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Produced Water

Practical Guidelines for Application of Natural Resource Valuation Concepts for Remediation of Produced Water Impacts on Groundwater

This study provides practical guidelines to develop groundwater remediation strategies that protect human health and the environment, in balance with considerations of the economic viability and conservation of the natural resource. Under many regulatory systems, groundwater remedies are selected with a preference for contaminant removal, combined with the assumption that the groundwater, regardless of its quality or use, will be used as a future source of drinking water. This approach provides a large margin of safety for protection of human health, but can result in damage to the groundwater resource itself and the other natural resources that may be consumed in the remediation effort. To achieve health protection goals in a sustainable manner, in addition to consideration of health protection goals, groundwater remediation alternatives can be evaluated in terms of the associated capital and resource consumption relative to the value of the lost service. Restoration methods whose costs are greater than the replacement value of the lost service will fail to meet sustainability objectives because they consume greater value than they restore. In our study, we provide practical steps for the use of groundwater resource valuation procedures to characterize beneficial use of the resource and evaluate the relative benefits of a lower-intensity, longer-term remedy (e.g., monitored natural attenuation) vs. a higher-intensity, shorter-term remedy (e.g., groundwater pumping and treatment) on a site-specific basis. For a brackish groundwater unit that is not a current drinking water supply but is considered a reserve supply for possible future use, the cost of active pumping and treatment to restore the groundwater unit could greatly exceed its replacement value. In such case, natural attenuation may serve as a more sustainable alternative to protect potential future users, at costs that are more commensurate with the lost value.

Mark Hemingway | GSI Environmental, Inc.

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The Water Challenge Program Pilot – Helping Companies Advance Water Management Strategies

The Water Challenge (WC) Program was created recognizing that continuous improvement is not only feasible, but also essential for both operational and environmental sustainability. The WC Program structure supports technical and operative water management strategies aimed to reduce fresh water usage, increase produced water recycling/reuse in operations, and foster transparent water management reporting. By advancing these strategies (also known as most applicable practices [MAPs]) and identifying opportunities to continuously improve operational performance, companies can increase shareholder value, enhance products/services for stakeholders and demonstrate sustainable water management commitments. Operators participate in the Water Challenge (WC) Program by implementing and transparently reporting water management strategies the company knows to be most effective/applicable.

The Environmentally Friendly Drilling Systems (EFD) Program, managed by HARC, works with industry, academia, regulators, environmental organizations and other stakeholders to provide unbiased science addressing environmental/societal aspects associated with petroleum drilling and production operations. A pilot of the Water Challenge has been initiated in the Permian Basin with the objective to identify improvements that could be made, provide feedback from industry and state regulators on the structure and to begin recruiting participants for the Water Challenge when it is rolled out.

The presentation will outline the Water Challenge and discuss how others may become involved.

Andra Wilcox | Research Scientist, HARC Energy Production | HARC - Environmentally Friendly Drilling (EFD) Program

Andra Wilcox, MSc, PMP, is a Research Scientist at HARC (Energy Production), with the Environmentally Friendly Drilling Systems (EFD) Program. The EFD program works with industry, academia, national laboratories and environmental organizations, where the objective is to provide unbiased science to address environmental/societal issues associated with O&G development. Andra engages regional partners to address regional issues to fit local needs. She serves as Project Manager for the EFD Virtual Site, an online interactive workforce development tool using gaming technology to provide education/outreach, and The Water Challenge Program, working with the O&G industry to address water management and conservation aspects.

Permian & Anadarko Basin Produced Water Recycling: Keys to Success

Demand for recycling of produced water in the Permian & Anadarko Basin are expanding. Although 2017 hasn't necessarily been a drought year, some areas remain short on available water. Moreover, the considerations that producers must account for is vastly expanded over prior years. Issues such as Induced Seismicity, limited disposal zones for Class II wells, water availability, costs for fresh water, environmental concerns, and more are all expanding interest in produced water recycling! However, there are a multitude of options available that can be used for recycling and many companies have spent years vast amounts of money trying to test or evaluate various technologies. This paper discusses a very basic and successful approach to water recycling in some key development areas of the mid-continent and associated keys to success. For instance, Class II Disposal Wells can play a critical role in making a recycling project successful.

Dan Arthur | President/Chief Engineer | ALL Consulting

Mr. Arthur is a registered professional petroleum engineer in 33 states specializing in fossil energy, planning/engineering analysis and environmental/regulatory issues. He has more than 30 years of diverse experience that includes work in industry, government and consulting. Mr. Arthur is a founding member of ALL Consulting and has served as the company's President and Chief Engineer since its inception in 1999.

Additional Authors

Mark Faucher (ALL Consulting)
Steve Tipton (Senior Engineer, ALL Consulting)

Stepwise Progress to Alternate Uses of Produced Water in New Mexico

New Mexico is subject to frequent droughts. Over the last 117 years, 65 years have had below- average rainfall in the state. Alternate sources of water, including produced water, thus attract interest, particularly in the southeast and northwest oil- and gas-producing regions. I will highlight recent research studies and state regulatory efforts to improve the potential of using produced water both in and outside of the oil and gas industry. Transportation, treatment, and geospatial information databases play an important role in determining feasibility of use. Modeling efforts to help calculate costs and to match correct treatment methods with the water quality are ongoing. Evaluation of state water rights law indicates that produced water is not subject to a right, increasing the feasibility of use. The largest barriers to use appear to be distance from source to point of use, feasibility of treating highly saline waters, and the cost to treat. Another barrier is the cost to dispose of wastes associated with treatment and the location of waste disposal. Social factors that must be addressed include overcoming resistance to using a treated waste material, and determining who will pay for the underlying infrastructure investments. A review of available models that can calculate the costs to treat and transport produced water found four models that were feasible to use with some limitations. One of the four met AACEI level 5 cost estimation criteria and was up-to-date for coalbed methane produced waters only.

Enid Sullivan Graham | Research Professor | University of New Mexico

Dr. Sullivan Graham is a Research Professor in the Civil Engineering Department, Center for Water and the Environment, at the University of New Mexico. Prior to this she was a scientist in the Chemistry Division at Los Alamos National Laboratory. She is a hydrogeologist and geochemist with 30 years of experience in environmental chemistry studies. She studies produced water chemistry, treatment, and regulation. Dr. Sullivan Graham was a science advisor to Secretary David Martin of the New Mexico Energy, Minerals, and Natural Resources Department from 2013-2016. She is a certified professional geologist, and earned her PhD in Earth and Environmental Science from New Mexico Tech.

