2022
QUARTER 2

THE RYDER SCOTT QUARTERLY

Missing Values and Sparse Data

2022 Ryder Scott Reserves Conference

Zhang Presents SPE Paper at 2021 SPE-ATCE Conference

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Welcome Note

By: Dean Rietz, CEO

As announced in the first quarter edition of our newsletter, previously named "Reservoir Solutions," we are embarking on a new era of this publication, now "The Ryder Scott Quarterly. " I hope you are as impressed as I am to see some subtle and some obvious changes, intended to update and refresh our newsletter as we continue to provide you with what's going on at Ryder Scott, along with new trends and developments within our industry. Congratulations to Pamela and her team on this inaugural edition of "The Ryder Scott Quarterly." I anticipate that Pamela will continue to look for ways to build on and improve both the look and content of our newsletter. On that note, please feel free to send comments to Pamela or me with feedback on the new look to our quarterly publication. We look forward to hearing from you. Thank you for your continued support; it means a lot to all of us within the Ryder Scott family.

Editor's Note

By: Pamela Sabo

Welcome to The Ryder Scott Quarterly. I am happy to take on the challenge of providing articles and information pertaining to the industry, to you, our readers. At the same time, I hope to highlight our staff's expertise through staff-written editorial contributions. As Dean mentioned in his note, adjustments will be made throughout the year to improve the newsletter. I look forward to hearing from you.

"The secret of change is to focus all of your energy, not on fighting the old, but on building the new." Dan Millman, Author

Missing Values and Sparse Data

By: Melanie Adelman
Associate Geologist at Ryder Scott

Article adapted from the presentation: "Missing Values and Sparse Data, International Geostatistics Congress 2021," Prepared By: Melanie Adelman & Jeffrey Yarus, Professor at Case Western Reserve University

Today, we are in the midst of a digital revolution in which people are integrating machine learning methods with earth modeling. Big data sets have made traditional techniques that rely on manual operations extremely difficult. Big data sets are too complex for simple well-by-well methods that may overlook subtle yet important relationships in the data. Many geoscientists are not familiar with these new techniques and may overlook business opportunities that these mountains of information could provide. So how do we move forward as project size continues to increase along with demands for cost and time efficiency?

Part of the answer is to better understand the nature of big data. A data set that is classified as big is not necessarily perfect. Geoscientists are often confronted with two fundamental problems in earth modeling: missing values in petrophysical well log data and sparsity of wells in a given area in which seismic coverage is not available. The objective of the research is to produce reliable models in the presence of missing values and sparse data with an eye towards automation of the modeling process.

Figure 1 is a cartoon showing a well with missing data occurring in the well log curves.

The Y-axis represents depth from the top of the logged interval to the total depth of the well. Each column on the X-axis represents a wireline log curve in the well. Examples of missing data existing in the logs are denoted by the yellow cells. These missing values can be in the form of a missing data value, a missing interval, or an entire missing well log. A common example of this problem is a field with numerous wells drilled by different entities over a lengthy time span. The density-neutron log may be the best porosity indicator for the field reservoirs, but only a portion of the wells have been logged with this tool. Some data have simply been lost over time. Can the missing data be reconstructed reliably?

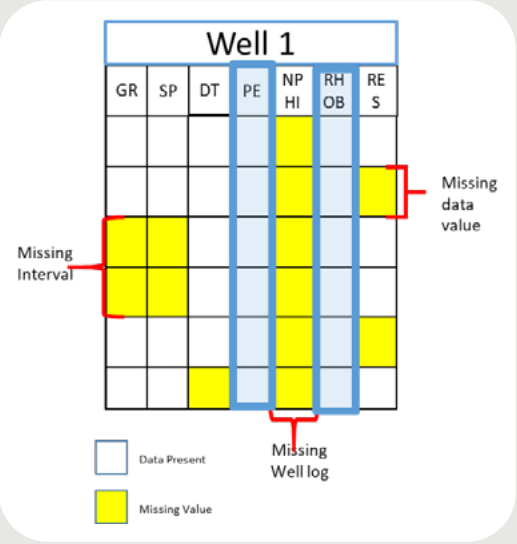


Figure 1—Different patterns of missing data

Depending on the software package being used, the default method executed on a data set with missing values may be listwise or pairwise deletions. In listwise deletions, an entire row is deleted from the analysis where an observation is missing a value in one of its variables. Thus, all variables could possibly be lost from the analysis. In pairwise deletions, an entire column is deleted from the analysis where a missing value is detected. The deleted data only pertains to the variable where the missing observation occurs. Thus, possibly the entire variable is lost from the data set. It has become common practice to insert null flag values (e.g., -999.25) to mitigate the listwise/pairwise loss of data by ignoring the missing values. However, this does not repair the data sparsity.

