required. Uncertainty is not only present in the algorithm that the modeller chooses to apply; it is also present in all the parameters and the data used in those algorithms. Uncertainty about correlation coefficients, variogram range, or with porosity distributions requires a sensitivity analysis of all modelling input parameters. When dealing with uncertainty, the most important factor is to know which parameters govern and dominate a geological setting or model, so that the workflow can be optimized and steps can be taken to reduce this uncertainty. Integrated G&G software suites can help and guide the user in this process to substantially reduce model uncertainty.

The ultimate output resulting from a G&G software is the mathematical transform from static to dynamic models. The 3D model may be discretized to automatically construct a flow simulation grid, where all necessary faults are taken into account and all cell geometries are optimized for a high-performance flow simulation. Up-scaling between the fine-scale geologic grid and the coarser flow simulation grid should assure spatial integrity.

As the final step in modelling, the reservoir flow simulation grid can now be constructed in any geological setting for reservoir simulation and a so-called history matching. This includes fault geometry or fault inclusion in the flow simulation model by incorporating all faults, which are needed to perform an acceptable history matching. This is crucial and critical in all reservoir characterization tasks.

Most of the software application suites are built atop of a multi-user, multi-site and multi-OS data management platform. All modelling processes are encapsulated inside workflow management guides to also assist the occasional user, as well as to store all the parameters used to construct a model for audit ability and QC purposes.

Special attention should be given to the fact that all software applications are open, allowing outside vendors to add proprietary or third-party technologies as added on software solutions. This can involve plugins that have full access to other data models or an open framework for a fast prototyping environment that allows developers to creating new commands into the 3D visualization window and dialog boxes, and insert them into existing menus. Some G&G solutions even offer a high-level programming language to add new algorithms and processes directly within the user interface.

Well planning and management module

A well planning package is used to plan trajectories of new wells or side-tracks, multilaterals, and re-entry from existing wells. The trajectories simulations start from existing wellbore information and trajectories stored in the common database (Fig. 4.2.9). All critical well information, like local boundaries, lease lines, casing sizes, borehole sections, comments and survey tools error margins can be defined and visualized at this stage of the planning process.

Engineers usually start the well planning process with the collection of topographical field information, e.g., available GIS data and the global position of fields, sites and borehole locations in geographic coordinates (Fig. 6.8). On the computer screen the planner visualizes and identifies targets, including their shape, dimension, thickness, rotation, dip and offset in that planning stage.

Geological surfaces and faults can also be incorporated at this stage for visualization, and intersections by the simulated well trajectory computed and displayed. The well planning software runs using a common database for all wellbore data, including mechanical, directional, geophysical, petrophysical and geologic field and well information.

Fig. 4.2.9: Horizontal well trajectory for the Campi Flegrei deep drilling project in Italy

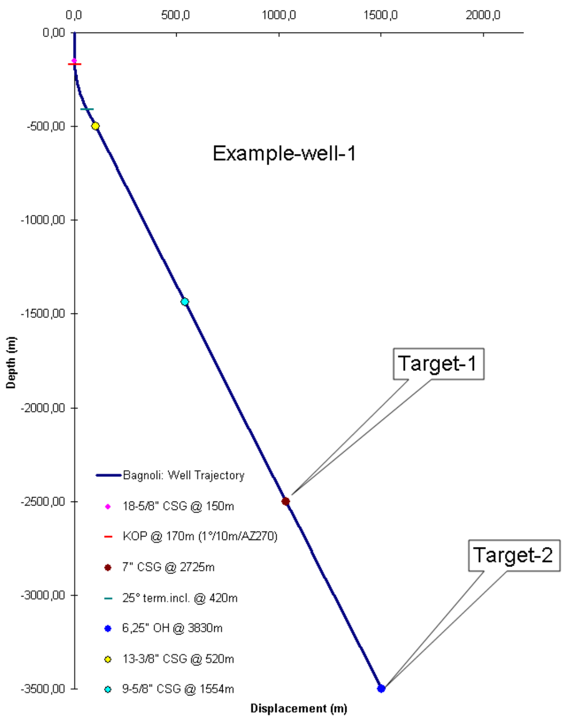

Fig. 4.2.10: Directional well plan for Campi Flegrei project in Italy

In reference to wellbore position uncertainty, the planning engineer in charge of designing the well trajectory has a full range of modelling techniques at hand for evaluating the different magnetic and gyroscopic survey data of the bore. This allows him to define the critical confidence level of calculated borehole subsurface coordinates for the present position of the borehole. Cones of uncertainty typically represent these confidence areas, as they need to be determined after Wolff and de Wardt, in SCWSA magnetic models, or in the manufacturer's gyro models (Fig. 4.2.11).

