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Unique Engineering Software Developed for Lost Circulation Planning and Assessment

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Abstract

An innovative software program has been developed to explore and assess operator and well-specific lost-circulation problems and link them to available solutions. The software tool is an integral part of an underlined process that focuses on existing resources, such as lost-circulation products, procedures, geo-mechanical models, logs and mineralogy/geology analysis to create project-specific plans and solutions.

The software contains four key modules designed to (a) consider well-specific data, (b) determine the most likely thief zones, (c) locate the position of potential thief zones relative to key depths of interest, such as the casing/liner shoe, and (d) identify the most appropriate preventative and treatment measures. Case histories will be included to demonstrate its use and outline lessons learned.

The goal of this software and the process to which it is associated to is to minimize and prevent lost-circulation problems rather than an after-the-fact cure. The integrative pre-planning process analyzes offset histories and formation data to identify risk zones, but also to gather information on the exact fracture and pore size as well as fracture density. Afterward, detailed interval-specific solutions are developed for stopping losses encountered while drilling or tripping in.

Introduction

The problem of lost circulation (LC) became apparent in the early history of the drilling industry and was magnified considerably when operators began drilling deeper wells and/or through depleted formations. The industry spends millions of dollars a year to combat lost circulation and the detrimental effects it propagates, such as lost of rig time, stuck pipe, side-tracks, blow-outs and, occasionally, the abandonment of expensive wells. It is estimated that lost circulation costs the industry around $800 million per year, while the LC products could represent as much as $200 million. Moreover, lost circulation has even been blamed for minimized production in that losses have resulted in failure to secure production tests and samples, while the plugging of production zones has led to decreased productivity.

Deepwater drilling has brought LC control to a more critical level as it involves narrow pore-pressure/fracture-gradient windows, cold drilling fluid temperatures, high equivalent circulating densities (ECD's), high cost-per-barrel of synthetic-based fluids (SBM) and a high cost for lost rig time/non-productive time (NPT).[1, 2, 3, 4]

Traditionally the control of the lost circulation has been a reactionary process. The Lost Circulation Assessment and Planning (LCAP) process involves proactively exploring and assessing project-specific lost-circulation problems and linking them to existing lost-circulation products, systems and services.

The process focuses on available products (*i.e.* conventional LCM, specialized polymer crosslinked pills, software tools) and uses existing resources (offset well analysis, logs, mineralogy/geology analysis) to create project-specific plans and solutions. For maximum success, emphasis is placed on assessment and planning rather than individual products. This methodology prevents and minimizes LC problems rather than pursuing an after-the-fact cure. Careful preplanning simplifies the process of choosing from the 177 specialized LC products offered by 46 different drilling-fluid suppliers.

Lost Circulation Assessment and Planning – The Process

The Lost Circulation Assessment and Planning concept is a process that involves exploring and assessing project specific LC problems and links them to existing LC products, systems and services.

The process focuses on using existing resources to create project-specific plans and solutions.[5,6,7] There are five key elements to this process (Fig. 1):

- Exploration
- Development
- Implementation
- Execution
- Evaluation

Exploration Phase: During this phase, candidate wells for LCAP process are identified, the magnitude of the lost-circulation potential is assessed, and strategic plans are developed.

Development Phase: A technical development team analyzes the offset wells data to identify the most probable thief zones, links existing LC products and technology with potential for solving the specific problem, uses existing engineering tools to develop the Lost Circulation Assessment and Planning Program (LCAP Program).

The Lost Circulation Planning and Assessment Program software is used during the *Development* phase.

There are three key steps to the Lost Circulation Assessment and Planning Software:

- Gathering and processing all the available project-related and problem-specific data (*i.e.*, pore pressure and fractiure gradients, geology/lithology etc.)
- Identifying the most probable thief zone(s), loss mechanics, and the relative position to bit
- Identifying the best conventional LC treatments, and recommending the contingency specialized treatments (i.e., crosslinking pills, gunk squeezes) including detailed operational procedures.

