Unconventional Reserves Task Force

Final Report - 1st March 2016

A — Orientation

This report was created by the "Unconventional Reserves Taskforce", a multi-society initiative of SPE, SPEE, AAPG, SEG, SPWLA and WPC. It follows a multi-society summit which took place in the Woodlands, Texas, USA on 18-19 August 2015. This summit was organized by the Unconventional Reserves Taskforce and facilitated by SPE.

The statements contained in this report were formulated by members of the taskforce. During review, the taskforce members did not always agree unanimously on each individual item, but the statements were submitted "as stated" to the vote of the summit participants. Therefore, opinions expressed in this document do not necessarily represent the position of any of the participating societies; however, they represent the majority opinion of the summit attendees. Voting results are detailed for each statement.

The goal of the taskforce was to be more assertive and to submit recommendations aimed at advancing the process of establishing industry-accepted workflows. As such, this document contains more than just the content and context of the discussions and break-out sessions which took place during the Summit.

The Summit consisted of presentations and discussions among the 85 attendees, most of whom are subject matter experts (SME) in their various disciplines. The Summit was a "technically dense" event, and it would have been impossible to allocate the time necessary to state any formal conclusion(s). Even if such time was available, it would have been impossible to achieve unanimity among such a large and diverse audience.

Therefore, after the summit, the following process was established:

- Discussion and breakout session elements were integrated into this document in a manner similar to and consistent with SPE workshops and forums.
- The taskforce formulated several recommendations that required consensus among the taskforce members. Some recommendations were the result of summit breakout sessions. Other recommendations were formulated based on occasionally disparate elements gathered during the different discussions.
- These recommendations were presented to the summit participants using an online survey. Participants were asked to approve or disapprove the recommendations on a case-by-case basis. The results are presented as a set of pie charts following each corresponding recommendation, distributed among the different discipline groups.

B — History of the Taskforce

The original concept for this summit was proposed in January 2013 and its purpose was to attempt to bridge the perceived gap between physical reservoir models and the methods used to calculate the different reserves.

A draft for a project proposal was informally sent to SPEE, AAPG, SEG and WPC. It received unanimous positive feedback. In August 2013, a multi-society exploratory committee was created. Because an SPE-organized summit involving multi-societies carried a number of contractual, organizational and copyright issues, it was decided to use a multi-society taskforce to better organize the event. The proposal for this multi-society taskforce was submitted by the SPE Reservoir Description and Dynamics (RDD) Technical Director and the SPE Oil and Gas Reserves Committee (OGRC) chair.

The multi-society taskforce was approved by the SPE Board of Directors in March 2014. The Unconventional Reserves Taskforce was created in September 2014 based on the recommendations of the exploratory committee. At this point, invitations were extended to SPWLA and ASC society members to serve on the Taskforce. For reference, the AAPG, SEG, SPE, and WPC members were taken from the original multi-society exploratory committee.

The SPE multi-society Summit on Unconventional Plays — Reservoir Meets Reserves took place 17-18 August 2015. The taskforce is scheduled to be disbanded after submitting a final report to the contributing societies, but it may be extended if its leadership and contributing societies agree.

C — Multi-Society Summit on Unconventional Plays – Reservoir Meets Reserves

As noted above, the "Multi-Society Summit on Unconventional Plays — Reservoir Meets Reserves", was held 17–18 August 2015 in The Woodlands, Texas, USA, with 85 "invitation-only" participants in attendance. The following professional societies participated:

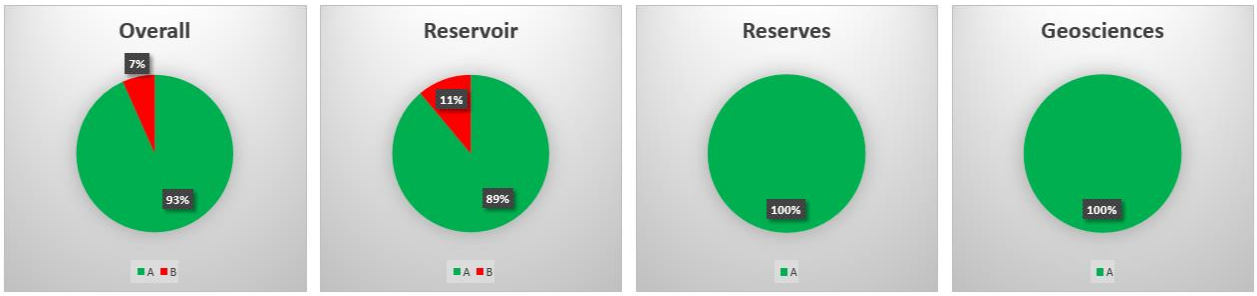
- American Association of Petroleum Geologists (AAPG),
- Society of Exploration Geophysicists (SEG),
- Society of Petroleum Evaluation Engineers (SPEE),
- Society of Petrophysicists and Well Log Analysts (SPWLA),
- World Petroleum Council (WPC), and
- Society of Petroleum Engineers (SPE), which also served as the "convener" of the Summit.

The summit utilized 6 technical sessions to introduce the issues and opportunities related to unconventional reserves from the perspectives of the geoscience, petrophysics, reserves evaluation, engineering, and regulatory communities, which led to the title of the summit, "Reservoir Meets Reserves." The summit also included an extended breakout and reporting session at the end of the meeting from which much of this executive summary is drawn.

Prior to the event, a dedicated website was created (www.unconventionalreserves.org) where participants could download the Summit pre-reads (Annexes 1, 2 and 3), contribute to the different surveys, and access survey results. It is worth noting that 83 of 85 participants registered on the Summit website.

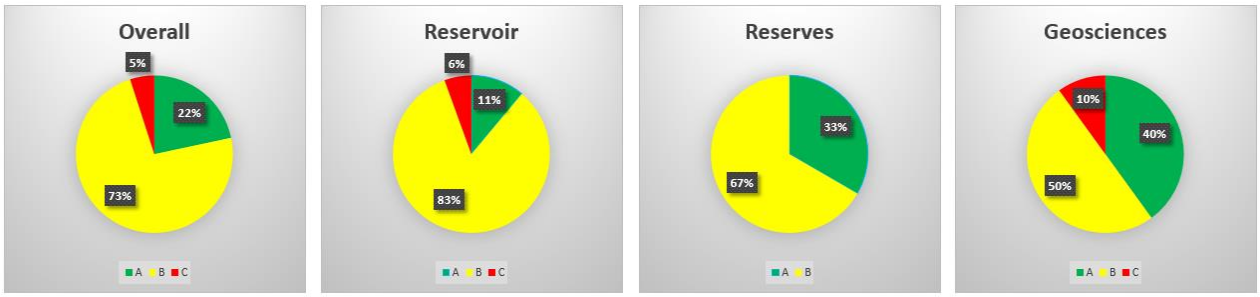
The first survey after the summit included a post mortem feedback and for each question in this survey we present the overall answer and a categorical split between Reservoir Engineers, Reserves Analysts, and Geoscientists (Geoscientists = Geologists, Geophysicists, or Petrophysicists).

To the question on the overall relevance of the summit, the overall answer was positive at 93%, with the only negative answers received from some reservoir engineers who we believe may not have been properly prepared for the format and substance of the summit (*i.e.*, we believe the negative votes came from those who did not utilize the pre-read materials nor review the structure/format of the summit prior to the summit).