From Produced Water to Fresh Water - Technologies and Challenges

Treating produced water to a quality where it can be discharged back into the environment is not a new concept. Historically, particularly west of the 98th Meridian, certain produced waters, particularly those from unconventional coal bed methane (CBM) production, have been treated for beneficial discharge for agriculture or wildlife. Additionally, there have been several recent studies where produced water treatment to allow for irrigation of salt tolerant range grasses and non-consumable crops such as cotton have been investigated. East of the 98th Meridian, there are known discharges of treated produced water that do occur with proper State and Federal permitting. Where treated produced water has been permitted for some beneficial discharge purpose, there is a requirement for monitoring of dozens of water quality characteristics to insure that contamination or pollution is not taking place. With this in mind, there are conversations currently underway regarding how many potential constituents of concern may actually be in produced water, whether it is possible to fully remove all of the constituents of concern and are we sufficiently testing for enough compounds to know the treated water is fully suitable for discharge? This presentation will cover common naturally present organic and inorganic compounds found in most produced waters along with manmade chemicals that may be added during the completion or production phases. Focus will then be on many of the technologies available today and a discussion of what contaminants they would be expected to remove. Lastly, the talk will focus on known gaps in conformational data with an eye to future analytical work.

Rick McCurdy | Manager – Corrosion, Chemicals & Water | Chesapeake Energy Corporation

Rick currently leads the team that oversees Chesapeake's flow assurance and asset integrity programs. In addition to serving as a subject matter expert in those fields, he serves in the same role for completion additives and is one of the primary architects of Chesapeake's Industry-leading GreenFrac® program that focuses on environmentally friendly hydraulic fracturing additives. Rick is also a corporate advisor on produced water treatment and use, the use of alternative water sources for hydraulic fracturing and is a principal of Chesapeake's initiative championing beneficial use of produced water – AquaRenew®. During his career, Rick has worked with corrosion, chemical and water issues from the North Slope of Alaska to the Gulf of Mexico and from offshore California to the Marcellus Shale in the northeast. Rick is an active member of the Society of Petroleum Engineers, NACE International and Mensa International. He served as a technical expert during the US EPA workshops on hydraulic fracturing and has presented to the National Academy of Sciences, the Government Accountability Office and the Department of Energy regarding water use in the Energy Sector. Rick has an AAS degree in Petroleum Technology.

Pozzolanic Cement, Road Building, and Other Produced Water Reuse Alternatives

This presentation will explore alternative reuse options for oil and gas produced water, particularly low-salinity produced water in the STACK/SCOOP, that bypass the need for more expensive desalination processes. The presentation will explore two examples in Oklahoma in which produced water volumes are co-located with available mineral deposits: mixing with volcanic ash for pozzolanic cement production, and with gypsum for road and drilling pad construction. The needed investment and expected returns will be examined in detail.

Michael Ford |Economist | Bureau of Land Management

Michael Ford is exploring less energy-intensive alternative reuse options that can convert oil and gas produced water management from an operational challenge for operators and communities into an asset that can help relieve the burden on freshwater availability.

Michael is pursuing this work as a personal project. He also works full-time as an Economist in Washington, D.C. with the Bureau of Land Management's Office of Energy, Minerals, and Realty Management. Prior to this, Michael worked as an Economist with the U.S. Energy Information Administration, and the Maryland Department of Budget and Management. In his free time, Michael enjoys biking, playing soccer, and performing standup comedy.

Regulatory View of Produced Water: Increasing Optionality

Increasingly, operators are being asked whether the company is willing to keep produced water at the surface for another beneficial use. Operators are often willing to do so if the cost, risk and liability are addressed. The current regulatory regime can pose barriers to providing water for other beneficial uses. This presentation will lay out a simple overview of and options to address the challenges.

Jill Cooper | Director Environment, Audit and Reporting | Anadarko Petroleum Corporation

Jill Cooper is a Corporate HSE Director of Environment, Audit, Data, Reporting & Advocacy for Anadarko Petroleum Corporation and works on global health, safety, and environmental matters for the company. She received her MBA in International Business at Thunderbird School of Global Management and continued on to receive her JD in Environmental Law at the University of Colorado Law School (1996). She has since then held several positions including the Senior Advisor to the Executive Director on environmental matters, Director of the Sustainability Division and Legal Administrator for the Air Pollution Control Division at the Colorado Department of Public Health & Environment.

Aquifer Storage & Recovery

An Aquifer Storage and Recovery System to Preserve and Rehabilitate Native Groundwater in Hastings, Nebraska

The conventional method of an Aquifer Storage and Recovery (ASR) process used to replenish and store ground water resources for later beneficial use has been slightly modified to increase and rehabilitate the quality of the native ground water in the Platte River Floodplain of south-central Nebraska. A co-occurrence of nitrate and uranium contamination within the regional alluvial aquifer has been documented as far west as the Platte River, and is likely the result of urban and rural fertilizer use accelerated by irrigation. As an effort to control and amend the high levels of these contaminants, the City of Hastings Utilities has designed an ASR project to supply the City of Hastings, NE, Village of Trumbull, NE and Hastings wholesale customers with a sustainable supply of potable water. The Hastings Utilities ASR project utilizes a number of components: local and regional nitrate management planning, a dual pumping technique (DPT), focused water treatment, irrigation reuse and management, and blending and storage. Five ASR wells are authorized in the pending Hastings ASR Class V UIC permit, along with the proposed DPT will be employed in order to more efficiently treat contaminated ground water, reducing capital and operating expenses. Nitrate contaminant levels are more concentrated in the upper aquifer and will be targeted by the DPT and focused water treatment system, while water from the lower aquifer will be able to bypass the main treatment system if contaminant levels are low enough. Treated water will be blended with lower aquifer water and stored until injection, which will occur as needed up-gradient of the Hastings Utilities municipal water supply wells. The projected time of travel from the Hastings Utilities ASR wells to the closest municipal water supply wells is approximately six months.

Amanda Jones | Underground Injection Control/Mineral Exploration Coordinator | Nebraska Department of Environmental Quality

Amanda Jones is the Underground Injection Control (UIC) program and Mineral Exploration (ME) program coordinator for the State of Nebraska Department of Environmental Quality (NDEQ). She received her B.S. in Geology from the University of Nebraska – Lincoln in Spring 2015, and anticipates completion of an M.S. in Earth and Atmospheric Sciences from the University of Nebraska – Lincoln in Spring 2018. She has been with the NDEQ full-time since May 2016, and held the position of UIC/ME coordinator since April 2017.

