ConocoPhillips

Spirit

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Water

Technology & Projects: Partnering for growth

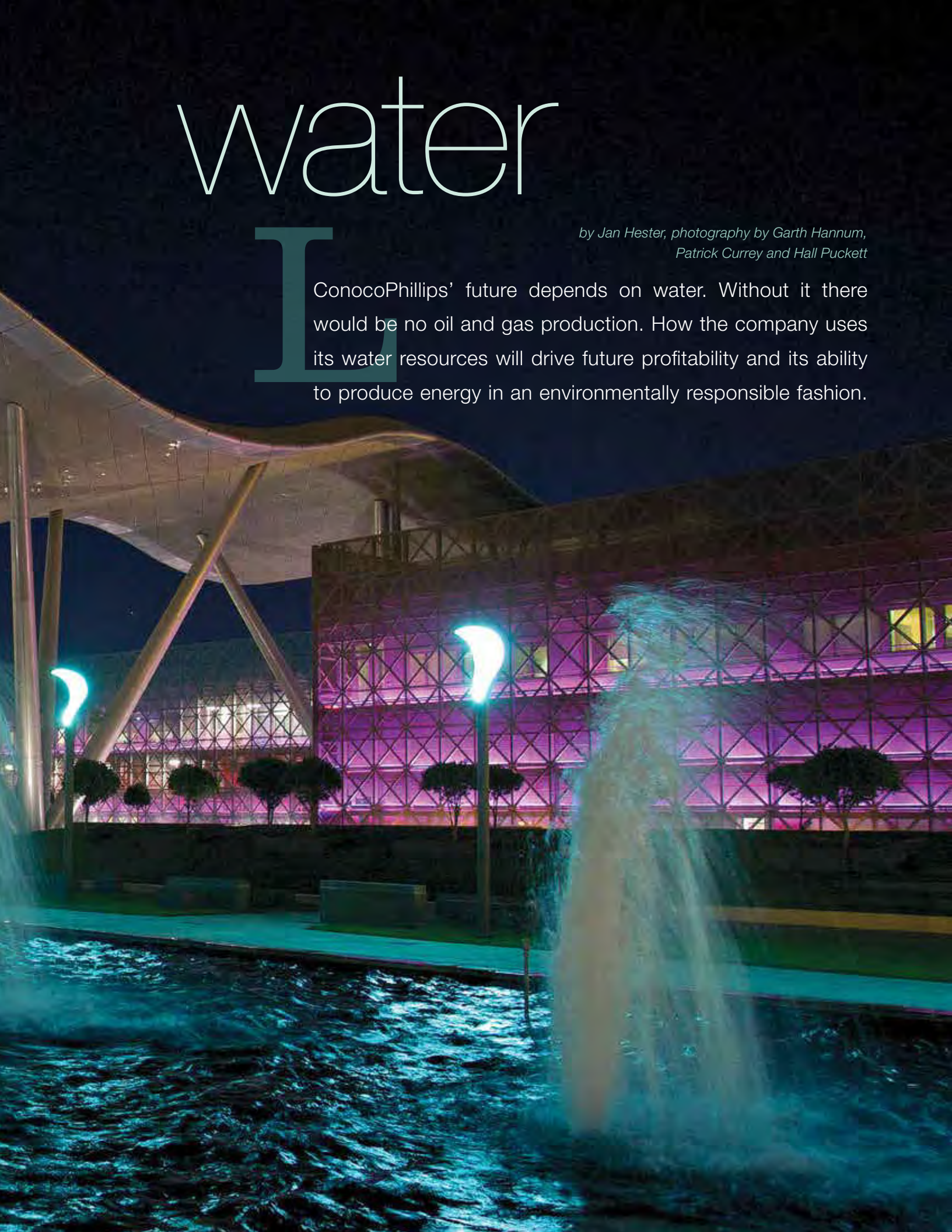
Finding a way in Bohai Bay

WATER

water

by Jan Hester, photography by Garth Hannum, Patrick Currey and Hall Puckett

ConocoPhillips' future depends on water. Without it there would be no oil and gas production. How the company uses its water resources will drive future profitability and its ability to produce energy in an environmentally responsible fashion.