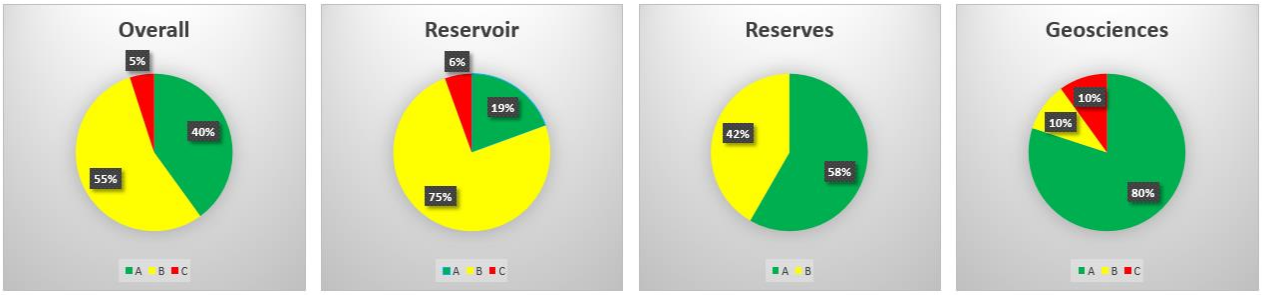
Was this Summit worth the two days you spent?
Green=Yes; Red=No

To the question on how much participants learnt on their own technical disciplines, 73% answered that it had essentially comforted them (*i.e.*, confirmed their prior beliefs), while 22% stated they had learned a lot. Answers were generally more positive amongst the Geoscientists and Reserves Analysts.



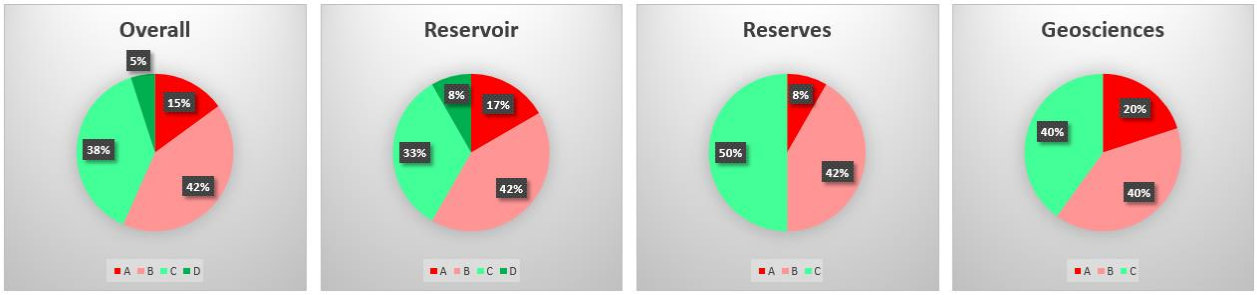
What did you learn in YOUR discipline?
Green=a lot; Yellow=comforted me; Red=not so useful

Regarding what was learned from other disciplines, a majority of Geoscientists and Reserves Analysts estimated that they learnt a lot, while still 75% of the Reservoir Engineers believed they had sufficient knowledge prior to the summit. Overall 40% of the attendees considered that they learnt a lot regarding what other disciplines do relative to unconventional reservoirs.



What did you learn in OTHER disciplines?
Green=a lot; Yellow=comforted me; Red=not so useful

One of the unique aspects of this Summit was that the fees had been waived by the contribution of sponsors. The underlying idea is that we wanted the best attendance we could and we did not want a 700 US$ fee to hinder potential key contributors who would not obtains funds approval from their company in the current economic context. 57% of the participants answered that they <u>might not</u> have come if the summit had not been free.



Would you have come if it was USD 700?
Green=Of course; Light green=Yes; Pink=Maybe not; Red=No

D — On the Value of Information

The following statement / recommendation was submitted to the attendees for a vote

On the Value of Information and Understanding Physics in Unconventional Reservoirs

The oil and gas industry initially regarded the production of unconventional resources as a "mining" (or "manufacturing") process, where only drilling and hydraulic fracturing efficiency/effectiveness were the major factors (i.e., the well construction/well completion processes were the critical components for unconventional reservoir development). In this view the reservoir is merely seen as a "volume of rock" that will deliver hydrocarbon production based on the well completion and stimulation, with a bit of influence from Geology and phase behaviour.

In fact, Reservoir Engineering became a minor component of unconventional reservoir development, and little time and resources were allocated to the understanding of the production mechanism as part of a standard workflow. The concept of the "mining" model has passed, but now it seems that most companies want to simply jump to the "sweet spot" in a given play based on a combination of geology, reservoir properties, and the effectiveness in well stimulation.

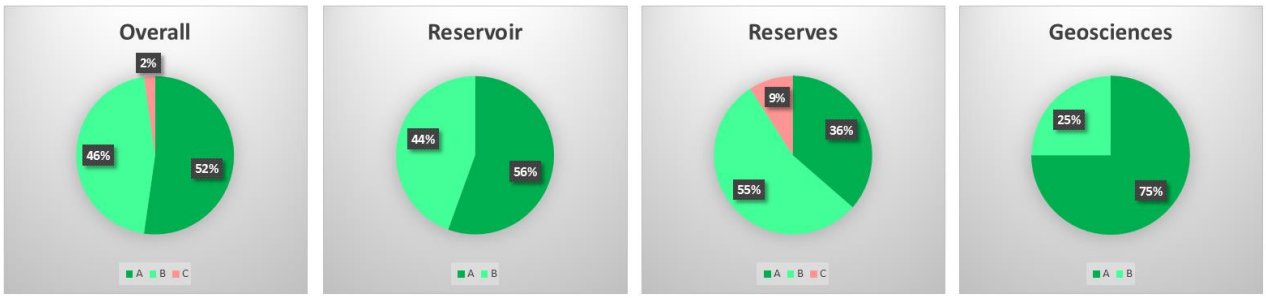
Given the current financial state of the industry, companies are reconfiguring cost structures and re-planning development strategies. Though it may look counter-intuitive it is about time for organizations to focus on the fundamental flow aspects in unconventional reservoir systems and to use advanced reservoir modelling to better understand reservoir performance. In short, the industry in North America (in particular) has relied on the drill bit and the frac-truck to optimize production from unconventional reservoirs, now is the time to focus on:

- *The fundamentals physics of fluid flow in unconventional reservoir systems*
- *The value of information derived from production, reservoir, geoscience and completion data*
- *The relevance of reservoir engineering tools for unconventional reservoir systems*
- *The significance of "reserves versus performance" for unconventional reservoir systems*

The statement above, as well as all the other highlighted statements in this document, was put to a vote. The possible answers were:

- Dark green = I would totally approve
- Light green = I would globally approve though I do not share everything written
- Light red = I would globally disapprove though I agree with some of the statements
- Dark red = I would totally disapprove
- Grey: No opinion / not in my area of expertise

On this first statement, 98% fully or globally agreed, with a slight majority fully agreeing that understanding the underlying physics is a critical aspect of unconventional reservoirs. There was no opposition at all from reservoir engineers and geoscientists, which we believe validates the need to ensure that, moving forward, we always consider the aspects of flow physics for unconventional reservoirs.

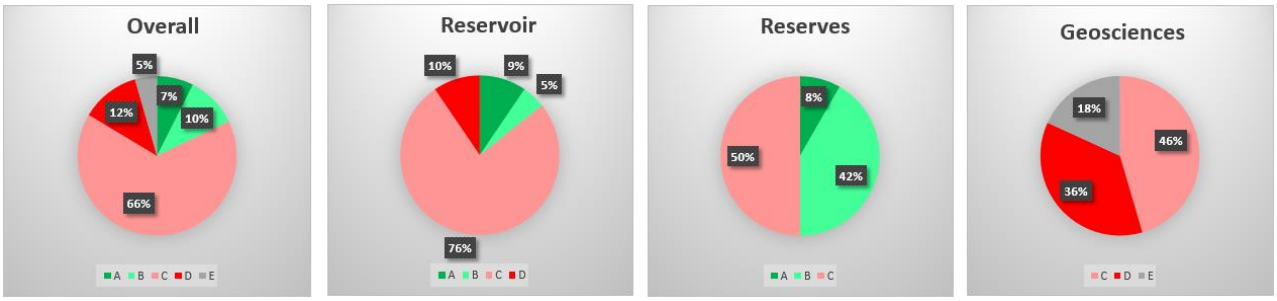


Statement vote on Value of Information and Understanding Physics in Unconventional Reservoirs
dark green = totally approve; light green = globally approve; light red = globally disapprove
dark red = totally disapprove; grey = no opinion or not in my area

E - On an Ongoing difference between Reservoir and Reserves on Decline Curve models

One of the key "misunderstandings" identified during the Summit was regarding the confidence in Decline Curve Analysis (DCA) to properly estimate Reserves. Before the Summit the question was asked to the participants on the relevance of DCA for calculation of Reserves in general, with no particular focus on the different categories of reserves.

