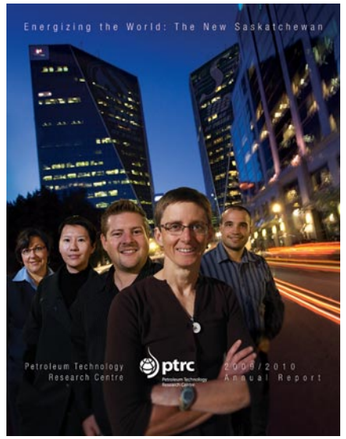
Energizing the World: The New Saskatchewan

Petroleum Technology Research Centre

ptrc
Petroleum Technology Research Centre

2009/2010 Annual Report




**Front cover:** Photographed on Regina's Scarth Street, Saskatchewan Research Council scientist Gay Renouf is flanked on the left by PTRC's Ingrid Uhryn, Rongle Li and Kyle Worth, and on the right by Adam Fehler.



# PTRC
## Description and Mission Statement

### Description of the PTRC

The Petroleum Technology Research Centre (PTRC) is a not-for-profit corporation founded in 1998 by the University of Regina, the Saskatchewan Research Council, Saskatchewan Energy and Resources, and Natural Resources Canada. It is located in the Innovation Place Research Park in Regina, Saskatchewan, adjacent to the University of Regina campus. Its diverse portfolio of research projects is funded through ongoing contributions from several federal, provincial and private sector partners, including direct funding from:

- Government of Canada: Western Economic Diversification, Sustainable Development Technology Canada, Networks of Centres of Excellence, and Natural Resources Canada.
- Saskatchewan Government: Ministry of Energy and Resources, Ministry of Environment, Enterprise Saskatchewan.
- Private sector: Western Canadian and internationally based oil and gas companies, utilities and technology providers.

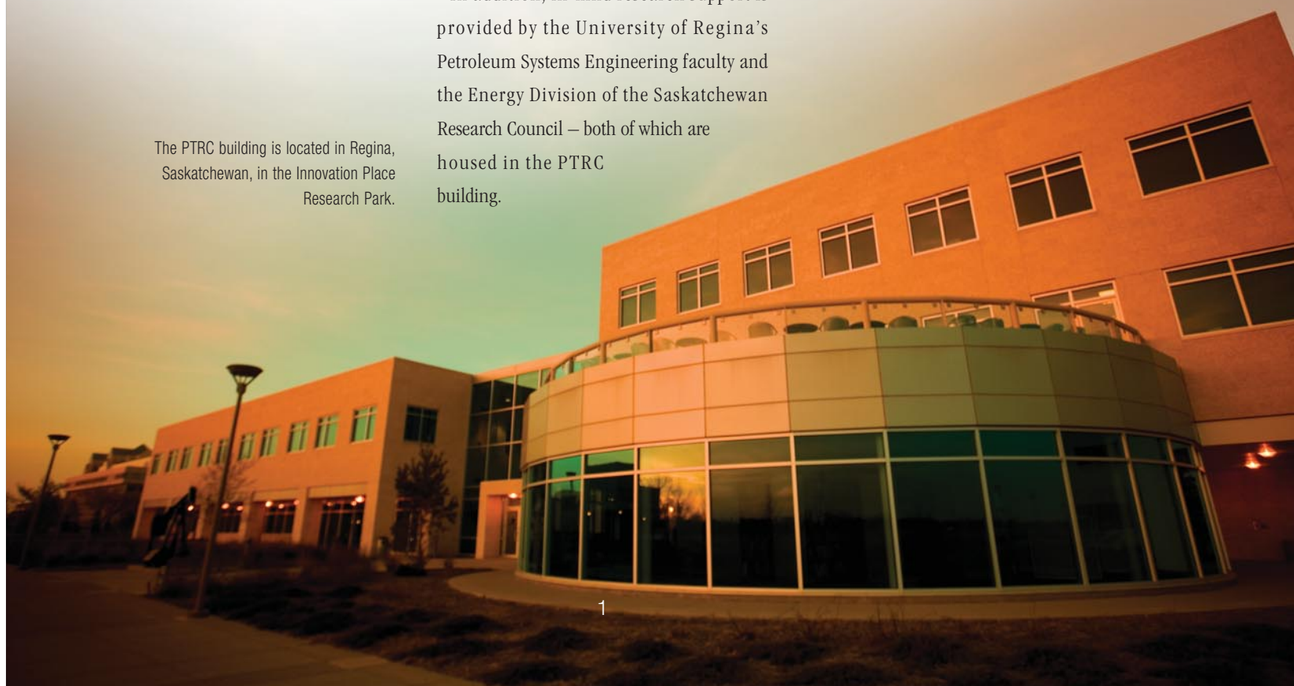
In addition, in-kind research support is provided by the University of Regina's Petroleum Systems Engineering faculty and the Energy Division of the Saskatchewan Research Council – both of which are housed in the PTRC building.

The PTRC is governed by a Board of Directors comprising representatives of the founding partners and of industry leaders operating in western Canada. Its laboratory and modeling (physical and numerical) facilities in Regina, shared with the University of Regina and Saskatchewan Research Council, are among the most advanced and complete in North America.

### PTRC Mission Statement

The PTRC's mission is to develop world-leading enhanced oil recovery and $CO_2$ geological storage technologies that ensure sustainable and environmentally sensitive development of Canada's energy resources. The PTRC manages enhanced oil recovery research and delivers basic and applied research results and technologies to its partners for field application. It serves as the managing agency for major research consortia. The organization enables governments and industry to combine resources and fund research in areas thought to be key to the nation's and, by extension, the world's energy security.

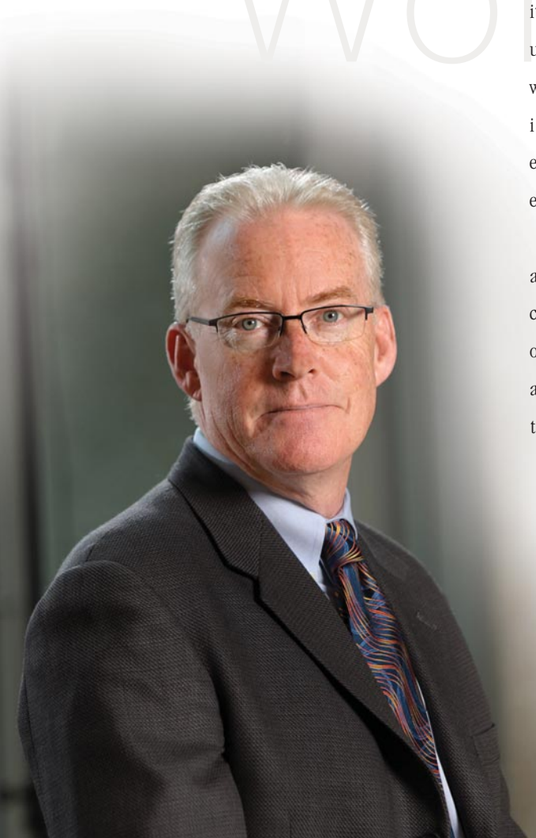
The PTRC building is located in Regina, Saskatchewan, in the Innovation Place Research Park.



# Message from the Chair

"Its future may rest in the rising acclaim of its universities, researchers and industry captains."

Energizing the World



Sometimes, as an observer looking in at Saskatchewan, my perceptions are coloured by the usual stereotypes Canadians hold for the province – wide open spaces; blue, clear skies; waving fields of grain.

It's easy to be complacent with these images; after all, who doesn't long for space in an increasingly crowded and busy world? But my hands-on experiences with Saskatchewan have been anything but wind-swept and remote. They're rooted in cutting-edge research and science – first, in my position as VP of the Saskatchewan Research Council back in the early 2000s, and now as Chairman of the Board of Directors for the PTRC.

Saskatchewan can thank geological time for the magnificence of its natural resources, but its future may rest in the rising acclaim of its universities, researchers and industry captains, who are creating the companies and institutions where the future of Canada's energy industry and, indeed, the R&D pre-eminence of its two biggest cities are rooted.

You'll notice a change in this year's PTRC annual report over previous years. The careers created by the PTRC are front and centre on our cover for the first time. Last year, we made a sly wink towards Regina by including it in the background of our cover, which was dominated yet again by a pump jack and fields of grain. This year urban Saskatchewan deservedly takes centre stage.

On my last trip to Regina I was taken with the changes that had happened to Innovation Place Research Park, the location of the PTRC's building.

Across the street a brand new provincial disease control centre had just been completed, and researchers were moving into their new digs. In our meetings at the PTRC's building, leaders in the oil industry from Saskatchewan, Alberta and across the country gathered to discuss the future direction of research in enhanced oil recovery and carbon storage. Just next door the University of Regina's International Test Centre for $CO_2$ Capture was hosting international delegates anxious to find out about its world-leading capture technologies.

So let's hear it for a world-class energy future for Saskatchewan – one that recognizes and pays tribute to agrarian roots and resources, while celebrating one of its most important research assets: the Petroleum Technology Research Centre.

I'd like to close by personally thanking two departing members of the Board of Directors – Dr. R.W. (Bob) Mitchell and John Zahary – who have greatly supported and steered the PTRC into the 21st century. Their contributions have been significant and appreciated.

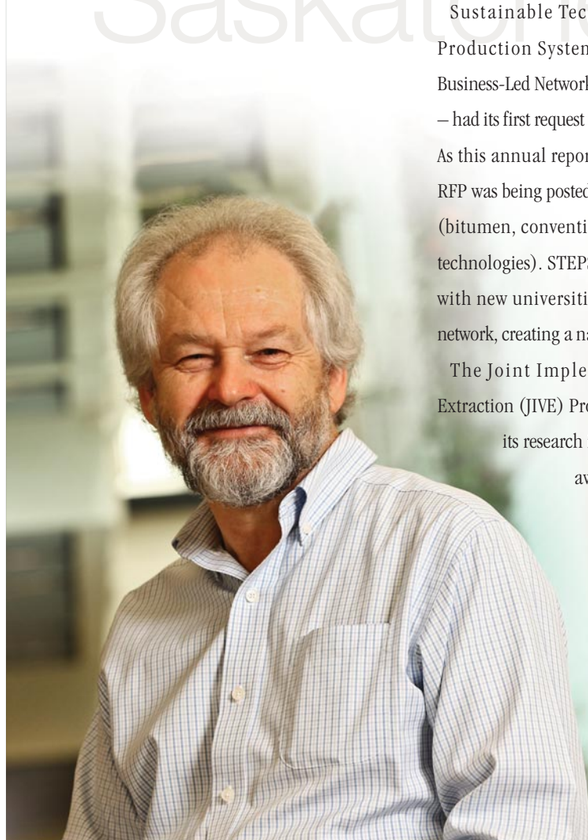
Dr. Patrick Jamieson



# Message from the Acting Executive Director

"Saskatchewan is fast becoming an economy that is driven by its research potential."

the new Saskatchewan



This year the PTRC faced a number of challenges head on, continuing to adapt to the demands of industry, government and researcher organizations while remaining focused on our main goal: the development of more environmentally friendly and economically enhanced hydrocarbon recovery and carbon storage technologies.

