LWD/MWD Proximity Techniques for Relief Well Projects

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INTRODUCTION

Relief well projects can now employ aggressive techniques that will dramatically improve overall efficiency and reliability. These techniques are the use of the proprietary LWD/MWD tool ("MagTrac[1]") with sound project management, well planning and the appropriate directional drilling tools. Utilizing this tool and special techniques allow the relief well project to be completed in less time and risk. Hole problems are potentially reduced because open hole logging and tripping out of the pipe is eliminated during ranging the ranging to target phase. Reducing the overall time and costs required to reach the objective positively effects pollution impacts and reserve losses. The overall result is an aggressive relief well strategy with minimal risks.

The Method

The method uses a combination of drilling techniques and specialized logging services and tools. These are:

* Specialized trajectory and well planning unique to relief wells and this ranging technique
* Knowledge and understanding of the position uncertainties in the target and relief well
* Directional drilling and engineering
* LWD/MWD proximity logging (wireline is an alternative option)
* Gyro surveys on relief well
* Use of the appropriate directional drilling tools and techniques that accomplish the design trajectories
* Integration of the kill and intercept strategy into the overall relief well plan

Ranging Requirements for Relief Wells

The objectives of a relief well project are to intercept, communicate and control the blowout. The key to success is to overcome the unknowns in the position of the blowout out well known as the ellipse of uncertainty. These uncertainties are usually so large that intercepting the blowout well with the relief well would be impossible unless the relative position of the blowout can be mapped relative to the relief well. Ranging must be performed and the direction and distance determined. Once the relative position is known the relief well trajectory can be modified to make an intercept. Figure 1 shows how an LWD/MWD tool can be used investigate the ellipse of uncertainty in a systematic way. The authors suggest that a target depth interval for proximity detection can be chosen and the borehole then tracked across the ellipse and turned in an ever tightening path until the blowout casing or drill string is precisely located.

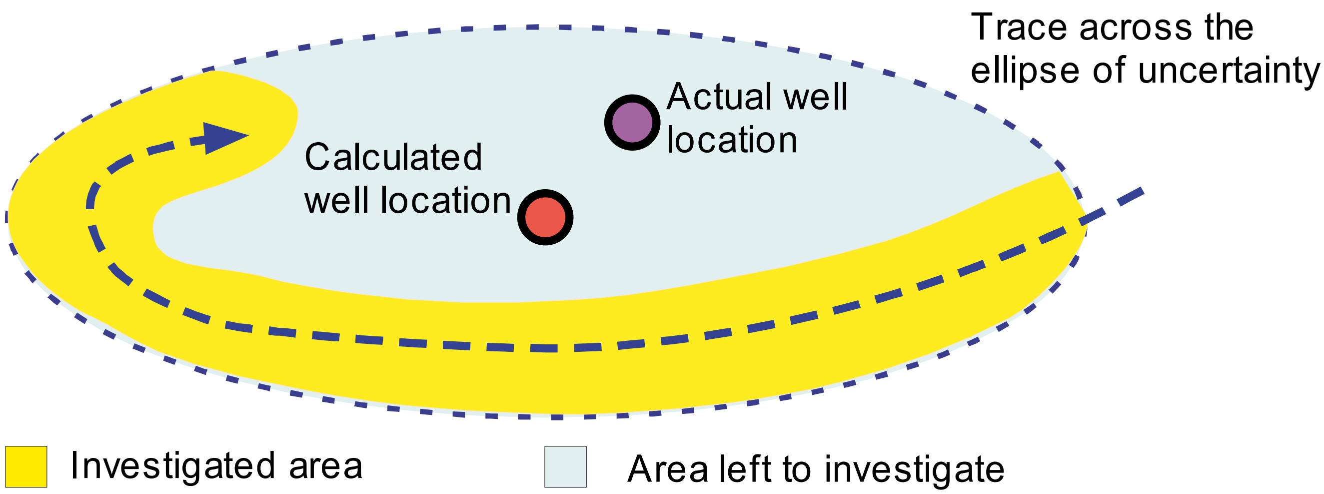


Figure 1

Trajectory

The trajectory must be planned to take advantage and optimize the tool and techniques. The tool has a limit to its range (see tool section for tool specifications) requiring that proximity detection takes place within the detection range of the tool. Figure 2 illustrates a trajectory that would be drilled to use LWD/MWD proximity detection to reduce a large ellipse of uncertainty. By planning an effective sweep pattern, the relief well and target survey uncertainties are combined and a relief wellplan is designed to detect any target within a cylinder along the target survey path.

