Fully Automated Collision Avoidance Analysis and Wellbore Quality Monitoring in Real-Time

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Outline

- Scope & Objectives
- Workflow
- Directional Metrics
- Automated Offset Survey Loading
- The Discreet Boundary Model
- Model Validation
- Ladder Plot
- Summary, Future Work, and Q&A

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KA1 Karimi, Ali, 6/29/2021

Scope and Objectives

- **Phase I (current capabilities)**
  - Receiving and processing surveys in near real-time
  - Comparing planned with actual trajectories
  - Applying directional drilling metrics to evaluate wellbore quality
  - Obtaining offset well lists and surveys from several data sources
  - Calculating center-center distance to offset wells
  - Generating ladder plots & conservative SF
  - Near real-time updates

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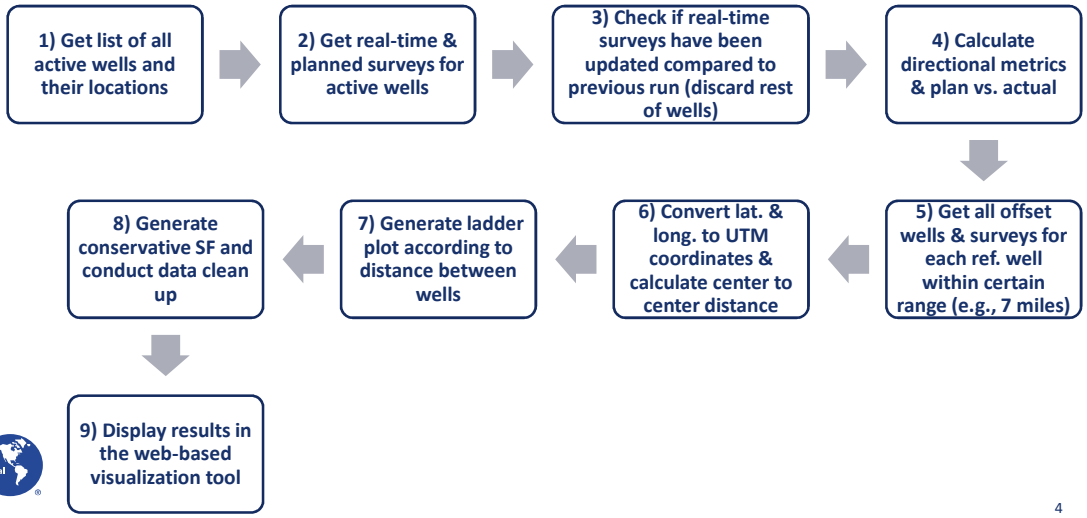
Workflow



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Real-Time Survey

- Real-time survey is streamed for all active wells.
- Corrections might be needed for real-time surveys.
- When real-time surveys are not available, planned surveys are used for analysis.

WellId	MD	Inclination	Azimuth	TVD	DLS	North	East	VerticalSection
3001547957	0	0	0	0	0	0	0	0
3001547957	93.1	0.48	273.75	93.1	0.52	0.03	-0.39	0.39
3001547957	182.6	0.78	254.24	182.59	0.41	-0.12	-1.35	1.33
3001547957	272.7	0.67	234.26	272.69	0.3	-0.59	-2.37	2.27
3001547957	367.1	0.39	291.96	367.08	0.6	-0.79	-3.11	2.59
3001547957	461.9	0.3	265.66	461.88	0.19	-0.69	-3.66	3.7
3001547957	556.3	0.36	49.89	556.28	0.67	-0.52	-3.68	-3.15
3001547957	637	0.09	24.83	636.98	0.35	-0.3	-3.46	-1.73
3001547957	725	0.04	203.01	724.98	0.15	-0.26	-3.44	1.58
3001547957	815	0.07	280.86	814.98	0.08	-0.28	-3.51	3.39
3001547957	906	0.15	271.29	905.98	0.09	-0.27	-3.68	3.67
3001547957	998	0.26	233.4	997.98	0.18	-0.39	-3.97	3.42
3001547957	1090	0.31	271.17	1089.98	0.21	-0.51	-4.39	4.38
3001547957	1182	0.31	227.28	1181.98	0.25	-0.67	-4.82	4
3001547957	1274	0.27	244.42	1273.98	0.1	-0.94	-5.2	5.1
3001547957	1366	1.18	27.14	1365.97	1.53	-0.19	-4.96	-2.43