The fiscal year ended with a departure, and also an opportunity for renewal. We bid farewell to our Executive Director of over two years, Dr. Carolyn Preston, who resigned from the PTRC to pursue career options elsewhere. This left an immediate void at fiscal year end, into which I was asked to step on a temporary basis. I am confident in the strong day-to-day management skills of Dr. Steve Whittaker and his PTRC team, and have found my brief tenure rewarding.

Sustainable Technologies for Energy Production Systems (STEPS) – the new Business-Led Network of Centres of Excellence – had its first request for proposals in heavy oil. As this annual report went to press, another RFP was being posted in new areas of research (bitumen, conventional oils, and enabling technologies). STEPS has an exciting future, with new universities joining the research network, creating a national research focus.

The Joint Implementation of Vapour Extraction (JIVE) Project wrapped up most of its research in 2009-2010, and we are awaiting the final reports on this very successful field demonstration project. Likewise, the IEA GHG Weyburn-Midale $CO_2$ Monitoring and Storage Project completed its penultimate year of research, and preparations have begun on the project's final goal: a best practices manual to help $CO_2$-EOR operations transition into long-term storage.

Perhaps most importantly, the two newest PTRC projects – Aquistore and Saskatchewan Phanerozoic Fluids and Petroleum Systems – illustrate the lead that Saskatchewan is taking in both carbon capture and storage and geological characterization.

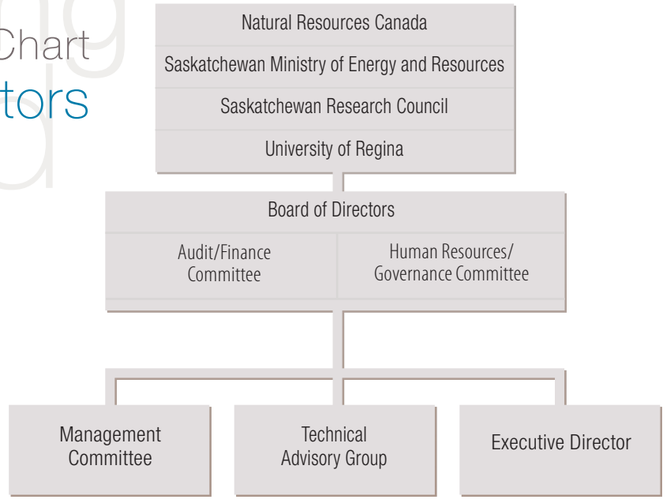
Aquistore began preparations for the drilling of a $CO_2$ injection well and initiated its public communications and consultation efforts. The Fluids project held its first meetings, and research began into mapping and understanding the location of fluids in the Saskatchewan subsurface – a critical activity for oil exploration.

As the PTRC moves towards completion of some projects and the expansion of others, we are discovering that the most important resource of all is our people – both within the PTRC and within the many research organizations that receive funding from us. As this year's annual report suggests, Saskatchewan is fast becoming an economy that is driven by its research potential. The PTRC is proud to be an integral part of realizing that potential.

Dr. Malcolm Wilson

Energizing the world

# PTRC Organizational Chart and Board of Directors




## 2009-2010 PTRC Board of Directors

**Dr. Patrick Jamieson** (Chair) Technology Advisor, Nexen Inc.

**Brian Watt** (Vice Chair), Operations Engineering Manager, Heavy Oil and Gas Business Unit, Husky Energy Inc.

**Ernie Pappas**, Vice President, Energy, Saskatchewan Research Council

**Dr. Malcolm Wilson**, Director, Office of Energy and Environment, University of Regina

**Kent Campbell**, Deputy Minister, Saskatchewan Ministry of Energy and Resources

**Chantal Abou Debs** (non-voting observer), Senior Program Manager, Business-Led Networks of Centres of Excellence

**Dr. Vincent Saubestre**, Manager, Technology and R&D, Total E&P Canada

**W.A. (Bill) Jackson**, Manager, Public & Government Affairs, Apache Canada Ltd.

**Geoff Munro** (non-voting observer), Chief Scientist and Assistant Deputy Minister, Innovation and Energy Technology Sector, Natural Resources Canada

**Mike Monea**, Vice President, Integrated Carbon Capture & Sequestration Projects, SaskPower

**David Payne**, Vice President, Exploration – Central, Canadian Natural Resources Ltd.

**Dan Schiller**, Vice President – Eastern Oil Business Unit, Cenovus Energy Inc.

**Dr. R.W. Mitchell**, Independent Director (Retired, November 2009)

**John Zahary**, President and CEO, Harvest Energy Trust (Retired, February 2010)

**The PTRC Board of Directors as photographed in March 2010.**
**Front Row (Seated) Left to Right:** Chantal Abou Debs, Networks of Centres of Excellence; Brian Watt (Vice Chair), Husky; Dr. Vincent Saubestre, Total E&P Canada; Dr. Carolyn Preston, Executive Director (resigned, May 2010). **Back Row (Standing) Left to Right:** W.A. (Bill) Jackson, Apache; Dr. Malcolm Wilson, U of Regina; Ernie Pappas, SRC; Geoff Munro, NRCan; Dr. Patrick Jamieson (Chair) Nexen; Mike Monea, SaskPower; David Payne, Canadian Natural Resources Limited; Dan Schiller, Cenovus.
**Missing:** Kent Campbell, SK Energy and Resources.



## Hydrocarbon Research Keeps Talent Here, and Draws It From Abroad

# Saskatchewan's Changing Face

Capital spending by oil and gas companies exceeded $2 billion.

The cover of our 2009-2010 Annual Report, for the first time, features people who work on the PTRC's projects. Aside from giving Ingrid Uhryn, Rongle Li, Kyle Worth, Gay Renouf and Adam Fehler their fifteen minutes of fame, the intent – by photographing them along Regina's Scarth Street – is to show a new, urban and energized Saskatchewan, one that is keeping its skilled people here and at work.

Ingrid Uhryn, manager of Corporate Services for the PTRC, oversees governance and human resources strategies. She brings a wealth of knowledge in these areas having worked with numerous 50 Best Employers in Regina. Project coordinator Rongle Li (Lee for short) gained a bachelor's in business administration from the University of Regina after arriving in Canada from Changsha, China. Saskatchewan Research Council scientist Gay Renouf has been working on the PTRC's enhanced oil recovery research for more than ten years. Kyle Worth is the longest-standing employee at the PTRC, hired in 2001 immediately after graduating from University of Regina with a B.Sc. in environmental systems engineering. His project work led him to gain a P.Eng. designation in 2005. Adam Fehler is following in his footsteps; hired this past fiscal year, immediately after graduating with a B.Sc. in industrial systems engineering, he's gaining knowledge of the cutting-edge R&D of the STEPS Business-Led Network of Centres of Excellence.

The oil and gas industry in this new Saskatchewan, according to the Ministry of Energy and Resources, was responsible for over 27,000 jobs in 2009-2010. Direct revenues to provincial coffers totaled over 1.3 billion dollars, and capital spending by oil and gas companies exceeded $2 billion. The PTRC – through helping to foster and encourage new technologies that extract the unique hydrocarbons located here – has contributed towards that economic success. More and more, Saskatchewan is seen as a scientific leader in enhanced oil recovery, environmental technologies, and greenhouse gas solutions such as carbon capture and storage.

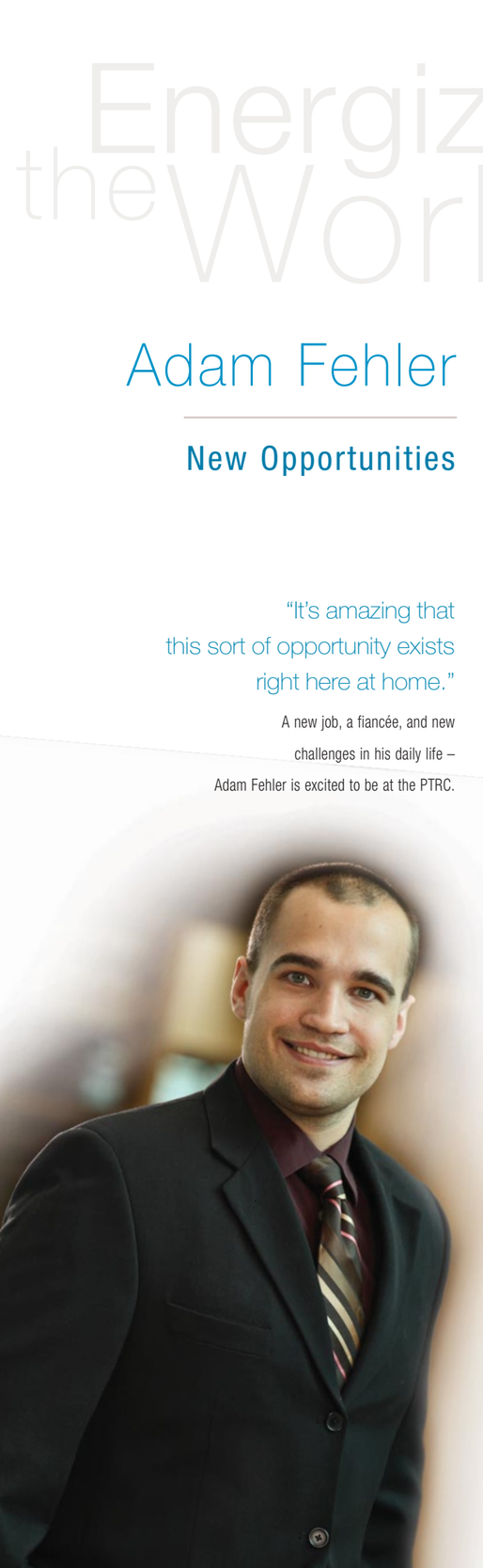
This year's Annual Report, for each of the PTRC's research projects and programs, presents an individual who has either remained in Saskatchewan, or arrived here from locales around the globe to contribute to our world-leading research and development. We hope this personal touch to our research illustrates the value, and diversity, that the PTRC continues to bring to the province, to Canada, and to the international research community. ■

# Adam Fehler

## New Opportunities

"It's amazing that this sort of opportunity exists right here at home."

A new job, a fiancée, and new challenges in his daily life – Adam Fehler is excited to be at the PTRC.



2009-2010 has been a challenging year for the PTRC's newly inaugurated Business-Led Network of Centres of Excellence. The former Enhanced Oil Recovery program became Sustainable Technologies for Energy Production Systems (STEPS) – an expanded research centre utilizing increased financial contributions of both the governments of Canada and Saskatchewan – and actively pursued the participation of additional research institutions through requests for proposals (RFPs).

To help manage those new RFPs, which are also aimed at expanding the focus of STEPS to include research in bitumen, oil sands, and emerging resources such as oil shales, the PTRC hired Adam Fehler, a recent graduate of the University of Regina's Industrial Systems Engineering program.