Furthermore, missing values can result in biased models if the missing values have a systematic relationship to any of the rock properties. Sparse data can be attributed to the overall difficulty in acquiring well data. Unconventionals are a good example of this scenario where many wells may be drilled but few are logged. When well control is sparse, the resulting model may have a higher-level uncertainty resulting in realizations being different from one another. Commonly, sparse data is supplemented with secondary data such as seismic. In order to create a reliable volume model, shown in **Figure 2**, secondary well data is necessary to supplement primary well data. What if seismic data is not available?

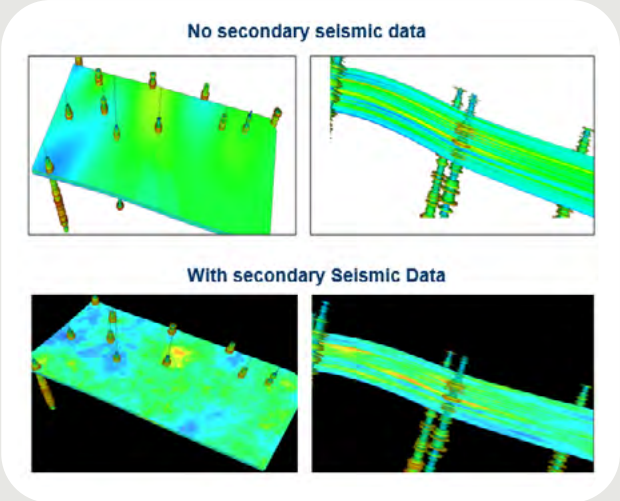


Figure 2—Top image shows surface with limited well data and no seismic and bottom image shows surface with limited well data supplemented with secondary seismic data. The top image is smoother with less detail than the bottom image.

Various tools are available to help address the problems associated with data missingness and sparsity. Using classical statistical and machine learning methods is proposed to predict missing values in well log data before simulation. Where these methods do not perform well, the remaining missing values are predicted during geostatistical kriging or conditional simulation. Under conditions of sparse data, shown in **Figure 3**, extracting properties from a burial history model or dynamic fluid flow model can be used as secondary data. Similar to seismic, basin model properties may have lower vertical resolution compared to well log data. Even so, this data can retain good horizontal resolution and can be used to improve model performance in the interwell space where log data are not available. Horizontal and vertical resolutions in basin models depend on the input resolution and number of well data included to build the model.

The classical or machine learning algorithms applied to the missing values are dependent on the missing value pattern existing in the data. Therefore, it is critical to identify the patterns of missingness and to treat each pattern separately to find a best performing model.

The results of the model prediction are also dependent on the strength of the relationship between the predictor and response variables. Using the other available well logs directly as predictors did not perform well where the predictor variables were also missing data. The resulting prediction drove model results toward a mean value rather than maintaining true geologic variance with depth. However, pretreating the variables with Principal Components – Factor Analysis (PCFA) preserves the variance in the data through eigendecomposition, creating a more robust predictor. Several models were run on each pattern including K-Nearest Neighbors, Bootstrap Forest, Boosted Trees, and Linear

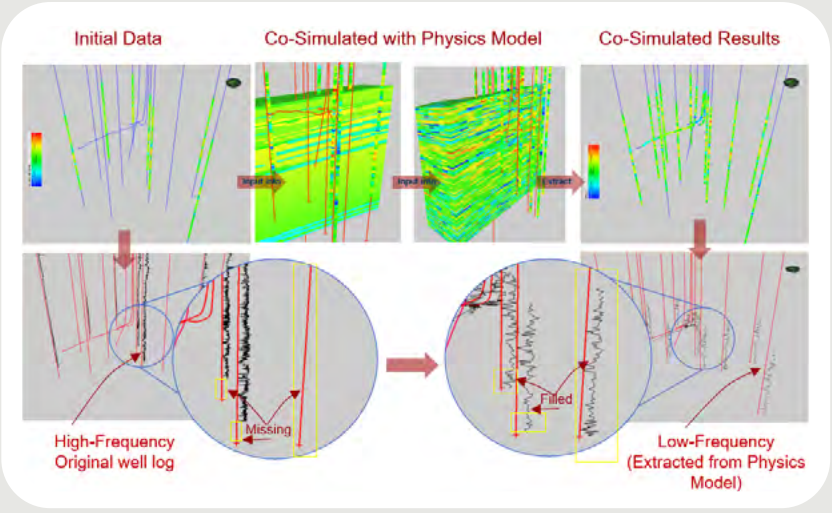


Figure 3—Sparse data set of 14 wells shown in the top left. A finite-volume physics model collocated with the primary well data creates a volume with missing data predicted where initial data is missing.