Risk Reduction

In the past 20 plus years the conventional method for ranging from the relief well to the target blowout well has been to use an electromagnetic logging tool that must be run in open hole to achieve the optimum data. LWD/MWD/Wireline techniques are now possible which will eliminate the need to pull out of the hole as the data will be pulsed to the surface either via the mud column or EM-MWD. A well being drilled will tolerate only a finite number of open hole logs and trips. Rotating and circulating while logging versus tripping out is well known to be much less risk than tripping the pipe and logging the well.

By the elimination of delays caused by hole problems (sticking, keyseats, sluffing, high drag, etc.) encountered during trips that are required for open hole ranging, a conservative estimate of rig time savings for ranging using LWD/MWD proximity detection is 80%.

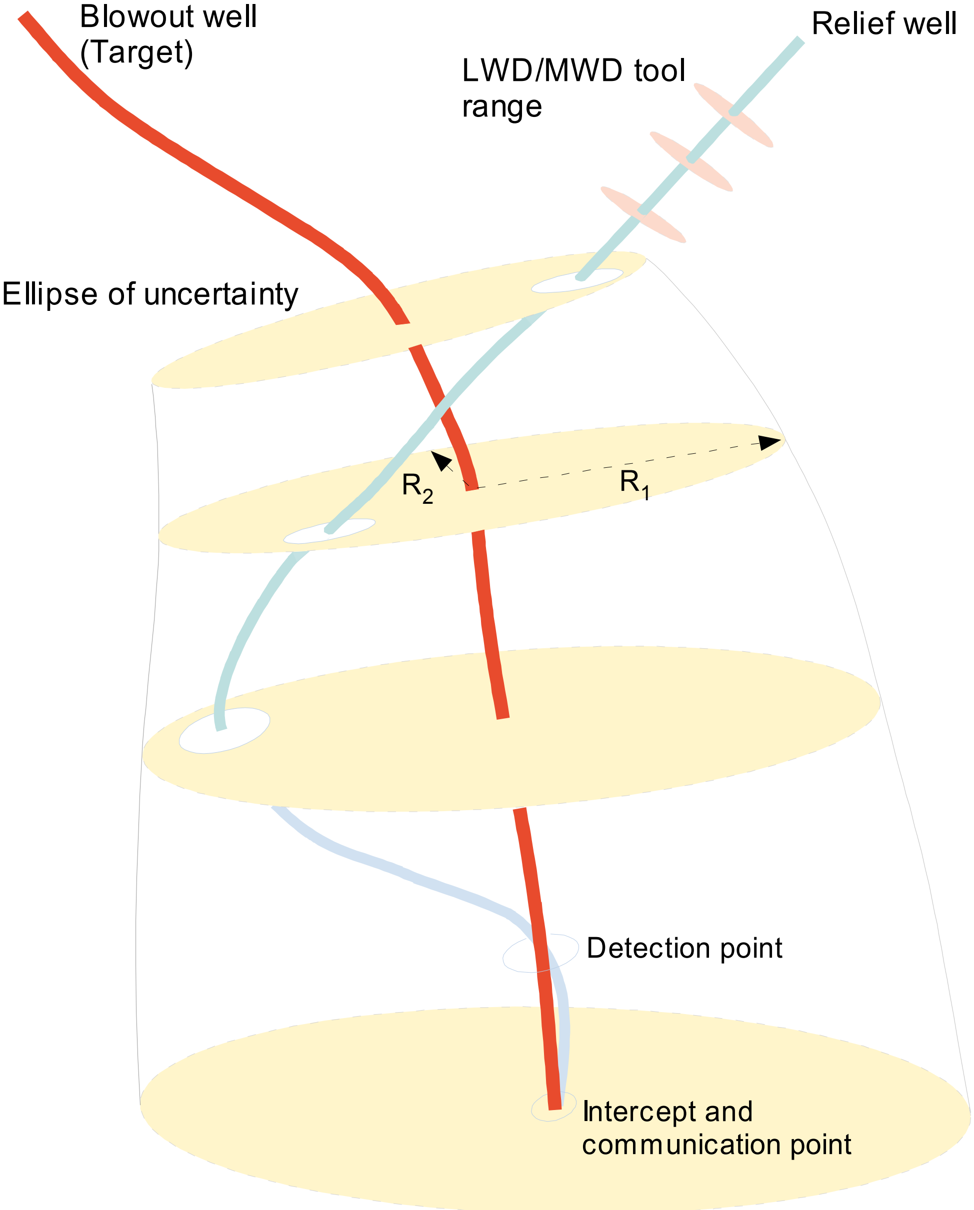
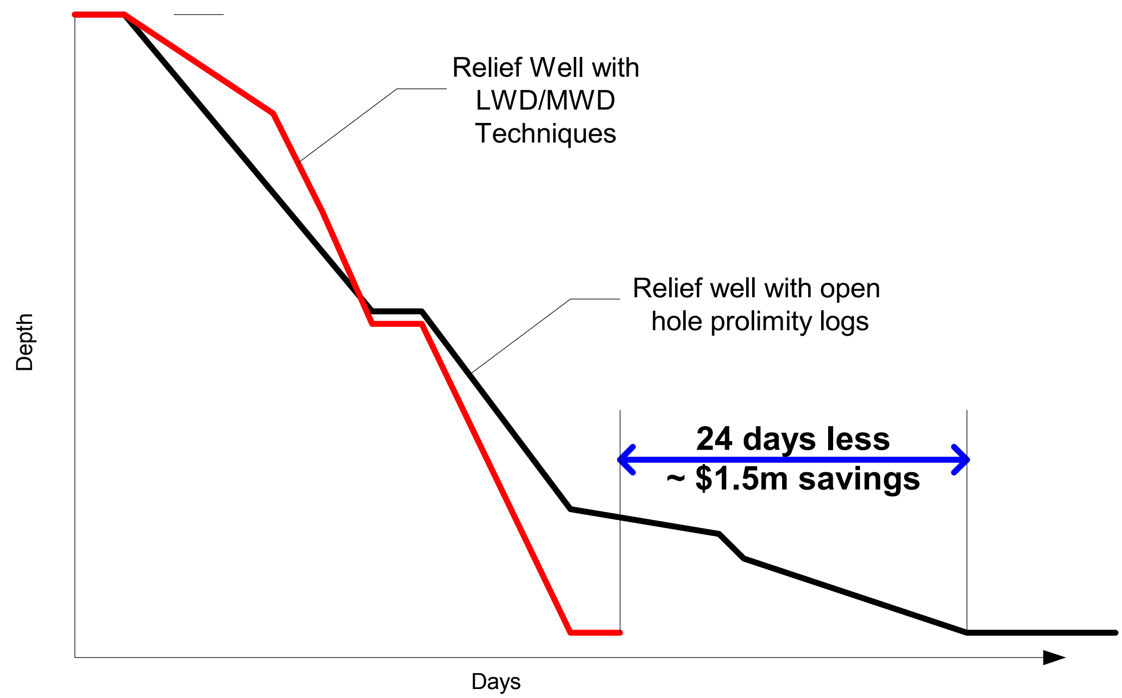