"The Water Solutions group can be a vehicle to connect across the BUs and to help us improve production, lower costs and manage the risks associated with water use." – *Perry Berkenpas*

"To be a great E&P company, we need to be a great water company," said Perry Berkenpas, vice president, Global Production Excellence. "For every barrel of oil we produce, we manage about three barrels of water."

Samer Adham, manager, Water Solutions, emphasizes the financial impact of water on ConocoPhillips' business. "If we handle several million barrels of water per day, our annual costs will be substantial. We must get more efficient and effective at managing water."

Right: (from top) **Perry Berkenpas, vice president, Global Production Excellence; Samer Adham, manager, Water Solutions; Karl Fennessey, director, Water & Biodiversity**

As the world population grows and the demand for energy increases, the corresponding greater demand for water will result in higher costs, stricter regulation and more interest from stakeholders.

Karl Fennessey, director, Water & Biodiversity, works to integrate water efforts across the company. "It's important that we continue to improve how we manage this critical resource. This year we have updated the ConocoPhillips Water Action Plan and put water projections into the long-range planning process for the first time." The action plan brings together the efforts from businesses and functions and sets prioritized goals related to water.

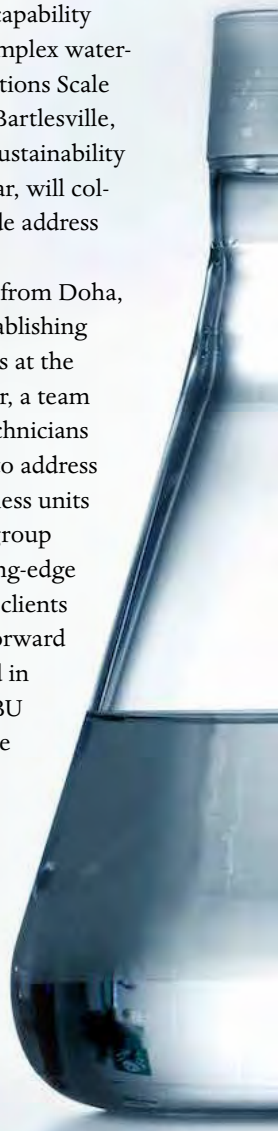
Water Solutions

The Water Solutions group was created under the Global Production Excellence (GPE) umbrella in 2013 to ensure the company has the technology and the technical capability needed to meet future water management goals. The team will apply its expertise to supporting business units (BU) worldwide while advancing technical capabilities and new technologies through research and development.

"We now have a strong group of experts who understand water use in our industry," said Dirk Faveere, manager, Engineering & Technology-Facilities. "We also have laboratories with world-class capability that can analyze and assess complex water-related issues. The Water Solutions Scale & Water Treatment group in Bartlesville, Okla., and the Global Water Sustainability Center (GWSC) in Doha, Qatar, will collaborate to help BUs worldwide address their water challenges."

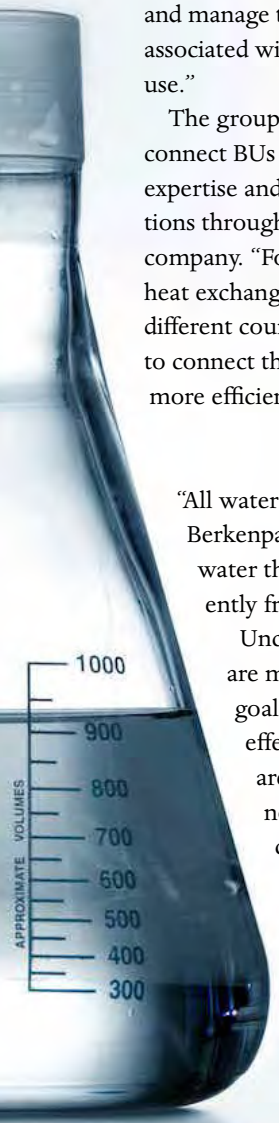
Adham recently repatriated from Doha, where he was in charge of establishing the GWSC. "In specialized labs at the Bartlesville Technology Center, a team of scientists, engineers and technicians use their analytical capability to address water issues confronting business units around the globe. The Doha group will continue to conduct cutting-edge research and support regional clients such as QatarGas, but going forward they'll be much more involved in company projects and global BU support. The two teams will be fully integrated and will work together to accomplish the company's water management goals."

