# A FOUNDATION FOR THE FUTURE: BUILDING AN ENVIRONMENTAL MONITORING SYSTEM FOR THE OIL SANDS

**A REPORT SUBMITTED TO THE MINISTER OF ENVIRONMENT**


**OILSANDS ADVISORY PANEL**
Liz Dowdeswell (Chair)
Peter Dillon
Subhasis Ghoshal
Andrew Miall
Joseph Rasmussen
John P. Smol


December 2010

# TABLE OF CONTENTS

The Panel gratefully acknowledges the generosity of many individuals and organizations who contributed their views and expertise. Representatives of federal and provincial government departments, First Nations, industry, academia, non-governmental organizations and citizens spoke with us and shared information that was instrumental in developing our understanding of the issue.

The Panel also wishes to express its appreciation to a small team of individuals, led by Dan Wicklum, who provided scientific, logistical and administrative assistance during the course of the Panel's work.

# CHAPTER ONE

# PREFACE AND CHARGE TO THE PANEL

## CHARGE TO THE PANEL

On September 30, 2010 the federal Minister of the Environment announced the establishment of an Oil Sands Advisory Panel on water monitoring for the Lower Athabasca River Basin and connected waterways.

The Minister noted that "serious concerns have been raised about oil sands pollution entering the Basin and whether environmental monitoring systems are well-designed and implemented." He believed that "these concerns must be fully explored to ensure that a first-class, state-of-the-art monitoring system is in place, serving the public interest by providing the necessary information to protect the environment." He sought independent advice.

Specifically, the Advisory Panel was asked to:

1. Document, review and assess the current body of scientific research and monitoring;
2. Identify strengths and weaknesses in the scientific monitoring, and the reasons for them.

Within 60 days of being established, the Advisory Panel was to present a written report of its findings and conclusions, including recommendations, that if implemented would ensure that scientific issues would be effectively addressed.  The Advisory Panel's report and recommendations were to be made public.

## APPROACH

One of the most vexing challenges of our times is how to meet ever-increasing energy needs in a responsible and environmentally sustainable way. Any analysis of the current state of geopolitics and economic development in a carbon-constrained world reveals a pervasive sense of insecurity about future energy supply.

The environmental performance of oil sands development in Canada is under intense public scrutiny. The prevailing narrative positions their essential and significant contribution to Canada's economy and energy security against potential environmental damage and impact on First Nations communities. Recently there have been conflicting scientific opinions that call into question the availability of credible data used in making sound policy decisions and enforcing legislation and regulation in the oil sands region.

The Panel's contribution to the evolving dialogue and policy development was to examine whether or not there is an observation and monitoring system in the region of a quality that will provide decision-makers with the data and evidence necessary to safeguard the environment while supporting economic and social development. If not, then the Panel was expected to provide advice on recommended actions to bring about such a monitoring program.

Given the time available for the study, the Panel chose to prepare a concise report that was analytical rather than descriptive and that focused strategically on the future rather than a detailed evaluation of the past. The focus of our examination was the aquatic monitoring system.

An extensive catalogue of documentation, including key peer-reviewed scientific publications, was reviewed as part of the evidence base. The Panel was made aware of, but did not attempt to duplicate, numerous studies of oil sands development that had been or were in various stages of completion. We did not undertake original research to validate the observations and conclusions contained in these studies.

This documentation was supplemented with interviews and discussions with federal and provincial government experts, representatives of selected First Nations, recognized academic experts, industry practitioners and non-governmental organizations and a site visit. We did not undertake a comprehensive stakeholder engagement, given the time available.

## DEVELOPING A FRAMEWORK

Much has been written about how humans are altering the ecosystem. Environmental monitoring helps us understand that relationship by systematically measuring key environmental indicators over a period of time. Indicators are chosen as signals or proxies for environmental health, ecosystem functioning, human health and socioeconomic well-being. We seek scientific information about potentially affected ecosystems to:

- assess ecosystem health, identify stressors and provide early warning of environmental damage, now and in the future;
- assess compliance with legal requirements, standards and other obligations and commitments; and,
- verify implementation and effectiveness of prevention, remediation and mitigation measures.

Ultimately monitoring can provide the foundational data for developing policy and making sound decisions.

Monitoring is a continuous process beginning with an understanding of the baseline or normal conditions at multiple scales. It incorporates feedback generated in response to specific project or initiative monitoring. It addresses cumulative impacts observed over time, across media and in neighboring jurisdictions.

### DEFINITIONS

Many definitions exist for key concepts important to this paper. The Panel used the following definitions.

*Monitoring:* A scientifically-designed system of long-term, standardized measurements, systematic observations, evaluation and reporting.

*Surveillance:* A focused, short-term study to assess and report on a priority issue or specific threat.

*Research:* Systematic, science-based study used to establish facts and reach conclusions.

Aspirations and best practices for effective and leading-edge monitoring systems have been articulated in a wide variety of documents ranging from the comprehensive 2005 Millennium Ecosystem Assessment to the recent work of stakeholders in the region, such as the Oil Sands Research and Information Network.

The following principles for design and implementation of an effective monitoring system emerge:

- Holistic and comprehensive: a systemic approach that incorporates multiple essential components of the system as well as the relationships among the components, integrates multiscale spatial measurements and recognizes the temporal dimension, from past to future.
- Scientifically rigorous: a science-based approach that uses robust indicators, consistent methodology and standardized reporting, including peer-review, that will result in independent, objective, complete, reliable, verifiable and replicable data.
- Adaptive and robust: an approach that can be evaluated and revised as new knowledge, needs and circumstances change and that ensures stable and sufficient funding.
- Inclusive and collaborative: an approach that engages concerned parties in the design and execution, including the prioritization of issues and setting of ecosystem goals.
- Transparent and accessible: an approach that produces publicly available information in forms (ranging from raw data to analyses) in a timely manner that will enable concerned parties to conduct their own analysis and draw their own conclusions and that will make the basis for judgment and conclusions explicit.

Additionally, we recognize that there are different ways of knowing. Although the information base is to be found in published scientific literature, the richness and history of local and traditional aboriginal knowledge about ecosystem change will make a valuable and legitimate contribution. Seeking out information held by the private sector, practitioners and academics is essential.

If the monitoring system is to reveal dynamic processes and causal changes, modeling and the building of scenarios will be important and complementary activities to those of data collection and analysis. Models synthesize observations, analyze interactions among processes, including integrating pollutant fluxes in a mass-balance framework and fill gaps in information while scenarios may be used to examine cross-scale ecological feedbacks, articulate probabilities and uncertainties and prepare the system for ecological surprises.

Legislation under which jurisdictions monitor and derive associated roles and responsibilities are many and varied.  Using water as an example, the Province of Alberta sets industry monitoring and reporting requirements under the Alberta Environmental Protection and Enhancement Act, and provides a licensing and approval process for water withdrawals, releases, and enforcement measures under the Alberta Water Act.  The Alberta Land Stewardship Act and Cumulative Effects Management System enables a Land-use Framework by authorizing the development of regional plans and provides an adaptive, collaborative results-based environmental management framework to focus more resources on higher-risk environmental impacts.

The Government of Canada derives a mandate for science activity in the oil sands primarily from the Fisheries Act which prohibits deposition of deleterious substances into fish habitat, the Canadian Environmental Protection Act which provides a framework for management of toxic substances, the Canada Water Act which enables the government to enter into agreements to perform science activities including monitoring of transboundary waters, and the Canada National Parks Act, which establishes and protects the integrity of National Parks.   In addition, the Canadian Environmental Assessment Act provides the framework within which major development projects are approved or not and the Indian Act gives water responsibilities to the Department of Indian and Northern Affairs on northern and reserve lands.

These pieces of provincial and federal legislation are collectively responsible for ensuring the responsible use of water resources in the oil sands area.  They do so by requiring structured analyses before approval of major development, setting limits on how much water is used and ensuring water quality is protected.  All of these activities require sound information collected in a sound monitoring system.

Chapter 2 of this report describes the context in which our work was undertaken. Chapter 3 summarizes our observations about what we saw, were told and read about the nature of the development activity and its real or perceived impact, the key players and the monitoring system. It maps and assesses the current situation against the elements of the conceptual framework, identifying gaps as well as strengths. The final chapter presents recommendations for a strategic path forward.

## CHAPTER TWO

# THE CONTEXT

This chapter describes the context in which the Panel performed its work. It includes brief descriptions of the oil sands region, mining processes, environmental concerns related to oil sands development, oil sands monitoring organizations and major research organizations.

## WHAT ARE THE OIL SANDS?

The oil sands are considered to be one of the largest single accumulations of oil in the world. While some deposits of oil sands extend into Saskatchewan, presently the only recoverable resources are located in Alberta in three main regions: Athabasca, Cold Lake, and Peace River (Exhibit A). The deposits underlie 140,200 $km^2$ of boreal forest,

**EXHIBIT A**


*Source: (Source: Wikipedia/Created by Created by Norman Einstein, May 10, 2006)* muskeg peat bogs and northern prairie ecozones and are estimated to hold 1.7 trillion barrels of crude oil.

The Athabasca oil sands deposit near Fort McMurray is the largest and the only one where the oil sands are shallow enough (within 75 m of the surface) to permit open-pit mining. The oil within the deposits is contained in a mixture of crude bitumen (a semi-solid form of crude oil), silica sand, clay minerals, and water, therefore requiring specialized approaches for extraction and upgrading. With present technologies, about 10% (170 billion barrels of oil) is recoverable and ultimately 315 billion barrels of oil could be recovered. Exhibit B provides some summary statistics related to the oil sands development.

