

Production forecasts from unconventional plays too high, says Lee

Decline curves, type wells and parent-child wells at root of problem

Reservoir engineers forecasting production from unconventional plays, generally, could do a better job, said **John Lee**, professor at Texas A&M University and a leading reserves evaluation expert. He made his comments at the Ryder Scott reserves conference in Houston in September.

Shale revolution matures

For background, Lee discussed a *Wall Street Journal* article last year that tracked forecasts of oil production from America's four hottest drilling regions, including the crown jewel of the Permian, the Wolfcamp Delaware basin.

"Two-thirds of projections made by the fracking companies between 2014 and 2017 ... appear to have been overly optimistic, according to the analysis of some 16,000 wells operated by 29 of the biggest producers in oil basins in Texas and North Dakota," stated the *WSJ* article.

The publication also reported that producers began using the term EURs (estimated ultimate recoveries) when prices dropped this decade to de-emphasize reserves, which are commercially recoverable under current economic conditions.

Please see, "WSJ, Forbes send mixed signals on production forecasts," in *Reservoir Solutions* newsletter, April-June 2019, Page 2 at <https://www.ryderscott.com/wp-content/uploads/2019NL%E2%80%A2April.pdf>.

Overestimation has become a pervasive problem across U.S. unconventional plays, signaled Lee. It comes at a critical time in the industry, as some financial backers have fled and capital is starting to dry up.

Lee suggested that the first step to remedy the situation is for industry to use reliable forecasts based on flow regimes, characteristic declines and fracture geometry between parent and child wells.

"Type wells are really the source of the estimates that the *Wall Street Journal* and others have used for comparison with actual outcomes," said Lee. "These type wells are based on averages of production profiles of existing

wells and undeniably, they have tended to be overly optimistic."

He cited problems with fundamentals in three areas — creating type wells, formerly called type curves; plotting decline curves; and spacing and timing parent and child wells — all of which are part of the technical work scope underpinning reserves reporting, economic analyses and further field development. They, in turn, influence investment decisions and success levels in the oil patch.

Fewer players in the patch

Despite record oil production from North America shale plays (or because of it), low prices and credit lines have clobbered the E&P industry. At the end of the third quarter, 33 bankruptcies in North America had rubbed out \$13 billion in secured and unsecured debt, according to the latest count at press time by Haynes and Boone LLP.

Approach Resources Inc. filed for chapter 11 bankruptcy in November, all but assuring that 2019 would be the roughest year yet for the oil patch.

Late last year, a strong U.S. economy boosted market caps in the E&P sector five points from 25 percent down on an annualized basis in November to 20 percent a month later.

Please see Production Forecasts on page 2

"Interference is a big issue, particularly in the press and with investors"



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Decline curves, flow regimes

Evaluators in the shale have typically used the Arps empirical equation with a single b-factor to plot the expected production decline from hyperbolic to terminal. The trouble with that is b-factors change over time as flow regimes change.

Some evaluators get around that by using varying b-factors, including **Brent Biseda**, a senior engineer at Seneca Resources Co. LLC, at the time of his SPE paper, “Modified Arps Equation for Changing B-factor.”

He stated “modifications allow a single equation to be used with a vectorized b-factor ... to model a well as it transitions from linear ... to boundary-dominated flow and eventually back to pseudo-linear flow.”

Lee said b-factors in early flow regimes will be high (> 1) and the final b in the boundary-dominated flow regime, is going to be much lower (< 1).

He added that Arps b-factors have tended to be too high, particularly as used to forecast long-term production, so evaluators typically switch to a terminal decline late in the production history to lower the final decline rate and EURs.

He showed log-log diagnostic plots from the Bakken shale play that he said were a good way to identify flow regimes.

“What we see is an early ramp-up during hydraulic fracturing, cleanup and choke-back flow. That is followed by a long, transient flow regime, as the reservoir drains further away from the fractures prior to interference between adjacent fractures,” he said.

