A common method for choosing the drilling location for an exploration prospect is to simply drill the well on the crest of the structure. The main driver is to maximize the chance of discovering a hydrocarbon accumulation. However, a common situation for a crestal well is that the discovery of productive reservoir full-to-base with hydrocarbons has only proven a limited productive area. So the discovered resource volumes are too small to justify development and further downdip appraisal drilling is required, adding to exploration costs and delaying possible development. An alternative approach is to choose a well location where a discovery would exceed the minimum commercial field size (MCFS) needed to justify development. In practice, the drilling location is often based on a deterministic resource estimate using the mean value from a probabilistic assessment of resource volumes. A downdip discovery smaller than MCFS or even a dry hole with a thick, porous reservoir might tempt decision makers to sidetrack updip since the full probabilistic distribution of the updip resources had not been considered. This paper demonstrates the advantages of trying to choose a location that considers the full probabilistic resource distributions for the updip and downdip volumes relative to the drilling location and the chance of commercial success in the decision making process. The overlap of the two distributions can be significant and what might seem like a good drilling location based on the deterministic estimate exceeding MCFS actually might leave the decision maker with some regrets at the chosen location. Besides modifying the distribution of discovered resources, the chance of geologic success also changes as the location is moved further downdip. The goals are to maximize the chance of a commercial discovery and to choose a drilling location that if a dry hole occurs there will be no regrets or reason to undertake an expensive updip sidetrack or drill another test updip. To accomplish this, multiple drilling locations need to be evaluated with this process and the results plotted to analyze trends. The results are ready to be inputted into a decision tree for expected value calculations and allow answering management questions such as “If we drill 600 acres downdip of crest, what is the probability we make a commercial discovery and what is probability of leaving commercial resource volumes updip? And how does this compare if we drill only 500 acres downdip?”
Drilling a Downdip Location: Effect on Updip and Downdip Resource Estimates and Commercial Chance

Panel 1: Investigate a Downdip Drilling Location with its Effect on Chance, EUR and EMV

Drilling a downdip location can present several advantages and disadvantages compared to drilling updip. The primary driver is to maximize the chance of a commercial discovery and to choose a location that considers the updip and downdip resource impact on the chance of geologic and commercial success.

How do I ensure if the downdip well is a dry hole that there will be no regrets about potential updip volumes testing a decision-maker to drill a sidetrack or new updip well? And how do I ensure if the entire Updip and Downdip resource distribution relative to the chosen well location?

Is there a downdip well location that maximizes Expected Monetary Value (EMV)?

How do I maximize the chance of a discovery and the commercial success of a discovery? How do I maximize the net present value (NPV) of development? How do I maximize the oil recovery yield?

The goals are to maximize the chance of a commercial discovery and to choose a downdip location that is far enough away from the crest so that no regrets or reason to undertake an expensive updip sidetrack or another updip test well. To accomplish this, multiple distributions of net pay are considered for downdip options such that 600 acres downdip of crest, what is the probability we make a commercial discovery and what is being probability of having commercial resources updip versus downdip? And how does this compare (if only 600 acres downdip)?

Should always drill a crestal well to maximize chance of a geologic discovery? What if the crest well, if successful, can't prove sufficient volumes for development requiring further appraisal, additional costs and delayed development?

How do I maximize the chance of a downdip location so that a discovery will find Estimated Ultimate Recoverable (EUR) oil exceeding the Minimum Commercial Field Size (MCFS)?

What is a downdip well location's impact on chance of geologic and commercial success? How do I ensure if the downdip well is a dry hole that there will be 'no regrets' about potential updip volumes testing a decision-maker to drill a sidetrack or new updip well? And how do I ensure if the entire Updip and Downdip resource distribution relative to the chosen well location?

Is there a downdip well location that maximizes Expected Monetary Value (EMV)?

How does correlation between Area and Net Pay affect Updip and Downdip resources? How do I ensure if the downdip well is a dry hole that there will be 'no regrets' about potential updip volumes testing a decision-maker to drill a sidetrack or new updip well? And how do I ensure if the entire Updip and Downdip resource distribution relative to the chosen well location?

Is there a downdip well location that maximizes Expected Monetary Value (EMV)?

How do I compare different downdip locations and determine which one should be drill?
Drilling a Downdip Location: Effect on Updip and Downdip Resource Estimates and Commercial Chance

Drilling a downdip location will have an effect on our resource and commercial chance estimates. We ran a productivity analysis on a proposed drilling location and found that the downdip location will have a significant impact on our resource and commercial chance estimates. The downdip location will have a higher EUR than the updip location, which will result in a higher commercial chance of success. This evaluation shows how to use this information to select a drilling location that maximizes the commercial chance of success.

Observations

1. The maximum P90 is at 400 acres (Figure 9).
2. At a location of 400-500 acres, we would have a better chance of success, compared to about 30% commercial chance (Figure 9).

The Downdip location is preferred because it has a higher EUR (and therefore a higher commercial chance) than the updip location. The downdip location will have a higher EUR than the updip location, which will result in a higher commercial chance of success. This evaluation shows how to use this information to select a drilling location that maximizes the commercial chance of success.

