Oil Sands Monitoring Program: Recommendation Report (Part 2 of 2)

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OIL SANDS MONITORING PROGRAM

Canada

Alberta

Oil Sands Monitoring Program: Recommendation Report (Part 2 of 2)

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Foreword

In February 2018, work plans under the Oil Sands Monitoring Program (OSMP) for the 2018-2019 fiscal year were reviewed by an OSM Interim Science Review Committee with representation from the Government of Alberta, Government of Canada, local First Nations and Métis communities, science experts, and industry including CAPP and COSIA. Work plans were evaluated using several criteria, including the inclusion of assessments of current state, new and emerging priorities, and commitment to evaluating progress to date and integration across program areas.

The Interim Science Review Committee recommended the program synthesize the work that has been completed and formulate the path forward to support design and prioritization for 2019-2020 OSM work planning. A series of "Integration Workshops" was recommended.

In response to this recommendation, seven Integration Workshops were held between the end of October 2018 and early February, 2019 for the following Themes: Terrestrial Biological Monitoring; Groundwater; Surface Water and Aquatic Biology; Atmospheric Deposition; Geospatial Science; Mercury; and, Predictive Modelling. Participants at each workshop were asked to consider the following three questions: (1) where are we? (2) where do we need to go?; and (3) How are we going to get there?. These three questions were to be answered with respect to achieving the Three Core Outcomes of the OMSP: (1) assessment of accumulated environmental condition or state; (2) relationships between system drivers (stressors) and environmental response; and (3) cumulative effects assessment. All three of these core outcomes must be in relation to oil sands industry-related stressors.

The outcomes of the seven OSM Integration Workshops held between the end of October, 2018 and early February, 2019 are presented in a Workshop Summary Report. The Workshop Summary Report contains the prioritized key questions. These key questions were developed with the above three Core Outcomes in mind.

While workshop planning and implementation was going on, the Operational Framework Agreement (OFA) for the OSMP was negotiated and ultimately signed in November, 2018. The OFA provides the core principles, objectives, and broad implementation strategy for the OSMP. It is landmark agreement because it includes not only the federal and provincial governments, but also eighteen Indigenous communities. The agreement was also supported fully by the oil sands industry.

This report takes the results of the seven integration workshops, places them within the OFA context, and then provides recommendations.

The Purpose of This Report

This report presents recommendations for "what it will take" to address the priority key questions, achieve OSMP objectives, and integrate the OSMP in a manner consistent with the Operational Framework Agreement. In a nutshell, what it will take is "relentless implementation" which is consistent with the OFA. This report presents recommendations to the OSMP as opposed to recommendations from the OSMP and will need to be considered recognizing that prioritization and implementation over time are necessary.

Stella Swanson, Ph.D.

Recommendations for Integration

Integration within the Oil Sands Monitoring Program means the development and implementation of a cumulative approach of study that synthesizes the perspectives of individual scientific disciplines as well as Indigenous Knowledge into sets of integrated workplans run by teams which work together to meet the OSMP Objective and achieve the OSMP core outcomes in a coordinated and coherent manner.

The recommendations presented below are supported with more detailed information in Annex 1.

The following general recommendations are based on the results of the Integration Workshops as well as the Conceptual Framework prepared as the foundation for the workshops. The Conceptual Framework presented the three core OSMP outcomes as well as conceptual stressor-pathway-receptor/effects models. All OSMP projects must contribute to one or more of the three core outcomes (from JOSM 2011) which are:

1. Assess environmental condition or state and whether there been changes from baseline/reference in the oil sands region;
2. Determine relationships between stressors and responses and evaluate the extent to which responses are caused by oil sands-related stressors; and,
3. Assess cumulative effects.

Long-term, sustained support for the existing Integrated Environmental Analytics team within the OSMP is vital to integration.

- The analytics team brings the competencies which are fundamental to integration, such as geospatial science, and modelling.
- This team, currently under the leadership of Monique Dubé, will provide the basic building blocks of integration for review and approval via the OFA process, starting with the Science and Indigenous Knowledge Integration Committee (SIKIC).

Integration must contribute to one or more of the three OSMP core outcomes.

- Lessons learned during early integration efforts should be carefully tracked and used to inform the Science and Indigenous Knowledge Integration Committee (SIKIC).

Use Conceptual Models as the basis for OSMP programs [this activity is underway].

- Create a master conceptual model derived from the individual conceptual models used in the workshops; this master conceptual model will form the foundation for integration of OSMP programs, including the design of all OSMP projects.

- Use the master conceptual model and individual models to: (1) identify the most likely critical source-pathway-receptor linkages which would drive oil sands-related changes; (2) generate hypotheses regarding relative contribution of stressor sources, the fate and transport mechanisms of chemical stressors, effects mechanisms, and cumulative interactions (synergistic, antagonistic, additive); and, (3) identify critical gaps in our understanding of stressor-pathway-response linkages.

Start with the most realistic and practical near-term integration opportunities.

- Opportunities can be both within and among OSMP components.
- Evaluate the integration needed to address the priority uncertainties (see later section of this report) for actions which are the most achievable in the near-term.

Conduct a review of EIAs prepared for mining and in situ oil sands projects in order to identify critical requirements for predictive model verification through monitoring, as well as to compile and map predicted effects over the entire oil sands region.

- This review should compile predictions of environmental effects made in the EIAs. Priority should be assigned to those effects which were rated as significantly adverse, were associated with high uncertainty, and/or which were predicted to occur over wider spatial or temporal scales. Irreversible effects should also be noted, notwithstanding scale, particularly effects on listed species or on traditional resources.
- The review should include the application of geospatial science, including the mapping of combined spatial and temporal effects and the magnitude of those effects.
- The compiled, synthesized, and mapped predictions can then be used as another tool to prioritize both single and cumulative effects which have the greatest potential to be significantly adverse.
- The priorities identified during the above two approaches, in combination with the priorities identified during the integration workshops, can then be compared with current and planned OSMP monitoring and modelling in order to identify insufficiencies or gaps in the current OSMP.

A central location for all predictive models performed in support of the OSMP is recommended.