That’s followed by a transition period that is “pretty long, more than one log cycle.” With enough history, the final BDF regime is evident and signifies when all fractures along the well exhibit interference.

Lee recommended that evaluators be more realistic about the decline rate during early transient flow in horizontal wells with multiple fractures. See chart of the Arps hyperbolic model with 30-percent decline rate at switchover to transient flow.

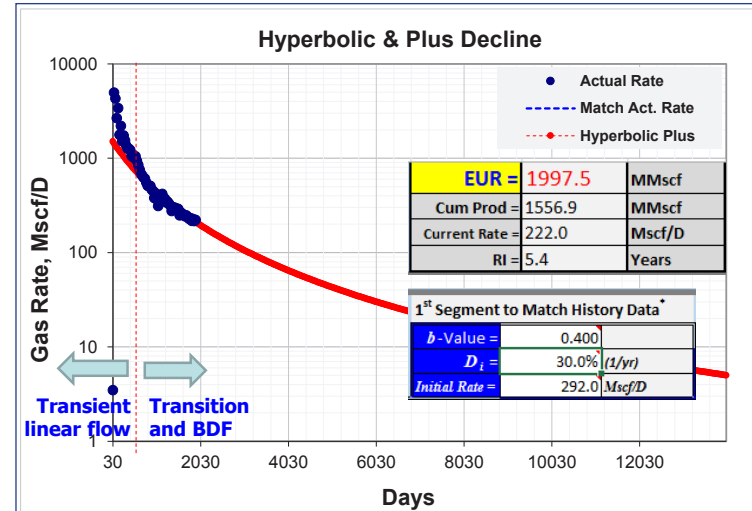
“The decline rate at the time we switched flow regimes was not 5 percent or 10 percent per year. It was 30 percent per year because of the effects of boundaries,” he said. “I didn’t cherry pick data to come up with an example like this. It is quite common.”

Type wells: Not just averages

Lee said that creating type wells requires more than averaging production profiles. “We need to consider carefully placing wells with similar decline characteristics into individual bins and make sure we have a statistically significant sample size of wells in each bin,” he remarked.

Please see, “High-side forecasts with type wells caused by ‘survivor bias,’ says Lee,” in *Reservoir Solutions* newsletter, July-September 2017, Page 5 at www.ryderscott.com/wp-content/uploads/2017NL_July.pdf.

Arps Hyperbolic Model Fitted with BDF Data Only for Forecasting



The article discusses survivor bias, binning, probit charts, off-trend data and scaling.

Lee said, “It’s important to scale data as needed with the goal of minimizing the number of separate bins and maximizing the number of wells in each bin.”

He recommended sorting wells based on permeability-thickness, number of fracture stages and drawdown — all factors that affect post-peak rate well performance in unconventional plays.

Parent, child wells: Interfere, but not too much

Lee also pointed to production from infill and pad wells that either causes too much or not enough interwell interference. Too much is overkill. Too little lowers recovery efficiencies. Wider spacing increases EUR per well but decreases EUR per section.

“We shouldn’t try to avoid interference. If we do, we’re going to leave large areas undrained in acreage we’re developing,” he said. “We need some interference – if we don’t have it, we’re not draining all the rocks.”

This issue has not gone unnoticed in the press.

“Interference is a big issue, particularly in the press and with investors,” he said. “We’re not properly taking interference into account.”

Lee suspects that to estimate the EURs of infill wells, industry is using production profiles based on older wells and looser spacing, which underestimates interference.

“We think if we have a typical P90 production profile for a well and drill a couple infill wells, we can just multiply that profile by a factor of three, and we’ve got a good forecast,” he said. “Well, it doesn’t turn out to be that simple.”

Lee said that history-matched dynamic modeling cited in SPE paper (No. 191799-MS) published in 2018 by Defeu et al from Schlumberger Ltd. has provided insights into the

parent-child relationship in drilling offsets.

