Real-time, 3D visualization drilling supervision system targets ECD, downhole pressure control

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EDRILLING IS A new and innovative system for real-time drilling simulation, 3D visualization and control from a remote drilling expert centre. The concept uses all available real-time drilling data (surface and downhole) in combination with real-time modeling to monitor and optimize the drilling process. This information is used to visualize the wellbore in 3D in real time. eDrilling has been implemented in an onshore drilling center in Norway and has been used on several drilling operations. This article focuses on utilization of an advanced flow model for real-time supervision and control of ECD and ECD-related effects.

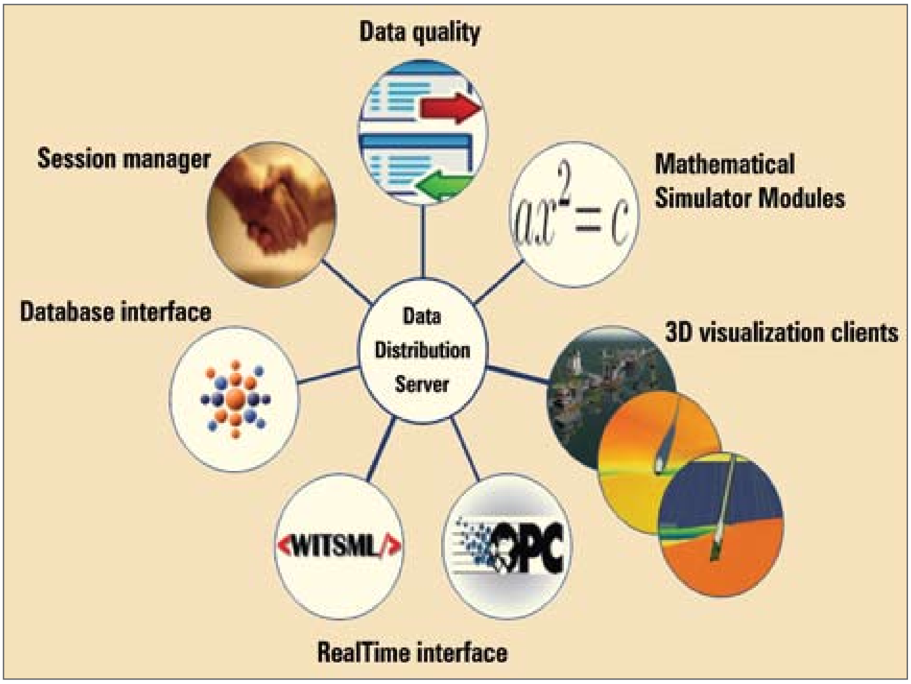


Figure 1: eDrilling uses all available real-time drilling data to monitor and optimize the drilling process. A typical eDrilling system infrastructure is shown above.

REAL-TIME MODELING

The key elements of eDrilling are real-time simulation, visualization in a virtual wellbore and decision support (Ref 1-3). The infrastructure allows for simulation of the drilling sub-processes by integrated drilling models driven by the process itself. This RT-enabled integrated drilling simulator creates a "mirror" of the drilling process itself, and gives important information on key drilling parameters like hydraulics profile (ECD), temperature profile, friction conditions along the drillstring and wellbore, cuttings transport conditions, well instability tendencies, pore pressure ahead of drill bit, optimal ROP — all in real time.

The system also makes automatic diagnosis of upcoming drilling problems by combining real-time simulations with drilling data.

The virtual wellbore is another key element of eDrilling. The 3D visualization of the drilling itself (drill bit, string, BHA, etc) in real time is supplemented with VR visualization of simulation results. This makes the virtual wellbore the key tool to communicate well status as well as inform across boundaries (drilling, geology, asset team, etc) during the drilling operation.

