

## Aging Platform Revitalization in Gulf of Mexico: Addressing the Well Collision Risks

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### Abstract

In recent years, revitalization of aging platforms has increasingly become an interesting option for production optimization, especially for small producing companies with limited CAPEX, who bought aging platforms from the Oil and gas Majors. The revival of mature platforms is less capital-intensive and has a shorter cash-flow cycle compared to capital-intensive and long-term projects pursued by the major oil companies.

At the same time, since the peak in the discovery of giant fields several years ago (SPE-93884), advanced developments in technology have rendered mature platform revival practices more cost effective. Therefore, extending their economic life has become a very attractive option to maximize return on investment. Revitalizing aging platforms poses unique challenges. On mature platforms, the maximum number of wells that can be drilled is reached, the density of wells is very high and well paths are very complex. There is no more opportunity to drill new wells, so only three options available are: slot recovery, slot addition, and re-entry drilling.

Each of these three options entails placing a new borehole in a high-well-density environment where hundreds of wells drilled decades ago and surveyed with older, low accuracy surveying techniques, pose unique well collision risks. Large surveying errors associated with those legacy surveys generate very large wellbore positional uncertainties which render placing and drilling a new borehole in such environment uniquely challenging. Based on a few Gulf of Mexico case studies, this paper presents a systematic approach to evaluate, plan, mitigate and monitor the increased hazards of well collisions in highly congested aging platforms.

### Introduction

Planning and executing a new directional well from an aging platform in the Gulf of Mexico (GOM), to tap remaining bypassed reservoir pockets, is critically important to aging platform revitalization. The worldwide oil recovery factor averages 35%. As a platform ages, the production rate reaches a peak, then starts a gradual decline. An aging platform is defined as a platform that has reached its production peak and is in production decline mode. Fig.1 shows a typical GOM aging platform production life.

The worldwide growing demand in oil and gas, combined with recent advances in technology and innovation has allowed operators to boost the productivity of aging

platforms or to slow the natural productivity decline of aging platforms. The latest advances in re-entry drilling technology (slot recovery, slot addition, milling, whipstock and fishing (SPE-49255)), in rotary steerable systems and in borehole surveying systems eliminate the need to build a new platform from scratch. Multilateral sidetracks that are drilled out of a single mother borehole eliminate the need to drill new wells.

On aging platforms, all the slots are already in use, the density of wells is high (Fig.2), and many of the wells were drilled decades ago, when wellbore surveying techniques were still in an embryonic stage and rigorous survey database management was almost inexistent. Therefore, the positional uncertainties on these existing wells are exceptionally large and placing a new wellbore in such environment poses unique challenges in terms of well collision. As more wells are drilled from an aging platform, placing the next well while avoiding collision with existing wells becomes increasingly difficult. The consequences of a well collision with an existing wellbore can be health, safety and environment (HSE) ones and/or financial ones and can range from economic loss only to loss of life (SPE/IADC-184730-MS). The systematic approach presented in this paper to minimize and mitigate well collision risks in crowded mature platforms consist of:

- Ensuring that the existing wellbore survey database is accurate and complete
- Estimating the existing wells' positional uncertainties
- Evaluating the available space below the platform and planning the new well trajectory accordingly to the clearance available
- Optimizing the new well trajectory by maximizing the drilling tunnel to avoid collision
- Building a surveying program that properly addresses the high external magnetic interference present from the slots down to hundreds or thousands of feet measured depth below the platform
- Monitoring while drilling in the close approach intervals.

This paper is intended to help well planners and drilling engineers minimize and mitigate the well collision risk associated with planning, executing and monitoring of re-entry wells in highly congested aging platforms.

### Typical mature platform revitalization practices

In recent years, advances in technical creativity and innovation have made possible the development of multiple techniques for mature platforms revitalization. The techniques covered here are in the domain of well engineering. The objective of well engineering techniques objective is to place an additional wellbore below the platform to tap residual oil, thus giving new life to mature declining platforms. After all the slots on a platform are used, a new well cannot be drilled from the platform: therefore, mature platform revitalization techniques such as slot recovery, slot addition/platform extension and re-entry drilling are the only remaining options.

#### - **Slot recovery**

The objective of a slot recovery project is to re-use slots on the platform. Slot recovery entails cutting, milling and pulling the entire casing string or part of it. Then, an openhole sidetrack is drilled (SPE-174718-MS and SPE-177581-MS). Another technique being used in the GOM is to cut the conductor at seabed, then drive from the same slot a new conductor into the seabed at an angle and at a specific orientation, causing the conductor to be laterally deviated from entry into the seabed soil to final deviated position (Fig.3). Normally conductor pipes are installed vertically, and directional work starts below the conductor pipe shoe. In this case, directional work starts at the mudline level, to avoid conflicts with previous hole underneath the slot. After a deviated conductor is in place, a new well can be drilled.

#### - **Slot addition/platform extension**

In some cases, it is possible to add additional slots to the platform, leading to smaller slot spacing (Fig.4). The objective of a platform extension project is to extend the existing platform by adding three to four well slots to the platform to accommodate additional wells (SPE-161506). Many of the mature platforms are heavily used with little to no space for expansion. When there is some room for expansion, adding a couple of additional wellslots to the platform represents a huge cost saving compared to building a new platform.