The study showed that in the Wolfcamp Delaware Basin, hydraulic fractures in wells closer to the parent well grow toward adjacent, depleted areas. Those child wells experience increased depletion times and up to a 50 percent reduction in production compared to the parent, the paper states.

At the same time, the adjacent parent well may suffer from “frac hits” from the child well undergoing fracture treatments, which can cause premature production decline in the parent.

“At large well spacing, little impact is observed because of limited interference between wells,” said Lee.

Not only does well spacing matter, so does timing for infill

Facilities engineer joins Houston office

The new head advisor—upstream and midstream integrated services is **Sandeep Khurana**. He joined Ryder Scott in October.

Khurana is the team lead for surface facilities and midstream areas. He collaborates with reservoir engineers and geologists to determine various midstream options.

The addition of Khurana enables Ryder Scott to offer inhouse expertise beyond the subsurface and wellhead.

Previously, he was head of advisory development & operations at Granherne, a subsidiary of KBR Inc., where he worked more than five years. He advised governments and NOCs on assets and master plans.

Khurana analyzed midstream business, contractual issues, LNG value chain, plants and pipelines. He also evaluated onshore development plans, appraised commercial plans and provided concept selection, contracting strategies and bids for floaters and subsea installations.

Before that, he was manager development, major projects group, at Noble Energy Corp. from 2010 to 2014. He ensured front-end loading, planning, and execution for major assets and projects. Khurana also managed integration of drilling, environmental and regulatory considerations, and lease requirements in the frontier areas. Khurana also performed concept screening for gas export infrastructure for unconventional resource plays and assisted in the sanctioning of an onshore mini LNG plant.

During 2010 to 2016, he worked at Devon Energy Corp. as a facility advisor in international operations, then as a senior advisor in domestic and international operations. He provided technical counsel during farm-ins and farm-outs in exploration and exploitation-support initiatives and managed operations upgrade work on offshore facilities, pipeline, and onshore gas LPG plant in Cote d’Ivoire.

Khurana also won government and partner approvals on a \$750-million development plan for a subsea tieback to an FPSO in Equatorial Guinea. Later at Devon, he headed and

drilling and production, the SPE paper concludes. Fractures from a child well tend to propagate selectively into the pressure-depleted areas near the parent well vs. spreading into undrained immediate areas.

“That’s going to lead to poor overall recovery, which leads to overoptimistic estimates of ultimate recovery from this parent/child well combination,” said Lee.

Authors of the paper have observed significant propagation of fracturing from the child well to pressure-depleted areas of the parent well 36 months after the parent has been on production.

Please see *Production Forecasts* on page 8



Sandeep Khurana

managed oil and gas projects, and provided technical expertise in field development planning with a multidisciplinary team, including subsurface, drilling, operations, and commercial. Much of the work was in Brazil, China and Gulf of Mexico.

During 2003 to 2006, he was a project manager, subsea systems & facilities at Kerr-McGee Corp. and at Anadarko Petroleum Corp. as a consultant after the acquisition. He managed subsea tieback projects from concept engineering to equipment installation followed by commissioning and operations support.

Before that, he was a principal facilities engineer at Halliburton from 2000 to 2003. Khurana performed field development evaluations, reduced capital costs, and developed new technology with a multi-disciplinary team. He also performed studies on rigless well intervention, wireline, coiled tubing, hydraulic work-over techniques and applications, and technical issues in subsea well intervention.

Khurana was also a facilities project engineer at Paragon Engineering Services Inc. during 1996 to 2000. He conducted facilities engineering work on onshore plants and offshore facilities developments, including those in Nigeria, West Africa and the Gulf of Mexico.

He began his career as a marine engineer at Brown & Root Energy Services in 1989, and then joined Petro-Marine Engineers of Texas Inc. as a senior engineer in 1994.

Khurana has an MS degree in science from Rice University. He is a registered professional engineer in Texas, registered Project Management Professional and member of SPE.