### EXHIBIT B: OIL SANDS STATISTICS

- Of the total 170.4 billion barrels established as oil sands reserves, approximately 20% (34 billion barrels) of the resource is accessible through surface mining while the remaining 80%) requires some form of in-situ production techniques.
  **(Government of Alberta-Energy: http://www.energy.alberta.ca/OilSands/791.asp)**
- In 2008, 45% of bitumen was produced in-situ (584,000 barrels per day) with the remaining 55% coming from surface mining operations (722,000 barrels per day**).**
  **(Government of Alberta-Energy: http://www.energy.alberta.ca/OilSands/791.asp)**
- Capital and repair expenditures, primarily in the oil sands are estimated to have averaged $CDN 16.4 billion per year from 2007-2009. (**Statistics Canada**).
- As of August 2009, there were 91 active oil sands projects in Alberta. Of these, four were open-pit mining projects, while the remaining projects used various *in-situ* recovery methods.
  **(Government of Alberta-Energy: http://www.energy.alberta.ca/OilSands/791.asp)**
- In 2010, oil sands production will comprise 55% of western Canada's total crude oil production, and is projected to grow from 1.3 million barrels/day in 2009 to approximately 3.5 million barrels/day by 2025.
  **(CAPP 2010)**
- In SAG-D operations, up to half a barrel of fresh water is required to produce each barrel of bitumen
  **(Government of Alberta-Energy: http://www.energy.alberta.ca/OilSands/791.asp)**
- Surface mining requires 2-4 barrels of freshwater for each barrel of oil produced (**CAPP 2009).**
- The amount of water permitted to be withdrawn from the Athabasca River for all oil sands projects – existing and future – is equivalent to less than 3% of its average annual flow. During periods of low river flow, Alberta Environment limits water consumption to 1.3% of annual average flow. At times, this can mean that industrial users will be restricted to less than half of their normal requirement given current approved development. *Source: Alberta Environment.*

The Athabasca River system and some of its tributaries flow through the Athabasca oil sands deposits near Fort McMurray. The river originates from the eastern slopes of the Rocky Mountains in Alberta, flows northeast and drains an area of approximately 160,000 km$^2$, eventually flowing through the Peace-Athabasca Delta and discharging into Lake Athabasca. The main environmental concerns regarding water quality, quantity and ecosystem health related to oil sands development are focused in the lower portions of the Athabasca River, primarily downstream of Fort McMurray. This lower portion of the Athabasca River drains an area of approximately 58,000 km$^2$ and includes the Clearwater, Christina, Steepbank, MacKay, Muskeg and Ells river watersheds. Some of the tributaries do not drain through areas that have oil sand exposures and typically it is only the lower reaches of the tributaries that are incised into the oil sands formation.

Two distinct approaches are being used to mine/extract the crude bitumen from the oil sands – open-pit mining of the shallow deposits that involves the use of waste tailings ponds, and *in-situ* recovery or in place drilling methods which do not use tailings ponds. *In-situ* extraction or Steam Assisted Gravity Drainage (SAG-D) involves heating the bitumen through the injection of pressurized steam, and then recovering flow. Open-pit mining requires approximately 2-5 barrels of fresh water for each barrel of oil produced, while SAG-D currently requires an average of 0.5 barrels of fresh water for each barrel produced. In addition, there are other emerging and experimental technologies being developed for *in-situ* extraction. These include: Toe to Heel Air Injection – which is a new *in-situ* combustion and extraction method potentially requiring less steam, and; Combustion Overhead Gravity Drainage – which employs a combination of air injection wells and combustion methods that will be less water demanding. Clearly technology and associated environmental issues related to oil sands mining, extraction, and production are changing rapidly.

### EXHIBIT C: PHASES OF OIL SANDS DEVELOPMENT

**Phase One – 1967 Pre-development**
The pre-development phase, ended in 1967 with the first development, Great Canadian Oil Sands project. Until development started, any pollutants in the system would have been of natural origin. The oil sands are exposed along the banks of the Athabasca River and its tributaries, and during warm weather the viscosity of the bitumen decreases to the point that liquid crude oozes slowly from the exposure faces into the surface waters. Also, migrating subsurface waters pass through the oil sands at depth, and are eventually discharged into surface waters. It is reasonable to assume that toxic bitumen has always naturally leached into surface water. These natural loadings of bitumen into surface waters continue today although insufficient data exist for unequivocal confirmation.

**Phase Two – 1967-2010 Initial Development**
The initial development phase includes the start-up of the current major surface-mining projects and the installation of upgraders and other processing facilities. This phase saw the development of major strip mines with large-scale surface disruption of the boreal forest, the construction of large tailings ponds, and a major increase in air and water pollution from the industrial plant. Leakage from tailings ponds into the surface waters is also suspected to have occurred. Dust from coker plants and from the mining process and from the movement of heavy equipment became a major problem and a significant vector for pollutant distribution.

*In-situ* extraction projects began during this phase. Industry, aided by government and academic research programs, worked to improve the efficiencies of the extraction and processing systems significant reductions were achieved in the use of water and energy for extraction. The most significant advance was the development of technologies to treat tailings and dramatically expedite reclamation. In the large tailings ponds it had been expected that the silts and mud would gradually settle, allowing the ponds to be dried out and the land reclaimed. However, in practice settling was observed to be an extremely lengthy process, and it was anticipated that it would take up to 40 years for full reclamation. This fact made new tailings ponds and associated enormous surface disruptions were necessary. New processes will change this scenario. Suncor for example, treats fine tailings with a common waste-water treatment chemical, polyacrylamide. With this treatment, tailings settle within a few years, now ponds can undergo reclamation within ten years. This will result in a reduction in the area of ongoing surface disruption of about 75%.

The first tailings pond, Suncor pond #1, built on the banks of the Athabasca River, is at an advanced phase of reclamation and it is expected that the new settling process will be applied to Pond #5 starting in 2010.

Given the improvements in extraction, treatment and processing, and the introduction of the new tailings treatment process, phase two of the oil sands development may well be viewed retrospectively as the most dismal phase in terms of overall pollution levels and the scale of the environmental footprint.

**Phase Three – 2010-2030 Transition from Surface to *In-situ* Dominant**

This phase, which has begun and will continue for the next 10 to 20 years, represents the period when surface mining reaches its maximum development, and during which many of the *in-situ* projects may start operation. Although new mines and tailings ponds will be developed, it is anticipated that the surface disruption associated with each will be less than during phase two because of the improvement in tailings management. However, potential current environmental impacts are many and complex. Issues of particular concern are identified in the section *Environmental Concerns Related to Oil Sands Development*.

Continued improvements in extraction and processing will be driven by industry imperatives for increased efficiency and by societal demands for improvements in the environmental footprint of oil sands operations. Many applied research projects directed towards these ends are already underway in industry research laboratories and at universities, many funded by NSERC, many funded and coordinated by the Alberta Water Research Institute, typically with corporate partnerships.

**Phase Four – *In-situ* Dominant**

As the era of surface mining draws to a close, oil sands operations will become dominated by *in-situ* projects. Although these require significant areas for surface installations, the depth of surface disruption is substantially less, and these projects require no tailings ponds. It is therefore anticipated that surface reclamation can be much more rapid.

However, the cumulative effects of *in-situ* extraction on the groundwater system have yet to be fully evaluated. The SAG-D process is currently the most widely used, but several other processes are under development, and all could have significant environmental consequences, which will need to be explored and managed. Furthermore the scale of activity in the region is expected to increase and that in itself may increase emissions.

The key issue for monitoring as the sector completes phase three and enters phase four is that the sector will change dramatically, the potential environmental consequences will change, and as a result the monitoring system must be in place and be adaptable to ensure changes are tracked and evaluated.

## ENVIRONMENTAL CONCERNS RELATED TO OIL SANDS DEVELOPMENT

Monitoring systems must be designed to answer specific questions. Question definition and sound experimental designs are what separate effective monitoring systems that can advance knowledge and provide a basis for environmental management, from uninterpretable data collection. This section identifies some key issues and questions to guide monitoring in important environmental media (e.g. water, air, wildlife). The integration of distinct media monitoring and the magnitude and rate of fluxes, especially of contaminants, is vital to an understanding of cumulative effects.

The following section is not comprehensive but presents the issues of concern to the Panel as it inspected the current monitoring system.

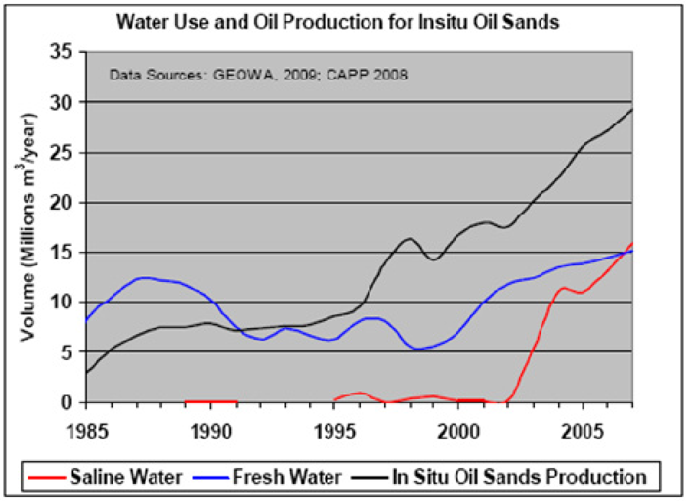
***Natural versus anthropogenic contamination of surface and groundwater –*** An overarching issue in environmental management in the oil sands region is that the Athabasca River and its tributaries flow through natural bitumen deposits associated with the extensive McMurray Formation. It is therefore a scientific challenge to distinguish between the types and levels of hydrocarbon-associated contaminants that occur naturally in surface and groundwater from those arising from anthropogenic activities such as oil sands mining and upgrading. A starting point would be to measure groundwater pollution levels in oil sands volumes as if unaffected by industrial activity. Tracking past contaminant levels in lake sedimentary profiles, as discussed later in this report, is another important avenue to pursue.

***Water quality and tailings pond management –*** Similar to many other mining operations, the open-pit oil sands extraction process creates tailings and associated tailings ponds, which are a potential hazard to regional surface and groundwater water quality, wildlife and habitat. Tailings ponds are created at oil sands mining operations from the leftover water, clays, sands and fine-silts of the bitumen separation process. As a by-product of the extraction process, the tailings ponds also contain elevated concentrations of salts and toxic compounds such as metals, polycyclic aromatic hydrocarbons (PAHs) and naphthenic acids and solvents that are added to the bitumen during the separation process. Given that the Government of Alberta maintains a zero-discharge policy for surface mined oil sands operations, all process affected water and tailings must be stored on-site to allow the particles to settle and water quality to recover. The zero-discharge policy means that tailings, and especially the fluid fine tailings, continue to accumulate.

