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Wet Gold — Industry

You hit gravel country about half an hour south of Onoway, west of Edmonton. Smooth-sided hills of rock, sand, and silt rise out of the prairie landscape, interspersed with the gaping pits they came from. Up close, the man-made mounds tower at least three stories above your head; the bulldozers on top of them look like Tonka toys in comparison. These hills are but a small chip off the global crushed rock block, an industry that produces about 19 billion tonnes of sand and gravel worth $76 billion U.S. a year.[1]

B.J. Vickery drives his truck into the Onoway Wash Plant wearing the requisite safety helmet and vest. As director of Lafarge North America's environmental and regulatory affairs in western Canada, he knows a lot about how gravel affects the watershed.

Vickery walks up to an edifice of steel girders and conveyor belts. This gravel washing machine, about the height and length of a small warehouse, cleans hundreds of tonnes of gravel a day trucked in from five local pits, he says. Excess wash-water drips into a pool beneath its first conveyor belt.

"It's a simple business," Vickery says of the gravel industry. "We take big rocks and make small rocks and then wash them."

Simple, but also controversial. Gravel extraction is widely perceived as one of the bad-boys of water use in the Sturgeon, and also has the largest amount of water licensed to it in the region.[2] People complain about the dust, the noise, the traffic, and, most controversially, the effect the mines have on local water supplies.

Gravel extraction is just one of several big industries in Alberta, all of which run on a cool clear fuel called water. Industry, including commercial cooling, oil and gas, and oilfield injection, accounted for about 37 per cent of all licensed water withdrawals in 2003, making it the second-greatest water user after irrigation.[3] The oil industry needs five barrels of water to pump just one barrel of oil, which (under some definitions) makes it the most water-hungry industry in Alberta.[4] A coal-fired power plant needs 140 litres of water to produce one kilowatt-hour of electricity, which is why eight of the top 10 largest surface water allocations in the North Saskatchewan are dedicated to power generation.[5] An average metal-making plant uses 250 million cubic meters of water a year in its operations, and a pulp mill uses 435 million.[6] In short, Alberta's current way of life will grind to a halt if it can't find the water it needs to power these industries.

Water, On the Rocks

Sand and gravel mines affect both surface and groundwater. The mines strip away acres of surface and riparian vegetation, which can affect water quality. Industrial accidents can also leak toxic oils into aquifers and rivers, contaminating both. Gravel companies have to clean their product before they sell it, and use river water to do so.

The Onoway wash plant takes its water from Kilini Creek, a slow stream that feeds into the Sturgeon River. "The problem with this plant is that it's an open circuit," Vickery says,

meaning it pours silt-and-mineral-laden wash-water back into the creek. Most plants are closed system, he says, and recycle the water they use. Lafarge could have modified this plant to do just that when it bought it in 2001, he says, but the giant cement company determined it would cost more than the plant was worth.

Built in the '50s, the plant pulls about 3.2 billion litres of water out of the creek per year and returns about 2.9 billion, he says, a difference equivalent to 99 Olympic-sized swimming pools. The missing water either seeps back into the ground or evaporates, so there's no net loss to the local water system, he maintains. Recently, he adds, the company has started regulating its release of wash-water so it doesn't affect fish, at least while they're spawning.

What's an aquifer?

A region of porous rock that contains water and readily transmits it to the surface in the form of wells or springs.

Aquifers are "recharged" when surface water percolates down to them through the soil. If you withdraw water faster than the recharge rate, you "mine" the aquifer's water, and risk draining it entirely. Unfortunately, since you usually can't tell how much water is in an aquifer, it's tough to tell if you're mining an aquifer or not.

Aquifer contamination can be dangerous. Since there's nowhere for the contaminants to go, even a little bit of pollution can ruin an entire aquifer for years.

