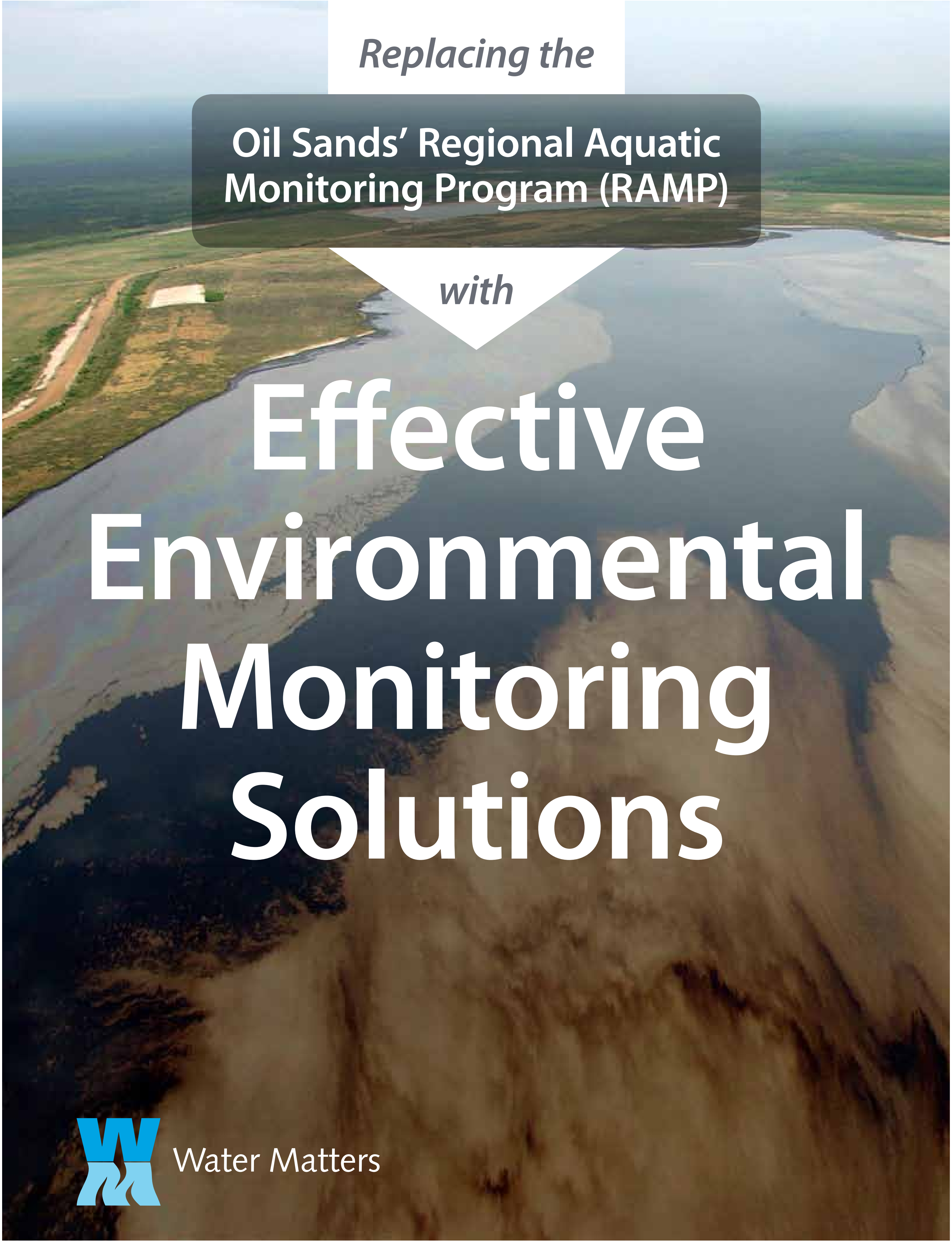

Replacing the

Oil Sands' Regional Aquatic Monitoring Program (RAMP)

with

Effective Environmental Monitoring Solutions

Water Matters

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Executive Summary

There is no question that developing the oil sands provides economic benefits, but it is equally important to protect the Lower Athabasca Basin from irreparable environmental harm caused by irresponsible oil sands development. However, in recent years the Government of Alberta and the oil sands industry have come under increasing criticism because of a growing perception that the development of the oil sands in northeastern Alberta has been allowed to expand too quickly and without sufficient consideration of the environmental impacts it causes. What should be a relatively simple scientific question – Are there any identifiable, significant environmental effects of oil sands development? – has been marginalized by intense, non-scientific high-stakes posturing between government, industry and ENGOs driven by different perspectives on oil sands development at local, provincial and even international scales.

Despite its legal obligation to monitor water quality in Canadian inland waters and transboundary air pollution, the Government of Canada is not monitoring the effects of oil sands development on the Lower Athabasca River and its tributaries or regional lakes. Independent scientific studies, external reviews, and three recent reports from the Commissioner of the Environment, the Royal Society of Canada, and the federal Oilsands Advisory Panel all have highlighted the need to completely rebuild the environmental monitoring programs in the oil sands region based on scientific best practice rather than political or stakeholder priorities. This is necessary because the Government of Canada has delegated its responsibility to monitor and protect the environment to the Alberta government, and the Alberta government in turn has delegated responsibility to the oil sands industry. Allowing multi-stakeholder organizations such as the Regional Aquatic Monitoring Program (RAMP) to use a consensus-based approach to environmental monitoring, in which the oil sands industry plays a major role in decision making, has compromised the quality and integrity of environmental monitoring that are necessary to ensure oil sands developments are undertaken responsibly, sustainably and in accordance with the law.

The rebuilding of environmental monitoring in the oil sands region must begin with the establishment of clear objectives and strong scientific oversight and direction, and include adoption of appropriate scientific techniques and strategies that permit detection and interpretation of complex interactions and cumulative effects of oil sands development. In addition to the monitoring of environmental trends, there is a critical need for coincidental research into the causes of the observed changes and the accuracy of predicted outcomes of approved and planned industrial expansion. These causes must be understood, or we will never be able to develop a plan to prevent them or respond to them if and when they occur.

Overarching all of the problems described in this report is the failure of the Government of Canada to commit sufficient resources to environmental monitoring related to oil sands development in the Lower Athabasca River Basin. Currently, the Government of Canada expends a little more than $10 million a year on water quality monitoring in all of Canada. Compared to the trillion dollar value of the oil sands resource and capital expenditures associated with its development in the range of tens or hundreds of billions of dollars, a robust and adaptive water monitoring program is a relatively inexpensive form of insurance and due diligence necessary to minimize future environmental costs.

Implementing an effective, scientifically-defensible environmental monitoring program requires a firm commitment by decision-makers. State-of-the-art water quality monitoring is in the public interest, as well as in the interest of the oil sands industry. In the absence of a political commitment to long-term funding of scientifically legitimate environmental monitoring, it is likely that Albertans will face financial liability for substantial environmental harm that is the legacy of oil sands development. The test of our political decision-makers' current leadership will be their willingness to make the difficult but necessary decisions about the future of industrial development of our oil sands resources, to ensure that it adheres to the tenets of environmental protection that are the foundation of our environmental laws.

In this report, we outline how federal monitoring and RAMP, upon which industry, Alberta, and Canada have largely relied, have failed to meet the standards of acceptable scientific practice in environmental monitoring, and provide recommendations for the creation of a scientifically defensible environmental monitoring program.

Our recommendations for improvement of environmental monitoring in the oil sands region include:

1. The Government of Canada needs to commit sufficient long-term administrative and operational resources that are commensurate with its legal obligations to assess, integrate, and interpret the results of comprehensive cumulative effects assessment and aquatic monitoring programs.
2. Government of Canada scientists need to be given responsibility for developing, implementing, conducting, and managing aquatic monitoring programs to determine the effects of oil sands development in the Lower Athabasca River Basin.
3. Aquatic monitoring programs should be designed, overseen, and performed by expert scientists who do not rely on oil sands companies for current or future employment or payment, at a minimum.
4. Experts engaged for the design of monitoring programs should be practicing research scientists.
5. Monitoring programs should be designed according to accepted scientific best practice.
6. Monitoring programs need to be designed to identify and quantify critical ecological thresholds and environmental change.
7. Monitoring must be sufficiently intensive—both spatially and temporally—in the early stages of any monitoring program to determine natural variation.
8. Once a greater understanding of natural variation has been attained, a long-term monitoring program should be refined and made more efficient.
9. Expert, scientifically defensible assessment of monitoring program data must be considered a critical part of environmental effects assessment and long-term aquatic monitoring programs, and funds must be committed to this critical task.
10. Data from all environmental monitoring associated with oil sands development needs to be stored in an organized and searchable format, and these data and all scientific assessments must be made publicly accessible.

Peace–Athabasca Delta, Alberta.
Credit: W. F. Donahue

1 Introduction

Canada is fortunate to have strong legislation intended to ensure the long-term protection of healthy aquatic ecosystems. These systems provide us with critical environmental services such as commercial and recreational fisheries, recreational activities, and ample supplies of fresh water for personal, municipal and commercial uses. In Canada, the legislation and policy supporting environmental protection and sustainability require that development proposals provide evidence and assurances that new or additional water uses will not result in environmental harm. Similarly, our laws generally prescribe that the people or companies responsible for environmental harm remediate damage (i.e., the "polluter pays" principle), and that offenders will change their behaviour to prevent additional harm from occurring.

The rule of law also extends to the role of government. Legislation compels governments to apply and enforce the environmental laws of the land. Where individuals, businesses and corporations don't adhere to the laws, governments are obliged to penalize them accordingly. In recent years, Canadians have become more concerned about environmental sustainability.[1] Canadians increasingly expect compliance with environmental laws and more sustainable business practices. Higher public expectations have encouraged business leaders to recognize the importance of environmental sustainability as something more than merely a matter of regulatory compliance. Corporate environmental performance now has implications pertaining to market access, developing corporate opportunities, reducing risk, and responding to increasing demands for more transparent corporate governance and disclosure of environmental risks and their financial implications.[2] Increased public awareness of environmental problems and demands for corporate action, in addition to pressure from investors, has made it more difficult for industry to ignore environmental challenges.

In recent years, the Government of Alberta and the oil sands industry have faced an increasing critical perception that the development of the oil sands in northeastern Alberta has been allowed to expand too quickly and without sufficient consideration of the environmental impacts it causes. What should be a relatively simple scientific question—What are the identifiable, significant environmental effects of oil sands development?—has spawned a myriad of social, political, and even ideological controversies. The growing controversy has resulted in a pitched publicity battle between the Alberta government and the oil sands industry on one side, and some First Nations and environmental groups on the other.

Because the majority of publicly available information is not subject to the same high standards of proof and honesty to which scientific studies are, the barrage of mixed messages often leaves the public confused about the environmental impacts of oil sands development. This confusion is exacerbated because most people do not recognize the difference between high-quality science, technical reports that include minimal analysis, opinions, and what are basically biased advertisements intended to paint a false picture of reality. As a result, the public in Alberta, Canada and abroad are left to decide between the conflicting messaging of both public relations campaigns: that there is no evidence of harm and oil sands development is environmentally benign and sustainable; or that government oversight of industry has been grossly insufficient and there is already clear evidence of environmental harm that will only worsen in the future.

There is no question that developing the oil sands provides economic benefits, but it is equally important to protect the Lower Athabasca Basin from irreparable environmental harm caused by irresponsible oil sands development. Implementing adequate environmental monitoring systems is the only way to determine whether oil sands development has already caused significant environmental harm or will do so in the future. In most cases, environmental monitoring is undertaken to determine whether industrial or other human development is negatively impacting the environment and the ecosystem services on which we rely. A fundamental part of detecting these impacts is to utilize rigorous monitoring systems that can distinguish between environmental change driven by natural forces and other changes caused by human activity. Without a well-designed environmental monitoring program that both quantifies changes and determines their causes, it is impossible to determine (and therefore manage or eliminate) the environmental impacts of any given human activity.

Ideally, expert scientists design and perform environmental monitoring mandated by robust public policy. This type of monitoring has not been evident in the development of the oils sands. As the Alberta government-commissioned Radke Report made clear, a consensus-based, multi-stakeholder approach to reviewing, monitoring, and addressing environmental issues "can result in decisions being watered down to the extent that they do not meet the best interests of any party or the environment."[3] At the very least, discretionary decision making and stakeholder consensus building should only be concerned with *whether environmental monitoring should be pursued* and, once it has been conducted, *what the response to the results should be*, not with *how* the monitoring protocols are designed, implemented and assessed.

