Improving The ISCWSA 3-d Positioning And Error Models Using Changes To Along-hole Depth Calculation

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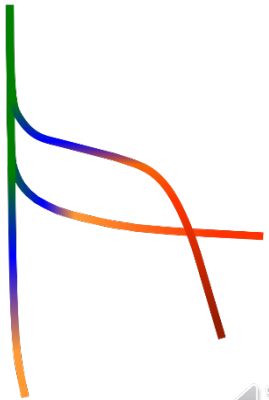
PathControl 2017 – Present

- 21 Years working on directional survey and well positioning, drilling engineering and well placement special projects

PathControl Specializes in :

- Directional Survey Database and survey Management
- Relief Well, Plug & Abandonment and Blow Out well Intercept services
- Magnetic Ranging, Collision Avoidance, Advanced Directional Software Audit and Setup



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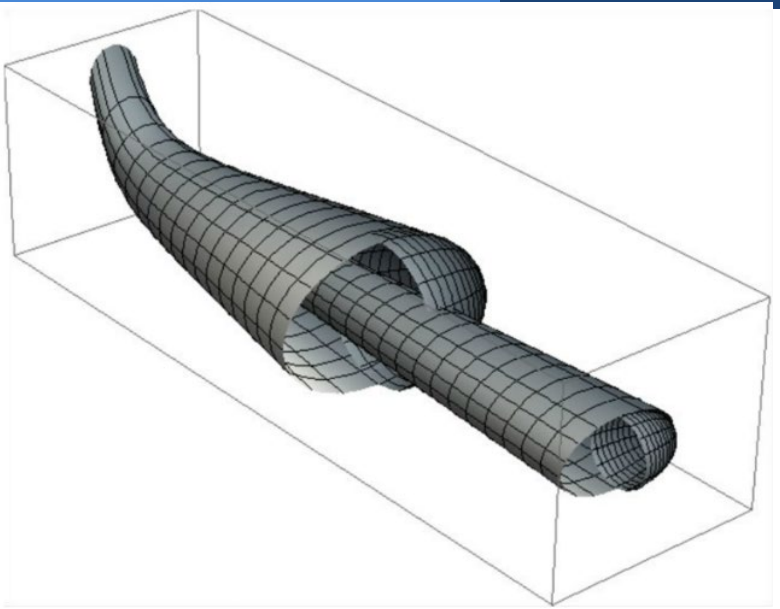
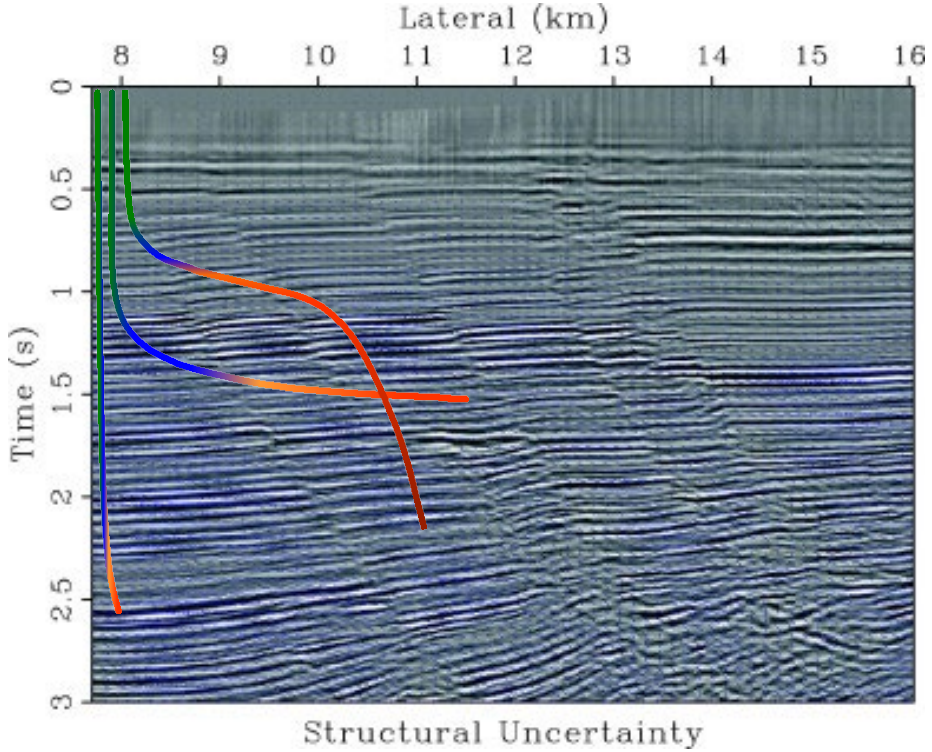
Overview:

- Why we are talking about 3-d positioning uncertainty
- True along-hole (TAH) depth
- Generic correction and uncertainty model components
- Correction model uncertainty
- What is new



Along hole Depth is Tied to the Seismic Section



Estimated structural uncertainty in the seismic image displayed as displacements.