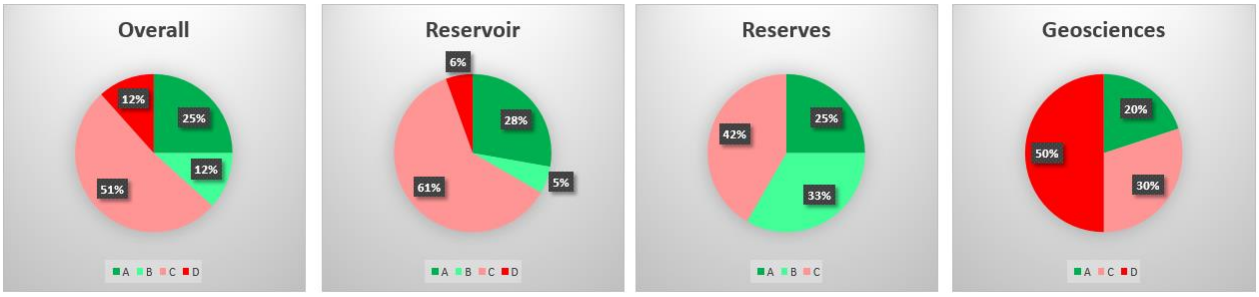
The results of this survey showed a strong difference between the positions between technical disciplines: 50% of reserves analysts would give universal approval to DCA, while 14% of Reservoir Engineers and 0% of Geoscientists would do the same.



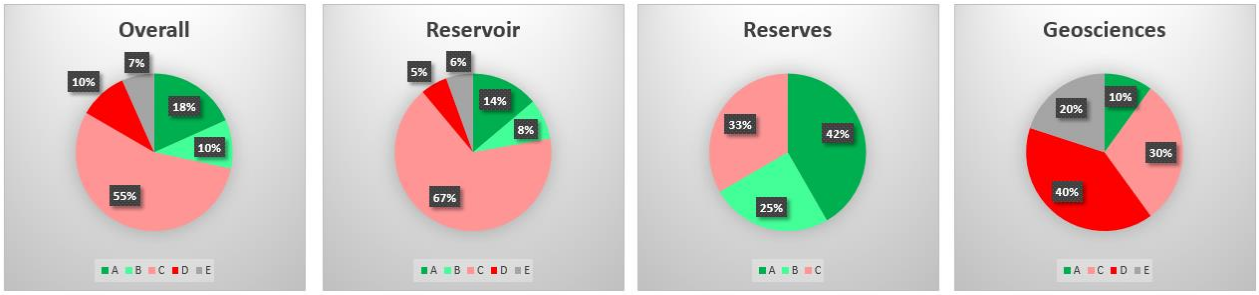
*What is your opinion on the use of decline curve models to calculate **reserves**?*
Dark green = totally sufficient
light green = currently insufficient but empirical knowledge will get us there
light red = methods have to evolve to become more physics based
dark red = methods must be replaced by physics based models
grey = no opinion or not in my area

The relevance of DCA for the calculation of reserves was the subject of animated discussions during the summit. One clarification from Reserves Analysts somewhat smoothed the positions — the reserves reported to the regulators in the USA and Australia are actually 1P (proved) reserves, while the reserves used for business decisions are the 2P (proved+probable) reserves, *for which physics based models are also used by most operators*. It was agreed that DCA methods used in a conservative way can indeed be realistic for proved reserves. It was also noted that the Canadian regulators also require reporting of 2P reserves.

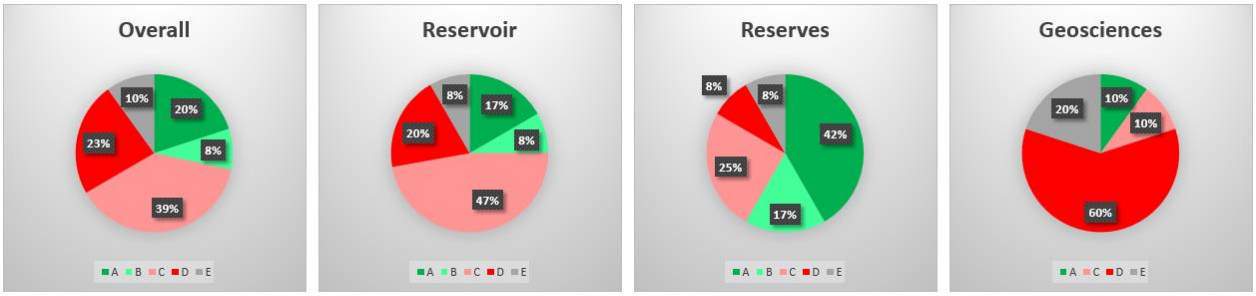
After the summit the taskforce decided to re-submit the same survey — but specific for 1P, 2P and 3P reserves. As one can see the statistical difference remains between the Reserves Analysts and the Reservoir Engineers and Geoscientists on the other side, but the difference of opinions has narrowed somewhat.



What is your opinion on the use of decline curve models
*to calculate **1P** (proved) reserves?*
Same possible answers as above



*What is your opinion on the use of decline curve models to calculate **2P** (proved+probable) reserves? Same possible answers as above*



*What is your opinion on the use of decline curve models to calculate **3P** (proved+probable+possible) reserves? Same possible answers as above*

F — On Decline Curve Analysis (DCA)

Break-out Discussion 1:

This discussion comprised 13 participants from several E&P operators, consulting firms and a software vendor, and these participants addressed the topic of "Time-Rate Analysis." The group considered how the topic of using time-rate analysis for reserve estimation and production forecasting in unconventional reservoirs had been received by the entire summit audience. In general, the break-out group members felt that the audience members with significant experience in reserves estimation were supportive of the time-rate analysis method as “fit-for-purpose” when used for proved reserve estimation either in regulatory disclosures or internal company evaluations only when good engineering judgment was used to constrain the forecast to properly conservative values (including decline rate limits, such as a terminal exponential decline rate). The group noted some audience concerns with the DCA methodology, but felt that these concerns came from members without a clear understanding of reserve definitions and practices. In hindsight, audience members with no reserves experience could have benefitted from presentations clarifying both reserve definitions and practices to provide a broader perspective on what “Reservoir Meets Reserves” means.

The discussion group concluded that it is important that the E&P operating companies and reserves consulting firms represented all commonly used time-rate analysis (with limits as noted) for reserves disclosures. This is because it represents an industry view on “generally accepted reserves evaluation practices”, a concept similar to the accounting profession's use of generally accepted accounting principles (GAAP). While there is no formal equivalent of GAAP for reserves analysts, the comments from this break-out include a wide distribution of industry experts representing larger and smaller operators, consulting firms, and academia concluding that this approach has been shown to work for proved reserves, as well as other categories when properly applied.

The discussion group felt that time-rate analysis was the typical first step for reserves evaluation and is therefore the most commonly used methodology. DCA offers advantages of being very fast and is available in many commercial software packages. The group also felt that when properly used, this method is accepted by both company management and industry regulators. The method is often combined with analysis of the flow regime for the well being evaluated in order to better understand how to develop an appropriate forecast.