Unfortunately, this is exactly what has been allowed to occur in Alberta. By allowing multi-stakeholder organizations such as the Regional Aquatic Monitoring Program (RAMP) to use a consensus approach to environmental monitoring, the Government of Canada has inappropriately delegated its responsibility to monitor and protect the environment in northeastern Alberta. Consensus-based decision making in Alberta in relation to oil sands development has compromised the quality and integrity of environmental monitoring necessary to ensure such developments are undertaken responsibly, sustainably and in accordance with the law. As a result, current environmental monitoring and impact assessments related to oil sands development are neither adequate nor scientifically defensible. Accordingly, neither level of government can adequately measure impacts that have been caused by existing oil sands developments nor predict what the effects of approved or planned projects will be. Consequently, until this situation is remedied, federal and provincial decision making concerning coincidental management of the environment and oil sands development will continue to be deeply flawed.

Based on the most compelling testimony from recent government hearings on the impacts of oil sands development on freshwaters, Water Matters and other environmental non-governmental organizations (ENGOs) have already provided recommendations regarding federal oversight and enforcement of the Government of Canada's legal responsibilities on water issues in the oil sands.[4] Of the ten recommendations, perhaps the most critical remains the need for the federal government to fulfill its legal obligations and assume lead responsibility for monitoring the environmental impacts of oil sands development on water resources.

This report builds upon our earlier recommendations by describing an appropriate design and implementation strategy for an effective environmental monitoring program that can determine the impacts of oil sands development in northeastern Alberta. It also outlines the specific role and obligations the Government of Canada bears when it comes to environmental monitoring associated with these kinds of large, industrial projects. In doing so, we outline the basis for an alternative to RAMP, which has been relied upon in oil sands development decisions despite the fact it has failed to meet the standards of acceptable scientific practice in environmental monitoring. We hope the recommendations provided here will spur the creation of a scientifically defensible environmental monitoring program from which governments can make responsible oil sands development decisions in the interest of environmental protection.

Syncrude oil sands operations.
Credit: David Dodge, The Pembina Institute, www.oilsandswatch.org

2 Background

The oil sands region covers an area roughly the size of the state of New York (140,200 km^2) in the Peace, Athabasca and Beaver river drainages. The Athabasca River Basin is almost twice the size of Nova Scotia, covering an area of 138,000 km^2 and stretching from its headwaters in the Rocky Mountains to Lake Athabasca in the northeast corner of Alberta. Alberta's mineable oil sands are in the Lower Athabasca River Basin, 4,750 km^2 of which are accessible via surface mining because the bitumen-bearing formations are relatively close to the surface (75 to 100 meters).[5] The remainder of Alberta's oil sands resources must be recovered using a variety of *in situ* processes that generally involve injecting steam and/or solvents down wells into deep bitumen-bearing formations and then pumping the heated and less viscous heavy oil to the surface for recovery. Tailings ponds associated with oil sands mining operations are used to collect contaminated process water, fine tailings that have been separated from bitumen, and residual bitumen. As of March 2009, there were more than 602 km^2 of boreal forest and wetlands disturbed by oil sands mining operations. There also are more than 170 km^2 of tailings ponds that as of 2010 store more than 840 million m^3 of mature fine tailings in close proximity to the Lower Athabasca River, an increase of 120 million cubic meters (17 per cent) over the last two years.[6] Without changes to upgrading processes, the total tailings volume is forecast to exceed one billion m^3 by 2014, two billion m^3 by 2034 and 2.4 billion m^3 by 2040.[7]

The startup of the Suncor mine in 1967 marked the beginning of major oil sands project development in Alberta, followed in 1978 by the opening of the Syncrude mine. Oil sands production increased slowly but steadily until the end of the twentieth century, when increasing oil prices significantly escalated the pace of capital investment and development in the oil sands. Oil prices continued to rise in the twenty-first century, providing a strong incentive for both industry and the Government of Alberta to pursue new oil sands development projects. By 2008, production of crude oil from Alberta's oil sands had reached 1.31 million barrels per day.[8] Despite a global economic recession that dampened industrial expansion in the oil sands, recent increases in oil prices have rejuvenated numerous oil sands projects.

Proven oil reserves in Alberta are now considered the second largest in the world (after Saudi Arabia's), and crude oil production is expected to increase to up to four million barrels per day by 2020.[9] Alberta oil sands are a potential trillion dollar resource,[10] and existing and planned capital investment is already on the order of $100 billion.[11] As a result, development will likely continue at a significant rate for the foreseeable future, as long as oil prices stay at current or higher levels.[12]

In 2006, a scientific paper published in the prestigious *Proceedings of the National Academy of Sciences* (PNAS) attracted a great deal of public, political, and media attention. Entitled "*An Impending Water Crisis in Canada's Western Prairie Provinces*," it pointed to the exceptionally large amounts of water being used in the extraction and processing of bitumen from Alberta's oil sands, as well as evidence of long-term declines in water supply as a result of climate change and other factors. Together, these factors pose long-term risks for both the Athabasca River and the industrial activities that rely so heavily on declining fresh water supplies.[13]

The majority of mineable oil sands that have been developed are in close proximity to the Lower Athabasca River. Approximately 88 per cent of the water allocated under licenses to oil companies for oil sands production is from surface waters, most of which comes from the Athabasca River.[14] With the rapid pace of growth in the oil sands industry, water use will increase significantly. Based on existing water licenses, and in the absence of limits on water use, current and proposed projects could withdraw more than 15 per cent of the Athabasca River's water flow during its lowest flow periods.[15] However, the proposed Phase 2 Water Management Framework for the Lower Athabasca River would limit withdrawals to 4.4 m^3/s when natural river flow declines below 87 m^3/s.[16]

Unfortunately, climate change and its observable effects on natural water supplies in the Athabasca River Basin have not been considered in planning oil sands expansion or water allocation and management. For example, the Lower Athabasca River's annual flows have declined by more than 25 per cent in the last 50 years (Table 1). Since the early 1970s, the amount of water delivered to the main stem of the Athabasca River from the surrounding landscape has declined by approximately 50 per cent in the 93.7 per cent of the basin that is downstream of Hinton.[18] Very simply, we face an impending collision between rapidly increasing demands for freshwater by the oil sands industry and long-term and likely continuing declines in surface water supplies in northeastern Alberta.[19]

Table 1. Trends in Flow in the Athabasca River
(1958-2008; Water Survey of Canada data[17])

Athabasca River d/s of Ft. McMurray	Discharge Rates (m3/s)			
Flow Variable	1958	Annual decline	2008	% change
Annual (Nov – Oct)	732.6	-3.81	538.1	-26.5%
Summer (May - Sept)	1,260.9	-6.52	928.2	-26.4%
Open water (May – Oct)	1,154.7	-6.02	847.8	-26.6%
Winter (Nov – Apr)	295.9	-1.39	224.9	-24.0%
Minimum Daily Flow	156.5	-0.64	123.8	-20.9%
Maximum daily flow	2,511.2	N/S	2,511.2	N/S

The deaths of 1,600 ducks on a Syncrude tailings pond in April 2008 drew additional domestic and international attention and criticism to environmental problems associated with Alberta's oil sands. Syncrude subsequently was fined $800,000, the maximum permissible for the provincial and federal charges for which it was found guilty, and penalized an additional $2.2 million for its offences. Despite significant domestic and international public relations campaigns touting the environmental sustainability of the oil sands by both industry and the Government of Alberta, this single event and the negative media attention it attracted appears to have galvanized people here and abroad in their concerns about the environmental sustainability of oil sands development.

Criticisms of oil sands development were further reinforced in the last year by the publication of two more scientific studies in the *Proceedings of the National Academy of Sciences* that describe the accumulation of organic contaminants and heavy metals in the lower Athabasca River Basin as a result of regional oil sands development.[20] Included in these studies were harsh criticisms of RAMP, which was initiated in 1997 by industry and the Governments of Alberta and Canada to assess impacts of oil sands development. In response to these studies, both levels of government quickly convened panels of scientific experts to review the apparent contradiction between these two, peer-reviewed studies and the conclusions provided in RAMP's annual technical reports.

In late December 2010, the findings of the federal Oilsands Advisory Panel were released. It is notable that the federal panel's mandate was quite narrow: It was to assess the state of monitoring in the lower Athabasca River watershed and make recommendations on what would constitute a state-of-the-art monitoring program. The federal panel was to focus only on an ideal water monitoring program, and not consider legal or regulatory issues relating to environmental monitoring associated with oil sands development in northeastern Alberta. Because they have been described elsewhere, the federal panel did not focus on the failings of the RAMP monitoring program, but rather made recommendations for improving and scientifically legitimizing aquatics monitoring associated with determining the environmental impacts of oil sands development.

At the end of January 2011, the second 5-year science review of RAMP was released, and it provided a detailed description of the scientific failings of environmental monitoring in the oil sands region.[21] It is expected that the provincial panel's report will be similar to the federal report and reiterate the systemic failures of environmental monitoring programs in the oil sands region that are contained in the other recent reports and independent scientific studies described in this report. While these reviews and recommendations are important and necessary, they will do little in and by themselves to address the significant environmental issues that must be reconciled in Alberta's oil sands region.

Oilsands and the Athabasca River, Alberta.
Credit: W. F. Donahue

3 The Nature of the Problem

3.1 Environmental Impacts of Oil Sands Development

The sheer scale of the oil sands industry has led to serious concerns about its cumulative impacts on water. Projections for future development only increase these concerns.

The main environmental impacts of oil sands development are related to clearing forests and wetlands for mine and site construction, releasing toxic contaminants into the surrounding environment, and using significant amounts of water in bitumen extraction and processing. The destruction of forests and wetlands reduces the ability of the landscape to store water, thereby drying it out and increasing the incidence of high and low flow events in streams and rivers that drain these lands.[22]

Mining with tailings pond
Credit: David Dodge, The Pembina Institute, www.oilsandswatch.org

The potential for oil sands-related contamination of surface and groundwater constitutes a serious environmental risk. Bitumen is a complex mixture of organic and inorganic chemicals. In addition to the oil for which it is valued, it contains a toxic mix of heavy metals, organic contaminants such as polycyclic aromatic hydrocarbons (PAHs), and naphthenic acids (see below). While these compounds are present in natural bitumen deposits, bitumen mining and processing releases them into tailings ponds and the air in higher concentrations than would otherwise be present. Emissions of sulfur and nitrogen compounds released into the air during mining and upgrading of bitumen into other petro-chemical products can potentially acidify surrounding landscapes and surface waters. Many of the chemicals released by oil sands mining and upgrading can accumulate in the environment over time, are toxic and/or cause genetic mutation when they enter the food chain, and can cause large-scale changes that significantly harm ecological function.[23]

In addition to water quality impacts associated with leaks, direct effluent releases, and atmospheric deposition of emissions from smokestacks, the production of this unconventional oil requires two to five barrels of water per barrel of oil produced.[24] Consequently, oil sands development requires a long-term, stable supply of fresh water for oil and petrochemical production and refining, and for dilution and reduction of harmful effects of the pollution that it releases into the regional environment via atmospheric deposition, accidental releases or groundwater seepage.

It is reasonable to expect that water quality in the Lower Athabasca River and downstream freshwater systems will decline as more oil sands projects are approved and developed, because of the associated increases in pollution and a continued long-term decline in flows throughout the year. Ultimately, as the joint federal and provincial regulatory panel concluded in its Kearl Oil Sands Decision in 2007, it is entirely possible that water will be the primary factor that limits oil sands development.[25] For this reason, a clear understanding of the impacts of the oil sands on aquatic ecosystem health in northeastern Alberta is critical to ensuring protection of the Athabasca River, its tributaries, and the Peace-Athabasca Delta, and to reduce economic risks associated with potential closures of oil sands operations during low flow or other ecologically sensitive periods that will likely increase in frequency and duration in the future.

3.2 Federal Responsibility for Environmental Protection

Canadian law is clear about the role of the federal government in ensuring environmental protection in Canada. Under the Canadian Constitution, responsibilities for environmental protection are divided between federal and provincial governments. As they relate to oil sands development, the province of Alberta maintains constitutional authority over the following: management of public lands; local matters, works and undertakings; and exploration, development, conservation, and management of non-renewable natural resources.[26] Conversely, the federal government also has authority over other matters, including: the regulation of trade and commerce; navigation and navigable waters; inland fisheries; works that are for the general advantage of Canada or for two or more provinces; Indians and lands reserved for Indians; criminal law; and maintaining "peace, order, and good governance" as they relate to matters of national concern.[27] The Supreme Court has held that federal authorities extend to environmental issues, including toxic substances, interprovincial waters, and transboundary pollution (air or water). Furthermore, it is clear that where provincial and federal laws conflict concerning matters of joint authority or responsibility, federal law prevails.[28]

Between 2008 and 2010, the House of Commons Standing Committee on Environment and Sustainable Development studied the effects of oil sands development on freshwaters in northern Alberta, and held a number of public hearings at which they heard evidence from more than sixty government, industry, academic (scientists and legal experts), aboriginal, and NGO witnesses. Unfortunately, a final report of the Committee's findings was not released, because of a failure to reach a consensus on recommendations or conclusions. However, the Liberal and NDP members of the Committee released two reports outlining the evidence of impacts of oil sands development and the failure of the Government of Canada to uphold its legal responsibilities or exert its authority in ensuring the protection of fisheries, trans-boundary waters, or other matters of federal concern in the region.[29]

Regulatory Joint Review Panels that represent *both* provincial and federal government ministries assess major industrial projects like oil sands developments precisely because of the shared legal responsibilities for preventing environmental harm detailed above. Relevant federal environmental laws include[1]:

- *Navigable Waters Protection Act*, S.C. 1985, c. N-22;[30]
- *Canadian Environmental Assessment Act*, S.C. 1992, c. 37 [CEAA];
- *Fisheries Act*, S.C. 1992, c. 37;[31]
- *Migratory Birds Convention Act*, S.C. 1994, c. 22;
- *Species at Risk Act*, S.C. 2002, c. 29 [SARA];
- *Canadian Environmental Protection Act*, S.C. 1999, c. 33 [CEPA]; and
- *Constitution Act*, 1930 20-21 George V, c. 26 (U.K.) and *Alberta Natural Resources Act*, 1930, c. 3.