The water returned to the creek is the colour of weak coffee — well below the regulated limit for sediment, Vickery claims. It's in the company's interest to make the water as clean as possible, he adds; not only do they reuse much of their wash-water (the plant's intake is downstream of its outflow pipe), but they can also sell the silt. Lafarge regularly tests the water for oil and chemical contaminants, since greasy gravel makes bad product.

The gravel pits also affect groundwater. There are about 5,900 sand and gravel pits in the province. Combined, they cover an area about a third the size of Edmonton.[7] Lafarge operates 13 of the roughly 70 sand and gravel pits in the Sturgeon watershed, Vickery says. It is the largest

licensed user of groundwater in the North Saskatchewan, with most of its license going towards drainage (or dewatering) activities.[8] In recent years, Sturgeon residents have started worrying about the effects of these pits on their groundwater, and for good reason: they are among the 600,000 Alberta residents that rely completely on wells for their drinking water.[9]

Gravel pits have both temporary and permanent effects on groundwater, says Alan Hingston, the Alberta Environment engineer responsible for groundwater licensing in Sturgeon County. Most gravel deposits are above the water table, but many in Sturgeon County are below it, and must be drained before they can be mined. Unfortunately, a gravel deposit that's below the water table is otherwise known as an aquifer, a major source of groundwater. Drain it, and you could drain the wells that rural residents drink from. Studies show that the water level in test wells dug around the gravel extraction zone in the county dropped 1–10 meters during the drainage process.[10]

Dewatering can also affect the Sturgeon River, Hingston says, since it sits on top of the aquifer the companies are mining. Robert Lema lives near several gravel pits, and says the river by his house is lower in the spring when dewatering begins than it is in the fall when it ends. He blames this on the mines.

Most wells in the Sturgeon take their water from an aquifer that's much deeper than the ones the local gravel companies are mining, Hingston contends, so they aren't affected by dewatering. Nor does dewatering permanently remove water from the ground. Companies used to be able to dump the water directly into rivers like the Sturgeon, but now they have to shunt in it into another pit in the same aquifer to ensure no water is lost. You lose a little bit to evaporation, and the water quality suffers slightly due to exposure to the air, but that's about it,

Hingston says. The province can order any company that does affect a person's groundwater to drill a new well or pipe in water and pay the expense, he adds.

Dewatering aside, gravel pits do have one major permanent effect on groundwater: they destroy aquifers. "If you mine a layer of gravel, and it's an aquifer, you have removed the aquifer," Hingston explains. Reclamation efforts reduce the impact by replacing the gravel with sand, but this can only do so much. "You end up with about a meter of sand replacing five meters of gravel, and you have a much poorer aquifer than before," he says.

You also end up with a big hole in the ground. "When you fly over parts of the Sturgeon watershed," comments Lorne Fitch of the environmental group Cows and Fish, "what strikes you is how so many of the lakes are rectangular." All those lakes, he notes, are old, restored gravel pits. "Restored" is a relative term, of course: while it's possible to turn a pit back into farmland or a small stand of trees, it's impossible to completely restore the diversity of life that the region's original forests, wetlands and riparian zones represented.

It's tough to gauge what effect gravel mines have had on groundwater in the Sturgeon, since no one has done a comprehensive study on the region's aquifers. Mining could block the passage of water from aquifer to aquifer, affecting wells downstream. It could also permanently affect flows in the Sturgeon River, since aquifers do contribute to its flow.[11]

That's why some local residents are calling for a moratorium on all new gravel pits until such a study is done. Ian Skinner and Mike Northcott together head one of the region's most active environmental groups, the Onoway River Valley Conservation Authority, and have frequently criticized gravel operations in the Sturgeon. They say the province needs to do a full environmental assessment of the Sturgeon to find the cumulative effects of these gravel mines, and have written to the minister of the environment to ask for one. "We don't want to get to the

point where this natural infrastructure, this river, is destroyed," Northcott says. "We want to see what the cumulative impact [the industry] has had so far is."