Figure 2

Cost and Exposure vs. Benefits

Proximity surveys take less than one hour including the data interpretation. By comparison the open hole technique requires that the pipe to be tripped out and wireline run it and then the log run, which can take as much as 36 hours in a deep well. The cost benefit can be significant given that ten (10) or more surveys may be required. Figure 3 illustrates the potential time saving on an actual relief well project. Considering the cost of some offshore operations ten (10) logging runs would result in significant cost reduction.



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Schedule is often an important consideration in relief well operations. LWD/MWD proximity runs provide a definite advantage over open hole methods.

Perhaps the most important consideration is that if pollution is occurring, the clean up or environmental damage will be reduced because the time that the well will be out of control will be reduced. To summarize, the benefits are:

* Reduces the days vs. depth to reach the objective
* Compresses the overall project timeline therefore reduces the cost
* Eliminates open hole logs therefore reduces the well to risks for tripping and potential hole stability associated with logging operations
* Keeps the string in the hole the majority of the time thus adds well control reliability (e.g., the ability to circulate the well from TD at all times)

Coordination of Objectives

The primary goal of a relief well project is to bring the wild well under control. Each phase of the project will be performed to support this final objective. To accomplish this most effectively, many aspects of the planning, engineering and execution must done in such a way that the objective of each individual subsection is not compromised. The relief well project requires several complex engineering tasks and experienced based operations. Hydraulic simulations using sophisticated software with two-phase transient capabilities may be required. Often intense diagnostics are necessary to determine the most probable scenario in the blowout. Additionally a communication strategy must be developed that fits with the overall kill design. All must be feasible and operationally sound for the particular circumstances.