ASR – Enhancing the Equus Beds Aquifer; 2 Billion Gallons and Counting

Driven by a critical projected water shortage, the City of Wichita has executed a bold project to protect and replenish the Equus Beds Aquifer, a crucial component of the City's future water supply. The ever-growing demand on the storage in the aquifer from local municipalities and agricultural users continues to exceed the system's natural recharge rate, causing substantial aquifer depletion, compounded by an impending threat of chloride contamination. As the first Aquifer Storage & Recovery (ASR) project in Kansas, City officials and key stakeholders have successfully combined integrated water supply planning and technical innovation on an unprecedented scale.

The unique design of the City's ASR project allows this system to be powered up and shut off at a moment's notice. The advanced ASR water treatment plant cleans water to drinking water standards and is able to respond to rapidly changing river conditions such as flow and water quality to ensure the maximum capture of transient river flows. This system also boasts the world's largest advanced oxidation system — six times larger than anything of its kind — allowing the system to eliminate surface water contaminants like atrazine.

The project was nominated for the Global Water Intelligence Water Project of the Year at the 2015 Global Water Summit, which recognized the most significant achievements in the international water industry. This local and internationally significant ASR project has recharged nearly 2 billion gallons of water to date, enhancing and securing natural aquifer supply for future generations.

Brian Meier | Burns & McDonnell | Associate Environmental Engineer

Class V UIC Forum & Discussion

And Now for Something Completely Different: Unusual Class V Wells in Texas

The predominance of the 48,000+ Class V injection wells in Texas are low-tech wells associated with aquifer remediation, closed-loop heat pumps, sanitary wastewater disposal, and stormwater drainage. A few, however, are deep, high-tech and/or large-volume wells, more closely resembling Class I injection wells in aspects of construction, operation, and closure. Information is provided for select wells installed for purposes of disposal of drinking water treatment residuals, experimentation on CO2 sequestration, testing for industrial disposal, and large-volume aquifer storage and recovery. Details covering authorization application requirements, well construction, testing and monitoring, operational reporting, financial assurance for well closure, and aquifer exemption are included in this presentation.

Lorrie Council |Manager, UIC Permits Section | Texas Commission on Environmental Quality

Lorrie Council manages the Texas Commission on Environmental Quality's UIC Permits Section, specifically Class I and V injection wells. Her work experience includes injection wells, coastal erosion response, environmental assessment, groundwater quality assessment and remediation, and program and project management. She worked 20 years as an environmental consultant and 16 years for the state of Texas. Ms. Council is a licensed professional geologist in Texas and Arizona. She earned a B.S. in Geology from the University of Oklahoma.

Class II & VI UIC Forum & Discussion

Class II SWD Disposal Well Issues: Myth versus Reality…and Impacts we can Anticipate (and Avoid).

This covers produced water, seismic, and formation pressurization for UIC trends. Our pressure analysis study is now complete so we can include that as well! Laura Capper/Allen Blanchard discuss findings from their firms' report on Disposal Well Practices and Operational Risk Management in Upstream Oil and Gas. Topics covered include the root causes of induced seismic activity, the "top ten" contributing factors for seismicity to occur from UIC programs, regional trends on Class II UIC wells pressuring up, relationships between injection volumes and pressures, complexities in interpreting public data trends, regulatory permitting trends, and life cycle / best practices for operators wishing to mitigate disposal well risk and assure supply continuity.

Laura Capper | President | EnergyMakers Advisory Group

Laura Capper is a founder and CEO of CAP Resources and a principal in EnergyMakers Advisory Group.

She specializes in oilfield-related market assessment, strategy development for emerging market issues, technology commercialization, operations planning, and due diligence / transaction support services for oil and gas technology and service companies and their investors. Together, her team has serviced over 600 clients and contributed to the development of over $4.0 Billion in value associated with new venture launches as well as support for mergers, acquisitions and investment activity with oil and gas companies, oilfield service companies, and their investors. The firm's primary focus is related to unconventional exploration and production trends and practices, water management and treatment technologies, disposal well and seismicity risk management, and environmental and waste handling practices in the oilfield, among other areas.

Laura and her partners have authored a series of in-depth reports tracking the state of Water Management and investment opportunities in U.S. and World unconventional shale plays, with 2014 reports published by IHS. CAP Resources has helped assess some 400+ providers of water treatment technologies, numerous water management software platforms, logistics management approaches and fixed facilities, and a breadth of proprietary technology providers. In concert with sister company EnergyMakers' Advisory Group, in 2017 the firms will be jointly publishing a report on "Taking Stock of U.S. UIC Formation Health and potential Risk Factors associated with US Class II Disposal Wells: Best Practices and Mitigation Strategies".

Laura is a B.S.E.E. from Rice University with minors in Bioengineering and Computer Science, and currently serves as Director of 5 privately held companies, and is a Director or advisor to 4 non-profits tasked with advancing technology development and access to education.

Reinvigorating Geologic Sequestration

When EPA promulgated the Class VI UIC Program for geologic sequestration in December 2010, EPA committed to reviewing the regulations and their implementation after six years. The history of pursuing geologic sequestration through research, development and demonstration over the years -- primarily through pilot and demonstration projects -- has provided a number of valuable lessons on steps that can be taken to reinvigorate the development of carbon capture and storage (CCS) technologies. This presentation will review that history and provide a number of specific recommendations for modifications and improvements in EPA policies and requirements to foster more effectively the further development of CCS, without which the future of fossil fuel use will be impaired.

Robert Van Voorhees | Executive Director | Carbon Sequestration Council

Bob Van Voorhees has worked for many years in the areas of energy and environmental regulation. Over the past twenty-five years he has represented individual companies in the chemical, petroleum, commercial waste management, uranium recovery and other industries in dealing with regulatory and legislative issues relating to underground injection control (UIC). The Ground Water Protection Council (GWPC) presented its Award of Excellence in Ground Water Protection to him in 1996 for his outstanding contribution in the development of sound national regulations for underground injection control. Currently, he serves as Executive Director to the Carbon Sequestration Council and the Underground Injection Technology Council. He is helping companies address issues relating to geologic sequestration of carbon dioxide, permitting of experimental injection wells for this and other purposes, and addressing issues relating to oil and gas production using hydraulic fracturing and other advancing technologies. He has represented clients in dealing with various aspects of permitting, compliance and enforcement for each of the current six classes of injection wells under the UIC program before both state and federal agencies.