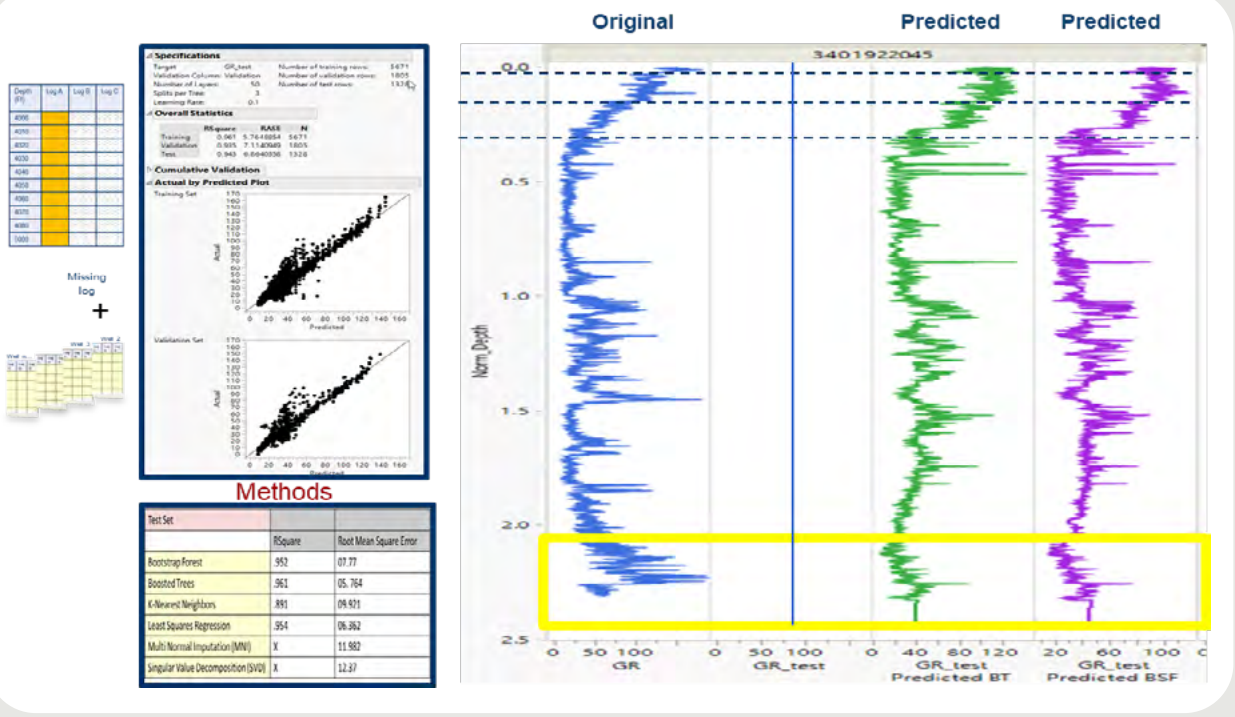


Figure 4—Example of a gamma ray log. Original log, shown in blue was manually deleted as a test set. All logs in all wells were used to generate the factors for factor analysis. Boosted Trees (green) and Bootstrap Forest (purple) were the best performing models. The models do not perform well at the bottom of the well since this is the deepest well log, and, at this level, there is not enough information from surrounding well control.

Regression and Imputation methods such as MNI and SVD. After several test cases of limiting the use of PCFA from neighboring wells, PCFA performed better with more well input. Model results were assessed quantitatively using cross-validation and a comparison of pre- and post-descriptive statistical measurements. As in **Figure 4**, viewing results in log format allowed for a qualitative measure of model performance.

The machine learning methods performed effectively on individual wells, particularly when using all of the data from the neighboring wells through factor analysis. However, when a well is missing all of the logs or missing data below the logged interval, machine learning algorithms perform poorly, as they are not designed to handle spatial correlations over large distances. Geostatistical simulation can be used to help mitigate the problem. If data are sparse and seismic is not available, properties from a finite volume basin model can be used. Basin models are not difficult to produce and are inexpensive compared to seismic.

Sequential Gaussian Simulation (SGS) is a stochastic geostatistical technique used here to simulate the well log properties (e.g., gamma ray, porosity, density). In order to calculate the level of uncertainty, 30 realizations were run on each model. Stochastic realizations are all equally probable models. The degree to which they differ from one another is a measure of the model uncertainty. When the data are sparse, simulating a property with missing values and no secondary data results in a low-resolution model with highs and lows distributed randomly across the volume. Each realization will be very different, an indication of high model uncertainty. By comparison, simulating a property that has imputed or predicted missing values and sparse data supplemented with secondary data from the basin model results in a more reliable earth model. **Figures 5 and 6** show the results of three different neutron porosity (NPHI) models generated using SGS. Model 1 was simulated using only NPHI, while Model 2 used NPHI collocated with density (RHOB), a more abundant property but still sparse. Model 3 was generated using NPHI with missing values predicted before simulation and collocated with a pervasive property extracted from a finite-volume basin model.

