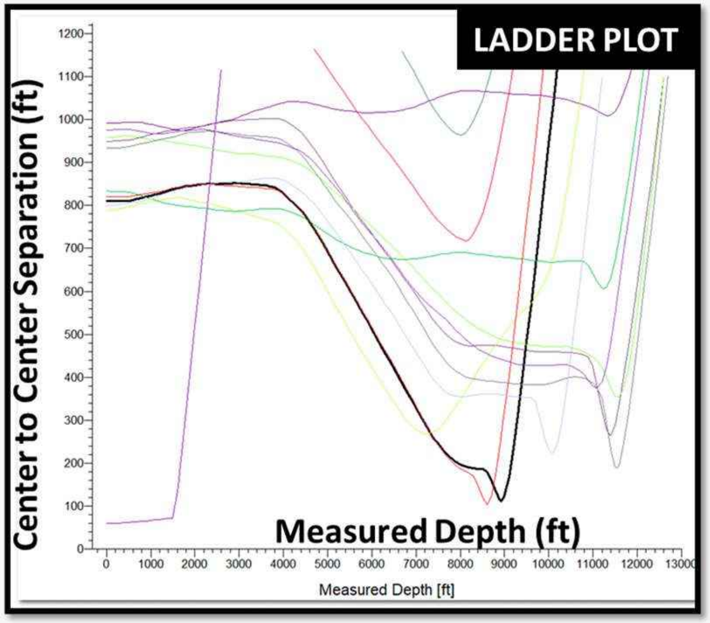
Offset Operator Close Approach



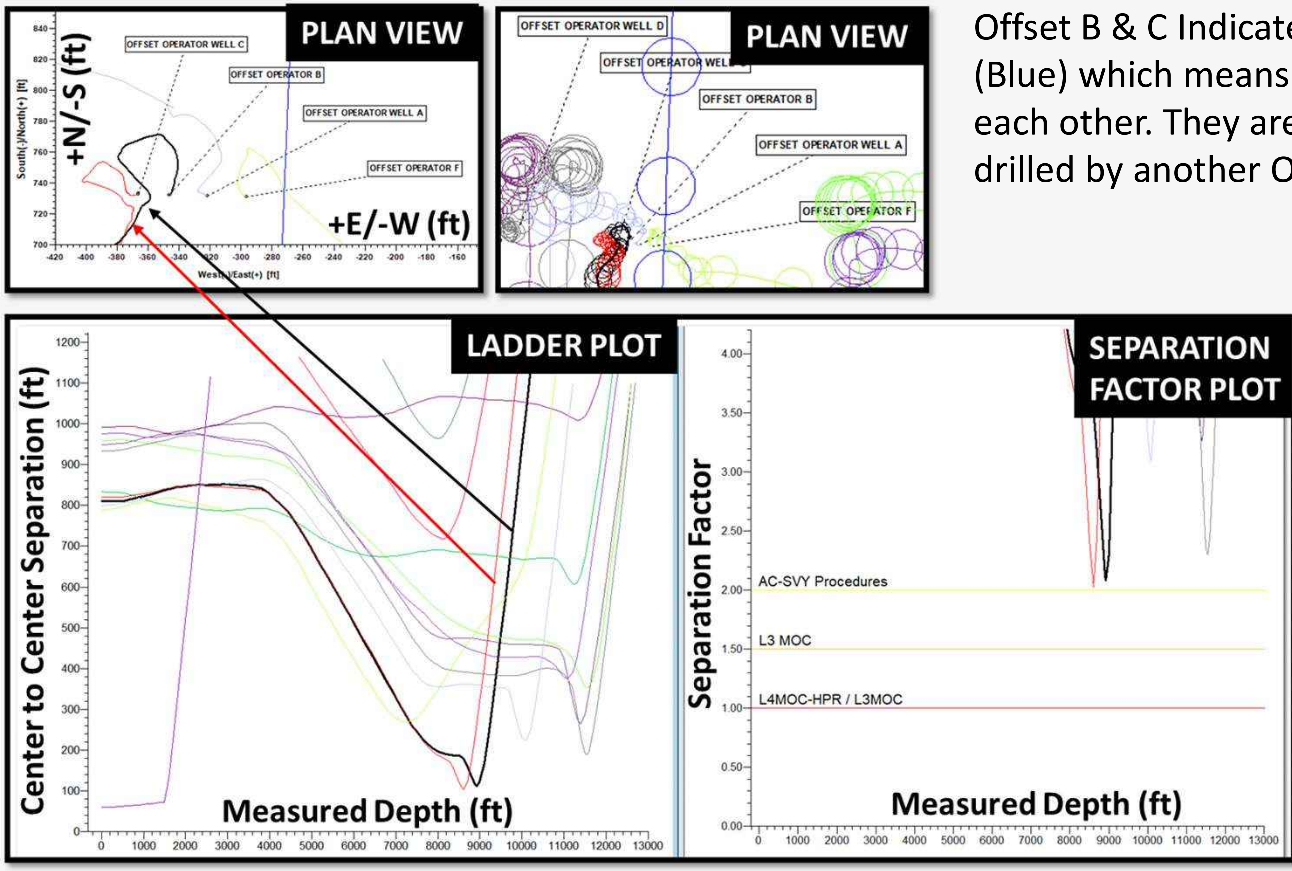
Safe Separation Plots –
Ladder & Separation Factor



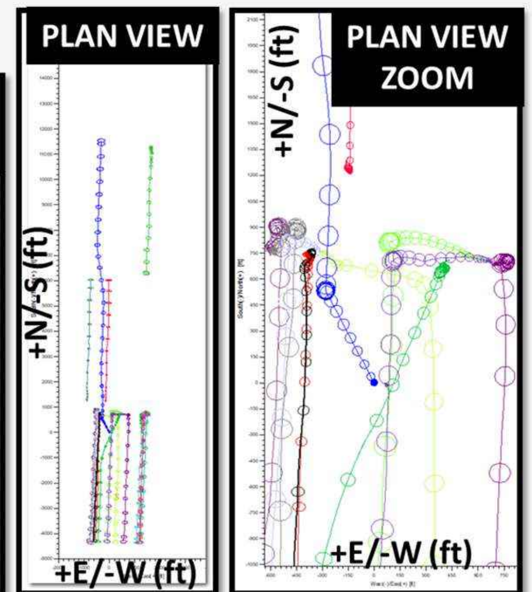




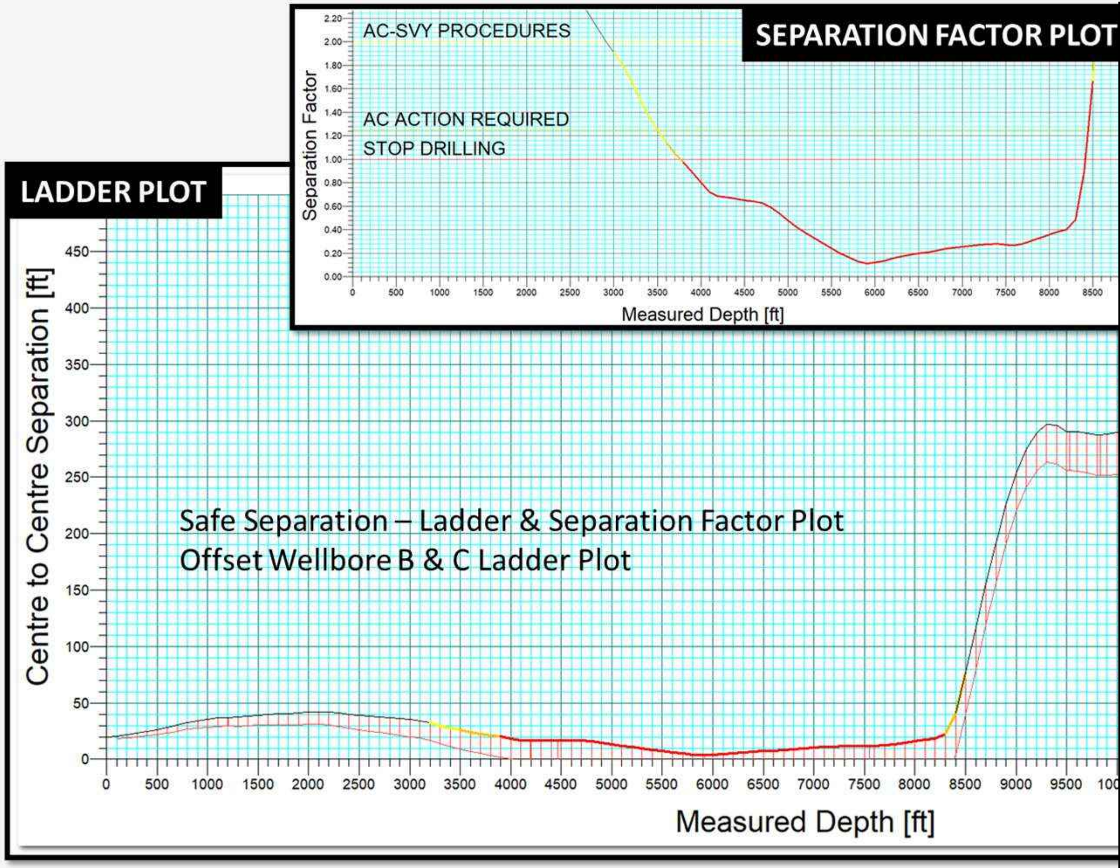
Safe Separation Plots – Ladder & Separation Factor

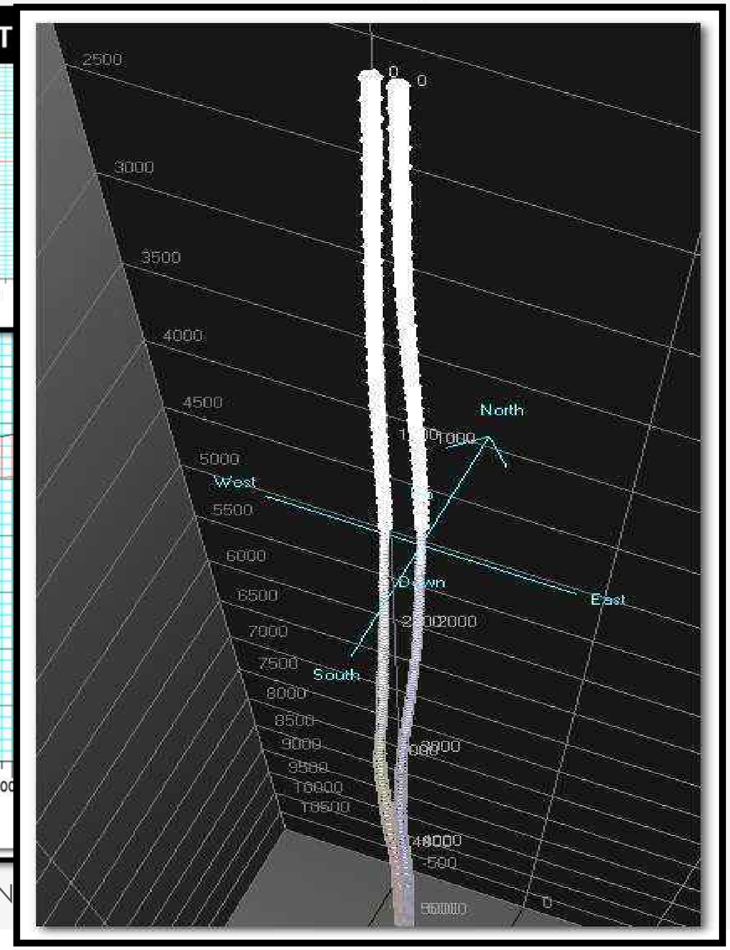


Offset B & C Indicates similar distance from planned well (Blue) which means these wellbore are very close from each other. They are neighboring slots on a four well pad drilled by another Operator.



Safe Separation Plots – Ladder & Separation Factor

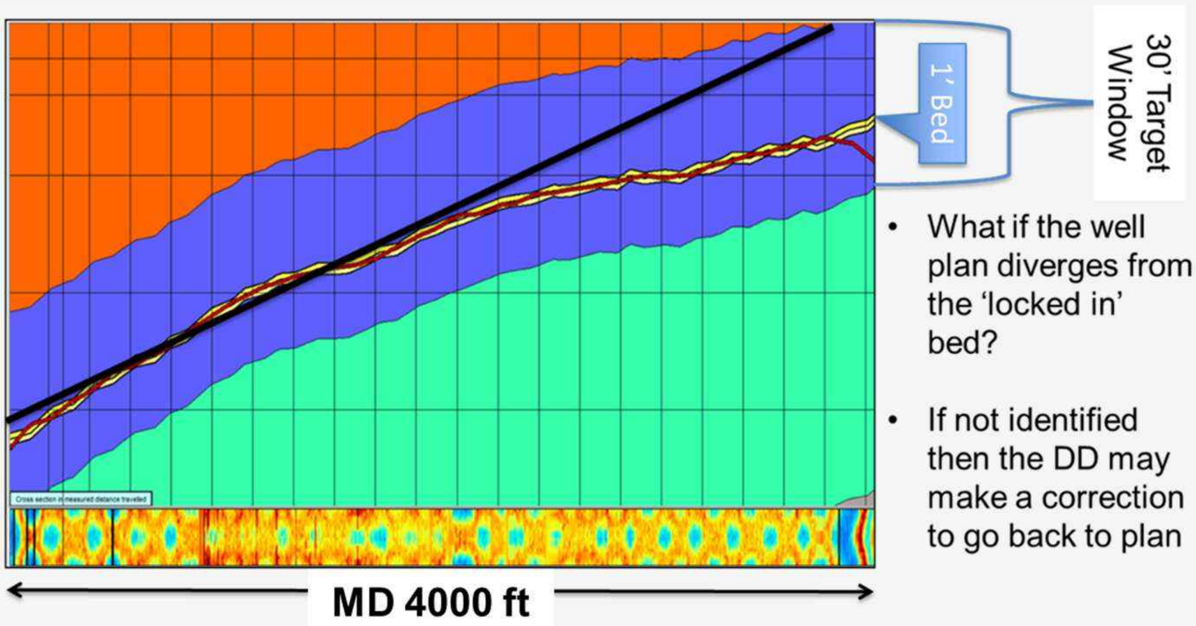




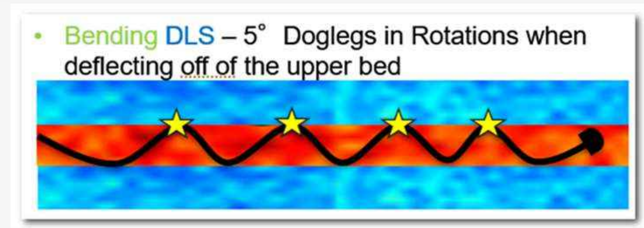
Case Study

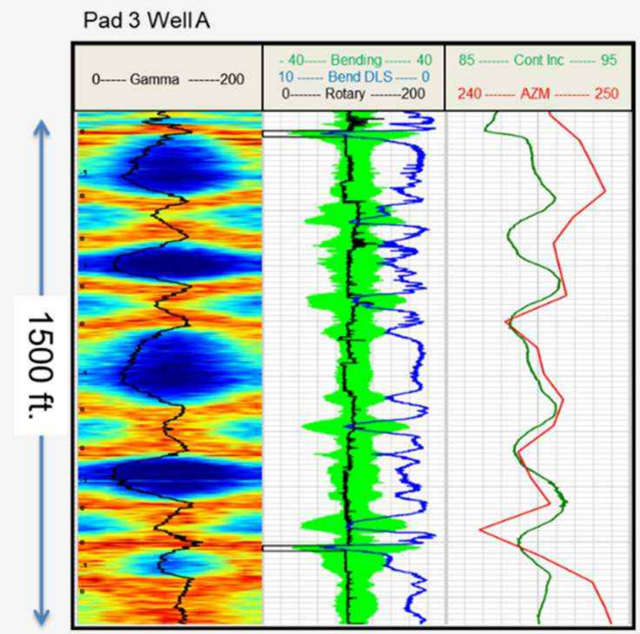
Lateral Undulations
Key Performance Indicators
Steerable Motor Curve
Lateral Tortuosity