The pumping plant must be sized and constructed for a certain horsepower and deliverability based on the hydraulic simulations. This is primarily based on the rhelogy of the kill fluid and the geometry of the relief well as well as the reservoir parameters. If a liner is run versus not run, the friction losses could result in higher horsepower requirements. Therefore the results of drilling the relief well may have huge impacts on the killing requirements after interception with the blowout well.

For this reason, various critical factors in the relief well must be coordinated in the planning and execution. We illustrate the concept of overlapping responsibilities by a Venn diagram as show in Figure 4.

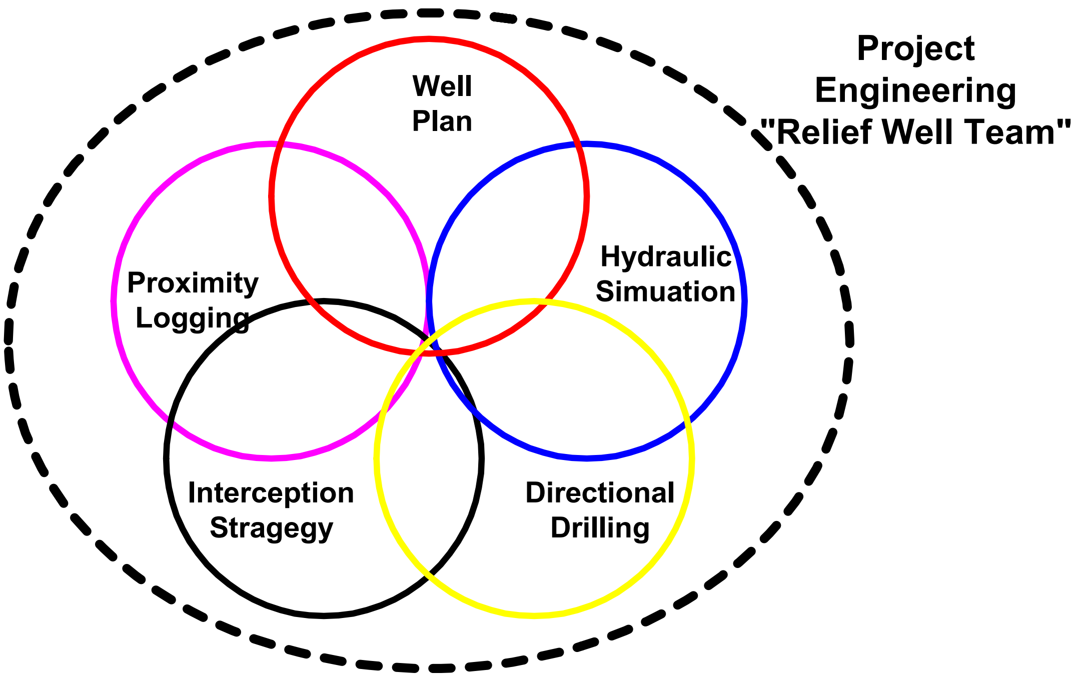
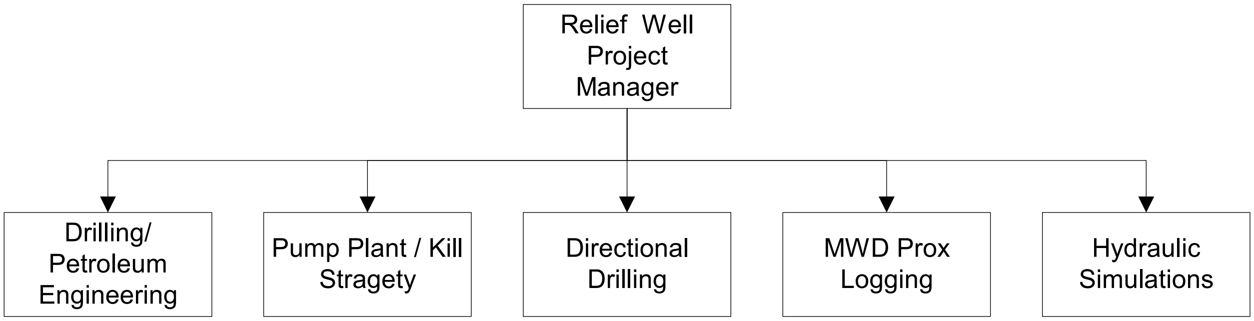