Class III UIC Forum & Discussion

Underground Storage of Natural Gas Liquids in Ohio's Underground Salts

With development of the Marcellus and Utica Shales in Appalachia combined with demand for various NGLs, storage has become a critical issue. The State of Ohio lies directly in the center of attention relative to underground storage because of its location and the presence of deep underground salt deposits. However, the process to get a facility and the associated storage wells in operation requires an abundance of considerations and regulatory hurdles. Permitting alone requires coordination with multiple agencies, development of solutions for handling under saturated brine, potentially productive hydrocarbon reservoirs both above and below the salt, and more. This paper will cover both technical and regulatory considerations.

Tom Tomastik | Senior Geologist & Regulatory Specialist | ALL Consulting, LLC

Mr. Tomastik is a professional geologist with over 33 years of diverse expertise and experience in the energy sector, government, and consulting. He has been involved in the planning, drilling, permitting and development of oil and gas and Class II saltwater disposal wells, stray gas investigations, groundwater contamination cases, induced seismicity, seismic monitoring and installation, and expert witness testimony.

Additional Authors

Dan Arthur | President/Chief Engineer | ALL Consulting, LLC

Implementing Cooperative Federalism in the UIC Program

President Trump has announced a program to implement cooperative federalism by reassessing regulatory approaches at the federal level, including the way that federal agencies interact with state agencies through federal-state partnership programs. The President issued a series of executive orders that explain the approach and provide directives and procedures for federal agencies to follow. The Executive Orders reiterate "the national interest to promote clean and safe development of our Nation's vast energy resources, while at the same time avoiding regulatory burdens that unnecessarily encumber energy production, constrain economic growth, and prevent job creation." They also direct agencies to obtain "input and other assistance, as permitted by law, from entities significantly affected by Federal regulations, including State, local, and tribal governments, small businesses, consumers, non-governmental organizations, and trade associations." One primary objective is to avoid duplication of state and federal activities. The UIC Program has a long history of effective state and federal cooperation, obtaining effective stakeholder input and achieving effective resolution of many regulatory challenges. This presentation will identify some specific opportunities to improve cooperative federalism by applying both the principles announced by the Trump Administration and historical precedents within the UIC Program to solve issues that have been facing state and federal officials in some cases for a number of years.

Robert Van Voorhees | Executive Director | Bryan Cave LLP

Bob Van Voorhees has worked for many years in the areas of energy and environmental regulation. Over the past twenty-five years he has represented individual companies in the chemical, petroleum, commercial waste management, uranium recovery and other industries in dealing with regulatory and legislative issues relating to underground injection control (UIC). The Ground Water Protection Council (GWPC) presented its Award of Excellence in Ground Water Protection to him in 1996 for his outstanding contribution in the development of sound national regulations for underground injection control. Currently, he serves as Executive Director to the Carbon Sequestration Council and the Underground Injection Technology Council. He is helping companies address issues relating to geologic sequestration of carbon dioxide, permitting of experimental injection wells for this and other purposes, and addressing issues relating to oil and gas production using hydraulic fracturing and other advancing technologies. He has represented clients in dealing with various aspects of permitting, compliance and enforcement for each of the current six classes of injection wells under the UIC program before both state and federal agencies.

General Session: Emergency Response to Weather Related Events

Environmental Response & Concerns from the 2017 Hurricane Season

Dr. Bryan Shaw | Chairman | Texas Commission on Environmental Quality

Dr. Bryan W. Shaw is an associate professor in the Biological and Agricultural Engineering Department of Texas A&M University (TAMU) with many of his courses focused on air pollution engineering. The majority of his research at TAMU concentrates on air pollution, air pollution abatement, dispersion model development, and emission factor development. Dr. Shaw was formerly associate director of the Center for Agricultural Air Quality Engineering and Science, and served as Acting Lead Scientist for Air Quality and Special Assistant to the Chief of the U.S. Department of Agriculture Natural Resources Conservation Service.

Dr. Shaw also served as a member of the U.S. Environmental Protection Agency (EPA) Science Advisory Board (SAB) Committee on Integrated Nitrogen, the EPA SAB Environmental Engineering Committee, and the Ad Hoc Panel for review of EPA's Risk and Technology Review Assessment Plan. Additionally, he is a member of the U.S. Department of Agriculture–Agricultural Air Quality Task Force. Since his appointment to the TCEQ, Dr. Shaw has served on the Texas Environmental Flows Advisory Group and as chair of the Texas Advisory Panel on Federal Environmental Regulations. Shaw also is a member of the Environmental Council of the States, serving on the Executive Committee as the Air Committee Chair.

Dr. Shaw received a bachelor's and master's degree in agricultural engineering from TAMU and a doctorate degree in agricultural engineering from the University of Illinois at Urbana-Champaign. He is a licensed professional engineer (P.E.) in the State of Texas.

From Waste to Resource: A Changing Role for Storm Water

Extreme weather events can impact all infrastructure. Generally, the focus is on that which is seen (roads and bridges) and not water and wastewater infrastructure. However, when drinking water and wastewater services are impacted there can be not only health and environmental effects but also economic impacts.

Critical to reacting to flooding and other water infrastructure failure is planning. Rising flood waters, storm water runoff and snow melt can become contaminated through sanitary sewer overflows (both combined and separate), inundated industrial and municipal treatment facilities, everyday chemicals that are applied to landscaping, crops, roads and bridges, products or raw materials stored outside, etc. A proactive approach can reduce the impact that these flood waters have not only to surface and ground water quality and quantity but also to industry and oil and gas operations that rely on underground injection for disposal.

Predictions of continuing drought, increasing number and magnitude of significant weather events and the shifting of population is leading to new approaches to ensure water for the future for drinking, economic development and maintenance of way of life. A key step in moving toward becoming more water resilient is recognizing that storm water can be harnessed as a resource.

This presentation will focus on proactive steps states, communities and industries can take to lessen the impact of flooding, reduce the amount of contaminants reaching ground and surface water and even take advantage of storm water as a resource to augment ground water aquifers and protect wells. The role of green infrastructure and the use of "old" technology in a "new" way will be discussed.

Shellie Chard | Water Quality Division Director | Oklahoma Department of Environmental Quality

Shellie Chard obtained a Bachelor of Science Degree in Chemical Engineering and Biotechnology in 1992 from the University of Oklahoma. She has been the Division Director of the Water Quality Division of the Oklahoma Department of Environmental Quality since January 1, 2010 and has 25 years of experience in the drinking water and wastewater profession. Today she oversees all aspects of drinking water, wastewater and storm water for DEQ including permitting, compliance, enforcement, technical assistance, Drinking Water State Revolving Fund loan program and the operator certification training and licensing program.

