

Validation of Well Placement within the Planned Ellipse of Uncertainty

Daniel Pina and Josh Albright, Superior QC

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Abstract

Arguably the most crucial phase in developing unconventional oil and gas assets is the planning phase. When planning the drilling and completions program, substantial resources are dedicated to optimizing well placement from both the geological and geographical perspectives, with the goal of maximizing reservoir recovery while minimizing associated risk. It is often assumed that the error models used when planning the survey program are adequate to properly quantify the uncertainty in wellbore position under most reasonable circumstances. To test this assumption, a study was conducted to analyze the frequency with which as-drilled wellbores were found to be outside the predicted Ellipse of Uncertainty (EoU) used in the planning phase. The objective was to assess the risks and implication of utilizing uncorrected MWD surveys (ISCWSA MWD Standard error model) and the associated Ellipse of Uncertainty (EoU) in horizontal wells.

The study looked at over 3800 wells drilled in basins all across US land, by various operators and service companies. When taking all surveys into account, the results revealed that wells are 6 times more likely than predicted to fall outside of the planned 2-sigma EoU used for evaluating anti-collision risk. Furthermore, given the magnitude of the positioning errors observed, the planned well to well spacing, which is designed to maximize production, is also compromised in significantly more instances than predicted. The production loss is also likely compounded by the observation that the errors did not tend to strongly prefer one direction.

Introduction

It is often believed that when planning a well, or a pad, if there are not anti-collision or lease line concerns a third-party multi-station analysis (MSA) provider is unnecessary. When the well is planned it is assigned an ellipse of uncertainty (EoU) based off the magnetic model, and whether MSA is being used. Once it is chosen it is then assumed that all surveys for the well will fall within that EoU. To show the possible negative impacts of such thinking the authors analyzed a dataset of 1750 wells. All these wells ran Fault Detection Isolation, and Recovery (FDIR), an advanced MSA algorithm in real time. The analysis was to see how many wells corrected position fell outside of the raw EoU. Any mention of being outside of the EoU, in this paper, is referring to left or right movement.

After the initial dataset was analyzed and presented at ISCWSA #58 there was feedback that any well that had surveys whose raw data failed the acceptable criteria should not be included in the set. That led to expanding the initial 1750 well study to 3820 and then removing any well that had lateral surveys that were deemed "Out of Spec."

MWD Quality Control

The most common wellbore survey method in directional drilling operation is the use of MWD survey tools. The wellbore's position is derived from two measurements taken with an MWD tool along the wellbore path: inclination and azimuth and then combined with the measured depth, which is obtained while drilling. The wellbore position can be estimated using the minimum curvature method between two survey stations. However, due to the nature of the MWD measurement, there is a remaining uncertainty associated with the wellbore position. These uncertainties propagate from survey to survey, as defined in the industry standard error model developed by the Industry Steering Committee for Wellbore Survey Accuracy (ISCWSA) (Williamson, 2000). Additionally, the error model considers that MWD surveys passed the quality control on G total, B total, and Dip based on the field acceptance criteria (FAC) and assumes: the MWD tool has a valid tool calibration, survey intervals are no greater than 100 ft, enough non-magnetic spacing was used to keep the axial magnetic interference (AMI) within specification.

When planning a wellbore path, substantial resources are dedicated to optimizing well placement from the geological and geographical perspectives, with the main objective of maximizing reservoir recovery while reducing risk. This relies on the assumption that all surveys used for the calculation of the wellbore's position comply with the requirements previously listed. However, based on a study conducted to analyze how often the MWD survey passed the minimum quality control at the field level, it was found that the final wellbore position didn't fall within the predicted EoU (Ellipse of Uncertainty).

Wellbore Position Statistics

The analysis was focused on those MWD six-axis survey passing the quality control criteria using the limits established on the IPM (Instrument Performance Model) (Ekseth et al.,

2006; Willerth & Maus, 2019). When classifying the MWD survey data, wells were excluded from the analysis if any of its existing MWD runs in the lateral section contained surveys deemed “Out of Specification”. Additionally, the length on the horizontal section of the well should extend for at least one mile to be included in the study.