Along-hole depth uncertainties

Image Taken from :
Structural uncertainty of time-migrated seismic images, Sergey Fomel and Evgeny Landa, Journal of Applied Geophysics, Volume 101, February 2014, Pages 27-30

https://www.sciencedirect.com/science/article/pii/S092698511300267X

Asset Lifetime Uncertainty

Measurement relevance	Domain relevance	Uncertainty @ 10,000 ft
Seismic 3-d geologic mapping	Major geological events	**+/- 100 ft**
Well construction	Significant reservoir events	**+/- 50 ft**
Mechanical service operations	Minor reservoir events	**+/- 30 ft**
Reservoir geometry	Major bed events	**+/- 15 ft**
OWC/GWC mapping	Minor bed events	**+/- 5 ft**
Detailed OWC/GWC mapping **Fracture identification**	Minor bed events	**+/- 2 ft**
Across reservoir fluid level management	Detailed fluid levels Compaction events	**+/- 1 ft**

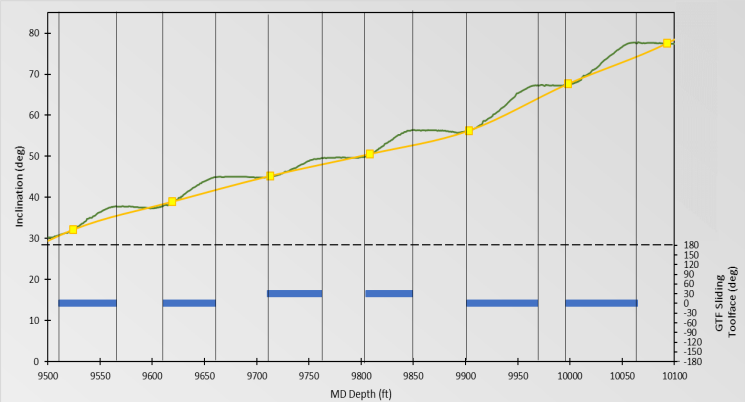
TVD Uncertainty Value?

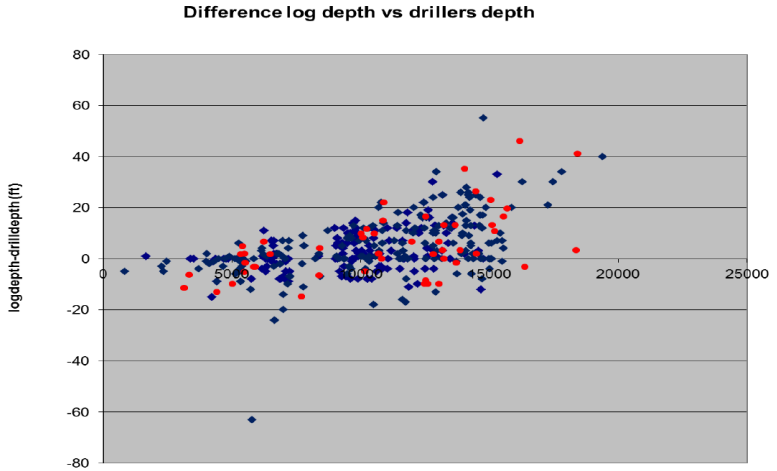
Oil, Gas and Water companies Uncertain of the Effect Uncertainty has on their Asset Value and Production Efficiency

Ed Stockhausen (Chevron 1970 - 2055) stated :
"1 ft of TVD error costs 10k to 100k Bbls" = ***$600k to $6,000k***

API RP-78 includes the requirement for well data along-hole depth uncertainty as a *QA/QC* requirement.

TVD Uncertainty Value?





- "Incorrect True Vertical Depth can affect project estimated project pay value and production rates"
- "Extreme cases : Up to 1 MM bbl per TVD foot Error in Reservoir Modeling and Production Rate Estimates"

What is True Along-hole (TAH) Depth ?