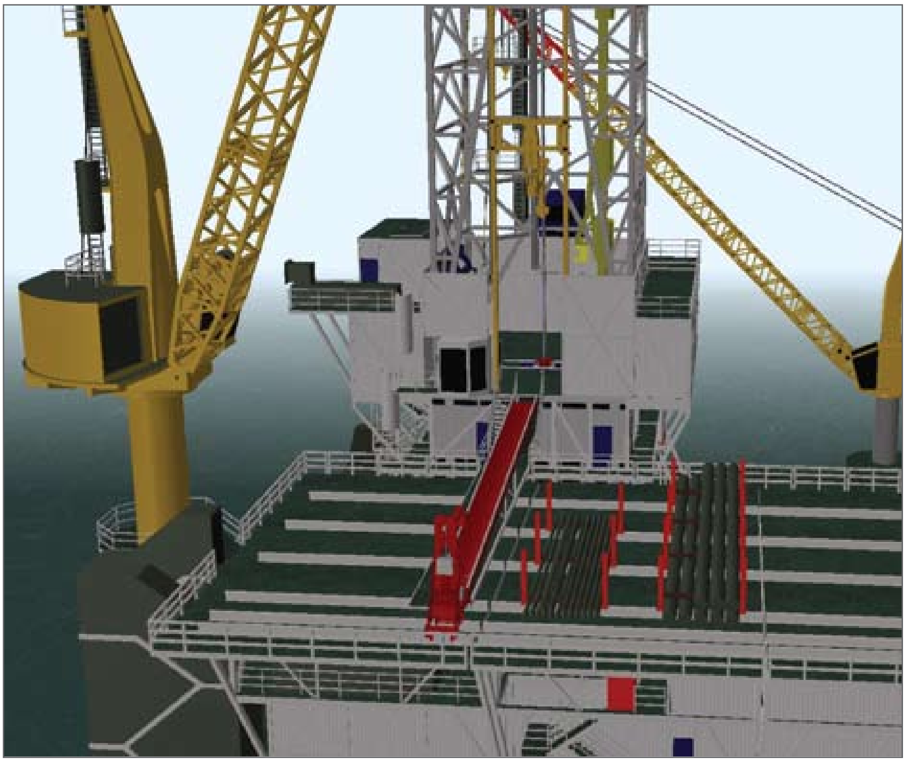


Figure 2: The eDrilling system can import high-complexity 3D models and zoom into subsurface details as seen here.

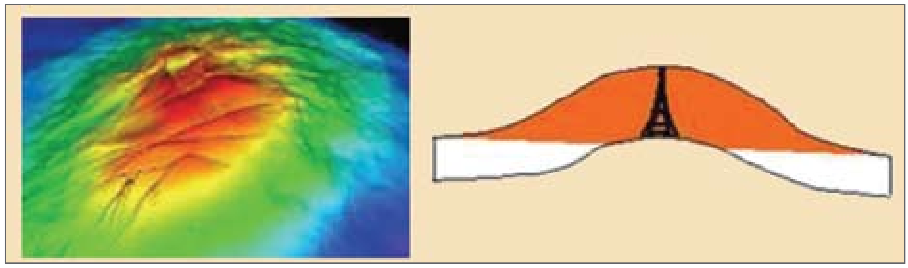
Quality of real-time data from external sources into the eDrilling system is important because models need good input data to produce accurate and reliable results. Thus, one benefit of using models online is that data deficiencies, including signal transmission errors, are revealed and can be addressed or accounted for. When using the eDrilling system, data quality is addressed in several ways:

• Improve data sources and signal transmission.

• Filter invalid data.

• Correct data before used by models.

The last two points are addressed by a dedicated data quality module (DQM), which corrects data by various calculations.



Figures 3a (left) and 3b (right): The Ekofisk field was found in 1969 and has produced 2.1 billion bbl/day of oil and 124 billion cu m/day of gas as of 2004, and will continue to be in production for years. In the visualization figures above, orange indicates oil.