"I had heard that an entry level position was open at the PTRC, and so I applied. I had diverse experience through my co-op placements at U of R, everything from working in a pulp and paper plant in Thunder Bay, to the General Motors plant in Oshawa in 2006."

It was Fehler's diversity of training during his degree, across different sorts of manufacturing and engineering companies, that impressed. The PTRC – in need of someone who could be trained to manage the reporting on a diverse portfolio of ongoing and new research projects – offered Fehler the position in August 2009.

"I currently manage the reporting on 48 projects under STEPS," Fehler notes. "Some of those have the research complete and we're awaiting final reports, others are just beginning, and I assure that proper documents and budgets have been received."

Fehler has also been tasked with reviewing and suggesting improvements to final reports that are received, and handling stakeholder requests about research and the progress of projects. In 2009-2010 STEPS had nine industry sponsors contributing over $800,000 towards research. Those same sponsors play a role in shaping the research program by participating on the STEPS Technical Advisory Group, which evaluates proposals that come in and determines those that go forward.

"This has been a great job, and I'm learning a lot about request for proposal processes and the needs of our clients. I've been able to develop templates for our RFPs, and improve them over time."

Fehler has seen change outside of work, too. At 25, he and his fiancée Faye are to be married in October 2010. They met on the first day of university back in 2003. She graduated the same year as Fehler in environmental systems engineering.

"STEPS is continuing to evolve," he notes. "And so am I. I think it's amazing that this sort of opportunity exists right here at home for a new engineer such as myself." ❑

Read more about the researchers involved in STEPS in the five profiles that follow.

The PTRC gratefully acknowledges the Governments of Canada and Saskatchewan for their funding of the STEPS Business-Led Network of Centres of Excellence.



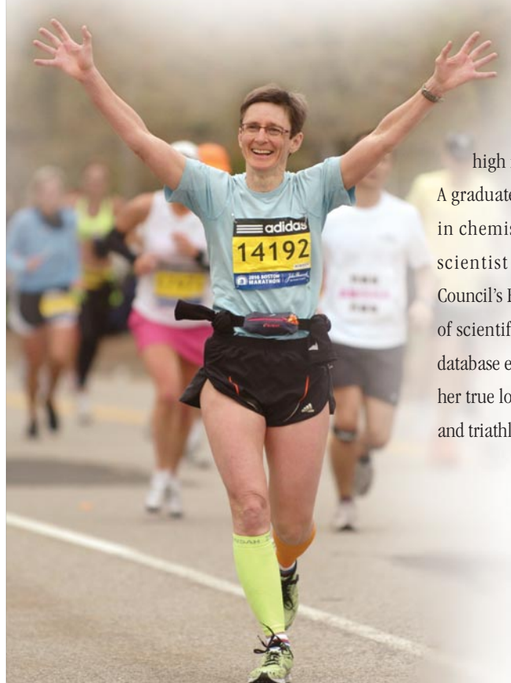


# Gay Renouf

## Scientific Method is on the Run

A newer database will allow clients to see what kinds of heavy oil fields respond most favourably to different waterflood methods.

Gay Renouf successfully completes the Boston Marathon in 2010.




On a computer screen before her, Gay Renouf surveys spreadsheets detailing the latest statistics on a heavy oil flood in western Saskatchewan. These particular sheets include data from individual heavy oil production wells, but a second, newer database will show the relationships between injector-production well pairs, allowing researchers and clients in the STEPS Network to see with even more clarity what kinds of heavy oil fields respond most favourably to different waterflood methods.

"The first year we introduced the database," Renouf recalls, "it was sort of a reassurance for companies that they were on the right path with the choices they were making in their own heavy oil waterfloods. That year, it was like generating a report card about which fields and operators had been better at producing oil."

She laughs.

"Of course why would anyone want that? Who wants a bad report card?"

Renouf, herself, has been scoring high marks from clients for her database. A graduate of the University of Saskatchewan in chemistry, Renouf is a senior research scientist in the Saskatchewan Research Council's Energy Division. She credits her love of scientific method for both motivating the database effort and pushing herself to excel in her true love outside the workplace: marathon and triathlon competition.

"I'm really into running and triathlons. And I think one of the reasons I do is that I love scientific method. I coach, as well, and I get to see the results of my experiments, if you like, on race day."

Waterflooding is a straightforward method for increasing oil production from depleting reservoirs that has been used in the oil industry for decades. But heavy oil waterfloods are not as easily understood as their conventional counterparts. In conventional waterfloods, the oil is displaced by the water's piston-like action forcing the oil to production wells, but heavy oil doesn't want to move in the same way. The oil is dragged through the reservoir, and possibly gets emulsified by surfactants already present in the formation. This leads to varying degrees of success that a database is critical for assessing.

The database details not only heavy oil reservoirs, but many medium oil (from 20° to 30° API) waterfloods as well. Overall, clients can turn to results generated from the database to help develop new methods to optimize recovery from their own reservoirs. Future work may include recording the additives used in different floods to greatly enhance the data.

"The data comparison between heavy and medium is useful, even though they're creatures of a different sort," notes Renouf, smiling. "Just like the comparison between running styles. My son also runs marathons and, well, I'd be a poor scientist if I didn't admit we'd learned from each other despite our differences." ❑

# Energizing the World

## Peter Gu

### "Re-creating" SVX Research

"We've moved into a more exciting phase of development."

Floor hockey has become a passion for Dr. Gu since his arrival in Regina.

Peter Gu remembers well his first day in Canada. It was June when he left the steamy environs of Houston, Texas, with his wife, Carol Song, on a four-hour flight to Edmonton to begin his Ph.D. at the University of Alberta.

"We didn't like it in Canada at all," he confides. "We lived in Edmonton in a basement suite near the university. And when the winter came, well, from 35 degrees to minus 35 is quite a change."

His route to Canada was a circuitous one – after completing an undergraduate degree in mechanical engineering and a master's in fluid mechanics at the Nanjing University of Science and Technology in the 1980s, Gu travelled to Houston to begin theoretical doctoral work on fluid mechanics in the 1990s.

"Basically, my dissertation ended up being much more about mathematics than about hands-on engineering," Gu notes. "I found it uninteresting and really didn't want to be working for NASA for the rest of my days."

That's when he moved to Canada, and by 1999 he'd graduated with a Ph.D. in mechanical engineering, looking at the interactions between oil drops and aqueous solutions. It's this work that brought him, ultimately, to the University of Regina and its petroleum systems engineering program, and to the PTRC's STEPS research.

"To directly apply my learning to research that could have a real impact in the field is important to me. In the past few years of solvent vapour extraction research, our focus has been on experimental results. But now we've moved into a more exciting phase of development, using those experimental results to conduct numerical and mathematical modeling in the process of scaling up SVX innovations to field scale."

In a way, Gu has come full circle – from theory, to laboratory research, and back again – bringing to bear his doctoral knowledge of the ways solvents disperse on the SVX process, while developing models that will help field operators maximize their oil production.

And in the years he's been in Saskatchewan, he and his family have also made a transition into new ways of being.

"My wife is an engineer, as well, and along with my daughter we love to hike many of the local spots, like Half Moon Trail."

"I've also joined drop-in floor hockey on campus. Thankfully, the skill levels are variable," he laughs "so I fit right in! And learning this team sport has been really valuable to me in my work experience. There's a good reason why sport is sometimes called recreation. Hockey requires working together for a common goal, "re-creating" on the fly. Our research requires innovation and team work, between me, students, our industry partners and the PTRC." ❑



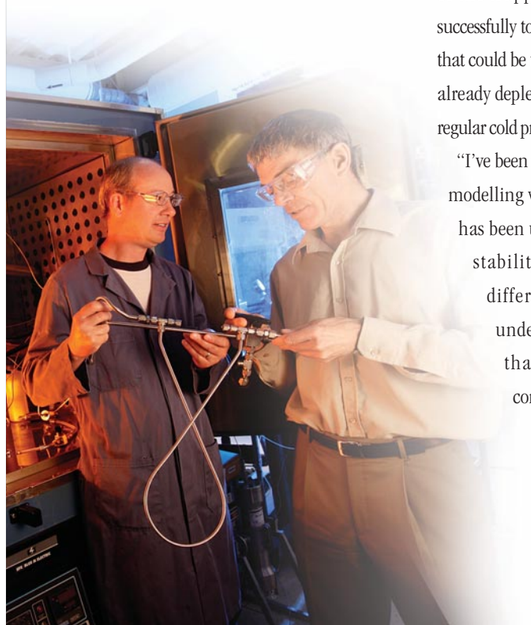
Sustainable Technologies for Energy Production Systems (STEPS)

# Ray Exelby

### Heating Up the Prairie

It's a technology that could be used in heavy oil reservoirs that are already depleted and contain wormholes after regular cold production methods.

Principal research technologist Ray Exelby works with SRC's Dr. Norm Freitag on a PVT apparatus.



When Saskatchewan Research Council principal research technologist Ray Exelby began laboratory work with Dr. Norm Freitag on STEPS-sponsored experiments in the area of in-situ combustion, he brought with him an awareness of how such technologies had fared in the past.

"I knew that there'd been a few in-situ combustion recovery efforts tried in the 1980s in a couple of Saskatchewan's heavy oil fields," he says. Those field trials, while they showed initial promise, were not successful.

Researchers at both SRC and other organizations began to investigate what conditions might make the technology work better in the field, focusing on a particular aspect: establishing a stable combustion front in the reservoir. In-situ combustion works by creating a controlled burn within the reservoir and allowing the generated heat to advance in the field. The generated heat lessens the viscosity of the trapped heavy oil so it flows more successfully to production wells. It's a technology that could be used in heavy oil reservoirs that are already depleted and contain wormholes after regular cold production methods.

"I've been involved with our simulation and modelling work," Exelby notes. "Dr. Freitag has been using simulations to predict the stability of the combustion fronts in different sorts of reservoirs, and to understand the chemical reactions that determine whether or not a combustion front remains stable."

Exelby has been with SRC's Energy Division since its beginnings, in the early '80s. He was with SaskOil in 1984 when it sold its energy division to SRC, ushering in a new era of research for the Treasury Board crown corporation.

"In the lab, I use a low temperature oxidation/pyrolysis reactor to study the reactions of the oil at that combustion front. Where you create the controlled burn, the front ahead of that reaction will be very hot, but that heat – in the absence of oxygen – upgrades and cracks the oil."

Exelby draws his knowledge in the lab from two different training courses – a mechanical engineering diploma from Saskatchewan Institute of Applied Science and Technology in 1982, and an additional certification in electronics technology in 1990. But he also understands the geography and lay of the land in Saskatchewan. He and his wife of 24 years farm a quarter section of land just north of Craven.

"We love to farm. And we've raised our two boys – they were big into soccer, and in fact I coached for over ten years – so now we've got some time for ourselves," he notes, but then comes back to the research at hand. "For me, I think I'd like to see some of Dr. Freitag's research actually tested in some depleted heavy oil fields."

