Quantifying and Managing Exploration and Development Risk and Uncertainty in LNG Backfill Projects

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ABSTRACT

What does it take to guarantee enough backfill gas from an exploration portfolio for a new LNG train? How many exploration wells must be drilled? What combinations of exploration success provide sufficient gas and how can these be optimally developed? These are some of the critical questions facing Upstream gas suppliers in the quest to ensure LNG plants remain full. In such cases, the exploration premise is thus "discovering and developing enough economically attractive gas in time to ensure required gas rates are sustained throughout the gas sales contract period". Addressing this premise requires consideration of the inherent risks and uncertainties of exploration, and an integrated exploration – development approach to define, manage and mitigate these. This paper describes our approach to risk and uncertainty management in such a project through development of a "Case Map", which describes variations in the exploration drilling sequence and development scenarios required meet the premise, while addressing the risk of failure in individual prospects, and volumetric uncertainty in discoveries. By describing combinations of exploration success and failure, and their associated urban development plans, the Case Map provides valuable insights into our critical questions. So, what does it take to guarantee enough backfill gas from exploration for a new LNG train? Our work demonstrates that for our selected project and portfolio, as few as four and as many as eight prospects must be drilled to deliver >80% chance of securing our premise. Fourteen corresponding unique urban development plans are described, providing decision makers with critical information on the scope required, and attractiveness of, exploring to backfill a new LNG train.

Keywords: Uncertainty, Risk, Mitigation, Backfill, Drilling sequence, Development Scenario, Decline curve.

INTRODUCTION

Methods for portfolio risk and uncertainty management in gas projects typically describe quantification of facility, well, reservoir or financial risk and uncertainty for discovered resources (Koosh *et al.,* 2003; Back & Guercio, 2010; Allen, 2017; Surovtsev & Sungurov, 2017). When considering undiscovered, exploration backfill gas supply to an existing plant (Figure 1a), exploration risk and uncertainty is typically handled via applying the individual prospect probability of success (POS) to the prospect mean volume, to generate a risked prospect volume (i.e. an expected value) which can then be forecast, such as in Figure 1b (Maharaj *et al.,* 2003; Back, 2016). This method has the beauty of simplicity and is therefore widely adopted for exploration portfolio summation (Rose, 1992).

When forecasting discovered gas resources, this method of simply stacking resource wedges (Figure 1b) has the advantage of simplicity, although it does not account for the range of gas volumes in an individual exploration prospect (this can be estimated using stochastic methods, such as described by Allen, 2017).

Take for example, the probability that Prospects A, B, C and D are all successful, as shown in Figure 1b. The chance of occurrence of this outcome is calculated simply as the product of the individual prospect POS, i.e. the cumulative probability that Prospects A through D are all successful is ~10%. Considering this low probability event of exploration success in prospects A through D and combining with the probability that each prospect discovers precisely the risked volume shown in Figure 1b,

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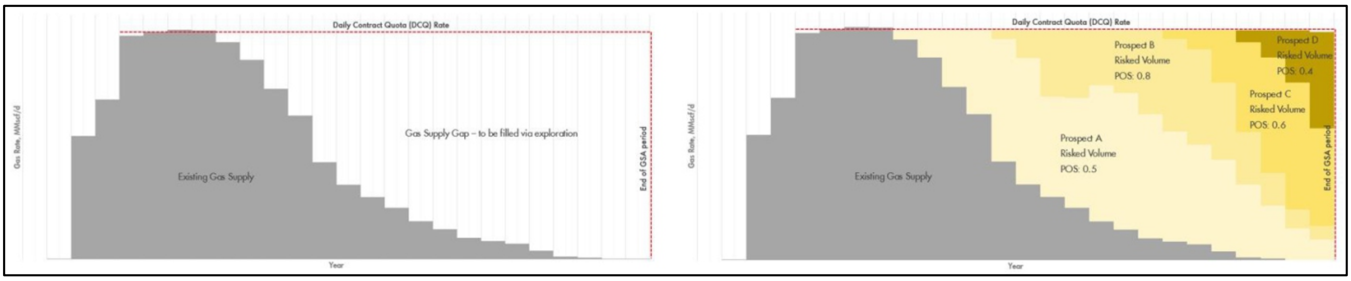


Figure 1a (left): In this case study, an LNG plant with existing supply is able to meet its daily contract quota (DCQ) for a finite period. Thereafter, field decline sets in with the supply gap growing towards the end of the Gas Sales Agreement (GSA) period. The supply gap is the area required to be filled by the exploration portfolio and can be simply expressed as a gas volume, with more nuanced approaches specifying the supply gap in terms of a gas rate and duration.