Lateral Undulation Period - TVD Accuracy



- What if the well plan diverges from the 'locked in' bed?
- If not identified then the DD may make a correction to go back to plan

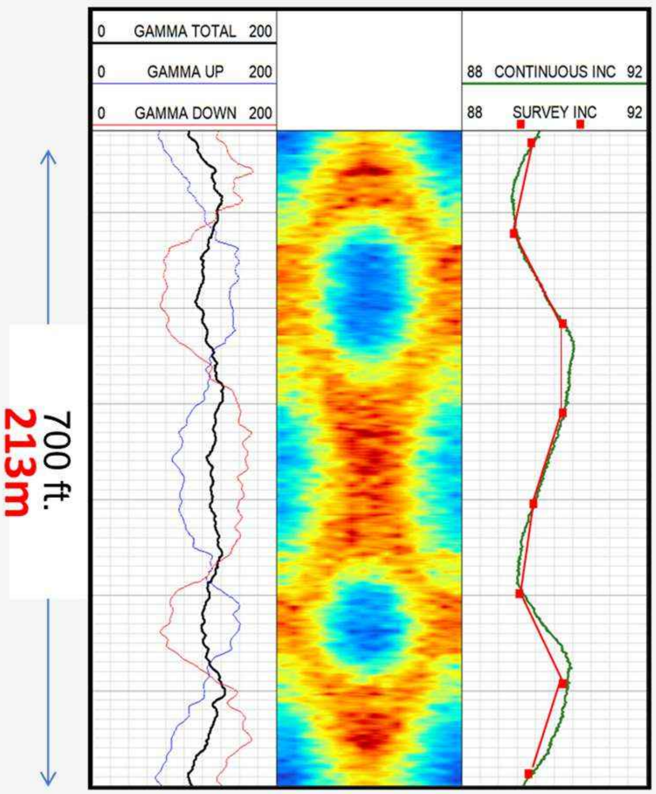




Viens, Christopher , Clark, Tyler , Lightfoot, Jonathan , and Carlos Mercado. "**Real-Time Downhole Data Resolves Lithology Related Drilling Behavior."** Paper presented at the IADC/SPE Drilling Conference and Exhibition, Fort Worth, Texas, USA, March 2018. doi: https://doi.org/10.2118/189697-MS