#### - **Re-entry drilling**

Given that there is no more slot available for a new well, re-entry drilling consists of entering existing wellbore and drilling sidetracks to tap new production zones. The most important aspect of re-entry drilling is either to mill a window into existing casing then perform a cased hole sidetrack, or to perform an open hole sidetrack. Multiple lateral sidetracks (Fig.5) can be drilled from a single parent wellbore, boosting platform productivity at a reduced platform construction costs.

### Revitalization project well collision risk challenges

The biggest challenge in implementing any of the mature platform revival practices discussed above, is to thoroughly understand and effectively manage the well collision risks with existing wellbores below the platform. As stated above, the consequences of an unplanned well collision with an existing wellbore can be financial or they can be related to HSE. An

HSE well collision risk involves an uncontrolled release of hydrocarbons in the subsurface or/and at seabed or/and at surface (SPE 184730). A collision affecting HSE can result in a catastrophic blowout, severe damage to the environment and loss of life. For a non-HSE-related collision, the consequences of well collision with existing offset well can be addressed in financial terms only, such as damages to equipment, rework...

Well collision avoidance is based on maintaining a suitable and conservative separation distance from any offset well. This separation distance called the minimum allowable separation distance (MASD), it varies with depth and it depends entirely on the spacing between the wells and the positional uncertainty related to each well. Below aging and crowded platforms, maintaining a positive MASD is in the best case very challenging and in the worst case impossible (Ref: SPE 184730).

#### - **Survey database completeness and correctness**

The first challenge in collision avoidance below an aging platform is to construct the directional database as accurately and as completely as possible. The directional database is a 3D representation of all the wellbores below the platform. Most of the wells drilled on those aging platforms were drilled decades ago, when database integrity and management were at an embryonic stage, and in most cases the directional database is not yet constructed in the master database. It must be constructed from scratch well by well. It is crucial to gather the complete list of wellbores below the platform, then gather the positional surveying information of each of the wellbore. In the GOM, public tools such as the Bureau of Safety and Environmental Enforcement (BSEE) data center and the Strategic Online Natural Resources Information System (SONRIS) and third-party tools such as Offshore Well and Lease (OWL) are used to pull those data.

BSEE, established in 2011, is an agency under the United States Department of the Interior. BSEE oversees improving safety and environmental protection related to oil and gas industry on the United States Outer Continental Shelf (OCS). The BSEE data center contains public well information that users can access via online queries. It is the official repository of well lists and survey data (Fig.6).

The OWL database is a third-party database designed to search, report and map OCS data (Fig.7). SONRIS is a Louisiana state agency under Department of Natural Resources. Its data portal contains oil and gas well information accessible via online queries for wells close to the Louisiana shore (Fig.8). The operating company is another source of well information. After the data are searched and pulled from any of the above sources, every survey data must be verified, checked and validated using all available sources. The platform must be constructed in the database, and then all the offset wells are constructed manually one by one into the database. It is a time-consuming and error-prone process; care must be taken to double-check every entry.

### - **Legacy survey accuracy**

A survey provides definitive data that depict the position of a wellbore at a given depth. Errors are present in each survey measurement. These errors, inherent to the survey tools or environment, are estimated using an appropriate instrument performance model (IPM) as per ISCWCA (SPE 67616), and they drive the positional uncertainty of the wellbore. An IPM is an error model, consisting of a set of statistical coefficients used to generate the required volume of uncertainty around the wellbore. At each survey measurement, a volume of uncertainty (ellipse of uncertainty) is calculated based on the summation of the errors. Many wellbores below an aging platform are 30 years old or older. They were drilled and surveyed with unknown or low-accuracy surveying tools, and so are prone to very large positional uncertainties. The surveying tools used then were at an embryonic stage in terms of accuracy and errors modeling. In the past, survey tools such as drift indicators which measure only inclination, photo mechanical free gyro systems and photo mechanical compass systems were mainly used. Older surveys have relatively large errors and consequently very large uncertainty envelope. Statistically if two offset ellipses of uncertainty are touching each other, it means there is no room to place an additional well between those two offsets. A larger uncertainty envelope translates into very tight clearance, or in most cases, to nonexistent clearance to place an additional wellbore, leading to higher probability of well collision (Fig.9). Below mature platforms, large uncertainty volumes due to low-accuracy survey tools touch each other, generating very tight control on additional well placement. The ellipses of uncertainty are used to draw an increasing tube of uncertainty around any wellbore, and the juxtaposition of all adjacent tubes of uncertainty is used when a new well is planned under the platform to avoid intersecting wells. Often, it is necessary to recommend to the operator to resurvey one or more nearby wells to reduce the positional uncertainty.

### - **Nonexistent drilling tunnel**

Below an aging platform, because of the proximity of adjacent wells and the very large ellipses of uncertainty due to older, low-accuracy survey tools, it is very challenging to plan a new wellbore to hit the geological targets without an increased risk of well collision. In most cases there is no clearance left below the platform to place an additional well. The procedure used to plan a new wellbore in such environment is an iterative process and it consists of the following steps:

- 1- Build a survey program with contingencies that help maximize the clearance between the planned wellbore and the adjacent wells. A survey program is a suite of surveys tools, tool code, survey frequency, surveying parts and surveying requirements that will be used while drilling the subject well (AADE-17-NTCE-022). The survey program defines the surveys error model that will be used. It

therefore defines the size of the uncertainty volume surrounding the subject well (SPE-101719). It is extremely important to choose an adequate error model to minimize wellbore positional uncertainty, thus minimizing the volume of uncertainty. Smaller uncertainty volume means greater clearance. A trade-off must be found here between the potential expense of high accuracy survey tools and the optimization of the drilling tunnel.