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1 See Appendix 1 for details on relevant legislative powers and provisions.

Syncrude oil sands mining operations.
Credit: David Dodge, The Pembina Institute, www.oilsandswatch.org

Major industrial projects must pass the standards set by provincial and federal environmental laws that are ostensibly upheld by the regulatory bodies charged with assessing projects before they are approved. For oil sands development projects, an environmental impact assessment is presented by an oil company (i.e., the "proponent") to a regulatory body, and experts are paid to testify on behalf of the oil company on the lack of direct or long-term environmental effects of the project. Other parties who support or oppose the project (i.e., "intervenors") may also make arguments either for or against the project, based on their own interests and what they or their experts conclude about the impacts of the project. Often it is First Nations and environmental groups who oppose proposed oil sands projects, but in the past other oil sands companies also have opposed new projects.[32]

Regulatory boards, such as Alberta's Energy Resources Conservation Board (ERCB, formerly Alberta Energy and Utilities Board or AEUB) or Joint Review Panels (JRPs) that represent both provincial and federal regulatory bodies, then consider the evidence and make their decision regarding approval of the project. However, regulatory boards have been criticized for a refusal to consider broad socio-ecological concerns related to individual projects, based on a denial of legal authority to address environmental or social concerns.[33]

Thus far, regulators have not rejected any major proposed oil sands project, despite the *absence* of scientifically sound environmental monitoring or adequate assessment of existing and proposed oil sands projects, and *growing* concerns about the local and regional *cumulative* negative effects of oil sands development. This was clearly demonstrated in the recent regulatory approval of Total's proposed Joslyn North oil sands mine, in which the JRP concluded that "While evidence provided by [Environment Canada] suggested that there may be some detectable cumulative effects downstream from mineable oil sands operations, the Panel finds, on the basis of the RAMP data, no reason to believe that these effects are significant."[34] This statement was made despite all the evidence presented by government, First Nations, and environmental groups testimony to the failures of RAMP and evidence of cumulative effects, and more than six weeks after the federal Commissioner of the Environment and Sustainable Development, federal Oilsands Advisory Panel, and Royal Society of Canada had all released their highly critical reports on the failures of environmental monitoring or assessment of cumulative effects in the oil sands region. In its ruling, the JRP referred to the federal Oilsands Advisory Panel's report as if it had not yet been released at the time the decision on Total's proposed mine was made, clearly indicating that the JRP's reliance upon RAMP's data and conclusions as scientifically valid continues, unaffected and uninformed by the overwhelming evidence to the contrary.

It seems reasonable to conclude that the desire of the Government of Alberta to accelerate the development of oil sands resources has limited the mandate of regulatory boards—whether provincial or joint provincial-federal panels—to the approval of energy projects, or at the very least made them more reluctant to deny projects on the basis of likely or potential negative environmental impacts. Nevertheless, the Government of Canada still has clear legal responsibilities and the authority to identify and prevent environmental harm from industrial development, but the evidence suggests it is failing to do so with regards to Alberta's oil sands industry.

3.3 Failure of the Government of Canada to Adequately Monitor Aquatic Ecosystems

A succession of federal governments has failed to fulfill their obligation to apply and enforce Canada's environmental laws when it comes to oil sands development in Alberta. Despite the clear role and responsibility for the Government of Canada to monitor and prevent environmental impacts of oil sands development, and despite the immense scale and intensity of industrial development in Alberta's oil sands region, very little monitoring has been performed. For example, a recent report by the Commissioner of Environment and Sustainable Development highlighted that the only Environment Canada water quality monitoring station in the Athabasca River Basin is located at the very end of the river, 150 km downstream of oil sands development.[35] This single station is equipped with instruments to measure nutrient loads from pulp and paper mills, the closest of which is hundreds of kilometers upstream, rather than the heavy metals and toxic organic contaminants associated with oil sands development. In 2009, it was recommended that the station be upgraded to also monitor compounds associated with oil sands, but this recommendation has yet to be followed.[36]

Unfortunately, the federal Department of Fisheries and Oceans (DFO) also has failed to do the monitoring necessary to enable it to manage the fisheries of the Athabasca River, its tributaries and regional lakes in a way that is consistent with the *Fisheries Act* or DFO's *Policy for the Management of Fish Habitat*.[37] This has been made worse by an apparent lack of communication between managers and decision makers within DFO, and the freshwater and fisheries scientists within its science arm, DFO Science. The result is that DFO often promotes management plans or approves oil sands proposals without adequate prior scientific assessment. For example, the Phase 2 Water Management Framework for the Lower Athabasca River is the proposed plan for managing instream flow needs (IFNs) for the Lower Athabasca River. In a recent evaluation performed several years after the plan was developed and refined, DFO Science concluded that it was unable to estimate the effects of industrial water withdrawals and climate change on the amount of water available in the river.

DFO is the *sole* government agency charged with management of inland fisheries; arguably this is why DFO was created. But DFO Science concluded that the absence of sufficient information on fisheries—including population sizes of different fish species and if, when, where and how different habitats were used (e.g., for spawning, rearing, over-wintering, feeding)—made it "impossible to assess the precise extent of potential losses to fish habitat" or fisheries caused by interactions between oil sands development and climate change.

Further, all of the assumptions about fisheries that were incorporated into the Phase 2 Water Management Framework *could not be validated*, because of a lack of information on fisheries.[38] Other DFO Science findings include that:

- the relationship between minimum water depths and lost connectivity between Athabasca Delta channels is unknown, as are how channel depth, water speed and flow relate to fish ecology;
- the importance of perched lakes and "winter kill" in the Athabasca Delta to fish and fish habitat is unknown;
- no information on habitat is available for 24 of 31 fish species known to occur in the Lower Athabasca River system; and
- the role of tributaries and influence of riparian zones as fish habitats are unknown, despite the fact such areas are usually important.

That the fisheries scientists of DFO Science were not involved in the creation of the primary fisheries management plan for the Lower Athabasca River, and professional science standards were not reflected in it, is unbelievable. Clearly, the Government of Canada has failed to fulfill its obligations to monitor the impacts of oil sands development in the Lower Athabasca River Basin. Rather than fulfilling its requirements to monitor water quality and environmental health, the Government of Canada appears to have relied entirely upon the validity of RAMP and other stakeholder-based organizations' initiatives and reports to assess the environmental impacts of oil sands development.[39] These reports have been the primary source of information concerning the state of water and sediment quality, the health and sustainability of fisheries, and contaminant deposition, dynamics, and toxicity. As detailed below, they have proven inadequate for providing the information necessary for the Government of Canada to adequately monitor the impacts of oil sands development on water in northeastern Alberta.

3.4 Alberta's RAMP - Designed for Stakeholder Consensus not Scientific Accuracy

The Government of Canada has effectively delegated monitoring to the Government of Alberta, which in turn has delegated monitoring to industry. According to the federal Oilsands Advisory Panel, the development of RAMP has been driven by the needs of independent oil sands projects and their associated environmental assessments to meet industrial project approval and licensing requirements, rather than protection of the environment.[40] The Panel also highlighted that "policies and decisions are influenced by many considerations, but in environmental matters, science is central", implying that there must be distance established between oil sands proponents and environmental monitoring. The Royal Society of Canada in their recent critique of monitoring for oil sands impacts supported the federal Panel's conclusions, stating that the environmental monitoring process relied upon by decision makers is "seriously deficient when compared to international best practices."[41]

Industry's environmental monitoring is largely performed by consultants. Unfortunately, inexperience and lack of understanding of scientific standards in monitoring, sample management and analysis, data analysis, and interpretation all have contributed to scientifically indefensible monitoring programs and environmental assessments, some details of which are described below.

By necessity, a scientifically defensible monitoring program demands an interdisciplinary approach that includes theoretical and practical expertise in biogeochemistry, contaminant chemistry and dynamics, environmental toxicology, ecology, environmental study design, environmental monitoring, and sample handling and analysis techniques. Merely going out and collecting water or sediment samples and determining concentrations of chemicals in them will not provide required contextual information about sources of contaminants, the routes they travel into the environment, or their effects. Poorly designed sampling and analysis strategies may not even provide basic information such as environmentally relevant concentrations of chemicals.

Unfortunately, RAMP has failed to fulfill its three primary goals, i.e., characterizing existing variability, detecting regional trends and cumulative effects, and monitoring to verify Environmental Impact Assessment predictions. In particular, as early as 2004, RAMP has been criticized for:

1. its lack of scientific oversight;
2. an inadequate number of monitoring sites;
3. its inability to detect effects:
4. not making data publicly available;
5. the lack of transparency regarding the methods it has used to analyze, interpret and report the data;
6. sampling practices that could neither measure nor detect impacts;
7. and a general inability to assess cumulative impacts or regional development on water quality.[42]

The Government of Canada's reliance upon RAMP is troubling and paradoxical. The federal government's *own scientists* criticized RAMP in an external scientific review in 2004 for "the lack of details of methods, failure to describe rationales for program changes, examples of inappropriate statistical analysis, and unsupported conclusions."[43] Government of Canada scientists also found that RAMP has serious systemic problems, including a lack of scientific leadership and the fact that "individual components of the plan seemed to be designed, operated and analyzed independent of other components, that there was no overall regional plan, that clear questions were not addressed in the monitoring, and that there were significant shortfalls with respect to statistical design of the individual components."

Included in this 2004 external science review of RAMP's first five years of monitoring were detailed critiques of various components of RAMP's freshwater monitoring program, including climate and hydrology; water quality; sediment quality; benthic invertebrates; fish populations; aquatic vegetation and acid sensitive lakes. Substantial problems also were described in RAMP's use and interpretation of biostatistics. A few of the common problems related to sampling techniques and study designs are described below.

According to the most recent independent scientific review of RAMP's environmental monitoring programs and reports, released in January 2011, RAMP has continued to fail to meet the majority of its scientific objectives. Specifically, RAMP continues to be incapable of detecting regional trends and cumulative effects, has failed to collect adequate baseline information, has not collected sufficient data to enable current or future assessment of predictions contained in environmental impacts assessments produced by oil sands companies for regulatory approval (or even track those predictions), and has failed to adequately communicate monitoring and assessment activities, results, and recommendations to regional communities, regulatory agencies, or other interested parties.[44] In fact, the only scientific objective that has been met by RAMP is the commitment to conduct periodic peer-reviews of their objectives against the results of their activities, for the provision of recommendations for program adjustments that are necessary for RAMP to successfully meet its objectives. This can hardly be considered an accomplishment, however, since the recommendations made in the first 5-year review in 2004 were evidently not followed.

The consequence of these failings is that RAMP is incapable of detecting environmental changes if they occur or identifying the source of any potential change if one were identified, and is not posing the appropriate scientific questions or monitoring the appropriate criteria to answer the correct questions. Simply, RAMP is as complete a scientific failure as can be imagined for a monitoring program, yet this has not prevented the Governments of Alberta and Canada from relying upon it as the primary scientific authority for their regulatory approvals of oilsands development proposals.