When addressing the question of what we don't understand, the group noted that how time-rate analyses should be used to incorporate/demonstrate uncertainty was still unclear. It was also unclear how this method could be used in potential future reservoir conditions where we currently have very limited experience (*i.e.*, vague flow regimes, changing flow conditions (like fracture closure), multi-phase flow after dropping below the bubble-point pressure, the impact of well interference from infill drilling, and/or late-life terminal decline rates).

The group considered issues for future focus to be how to handle uncertainty, and develop an understanding of what the terminal decline rate represents so it can be modified for different well completions or well spacing, and to forecast in the period between after linear flow and before boundary dominated flow. The general theme of developing a normalizing (or other modification) method to enable use of type-rate analysis learnings from one well situation to others was noted during feedback provided to the entire summit audience.

The discussion group identified that the "next steps" are improvements in tools and methods. Examples include tools to integrate all time-rate analysis methods with flow regime diagnostics, methods to aid the transition from type curves (type well forecasts) to an early life time-rate based forecast, and software methods to investigate a range of outcomes in support of an uncertainty analysis.

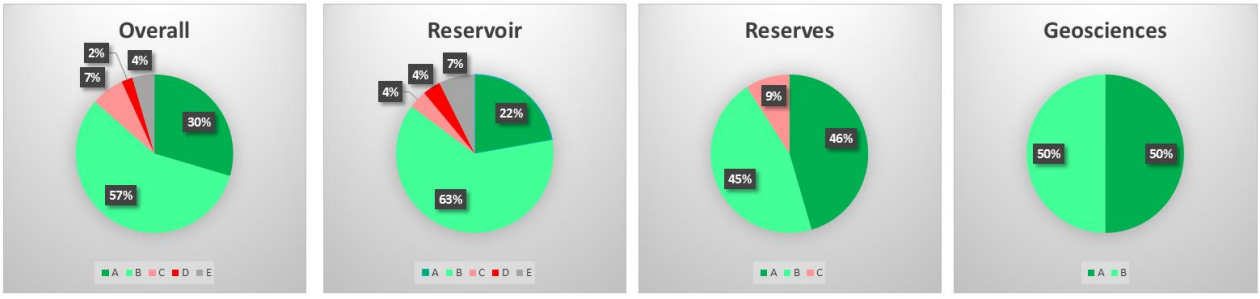
The following statement/recommendation was submitted to the attendees for a vote:

On the Need for Time-Rate Analysis for Unconventional Reservoirs

One of the major motivating factors for this summit was the need to move towards a consensus for the use of time-rate (decline curve) analysis for estimating reserves and making production forecasts for unconventional oil and gas reservoirs. This is not a trivial matter as in the last five years there has been a proliferation of time-rate relations proposed for the analysis and prediction of time-rate (production) data. Most of these relations are patently empirical, derived from observed behavior and/or proposed assumed behavior (for example, the case of an early hyperbolic trend due to linear flow ($b \approx 2$) combined with a later trend imposed at a specific decline rate — possibly an exponential, hyperbolic, or other hybrid relation).

The need to assess ultimate recovery and make relevant production forecasts is critical and warrants considerable focus, if not consensus. At present, the "modified Arps relation" (early hyperbolic/late exponential) is the "currency" of reserves analysts for unconventional reservoirs — this relation needs to be clearly documented and validated in terms of all of parameters (q_i, D_i, b, D_{limit}) and its associated functions ($D(t)$, $b(t)$, etc.) to ensure consistency in application and interpretation. The "recommendation" at this point is to propose a standard protocol that for any time-rate relation which is used for unconventional reservoirs, this relation must be validated in terms of its diagnostic behavior — that is, the $q(t)$, $D(t)$, $b(t)$ functions computed from data (and any other associated/defined functions) must conform to the $q(t)$, $D(t)$, $b(t)$ behavior derived from a given time-rate relation.

Results of the voting were as follows:



Statement vote on the Need for Time-Rate Analysis for Unconventional Reservoirs
dark green = totally approve; light green = globally approve; light red = globally disapprove
dark red = totally disapprove; grey = no opinion or not in my area

87% of participants globally approved the statement. Nine percent (9%) disapproved, including one reservoir engineer who totally disapproved; three (3) reservoir engineers did not consider themselves to be competent enough to vote/comment on time-rate analyses.

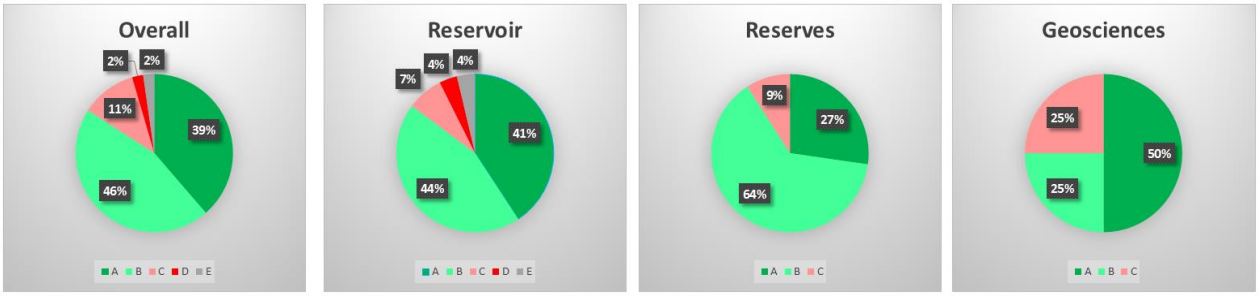
Another statement / recommendation was submitted to the attendees for a vote:

On Standard Practices Regarding Production Type Curves for Unconventional Reservoirs

Discussions at the Summit confirmed the perception that most (time-rate) production type curves (constructed from averaging) tend to be overly optimistic. The recommendations for the construction of (time-rate) production "type curves" are:

- *Grouping/well selections for type curves should be based on similar production profiles, not simple averaging.*
- *"Probability averaging" for type curve development can be used for exhaustive data sets (>30 wells).*
- *All type curves should have some type of statistical indicator to ensure consistency.*
- *Alternate methods for type curve construction should be considered (e.g., the "Fetkovich" reference curve match).*

Results of the voting were as follows:



Statement vote on Standard Practices Regarding Production Type Curves for Unconventional Reservoirs
dark green = totally approve; light green = globally approve; light red = globally disapprove
dark red = totally disapprove; grey = no opinion or not in my area

The overall majority (85% of participants) globally approved the statement, although less than 40% totally approved. The 13% disapproval was split over the different disciplines.

G — On Rate Transient Analysis (RTA)

Break-out Discussion 2:

The second break-out session addressed the topic of Rate Transient Analysis (RTA) and the application of RTA methods for reserves estimations. The participants of the break-out session were all knowledgeable on the subject of RTA, and almost all of the participants contributed to the discussion.

First and foremost, the group agreed that a proper definition for RTA would eliminate confusion on RTA's applicability. It was emphasized that RTA was a model-based analysis approach based on a relevant physical description of the system which could allow engineers/analysts to: integrate completion and subsurface parameters into our models; evaluate certain of their aspects and yield forecasts as functions of these parameters. Some group members pointed out that the models used for RTA could be complex and challenged the notion that RTA utilized only simplified models (which has led to the perception that RTA is a "simplified" approach). A basic statement was made that RTA is an analysis and interpretation procedure, which is heavily impacted by data quality — and that any model ranging from the most simple reservoir model to the most complex ones can be utilized. Statements on data acquisition such as high frequency measurements, permanent downhole gauges were made as a means of achieving higher confidence in results.