A total of 3,820 wells located across the main US basins (Midland, Delaware, Eagle Ford, Marcellus, Haynesville, and Utica) were included in this analysis, Figure 1. To determine whether the final position of the wells fell within the expected EoU of the base MWD error model, the raw surveys were corrected using an advanced survey correction algorithm which estimates and corrects existing errors on the magnetometers and accelerometers used to calculate inclination and azimuth. During this process the raw six-axis data was classified as illustrated on Table 1. Surveys were evaluated with the field acceptance criteria using a 3-sigma and the quality control limits based on the ISCWA error model rev 5. Additionally, the raw EoU size for the 2-sigma and 3-sigma were calculated along with the horizontal correction at final depth.

Looking at the dataset as a whole it is observed that almost 30% of the wells fall outside of the 2-sigma EoU, and 16% fall outside of the 3-sigma EoU. 1,127 wells fell outside of the 2-sigma, and 76% of those wells had lateral surveys that were classified as “Out of Specification.” Of the entire dataset, 45% of them had surveys “Out of Specification,” and for the sake of this study were removed. The authors felt it was important to still mention the large number of wells that had surveys that should fail FAC, and would have very large well placement error if survey corrections were not performed in real time. Of the 1701 wells removed from the list, 50% of them fell outside of the 2-sigma EoU.

Once the wells deemed “Out of Specification” were removed the remaining wells were broken into three levels of raw data classification. “In Specification” is within 5% of the error model limits. “Possibly Out of Specification” is between 5 and 50%, and then “Likely Out of Specification” is anything above that and still within the limits of the error model.



Figure 1

Table 1

Raw Data Classification	Well Count
In Specification	512
Possibly Out of Specification	776
Likely Out of Specification	831
Out of Specification	1701

After processing each well with an advanced MSA software and obtained the corrected position of the wellbore at final depth, the sigma ratio between corrected and raw was calculated using the lateral correction and the semi-major axis length to determine if the corrected position fell within the EoU.

- Sigma ratio was less or equal to 2.0, the corrected well position fell within the EoU, and raw surveys could be considered valid under the IPM MWD rev5. Figure 2.
- Sigma ratio greater than 2-sigma, the final corrected position of the well fell outside the EoU, and raw surveys could be considered invalid to use the IPM MWD rev5 as tool code. Figure 3.

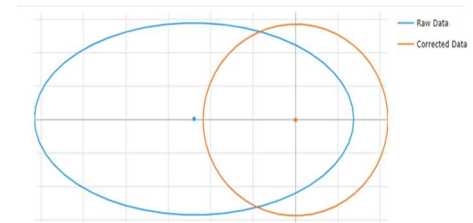


Figure 2

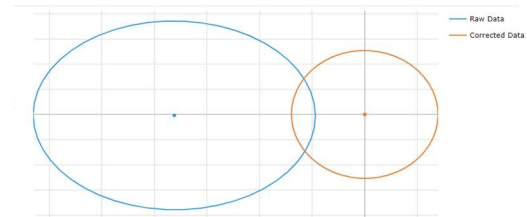


Figure 3

Table 2

MWD survey rating	Sigma < 2	2<=Sigma<3	Sigma >= 3
In Specification	498	13	1
Possibly Out of Specification	695	76	5
Likely Out of Specification	653	138	40

The impact of MWD surveys being classified as “In Specification” but not meeting the quality standards required by the IPM MWD rev.5 can lead to incorrect estimations the well’s position. This can significantly affect geological correlation and production estimation.

From this study conducted on these 2,119 wells, 12.9% of the wells fell outside the 2-sigma EoU, which is 2.5 times the expected value. Additionally, 2.2% of the wells fell outside the 3-sigma EoU, which is 7.2 times the expected value. A subset of 150 wells drilled with an azimuth East/West +/- 30 deg showed that 32.6% fell outside the EoU. And a secondary subset of 1,027 wells drilled with an azimuth North/South +/- 30 deg showed that 9.8% of the wells located outside the EoU. Figure 4 displays a bar chart that shows the expected value of wells falling outside of the 2-sigma EoU based on the number of wells for each spec rating.