A consistent problem throughout RAMP's history has been the employment of inappropriate sampling techniques and insufficiently robust laboratory analytical techniques. For example, attempts to determine PAH concentrations in water have typically been determined by analyzing water concentrations. However, because these compounds are normally present at very low concentrations and cannot easily be detected in a water sample, these compounds were not detected. However, environmental toxicologists normally use what are referred to as polyethylene membrane devices or semi-permeable membrane devices to sample for PAHs in surface waters. These devices are left suspended in a lake or river for up to 30 days or more, so concentrations in the devices can reach equilibrium with those in ambient water being sampled. The PAHs are then extracted and analyzed. This technique has detection limits between 0.2-1.3 ug/L, depending on the particular PAH, which is below concentrations typically found in surface waters.[45]

In addition to RAMP's inability to determine PAH concentrations in surface waters, until the fall of 2009 the detection limit of the analytical technique used by RAMP to determine concentrations of naphthenic acids in surface waters was 1 mg/L,[46] despite the fact their ambient concentrations with potential toxicological effects in northern Alberta rivers are typically less than 1 mg/L. This is compared to concentrations in oil sands process water that are typically 110-120 mg/L.[47] This problem associated with ecologically important concentrations of contaminants and the inability to measure them was identified by Environment Canada and academic scientists at least as far back as 2004.[48] For some unknown reason the decision makers in RAMP and their consultants performing the environmental assessments were unaware of this problem until informed of it by a University of Alberta researcher some time after RAMP's 2008 Technical Report was completed. Subsequently, RAMP switched from a commercial laboratory (ALS Environmental) to the Alberta Research Council's analytical facilities to permit detection of environmentally relevant concentrations of naphthenic acids.[49] Although this problem has recently been addressed, it should not have taken at least five years to do so. The fact that this problem persisted for a number of years indicates a lack of familiarity with the relevant scientific literature, the environmental behaviour of an important class of contaminants associated with oil sands development, and the analytical techniques required to detect them.

RAMP has also failed to use appropriate techniques for taking sediment samples from lakes that are included in its annual sampling program, including Kearl, Isadore, Shipyard and McClelland lakes. As part of each survey of sediment quality, including heavy metal and PAH contaminant loads and toxicity, 6" x 6" Ekman Dredge samples were taken from lake bottoms. An Ekman dredge is basically an open scoop that is lowered to the sediments at the bottom of a lake and when triggered closes and captures a somewhat standardized sample of sediments that can then be extracted from the surrounding sediments in a lake or river.[50] Usually they are used for assessing environmental variables on an areal surface, because the depth to which the dredge penetrates and captures sediments is not easily controlled.

However, sediments in lakes often are deposited over time in a way that sediment layers creates a temporal history of lake chemistry and biology, as older sediments are covered by more recent sediments that settle out of the water column. In lakes in the oil sands region for which rates of sediment accumulation were calculated, sediments laid down in 1975 were 7.4 ± 2.2 cm below where sediment and water meet at the bottom of lakes, and those laid down in 1950 were 11.0 ± 3.9 cm deep.[51] Therefore, an Ekman dredge lowered into the sediment at the bottom of these lakes will result in scooping up sediments that have been laid down over decades, and perhaps as far back as before oil sands development even began. That no patterns or year-to-year change in contaminant concentrations were evident in sediments from regional lakes is not surprising, because the concentration of any contaminant in sediments sampled with an Ekman dredge would represent some long-term average of the concentrations of all the mud laid down in layers over a long period of time.

Surveys of approximately 600 lakes in Saskatchewan and Manitoba have demonstrated that very small lakes with low conductance, base cations, and alkalinity are particularly sensitive to acidification caused by nitrogen oxide emissions (which are emitted by oil sands development activity), and that a significant percentage of lakes are sensitive (60 per cent) or very sensitive (8 per cent) to acid deposition.[52] However, while RAMP routinely monitors 50 lakes as part of its Acid Sensitive Lakes Program, few of them are very small. Of those, while at least four have been identified as acidic,[53] RAMP has not identified any as acidified as the result of acid inputs from oil sands development.

It is entirely possible that RAMP has found no evidence of a link between acid inputs from oil sands activity and acidification of regional lakes, but it must be kept in mind that RAMP was only created in 1997 while oil sands development began in 1967. Because RAMP has no information on the first 30 years of oil sands development and the potential or actual impacts associated with its acid emissions, it is impossible to conclude on the basis of RAMP data that there have been no effects; only that RAMP data do not demonstrate any acidification effects. In other words, the baseline against which RAMP is comparing regional lake conditions today is 1997, rather than pre-development conditions of 1967. Without knowing what those earlier baseline conditions were, it is impossible to conclude that there have been no impacts of oil sands development on regional waters solely on the basis of RAMP data.

In addition to the problems described above, annual changes in the location of monitoring sites and the absence of sampling of aquatic invertebrates—which are commonly used as indicators of aquatic ecosystem health,[54] and are considered a component of fish habitat because of their importance as fish food—in many tributaries and main-stem sites on the Athabasca River are serious problems. But perhaps the most critical failure of RAMP is the fact that at no point during the history of monitoring related to the effects of oil sands development in the Lower Athabasca River Basin has there been sufficiently intensive sampling to establish an understanding of natural variation or baselines.[55]

These serious problems with RAMP do not represent an exhaustive list, and much more detail can be found in RAMP's 5-year reviews performed by Government of Canada scientists in 2004 and by independent academic and government scientists in 2011.[56] The more obvious problems described here that are easily explained to a non-scientific audience are intended to highlight the sorts of fundamental problems that have persistently plagued RAMP.

3.5 Independent Studies - Contextualizing RAMP and Oil Sands "Science"

There is an abundance of "grey" literature available to the public on the environmental impacts of oil sands development, but it is not subject to the same high standards and rigorous review to which the relatively few scientific studies on the environmental impacts of oil sands development have been exposed.[57] At the same time, industry and government have made unsubstantiated claims that there have been no impacts of oil sands development on the Athabasca River or its tributaries, and/or that contaminant levels in regional surface waters are the result of natural processes affecting naturally exposed bitumen deposits, not industrial development.[58]

For example, the Government of Alberta website maintains that:

> "The Athabasca River region is unique because of the naturally occurring oil sands that the river runs through. Sediment from the banks of the river are caught in the current and because of this, there are naturally occurring contaminants in the water. Data from the Regional Aquatics Monitoring Program indicates no increase in concentrations of contaminants as oil sands development has progressed. The Regional Aquatics Monitoring Program also monitors polycyclic aromatic hydrocarbons (PAH) levels in the river. *There is no doubt that PAHs are in the sediments downstream of the oil sands. This is due to the magnitude of the oily sand along the river banks through which the river has eroded naturally. PAH levels found in samples on other rivers in the area with absolutely no industrial oil sands activity have been found to be higher than samples taken downstream from oil sands developments. The sources in the area are natural.*" [59](Emphasis added.)

The Government of Canada has made similar statements in an attempt to minimize the apparent environmental impacts of oil sands development. However, environmental NGOs and government scientists have pointed out that serious impacts already have been acknowledged,[60] and there is no scientific evidence that government claims to the contrary are valid or accurate.

Given the prevalence of inaccurate information and unsubstantiated claims from all sides in the oil sands debate, it is imperative that we rely on the best available, peer-reviewed scientific studies to answer important scientific questions or make decisions that have the potential to impact human and natural communities in the oil sands region. Where such studies are unavailable or insufficient to answer critical questions or make claims regarding presence or absence of impacts, the precautionary principle calls for highly conservative decisions about the pace and scale of development until such time as high-quality scientific information is available.[61]

Fortunately, several recent, peer-reviewed scientific studies have been published by independent (i.e. non-government, non-industry and non-ENGO) scientists. These studies, described below, have clearly demonstrate that heavy metal and PAH contaminants have accumulated in the Athabasca River and its tributaries, and that acidification and other defects in regional lakes have been caused by the release of acidifying compounds from upgraders.

3.5.1 PAHs in Surface Waters in the Lower Athabasca River Watershed

Despite government and industry claims that there has been no discernible effect of oil sands development on water quality, such effects have been reported elsewhere.[62] Kelly *et al.* (2009) recently identified oil sands upgrading operations in the oil sands region as a significant source of air-borne PAH contamination to the Lower Athabasca Region, via wet and dry deposition. High concentrations of these compounds were found to have accumulated in the snowpack (up to 4.8 ug/L), which means seasonal snowmelt may contribute pulses of PAHs into regional surface waters in concentrations high enough to be toxic to fish embryos. Landscape disturbance related to oil sands mining also was identified as another significant source of PAHs to regional tributary surface waters.

As described above, it has been frequently asserted that contaminants in the Athabasca River and its tributaries come from natural sources that are exposed to river and stream water (i.e., the McMurray Geological Formation, which is the bitumen-bearing layer in the oil sands region). However, Athabasca River tributaries downstream of oil sands mines demonstrated summer water concentrations of PAHs more than *20-times higher* than sites upstream of development, with 10-fold to 50-fold increases observed in individual tributaries.[63] More importantly, there was no increase in PAH concentrations downstream of exposed outcroppings of bitumen in the McMurray Formation, suggesting concentration increases were from industrial rather than natural sources.

PAH concentrations were generally low at most sites on the Athabasca River, Athabasca Delta, and Lake Athabasca, but they were higher in summer than winter. They also were higher in winter at sites near oil sands upgrading facilities and tailings ponds, and in summer at sites immediately downstream from new oil sands development. The chemical fingerprint of the suite of PAHs present in the waters of the Athabasca River tributaries also is very similar to those present in oil sands.[64]

These results indicate that when upstream oil sands development was insignificant, the flow of stream or river water through sites with natural exposure to the eroding McMurray Formation did not affect PAH concentrations. The strongest relationship identified was between elevated concentrations of PAHs and the presence of significant new land disturbance or mining activity expansion in the two years preceding sampling. *This suggests that natural sources of PAHs were not solely responsible for increased concentrations of PAHs downstream of oil sands operations, and that oil sands operations quite likely contributed significantly to accumulation of PAHs in surface waters in close proximity to them*.[65]

It is also clear that oil sands development activity has been contributing significantly to regional atmospheric deposition of contaminants, and that regional snowpack functions as a significant delayed source of PAHs at relatively high concentrations in the oil sands region during periods of snow melt. These seasonal pulses of organic contaminants may very well have toxic effects in regional waters. White sucker and fathead minnow embryos have shown higher mortality rates, lower growth rates and pathological signs of PAH toxicity when exposed to concentrations of alkyl phenanthrene from oil sands leachates and wastewater pond sediment concentrations lower than those observed by Kelly et al (2009, 2010), and the severity of toxicological effects increased with exposure.[66]

3.5.2 Heavy Metals in Surface Waters in the Lower Athabasca River Watershed

RAMP has been monitoring the Lower Athabasca River Basin for a number of priority pollutant heavy metals in surface waters [e.g., aluminum (Al), antimony (Sb), arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), molybdenum (Mo), silver (Ag) and vanadium (V)]. However, interpretation of the concentrations has been largely limited to percentages of guideline exceedances, variation in concentrations, and perhaps seasonal patterns where they were evident (although because natural variation is unknown, conclusions related to seasonal patterns may be meaningless).

RAMP's results indicate that concentrations of many heavy metals are highly variable from site to site and year to year, with no apparent patterns. They have therefore concluded that there is no apparent relationship between heavy metal concentrations in the regional environment and oil sands development. If there were a relationship, it stands to reason, then it would show up as increasing concentrations of heavy metals in the lower reaches of the Athabasca River, or at least at some sites.

The problem with this conclusion is that it reaches beyond what RAMP's monitoring program is capable of measuring or assessing. Like with PAHs described above, the RAMP sampling sites were not selected to assess how heavy metal deposition and accumulation changes over relatively short distances from oil sands development. This means conclusions *cannot be made* about local and regional effects of oil sands development on heavy metal contamination.

Fortunately, other scientists have stepped in to fill this vacuum, using different methodologies to assess the concentrations and patterns of 13 EPA heavy metal priority pollutants in surface waters and snowpacks in the Lower Athabasca River watershed.[67] To discern the potential impacts of oil sands

operations on aquatic systems, concentrations of heavy metals in snow and water were compared to the degree of relative land disturbance calculated for each watershed and to proximity to synthetic crude upgraders.[68] The average particulate deposition of a number of the metals in snow was up to 30 times higher within 50 km of the Suncor and Syncrude upgraders than in samples taken from farther away, with maximum deposition as much as 120 times higher.[69] Some metals, including arsenic, were only found at sites near development, with maximum concentrations at the site nearest to the Suncor and Syncrude upgrading facilities.

Concentrations of heavy metals in the Athabasca River's tributaries were found to be higher downstream of oil sands development than upstream of it, refuting the "no impact" claims of government and industry based on RAMP's monitoring and analysis. These higher concentrations were unrelated to either contact of water with the McMurray Formation or the proportion of the watershed made up by the McMurray Formation. There also were significant increases in heavy metal concentrations near oil sands development that correlated strongly with how much development there was in a watershed, and the difference was greater in summer than winter. Furthermore, concentrations of a number of heavy metals were higher immediately downstream of tailings ponds, impoundments, or other oil sands development infrastructure compared to upstream sites, and some concentrations were elevated all the way to the Athabasca Delta and into Lake Athabasca.[70] Finally, under-ice concentrations of some heavy metals that are elevated in oil sands process water were much higher in the Athabasca River only immediately downstream of tailings ponds or oil sands development, suggesting either tailings pond leakage or discharge are local point sources for these contaminants.

These findings indicate that RAMP's contention that there is no apparent relationship between heavy metal concentrations in the regional environment and oil sands development is false.