- Current models are located in many different government, academic, and industry locations. This creates a barrier to integration. Assembling all of the models which have been used to produce the current understanding of status, condition and trends in one place will greatly assist in the integration and consolidation of modelling efforts in service of the OSMP objectives.

Model verification and validation must be an integral part of the OSMP.

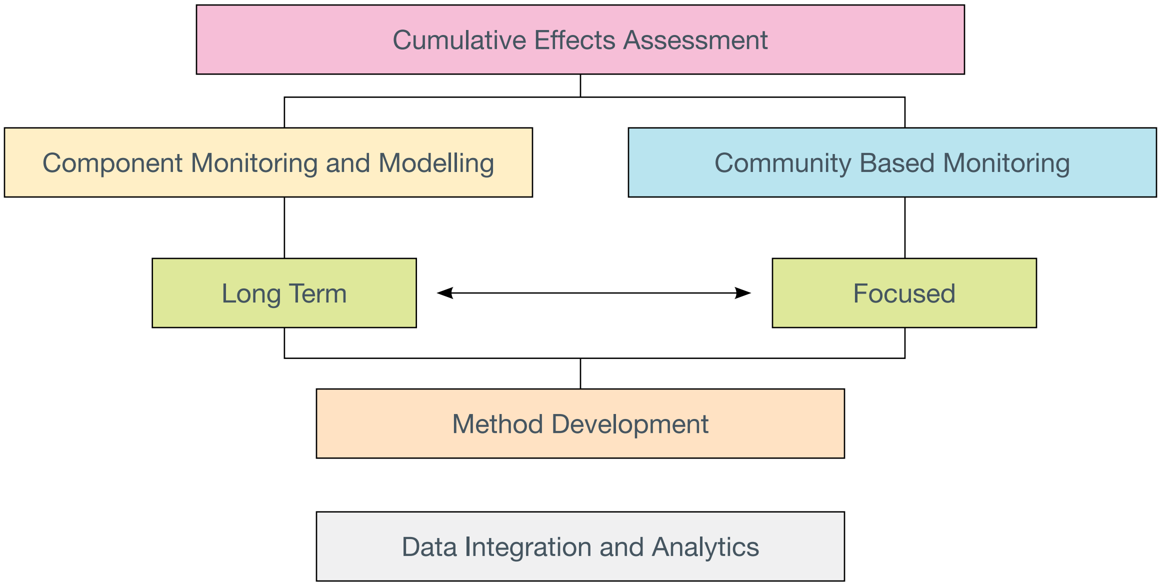
- Verification confirms that the model has been correctly implemented with respect to the conceptual model (it matches specifications and assumptions which are judged to be appropriate to the modelled system).
- Model validation checks the accuracy of the model's representation of the real world. Monitoring must be coordinated with modelling in order that model predictions can be compared with observations at mutually agreed-upon scales and with consensus on essential supporting parameters (predicted and measured.

There was strong consensus at every Integration Workshop about the importance of accessible, reliable, and up-to-date data. Now that data management has been moved to Service Alberta, clear, consistent and strong input from the OSMP through SIKIC to Service Alberta will be required in order that the crucial data needs of the OSMP are met.

Recommendations for the Operational Framework Agreement Components

Cumulative effects assessment should be placed at the top of the OFA component hierarchy.

The six OSMP Programs presented in the Operational Framework Agreement (OFA) (Dubé et al. 2018) should be nested beneath cumulative effects assessment. Cumulative effects assessment is fundamental to the OSMP because it provides the overarching framework for all other programs and because information from other programs would feed into this program.



Clarity regarding the role of the OSMP in cumulative effects assessment in the oil sands region is required.

The OSMP uses western science and Indigenous Knowledge to inform policy and regulation regarding cumulative effects of the oil sands industry. This is in accordance with the Memorandum of Understanding (Government of Alberta and Government of Canada 2017) which states that timely assessment of cumulative effects from oil sands development is part of the Purpose of the OSMP "in accordance with existing legislative and regulatory controls". The MOU also states that data and information from the OSMP will be provided to decision-makers to inform management and regulatory action.

Cumulative effects assessment requires thresholds which can then be used to indicate the need for management action. The role of OSMP is to provide the science behind risk-based thresholds of cumulative effects. While science can contribute to the development of these thresholds, social, cultural, and economic criteria are also required.

Review of relevant CE policies is recommended, including the current CE policy in British Columbia (BCCEF 2017a). The BC policy is specifically recommended because it provides an overarching framework which encompasses both cumulative effects assessment and cumulative effects management. It also provides foundational information that can be used to inform engagement with Indigenous communities. More information is provided in Annex 1.

Recommendations Regarding Cumulative Effects

Create an overarching framework for cumulative effects (CE Framework). (This activity is underway).

The OSMP CE Framework is being custom-built to be consistent with the OFA as well as reflect current cumulative effects practice. A notable requirement will be to ensure that the CE Framework addresses the integration of western science and Indigenous Knowledge.

The OFA stipulates that the OSMP is risk-based. Therefore, the CE framework should incorporate fundamentals of a risk-based approach, starting with the use of conceptual models.

A risk-based approach also requires the development of thresholds of acceptable risk. As noted above, the role of OSMP is to provide the science behind risk-based thresholds. Other agencies/legislation/regulation provide thresholds which incorporate additional criteria such as social, cultural and economic factors.

Regular and effective information exchange and coordination among policy makers, regulators and the OSMP is required. Management of cumulative risk is driven by policy and regulation. Cumulative effects assessment results generated by the OSMP can inform larger-scale risk management (e.g. under the Lower Athabasca Regional Plan) as well as regulation of the oil sands industry.

Basic features of the CE Framework should include:

- A definition of cumulative effects;
- The Master Conceptual Model (which is under development) supported by individual conceptual models;
- Representative receptors (also called Valued Components);
- Explicit spatial and temporal boundaries (which will vary according to combinations of stressors, pathways and receptors);
- A decision-tree process based upon the decision-making process in the OFA which identifies when there is sufficient confidence in source attribution and causation to support decision-making by incorporating the concept of "tolerable decision error"; and
- Clarity regarding the appropriate use of stressor-based and effects-based approaches within the OSMP CE Framework (good CE assessment requires both);

Recommendations Regarding Component Monitoring and Modelling

The mercury component should be combined with the Atmospheric Deposition Component.