In addition to her activities at DEQ, her professional activities include: serving on the Board of Directors for the Oklahoma Water Environment Association, the Executive Committee of the Ground Water Protection Council, as a Past-President of the Association of Clean Water Administrators, past Board member of the Association of Safe Drinking Water Administrators, and is a member of the Government Affairs Committee and the House of Delegates of the Water Environment Federation.

Seismic Activity & Responses

Evaluating the Efficacy of Wastewater Disposal Reductions in Oklahoma

In response to an unprecedented increase in seismicity throughout north-central Oklahoma, the Oklahoma Corporation Commission (OCC) has instituted voluntary wastewater injection reductions with narrow focus around certain regions in Oklahoma. In early 2017, the OCC announced broader mitigation for wastewater injection wells completed into the Arbuckle in the area of Oklahoma experiencing seismicity, with limits of 10,000 bbl/day in the north-central portion of the state and 15,000 bbl/day in western Oklahoma. The Oklahoma Geological Survey (OGS) monitors seismicity throughout the state utilizing permanent and temporary seismometers installed by OGS and other agencies, while maintaining an earthquake catalog. The catalog is complete down to M2.4 since mid-2014, despite the significant workload for a solely state-funded regional network. We test what effects these reductions have had on mitigating seismicity. We will present a detailed spatio-temporal analysis of seismicity and wastewater injection over the last few years and test what effects regulatory actions have had on seismicity. We will test the earthquake catalogs for any rate changes associated with the past targeted wastewater reductions and report on progress towards understanding the effect of the early 2017 reductions. The results of this study highlight the continued need for an expansion and densification of seismic monitoring throughout Oklahoma.

Jake Walter | State Seismologist | Oklahoma Geological Survey

Jake Walter was named the State Seismologist of Oklahoma in November 2016. He was previously a research associate at the Institute for Geophysics at the University of Texas at Austin. He has conducted research in Antarctica, Costa Rica, Solomon Islands, Greenland, Texas, and Alaska. Walter earned his BA in geology at the University of Colorado at Boulder and his PhD in Earth Sciences at the University of California, Santa Cruz.

Additional Authors

Kyle Murray | Hydrogeologist |Oklahoma Geological Survey
Jeremy Boak |Director | Oklahoma Geological Survey

2017 Review of UIC Risk Factors in Leading Onshore Oil and Gas Basins

Laura Capper discuss findings from her firms' report on Disposal Well Practices and Operational Risk Management in Upstream Oil and Gas. Topics covered include regional variances in seismic trends and induced seismicity causes; correlations between pressures, volumes, and seismicity; operational risk factors associated with UIC wells; regional trends on overpressured UIC formations and formation pressure increases, regional concerns about UIC injection into productive formations, complexities in interpreting public data, review of state regulatory responses, and hot topics in seismic research today.

Laura Capper | CEO | CAP Resources

Laura Capper is a founder and CEO of CAP Resources and a principal in EnergyMakers Advisory Group.

She specializes in oilfield-related market assessment, strategy development for emerging market issues, technology commercialization, operations planning, and due diligence / transaction support services for oil and gas technology and service companies and their investors. Together, her team has serviced over 600 clients and contributed to the development of over $4.0 Billion in value associated with new venture launches as well as support for mergers, acquisitions and investment activity with oil and gas companies, oilfield service companies, and their investors. The firm's primary focus is related to unconventional exploration and production trends and practices, water management and treatment technologies, disposal well and seismicity risk management, and environmental and waste handling practices in the oilfield, among other areas.

Patterns of Induced Seismicity in Central and Northwest Oklahoma

Oklahoma experienced on average 1.6 earthquakes of Magnitude 3 or greater (M3.0+) from the 1980s through 2008. Since then, seismicity increased to 903 M3.0+ earthquakes in 2015, then declined to 623 in 2016, and ~320 in 2017. >95% of these earthquakes occur over <20% of the area of Oklahoma. Seismic moment peaked in 2016, with three M5.0+ earthquakes, unprecedented in Oklahoma's recorded history. A recent issue of Seismological Research Letters highlights studies of the September 3, 2016 M5.8 Pawnee earthquake, the largest recorded in Oklahoma.

Rising seismicity is attributed to increased injection of saline formation water into underpressured and permeable Arbuckle Group sedimentary rocks, which lie directly on Precambrian crystalline basement. This water came primarily from high water cut wells in the Hunton and Mississippian Limestone plays, with earthquake pulses beginning in 2009 and 2013, respectively. Pressure communication from the Arbuckle Group to faults in the basement is interpreted to have reduced stress on the faults. Stress reduction allows faults aligned favorably with respect to the regional stress field (SHMax = N 85° E) to generate earthquakes. Poroelastic effects have recently been interpreted to play a role as well.

Reduction in earthquake frequency appears to result from a 1.4 million barrel per day decrease in injection in ~700 Arbuckle disposal wells in the area. These reductions occurred in part due to 1) production decline from/shutting in of wells because of the significant oil price drop in 2014 - 2015, and 2) directives of the Oklahoma Corporation Commission following a position paper by the Oklahoma Geological Survey attributing seismicity to injection. This talk will discuss the evolution of Oklahoma seismicity, regulatory actions taken to reduce it, and investigations of earthquakes outside the main Area of Interest apparently in location and time with oil and gas well completion activity.

Dr. Jeremy Boak | Director | Oklahoma Geological Survey

Dr. Jeremy Boak started as the Director of the Oklahoma Geological Survey in July 2015. Before coming to Oklahoma, he was a research center director at the Colorado School of Mines, a project manager at Los Alamos National Laboratory and the U. S. Department of Energy (DOE), and an exploration geologist at ARCO Oil & Gas. He has Bachelors, Masters, and Doctoral degrees from Harvard University, and a Masters from the University of Washington, all in Geological Sciences.

Induced Seismicity Management for Operators

As an operator of multiple hydrocarbon storage facilities in seismically active regions of France for over 50 years, Geostock has developed a process and set of tools to identify, assess, and mitigate the risk of induced seismicity during fluid injection operations. This presentation will walk through the 3-phase modular approach that progressively adapts to the evolving requirements of each location.

Phase 1 - Risk Analysis and Data Evaluation - In this phase, potential risks associated with induced seismicity are identified and assessed. The initial evaluation is performed using currently available data:

- Seismicity data: Existing local, regional, national and international earthquake catalogues
- Geological and structural mapping
- Reservoir dynamics

Based upon the initial assessment, additional data collection and evaluation may be necessary. This one-off analysis can be tailored to include deterministic and probabilistic analyses depending on the specific nature of each case.