Lateral Undulation Period - TVD Accuracy

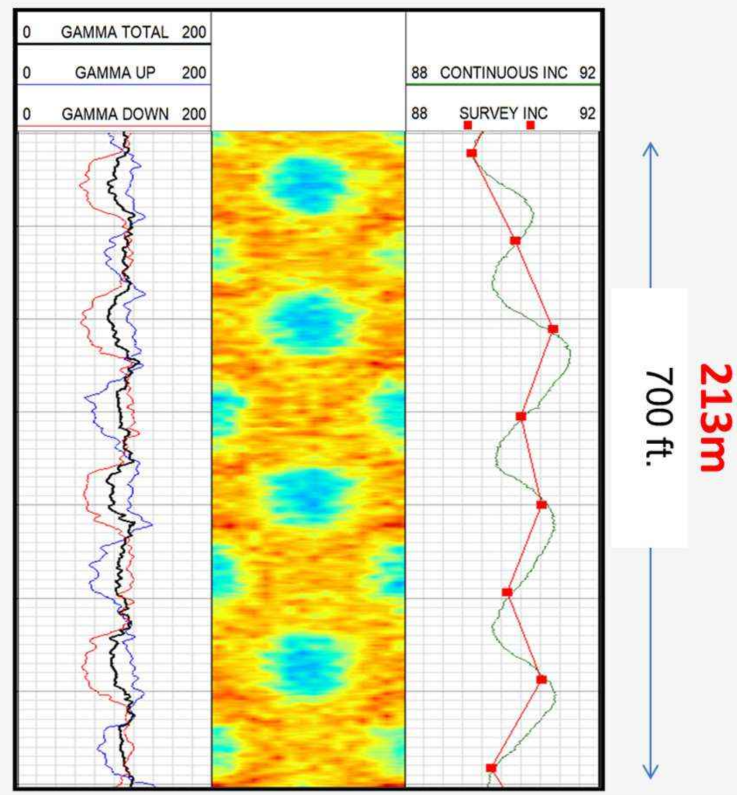
Pad 2 Well A



Left: 90’ (27m) surveys adequate to due large period of oscillation

Right: 90’(27m) surveys inadequate to short oscillation period

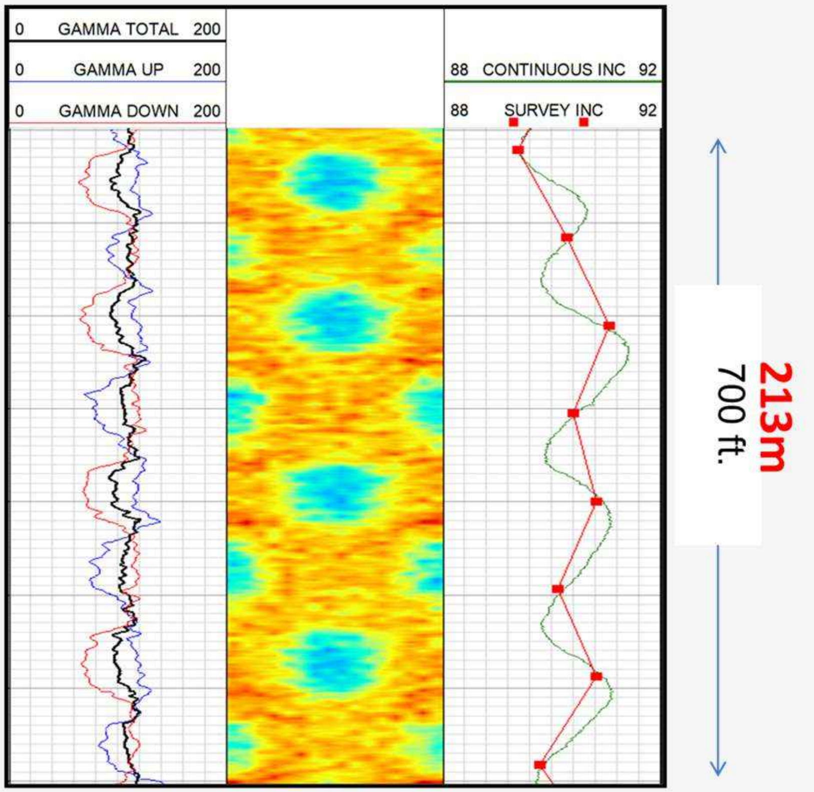
Pad 1 Well A



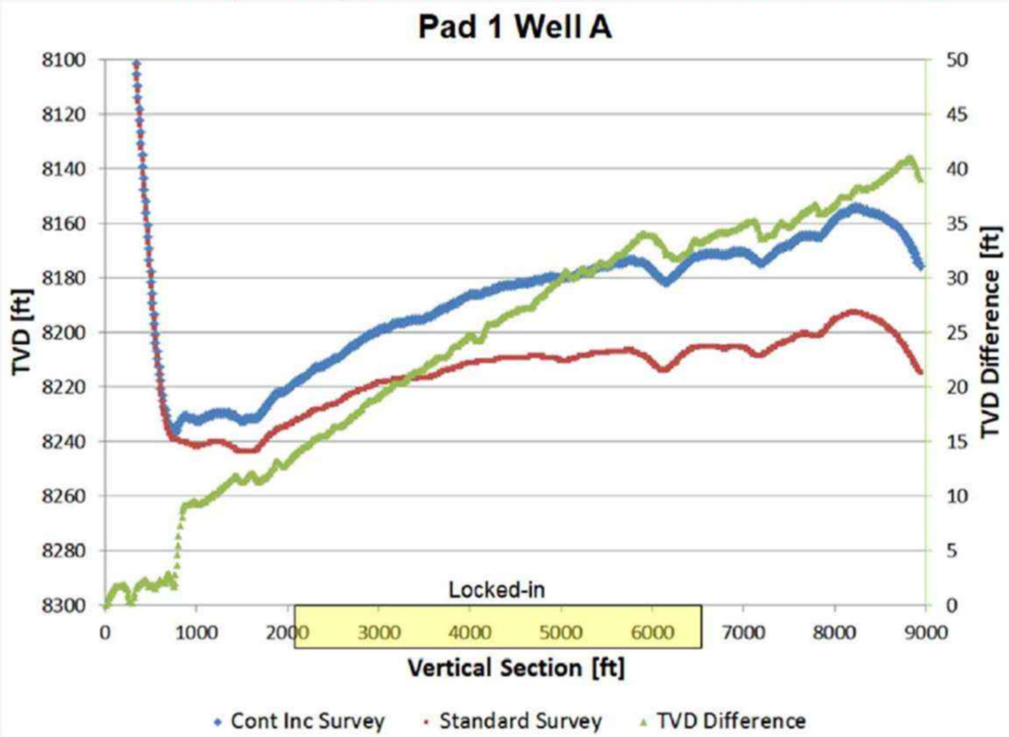
IADC/SPE-189697-MS

Lateral Undulation Period - TVD Accuracy

Pad 1 Well A

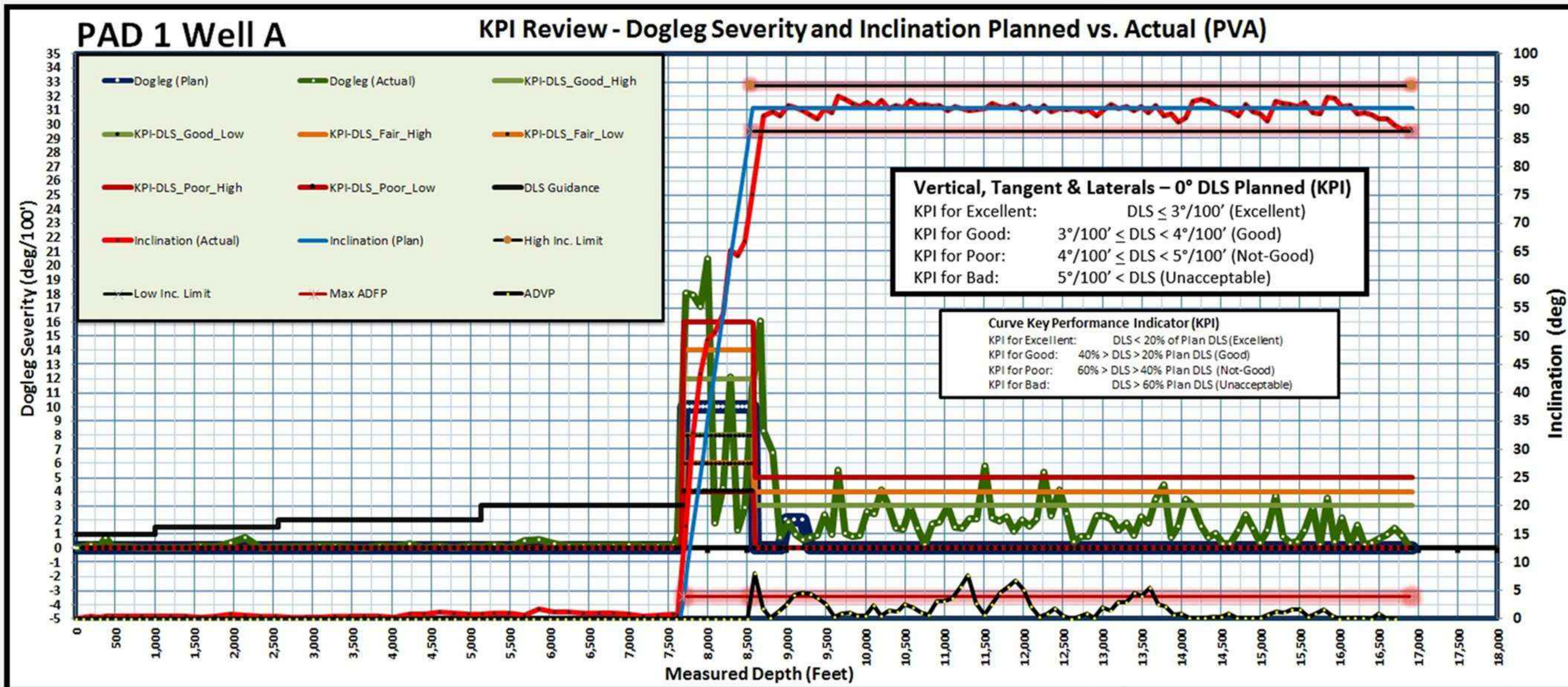


40ft (12.2m) Delta in TVD at the end of the lateral



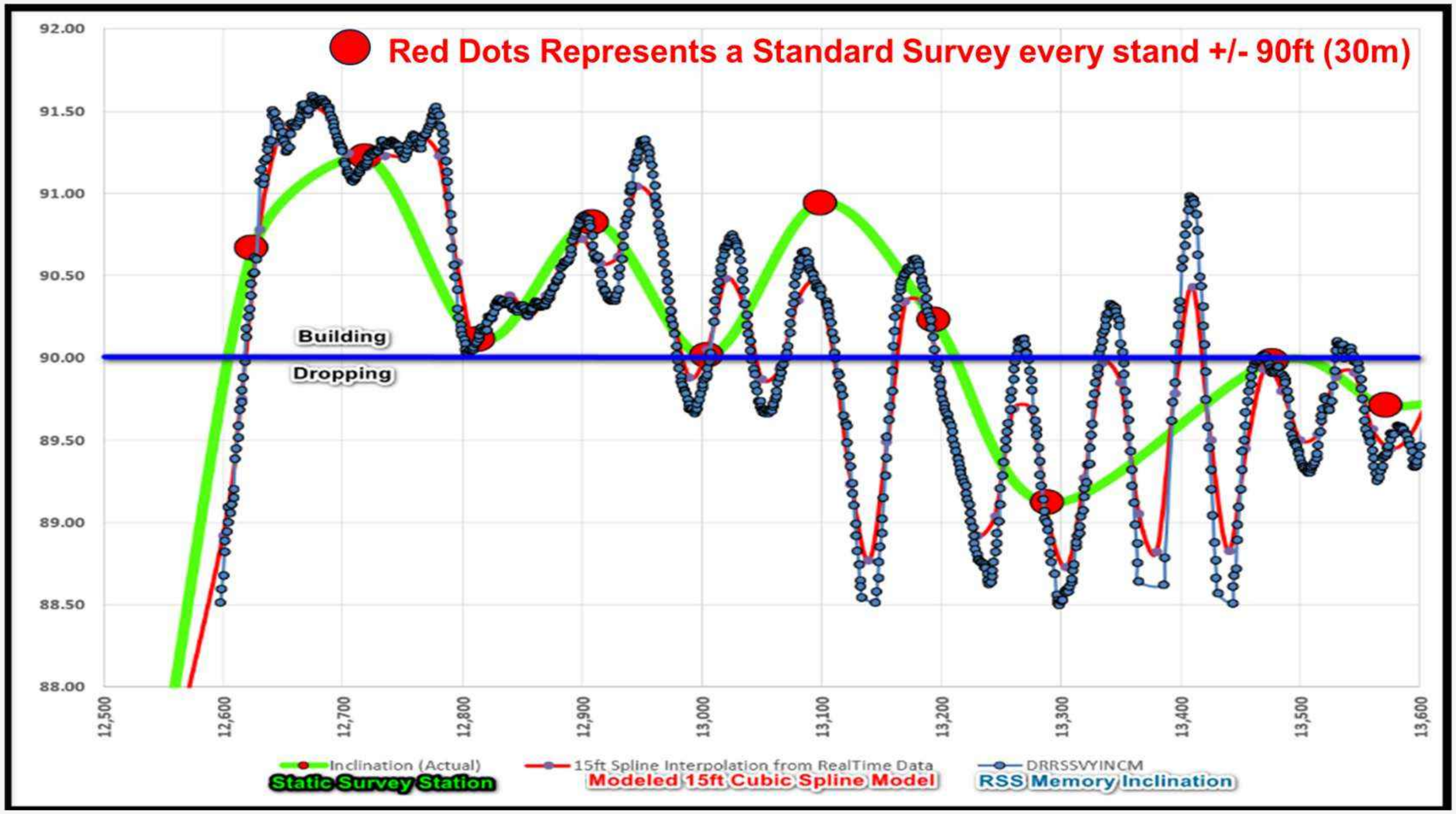
IADC/SPE-189697-MS

Directional Drilling Key Performance Indicators



IADC/SPE-189697-MS

Lateral Undulation Period – RSS Example



Slide / Rotate Effect – Curve TVD Accuracy

Starting Survey = 10,000 ft (3048m) MD

Inclination 30° (9m) & Azimuth 45°

- **Case A: Slide 30 ft (9m) then Rotate 70 ft (21m) @ 10°/100'**
- **Case B: Rotate 70 ft (21m) then Slide 30 ft (9m) @ 10°/100' (30m)**

Final Inclination 40° & Final Azimuth 45°

Case A: Survey at 10,030' & at 10,100'

- *DLS 16.7°/100 ft & TVD 9,082.6 ft (2768.4m)*

Case B: Survey at 10,070' & at 10,100'

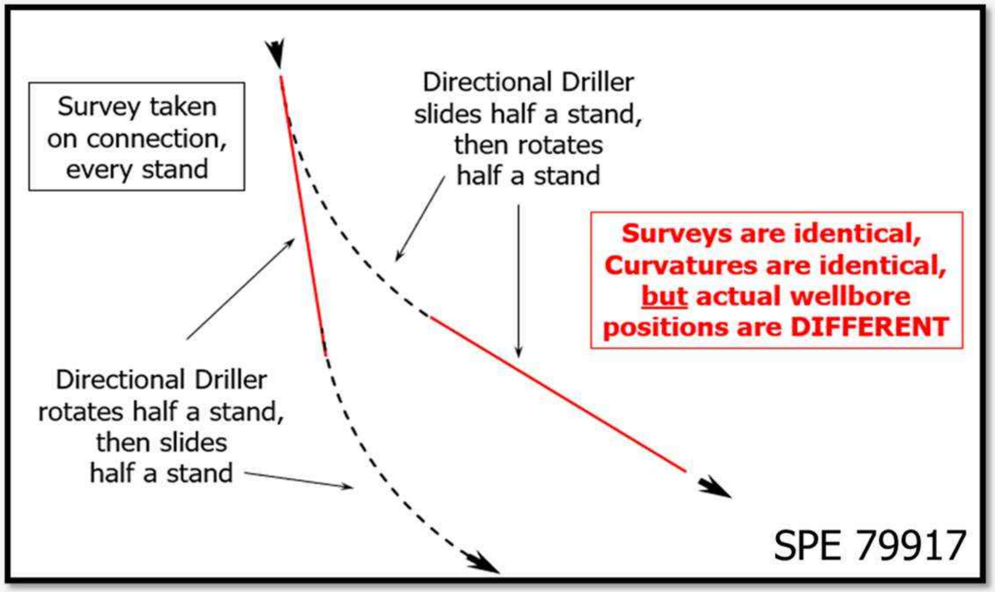
- *DLS 16.67°/100 ft & TVD 9,085.9 ft (2769.4m)*

Case C: Survey only at 10,100'

- *DLS 5°/100 ft & TVD 9,084 ft (2768.8m)*

Case A vs. Case B have a TVD difference 3.29 ft (1m) over only 100 ft of MD (1-Stand)

A total of 29.6 ft of TVD Difference between Case A and Case B



Consider the full curve build up section from Vertical to Horizontal @ 10°/100 ft (30m). This difference represents 900 ft ((274m) MD which equals 29.6 ft (9m) of TVD Difference in the Landing Depth

Directional Drilling Key Performance Indicators

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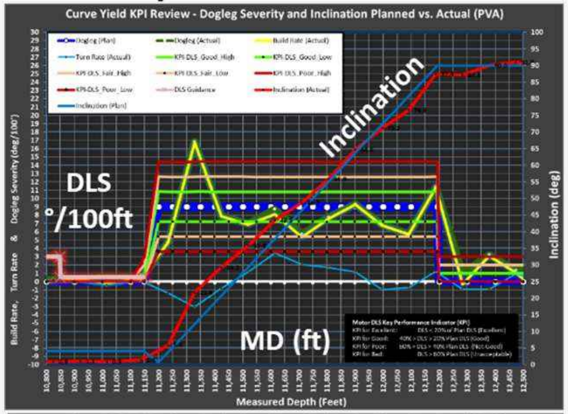
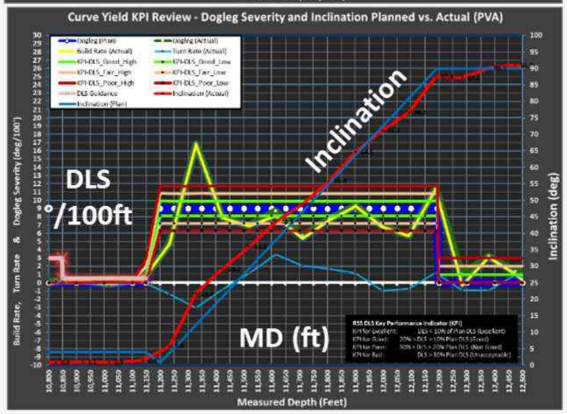
Directional Drilling Dogleg Severity Control Key Performance Indicators

Directional Tools & Hole Section Type	Excellent	Good	Not-Good	Unacceptable RCRA Required
Vertical Intervals	DLS ≤ 2	2 < DLS ≤ 3	3 < DLS ≤ 4	4 < DLS
Tangent Intervals	DLS ≤ 2	2 < DLS ≤ 3	3 < DLS ≤ 4	4 < DLS
Lateral Intervals	DLS ≤ 2	2 < DLS ≤ 3	3 < DLS ≤ 4	4 < DLS
Directional Motor Steering Interval	DLS < +/- 20% of Planned DLS	Between 20-40% of Planned DLS	Between 40-60% of Planned DLS	DLS > +/- 60% of Planned DLS
Directional RSS Steering Interval	DLS < +/- 10% of Planned DLS	Between 10-20% of Planned DLS	Between 20-30% of Planned DLS	DLS < +/- 30% of Planned DLS

Offset Operator Motor Curve



Motor Curve KPI Chart 20-40-60%



RSS Curve KPI Chart 10-20-30%

Slide / Rotate Effect – Curve TVD Accuracy

Case A: Slide 33 ft, Rotate 33 ft and Slide 33 ft from 0° to 90° Inc.

Case A Directional Survey

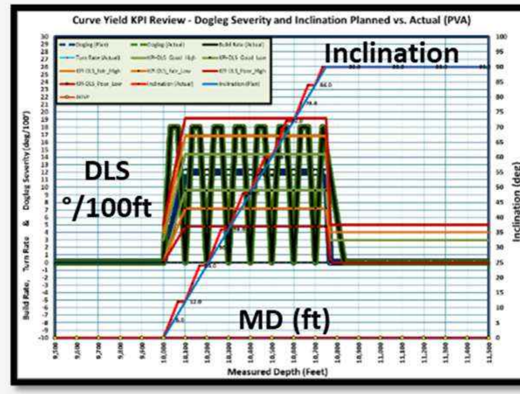
MD	Inclination (Actual)	Azimuth (Actual)	Course Length	TVD	Vertical Section	+N / - S	+E / -W	Colousre Distance	@ AZM	Dogleg (Actual)	Build Rate (Actual)	Turn Rate (Actual)
0.00	0.00	45.00	******	0.00	0.00	0.00	0.00	0.00		0.00	*****	*****
10,000.00	0.00	45.00	10000.00	10000.00	0.00	0.00	0.00	0.00	45.00	0.00	0.00	0.00
10,033.33	6.00	45.00	33.33	10033.27	1.26	1.23	1.23	1.75	45.00	18.00	18.00	0.00
10,066.67	12.00	45.00	33.33	10066.18	5.03	4.92	4.92	6.96	45.00	18.00	18.00	0.00
10,100.00	12.00	45.00	33.33	10098.78	10.05	9.82	9.82	13.89	45.00	0.00	0.00	0.00
10,133.33	18.00	45.00	33.33	10130.97	16.29	15.92	15.92	22.51	45.00	18.00	18.00	0.00
10,166.67	24.00	45.00	33.33	10162.07	24.92	24.36	24.36	34.45	45.00	18.00	18.00	0.00
10,200.00	24.00	45.00	33.33	10192.52	34.73	33.95	33.95	48.01	45.00	0.00	0.00	0.00
10,233.[illegible]	30.00	45.00	33.33	[illegible]222.21	45.67	[illegible]64	44.64	[illegible]13	[illegible]5.00	18.00	18.00	0.00
10,26[illegible]66	36.0[illegible]	45.00	33.33	10250.1[illegible]	58.8[illegible]	[illegible]47	[illegible]47	[illegible]28	45.00	18.[illegible]	1[illegible]	0.00
10,3[illegible]00	[illegible]6[illegible]	45.00	33.33	[illegible]27[illegible]12	7[illegible]98	[illegible]33	71.[illegible]	1[illegible]87	[illegible]5.00	[illegible].00	0.00	0.00
10,33[illegible]33	42.00	45.00	33.33	[illegible]30[illegible]01	8[illegible]15	[illegible]1[illegible]	86.[illegible]	1[illegible]84	4[illegible]00	[illegible]8.00	18.00	0.00
10,366.[illegible]	48.[illegible]	45.00	33.33	[illegible]32[illegible]57	105.[illegible]	1[illegible]2.81	102.[illegible]	1[illegible].40	[illegible]5.00	[illegible]8.00	[illegible]	0.00
10,400.00	48.00	45.00	33.33	10348.87	123.11	120.33	120.33	170.17	45.00	0.00	0.00	0.00
10,433.33	54.00	45.00	33.33	10369.84	141.84	138.64	138.64	196.06	45.00	18.00	18.00	0.00
10,466.66	60.00	45.00	33.33	10387.99	162.06	158.40	158.40	224.01	45.00	18.00	18.00	0.00
10,500.00	60.00	45.00	33.33	10404.66	182.94	178.81	178.81	252.87	45.00	0.00	0.00	0.00
10,533.33	66.00	45.00	33.33	10419.78	204.42	199.80	199.80	282.56	45.00	18.00	18.00	0.00
10,566.66	72.00	45.00	33.33	10431.72	226.92	221.79	221.79	313.67	45.00	18.00	18.00	0.00
10,599.99	72.00	45.00	33.33	10442.02	249.86	244.21	244.21	345.37	45.00	0.00	0.00	0.00
10,633.33	78.00	45.00	33.33	10450.64	273.14	266.97	266.97	377.55	45.00	18.00	18.00	0.00
10,666.66	84.00	45.00	33.33	10455.86	296.94	290.24	290.24	410.46	45.00	18.00	18.00	0.00
10,699.99	84.00	45.00	33.33	10459.34	320.93	313.68	313.68	443.61	45.00	0.00	0.00	0.00
10,733.33	90.00	45.00	33.33	10461.08	345.00	337.20	337.20	476.88	45.00	18.00	18.00	0.00

