flow rate, % bit pressure loss and bit total flow area (TFA) calculations. Bottom hole horsepower curves can be generated, showing hydraulic power and impact force with varying flow rate and bit TFA. Nozzle configuration and TFA can be calculated depending on flow rate and surface pressure conditions, thus enhancing and optimizing the bottom hole hydraulic energy for maximized rate of penetration (ROP). Other responses and feedback mechanisms from a hydraulic software package are the calculation of the maximum running speed for BHA's and casing strings (with both open and closed pipe) in order to avoid borehole damage due to surge and swab pressure effects.

For the selection of most efficient parameters, a sensitivity analysis allows the calculation of all pressure limits and tolerable ECDs at varying flow rates, indicating minimum and maximum flow rates.

Casing and tubing analysis

A modern casing design package allows the drilling engineer to design the minimum number of casing strings required to safely complete a well, thereby maximizing drilling efficiency and optimizing well capital cost (Fig. 4.2.14).

For each casing selection, the casing setting depths are automatically calculated in the casing analysis package based upon pressure data and user-defined constraints such as trip margin, kick tolerance and maximum open-hole distance.

The design procedure of a casing string and its strength analysis should include: 1) uni-axial, half bi-axial, full bi-axial and tri-axial stress checks for axial load cases; 2) bust and collapse load cases for all stages of the well's life cycle, including all drilling phases with their changing mud properties or pressure imbalances; the latter includes well-kicks or mud losses and the analysis of the well production phase after drilling under different temperature and pressure conditions; 3) graphical plots, tabular data and traffic light pass/fail indicators should allow rapid identification of problematic loading conditions.

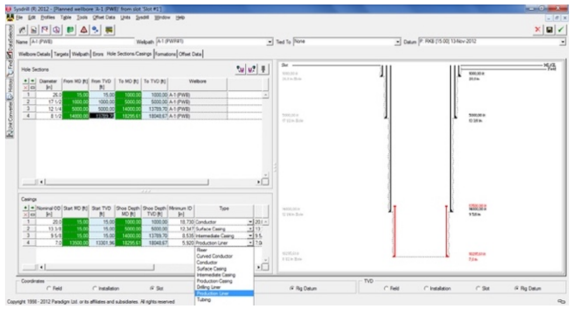

Fig. 4.2.14: Casing design and calculation template from Sysdrill well planning & engineering suite.

As casings do wear with time and with the deepening of the well due to the friction by the rotating drill string, a casing wear module should be applied to predict internal casing wear for a number of drilling operation and should be able to de-rate casing thickness for burst and collapse calculation accordingly. Alternatively, a calliper log can be incorporated as a percentage-wear identification measurement device and used to planning ahead the drilling process.

Cementing engineering

A cementing engineering and analysis module is used to plan cementing operations in order to ensure the safe slurry pumping schedule among casing strings and drilled hole, the annulus, or and cement plugs for directional drilling side tracks or plug and abandonment programs. It optimizes pumping operations for variable flow rate schedules, i.e., fixed flow rate, fixed bottom hole pressure, and free fall cement in order to safely manage down-hole pressures during such operations to avoid to fracture the formation, underbalance the well, or either collapse or burst the casing. This software module most often stands as a back-up and Quality-Control (QC) check to service company proprietary cementing programs also to assure proper well integrity results.

An animated wellbore cementing analysis calculation allows monitoring of fluid flow regimes (lineal or turbulent), bottom hole pressures, ECDs, and flow rates as cement is circulated into position. Simultaneously, expected pump, choke and hydrostatic pressures and pressure losses are calculated. Bottom-hole pressures during cementing are plotted against formation fracture gradient and breakdown gradient in order to detect and prevent fracking and loss of fluids in the well. The cement volume calculator, which is available via the cementing or hydraulics software modules, will further provide solutions to many common well site volumetric problems, including pill spotting and balanced cement plugging.

Downhole Pressures and Well Control

Drilling across different formations and depths exposes staff and equipment at the rig site to unexpected downhole pressures and the corresponding fluids. Accordingly, pressures need to be properly controlled with pressure barriers and well control procedures. Along the development of the well planning and the acquisition of geological details, personnel in charge must analyse the potential of unexpected formation pressures carefully, especially when pressurized sedimentary formations will be truncated. Unexpected and uncontrolled downhole pressures and formation flows, commonly called kicks, could lead to blow out situations which can be disastrous and lead to complete project failure.