The group is also building a tool kit of technologies to help the company deal with the whole spectrum of handling and processing



water. "We will look at our current business, technologies and capabilities," Berkenpas said. "Then we'll look at where the company will be in the future and determine what we'll need to support that business. The Water Solutions group can be a vehicle to connect across the BUs and to help us improve production, lower costs and manage the risks associated with water use."

The group also will connect BUs with expertise and solutions throughout the company. "For example, using water to cool heat exchangers has introduced problems in four different countries," said Berkenpas. "We need to connect the dots so that knowledge is shared more efficiently."



It's complicated

"All water is not created equal," said Berkenpas. "Some water, such as the fresh water that people drink, is regarded differently from others."

Unconventional reservoirs and oil sands are major contributors to the company's goal of profitable organic growth, and effective water management in these areas will be critical. There is, however, no template for confronting water challenges.

The amount of water required to drill a well varies widely from region to region and even well to well. In the Eagle Ford Shale in Texas, approximately 6.1 million gallons are used per well, including 125,000 gallons for drilling and 6 million gallons for fracturing. Things look very different in Niobrara in Colorado, where the average is 3.3 million gallons per well, 300,000 gallons for drilling and 3 million for fracturing.

The amount of produced water also fluctuates. "For example, in the Eagle Ford only 10 percent of the water injected for hydraulic fracturing comes back as produced water," said Greg Leveille, technical program manager, Unconventional Reservoirs. "In the Permian Basin that amount is more than 80 percent. It all depends on the geology, and it impacts every aspect of our operations."

Steve Jester, senior principle environmental engineer, Lower 48, focuses on issues related to hydraulic fracturing, including water and stakeholder engagement. "There's a real external push for oil and gas producers to recycle produced water," Jester said. "But it's not that simple. We're working to make processes as efficient as possible. When we're looking at water management overall, we may find that sourcing challenged water can ultimately save more fresh water than recycling produced water."

Berkenpas notes that water also introduces a complex set of problems, including corrosion, scale, solids, films and biological substances. "It's

Above: **Mary Katebah, assistant engineer, GWSE**

Left: **Dirk Faveere, manager, Engineering & Technology-Facilities**

water basics

Fresh water is not salty. It can come from surface sources, rivers, lakes and aquifers.

Challenged water, also referred to as brackish, is nondrinkable.

Produced water refers to all water that is returned to the surface through a well borehole during the extraction of oil and gas. It generally consists of water originally present in the formation, water injected to maintain reservoir pressure and chemicals used throughout the production cycle.

Water Solutions team members, photographed at the GWSC: *(front, from left)* Eman Al-Shamari, Vini Varghese, Kris Bansal, Mary Katebah, Ana Santos; *(back, from left)* Isik Turkmen, Nabin Uphadyay, Arnie Janson, Altaf Ahmed Hussein, Samer Adham, Joel Minier Matar and Samir Gharfeh.

Below: **Greg Leveille, technical program manager, Unconventional Reservoirs**

Bottom: **Steve Jester, senior principle environmental engineer, Lower 48**

like taking medications," said Berkenpas. "You have to consider the side effects."

According to Faveere, the challenges associated with water are diverse and highly specialized. "We could be working with a BU to help minimize their fresh water consumption. At the same time they could also be dealing with scaling that's a byproduct of produced water. Simple or complex, our water professionals are available to strategize and troubleshoot."

Regulations add to the range of issues involved. For example, Australia doesn't allow deep well reinjection, so producers are required to recycle and treat produced water. Also, Canada encourages producers to recycle 80 to 90 percent of fresh water from aquifers. "We have to make sure we stay involved in the regulatory process," Jester said. "It's important at both the state and federal level for us to be able to comment on what works and what doesn't."

Ramesh Sharma, staff process engineer, Water Solutions, admits that the challenges are complicated. "Our mandate is to provide cost-effective solutions. We try to find technologies that reduce operating costs and don't produce byproducts that are difficult to manage."

Unconventional reservoirs and oil sands

Companies that produce oil and gas are progressively using more unconventional methods, most of which require significant amounts of water. To date, the industry has mostly conducted hydraulic fracturing using potable water from surface sources, rivers, lakes and aquifers.

"It's expensive to truck around fresh water, and we're sensitive about using a vital resource," said Leveille. "We're trying to utilize less fresh water by developing technologies that will allow us to use more challenged water, and we're making good progress. In the Permian Basin pilot test where we used 100 percent recycled produced water, it cost less than if we'd used fresh water *(see Success story: Permian Basin)*. That's good for the environment, the company and the shareholders."

