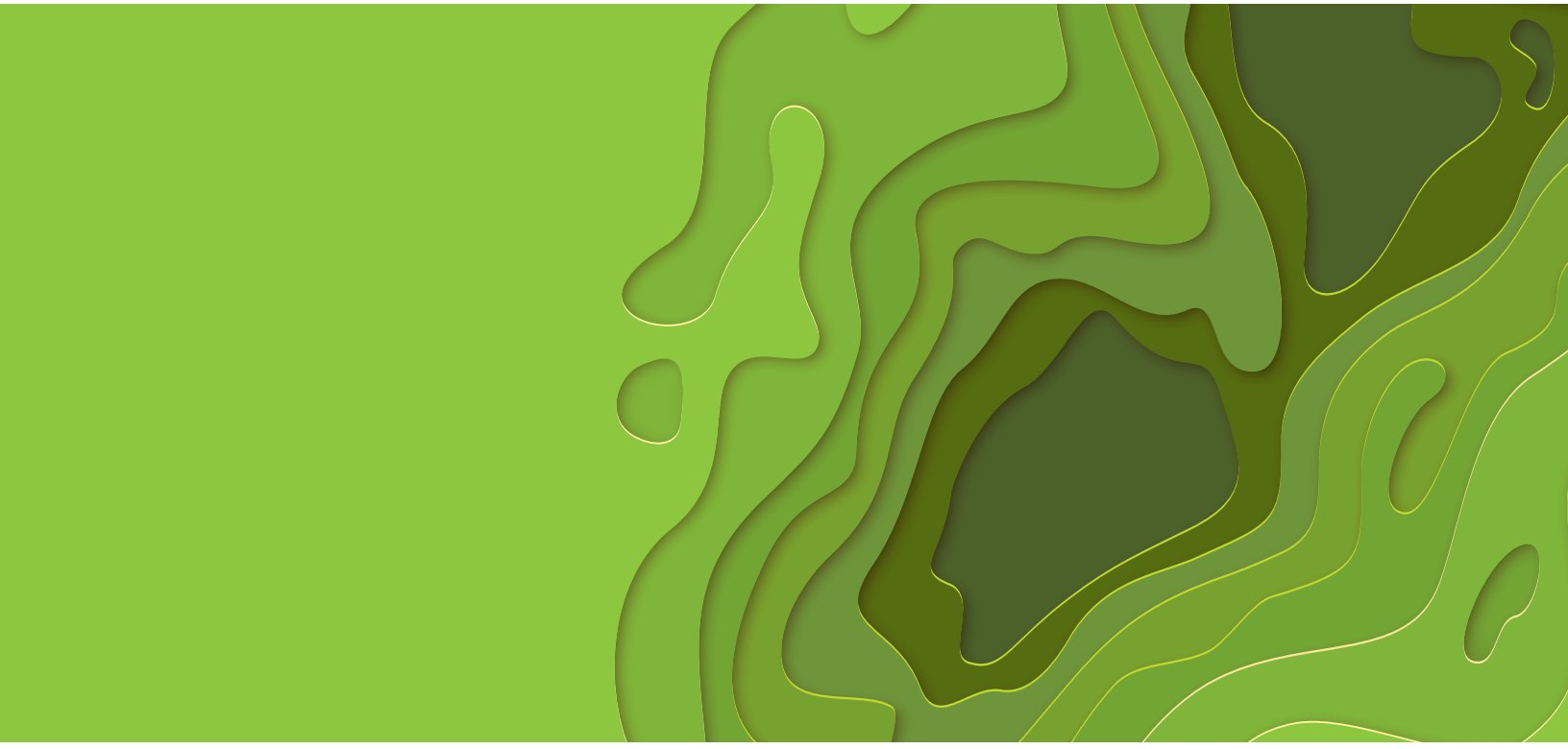
# Knowledge for a Changing Environment



## 2019-2024 Science Strategy

MARCH 2019

Alberta
Environment
and Parks
Office of the Chief Scientist

# A Five-Year (2019-2024) Science Strategy for the Environmental Science Program to monitor, evaluate and report on the condition of the ambient environment in Alberta.

*~ Alberta Environment and Parks, Chief Scientist*

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# Table Of Contents

# Executive Summary

In 2016, under Alberta's Environmental Protection and Enhancement Act (Section 15), the role of the Chief Scientist was established with the mandate to develop and implement an environmental science program to monitor, evaluate and report on the condition of the environment to Albertans. To support this mandate, the Environmental Monitoring and Science Division (EMSD) of Alberta Environment and Parks (AEP) was also formed with an accountability to provide scientific leadership for the planning, coordinating and conducting of environmental monitoring and science in Alberta and the subsequent reporting of the analysis, evaluation and assessment of the information.