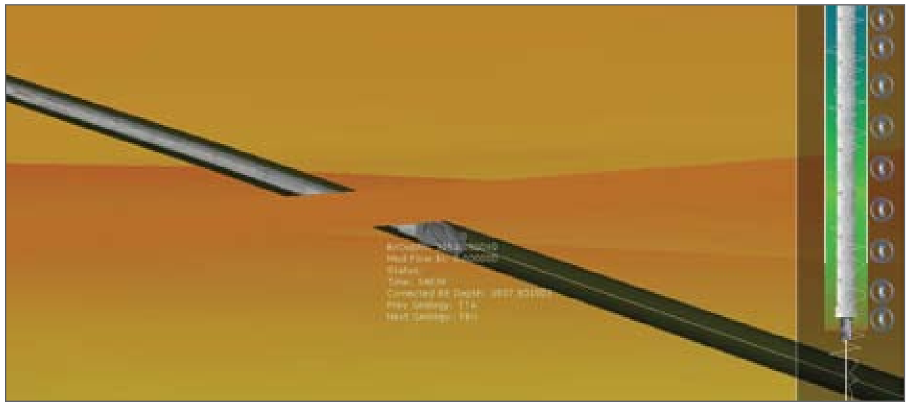


Figure 4: When visualizing geology, eDrilling aims to show users the actual layer and let drillers know when equipment is passing through different formations.

Infrastructure. The Data Distribution System (DDS) is the kernel for data distribution in the eDrilling system. Clients can subscribe and publish data to the DDS server. External data is published into the server via interface clients. At the Ekofisk pilot, OPC and ODBC clients are used for this purpose. WITS data from **Halliburton** (**Sperry Sun**) are fed into the system via the OPC client, and Peloton WellView data are fed into the system via the ODBC client. In the near future, the DDS system will have a WITSML DDS client enabling WITSML communication. Figure 1 shows a typical eDrilling system infrastructure.

3D visualization. The eDrilling 3D engine has the capability to import 3D models with high complexity and zoom into subsurface details. Figure 2 shows an example:

Visualization of geology. The Ekofisk field was found in 1969 and has produced 2.1 billion bbl/day of oil and 124 billion cu m/day of gas as of 2004, and will still be in production for many years. Average production is 350,000 bbl/day oil, 350 million standard cu ft with a water injection of 900,000 bbl/day. The thickness of the Ekofisk reservoir complies with the Eiffel tower. Orange indicated oil (Figures 3a and 3b).

In eDrilling, the focus related to geology is to show the user the actual layer and give real-time information to the driller and other users about when equipment is passing through different formations/layers (Figure 4).

Virtual well. The eDrilling 3D visualization system enables the user to get a true overview of the well by displaying all relevant information in real time 3D. Figure 5a and 5b show visualization examples.

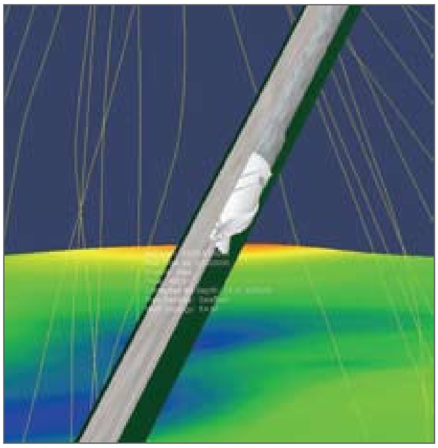
Well description with drilling experiences. The well used for this presentation is a sidetrack from the main wellbore. The operational sequence covered in this presentation is to drill out the shoe track and continue to drill into the reservoir. The presentation covers three days of operations, 2-5 September 2007. The drillstring consisted of an 8 ½-in. x 9 ½-in. Geo-Pilot steering assembly, with a formation pressure tester and MWD pulse telemetry system.