Case B: Survey Every 100 ft from 0° to 90° Inc. (16 ft TVD Delta)

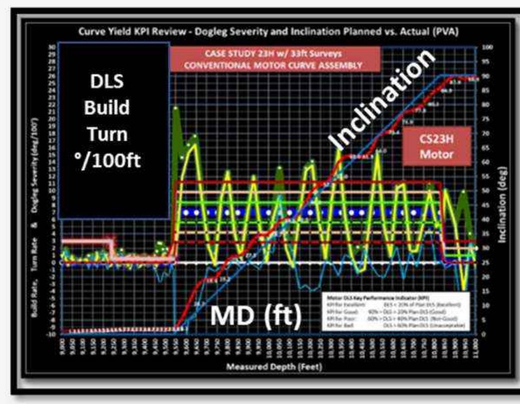
Case B Directional Survey

MD (Plan)	Inclination (Plan)	Azimuth (Plan)	Course Length	TVD	Vertical Section	+N / - S	+E / -W	Closure	@ AZM	Dogleg (Plan)	Build Rate	Turn Rate
0.00	0.00	0.00	******	0.00	0.00	0.00	0.00	0.00		0.00	*****	*****
10,000.0[illegible]	0.00	45.00	[illegible]0000.00	10[illegible]0.00		0.[illegible]0	0.00	[illegible]00		0.00	0.00	0.45
10,100.[illegible]	[illegible]00	[illegible]5.00	100.00	10[illegible]9.2[illegible]	[illegible]7.55	7[illegible]8	[illegible]	1[illegible]43	45.0[illegible]	[illegible]	[illegible]	[illegible].00
10,200.[illegible]	[illegible]00	[illegible].00	100.00	10[illegible]4.[illegible]	[illegible]9.[illegible]	29[illegible]19	29.1[illegible]	4[illegible]28	[illegible]5.0[illegible]	[illegible]2.00	[illegible]	0.00
10,300.[illegible]	3[illegible]00	45.00	[illegible]00.00	10[illegible]0.6[illegible]	65.[illegible]	64[illegible]8	64.4[illegible]	9[illegible]19	[illegible].0[illegible]	[illegible]2.00	[illegible].00	0.00
10,400.00	48.00	45.00	100.00	10354.83	114.29	111.71	111.71	157.98	45.00	12.00	12.00	0.00
10,500.00	60.00	45.00	100.00	10413.50	172.71	168.81	168.81	238.73	45.00	12.00	12.00	0.00
10,600.00	72.00	45.00	100.00	10454.10	238.68	233.29	233.29	329.92	45.00	12.00	12.00	0.00
10,700.00	84.00	45.00	100.00	10474.85	309.32	302.33	302.33	427.56	45.00	12.00	12.00	0.00
10,750.00	90.00	45.00	50.00	10477.46	345.42	337.62	337.62	477.46	45.00	12.00	12.00	0.00

SIMULATED EXAMPLE



ACTUAL EXAMPLE

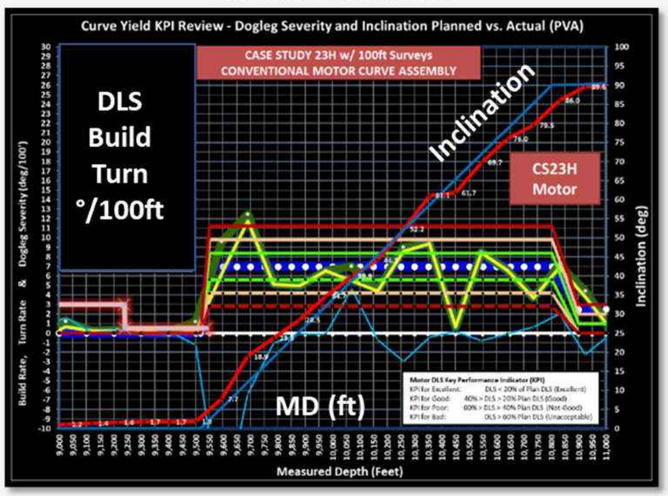


Case Study - Steerable Motor Curve

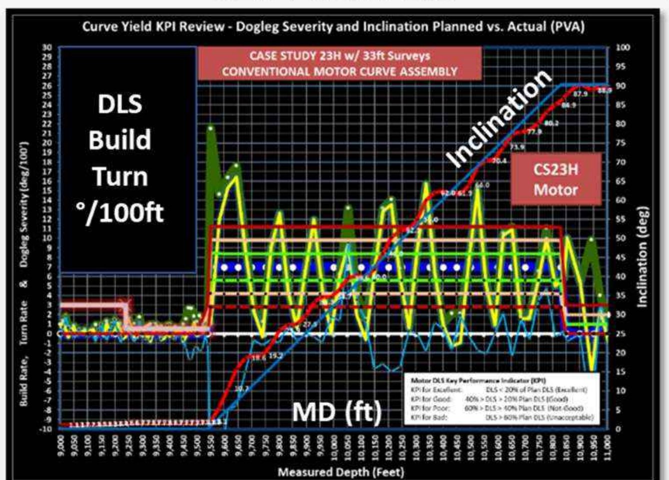
- **Survey Frequency is Important for Medium Radius Curves (Build Section)**
- **If slide % is less, consider surveying twice a stand or every joint**
- **When sliding > 75 ft (27m) per Stand survey position is less prone to TVD error**

Takeaway: Use a Smaller Bent Housing and Slide more footage in the Curve!

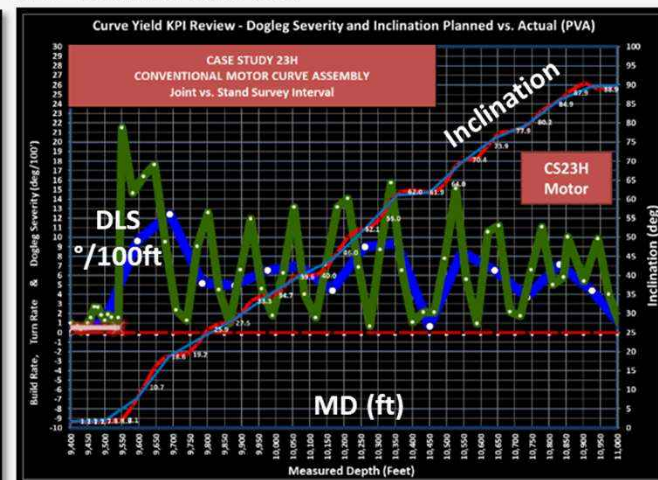
96 FT SURVEYS



32 FT SURVEYS



DLS COMPARISON

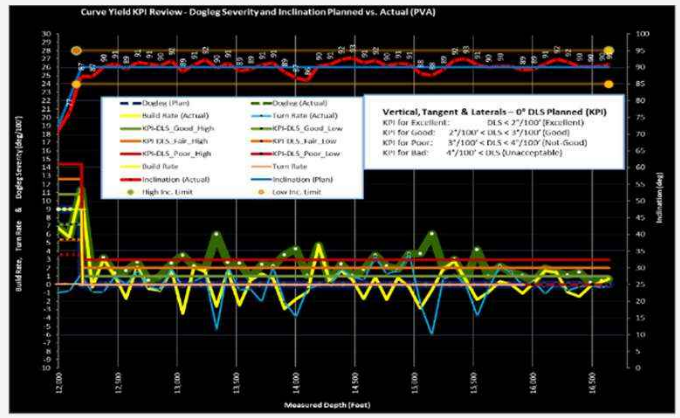


Lateral Tortuosity KPI – Case Study

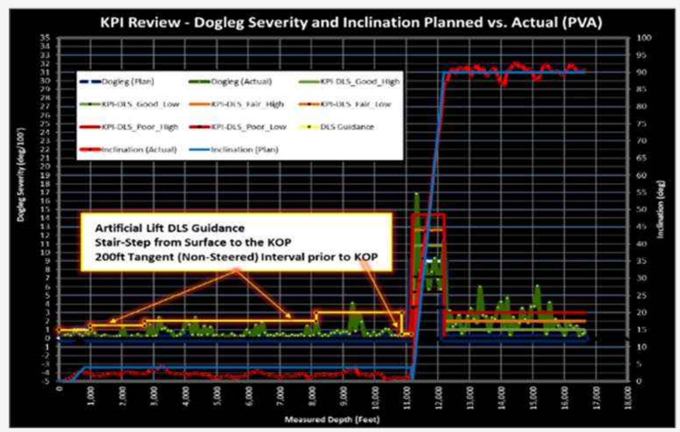
Establish KPI's based on expected maximum dogleg severity

- **Surface**
- **Tangent**
- **Curve**
- **Lateral**

Directional Drilling Dogleg Severity Control Key Performance Indicators				
Directional Tools & Hole Section Type	Excellent	Good	Not-Good	Unacceptable RCRA Required
Vertical Intervals	DLS ≤ 2	2 < DLS ≤ 3	3 < DLS ≤ 4	4 < DLS
Tangent Intervals	DLS ≤ 2	2 < DLS ≤ 3	3 < DLS ≤ 4	4 < DLS
Lateral Intervals	DLS ≤ 2	2 < DLS ≤ 3	3 < DLS ≤ 4	4 < DLS
Directional Motor Steering Interval	DLS < +/- 20% of Planned DLS	Between 20-40% of Planned DLS	Between 40-60% of Planned DLS	DLS > +/- 60% of Planned DLS
Directional RSS Steering Interval	DLS < +/- 10% of Planned DLS	Between 10-20% of Planned DLS	Between 20-30% of Planned DLS	DLS < +/- 30% of Planned DLS

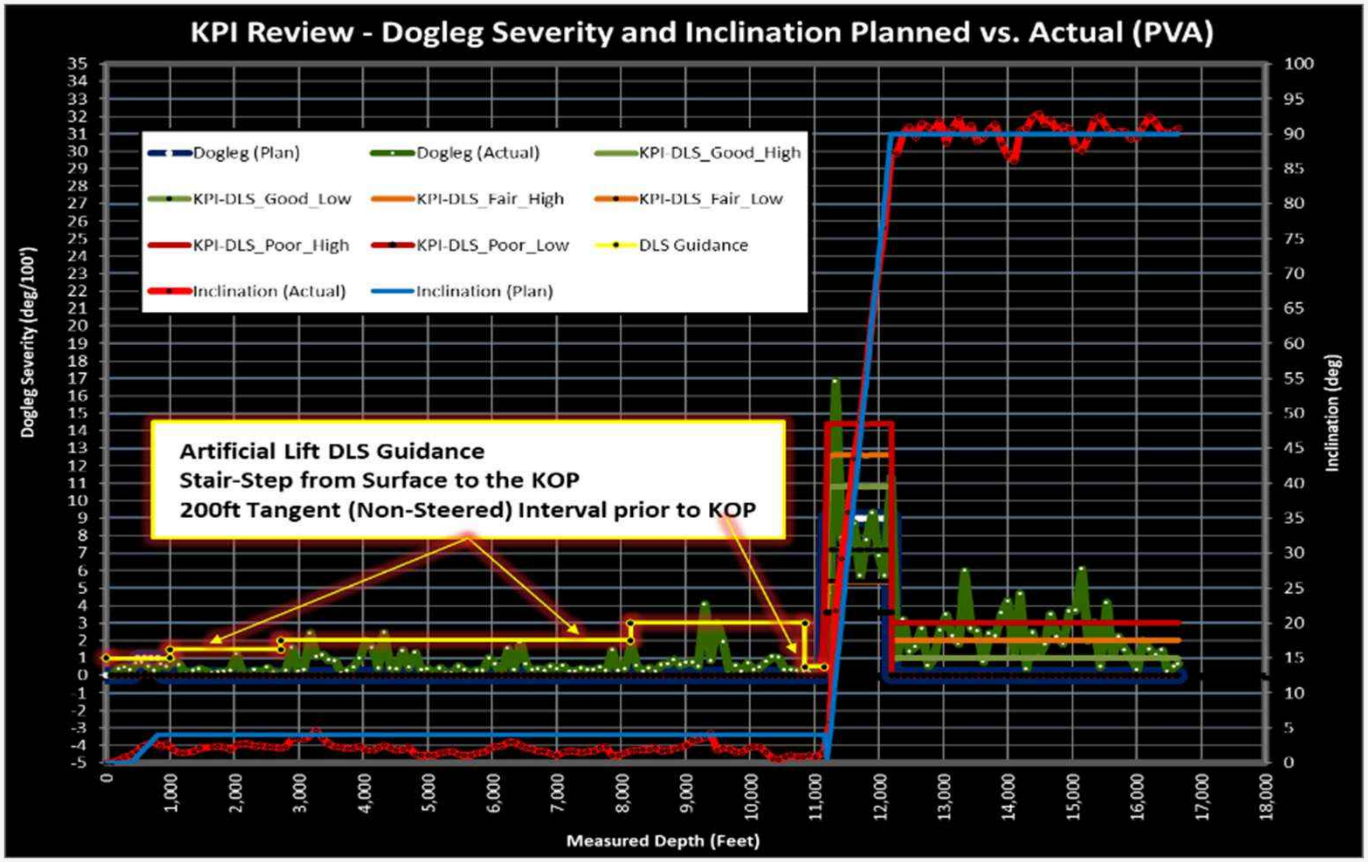


Lateral DLS Build & Turn Rate KPI Chart With Inclination +/- Allowable Deviation from Plan