The ***Five-Year (2019-2024) Science Strategy*** is the strategic framework for the environmental science program that outlines the collaborative approach, tools, processes, and priority areas where both science and local Indigenous knowledge systems will individually and collectively generate information to contribute to the evidence-informed and policy-relevant priorities of the AEP. The ***Science Strategy*** is not intended to reflect all aspects of AEP's work in the domain of environmental monitoring and sciences, but is intended to inform the public and relevant internal and external monitoring and science programs of the approach to developing and implementing an adaptive environmental monitoring program that enables understanding of status, trends and changes in Alberta's ecosystems.

The ***Science Strategy*** identifies ***five priority areas*** for environmental monitoring and science that collectively address key environmental issues and challenges being faced in Alberta, and will better support progress in achievement of the ultimate outcomes in the AEP Business Plan. These five areas build on existing strengths and programs and increase our ability to understand and predict the cumulative effects of multiple environmental stressors on the condition of the environment. The ***five priority areas*** are **(2.1) biological and ecological change, (2.2) consequences of a changing and variable climate, (2.3) condition and sustainability of Alberta's water resources, (2.4) chemical contaminants and biological stressors in the environment,** and **(2.5) environmental responses to natural resource development.**

The ***Science Strategy*** seeks to broaden the way we understand the implications of a changing environment through adopting a multiple evidence-based approach, which includes braiding Indigenous, local and scientific knowledge.

The ***Science Strategy*** will serve as a foundation and a catalyst for ongoing dialogue and collaboration with internal government organizations as well as external partners, in the planning and delivery of an integrated, inclusive, adaptive, transparent and scientifically credible environmental science program. The environmental science program seeks to answer pertinent questions, relevant to all Albertans, on current and emerging environmental issues.

# 1. Monitoring, Understanding, and Sharing Knowledge of Alberta's Changing Environment

Alberta's natural resources and ecosystems are the foundation for the economic, social, and environmental systems, which form the quality of everyday life for Albertans and Canadians. Environmental systems are complex and so too are the decisions that responsible stewards of the land, water, and air face in finding a balance and evaluating potential trade-offs between the economic, social, and environmental benefits and costs associated with human use of our environment.

Alberta has received intense public scrutiny on the international stage for decisions around the development of its natural resources and has called upon external expert panels to openly evaluate its approach to environmental monitoring. Alberta has taken steps to improve the credibility of monitoring, evaluating and reporting on the condition of the environment by legislating the establishment of a Chief Scientist. The role of the Chief Scientist is to implement and oversee the environmental science program, as well as two independent advisory panels: the Science Advisory Panel (SAP) and the Indigenous Wisdom Advisory Panel (IWAP). These panels periodically review and assess the integrity and credibility of the program.

This ***Science Strategy*** defines priority areas and opportunities for the implementation of an integrated, inclusive, adaptive, publicly transparent, and scientifically credible environmental monitoring and science program for Alberta (**Figure 1**). The Environmental Monitoring and Science Division (EMSD) plays a key leadership role within the Department of Alberta Environment and Parks (AEP) for the environmental monitoring and science program.

However, the success of the program relies on the appropriate collaboration of relevant science programs led by other AEP Divisions, Government of Alberta Departments, external research and academic institutions, and community organizations.


**Figure 1.** Components for the successful design and delivery of Alberta's Environmental Monitoring and Science Program

## 1.1 Advancing a Knowledge Network

Advances in the ***five priority areas*** for the environmental science program will require enhanced coordination with the scientific programs and monitoring activities conducted within AEP (e.g., invasive species, species at risk), with other member departments in the Government of Alberta's Integrated Resource Management System (IRMS) (e.g., monitoring and reporting for Land Use Framework Regional Plans, initiatives related to Climate Change), and with other external science and technology partners such as federal government science departments (e.g., Environment and Climate Change Canada), academia, and provincial, national and international environmental organizations. A network approach with the broader scientific community will allow expertise to be leveraged across the research community and enhance program synergies in areas of mutual interest. Continuous improvement in an environmental monitoring system requires the adoption and application of new technologies as well as advances in the analytical and monitoring methodologies, data & information management, and big data. A network approach will seek to build from the areas of applied research strengths and strategic directions set out in the Research Plans of the University of Calgary, University of Alberta, University of Lethbridge, and Alberta Innovates Strategic Plan.