Figure 1b (right): The typical or traditional approach to exploration portfolio management in this setting is to forecast based on the expected (risked) volume and stack exploration projects in order. With a large enough exploration portfolio and an unlimited supply of capital to explore, this approach will be successful at a portfolio level, although the probability of any individual prospect performing as shown is extremely small.

results in an extremely low chance (<<1%) that the forecast in Figure 1b will match reality.

This simple stacking of risked production forecasts is an appropriate planning method where both the exploration portfolio and the available capital are unconstrained – over time, and with sustained investment in exploration, the exploration portfolio will deliver the risked volume (Rose, 1992). However, in a cash-constrained exploration business with a finite portfolio of opportunities, this method for gas backfill planning fails to address three fundamental questions:

1. In order to fill the gas supply gap, how many exploration wells must be drilled to find the required gas volume?
2. Assuming a finite portfolio of opportunities to drill, what is the probability of finding enough volume to fill the supply gap?
3. Given the inherent uncertainty around pre-exploration gas volume ranges, what combinations of portfolio success and failure will close the supply gap, and what will that cost?

This case study documents a method to address these questions, resulting in critical insights into the robustness of, and risk in an exploration portfolio destined to backfill a gas plant.

WORKFLOW & RESULTS

Given a portfolio of eight prospects (Figure 2) and considering that each prospect has four possible outcomes when drilled (dry hole, low, mid and high volume), there are 4^8 (>65,000) unique scenarios if the entire portfolio is tested. This is too many to practically consider, especially if one is only interested in scenarios that close the supply gap. To solve this challenge, ~100 portfolio outcome scenarios were selected and tested against a simple volume criterion – did these scenarios yield enough gas to backfill the plant? From these ~100 scenarios, ~30 met this criterion. A subset of 13 of the ~30 scenarios were then selected for further analysis and tabulated into what is referred to as "the Case Map" (Figure 3).

The Case Map is bound by "extreme high" (Case I) and

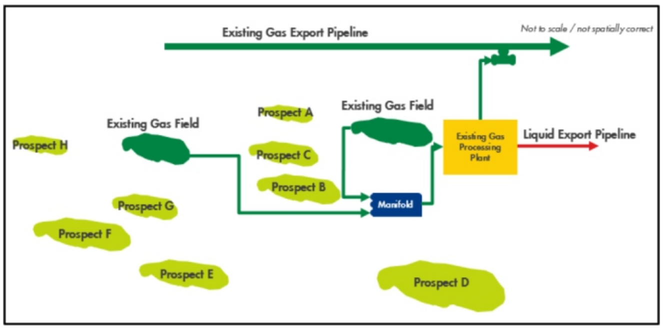


Figure 2: Schematic of the exploration portfolio considered in this case study. Each prospect has a POS and volume range (low-mid-high) assigned.

Case ID		Exploration Case Map							
		A	B	C	D	E	F	G	H
I	Extreme High	High	High	High	Mid	Not drilled	Not drilled	Not drilled	Not drilled
II		High	Mid	Mid	High	Not drilled	Not drilled	Not drilled	Not drilled
III		Mid	Mid	Mid	Dry	Mid	Mid	Not drilled	Mid
IV		Mid	Mid	Mid	Dry	Mid	Dry	Mid	Mid
V		Mid	Mid	Mid	Dry	High	Dry	Dry	High
VI		Mid	Mid	Mid	Dry	Low	High	Mid	Low
VII		Low	Low	Not drilled	Mid	Mid	Dry	Mid	Mid
VIII		Low	Low	Not drilled	Mid	Dry	High	Mid	Dry
IX		Dry	Dry	Not drilled	Dry	High	Mid	Mid	High
X		Dry	Dry	Not drilled	Dry	Mid	High	High	Mid
XI		Dry	Dry	Not drilled	Mid	Mid	Mid	Dry	Mid
XII		Dry	Dry	Not drilled	High	Mid	Dry	Dry	Mid
XIII		Dry	Dry	Not drilled	Dry	Mid	Mid	Mid	Mid
XIV	Extreme Low	Low	Low	Not drilled	Low	Low	Low	Low	Low

Figure 3: The Case Map. Scenarios included in the case map were selected as they met a simple volumetric criterion to close the supply gap and represent a range of mixed success-failure outcomes across the portfolio; many other scenarios also meet this criterion and are not included. An extreme high and low case are also included to bracket the ranges of subsurface outcomes.