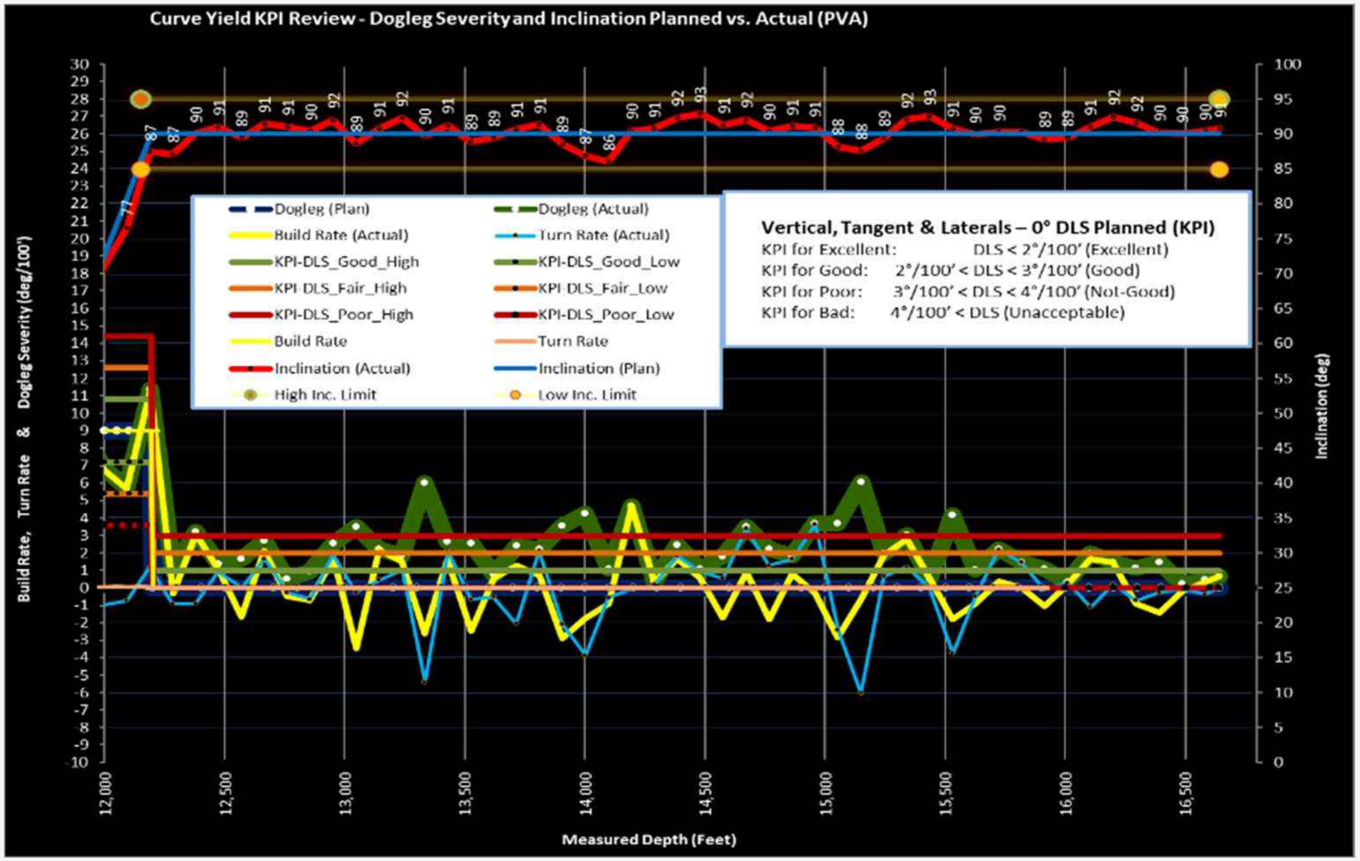
Surface to TD DLS KPI Chart with Artificial Lift DLS Guidance for Surface & Intermediate

Lateral Tortuosity KPI – Case Study



Surface to TD DLS KPI Chart with Artificial Lift DLS Guidance for Surface & Intermediate

Lateral Tortuosity KPI – Case Study



Lateral DLS Build & Turn Rate KPI Chart With Inclination +/- Allowable Deviation from Plan

Curve Lateral Tortuosity KPI - RSS Examples

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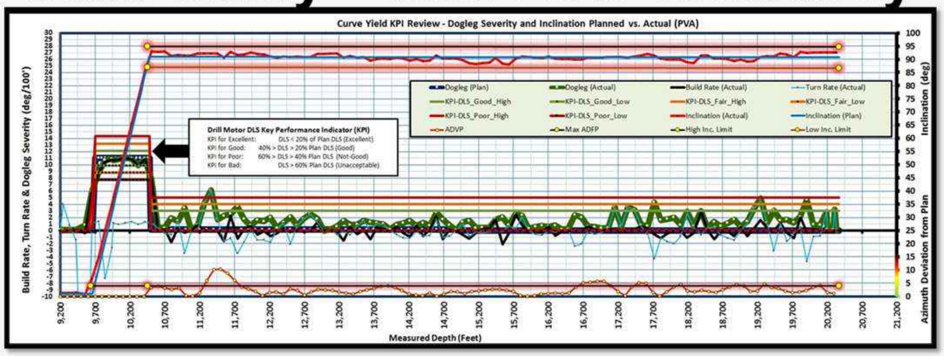
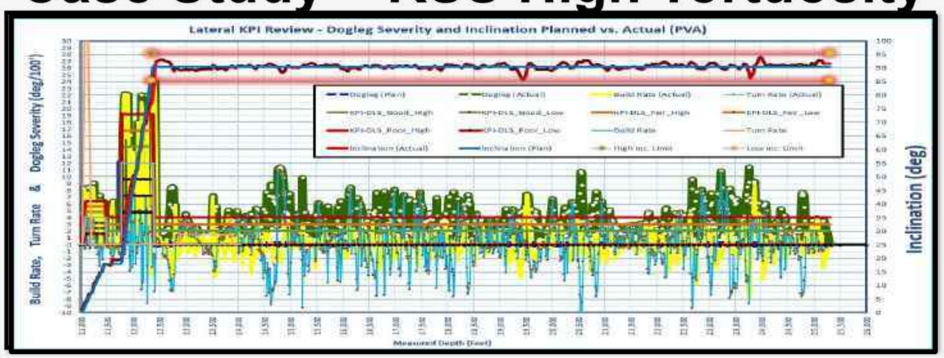
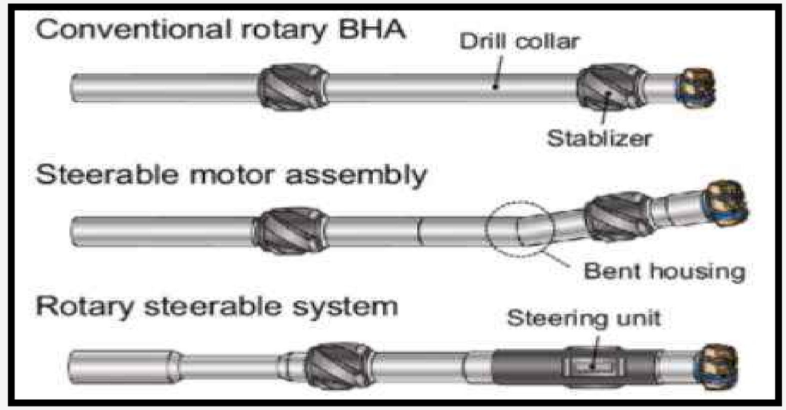
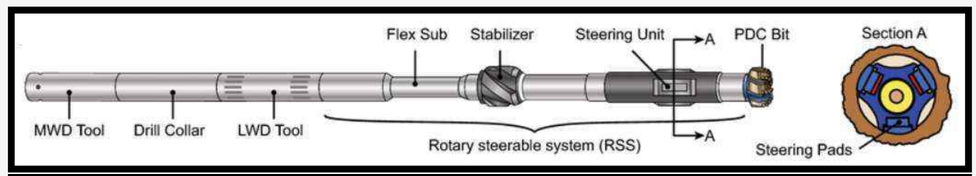
Case Study – RSS Low Tortuosity