## 1.2 Expanding the Field of View

Understanding the nature, magnitude and consequences of a changing environment at local, regional and provincial scales is necessary to make informed decisions about development, natural resource management, conservation, cumulative effects management, and climate change resilience and adaptation. Building understanding hinges on having access to the best available knowledge - irrespective of its epistemological origin (e.g., Indigenous or scientific knowledge systems). To this end, the environmental science program will apply a Multiple Evidence-Based (MEB)[1] approach - a knowledge co-production framework[1] recognizing Indigenous, local, and scientific knowledge systems as complementary manifestations of humankind's collective understanding of the world and our relationship with it (Tengö et al. 2014, 2017).

There are similarities, and some important differences, between the way in which knowledge is produced and applied in both Indigenous, local, and conventional scientific knowledge systems (Barnhardt and Kawagley 2005). Indigenous knowledge can be described as intuitive and holistic, subjective, qualitative, diachronic (e.g., long-term in one place), orally transmitted, and the relationships with nature are imbued with spirit (Stephens 2000). Conventional science is described as analytical and reductionist, objective, quantitative, and synchronic (many observations over a large area) (Tsuji and Ho 2002).

The braiding of information from a variety of knowledge systems is important to ensure that a holistic environmental science program produces integrative information to the public and relevant environmental decision-makers. Adopting an MEB approach develops a respectful and equitable relationship between Indigenous knowledge and conventional science.

[1] MEB is used by the UN's Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), an intergovernmental body that, under the auspices of the United Nations, assesses the state of biodiversity and ecosystem services, in response to requests from decision makers (https://www.ipbes.net/).

## 1.3 Adaptive by Design

Multiple environmental drivers and pressures, ranging from local or regional development projects to global and large-scale pressures such as a shifting climate regime and long-range atmospheric transport of pollutants, contribute to constant change in Alberta's environment. Resource development and diversification contributes to a prosperous economy, but also has complex and cumulative effects[2] on the environment. The ways in which people use the environment also changes over time, as technology changes and recreational and resource needs shift, adding to the complexity of our understanding of the environment. The individual environmental impact of each human activity varies over time and space, leading to cumulative effects that cause functional or structural changes in ecological systems that are challenging to foresee (Dubé et al., 2013). Albertans recognize this and expressed concern about the cumulative stresses on their air, water, soil, biodiversity, and ecosystem and human health and well-being.

Environmental monitoring seeks to identify and characterize environmental changes, related to human activities that are occurring in the physical, chemical, and biological attributes of ecosystems and subsequently inform management actions. Environmental monitoring holds significant challenges in determining what to measure (e.g., what is social or scientifically relevant to measure) and how to interpret any differences observed (e.g., based on philosophical views of the environment). Employing an adaptive monitoring approach can ensure the monitoring program converges towards an ideal design over time (Arciszewki et al. 2017).

Alberta's environmental science program and related provincial monitoring networks are evolving towards an adaptive design. Component areas such as surface and groundwater, air, wetlands, land and biodiversity monitoring networks are undergoing review to define and focus the monitoring objectives and science questions that need to be answered. An adaptive design used in conjunction with Cumulative Effects Assessments and Cumulative Effects Management systems can create optimal monitoring strategies that better understand and consider site selection, spatial and temporal sampling frequencies, and relevant physical, chemical and ecological processes to assess environmental impacts. This new design will allow available resources to be optimized to produce scientifically credible, timely and relevant information, addressing present and future stakeholder needs and concerns. Adaptive monitoring is a core activity that informs our understanding of the condition of Alberta's environment and the subsequent Cumulative Effects Assessments and ultimately Cumulative Effects Management Systems (**Figure 2**).

[2] Cumulative effects are changes to the environment that accumulate over time and space. Each effect may in itself be insignificant, but together, multiple effects can interact to cumulatively be significant to environmental ecosystems.

EMSD scientists, together with partner and collaborative organizations, are designing and implementing adaptive monitoring:

- to address specific hypotheses and questions linked to management questions and stakeholder issues to fill knowledge gaps;
- to allocate effort and investment in future monitoring programs (i.e., defining and assessing against environmental stressors, triggers, and tiers in related additional monitoring or focused research);
- to understand the variability of change in a system, and the rate that specific variables are changing over time in a system; and
- to reassess on a regular basis if existing approaches and indicators are appropriate and linked to an effective adaptive management cycle through data and evaluations that address defined management thresholds, limits and outcomes.