Most of the group members contributed to discussion stating the benefits of RTA in analysis and forecasting of production performance, including: well to well interference, multi-phase production analyses and forecasts, stress-dependent reservoir properties (to name a few). It was also mentioned that an understanding of issues required a thorough understanding of data behaviour throughout the production diagnostics process — in particular, for flow regime interpretation. On the other hand, limitations for the application of RTA include the requirement regarding the availability and quality of production data, and the influence of operational issues. Further, it was stated that significant uncertainty in RTA results could (and likely would) exist without the integration of other data sources (*i.e.*, from other disciplines). Participants elaborated on certain complexities regarding existing challenges in integrating geomechanics and the issue of complex drainage area patterns which affect forecasts using RTA.

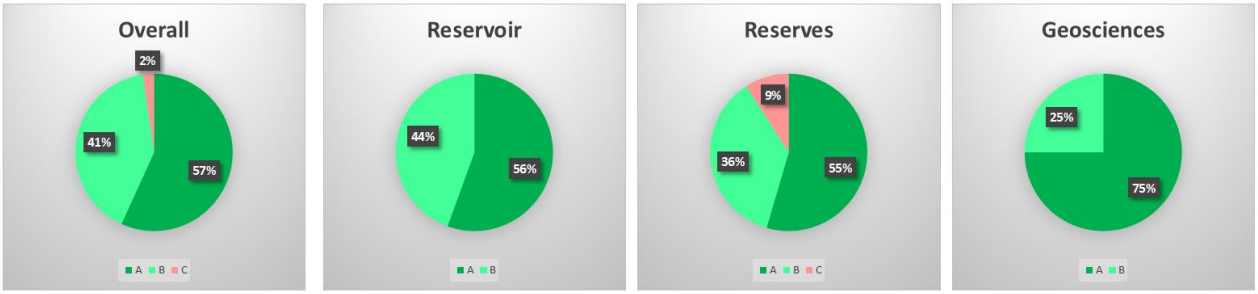
There was consensus within the group that RTA could be used to forecast reserves with proper constraints; however, the question still remains as to how to translate RTA results to 1P reserves and to correlate RTA results with decline curve analysis (DCA) parameters for use in economic software (recall that the software are all tied to the DCA (time-rate) forecast models). Furthermore it was all agreed that efficient workflows needed to be developed to efficiently apply RTA and forecast production for multiple wells simultaneously. In summary, the requirement that integration of data from other disciplines must be used to address uncertainty is critical and the importance of data quality, acquisition and frequency should not to be overlooked as non-uniqueness is a major issue for RTA work. There were also important comments on training and proper use of RTA. One member of the breakout group suggested that more work be performed using probabilistic methods to achieve forecast ranges.

The following statement/recommendation was submitted to the vote of the attendees:

On the Need for Pressure Measurements in Unconventional Reservoirs

In conventional formations Pressure Transient Analysis (PTA) and Rate Transient Analysis (RTA) are complementary disciplines using models which are identical, and methods which have much in common despite the fact that PTA focuses on "event analysis" and RTA focuses on "history analysis". For unconventional plays, PTA may provide useful insight in terms of stimulation efficiency and flow regimes. However PTA cannot provide a unique estimate of reservoir properties (in particular, reservoir permeability). In the case of RTA, we can use these methods to diagnose and analyze early and transitional reservoir performance, recall that for the most part, reservoir performance is governed by the so-called "stimulated reservoir volume" (or SRV). As a methodology, RTA has taken over the role of both disciplines (i.e., PTA and RTA) due to the slow transients which allow RTA methods to identify flow regimes which would typically be detected during build-ups in conventional plays. Because RTA has its historic roots in both empirical (time-rate) decline curve analysis and the extensions PTA methodologies for the simultaneous analysis of rate and pressure data, there can be confusion.

For a proper analysis it is critical to utilize BOTH production rate and pressure data in the RTA diagnostic and analysis methods. It is also critical to do so in the validation of data (i.e., the correlation of rate and pressure data). As a minimum requirement, we advocate the recording of accurate and relatively high frequency surface pressure data (e.g., at least 1 point day, preferably 1 point an hour or more frequent). It is also incumbent on the engineer to have a properly correlated wellbore model in order to estimate the bottomhole flowing pressures using the surface rates and pressures. In simple terms, without pressures it is impossible to discriminate reservoir effects and operational changes. Therefore, whether we are performing time-rate decline curve analyses or rigorous time-rate-pressure RTA (model-based) analyses, we must have a source of pressure data which robust and of high fidelity.



Statement vote on the Need for Pressure Measurements in Unconventional Reservoirs
dark green = totally approve; light green = globally approve; light red = globally disapprove
dark red = totally disapprove; grey = no opinion or not in my area

The vote was essentially unanimous regarding the need for pressure measurements for reserves analysis in unconventional reservoirs. Only one reserves analyst globally disapproved of this statement.

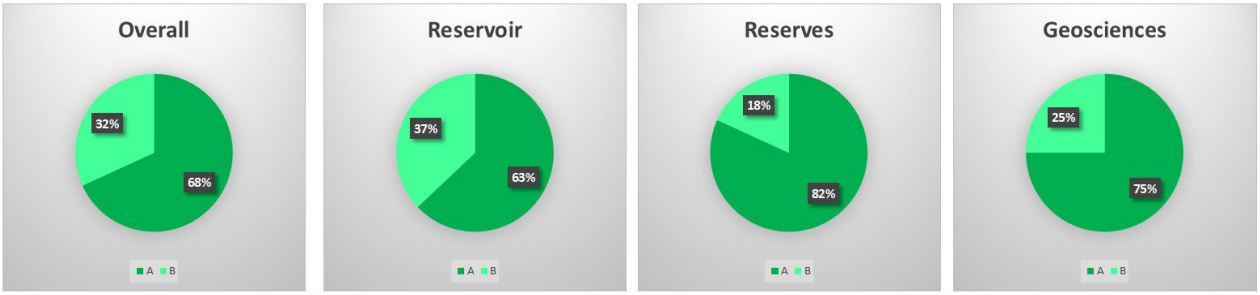
Another statement / recommendation was submitted to the vote of the attendees:

On the Need for Downhole Pressure Acquisition in Unconventional Reservoirs

The issue of "downhole" pressures always distils to "cost-benefit analysis" — everyone recognizes the need for pressure measurements (instead of calculations), but what is missing is that there is literally no substitute for downhole pressure measurements. As practice, "production" pressures are acquired at surface while analysis and modelling techniques require pressures at sandface conditions — hence the myriad of wellbore models used to convert surface to downhole (or sandface) pressures.

We acknowledge that the use of surface pressures corrected to sandface conditions is a reasonable, cost effective option — but we must also emphasize that since such "wellbore models" never perfectly defined in terms of the wellbore structure, the fluids in the wellbore, and energy balance relations used to derive a given wellbore model, computational methods may (and likely will) introduce errors that are difficult to assess. We also acknowledge that under the current financial conditions it is unrealistic to expect that each and every well should have a permanent downhole gauge (PDG). However, a practical alternative is to install a PDG in a certain number of wells to provide both reservoir surveillance and a source of hard data in which to correlate surface pressures to downhole pressures. As a final comment, those who have installed PDGs in unconventional plays have noted that these data provide unique insight into well-to-well communication in some cases, and that the downhole data always provide better production diagnostics than surface data.

Remarkably, ALL of the Summit participants approved the statement recommending the usage of permanent downhole gauges, with more than two-thirds totally approving this statement.



Statement vote on the Need for Downhole Pressure Acquisition in Unconventional Reservoirs
dark green = totally approve; light green = globally approve; light red = globally disapprove
dark red = totally disapprove; grey = no opinion or not in my area

A final statement/recommendation on RTA was submitted to the vote of the attendees:

On the Organization of a Forum on Rate Transient Analysis (RTA) for Unconventional Plays

From the discussions at the Summit, it is clear that Rate Transient Analysis (RTA) is the most appropriate analysis and interpretation methodology for production rate and pressure data from unconventional reservoirs. There are caveats, such as the perception of RTA as a mid-level modelling approach (between time-rate decline curve analysis at the low-end, and full reservoir simulation at the high-end), but RTA provides a unique depth and breadth of analysis and interpretation of production rate and pressure data. And when properly tuned to an appropriate reservoir model, RTA provides unique production forecasts and consistent estimates of EUR, all relative to a prescribed reservoir model.