Gravel companies don't have to mine aquifer gravel, Vickery admits, but that would put a lot of product out of reach. It would also make gravel more expensive: the price of a tonne of gravel goes up a dollar every ten kilometres it travels, and since Alberta uses about 45 million tonnes worth a year (mostly on roads and concrete), that's a lot of money. It's a trade-off, he argues: society loses a little bit in terms of environmental damage, but gains a lot in terms of valuable infrastructure material.

Skinner strongly disagrees. "It's not sustainable," he says. "You can't re-grow an aquifer like you do a forest."

Oil from Water

A little east of gravel country, you find oil land.

About 50 oil wells, a fraction of the 17,500 in Alberta, sit on the north shore of Big Lake northwest of St. Albert.[12] They help feed the world's oil habit, a habit that's brings about $7 billion in royalties to Alberta's coffers a year and 275,000 jobs to its economy.[13]

Oil extraction affects water several ways, says Mary Griffiths, an analyst with the Pembina Institute, an Alberta-based environmental think-tank, and co-chair of the provincial advisory committee on water use by the oil industry. Drillers use water to create a sort of slurry to lubricate their drill bits, for example, which can cause water shortages in dry areas and a risk of contamination. Building the wells and the roads that lead to them also involves clearing large areas of land, which can affect riparian zones and surface runoff patterns. Oil sands are sometimes mined in open pits, which can punch a hole in the land several city blocks wide and

around 100 meters deep. Digging a pit involves destroying any forests or vegetation in the area, which affects surface runoff. The pit must be dewatered, which drains local aquifers and wetlands, affecting drinking water and animal habitat. The wells themselves need plenty of water to extract the black gold from the sand.

There isn't a lot of oil and gas activity in the Sturgeon compared to other watersheds in the province, says Robert George, a groundwater specialist with Alberta Environment. Government records show there are currently no active licenses to divert water for the purpose of oil or gas extraction in the region, and no plans for enhanced recovery or *in situ* oil operations (see below for explanation).[14] Nor does oil extraction use a lot of water compared to other activities; just five per cent of all licensed withdrawals go towards it.[15] Industrial cooling for power generation takes much more water, coming second only to irrigation in terms of licensed withdrawals.[16]

Oil and the boreal forest

Most of Alberta's oil sands lie near Cold Lake and the Athabasca River, both parts of the boreal forest region of the province. That forest covers some 30 per cent of Canada, and is a major regulator of the nation's climate and greenhouse gas emissions.

Wetlands make up 45 per cent of the boreal forest in Alberta, and act as important sponges and filters in Alberta's water system, storing and cleaning it before it enters the province's rivers. Since they feature such a diverse array of life, it's very difficult to replace them once destroyed.

Oil sands development has disturbed an enormous amount of the boreal forest; as of 2004, there were 950 square kilometres of land either disturbed or approved for disturbance in the region.

All existing, approved, and planned future oil sands projects will affect about 2,000 square kilometres of the boreal, an area equal to 28,465 NFL football fields, three Edmontons, or one Tokyo, Japan (Woynillowicz, Severson-Baker, and Raynolds 36, 42).

The real problems with the industry are threefold: how it uses its water, the kind of water it uses, and the amount it'll be using in the future. Enhanced oil recovery operations are a good example. They've been around in Alberta for over 30 years, but only recently have they drawn attention to themselves. Wells lose pressure as you pump the oil out of them, so in enhanced

recovery operations, companies pump freshwater back into them. “The oil you get out, you’re replacing with water,” Griffiths explains. That entombs that water hundreds of meters underground, beyond the reach of wells and the environment, removing it from general circulation for tens of thousands of years. Some 48 million cubic meters of water, equivalent to 19,000 Olympic-sized swimming pools, were pumped underground in 2001 alone, four fifths of this being freshwater and one fifth saline water.[17] Most of the freshwater (73 per cent) came from lakes and rivers in the South Saskatchewan basin, which is already under water stress due to agriculture. The rest (28 per cent) came from groundwater. Most of these groundwater diversions are clumped southeast of the Sturgeon near Drayton Valley.[18] With dugouts already going dry from drought, many Albertans were understandably concerned and outraged when they learned of enhanced oil recovery’s water use.