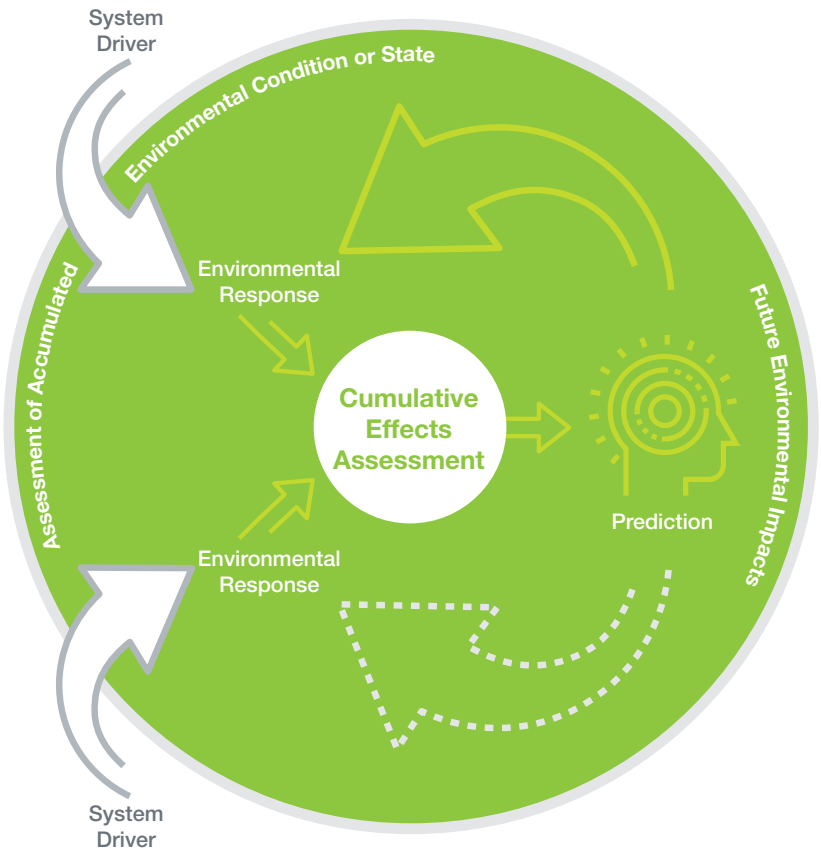



**Figure 2.** Inter-relationships between Adaptive Monitoring, and Cumulative Effects Assessment and Management Systems

## 1.4 Extending Channels of Communication

The value and relevance of Alberta's environmental science program resides in the ability to share timely information to the public based on the scientific assessments and evaluation of the data collected on the current and projected changes in environmental condition.

The program will distribute funds and resources to not just the collection of data and scientific assessment but also to the translation of data and information to enhance a wider understanding of the condition of Alberta's environment.

Science reporting products will be accessible and understandable to end users including, individual Albertans, Indigenous communities, researchers, environmental groups, industry groups as well as policy and decision makers. Underlying data from which assessments and evaluations are based will also be publicly reported and openly available as part of the commitment to timely reporting as required in the **Condition of the Environment Public Reporting Schedule**.

Sharing of condition of environment information is only one part of two-way communication. The second part of communication requires the engagement and feedback from the end users of that information. For example, new knowledge and information gained from the priority areas for monitoring and science can assist Alberta in determining progress towards the Environment and Climate Change Innovation Targets and Focus Areas in Alberta's Research and Innovation Framework.

Continuous improvement of an adaptive environmental monitoring and science program is not fully realized without the engagement of informed citizens, Indigenous and local communities, stakeholders and the greater research community. These perspectives are required to identify concerns, issues and knowledge gaps, inform research priorities, and effectively plan for or adapt implementation. This ***Science Strategy*** is a starting place for encouraging ongoing dialogue and collaboration in the subsequent planning and delivery of the environmental science program.

# 2. Priority Areas of Environmental Monitoring and Science

Over the next five years (2019-2024) the environmental monitoring and science program will focus capacity towards advancing ***five priority areas***. The priority areas aim to provide the necessary credible data, information and analyses to inform and address challenges and related government and societal decision-making processes. The ***five priority areas*** are:

- Biological and Ecological Change
- Consequences of a Changing and Variable Climate
- Condition and Sustainability of Alberta's Water Resources
- Chemical Contaminants and Biological Stressors in the Environment
- Environmental Impacts of Natural Resource Development

The program design and delivery of these five priority areas are not mutually exclusive of one another. In designing and delivering the environmental science program appropriate programmatic integration must occur within and between natural science disciplines, knowledge systems, and environmental media to meet data and information needs within and across the areas and to assess cumulative effects.