In part, the earlier field experiments with in-situ combustion failed because of the weak oil prices and economic conditions of the early 1980s. But with today's better oil prices, finding a company or consortium of companies to field test SRC's technology may not be far off. ❑

# Energizing the World

## Mars Luo

### To the Land of Ice and Oil

"When I discovered there was an actual program, funded by the PTRC, looking at miscible and immiscible solvent flooding, it was a perfect fit."

It's a long way from Hunan, China, to Regina Beach, but Mars Luo has found that he fits in well to his adopted Saskatchewan home – both professionally and personally

A research engineer in the Saskatchewan Research Council's Energy Division, Luo completed his first two university degrees in China (chemical engineering at Sichuan University , followed by a master's in applied polymer science in 2002 from Hunan University) before getting his Ph.D. in petroleum systems engineering from the University of Regina in 2008.

"I moved from graduate studies at the U of R right into a job here at SRC," Luo notes. "My background was in solvent flooding, so when I discovered there was an actual program, funded by the PTRC, looking at miscible and immiscible solvent flooding, it was a perfect fit."

Luo's specific research is looking into optimizing displacement efficiency and reducing oil viscosity by testing different solvents during immiscible flooding of heavy oil reservoirs. Heavy oil – his native China has significant reserves in the north of the country – allowed him to quickly develop an affinity for Canada. His Ph.D. was in asphaltene precipitation and its effect on solvent-based heavy oil recovery processes, a major area of interest in Canada's heavy oil and oil sands industries.

"I like the idea of helping companies become more efficient, and therefore make more money with fewer impacts," he says. "I'd like to transform my knowledge into increased oil recovery."

Fitting into Regina was never much of a problem, Luo insists. He was president of the badminton club at the U of R for three years, and often still plays at lunch time (his office is in the PTRC building, near the campus).

"I also met my wife Jean here," he says, smiling. "She was a fellow student when I was taking graduate courses at U of R. She works now in Regina for Trans Gas."

The couple have a daughter, Judy, almost 5 years old.

Science is not the only endeavour that transitioned Luo quickly into becoming a Saskatchewanian. Having come from Hunan province, he'd never experienced temperatures below minus 5°C. Yet he's put himself, literally, on ice in his first several winters as a Canadian.

"I love to ice fish! It's one of my favourite things. In winter I head out to Katepwa Lake, and also fish for pike at Regina Beach in summer." ❑

"I like the idea of helping companies become more efficient, and therefore make more money with fewer impacts."

In just a few years, Dr. Mars Luo has learned of the best locations to catch jackfish at Regina Beach.





## Huazhou (Andy) Li

### Steps Towards a Ph.D.

One of the goals of the PTRC's STEPS Network is to foster the next generation of researchers.

**Above:** Andy Li works with his thesis supervisor, Dr. Tony Yang.
**Below:** Andy strikes a pose in front of the University of Regina's Kinesiology Building where he swims.

Andy Li is grateful for a lot of things – for the opportunities he's gained from coming to the University of Regina to work on his Ph.D.; for the clean Saskatchewan air he's breathed since leaving his industrialized home province in China; and for the famously polite drivers on Regina's roads.

"I can actually walk across a road here," he says, "and people will stop for me! Back in Qingdao, that would never happen. The driving can be a bit crazy."

Qingdao (in China's northern province of Shandong) is home to China's University of Petroleum where Li received his undergraduate and master's degrees in engineering. The university has a substantial reputation, and Li's thesis looked at a new technology – an abrasive water jet to cut bad casings on oil wells.

"I arrived in Regina just last year," he notes. "Dr. (Tony) Yang applied for STEPS funding to start conducting research on the behaviour of solvents in heavy oil, and I developed my thesis work specifically to suit the research we are doing."

Dr. Yang's research project is looking at the phase behavior of solvents when combined with $CO_2$ in heavy oil reservoirs under subcritical and supercritical conditions. The use of $CO_2$ during thermal heavy oil recovery processes is already well known in the industry, but Dr. Yang and Li, through his research work, hope to examine how the addition of solvents will accelerate and increase oil recovery.

"So far we've completed our literature review of work done in this area," says Li. "The results from our experimental work will make up some of the findings in my thesis. All of this work could prove very useful for recovering more of the heavy oil in Saskatchewan, and also have application in heavy oil fields elsewhere, like in the northeast of China."

Li's time in Saskatchewan has been focused on his research – one of the goals of the PTRC's STEPS Network is to foster the next generation of researchers – but he's also found time to fit into his new city and its environs.

"Everyone is very, very friendly here. And although I lived in northern China, where it can be cold, it's not nearly as cold as here in the winter. In the winters, I swim a lot at the pool on campus. It's how I stay in shape."

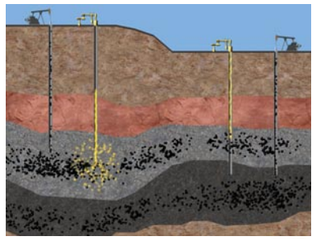
His success as a Ph.D. student reflects the success of the STEPS program. A completed solvent behavior project will likely mean a defended thesis and a university degree.

"I'm not sure what I'll do when I graduate," he says. "If there is an opportunity here, yes, I would like to stay. But I'm also excited by the possibility of taking what I've learned and applying it to oilfields back home. That's important too." ❑

# Energizing the World

## Kyle Worth

### Coming Together to Solve Common Field Challenges



One of the JIVE field trials involved injecting solvent into one well, and drawing the combined oil and solvent up in a production well, as indicated here.

**Joint Implementation of Vapour Extraction**

Since he began his professional engineering career at the PTRC, the word 'field' has come to conjure up different meanings to Kyle Worth than it did when he was a teenager and student. Growing up in Semans, Saskatchewan, Worth was – and still is – very active in sports. From double A hockey, to volleyball, and ultimately to baseball (his team won the provincial championship) – fields, arenas and rinks have been places to test his skills.

> The technology offers significant environmental benefits over steam-assisted gravity drainage.

"I suppose it really hasn't changed all that much since I graduated and began to work at the PTRC, except that now the challenges in the field, and the skills needed to meet them, are about oil recovery and environmental stewardship, not athletics."

With nine years of experience at the PTRC, Worth is the longest serving employee of the organization, and has seen his role move from assisting with the management of the Weyburn-Midale $CO_2$ Monitoring and Storage Project through to his current role as project manager for both the Joint Implementation of Vapour Extraction (JIVE) Project and Aquistore.

JIVE has been a particularly rewarding and challenging project for Worth. Solvent vapour extraction technology is an enhanced oil recovery process involving the injection of a gaseous hydrocarbon (usually butane or propane) into a heavy oil reservoir. The solvent is miscible with the heavy oil and diffuses into it, reducing the viscosity of the oil and causing it to flow more easily. The technology offers significant environmental benefits over steam-assisted gravity drainage by virtually eliminating water use and reducing greenhouse gas emissions because steam does not have to be produced during production.

JIVE employed solvent vapour extraction technology in five separate field trials. Three participating companies – Nexen Inc., Husky Energy, and Canadian Natural Resources Ltd. – tested combinations of solvents in heavy oil fields with differing characteristics. The trials ended in 2009, showing positive results for increasing oil recovery. Worth says that, given the right reservoir and solvent price, the SVX process could be economically viable.

"One particularly valuable result was the 3D scaled physical modeling completed in 2009-2010 which helped to analyze the SVX process and also identified asphaltene precipitation as a potential operations issue."

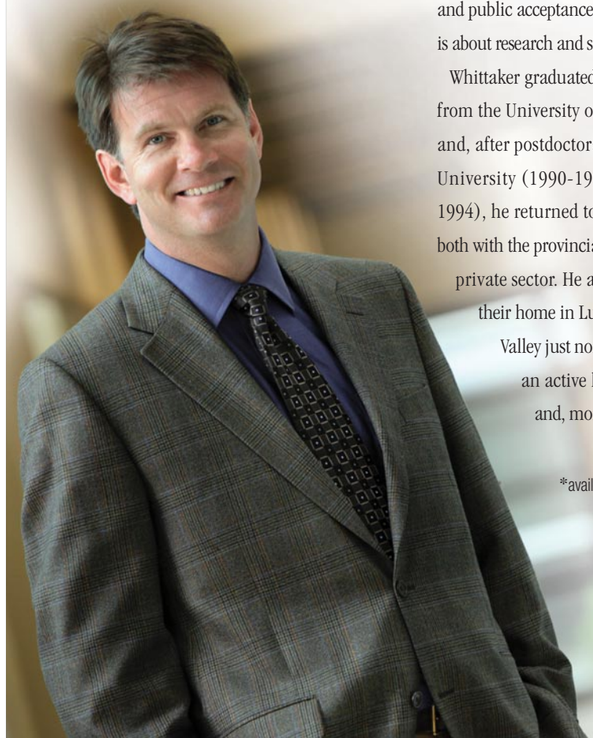
"The JIVE project is a successful example where three companies co-operated to more effectively address EOR issues that they all were facing. It advanced the technology much faster than would have happened had each done the work alone. It's the sort of teamwork that I've seen succeed in all sorts of fields of operation, from baseball to industry. I'm proud to have been a part of it." ■



## Steve Whittaker

### Managing the Expectations of a Worldwide Audience

> "This project is as much about knowledge sharing and public acceptance for the technologies as it is about research and science."



**The IEA GHG Weyburn-Midale $CO_2$ Monitoring and Storage Project**

In 2008, when Steve Whittaker joined the PTRC to oversee the management of the IEA GHG Weyburn-Midale $CO_2$ Monitoring and Storage Project, he was already largely familiar with the research that had been done up to that point. As one of the co-authors of the project's first phase report* he had been in charge of the geological characterization of the site while employed as a senior research petroleum geologist at the Saskatchewan Geological Survey.

"Weyburn had been an ongoing and significant project for a number of years," he notes. "Getting the job as the overall project manager gave me the opportunity to fully understand and study all the sides of the project – from geochemical and geophysical modeling, to wellbore integrity, to risk assessment and public engagement. I came to realize this project is as much about knowledge sharing and public acceptance for the technologies as it is about research and science."

Whittaker graduated with a Ph.D. in geology from the University of Saskatchewan in 1989 and, after postdoctoral work at both Queen's University (1990-1992) and McGill (1993-1994), he returned to Saskatchewan to work both with the provincial government and in the private sector. He and his wife, Jean, make their home in Lumsden in the Qu'Appelle Valley just north of Regina, and he has an active life that includes hockey and, more frequently, running.

"I recently threw my back out," he says. "That led to a lot more lying around than running, but I try to get out as often as I can."

Under his tenure in 2009-2010, the Weyburn-Midale project moved into its penultimate year of scientific research; a best practices manual, the project's final deliverable in 2011, will help other $CO_2$ enhanced oil recovery operations transition into long-term storage. A number of key scientific projects and public engagement initiatives moved forward.

"This past year we got approval to do the field wellbore integrity testing, and have developed the various tools specifically for that purpose. As well, as part of the legacy Weyburn will leave on a broader public level, a website was built that is one of the most comprehensive educational tools ever put together on carbon capture and storage (www.ccs101.ca)."