Step 1: Gathering and processing all the available project-related and problem-specific data. This represents a key difference from the after-the-fact, reactive approach to lost circulation. The type of data available includes (Fig. 2):

- Pattern of lost circulation as part of geology, lithology and stratigraphy analysis
- Pore pressure and fracture gradient
- Logging data (*i.e.*, imaging, wireline, pressure-while-drilling, array resistivity logs)
- Drilling reports (indicating pre-loss and post-loss drilling conditions, drilling events etc.)
- Offset wells lost-circulation analysis (treatments and results, lessons learned)
- Hydraulics analysis, pressure loss and ECD/ESD simulations
- Evaluation of historical cost associated with lost circulation

Step 2: Identifying the most probable thief zone (type and location). The type of thief zone refers to the nature of the loss zone (i.e., induced fractures, natural fractures, permeable formations) and the location refers to the relative position of the loss zone. The types of tools/methods available for thief zone identification are (Fig. 3 and 4):

- Pressure Transducer Surveys, Openhole Logs (*e.g.* UBI, CDR), Hot Wire Surveys, Radioactive Transducer Surveys, Temperature Surveys, and Spinner Surveys.
- Best practices and the pre-loss events analysis
- Real-time geomechanical analysis methods
- If available, use lost circulation expert software tools. The use of the expert software requires a good understanding and knowledge of pre-loss conditions.

Step 3: Identifying the best conventional lost-circulation treatments, and recommending subsequent contingency specialized treatments (*i.e.*, crosslinking pills, gunk squeezes) including detailed operational procedures (Fig. 5 and 6).

At the end of this step a formal project-specific Lost Circulation Assessment and Planning Program should be developed and provided to well execution team. The recommended LC treatments should always include both conventional LCM pills and treatments (*e.g.* blended pills of granular, flaky and fibrous materials, etc.) and specialized LC treatments (*e.g.* crosslinking technology, oil gellant pills, etc.). Always include pre-treatment procedures (*i.e.*, LCM mixed in the whole drilling fluid system). Check with the drilling/directional engineer and the MWD/LWD operator for the smallest passage in the downhole tools (*i.e.*, smallest clearance in the MWD tool) and verify that the D_{90} particle size distribution of the chosen LCM passes through the tool openings. Include detailed mixing and spotting procedures for all the pills that will be mixed as a stand-alone spotting pill treatment. Make sure that considerations are given to the rig-specific mixing equipment and mixing tanks. Identify the pill mixing tanks/pits and determine the dead volume. Always consider the dead volume in the mixing procedures (*i.e.*, add the extra volume). For all cross-linking pills, best practices include the use of cementing units for pumping and squeezing.[5]

Case Study – Induced Fractures in Deepwater

Planning for a deepwater, sub-salt Gulf of Mexico well included the LCAP process because of expected lost circulation problems, as experienced during the offset wells.

Three intervals were analyzed: 14½-in., 12¼-in. and 9⅞-in. Miocene-type lithology (shale and sandstone) typified the first two intervals; the bottom section was a transition Miocene – Oligocene with the possibility of limestone stringers. The thief zone immediately below the salt formation (the first interval) was expected to be a typical rubble zone of highly fractured shale.

The fracture gradient in the rubble zone was less relevant, but could present important variations (much lower values) from the estimated range (14.5 – 15.0 lb/gal mud weight equivalent).

A development team was assembled, all the necessary data was gathered and a LCAP process document was generated. The highest potential loss zone to be encountered, other than the rubble zone, was determined to be induced fractures shale, followed very closely by porous sandstone, induced fractures sandstone and natural fractures sandstone.

Wells of this nature are typically drilled with synthetic-based mud (SBM). Some types of material, such as synthetic graphite, have a neutral surface and can work in both types of fluid (WBM and SBM). Accordingly, a typical formulation for curing seepage losses may contain a blend of granular calcium carbonate and synthetic graphite. Optional treatments, ranging from conventional to specialized, follows:

- Pre-treating the whole mud system with $CaCO_3$ (8 - 10 lb/bbl) and synthetic graphite (8 - 10 lb/bbl)
- Mixing fiber-based particulate LCM (20 to 25 lb/bbl) in the system as passing through the seepage loss zone
- Pumping 15 to 20-lb/bbl synthetic graphite sweeps (25 to 50-bbl volume) at a frequency of one sweep every third stand, and if needed as often as one every stand
- Spotting a sequence of blended LCM pills as needed starting with 35 lb/bbl, then 65 lb/bbl and 95 lb/bbl respectively, followed if needed by a soft set pill (*i.e.*, PCP) or a reverse gunk squeeze.