Adam Cagle, data science coordinator at Ryder Scott, is a liberator armed with artificial intelligence. He's not a super hero. Or even an avenger. Disguised as a mild-mannered petroleum engineer, Cagle is on a crusade to free those who typically spend more than half their work time to integrate, format, route, compile and cross-reference data.

He understands that the goal is to analyze the data.

"I want to liberate them (employees) from mundane tasks so they can spend more time on activities they actually enjoy and that are fulfilling. This will unlock their full potential," he said.

Cagle presented, "Talking Shop: Data Science at Ryder Scott," at the firm's Houston conference late last year. It updated progress on the firm's data science initiative that began a year ago.

He showed a slide on a recent *New York Times* article that found project teams spend 50 to 80 percent of their time "munging," which is manually cleaning up data sets.

Some have referred to it as data wrangling. Practitioners in the reserves sector often have to wade through large quantities of data – an all-too-familiar occupational drudgery that cannibalizes productive time.

"For technical people nothing is more frustrating than having a great idea, but not having the time, tools and resources needed to experiment. Our goal is to provide that," said Cagle.

Artificial intelligence to

End game

Cagle has his sights on developing a machine learning system or other type of artificial intelligence with petroleum engineering input that would enhance current prediction techniques. However, he is taking a data first approach, initially focusing on data integrity.

That step comes before leveraging data science and creating infrastructure, tools and routines to statistically analyze those quality data sets.

The end game is increased efficiency and more reliable production forecasts. For instance, supervised, calibrated machine learning improves estimates of uncertainty in probabilistic production forecasts, some studies have shown.

New product in the making

The earlier stages of the work will also open up opportunities for Ryder Scott to provide a new deliverable to clients — a quick-look report with a statistical summary that will be "there when you need preliminary, reliable, fast answers of the highest quality."

While providing useful information, the automated report will be based on public data, and will not replace reserves or resources studies.

The plan is for the client to provide a list of wells in a geographic area to Ryder Scott, and in return, the firm will produce a report with technical volumes for oil, water and gas, and ultimate recoveries over time.

Ryder Scott is no stranger to database work to improve forecasts. Please see sidebar on Page 5.

No tearing down the silos

Ryder Scott possesses project data that is confidential and restricted. Various evaluation teams keep and protect project data and interpretations in silos "because each project should only use the data to which it is entitled," said Cagle.

That said, petroleum geologists and engineers do not operate in a vacuum. They gain knowledge through project work and leverage that experience to accelerate learning curves and ultimately, improve forecasting in oil and gas trends.

Standardization

"We have another challenge as well," said Cagle. "Every client is different, and every job we work is different."

He added that standardization is an essential part of his data management project because it will allow Ryder Scott to easily combine interchangeable data sets from multiple sources, so long as they have a common format.

"Standardization and interchangeable data sets are as important of a concept of the digital revolution as interchangeable parts was for the industrial revolution," said Cagle.

heavily leveraged open-source software tools," said Cagle. "In my view, open source has been as important to the digital revolution as has been any other breakthrough technology. It's amazing that anyone with an Internet connection is able to download these tools for free, find all the resources they need to learn how to use them and get help running them through the large communities that built, use and maintain them."

Cagle developed a new open-source tool, Well Collator, using open source code that anyone can modify and enhance. The "shiny app" is posted on the Ryder Scott website at www.ryderscott.com/software/well-collator/.

See article, "Data Analytics," on Page 1 of *Reservoir Solutions* newsletter, October-December 2019 at <https://www.ryderscott.com/wp-content/uploads/1Rs4thQtr-WEB-Oct30th-LinksMSTR.pdf>.

The benevolent liberator, dedicated to stamping out "grunt work," reassured the audience of working corporate professionals.