Sample real-time survey

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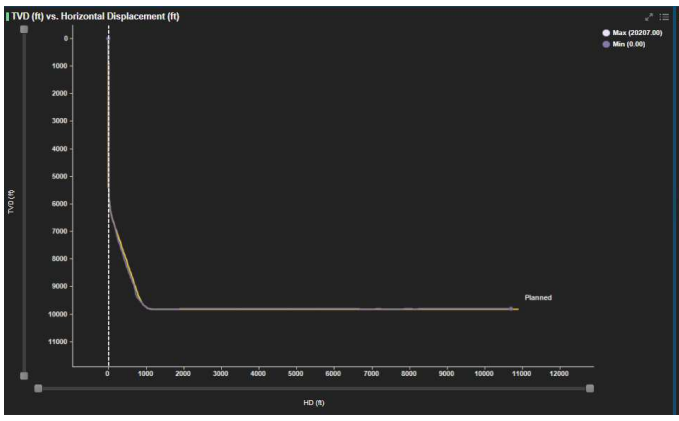
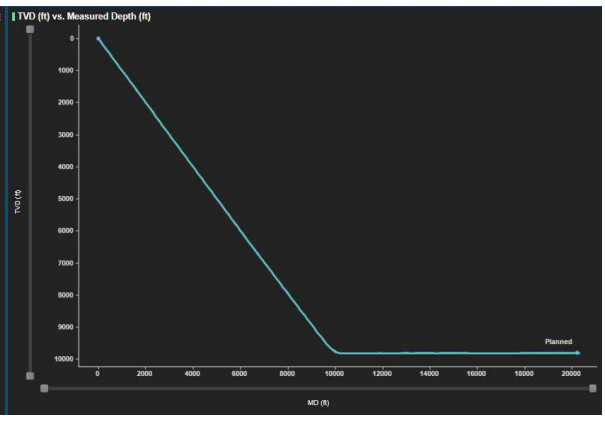
Plan vs. Actual



Plan vs. Actual (TVD vs HD)



Plan vs. Actual (TVD vs MD)

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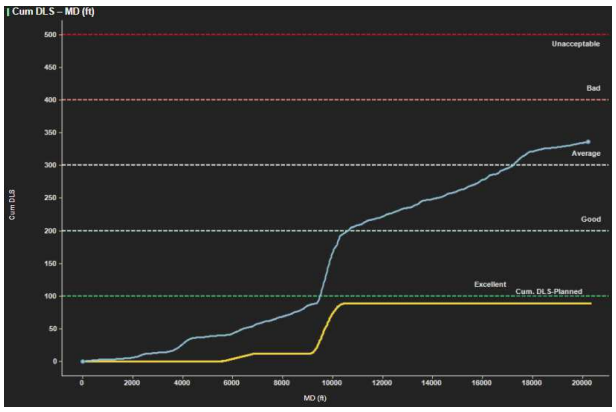
Plan vs. Actual (Continued)

Plan vs. actual (top left: DLS, top middle: Inclination, top right: Azimuth, bottom left: Tortuosity, bottom middle: Build Rate, bottom right: Effective Turn Rate)

Plan vs. Actual (Continued)



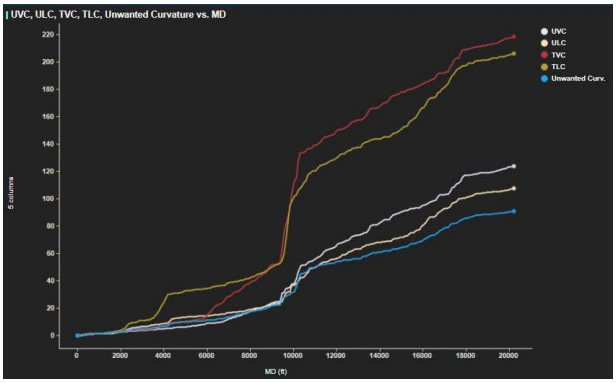
Plan vs. Actual (Cum. DLS)

Plan vs. Actual (Cum. Tortuosity)