- 2- Study the clearance available below the platform, by studying the juxtaposition of all existing wells tubes of uncertainty. Due to the proximity of existing wells, it is impossible to plan a new well without an increased risk of well collision.
- 3- Place and optimize the new well path in the clearance available. Due to high congestion, a 3D well path is always used (Zhihua Wang and Tom A. Inglis, SPE, 1990). After a trajectory is generated, its tube of uncertainty is computed based on the survey program (SPE-124246). Then its tube of uncertainty is compared to adjacent wells paths, to verify that the separation between planned and adjacent wells is maximized. If the separation is not maximized, then the proposed well path is modified, taking into consideration the capability of the drive mechanism to be used, the allowable dogleg severity and the allowable inclination and azimuth at that depth. In most cases, many iterations are conducted before an optimal proposed well trajectory is chosen.

### - **External magnetic interference**

Drilling a new well below a congested and mature platform poses a unique challenge regarding measurement-while-drilling (MWD) surveys being affected by external magnetic interference. Since the early 1980s, the MWD survey tool has become the standard survey tool used worldwide. It uses a set of accelerometers and magnetometers to measure borehole inclination and azimuth. Azimuth is measured in reference to the earth's magnetic field. In a congested environment, nearby wells are cased, and these metallic casing strings generate a magnetic interference; thus, the azimuth is no longer measured in reference to earth magnetic field, resulting in bad surveys that compromise required positional accuracy of the subject well. Anti-collision practices are based on industry standard MWD surveys quality. The blind zone is the external magnetic interference interval. Drilling blind in such environment has a high probability of resulting in a catastrophic well collision. During the planning phase, the blind zone is estimated, anticipated and managed. The gyro-while-drilling (GWD) tool has become the preferred solution used to drill through the blind zone in the GOM mature platform revitalization projects. GWD uses gyroscopes instead of magnetometers, and therefore is not subject to external magnetic interference (SPE-174718-MS). GWD introduces smaller ellipse of uncertainty (EOU), minimizing well collision risks and reducing directional

uncertainties. Another solution used in the GOM is to run multi-shot gyro surveys on wireline; this is less used because of the inefficiencies it introduces into the operations.

#### - **Producing offset wells**

To assess the likelihood and the severity of a well collision, it is crucial to assess the flowing status of offset wells. If the offset is plugged and abandoned (P&A), the worst case of well collision will result in financial loss only, such as damage to the casing, damage to drilling equipment. If the offset is a producing well, an in-depth and thorough assessment needs to be conducted to ensure that the HSE risk is minimized. Prevention and mitigation measures must be jointly discussed and agreed upon by the operator and the drilling contractor. Setting a plug below the close approach interval, shutting down any lifting mechanism while drilling the close approach interval, shutting in the producer at the downhole safety valve, maintaining while drilling a hydrostatic overbalance over the producer and recommending magnetic ranging technologies are some of the prevention and mitigation measures the operator needs to implement to reduce the well collision HSE risk. Magnetic ranging technology uses MWD surveys to detect offset well position, then steer the subject wellbore away, thus minimizing well collision risk.

#### - **Well collision risk escalation protocol**

Escalation in the context of well collision risk is defined as a formal process to highlight the well collision risk to higher authorities and to all stakeholders. All stakeholders must be aware of well collision risks, to assure themselves that appropriate actions are being taken to protect and safeguard the rig crew, the environment and their assets. Well collision risk requires a higher level of intervention because of its catastrophic consequences, and because many times the personnel other than the drilling engineer are responsible for decision making and for the resources needed to minimize and to manage the well collision are beyond the drilling engineer. For a small operator, the decision to shut in a producing well for couples of days has huge financial implications that go beyond the drilling engineer's horizon. Well collision escalation protocol provide for:

- There is effective communication, i.e, all stakeholders are aware of the collision risk and the mitigation measures in place, in a timely manner
- There is a clear and effective system in place for assessing, analyzing, minimizing and managing the risk and for recognizing where there is a need to communicate
- There is a system in place to check that all planned prevention and mitigation measures are effectively implemented
- Clear roles and responsibilities of risk escalation and management are set out

In the GOM, a combination of hazard analysis and risk control (HARC) and exemption is used to properly escalate the well collision risk (SPE/IADC-108279). HARC is a systematic approach to analyze hazards and to develop prevention and mitigation measures. It is the foundation of well collision risk assessment. It requires a higher-level approval, escalating the collision risk in the organization. An exemption is required for wells that break the anti-collision rules. Any well that breaks the center-to-center distance rule or with an oriented separation factor (OSF) < 1.5 requires an anti-collision exemption. Due to the highly crowded subsurface, during 2018, all aging platforms revitalization projects in the GOM require an anti-collision exemption. The exemption clearly defines the type of well collision risk (HSE or financial) and the prevention and mitigation measures to have in place and provides a precise assessment of the worst-case scenario. It is a powerful tool used to communicate with the operators regarding the well collision risk management.