3.5.3 Effects of Acid Emissions and Inputs in the Lower Athabasca River Watershed

Two recent studies have identified significant effects of nitrogen oxide acid inputs from oil sands activities into regional lakes. Both of these studies involved coring of lake sediments in lakes that were already part of the RAMP Acid Sensitive Lakes surveys but had not been cored as part of RAMP's activities.[71] From these sediment cores, the histories of chemical and biological change in the lakes were reconstructed based on chemical signals and remains of algae stored over time in sediments. While it appears that lake acidification caused by oil sands development is not a significant *regional* problem, it can be a significant localized problem. One of the 12 lakes sampled showed strong evidence of long-term acidification.[72] In addition, of those studied, the acidified lake via sediment coring was the smallest and had the shortest water residence time, consistent with the type of lakes identified as most sensitive to acid inputs in surveys of lakes in Saskatchewan and Manitoba. This suggests that more very small lakes in the oil sands region should be monitored for effects of acid inputs, or the likelihood of detecting regional acidification effects may be low. These studies also indicate that oil sands development may be having a significant nutrient enrichment effect in most of the lakes.

Perhaps most concerning is the fact that elevated concentrations of contaminants downstream of tailings ponds suggest that, contrary to government and industry claims, tailings ponds are leaking. It is critical that further research and monitoring be performed to identify how these contaminants are moving through the environment, and what their direct and indirect toxicological effects are. The recent peer-reviewed scientific studies described above refute the assertion that there is no evidence of any impacts of oil sands operations on local or regional water quality. Accordingly, it is reasonable to conclude that long-term monitoring of heavy metals, organic contaminants and acid inputs in surface waters of the oil sands region has been inadequate, that the toxicity and ecosystem effects of these contaminants have not been assessed, and that the accumulation of undetected contaminants may be having a negative effect on water quality and ecosystem health. In summary, the majority of regional and cumulative environmental impacts of oil sands development in the oil sands region remain unidentified and unassessed.

4 Environmental Monitoring Programs - Getting it Right

Because of the shortcomings of RAMP, the need for a robust monitoring program in Alberta's oil sands region remains critical for decision makers tasked with safe-guarding the public interest. Alternatives to RAMP are presented here for a reform of environmental monitoring in the region that is long overdue.

Determining "baseline" (i.e., natural, pre-oil sands development) conditions in the Lower Athabasca River Basin is difficult because RAMP's environmental monitoring program did not begin until 1997, thirty years *after* the first oil sands mine opened in 1967. What PAH and heavy metal concentrations in the Athabasca River and its tributaries were *before* the first hole was dug in the ground is uncertain, but there may be ways to determine these unknowns.

As described above, RAMP's claim of *no evidence of impacts* does not support a *conclusion that oil sands development has not negatively impacted* the region's lakes, rivers and wetlands. The independent studies cited above demonstrated that there have been significant impacts of oil sands on the Athabasca River, the Athabasca Delta and regional lakes. However, the extent and ecological implications of these impacts is unknown because many of RAMP's methodologies are flawed and the baseline against which environmental conditions are compared is 1997. Significant changes caused by regional oil sands development may already have occurred by then: biogeochemical cycles may have been seriously altered, and lakes and rivers may be less sensitive to additional industrial pressure. If RAMP's 1997 baseline is the standard against which future rehabilitation will be measured, it may simply ensure that latent or unknown problems in the region's freshwater ecosystems will continue far beyond the life of the region's oil sands operations.

Without appropriate environmental research and monitoring of oil sands development effects on critical ecological processes and thresholds, and the adoption of legitimate adaptive management to reduce environmental impacts below critical levels, we can expect substantial declines in ecosystem health in the Lower Athabasca River Basin and further downstream into Lake Athabasca and the Slave and Mackenzie River systems. With reduced ecosystem health, we can expect a substantially increased likelihood of long-lasting ecological collapses.

An effective monitoring program can help prevent this by revealing important information that is needed to responsibly manage industrial development and ensure adequate environmental protection. Improper site selection and inappropriate sampling, which define the current approach, cannot assure accurate results or understanding of the environmental impacts of oil sands development. For an environmental monitoring program to be effective, a baseline in aquatic ecosystem health prior to industrial development is needed. In addition, detailed information on critical thresholds and relationships between species and important environmental conditions, as well as how industrial development affects those relationships, must also be gathered using monitoring programs designed specifically for this purpose.

4.1 Criteria for Robust Monitoring Programs in the Oil Sands Region

There is a vast body of scientific literature on the design of environmental monitoring programs and the assessment of monitoring data.[73] Put simply, a monitoring program must be designed to answer two main questions:

1. Is there evidence of impact of oil sands activity on nearby and regional landscapes and surface waters?
2. What are the critical thresholds of impacts beyond which impairment of ecological processes and services will occur?

A monitoring program needs an integrated, comprehensive approach to address these questions. It must be designed to assess environmental trends or patterns and the critical biogeochemical and physical processes that determine aquatic ecosystem health. For example, it is important to identify whether there are increased contaminant levels in surface waters near oil sands development, and that would demand replicated sampling in lakes, streams, and rivers, from sites that are close to oil sands developments and those that are farther away. In a river or stream, it should involve sampling upstream and immediately downstream of a project, and then successively farther and farther downstream. For lakes, it would involve selecting a suite of lakes at different distances and in different directions from oil sands development. This would permit assessment of effects related to amounts of pollution deposited and the extent of contamination based on effects based on prevailing winds. These types of monitoring programs have not been implemented as part of either RAMP or government monitoring programs, but independent studies using these more robust study designs have demonstrated that there are already significant impacts of oil sands on aquatic ecosystems.

In addition to monitoring program designs intended to reveal comparative, descriptive information (i.e., patterns of impacts), monitoring programs must also be designed in a way that will provide information on the mechanisms causing the impacts.[74] This could include identifying the sources of contamination, how contaminants move through and accumulate in the environment, and what their ecological effects are.

As highlighted by DFO Science in its assessment of the Phase 2 Water Management Framework for the Lower Athabasca River, in addition to assessing fish populations and range, monitoring must be designed and implemented to identify the causes for the impairment of the fisheries:

1. Is it related to natural changes in a river, such as declining flows or increasing water temperatures?
2. Is it the result of accumulation of contaminants and their toxic effects on hatching, growth or reproduction?
3. Is it the result of increased siltation from habitat degradation, such as roads and mining activity?
4. What are the critical thresholds of impacts beyond which impairment of ecological processes and services will occur?

These kinds of questions require a monitoring program specifically designed to answer them, one that will allow scientists to identify the critical degree of impacts beyond which significant impairment of ecological processes and services will occur, such as collapses in fisheries, degradation of suspended wetland complexes in the Delta region, or declines in health of riparian zones adjacent to surface waters and associated secondary impacts on terrestrial or aquatic birds and mammals. Without this information, decision makers can have no foundation upon which to base their management decisions related to development of oil sands or protecting aquatic ecosystem health in the oil sands region.

4.5 Designing Effective Monitoring Programs

A monitoring program is a means of collecting critical information that is not currently available. Monitoring programs must be based in science, provide answers to scientific questions, and provide meaningful information to decision makers that they would otherwise lack. Most importantly, environmental monitoring programs must possess the scientific rigour and breadth to identify whether and how oil sands development are resulting in environmental impacts, what those impacts are, and at what point environmental changes will be sufficient to trigger ecological collapses.

Existing monitoring programs are unable to identify and quantify the environmental impacts of oil sands development that are already occurring. Until now, the Governments of Alberta and Canada have relied on what is essentially a third-party monitoring program that often has not employed the appropriate study design, sampling and analytical techniques or statistical methods necessary to detect environmentally relevant changes. Instead, monitoring programs have evolved as response to the needs of independent oilsands projects and their associated environmental assessments to meet industrial project approval and licensing requirements. It is clear that the Government of Canada is unable to determine the impacts of local or regional oil sands development on freshwaters in the Lower Athabasca River Basin. Consequently, there is no understanding of pre-development baselines, and no way to determine whether concentrations of contaminants in the future will be higher than baseline conditions. These are the consequences of using incorrect sampling and analytical techniques.

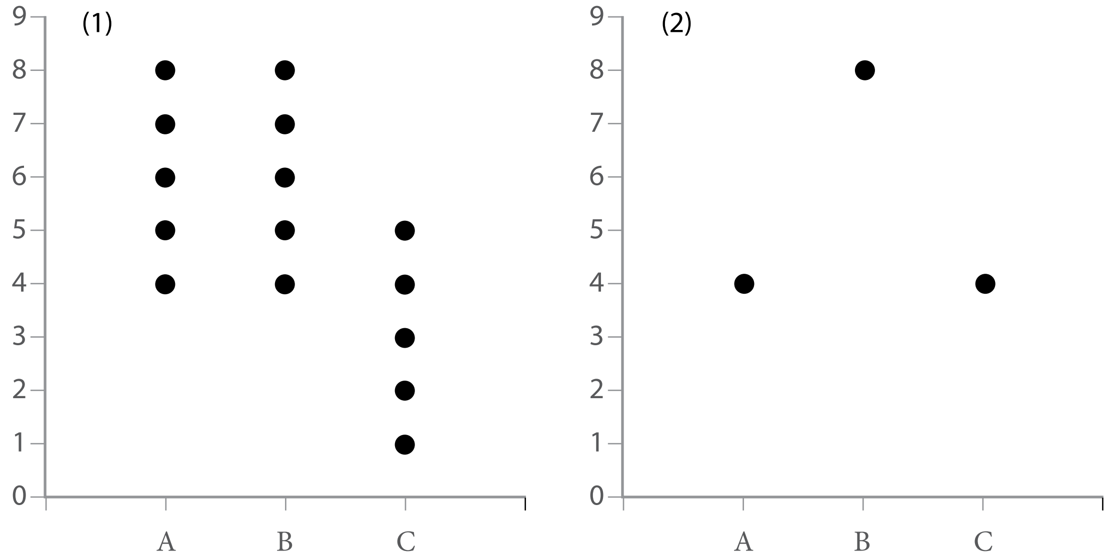
An ininformed, cookie-cutter approach to designing and implementing an environmental monitoring program does not result in effective monitoring. This is because such monitoring is not focused on providing critical missing information, and instead yields data that may be of little or no use in anticipating and assessing different sorts of critical problems that are evident at different sites, in different systems or in different regions. In other words, despite the fact that samples may be collected and analyzed, and data generated, an assessment of environmental impacts will not have been performed, and conclusions related to impacts or their absence will be highly questionable.

The kinds of problems with existing aquatic monitoring programs in the oil sands region that are described in this report and elsewhere are typical of those that occur when government abdicates its responsibility to take a leadership role in environmental monitoring: inappropriate program designs, sampling techniques, and analytical methods are employed by consultants who often do not possess sufficient expertise to even be aware of the problems inherent in what they are doing. Continued reliance upon inappropriate monitoring programs and practices will ensure that the oil sands industry will not be held responsible for its impacts, will not take actions to repair any additional harm they cause, and will not change their operations to prevent further harm. Similarly, the effects of government decisions concerning the pace, nature or extent of oil sands development as they relate to management and protection of the Lower Athabasca River and other surface waters in the region will be unknown, and the fate of the region's water, wildlife, forests and even people will be unknown—perhaps until it is too late.

The development of Alberta's oil sands appears to be axiomatic. Only by designing, implementing and funding a scientifically defensible, long-term monitoring program can we be confident that the real impacts of oil sands development - including harmful alterations and disruptions or destruction of critical elements that support and maintain aquatic ecosystem health - are being detected. Appropriate environmental monitoring will also serve to confirm or refute predictions of the impacts, or lack thereof, made by project proponents during the planning and regulatory assessment phases of the development project. Scientifically defensible monitoring programs will also enable the true application of the adaptive management promises that are universally made when projects are proposed, and upon which regulatory approval is conditional. That we can only manage what we measure applies especially well to environmental harm.

4.5.1 Power Analyses—How many sites and how many samples?

One purpose of environmental monitoring is to detect an ecologically significant impact, and this purpose has two parts: first, monitoring programs must detect impacts; and second, they must determine that these impacts actually exist. These requirements are necessary to avoid two types of errors associated with environmental monitoring: one, concluding that an environmental impact has occurred when it has not (a false positive, or "Type I" error); and two, concluding that no environmental impact has occurred even though one has (a false negative, or "Type II" error).



A simplified illustration of common types of errors in monitoring programs that result from insufficient replicate samples. Consider a case where (1) the average values and natural variation are the same at sites A and B and lower at site C, and lower values indicate nagative environmental impacts. Taking too few samples from each site can lead to wrong interpretations, including (2) conclusions of significant impacts where none exists (site A, relative to B; Type I error), and conclusions of no impact where significant impacts have actually occurred (site C, relative to A; Type II error).