"extreme low" (Case XIV) end-members representing the best and worst possible portfolio outcomes. The remainder of the cases are mixed success-failure scenarios representing possible portfolio outcomes after exploration drilling. While the probability of any individual scenario being encountered is extremely

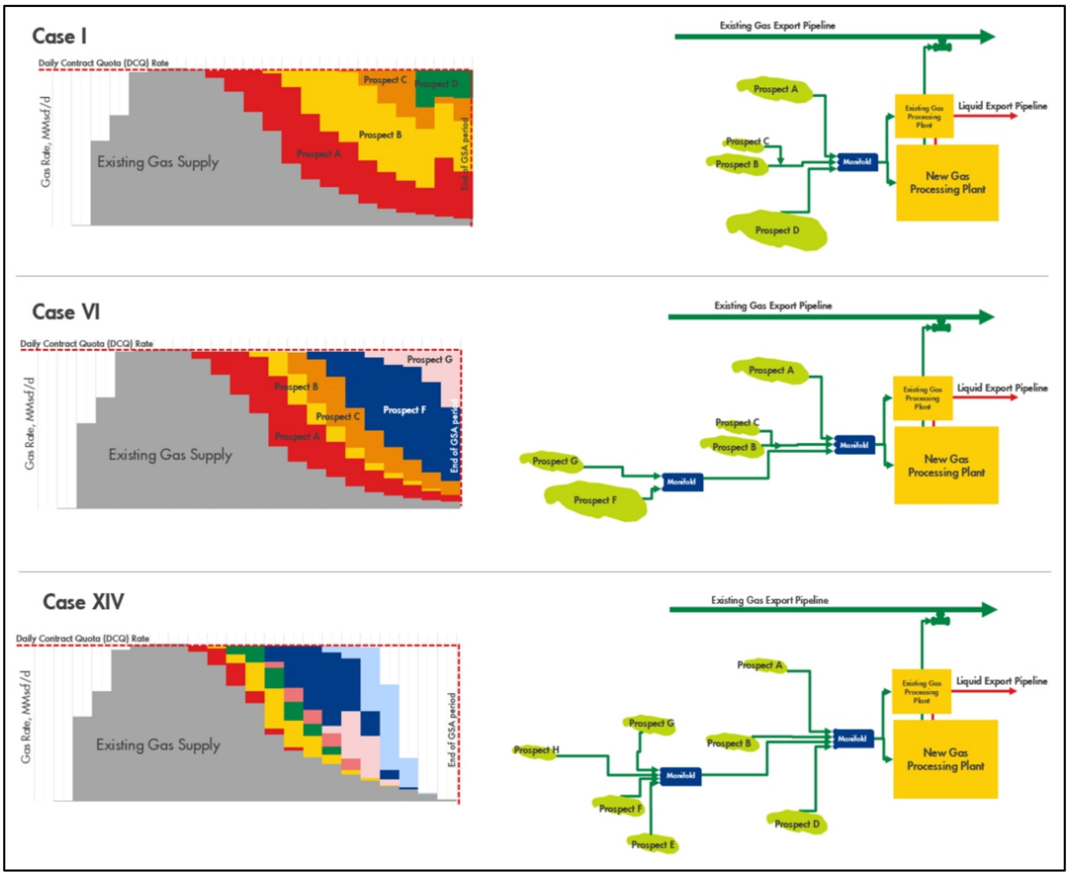


Figure 4: Selected case map model outputs based on scenarios described in the case map. Case I is the extreme high case and represents the best possible subsurface outcome considered, which translates to the simplest and lowest cost notional development plan. Case VI is an example of a mixed success-failure case requiring relatively higher effort to develop. Case XIV is the extreme low case where volumes are small and distributed throughout a large area, requiring very high effort and cost to develop.

low, by bracketing scenarios between high and low end-members, and sampling representative mixed cases, we are able to describe ranges of outcomes useful for highlighting and managing exploration portfolio risk and uncertainty.

