Resource Assessment of a Prospect with Two Separate Structural Closures Linked by a Saddle - Challenges, Pitfalls and Solutions in Creating a Geologically Correct Probabilistic Model*

Per Audun Hole[1]

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[1]Schlumberger, Software Integrated Solutions, Norway (phole@slb.com)

Abstract

The objective of prospect risk and resource assessment is to build a probabilistic model capturing the possible geological success scenarios with volume uncertainty and chance of success (COS). Prospects with multiple structural closures with possible fluid communication are challenging to model correctly. In this article a generic prospect with two separate structural closures sharing a saddle above the prospect maximum hydrocarbon water contact is used to present a methodology for building a probabilistic prospect assessment that correctly model the fluid communication across the saddle and produce the success scenarios as identified from the geological model.

Prospect Description

The prospect has two separate structural closures, hereafter called the 4-Way and 3-Way segment. The two segments are separated by a saddle at 1060 m and have a deeper combined maximum structural spill point at 1080 m (Figure 1). Both segments can be sourced independently and there are no source limitations. The play is proven. Both segments have the same reservoir and the prospect is assessed as an oil case. The two segments share the reservoir and source presence, but not the trap effectiveness since they have different trap type. Risk and volume parameters are listed in Table 1 and Table 2.

The following success scenarios are predicted from the geological model:

A) Both segments work and have a common contact below the saddle at 1060 m or have independent contacts shallower or equal to the saddle at 1060 m. This scenario can be further subdivided into 4 different scenarios driven by the spill across the saddle and the individual segments HWC ranges, see Figure 3.

B) The 4-Way works while the 3-Way fails on trap effectiveness, as a result the 4-Way cannot be filled below the saddle.

C) The 3-Way works while the 4-Way fails on trap effectiveness, as a result the 3-Way cannot be filled below the saddle.

Workflow

The workflow for building the probabilistic prospect model used in this article can be summarized as a four-step process:

1) Identify all possible success case scenarios of the prospect based on the geological model.

2) Subdivide the prospect into segments that enable creating the scenarios identified in step 1, through success/failure combinations. The different segments are assessed individually with respect to risk and volume.

3) Enroll the assessed segments into a prospect where risk dependency, possible fluid communication and correlations are modeled.

4) Verify that simulation results only give the predicted success scenario in step 1.

Modeling and Input Requirements

The objective of this prospect assessment is to build a probabilistic simulation model that generates only the predicted success scenarios (A, B and C), given that both closures are tested. The first step will be to identify the critical elements in the geological model that must be included in the Monte Carlo simulation to generate the predicted scenarios.

To capture this specific prospect success scenarios in a probabilistic model, the following setup, modeling capabilities and inputs are needed:

- The two structures, 4-Way and 3-Way, must be modeled as individual segments with separate volumetric and risk. This to model the effect of the trap effectiveness which can succeed and fail independently for the two segments, and model success cases where the two segments have different hydrocarbon water contacts (HWC).

- The volume model for the segments must have depth-dependent input to enable modeling different HWC in the two segments and spill across the saddle.

- The two segments are enrolled into a prospect where risk dependency, spill across the saddle, and parameter correlations between the segments are added.

- Risk dependencies must to be defined on the individual risk factors. This is to enable modeling the full dependency for reservoir presence and source presence COS between the two segments while the trap effectiveness COS is kept independent.

• The saddle between the two structures must be defined in depth. This is to model the limitation in the fill of one structure when the other fails on trap effectiveness or has an HWC above the saddle.

• There must be input on correlations for all relevant volumetric and fluid parameters. This is to limit the freedom of the Monte Carlo simulator to combine illogical random values from the input distributions. The objective is to get a valid geological model for the prospect on a trial-by-trial basis.

To quality control the result of the Mont Carlo simulation, we must be able to sort the resulting trials into success scenarios representative of the predicted success scenarios. The final verification of the prospect model is achieved when the result scenarios from the simulation match the predicted success scenarios.