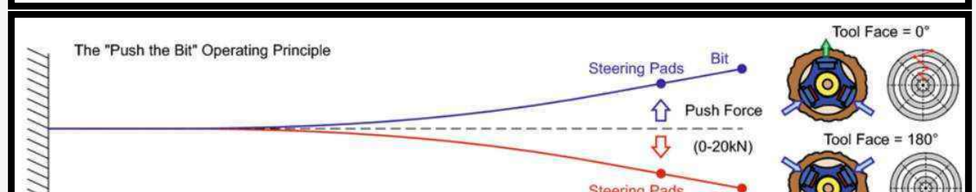


Case Study – RSS High Tortuosity



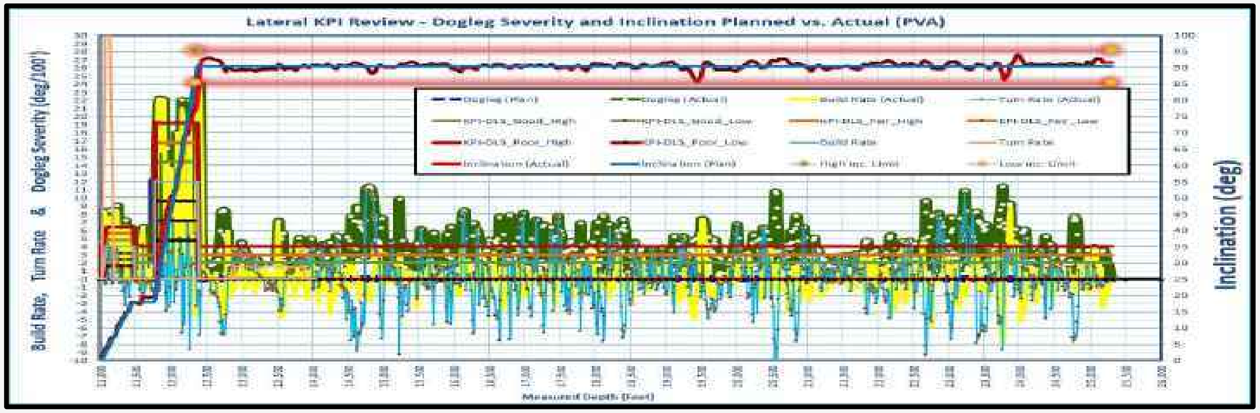


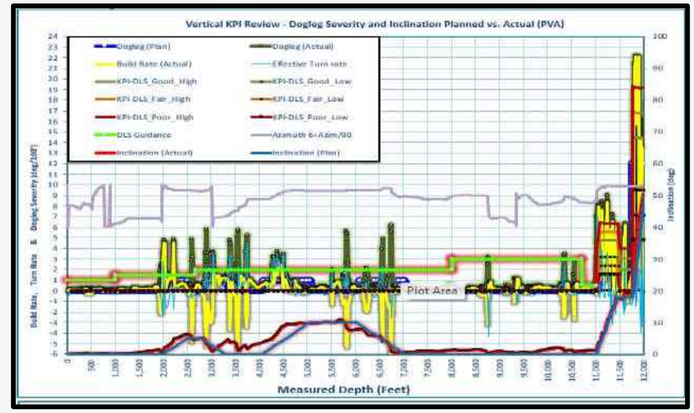


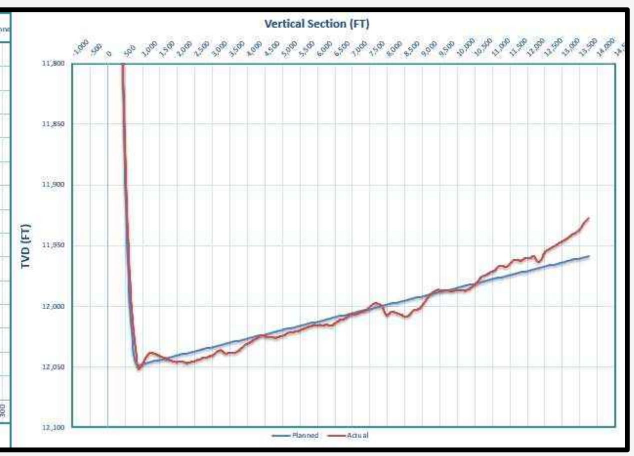


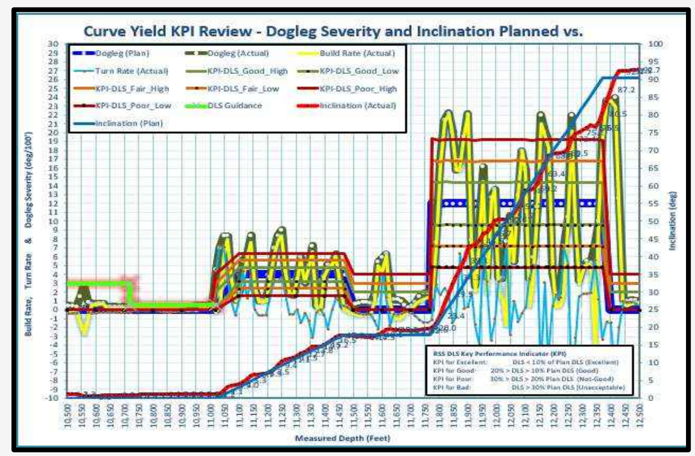
Schematic of the RSS – Research Gate

Curve Lateral Tortuosity KPI - RSS Example

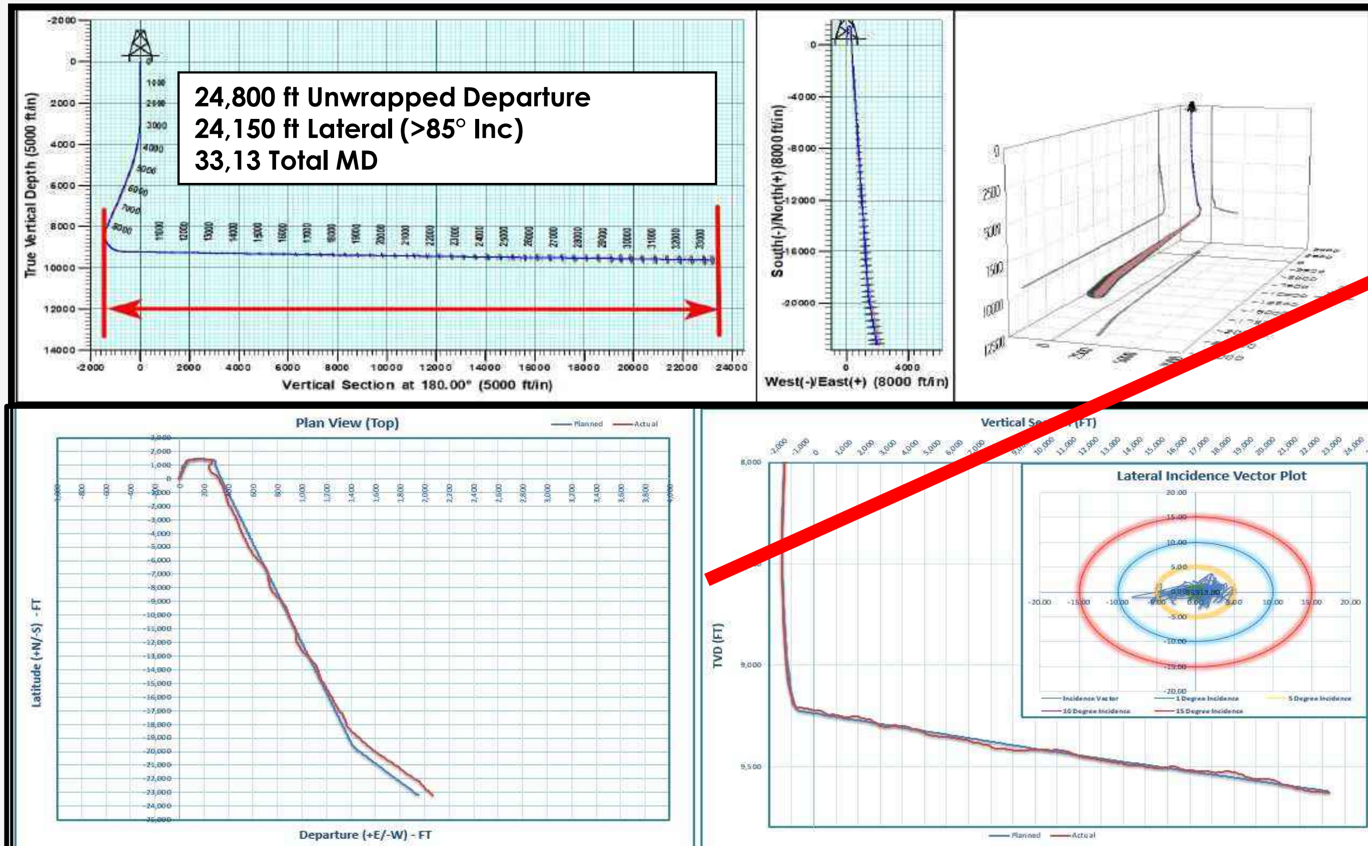


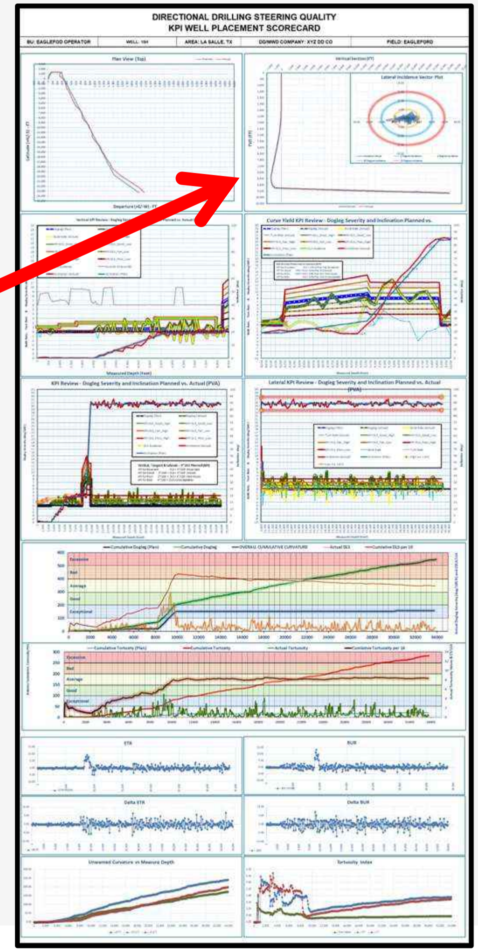




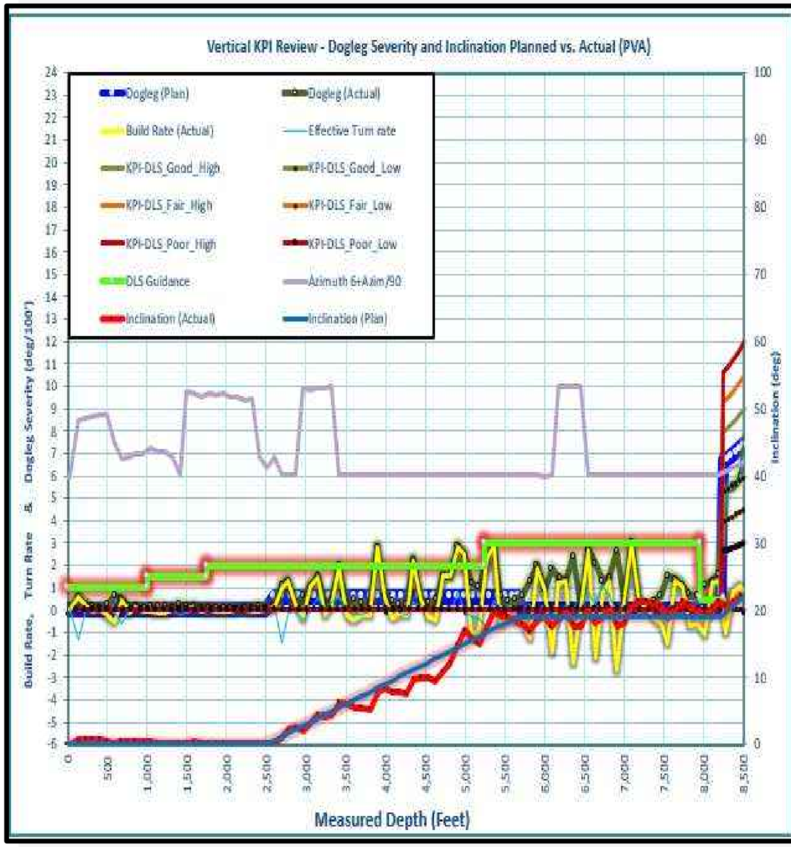


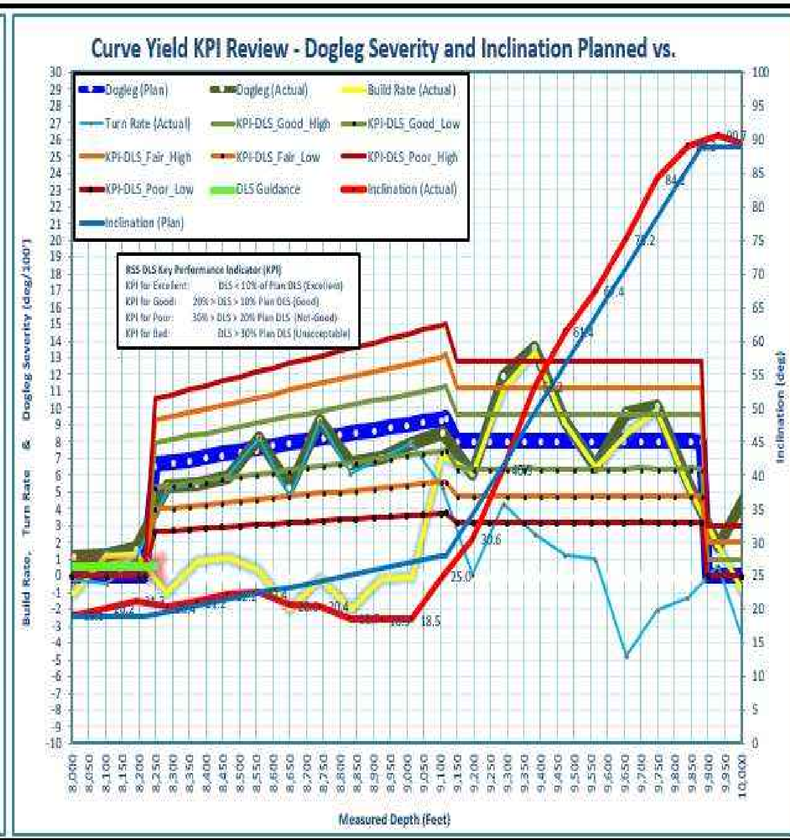
TX EXAMPLE – DirDrlg KPI SCORECARD

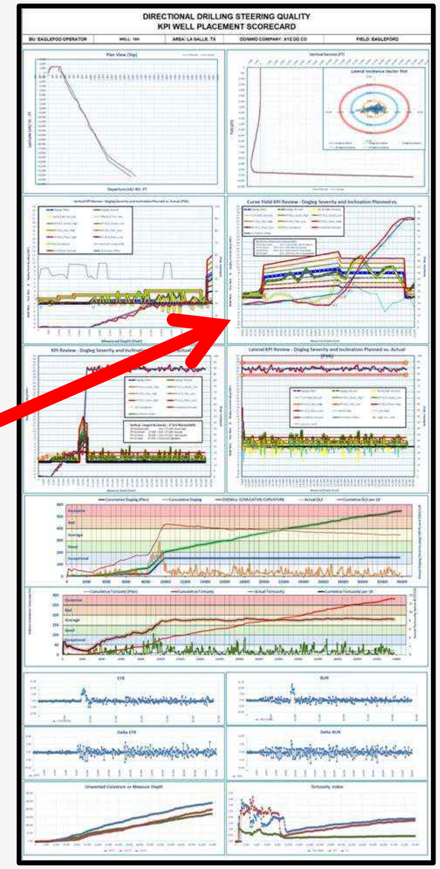




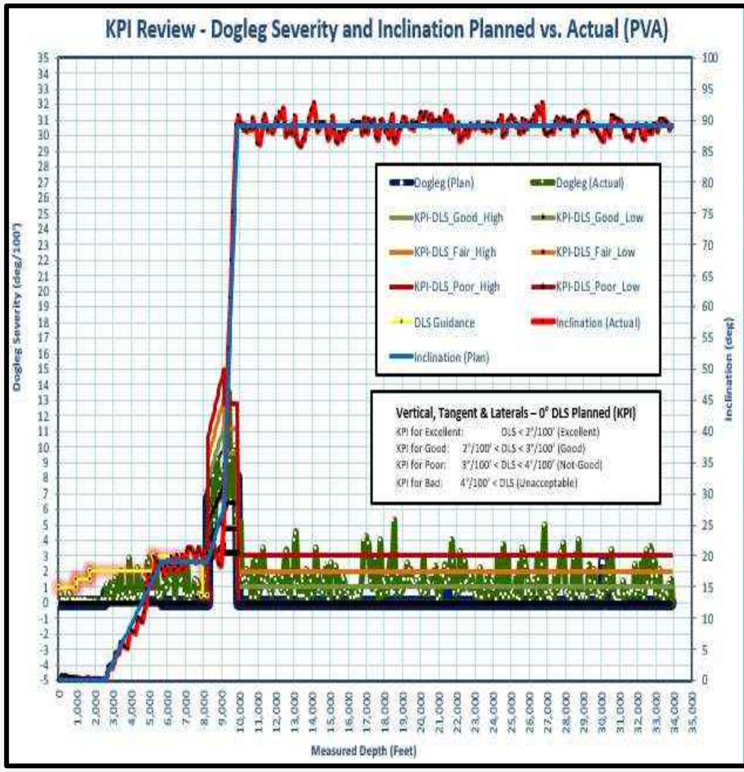
TX EXAMPLE – DirDrlg KPI SCORECARD

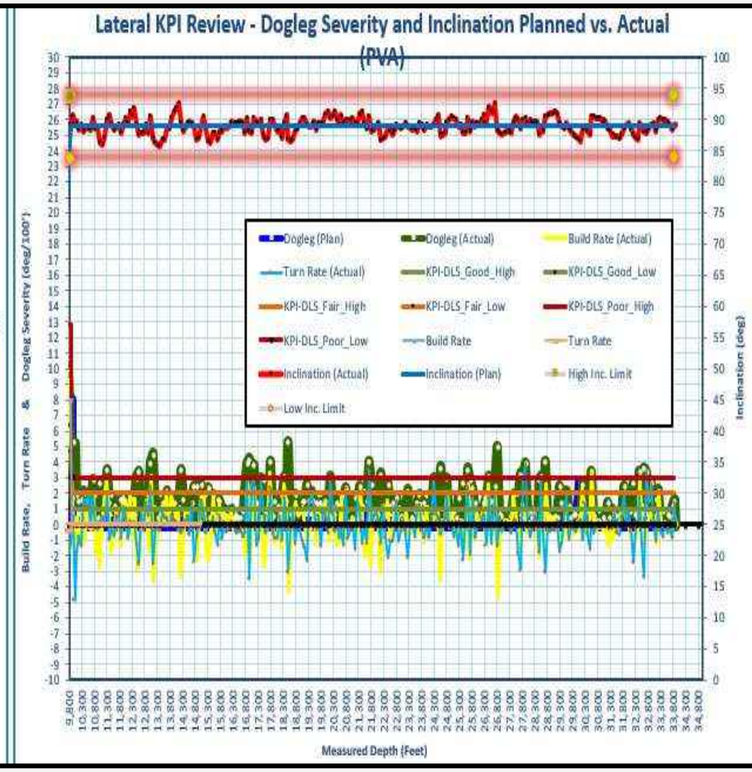






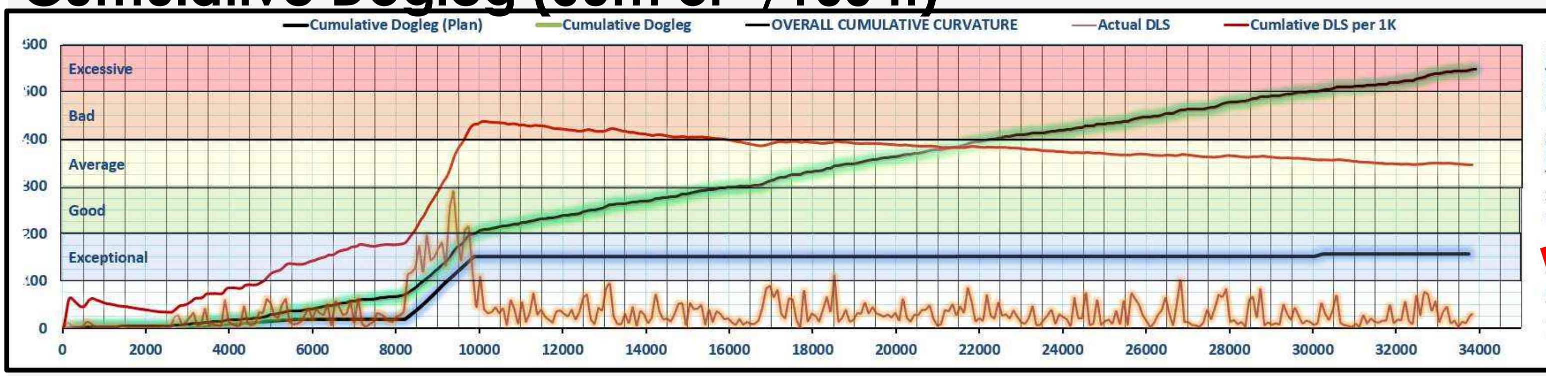
TX EXAMPLE – DirDrlg KPI SCORECARD



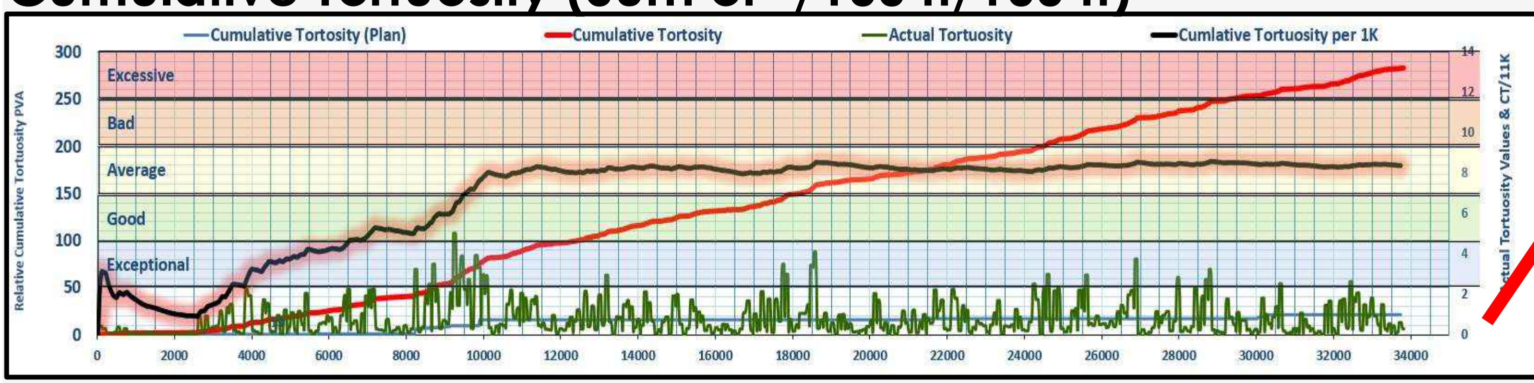


TX EXAMPLE – DirDrlg KPI SCORECARD

Cumulative Dogleg (Sum of °/100 ft)



Cumulative Tortuosity (Sum of °/100 ft/100 ft)



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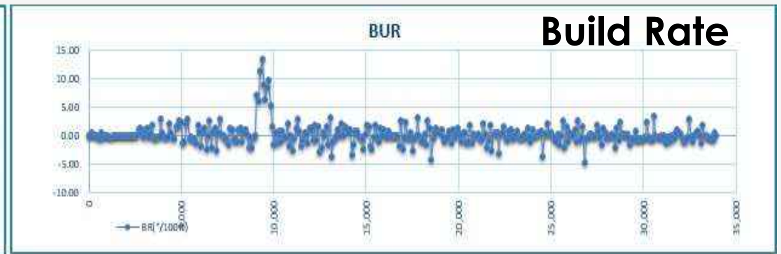
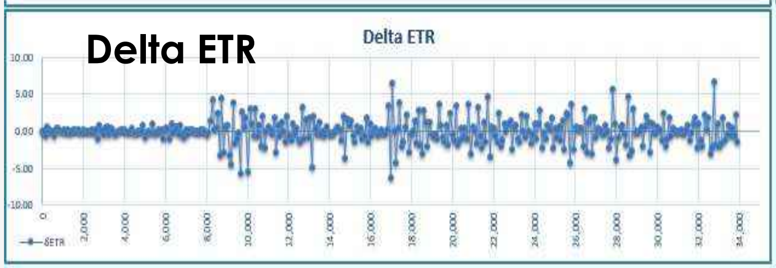
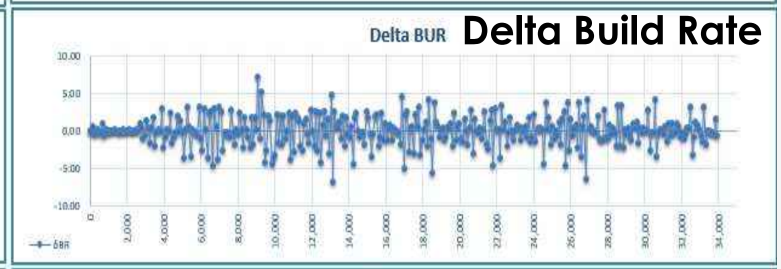
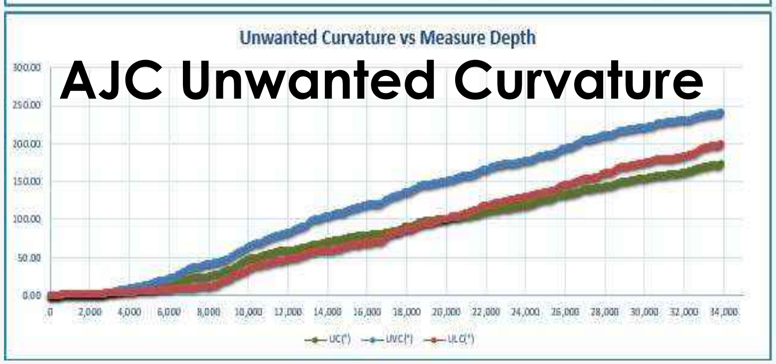
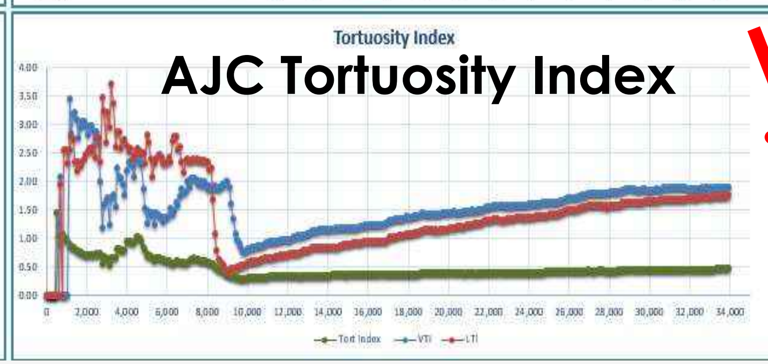
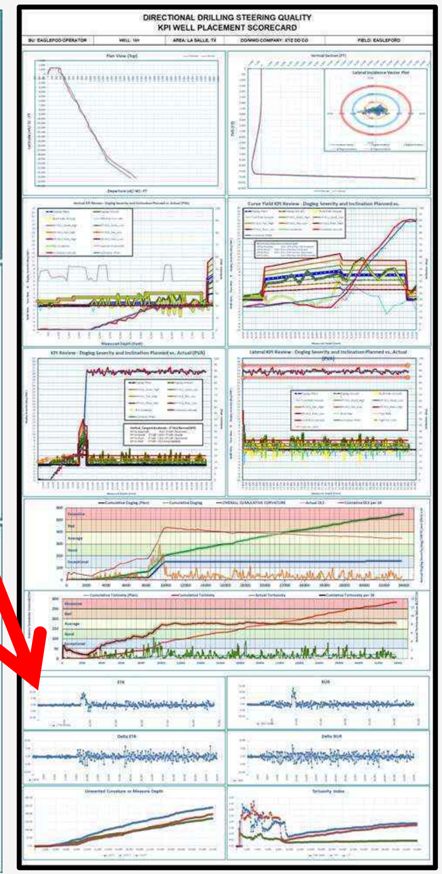












Key Takeaways

- As demonstrated in these case studies, Safe Separation collision avoidance methods are designed to safely separate wellbores while also improving wellbore position accuracy.
- The survey interval should be considered during both the drilling planning and execution phases.
- Key performance indicators aid in achieving the objectives and expectations of directional wells.
- Wellbore Surveying and Positioning Practices
  - Provides a primary source of technical information for all subsurface borehole construction applications.
  - Contributes to the modernization of the wellbore construction industry by promoting safe separation procedures.
  - All participants in wellbore construction should support the collaborative effort of a committed group of industry volunteers. The desired outcome is industry-wide adoption.