#### - **Real-time monitoring**

To minimize well collision risk during execution, continued active monitoring and vigilance are required during planning and during execution. The first step of real-time monitoring consists of verifying that preconditions set during planning are still valid, confirming nearby wells flowing status, confirming that the planned trajectory is correct and approved, and confirming that everything operational is as per plan. The second step, as we drill through the close approach interval, is to compute and plot the position of drilled trajectory as each survey comes in, to conduct projections to the bit and at least 180ft ahead of the bit. Then it is very important to perform an anti-collision scan against adjacent wells, to determine if it is safe to continue drilling to the next survey point. The projection to the bit and ahead of the bit and wellbore anti-collision proximity scan are repeated every survey as drilling progresses. A management of change is initiated for any deviation from plan, for any change during execution.

#### **Case Studies**

Many mature platform re-entry wells are currently being drilled in the GOM, following the well collision prevention and mitigation processes and techniques presented above. The following two case studies illustrate the unique well collision risks posed by planning and drilling re-entry wells on aging platforms. The two wells were drilled in the GOM continental shelf during 2018.

##### - **Case study 1: Slot recovery in West Delta 73**

The first case study involves a mature platform revitalization project in West Delta 73 (WD73) field in the GOM. West Delta Block 73 field is located 27 miles southeast of Grand Isle, Louisiana, and 17 miles west of the mouth of the Mississippi River's Southwest Pass. Water depth is 175 ft. This field was discovered in 1962, and oil production started in 1963.

Production peaked late 1960s and early 1970s (Fig.1), and since then it has experienced the gradual decline experienced by all mature fields. Two platforms (C and D) are operating in the block. Platform C started operation in 1964 and platform D started operations in 1965. This field was bought by a small Oil & Gas Company from ExxonMobil in 2010. The objective of this revitalization project is to increase recovery rate by drilling a horizontal well to tap additional reservoir from platform C. Platform C has 28 slots and 63 boreholes (Fig. 10). The adjacent platform (D) has 92 boreholes. All 28 slots of platform C are used; the plan is to re-use slot 41 (Fig. 11), cut and pull the current conductor at the seabed and then drive in to the seabed a deviated conductor next to it. At seabed, the center-to-center distance between previous conductor and new conductor is less than 3 ft.

The first step was to build the two platforms in the well planning software, then search in BSEE and OWL databases 155 borehole directional surveys and cross-check and validate each borehole surveys against other data sources. Finally, each borehole is imported into the database. It is a very tedious and time-consuming process. By experience, 20 boreholes can be searched, validated and constructed in the database per day. Therefore, for 155 boreholes, it takes 8 full days to completely build as accurately as possible the two platforms and 155 boreholes in the database (Fig. 12).

The next steps were to assess the clearance available in this tangle of wellbores and then plan a new wellbore trajectory that would maintain the greatest allowable deviation from plan (ADP) against each of the offset wells while hitting the geological targets and maintaining the drill-ability requirements (dogleg). This is an iterative “trial and error” process. The result was a 3D well with directional work starting at the mudline. After an optimized well trajectory is obtained, an anti-collision scan is run to assess the well collision risk of the new wellbore against each offset well. Given the very tight clearance below the platform, the ADPs of 34 offset wells were negative. ADP defines the drilling tunnel. A negative ADP means that there is no drilling tunnel. This means those offset wells with negative ADP fail the major anti-collision rule ( $OSF < 1$ ) or the minor anti-collision rule ( $1 < OSF < 1.5$ ). The drill-ahead rules are violated and drilling under these conditions can potentially pose a risk of injury to the field crew, of serious harm to the environment or economic loss. Therefore, an anti-collision exemption was needed to escalate the high risk of well collision and to implement proper prevention and mitigation measures to minimize the high well collision risk. The following prevention and mitigation measures were implemented:

- Use GWD down to 3800ft measured depth, to prevent nearby casings magnetic interference on the surveys and to reduce the current wellbore ellipse of uncertainty.

- Put a procedure in place to shut off and bled down the gas lift on all the producing nearby wells.
- Shut in all producing wells at the downhole safety valve. All the close approach intervals are close to the surface, therefore the subsea safety valve (SSSV) can isolated the hydrocarbons downhole from the surface.

The first two measures are done so that a well collision with an active well will not result in the release of hydrocarbon at the surface. The HSE risk is eliminated, and only the financial risk from a well collision remains. During the execution phase, the planned prevention and mitigation measures were implemented and monitored carefully: the well was drilled to total depth, and successfully completed with no well collision concern.

#### - **Case Study 2: Slot addition in Ewing Bank 306**

The second case study is a slot addition project in Ewing Bank 306 (EW306), GOM. Production started on EW 306 in 1986; it peaked late 1990s then started a gradual decline (Fig. 13). Platform A operates on EW306. It has 18 slots (all used) and 58 boreholes (Fig.14 and Fig.15). The objective of this mature platform revitalization project is to add an additional slot (A20) between two existing slots (A14 and A06) (Fig.16), then drill a new borehole to tap three known sand reservoirs and to explore two deeper sand reservoirs. The minimum center-to-center distance between two existing slots on the platform is 8 ft; adding a slot between two existing slots cuts that minimum distance in half, exacerbating the well collision risk.