Several environmental and monitoring concerns that have been identified relate to open-pit mining and tailings pond management. These include: whether the tailings ponds (many of the historical ponds are located adjacent to the banks of the Athabasca River) and their perimeter seepage recovery systems are adequately protecting local and regional surface and groundwater quality; whether there is any seepage and associated impact of contaminated water in deep aquifers, whether tailings pond remediation strategies including end-pit lakes, can produce water of appropriate quality to be discharged back into the Athabasca River system; and whether contaminant loads in fish are changing. The health of fish populations is of particular concern to First Nations.

***Regional water quantity –*** Water is used in oil sands extraction to help separate the bitumen from the sand, clay and water that make up the oil sands. Water is also needed to produce the hydrogen used to upgrade oil sands crude oil and to remove impurities. During the mining and bitumen separation process, it can take 12-14 barrels of water to produce one barrel of bitumen. About 75 percent of this water is recycled so approximately 2-5 barrels of "new" water are required, which is extracted under license from the adjacent rivers and/or groundwater systems. Increasing SAG-D developments are also placing an increasing demand on regional water resources, particularly groundwater (see Exhibit D).

**EXHIBIT D**




*Source: (GEOWA, 2009; CAPP, 2008)*

Water is critical for *in-situ* oil sands production, so as the industry grows, so does the requirement for source water. By 2020, *in-situ* production is forecast to use between 25-45 million $m^3$ of freshwater per year, to produce an estimated 1.6 million barrels of oil per day. Increases in freshwater demand will be offset by projected increased use of deep aquifer saline water and improved recycling technologies. Sources: CAPP (2008), GEOWA Information Technologies Ltd., Calgary (2009).

Although a high level of water recycling is involved, given the projected growth of SAG-D recovery developments, the cumulative impacts on surface and groundwater resources remain of great concern. There are projected increases in use of both deep saline groundwater and surface water to meet production requirements. Key environmental concerns related to water availability and use include: the impact of water withdrawals from local rivers and aquifers on the aquatic environment and some First Nations communities; effects on river ecological flow needs; and uncertainties regarding the sustainability of current water licensing practices, particularly in light of predicted changes in surface flow due to climate change.

***Air pollutant emissions –*** The oil sands mining and upgrading operations encompass four major technologies that require energy and hence the production of greenhouse gas and air pollutant emissions: mining, extraction, upgrading of heavy bitumen to high quality, sweet crude oil and utilities. Sources of emissions in oil sands mining operations include the burning of fuel to operate trucks, shovels and road graders, and the use of boilers or generators on-site for heat and electricity production. In addition, the surface mining tailings ponds produce fugitive emissions from the presence of trace amounts of solvents in the tailings used to help separate the bitumen and by the biological activity of natural bacteria in the ponds. The steam used in sub-surface *in-situ* oil sands production is normally generated through the use of natural gas, which causes emissions of GHG and air contaminants such as nitrogen oxides.

Contaminant issues that have been identified in relation to air emissions are related to: the general air quality in the region, including potential impacts of acidifying emissions; possible deposition/influx of pollutants arising from open-pit mining operations including the movement of heavy equipment (e.g., particulates, dust) or from upgrader stack emissions; and, uncertainties related to the influx of pollutants to the aquatic and terrestrial environments through contaminated snowpacks in both the immediate oil sands regions and further afield including in other jurisdictions like acid sensitive lakes in northern Saskatchewan.  Questions have also been raised regarding the adequacy of the regional air quality monitoring program in addressing these concerns.

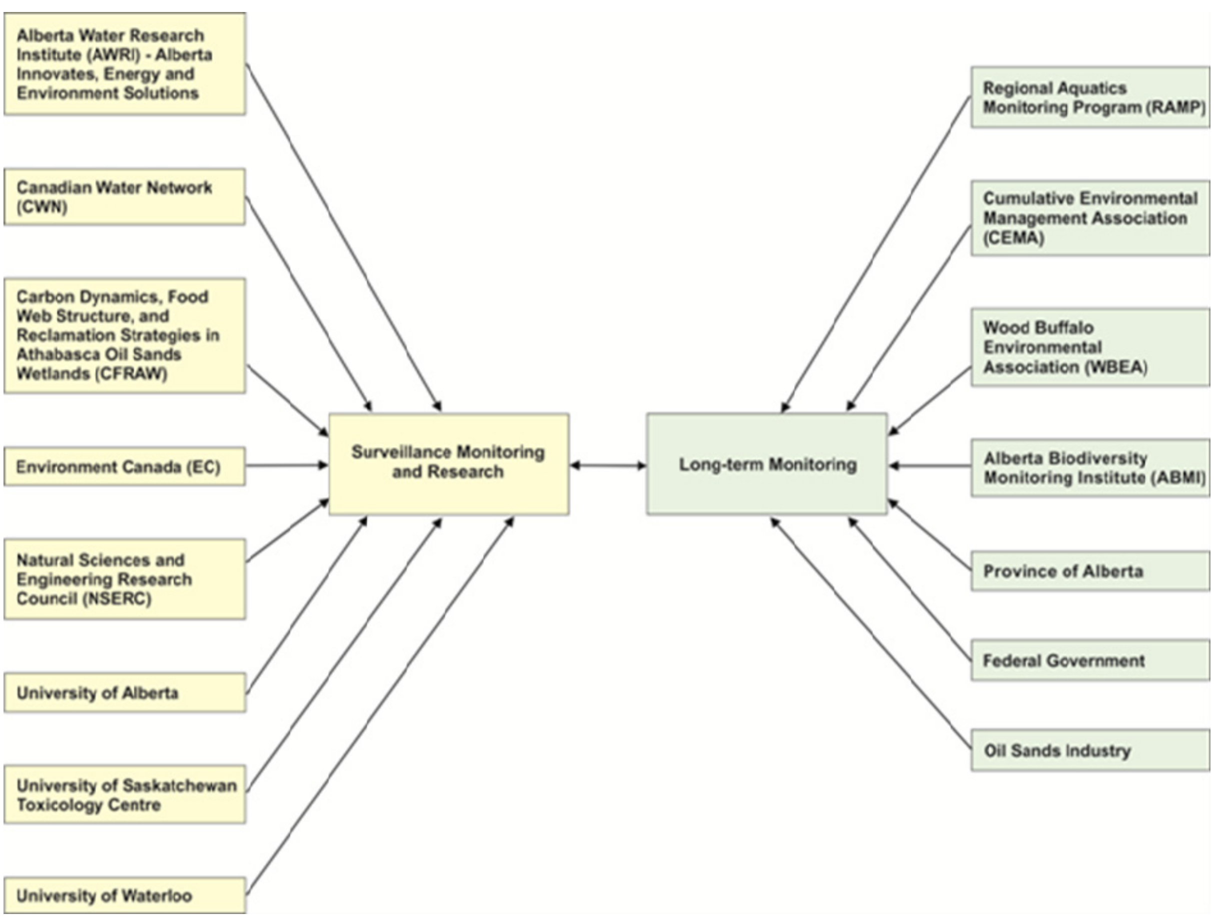
***Landscape disturbance and habitat/biodiversity impacts –*** Oil sands development, including extraction and upgrading facilities and associated infrastructure, has marked effects on habitat and associated wildlife and biodiversity at both the local and landscape levels. Three issues have risen to particular prominence.  Firstly, the decline of Woodland Caribou (Boreal subspecies), which has been linked to habitat fragmentation. Secondly, the periodic loss of waterfowl after landing in tailings ponds.  Thirdly, concerns over contaminant loads in foods collected or harvested in the oils sands area.

***Regional nature of the problem –*** Although industrial activities in the oil sands region currently take place exclusively in Alberta, the potential effects extend beyond provincial boundaries.  Lake Athabasca is downstream of the industrial operations while north-western Saskatchewan is downwind.  An adequate environmental monitoring program must extend beyond political boundaries and address concerns in multiple jurisdictions.

## MONITORING ORGANIZATIONS IN THE OIL SANDS AREA

During the first month of the Panel's tenure, considerable effort was expended to understand the breadth of monitoring activity underway in the oil sands region. We met with numerous organizations and received many briefs on activities. We have organized this section into two groups: 1) those with a substantial amount of typically medium to long-term monitoring activity that is usually undertaken for status and trends reporting, compliance and licensing requirements, often based on sizeable inter-governmental/industry agreements; and 2) those that are typically more short-term, surveillance, monitoring and research activities that are more tactically directed at addressing a specific question or used to obtain a process-level understanding of specific system dynamics. This chapter is not an exhaustive description of monitoring details but serves as a short summary to illustrate the considerable breadth of oil sands-related monitoring activities underway.

### EXHIBIT E: KEY PLAYERS INVOLVED IN LONG-TERM AND SURVEILLANCE MONITORING/RESEARCH IN THE OIL SANDS REGION.



## LONG TERM MONITORING

### Regional Aquatics Monitoring Program (RAMP)

Initiated in 1997, RAMP is an industry-funded, multi-stakeholder environmental monitoring program mandated to determine, evaluate and communicate the state of the aquatic environment and any changes that may result from cumulative resource development within the Athabasca oil sands region.

RAMP attempts to collect baseline data to characterize natural variability in the aquatic environment in the Athabasca oil sands region and compares data against which predictions contained in environmental impact assessments can be assessed. RAMP also collects data that satisfy the monitoring required by regulatory approvals of oil sands and other developments and that of company-specific community agreements. Monitoring and assessment activities, results and recommendations are communicated to communities in the Regional Municipality of Wood Buffalo, and regulatory agencies.

RAMP collects environmental data each year from the Athabasca River and its tributaries, the Athabasca River delta, and regionally important lakes and wetlands. Sampling and field surveys are focused on six key components of the aquatic environment: climate and hydrology, water quality, benthic invertebrate communities, sediment quality, fish populations, and acid sensitive lakes. The monitoring program is designed and overseen by the RAMP Technical Program Committee, comprised of stakeholders from industry, an aboriginal community, government, and environmental organizations. In its 13 years RAMP has twice undertaken external scientific peer review of its entire program, the most recent of which (initiated in June 2010), is expected to be completed by the end of 2010.

### Cumulative Environmental Management Association (CEMA)

Established in 2000, CEMA provides recommendations to regulators on how to best manage impacts resulting from direct and indirect industrial development within the region. CEMA is also a multi-stakeholder organization that is a key advisor to the provincial and federal governments committed to inclusive dialogue to make recommendations to manage the cumulative environmental effects of regional development on air, land, water and biodiversity.