API RP78 Status Update

AADE
AMERICAN ASSOCIATION of DRILLING ENGINEERS

How far we have come…

- 2012 - OWSG Formed (Operator's Wellbore Survey Group)
- 2015 - SPE-178843-MS OWSG Std Survey Error Model Set (Published March 2016)
- 2016 - API DPOS RP 78 Task Group – 3/2/2016 & SPE-178843-MS OWSG Std Survey Error Model Set
- 2017 – SPE WPTS / ISCWSA QA/QC Text Reduction for Magnetic-Gyro-Depth
- 2018 – SPE Well-Collision-Avoidance Management and Principles SPE-184730-PA
- 2019 – BSEE Report on Surveying & SPE Well-Collision-Avoidance Separation Rule PA Paper SPE-187073-PA
- 2020 – Combined 1st Build of Document
- 2021 – API Working Draft
- 2022 – Recommended Practice Technical Writing & Editing
- 2023 - AADE National Technical Conference & Exhibition (NTCE) Paper
    - Introduction to API RP 78, Wellbore Surveying and Positioning (Lightfoot/Tank-Oxy & Coco-API)
- 2023 – Pre-Ballot Revision
- 2024 – Final Ballot Preparation & Technical Edits
- 2025 – Balloting & Consensus
- 2025–26 Ballot Comment Resolution – (In Progress)

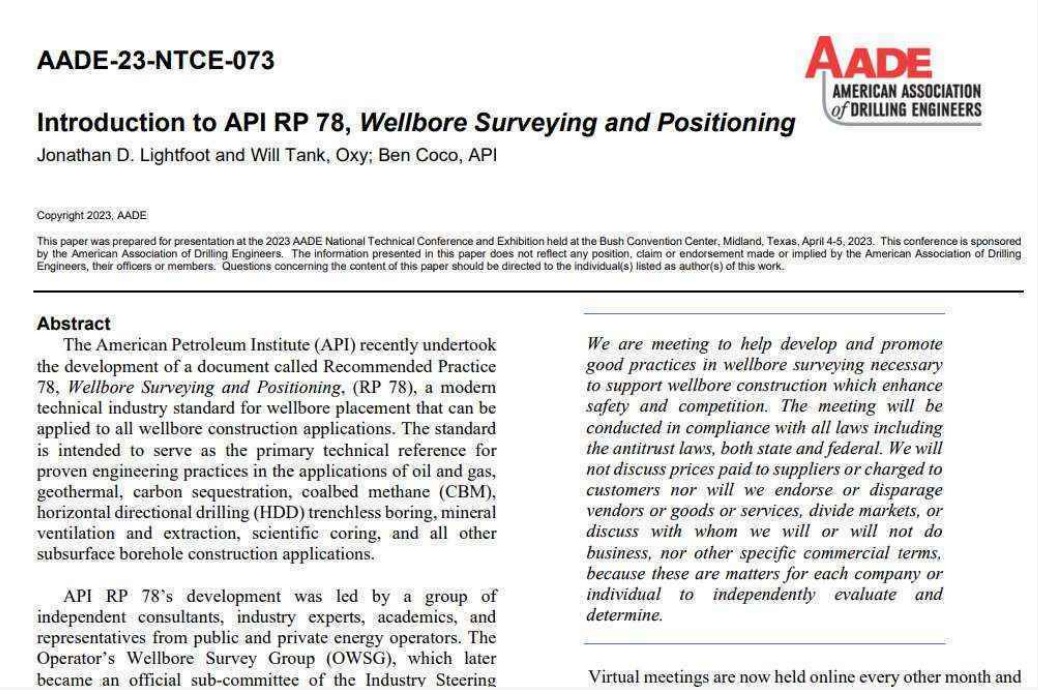
AADE AADE-23-NTCE-073

[INTRODUCTION TO API RP78](https://www.aade.org/download_file/4719/635)

Jonathan Lightfoot (Oxy)

Will Tank (Oxy)

Ben Coco (API)



AADE-23-NTCE-073

Introduction to API RP 78, *Wellbore Surveying and Positioning*

Jonathan D. Lightfoot and Will Tank, Oxy; Ben Coco, API

Abstract

The American Petroleum Institute (API) recently undertook the development of a document called Recommended Practice 78, *Wellbore Surveying and Positioning*, (RP 78), a modern technical industry standard for wellbore placement that can be applied to all wellbore construction applications. The standard is intended to serve as the primary technical reference for proven engineering practices in the applications of oil and gas, geothermal, carbon sequestration, coalbed methane (CBM), horizontal directional drilling (HDD) trenchless boring, mineral ventilation and extraction, scientific coring, and all other subsurface borehole construction applications.