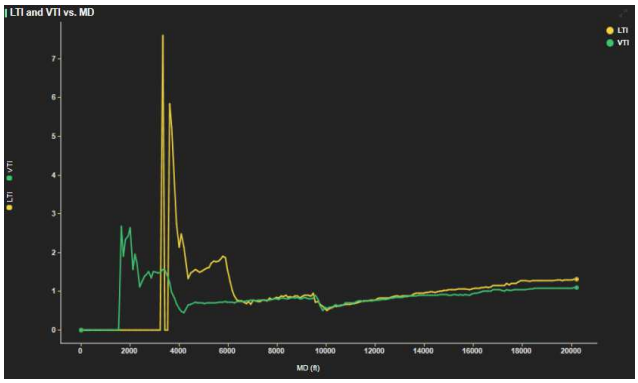
Deriving Wellbore Quality Metrics from Trajectory Calculations. Jamieson, 2019

Improved Wellbore Quality Using a Novel Real-Time Tortuosity Index. Zhou et al. (2016). RAPID at UT Austin

Directional Metrics



UVC, ULC, TVC, TLC, Unwanted Curvature vs. MD



LTI and VTI vs. MD

Deriving Wellbore Quality Metrics from Trajectory Calculations. Jamieson, 2019

Improved Wellbore Quality Using a Novel Real-Time Tortuosity Index. Zhou et al. (2016). RAPID at UT Austin

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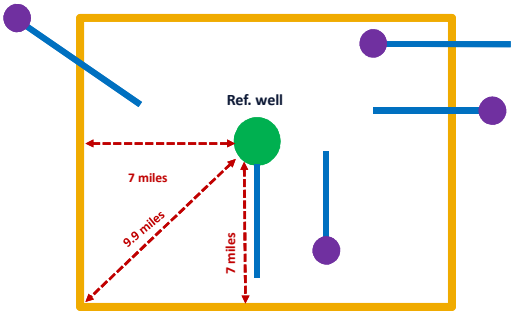
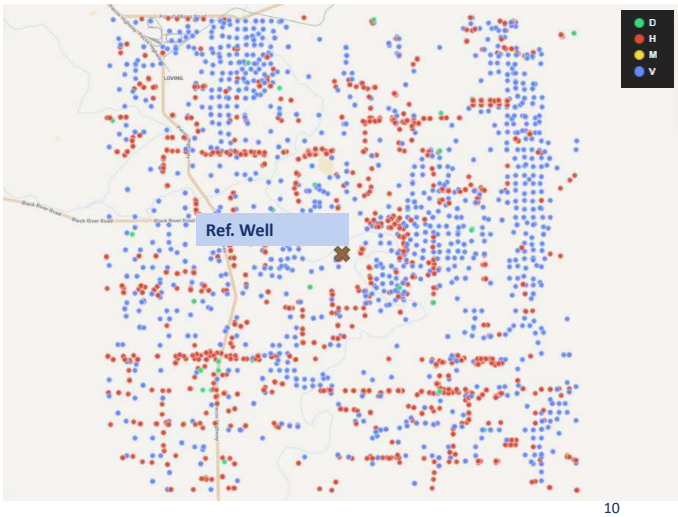
Offset Wells - Search Box

- Initial search is conducted based on surface location of the reference well. Default search distance is set to **7 miles**.





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Offset Surveys

- 3 data sources are used:
  - Company definitive surveys
  - I.H.S central database (roughly, half a million surveys available)
  - Company planned surveys
  - Fake surveys are automatically generated for missing wells