The scenarios described in the Case Map were entered into the computational tool PetroVR (Petroleum Ventures and Risk) where the production forecasts resulting from each case and the corresponding notional appraisal and development plan were constructed.

For each Case Map scenario, a suite of outputs was generated (Figure 4), consisting of a production forecast, notional development plan and exploration, appraisal and development costs. Subsequently, the unit-development cost at a discount rate of 0% (UDC0) was calculated for each case. A probabilistic portfolio volume distribution was also generated at this stage to demonstrate cumulative risked low-, mid- and high-case volume scenarios to complement the scenario-based approach modeled in PetroVR.

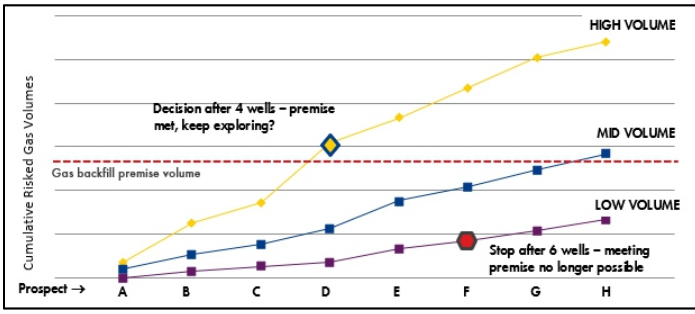
Insights

In a cash-constrained exploration business with a finite portfolio of opportunities, gas backfill planning must address three fundamental questions, namely, (1) How many exploration wells must be drilled to find the required gas volume, (2) What is the probability of finding enough gas to close the supply gap, and (3) Given the inherent uncertainty around pre-exploration gas volume ranges, what combinations of portfolio success and failure will close the supply gap, and at what cost? Using the Case Map in conjunction with the modeling capabilities of PetroVR, and a probabilistic portfolio volume model, we can now address these questions.

The number of wells required to find the required gas volume to close the supply gap is a function of the overall outcome from drilling the exploration portfolio. Figure 5a illustrates these outcomes via a series of cumulative volume curves representing a low-, mid- and high case for the portfolio, assuming we drill prospects A through H in order. If the volume results are trending along the cumulative high-case curve, after 4 wells the minimum volume threshold to close the supply gap will have been met and the exploration campaign can be stopped. Conversely, if the volume results are trending along the cumulative low-case curve, after 6 wells it will be clear that there is no possibility of meeting the required volume, and therefore the exploration campaign should be stopped. If volume results trend along the cumulative mid-case curve, then all 8 prospects in the portfolio must be drilled to surpass the minimum volume threshold.

The key information to decision makers is therefore that we require between 4 and 8 exploration wells to close the supply gap, with a failure outcome apparent after 6 wells.

Assuming exploration portfolios and budgets are finite, it is critical to understand the probability of exceeding the threshold volume required to close the supply gap from our portfolio. Figure 5b builds on the results of the probabilistic volume model in Figure 5a and tests the probability of exceeding the threshold volume. Given the portfolio in this case study, there is an 80% chance of



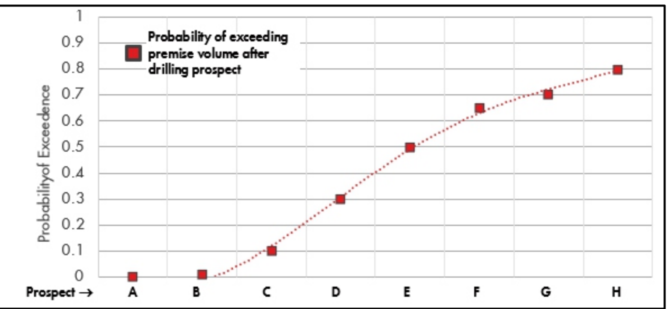


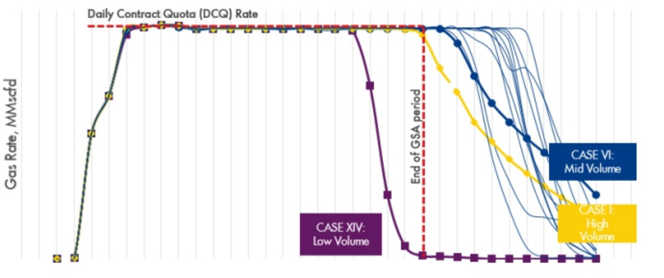
Figure 5a (left): Results from a probabilistic cumulative volume model run for this portfolio demonstrating the range in the number of exploration wells required to properly test the portfolio and meet the volumetric premise to close the gas supply gap.