Prospect Model

The 4-Way and 3-Way are built as separate segments analysis. The segment volume is defined using depth vs. area and thickness for the area draining into the 4-Way and 3-Way closures, respectively. The spill point in each segment is set to the deepest combined spill at 1080 m. The HWC range is set from 1020 to 1080 m with a mode at the saddle (1060 m) for both segments. The volume and fluid parameter are the same in both segments since they belong to the same reservoir sequence. For each risk factor, the two segments have the same COS values, except for the trap effectiveness risk where the 4-Way has 80% and the 3-Way has 50% COS. The two segments analysis are enrolled into a prospect and stochastically aggregated using a Monte Carlo simulator to give the resulting prospect COS and volume distribution. Maximum risk dependencies are defined for the reservoir presence (60%), since our geological model predicts that if reservoir is present in one segment it must be present in the other in the same prospect trial. Full risk dependency is applied for source presence (70%) based on the same logic. The trap effectiveness is independent between the two segments due to different trap types, no risk dependency applied. A fluid communication over the saddle at 1060 m between the 4-Way and 3-Way is defined in the simulator as a “leak connection”. This enable the simulator to model spill over the saddle from one segment to the other. The objective is to achieve the following;

• If the 3-Way or the 4-Way is failing on trap effectiveness or have a HWC shallower than the saddle, the 4-Way or the 3-Way respectively cannot fill below the saddle in that trial.

• If both are filled below the saddle, they will have a shared contact in that trial.

Relevant correlation on reservoir thickness, petrophysical and fluid parameters are added to get results correctly reflecting the geological model on a trial by trial in the simulation.

In Figure 3 the simulating results are grouped into possible combinations of success and failure of the two segments. This is done using a trial browser to sort the results into trial groups based on the success combinations of the two segments. The most likely case is finding the 4-Way alone (17,1% Scenario B), closely followed by the both succeeding together (16,7% Scenario A) and the least likely case is the 3-Way succeeding alone (4,4% Scenario C). Based on the prospect model, the expectation is to have small volumes in scenario B and C when the

HWC is at or above the saddle, whereas a large volume is expected for scenario A when both segments are filled below the saddle and have a shared HWC. Aggregation scenarios with small and large volumes into one prospect volume distribution will in many cases give a bimodal distribution. This is clearly the case for this prospect as shown in Figure 4. Also note that the P50 and the mean of the recoverable volume fall between the two modes on the density curve. Since the total resource distribution for the prospect is a probabilistic aggregation of the mutually exclusive scenarios A, B and C, the key question is: Will only knowing the total aggregated resource distribution be good enough for our decision process, or will knowledge of scenario A, B and C volumes and COS give added value? If the answer is yes, you will need to create these scenarios by sorting all the individual prospect success trials into groups representing the different geological scenarios. By sorting all trials from the simulation into scenario A, B and C, using a trial browser, we get the individual scenario probabilities as well as the scenarios volume distributions, see Figure 5. This gives more detailed and geologically correct information, enabling verification of the model through comparing the results with the predictions. It also gives important information to engineers/economists through calculating the COS for each of the scenarios and its associated volume distribution, enabling more realistic value assessments of the prospect based on possible geological success scenarios. It is important to notice that these success scenarios are mutually exclusive. Given discovery, only one of the predicted scenarios will be found!

Pitfalls

The most common pitfall in this type of prospect assessment is oversimplifying the volume model, resulting in success scenarios that do not reflect or can be verified against the geological model. If direct input of gross rock volume (GRV) or any other non-dept dependent method is used for volume calculations on the individual segment, it will be impossible to compute the effect of spill over the saddle combined with the effect the individual segments HWC has on volume and COS of the different success scenarios. To model this effect, the segment volume input must to be related to depth, either depth vs. volume or depth vs. GRV. In addition, to enable modeling potential fluid communication between segments, the probability for and the depth where the communication between the segments take place, need to be part of the input and used in the simulation.

An alternative to modeling the communication between the two segments as described above, is to create one prospect model for each of the three scenarios A, B and C and "guess" instead of simulating the scenario probability. Note that the probability of the individual scenarios will have a significant impact on the overall prospect volume and value, hence our ability to "guess" the correct scenario weight becomes an important additional uncertainty using this method. Scenario A will in addition be specifically challenging, since modeling the volume correctly without simulating the effect of the possible combination of segment trap failures and the HWC effect on spill over the saddle (Figure 3), will be difficult if not impossible and add increased uncertainty to the result.

Conclusions

The prospect assessment method in this article demonstrate a robust methodology for building one single probabilistic prospect model capable of simulating the predicted success scenarios as identified in our geological model. To achieve this, two main simulation capabilities are needed;

1) Risk dependency must be defined independently for the different risk factors.

2) The spill over the saddle between the two segments must be explicitly defined in depth and honored in the simulation.