A common requirement of all five priority areas is enhanced development and implementation of improved, integrated and openly accessible data and information resources. Through ongoing collaboration and partnership arrangements with internal and external monitoring and research initiatives, AEP will continue to operate in an open manner and provide credible data and information in accordance with appropriate quality assurance, culturally appropriate protocols, and data management standards.

Additionally, to meet the growing challenges associated with increasing data and information needs, the application of cross-cutting innovation will be pursued through exploring citizen science and testing and implementing state-of-the art monitoring and analytical technologies. In order to reduce redundancies and considering affordability of new technologies we will seek to enhance and leverage expertise across a network of environmental analytics professionals including universities, research and science institutes and non-profit ventures. This will advance capabilities to provide timely (i.e., early-warning) and more comprehensive environmental data across media (i.e., air, water, land) and biological scales.

## 2.1 Biological and Ecological Change

***Monitor, assess and predict the status and trends in environmental stressors and stressor responses of Alberta's plants, animals, habitats and ecosystems, including changes in accumulated condition and cumulative effects.***

The conservation, protection and restoration of Alberta's biological and ecological resources requires relevant information to understand the current environmental conditions and predict the future condition of these resources as well as their trends over time and space. Aquatic and terrestrial ecosystems provide vital direct and indirect ecological goods and services that contribute to human well-being and socio-economic benefits received from the environment, such as: provision of forestry and agriculturally-related products, purification of air and water, detoxification of wastes, areas for recreational use, cultural education, psychological health and spiritual experience and mitigation of floods and droughts (Millennium Ecosystem Assessment, 2005; Federal, Provincial, and Territorial Governments of Canada, 2010).

Monitoring and research of Alberta's ecosystems creates new knowledge on the causes and consequences of observed biological and ecological change. This allows for assessments and recommendations to be provided on approaches for protecting and managing the biological and ecological components and processes of ecosystems, along with interpretation for policy makers on how current and future rates of change will affect these natural resources and the implications for present and future policy development. Working in partnership with external monitoring, research and scientific organizations, we can enhance our knowledge base around understanding biological and ecological change, and how to best monitor change in order to better define conditions regarding regional diversity of key indicator terrestrial and aquatic species and relevant attributes and endpoints to inform conservation and protection efforts.

Alberta's complex and diverse geology and biogeography underlay the range of associated ecosystems, habitats and species, which are equally diverse and complex. No single environmental and/or human-caused driver operates in isolation; hence understanding the complex cumulative effects of multiple stressors on biological and functional diversity requires a systematic approach of regional monitoring coupled with focused, hypothesis driven research to try to fill in knowledge gaps.

## Actions:

- **Assessment of the existing accumulated environmental condition** to identify critical changes, their causes and their effects, in the environment and associated principal environmental stressors (e.g., additions of toxic substances, loading of nutrients, and physical habitat modification).
- **Understand the status and trends of valued ecosystem components** by analyzing sources of stress, including understanding and predicting changes to the distribution, interactions, and conditions of species as well as the conservation requirements of organisms caused by human (e.g., roads, pipelines) and non-human (e.g., natural disasters, predator/prey relationships) disturbances.
- **Cumulative effects assessment** capacity is enhanced through monitoring of existing accumulated environmental conditions linked to forecasting and through predictive modelling of future environmental conditions in Alberta's terrestrial and aquatic ecosystems given different development trajectories and considering multiple environmental stressors.