Figure 4

The Relief Well Team

There are very few relief well projects and consequently there will be little if any hands-on experience with relief well projects. For that reason, an experienced relief well team may need to be outsourced from the consulting and/or service organizations. The most desirable situation is a small and efficient group lead by an experienced multi-talented team leader that can provide solutions to the many tasks that will be required for a successful fast track difficult and challenging project. To allow this technique to be fully effective the authors suggest that an experienced team as described below in Figure 5 be fielded and given the responsibility for designing and implementing the relief well project. If this is team is put to the task the project will have its best chance of success.



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Such a team will provide a fully integrated service that includes:

* Project management of the overall relief well project
* Well Planning
* Directional Drilling Services
* Wellbore surveying
* MWD/LWD
* MWD Proximity logging services
* Hydraulic kill simulations
* Pumping Plant Design/Fabrication/Kill supervision
* Interception and Communication

Passive Ranging Tools-History

Passive ranging technology has a long history beginning with Shell's work[2] in 1972. At that time electronic multishot tools were not available and the actual analysis of the total field and single shot compass logs was extremely cumbersome. The increased sensitivity and transmission capability of today's 16 bit MWD technology makes passive ranging a reality. LWD, EMS, and wireline technology now allow use of magnetic proximity logs to rapidly determine the range and direction to a nearby casing string or fish. Table I compares the LWD/MWD technology and method to the electromagnetic tool methods.

Table I LWD/MWD vs. Electromagnetic Ranging

Factor to compare	LWD/MWD tool	Electromagnetic Tools
Range in best conditions to a 9-5/8" casing shoe	25m*	50m
Expected range in oil base mud	25m	25m
Range when approaching with incident angle > 45 deg	25m	Small to Nil
Range while running MWD or inside drill string	25m	5-10m but many restrictions apply and cannot be run MWD
Time to obtain a proximity log (range, direction, orientation of target)	No trip 1hour (mud) 15-20 minutes (EM)	1 hour plus time to condition hole for open hole logs and to trip out for log
Risk for anti-collision	Small (low incident angle approach)	High no system for warning for collision
MWD	MWD Capability	Cannot be run conventional with MWD tools
Complex Geology Effects	None	Affected by oil base muds and formation resistivity
Ranging Trips	None	Trips required each ranging run
Ranging Points	multiple target proximity "shots" over an interval by pulling or running without rotation or cycling the pumps and drilling ahead	multiple target proximity "shots" over an interval by pulling or running wireline tools

*special methods are available to extend the maximum range of LWD/MWD proximity detection

Passive Ranging Tools-History

LWD/MWD proximity detection was developed to provide a technology that would reduce rig-time and wireline requirements for ranging operations. When ranging, LWD/MWD proximity detection uses high-precision MWD “shots” to obtain a magnetic proximity log. The proximity log is then used to indicate target range and direction.

In the 1970’s tests[2] established that the magnetic interference from a nearby casing string could be interpreted to yield range and direction to the casing string. At that time, EMS (electronic multi-shot) tools were not available. Careful (and tedious) analysis of multiple dip and compass shots guided intercept operations. An intermediate step in the development "passive" ranging was the well-known MagRange tool[3]. The introduction of 16-bit MWD technology made MWD proximity detection a reality. Using MWD tools to measure and interpret casing interference LWD/MWD proximity detection addresses the previous limitations of passive ranging with a precise magnetic model of the target casing and dogleg induced variations in the earth field components.

A key element in the successful completion of a relief well is the well planning based on proximity log analysis. LWD/MWD proximity detection includes calculations to provide a XYZ directional target for well planning purposes.

LWD/MWD proximity detection has successfully guided relief wells to intercept of vertical and small diameter casing without benefit of survey data on the target. LWD/MWD proximity detection has also been successfully deployed for a first-pass intercept of low angle near vertical targets without need for specialized ranging tools.