Through sorting, it is possible to group the simulated success trials into geological scenarios and through this find the volume distribution and probability for each of the possible success scenarios. The ability to create trial groups and inspect the individual trials in these groups, enables thorough and detailed quality control of the simulation results. The ability to extract these geological success scenarios from the prospect simulation gives increased understanding and quantification of the prospect potential as well as provide more geologically correct scenarios to prospect value assessment to enable better exploration decisions.

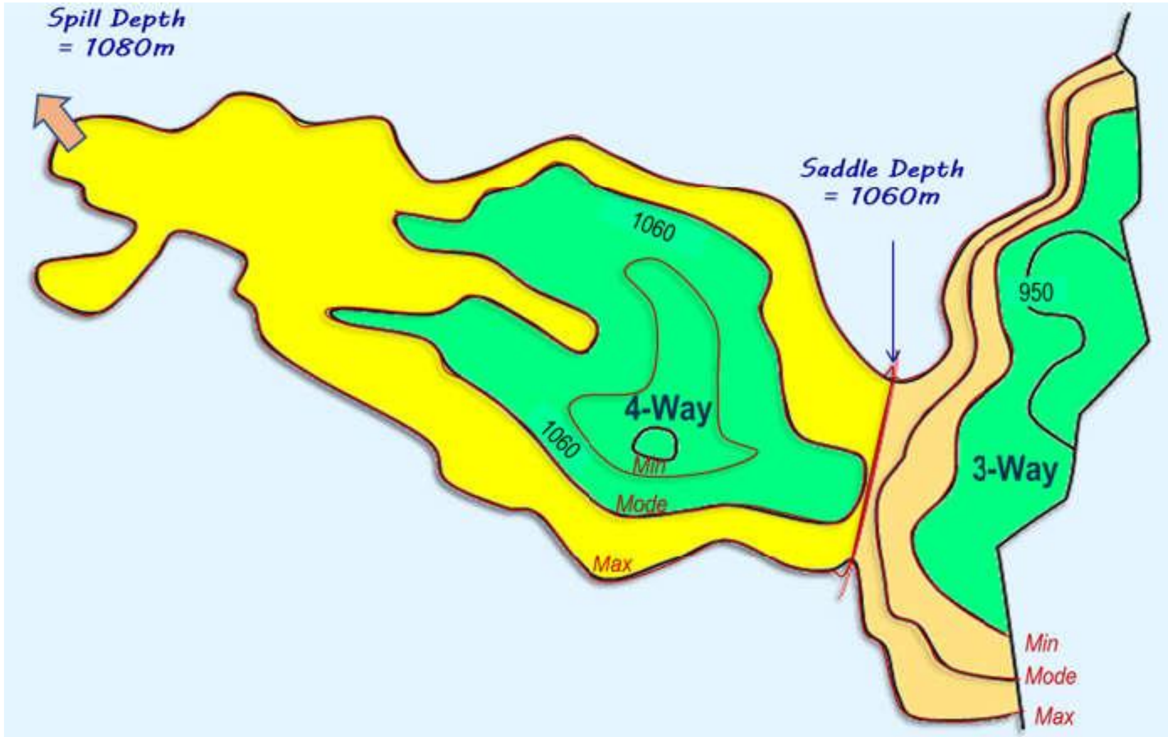

Figure 1. Structural depth map of simulation.

COS elements	4-Way	3-Way
Trap Structure	100 %	100 %
Trap Effectiveness	80 %	50 %
Reservoir Presence	60 %	60 %
Reservoir Quality	100 %	100 %
Source Presence	70 %	70 %
Source Migration	100 %	100 %
COS	**34 %**	**21 %**

Table 1. Risk input

Parameter	Min	Mode	Max
OWC (m)	1020	1060	1080
Net/Gross (%)	40	50	70
Porosity (%)	14	20	25
Oil saturation (%)	60	75	90
1/Bo	0.6		0.9
GOR		100	
Recovery (%)	30		40