The situation is different in the Eagle Ford, where wells produce almost water-free. "Our options are to use challenged groundwater sources, and we've started to run some experiments around that," Leveille said. "Reducing the total volume of water used is also valuable, and in Eagle Ford we've reduced water use by 45 percent per well by optimizing hydraulic fracturing."

Left: **David Brown, program manager, Oil Sands & Heavy Oil**

Below left: **Kris Bansal, engineering fellow, Water Solutions**

David Brown, program manager, Oil Sands & Heavy Oil, describes the challenges of producing from oil sands at Surmont in Canada. "The demand for water for all operators means that we have to pull more and more challenged makeup water from deeper underground. If we don't remove the minerals and organics from feedwater, we get fouling that requires us to shut boilers down periodically for cleaning. As well as causing downtime, this makes it difficult to meet the 90 percent produced water recycle goal."

Optimizing the water-handling process requires quick, effecting monitoring tools. "Those capabilities have not been in place for the types of water that we're dealing with," Berkenpas said. "We're testing some new tools on that front to enable us to get online, real-time testing results. That way we can adjust processes along the way."

Online testing can speed up production processes, lower costs and help reduce environmental impact. One application at Surmont addresses the need for monitoring the silica management process to minimize boiler fouling. "We have developed two industry-leading online monitoring systems, with more on the horizon," said Kris Bansal, engineering fellow, Water Solutions.

The online silica monitor, the first in the SAGD industry, helps prevent boiler fouling. "With online monitoring we can see the precursors of events before they cause major problems," Brown said. "Then we can take steps to mitigate these issues and reduce downtime."

Brown points out that when Surmont 2 comes

Success story: Permian Basin

Water is scarce in the Permian Basin of West Texas, where there is little rainfall, and energy companies compete with agriculture for fresh water. Ramesh Sharma, staff process engineer, Water Solutions, and a committed multidisciplinary team from the Permian Basin BU headed by Austin Shields, completions engineer, looked at ways to complete wells using challenged water.

The team recently completed their first well using 100 percent treated, recycled produced water.

"Produced water is a plentiful resource, especially in the Permian, so it makes sense to use it instead of disposing of it," Sharma said. "We're getting experience under our belt. This was our third in a series of five wells. We worked up from using 50 percent recycled water on the first and 75 percent on the second well. We'll use 100 percent recycled water to complete the fourth and fifth wells. As of the end of October, we will have used 90,000 barrels of treated, recycled produced water in 30 stages of hydraulic fracturing.

Austin Shields *(left)* and Ramesh Sharma

"It all started with our project and an idea," said Sharma. "The project worked beautifully because the Permian team was so supportive. We were incredibly fortunate to find a business partner with a problem and a commitment to solving it. Water Solutions is an appropriate name for the group. This is what we do – come up with solutions for difficult problems."

Water matters for our future

How ConocoPhillips manages water is a metaphor for sustainable development because it matters to people, the planet and profits.

Communities naturally care about protecting potable sources to ensure ample supplies of clean water, so they ask about potential impacts from drilling and hydraulic fracturing. This underscores the link between environmental and social impacts of water stewardship.

There is also economic value to responsible water use, with conservation and spill prevention measures effectively reducing financial and reputational risks to the company. Specifically in Eagle Ford, optimizing hydraulic fracturing has reduced water use by 45 percent per well – netting a measurable improvement to the bottom line.

Respecting water resources offers great environmental, social and economic benefits. ConocoPhillips takes this seriously, with a comprehensive approach and action plan to support the company's sustainability.

Preserving and Conserving Water is one of the company's four Global Onshore Well Management Principles. More information about how the company manages water can be found in the Water section of the Sustainable Development Report on *www.ConocoPhillips.com*.

Below: (from top) **Dan Smallwood, manager, Gulf of Mexico Deepwater Asset Development; Cindy Smith, supervisor, Water Solutions; Greg McLelland, staff scientist, Water Solutions**

on line, the water treatment process will be more efficient because of new technologies that have the potential to help the company more cost-effectively increase the percentage of recycled water used, comply with regulatory guidelines and significantly reduce the environmental impact.