These are difficult conditions for any ranging technology because they require precise toolface orientation. Proprietary methods allow LWD/MWD proximity detection to obtain target location with respect to magnetic toolface, even in the presence of the strong magnetic interference produced by the target. LWD/MWD proximity detection has also accomplished first-pass intercepts on target casing as small a 4-1/2"OD.

Operationally, LWD/MWD proximity detection requires that pumps be off during data collection. Usually this is best accomplished by drilling to a preset depth and acquiring the proximity log with pumps off by picking up the drillstring at preset intervals over a stand. Alternatively, the proximity log can be acquired by cycling the pumps and drilling ahead over each data interval.

Wireline can be used to substitute for mud pulse or EM data recovery. This method requires that a mono-cable wet connect be made when survey data is taken. Alternatively, the data can be memorized in the downhole package and recovered when the assembly is brought to the surface. Wireline techniques may be advantageous in projects where cost is an important and overriding factor. Regardless of the method of data recovery, the data collection is performed in by the same downhole instrument package.

LWD/MWD/Wireline proximity detection: Case Histories

The tool was recently used to plug and abandon two wells in New Mexico (near Farmington) and West Texas (Permian Basin). In these projects (non-blowout conditions) wireline was used to recover the data rather than adding the expense of mud pulse data transmission. The difference in these P&A projects and a relief well was that a pump-to-kill operation was not required. Otherwise all the facets of ranging, locating casing, interception and communication were identical to a wild well control operation.

In the New Mexico gas well, the first attempt to P&A the well and re-enter the lower portion of the well from the original well bore failed. The P&A objective was to intersect severely damaged casing in the presence of unknown "junk" at about 1000' TVD. LWD/MWD/Wireline proximity detection was used to range from the failed "sidetracks" back to the corroded well bore from the outside of the casing. The well was paralleled, until the target was judged undamaged from the proximity log. The sidetrack was used to re-enter the original un-corroded section of casing. The target well was cased with 4-1/2 inch, near vertical and had no survey data available. Figure 6 shows the complex path of the target well and the resulting ranging shot that enabled a first pass intersect of this target casing. The target well was drilled "vertical" and as such had severe changes in azimuth. As illustrated in this figure, the target turned "under" itself and intercept was achieved drilling a NW path.