Table 2. Volume and fluid input

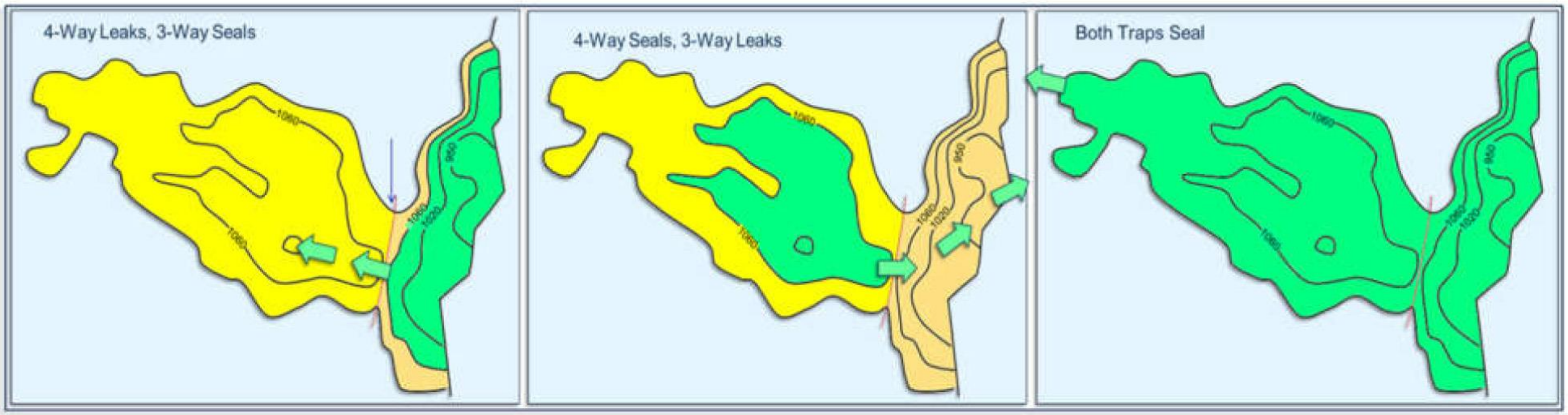

Figure 2. Predicted main success scenarios based on the geological model. The scenario where both segments work can be further subdivided into 4 scenarios (See Figure 3).