In this case, as in the previous case, the platform and its existing 58 boreholes was manually built into the well planning software, while making sure each that each of the borehole surveys were cross-checked and validated. Then, a zigzagging 3D trajectory (Fig.17) was iteratively designed to avoid nearby boreholes and to maximize the drilling tunnel. An anti-collision scan performed on this trajectory revealed 19 offset boreholes failing the major anti-collision rule ( $OSF < 1$ ). Among the 19, 3 were flowing naturally and 2 were flowing aided by gas lift; the rest were permanently plugged and abandoned. Therefore, the anti-collision analysis showed an HSE risk; the following adequate HSE risk prevention and mitigation measures were taken and were strictly followed to transform the HSE risk to financial risk only:

- All flowing nearby wells were shut-in while drilling the close approach interval (from surface down to 1,140ft MD). After 1,140ft MD, there is more space between wells and the well collision risk is reduced to a minimum.
- All gas lifts on the flowing wells were shut down and bled off while drilling the close approach interval
- One of the offset wells (A14) has a low-pressure regime; the drilling hydrostatic column was more than enough to balance the pressure in that well.
- Wireline gyro was used down to 700ft MD. Then GWD was used down to 2,600ft MD below the platform, where

MWD surveys were no longer affected by external magnetic interference.

During the execution phase, a close monitoring of well collision risk was conducted: a full anti-collision analysis was performed after every survey and after projections to the bit and travelling cylinder (TC) plots were utilized to keep the drilled well path and projections ahead of the bit in the drilling tunnel. TC plots are a very effective anti-collision tool used to visualize the current trajectory position in respect to offset wells. The EW306 A20 was drilled to total depth with no issue. The well encountered approximately 120 ft of pay across five sand reservoirs. Completion was made in the third quarter with an initial production rate of approximately 2.2 MBoe/d; production started in September 2018.

### Conclusion

This paper presented a systematic approach to tackle well collision risks posed by drilling an additional wellbore below an aging and highly congested platform in the GOM. Due to the dynamics of the world oil market, aging platform revitalization projects are becoming more and more economically attractive. Aging platform revival practices pose a unique well collision risk; drilling from such a platform reduces the already small center-to-center distance between the platform wells and the drilling tunnel is nearly nonexistent.

The well collision avoidance approach presented in this paper is based on the following practices:

- 1- Build in the well planning software the most accurate representation of the platform, its slots and its existing boreholes. Public databases and the operator's database are used to gather, to cross-check and to validate all the data needed. Surveys taken decades ago with older-technology surveying tools intensify the well collision risk with massive positional uncertainties.
- 2- Use an iterative process to plan the well path in the tangle of boreholes below the platform and to simultaneously run an anti-collision scan on the generated well path. An optimized trajectory is the one that maximizes the ADP, thus the drilling tunnel, while at the same time hitting the driller's targets within the dogleg requirements.
- 3- Analyze all offset wells that fail the drill ahead rules to determine whether the well collision risk is HSE or financial.
- 4- Have in place well collision prevention and mitigation measures that are strictly followed during planning and during execution to ensure that the well collision risk is adequately minimized and properly managed.
- 5- Monitor well collision risk during execution to check that the plan is followed and anything deviating from

the plan is properly managed through a management of change (MOC).

Two case studies have shown that this approach can be effectively used to deliver safely and economically an aging platform revitalization project without any harm to the people or to the environment.

### Nomenclature

<i>ADP</i>	= Allowable deviation from plan
<i>BSEE</i>	= Bureau of Safety and Environmental Enforcement
<i>CAPEX</i>	= Capital expenditure
<i>EOU</i>	= Ellipse of uncertainty
<i>GOM</i>	= Gulf of Mexico
<i>GWD</i>	= Gyro while drilling
<i>HARC</i>	= Hazard analysis and risk control
<i>HSE</i>	= Health safety and the environment
<i>IPM</i>	= Instrument performance model
<i>ISCWSA</i>	= Industry Steering Committee on Wellbore Survey Accuracy
<i>MASD</i>	= Minimum allowable separation distance
<i>MOC</i>	= Management of change
<i>MWD</i>	= Measurement while drilling
<i>OSF</i>	= Oriented separation factor
<i>OWL</i>	= Offshore Well & Lease Databases
<i>P&amp;A</i>	= Plug and abandon
<i>SONRIS</i>	= Strategic Online Natural Resources Information System