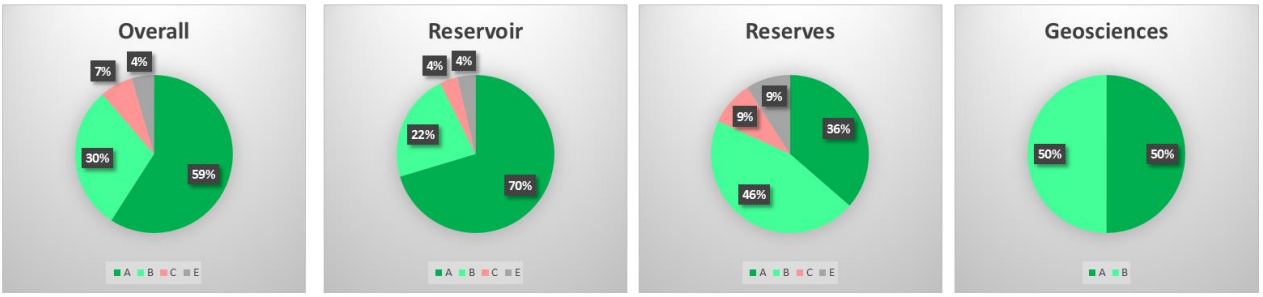
At a time when the industry is still relatively low on the learning curve for the understanding the well and reservoir performance of unconventional reservoirs (particularly in lesser developed plays), an increasing number of companies using pilots/ demonstration projects to enhance learning and improve both productivity and recovery. In addition, a given RTA workflow has a unique focus on estimating reservoir properties and reservoir volume, and as such, we can expect consistent diagnostic interpretations and results from RTA. As a specific proposal, the Summit attendees recommend that SPE initiate a Forum on the "Implementation of Rate Transient Analysis and Related Modelling for Unconventional Reservoirs."

The following conditions to participate in this Forum are proposed:

- *Participating operators must to commit on presenting sanitized data (i.e., no labels/scales). Conversely, operators not committed on presenting such data will NOT be allowed to participate*
- *Service companies may present/comment/discuss on emerging (but not existing) technology(s).*
- *Academic, research personnel, etc. may present/comment/discuss on research or application projects.*
- *The standard rule of "no-note taking" must be observed. (standard SPE Forum practice)*
- *A public summary statement WILL be generated in compliance with the confidentiality of the discussions*

The preference would be that this Forum be organized by SPE as a product of the current taskforce — however; if there is no consensus approval for such a Forum from SPE, another partner can be sought (e.g., AAPG, SEG, etc.).

Approximately 90 percent of the Summit participants globally approved the principle of a SPE Forum on the subject of Rate Transient Analysis (RTA) applied to unconventional reservoirs.



Statement vote on the Organization of a Forum on Rate Transient Analysis (RTA) for Unconventional Plays
dark green = totally approve; light green = globally approve; light red = globally disapprove
dark red = totally disapprove; grey = no opinion or not in my area

H — Modelling Diffusion in Unconventional Plays

Break-out Discussion 3:

This breakout focused on the application of reservoir models for unconventional evaluations. The Forum helped to validate known issues; however, no new material technical insights evolved from the discussions. Integration of data from different sources and disciplines is a challenge. The need to improve model physics was highlighted and important for leading to wider acceptance of numerical modelling.

Water production issues that are important for specific play development are not well understood. Other areas where deeper understanding needs to develop are in the area of describing hydraulic fractures, characterization of natural fractures and the basic mechanisms of storage and transport.

The breakout group recommended that key future focus areas include 1). Evaluation of quantitative impact vs. complexity; 2). Deeper scrutiny of model inputs such as matrix and fracture properties and the collection of all relevant data inputs 3). Practical consideration as to development planning and appraisal needs in areas such as well spacing, target zones, and fracture design and stage requirements. Best practices need to be developed for model application.

Suggested next steps are to incorporate improved physics in models with appropriate sensitivity studies. There is a dire need to educate all involved with unconventionals about the value and limitations of model-based approaches. Integration of both static and dynamic data are important. Finally, cycle times need to be improved and be tied to key decision making and project recommendation timing.

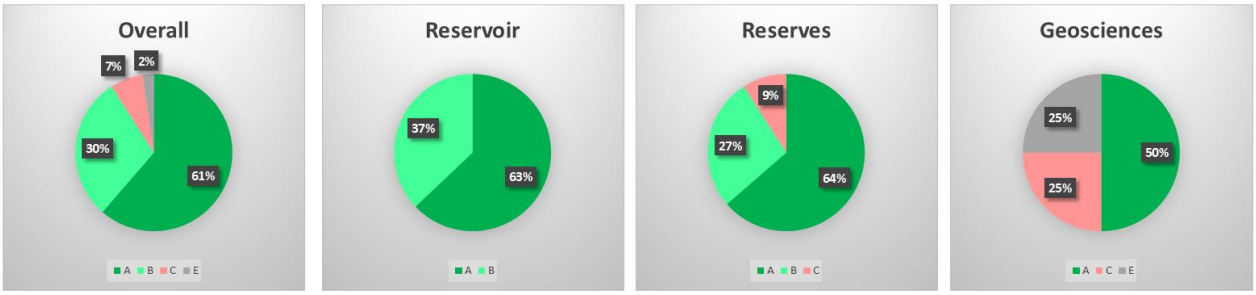
The following statement / recommendation was submitted to the vote of the attendees:

On the Use of Darcy Models Inherited from Conventional (High Permeability) Flow Concepts

During the Summit, a series of discussions lead to question the relevance of Darcy's law in unconventional plays. Studies at nanoscale and microscale have apparently little in common with the Darcy based diffusion equations used at macroscale. Uncertainties remain on the contribution of organic components on porosity, permeability and PVT properties. However we are not over with these nanoscale studies and their potential upscaling to macroscale. We cannot assume that the result will totally invalidate our current models. One encouraging clue is that the behavior observed on most of the wells (linear flow, SRV flow, etc.) are consistent with what Darcy based models predict.

Not taking anything for granted it is not unreasonable to believe that the eventual macroscale equations resulting from the nanoscale upscaling will integrate a strong Darcy component, in a way similar to what Forchheimer's equation gives us. In the meantime the most reasonable option for flow models is to continue using Darcy's law, keeping in mind that deviations may result from the reality of the flow at nanoscale level.

The concept of using Darcy's Law was globally approved by more than 90 percent of the respondents (including all reservoir engineers). Disapproval came from a minority of geoscientists and reserves analysts.



Statement vote on the Use of Darcy Models Inherited from Conventional (High Permeability) Flow Concepts
dark green = totally approve; light green = globally approve; light red = globally disapprove
dark red = totally disapprove; grey = no opinion or not in my area

Break-out Discussion 5:

The Fifth Breakout Session was titled “Models Won’t Solve Our Problems” and focused on four key questions regarding models and alternatives to modelling: 1) What have we learned?, 2) What don’t we understand?, 3) What questions and issues should we focus on?, and 4) What are the next steps?.

In terms of “What have we learned?”, it’s clear that a simple technique such as decline curve analysis requires an order-of-magnitude less time to conduct than rate transient analysis, which requires an order-of-magnitude less time to conduct than numerical modelling. So what justifies using these more time-consuming techniques? They are useful for understanding reservoir mechanisms, testing “what if” scenarios, and quantifying uncertainty, but are not very accurate in a predictive sense and are not very useful for reducing uncertainty. Alternatives to modelling include the use of “close-ology”, commercial and non-commercial analogs, exploratory data analysis, and demonstration projects (if you can’t model it, measure it!). These can all be used to calibrate and constrain the modelling effort, which will also be influenced by management mandates, investor impressions, and whether a company is buying or selling an asset.