Phase 2 – Real-Time Monitoring and Early Warning Systems - If potential risks are identified in Phase 1, a real-time monitoring and early warning system is developed for each specific case. This phase also includes the development of techniques to estimate operational and seismic parameters (injection/withdrawal rates, fluid pressures, mean magnitudes), which are designed to prevent inducing significant seismic activity. Activities during this phase consists of:

- Real-time data acquisition and processing
- Real-time state-of-the-art earthquake science analyses of the data
- The development of a 4-level traffic light warning system
- Real-time safe operation parameter optimization
- Periodic reporting of events detected and network performance

Phase 3 – Specific Studies and In-Depth Causative Analyses - In the situations where significant and frequent induced seismicity is a concern, provided there are enough observations of the structure and dynamics of the system, an in-depth analysis combining geomechanical flow simulators with models of fault dynamics could give insight into strategies to mitigate induced seismicity.

Mikel Diez | Geophysics Consultant | Geostock

Mikel Diez is a geologist and geophysicist conducting research at the University of Bristol, and working as a scientific consultant for Geostock, France. The theme of Mikel's research is the deformation of multiphase rocks undergoing stress and damage driven compaction and fluid segregation in the crust. Such theme is important in both basic and applied science (industry and technology): in basic science it underpins the formation of

planetary crust, dynamics of volcanic/magmatic systems and tectonics. And in industry and technology it is essential in the oil and gas industry, for example, from exploration to production, and associated seismicity.

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Data Mining the Known Unknowns of Oklahoma's Class II UIC Data to Improve Injection Induced Seismicity Studies

Background seismicity in Oklahoma, for 2008 and the prior historical record, equates to about two M3.0+ earthquakes per annum statewide. From 2009 through 2017, the Oklahoma Geological Survey seismic network recorded between 20 (2009) and 903 (2015) M3.0+ earthquakes per annum. The number of M3.0+ earthquakes occurring in Oklahoma represents a known known. Numerous scientific studies have correlated saltwater disposal (SWD) rates and seismicity in Oklahoma because SWD rates increased from about 2.24 million barrels per day (MMBPD) in Oct 2009 to more than 4.54 MMBPD in Oct 2014. However, investigations that rely on SWD data have numerous fundamental flaws, Rumsfeldian known unknowns and unknown unknowns. These include the accuracy of the SWD volumes and the completeness of the SWD volume data. Our study attempts to define the known unknowns for SWD volumes from 2009 to 2016 period by cross-validating Oklahoma Corporation Commission (OCC) compiled records with individual electronic Annual Fluid Injection Reports (1012A Forms). We also use database methods to detect outliers and optical character recognition (OCR) to identify typographical or human errors on 1012A Forms, specifically targeting incorrect reports of barrels per day (BPD) rather than the 1012A required barrel per month (BPM). For some SWD wells, rates compiled by OCC are about one-thirtieth of the actual rate because of this common error. However, the unknown unknown is how much do the reported rates vary from actual SWD rates each year? Preliminary results indicate that records for recent years (2015 and 2016) are very accurate (<5% underestimated rates), but rates for former years (2009 to 2012) could be underestimated by as much as 20%. Our project goal is to produce a complete and accurate SWD database for 2009 to 2016, but also to fill in the unknown unknowns for years prior to 2009.

Dr. Kyle Murray | Hydrogeologist | Oklahoma Geological Survey

Dr. Kyle E. Murray earned a PhD in Geological Engineering from Colorado School of Mines in 2003. He is currently employed as a Hydrogeologist for the Oklahoma Geological Survey (OGS), which is part of the University of Oklahoma (OU) Mewbourne College of Earth and Energy. His research team investigates physical and chemical properties of geologic materials that store and produce fluids, and conducts regional-scale studies of water, earth, and environmental resources. Because of recent seismic activity in Oklahoma, Dr. Murray is partnering with other geoscientists to understand relationships between geologic factors, resource management, and seismicity.

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Forecasting Injection-Induced Earthquake Hazards in Oklahoma and Kansas

Traditional earthquake hazard maps rely on the pre-condition of long-term stationarity of seismicity related to large-scale tectonic processes. Application of these methods to induced seismicity is inherently problematic since injection rates and earthquake rates can vary markedly in space and time. We present a novel physics-based method to forecast regional injection-induced earthquake hazards in north-central Oklahoma and southern Kansas. Our model incorporates spatial and temporal variations of saltwater injection rates, and a regional hydrologic model to predict injection-induced pressure changes at seismogenic depth. Due to decreasing injection rates since mid-2015, pressure increases at depth are slowing down such that fewer pre-existing faults are expected to be pushed beyond stability. Considering the predicted pressure changes and regional variations of number and tectonic stress state of pre-existing basement faults, we present predictive maps of magnitude exceedance probabilities. In 2015 and 2016 the probability of injection-induced earthquake damage ($M > 5$) was as high as 70±10%. Our model predicts that the injection rate reductions will have a delayed, but long-lasting mitigation effect on the seismic hazard. At the current level of saltwater injection, the earthquake hazard is expected to continuously decrease through 2017 and beyond. However, for 2017 (2018, 2019, 2020) our model still predicts a 45±4% (21±2%, 13±1%, 10±1%) probability of potentially damaging induced earthquakes. Our model can be used as a physics-based decision making tool to assess the effectiveness of past and potential future injection regulations in Oklahoma and Kansas.

Dr. Cornelius Langenbruch | Department of Geophysics | Stanford University

Cornelius Langenbruch is a geophysicist working in the department of geophysics at Stanford University. Dr. Langenbruch conducts research on induced and triggered seismicity, geomechanics, rock physics and statistical seismology. He is a postdoc funded by the Stanford Center for Induced and Triggered Seismicity (SCITS). In his current research project, he combines statistical and physical methods to characterize and forecast earthquake hazards induced by produced-water injection in Oklahoma and Kansas.

Additional Authors

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Class I UIC Forum & Discussion

How Several Common Factors Influence Injection Well Performance, Testing and Permitting: Density, Temperature, and Friction

Injection of fluids into the subsurface through a well requires a pressure gradient to drive flow. In the simplest terms, fluids find the path of least resistance and move from zones of high pressure to zones of low pressure in flowlines, wells and injection formations. A variety of common factors generate pressures and influence the resistance to movement that fluids encounter within injection systems. These factors are important in tubing as well as in the porous media. Some of these factors are inter-related and have effects that are not always obvious. Factors that affect well performance are relevant to well design and feasibility, well economics, well maintenance, permitting and compliance. Understanding how factors define well performance allows insight into these issues. There can be misconceptions about how these factors contribute to defining well performance. To optimize permitting and operations these factors should be understood and appropriately considered.