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## Figures

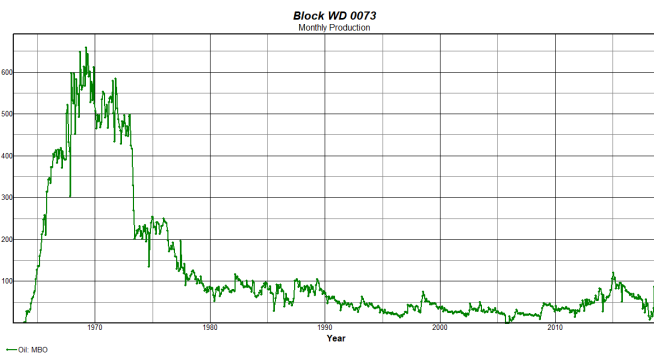


Fig.1: Block WD73 production profile over time

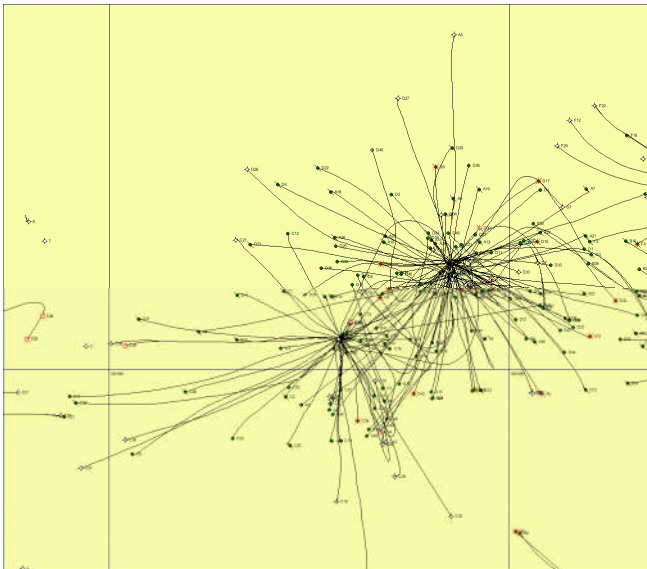


Fig.2: Plan view of two high well-density platforms in the GOM

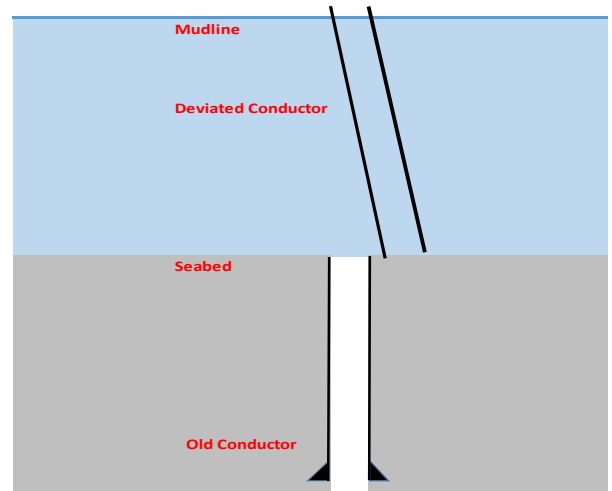


Fig.3: Slot recovery, deviated conductor



Fig.4: Adding an extra slot to an existing platform

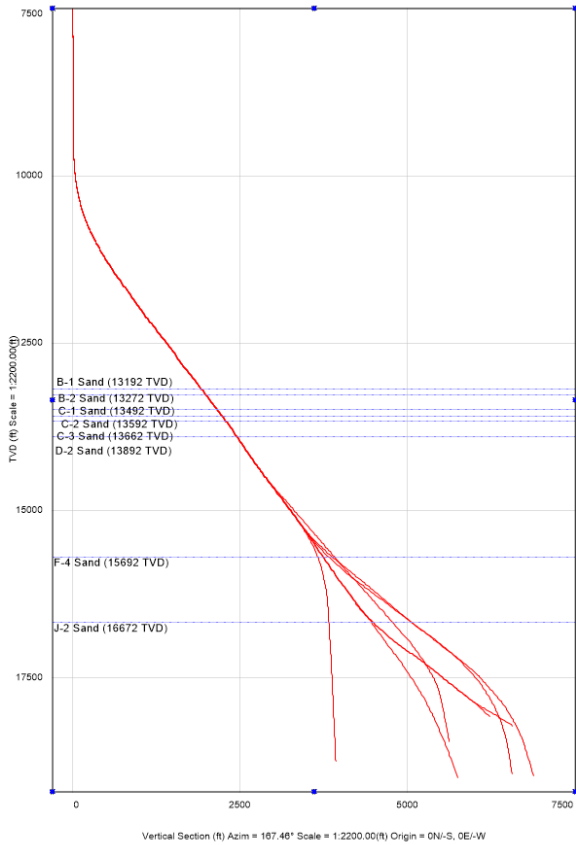


Fig.5: Sidetracking multi-laterals from a single motherbore

