Optimizing Appraisal Strategies for Tidal Clastic Reservoirs*

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Abstract

Tidal sandstones have proven to be good reservoirs in several fields. However, subsurface uncertainties associated with their heterogeneity, specifically reservoir distribution, extent, and properties make them challenging development targets. This study assesses different appraisal strategies to reduce the reservoir uncertainties in the tidally influenced oil-bearing Upper Bahariya sandstones in a field in the Abu Gharadig Basin in the Western Desert, Egypt. The clastic reservoir-units within the shallower Abu Roash Formation are well developed with most of the wells in the field targeting these sands. Four crestal wells that penetrate the Upper Bahariya reservoir produced gas from the deeper Kharita reservoir. While the Upper Bahariya can be imaged on 3D seismic data, the individual reservoir-units are below seismic resolution. The limited data suggests low reservoir connectivity, however, analogues from fields in the Basin have shown that the Bahariya has reasonable production potential. This re-enforced the need for appraisal to ascertain the size of the prize to optimize field development strategies. Two appraisal approaches were analysed, local appraisal and field-wide appraisal. The local approach focuses the appraisal around existing wells to establish reservoir connectivity, while the field-wide approach addresses uncertainties in structure and oil-water contact. An appraisal campaign that combines the two approaches was proposed to accelerate development and maximize recovery.

Subsurface uncertainties were identified, and different geological realizations were conceptualized. A well-test conducted in good reservoir quality sands indicated limited connected volumes around the producer alluding to uncertainties in reservoir distribution and connectivity. Hydrocarbon column height and saturation were also found to be the top uncertainties as the crestal wells did not log the oil-water contact nor did they penetrate the saturation transition zone. Sand distribution realizations were based on facies interpretation from well-log signatures from the field and core from regional analogues. These realizations were then used to estimate a range of in-place volumes, production potential, and sand predictability. Primary and secondary reservoir-unit appraisal targets were established based on these parameters. Appraisal well locations were selected to address different local and field-wide uncertainties and were ranked based on their appraisal value. The

downside of encountering water-wet sands or shales and the inability to convert the appraisal well into a development well was considered as a risk that also influenced the ranking of well locations.

The local appraisal approach tests the geological realizations to explain the limited reservoir connectivity around the producer by testing for structural or stratigraphic compartments. The field-wide appraisal approach addresses the uncertainty in column height by appraising the unpenetrated flanks. It also addresses the uncertainty in the overall facies depositional trends by appraising different directions based on the conceptual geological models. Although the local appraisal approach carries lower risk than the field-wide appraisal, it has a lower appraisal value. This is because local appraisal fails to address the column height uncertainty or test the upside opportunity of encountering unpenetrated tidal-channel sands. The best technical solution was found to be an appraisal campaign that combined the two approaches. The proposed appraisal strategies present decision-makers with viable options along with the knowledge of the potential up-sides and risks associated with each approach, thus enabling the acceleration of development decisions.

Discussion

Tidal sandstones have proven to be good reservoirs in several fields. However, subsurface uncertainties associated with their heterogeneity, specifically reservoir architecture and properties make them challenging development targets. The tidal clastic Cenomanian Bahariya Formation was deposited in the Abu Gharadig Basin in the Western Desert, Egypt. Although, Bahariya has proven production potential elsewhere in the basin, it was produced for only a few months in this field. Most of the production from the field is from the reservoirs in the shallower Abu Roash Formation, leaving the Bahariya Formation under-appraised. The potential of the Bahariya reservoir was assessed in order to maximize the recovery from this field. The size-of-the-prize and recovery technique are likely to be the primary controls for optimizing the field development plan. Developing this reservoir could potentially extend the oil production plateau of the field and augment the value of the concession before the end of license. Limited available data from this reservoir made appraisal planning the first step in narrowing uncertainty to accelerate development.