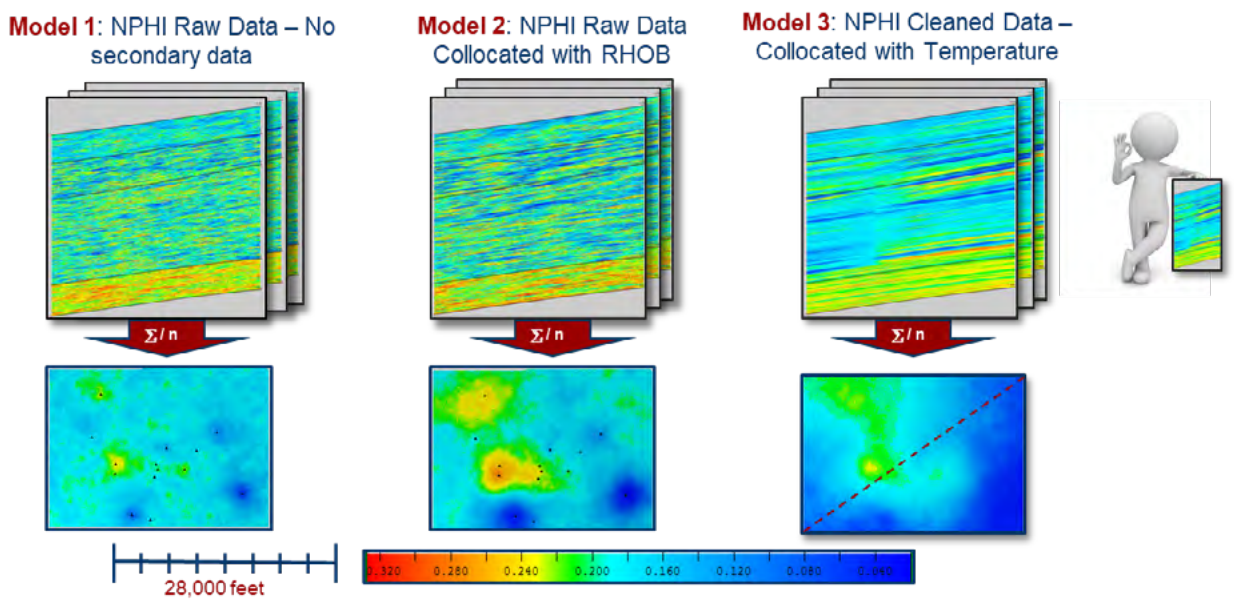


Figure 5—Results from each NPHI model. The top image in each model is showing a cross-section of 1 realization out of the 30 runs. The mean of each model was constructed and shown in the bottom image of each model. Models 1 and 2 appear highly pixelated, lacking continuity with highs and lows distributed everywhere. The mean layers of these models appear smooth due to averaging of highly different realizations. The Model 3 mean solution appears much more similar to each individual realization depicting more consistent continuity. Temperature explains 40% of the variance (r=0.6), but temperature is not highly variable thus why Model 3 appears smoother with less variance than Model 1 and Model 2.