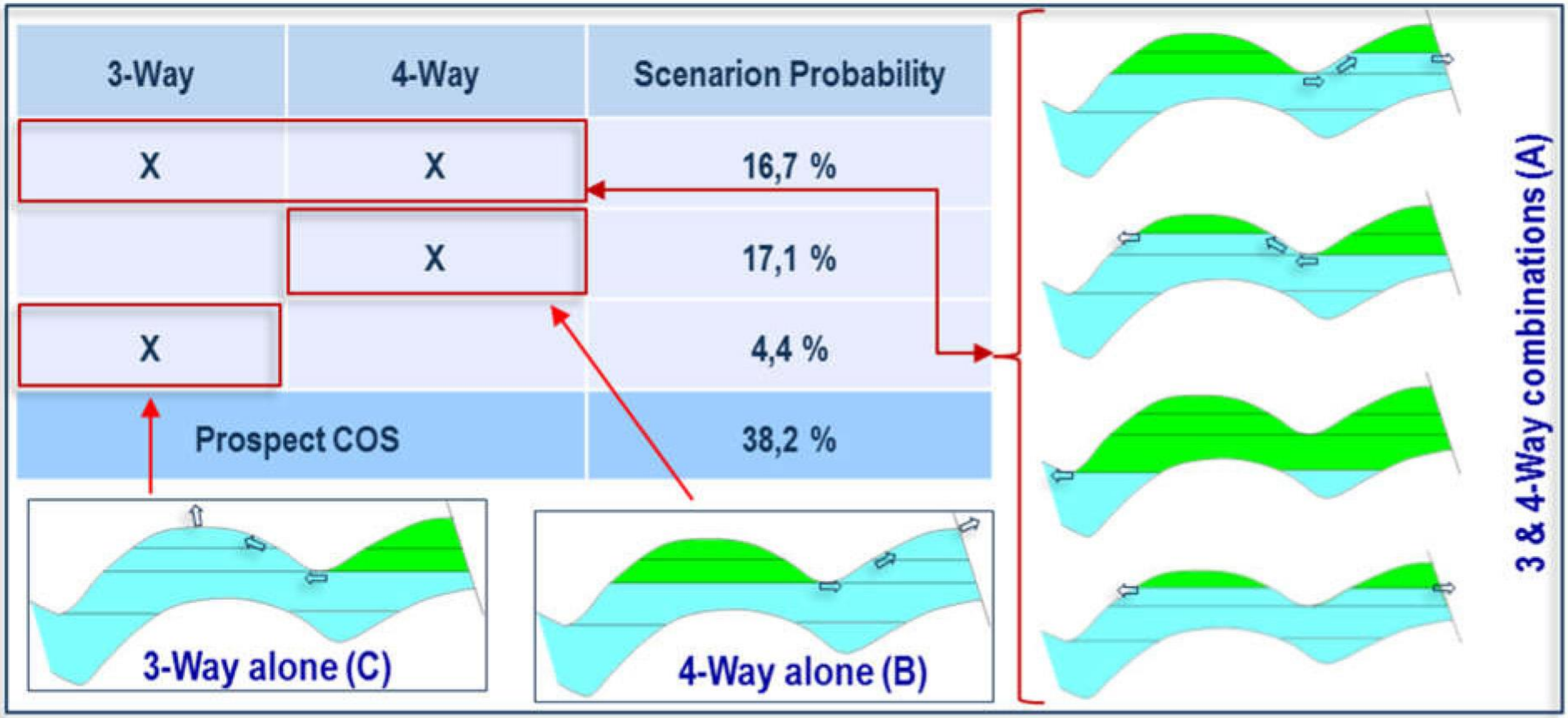

Figure 3. Simulated result combinations of the two segments with probabilities.
A) Both segments work and have a common contact below the saddle at 1060 m or independent contacts shallower or equal to the saddle at 1060 m. The 4 different scenarios are driven by the spill across the saddle and the individual segments HWC ranges. The arrows indicate where the leak across the saddle and out of the segment occur.
B) The 4-Way works while the 3-Way fails on Trap Effectiveness, the 4-Way cannot be filled below the saddle.
C) The 3-Way works while the 4-Way fails on Trap Effectiveness, the 3-Way cannot be filled below the saddle.

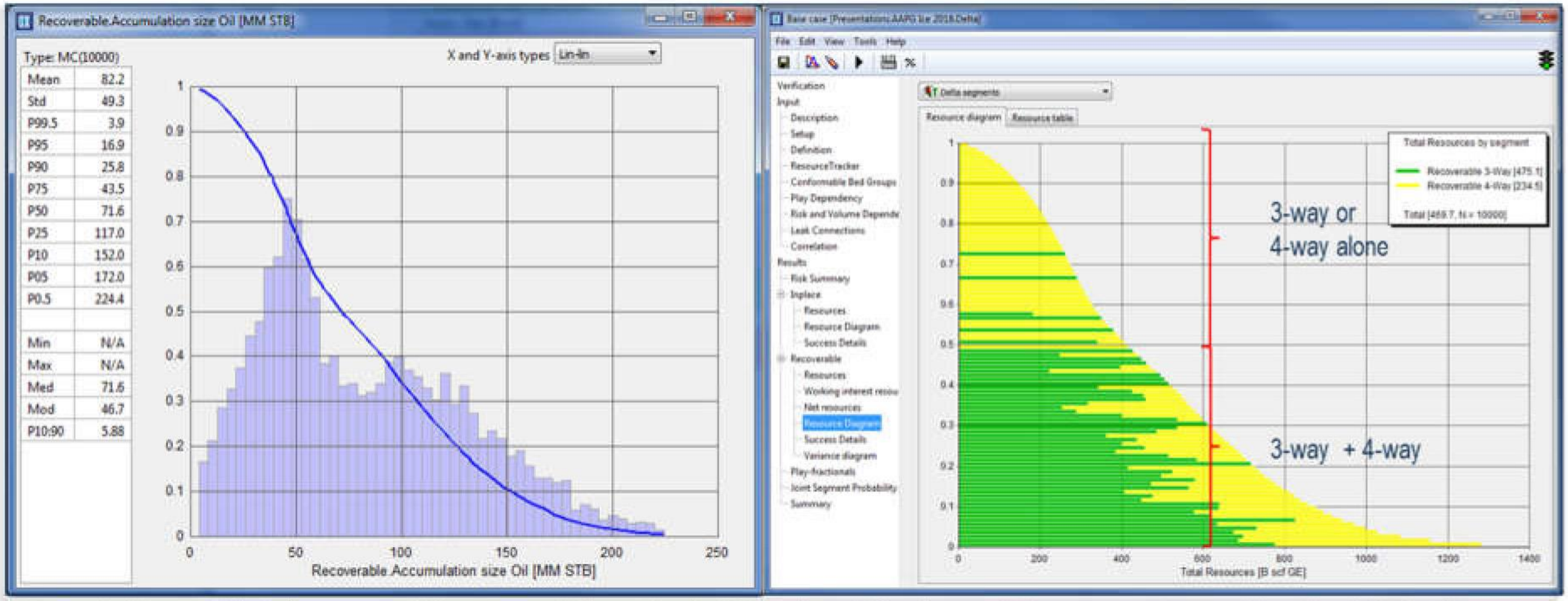

Figure 4. Prospect total recoverable accumulation size (left), and combinations of the segments creating the distribution (right).