- The first task regarding mercury must be to increase our understanding of mercury sources and speciation in order to establish whether the oil sands industry is a significant source of mercury relative to other sources. If the oil sands industry is confirmed as a significant source of mercury, then work can proceed regarding improving the understanding of the fate and transport of mercury.

Geospatial Science and Predictive Modelling should be explicitly integrated with all components.

- The Geospatial Science workshop identified priority uncertainties and key questions for near-term and longer-term application of geospatial approaches (Annex 1). These priorities should be the basis for planning for integration of geospatial science. Some of this integration has already begun.
- The Predictive Modelling workshop identified priority pathways (also called linkages) within conceptual models which should be addressed through the use of modelling (Annex 1). These priorities should be reviewed and built into work plans for relevant components (and combinations of components). For example, integration of groundwater and surface water modelling is needed with respect to the location of groundwater-dependent ecosystems in the oil sands region.

Recommendations Regarding Long-term Monitoring

The long-term monitoring program (also called the "core program") should be fully integrated.

- Non-integrated long-term monitoring does not meet the OFA objective of being comprehensive and inclusive, nor does it meet the objective of being cost-effective.

An evaluation of the current status of OSMP long-term monitoring should be completed.

- This evaluation should identify current strengths and weaknesses relative to the objectives stipulated in section 2.3 of the OFA. In particular, current long-term monitoring should be evaluated in terms of its effectiveness in reliably measuring change in response to oil sands industry-related stressors.

All long-term monitoring must be in the context of the OSMP conceptual models.

- There must be clarity regarding how the long-term monitoring is measuring stressor sources, pathways/mechanisms, and effects and how those measurements, taken together, can be used to build multiple lines of evidence regarding the effects of oil sands industry-related stressors.

On-lease data from compliance monitoring must be considered for inclusion in the long-term monitoring database.

Long-term monitoring must be supported by modelling and geospatial analysis.

- Modelling and geospatial analyses are required to test and validate spatial and temporal boundaries, sampling frequency, and requirements for supporting information.
- Modelling and geospatial analysis should also be used for retrospective assessment of past monitoring data and for comparison of plausible future scenarios.

Long-term monitoring must be integrated with community-based monitoring.

Long-term monitoring of integrated reference sites is required.

- Consensus on appropriate reference sites which are useful for integrated monitoring must be established.
- The concept of "super sites" should be considered and discussed.

Long-term monitoring must continuously be updated as new tools and approaches are developed and shown to be applicable to the OSMP.

Recommendations Regarding Focused Monitoring

Focused monitoring should address priority uncertainties and key questions (verified by the OSMP) and should also be explicitly related to conceptual models.

- Focused monitoring must address one or more of the following:
    - identification and confirmation of change in important stressors or effects for which insufficient information is available;
    - investigation of causation;
    - opportunities for integration among OSMP components; and
    - supporting geospatial analysis and predictive modelling.

Recommendation Regarding Community Based Monitoring

The key questions produced at the Integration Workshops and subsequently verified by the OSMP should be considered by the Community Based Monitoring Advisory Committee (CBAMC) and compared to the priority concerns identified by communities.

- This comparison can be the basis of identifying the key questions which require input from community-based monitoring.
- Key questions arising from community concerns which were not addressed by the Integration Workshops should be communicated to the SIKIC.

Recommendation Regarding Data Integration and Analytics

There was strong consensus at every Integration Workshop about the importance of accessible, reliable, and up-to-date data. Now that data management has been moved to Service Alberta, clear, consistent and strong input from the OSMP through SIKIC to Service Alberta will be required in order that the crucial data needs of the OSMP are met.

Recommendations Regarding the Priority Uncertainties and Key Questions Which Require an Integrated Approach

Specific recommendations with respect to the priority uncertainties (with associated key questions) which require integration are presented in Annex 1. The priority uncertainties and key questions are subject to verification by the OSMP via the processes stipulated in the Operational Framework Agreement. Therefore, the recommendations in this report are subject to amendment according to the verification process.

What It Will Take to Achieve Integration

The following points summarize guidance provided in the literature regarding collaborative science and integrated scientific teams. More details are provided in Annex 1.

Leadership

Integration of OSMP programs will require strong, focused and dedicated leadership from within the OFA structure.

Effective leadership has the following characteristics:

- Foresight
- Commitment
- Authenticity
- Skilled Communication
- Ability to delegate
- Ability to inspire

Adequate Resources

As noted above, long-term, sustained support for the existing analytics team within the OSMP is vital to integration. There must also be sustained and adequate resources provided for the support of administrative and communication functions provided by the OSM Program Office; these functions will be key to the success of integrated teams.

Suggested Principles for Integration of OSMP Programs

Integration requires teamwork. Some guiding principles for successful multidisciplinary research and monitoring teams are provided by Bennett et al. 2010, Bennett and Gadlin 2012, Lustig et al. 2015, and Roncaglia 2016. These are presented (with adaptations to the OSMP) below.

- All team members must be familiar with the OFA, including its governance structure, principles, and objectives. The OFA provides the shared Vision and Mission for integration teams.
- Make operational plans for each integrated team.
- Make provisions for appropriate recognition and credit.
- Ensure that team members achieve clarity and agreement regarding how financial resources provided by the OSMP are shared among their agencies and institutions.
- Implement effective project and time management.
- Encourage open team communication through a variety of methods.
- Share the excitement of progress and discovery.

Managing and Mitigating Risks to Effective Integration

It is recommended that all of the committees within the OFA plus the specific integrated scientific teams be aware of and prepared for the following risks to effective integration. Some mitigation measures that can reduce those risks are provided by the literature (see above citations as well as details in Annex 1).