A series of lost-circulation decision trees were developed to address lost circulation problems for this deepwater prospect (Fig. 3).[6]

Case Study – Naturally Fractured Carbonate

Lost circulation is a significant drilling problem in this Central Asia fractured carbonate field. Whole mud losses in some of these wells has reached 10,000 to 80,000 bbl including productive horizons. The analysis of the severity and pattern of the lost circulation included lithology data, logs, pore-pressure and fracture-pressure analysis, casing programs, daily drilling reports and end-of-well recaps.

The lost circulation has been attributed to severely fractured and/or highly porous reservoir, 1-meter to 7-meters cavities and excessive mud weights due to insufficient initial geological and pore-pressure data.

Typical mixed LCM pills, gunk squeezes and cement were not effective. From the analysis of the offset wells, a 200-lb/bbl pill was designed specifically for these formations. This pill is formulated with grit, very coarse, coarse and medium calcium carbonate. The proposed specialized treatment included a soft-set, crosslinked polymer pill.[7] Well-interval-specific flow charts are presented in Fig. 4. Even though these pills worked over moderate intervals, the lost-circulation zone was so long that eventually the well was only being completed using mud cap drilling.

LCAP – Process Overview and Benefits

Being a project specific methodology, the LCAP process involves exploring and assessing well- and interval-specific lost-circulation problems and links them to existing LC products, systems and services in order to create project-specific plans and solutions.

The dynamics of the LCAP process are exploring specific project needs, using existing resources (software), developing the LCAP program followed by implementing and executing the process (Fig. 7 and 8)

The LCAP program overall benefits are as follows:

- Gets problems solved, or at least makes progress as part of a continuous improvement process
- Extensive pre-planning allows for in-depth data gathering and a greater chance for success
- The well-execution team receives a documented process/plan - Lost Circulation Assessment and Planning Program - to follow and to measure performance with regard to technology, cost, training etc.
- Provides fit-for-purpose solutions
- The project- and well-execution team gets an opportunity to input project specific problem needs into the Lost Circulation Assessment and Planning process.

Acknowledgements

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SI Metric Conversion Factors

bbl	x 1.5897	E-01	= m^3
°F	x (°F-32) X 5/9		= °C
ft	x 3.048	E-01	= m
gal	x 3.785	E-03	= m^3
in.	x 2.540	E-02	= m
lb	x 4.536	E-01	= kg
lb/bbl	x 2.853	E+00	= kg/m^3
lb/gal	x 1.198	E+02	= kg/m^3
lb/gal	x 1.198	E-01	= specific gravity (SG)

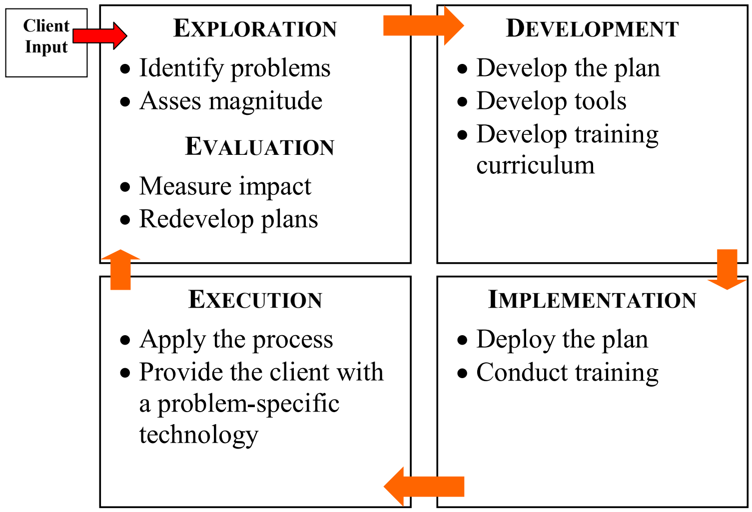

Fig. 1: The Lost Circulation Assessment and Planning concept is a process that involves exploring and assessing project specific lost circulation problems and links them to existing lost circulation products, systems and services. The process focuses on using existing resources to create project-specific plans and solutions.