UWI	SOURCE	DIR_SRVY_ID	MEASURED_DEPTH	TV_DEPTH	DERIVED_IND	DEVIATION_N	DEVIATION_E	DEVIATION_ANGLE	DEVIATION_AZIMUTH
30025458720000	PI	1	0	0	(null)	0	0	0	0
30025458720000	PI	1	26.5	26.5	(null)	0	0	0	0
30025458720000	PI	1	104.4	104.399	(null)	0.28	0.14	0.39	183.27
30025458720000	PI	1	133.7	133.699	(null)	0.47	0.16	0.34	188.47
30025458720000	PI	1	162.6	162.598	(null)	0.64	0.2	0.37	202.27
30025458720000	PI	1	189.4	189.397	(null)	0.8	0.28	0.41	209.5
30025458720000	PI	1	214.4	214.397	(null)	0.95	0.37	0.4	212.17
30025458720000	PI	1	242.5	242.496	(null)	1.11	0.49	0.38	221.14
30025458720000	PI	1	271.5	271.496	(null)	1.24	0.62	0.37	230.01
30025458720000	PI	1	334.5	334.494	(null)	1.47	0.94	0.33	236.59
30025458720000	PI	1	43.4	43.4	(null)	0.02	0.03	0.24	240.32
30025458720000	PI	1	71.7	71.7	(null)	0.1	0.1	0.25	201.42
30025458720000	PI	1	303	302.995	(null)	1.36	0.78	0.36	233.56
30025458720000	PI	1	366	365.994	(null)	1.57	1.09	0.33	241.39
30025458720000	PI	1	397.5	397.493	(null)	1.64	1.25	0.33	248.36
30025458720000	PI	1	429	428.993	(null)	1.7	1.42	0.31	254.04
30025458720000	PI	1	460.5	460.492	(null)	1.75	1.59	0.32	251.92
30025458720000	PI	1	492	491.992	(null)	1.8	1.76	0.33	255.08
30025458720000	PI	1	523.5	523.491	(null)	1.85	1.95	0.4	256.68
30025458720000	PI	1	555	554.99	(null)	1.89	2.19	0.46	265.39
30025458720000	PI	1	586.6	586.589	(null)	1.91	2.44	0.48	265.11
30025458720000	PI	1	618.1	618.088	(null)	1.94	2.71	0.49	260.8
30025458720000	PI	1	649.6	649.587	(null)	1.99	3	0.58	260.49
30025458720000	PI	1	681.1	681.085	(null)	2.05	3.32	0.6	256.44
30025458720000	PI	1	712.6	712.583	(null)	2.14	3.63	0.59	252.99
30025458720000	PI	1	744.1	744.082	(null)	2.24	3.95	0.63	252.91
30025458720000	PI	1	775.6	775.58	(null)	2.34	4.28	0.62	251.77
30025458720000	PI	1	807.1	807.078	(null)	2.45	4.6	0.61	249.9
30025458720000	PI	1	838.6	838.576	(null)	2.56	4.93	0.65	253.69
30025458720000	PI	1	852.6	852.575	(null)	2.61	5.1	0.79	252.82

Sample survey data from I.H.S database

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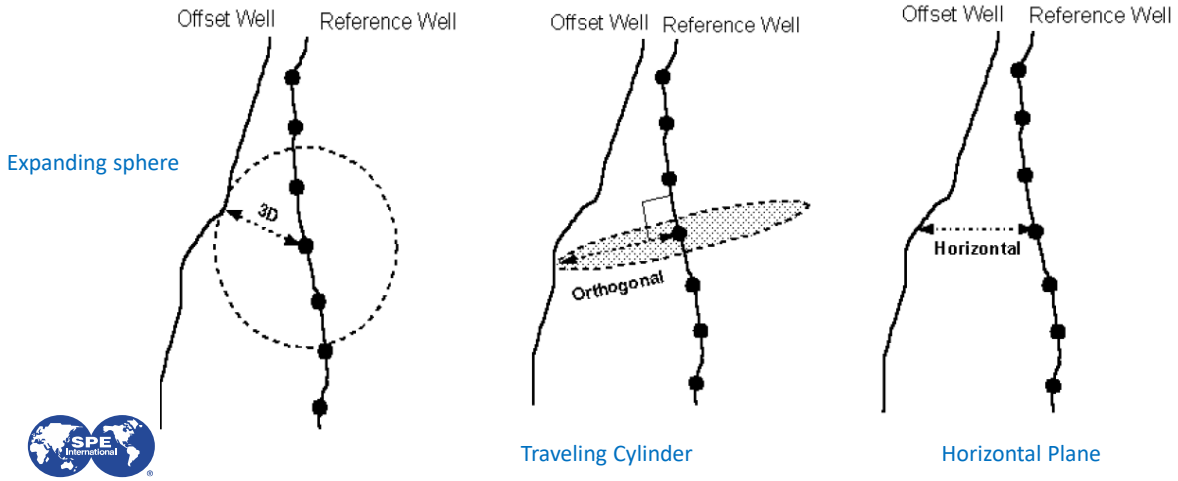
Traditional Scan Methods