Deepwater

In offshore operations, high equipment costs can make a project uneconomical. To be successful in this key area, ConocoPhillips will have to embrace new technologies with minimal footprint and weight, two key things that add to the cost.

The company is currently undertaking conceptual studies to compare traditional water management systems for both injected seawater and produced water. One emerging technology is subsea water injection, boosting water from the seabed instead of the surface. "This will depend on several factors, including how much water we need to inject, the subsea architectural layout and our ability to process fluids to meet the specified water quality," said Dan Smallwood, manager, Gulf of Mexico Deepwater Asset Development.

Supporting worldwide operations through collaboration and teamwork

In Bartlesville, Cindy Smith, supervisor, Water Solutions, and her team help global business units address their water challenges. The group's services include assessing, adjusting and adapting the analytical methods used in production and operations and identifying unknown debris and fouling material.

"If a BU finds new material in process equipment, pumps, strainers or filters, we get a call to identify it and come up with a strategy for getting rid of it," said Smith. "Sometimes it's not as easy as one might think. It may require various disciplines, skill sets, collaboration and out-of-the-box thinking to identify and mitigate an unknown."

Left: **Karsten Sjursaether, scale field specialist, Water Solutions**

Far left: **Doha skyline**

Greg McLelland, staff scientist, wants the business units to know that the group is open for business. "We're a service organization, not just a research and development group. If you have a water problem, we're here to help."

When addressing BU-specific operations and production issues, the group functions as a neutral third party, performing only technical analyses. "The BU might inform us that their inhibitors aren't working properly, that they have scaling or flow assurance issues," said Smith. "One size doesn't fit all. We address the problem from a holistic perspective, from all scientific angles."

Principal Scientist Tom Baugh focuses on scale, as well as consulting for the corrosion group on water chemistry. Baugh and his team recently completed a project for the Alaska and Norway BUs to identify the best scale inhibitors for various conditions. "One inhibitor might be excellent at addressing scale but less compatible than other products with corrosion inhibitors," Baugh said. "After getting input from everybody on the team, we make technical recommendations to the BU."

Scale Field Specialist Karsten Sjursaether emphasized the importance of this recent project. "It will have a huge impact on our future treatment strategy. You can waste a lot of money if you haven't optimized your chemical programs. We now have a template we can share with other BUs."

The group is focused on sharing solutions across the company. "In Bohai Bay, there were issues with naphthenic acids, something they were unfamiliar with," said Baugh. "We characterized them, determined what caused the problem and designed a mitigation strategy. We're now seeing naphthenic acids pop up in other production areas, so we can apply what we've learned in China to those BUs. We're always pleased when we can add value for ConocoPhillips by sharing information that way."

Sjursaether also heads up the Global Chemical Network, the company's first Network of Excellence (NoE), and believes one of the group's key strengths is troubleshooting to address ongoing issues and sharing that knowledge. "We're doing ongoing work to combat, prevent and improve scale management," Sjursaether said. "Along the way we see similarities between issues and

Above: **Tom Baugh, principal scientist, Water Solutions**

Left: **In the Doha labs: Isik Turkmen, scientist, Water Solutions, and Joel Matier Matar, engineer, Water Solutions**

Above: **Exterior, Qatar Science and Technology Park**

Below right: **Interior, Doha's Museum of Islamic Art**

solutions. We want to take advantage of opportunities to share what we've learned from one BU with another without having to reinvent the wheel. It's also important to have the right processes in place so you can make the right decisions in a timely fashion."

McLelland and his team are currently involved in two key areas. The first is scale inhibitor evaluation using core flow equipment to simulate an inhibitor squeeze into the reservoir, a common scale control technique. During production, the inhibitor dissolves into the brine and prevents scaling.

"We've been doing work for Kuparuk and Alpine in Alaska, where they do a lot of scale inhibitor squeezes," McLelland said. "The challenge is to get the inhibitor into the water stream before the scale has a chance to form. If scale is forming deep in the well bore, the only way to get it into solution is to place the inhibitor into the reservoir and adsorb it into the rock surface. Then the scale inhibitor dissolves into the water stream and guards against scaling up to the well head."

McLelland and his team also support the Alaska and Norway BUs to determine the viability of a chemically enhanced oil recovery (CEOR) project. "The reservoir group is evaluating the technical merits and economics," said McLelland. "If it were successful, we'd have the potential to recover an additional 800 million barrels from Kuparuk over the life of the project. We're in the early stages, so there are still a lot of challenges to be met."