Sharing the water spotlight with injection are *in situ* oil sands operations. Just 19 per cent of Alberta’s oil sands are close enough to the surface for easy mining; the rest is deep underground, and has to be pumped out like crude oil. But bitumen, the tar-like substance that is the oil in oil sands, doesn’t flow naturally, so companies first liquefy it by injecting steam into the ground. Much of that steam comes from groundwater, and not all of it comes back. The industry needs about three bath-tubs of water to get one tub of oil from the sands, and loses one tub in the process.[19] In fact, if you look at just groundwater use, oil extraction and processing uses more water than any other activity in the province, accounting for about 29 per cent of all licensed groundwater withdrawals.[20]

Most *in situ* operations in Alberta are concentrated around the Athabasca River near Fort McMurray, which puts great stress on local water resources. About 65 per cent of all licensed withdrawals in the Athabasca River basin go to the oil sands, a volume of water equivalent to twice the amount of water used by Calgary in a year.[21] "Even with [just] the projects we have now, the [water] allocations are equivalent to about 10 per cent of the winter flow in the Athabasca River," Griffiths notes. Water withdrawals continue year round, meaning they could significantly affect fish habitat in the winter when flows are low.

Two obstacles prevent Alberta from easily reducing the amount of water used by the oil industry, and both involve the water licensing system. Like irrigation, many licenses for oil operations (about half, Griffiths says) are very old and were issued in perpetuity, giving oil companies a legally protected leg-up on other people when it comes to getting their share of scarce water resources. "At the moment, we're relying on voluntary returns of that water," Griffiths says. If the government tries to forcefully repossess the licenses in the future, it will probably face lawsuits, she adds. The amount of water licensed for oil operations has almost doubled since the '70s to 170 million cubic meters from 95 million.[22]

Oil sands and global warming

Companies burn 1,000 cubic feet of natural gas to make the steam needed to extract one cubic meter of bitumen from the oil sands, enough to heat a typical Canadian home for about six days.

This, combined with other gases released when refining the bitumen into oil, makes the oil sands industry Canada's biggest single source of greenhouse gas emissions (Woynillowicz, Severson-Baker, and Raynolds 12, 19).

Thing is, the province doesn't know how much of that licensed water the oil industry is actually using, or how much it could cut back. Alberta Environment tracks the amount of water it has licensed, but not how much of that license is used. In 2002, for example, oil and gas companies had licensed 438 million cubic meters of water for withdrawal, or about twice the

amount used by Calgary in a year, but only about a fifth of this was actually used for injection purposes.[23] Some oil projects also need less water as they advance in age. An enhanced recovery well needs a lot of water at first but less later on since some of the water it injects comes back up with the oil, allowing workers to recycle it. Estimates suggest the oil industry has actually reduced by half the amount of water it is diverting into wells since the '70s due to recycling and new technologies.[24] Some wells recycle up to 90 per cent of their water, adds Griffiths. The Pembina Institute has recommended that Alberta Environment start tracking actual water use to fill this data gap.

Nor does the province know how much it should cut back. Alberta Environment has very little data on what is affecting water flows in Alberta. Despite having a large network of groundwater monitoring wells, for example, the department doesn't have long-term data on their levels or what causes them to change.[25] Only a small percentage of complaints about rural water supplies have been conclusively linked to oil and gas activity, Griffiths says, partially because it's so hard to tell what specific activity — irrigation? drought? oil wells? population growth? — causes a region's wells to go bad.

In its defence, the oil industry says improved technology will let it harness Alberta's oil without sacrificing its water. It now uses 10 times more saline water in its operations than it did in the '70s, for example, meaning it needs less freshwater, and recycles much of the water it does use.[26] Companies are also working on water replacements like nitrogen gas and chemical solvents.