Traveling Cylinder

Horizontal Plane

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Reference: COMPASS™ Software Release 5000.1.7 Training Manual

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KA3 Karimi, Ali, 7/27/2021

Approach: The Discrete Boundary Model (DBM)

International Journal of Graphics
Vol. 1, No. 1, November, 2010

Study of Distance Computation between Objects Represented by Discrete Boundary Model

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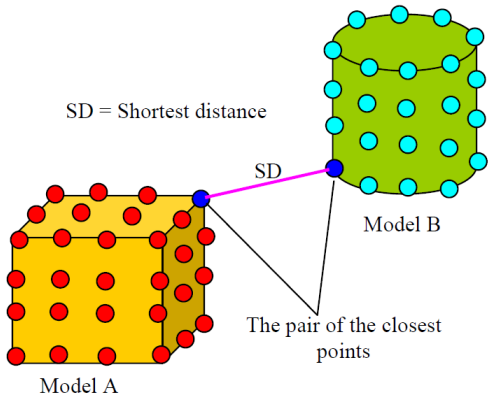

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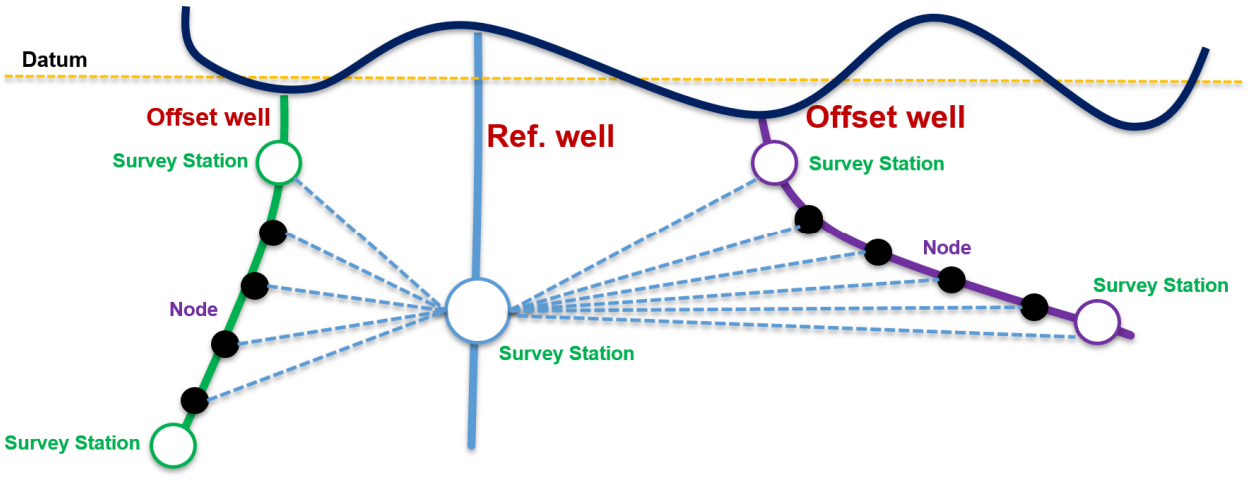
DBM Implementation



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Calculating Distance Between Two UTM Points

- Approach 1: Cartesian Coordinates
- Approach 2: Haversine formula

Haversine formula:

$a = \sin^2(\Delta\varphi/2) + \cos\varphi_1 \cdot \cos\varphi_2 \cdot \sin^2(\Delta\lambda/2)$

$c = 2 \cdot \text{atan2}(\sqrt{a}, \sqrt{(1-a)})$

$d = R \cdot c$

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$$

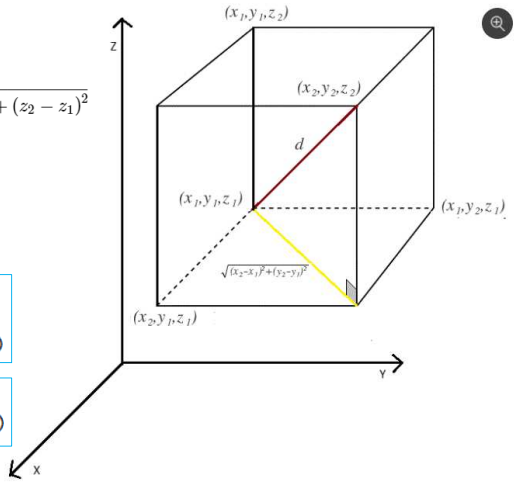
where φ is latitude, λ is longitude, R is earth's radius (mean radius = 6,371km); note that angles need to be in radians to pass to trig functions!