- Communication Barriers
    - "…scientists would rather be doing science than concerning themselves with discussions about how they are all getting along".
- Inadequate Resources: Accessibility and Availability
    - Financial and organizational constraints can lead to fragmented work patterns and working off sides of desks. Staff turnover can interrupt work flow and create delays in reaching milestones.
- Lack of Trust, Disagreement and Conflict
    - Issues of boundaries and territory may arise when group members feel that they are treading on each other and there is a lack of clarity and productivity. Acceptance of the lead professional from a different discipline can be an issue. Some team members may be uncomfortable with group decision-making. There may be disconnects between the goals of the team and the aspirations and career needs of team members.

Recommended Performance Metrics for Integration

The overarching purpose of a measurement system should be to help the OSMP gauge its progress towards integration. A balanced set of metrics which reflect important contributors to team performance is recommended.

The following performance metrics are suggested:

- Internal team communication and collaboration: team in-person and on-line meetings; workshops (including field visits), tracking of issues and the resolution of those issues.
- Knowledge generation: # of team publications; publications with interdisciplinary authorship; mentoring and training of team members.
- Policy and management outcomes: compliance with OFA principles and objectives; on-time and on-budget performance.
- Innovation: improved or new methods, products, approaches and analyses.
- Public outreach: common language publications and other accessible products such as maps and visualizations; participation in community meetings, panel discussions, public seminars.

Suggested Topics for Future Workshops

In order to build and maintain momentum towards integration, the following workshop topics are recommended.

1. Workshops on Integration of Indigenous Knowledge and Western Science. The first workshop occurred on June 6-7, 2019. See above recommendation for referring to the key questions developed at the Integration Workshops and identifying those which lend themselves to integration with community-based monitoring and traditional knowledge.
   - A second workshop is recommended for fall or early winter.
2. NOTE: it is recommended that integration of work in the Peace Athabasca Delta receive specific attention, with the goal of achieving a suite of jointly-designed and implemented projects aimed at discriminating oil sands-related effects from other effects (such as the effect of uInaugural Cumulative Effects Program Workshop. To be led by the team currently working on the Master Conceptual Model and Cumulative Effects Framework. The workshop goals will be to achieve consensus on foundational aspects of the cumulative effects program.
   - Geospatial science and predictive modelling will be central to the cumulative effects assessment program; the roles to be played by these two disciplines will be stipulated in the draft Cumulative Effects Framework.

- Recommendations produced by the TK/WS workshops regarding work on the Peace Athabasca Delta should be discussed in light of requirements of the assessment of cumulative effects in the Delta.

3. Wetland Integration Workshop. This workshop will identify the best opportunities for integration across groundwater, surface water, terrestrial, and aquatic biology disciplines with the support of Geospatial Science as well as modelling.

4. Causation workshops: one for Terrestrial and one for Aquatic. One or two-day workshops to develop methods for investigating the cause of observed effects on terrestrial and aquatic biota in order to discriminate the relative contribution of oil sands operations to the effects.

5. Integrated Long-term Monitoring Workshop. This workshop will be based on a critical review of how well current long-term monitoring addresses OSMP objectives. Opportunities for improvement will be identified. Ideas such as "super sites" and "representative watersheds" will be discussed.

6. Cumulative Effects Program Workshop #2. The goal of this workshop would be constructing a set of projects within the Cumulative Effects Framework to test the effectiveness of the Framework.

7. Risk-based Benchmarks workshop. This workshop will focus on the approaches for development of risk-based benchmarks required to establish change and, in turn, effects in the context of monitoring.

Recommended Yearly Workshops

- Yearly Integration Workshops which continue to use and refine the Master Conceptual Model as well as theme-specific conceptual models to help identify the top priority uncertainties with associated key questions which require integration. (See Annex 1 for specific recommendations for each priority uncertainty).

Annex1: Recommendations for Integration with Additional Supporting Information

General Recommendations

Integration within the Oil Sands Monitoring Program means the development and implementation of a cumulative approach of study that synthesizes the perspectives of individual scientific disciplines as well as Indigenous Knowledge into sets of integrated workplans run by teams which work together to meet the OSMP Objective and achieve the OSMP core outcomes in a coordinated and coherent manner.

The following general recommendations are based on the results of the Integration Workshops as well as the Conceptual Framework prepared as the foundation for the workshops. The Conceptual Framework presented the three core OSMP outcomes as well as conceptual stressor-pathway-receptor/effects models. All OSMP projects must contribute to one or more of the three core outcomes which are:

1. Assess environmental condition or state and whether there been changes from baseline/ reference in the oil sands region;
2. Determine relationships between stressors and responses and evaluate the extent to which responses are caused by oil sands-related stressors; and
3. Assess cumulative effects.

Integration must contribute to one or more of the three OSMP core outcomes.

- The integration workshops provided an understanding of "where we are" with respect to the three core outcomes and then identified priority uncertainties to be addressed ("where we need to go") with associated key questions ("how we are going to get there").
- The workshop report provides an important place to start when planning integration because the report provides the record of discussions (and thus the context) for the priorities produced by workshop participants, as well as a range of ideas regarding methods and approaches.

Use Conceptual Models as the basis for OSMP programs [this activity is underway].

- Create a master conceptual model derived from the individual conceptual models used in the workshops; this master conceptual model will form the foundation for integration of OSMP programs, including the design of all OSMP projects.
- The master conceptual model and individual models will synthesize our current knowledge of sources, pathways, and effects.
- The conceptual models are not meant to be rigorous depictions of detailed mechanisms and processes; rather, they are meant to provide a general representation of the possible linkages between oil sands-related stressors and effects in order to stimulate the identification of knowledge gaps, hypotheses to test, and integration required.
- Use the master conceptual model and individual models to: (1) identify the most likely critical source-pathway-receptor linkages which would drive oil sands-related changes; (2) generate hypotheses regarding relative contribution of stressor sources, the fate and transport mechanisms of chemical stressors, effects mechanisms, and cumulative interactions (synergistic, antagonistic, additive); and, (3) identify critical gaps in our understanding of stressor-pathway-response linkages.

Start with the most realistic and practical near-term integration opportunities.