Many factors influence well performance and to address each in detail would exceed the allotted presentation time. Therefore, three of the most common and variable factors are discussed. This presentation provides an introduction to how wells work and more specifically how density, temperature and friction in well systems work, are inter-related, and how they influence well performance. Overviews of well systems are presented to show how understanding the resulting well performance changes that can occur due to changes in each factor can help with interpreting test results, verifying compliance and optimizing operations. Well systems and factors are described in terms and graphics that will help both technical and non-technical staff visualize the injection process. Some examples are presented to illustrate real-world impacts on regulatory requirements, permitting, petition compliance, and maintenance decisions. Practical observations about obtaining data that characterizes these factors and complications to look for are presented based on Class I operating experience.

Ken Cooper | Engineering Manager and Principal | Petrotek Engineering Corporation

Ken Cooper is a managing principal of Petrotek Engineering Corporation. He holds B.S. and M.S. degrees in Petroleum Engineering and is a registered professional engineer in numerous states. Prior to helping found Petrotek in 1993, he gained engineering experience working in the petroleum industry and for petroleum /uranium/injection well consultancies. Ken has 30 years of experience working with all classes of injection wells and specializes in investigating well feasibility, reservoir testing and simulation, well compliance and permitting, along with optimizing injection well operation and maintenance. Ken has given a variety of talks regarding subsurface injection, well testing, and the simulation of subsurface fluid flow over the years, is a GWREF board member and a member of the GWPC and the Society of Petroleum Engineers since the 1980s.

Additional Authors

Lewis Wandke, PE | Senior Engineer | Petrotek Engineering Corporation
Richard Pitts | Staff Engineer | Petrotek Engineering Corporation

Innovative Annulus Pressure Monitoring and Control Design for High Pressure Class I Wells with Depths in Excess of 10,000 Feet

High pressure injection of liquids can be challenging in Class I wells where depths exceed 10,000 feet and extreme temperature variations occur between injection and shut in conditions. Elevated downhole temperatures at these depths create a high temperature differential between the injectate and annular fluid resulting in significant swings of annulus pressure and surface seal pot volumes. One-way micro tubing leaks at joints have also occurred due to these conditions.

The injectate cools the annular fluid resulting in contraction of the annular liquid and lowering of the seal pot volume, which requires addition of fluid into the annulus. Once the wells are shut in, annular pressures rise as the annulus fluid is warmed by the native formation fluid, creating an increased pressure differential on the downhole components and increasing the seal pot volume and potentially creating high pressure situations in the annulus. In addition to the labor-intensive operation of having to add and remove liquid from the annular space, greater downhole pressure differentials may affect long-term integrity of the injection tubing and protective casing.

Maintenance of an annulus pressure that is less than the injection pressure, similar to the operation of more shallow Class I wells, is impractical under the operating scenario for deeper wells. It also creates the potential for fluid migration from the tubing into the annular space in the event of a leak. This presentation will focus on our design and implementation of an innovative high pressure annulus monitoring system that mitigates the presence of micro tubing leaks in joints, and pressure and temperature swings of the annulus.

Monte Markley | Vice President | SCS Engineers

Monte Markley obtained a Bachelor of Science degree from Lamar University and is licensed as a professional geologist in Kansas and Missouri. He holds a Vice President position in the Wichita office of SCS Engineers. Monte's project experience includes geologic isolation of fluids and compressed gasses, hydrogeological investigations, engineering geology evaluations related to salt caverns, regulatory compliance and permitting, groundwater investigations at superfund and RCRA facilities, and remedial system design.

Additional Authors

Stephanie Hill | Senior Project Manager | SCS Engineers

The Calculation of Injection Effects to Establish the Area of Review (AOR) for Class I Injection Wells

The calculation of injection effects to justify an Area of Review (AOR) for many types of injectors including Class I disposal wells is typically conducted to evaluate the impact of long-term injection on an injection interval, to ensure protection of any Underground Sources of Drinking Water (USDW), and to satisfy regulatory requirements. The AOR defines the lands surrounding a well where artificial penetrations must be identified and evaluated to assess the potential for vertical migration of fluid out of an injection zone and assess the need for potential corrective action. Specific properties of an injection interval and USDW, as well as operational timelines and injection rates are required as inputs.

This paper presents an introduction to the concept of AOR and a review of calculations and methods used to evaluate the reservoir pressure rise from injection that defines the zone of endangering influence (ZOEI), or cone of influence (COI) as defined in some state programs, as well as the evaluation of the area of the waste emplacement that is projected to be caused by the displacement of injection fluid into a permitted interval over the duration of well operation. An evaluation of critical pressure rise is also discussed that defines the allowable reservoir pressure rise from injection that is acceptable to ensure protection of overlying USDWs. An overview of these calculations is provided with simplified graphics to allow the visualization of these concepts. Regulatory requirements applicable to the determination of AOR according to the federal statutes and several state programs are also summarized. Examples illustrating the impacts of a range of reservoir parameters on AOR are also presented. In addition, a discussion regarding the evaluation of plugged artificial penetrations and a summary of how mud weight and plugs present in abandoned wells can impact the calculation of critical pressure is also provided.

Aaron Payne | Senior Hydrogeologist | Petrotek Engineering Corporation

Aaron Payne is a Senior Hydrogeologist at Petrotek Engineering Corporation in Littleton, Colorado. He holds a B.A. degree in Geology from Bowdoin College and an M.S. degree in Geology from the University of Wyoming and is a registered professional geologist in Wyoming, Kansas and other states. Prior to joining Petrotek in 2008, he gained geology experience working in the petroleum industry for a major wireline service company and for an environmental consulting firm.

Aaron has experience working with all classes of injection wells and specializes in characterizing formations and resources, investigating feasibility, permitting wells, and conducting reservoir/groundwater simulation studies to service the injection well, uranium mining and petroleum industries. Aaron is a member of the National Groundwater Association and the Wyoming Geological Association.