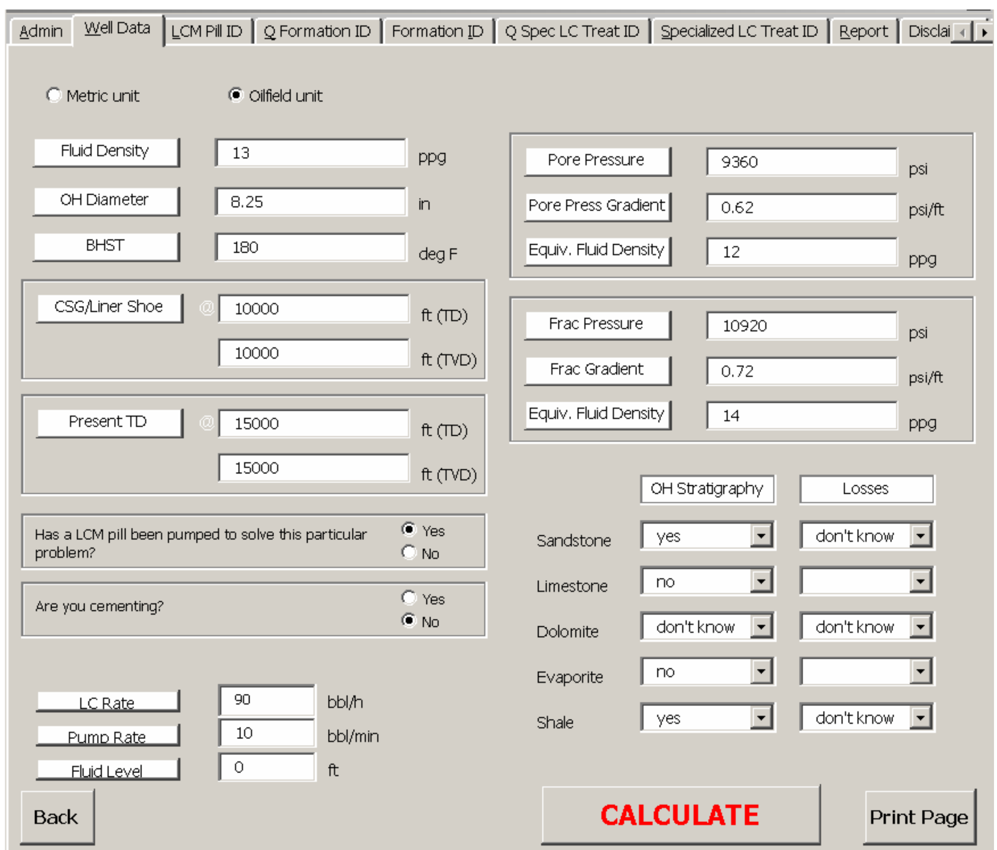

Fig. 2: Gathering and processing all the available project-related and problem-specific data.