"I truly believe that data science

liberate workforce, says Cagle

Ryder Scott no stranger to database work to improve forecasts

Ryder Scott has built large regional databases with public and proprietary information to create maps of oil and gas trends with tens of thousands of data points for each North America unconventional plays and elsewhere, including the following areas:

- Bakken
- Eagle Ford
- Wolfcamp
- Haynesville
- Marcellus
- DJ-Wattenberg Basin
- Powder River Basin
- Scoop/Stack
- Tuscaloosa Marine Shale
- Montney in BC/AB, Canada
- Duvernay in AB, Canada
- Viking in AB/SK, Canada
- Bakken in SE/SK, Canada
- Vaca Muerta in Argentina

Database "building blocks" include well locations in sweet and trouble spots, initial and daily production rates, estimated recovery factors and ultimate recoveries correlated with mapping by area and depth.

Ryder Scott generates and inventories type curves for comparative analyses to identify best-fit performance analogs. The firm's analysis of statistical performance data yields predictable, repeatable reserves estimates in analogous areas.

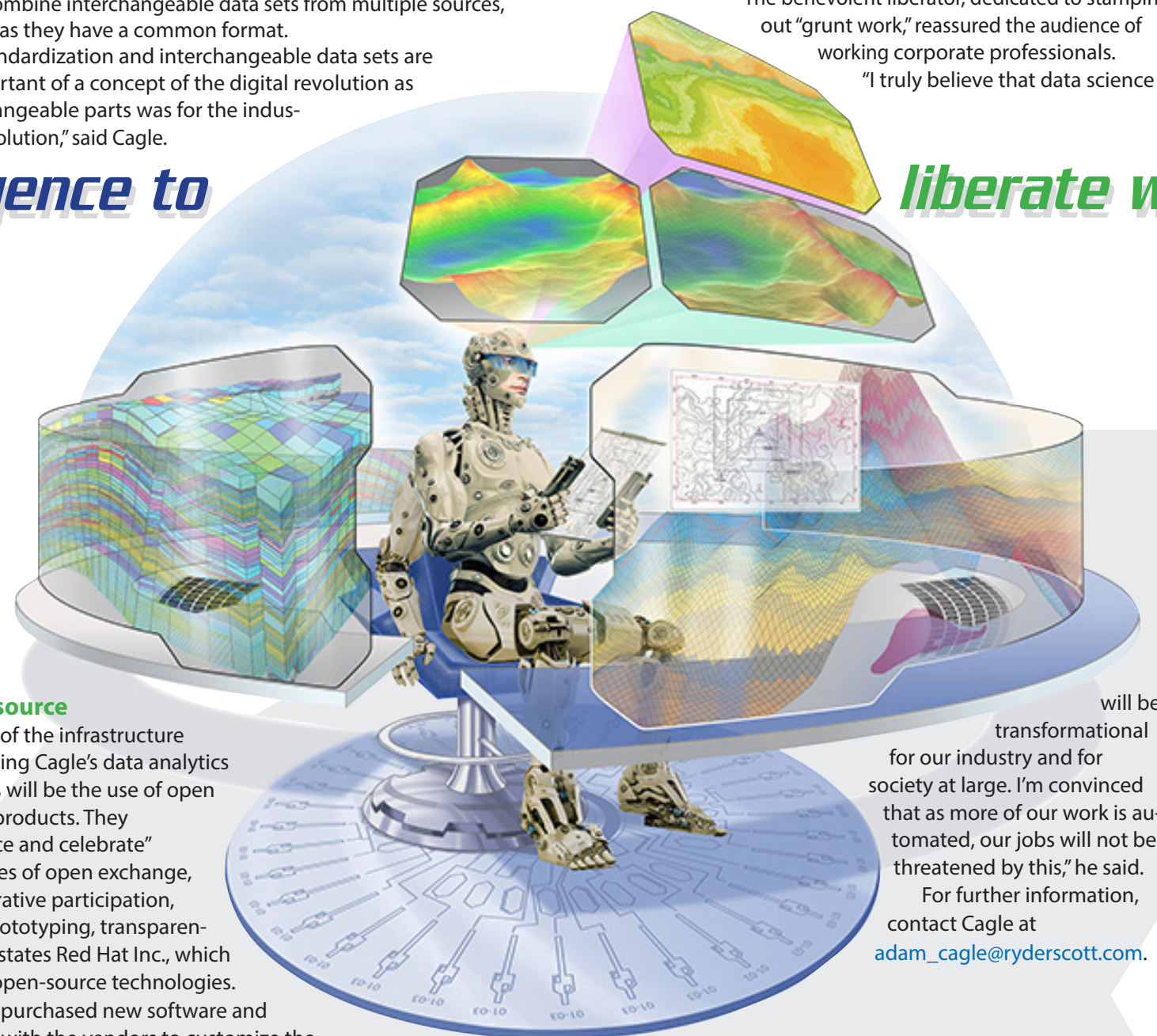
Ryder Scott evaluates and catalogs well-test results, fluid properties, drilling-and-completion techniques, such as well trajectories, TVDs, lateral lengths, frac stages and proppant amounts. Key geological information, such as thermal-maturity and TOC data, is also stored and indexed.