The Bahariya Formation in the field is divided into the Lower Bahariya gas-bearing reservoir and the Upper Bahariya oil-bearing reservoir by an Intra-Bahariya tight limestone bed. The structure is a threeway dip closure, bound to the south-west by a normal fault (Figure 1). The serrated log character seen in the four crestal wells that penetrate the Upper Bahariya reservoir, indicate that heteroliths dominate. High heterogeneity is inferred from the differences in log character seen at two adjacent wells separated by only 200m. The un-appraised northwestern flank and no logged oil-water-contact make hydrocarbon column height a large uncertainty. Well-3 produced from clean good quality sands in the Upper Bahariya for eight months before it was commingled with the reservoirs in the Abu Roash Formation. Pressure analysis suggested that the connected volumes were small, implying that reservoir distribution and connectivity are uncertainties. The available 3D seismic data provides limited information about the distribution and extent of these thin sands. An appraisal plan was designed to reduce the uncertainty around oil-column height, reservoir distribution, and connectivity.

To facilitate appraisal planning, the 80-100m thick Upper Bahariya reservoir was sub-divided into units based on correlatable shales. This enabled prediction of sand-bearing good reservoir quality intervals, as variations in tidal depositional settings could be identified from well logs signatures, with the help of regional analogues. Three to four reservoir facies have been identified in the Bahariya from regional well logs and core. Tidal channels and bar facies form the main oil-bearing intervals, while silty tidal flats and lagoonal deposits show some evidence of oil charging.

Having proven production potential, the UB1a unit was the primary target for appraisal, while the other units with good reservoir quality in the field or nearby fields, were considered as a potential up-side. Different geological realizations were considered to capture the range of uncertainty in reservoir facies distribution. The reservoir facies that was produced in UB1a was assumed to be tidal bar facies with limited lateral extent in the low case realization, and tidal channel facies with possible sub-seismic faults limiting connectivity in the high case.

Two appraisal strategies were analyzed: (1) field-wide or “leap” and (2) local appraisal or “step” (Figure 2). The *leap* appraisal would have a larger step-out from existing wells to appraise the contact and the northwestern flank. The *step* appraisal would focus on improving the understanding of reservoir connectivity around the producer. In both the strategies, drilling was assumed to be sequential, wherein the results of each well could be analyzed and would dictate the location of the subsequent well. As a result, the location of the first appraisal well would be crucial. The criteria for selecting the location of the *step* appraisal well was that the well should establish connectivity with the producer, while in the case of *leap* appraisal, the well had to appraise the contact and the undrilled northwestern area. In the case of *leap* appraisal, if a well would yield positive results, i.e. if oil-bearing sands or heteroliths were encountered, then the next well would either be location further down-dip or towards the north-west. On the other hand, if the well would yield negative results, i.e. if the well encountered water-bearing sands or shales, then the next well would be up-dip or towards existing penetrations. In the case of *step* appraisal, if the first well met its objective of encountering depleted reservoir, then the next wells would be further towards the north-west. However, if the first appraisal well would encounter un-depleted reservoir, then other depositional trends would be tested by the subsequent wells.

While each approach has its advantages, at least one of the major uncertainties that would influence development decisions would not be addressed. In the *step* appraisal approach, the large uncertainty in contacts would not be addressed. Most of the north-west flank would remain unpenetrated. Thus, the uncertainty in the size-of-the-prize would persist. In the case of *leap* appraisal, although the uncertainty in in-place volumes could be narrowed, the uncertainty in reservoir heterogeneity, which influences the choice of recovery techniques, would remain. To circumvent this problem, an appraisal campaign through batch drilling of a minimum of three wells was proposed as the best technical solution (Figure 3). In contrast to the previous strategies, the wells would be drilled in immediate succession without incorporating the results of each well into the appraisal plan before drilling the next one. As a hybrid of the *step* and *leap* strategies, the uncertainties in in-place volumes and reservoir connectivity could be addressed.