A key function is to recommend management frameworks, best practices and implementation strategies that address cumulative effects on air, land, water and biodiversity to protect, sustain and restore the environment and to be protective of human health.  CEMA's recommendations have been the basis for the formulation of the Alberta Government's Lower Athabasca Regional Plan, surface water management protocols and certain project environmental impact assessments.

The Surface Water Working Group is tasked with: developing a recommendation for the lower Athabasca River Phase 2 Water Management Framework; establishing the in-stream flow needs of the lower Athabasca River; defining indicator criteria and thresholds of the lower Athabasca River used in managing activities to ensure watershed integrity; and communicating information on surface water quantity to the public.  The focus of CEMA's air-related research is to increase understanding of potentially harmful emissions. CEMA is working to assess the potential impacts of oil sands air emissions (i.e., discharges from smoke stacks) on the environment and recommend actions to keep the air clean and minimize the effects of emissions.

### Wood Buffalo Environmental Association (WBEA)

Originally known in the late 1980s as the Regional Air Quality Coordinating Committee (RAQCC), it was reformed into the Wood Buffalo Environmental Association (WBEA) in 1997.  WBEA is a collaboration of communities, environmental groups, industry, government and aboriginal stakeholders focused on monitoring air quality and air quality-related environmental impacts to generate accurate and publicly available information which enables stakeholders to make informed decisions.

The WBEA monitoring programs includes air, land and human exposure information and prides itself on being the most extensive ambient air network in Alberta with 15 air monitoring stations and 27 passive monitoring stations. The program is an integral component of Alberta environmental regulatory compliance for member companies. WBEA reports continuous ambient air quality data, in real time.

### Alberta Biodiversity Monitoring Institute (ABMI)

Initiated in 2003 and formally established in 2007, the Alberta Biodiversity Monitoring Institute (ABMI) is an independent, not-for-profit, science-based organization that monitors the condition of living resources throughout Alberta's lands and waters. The

Institute measures and reports on thousands of species, habitats, and human footprint activities at more than 1600 monitoring sites across the province to support decision-making with scientific knowledge about provincial biodiversity. The ABMI employs a cumulative-effects monitoring approach that is targeted at detecting the ecological effects of a diverse set of environmental stresses on broad suites of indicators.

Its data, metadata (including full detailed reports of data collection methods and biotic and abiotic laboratory protocols), sampling locations, 11 reports mentioning oil sands, and knowledge products are value-neutral, arms-length and publicly accessible. Some aquatic ecosystem components are monitored including fish and benthic invertebrates.

### Alberta Environment

Alberta Environment's various acts and codes of practice necessitate a substantial and wide range of monitoring activities including those required by approvals and licensing, environmental assessment, substance release and release reporting, and conservation and reclamation. There are also various standards and guidelines that support monitoring including ambient air quality objectives, air quality modeling guidelines, emission standards and guidelines, and the management of acid deposition. Further, compulsory monitoring and reporting by the regulated community is also required under the general umbrella of compliance monitoring and enforcement. To our knowledge Alberta Environment contracts out much of its scientific work.

On water specifically, Alberta Environment has been monitoring water quality in the oil sands region since the early 1970s. In the 1990s Alberta Environment increased monitoring efforts by establishing and joining the RAMP, which collects thousands of water samples from across the region each year. In January 2007, Alberta Environment staffed a new Oil Sands Environmental Management Division dedicated to developing the resource in an environmentally responsible way. In December 2008, the Alberta government released an integrated land-use planning approach (Land-use Framework, LUF) which was followed in the spring of 2009 by the Alberta Land Stewardship Act (ALSA). The LUF and ALSA divide the province into seven regions and commit land and resource managers in those regions to taking a cumulative effects approach to land-planning and related management activities. The first of the seven land-use regional plans addressed is the Lower Athabasca Regional Planning (LARP) area, encompassing activities in the Cold Lake/Beaver River Basin extending north through the oil sands regions of the province to the Northwest Territories border. Management frameworks have been developed for air quality, surface water quality and groundwater in this region as guiding frameworks to manage this valuable resource to ensure sustainable development.

The Alberta Environment Minister has launched an Advisory Panel to assess key recent academic research findings that concluded that oil sands industrial operations were the origin of contaminants found in the Athabasca River system. A report is expected in February 2011.

### Government of Canada

Various federal-provincial monitoring programs under the provisions of the Canada Water Act, led by Environment Canada, exist in the area. For example, the Water Survey of Canada's hydrometric program has long-term water quantity monitoring stations in the oil sands area, and Environment Canada also monitors water quality at boundary sites in the Wood Buffalo region.

Parks Canada (with other government, aboriginal and non-governmental partners) also leads some monitoring activity relevant to the oil sands region under the banner of the Peace-Athabasca Delta Ecological Monitoring Program (PAD-EMP), which currently includes water quality monitoring, reference condition monitoring, and vegetation and wildlife surveillance.

### Industry

Industry monitoring activity in the oil sands region is considerable. The bulk of this activity is undertaken for regulatory compliance and licensing needs. Although some of these data and information remains proprietary, a growing amount of monitoring activity is subsumed and reported on under the RAMP program. In addition to these activities, the oil sands companies engage in a considerable amount of monitoring and research towards documenting environmental performance. This includes focused effort in reducing freshwater consumption through improved recycling, better managing steam loss during *in-situ* oil sand extraction and in tailings reclamation, to name a few.

## SURVEILLANCE MONITORING AND RESEARCH

### Alberta Water Research Institute (AWRI)

The Alberta Water Research Institute was established in the spring 2007 to coordinate world-class and leading-edge research to support Alberta's provincial water strategy, Water for Life: A Strategy for Sustainability. Administered through the Alberta Innovates - Energy and Environment Solutions, the Water Institute funds specific research initiatives in support of the Water for Life goals and objectives of:

- Safe, secure drinking water supply
- Healthy aquatic ecosystems
- Reliable, quality water supplies for a sustainable economy

The Water Institute serves as a knowledge broker – providing analysis and context to water research for decision- and policy-makers, and ensuring that the information is understandable, relevant and accessible. Dedicated to seeking the best solutions and ideas, the Water Institute's scope is not limited by geographic boundaries. It seeks out both the best thinkers and the best information provincially, regionally, nationally and internationally to help secure the long-term safety, quality and sustainability of Alberta's water resources.

There are currently substantial eight oil sands-related projects under The Water Institute in various stages of completion. The Water Institute investment over the life of these projects is about $15M. These projects focus on water supply (quantity and quality), accelerated de-watering of oil sands fine tailings, water recycling, water purification, and water management. The Water Institute is also a partner funder of two NSERC Industrial Research Chairs dealing with water and water quality management in the oil sands.

### Canadian Water Network (CWN)

Established in 2001 and headquartered in Waterloo, Ontario, CWN was created by the NSERC Networks of Centres of Excellence (NCE) Program to connect Canadian and international water researchers with decision-makers engaged in priority water management issues. CWN brings together researchers, engineers and their students, along with practitioners and implementers, pooling their resources and uniting expertise to respond to water challenges and ensure a prosperous and healthy future for generations of Canadians.

The Canadian Water Network catalyzes and supports multidisciplinary research and related initiatives that address key challenges in water management across three programs: (i) protecting Canada's watersheds and ecosystems; (ii) protecting the health of Canadians; and (iii) ensuring that Canada has sustainable water infrastructure.

There are currently two four-year (2008-12) multi-thematic, multi-partner (university; government; industry) oil sands-related studies under CWN dealing with:

1. *Surface and groundwater management in the oil sands industry* – focused on providing advanced monitoring tools for risk managers involved with evaluating environmental health related to oil sands mining.
2. *Priority toxic elements (vanadium, antimony and arsenic) – source water protection and drinking water treatment* – to assess the distribution, speciation, bioavailability and health effects of antimony and arsenic in Canadian drinking water, and examines the potential for various treatment technologies to remove antimony, arsenic and vanadium in process-affected water from the oil sands.

### Carbon Dynamics, Food Web Structure, and Reclamation Strategies in Athabasca Oil Sands Wetlands (CFRAW)

CFRAW is a joint research venture among five Principal Investigators at four Canadian universities (UAlberta; USask; UWaterloo; UWindsor) in collaboration with seven sponsoring partner companies in the oil sands industry. Research under CFRAW is unified by three major themes:

1. *Carbon Dynamics: Tracking materials through the food web* – to assess several classes of wetland differing in reclamation type (reference vs. soft-tails amended), age (young vs. older), and organic base (poor vs. rich; vegetative materials vs. hydrocarbon-derived materials).
2. *Biological effects of oil sands process materials (OSPM)* – in addition to 'metabolic' carbon flow, the parallel transport of constituents of potential concern (PAHs, naphthenic acids, arsenic, selenium, trace metals) through the biota to the wildlife that form the top of the food web is being studied.

3. *Predicting changes and recommending reclamation strategies* – to provide fundamental knowledge on the succession and energy flow processes in both natural and constructed wetlands.

Ultimately, research results from the CFRAW Project will provide guidance to industrial partners regarding the most effective reclamation strategies and techniques for developing viable systems and for monitoring their developmental progress and health.

### Environment Canada – Oil Sands Monitoring and Research

Environment Canada is the most active federal monitoring and research agency in the oil sands area, driven by various legislative responsibilities, principally enforcement-related monitoring under the Fisheries Act and Canadian Environmental Protection Act, in addition to surveillance monitoring in support of the Fisheries Act. Much of this activity is partnered with Alberta Environment, other federal/provincial departments, and universities.

This activity is focused on:

- tailings pond management and impacts on groundwater and surface water quality;
- chemical profiling to distinguish industrial vs. naturally occurring oil sands hydrocarbons;
- tailings pond and riverine toxicology (water, sediment);
- regional air quality assessment and modelling;
- regional water availability and instream flow needs; and
- tailings pond enforcement-related inspections.

Research interest on ecological flow needs is shared by the Department of Fisheries and Oceans and Alberta Environment who have recently tabled a science evaluation of instream flow needs for the Lower Athabasca River. In addition, Natural Resources Canada, with partners, is expanding activities as it relates to groundwater geochemistry issues in the oil sands region.