Corporate HSE expands water metrics

In conjunction with the Water Issues Working Group, the Environmental Assurance and Performance Assurance groups are working to expand water metrics tracked by the company, including sources and uses, discharge and disposal and recycling and reuse. The data collected will help contribute to improved water management and supports the Corporate Water Strategy and Action Plan.

"Before 2013, we only reported total fresh water use and total discharged," said Jennifer Barringer, manager, Environmental Assurance. "The new requirements will give the company a more complete picture of how this important resource is handled and where we may need improvements. It will also help keep us aligned with our peers in the industry."

New data collection requirements apply only to operated assets. Data will be collected in 2013, with an initial roll-up in 2014.

Left: **Samir Gharfeh, GWSC principal scientist**

Far left: **In the Bartlesville labs: Paul Schmidt, senior associate technician, Water Solutions, and Ying Xu, senior scientist, Water Solutions**

A center of water excellence in the desert

On a sprawling, science fiction-modern campus at Doha's Qatar Science & Technology Park, scientists at ConocoPhillips' GWSC are conducting groundbreaking research that will help business units worldwide address location-specific water issues associated with oil and gas production. The GWSC uses its state-of-the-art analytical capabilities to advance the science around produced water treatment, seawater desalination and water reuse and recycling.

Qatar, a nation that relies on desalinated sea water for 99 percent of its fresh water supply, is a fitting location for the facility. "Water is something precious," said Eman Al Shamari, assistant scientist, GWSC. "Here in Qatar everything depends on water."

Since its inauguration in 2010, the GWSC has staffed up and is now focused on fully integrating and collaborating with the Bartlesville and Houston Water Solutions teams. With their proximity to business units in Asia and the Middle East, the team is perfectly positioned to spread its wings. In addition, the group educates the public and promotes water conservation through its visitor center.

The newly established GWSC cut its teeth by providing analytical support and treatment testing for the startup of the QatarGas 3 liquefied natural gas (LNG) megatrain. The company had no labs ready at the time, so they asked the GWSC to provide daily analyses of their injecting chemicals. "The startup was flawless, and it was an excellent opportunity for us to initiate the lab equipment and demonstrate value for ConocoPhillips," Adham said. "QatarGas had two major goals: to remove field chemicals before injection and to recycle 50 percent of produced water. We were successful in evaluating several methods to remove field chemicals and treat produced water, and it was a great opportunity for us to learn together in a unique environment." The GWSC continues to provide specialized technical support to QatarGas and other local governmental organizations pertaining to water sustainability, all in support of Qatar National Vision 2030 and other related national development strategies.

The GWSC team's ultimate goal is to use the knowledge they capture in Doha to support worldwide strategic projects. "Along with our advanced lab equipment, we have the expertise to utilize and apply technology," said Principal Scientist Samir Gharfeh. "We have expertise that can help ConocoPhillips beyond just this region."

Advancing technology

As the company moves forward it must find cost-effective ways to reduce fresh water use and lower the cost and impact of sourcing, transporting, treating and disposing of water. To meet these goals, the Water Solutions group is developing a portfolio of technologies to assist business units in addressing their specific issues.

Reverse osmosis

Widely regarded as the most energy efficient method of desalinating feedwaters, reverse osmosis uses a semipermeable membrane and high-pressure pumps to separate feedwater containing dissolved minerals and other contaminants into two streams – brine (reject) and purified water (permeate).

How important is water to ConocoPhillips?

For every **1 barrel** of oil production the company:

- Produces **1.25 barrels** of oil equivalent (BOE) of gas.
- Produces **2 barrels** of water.
- Sources **1.25 barrels** of water (approx. 0.2 barrels fresh).
- Treats **3.25 barrels** of water.
  - Discharges 0.5.
  - Disposes 0.25.
  - Injects 2.5.

These are approximate gross numbers for ConocoPhillips-operated assets.

Above: **Arnie Janson, principal engineer, GWSC**

Above right: **Eman Al Shamari, assistant scientist, GWSC, and Ana Santos, engineer, GWSC**

Membrane distillation

This hybrid desalination process uses a temperature difference across a membrane as the driving force to produce high-quality distilled water from seawater or high-salinity brines. The process operates at ambient pressure and can use low-grade waste heat as the key energy source.