But a lot of these technologies have problems, Griffiths says. You have to purify saline water to use it in steam injection, for example, and purification produces polluted sludge. Oil-sands company EnCana estimates that its Foster Creek plant alone will dump 48 billion litres

of sludge down deep wells over the next 25 years.[27] Recycling injection water also removes it from the water system for the life of the oil project, which can be upwards of 30 years.[28] As for chemical and gas substitutes, she says they're at least a decade away from widespread commercial readiness. In the meantime, the oil industry shows no signs of slowing down: water demand for *in situ* operations is expected to triple by 2020, she notes.

Water for Life Summary: Industry

Today, Alberta is one of the richest provinces in Canada because of its rampant industrial growth. If it wants to stay rich, it needs to bring that growth under control.

Industry and agriculture both depend on water, but affect it in different ways. With agriculture, we're concerned with cumulative effects, or what all those cows together do to a watershed. With industry, we're worried about permanent effects. While farms can do a lot of harm to water, it's easy to fix; remove the farms, and you remove the harm. It's different with oil and gravel; once you mine a gravel aquifer or plough under a wetland, those things are gone for good. Modern science can create rough equivalents, but it cannot completely replace the water-cleansing properties of a natural wetland, the water-holding capacity of a gravel aquifer, or the water lost to an oil well.

Alberta's industries are growing at a pace that threatens its Water for Life goals for secure water supplies for its economy and healthy aquatic ecosystems. One expert estimates the province will use five billion tonnes of sand and gravel in the next 50 years, which will mean digging a number of pits equal in area to about one and a half times the size of Edmonton.[29] Investment in terms of capital spending in the oil patch almost doubled over the last eight years and shows no sign of slowing down any time soon, with oil sands production expected to

quintuple to five million barrels a day by 2030.[30] The oil sands alone have already affected at least 430 square kilometres of the boreal forest (roughly three-quarters the size of Edmonton), ploughing thousands of acres of water-storing wetland underground.[31]

The province has taken tentative steps towards limiting water use by industry. As of May 2006, Alberta now requires oil companies that want to use freshwater for enhanced recovery operations to prove that they have explored every feasible alternative to freshwater, and to consider delaying any such projects until a viable alternative emerges.[32] Alberta Environment's plan to protect the Athabasca River (still in development as of this writing) proposes some reduction in the amount of water taken from the basin by oil sands, but since the plan relies mostly on voluntary measures and does not account for the effects of climate change, it's unlikely to make much of a dent in actual water use.[33] As for gravel in the Sturgeon, county and provincial officials have rejected Northcott's call for a moratorium on development, and have said they were either uninterested in or unable to conduct the environmental assessment he wanted.[34]

Water for Life has a few initiatives that might control industrial growth, but these won't be ready anytime soon. Increasing the price of water, for example, could encourage more conservation and discourage rapid oil development. But to date, the province has not even started its study of how it might introduce a price change, although it has hired a consultant to do a study on how to do the study.[35] Watershed committees could negotiate voluntary agreements to control industrial growth, but with the exception of the South Saskatchewan none of them are organized enough to do this right now.

The Advisory Committee on Water Use Practice and Policy, appointed by the province to study water and enhanced oil recovery operations, has made two recommendations that could

have far-reaching consequences should the province adopt them.[36] First, it recommended the province study "economic instruments" as means to reduce water use. Considering the extremely low cost of water in Alberta (about $90 to get a license for 63 million litres a year), expensive but waterless technologies like nitrogen gas injection won't catch on without some serious financial help. Alberta will definitely need to change the price of water if it wants more efficient use of it — more on this later.