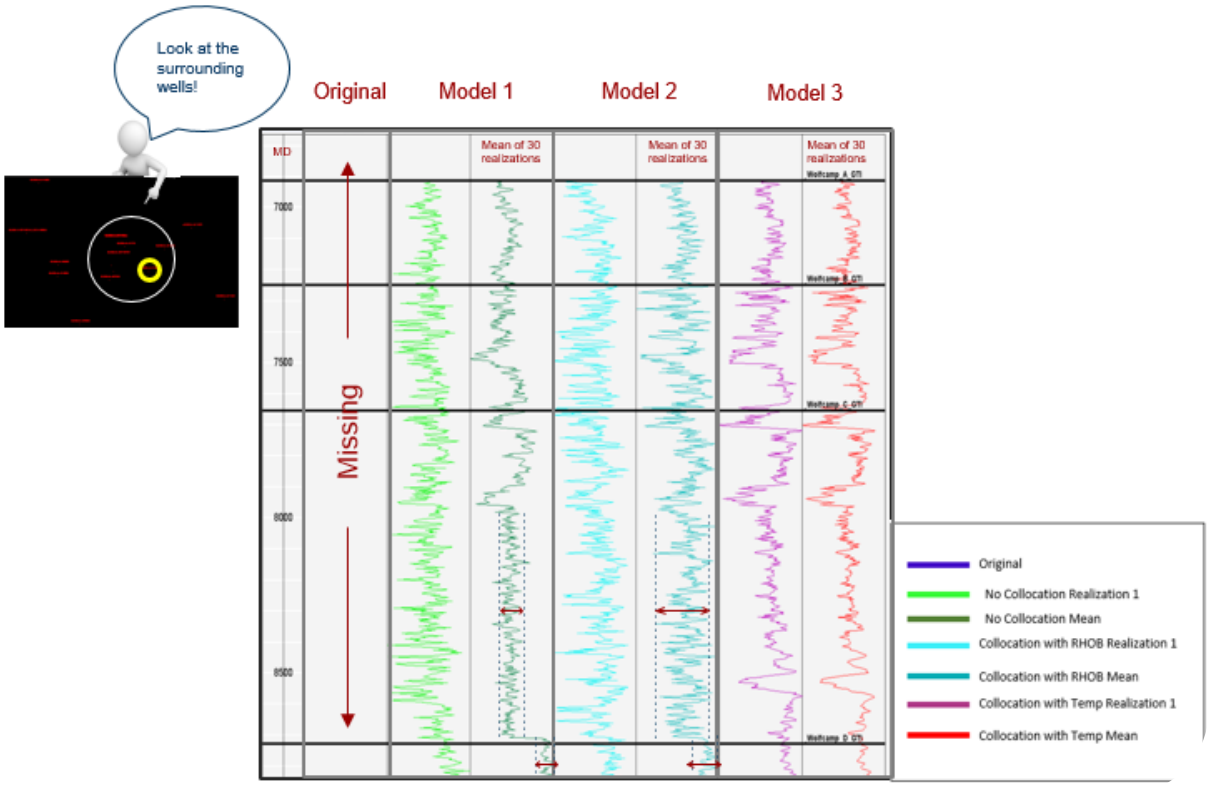


Figure 6—Extracted well logs from each model shown in Figure 6. The logs shown in each model include a log from 1 realization out of 30 and a log from the mean solution. Original NPHI log is completely missing and is surrounded by several wells with NPHI logs present.

Ryder Scott's annual conference has moved from September to May this year. The 18th Annual Reserves conference will be held virtually via the Zoom platform on the mornings of May 11th and May 12th CST.

The first 15 conferences were held in-person at the DoubleTree and Hyatt Regency hotels in downtown Houston. The annual conference grew to be the largest in-person gathering of reserves evaluators, with a full house of approximately 400 attendees. The pandemic in 2020 brought unexpected challenges; however we were able to find an alternate solution to the in-person event by streaming the conference virtually, allowing us to reach a much wider audience.

The first Ryder Scott Virtual Conference in 2020 was a great success with over 500 attendees around the globe. Our last conference reached more than 30 countries with 600 attendees. We expect to exceed these numbers this year, as we have decided to broadcast the conference twice in order to accommodate international industry professionals.

The conference will be broadcast at 8:00 AM CST on May 11th and May 12th. A second showing will be aired at 7:00 AM GST on May 12th and May 13th. The second airing has been added in an effort to reach our international clients and friends. Licensed petroleum engineers in attendance will receive a certificate to document earned CEUs (Continuing Education Units), which are required to maintain certain annual P.E. licensing requirements. The conference ends with an "Ethics Hour" that qualifies as a one-hour credit necessary to fulfill most state's annual ethics requirement for licensed engineers.

The 18th Annual Conference lineup includes well-known industry professionals. Speakers and agenda may change closer to the event. Updates will be posted at https://ryderscott.com/ryder-scott-reserves-conference/.

The conference will host the following speakers:

- Dr. John Lee, Professor at Texas A&M
- Miles Palke, Managing Senior Vice President at Ryder Scott
- Alexander MacKay, Project Engineer at Ryder Scott
- Effiong Okon, Executive Director, Operations at Seplat Energy Plc
- Herman Acuña, Executive Vice President at Ryder Scott
- John Allen, Senior Geologist at Ryder Scott
- Mukul Hariharan, Director and Manuel Amaro, Director of Engineering at Houlihan Lokey
- Panel Discussion, Moderated by Ron Harrell, Chairman Emeritus at Ryder Scott
    - Logan Burt, Managing Director at Morgan Stanley
    - Christine Ehlig-Economides, Professor at University of Houston
    - John Hessenbruch, Geological Consultant

If you are interested in attending the conference, please send an email to RSCConfHouston@ryderscott.com. Invites will be sent out in mid-April.

Zhang Presents SPE Paper at 2021 SPE-ATCE Conference

Vice President, **He Zhang**, presented the paper "An Integrated Workflow for Reserves Evaluation in the U.S. Permian Basin Based on SPEE Monograph 3" virtually at the SPE-ATCE Conference held in September 2021 in Dubai, which he coauthored with **Xiaoyang (Jeremy) Xia**, Senior Petroleum Engineer at Ryder Scott.

Other Ryder Scott coauthors include **Larry Connor**, Executive Vice President, **Dan Olds**, Managing Senior Vice President, and **Eric Nelson**, Managing Senior Vice President.

The paper was selected by an SPE program committee based on the submitted abstract, which is included below.

To read the full article, please visit: https://onepetro.org/.

Abstract

In 2011, the Society of Petroleum Evaluation Engineers (SPEE) published Monograph 3 as an industry guideline for reserves evaluation of unconventionals, especially for probabilistic approaches. This paper illustrates the workflow recommended by Monograph 3. The authors also point out some dilemmas one may encounter when applying the guidelines. Finally, the authors suggest remedies to mitigate limitations and improve the utility of the approach.