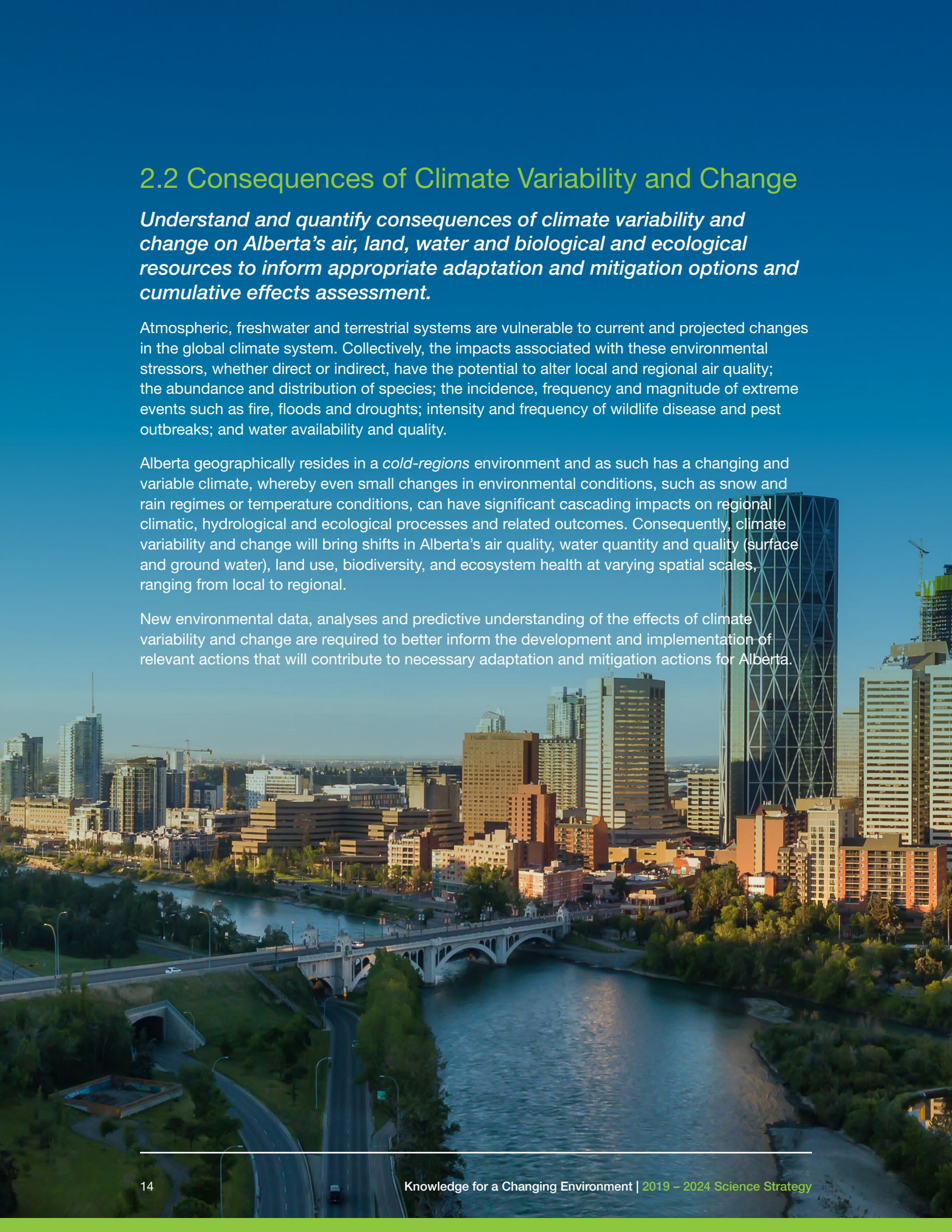
## 2.2 Consequences of Climate Variability and Change

***Understand and quantify consequences of climate variability and change on Alberta's air, land, water and biological and ecological resources to inform appropriate adaptation and mitigation options and cumulative effects assessment.***

Atmospheric, freshwater and terrestrial systems are vulnerable to current and projected changes in the global climate system. Collectively, the impacts associated with these environmental stressors, whether direct or indirect, have the potential to alter local and regional air quality; the abundance and distribution of species; the incidence, frequency and magnitude of extreme events such as fire, floods and droughts; intensity and frequency of wildlife disease and pest outbreaks; and water availability and quality.

Alberta geographically resides in a *cold-regions* environment and as such has a changing and variable climate, whereby even small changes in environmental conditions, such as snow and rain regimes or temperature conditions, can have significant cascading impacts on regional climatic, hydrological and ecological processes and related outcomes. Consequently, climate variability and change will bring shifts in Alberta's air quality, water quantity and quality (surface and ground water), land use, biodiversity, and ecosystem health at varying spatial scales, ranging from local to regional.

New environmental data, analyses and predictive understanding of the effects of climate variability and change are required to better inform the development and implementation of relevant actions that will contribute to necessary adaptation and mitigation actions for Alberta.



By working in partnership with collaborative organizations, as well as with community and Indigenous knowledge holders, current initiatives and monitoring networks will be enhanced to better address information gaps in areas such as hydroclimatic and ecosystem effects, and interactions with changes in land use. Improvements in predictive and analytical tools for use by resource managers and decision-makers will also help inform adaptation strategies to climate change and related ecosystem disturbances.