Second, the committee acknowledged that the province might have to review the first-in-time, first-in-right water licensing system since that system does not address water conservation issues; a license for drinking water carries the same weight as one for *in situ* injection. Specifically, the committee said the province should consider limiting the amount of water it allocates towards certain economic sectors (including the oil patch) instead of doling it out on a first-come, first-serve basis. This would be an essential step towards a provincial water management plan and a major shift in direction for Water for Life, which currently enshrines the first-in-time, first-in-right system. The province could significantly advance its Water for Life goals and ensure ecologically sustainable growth in its economy if it adopted these reforms.

Vickery would not say specifically what Lafarge Inc. would do to adapt to a Water-for-Life future, but says his company knows both the necessity and the advantages of doing so. "We recognize that it's a privilege to use this water," he says. "We think we have done our due diligence and that we are better for it."

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[1] Robert Peel (former Alberta Environment geologist who studied aggregate extraction for 13 years), "Sustainable Development of the Aggregate Resources of Alberta," (Master's thesis, University of Alberta, 2004), 121.

[2] Based on records obtained from Lorne Edinga of Alberta Environment. As of March 2006, about 44 per cent of all licensed diversions in the Sturgeon went towards aggregate washing and dewatering by aggregate extractors. The total licensed amount of water was about four million cubic meters, or about a

million more than that licensed for stock-watering and crops. Note, however, that gravel operations have very low water consumption, representing just 10 per cent of all consumption in the Sturgeon, and return almost all the water they use to the watershed. This water, as noted later, may be of lower quality due to sediment.

[3] Wilkie, 9. Alberta Environment divides the industrial sector into several categories, making it tough to gauge exactly how much water it has licensed. The 37 per cent includes the categories of commercial cooling, commercial/industrial, industrial (oil and gas), and oilfield injection, totalling 3.6 trillion litres of water. Note that most commercial cooling is used for power generation.

[4] Ibid., 11.

[5] Brandes and Ferguson, *Flushing*, 13; Aquality Environmental Consulting Ltd., 173.

[6] Shiklomanov and Penkova, 16. A wood pulp and paper plant producing 500,000 tonnes per year needs 435 million cubic meters of water, and a metallurgical plant making that same mass of product needs 250 million.

[7] Peel, 31. Alberta Environment estimates that all the gravel pits in Alberta have a total area of about 260 square kilometres.

[8] Aquality Environmental Consulting Ltd., 175.

[9] Alberta Environment, *Water and Oil: An Overview of the Use of Water for Enhanced Oil Recovery in Alberta*, Edmonton, Alta.: Alberta Environment 2004, 6.

[10] D. Borneuf and N.H. Fernuik, "2004 Groundwater Monitoring Program Villeneuve-Calahoo Gravel Extraction Area," Edmonton, Alta.: Thurber Environmental Consulting 2005, 3–4. Studies of gravel mines in the Sturgeon found that dewatering caused water levels in test wells to drop 1–10 meters. Most of the wells returned to their former level once dewatering stopped.

[11] Ernie Ewaschuk, Land Stewardship Centre, in-person interview by author supplemented by email and telephone conversations, St. Albert, Alta. 13 July 2005; Alan Hingston, hydro-geologist in charge of groundwater licensing in Sturgeon River region, in-person interview by author supplemented by phone and email conversations, St. Albert, Alta. 16 July 2005.

[12] Derek Richmond, former environmental consultant for the City of St. Albert, in-person interview by author supplemented by emails, St. Albert, Alta., 12 July 2005; Alberta Energy, "Oil Statistics," [online] Edmonton, Alta., Alberta Energy 2006, available from http://www.energy.gov.ab.ca/803.asp, Internet, accessed 3 April 2006.

[13] The Canadian Association of Petroleum Producers (CAPP) reports that Alberta made $52.8 billion in royalties, fees, and bonuses from oil and natural gas production from 1997–2004, averaging $6.6 billion a year, and employed (directly and indirectly) 250,000 people in 2003–04.

[14] Records provided by Lorne Edinga of Alberta Environment show there were 15 issued in the last six years, each involving less than 1,000 cubic meters of flow and lasting less than a month, likely for construction purposes.