- Opportunities can be both within and among OSMP components.
- Evaluate the integration needed to address the priority uncertainties (see later section of this report) for actions which are the most achievable in the near-term.
- Lessons learned during early integration efforts should be carefully tracked and used to inform the Science and Indigenous Knowledge Integration Committee (SIKIC).

Conduct a review of EIAs prepared for mining and in situ oil sands projects in order to identify critical requirements for predictive model verification through monitoring, as well as to compile and map predicted effects over the entire oil sands region.

- This review should compile predictions of environmental effects made in the EIAs, including the spatial and temporal scales, magnitude, duration, frequency and reversibility of the predicted effects. Priority should be assigned to those effects which were rated as significantly adverse, were associated with high uncertainty, and/or which were predicted to occur over wider spatial or temporal scales. Irreversible effects should also be noted, notwithstanding scale, particularly effects on listed species or on traditional resources. Priority effects should be the focus of verification monitoring.
- The review should include the application of geospatial science, including the mapping of combined spatial and temporal effects and the magnitude of those effects. The compiled and mapped predictions can then be used as another tool to prioritize both single and cumulative effects which have the greatest potential to be significantly adverse.

- The compiled, synthesized, and mapped predictions can then be used as another tool to prioritize both single and cumulative effects which have the greatest potential to be significantly adverse.

- The priorities identified during the above two approaches, in combination with the priorities identified during the integration workshops, can then be compared with current and planned OSMP monitoring and modelling in order to identify insufficiencies or gaps in the current OSMP.

A central location for all predictive models performed in support of the OSMP is recommended.

- The predictive modelling workshop revealed how current models are located in many different government, academic, and industry locations. This creates a barrier to integration. Assembling all of the models which have been used to produce the current understanding of status, condition and trends in one place will greatly assist in the integration and consolidation of modelling efforts in service of the OSMP objectives.

Model verification and validation must be an integral part of the OSMP.

- Verification confirms that the model has been correctly implemented with respect to the conceptual model (it matches specifications and assumptions which are judged to be appropriate to the modelled system). Therefore, verification of models used in the OSMP must be based upon the Master Conceptual Model (see above recommendation) as well as more detailed individual conceptual models, all of which have been peer-reviewed. Model output can be examined for reasonableness under a variety of input parameter scenarios. Model verification can include comparison of the performance of models vis-à-vis the Master Conceptual Model as well as individual conceptual models (e.g., Soil and Water Assessment Tool – SWAT can be compared with the Modélisation Environmentale – Surface et Hydrologie – MESH model; or, the the MODFLOW and FEFLOW groundwater models can be compared).

- Model validation checks the accuracy of the model's representation of the real world. Monitoring must be coordinated with modelling in order that model predictions can be compared with observations at mutually agreed-upon scales and with consensus on essential supporting parameters . Model validation can also include review by people knowledgeable about the oil sands region regarding whether the model results appear to be a reasonable representation of real-world processes, patterns, and trends.

- There must be sufficient data to support credible conceptual models and to validate the computational models based upon the conceptual models. Data requirements include enough data to support the understanding of fundamental processes and mechanisms (e.g. regional groundwater flow paths), natural variability, and statistical distributions within specified error limits. This is a key challenge which was identified at the integration workshops; e.g., a comprehensive groundwater conceptual model was identified as a priority, yet there were substantial data-related challenges such as the understanding of the shallow groundwater system and connections between groundwater and surface water.

There was strong consensus at every Integration Workshop about the importance of accessible, reliable, and up-to-date data. Now that data management has been moved to Service Alberta, clear, consistent and strong input from the OSMP through SIKIC to Service Alberta will be required in order that the crucial data needs of the OSMP are met.

Recommendations for OFA Components

Cumulative effects assessment should be placed at the top of the OFA component hierarchy.

The six OSMP Programs presented in the Operational Framework Agreement (OFA) (Dubé et al. 2018) should be nested beneath cumulative effects assessment (Figure 1). Cumulative effects assessment is fundamental to the OSMP because it provides the overarching framework for all other programs and because information from other programs would feed into this program. Identifying cumulative effects assessment as the overarching framework is a strategic move designed to ensure that cumulative effects are always “top of mind”.

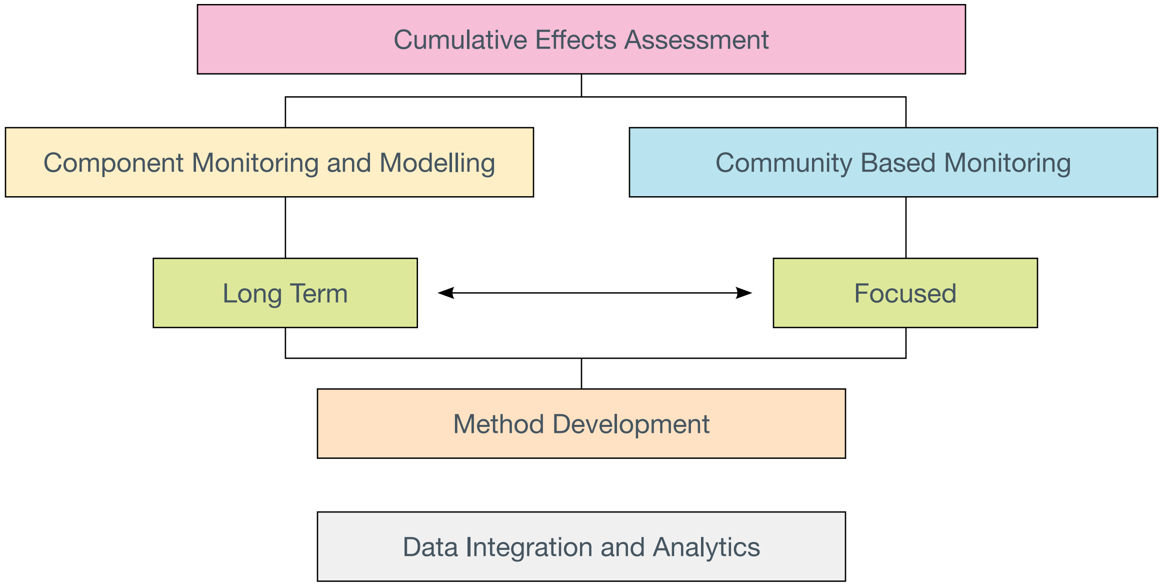


Figure 1. A Suggested Hierarchy of OSM Programs

Clarity regarding the role of the OSMP in cumulative effects assessment in the oil sands region is required.