Oil-based mud was used. The mud in the well at the start of this sequence had a density of 14.7 ppg. This was displaced with mud having density of 9.5 ppg at the start of this sequence. Mud density fell slightly during this sequence and was later increased first to 10.0 ppg and later 10.2 ppg.

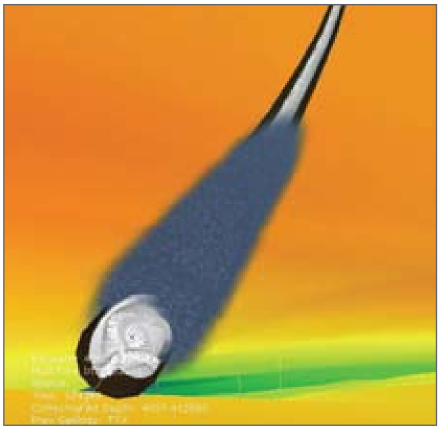
Inclination angles for this section were stable around 9º with a slight swing in azimuth to the right.

Many problems were encountered with this well, both before, during and after this section. Problems include mud loss, gas influx, tight hole and equipment failure.

Supervision of ECD. An advanced pressure and temperature model, optionally with automatic or semi-automatic calibration, will run continuously during drilling operations, and help convert raw data to useful information easier and more reliably. A comprehensive presentation of the model is given in Reference 4, and several applications are presented by References 5-10, but then not integrated in the eDrilling system. The



Figures 5a (above) and 5b: eDrilling's 3D visualization system provides an overview of the well by displaying all relevant information in real time 3D.



example discussed here is from a real well with the model integrated in the eDrilling system.

Figure 6 shows flow model results when replaying data from the well on Ekofisk through the eDrilling system. A drilling and reaming sequence of 1.5 days is shown. The decreases and increases in pressure after 3.1 days are due to mud density increases. In this sequence, the model reproduced variations accurately without continuous tuning; only a constant 10% correction was applied. There is some deviation between model and data shortly after 2.75 days, most likely due to inaccurate information on mud density changes. The good match with measured standpipe pressure supports the calculated bottomhole EMW. The model calculates also ECD at other positions along the open hole, and the result is compared with the most recent collapse, pore and fracture pressure available. The 3D view will then clearly warn operators and engineers when getting close to or outside borders.

Pressure points measured while drilling are added in Figure 7. Gas return was observed in this period, and mud density was increased several times, which seems consistent with the fact that some pressure points are above calculated EMW. See further discussion in the section on diagnosis below. With an accurate estimated pore pressure profile, the system would give early warnings on these events.

Diagnosis of problems. The availability of real time-enabled advanced models and methods prepare the way for much a more robust and reliable diagnostic system. Early versions of the following sub-systems have been implemented as integrated parts of the eDrilling system:

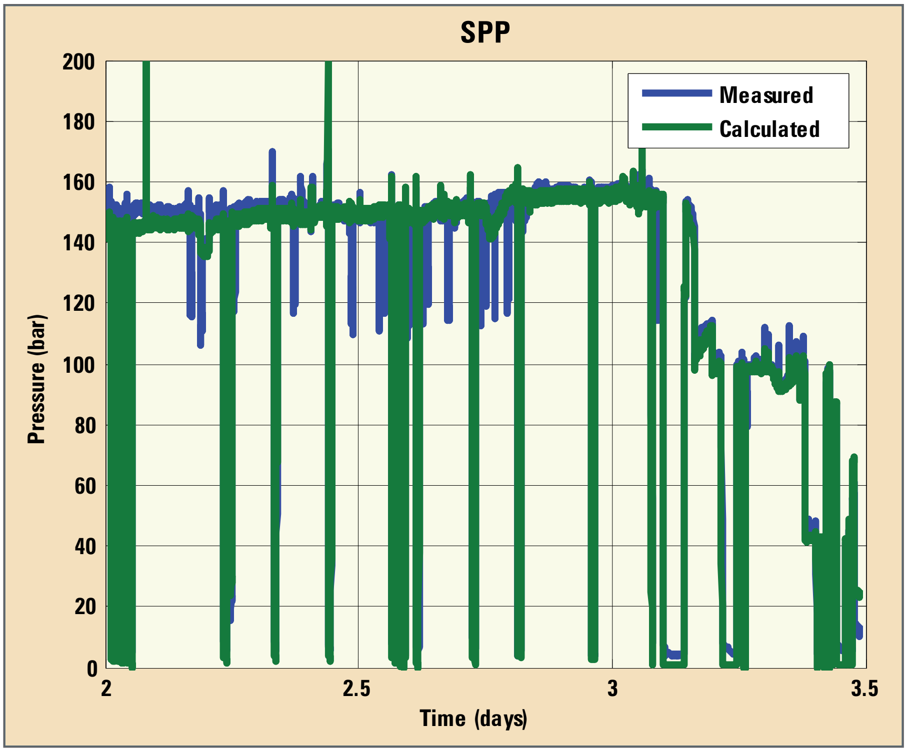
• Early kick and loss warning. The system monitors the ECD vs pore and fracture pressure profile, and gives a warning when these limits are exceeded. In Figure 8 the relative ECD vs relative pore pressure is shown. The mud density is increased two times in order to combat kick indications. The eDrilling system detected this early and gave a warning that a kick was possible (Figure 9).

• Improved volume monitoring.

• Improved hole cleaning monitor.

• Improved detection of impending stuck pipe and early detection when going stuck.

• Improved ROP monitoring.



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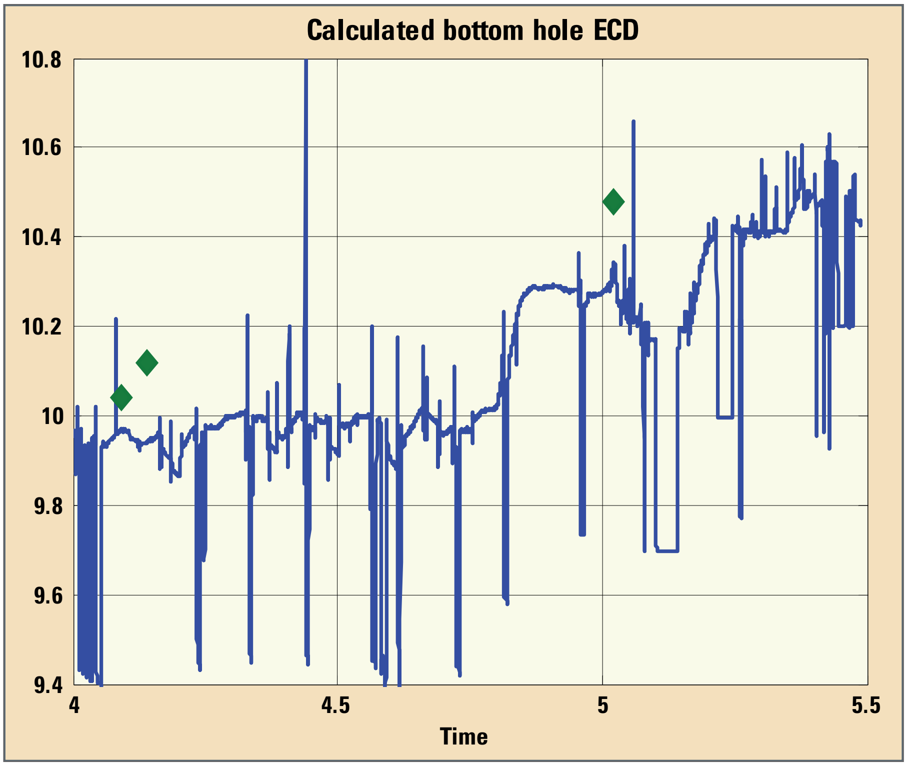


Figure 7: Over the same period as in Figure 6, pressure points measured while drilling are added. Gas return was observed in this period, and mud density was increased several times. With an accurate prognosed pore pressure profile, the system would give early warnings on these events.