## Actions:

- **Monitor key components of the physical environment to increase our capacity to understand and predict current and future atmospheric and hydrological conditions** in Alberta at geographically relevant scales (e.g., development of process-based and distributed regional hydrology, climatology, and models to forecast and quantify impacts of land-use change and climate change interactions).
- Using scientific, Indigenous and local knowledge, **monitor ecological systems and species to identify changes in the geographical distribution and abundance of both terrestrial and aquatic species and habitats,** including identifying species and habitats most at risk, as well as the intensity and spread of invasive species, and insect and disease outbreaks.

## 2.3 Condition and Sustainability of Alberta's Water Resources

***Monitor, assess and predict freshwater availability, trends in water quality and quantity, and potential changes caused by increasing demands related to industrial growth, human population and from current and projected climate change and other environmental drivers including cumulative effects.***

Access to safe, accessible and sustainable fresh water is vital for people, communities and ecosystems. Factors such as the expanding human population, land use changes, resource development and climate change will all have impacts on Alberta's freshwater resources. Alberta's north flowing river basins contain the majority of the province's water resources; however, the majority of Alberta's population is concentrated in the southern part of the province. Given this, the pressures and demands on Alberta's freshwater resources vary significantly across the province. For example, the South Saskatchewan River Basin contains 13% of Alberta's surface water as well as over 85% of Alberta's population (**Figure 3**).

The province is also the fourth largest per capita user of water in Canada (Environment Canada, 2009) and sustained water availability is a key driver of Alberta's economy. Water use is predominantly from surface water sources, although ground water sources now also contribute almost 5% of Alberta's total licensed water allocations (German-Canadian Centre for Innovation and Research, 2015).

AEP's environmental monitoring, focused research, evaluation and reporting activities are targeted on providing an improved understanding of the current and projected status of the province's water resources and developing a capacity to forecast water needs and supplies into the future.

### Actions:

- **Improve integrated design and implementation of the existing provincial surface and groundwater monitoring network** to better understand current conditions, and to identify and project short and long-term changes of water quantity and quality in relation to current and projected supply and demand associated with approved and future land use planning scenarios.
- **Develop improved, integrated environmental prediction systems** to assess the status and future trends in the availability and condition of Alberta's surface and ground water resources.
- **Identify which watersheds and groundwater systems are most vulnerable** to natural and anthropogenic stressors and cumulative environmental change.

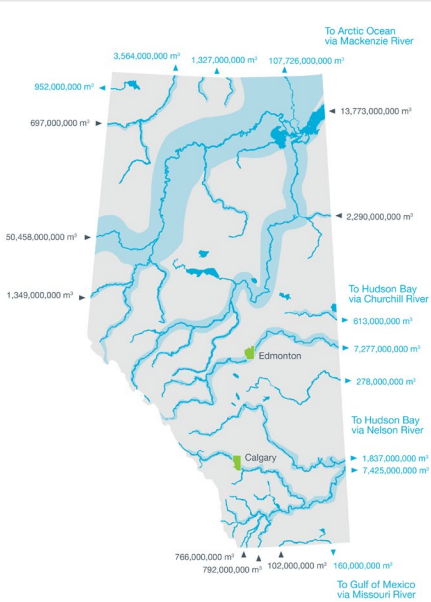



**Figure 3.** Inflow and outflow of major rivers in Alberta

## 2.4 Chemical Contaminants and Biological Stressors in the Environment

***Produce timely, credible monitoring and reporting of chemical contaminants and/or biological stressors of concern entering the environment in order to assess whether, through exposure, there are potential or observed impacts on human and/or ecosystem health.***

Identifying the sources, environmental fate and biological/ecological effects of priority and emerging chemical contaminants and biological stressors of concern is critical to assessing the health and sustainability of terrestrial and aquatic ecosystems. This involves designing and implementing a range of integrated physical, chemical and biological monitoring programs and related research aimed at identifying and quantifying airborne and waterborne contaminants entering the environment, and assessing the local and regional effects of exposure on biota and ecosystems. This information can be used to further assess implications to human health and well-being.

Integrated design requires a network of collaboration between scientists, local and Indigenous knowledge holders, and monitoring experts across disciplines. It involves teams of hydrologists, environmental chemists, atmospheric scientists, biologists, toxicologists, ecologists and modellers who apply advanced analytical methods, laboratory and field investigations to understand the occurrences of chemical contaminants and biological stressors of concern in air, water, and land, and the associated effects of exposures to biota and ecosystems. Priorities of this work are informed through public interest and concerns from Indigenous communities and a growing network of stakeholders, as well as other provincial and federal government departments and agencies, industry, non-governmental organizations and academia.