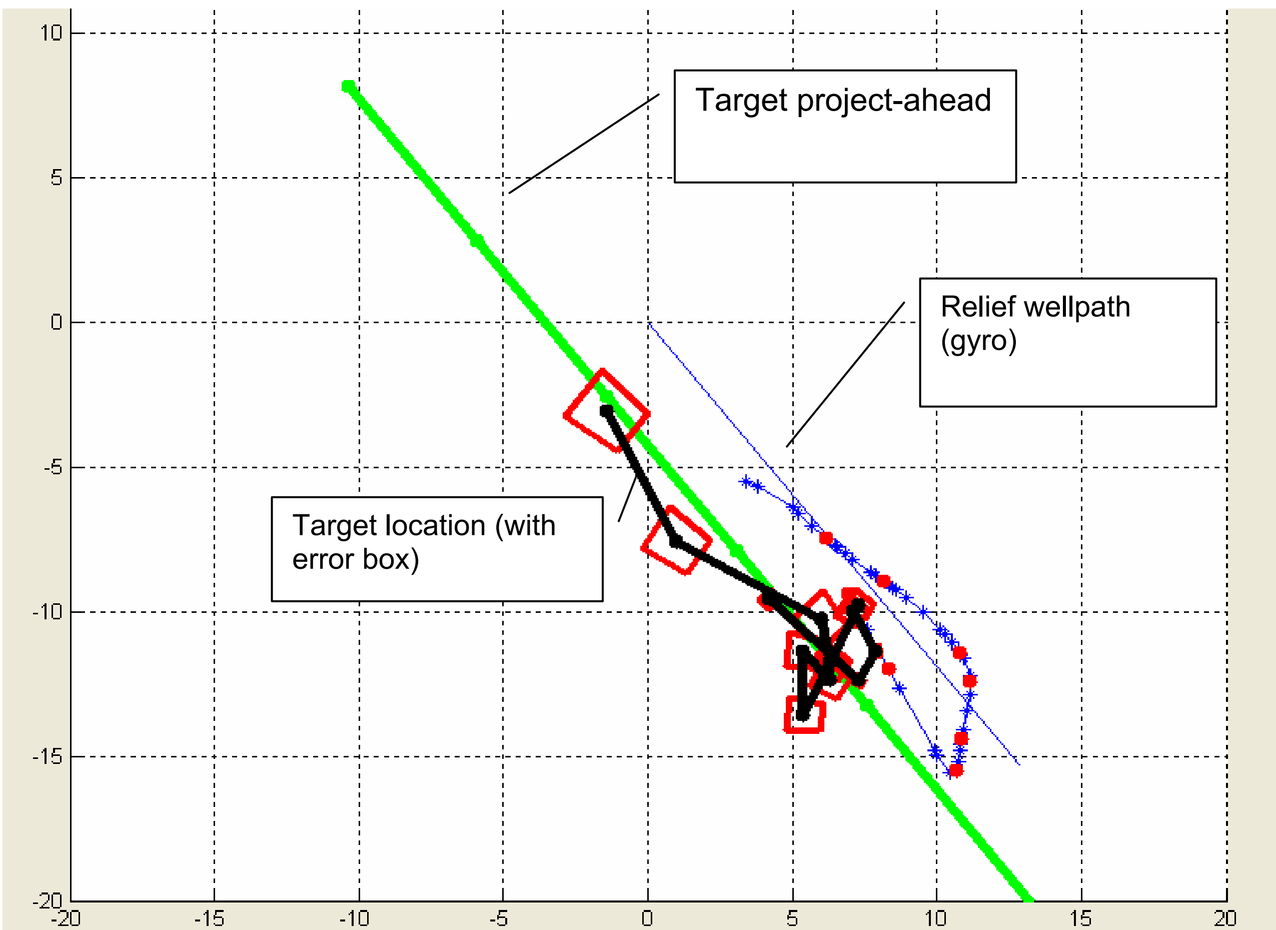


Figure 6

In West Texas LWD/MWD/Wireline proximity detection was used in a more conventional plug and abandon application where survey data was available. On this job, LWD/MWD/Wireline proximity detection was used to P&A a problem well at 4000' TVD as required by Texas Railroad Commission rules. Proximity detection shots determined target survey offsets from which a down hole projection of target was based only on the remaining down hole survey shots. (Light blue line in Figure 7). As a result the target and possible doglegs are mapped in detail improving the likelihood of a first pass intercept. The target was successfully milled and re-entered and P/A operations completed.