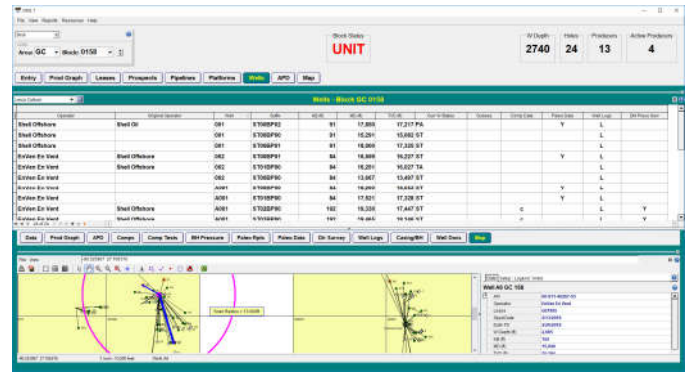


Fig.7: OWL data center

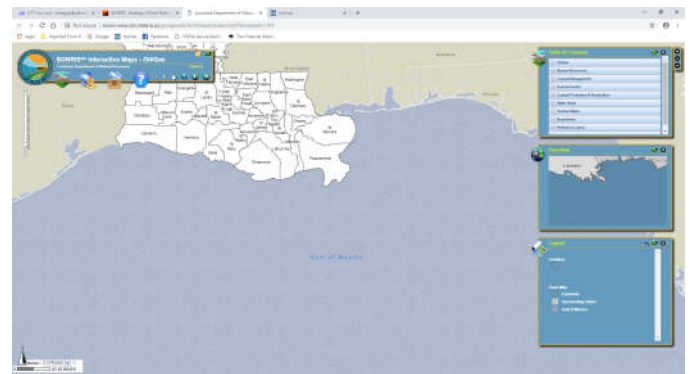


Fig.8: SONRIS data portal

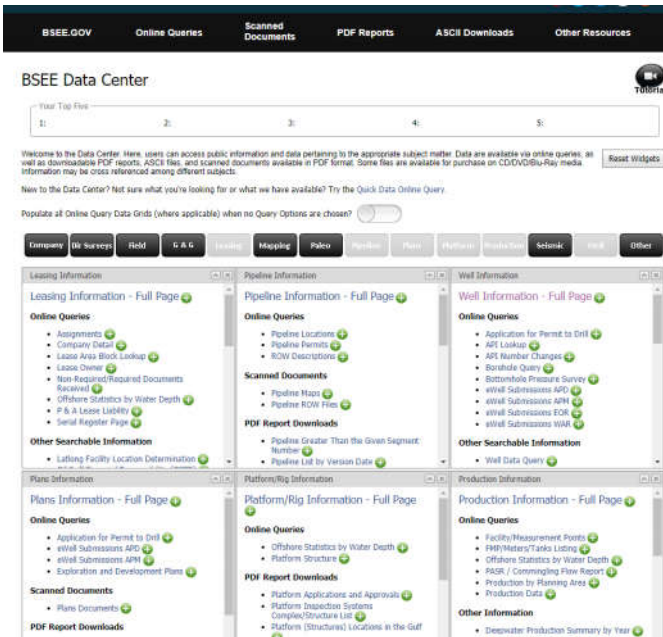


Fig.6: BSEE data center

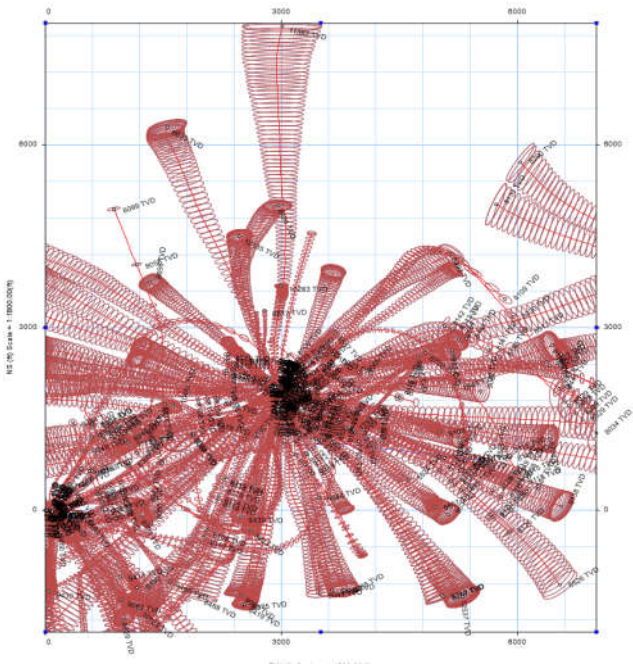


Fig.9: Example of aging platform tangle of uncertainty envelopes

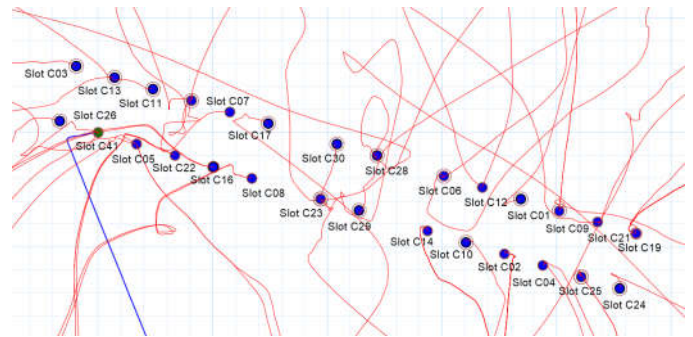


Fig.11: WD73 platform C slot C41

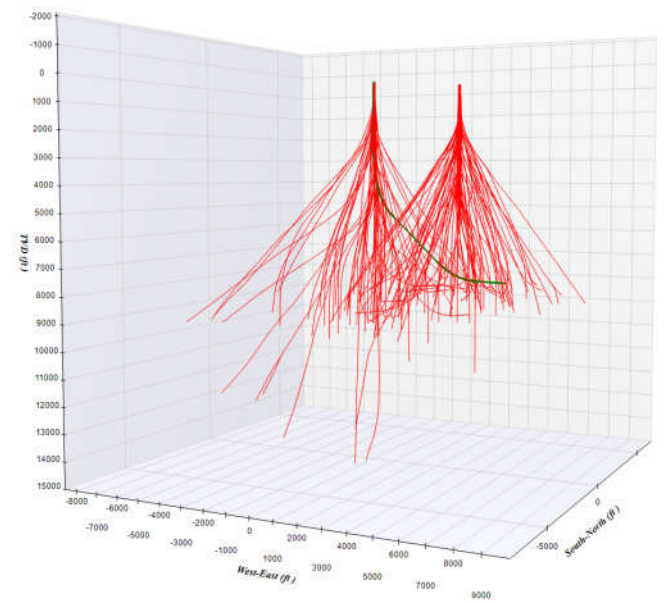


Fig.12: Block WD73 tangle of boreholes