Whittaker is also aware of the importance being placed on the best practices manual, particularly from the perspective of the Canadian and United States governments who are major sponsors of the research, and who committed in 2009-2010 to additional funding to cover the wellbore integrity research.

"Weyburn is going to help instruct the world in the best practices for transitioning EOR into long-term storage," he says. "Our corporate and our government sponsors see this as the key deliverable and our research this past year has set us up well for achieving that deliverable in time by the close of 2011." ■

*available at the PTRC's website at http://www.ptrc.ca/ siteimages/Summary_Report_2000_2004.pdf)

# Energizing the World

## Scott Rennie

### Transporting the Best to Saskatchewan

"Aquistore will be one of the first integrated carbon capture, transport, injection, storage and research projects operating in the world."

Scott Rennie, kayaking at Swan Lakes on the Kenai Peninsula, Alaska.

"From a technical standpoint," says Scott Rennie, Project Manager with Schlumberger Carbon Services, "Aquistore makes a lot of sense for us as a project. It provides an opportunity for Schlumberger to demonstrate its carbon dioxide ($CO_2$) geological storage capabilities in Canada, bringing experience from other CCS projects we are involved in around the world; and PTRC's team is great to work with."

Rennie, like the burgeoning carbon capture and storage (CCS) industry itself, has a background that is a diverse compilation of technology and research skills, in his case resulting from different roles held over a decade in the oil and gas industry. His father, a Canadian petroleum engineer, travelled the globe with his young family to France, Turkey, and Indonesia. It was in Turkey where Scott was born, and he attended an expatriate high school in Indonesia. A love of baseball drew him to the United States for university, where he completed an M.Sc. in mechanical engineering at Rice University (Houston) in 1998.

"I didn't plan to work in the oil industry. But an offer came in from Atlantic Richfield Company on the North Slope in Alaska and I took it right out of university. I worked in Alaska until 2005, and actually met my wife there. By that time the company, through some mergers and acquisitions, had become ConocoPhillips, and I moved with them to Houston and Venezuela over the next couple of years. After returning to Houston from Venezuela in 2007, I took a job that gave me the opportunity to both develop CCS projects and undertake research to adapt oilfield technologies to the application of $CO_2$ storage."

Now settled in Calgary, but travelling frequently to Regina to help Aquistore establish its injection and monitoring wells, Rennie took the job with Schlumberger Carbon Services after actively investigating the companies that were leaders in CCS.

"I knew which companies were active in CCS research and projects, and really it was down to a few that have the intent and capability to lead in $CO_2$ storage. Also, when I returned to Houston in 2007 after my time in Venezuela, I was interested in getting back to Canada."

Schlumberger, with extensive experience in subsurface characterization and reservoir management, had already positioned itself at the forefront of CCS technology. Rennie joined Schlumberger Carbon Services in part because of the significant projects in the works north of the border. Aquistore is proving to be one of the most exciting.

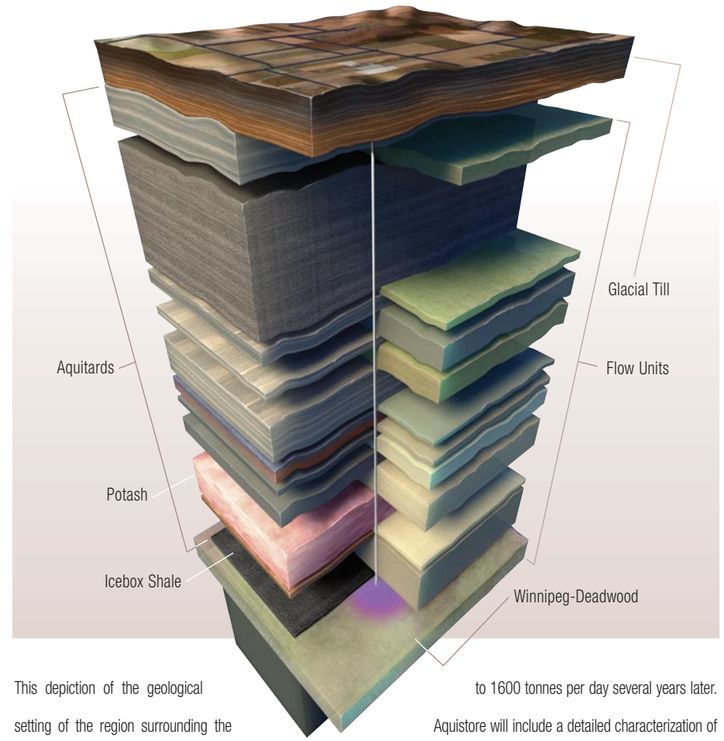
"Aquistore will be one of the first integrated carbon capture, transport, injection, storage and research projects operating in the world, and maybe the first involving saline $CO_2$ storage in Canada. The team working on it is exceptional – the PTRC, Consumers' Co-operative Refineries Limited, SaskEnergy, Enbridge, ourselves, SaskPower, and Canadian leaders in CCS research."

For Aquistore, 2009-2010 saw the achievement of some key milestones, and significant progress on others. The Scientific and Engineering Research Committee (SERC), made up of members from the major universities and organizations that will be conducting the research accompanying the project, completed a plan that outlines the full program – from site characterization prior to injection, to post-closure and ongoing monitoring. Likewise, the Aquistore Communications Steering Committee, made up of communicators from all the major participating companies, finalized an engagement plan that seeks to keep the general public and other stakeholders informed about project development.

A broad area north of Regina has been carefully screened and a specific site identified for the possible location of the $CO_2$ injection and monitoring wells. The well permit application process has begun, and the PTRC has initiated discussions with local stakeholders and municipal leaders. As well, Schlumberger Carbon Services was engaged by Aquistore to begin the well engineering and design work, leading to the identification of a specific site. The actual drilling of the well is scheduled to occur in the fiscal year 2011-2012.

"CCS projects are challenging due to the mix of commercial, regulatory, technical and social factors that need to come together to create a viable project. In that sense, it's great to be working on Aquistore, which has real legs," Rennie notes. "I'm back in Canada, working on things I'm really interested in, and in a city (Calgary) where my wife and I can do the sorts of outdoor activities we love. We backpack, and bike, and I'm willing to go just about anywhere to kayak."

"I love travelling and seeing new places and cultures. It's hard to shake my own family history in that department. And now that same history has also, in a curious way, brought me to Regina and this project." ■




This depiction of the geological setting of the region surrounding the proposed injection site shows geologic strata separated into flow units and aquitards, or packages of rock that impede vertical movement of basin fluids or injected $CO_2$. The basal unit is the Winnipeg-Deadwood succession which is the target for $CO_2$ injection; near the proposed injection site the base of these rocks is around 2200 m. Aquistore initially will inject approximately 550 tonnes of $CO_2$ per day into these units and will scale up to 1600 tonnes per day several years later.

Aquistore will include a detailed characterization of the formation ahead of injection, and a $CO_2$ measurement, monitoring and verification program prior to and during injection. The partners in Aquistore, as of March 31, 2010, include Consumers' Co-operative Refineries Limited, PTRC, Enbridge, Schlumberger Carbon Services, SaskEnergy, SaskPower, Sustainable Development Technology Canada, and the Saskatchewan Ministry of Environment's Go Green Fund.

Energizing the World

# Erik Nickel

## Action on the Field and Below

It's a project that, as Nickel observes, could not be done without the unique consortia-building approach of the PTRC.

## Saskatchewan Phanerozoic Fluids and Petroleum Systems (SPFPS)

In 2009-2010, the PTRC established its work program for mapping the complete hydrogeological subsurface of Saskatchewan and identifying areas of likely hydrocarbon generation and migration pathways. Working with a one million dollar grant from the Saskatchewan government, teams of scientists from the universities of Regina and Alberta, as well as geologists from the Saskatchewan Geological Survey (SGS), developed a program that will help determine how hydrocarbons and other basinal fluids have evolved and migrated in the subsurface over time.

One of the researchers key to this work is Erik Nickel, a senior research petroleum geologist at the Saskatchewan Geological Survey.

"'Fluids' is a very diverse project, utilizing elements of geology, hydrogeology and geochemistry," Nickel notes. "But it's not just about oil, it is about the burgeoning fields of carbon capture and storage, brine chemical production, and many other elements."

Saskatchewan Phanerozoic Fluids and Petroleum Systems seeks to provide a complete picture of the fluidic subsurface of the province, helping to identify deep saline aquifers as potential $CO_2$ storage sites, as well as oil migration routes and locations. It's a project that, as Nickel observes, could not be done without the unique consortia-building approach of the PTRC.

"The key to the project's success, for the Ministry of Energy and Resources, has been the partnership with the PTRC. Through this collaboration we have been able to bring to bear the full power of the PTRC's relationships with the nation's top researchers in pertinent fields."

Nickel knows Saskatchewan – both surface and subsurface – very well. Married, with a six-year-old son named Jacob, Nickel was born in Biggar and raised in the North Battleford area. He attained his undergraduate degree in geology at the University of Saskatchewan in 1994 before gaining his M.Sc. from Regina in 2007. His early geological work was done for Cameco, field mapping and prospecting in the province. Those tasks fit well with his predilection for the outdoors.

"I really enjoy all the seasons – golf in the summer, skiing in the winter, and hunting in the fall. I feel blessed that this province has an outdoors that many people pay thousands of dollars and travel miles to take part in. And of course, being born and raised a Saskatchewanian, I have a passion for all things Roughriders!"

The 'Fluids' project will be an opportunity for Nickel to get not just on the field but below it, and help improve the province's knowledge base and, in turn, its access to resources.

"This project is maximizing the government's investment in geological research, which will benefit the citizens of Saskatchewan. But it will also benefit all the companies working here, by providing results that can be shared with them." ■

Erik Nickel, at work in a laboratory at the Geological Survey of Saskatchewan.



## STEPS Bitumen and Heavy Oil Research Program, 2009-2010

The following project descriptions are snapshots, at March 31, 2010, of the work being carried out in the PTRC's STEPS research program.

### Heavy Oil (Post) Cold Flow

#### Heavy Oil Cold Production Optimization

The main objectives of this research project are to understand the critical effects of wormhole structures on primary cold production and post-cold production. In turn, this will help optimize the field operation and cold production system so as to improve the recovery of heavy oil, and to suggest infill drilling locations. The project will evaluate CHOPS well performance, and support decision-making during post-cold production processes.

**Project Leader:** G. Zhao, University of Regina.

#### Cyclic Solvent Stimulation for Cold-Produced Reservoirs

This project is aimed at providing a more accurate simulation of the cyclic solvent stimulation process for cold-produced reservoirs (oilfields in which sand was deliberately co-produced with the oil, creating high-permeability channels called wormholes). SRC's multi-well cold production numerical model will be modified to better simulate the direction in which wormholes grow in such reservoirs. The proximity of wormhole networks that develop from each cold production well influences the sweep efficiency of the solvent in cyclic solvent injection processes. Once the model is improved, it will be used to investigate the effect of the solvent type ($CO_2$/propane or methane/propane) on the process.