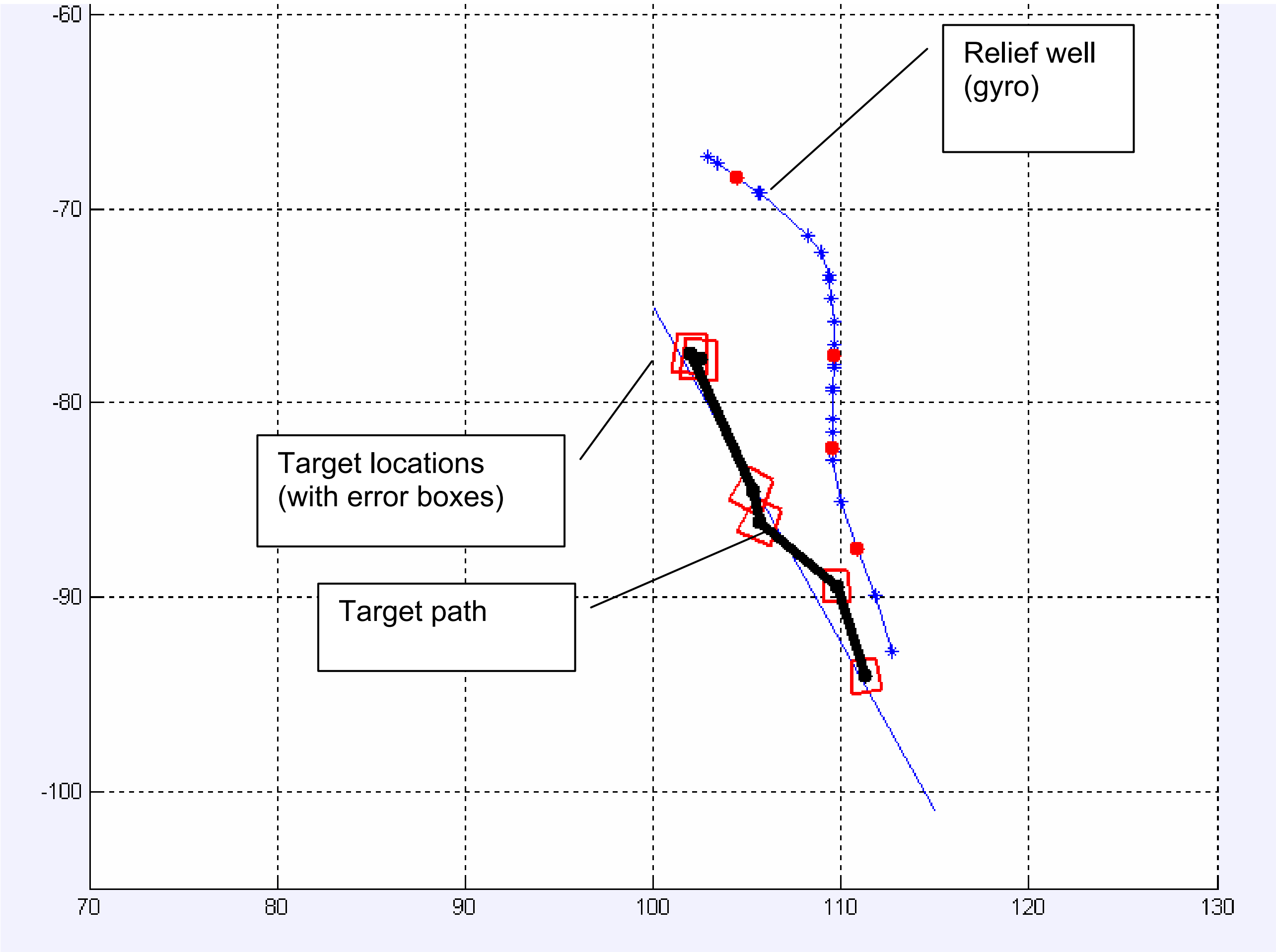


Figure 7

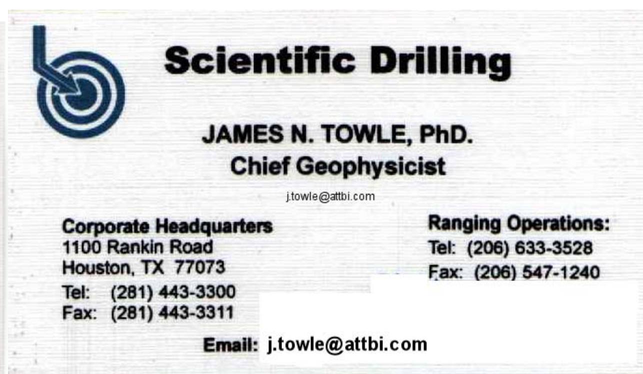
Conclusion

This technique can be used to introduce an aggressive relief well strategy provided the team concept is allowed to function. The MWD tools with proximity detection capabilities can revolutionize the relief well project by compressing the schedule and enhancing its overall reliability; however specialized drilling techniques are required to take advantage of this highly advanced tool.

Author Biographies

L. William (Bill) Abel, P.E. Mr. Abel graduated from Texas Tech University with a BS Civil Engineering 1974 and Southern Methodist University with an MBA, 1974. He formed ABEL Engineering in 1984 and has been involved in over 200 well control events world wide, including the Kuwait Oil Fires in 1991. His experience includes numbers relief well projects and well capping operations. He has published 34 technical articles and is a registered professional engineer in Texas and Oklahoma and a member of SPE.

James N. Towle, PhD, P.E. Dr. Towle has a BSEE from Cornell University in 1965 and a PhD from Washington University in 1972. He is Manager of Magnetic Services at Scientific Drilling. After 15 years with the U.S. Geological Survey as a research geophysicist he joined Phoenix Geophysics (Denver, CO) as Senior Geophysicist in 1985. At Phoenix he was responsible for frontier hydrocarbon exploration plays using the magneto-telluric survey method. After a brief period “exploring” for wellbore casing during construction of the LA subway, Dr. Towle joined Scientific Drilling in 1994 to bring this technology to well control and P&A operations. His professional engineering license is from Washington State. He has published 30 technical papers, is a registered professional engineer, a member of SPE and a registered Geophysicist in California.



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