- Distance comparison from (32, -103) to (32.1, -103) is **11089.2** m in comparison with **11119.49** meters: **~0.3% error**.

```
utm.from_latlon(32.1, -103)

(688722.178086404, 3553270.7966073537, 13, 'S')
```

```
utm.from_latlon(32, -103)
(688927.6380695379, 3542183.4911190174, 13, 'S')
```



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Model Validation: Distance Between Surface Locations

Validation is conducted by using the industry standard commercial software and open-source tools

Well Name	Oxy AC	HAL Compass	ABS Difference (ft)
Offset Well 1	35.00	35.04	0.04
Offset Well 2	69.98	70.01	0.03
Offset Well 3	179.99	180.08	0.09
Offset Well 4	183.23	183.32	0.09
Offset Well 5	192.85	192.95	0.10
Offset Well 6	571.12	571.27	0.15
Offset Well 7	637.80	637.98	0.18
Offset Well 8	2652.50	2652.85	0.35
Offset Well 9	2700.26	2700.65	0.39

Excellent agreement was observed (for practical applications)

Point 1: 32.2109113 , -104.010666

Point 2: 32.2109109 , -104.010553

Distance: **0.01065** km **Or 34.94 ft**

Source: https://www.movable-type.co.uk/scripts/latlong.html

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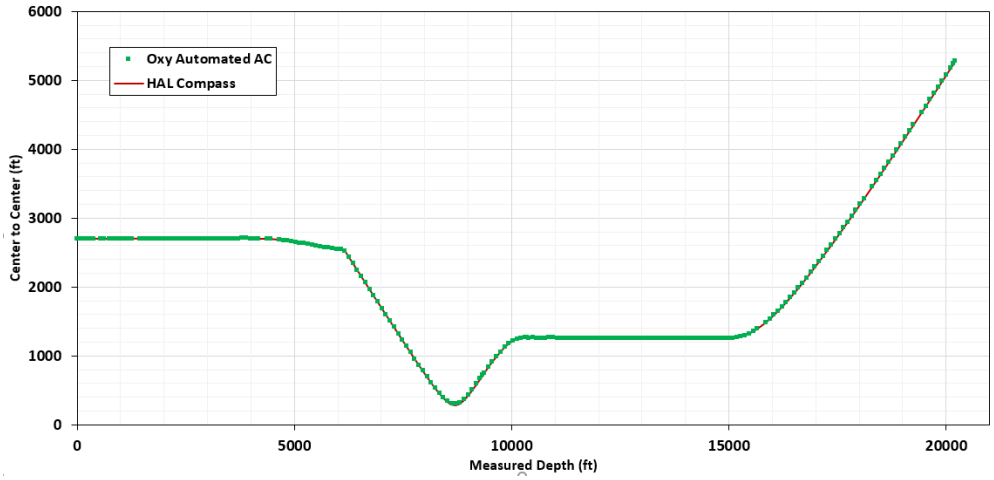
Model Validation (Center to Center Distance): Example 1