Additional Authors

Ken Cooper, PE | Engineering Manager | Petrotek Engineering Corporation

UIC Class I Regulatory Challenges and Opportunities

President Trump has signaled a theme of reassessing regulatory approaches at the federal level, including the way that federal agencies interact with state agencies through federal-state partnership programs. Executive Order 13771 of January 30, 2017 announced a policy of "prudent and financially responsible" expenditures "from both public and private sources," including consideration of "the governmental imposition of private expenditures required to comply with Federal regulations." EO 13771 also called for eliminating two prior regulations for every new regulation issued. Executive Order 13777 of February 24, 2017 announced a policy "to alleviate unnecessary regulatory burdens," and directed agencies to designate Regulatory Reform Officers (RROs) to "oversee the implementation of regulatory reform initiatives and policies to ensure that agencies effectively carry out regulatory reforms, consistent with applicable law." EO 13777 further directed agencies to obtain "input and other assistance, as permitted by law, from entities significantly affected by Federal regulations, including State, local, and tribal governments, small businesses, consumers, non-governmental organizations, and trade associations." Executive Order 13783 of March 28, 2017 announced "the national interest to promote clean and safe development of our Nation's vast energy resources, while at the same time avoiding regulatory burdens that unnecessarily encumber energy production, constrain economic growth, and prevent job creation." EO 13783 also announced a policy that "all agencies should take appropriate actions to promote clean air and clean water for the American people, while also respecting the proper roles of the Congress and the States concerning these matters in our constitutional republic." [Emphasis added.]

On April 13, 2017 EPA published a Federal Register notice "seeking input on regulations that may be appropriate for repeal, replacement, or modification" in accordance with EO 13777. 82 Fed. Reg. 17793. The Ground Water Protection Council (GWPC) and numerous other organizations submitted comments in response to that request, and GWPC has a long history of coordinating efforts among its state members, EPA and its regional offices, and other stakeholders to develop recommendations for effective regulatory revisions. Accordingly, this presentation highlights both new and longstanding recommendations for regulatory revisions that will improve the efficiency and effectiveness of the underground injection control (UIC) Program implemented through the federal-state partnership designed by the Safe Drinking Water Act (SDWA), under which state UIC programs are the principal vehicle for implementing national standards. The focus will be on potential improvements for Class I wells in the specific areas of identifying underground sources of drinking water and exempted aquifers, processing and approving no migration demonstrations that support exemptions for injecting hazardous wastes, reducing administrative burdens for the processing and approval of permits, permit modifications, monitoring, and reporting. Included are several specific recommendations for eliminating outdated and unnecessary regulations. The main challenge is always to achieve improvement while protecting USDWs from endangerment.

Robert Van Voorhees | Underground Injection Technology Council

Bob Van Voorhees has worked for many years in the areas of energy and environmental regulation. Over the past twenty-five years he has represented individual companies in the chemical, petroleum, commercial waste management, uranium recovery and other industries in dealing with regulatory and legislative issues relating to underground injection control (UIC). The Ground Water Protection Council (GWPC) presented its Award of Excellence in Ground Water Protection to him in 1996 for his outstanding contribution in the development of sound national regulations for underground injection control. Currently, he serves as Executive Director to the Carbon Sequestration Council and the Underground Injection Technology Council. He is helping companies address issues relating to geologic sequestration of carbon dioxide, permitting of experimental injection wells for this and other purposes, and addressing issues relating to oil and gas production using hydraulic fracturing and other advancing technologies. He has represented clients in dealing with various aspects of permitting, compliance and enforcement for each of the current six classes of injection wells under the UIC program before both state and federal agencies.

General Session: Slurry Injection

Injecting Oilfield Solids via Class II Disposal Wells

Managing solids generated as part of unconventional oil & gas activities has been a considerable challenge in every area of development. Although there are a variety of methods utilized, this objective of this paper is to present and discuss the use of Class II Disposal Wells for permanent underground placement of these oilfield wastes. The idea of injecting solids underground via Class II wells is not new and the practices has been utilized from the North Slope of Alaska to Texas. However, the practice is gaining renewed interest in a variety of areas. This paper will present details about the need for the practice, regulatory considerations and variations, and practice details used to safely operate these wells and assure that wastes remain in the permitted injection zone.

Dan Arthur | President/Chief Engineer | ALL Consulting, LLC

Mr. Arthur is a registered professional petroleum engineer in 33 states specializing in fossil energy, planning/engineering analysis and environmental/regulatory issues. He has more than 30 years of diverse experience that includes work in industry, government and consulting. Mr. Arthur is a founding member of ALL Consulting and has served as the company's President and Chief Engineer since its inception in 1999.

Additional Authors

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Slurry Injection Design and Monitoring for Waste Containment Assurance

Slurry injection is a commonly used technique to dispose of industrial, municipal, or oil and gas wastes. Although slurry injection is most effective when hydraulic fractures are created, safe operations demand that the fractures remain contained below one or more confining layers that are situated above the permitted injection zone.

Subsurface geomechanics and petrophysics play essential role in safe operations of slurry injection wells. The fluid rheology and pumping schedules drive much of the subsurface behavior: slurries are often composed of ground-up solids combined with a variety of wet wastes that the injection facility receives. Batch injections are performed at flow rates high enough to ensure that the resultant bottom-hole pressure is enough to stimulate one or more propagating fractures; these fractures may emanate from perforations made in the well's casing within the permitted injection interval or be created as off-shoots from an existing fracture produced during a prior injection. In both cases, the fractures may extend both laterally and vertically during continued operations.

Assurance of adequate containment is part of many states' regulations for well siting, construction and ongoing operations. Most regulators will only permit injection in rock strata which have an impermeable layer (such as a shale) above the injection interval (a "confining" layer or "cap rock" layer) to arrest any upward fluid migration which could otherwise contaminate shallower sources of groundwater. However, when conducting slurry injection, there is a potential for the fractures created during injection to propagate into or through the confining layer which can create a flow path for injected fluids to migrate out of the permitted interval. As such, a deep understanding of the geomechanics of the injection and surrounding layers is critical to assuring both fluid and fracture containment. Fractures can be contained by a combination of three main modes: stress barriers, modulus barriers, and permeability barriers which can be identified through a combination of geomechanics interpretation and hydraulic fracture simulations.

In addition to proper upfront design and feasibility studies, the best way to prevent loss-of-containment is through real time monitoring of well performance coupled with well injection tests to determine the reservoir properties during and after injection. Expert interpretation of this test data can determine if a fracture is being created, its length and height, and if fluid has made contact with faults or natural fractures.

Omar Abou-Sayed | CEO | Advantek Waste Management Services

Omar Abou-Sayed's experience spans the global energy industry, including oil and gas, chemicals, oilfield services, and renewables. He has worked in a diverse set of engineering, business, and organization-wide leadership roles within SuperMajor oil companies, management consulting firms, private equity funds, and venture-backed startups. He currently serves as CEO of Advantek Waste Management Services, a waste management company which utilizes proprietary slurry injection technologies dispose of oilfield waste and organic waste sludges. Omar holds a Bachelors of Science in Mechanical Engineering from the University of Texas at Austin, and an MBA from the Harvard Business School.