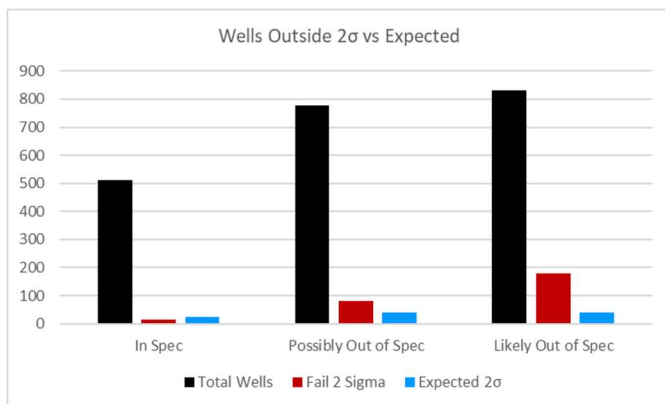


Figure 4

The survey sets on the lateral section for the wells considered in this study were classified other than “Out Of Specification.” Although the MWD tool code appeared to be valid to use on those surveys, when the field acceptance criteria were classified as “Possible Out” or “Likely Out,” the probability of the corrected position of the well fell falling outside the ellipse of uncertainty increased.

Raw to Corrected Position Statistics

Another way to analyze this data set is by comparing the raw bottom hole location to the corrected bottom hole location. Even if the corrected position falls within the raw EoU, the deltas between the raw and corrected positions could have large impacts on well spacing when pad drilling.

When looking at this data the absolute value of distance between raw and corrected positions is used. The average movement for all the wells in the dataset was 80.76 ft. Removing the “Out of Specification” surveys the number decreases to 53.13 ft. Additionally, 15% of the wells that were classified within specification moved 100 ft or more. The direction of movement was pretty close to even with 43% of wells moving right, and 57% of wells moving left.

Figure 5 shows the distribution of correction size by specification rating.

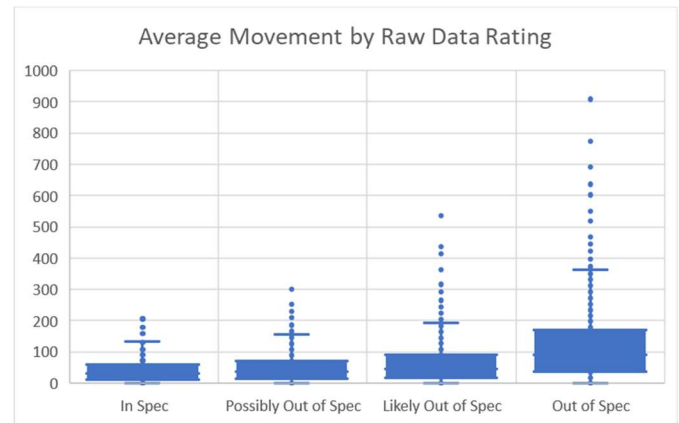


Figure 5

Conclusions

During the planning phase of drilling a well, it is essential to analyze the MWD survey viability for the error model selected for each drilling section. Additionally, it is important to incorporate quality processes to ensure the reliability of the MWD tool and verify that its calibration complies with the minimum requirements for the planned tool codes to consider its surveys valid. Furthermore, it is necessary to verify that surveys included in the definitive survey listing pass the Field Acceptance Criteria (FAC) based on the limits defined in the error models when surveys have not been corrected using an advanced survey correction algorithm.

Failing to implement a quality assurance program can increase the risk of well collision, reduce the well production due to improper placement. Even when the surveys fall within FAC there is increased risk that they will fall outside of the EoU, or have a large raw to corrected delta which can effect the production of the wells across a pad.

Nomenclature

EoU = *Ellipse of Uncertainty*

FAC = *Field Acceptance Criteria*

MSA = *Multi Station Analysis*

References

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