Although the batch drilling appraisal campaign may be the best technical solution in this case, economic factors like the oil price, contractual commitments etc., could make the other strategies more lucrative. By providing the decision makers with different options along with the potential benefits and risks, technical teams can provide an effective grounding for accelerating development decisions.

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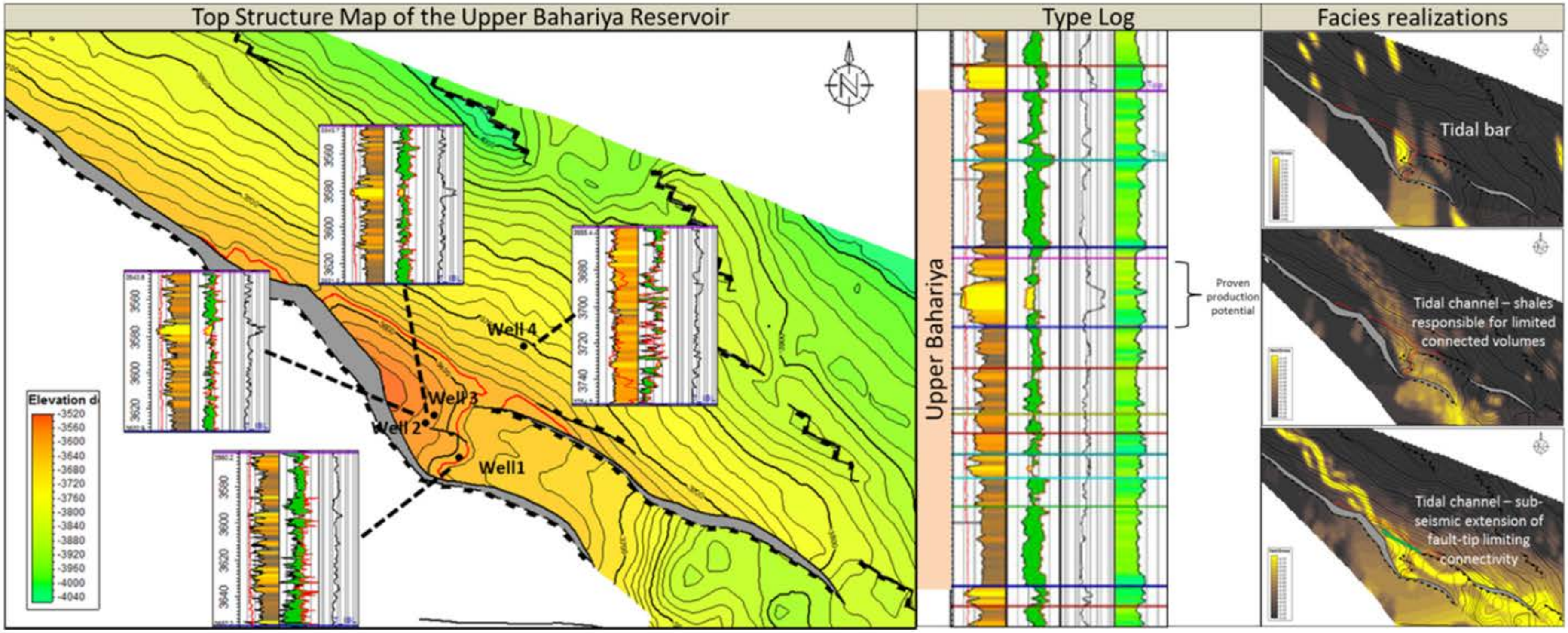

Figure 1. Well logs from the four wells suggest a high degree of heterogeneity. Different geological realizations were considered to capture the range.