Example 1



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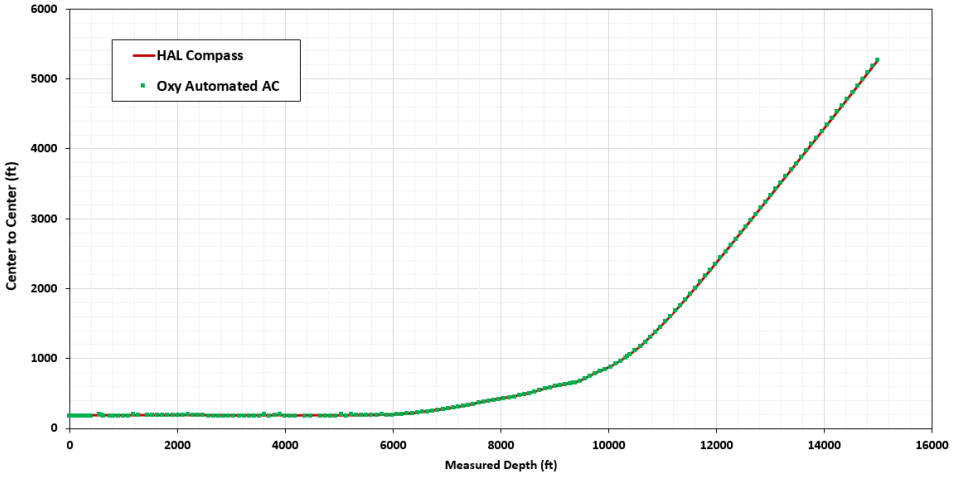
Model Validation (Center to Center Distance): Example 2

Example 2



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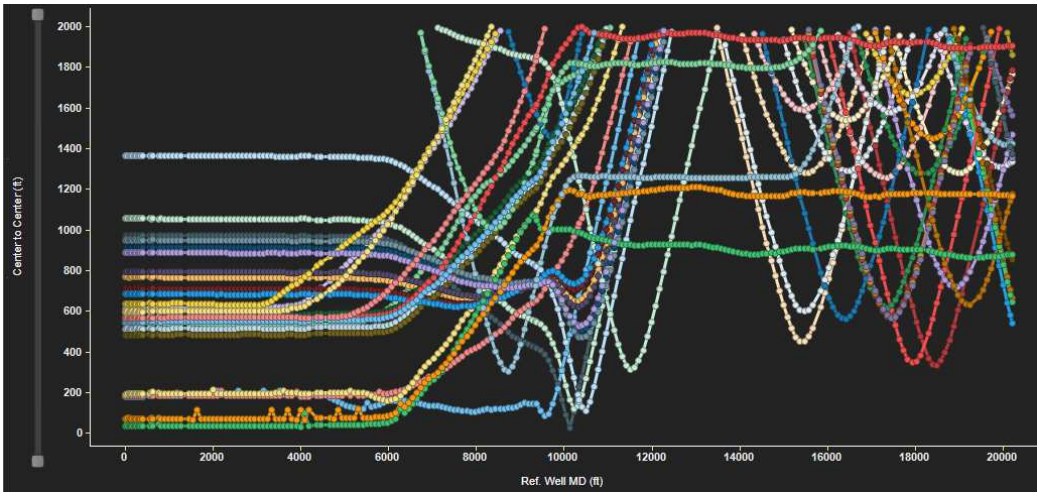
Ladder Plot

Ladder plot for all offset wells (center to center distance)



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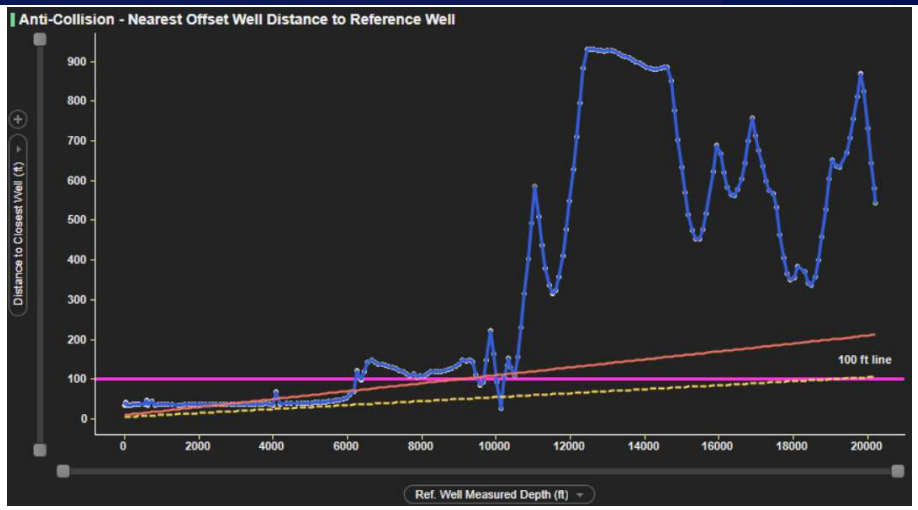
Nearest Distance Ladder Plot (Continued)