The benefits of this system are several:

• Earlier warnings.

• More reliable warnings, i.e., fewer false alarms and fewer real events with no alarm.

• Continuous focus on the process also through tedious periods that are considered low risk by the drilling crew.

CONCLUSIONS

A comprehensive system with multiple models and a 3D visualization application integrated with live drilling data in real time has been developed and demonstrated on data from a real well. An immediate benefit of the system is easy access to very advanced modeling for drilling crew and experts who monitor operations from onshore or on the rig.

This article uses dynamic flow modeling as an example to illustrate how a slightly calibrated model reproduces accurately standpipe pressure, and thus most likely gives an accurate picture of open hole pressure, which can be automatically compared to expected collapse, pore and fracture pressure along the open hole section.

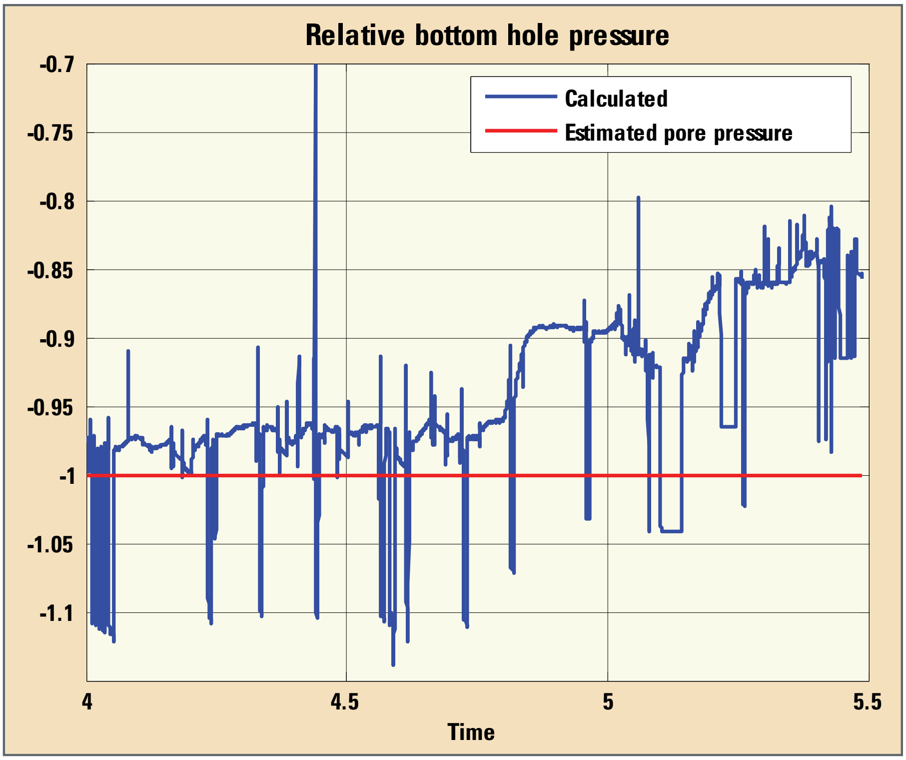
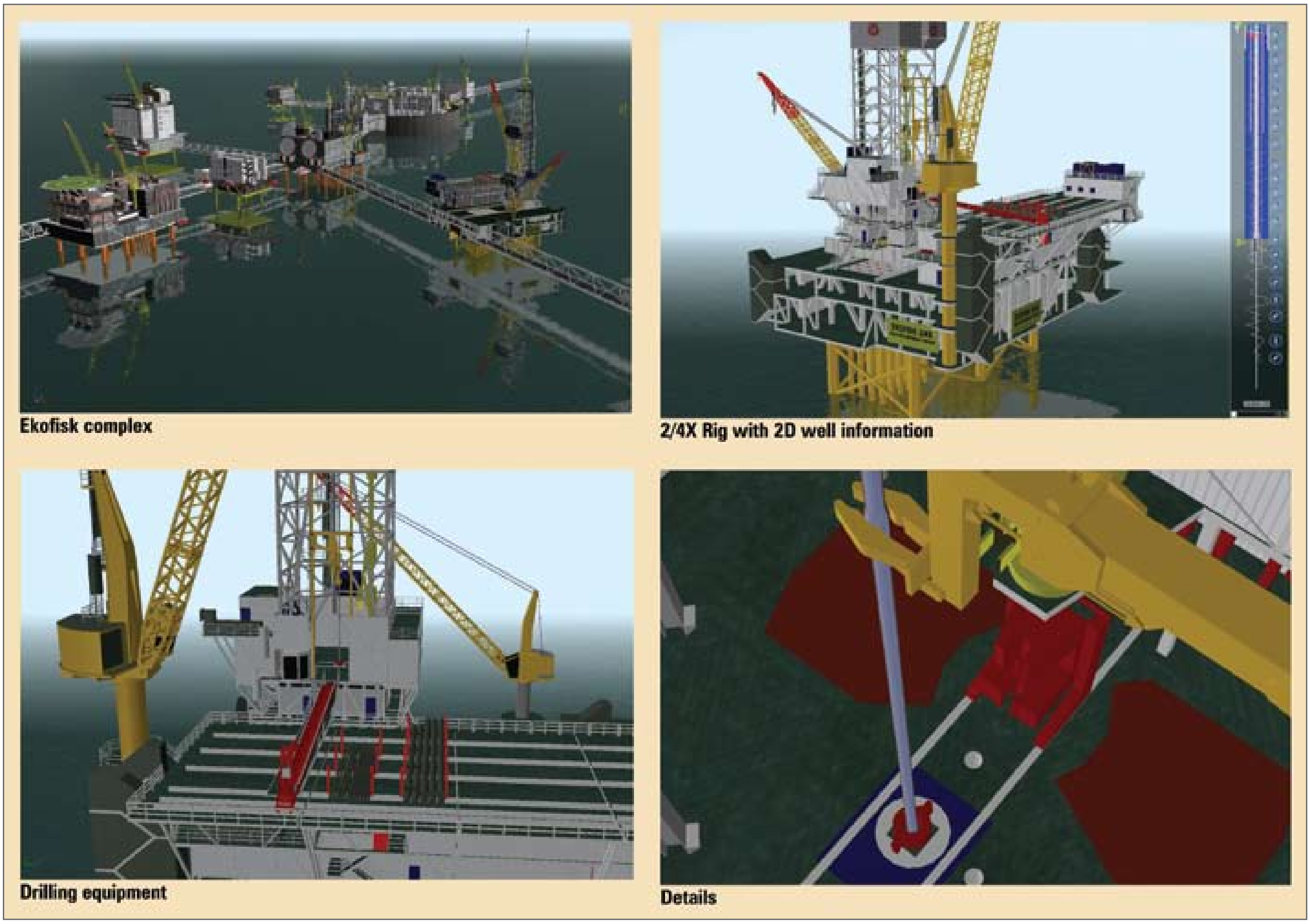


Figure 8: The eDrilling system monitors the ECD vs pore and fracture pressure profile and gives warning when those limits are exceeded.



3D visualizations of Ekofisk Complex with the eDrilling 3D engine.

Furthermore, there is an ongoing development of a more automatic diagnosis system, which combines results from modeling and real time data to give early warnings on and reliable interpretation of unwanted events. We have shown this applied on ECD monitoring and early kick detection and warning.