Wireline, drill pipe or any other – observed depth

Depth measurement
+ Correction
+/- Uncertainty

= True Along-hole Depth, TAH

*Corrected depth together with an uncertainty term defining the uncertainty reported to one (1)-sigma**

This is applicable to all AHD data values

* ref.: Along-hole Depth Rev6.0, www.lulu.com

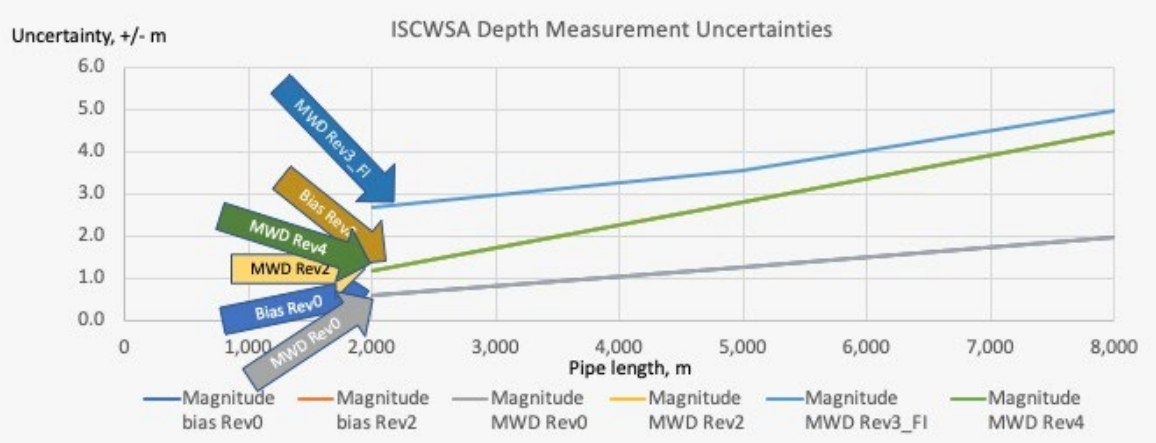
ISCWSA current terms (2021)

- Reference, *Measurement/calibration*, CORRECTION

- Reference errors – systematic (survey datum, wind, tides, weather, CABLE SAG)
- Reference errors – random (waves, weather tides/ballast, pipe stick-up, log picks)
- Scale factor errors – systematic (MWD/LWD) (*tape measure, measurement temperature*, WEIGHT-ON-BIT, PUMP-OFF, DIFFERENTIAL PRESSURE, ANNULUS DRAG, NOZZLE THRUST, ROTARY TORQUE)
- Scale factor errors – well by well (wireline) (*wireline wheel wear*, WHEEL SLIPPAGE, *marking temperature, marking accuracy*)
- Stretch type errors – systematic (wireline) (*wireline* INELASTIC *stretch*, TEMPERATURE, PRESSURE, TORSION)
  Stretch type errors – global (MWD/LWD) (DRILLPIPE ELASTIC STRETCH, TEMPERATURE, HYDROSTATIC)

- Brooks, Wilson, Jamieson & McRobbie, SPE-956111

Industry Depth Uncertainty Changed
ISCWSA Error model Sub-Committee summary Rev5.03



- Model values have changed over time (Rev 0 – 5), while not referencing actual measurement conditions, calculation and Uncertainty
- Propose Actual Measurement values used to propagate the Error model Depth Terms

Shows output of variety of ISCWSA EM depth uncertainty

Illustrates disconnect of the output to real world conditions

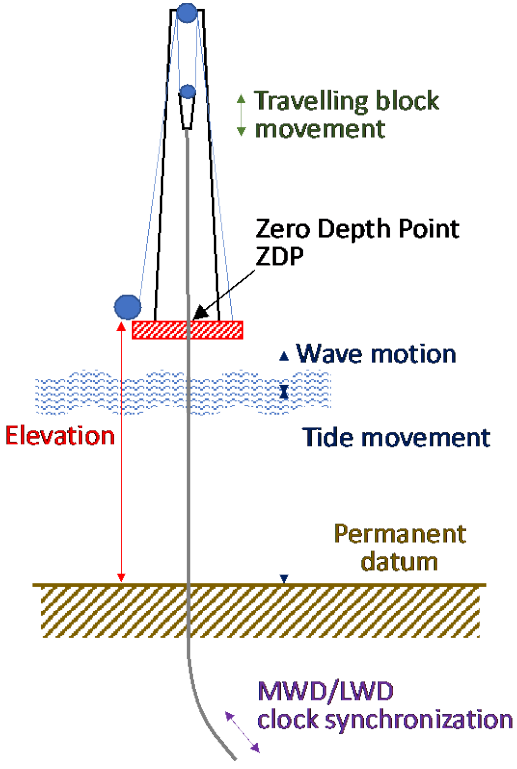
Opportunity for Industry to manage AHD Uncertainty