Regarding “What don’t we understand?”, these issues include phase behaviour, pore connectivity, visco-plasticity, and characteristics of the natural fracture system. We also don’t have a good understanding of how key reservoir properties change spatially and through time. There is also much to learn about the interaction between natural fractures, hydraulic fractures, and the matrix, including the transfer of fluids between these and how productivity is affected by changes in subsurface stress with time. The bottom line is that we have little idea of “what’s flowing where” and this lack of understanding may not change very much in the next five years.

With respect to “What questions and issues should we focus on?”, perhaps the most important is the appropriate use of empirical methods since these are the primary means by which type curves are built and forecasts are made. These methods need to be calibrated to well performance (especially pilot wells in new areas) by building production/completion relationships and focusing on those parameters that have the greatest impact on success. Analogous wells, especially those nearby in the same reservoir trend, are an important component to incorporate in this analysis. We should also continue our efforts to build representative analytical and numerical models to provide insights and direction, but we need to keep in mind their weaknesses and limitations.

Finally, the question of “What are the next steps?”, can be divided into three topics: data gathering, modelling, and processes. Data gathering should be focused on resolving the key questions that really matter, and will require more novel and intense data collection from fracture stimulated wells to better quantify performance. This, in turn, will require more data consortia and data sharing given the current low cost environment. Modelling should be focused on helping us understand and quantify uncertainty. The results should lead us to try different approaches in the field which will provide feedback for revising the models. Throughout this process, modelling should be kept within the proper context and expectations from modelling should be realistic. In terms of the processes we’re using in our work, it’s critical to assemble the best people, create an integrated (unified) approach, and provide appropriate incentives.

I — On Data Analytics

Break-out Discussion 4:

This discussion was led by a proponent of data-driven models and consisted of participants expressing interest in such. All participants agreed that these technologies cannot/should not be overlooked. The question was more about assessing what these technologies could bring — and when. Opinions around the table ranged from a long-term interest to the belief that deliverables are here now (*i.e.*, there are tools capable of providing competent results). There were also comments that, as with any 'hot topic', these technologies are now at risk of being oversold. The basis of data-driven models (and data analytics in general), is that in the mass of available data, there is quantifiable information that does not require a formal model to be used to assess/extract this information. Further, that techniques exist now to extract this information, identify trends, and correlations — and specifically tools/techniques which provide assessments which do not require the intermediate step of understanding the physics.

In the context of this summit, the focus was about the potential use of these techniques to help in the assessment of reserves as an alternative to decline curves and rate transient analysis. In considering data-driven analytics as an alternative of DCA and RTA, the question arises as to the ability for such a system to calculate reserves using current well production and be able to forecast a production that will yield EUR. Some reservoir engineers in attendance warned that a systematic pre-processing of the data would be required to increase the chance of delivering relevant trends. As stated in one general session, using rates without pressures amounts to one equation and two unknowns. This cannot be solved, whatever the technique — and data analytics would be no exception.

In the particular case of using data analytics as an alternative to RTA, systematic pre-processing, such as pressure normalization or even deconvolution, could be used without any human intervention to obtain a set of data from which more meaningful information could be extracted. However, the discussions stressed that the absence or insufficiency of data remains a major issue with unconventional plays and it should be noted that the discussion was not limited to production forecasts and EUR. Other potential contributions of data analytics were also discussed, such as qualitative cross-correlations and assessments.

The next step proposed is to initiate a pilot study that would allow us to assess the potential of these techniques in a more impartial manner. This would include the determination of the data that are needed and a double-blind system where two teams would address the data differently — one with traditional DCA and RTA, the other using data analytics. Another possibility would be to use only the early portion of the production data and assess how each technique was able to forecast the later portion of the production data.

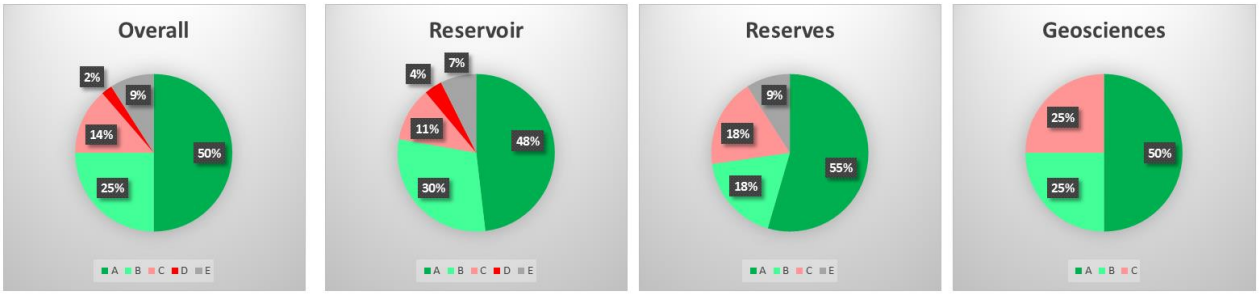
The following statement / recommendation was submitted to the vote of the attendees:

On a Pilot Test on Data Analytics for Forecasting EUR in Unconventional Reservoirs

The present popularity of "data analytics" technologies (cluster analysis, neural networks, parametric and non-parametric optimization, etc.) for potential use in forecasting production and EUR for unconventional resources warrants attention.

We recommend that a multi-Society initiative to compare/contrast "data analytics" on a field sample — analogous to the "Comparative Solution Projects" initiative for reservoir simulation conducted in the 1980s and 1990s. The goal of this proposal is to establish recommended practices for forecasting EUR and production forecasts for unconventional reservoirs using "data analytics" techniques — as with the studies on reservoir simulation, to ensure that the most appropriate tool(s) are being applied to the given problem, in our case the correlation and prediction of EUR and production forecasts for unconventional reservoirs.

In terms of our survey, the principle of a pilot test on data analytics was totally approved by half of the respondents and globally approved by approximately three-quarters of the participants.



Statement vote on a Pilot Test on Data Analytics for Forecasting EUR in Unconventional Reservoirs
dark green = totally approve; light green = globally approve; light red = globally disapprove
dark red = totally disapprove; grey = no opinion or not in my area

J — On Operational Considerations

Break-out Discussion 6:

This discussion included 13 participants from several E&P operators and consulting firms and these participants were tasked to address the topic of "Operational Considerations". The group considered how the Operating Companies might enhance our understanding of an Unconventional Reservoir through planning and implementation of a comprehensive testing and data acquisition program. In general, the break-out group members felt that the earlier in the initial drilling and completion phase we begin this process the better we will begin to understand what we do not understand and begin to adjust our acquisition efforts accordingly

The discussion group concluded that the most important data investment that E&P operating companies could make was for quality high frequency production data, both rates and pressures. Particular attention should be paid to volume allocations and pressures should be recorded hourly for 3 months and daily thereafter. Data is key to the initial determinations of well and completion performance leading to first estimates of recovery and well density (spacing).

The discussion group felt that an integral part of an early data acquisition program should include vertical pilot wells designed to acquire whole core data and a detailed suite of logs including fracture identification data. We know that these data can vary significantly over the depositional area of these resources. Therefore several of these pilot wells should be included across the acreage to provide areal perspective to the resulting data and make the data acquired statistically meaningful. Also, the same enhanced data set should be acquired in all pilot wells. Once data acquisition was completed these vertical wells could be converted to horizontal laterals. At that time consideration should be given to the acquisition of log data along the lateral to enhance knowledge of fracture distribution.