"You can extract fresh water vapor from a salt water stream," said Adham. "Reverse osmosis is the most common technology for desalinating with a membrane, but the salinity is a limitation. Membrane distillation has an advantage over reverse osmosis because the process is not affected by the salt content.

"Membrane distillation is an emerging technology that could be applied to treating produced waters for recycle or reuse. Through field trials in Qatar we know that it works on concentrated sea water from a desalination plant. We're testing in the field to benchmark the two side-by-side technologies. Hopefully the knowledge we capture can be adapted and applied to purifying and desalinating produced water."

Membrane bioreactors

In produced water there are two categories of chemicals: inorganics and soluble organics. While membrane distillation and reverse osmosis can remove inorganics from produced water, biotreatment is the most effective way to remove organics. This technology is well established in industrial water treatment. Sewage treatment facilities worldwide use microbes to remove organics from water.

"One promising new technology combines biotreatment with membrane filtration," Adham said. "Water treatment at Surmont in Canada's oil sands is highly challenging. We're able to manage that water as effectively as, if not better than, some of the other producers. In Doha we've been able to apply membrane bioreactors to waters that are less challenged than at Surmont. We will continue to evaluate the feasibility of using membrane bioreactors to remove organics from produced water such as Surmont's."

Water in the industry

- Source.
- Gather.
- Produce.
- Separate.
- Transport.
- Treat.
- Discharge.
- Dispose.
- Inject.

Forward osmosis

Water Solutions scientists are just beginning to research forward osmosis, another emerging technology that uses a semipermeable membrane and a high osmotic pressure draw solution to concentrate organics in feedwater. In the GWSC research, the feedwater is produced water from Qatari gas fields.

Ceramic membranes

Another process being tested as part of global engineering support is the application of ceramic membranes for produced water treatment. "We put commercially available ceramic membranes into a vessel, and clean filtered water comes out the side," said GWSC Principal Engineer Arnie Janson. "Ceramic membranes can cost-effectively remove suspended particulates from a variety of feedstreams, either as primary filters or as

polishing filters. It's an established technology that we're applying to produced water treatment because membranes are robust and can operate at high temperatures."

Assessing risk

Fennessey says that early efforts on water management in ConocoPhillips were led by small pockets of interested participants who believed the situation could be improved through increased collaboration. "As our experience has grown, this informal group has evolved into the Water Issues Working Group, a team with the expertise to develop corporate action plans on water."

The company has made real progress in the area of assessments and data collection. "When we looked at the data we need to gather in order to understand our footprint and opportunities, we recognized that a common set of tools was not available in the industry," Fennessey said. He and his team worked with the International Petroleum Industry Environmental Conservation Association (IPIECA) and Global Environmental Management Initiative (GEMI) to develop standardized tools for the industry to assess water risk locally and globally.

The IPIECA tool examines the entire portfolio of assets with respect to water scarcity. The GEMI tool is for local application and can be used to assess risk exposures and track action plans for mitigation. Both tools are now being integrated into the company's routine risk assessment processes.

Looking to the future

The future looks bright for Water Solutions, with a seemingly endless supply of interesting projects coming down the pike. "It's a good place to be right now with so many new things going on," said Karsten Sjursaether. "We're at an interesting turning point with many of the BUs. We expect new regulations and stakeholder expectations to continue to play a significant role in the future, and we'll work hard to be ready to take on those future challenges."

Adham outlines the Water Solutions group's 2014 objectives. "We realize that the water issue is complex, diverse and field-specific. Next year we will complete due diligence on attractive prospects to help us identify and prioritize our best opportunities. We will also focus on developing a deeper understanding of how water impacts ConocoPhillips' business – its value, volume and costs associated with production in the future." The group will also continue to expand the water technology toolkit by building internal capabilities and exploring commercial or new technologies available in the marketplace.

Janson wants ConocoPhillips BU staff around the globe to think of Water Solutions when they have a water problem. "Our biggest challenge is to understand the unique nature of each issue. People think there is a magic bullet, but in reality it's just plain hard work – testing, learning, retesting and finally coming up with a solution. But it's exciting and satisfying to know we're helping to solve water problems around the globe." ■

Above: **Altaf Ahmed Hussain, engineer, GWSC**

Above left: **Spice market in Doha**