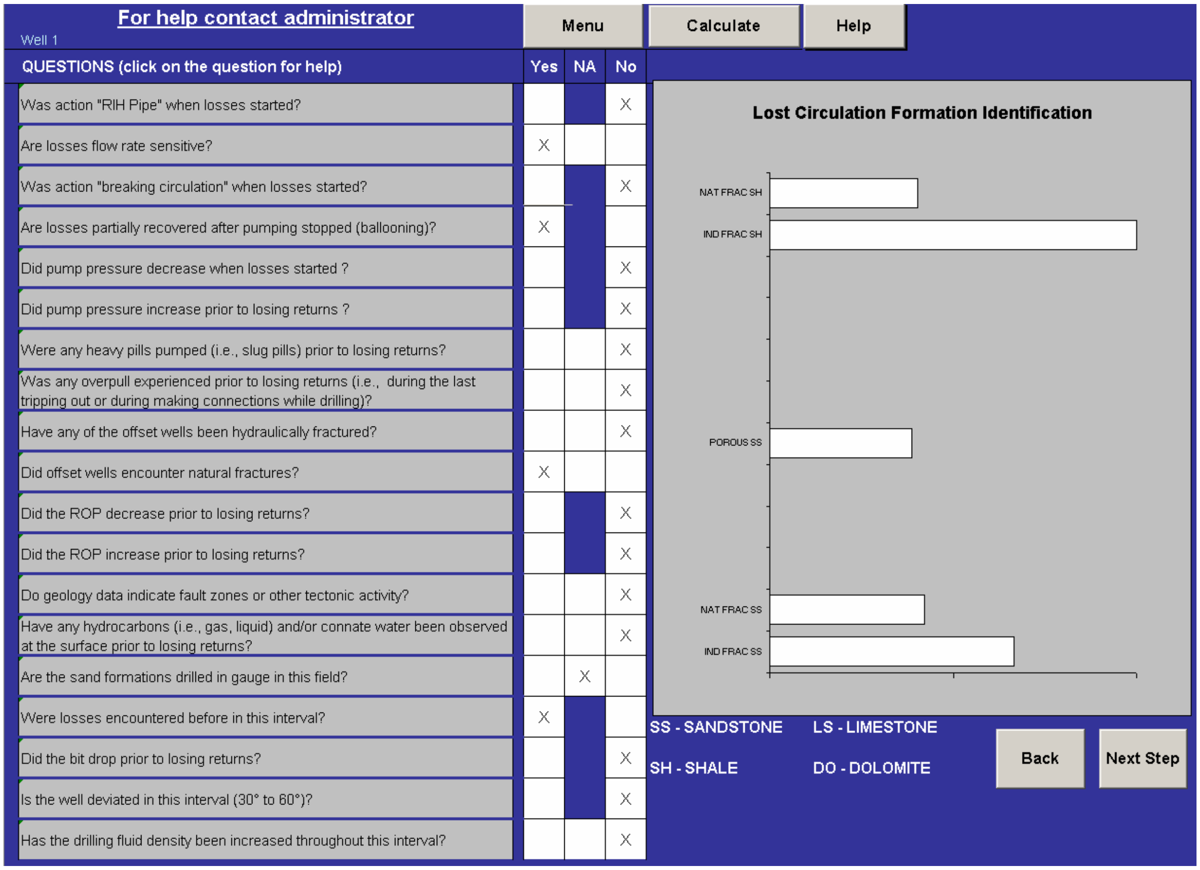

Fig. 3: Identifying the most probable thief zone(s), loss mechanics, and the relative position to bit.

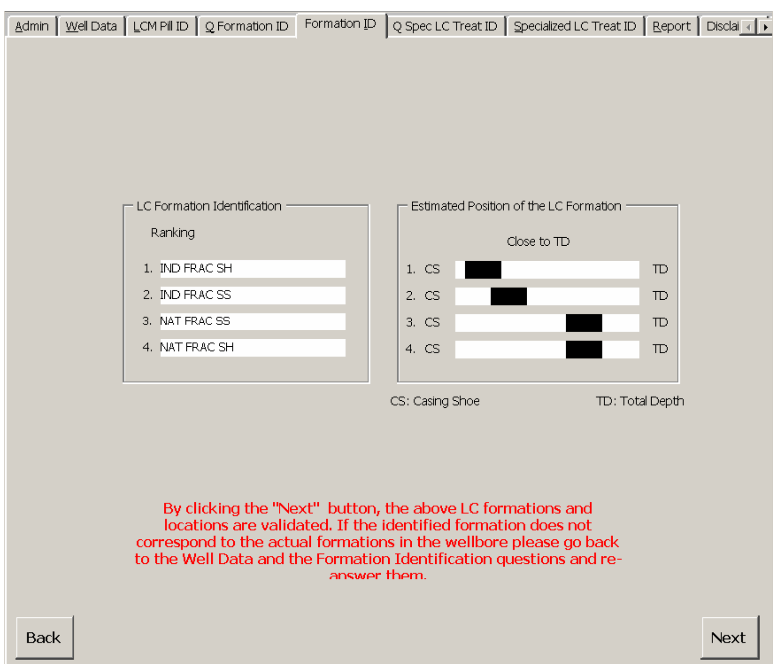

Fig. 4: Identifying the most probable thief zone(s), loss mechanics, and the relative position to bit.