Figure 5b (right): Analysis from the probabilistic volume model plotting the probability of exceeding the threshold volume to close the gas supply gap after the drilling of each prospect A-H in order. After drilling the entire 8 well exploration portfolio we achieve an 80% chance of having passed our threshold volume.

exceeding the threshold volume after drilling all 8 prospects in the portfolio. After 4 wells, there is a 30% chance of exceeding the threshold, i.e. the high-case cumulative volume curve from Figure 5a has a 30% probability for this portfolio and backfill requirement. For decision makers, it is important to understand that exploring this portfolio does not guarantee sufficient gas will be discovered to close the supply gap, and a 20% residual risk of a supply shortfall remains.

combinations of success and failure close the supply gap, and at what cost (expressed as UDC0).

Contrasting the insights gained from the case map with the traditional portfolio management approach illustrated in Figure 1b, fundamental differences in the conclusions drawn are observed (Table 1). A simplistic approach to managing a risky and uncertain gas backfill portfolio results in an overly optimistic view of the exploration effort



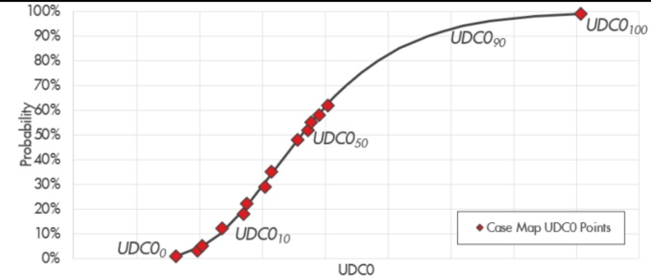


Figure 6a (left): Combined forecast plot for the case map scenarios highlighting Cases I, VI and XIV documented in Figure 4.

Figure 6b (right): UDC0 values generated from case map outcomes fit a lognormal trend from which we can extract P10, P50 and P90 UDC0 values, giving decision makers a range of notional development costs to ensure the gas supply gap is closed.

Table 1: Contrasting key conclusions regarding exploration effort, risk and cost based on a traditional portfolio approach to gas backfill versus the case map approach to the same business challenge.

	Typical/Traditional approach	Case Map approach
Number of exploration wells required	4	4-8
Probability of discovering required volume	Implied 100%	Quantified at 80%
Notional unit development cost	Single, deterministic UDC0	UDC0 range

Having established that drilling between 4-8 exploration wells results in an 80% probability of discovering enough gas to close the supply gap, the combinations of success that will produce gas at the required rate and for the required duration can be examined, and an estimate of the range of costs to develop the corresponding discoveries can be considered. Figure 6a plots the case map scenario results in terms of production forecast, establishing that in all cases tested except Case XIV (extreme low case), it is possible to backfill the gas plant with enough gas and at sufficient rate to reach the end of the GSA period. Each case has an associated unit development cost; these are plotted and fit a lognormal distribution with an assumption that the extreme high case (Case I) and extreme low case (Case XIV) bound the possible UDC0 range (Figure 6b). Exploration risk and uncertainty in the portfolio is now accounted for while addressing the question of what

and probability that a portfolio will deliver the desired results, combined with a single, deterministic view of the associated development costs. By using the Case Map approach, exploration risk and uncertainty is captured and accounted for, estimates of effort and expenditure required to close gas supply gaps are better expressed, and ultimately decision makers are better informed.

CONCLUSIONS

This case study documents a framework to help decision makers manage exploration and development risk and uncertainty in backfill gas projects. Numerous combinations of exploration success and failure can satisfy our premise of closing the gas supply gap, with an 80% probability of this condition being met for this portfolio and supply gap combination. This will require an exploration effort of between 4 and 8 wells to achieve (not including appraisal), with the range of corresponding development costs (UDC0) also articulated. This result deviates from the conclusions drawn from a simple portfolio view which would suggest drilling of 4 prospects would deliver the required volumes on a risked basis, and would yield only a single, deterministic UDC0.

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