"Our databases aid and guide our traditional reserves reports," said **Dean Rietz**, CEO. "We work hard to ensure that proprietary data stays within the specific projects and clients to which they belong."

Open source

Part of the infrastructure supporting Cagle's data analytics projects will be the use of open source products. They "embrace and celebrate" principles of open exchange, collaborative participation, rapid prototyping, transparency, etc., states Red Hat Inc., which makes open-source technologies.

"We purchased new software and worked with the vendors to customize the solutions to serve our purposes, but we've also



will be

transformational for our industry and for society at large. I'm convinced that as more of our work is automated, our jobs will not be threatened by this," he said.

For further information, contact Cagle at adam_cagle@ryderscott.com.



Adam Cagle

Editor's Note: "When new technology enters the oil and gas scene, talk of layoffs can creep into water-cooler conversations," wrote Heather Saucier, correspondent at the AAPG Explorer magazine, in the December issue. Artificial intelligence and machine learning technologies are interpreting seismic data at record speeds "often delivering results that rival, if not surpass, those of humans," she wrote. Companies offering the service advertise it as "real-time" seismic interpretation.

Ryder Scott reserves evaluations for T&T, Abu Dhabi make the news

Countrywide studies featured in November press reports

Ryder Scott independent estimates for gas reserves for Trinidad & Tobago and conventional oil and gas reserves in the United Arab Emirates were good news for both countries recently.

Herman Acuña, executive vice president, spoke at a press conference on Nov. 20 held by the T&T Energy Ministry, saying T&T had a reserves replacement ratio in 2018 greater than 100 percent. *The Trinidad & Tobago Guardian*, *Trinidad & Tobago Newsday*, *Trinidad Express* and other publishers in the country reported on the press conference.

Through a press release, Acuña also confirmed the Supreme Petroleum Council announcement on Nov. 4 that the Abu Dhabi National Oil Company's (ADNOC) conventional oil and gas reserves base increased 7 billion barrels of oil and 58 Tcf of gas.

T&T: No other report is more important

As published by the *Guardian*, T&T Energy Minister **Franklin Khan** said, "The Ryder Scott Report is probably the most important report that is presented in the country annually because of its importance for the country's economic future. There is no other report produced for this country that is more important than this."

He added, "In a very real sense, this country's future is largely dependent on what the Ryder Scott report says."

Acuña confirmed that gas production for 2018 increased to almost 1.3 Tcf with the "lion's share" of the increase at 61 percent coming from BP Trinidad and Tobago.

Although proved reserves stayed relatively the same year over year, proved plus probable reserves increased 5.6 percent. Oil and gas companies typically build business cases for new field projects on 2P estimates.

UAE leapfrogging

With the updated reserves estimates, the UAE moved up in global rankings of countries — from seventh largest reserves in the world to sixth, said the Minister of State **Sultan Ahmed Al Jaber**. ADNOC said it plans to continue to increase production in the UAE to 4 million BOPD in 2020 and 5 million B/D in 2030, in part, through stakes awarded to international oil companies.