- Realities of real world well conditions
- Measurement technology used
- Drill string architecture and rig state
- Measurement and correction accuracies
- Correction model accuracies and options
- Uncertainty requirements/expectations set

What's New – Proposed Uncertainty Components

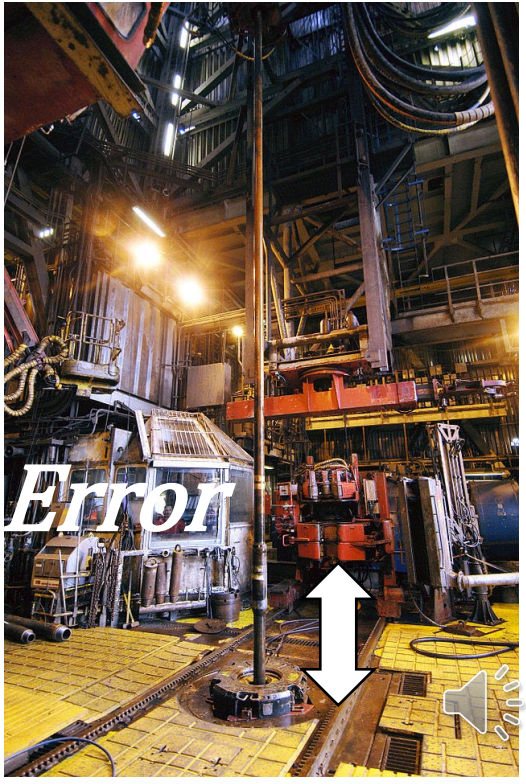
- Reference integrity and stability
- Length measurement calibration accuracy
- Correction accuracy
- Correction model fit
- Uncertainty calculation

References Need to be Managed



Drill pipe measurement reference point locational position and stability uncertainty

Tool Joint Error



Different Drillpipe Depth Correction Calculations

Correction method
Elastic stretch for pipe freely suspended (Reistle & Sikes, 1938)
Elastic stretch for mixed strings freely suspended (Reistle & Sikes, 1938)
Elastic stretch (Milan, 1992)
Elastic stretch (Esketh, 1998)
Elastic stretch and temperature (Gabolde & Nguyen, 2006)
Elastic stretch (Pedersen & Constable, 2006)
Elastic stretch (Baker Oil Tools, 2011)
Driller's Way-point Depth (Bolt, 2017)

DwpD[1]

[1] A Method For Determining Well Depth, Driller's Way-point Depth, International Patent Application No. PCT/GB2018/000030, February 2017

New: Average Correction Value at Any Point

$$Average\ correction\ value = \frac{\int_{ZDP}^{depth} (\boldsymbol{polynomial})}{depth}$$

The average correction at a given point is the correction averaged between the given point (survey Station) and the ZDP

New: Way of Determining Correction Uncertainty

- Difference between the Traditional Industry theoretical (modelled) correction value and the applied correction value is the error of the applied correction

$$\frac{u}{Z} = \frac{\left| \int_{ZDP}^{depth} correction\ polynomial - \int_{ZDP}^{depth} real\ polynomial \right|}{\int_{ZDP}^{depth} real\ polynomial}$$

The accuracy of the model is calculated by subtracting the areas under the two polynomial curves

Choosing a Typical Survey Program Accuracy Range

- DwpD: measurement stations, during POOH, constant speed, simple sliding motion, discrete intervals with (near) linear progression of correction parameters.