### Natural Sciences and Engineering Research Council of Canada (NSERC)

The Natural Sciences and Engineering Research Council of Canada (NSERC), through its Discovery and Strategic Grants, funds a multitude of individual oil sands-related research projects at universities across Canada. Through its Networks of Centres of Excellence (NCE) Program, NSERC supports research networks that deal with issues related to oil sands (e.g., the Canadian Water Network). NSERC has also appointed a number of Canada Research Chairs that direct research related to oil sands and oil sands production.

### University of Alberta: D. Schindler Laboratory

Dr. David Schindler and his research laboratory and collaborators have been conducting studies related to water quality and ecosystem health on the Athabasca River and other northern basins for several decades. In 2007, he formed an oil sands research group that has been conducting a series of studies assessing the claim of the oil sands industry and Alberta government that toxins in the Athabasca River and its tributaries are from natural seepage from bitumen deposits. Their peer reviewed publications to date (e.g., Kelly *et al.* 2009 – PNAS 106, Kelly *et al.* 2010 – PNAS 107, Schindler 2010 - Nature) have raised serious questions regarding the adequacy and credibility of current environmental monitoring programs in the Lower Athabasca system and have identified new concerns regarding the relative importance and potential effects of point- and non-point source oil sands contaminants on regional water resources.

### University of Alberta: Centre for Oil Sands Innovation (COSI)

This Centre for Oil Sands Innovation (COSI) was established in 2005 at the University of Alberta, a partnership between Imperial Oil Resources Ltd. and the Faculty of Engineering at the University of Alberta. The vision for the centre is to provide the research base to enable oil sands operations with a reduced environmental footprint by minimizing water use, consuming less energy, lowering greenhouse gas and other emissions, and yielding high-quality products at lower cost. COSI aims to achieve this objective by promoting research on oil sands, building research capacities and funding breakthrough research that leads to environmentally and economically sustainable development of Canada’s oil sands resources. Since its inception, COSI has grown into a research network that involves four universities, Imperial Oil and government agencies in the quest for breakthrough technologies for the oil sands.

Research programs at the Centre for Oil Sands Innovation are focused on four areas of research with the objective of environmental footprint reduction:

1. *Bitumen and Mineral Fundamentals* – research on bitumen composition, molecular behaviour, interfacial interactions between bitumen components and minerals, and behaviour of clays and minerals at oil-water interfaces.
2. *Bitumen Separation and Upgrading* – research on new approaches to separation of desirable from undesirable components, reaction of bitumen feeds, catalysis, and production of value-added products.
3. *Environmental Footprint Reduction* – development of new methods for the rapid dewatering of tailings.
4. *Extraction* – research leading to water-free processing of oil sands, technologies that use a significantly smaller volume of water or allow most of the water to be recycled, and integration between extraction and tailings handling to enable the immediate return of fine solids to the mine.

### University of Saskatchewan – Toxicology Centre and Canada Research Chair in Environmental Toxicology

Well-known for its work with northern ecosystems, the Toxicology Centre at the University of Saskatchewan (UofS) became the focus for the Northern Ecosystems Toxicology Initiative (NETI) which was identified as a priority area by the University in 2000. This was reaffirmed in 2007 with the opening of a $12-million expansion that included new labs and analytical equipment. Over the next few years, more than 50 researchers and support staff will join the core group of 14 researchers currently at the Centre.

The Toxicology Centre is the largest toxicology centre in Canada, and has a world-renown eco-toxicology program with interests in both the fates and effects of potentially toxic compounds and elements, particularly in the area of ecological risk assessment. Oil sands-related research includes: research into the movement, bioaccumulation, and effects of toxic substances at different levels of biological organization, ranging from biochemical to ecosystem; extensive research in the areas of metal speciation, multi-species toxicity testing, biochemical indicators of stress in aquatic organisms, fate and effects of PAHs, halogenated hydrocarbons, including chlorinated dibenzo-dioxins and -furans, PCBs and pesticides; evaluating the toxicity of oil sands process-affected waters

(OSPWs) from oil sands mining activity; examining the potential for degradation and associated reduction in aquatic toxicity of OSPWs in laboratory microcosms, which are used to simulate natural wetland environments; and a related project evaluating the leaching of trace metals from coke, a by-product of bitumen upgrading, and the potential toxicity of this leachate and associated metals to aquatic life.

### University of Waterloo

Through a collaborative network of University of Waterloo and external Principal Investigators, considerable research is being undertaken on monitoring contaminant levels (surface and groundwater), fate of contaminants, and effects of contaminants on aquatic organisms in the oil sands region. Current thesis studies include: the effects of oil sands processed material on Japanese medaka (*Oryzias latipes*) and blackworms (*Lumbriculus variegatus*); toxicity assessment of oil sands process-affected water using fish cell lines; the influence of Athabasca oil sands constituents on fish reproduction; seasonal and spatial trends in production and stable isotope signatures of primary producers and utilization by primary consumers in oil sands processed-material wetlands; and photodegradation and microbial degradation of oil sands hydrocarbon contaminants and the utilization of oil sands sources by primary consumers.

# CHAPTER THREE

# PANEL OBSERVATIONS AND ANALYSES

## OUR APPROACH

The Panel's goal was to assess what we saw, were told and read about the monitoring system against the principles inherent in a world-class monitoring system that we had identified in Chapter One. While we collected facts about all environmental media, we were asked to focus our efforts predominantly on issues of water quality and quantity monitoring.  Nonetheless, our collective mindset was systemic and holistic.

We did not attempt to describe monitoring program details (e.g., specific sampling locations, sample sizes, parameters measured). Rather we examined the real or perceived environmental impact of the oil sands development activities through the lens of monitoring, the interaction and synergy among key players and the general scope of monitoring activities.

Over the past 60 days the Oil Sands Advisory Panel reviewed an extensive amount of information that included oral and written submissions and face-to-face meetings with the various stakeholder and monitoring groups within the lower Athabasca basin. Briefings or presentations were provided by federal government departments and agencies, the Government of Alberta, oil sands industry representatives, environmental organizations and regional monitoring program representatives. In addition, discussions were held with representatives of First Nations groups (Mikisew Cree First Nation, Fort McKay First Nation, and Athabasca Chipewyan First Nation).  We benefitted from numerous informal conversations with individuals.

Key peer-reviewed scientific journal articles, technical reports, independent reviews and science perspectives were also reviewed as part of the Panel's attempt to gather evidence. The Appendix provides a summary of some of the publicly available documents reviewed by the Panel.

It was immediately apparent that there are, and have been, many people and organizations involved in research, monitoring, and environmental assessment programs in the Athabasca River system over the past couple of decades. Specific to oil sands related programs, the Alberta Oil Sands Environmental Research Program (AOSERP) in the mid-1970s led the way. Subsequent targeted research and monitoring initiatives include: the Northern River Basins Study (1991-1996); Peace-Athabasca Delta Technical Studies (1993-1996), the Northern Rivers Ecosystem Initiative (1998-2004); the Panel for Energy and Resource Development program (PERD; 2002-present); the Regional Aquatic Monitoring Program (RAMP; 1997-present); the Cumulative Effects Monitoring Association (CEMA; 1999-present); and the Wood Buffalo Environmental Association air quality monitoring program (WBEA; 1997-present).

Given the limited time it was not possible for the Panel to document and assess strengths and weaknesses of all monitoring currently being conducted. Past reviews identified criticisms and shortcomings. Some organizations have made positive changes recently and others have committed to do so. For example, RAMP has pledged to ensure that all its data will be publicly available by the end of 2010. Environment Canada has recently significantly increased its science presence in the oil sands areas including investing in additional ground water surveillance and the launch of a study to quantify aerial deposition of contaminants. WBEA has recently adopted a sound, transparent science approach that permeated all of its activities.

## OBSERVATIONS AND FINDINGS

A high level summary of our observations and key findings follows below.

### Real or Perceived Impacts of Oil Sands Development

We found that a wide range of polarized opinions, perceptions and facts exist concerning the real or perceived impacts of oil sands development on the environment. Although a significant level of monitoring and research activity is occurring within the oil sands region, it is dwarfed by the level of activity that was expended on other major environmental issues of the past few decades, such as the acid deposition problem in eastern Canada.  Furthermore, work carried out to date has not led to a consensus on the degree of impacts.

This lack of consensus stems from a number sources.  The sheer number of institutional and academic players has resulted in a vast quantity of data and literature.  It is difficult for any one player or institution to have a comprehensive view of the evidence of oil sands impacts across environmental media.  However, there is not a widespread scientific acceptance of this negative finding because of the lack of complete confidence in the monitoring system that produced the result. Many of the monitoring programs were unable to definitively distinguish (with reasonable statistical confidence and/or power) oil sands industrial impacts. This inability to adequately measure impacts was often attributable to deficiencies in sampling program design (including insufficient replication in space or time), lack of hypothesis-driven sampling regimes, ill-defined or undefined baseline conditions for inter-comparisons and inadequate analytical capabilities.

The Panel recognized the extremely challenging environment in which monitoring and research must be performed in the oil sands. Remote sites are expensive and time consuming to access, although to provide perspective, the costs probably represent only a fraction of the profits generated by the oil sands.  The landscape is already unavoidably impacted because of existing monitoring activities.  Sampling locations that had been monitored for some time when they were undisturbed, and could have been assumed to represent a baseline condition, have been overtaken by development and are now clearly impacted.  It is likely that the continued rapid pace of development will result in further loss of baseline monitoring stations to development.

Natural loadings of bitumen into surface waters continue today but unfortunately the magnitude of these contributions has not been quantified.  This situation is almost unique in monitoring for toxic compounds.  Although challenging, it is important to establish as rigorously as possible the background or baseline level of pollution, against which any future trends can be assessed.