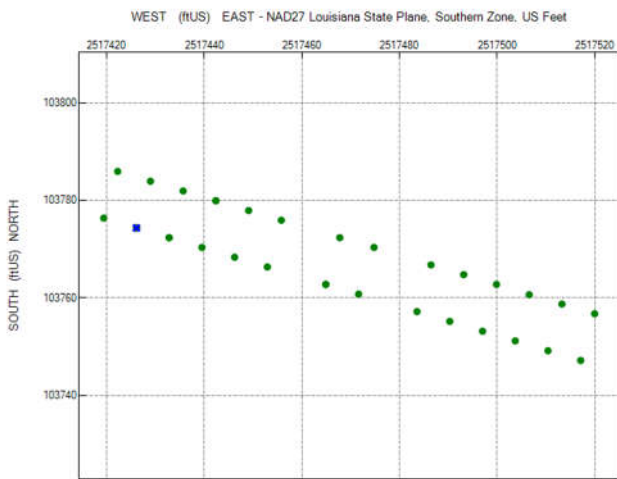


Fig.10: WD73 platform C slot map

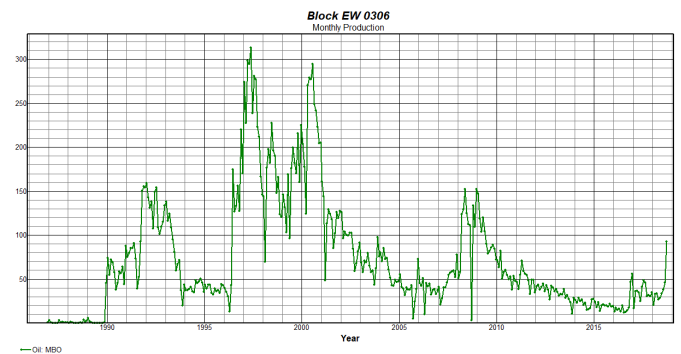


Fig.13: EW306 production profile over time

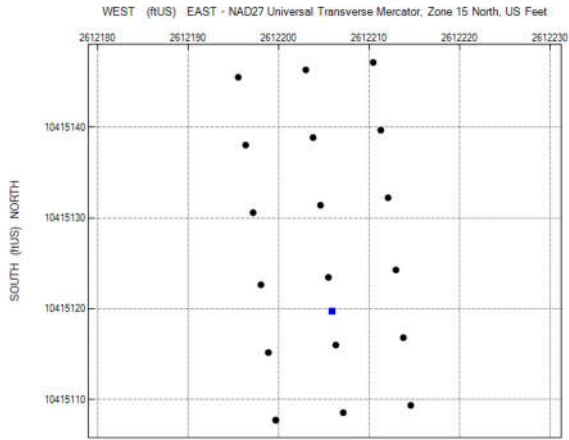


Fig.14: EW306 slot map

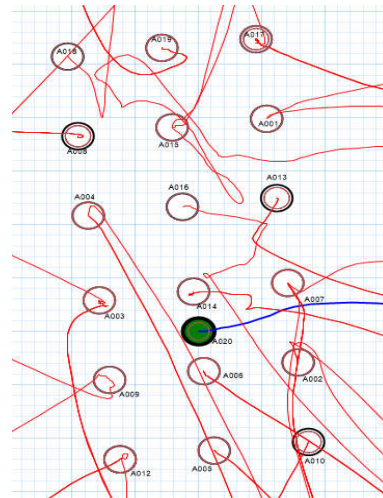


Fig.16: Added slot A20

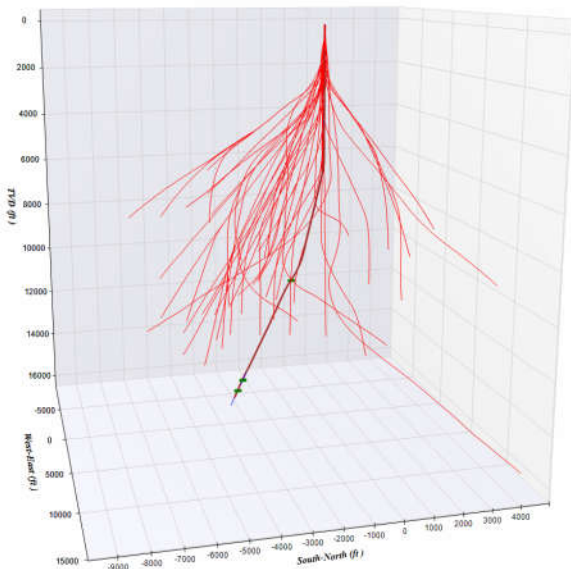


Fig.15 EW306 tangle of boreholes

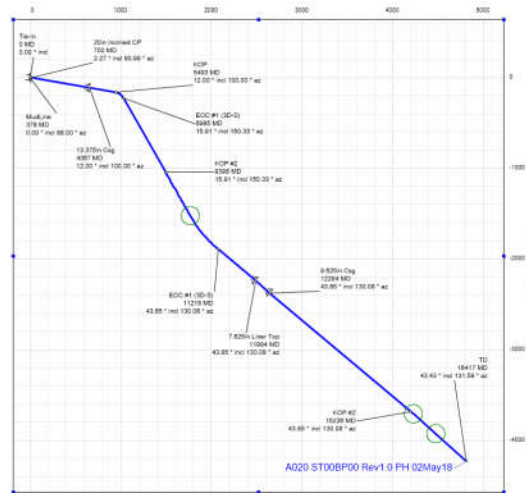


Fig.17: EW306 A20 well trajectory: plan view