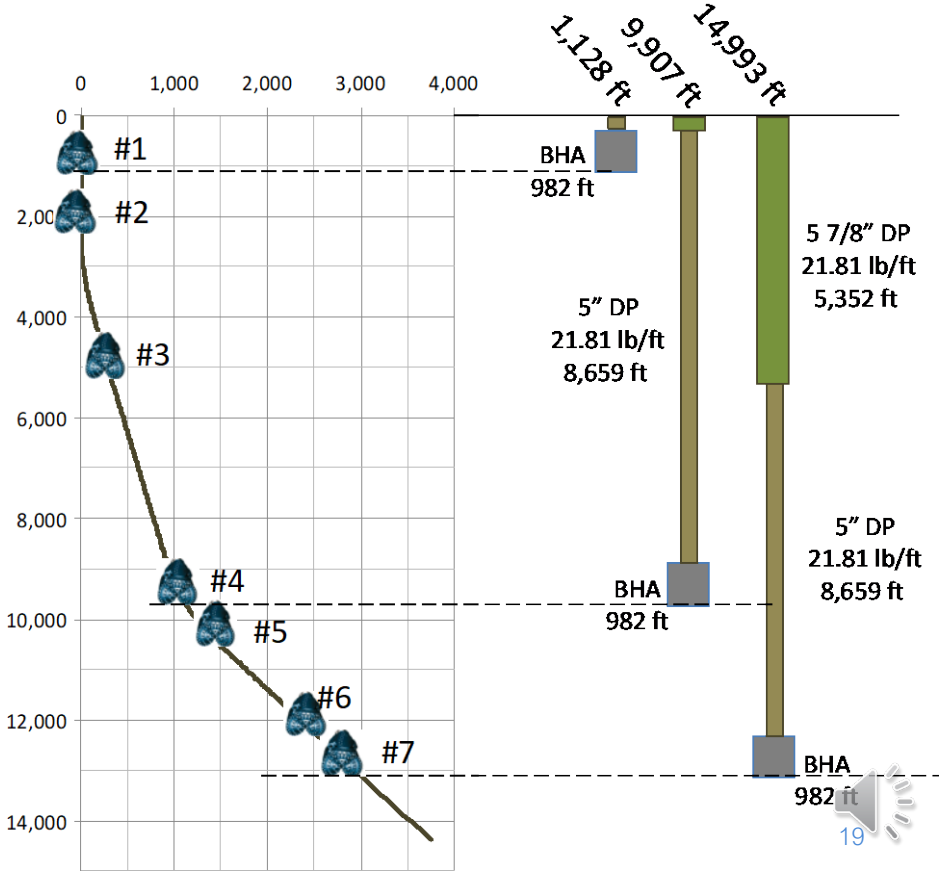
Measurement	Method	Typical accuracy
Pipe length calibration	Strapped pipe	+/- 0.05% to 0.2%
	Lasered pipe	+/- 0.015% to 0.02%
	Additional on-site variance	Accuracy +50% to +100%
Tool joint error	Rig floor visual	+1 ft to +3 ft
Surface hook load	Dead weight sensor	+/- 5% to +/- 10%
BHA mud temperature	LWD sensor	+/- 1%
Stretch coefficient	Young's Modulus for steel	+/- 5%
Thermal expansion coefficient	Thermal coefficient for steel	+/- 5%

New: The Role of Polynomials

- Historically :
  - Tension / Compression, Reference and Temperature effects models were typically not widely used
- Proposed :
  - Well site drilling data to be used on a per Measurement Station basis to create Correction Parameter Profiles
  - Each Measurement Station has a bespoke correction value AND uncertainty value
  - This arrives at TAH Depth

Case Example

- 15000ft , North Sea well
- Logged on Drill pipe, depth with DwpD
- Used 7 measurement stations
- Produced :
  - Correction Polynomial
  - AHD Uncertainty Polynomial



Case Results

Purple Ellipsoids
No TVD corrections
No Depth correction
TVD vertical = +/- 71 ft

Purple Ellipsoids
Advanced inclination correction
No depth correction
TVD vertical = +/- 68 ft

Yellow Ellipsoids
No inclination correction
High accuracy Depth
Correction
TVD vertical = +/- 35 ft

Yellow Ellipsoids
High accuracy inclination
High accuracy Depth
Correction
TVD vertical = +/- 27 ft.

True Vertical Depth has independently calculated Uncertainty, reported at 3-sigma

What's New ?

- Correction Parameters measured POOH - Drill string in tension in simple sliding motion
  - Correction incremental from TD to ZDP
  - Correction Uncertainty at each measurement correction station

- Directional survey log with corrected AHD value and uncertainty
  - Replace ISCWSA Depth Uncertainty Terms with Calculated Depth Uncertainty Polynomial
  - New survey Ellipsoid of Uncertainty volumes
    - 3-d visualization, more robust geo models, Improved well placement knowledge
    - More..

Improvement Potential

- Reduced Vertical Depth Uncertainty when needed
- Geo modelling
  - Define bed boundaries with reduced Wireline vs Drill Pipe LWD Vertical Depth Difference
  - Well placement – landing the well
  - Pay thickness confidence
- Fluid contact determination
  - Reduce early water cut
- Casing shoe depth
  - Manage pressure ramp before and while intersecting high / low pressure zones
- Geo-structure and geohazard
  - Fault or fracture zone management





Questions

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