While drilling the well the first downhole pressure barrier is the drilling fluids specific weight or density. It serves to generate sufficient hydrostatic pressure values slightly higher (overbalanced) than the expected normal formation pressures. Once a well is drilled deeper with cased and cemented sections, it is necessary to identify the sensitive fracture depth interval. This is the transition zone between the casing shoe and the open hole section in the case of a kick occurring. A well control-kick tolerance calculator is used to verify that casing shoes are set and cemented securely at safe depths to avoid formation break-down due to increasing hydrostatic pressure. Such overpressure may occur during the cementing of the well or due to kick migration and gas pressure expansion while drilling. The software tools allow to simulate a kick of a given size and to determine the maximum allowable influx volume and pressure at the casing shoe to avoid formation damage.

With the software tools kill sheets will be produced, including dynamic maximum allowable surface pressure (MAASP), volumes, strokes and a pressure step down chart to safely control the well in emergency situations. Should, during drilling, the well show possible kick indicators such as increasing drilling fluid volume, gas in the mud circulating system, a sudden increase of the rate of penetration, torque and drag, or a flowing well while pumps are shut down , then the driller will position the BHA, activate the BOP rams, and shut down the well. In order to bring the well back under control and to resume operations safely drillers will follow API best practices and international well control procedures of drilling and completions operations.

The well control methods and procedures require that the rig pressure control system specifications (Blow Out Preventer, surface lines, manifold, manifold choke, tanks, separators, and flares) are predefined to withstand well pressure and temperature maximum parameters during operations and that the well control methods are pre-established during the well planning phase including the casing design parameters, cementing programs, and the drilling fluid program. For the execution phase the PIs together with the company man will coordinate and review assigned tasks of the established procedure. The experience of the 'Company Man' at the rig site is fundamental to lead efficient and safe operations during the decision-making process.

Integrated workflows

Many well-planning and engineering software packages today offer a tight integration with other software applications, running on one data management infrastructure. Thereby a common data management environment is essential for multidisciplinary teams of geoscientists and drilling engineers who plan and monitor wells to ensure optimal wellbore design and drilling progress. In figure 4.2.15 such integrated workflow is depicted.

A two-way link with seismic interpretation applications could be integrated for interactive well-design and trajectory monitoring workflows in a 3D interpretation environment, which interconnects the well database into combined well-planning, engineering and geo-steering workflows.

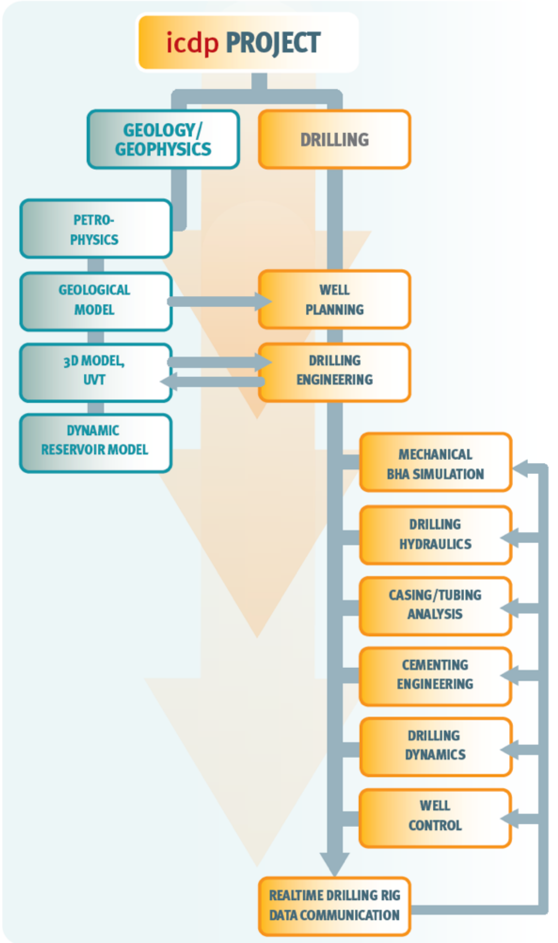

Fig. 4.2.15: ICDP well engineering flow chart

Abandonment and Decommissioning

The final step of scientific drilling field operations is the proper management of well abandonment and surface facilities decommissioning to shut downfield operations.

Abandonment and decommissioning expenses including all capital and operational expenditures have to be accounted for early on in the project budget calculation. Scientific drilling projects often evolve during the operations when new open science question arise. This results in changing research objectives and more ambitious operational targets such as deeper wells using high-technology applications and long-term utilization of the well that may