When discussing the question of what we don't understand the group noted that the well spacing, or the distance between lateral wells was perhaps the most impactful development planning variable that we face. Drilling too many expensive horizontal wells in an area can render the development inefficient both from a resource recovery point of view and yield poor economic performance. Early in the evaluation program a plan to drill Pattern Pilot horizontal wells should to undertaken, perhaps at different well spacing, to test well performance and the effects of hydraulic fracture interference.

Below are listed some additional issues which should be given serious consideration during operations planning for any unconventional resource development.

1. Well Design
2. Drilling – Where to drill and at what orientation
3. Completion – Fracture Design
4. Stress Field Orientation
5. How many Stages and Spacing
6. Operations

a. Artificial Lift
b. Drawdown Management
c. Maximize Recovery

7. Prioritize Data Acquisition

K – The Regulator's Point of View

Break-out Discussion 7:

The breakout group's major conclusion observed from the engagements with many of the Summit participants was that there was a general lack of familiarity with resource classification systems, such as the multi-society Petroleum Resources Management System (PRMS). The fundamental lack of knowledge in the resource classification was recognized in several areas for unconventionals but ultimately results in potential difficulties in efforts to comply with reporting regulatory compliant reserves and resources.

There was a limited understanding of the resource criteria to differentiate between a reserves and a resource. Such criteria are frequently applied to support quality business decisions which conveys both the uncertainty and confidence in a project are critical elements. These resource classification criteria elements applied were not well understood for internal project decisions which can then lead to improperly conveyed figures in external regulatory reporting. Also, it was observed that several participants perform separate evaluations for business decisions versus regulatory reporting which can be a concern if significant variance exists in the regulatory reported 2P, 2C and 2U figures. Overall, this lack of familiarity can cause difficulties with the linking of business decisions and smooth coordination of asset team efforts to comply with regulatory reporting requirements.

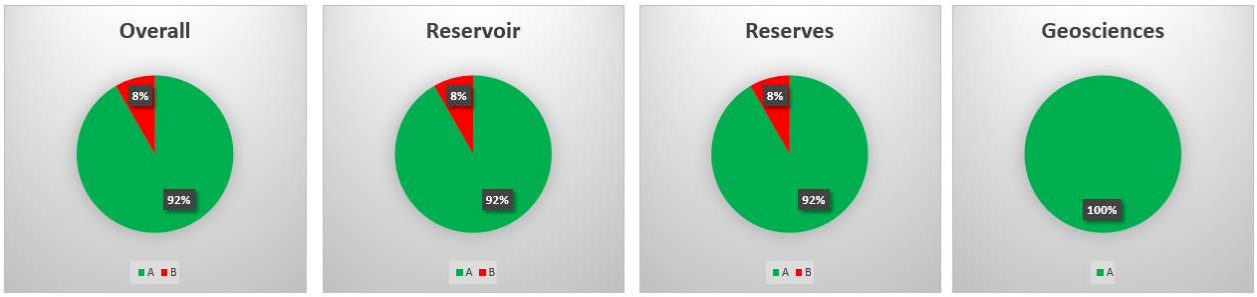
Additionally, the view was expressed that overbooking is still occurring in the industry due to the improper technical evaluation method(s) applied in unconventional evaluations. This concern was noted typically when the reserve evaluator does not understand the proper flow regimes or understand the concept behind the applied method which can lead to optimistic forecasting of 1P reserves.

Another example from many expert reservoir engineers and geoscientists participants is they appear to believe that the result of a best estimate production forecast is the appropriate economic Proved Reserves (1P) estimate to be reported to regulators. In fact, this "best estimate" production forecast is likely to lead to a Proved Plus Probable Reserves (2P) estimate, and, even then, will only qualify a portion as 2P reserves when certain additional technical and commercial criteria are satisfied. When these criteria are met, the resulting 2P estimate may provide the basis for the "business decision" case, but not the more conservative economic 1P case which is the focus of many companies that report to the SEC.

The confusion about the difference between 1P and 2P reserves illustrates the more general issue of lack of understanding of resource categorization of the production forecast outcome and how resource classification (and regulatory) systems deal with uncertainty in resource assessments. In summary, the breakout group concluded that there is a serious need for education of all technical specialists involved in resource assessment (e.g., reservoir engineers, geoscientists, modelers of all kinds, reserves analysts) and management who are ultimately responsible for the figures to ensure regulatory compliance with minimum acrimonious debate.

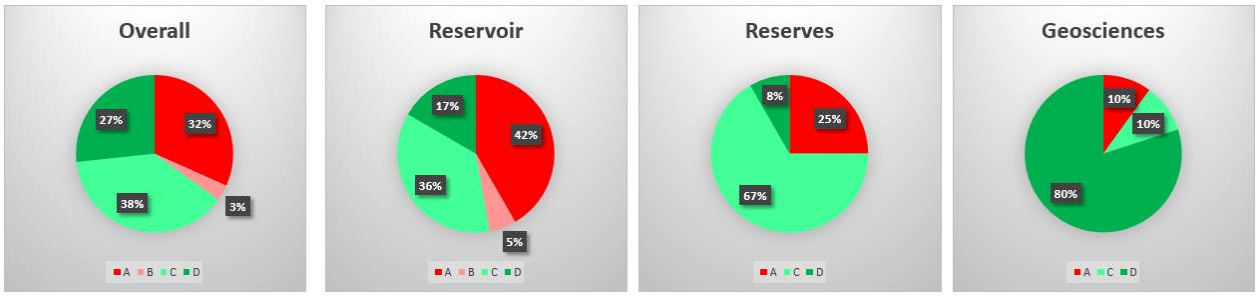
L – Recommended Path for Future Initiatives

In the post-meeting survey, participants were asked if they would attend a follow-up summit. A realistic date was set in the spring of 2017. 92% of the respondents answered that they would.



If we were considering a follow-up Summit in the spring of 2017. Would you attend if you could?
Green = Yes; Red = No

As for the perimeter, the question was asked whether the perimeter should be narrowed to reservoir engineering, kept the same, extended to include other disciplines such as completion and fracturing, or even made it wider beyond the scope of reserves. A very small minority (3%) recommended to keep it the same but then there was a split between those who would want to narrow it (32%) and those who would want to expand it (65%). So if expansion was the overall trend there was no unanimity here.



If we organized another Summit, what do you believe the perimeter should be?
Dark red = Narrowed down to Reservoir Engineering vs. Reserves
Light red = about the same focus as this summit
Light green = keep focus on reserves but extend topics to completion and hydraulic fracturing
Dark green = extend the range of discussion beyond reserves

It is the consensus opinion of the taskforce that this taskforce and summit were successful. We collectively submit *that this taskforce should be extended* — or another multi-society taskforce should be created to organize another summit in the spring of 2017. The experience gained from this first summit and this document should provide prudent guidance for future efforts (taskforces/summits/etc.).

As to the process, we specifically propose that the taskforce be continued or recreated (as appropriate) at the initiative of the SPE technical director for RD&D. A proposal for continuance will be submitted in January 2016 to the SPE F&S committee with closure of the taskforce on or before the 2017 ATCE.

M — Acknowledgements

This Summit could not have been a success without a concerted effort on the part of many contributors.

- We thank Anadarko Petroleum Corporation for hosting the event.
- We thank the Summit Underwriters for their generosity. Through their support, the registration fee was waived for this event.
- We thank SPE staff for their management of the summit logistics.
- Most importantly, we acknowledge — in advance — this assembly of the most experienced professionals in their fields for their contributions to the summit.

N — List of Annexes

1. Summit Pre-read #1: History and Purpose
2. Summit Pre-read #2: Taskforce Proposal
3. Summit Pre-read #3: The Reservoir Engineering Perspective
4. Survey #1 results: Pre-Summit
5. Survey #2 results: Post-Summit
6. Survey #3 results: Pre-Report

O – The Taskforce Members

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