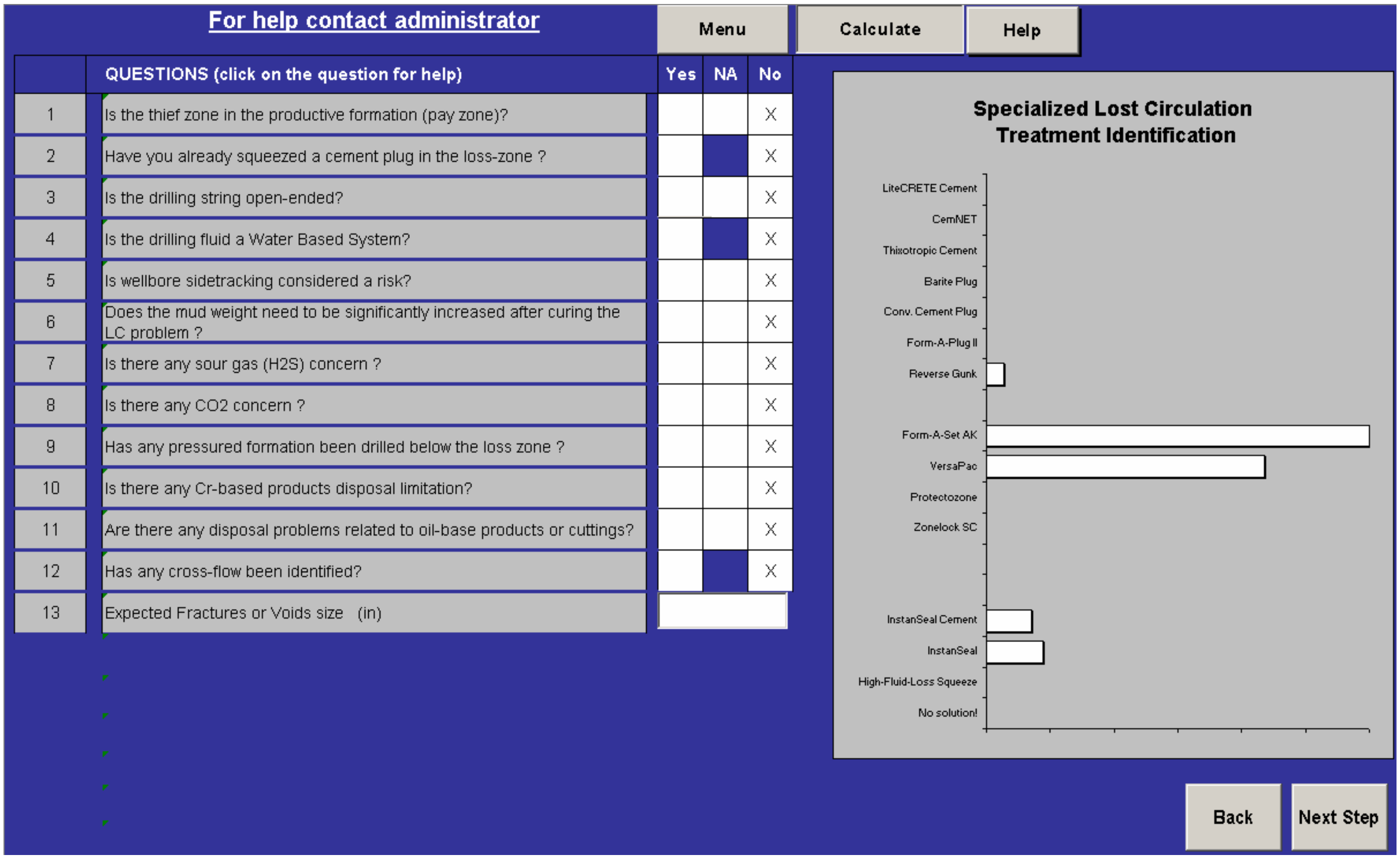

Fig. 5: Identifying the best conventional lost circulation treatments, and recommending subsequent contingency specialized treatments (i.e., cross-linking pills, gunk squeezes).

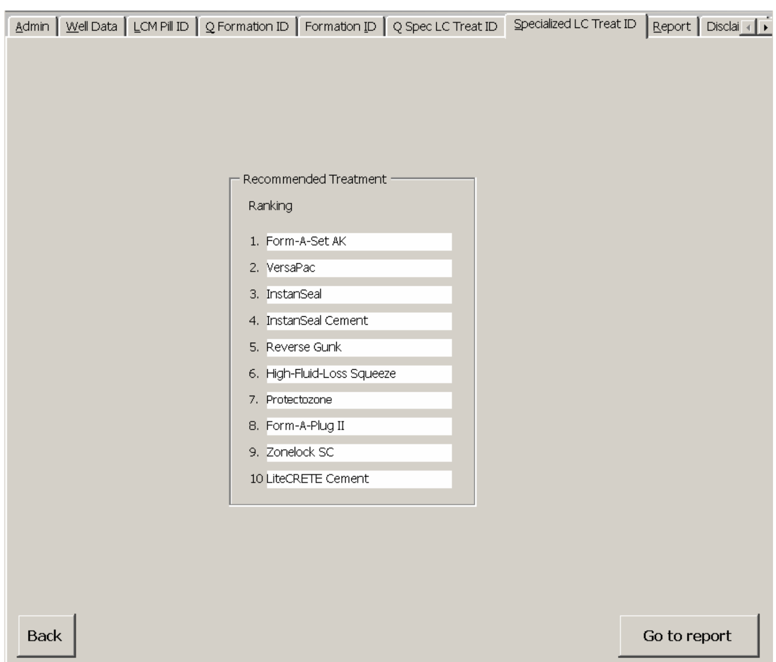

Fig. 6: Identifying the best conventional lost circulation treatments, and recommending subsequent contingency specialized treatments (i.e., cross-linking pills, gunk squeezes).