The natural, pre-development state of the waters could be further investigated by analysis of information preserved in sediment profiles that can be obtained from lakes and ponds that are situated in locations prone to river flooding (e.g., along the lower Athabasca River and its tributaries and within the floodplain lakes of the Peace-Athabasca Delta). In contrast, river bar deposits are unlikely to provide informative data, because rivers are dynamic systems where sediment is constantly remobilized and transported downstream. Within the watershed, there are many lakes and ponds that are likely to retain undisturbed, informative sedimentary records that extend back several centuries to millennia, where careful sampling and analysis could provide essential information on natural background levels of contaminants transported via the rivers and atmosphere and to quantify trends over time since the onset of industrial activities. Investigations of sedimentary records as a way of quantifying baseline, pre-impact conditions and post-impact trajectories provide an opportunity that has not been fully exploited in this region, at least not in a comprehensive manner that is required for this region.

There is considerable effort being put toward finding chemical fingerprints, unique substances that are only produced during oil sands development that could be used to distinguish between natural and anthropogenic sources of pollutants. This is a challenging but worthwhile pursuit.

Rivers are dynamic systems. Water quality can change very quickly, thus making monitoring a challenge in both space and time, as "spot" water samples can easily miss important pollution events. New developments in, for example, passive samplers that monitor water quality over extended periods of time, should be pursued aggressively. The panel recognizes that these are not fool-proof approaches, but a comprehensive program should be implemented employing passive samplers as part of an integrated monitoring protocol.

And as a final note, our site visits had an indelible impact. It is hard to forget the sheer extent of landscape disruption, the coke piles and the ubiquitous dust.

### The Key Players

The Panel wanted to understand who the key monitoring players are in the oil sands region. Did they share an integrated vision? What was the nature and extent of synergies and interactions among the programs? Were multi-stakeholder approaches to environmental monitoring effective?

We observed that while on the surface the multi-stakeholder approaches often appear equitable and balanced, they lack clearly defined and recognized and accepted leadership. An holistic and systemic perspective, a clearly focused set of objectives, and a statistically sound decision-making process that can allow for adaptive management in a rapidly changing oil sands environment does not exist. The system is driven by independent projects and their associate environmental assessments activities and licensing approval requirements.

Collectively the monitoring efforts by provincial and federal governments and other stakeholder groups including industry, lack a coherent data management framework where information can be uploaded, organized, and accessed in a standardized and coordinated manner. Until recently much of the data has been submitted to Alberta Environment in annual hard copy reports.

While some of the elements of an integrated, coordinated system can be seen working in WBEA, and to some extent in CEMA, they were most noticeably lacking in RAMP. The RAMP program is industry funded and is the largest aquatic monitoring initiative in the oil sands region. Although we are confident it was conceived and currently implemented by people with the best of intentions it is not designed to be systemic, holistic, or adaptive. There seems to be little integration across media or with other organizations. While environmental data is being collected on water quality and ecosystem parameters, the program suffers from a lack of scientific leadership, it is not focused on hypothesis testing, (i.e., the sampling program design is not effects based). It is not producing world-class scientific output in a transparent, peer-reviewed format and it is not adequately communicating its results to the scientific community or the public.

Significant aspects of RAMP have been publicly criticized (e.g., Ayles *et al.*, 2004; Kelly *et al.*, 2010; Schindler, 2010). Some groups flagged their doubts about the statistical power in RAMP sampling designs and whether endpoints that are the most sensitive to potential impacts are being selected. There is a perception that RAMP is designed to fulfill permit requirements but is not adequate for quantifying ecosystem change as a result of oil sands development. Although some of the formal criticisms of RAMP have been addressed there has been little communication of these changes. The timeliness of responses is also an issue that should be critically addressed. The net effect is the perception of a rigid organization and that is not open to active continuous improvement.

In addition to the established monitoring programs, there are significant academic-based environmental research activities concerning water quality in the oil sands region. Several of these studies have produced important results that challenge some of assertions made by some of the ongoing monitoring efforts. The inability of the institutional monitoring programs to explain the water quality issues raised in the research is of concern.

Despite the myriad programs ongoing in the oil sands region, the Panel observed that there was no evidence of science leadership to ensure that monitoring and research activities are planned and performed in a coordinated way, and no evidence that the vast quantities of data are analyzed and interpreted in an integrated manner. Similarly there was a lack of leadership on reporting on oil sands environmental performance across media.

### The Scope of Monitoring Activities

It is evident that a wide range of long-term and surveillance-based monitoring and research programs and activities are currently being conducted in the oil sands region involving many players (provincial and federal government, industry, stakeholder consortia, universities, First Nations). Each of these programs/activities was developed and implemented to address specific environmental issues or knowledge gaps.

For example for water quality in the Athabasca River and tributaries, Alberta Environment maintains a long-term, water quality monitoring network on the Athabasca system involving approximately 10 sites, Environment Canada maintains a water quality monitoring stations in the oil sands region, RAMP uses more than 40 monitoring/sampling locations for the Athabasca River and tributaries involving a wide range of sample types (e.g., geochemistry, sediments, biota, polyaromatic hydrocarbons (PAHs)) and individual companies monitor surface water as part of their permit requirements. However, there is often no consistency or coordination among these and other programs in Quality Assurance/Quality Control (QA/QC) protocols, sample size and the type and timing of environmental samples being taken. Hence while there is a significant amount of data being collected, there is a limited capability to ensure that the new knowledge created by the monitoring activity is actually able to be used by decision-makers.

Another observed shortcoming of the design and implementation of the monitoring programs in the oil sands region is that they are not fully adaptive to the different phases of oil sands development. Currently, the monitoring programs are attempting to address legacy environmental conditions resulting primarily from historical and present-day surface-mining operations, related tailings ponds, and increased emissions related to up-graders. However, it is the potential environmental effects associated with the likely rapid expansion of *in-situ* extraction projects that could be the most concerning in the future.

Specific areas where additional monitoring and research attention is required include: information of regional groundwater hydrogeology and related aquifer sustainability and water quality; interactions between aerial deposition and water quality and ecosystem impacts; connectivity between surface and ground water systems; and the assessment of cumulative impacts of multiple environmental stressors on aquatic ecosystem health and integrity; and more rigorous acid deposition quantification including transboundary deposition in Saskatchewan.

Future scenarios of climate change, technological change and fast-paced industrial development have not to date catalyzed thinking and action. A monitoring system that can effectively track potential future changes and produce reliable data will be essential for those who must make decisions that are both challenging and opportunistic.

# CHAPTER FOUR

# A PATH FORWARD

The Minister asked the Panel whether or not Canadians had a first-class state-of-the-art monitoring system in place in the oil sands. In the view of the Panel the answer is no – but.

We say BUT because we are convinced that the current activities could be transformed into a system that will provide credible data for decisions – a system that will allow us to know the current conditions and trends in the oil sands ecosystem and encourage the necessary foresight to prevent a compromised environment.

There are at least two reasons for optimism. The first is that in our conversations we found a universal interest in achieving responsible development of the oil sands among those involved in current monitoring. Stakeholders with whom we spoke were clear in their assertion that they welcomed constructive criticism and would embrace change if it were necessary to ensure a world-class monitoring system is in place.

The second cause for hope is the evidence that a significant amount of research, monitoring and environmental assessment has been amassed and that workable and successful frameworks have been demonstrated in other jurisdictions.

In Chapter One we articulated some fundamental principles to guide the design and implementation of a first-class system. We envisaged a system that would be comprehensive and integrated, adaptive and robust, inclusive and collaborative, transparent and accessible and scientifically rigorous. It was against those principles that we made our assessment and their importance was confirmed.

As the previous chapter stated, the Panel observed that notwithstanding some positive signs and clear strengths in certain monitoring components there are significant shortcomings in the monitoring system as a whole. We believe that unless these shortcomings are addressed, the debate on environmental performance in the oil sands will continue to revolve around the adequacy of the data collected and not, as it should be, on data interpretation and implications. Until this situation is fixed there will continue to be uncertainty and public distrust in the environmental performance of the oil sands industry and government oversight.

## A SHARED GOVERNANCE APPROACH

The starting point is a compelling vision of what could be. The vision should demonstrate a level of ambition that is worthy of the importance of the issue – a commitment to develop a world-class, scientifically credible and trusted monitoring and reporting system for the oil sands that will ensure sound environmental stewardship as this important resource is developed. In the Canadian context that vision requires coherent and collaborative leadership.

Implementing that ambitious vision of a comprehensive oil sands monitoring program cannot be done by any one jurisdiction or sector. The socio-scientific task is too big, complex and important. The current fragmented collection of monitoring and research activities will not adequately support the goals of environmentally sustainable development in the oil sands region. A new credible, coherent and collaborative governance model is required. The pace and scope of change in the oil sands region, the challenges of managing in a multijurisdictional setting and the significant and growing expectations of stakeholders require no less.

**We make but one over-arching recommendation. We recommend that a shared national vision and management framework of aligned priorities, policies and programs be developed collaboratively by relevant jurisdictions and stakeholders.**

We envision that the fundamental underpinnings of the vision and management framework would include:

- An holistic and integrated approach
- An adaptive approach
- A credible scientific approach
- A transparent and accessible approach

### An Holistic and Integrated Approach

*The natural world is integrated and holistic. A system designed to monitor the natural world must also be integrated and holistic.*

A systemic approach would address integration across:

- **Environmental media**: The monitoring system should address the reality that energy, nutrients and contaminants pass between living organisms and land, water and air. The contaminant component of the monitoring system should be built around the concept of estimation of fluxes among media. The system must recognize the complexity of interactions over time that will undoubtedly lead to cumulative effects.
- **Time**: There should be an ability to link past, present and future responses and trends in environmental variables. More attention should be given to techniques and strategies that could more systematically define historic and current baseline conditions against which potential change can be measured and evaluated.
- **Actors**: There is a complex institutional and jurisdictional landscape in the oil sands. Although actors must work within the confines of their legal rights and jurisdictions, a governance model should be developed that recognizes the interests of, catalyzes and supports the inclusion of federal, provincial and First Nations governments, industry, academia, citizens and non-governmental organizations.

The monitoring system must be part of a larger information system that includes hypotheses-based research, data archiving and reporting. Peer-reviewed research on implications of monitoring results must be integrated and conducted in concert with monitoring to ensure trends are not simply tracked, but that trends and effects can be attributed to natural or anthropogenic activities. Primary research will ensure that the data produced by the monitoring system will be used to increase understanding and knowledge.

Of primary importance is asking the right questions to which the monitoring system should be designed to respond. For example, have predefined thresholds been exceeded in all relevant environmental media? How much change in space and time has occurred in a critical environmental parameter? In our view, the current system has not been able to address questions like these adequately.