This case study includes about 300 producing shale wells in the Permian Basin. Referring to Monograph 3, analogous wells were identified based on location, geology, drilling-and-completion (D&C) technology; Technically Recoverable Resources (TRRs) of these analogous wells were then evaluated by Decline Curve Analysis (DCA). Next, five type-wells were developed with different statistical characteristics. Lastly, a number of drilling opportunities were identified and, consequently, a Monte Carlo simulation was conducted to develop a statistical distribution for undeveloped locations in each type-well area.

The authors demonstrated the use of probit plots and demonstrated the binning strategy, which could best represent the study area. The authors tuned the binning strategy based on multiple yardsticks, including median values of normalized TRRs per lateral length, slopes of the distribution lines in lognormal plots, ratios of P10 over P90, and well counts in each type-well category in addition to other variables. The binning trials were based on different geographic areas, producing reservoirs, and operators, and included the relatively new concept of a "learning curve" introduced by the Society of Petroleum Engineers (SPE) 2018 Petroleum Resources Management System (PRMS).

To the best of the authors' knowledge, this paper represents the first published case study to factor in the "learning curves" method. This paper automated the illustrated workflow through coded database queries or manipulation, which resulted in high efficiencies for multiple trials on binning strategy. The demonstrated case study illustrates valid decision-making processes based on data analytics. The case study further identifies methods to eliminate bias, and present independent objective reserves evaluations.

Most of the challenges and situations herein are not fully addressed in Monograph 3 and are not documented in the regulations of the U.S. Security and Exchange Commission (SEC) or in the PRMS guidelines. While there may be differing approaches, and some analysts may prefer alternate methods, the authors believe that the items presented herein will benefit many who are starting to incorporate Monograph 3 in their work process.

The authors hope that this paper will encourage additional discussion in our industry.

Ryder Scott Celebrates E-Week 2022

National Engineers Week, known as E-Week, took place February 20-26, 2022 to celebrate all engineers and the positive contributions that every engineering discipline and profession brings forth to improve overall quality of life. The week-long celebration was founded in 1951 by the National Society of Professional Engineers in order to recognize the importance of a technical education and a high level of math, science, and technological literacy. It motivates others to pursue engineering careers in order to provide a diverse and vigorous engineering workforce.

Currently, E-Week consists of more than 70 engineer, education, and cultural societies and more than 50 corporations and government agencies. E-Week in Houston, the Energy Capital of the World, reaches numerous schools, businesses, and community groups, and Ryder Scott is proud to be a business that gives back to those who recognize the benefits of pursuing engineering and technology careers. The Ryder Scott Company Friends of UHPE was created in 2012 in order to sponsor and support University of Houston (UH) petroleum engineering students as part of E-Week. Over the last 10 years, our donors have raised more than $90,000 for UH petroleum engineering students.

Ryder Scott Chairman Emeritus Ron Harrell with Trevor Eustaquio, recipient of the Ryder Scott Dr. John Lee Engineering Legacy Award and Juan Flores, recipient of the UH PEAB Dr. Thomas Holley Engineering Professionalism Award.

On Tuesday, February 22, Ryder Scott Company Friends of UHPE took part in the Engineers Week 2022 Program hosted by the UH Engineering Alumni Association (UHEAA). As one of the biggest sponsors of this event, Ryder Scott Friends of UHPE has a long-standing tradition of individuals at Ryder Scott coming together to support the petroleum engineering students at UH each year. This year, Ryder Scott raised more than $6,000 for the event. Thanks to our generous donors (some with no direct ties to UH), we were able to present eight petroleum engineering students with the Excellence in Petroleum Engineering Award and one student with the Dr. John Lee Engineering Legacy Award. Along with recognition of their outstanding academic achievements, each student received a cash award in the amount of $500.

Ryder Scott Company Friends of UHPE also supports other initiatives administered by the petroleum engineering department that benefit all of the petroleum engineering students. This includes the most recent initiative, the UH Petroleum Engineering Externship Program, which creates opportunities for students to get real-life working experience on projects led by industry partners.

Ryder Scott's Chairman and CEO, Dean Rietz, along with Ryder Scott's Chairman Emeritus, Ron Harrell, and Senior Petroleum Engineer and Data Science Coordinator, Adam Cagle, also serve on the UH Petroleum Engineering Advisory Board (PEAB) and help to raise funds for PEAB E-Week awards. Rietz, Harrell, and Cagle each presented a separate set of awards sponsored by PEAB to another group of deserving petroleum engineering students.

Reflecting on the success of this year's event, Cagle said, "Fundraising and coordinating with all of the donors and the school can be a lot of work, but going to the reception where I get to visit with these outstanding students and take part in recognizing them for their hard work makes it all worthwhile."