[15] Advisory Committee on Water Use Practice and Policy, *Advisory Committee on Water Use Practice and Policy: Final Report*, Edmonton, Alta.: Advisory Committee on Water Use Practice and Policy 2004, 12.

[16] Wilkie, 9. In 2003, there were 2,605,258,629 cubic meters per year of water licensed for the purpose of commercial cooling, equal to 26.8 per cent of all licensed withdrawals.

[17] GEOWA Information Technologies, Ltd., *Water Use for Injection Purposes in Alberta*, Calgary, Alta.: Alberta Environment 2003, i. Alberta Environment defines saline water as groundwater containing

more than 4,000 milligrams per litre of dissolved solids. It is unfit for drinking or irrigation. Griffiths says you could try and pump the water back out again, but unless you injected something else to replace it, the resulting vacuum would suck in more water from elsewhere.

[18] Advisory Committee on Water Use Practice and Policy 13. Rough estimate based on maps of surface water diversions for enhanced recovery operations provided by Robert George of Alberta Environment. The map shows several licenses in the Strawberry and Modeste watersheds south and southwest of the Sturgeon. Those watersheds contain the municipalities of Edmonton and Drayton Valley, respectively.

[19] Mary Griffiths and Dan Woynillowicz, *Oil and Troubled Waters: Reducing the Impact of the Oil and Gas Industry on Alberta's Water Resources*, Drayton Valley, Alta.: The Pembina Institute 2003, 10. Griffith's originally used the term "barrel," which refers to the 159 litre barrels typically used to hold oil. A typical bathtub holds a bit less than 159 litres of water.

[20] Ibid., 7. Note that agriculture is still the leading user of water overall.

[21] Dan Woynillowicz and Chris Severson-Baker, "Down to the Last Drop? The Athabasca River and Oil Sands," *Oil Sands Issue Paper* 1 (March 2006), ii.

[22] GEOWA Information Technologies Ltd., 23.

[23] Griffiths and Woynillowicz, 13.

[24] GEOWA Information Technologies Ltd., 34. Total water diversion fell to 48 million cubic meters in 2001 from 89 million cubic meters in 1972.

[25] Griffiths and Woynillowicz, 26.

[26] Advisory Committee on Water Use Practice and Policy, 14. The proportion of water diverted for injection purposes that was saline rose to 21 per cent from two per cent from 1972–2001.

[27] Dan Woynillowicz, Chris Severson-Baker, and Marlo Raynolds, *Oil Sands Fever: The Environmental Implications of Canada's Oil Sands Rush*, Drayton Valley, Alta.: Pembina Institute 2005, 33.

[28] Ibid., 30. The water also contains toxic sediments that settle out in containment ponds and can later leach into groundwater.

[29] Peel, 121. Peel estimates that the pits needed to get this amount of aggregate, put together, would total 940 square kilometres. According to Statistics Canada, Edmonton has an area of 684 square kilometres.

[30] Investment numbers from CAPP, which show total oil and oil sands capital spending rose to 25 billion from 14 billion from 1997 to 2004. Woynillowicz, Severson-Baker, and Raynolds, 5.

[31] Woynillowicz, Severson-Baker, and Raynolds, 42. This is a 2003 estimate based solely on developments in the Athabasca basin.

[32] Alberta, *Water Conservation and Allocation Policy for Oilfield Injection*, Edmonton, Alta.: Alberta Environment 2006, 1.

[33] Woynillowicz and Severson-Baker, 8–11.

[34] Assessment synthesized from interviews with Butler and others.

[35] Alberta Environment, *Report on the Implementation Progress of Water for Life Alberta's Strategy for Sustainability*, Edmonton, Alta.: Alberta Environment 2005, 27. "Clarity of methodology is required prior to determining the full cost of water. As an initial step, a consultant will be retained in 2005–2006 to develop the scope and parameters for this task."

[36] Advisory Committee on Water Use Practice and Policy, 18–22.