The OSMP uses western science and Indigenous Knowledge to inform policy and regulation regarding cumulative effects of the oil sands industry. This is in accordance with the Memorandum of Understanding (Government of Alberta and Government of Canada 2017) which states that timely assessment of cumulative effects from oil sands development is part of the Purpose of the OSMP "in accordance with existing legislative and regulatory controls". The MOU also states that data and information from the OSMP will be provided to decision-makers to inform management and regulatory action.

Cumulative effects assessment requires thresholds which can then be used to indicate the need for management action. The role of OSMP is to provide the science behind risk-based thresholds of cumulative effects. While science can contribute to the development of these thresholds, social, cultural, and economic criteria are also required.

Review of relevant CE policies is recommended, including the current CE policy in British Columbia (Province of BCCEF 2017a). The BC policy is specifically recommended because it provides an overarching framework which encompasses both cumulative effects assessment and cumulative effects management. It also provides foundational information that can be used to inform engagement with Indigenous communities. The policy informs the cumulative effects science conducted within BC regions and sub-regions; thus, it represents an effective bridge between cumulative effects practitioners and decision-makers. Successful regional-level cumulative effects assessments require frameworks which focus on the ultimate goal of informing decision-makers and which provide a consistent, logical process. The Province of British Columbia's Cumulative Effects Framework (BCCEF) includes policy, procedures, and decision support tools to improve the consideration of cumulative effects in natural resource decision-making in BC (BCCEF 2017b). The BCCEF is applied province-wide, with values and valued ecosystem components varying among regions. The spatial scale is generally landscape to sub-regional. A cumulative effects interim policy was approved in 2017 (BCCEF 2017a). The policy includes definitions, purpose and authority, key roles and responsibilities, engagement and collaboration requirements, and monitoring requirements. The policy also provides guidance for cumulative effects management.

Recommendations Regarding Cumulative Effects

Create an overarching framework for cumulative effects. (This activity is underway).

An OSMP cumulative effects framework (CE Framework) is required. Work on development of the CE framework has begun. The OSMP CE Framework is being custom-built to be consistent with the OFA as well as reflect current cumulative effects practice. A notable requirement will be to ensure that the CE Framework addresses the integration of western science and Indigenous Knowledge.

The OFA stipulates that the OSMP is risk-based. Therefore, the CE framework should incorporate fundamentals of a risk-based approach, starting with the use of conceptual models.

A risk-based approach requires the identification of receptors which not only can be exposed to a stressor because of where they live, what they eat, and their migratory patterns, but which are also sensitive to that stressor. The conceptual models can be used to identify receptors which are both likely to be exposed to oil sands-related stressors via direct and indirect pathways and which are also sensitive to the stressors being assessed.

A risk-based approach also requires the development of thresholds of acceptable risk. As noted above, the OSMP provides the science behind risk-based thresholds   Other agencies/legislation/regulation provide thresholds which incorporate additional criteria.

Regular and effective information exchange and coordination among policy makers, regulators and the OSMP is required. Management of cumulative risk is driven by policy and regulation. Cumulative effects assessment results generated by the OSMP can inform larger-scale risk management (e.g. under the Lower Athabasca Regional Plan) as well as regulation of the oil sands industry.

The OSMP CE Framework should include basic features common to current cumulative effects frameworks and methods such as those described by Noble (2015), including:

- A definition of cumulative effects;
- The Master Conceptual Model (which is under development) supported by individual conceptual models;
- Representative receptors (also called Valued Components) selected via the use of criteria which address western science, Indigenous Knowledge, and practical considerations;
- Explicit spatial and temporal boundaries (which will vary according to combinations of stressors, pathways and receptors);
- A decision-tree process based upon the decision-making process in the OFA which identifies when there is sufficient confidence in source attribution and causation to support decision-making by incorporating the concept of "tolerable decision error"; and
- Clarity regarding the appropriate use of stressor-based and effects-based approaches within the OSMP CE Framework (good CE assessment requires both);
    - Stressor-based is prospective in design – what might or could happen; the focus is typically on quantifying current (and sometimes past) levels, types and distributions of stressors and then projecting stressors into the future under different scenarios.
    - Effects-based is retrospective in design – focusing on what has happened. Effects-based approaches measure the accumulated environmental state and identify whether indicators are at or below acceptable risk thresholds.

The CE Framework should reference and incorporate as appropriate the work done by the Cumulative Effects Management Association (CEMA). CEMA provided recommendations and management frameworks pertaining to the cumulative effects of oil sands development. CEMA was comprised of more than 50 members organized into Indigenous, Government, Non-Government and Industry caucuses. It had working groups on Land, Air, Water and Reclamation. It delivered management frameworks for stressors such as ozone, acid deposition, trace metals, and nitrogen. Its work products and recommendations provide directly relevant information for use by the OSMP. However, although CEMA had a clearly articulated mission and goals, a cumulative effect framework was not produced.

Recommendations Regarding Component Monitoring and Modelling

The mercury component should be combined with the Atmospheric Deposition Component.

- The combination of the mercury component with the Atmospheric Deposition component will help ensure that there is coordinated, prioritized monitoring and modelling of mercury with no duplication of effort and with consensus regarding appropriate measurement and modelling approaches.
- The first task regarding mercury must be to increase our understanding of mercury sources and speciation in order to establish whether the oil sands industry is a significant source of mercury relative to other sources (as per the top-priority uncertainty identified at the Mercury Integration Workshop). If the oil sands industry is confirmed as a significant source of mercury, then work can proceed regarding improving the understanding of the fate and transport of mercury.

Geospatial Science and Predictive Modelling should be explicitly integrated with all components.