**Project Leader:** B. Tremblay, SRC.

#### Utilization of $CO_2$ for Pressure Maintenance and Improving Oil Recovery from Heavy Oil Reservoirs

Pressure maintenance through gas injection has been implemented for light oil reservoirs for many years, but the suitability of $CO_2$ for this purpose in heavy oil reservoirs has not been investigated. This project aims at conducting a comprehensive study, both experimentally and through simulation scenarios, for utilizing $CO_2$ for pressure maintenance in heavy oil reservoirs.

**Project Leader:** D. (Tony) Yang, University of Regina.

#### Post-Cold Production EOR: Air Injection Pilot Preparations

This multi-year project is devoted to a new air-injection process for heavy oil fields that have matured under cold production with sand. A renewed effort will be made to establish a producer consortium to prepare for implementing a field pilot. Meanwhile, the accompanying goal of reliable simulation methods for air injection will be advanced through laboratory kinetics tests to the point where genuine prediction of combustion front stability may become possible. In addition, pilot operating conditions will be screened with the use of a recently developed simulation model that incorporates wormholes from cold production.

**Project Leader:** N. Freitag, SRC.

#### Pyrolysis Kinetics of Low-Temperature Oxidation Residues from Heavy Oil Reservoirs

This project will determine the reaction kinetics for the pyrolysis of LTO residues formed by heavy oil and incorporate this into an overall reaction model to be assessed in numerical simulations of an air injection process. It offers a fundamental study of multi-phase flow at high temperatures during an air-injection process.

**Project Leader:** N. Mahinpey, University of Calgary.

### Enhanced Waterflooding

#### Optimized Surfactant-Polymer Waterflooding for Heavy Oils

This study aims to demonstrate the feasibility of the surfactant–polymer flooding technique for enhanced heavy oil recovery. Several important properties of the chemical solution in contact with the heavy oil (interfacial tension, viscosity, ability to form emulsions, and long-term stability) will be evaluated. A chemical mixture that tolerates high salinity and hardness will be designed that can minimize polymer degradation, chemical adsorption, and viscous fingering. Coreflood tests will then be conducted using the optimized chemical mixture.

**Project Leader:** M. Luo, SRC.

#### 2D Model Study of Chemical Flooding

This project is to develop a process of enhanced heavy oil recovery by chemical flooding. On the basis of previous research results, 2D physical model tests and a scaleup study will be conducted. This project will produce the chemical formulas for improving sweep efficiency and enhanced oil recovery by chemical flooding, and develop injection strategies. It will scale up parameters for heavy oil recovery by chemical flooding and provide a field scale prediction of oil recovery by chemical flooding.

**Project Leader:** M. Dong, University of Calgary.

#### Optimizing Regime-Based Waterflooding for Heavy Oil Waterfloods

This project continues SRC's statistical work on heavy oil waterfloods, with a new focus on determining best operating practices at different time stages of the floods. These stages are classified by their flow regimes: (I) oil only; (II) mostly oil; (III) water-in-oil emulsions; and finally (IV) water dragging clumps of emulsions. Other researchers consider Regime III to be the most productive waterflood period, but SRC's ongoing statistical studies suggest that Regime IV may perform better. We will examine the factors that separately contribute to success during Regimes III and IV.

**Project Leader:** G. Renouf, SRC.

#### Success of Heavy Oil Waterfloods - Factors and Predictions: Development of Neural Networks Tools

This project aims to complete a comprehensive study on developing and testing a current neural networks model for predicting the performance of waterflooding of heavy oil reservoirs. This will be done by evaluating the effect of a variety of field information on the outcome of this model. The project will incorporate additional geological data in the model.

**Project Leader:** F. Torabi, University of Regina.

#### Improving Conformance Control Technologies

This project will address the effects of brine salinity and divalent ion content as well as polymer shear history on polymer adsorption on unconsolidated heavy oil reservoir sands. Polymer gel injection patterns and the effects of gel volume and shear history on gel performance will be evaluated using a 3D physical model with a vertical injection well. In both cases, numerical simulation will be used to history match the laboratory experiments.

**Project Leader:** M. Luo, R. Wilton, SRC.

### Solvent Vapour Extraction (SVX)

#### Numerical Simulation of SVX Processes

This project includes extensive numerical simulation studies using previous 3D physical modelling data sets to improve numerical simulations of the SVX processes by better representing the three most important physical parameters: relative permeability curves, total effective solvent mass transfer, and non-equilibrium solvent solubility. This work will build on previous simulation studies, and introduce a novel history-matching approach using a non-equilibrium solvent solubility parameter derived from experimental data.

**Project Leader:** K. Knorr, SRC.

#### Asphaltene Precipitation and Its Effects on $CO_2$-Enhanced Heavy Oil Recovery

When $CO_2$ contacts heavy oil at certain pressures and temperatures, asphaltene precipitation occurs; the heavy oil in the reservoir is in-situ de-asphalted. Meanwhile, some precipitated asphaltenes may get deposited onto the reservoir sand grains and, thus, reservoir permeability is significantly reduced. Since $CO_2$-induced asphaltenes can be rather different from those induced by light hydrocarbons, this project will not only study the beneficial and detrimental effects of asphaltene precipitation and deposition on $CO_2$-enhanced heavy oil recovery but also analyze the physicochemical properties of $CO_2$-induced asphaltenes from crude oil samples under different experimental and heavy oil reservoir conditions.

**Project Leader:** Y. (Peter) Gu, University of Regina.

#### Evaluation of Solvent Vapour Extraction (SVX) Processes Using a 3D Physical Model

SVX processes offer an attractive alternative to thermal methods because they use less energy and water, avoid $CO_2$ production, and are more suitable for thinner, shallower, or partially depleted reservoirs. This study includes one experiment in SRC's 3D physical model, field scaling, and numerical simulations. It will determine the dependence of oil production rates and recovery on the combined effects of the solvent mass transfer rate and solubility by reducing the solvent injection rate while maintaining the total injected solvent mass. The results will be compared to a previous baseline run.

**Project Leader:** K. Knorr, SRC.

### Asphaltene Precipitation and Its Effects on the SVX Heavy Oil Recovery Process

When a solvent is in contact with heavy oil at high reservoir pressures during solvent vapour extraction, asphaltene precipitation occurs. The heavy oil in the reservoir is in-situ upgraded. Meanwhile, some asphaltenes may be deposited onto the reservoir sand grains and, thus, the reservoir permeability is reduced. Among the most important factors in precipitation are the operating pressures, reservoir permeability, solvent type and oil composition. This project will study asphaltene precipitation and deposition, and examine their beneficial (i.e., in-situ upgrading) and adverse (i.e., reservoir plugging) effects on SVX.

**Project Leader:** Y. (Peter) Gu, University of Regina.

### Solvent Dispersion Effect on the SVX Heavy Oil Recovery Process

When a solvent is injected into a heavy oil reservoir, significant heavy oil viscosity reduction is achieved through solvent dissolution (molecular diffusion and convective dispersion). Solvent dispersion may greatly accelerate the solvent dissolution into heavy oil during solvent vapour extraction. In practice, it has been found that solvent dispersion is strongly affected by several important operational factors, such as solvent type, injection conditions, horizontal well spacing and configuration, and reservoir characteristics. This project will examine the detailed effects of these factors on heavy oil and solvent production rates. A novel theoretical model will be developed to predict heavy oil production during the SVX process.

**Project Leader:** Y. (Peter) Gu, University of Regina.

### Underground Sonar for Detecting the Growth of the Chamber in SVX Processes

This project aims at utilizing acoustic sonar for detecting the shape of the vapour chamber in SVX processes. An experimental setup has been designed and digital signal processing algorithms have been developed and tested to help determine the shape and size of the vapour chamber in an environment of water-saturated sand. Currently, experiments in an oil environment are underway.

**Project Leader:** R. Paranjape, University of Regina.

## Gas Flooding (Miscible/Immiscible)

### Maximizing the Performance of Immiscible Gas Flooding in Heavy Oil Reservoirs

This research is aimed at optimizing immiscible gas flooding for heavy oils through improvements to displacement efficiency and reduction in oil viscosity. A comprehensive review will be conducted of SRC's previous research results for immiscible gas coreflooding with a variety of heavy oils and gases. Based on previous years' results, more solvents will be tested including $CO_2$ to find the most economical and effective injected solvents in gas flooding. In coreflood tests, various factors – slug size, injection rate, and injection scheme – will be evaluated to improve displacement efficiency.

**Project Leader:** M. Luo, SRC.

### Phase Behaviour of Solvent(s)-$CO_2$-Heavy Oil Systems under Subcritical and Supercritical Conditions

Conventional thermal methods often do not work for recovering heavy oil in thin reservoirs; $CO_2$ injection may recover additional oil through an immiscible process. Addition of solvents to a $CO_2$ stream will generally accelerate the process of swelling the oil and reducing its viscosity, and thus achieve higher oil recovery. This project will study phase behaviour of the solvent(s)-$CO_2$-heavy oil system under subcritical and supercritical conditions and subsequently determine the potential of $CO_2$-gaseous solvent mixtures for increasing oil recovery for thin heavy oil reservoirs.

**Project Leader:** D. (Tony) Yang, University of Regina.

### Investigation of Two- and Three-Phase Relative Permeability

This project will investigate the three-phase relative permeability relation for $CO_2$-oil-water systems through a series of carefully designed laboratory experiments. It is expected that the outcome of this research will enrich our fundamental understanding of the flow of $CO_2$ in oil reservoirs in the presence of both water and oil. In addition, the scientific findings will be of great benefit to oil companies that are interested in $CO_2$ flooding for reservoirs.

**Project Leader:** F. Torabi, University of Regina.

## Improving Heavy Oil Predictability

### Three-Phase Relative Permeability for Heavy Oil Systems

This project aims at experimental measurement and mathematical development of two- and three-phase relative permeability during multiphase flow of fluids in porous media containing heavy oil, water and solvent. Two- and three-phase relative permeability are key parameters for both history matching and future forecasting of most recovery processes at experimental and field scales. The effect of parameters such as oil viscosity, temperature, and rock wettability on three-phase relative permeability will be evaluated. Results obtained will then be used to develop a series of correlations that can predict the relative permeability trends for systems containing heavy oil.

**Project Leader:** F. Torabi, University of Regina.

### Improved Recovery for Heavy Oil Reservoirs Using Simultaneous Thermal and Chemical Flooding

This project is developing a process for enhanced heavy oil recovery using simultaneous injection of chemicals/thermal flooding. In the proposed process, thermal/chemical floods will be used to improve sweep efficiency, and displace heavy oil out of reservoirs. Research will be conducted into chemical formulas for improving sweep efficiency and oil recovery.