Practically speaking, the difference between these two types of error is significant. A false positive can result in an unnecessary commitment of time, energy and money to fight a false alarm, but this kind of error usually does not persist very long before it is discovered. However, a false negative will have significant short- and long-term costs, because environmental degradation continues longer than it otherwise would if detected, and the eventual costs of dealing with that problem continue to grow as long as it is not detected. In any event, both types of errors must be avoided, and it is in this context that the concepts of statistical power and power analysis arise and must be considered.[75]

The design of an environmental monitoring program requires a statistical exercise called power analysis to determine the number of samples and replicates that must be taken in order to avoid false positives and negatives. The technical aspects of the technique will not be discussed here at length, but suffice to say it involves initially making some assumptions about the magnitude of an ecologically significant impact, and specifying the desired probability (or power) of detecting that impact. Using data acquired via a simple preliminary sampling program with minimal replication, the necessary numbers of samples and replicates can then be calculated. For example, a 10 per cent change in one variable may be ecologically significant, whereas a 50 per cent change in another variable is ecologically significant. Provided the natural variation in both variables is the same, more replicates would have to be taken in order to detect significant changes in the first variable than would be necessary to detect changes in the second variable.

The preliminary step of employing power analysis not only ensures that real impacts will be detected and false impacts will not be implied, but it also informs the practical scope of a legitimate monitoring program: How many samples and replicates must be taken? What will the cost of the monitoring program be? Will the planned monitoring program have a reasonable chance of detecting the hypothesized or anticipated effects if they exist? An appropriate power analysis during the design of a monitoring program ensures the number of replicates and sites chosen are not arbitrary and reduces the chances of failing to detect significant environmental harm caused by development.

Unfortunately, most consultants are unfamiliar with power analyses and they are rarely performed as a critical preliminary step in the majority of environmental impact assessments.[76] Numerous power analyses were presented in the RAMP Five Year Report, but they were not performed correctly. Preliminary power analyses also were not used during the design phase of the monitoring program to determine the appropriate number of replicates and sampling sites to assess, for instance, the impacts of oil sands development on sediment quality, water quality, climate, hydrology, benthic invertebrates, fish populations, aquatic vegetation and acid sensitive lakes.[77]

4.5.2 Different Types of Monitoring Programs

In order to provide the kinds of important information described above, an effective monitoring program will include a variety of techniques and approaches, each of which is used to gather particular kinds of specific information, including:[78]

- Simple monitoring of individual parameters, such as spatial surveys that are designed to provide information regarding geographic patterns of impact and an understanding of variability in particular parameters of interest (e.g., patterns in contaminant deposition and concentrations, acidification of lakes or nutrient deposition);
- Assessment or proxy information to reconstruct historical baselines and changes in the chemical or biological status of lakes, in the absence of long-term temporal monitoring (i.e., reconstruction of historical ecosystem variables, contaminant deposition, and environmental impacts on food webs, based on analyses of lake sediment cores);

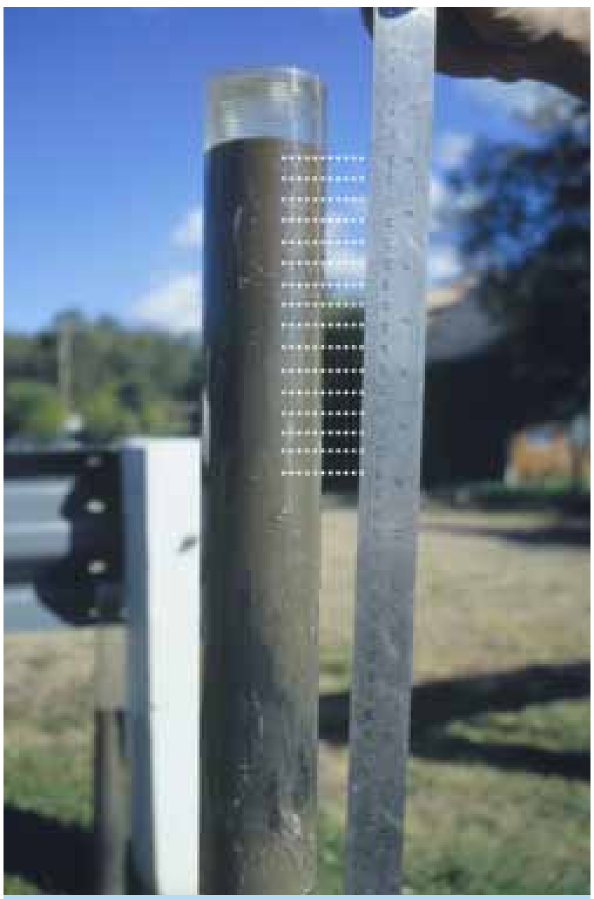
  and
- Integrated monitoring, which is associated with establishing cause and effect relationships, deriving pollution control or adaptive resource management programs, measuring environmental responses to such control measures, and to provide early warnings of new and unanticipated problems.

The simplest and best way of determining environmental impacts of a particular development is to begin monitoring before development occurs, and to monitor sites where there will likely be effects of development ("impacted" sites) and sites that will be unaffected (referred to as "control" sites). This will establish baselines for predevelopment conditions at both groups of sites. Monitoring should continue after the development proceeds at both groups of sites, and comparisons can then be made between the impacted and control sites, both before and after development. This is referred to as a before–after, control–impact (BACI) study design.

Where monitoring has not been performed prior to development, then two similar groups of sites must be selected (likely to be impacted, and controls that are likely to be unimpacted). Provided monitoring has been sufficiently intensive and frequent to determine the natural variation in variables of interest in each group of sites, the similarities and differences between these two groups of sites can be assessed. Statistically and ecologically significant differences between the groups of sites may be the result of the development in question, and at the very least should inspire further investigation as to the causes of the differences and whether they are related to oil sands development.

In the case of the oil sands, an obvious study design relates to distance from the source of emissions as a surrogate for exposure to potential harm from oil sands development. An ecologically relevant change in some variable with distance from oil sands development may be evidence of impact, and the lack of change is evidence of no impact. Monitoring designs for determining the impacts of oil sands development on contaminant deposition in rivers or lakes in the oil sands region includes those similar to the one used by Kelly et al. (2009, 2010), where monitoring is performed at different sites along the length of the Athabasca River and its tributaries or in different lakes, ranging from close to development to far away. Provided this type of monitoring program is continued from year to year, it can be determined whether exposure impacts change over time.

Where there has been insufficient pre-development monitoring to establish environmental and ecological baselines, assessment or monitoring of proxy information is necessary to understand the environmental impacts that already may have occurred by the time direct monitoring of surface waters has begun. By coring lake sediments and separating them into thin layers for separate dating and analyses, long-term historical changes in many biological, chemical, and physical processes going on in a lake and its catchment can be reconstructed. The most recent sediments, made up of various particles and dead organisms that have settled onto the bottom of the lake, were laid down last and remain at the top of a core, and sediments get older further down into the core. Appropriate analysis can date the individual layers in core samples.



Sediments accumulate constantly at the bottom of a lake and can act as a form of library of history of the lake and its basin. Chemical and biological changes in the lake can be determined by chemically dating and analysing a core of the sediments, layer by layer.
Credit: W. F. Donahue

Contaminants, nutrients, and other chemicals deposited into a lake, and the algae and zooplankton communities present in the water column, are all reflected in the sediments. The history of changes in the chemistry and biology of a lake can be reconstructed by chemically dating and analyzing the sediments layer by layer, just like counting the rings of a tree in a tree core. If the relationships between biological changes in the planktonic communities and environmental variables are known, then changes in these communities can also be used to infer historical changes in environmental variables that have affected a lake. Lake coring can be used to assess long-term changes in a variety of important environmental variables, including nutrient, contaminant and acidification inputs, and to distinguish between impacted and unimpacted lakes.

If an appropriate number and type of lakes are sampled, and they cover a range of distances from oil sands development, then the intensity and range of exposure to atmospheric inputs of heavy metals, organic contaminants, acidifying compounds and nutrients can be determined as a function of distance from development, in addition to long-term changes in regional lakes that have occurred naturally. This technique has been used elsewhere in Alberta to reconstruct, for example, regional contaminant deposition from coal-burning power plants in the Wabamun Lake area.[79] A recent study also found one lake in the oil sands region that has already experienced ecologically significant acidification caused by atmospheric inputs of NOx from oil sands development.[80]

Integrated monitoring is performed to establish cause-and-effect relationships, and is used to derive pollution control or adaptive resource management programs. It also is used to measure environmental responses to such control measures, and to provide early warnings of new and unanticipated problems (e.g., establishing the association between increased NOx emissions from oil sands development and their regional deposition, which in addition to limited acidification of lakes has resulted in fertilization or eutrophication of regional surface waters).[81]

It is important to keep in mind that an effective monitoring program and established baselines also benefit oil sands companies. If the Government of Alberta (or Canada) decides to limit development of the oil sands because of likely impacts on water, but the plan is not based on sufficient understanding of the actual impacts and environmental dynamics at work, then the limits imposed will be arbitrary. If a defensible monitoring program demonstrates that there is more flexibility in the natural function of aquatic systems in northeastern Alberta than initially presumed, then it is conceivable that arbitrary limits otherwise imposed by the government would be overly cautious, and that development could proceed further without resulting in significant impairment of aquatic ecosystem health.[82]

4.3 Conclusion

The four recent reports from the Commissioner of the Environment, the Royal Society of Canada, the federal Oilsands Advisory Panel, and the RAMP independent science review all highlight the need to completely rebuild the environmental monitoring programs in the oil sands region. This must begin with the establishment of clear objectives and strong scientific oversight and direction, and include adoption of appropriate scientific techniques and strategies that permit detection and interpretation of complex interactions and cumulative effects of oil sands development. In addition to the monitoring of environmental trends, there is a critical need for coincidental research into the causes of the observed changes and the accuracy of predicted outcomes of planned industry expansion. These causes must be understood in order to develop a plan to prevent them or respond to them if and when they occur.

Actually *implementing* an effective, scientifically-defensible environmental monitoring program requires a firm commitment by decision makers. State-of-the-art water quality monitoring is in the public interest, as well as in the interest of the oil sands industry. Compared to the value of the oil sands resource and the capital expenditures associated with its development, a robust and adaptive water monitoring program is a very cheap form of insurance. In the absence of a political commitment to long-term funding of legitimate environmental monitoring, Albertans will be financially responsible for any and all environmental harm that is the legacy of oil sands development. The test of our political decision makers' leadership will be their willingness to make the difficult but necessary decisions concerning the future of industrial development of our oil sands resources to ensure that it adheres to the tenets of environmental protection that are the foundation of our environmental laws.

5 Recommendations for Aquatic Monitoring Programs in the Oil Sands Region

1. The Government of Canada needs to commit sufficient long-term administrative and operational resources that are commensurate with its legal obligations to assess, integrate, and interpret the results of comprehensive cumulative effects assessment and aquatic monitoring programs.

   Overarching all of the problems described in this report is the failure of the Government of Canada to commit sufficient resources to environmental monitoring related to oil sands development in the Lower Athabasca River Basin. Currently, the Government of Canada expends a little more than $10 million a year on water quality monitoring in all of Canada. Despite its obligation to monitor water quality in Canadian inland waters and transboundary air pollution, the Government of Canada is not monitoring the effects of oil sands development on the Lower Athabasca River and its tributaries or regional lakes. Each additional water quality monitoring station costs approximately $54,000 per year. Considering the importance of the oil sands to Canada's economy, the trillion dollar value of the resource itself, and the tens or hundreds of billions of dollars in total capital expenditures expected for oil sands development, the financial cost of a robust, scientifically defensible aquatic monitoring program designed to determine the impacts of oil sands development on regional surface waters is miniscule.

2. Government of Canada scientists need to be given responsibility for developing, implementing, conducting, and managing aquatic monitoring programs to determine the effects of oil sands development in the Lower Athabasca River Basin.

   The kinds of problems with existing aquatic monitoring programs in the oil sands region that are described in this report and elsewhere are typical of those that occur when government abdicates its responsibility to take a leadership role in environmental monitoring: inappropriate program designs, sampling techniques, and analytical methods are employed by consultants who often do not possess sufficient expertise to even be aware of the problems inherent in what they are doing. Research scientists employed by the Government of Canada have a long history of doing world-leading research into impacts of industrial development on pollution dynamics and their effects on inland fisheries and aquatic ecosystem health. Federal government scientists at Environment Canada's Canada Centre for Inland Waters in Burlington and the Department of Fisheries and Oceans' Freshwater Fisheries Habitat Research Group at the Freshwater Institute in Winnipeg are fully qualified to establish, implement, and oversee the kinds of monitoring programs that are necessary to identify and quantify the direct and indirect impacts of oil sands development in northeastern Alberta, and to establish the necessary understanding of baseline environmental conditions and natural variation in aquatic systems in this region. The continued engagement of the people who have been in charge of monitoring thus far is strongly discouraged.