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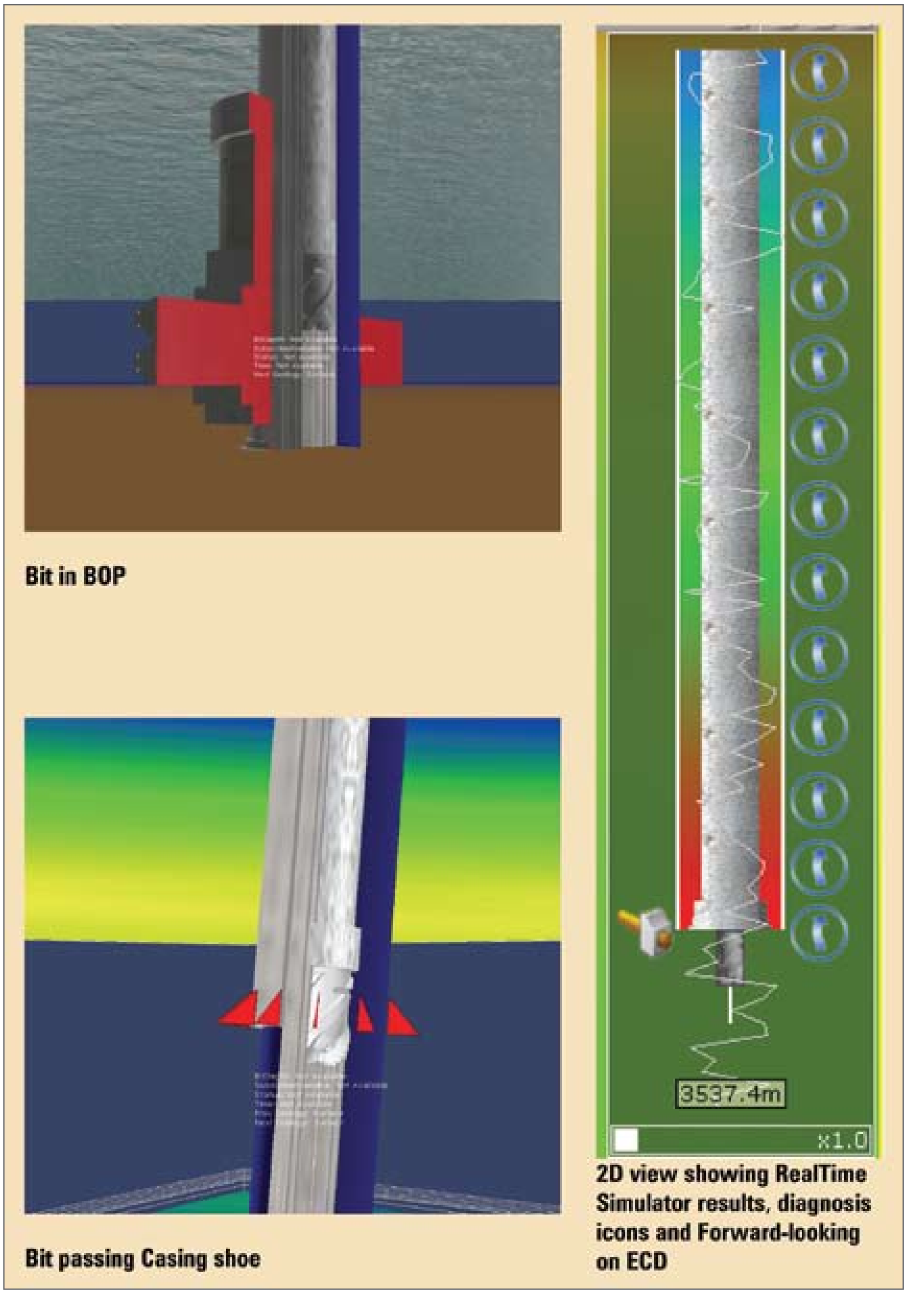

Bit in BOP

Bit passing Casing shoe

2D view showing RealTime Simulator results, diagnosis icons and Forward-looking on ECD

The eDrilling 3D visualization systems provides a true overview of the well.

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