Ladder plot for nearest offset wells (center to center distance)



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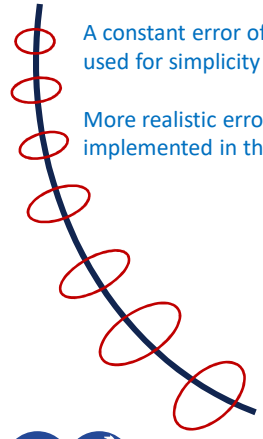
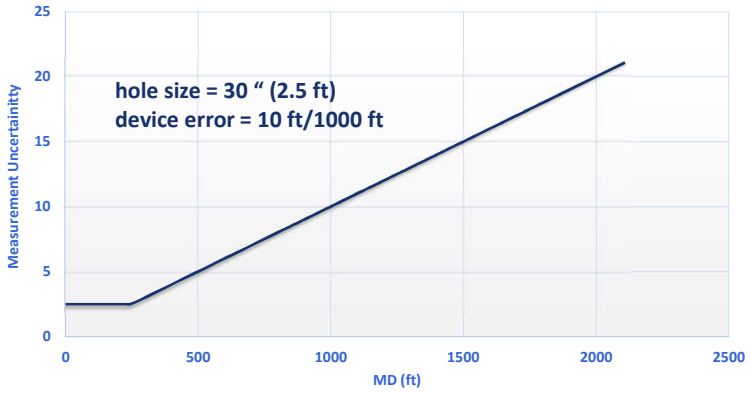
Separation Factor and Error Modeling (Future Work)



A constant error of 10ft/1000ft is used for simplicity

More realistic error models will be implemented in the future



$$Separation\ Factor\ (SF) = \frac{Center\ to\ Center\ Distance}{Minimum\ Separation}$$

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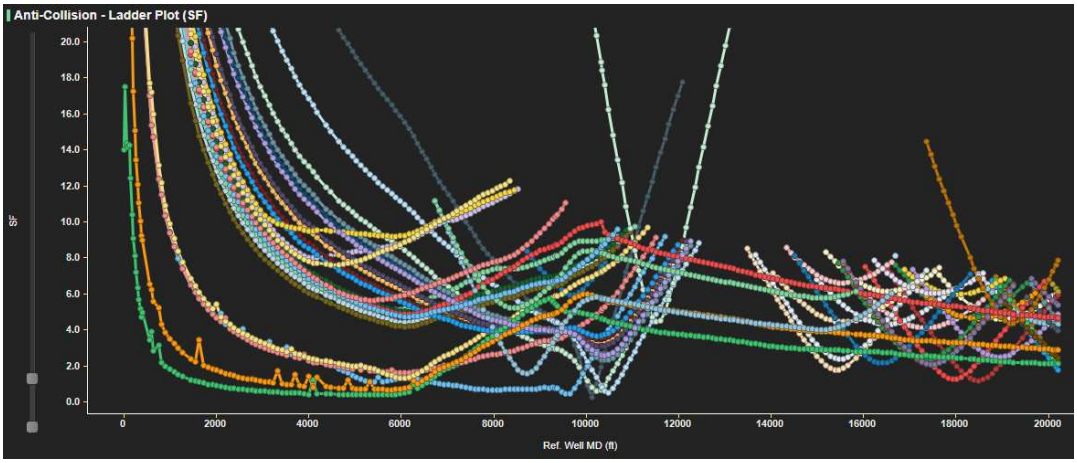
Separation Factor (Constant Linear Error Growth Assumption)

Simplistic SF plots for offset wells



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Summary and Conclusions

- A workflow was developed for the plan vs. actual and collision avoidance analysis in real-time
- Several metrics were implemented for monitoring wellbore quality in real-time
- DBM model was implemented to obtain C-C distance
- Validation results show an excellent agreement with the industry standard software
- Ladder plots are generated in real-time
- This tool can potentially result in delivering safer and smoother wells in shorter time

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Thank You

Fully Automated Collision Avoidance Analysis and Wellbore Quality Monitoring in Real-Time

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Jonathan Lightfoot: Jonathan_Lightfoot@oxy.com

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