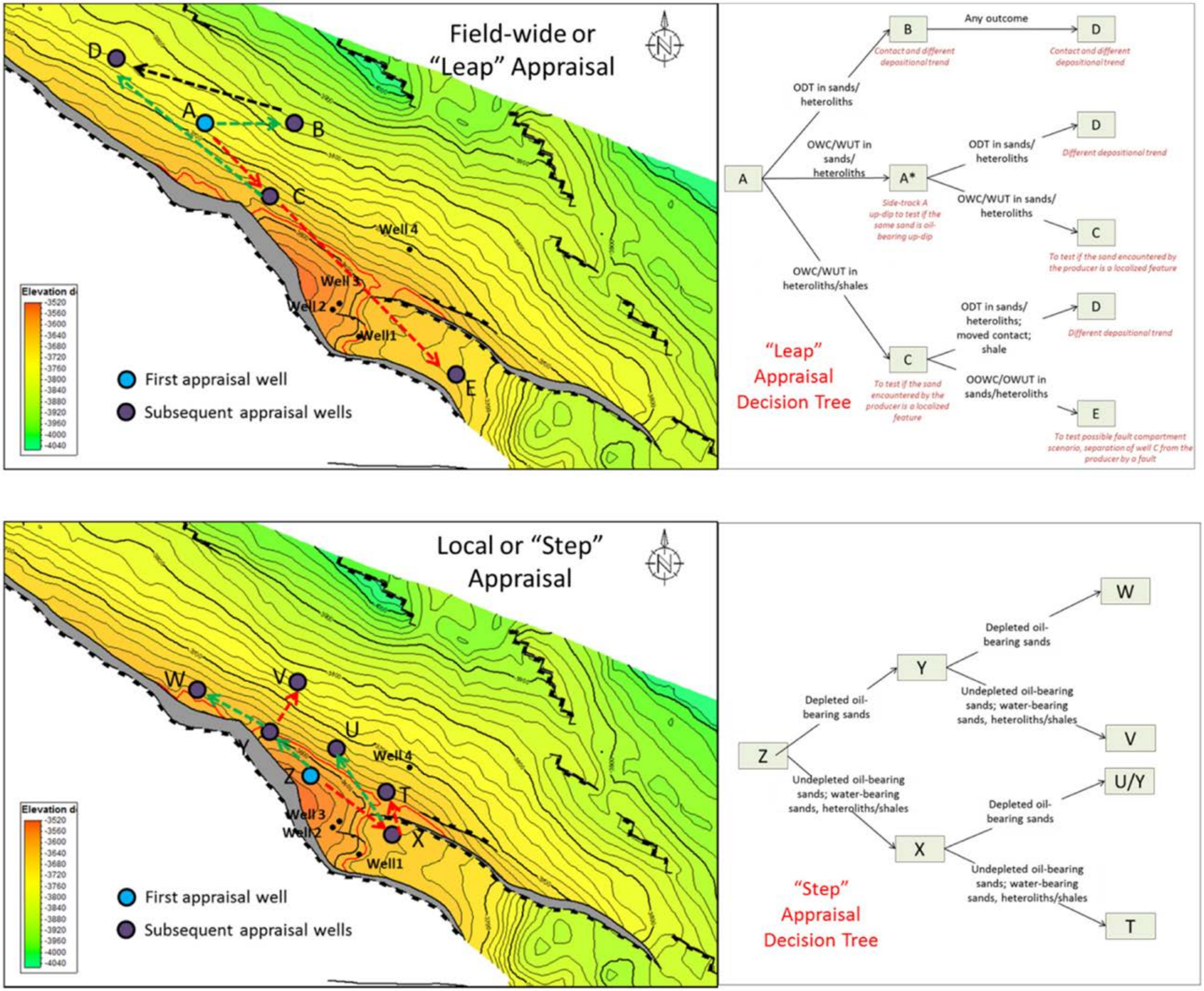

Figure 2. Field-wide appraisal and local appraisal plans for the Upper Bahariya reservoir.