- The Geospatial Science workshop identified priority uncertainties and key questions for near-term and longer-term application of geospatial approaches (Annex 2). These priorities should be the basis for planning for integration of geospatial science. Some of this integration has already begun.
- The Predictive Modelling workshop identified priority pathways (also called linkages) within conceptual models which should be addressed through the use of modelling (Annex 2). These priorities should be reviewed and built into work plans for relevant components (and combinations of components). For example, integration of groundwater and surface water modelling is needed with respect to the location of groundwater-dependent ecosystems in the oil sands region.

Recommendations Regarding Long-term Monitoring

The long-term monitoring program (also called the "core program") should be fully integrated.

- Non-integrated long-term monitoring does not meet the OFA objective of being comprehensive and inclusive, nor does it meet the objective of being cost-effective.

An evaluation of the current status of OSMP long-term monitoring should be completed.

- This evaluation should identify current strengths and weaknesses relative to the objectives stipulated in section 2.3 of the OFA. In particular, current long-term monitoring should be evaluated in terms of its effectiveness in reliably measuring change in response to oil sands industry-related stressors.
- This evaluation should start with the findings of the Integration Workshops regarding "where are we" with respect to the OSMP Objective and Three Core Outcomes.
- The evaluation must identify relevant, available long-term monitoring data available from other government, industry, or academic programs.
- The contribution of past long-term monitoring to the establishment of baseline conditions must be assessed and strengths and weaknesses identified.
- The evaluation should include identification of gaps or inadequacies in:
  - relevance to Indigenous concerns and Indigenous Knowledge;
  - temporal or spatial coverage (from the point of view of individual programs or components as well as according to the requirements of an integrated understanding of ambient environmental change);
  - measurement of stressors of concern (physical, chemical and biological);
  - measurement of important co-variables;
  - co-location of measurements among components such as air/surface water/aquatic biota;
  - coordination of timing of sampling;
  - data quality; and
  - data management.

All long-term monitoring must be in the context of the OSMP conceptual models.

- There must be clarity regarding how the long-term monitoring is measuring stressor sources, pathways/mechanisms, and effects and how those measurements, taken together, can be used to build multiple lines of evidence regarding the effects of oil sands industry-related stressors.

On-lease data from compliance monitoring must be considered for inclusion in the long-term monitoring database.

- On-lease data are required to fully address the stressor-pathway-response conceptual models.
- This information can be used to check for coherence and consistency of trends along a spatial gradient from “inside the fence” to near-field to far-field.

Long-term monitoring must be supported by modelling and geospatial analysis.

- Modelling and geospatial analyses are required to test and validate spatial and temporal boundaries, sampling frequency, and requirements for supporting information.
- Modelling and geospatial analysis should also be used for retrospective assessment of past monitoring data and for comparison of plausible future scenarios. The results of modelling and analyses can be used to identify which monitored indicators have changed, past and possible future trends in those indicators, and correlations between the indicator responses and stressor levels.

Long-term monitoring must be integrated with community-based monitoring.

- Community based monitoring can make substantial contributions to increasing spatial and temporal coverage. It is also key to integration of Indigenous knowledge into long-term monitoring information, including past conditions and patterns.

Long-term monitoring of integrated reference sites is required.

- Consensus on appropriate reference sites which are useful for integrated monitoring must be established.
- The concept of “super sites” was raised by Atmospheric Deposition workshop participants. Similarly, the concept of “representative study basins” was discussed by Groundwater as well as Surface Water/Aquatic Biology workshop participants. A fully instrumented representative basin was recommended at the Surface Water/Aquatic Biology workshop. The use of these concepts in assisting in integration of long-term monitoring should be evaluated.

Long-term monitoring must continuously be updated as new tools and approaches are developed and shown to be applicable to the OSMP.

Recommendations Regarding Focused Monitoring

Focused monitoring should address priority uncertainties and key questions (verified by the OSMP) and should also be explicitly related to conceptual models.

- Focused monitoring must address one or more of the following:
  - identification and confirmation of change in important stressors or effects for which insufficient information is available;
  - investigation of causation;
  - opportunities for integration among OSMP components; and
  - supporting geospatial analysis and predictive modelling.

Recommendation Regarding Community Based Monitoring

The key questions produced at the Integration Workshops and subsequently verified by the OSMP should be considered by the Community Based Monitoring Advisory Committee (CBAMC) and compared to the priority concerns identified by communities.

- This comparison can be the basis of identifying the key questions which require input from community-based monitoring.
- Key questions arising from community concerns which were not addressed by the Integration Workshops should be communicated to the SIKIC.

Recommendation Regarding Data Integration and Analytics

There was strong consensus at every Integration Workshop about the importance of accessible, reliable, and up-to-date data. Now that data management has been moved to Service Alberta, clear, consistent and strong input from the OSMP through SIKIC to Service Alberta will be required in order that the crucial data needs of the OSMP are met.

Recommendations Regarding the Key Uncertainties and Key Questions Which Require an Integrated Approach

Specific recommendations with respect to the priority uncertainties (with associated key questions) which require integration are presented below. The priority uncertainties and key questions are subject to verification by the OSMP via the processes stipulated in the Operational Framework Agreement. Therefore, the recommendations in this report are subject to amendment according to the verification process.

Some of the recommendations presented below are from workshop discussions regarding "how are we going to get there", as well as action items identified at the end of the workshops. The Workshop Summary Report should be referred to for details.

Some of the key uncertainties and key questions will require long-term monitoring, while focused monitoring may be sufficient for others. Many will require a combination of long-term and focused monitoring.

Specific items which are recommended for completion in the near-term are identified below. These items should be incorporated into the 2019-2020 and 2020-2021 workplans as much as possible.

NOTE: in all recommendations presented below, the Mercury component is considered to be part of the Atmospheric Deposition component. This is because definitive conclusions are required regarding whether the oil sands industry is a significant source of mercury before any substantial work on pathways and effects should proceed.