3. Aquatic monitoring programs should be designed, overseen, and performed by expert scientists who do not rely on oil sands companies for current or future employment or payment, at a minimum.

   This requirement for independence from industry is essential, because of the high degree to which public trust has been eroded regarding environmental monitoring associated with oil sands development. The consultants upon whom government and industry have relied have proven incapable of designing or implementing effective aquatic monitoring programs or scientifically defensible environmental impact assessments in the oil sands region. They also have proven equally incapable of interpreting the results of either monitoring programs or environmental impacts assessments in accordance with scientific—as opposed to industry—standards.

4. Experts engaged for the design of monitoring programs should be practicing research scientists.

   These experts should be involved in environmental research as a continuing professional practice, including the publication of studies in peer-reviewed scientific literature. A critical failure of those who designed, implemented and have been overseeing current aquatic monitoring programs in the Lower Athabasca River Basin is the obvious lack of familiarity with the body of scientific literature that deals with common, up-to-date sampling, analytical and interpretive techniques. Given the incredibly high economic and ecological stakes involved in developing Alberta's oil sands, this is unacceptable.

5. Monitoring programs should be designed according to accepted scientific best practice.

   Thus far, it is evident that standards and practices employed in the environmental consulting industry for the design, performance, analyses and interpretation inherent in aquatic ecosystem assessment and monitoring in the oil sands region are lacking a basis in science and are insufficient. This is not acceptable. The engagement of practicing research scientists should ensure that future cumulative effects assessment and monitoring programs meet the appropriate, generally accepted current and future scientific standards.

6. Monitoring programs need to be designed to identify and quantify critical ecological thresholds and environmental change.

   Thus far, monitoring programs have ostensibly been designed only to assess environmental change. Critical relationships between such things as river flow or contaminant concentrations and significant ecological impacts also must be identified. This will permit the establishment of meaningful ecological end-points for concurrent management of aquatic ecosystems and oil sands development. It also will enable development of a more ecologically effective and meaningful long-term environmental impacts monitoring program.

7. Monitoring must be sufficiently intensive—both spatially and temporally—in the early stages of any monitoring program to determine natural variation.

   This generally involves collecting a relatively large number of replicate samples from a large number of sites, throughout the year and during the first few years, in order to ascertain how much variables vary over time. This is necessary in order to gain an understanding of the variation that occurs naturally for all the relevant environmental variables of interest. The intensive spatial sampling is necessary to determine how much important ecological variables vary along the length of a river or within and between lakes, and the high frequency of sampling is necessary to determine how much variables change from season to season and from year to year. Without such an understanding of natural variation, conclusions cannot be drawn regarding the ultimate source of differences in values between sites or at a single site in different months or different years (i.e. the result of natural processes and natural variation, or indicative of harm caused by human activity).

8. Once a greater understanding of natural variation has been attained, a long-term monitoring program should be refined and made more efficient.

   Eventually, less intensive sampling will be necessary, and modifications in sampling sites, sampling times or sampling frequencies can be made with confidence that results will still be interpretable in the context of known natural variation. Relationships between variables can also be determined, and if strong relationships are evident then the numbers of variables sampled (i.e., the sampling effort and associated costs) can be reduced while maintaining an understanding of changes occurring in the full suite of variables of interest.

9. Expert, scientifically defensible assessment of monitoring program data must be considered a critical part of environmental effects assessment and long-term aquatic monitoring programs.

   Without competent and robust assessments of monitoring data, even the best monitoring data will remain unused, environmental impacts will remain unidentified and unassessed, and management decisions will remain uninformed. In line with the research-based monitoring programs recommended here, the Government of Canada must commit to rectifying its failure to perform the necessary research on the dynamics, fate and toxicity of most of the compounds of concern associated with oil sands development. Currently, the Government of Canada is unable to identify appropriate environmental limits for the release and accumulation of these compounds in surface waters of the Lower Athabasca River Basin, and this inability must be overcome if federal obligations and responsibilities related to promoting and ensuring environmental sustainability on an ecosystem basis are to be met

10. Data from all environmental monitoring associated with oil sands development needs to be stored in an organized and searchable format, and these data and all scientific assessments must be made publicly accessible.

   Currently, RAMP data may only be acquired by signing a Data Sharing Agreement with RAMP. Data in electronic form must be made freely and publicly available via a public internet portal as soon as it has been validated and verified. All quality assurance/quality control and study design information must be provided with the data or available from the same publicly accessible source.

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43 Ayles, G. B., M. Dubé, and D. Rosenberg. Oil Sands Regional Aquatic Monitoring Program (RAMP) Scientific Peer Review of the Five Year Report (1997-2001). 2004. Prepared for CEMA, pp.; http://www.andrewnikiforuk.com/Dirty_Oil_PDFs/RAMP%20Peer%20review.pdf.

44 2010 Regional Aquatics Monitoring Program (RAMP) Scientific Review, Integrated Water Management Program Alberta Innovates – Technology Futures, http://www.ramp-alberta.org/UserFiles/File/RAMP%202010%20Scientific%20Peer%20Review%20Report.pdf.

45 Kelly, E. N., et. al. 2009. Oil sands development contributes polycyclic aromatic compounds to the Athabasca River and its tributaries. *Proceedings of the National Academy of Sciences* 106 (52): 22346-22351. [Supporting Information, Table S1].

46 Table B.2-1, RAMP 2005 Technical Report, Appendix B; section 3.2.4, RAMP 2009 Technical Report.

47 Naphthenic acids are a complex mixture of naturally-occurring compounds found in bitumen that can account for up to four per cent (by weight) of raw petroleum. They do not degrade readily in the environment and are toxic to a variety of aquatic organisms, including fish and aquatic invertebrates. Because of the complexity of the mixture, identification of many of the different compounds and characterization of their toxicities remains unknown.

48 Headley, J. V., and D. W. McMartin. 2004. A review of the occurrence and fate of naphthenic acids in aquatic environments. *Journal of Environmental Science and Health* A39 (8): 1989-2010.

49 Section 7.2.1.1, RAMP 2009 Technical Report.

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54 Culp, J. M., C. L. Podemski, and K. J. Cash. 2000. Interactive effects of nutrients and contaminants from pulp mill effluents on riverine benthos. *Journal of Aquatic Ecosystem Stress and Recovery* 8: 67–75; M. Department of Natural Resources, WI Report Technical Bulletin No. 100, *Use of Arthropods to Evaluate Water Quality of Streams*, 16 pp.; Hilsenhoff, W. L. 1998. A modification of the Biotic Index of organic stream pollution to remedy problems and permit its use throughout the year. *The Great Lakes Entomologist* 31 (1): 1-12; Hodkinson, I. D. 2005. Terrestrial and aquatic invertebrates as bioindicators for environmental monitoring, with particular reference to mountain ecosystems. Environmental Management 35 (5): 649-666; Houston, M., D. Lowthion, and P. G. Soulsby. 1983. The identification and evaluation of benthic macroinvertebrate assemblages in an industrialised estuary—Southampton Water, UK, using a long-term, low-level sampling strategy. *Marine Environmental Research* 10: 189-207; Mandaville, S. M. Benthic Macroinvertebrates in Freshwaters—Taxa Tolerance Values, Metrics, and Protocols. 2002. Prepared for Soil & Water Conservation Society of Metro Halifax, xviii, 48 pp, Appendices

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56 *Ibid*; 2010 Regional Aquatics Monitoring Program (RAMP) Scientific Review, Integrated Water Management Program Alberta Innovates – Technology Futures, http://www.ramp-alberta.org/UserFiles/File/RAMP%202010%20Scientific%20Peer%20Review%20Report.pdf.

57 Timoney, K. P., and P. Lee. 2009. Does the Alberta Tar Sands Industry Pollute? The Scientific Evidence. *The Open Conservation Biology Journal* 3: 65-81.

58 For example, according to the Canadian Association of Petroleum Producers (CAPP), "As part of an industry commitment to compliance and continuous improvement, the Regional Aquatics Monitoring Program (RAMP), an industry-funded, multi-stakeholder environmental monitoring program, was initiated in 1997. RAMP integrates aquatic monitoring activities across different components of the aquatic environment, different geographic locations, and Athabasca oil sands and other developments in the Athabasca oil sands region, so that long-term trends, regional issues and potential cumulative effects related to oil sands and other developments can be identified and addressed. For more than a decade, detailed measurements have been taken both upstream and downstream of oil sands developments. Monitoring of the Athabasca River, upstream and downstream of development, has shown no impacts associated with oil sands development. That does not mean there are no naturally occurring hydrocarbons in the river. Bitumen from exposed oil sands along the river banks into the Athabasca River as it cuts its way thought the landscape. As a result, natural water quality includes measureable hydrocarbon compounds."[Excerpted from *Oil and Water Do Mix: Canada's Oil & Gas Industry Does Not Trivialize Water Conservation*, by Greg Stringham; http://www.capp.ca/aboutUs/mediaCentre/CAPPCommentary/Pages/WeDontTrivializeWaterConservation.aspx#tBW2GFn70Uha.

59 From: Frequently Asked Questions – Oil sands; http://environment.gov.ab.ca/info/faqs/faq5-oil_sands.asp.

60 See Mike De Souza, "Environmental impact study on Alberta oil sands slanted toward big oil: federal documents" *Can West News Services*, January 7, 2010; http://www.canada.com/business/Environmental+impact+study+Alberta+oilsands+slanted+toward+federal+documents/2417425/story.html (accessed December 9, 2010).

61 Sarigiannis, D. A. 2002. Integrated environmental and health protection: implementation of The Precautionary Principle. *Fresenius Environmental Bulletin* 11 (10a): 750-756.

62 Timoney, K. P. 2007. A study of water and sediment quality as related to public health issues, Fort Chipewyan, Alberta. Nunee Health Board Society, Fort Chipewyan, Alberta http://www.connectingthedrops.ca/resources;
Timoney, K. P. and P. Lee. 2009. Does the Alberta Tar Sands Industry Pollute? The Scientific Evidence. *The Open Conservation Biology Journal* 3: 65-81; Kelly, E. N., et. al. 2009. Oil sands development contributes polycyclic aromatic compounds to the Athabasca River and its tributaries. *Proceedings of the National Academy of Sciences* 106 (52): 22346-22351.

63 Tributaries used in this study had to have undeveloped sampling sites upstream and downstream of exposed erosional zones of the oil sands-bearing McMurray Formation, and oil sands mines downstream of exposed erosional zones of the McMurray Formation, in order to assess whether natural exposure to bitumen-bearing layers resulted in similar contamination as sites affected by development.

64 In both sample types, approximately 75 per cent of PAHs were three-ring structures, dominated by alkyl-substituted dibenzothiophenes, phenanthrenes/anthracenes and fluorenes, and the remainder was mostly four-ring structures including alkyl-substituted fluoranthenes/pyrenes and benzanthracenes/chrysenes. In neither sample type were there significant naphthalenes.

65 Little of the variability in PAH concentrations was explained by the proportions of the sub-basin overlaying the McMurray Formation, total surface land disturbance, or oil sands mining disturbance (Kelly et al. 2009).

66 Kelly et al. (2009). These exposure rates and toxicity effects were calculated from: Colavecchia, M. V., et al. 2004. Toxicity of oil sands to early life stages of fathead minnows (*Pimephales promelas*). *Environ. Toxicol. and Chem.* 23 (7): 1709-1718; Colavecchia, M. V., P. V. Hodson, and J. L. Parrott. 2006. CYP1A induction and blue sac disease in early life stages of white sucker (*Catostomus commersoni*) exposed to oil sands. *Journal of Toxicology and Environmental Health, Part A Current Issues* 69 (10): 967-994; Colavecchia, M. V., P. V. Hodson, and J. L. Parrott. 2007. The relationships among CYP1A induction, toxicity, and eye pathology in early life stages of fish exposed to oil sands. *Journal of Toxicology and Environmental Health, Part A Current Issues* 70 (18): 1542-1555.

67 Kelly, D. J., et. al. 2010. Oil sands development contributes elements toxic at low concentrations to the Athabasca River and its tributaries. *Proceedings of the National Academy of Sciences* 107 (37): 16178–16183. Heavy metals sampled include antimony (Sb), arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), silver (Ag), thallium (Tl), and zinc (Zn).

68 Emissions of these pollutants from upgraders are reported to Environment Canada's National Pollutant Release Inventory (NPRI).

69 For Be, the deposition patterns were spatially compressed compared to other metals, with Type 1 deposition only with two km of the main upgraders; the characterization of "near development" and "background" were adjusted accordingly.