## Actions:

- **Monitor and report on air, surface water and ground water quality and quantity and biological indicators** to align with both federal and provincial legislative requirements, as well as to inform the public on the condition of their air, water, plants, and animals.
- **Increase capacity to monitor and assess the spatial and temporal status and trends of environmental contaminants** of concern and corresponding risks of exposure to key biological and ecological components of the environment (e.g., monitoring of cyanobacterial and algal outbreaks, pharmaceuticals and pesticides in the environment and water, and toxins in water bodies and watersheds).

## 2.5 Environmental Responses to Natural Resource Development

***Monitoring, evaluating, and timely reporting on environmental responses to natural resource development helps to inform regulatory bodies and the public of the cumulative environmental impacts of the multiple industries and sectors, to assess the efficacy of current environmental policy and regulatory regimes, and to inform decision-making for areas of improvement.***

Alberta has an abundance of natural resources that impact our economic and social wellbeing. This includes water resources for hydroelectric power generation, vast deposits of conventional and non-conventional oil and gas, forests and related industries such as timber and pulp and paper production, and mining activities related to coal (thermal and metallurgical grades), gravel, and limestone (for cement production) extraction. Activities that utilize these resources have associated impacts on the ambient, or surrounding, environment. In a number of regions in Alberta many of these sectors are operating simultaneously, sometimes leading to the accumulation of unintentional or unknown environmental consequences.

Regional and provincial-scale ambient environmental monitoring programs provide credible, objective scientific data and information to inform the public and related regulatory regimes of the environmental performance across multiple industries and sectors. Monitoring science, associated applied research and timely reporting on the condition of the environment are important pillars of responsible resource development, and assist decision makers in balancing resource investment and development, with appropriate protection of the environment for present and future generations.


## Actions:

- **Provide scientific leadership and oversight in the design and implementation of the** Alberta-Canada Oil Sands Monitoring Program.
- **Develop spill response monitoring and focused research** to inform clean-up and associated remediation actions related to mining activities.
- **Increase the capacity of the province's monitoring systems** to assess the environmental impacts of natural resource sector developments.

# 3. Next Steps

Successful implementation of the ***Science Strategy*** will require ongoing dialogue among the scientific, policy-regulatory, Indigenous, industry, and stakeholder communities, combined with ongoing engagement with the public. New approaches need to be explored on how to best utilize both conventional scientific approaches with Indigenous knowledge and this must occur in early stages of monitoring program designs. With this comes a need to link the policy and regulatory decisions to the knowledge gained through the MEB approach.

The future holds many challenges and opportunities for EMSD and the other science-based monitoring and assessment programs being conducted through other Divisions of AEP and its external partners and collaborators. The consolidation of environmental, fish and wildlife, hydrological, atmospheric, and water-scientists as well as modelers and associated technical experts and data specialists brings together a significant body of interdisciplinary expertise within AEP to address the complex environmental issues and policy challenges facing Alberta. In addition, stronger linkages to non-government scientists adds to the wealth of knowledge that we can have to better understand the changes occurring in our environment. The establishment of a team with a dedicated work portfolio in advancing knowledge co-production in community based monitoring and citizen science brings new and exciting dimensions to the creation of new forms of data, information and knowledge through the braiding of western and Indigenous knowledge systems. The hope is that the ***Science Strategy*** will serve as a foundation and catalyst to create a more fully integrated environmental science program, where the priority areas and their linkages are collectively addressed.

In addition, given the growing scope and complexity of monitoring and science issues to be addressed in Alberta and the corresponding increasing demand for credible data and information, achievement of the actions outlined in the ***Science Strategy*** can only be efficiently and effectively attained through enhanced collaborative arrangements and partnerships with external organizations and expertise that leverage both intellectual and financial resources.

Periodic review of the ***Science Strategy*** will occur throughout its implementation alongside operational planning processes and evaluation of program delivery. Additionally, a “mid-term progress review” of the priority areas in the ***Science Strategy*** will engage the Indigenous Wisdom Advisory Panel and Science Advisory Panel in order to evaluate advancements made. The mid-term progress review will also serve to inform future strategic directions for Alberta’s environmental science program and to help guide the next five-year Science Strategy.

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