### An Adaptive Approach

*The environmental and technological conditions associated with the growth of the oil sands developments are changing rapidly. A monitoring system must be able to adapt in its design and implementation in response to the development of new knowledge and technologies.*

The mark of a successful organization is one that is continuously learning. That is particularly true of monitoring systems. Any monitoring system must be capable of responding to continuous feedback and enhanced scientific knowledge. For example, changes in climate (directional changes and variability) may markedly change the ability of the natural environment to buffer potential environmental impacts.

In addition, both technological and societal changes will define future issues. The evolution from open-pit mining operations towards *in-situ* extraction of bitumen may fundamentally change the nature of the likely environmental issues associated with oil sands development and even magnify certain environmental problems. The impact of future expansion of industrial activity related to oil sands extraction and processing is not yet fully known. The monitoring system must be able to respond in a timely manner. A scientific motoring program must recognize the dynamic nature of the river systems and the flexible nature of the sampling required given massive expansion of the oil sands. An understanding of cumulative effects will be indispensible.

## A Credible Scientific Approach

*A credible, trusted monitoring system must be founded on accepted scientific principles, most prominently a continuous and independent peer review of results.*

Policies and decisions are influenced by many considerations, but in environmental matters, science is central. Scientific information and knowledge for risk management and the regulatory regime arise from a continuum of activities that link monitoring, research, predictive modeling and scenario development.

A distinction should be made between long-term environmental monitoring for the purposes of assessing regional spatial and temporal (seasonal, inter-annual) trends versus more localized and shorter-term surveillance monitoring and research which is used to assess specific environmental impacts or exceedances (e.g., enforcement related monitoring). Both approaches are necessary to assess accurately and communicate environmental performance of oil sands operations.

A science culture will ensure the integrity of the system. A system respected by scientists would give evidence of the use of robust indicators and consistent methodology and peer review resulting in independent, objective, complete, reliable, verifiable and replicable data. A system that ensures a credible and timely response to criticisms is crucial. The setting of standards and development of a quality assurance program are essential.

A sustained effort to maintain capacity and expertise must be nurtured and maintained. Otherwise long-term records are vulnerable.

## A Transparent and Accessible Approach

*Trust and confidence is built and enhanced through openness and transparency*

An open and transparent system is one in which information in forms ranging from raw data to analyses is publicly available to enable those concerned to conduct their own analysis and draw their own conclusions. It makes the basis for judgment and conclusions explicit. Peer-reviewed literature is an essential element in establishing credibility.

Communication is not simply sharing information. It is shorthand language for engagement. It is the first step in building the kind of relationships that will bring about genuine, consistent and proactive dialogue.

## TOWARDS IMPLEMENTATION

Implementation of a monitoring system is not simply a matter of technical parameters. The Panel makes no claim to organizational design expertise, but we know that many models can be effective if they are based on a shared vision. We also agreed that a certain amount of pragmatism is needed. That led us to look for successful examples of integrated, transparent and holistic approaches to policy-relevant environmental monitoring and reporting.

Three examples of governance models that meet these criteria and have shown some signs of success. These are the United States Geological Survey National Water Quality Assessment Program, the Northern River Basins Study and the Great Lakes Water Quality Program. These approaches adopted many of the criteria outlined above and can serve as a possible starting point for the design of a new oil sands monitoring governance model and institutional framework.  (See Exhibits F, G, and H)

Successful implementation of the new governance model will be challenging but critical. Creating the conditions for successful implementation will require genuine leadership by the federal, provincial and territorial governments in developing a management framework that coordinates respective legislative responsibilities in the oil sands region.

We envision an implementation system in which:

- A management framework,, including coordination of respective legislative mandates, ,for the program design and implementation  would be overseen by a joint federal-provincial board, representing the complex intersecting interests of all other stakeholders with appropriate technical committees guiding the operations;
- the program would be managed by a senior executive;

- the program would develop clear understandings about expectations and accountabilities which would be confirmed through performance agreements linking activities and resources to results;
- an independent external scientific advisory committee, composed of nationally and internationally recognized scientists would be appointed to regularly assess the design and effectiveness of the program and oversee the effective communication of scientific findings in peer-reviewed publications;
- sustained effort would be committed through predictable and adequate funding and human resources commensurate with the increase in industrial activity and technological change;
- the monitoring and associated research program design and implementation would integrate rigorous and robust science from multiple disciplines;
- a collective commitment would be made to inclusivity of all stakeholders through effective, transparent and proactive communication, reporting and feedback;
- a dialogue process for continually considering information, new knowledge and technological developments, the identification of associated gaps and stakeholder concerns is developed among scientists, the monitoring and research community, decision-makers and the broad community of stakeholders;
- a mechanism for dispute resolution would be developed.

Finally, without attempting to pre-empt the process of developing the shared agenda, we would emphasize that the assignment of roles and responsibilities consider seriously existing strengths. In particular we have been told by many that the trusted and recognized organizational source of broad science capacity rests within Environment Canada. Designing, implementing, and operating the governance structure proposed by the Panel, and performing monitoring to fill identified gaps will require additional funding. The user pays principle should be the basis for determining funding responsibility, with industry being responsible for any new funding requirements.

### EXHIBIT F: THE NORTHERN RIVER BASINS STUDY (NRBS)

The Northern River Basins Study (1991-1996) was a 4 ½ year initiative that examined the relationships between industrial, agricultural, municipal and other developments on the water quality, quantity and ecosystem health of the Peace, Athabasca and Slave River Basins. The study was managed by a 25-member Study Board made up of aboriginal leaders, government officials, municipal representatives, along with members of the environmental, health, agricultural, industrial and public sectors. On a day-to-day basis, the Study was managed by a Study Office led by a Study Director and a science office and program led by a Science Director.

The Northern River Basins Study divided its monitoring and research into eight component areas. Work in each area was led by an expert component leader. Research groups included the following: contaminants, drinking water, food chain, hydrology/hydraulics, nutrients, other river uses, synthesis and modeling, and traditional knowledge. In total, 150 projects or "mini studies" were initiated. The NRBS science program was founded on the principle of best-available science, and scientific work was completed by private companies, individuals, government agencies and educational institutions. The science program design, implementation and reporting was overseen by the Study Board and a seven-member Science Advisory Committee, a group of renowned independent scientists. Throughout the Study, community gatherings, public meetings, science forums and workshops were held to gather public comments, concerns and suggestions. Input from the public provided local perspectives to the Board and assisted in the formation of the science program and development of final recommendations. Leaders of each component group developed a synthesis report that summarized research and scientific findings. The Study Board reviewed all scientific findings and recommendations, along with public comments, and developed a series of recommendations regarding the future monitoring, study and management of the Peace, Athabasca and Slave rivers. (http://www3.gov.ab.ca/env/water/nrbs/nrbs.html)

### EXHIBIT G: GREAT LAKES WATER QUALITY PROGRAM

Another potentially useful model for governance comes from the Great Lakes. Here, the Canada-Ontario Agreement (Respecting the Great Lakes Basin Ecosystem) is the mechanism that outlines how the governments of Canada and Ontario will cooperate and coordinate their efforts to restore, protect and conserve the Great Lakes basin ecosystem. It is also the means by which the numerous federal partners of the Canadian Great Lakes Program coordinate to interact with the various provincial ministries to help meet Canada's obligations under the Great Lakes Water Quality Agreement (GLWQA). This governance framework provides the approach to coordinate monitoring, surveillance and research activities, and report on the State of the Great Lakes. A key component of State of the Great Lakes Reporting is the biennial State of the Lakes Ecosystem Conferences (SOLEC), hosted by the U.S. Environmental Protection Agency and Environment Canada on behalf of the two countries. These conferences are a culmination of monitoring and scientific information gathered from a wide variety of sources and engage a variety of organizations. The conferences report on the state of the Great Lakes ecosystem and the major factors impacting it, and provide a forum for exchange of this information amongst Great Lakes decision-makers. It also serves to provide information to people in all levels of government, corporate, and not-for-profit sectors that make decisions that affect the lakes. It is a main vehicle for multi-sector discussion on research and monitoring status and also serves to identify additional required monitoring effort.

## EXHIBIT H: USGS NATIONAL WATER QUALITY ASSESSMENT PROGRAM

The US Geological Survey (USGS) implemented the National Water-Quality Assessment (NAWQA) Program in 1991 to develop long-term consistent and comparable information on streams, rivers, ground water, and aquatic systems in support of national, regional, state, and local information needs and decisions related to water-quality management and policy. NAWQA provides an analysis and understanding of: general water-quality conditions; whether conditions are changing over time; and how natural features and human activities affect the water quality conditions. Regional and national assessments are conducted through a standardized and consistent study designs that have uniform methods and protocols of data collection and analyses.

USGS scientists collect and interpret data about surface- and groundwater chemistry, hydrology, land use, stream habitat, and aquatic life in parts or all of nearly all 50 states. Monitoring data are integrated with geographic information on hydrological characteristics, land use, and other landscape features in models to extend water-quality understanding to unmonitored areas.

From 1991-2001, the NAWQA Program conducted interdisciplinary assessments and established a baseline understanding of water-quality conditions in 51 of the nation's river basins and aquifers, referred to as Study Units. Descriptions of water-quality conditions in streams and groundwater were developed in >1000 reports openly accessed through NAWQA publications. Non-technical Summary Reports, written primarily for those interested or involved in resource management, conservation, regulation, and policymaking, were completed for each of the 51 Study Units. Non-technical national summary reports on pesticides, nutrients, and volatile organic compounds (VOCs) also were completed, in which water-quality conditions were compared to national standards and guidelines related to drinking water, protection of aquatic life, and nutrient enrichment.

NAWQA activities for the period of 2001-2012 focus on national and regional assessments, all of which build on continued monitoring and assessments in 42 of the 51 Study Units completed in the first cycle.

Local, State, First Nations, and national stakeholders use NAWQA information to design and implement strategies for managing, protecting, and monitoring water resources in many different hydrologic and land-use settings across the US. (http://water.usgs.gov/nawqa)

## CONCLUDING REMARKS

The establishment and implementation of an effective oil sands monitoring program is fundamental to the long-term environmental sustainability and economic viability of a rapidly growing oil sands industry in Canada. The increasing regional, national and international public awareness and concern related to the credibility of the monitoring programs, accuracy of the scientific reporting and overall environmental performance of the oil sands industry is not just an Alberta issue, but has become a Canadian and an international concern. How Canada addresses the environmental issues surrounding the current and projected growth of the industry is of fundamental importance to Canadian trade and national and international energy security.