**Project Leader:** E. Shirif, A. Henni, University of Regina.

### Solubility and Diffusion Coefficients of Gases in SARA Fractions and Heavy Oils

In this project, the solubility and diffusion coefficients of carbon dioxide, ethane and propane will be measured for several western Canadian heavy oils and their SARA fractions. A gravimetric microbalance will be used for pressures up to 2 MPa, and equation of state and Solubility Parameter Theory models will correlate and predict the solubility data. Determining the solubilities of oils is critical to helping companies understand the amount and type of solvents to use in reservoirs, to help optimize recovery rates.

**Project Leader:** E. Shirif, A. Henni, University of Regina.

### Equation-of-State Characterization of Heavy Oils

The conventional correlations of the physical properties of oils, which are mainly based on light-oil data, generally become increasingly inaccurate when heavier oils are considered. This multi-year project addresses the overall need to provide reliable heavy-oil correlations that can be trusted during numerical simulations. Current year research uses a new and promising approach for prediction across temperature differences. The test will use SARA-fraction data from the experimental side of this program. A literature search for additional improvements will be conducted, and a recently uncovered, alternative correlation for oil viscosity will be tested.

**Project Leader:** N. Freitag, SRC.

## Incubation Projects

### Inexpensive Monitoring of Low Yield Oil Wells

Low productivity and marginally economic oilfields require careful management of expenses, human resources and equipment in order to maintain productivity and profitability. This project's short-term goal is to combine storage tank and individual well data in an integrated instrument package and to provide a low-speed, low-cost communications system to enable simple remote access to the data. The long-term goal is to acquire and integrate other data such as pumpjack performance and downhole pressure.

**Project Leader:** K. Runtz, T. Conroy, University of Regina.

### Increasing Temperature of Injection Water to Improve Heavy Oil Recovery

This project is studying the performance and applicability of hot waterflooding and comparing it with conventional waterflooding performed in heavy oil reservoirs, through simulation of the process using CMG-STARS. Increasing the temperature of injected water could reduce oil viscosity, which in turn could improve oil recovery, delay breakthrough, and reduce the water cut of heavy oils. Since viscosity of heavy oil has an exponential relationship with temperature, only a slight increase in temperature could result in a significant reduction of viscosity. Increasing the temperature of injection water can be accomplished with only minimal modification of facilities. In addition, the efficiency of other HOR techniques, such as $CO_2$-EOR techniques, may be increased when combined with hot waterflooding.

**Project Leader:** F. Torabi, University of Regina.



Petroleum Technology Research Centre Inc.

# Auditors' Report

## To the Members of Petroleum Technology Research Centre Inc.

We have audited the statement of financial position of Petroleum Technology Research Centre Inc. as at March 31, 2010, and the statements of operations and unrestricted net assets and cash flows for the year then ended. These financial statements are the responsibility of the Centre's management. Our responsibility is to express an opinion on these financial statements based on our audit.

We conducted our audit in accordance with Canadian generally accepted auditing standards. Those standards require that we plan and perform an audit to obtain reasonable assurance whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation.

In our opinion, these financial statements present fairly, in all material respects, the financial position of the Centre as at March 31, 2010, and the results of its operations and cash flows for the year then ended in accordance with Canadian generally accepted accounting principles.

REGINA, Saskatchewan
May 19, 2010

Virtus Group LLP
Chartered Accountants

Petroleum Technology Research Centre Inc.

# Statement of Financial Position

*as at March 31, 2010*

| | PTRC Operations $ | Aquistore $ | Fluids $ | JIVE $ | STEPS $ | Weyburn –Midale $ | 2010 Total $ | 2009 Total $ |
|---|---|---|---|---|---|---|---|---|
| **ASSETS** | | | | | | | | |
| CURRENT ASSETS | | | | | | | | |
| Cash | 7,950,416 | 3,332,551 | 215,377 | 1,818,436 | - | 4,000,847 | 17,317,627 | 7,350,785 |
| Accounts receivable | 4,866 | 1,928 | 13 | 291,483 | 1,028,743 | 1,273,360 | 2,600,393 | 8,920,128 |
| Prepaid expenses | 5,548 | - | 81,422 | - | 5,028 | 718,356 | 810,354 | 395,331 |
| | 7,960,830 | 3,334,479 | 296,812 | 2,109,919 | 1,033,771 | 5,992,563 | 20,728,374 | 16,666,244 |
| Property, Plant & Equipment – Note 3 | 61,503 | - | - | - | - | - | 61,503 | 240,789 |
| | 8,022,333 | 3,334,479 | 296,812 | 2,109,919 | 1,033,771 | 5,992,563 | 20,789,877 | 16,907,033 |
| **LIABILITIES AND NET ASSETS** | | | | | | | | |
| CURRENT LIABILITIES | | | | | | | | |
| Accounts payable and accrued liabilities | 424,987 | 130,364 | (103) | 182,966 | 650,997 | 667,789 | 2,057,000 | 1,868,991 |
| DUE TO (FROM) OTHER FUNDS – Note 6 | 6,719,676 | 81,823 | 5,354 | 46,200 | (6,963,915) | 110,862 | - | - |
| DEFERRED REVENUE – Note 4 | 547,704 | 3,122,292 | 291,561 | 1,880,753 | 7,346,689 | 5,213,912 | 18,402,911 | 14,489,907 |
| | 7,692,367 | 3,334,479 | 296,812 | 2,109,919 | 1,033,771 | 5,992,563 | 20,459,911 | 16,358,898 |
| NET ASSETS | | | | | | | | |
| Unrestricted | 329,966 | - | - | - | - | - | 329,966 | 548,135 |
| | 8,022,333 | 3,334,479 | 296,812 | 2,109,919 | 1,033,771 | 5,992,563 | 20,789,877 | 16,907,033 |

Approved by the Board

_____ Director _____ Director

*See accompanying notes to the financial statements.*



Petroleum Technology Research Centre Inc.

# Statement of Operations and Unrestricted Net Assets

*For the year ended March 31, 2010*

| | PTRC Operations $ | Aquistore $ | Fluids $ | JIVE $ | STEPS $ | Weyburn –Midale $ | 2010 Total $ | 2009 Total $ |
|---|---|---|---|---|---|---|---|---|
| REVENUE | | | | | | | | |
| Funding | | | | | | | | |
| Saskatchewan Energy & Resources | 892,296 | - | 208,439 | 514,950 | 572,119 | 17,797 | 2,205,601 | 805,000 |
| Enterprise Saskatchewan | - | - | - | - | - | - | - | 302,658 |
| Saskatchewan Environment | - | 219,096 | - | - | - | - | 219,096 | - |
| Western Economic Diversification Canada | - | - | - | - | 450,000 | - | 450,000 | 100,000 |
| Business-Led Networks of Centres of Excellence | - | - | - | - | 771,412 | - | 771,412 | - |
| Natural Resources Canada | - | - | - | - | 450,000 | 1,000,000 | 1,450,000 | 3,820,000 |
| Natural Resources Canada and US Department of Energy | - | - | - | - | - | 3,186,050 | 3,186,050 | - |
| Industry, other leveraged sources | - | 190,429 | - | 1,324,156 | 220,000 | 107,842 | 1,842,427 | 1,919,063 |
| Other – Note 9 | 369,185 | 31,575 | 217 | 4,991 | 7,407 | (239,164) | 174,211 | 616,103 |
| | 1,261,481 | 441,100 | 208,656 | 1,844,097 | 2,470,938 | 4,072,525 | 10,298,797 | 7,562,824 |
| OPERATING EXPENSES | 1,101,195 | 2,823 | - | - | 423,138 | 196,661 | 1,723,817 | 777,041 |
| PROJECT EXPENSES | 160,286 | 438,277 | 208,656 | 1,844,097 | 2,047,800 | 4,094,033 | 8,793,149 | 6,366,805 |
| TOTAL EXPENSES | 1,261,481 | 441,100 | 208,656 | 1,844,097 | 2,470,938 | 4,290,694 | 10,516,966 | 7,143,846 |
| EXCESS OF REVENUE (EXPENSE) | - | - | - | - | - | (218,169) | (218,169) | 418,978 |
| UNRESTRICTED NET ASSETS – beginning of year | 329,966 | - | - | - | - | 218,169 | 548,135 | 129,157 |
| UNRESTRICTED NET ASSETS – end of year | 329,966 | - | - | - | - | - | 329,966 | 548,135 |

*See accompanying notes to financial statements.*

# Statement of Cash Flows

*For the year ended March 31, 2010*

| | 2010 | 2009 |
|---|---|---|
| | $ | $ |
| **OPERATING ACTIVITIES** | | |
| Excess of revenue | (218,169) | 418,979 |
| Item that does not affect cash: | | |
| - Amortization - Notes 3, 5 | 75,537 | 101,277 |
| - Loss on disposal of property, plant and equipment | 128,953 | - |
| Net change in current assets | 5,904,711 | (5,805,981) |
| Net change in current liabilities | 188,009 | (305,596) |
| Net change in deferred revenue | 3,913,004 | 8,654,088 |
| **Net cash from operating activities** | **9,992,045** | **3,062,767** |
| **INVESTING ACTIVITIES** | | |
| Purchase of property, plant and equipment | (25,203) | (38,208) |
| **Net cash (used by) investing activities** | **(25,203)** | **(38,208)** |
| **INCREASE IN CASH RESOURCES** | **9,966,842** | **3,024,559** |
| **CASH** - beginning of year | 7,350,785 | 4,326,226 |
| **CASH** - end of year | 17,317,627 | 7,350,785 |

*See accompanying notes to financial statements.*

Energizing the World





# Notes to the Financial Statements

*March 31, 2010*

## 1. NATURE OF ORGANIZATION

Petroleum Technology Research Centre Inc. (The Centre) is an internationally recognized innovative leader in the petroleum research and development area that delivers world-class basic and applied research for the benefit of the people of Saskatchewan, Canada and their customers around the globe. The Centre is incorporated under the *Canada Business Corporations Act* as a non-profit corporation and is exempt from income taxes on its income.

## 2. SIGNIFICANT ACCOUNTING POLICIES

These financial statements are prepared in accordance with Canadian generally accepted accounting principles and the significant policies are as follows:

The accounts of the Centre are maintained in accordance with the principles of not-for-profit accounting. For financial reporting purposes, accounts with similar characteristics have been combined into the following major funding groups:

i) **PTRC Operations**

The PTRC Operations Fund reflects the general operations of the Centre primarily funded by Saskatchewan Ministry of Energy & Resources. In 2009-2010 initial work with a project focused on testing technology with the potential to reduce water usage and carbon dioxide ($CO_2$) emissions in the oil sands was included in the PTRC Operations Fund. The Centre has removed itself from further participation in the project and therefore will not experience any related additional costs in the future.

ii) **Aquistore**

The Aquistore project reflects the operations for the research project looking into capture of $CO_2$ from a Regina refinery for storage in a Saskatchewan deep saline formation. This is a multi-year project and is funded by a consortium that includes Sustainable Development Technology Canada (SDTC), Saskatchewan Ministry of Environment and three industry partners. This is the first fiscal year that this project is reported separately; initial work was done on the project in 2008-2009 and was reported under the PTRC Operations Fund.

iii) **Fluids**

The Saskatchewan Phanerozoic Fluids and Petroleum Systems (Fluids) project examines how basins, hydrocarbons and other fluids in the Saskatchewan subsurface have evolved over geologic times. This project is new in 2009-2010 and is funded by Saskatchewan Ministry of Energy & Resources.

iv) **JIVE**

The JIVE project reflects the operations for the collaborative project entitled *Joint Implementation of Vapour Extraction*. This multi-year project is funded by a consortium that includes Saskatchewan Ministry of Energy & Resources, Sustainable Development Technology Canada (SDTC) and three industry participants.