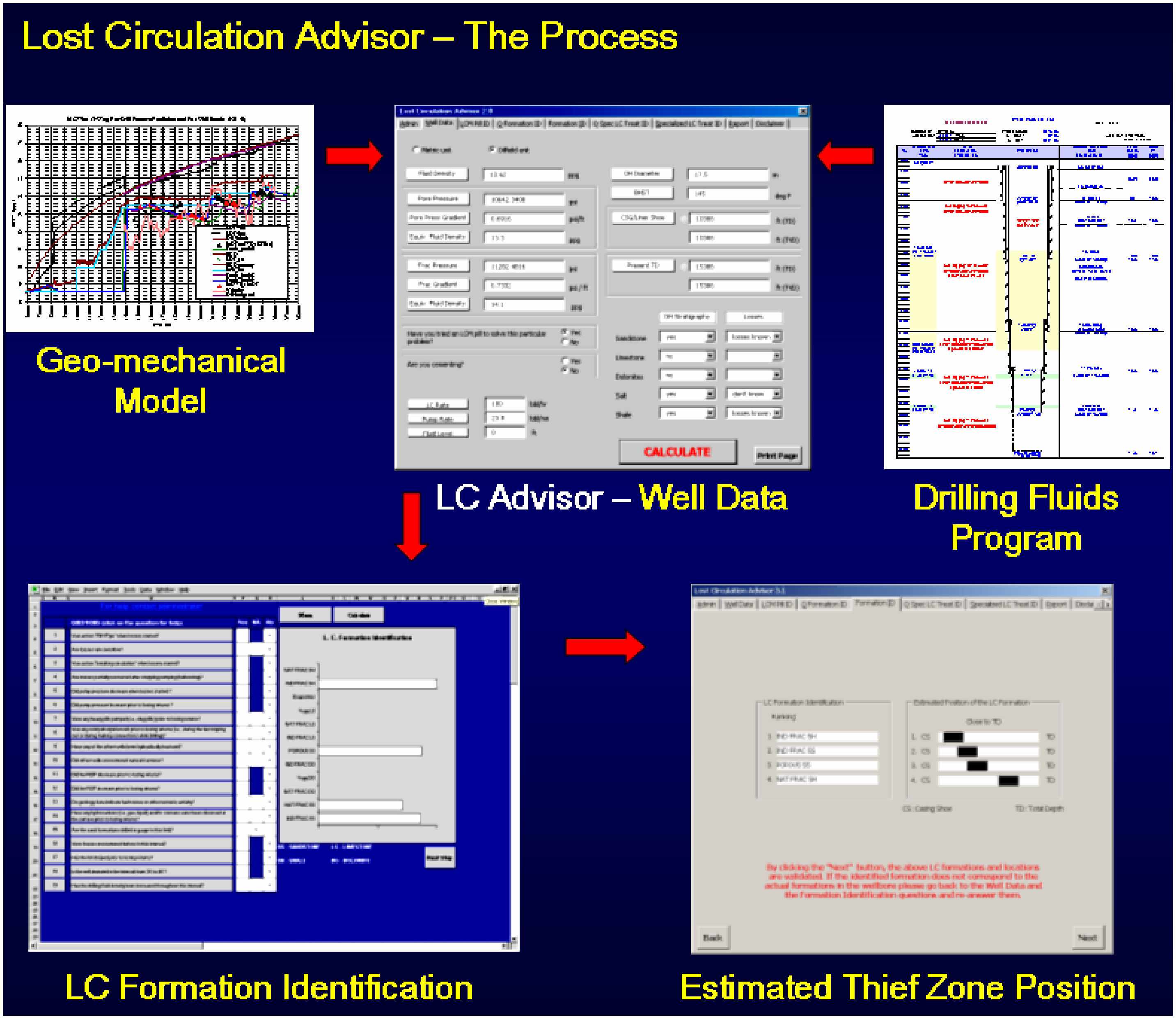

Fig. 7: The LCAP process involves exploring and assessing well- and interval-specific lost circulation problems and links them to existing lost circulation products, systems and services in order to create project-specific plans and solutions. The dynamics of the LCAP process are exploring specific project needs, using existing resources (software), developing the LCAP program followed by implementing and executing the process.