Timely implementation of the proposed new governance structure will aide in the development and implementation of new remedial actions and pollution prevention measures and regulatory guidelines and contribute to the development of new and effective cumulative impact assessment frameworks and related decision-support systems. The model also emphasizes the recognition of genuine engagement with the public and communities as a core component of environmental stewardship and decision-making.

The Panel hopes that the strategic recommendations it proposes will contribute to enhance trust and confidence in a time of transformative technological and social change. We acknowledge that it will not be easy – important endeavors rarely are. Taking a systemic view makes sense in the abstract, but often falls apart in implementation because of the complexity of jurisdictional relationships. But in recognition of our shared vulnerability there is no alternative. Visionary leadership is required.

# APPENDIX

## REFERENCE LIST

2030 Water Resources Group (2009). *Charting our Water Future: Economic frameworks to inform decision-making*: 2030 Water Resources Group.

Alberta Economic Development Authority (2008). *Sustainable Water Management and Economic Development in Alberta*. Calgary: Alberta Economic Development Authority.

Alberta Environment (2010). *Groundwater Flow Model for the Athabasca Oil Sands (In Situ) Area South of Fort McMurray*. Burnaby: Alberta Environment.

Alberta Environment, & Fisheries and Oceans Canada (2007). *Water Management Framework: Instream Flow Needs and Water Management System for the Lower Athabasca River*. Edmonton: Alberta Environment and Fisheries and Oceans Canada.

Athabasca Chipewyan First Nation Industry Relations Corporation (2010). *As Long as the Rivers Flow: Athabasca River Use, Knowledge and Change*. Fort McMurray: Athabasca Chipewyan First Nation Industry Relations Corporation.

Athabasca Chipewyan First Nation Industry Relations Corporation & Mikisew Cree First Nation Government and Industry Relations (2010). *The Relationship Between the Lower Athabasca River and the Traditional Uses and Rights of the Athabasca Chipewyan First Nation and Mikisew Cree First Nation: Summary Report*. Fort McMurray: Athabasca Chipewyan First Nation Industry Relations Corporation and Mikisew Cree First Nation Government and Industry Relations.

Ayles, G. B., Dube, M., & Rosenberg, D. (2004). *Oil Sands Regional Monitoring Program (RAMP). Scientific Peer Review of the Five Year Report (1997-2001)*. Winnipeg: RAMP.

Bruce, James. P. (2006). *Oil and water – Will they mix in a changing climate? The Athabasca River story*. Ottawa.

Canadian Association of Petroleum Producers (2010). *Upstream Dialogue: The Facts on Oil Sands 2010*. Calgary: Canadian Association of Petroleum Producers.

Carson, B. (2010). *Engaging Canadians: National Oil Sands Dialogues*. Calgary: Canada School of Energy and Environment.

CEMA (Cumulative Environmental Management Association) (2010). *Regional Groundwater Monitoring Network Implementation in the Northern Athabasca Oilsands (NAOS): Chapter 2 Program Summary*: CEMA.

Colavecchia, M. V., Backus, S. M., Hodson, P. V., & Parrott, J. L. (2004). Toxicity of oil sands to early life stages of fathead minnows (*Pimephales promelas*). *Environmental Toxicology and Chemistry, 23*(7), 1709-1718.

Colavecchia, M. V., Hodson, P. V., & Parrott, J. L. (2006). CYP1A induction and blue sac disease in early life stages of white suckers (*Catostomus commersoni*) exposed to oil sands. *Journal of Toxicology and Environmental Health, Part A, 69*(10), 967-994.

Commissioner of the Environment and Sustainable Development (2010). *2010 Fall Report of the Commissioner of the Environment and Sustainable Development. Chapter 2: Monitoring Water Resources*. Ottawa: Office of the Auditor General of Canada.

Council of Canadian Academies (2009). *The Sustainable Management of Groundwater in Canada*. Ottawa: Council of Canadian Academies.

Environmental Defence, The Pembina Institute & Equiterre. (2010). *Duty Calls: Federal Responsibility in Canada's Oil Sands*. Environmental Defence, The Pembina Institute & Equiterre.

Evans, M. S., Billeck, B., Lockhart, L., Bechtold, J. P., Yunker, M. B., & Stern, G. (2002). PAH sediment studies in Lake Athabasca and the Athabasca River ecosystem related to the Fort McMurray oil sands operations: sources and trends. *Oil and Hydrocarbon Spills III: Modelling, Analysis and Control*, 365-374.

Fisheries and Oceans Canada (2010). *Science Evaluation of Instream Flow Needs (IFN) for the Lower Athabasca River*. Ottawa: Fisheries and Oceans Canada. Canadian Science Advisory Secretariat.

Fort McKay Industry Relations Corporation (2010). *Appendix N*. Fort McMurray: Fort McKay Industry Relations Corporation.

Fort McKay Specific Assessment (2010). *Supplemental Information for the Shell Canada Limited Jackpine Mine Expansion and Pierre River Mine Project Application*: Fort McKay Industry Relations Corporation.

Giesy, J. P., Anderson, J. C., & Wiseman, S. B. (2010). Alberta oil sands development. *Proceedings of the National Academy of Sciences, 107*(3), 951-952.

Government of Alberta (2010a). *Comprehensive Contaminant Load Study: Water Quality Monitoring*. Edmonton: Government of Alberta.

Government of Alberta (2010b). *Groundwater Management Framework. Northern Athabasca Oil Sands Region. Part 1: Technical Framework*. Edmonton: Government of Alberta.

Government of Alberta (2010c). *Groundwater Management Framework. Northern Athabasca Oil Sands Region. Part 2: Supporting Document*. Edmonton: Government of Alberta.

Government of Alberta (2010d). *Lower Athabasca River Water Management Framework: Surface Water Quality Update*. Edmonton: Government of Alberta.

Government of Alberta (2010e). *Regulatory Enhancement Project Overview*: Government of Alberta.

Kelly, E. N., Schindler, D. W., Hodson, P. V., Short, J. W., Radmanovich, R., & Nielsen, C. C. (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.

Kelly, E. N., Short, J. W., Schindler, D. W., Hodson, P. V., Ma, M., Kwan, A. K., & Fortin, B. L. (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.

Liberal Report from the Study of the Standing Committee on Environment and Sustainable Development on the Impact of Oil Sands Development on Canada's Freshwater (2010). *The Hidden Dimension: Water and the Oil Sands*: Liberal Party of Canada.

McCart, P., Tripp, D., Withler, R., (1982). *Spawning and Distribution of Lake Whitefish (Coregonus clupeaformis) in Athabasca River and Lake Athabasca*. Calgary: Aquatic Environments Limited.

Mikisew Cree First Nation (2008). *Response to the Muskeg River Watershed Framework for Water Quantity and Quality, December 2007: Submission to Alberta Environment*.

Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-Being*. Millennium Ecosystem Assessment.

MSES (Management and Solutions in Environmental Science) (2010). *Scope of Work and Cost Estimate to Review PTI Group Inc.'s Beaver River Water Treatment Plant Project*. Calgary: Prepared for Mikisew Cree First Nation GIR.

Nature (2010). Editorial Comment: Citizen Scientists. *Nature, 468*(7323), 476.

New Democrat Report on the Standing Committee Review of the Impacts of Oil Sands Developments on Water Resources (2010). *Missing in Action: The Federal Government and protection of water in the oil sands*: New Democrat Party of Canada.

Northern Rivers Ecosystem Initiative (2004a). *Key Findings*. Edmonton: Governments of Canada, Alberta and the Northwest Territories.

Northern Rivers Ecosystem Initiative (2004b). *Northern Rivers Ecosystem Initiative: 1998-2003. Final Report*. Edmonton: Governments of Canada, Alberta and the Northwest Territories.

Northern Rivers Ecosystem Initiative (2004c). *Synthesis Report*. Edmonton: Governments of Canada, Alberta and the Northwest Territories.

NRBS (Northern River Basins Study Board) (1996a). *Ecosystem Health and Integrated Monitoring in the Northern River Basin*. Edmonton: NRBS.

NRBS (Northern River Basins Study Board) (1996b). *The Northern River Basins Study: Report to the Ministers*. Edmonton: NRBS.

OSRIN (Oil Sands Research Information Network) (2010). *Establishing a World Class Public Information and Reporting System for Ecosystems in the Oil Sands Region - Report*. Edmonton: OSRIN.

OSRIN (Oil Sands Research Information Network) (2010). *Review of Major Environmental Effects Monitoring Programs in the Oil Sands Region*. Edmonton: OSRIN.

RAMP (Regional Aquatics Monitoring Program) (2009). *RAMP: Technical Design and Rationale. Report prepared for RAMP steering committee by Hatfield Consultants*: RAMP.

RAMP (Regional Aquatics Monitoring Program) (2010). *RAMP: 2009 Technical Report. Prepared by RAMP 2009 Implementation Team*: RAMP.

Schindler, D. (2010). Tar sands need solid science. *Nature, 468*(7323), 499-501.

Stratos (2009). *Implementation Review of the Environmental Effects Monitoring Program: Final Report*. Ottawa: Stratos Inc.

Suncor Energy Inc. (2010). *2010 Summary Report on Sustainability*. Calgary: Suncor Energy Inc.

Tetreault, G. R., Mcmaster, M. E., Dixon, D. G., & Parrott, J. L. (2003). Using reproductive endpoints in small forage fish species to evaluate the effects of Athabasca oil sands activities. *Environmental Toxicology and Chemistry, 22*(11), 2775-2782.

Timoney, K. P., & Lee, P. (2009). Does the Alberta tar sands industry pollute? The scientific evidence. *Open Conservation Biology Journal, 3*, 65-81.

Timoney, K. P., & Ronconi, R. A. (2010). Annual Bird Mortality in the Bitumen Tailings Ponds in Northeastern Alberta, Canada. *Wilson Journal of Ornithology, 122*(3), 569-576.