## 2. SIGNIFICANT ACCOUNTING POLICIES continued

v) STEPS

The Sustainable Technologies for Energy Production Systems (STEPS) project evolved from the Enhanced Oil Recovery project that was previously included within the PTRC Operations Fund. This evolution was initiated by the Centre being named a Business-Led Network of Centres of Excellence, with $10,500,000 being forwarded to the Centre via the Natural Sciences and Engineering Research Council ("NSERC") and the Social Sciences and Humanities Research Council ("SSHRC") over four years. Funds are also received from Saskatchewan Ministry of Energy & Resources, Natural Resources Canada (NRCan), Western Economic Diversification Canada (WD) and nine industry participants to support the program which is focused on ensuring that light, heavy and extra-heavy oil production expands to keep pace with domestic and international demands, through developing technology to reduce the environmental footprint associated with increased production.

vi) Weyburn-Midale

The Weyburn-Midale project reflects the operations for the multi-year collaborative project entitled *Final Phase of the IEA GHG Weyburn-Midale $CO_2$ Monitoring and Storage Project*.

**Revenue Recognition**

The Centre follows the deferral method of accounting for contributions. Restricted contributions related to general operations are recognized as revenue of the PTRC Operations Fund in the year in which the related expenses are incurred. All other restricted contributions are recognized as revenue of the appropriate project in the year that related expenditures are incurred. Unrestricted contributions are recognized as revenue of the PTRC Operations Fund in the year they are received or receivable if the amount to be received can be reasonably estimated and collection is reasonably assured.

**Property, Plant and Equipment**

Assets of the Centre are stated at cost and are amortized over the estimated useful life of the assets, applying the following annual rates:

| | |
|---|---|
| Computers | 30% Declining balance method |
| Furniture and other equipment | 20% Declining balance method |
| Research assets | 30% Declining balance method |
| Leasehold improvements | Straight line method (3 years) |

**Foreign currency**

Monetary items denominated in foreign currency are translated to Canadian dollars at exchange rates in effect at the statement of financial position date, and non-monetary items are translated at rates of exchange in effect when the assets were acquired or obligations incurred. Revenues and expenses are translated at rates in effect at the time of the transactions. Foreign exchange gains and losses are included in other revenue.







## 2. SIGNIFICANT ACCOUNTING POLICIES continued

**Use of Estimates**

The preparation of financial statements in accordance with Canadian generally accepted accounting principles requires management to make estimates and assumptions that affect the reported amount of assets and liabilities and disclosure of contingent assets and liabilities at the date of the financial statements and the reported amount of revenues and expenses during the reported period. Since actual results may differ from the estimates, these estimates are reviewed periodically, and, as adjustments become necessary, they are reported in earnings in the period in which they become known.

**Financial Instruments – Recognition and Measurement**

Financial assets and liabilities are initially recognized at fair value and their subsequent measurement is dependent on their classification. Their classification depends on the purpose for which the financial instruments were acquired or issued, their characteristics and the Centre's designation of such instruments. The standards require that all financial instruments, including all derivatives, be measured at fair value with the exception of loans and receivables, debt securities classified as Hold to Maturity (HTM), and Available for Sale (AFS) financial assets that do not have quoted market prices in an active market.

Financial assets are classified as held-for-trade or loans and receivables. Cash is designated as held-for-trade and is carried at fair value. All receivables are designated as loans and receivables and are accounted for at amortized cost.

Financial liabilities are classified as other liabilities and are accounted for at amortized cost, with gains and losses reported in excess of revenue in the period that the liability is derecognized.

**Financial Instruments – Disclosure and Presentation**

The Centre has elected to continue to apply Section 3861, Financial Instruments – Disclosure and Presentation.

## 3. PROPERTY, PLANT AND EQUIPMENT

| | 2010 | | | 2009 |
|---|---|---|---|---|
| | Cost<br>$ | Accumulated Amortization<br>$ | Net Book Value<br>$ | Net Book Value<br>$ |
| Computers | 53,211 | 23,154 | 30,057 | 25,952 |
| Office furniture | 53,312 | 26,797 | 26,515 | 22,486 |
| Subtotal | 106,523 | 49,951 | 56,572 | 48,438 |
| Leasehold improvements | 14,794 | 9,863 | 4,931 | 9,863 |
| Research assets | - | - | - | 182,488 |
| Total | $ 121,317 | $ 59,814 | $ 61,503 | $ 240,789 |

Research asset amortization of $54,746 (2009 - $78,209) is included in project expenses.

# Notes to the Financial Statements



*March 31, 2010*

## 3. PROPERTY, PLANT AND EQUIPMENT continued

In the current year, The Centre recognized $128,953 as a loss on disposal of property, plant and equipment due to the obsolescence of the GRID networking computer research asset and other computer equipment.

The Centre's net investment in property, plant and equipment represents $61,503 (2009 - $58,301) of net unrestricted assets, calculated as total net book value less deferred revenue related to research assets.

## 4. DEFERRED REVENUE

The Centre receives contributions from government and industry for specific projects or programs. These funds are restricted in use as directed by the external sponsors. The Centre recognizes revenue for these projects on the same basis as expenditures are incurred. Any excess revenue in the year is deferred and recognized in future years as expenditures are incurred. Funding for research assets and prepaid maintenance contracts are also recorded as deferred revenue until such time as the related assets are put in use and amortized.

| | Beginning Deferred Revenue – March 31, 2009 | Funding Received 2010 | Revenue Recognized 2010 | Ending Deferred Revenue – March 31, 2010 |
|---|---|---|---|---|
| | $ | $ | $ | $ |
| PTRC Operations | 1,616,680 | - | 1,068,976 | 547,704 |
| Aquistore | 3,006,818 | 525,000 | 409,526 | 3,122,292 |
| Fluids | 300,000 | 200,000 | 208,439 | 291,561 |
| JIVE | 2,530,430 | 1,189,429 | 1,839,106 | 1,880,753 |
| STEPS | 2,805,000 | 7,005,220 | 2,463,531 | 7,346,689 |
| Weyburn-Midale | 4,230,980 | 5,294,622 | 4,311,690 | 5,213,912 |
| Total | $ 14,489,908 | $ 14,214,271 | $ 10,301,268 | $ 18,402,911 |

The beginning deferred revenues for Aquistore, Fluids and STEPS were included in the deferred revenue total for the PTRC Operations Fund at March 31, 2009 but have been separated above to reflect the actual activity of each project in 2009-2010. The deferred revenue is held to match with future project expenditures.







# Notes to the Financial Statements



*March 31, 2010*

## 5. SIGNIFICANT AGREEMENTS

The Centre has funding agreements in place at March 31, 2010 to support the future financial activity of each of the projects. The agreements specify the contribution schedule and the required spending deadlines.

The Aquistore project has contributions committed by SDTC totaling $5,000,000 over four years with expenses to be applied by December 31, 2013. Saskatchewan Ministry of Environment has committed $5,000,000 over five years to be used by March 15, 2014. Industry participants will contribute a total of $2,100,000 over three years with expenses to be through by December 31, 2015.

The Fluids project has an agreement with the Saskatchewan Ministry of Energy & Resources for contributions totaling $1,000,000 over four years with all funds to be used by March 31, 2013.

The JIVE project has contribution agreements requiring funds to be used in their entirety by the expiration date of October 5, 2010.

The STEPS project has contribution agreements with the Natural Sciences and Engineering Research Council ("NSERC") and the Social Sciences and Humanities Research Council ("SSHRC") representing a total award of $10,500,000 to be paid through 2012 and funds to be used by March 31, 2013. Saskatchewan Ministry of Energy & Resources has two annual funding agreements in place, the first a three-year agreement for $4,500,000 expiring on March 31, 2011 and the second, a three-year agreement for $3,120,000 expiring on March 31, 2012. A portion of the Saskatchewan Ministry of Energy & Resources contributions will be designated to PTRC Operations Fund as required to cover general operating expenses

The Weyburn-Midale project has contribution agreements requiring the funds to be used in their entirety by the expiration date of December 31, 2011.

## 6. DUE TO (FROM) OTHER PROJECTS

The PTRC Operations Fund holds the cash and makes payment on behalf of the STEPS Fund. On occasion, each project may make payments on behalf of another and at March 31, 2010 amounts due to and due from each project were outstanding.

| | PTRC Operations | Aquistore | Fluids | JIVE | STEPS | Weyburn - Midale |
|---|---|---|---|---|---|---|
| PTRC Operations | - | 81,639 | 4,758 | 46,043 | (6,967,536) | 115,420 |
| Aquistore | (81,639) | - | - | - | - | (184) |
| Fluids | (4,758) | - | - | - | - | (596) |
| JIVE | (46,043) | - | - | - | - | (157) |
| STEPS | 6,967,536 | - | - | - | - | (3,621) |
| Weyburn-Midale | (115,420) | 184 | 596 | 157 | 3,621 | - |
| Total (2010) | 6,719,676 | 81,823 | 5,354 | 46,200 | (6,963,915) | 110,862 |
| Total (2009) | 2,323,922 | N/A | N/A | (2,317,118) | N/A | (6,804) |

# Notes to the Financial Statements

*March 31, 2010*

## 7. UNREALIZED GAIN (LOSS)

In the Weyburn-Midale project the unrealized gain of $15,579 (2009 - $261,404) has been reclassified as other income. The reversal of the unrealized gain from the previous year is significant due to the appreciation in the Canadian dollar in 2009.

## 8. COMMITMENTS

The minimum payments under lease agreements for office premises and equipment are as follows:

| Year Ending March 31 $ | Minimum Lease Payments |
|---|---|
| 2011 | 59,417 |
| 2012 | 4,014 |
| 2013 | 4,014 |
| 2014 | 4,014 |
| 2015 | 2,007 |
| | 73,466 |

## 9. FINANCIAL INSTRUMENTS

**Fair Value of Financial Instruments**

The carrying amount of cash, accounts receivable and accounts payable approximates their fair market value because of the short-term nature of these items.

**Credit Risk**

The Centre does not believe it is subject to any significant concentration of credit risk related to accounts receivable.

## 10. CAPITAL MANAGEMENT

The Centre's objective when managing capital is to meet its current objectives as set out within its current strategic operating plan within its annual operating budget. This objective has remained unchanged from the prior period.

The Centre's capital consists of net assets plus deferred revenue contributions.

## 11. COMPARATIVE FIGURES

Certain comparative figures in the financial statement balances have been reclassified to conform to the financial statement presentation adopted for the current year.

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