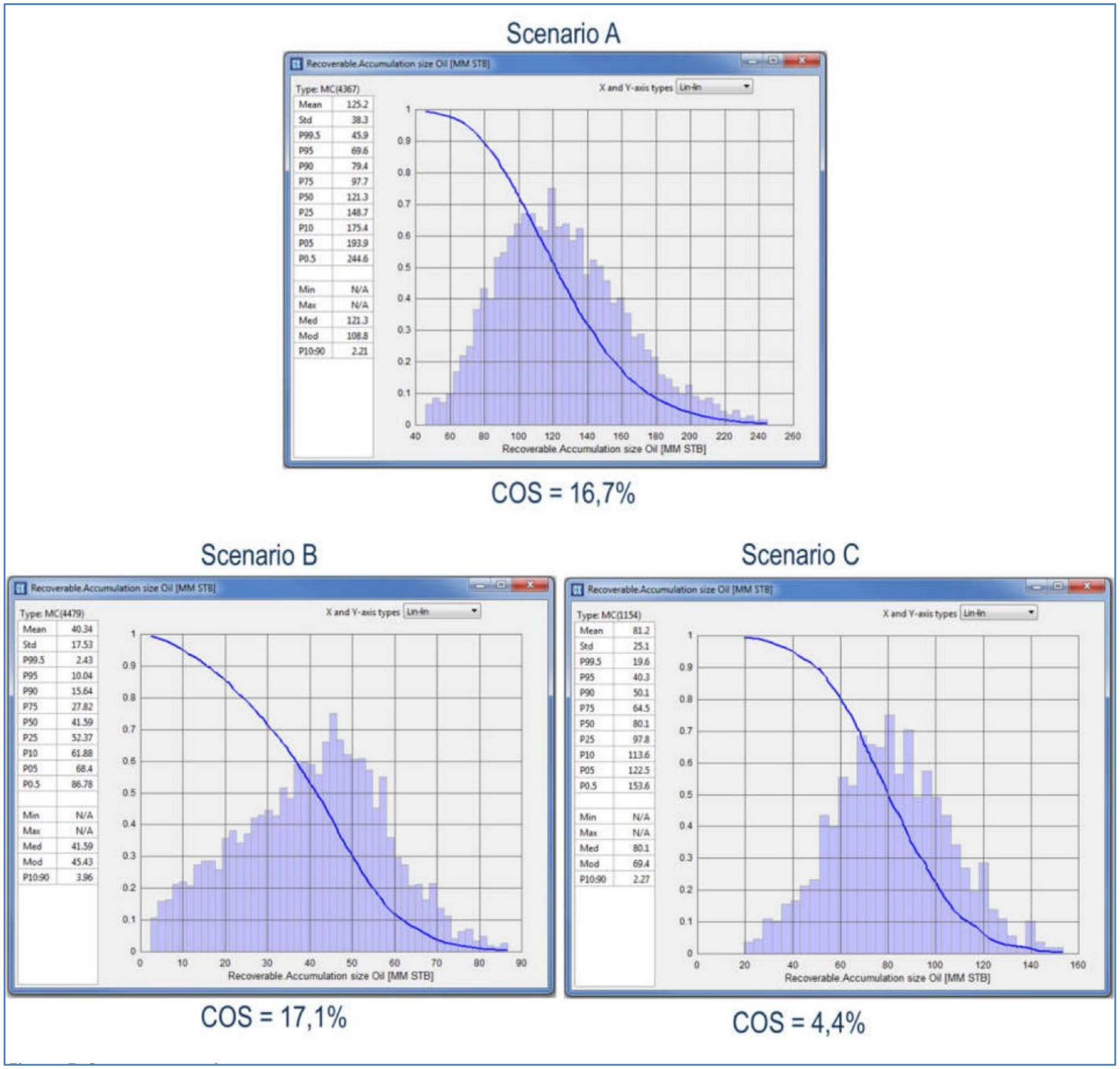

Figure 5. Success scenarios.

A) Both traps work and have a common contact below the saddle at 1060 m or independent contacts shallower or equal to the saddle at 1060 m. See Figure 3 for more details.
B) The 4-Way works while the 3-Way fails on Trap Effectiveness, the 4-Way cannot be filled below the saddle.
C) The 3-Way works while the 4-Way fails on Trap Effectiveness, the 3-Way cannot be filled below the saddle.