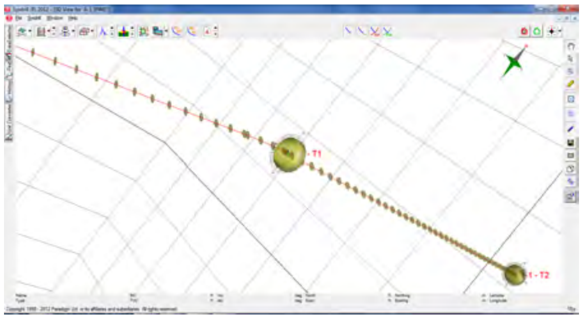

Fig. 4.2.11: 3D view of uncertainties ellipses of planned Monte Civitello well in Umbria/Italy

In addition, many packages do allow creating user-defined error models based on survey instrument manufacturer specification data. These position uncertainty models are particularly helpful in crowded borehole areas as they furnish an anti-collision analysis from the drilled and the neighbouring boreholes against offset wells stored in a common database. In this way a collision of new drilling wells with existing wells is avoided during directional or vertical drilling and a safe distance between wells is always kept. Results of this analysis typically include wellbore separation, ellipse separation, clearance factor and diverging depth ranges. The results are displayed in the form of ladder plots, a travelling cylinder or tabular formats, and accordingly highlight high, medium and low collision risks with a traffic light indicator.

For survey management, all recorded directional survey data during drilling or from logging runs, including overlapping surveys, are entered and stored in the systems database. The definitive wellbore is finally created by specifying proximity calculation and travelling cylinder plots. 3D views to/from depths for each survey section can be performed in order to eventually decide on a definitive and wellbore position and its final positional uncertainty. Once the final survey has been loaded, it is locked, thus ensuring the integrity of the database for anti-collision analysis or future side-tracks and new well drillings thereafter.

When the drilling is underway, a current drilling on real-time trend feed from measuring- and logging-while-drilling tools (MWD, LWD) can be analysed with the so-called project–ahead functionality in order to determine whether drilling corrective action on course is needed. If a correction is required, a revised trajectory is usually calculated by the drilling engineer based upon one of the selected modes 'return to plan', 'nudge/steer or 'project to target' definitions. Projections, including positional uncertainty, are at this stage visualized in 3D viewers and can be compared to the drillers' target or the earth model from the G&G suite for clarity and decision-taking purposes. All projections at this stage should be saved for quality-control (QC) purposes for later engineering analysis and decision-taking on the rig.

Ideally, the deepening progress of the actual wellbore can be interactively monitored in the 3D viewer and continuously compared to the planned wellbore and other wells in the vicinity. Thus, geological surfaces, casings, positions of uncertainty and drillers' targets are incorporated in the 3D viewer. The data should be written in electronic HTML format, allowing interactive viewing in a standard Web browser by other groups of researchers who can then remotely log into the database. All visualisations and calculations ought to be documented by an advanced well-planning software package through an extensive set of pre-defined plot and report templates. Users should be able to define plots and reports that can be saved and their settings later re-used. Customizable plan section, travelling cylinder, 3D and survey comparison plots should be standard by the majority of the advanced drilling planning software tools.

Bottom-Hole-Assembly Design

One of the first steps in drilling engineering is to validate the selected well trajectory by analysing the well bore profile mechanically and dynamically including the Bottom Hole Assembly (BHA). This helps to ensure that the drilling can actually achieve its objectives without drill string failure, injuries to people and loss of rig time. For this task the Torque (TQ) & Drag optimization and analysis software package is typically used by the drilling planning engineer in order to model all types of Bottom-Hole drilling Assemblies (BHA), casing and completion strings with respect to their suitability (Fig 4.2.12). This design phase provides a clear overview of the mechanical performance of the tools and the suitable wellbore trajectory and geometry, which will influence project budget. A pick & choose BHA string constructor is embedded in these engineering packages allowing complex BHA's to be quickly constructed by rapidly filtering through and selecting from extensive catalogues of industry supplied drilling equipment. The PIs should always consider the complexity of the calculation made by the engineer to take decisions or make suggestions to optimize resources while keeping high performance and quality. The software allows the engineer to create virtual simulations of using