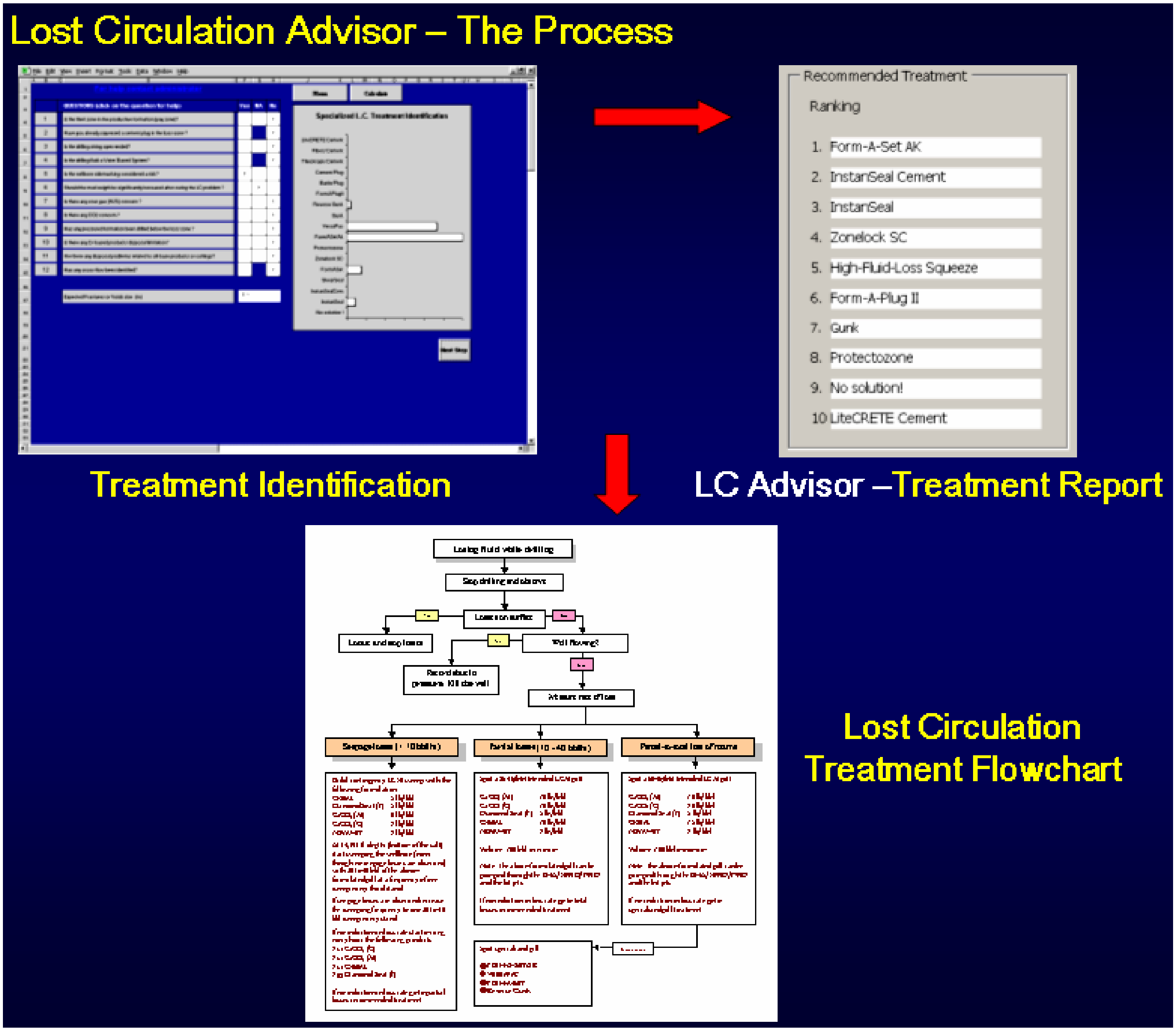

Fig. 8: The LCAP process involves exploring and assessing well- and interval-specific lost circulation problems and links them to existing lost circulation products, systems and services in order to create project-specific plans and solutions. The dynamics of the LCAP process are exploring specific project needs, using existing resources (software), developing the LCAP program followed by implementing and executing the process.