Ryder Scott designed and installed a corporate reserves management system (RMS) for ADNOC last year that helps the company analyze its various potential and existing concessions with IOCs.

The RMS combines and integrates processes, software and personnel to assist the company in tracking changes in reserves quantifications and classifications and making decisions on its property portfolio.

Acuña said, "After we set up the RMS, we performed due diligence to update our knowledge of the reservoirs and assess proposed changes to the property portfolio."

Over almost two decades of service, Ryder Scott has gained detailed insights into the geology and well performance of UAE oil and gas reservoirs.

Acuña points to T&T gas activity on an energy map of the Caribbean during his presentation at a press conference Nov. 20 in Port of Spain. Photo courtesy of Trinidad & Tobago Guardian newspaper and Nicole Drayton, photographer.



New business development manager named



Pamela Sabo

Pamela Sabo is the new business development and sales manager. Former business development manager **Mike Wysatta** is public relations manager.

Sabo has worked at Ryder Scott 18 years as a business development coordinator, simulation and engineering technician and analyst.

"Over the years, Pamela has demonstrated her ability to perform well under pressure and her desire to move the company forward in terms of workload, quality and reputation," said **Dean Rietz**, CEO.

Wysatta, business development manager for 22 years, will continue to manage external communications, including conceiving, writing and publishing *Reservoir Solutions*, also going into its 22nd year.

To contact Sabo, please send an email to pamela_sabo@ryderscott.com.



Mike Wysatta

Average annual oil price tumbles \$10 a barrel

What a difference a year makes. A year ago, Reservoir Solutions newsletter published an article headline, "Average annual oil price for SEC reporting soars 28 percent." The latest headline is a different story.

The annual average prices for reporting year-end 2019 petroleum reserves to the U.S. Securities and Exchange Commission showed a decrease in the WTI Cushing crude oil benchmark price from \$65.56 per barrel to \$55.60, a 15 percent drop. The Henry Hub gas benchmark dropped 17 percent — from \$3.101 per MMBTU to \$2.577.

The more resilient Brent crude oil benchmark settled in at \$63.15, close to a 12 percent annual decline. Other benchmarks and information on using differentials are posted at www.ryderscott.com/wp-content/uploads/FDOM_Benchmark_Prices.pdf.

The prices are based on the unweighted, arithmetic average of the first-day-of-the-month price for each month in the calendar year. E-mail inquiries to fred_ziehe@ryderscott.com.

Price history of benchmark oil and gas in U.S. dollars



Published, monthly-average, cash market prices for WTI crude at Cushing (NYMEX), Brent crude and Henry Hub and AECO gas.

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Interactive sections, new freeware, improved navigation and graphics**

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Reservoir simulation is the answer

Lee said how to determine spacing and proper fracture length is not obvious and requires careful economic analysis.

"The only way I now of currently, at least on a design basis, is to model what we think is likely to happen using calibrated history-matched reservoir simulation for various well-spacing schemes and fracture lengths. With that, come up with the

basis for the economic analysis and appropriate well spacing."

Editor's Note: Lee's presentation, "Wall Street is Angry: What Can We Do about It," summarizes various approaches to production forecasts with technical and analytical detail, acknowledgements and 14 charts/graphs. It is posted at the following web address: www.ryderscott.com/wp-content/uploads/RSC_Hou_Conf_2019_02_Lee.pdf. Both SPE papers referenced in this article are available for purchase at onepetro.com.

Publisher's Statement

Reservoir Solutions newsletter is published quarterly by Ryder Scott Co. LP. Established in 1937, the reservoir evaluation consulting firm performs hundreds of oil and gas reserves studies a year. Ryder Scott multi-disciplinary studies incorporate geophysics, petrophysics, geology, petroleum engineering, reservoir simulation and economics. With 116 employees, including 76 engineers and geoscientists, Ryder Scott has the capability to complete the largest, most complex reservoir-evaluation projects in a timely manner.

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