70 Concentrations of Cd increased significantly near oil sands development and correlated strongly with total land disturbance and with proportion of oil sands development within the watershed. In winter, concentrations of Hg, Tl, and Ni were as much as two-fold higher in watersheds with more development than in watersheds with less development, and in summer there was up to an eight-fold difference in concentrations. Concentrations of As, Be, Hg, and Se were higher in summer than in winter at more disturbed sites, but only Hg demonstrated such a seasonal difference at less disturbed sites. In the Athabasca River, concentrations of Cr, Hg, Ni, and Ag under ice were up to eight-fold higher immediately downstream of tailings ponds, impoundments or other oil sands development infrastructure compared to upstream. In summer, concentrations of Sb, As, Cr, Cu, Pb, Hg, and Ni were up to four-fold greater downstream and near oil sands development than upstream of it, and Be, Se, Ag, Tl, and Zn were detectible downstream and near development but not upstream of it. Relative concentrations of heavy metals in river water also were very similar to those in snow, which provides a link between airborne emissions and their sources and the Athabasca River and its tributaries. Concentrations of many heavy metals, including Sb, As, Cr, Cu, Pb, Hg, and Ni, were higher at downstream sites all the way to the Athabasca Delta, compared to sites upstream of oil sands development. At Lake Athabasca, near the discharge from the Delta, concentrations of Sb, As, Cd, Cr, Cu, Pb, Hg, and Ni were as much as two-fold higher than upstream of oil sands development, with some demonstrating higher concentrations in summer than in winter (Cr, Cu, Pb, Hg, Ni, and Tl) and Zn demonstrating the reverse.

71 Curtis, C. J., et. al. 2010. Paleoecological assessment of lake acidification and environmental change in the Athabasca Oil Sands Region, Alberta. *Journal of Limnology* 69 (Suppl. 1): 92-104; Hazewinkel, R. R. O., et. al. 2008. Have atmospheric emissions from the Athabasca Oil Sands impacted lakes in northeastern Alberta, Canada? *Canadian Journal of Fisheries and Aquatic Sciences* 65: 1554-1567.

72 Curtis, C. J., et. al. 2010. Paleoecological assessment of lake acidification and environmental change in the Athabasca Oil Sands Region, Alberta. *Journal of Limnology* 69 (Suppl. 1): 92-104.

73 For example: Alden, R. W., et. al. 2005. An integrated case study for evaluating the impacts of an oil refinery effluent on aquatic biota in the Delaware River: integration and analysis of study components. *Human and Ecological Risk Assessment* 11: 879-936; Alexander, C. R., et. al. 2005. An integrated case study for evaluating the impact of an oil refinery effluent on aquatic biota in the Delaware River: sediment core studies. *Human and Ecological Risk Assessment* 11: 861-877; O. o. Water Report EPA 841-B-99-002, *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, 2nd ed*, pp.; http://www.epa.gov/owow/monitoring/rbp/wp61pdf/rbp.pdf; Boulton, A. J. 1999. An overview of river health assessment: philosophies, practice, problems and prognosis. *Freshwater Biology* 41: 469-479; Brydges, T. 2004. Basic Concepts and Applications of Environmental Monitoring. In *Environmental Monitoring*, edited by G. B. Wiersma. New York: CRC Press; Cabral, H. N., and A. G. Murta. 2004. Effect of sampling design on the abundance estimates of benthic invertebrates in environmental monitoring studies. *Marine Ecology Progress Series* 276: 19-24; Cairns, J., P. V. McCormick, and B. R. Niederlehner. 1993. A proposed framework for developing indicators of ecosystem health. *Hydrobiologia* 263: 1-44; Canton, S. P., and J. W. Chadwick. 1988. Variability in benthic invertebrate density estimates from stream samples. *Journal of Freshwater Ecology* 4 (3): 291-297; Carls, M. G., and J. P. Meador. 2009. A perspective on the toxicity of petrogenic PAHs to developing fish embryos related to environmental chemistry. *Human and Ecological Risk Assessment* 15: 1084-1098; Chapman, P. M., et. al. 2003. Conducting ecological risk assessments of inorganic metals and metalloids: current status. *Human and Ecological Risk Assessment* 9 (4): 641-697; Debruxelles, N., et. al. 2009. Design of a watercourse and riparian strip monitoring system for environmental management. *Environmental Monitoring and Assessment* 156 (435-450); Elliott, J. M. 1977. *Some Methods for Statistical Analysis of Samples of Benthic Invertebrates*. 2nd ed, *Scientific Publication* 25: Freshwater Biological Association. 160 pp; Fairweather, P. G. 1991. Statistical power and design requirements for environmental monitoring. *Australian Journal of Marine and Freshwater Research* 42: 555-567; Hall, L. W., and D. T. Burton. 2005. An integrated case study for evaluating the impact of an oil refinery effluent on aquatic biota in the Delaware River: introduction, study approach, and objectives. *Human and Ecological Risk Assessment* 11: 647-656; Hall, L. W., et. al. 2005. An integrated case study for evaluating the impact of an oil refinery effluent on aquatic biota in the Delaware River: sediment quality triad studies. *Human and Ecological Risk Assessment* 11: 657-770; Hamer, A. D., and P. G. Soulsby. 1980. An approach to technical and biological river monitoring systems. *Water Pollution Control* 79 (56-69); Harwell, M. A., et. al. 1999. A framework for an ecosystem integrity report card. Bioscience 49 (7): 543-556; Hilsenhoff, W. L. 1998. A modification of the Biotic Index of organic stream pollution to remedy problems and permit its use throughout the year. *The Great Lakes Entomologist* 31 (1): 1-12; Jowett, D. C. 2002. Improved environmental monitoring–manual of best practice for the design of water quality monitoring programs. *Fresenius Environmental Bulletin* 11 (10a): 743-749; Larsen, D. P. 1997.

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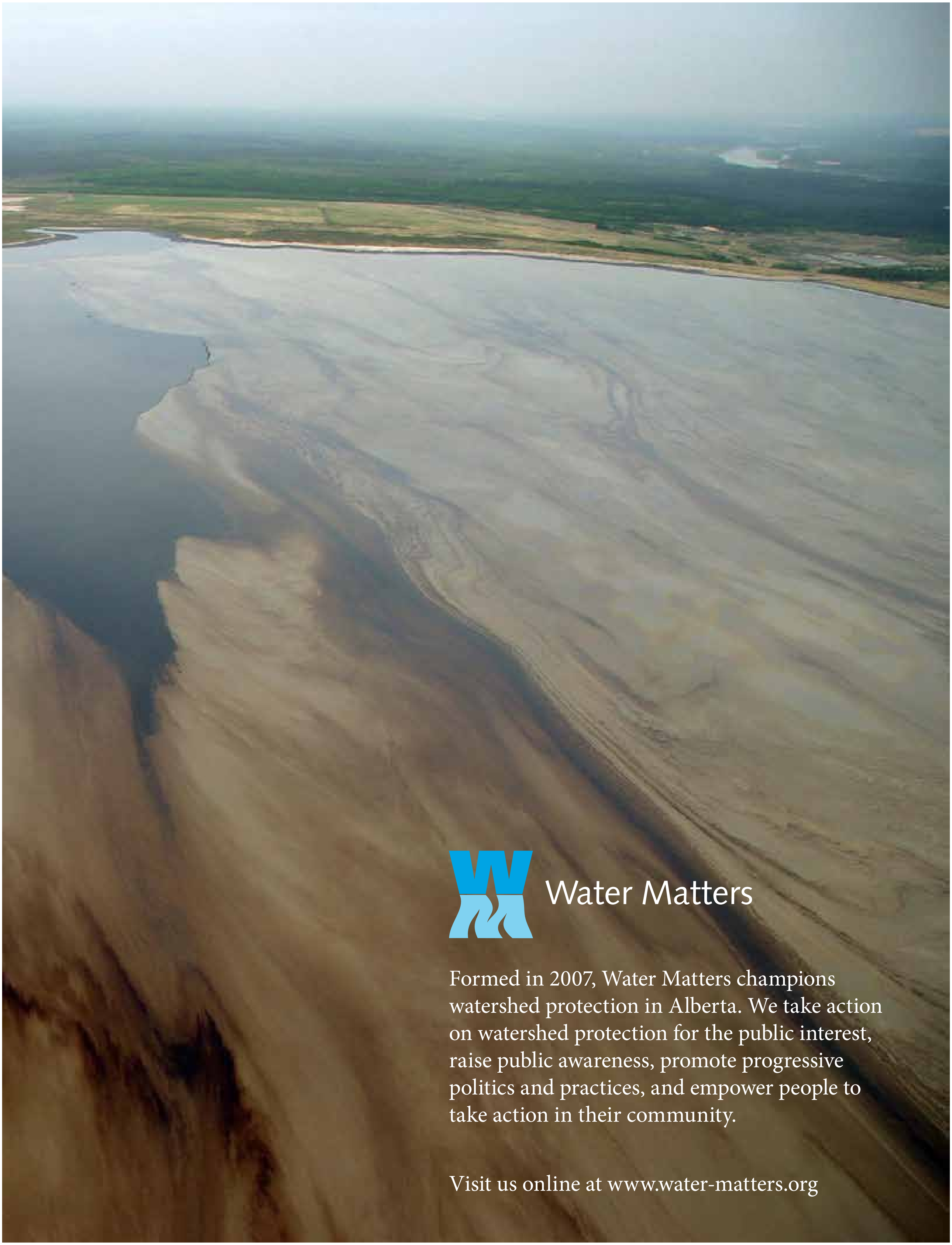
Appendix 1 – Federal Legislation Relevant to Environmental Impacts of Oil Sands Operations

- *Navigable Waters Protection Act*, S.C. 1985, c. N-22 – Any project that is built or placed in, on, over, under, through, or across any navigable water must be approved by the federal Minister of Transport (s. 5).
- *Canadian Environmental Assessment Act*, S.C. 1992, c. 37 [CEAA] – The purpose of the Act is to ensure that projects do not cause significant adverse environmental effects [s. 4(1)(a)]. Because inland waters are considered federal lands under the Act [s. 2(1)], the Act requires that federal authorities ensure that projects on inland waters in the Alberta do not cause significant adverse environmental effects in other provinces [s. 4(1)(c)]. With exceptions, where federal permitting is required, the Act also requires performance of an environmental assessment [s. 5(1)(d)].
- *Fisheries Act*, S.C. 1992, c. 37 – Prohibits any work that results in the harmful alteration disruption or destruction ("HADD") of fish habitat, which includes spawning grounds and nursery, rearing, food supply and migration areas upon which fish dependent directly or indirectly [ss. 34(1) and 35(1)]. The deposit of any sort of deleterious substance also is prohibited [s. 36(3)], as is the making of a false or misleading statement in the application for a license under the Act [s. 63(2)]. The Act also conveys the authority to the federal government to protect the unobstructed passage of fish, revive obstructed flow to levels sufficient for their passage, spawning and egg incubation, and restrict or close operations that cause harm to fisheries or fish habitat (ss. 22 and 37).
- *Migratory Birds Convention Act*, S.C. 1994, c. 22 – Prohibits the deposit of substances harmful to migratory birds in waters or areas frequented by them, or wherever harmful substances may subsequently enter such waters [s. 5.1(1)].
- *Species at Risk Act*, S.C. 2002, c. 29 [SARA] – Is intended to prevent species in Canada from becoming endangered (i.e., face the risk of extirpation or extinction), to provide for the recovery of species that are extirpated, endangered or threatened, and to prevent species of special concern from becoming endangered or threatened. The federal government is empowered to identify species at risk, develop recovery and management plans, and protect species' habitat. The killing, capturing, or harassing of extirpated, endangered, or threatened species are prohibited [s. 32(1)], as is the destruction of their residences to [s. 33].

- *Canadian Environmental Protection Act*, S.C. 1999, c. 33 [CEPA] – Declares that the protection of the environment is essential to the well-being of Canadians, that the Act's primary purpose is to contribute to sustainable development through pollution prevention, that pollution prevention is the priority approach to environmental protection, that the most harmful substances must be virtually eliminated, that pollutants must be controlled and managed if their release into the environment cannot be prevented, and that the Government of Canada is committed to employing an ecosystem approach that incorporates the precautionary principle to prevent environmental degradation even when there is a lack of full scientific certainty of serious or irreversible harm. It also conveys the power to Environment Canada and Health Canada to conduct research into toxic substances, and requires the federal Minister of Environment to monitor environmental quality and conduct research on environmental contamination, including hormone disrupting substances [ss. 44(1) and (4)], and the Minister of Health to conduct research on the effects of potentially toxic substances on illness and health [s. 45].
- *Constitution Act*, 1930 20-21 George V, c. 26 (U.K.); Alberta Natural Resources Act, 1930, c. 3 - Reserve the federal right to determine and secure sufficient flows in any rivers or streams in national parks, including Wood Buffalo National Park, as necessary to preserve their "scenic beauties" [in the former, Schedule 2, s. 16]. Also prohibit Alberta from reducing flows of any rivers or streams below said amounts deemed necessary to preserve national parks' "scenic beauties" [in the latter, Schedule, s. 16].



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