The EMV calculations can be prepared for the full range of possible resource and commercial chance estimates. The commercial chance of success for the prospect is 700% at 400 acres. Observation 9.4 MMBO = $119 MM

Decision tree using the drilling well location at 400 acres. The decision tree is used to determine if a commercial discovery has been made. The green curve assumes a 90% chance a discovery will exceed MCFS and the black horizontal line shown is the MCFS of 9.4 MMBO. Figures 11-13 have 12 and 13 decision trees that differentiate between downdip and updip locations. Downdip from crest will find EUR in excess of MCFS, but is that increased downdip chance warranted given the commercial chance in Updip resources?

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Drilling a Downdip Location: Effect on Updip and Downdip Resource Estimates and Commercial Chance

Panel 3: Investigate a Downdip Location of a Correlated Area — Net Pay Prospect Assessment

All previous discussion was for a prospect with no correlation between areas and average net pay. This panel uses the same prospect, but with assumption of a strong area-net-pay correlation. This may highlight the importance of considering the impact correlations have in the decision on the well location.

Figure 15 compares the positive EUR distributions with no area-net-pay correlation (r = 0.0) and a positive area-net-pay correlation (r = +0.8) in blue. The positive correlation increases the mean EUR for both the Updip and Downdip EUR.

Figures 16 and 17 show the positive uncorrelated and correlated EUR distributions for the drilling locations at 400 acres. Each figure displays the updip (orange) and downdip (purple) geographical EUR distributions and Downdip Commercial EUR (green) distributions. Figure 16 highlights the positive EUR overlap (tan rectangle) of the Updip and Downdip EUR distributions (P100 to P32 of Downdip Distribution). This significant EUR overlap is often surprising. A decision maker selecting a downdip well location to please-uppace or Downdip EUR could very well be missing the EUR potential of an updip location.

Along with Figures 18 and 21, this figure highlights the positive net-pay correlation (r = 0.0) in red and a strong correlation. The thick black horizontal line is the MCFS of 9.4 MMBO. Recall the chance at 400 acres that Updip EUR exceeds MCFS has significantly reduced to only 26% (P100 to P74 of Downdip Distribution). This 68% overlap (tan rectangle) of the Updip and Downdip EUR distributions (P100 to P32 of Downdip Distribution) has increased from 21% to 5% when considering the strong positive area-net-pay correlation.

The chance at 400 acres that Updip EUR exceeds MCFS has significantly reduced from 21% to 5% when considering the strong positive area-net-pay correlation. The positive correlation increases the Mean EUR and the P10/P90 net-pay correlation.

Figure 17 with the positive area-net-pay correlation highlights how the EUR overlap (tan rectangle) is 68% of the downdip EUR overlap with the updip EUR overlap. As always, this reinforces that strong area-net-pay correlation must be included in the assessment only when it’s justified. The positive correlation’s increased area-net-pay overlap provides a more definitive decision on the well location.

Figure 14 compares the impact of correlation by showing the chance of success as a function of the well location for the Updip and Downdip EUR with Net Pay as correlated and uncorrelated. The thick black horizontal line is the MCS of 9.4 MMBO. Recall in Figure 7 at 700 acres, the uncorrelated Mean Updip EUR was greater than the Downdip EUR while with the positive correlation the Mean Downdip EUR (purple) is higher than the Updip EUR due to the correlation with net pay. Note the chance the Downdip EUR exceeds MIS approaches 100% at 700 acres in Figure 20, whereas it is 3000 acres in Figure 14 for uncorrelated Downdip EUR.

Figure 18 highlights the Downdip Commercial EUR distribution with well location at 400 acres with no area-net-pay correlation (r = 0.0). Frequency distribution overlap with the Updip EUR has decreased to 26%.

Figure 19 compares the Downdip EUR distributions with no area-net-pay correlation (r = 0.0) and a positive area-net-pay correlation (r = +0.8). Downdip EUR distribution overlap with the Updip EUR is reduced to 20%.

Figure 20 shows the Downdip and Updip Mean EUR and the Updip "No Regrets" EUR as a function of downdip location. The thick black horizontal line is the MCS of 9.4 MMBO. Recall in Figure 7 at 700 acres, the uncorrelated Mean Updip EUR was greater than the Downdip EUR, while with the positive correlation the Downdip EUR (purple) is higher than the Updip EUR (brown) due to the correlation with net pay. Note the chance the Downdip EUR exceeds MIS approaches 100% at 700 acres in Figure 20, whereas it is 3000 acres in Figure 14 for uncorrelated Downdip EUR.

Figure 21: Chance of Success Case exceeding MIS range for Updip and Downdip Distributions. Compared to Figure 10, the choice of 400–600 acres is more definitive with the correlation.

While other issues (e.g., seismic data quality, shallow drilling hazards, surface location, reservoir compartmentalization, testing for oil and gas column, block boundary, well cost) impact the downdip well location decision and the required number of appraisal wells—taking into account the Updip and Downdip chance of geologic and commercial success and the full range of EUR are critical for the decision maker to understand the benefits and risks of drilling at downdip locations.

The broad uncertainty of the input parameters and uncorrelated output must always be taken into account. With these uncertainties in mind, there may be a single "best" well location because of 1) risk tolerance of the decision maker, 2) dogleg score for the well (taking into account 3) impact of changes based on the input assumptions. With the additional insights provided here, more informed decisions can be made.

Drilling at a location where EMV is maximized — due to ability to eliminate an appraisal targeted downdip to confirm commerciality or targeted updip to show potential internal behind-youres — can be a winning strategy.