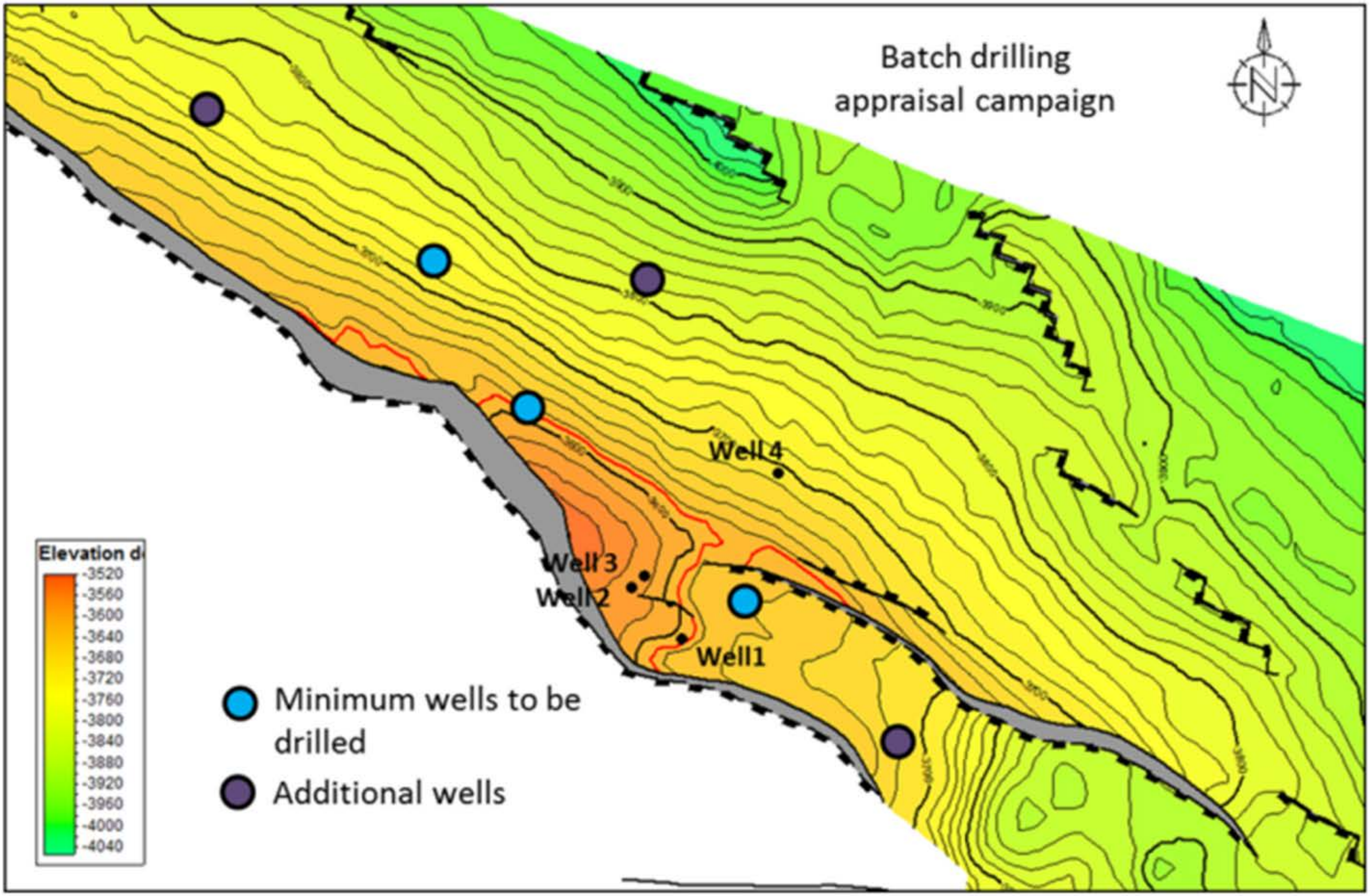

Figure 3. Batch drilling appraisal campaign for the Upper Bahariya reservoir.