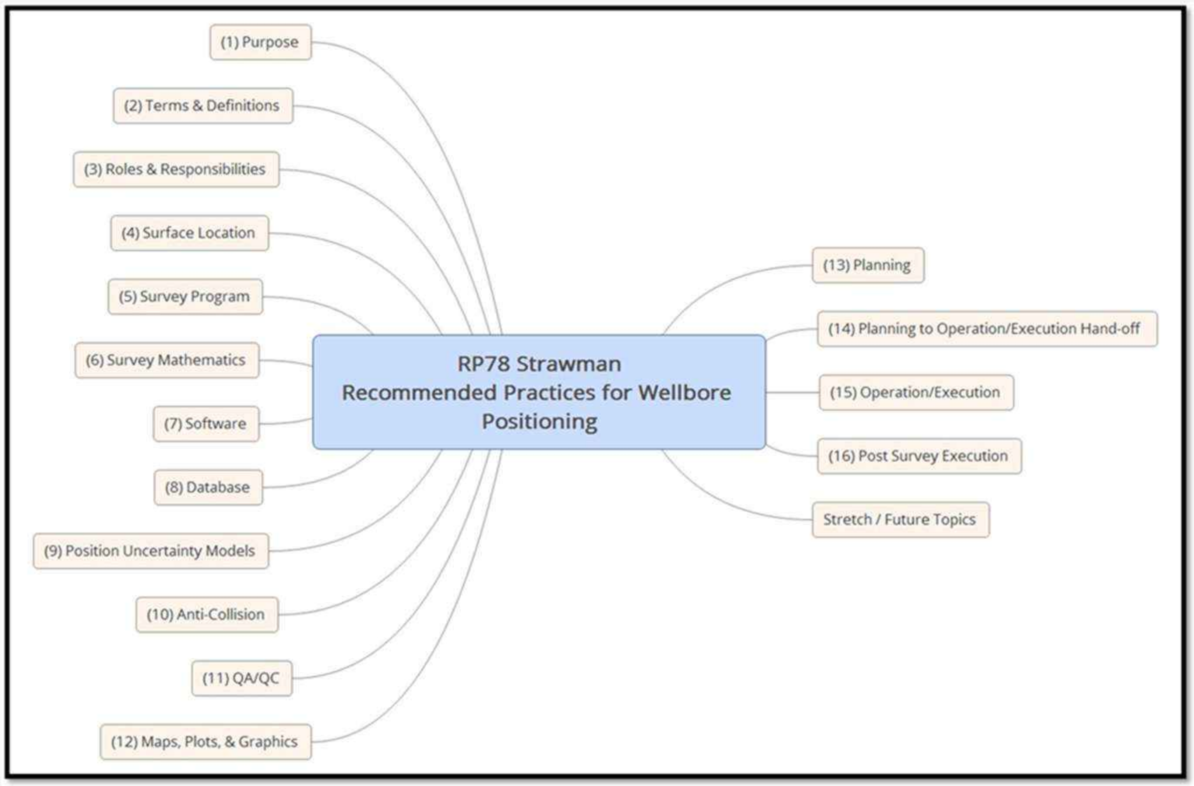
API RP 78's development was led by a group of independent consultants, industry experts, academics, and representatives from public and private energy operators. The Operator's Wellbore Survey Group (OWSG), which later became an official sub-committee of the Industry Steering

We are meeting to help develop and promote good practices in wellbore surveying necessary to support wellbore construction which enhance safety and competition. The meeting will be conducted in compliance with all laws including the antitrust laws, both state and federal. We will not discuss prices paid to suppliers or charged to customers nor will we endorse or disparage vendors or goods or services, divide markets, or discuss with whom we will or will not do business, nor other specific commercial terms, because these are matters for each company or individual to independently evaluate and determine.

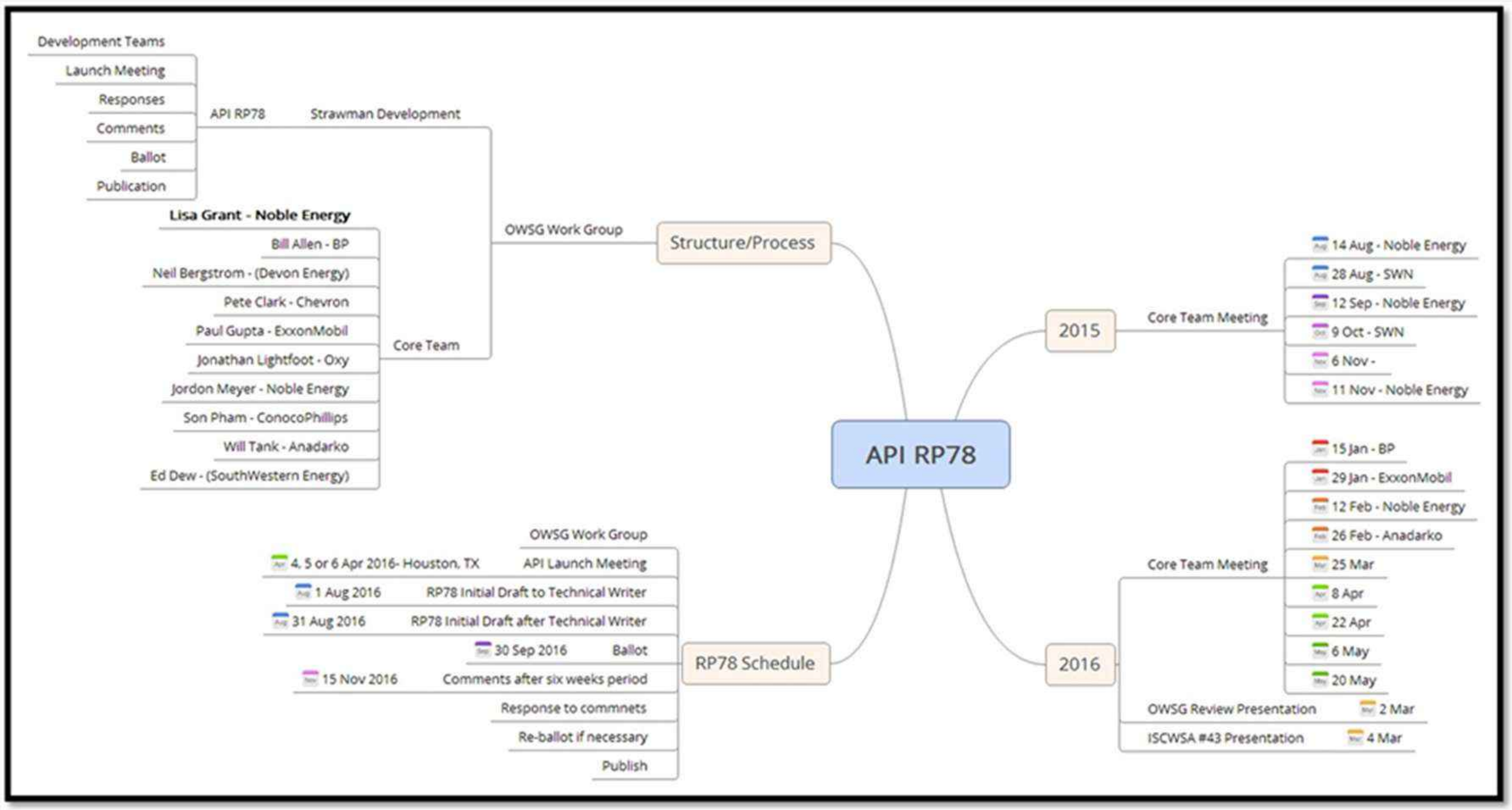
Virtual meetings are now held online every other month and

https://www.aade.org/download_file/4719/635

Overview: Original RP78 Strawman



Overview: Original RP78 Strawman



2025 BALLOT RESULTS

API Ballot Summary Sheet

Ballot: BALLOT: RP 78 Wellbore Surveying and Positioning

Ballot ID: 6610

Start Date: 2/13/2025

Closing Date: 3/27/2025

Associate: Jose Godoy

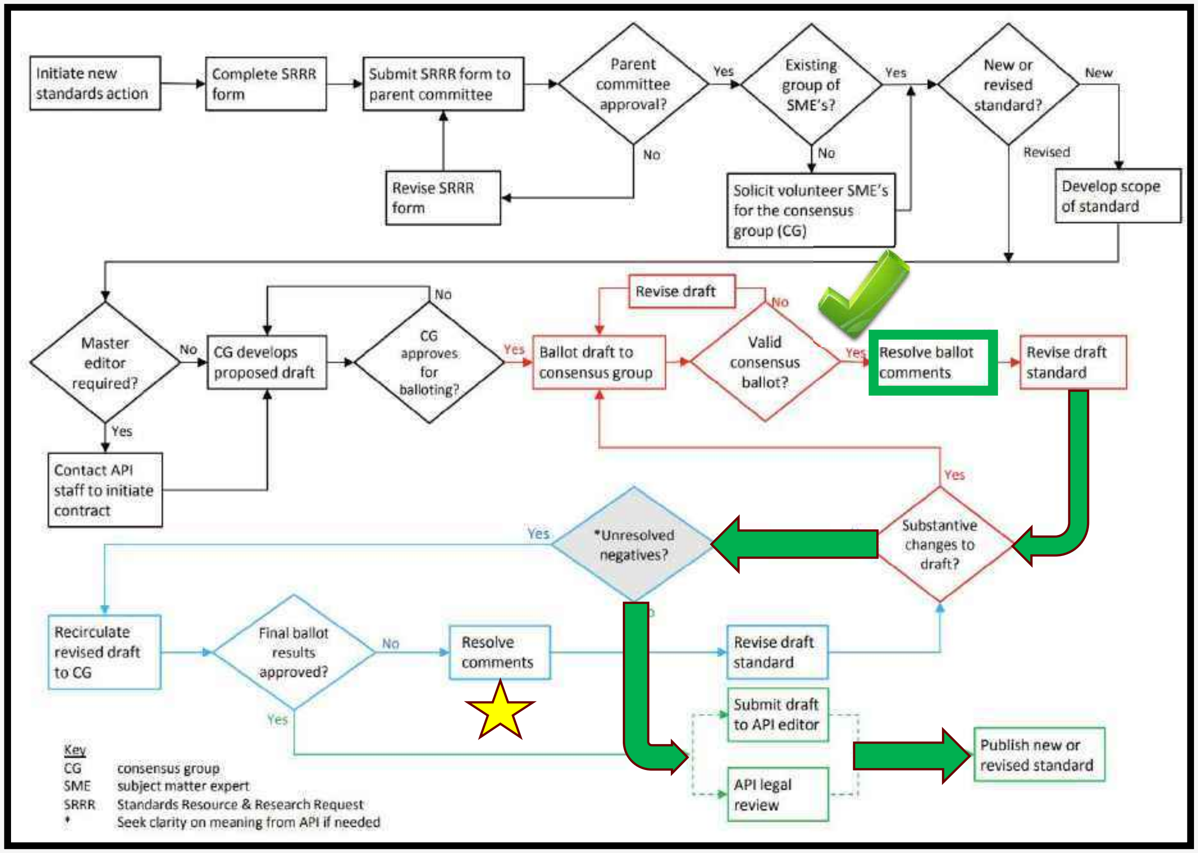
Coordinator: Jose Godoy

Proposal Review and comment on the first ballot for RP 78

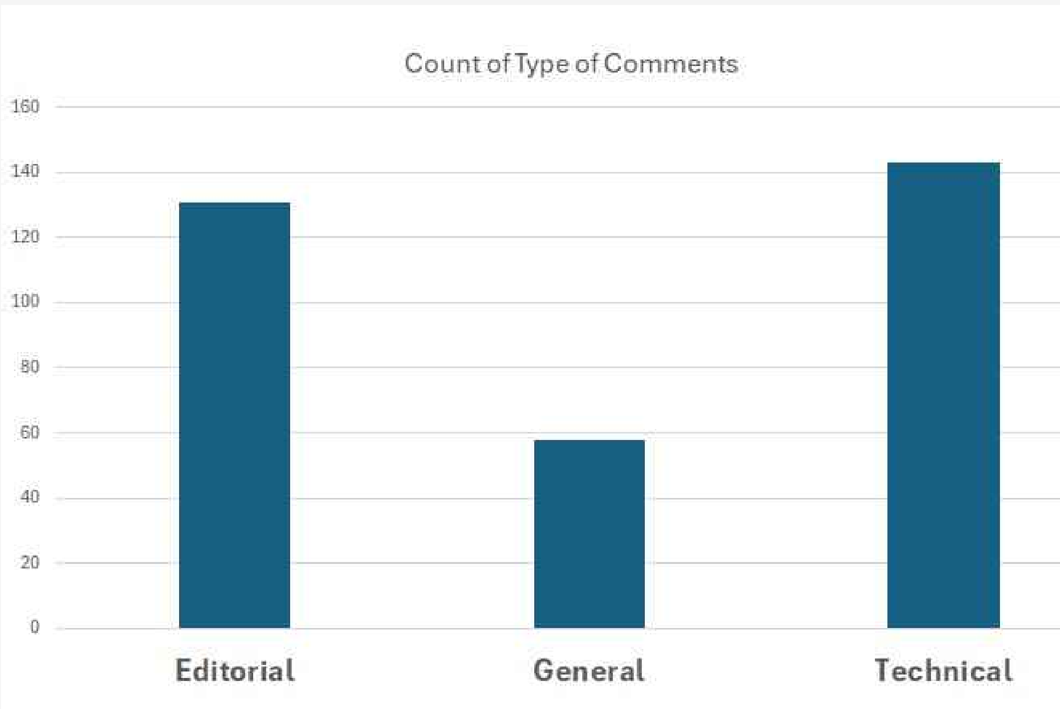
Affirmative	Negative	Abstain	Did Not Vote
20	2	0	20

Total Responses:	**22**	
Total Ballots:	**42**	
Response Rate= ((Affirmative + Negative + Abstain) / Total Ballots):	**52.38%**	Must be > 50%
Approval Rate = (Affirmative / [Affirmative + Negative]):	**90.91%**	Must be >= 66.67%
Consensus:	**YES**	

API STANDARDS DEVELOPMENT PROCESS



BALLOT COMMENTS – QTY & TYPE



Comment Status	Comment Count
⊞ Accepted	47
⊞ Accepted in Principle	35
⊞ Not Accepted	5
⊞ Noted	11
⊞ (blank) Unresolved	234
Grand Total	332

Next steps

- Update Draft Document to include Comment Edits
- Final Steps for the Comment Task Group
  1. Address Technical, General and Editorial Comments
  2. Finalize the Ballot Comment Draft
  3. Final Version Review by Comment Task Force
  4. API Technical Writer Review
  5. API Legal Review
  6. Final Copy Preparation
  7. Publish

Questions?

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WWW.API.ORG

WWW.ISCWSA.NET

WWW.SPE.ORG/WPTS

AADE NTCE (2023)