Adam Cagle with Ryder Scott Company Friends of UHPE student award winners

Ryder Scott remains dedicated to ensuring a diverse and well-educated future engineering workforce by increasing understanding of and interest in engineering and technology careers. We hope to encourage others to support their local educational institutions as well.

Ryder Scott New Hires

Andrew Thompson, **William Turner**, **John Allen**, and **Niels Snow** joined the Ryder Scott office recently, altogether bringing decades of diverse experience to the team.

Andrew Thompson rejoined Ryder Scott as a Senior Vice President and Manager of the Calgary office at the beginning of April 2022. He has over 30 years of diversified technical experience. His primary areas of expertise include reserves evaluations, reservoir modeling, drilling and completions, well testing and abandonment operations. Reservoir studies have included primary, secondary and tertiary recovery methods and analysis of unconventional low permeability and highly fractured reservoirs.

Most recently, Thompson worked as a Managing Director for Macquarie Group where he led the technical analysis for principle financings and investments in oil and gas companies. He conducted economic evaluations for oil and gas assets, led intensive due diligence processes, and monitored operations, production, and reserves updates.

Thompson was instrumental in developing and maintaining business operations in Calgary at Ryder Scott during his employment from 1995 to 2008. As the Manager of the Calgary office, he was a lead engineer and primary contact for several clients.

In the first five years of his career, Thompson worked as a Petroleum Engineer. He gained hands-on experience with various surface facility equipment at Magus Engineering Ltd where he performed on-site supervision of down-hole completions, well testing, work-overs, abandonments, and horizontal, directional, and under-balanced drilling operations.

Before that, Thompson prepared economic evaluations for oil and gas properties at Coles, Gilbert Associates Ltd. and then at Guard Resources Ltd. He began his professional career at the Alberta Energy and Utilities Board, preparing natural gas reserves estimates for long-term gas removal applications, pipeline applications, and reserves classifications.

Thompson is a member of the Association of Professional Engineers and Geoscientists of Alberta and Society of Petroleum Engineers. He has a BS degree in Petroleum Engineering from the New Mexico Institute of Mining and Technology. Before becoming an engineer, Thompson considered a career as a professional bareback rider in the 90s, traveling around Alberta, British Columbia, Saskatchewan and the northern United States, competing in rodeos as a novice bareback rider. He now enjoys mountain biking with his wife and getting in a few rounds of golf during his free time.

William Turner is a Senior Project Engineer in the Midstream and Upstream Integrated Services group at Ryder Scott. His diverse experience began with a decade of engineering, subsea and pipeline design, fabrication, and installation. His areas of expertise also include field development, production modeling, and cost and schedule estimation.

Before joining Ryder Scott in March 2022, Turner worked as a Lead Analyst for Rystad Energy. He monitored various elements of the energy supply chain including supply and demand, costs, and the financial strength of suppliers across all sectors from seismic to decommissioning. He also reviewed the energy transition to renewable sources such as offshore wind and solar.

Before that, he was the Vice President of Welligence Energy Analytics where he led the company's expansion into the US Gulf of Mexico and was instrumental in the launch of a product for use in evaluating assets for portfolio benchmarking, mergers and acquisitions, and new field developments.

From 2017 to 2019, Turner was a Senior Research Analyst for Wood Mackenzie. He started from bottom-up well-level analysis and field research, proceeded up to field level commercial analysis reports, ultimately developing a macro view of the region and the broader sector. With his extensive knowledge of deepwater technology, operations, cost estimation techniques, and project management, Turner brought a unique perspective to his team.

Turner began his professional career in 2007 at EMAS AMC, where he spent over 10 years and worked his way up to Deputy Project Manager. He managed major projects for subsea and pipelines for upstream and midstream operators.

He has a BS degree in Ocean Engineering from Texas A&M University and an MS degree in Technology Commercialization from the University of Texas at Austin. A true Texan, Turner owns and independently runs a small cattle farm. He enjoys spending his free time with his wife and two sons.

John Allen joined Ryder Scott in November 2021 as a Senior Geologist with more than 10 years of experience integrating seismic interpretation, geologic and geophysical data, and resource assessment to evaluate and develop profitable oil and gas prospects in conventional and unconventional plays. His specialties include integrated structural geology, tectonics, stratigraphy, geophysics, and play and prospect assessment.

Before joining Ryder Scott, Allen worked as a Geologist for the Department of the Interior in the U.S. Gulf of Mexico Regional Framework Unit. In this position, he collaborated with geologists and geophysicists to integrate regional salt body and tectonic datasets to create products for the evaluation of hydrocarbon systems in all known plays in the Gulf Basin.

From 2018 to 2020, Allen worked as a Senior Geologist for XTO Energy where he oversaw daily drilling operations and unit development planning. He also leveraged his expertise in risk and uncertainty analysis to create an innovative workflow for the characterization and valuation of subsurface volumetric resources in unconventional plays.

Allen began his career as a Geoscientist at ExxonMobil, where he worked for nine years, serving as team lead for risk and resource assessment. In this position, he managed multiple concurrent projects and provided geotechnical peer review for the exploration program, including prospect identification, maturation, operations, and acquisition and divestitures.

He has a BS degree in Geology from Furman University, an MS degree in Structural Geology from North Carolina State University, and a PhD in Tectonostratigraphicy from the University of Kentucky.

Niels Snow joined the Ryder Scott Houston office in December 2021 as an Associate Economist where he applies both qualitative and quantitative economic analysis to research pertaining to oil and gas. His specialties include economic analysis and cost and risk analysis.

Previously, Snow was a Market Research Analyst with Rare Petro. He researched, compiled, and analyzed information for assigned engineering projects. He also assisted with processes related to engineering, cost analyses, and podcast productions.

Snow has a BS degree in Petroleum Engineering and an MS degree in Mineral and Energy Economics from the Colorado School of Mines. He is a member of the Association of Petroleum Negotiators and the Society of Petroleum Engineers. Snow is a fourth-generation petroleum engineer. Before continuing in the family tradition, he enjoyed video editing and worked editing videos for YouTube.

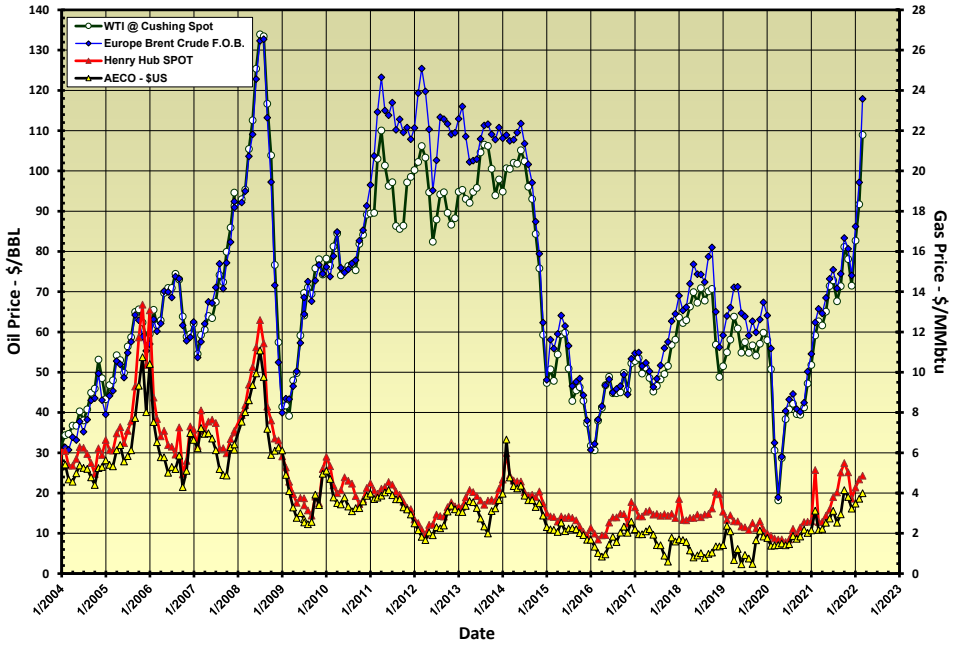
In Memoriam

Charles P. Milner, 91, passed away in March after a long life of devotion to the sciences and the arts. He joined Ryder Scott in 1967 as a petroleum engineer, working on major oil and gas projects throughout the world. Milner's expertise and work ethic served as an inspiration to colleagues and clients alike. He retired as President of Ryder Scott in 1990.

Former Ryder Scott employee and friend of Milner, Joe Magoto said "Will Rogers said, 'I never met a man I didn't like,' bottom line, I never met anyone who didn't like Charlie Milner."

Before joining Ryder Scott, Milner worked at Phillips Petroleum Company, followed by El Paso Natural Gas, and Tenneco. He received a BS degree and an MS degree in Petroleum Engineering from the University of Texas at Austin.

Price History of Benchmark Oil and Gas in U.S. Dollars



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is published quarterly by Ryder Scott Co., LP. Established in 1937, the consulting firm performs hundreds of independent studies a year and offers a wide range of services – including reserves evaluations, geological studies, reservoir simulation modeling, integrated studies, facility evaluations, data analytics, economic analyses, expert witness testimony, and sustainable energy consultancy to name a few. With 113 employees, including 77 engineers and geoscientists, Ryder Scott has the expertise and capability to complete the largest, most complex reservoir evaluation projects in a timely manner.

RYDER SCOTT | 85th Anniversary 1937 - 2022

Cover picture is of the Digboi Field, one of the oldest oil fields in the world. Picture taken by Dean Rietz, CEO.