Key Uncertainty: Discriminating among natural, oil sands industry-related and other anthropogenic stressor sources and effects

Key Questions: How do oil sands-related effects on terrestrial biota compare to effects from other anthropogenic stressors (at specific spatial or temporal scales)? What is the natural range of variability for groundwater quality and quantity? What are the differences in contaminant signatures from upper reaches to lower reaches in tributaries of the Athabasca River (e.g. Firebag (reference) vs Steepbank)? What are the differences in sources and loads of inputs among sites? What is the contribution of source input differences to ecological effects (e.g. role of interannual variation in flow)? What are the sources of fugitive dust and what is the magnitude and speciation of sources? What are the major sources of ammonia – oil sands vs non-oil sands (50 km from fence line)? What fraction of total nitrogen deposition is attributable to oil sands? Is the oil sands industry a source of mercury? What are the oil sands processes that could contribute to methylation of mercury? What are the mercury emissions outside of the oil sands region? What is the characterization of mercury emissions from stacks and land disturbance (including speciation)? What are the natural versus anthropogenic sources of mercury in the oil sands region? What is the spatial and temporal variation of source contributions?

Every component workshop produced key questions related to source attribution and four of the five critical pathways selected by participants at the predictive modelling workshop involve at least some degree of comparison among stressor sources.

Without confidence in source attribution, there cannot be confidence in advice given to decision-makers regarding adaptive management and regulation of the oil sands industry. Therefore, this uncertainty has been placed at the top of the list for integrated work planning and implementation.

Recommendations Regarding Source Attribution and Causation

Include source attribution and causation as a specific item for SIKIC deliberations and recommendations.

Information to provide to the SIKIC should include:

- Integrating the above key questions into a short list by removing redundant and overlapping questions and by crafting questions which are to be addressed in an integrated manner.
- Acquiring and evaluating relevant data from the oil sands industry in order to increase the understanding of which contaminants (including speciation) can plausibly be linked to oil sands processes.
- Workplans for investigation of cause based upon the results of the workshops, review of current evidence, literature reviews, and regular inter-component consultation, including consultation with Indigenous communities.

Key Uncertainty: Quality, quantity, safety and availability of traditional resources

Key Questions: (From the Terrestrial Biological Monitoring Workshop) What species should we focus on? Are we monitoring an appropriate range of spatial scales to answer communities' questions? (From the Surface Water and Aquatic Biology Workshop) What are the commonalities between existing OSM work and communities and how do you maximize exposure of OSM programs in these communities in response to community needs? Are the monitoring endpoints used by surface water and aquatic biology relevant to communities? (From the Mercury Workshop) What has been done to date to measure mercury in traditional foods? Where? How? Do the food items that have been measured encompass the full range of subsistence foods? Are the samples taken at the right place and time? How are traditional foods prepared and what is eaten? Does the perception of pollution from oil sands development affect use of subsistence foods? What consumption advisories have been issued? Do the advisories affect the use of subsistence foods?

Recommendations Regarding Quality, Quantity, Safety and Availability of Traditional Resources

- These key questions should be discussed and addressed as a set.
- Information on whether consumption advisories have been issued should be assembled as soon as possible. These answers should be assembled prior to discussions.
- These questions should be raised and discussed at the SIKIC as soon as possible with feedback provided to all OSMP components.
- Direct interactions between OSMP component investigators and Indigenous communities regarding these questions should be arranged through the OSM program office. These interactions should begin in 2019.
- A need for more fish tissue data for large-bodied fish was identified at the Surface Water/ Aquatic Biology workshop. Addressing this need should begin in 2019. A specific workplan should be prepared which integrates community-based monitoring and the Surface Water/ Aquatic Biology components.

Key Uncertainty: Knowledge held by Indigenous communities

Recommendations Regarding Integration of Indigenous Knowledge

There were no specific key questions developed for this uncertainty. The following recommendations come from workshop participants:

- It all starts with effective engagement with Indigenous communities.
- Work with communities has to be long-term, reciprocal and beneficial.
- Identify opportunities for integration of community knowledge with specific projects such as the projects conducted by Parks Canada regarding abundance of muskrat, amphibians, and macroinvertebrates in the PAD.
- Start a project for mapping community knowledge of traditionally access resources.
- Formalize entry points to communities for people who want to work with communities as well as communication protocols between western scientists and communities.
- Specifically discuss and identify effective approaches to building capacity in the communities through engagement with the communities and/or via SIKIC.
- Hold a workshop on community-based monitoring programs to align the existing or proposed programs with OSM and other government programs (optimize).

Key Uncertainty: What are the levels of uncertainty related to predicted and observed effects on biota including rare species

Key Question: What is an acceptable level of uncertainty when evaluating species?

This Key Question was identified by Terrestrial Biological Monitoring workshop participants. However, it applies to both terrestrial and aquatic environments.

Recommendations Regarding Acceptable Level of Uncertainty When Evaluating Effects

- According to OFA principles, a risk-based approach should be used to address this question. A series of risk-based benchmarks as described above should be development for species or communities.
- A risk-based benchmarks workshop in 2019 or early 2020 is suggested as a logical first step.

Key Questions: What pathways should be priorities for understanding effects on receptors? Is the current approach for setting priorities sufficient to predict future states? What approaches are needed to address this?

Recommendations Regarding Priority Pathways of Exposure

These key questions require integration of all components, with the support of Geospatial Science and Predictive Modelling.

- In the near-term, (2019-2020), the conceptual models should be used to:
  - Identify common stressors and pathways
  - Identify stressors, pathways and receptors which have not received sufficient attention
  - Set priorities according to the potential for exceedance of risk-based thresholds
  - Use the priorities as the basis for workplans for the first 5-year strategic plan

Key Uncertainty: Effects of atmospheric deposition

Key Questions: What are the effects of enhanced nitrogen deposition on vegetation communities? What are the effects of enhanced sulphur deposition on vegetation communities? How does the type of land cover, topography, etc. affect the mass of contaminant "x" deposited and accumulated? What is the spatial and temporal variability in the hydrological connection between the depositional areas and regional waterbodies? What are the key drivers of spatial and temporal variability in the hydrological connection between depositional areas and the waterbody? What is the fate of contaminant "x" once it is deposited to the landscape? What proportion of contaminant “x”, once deposited, is delivered to the waterbody and how does this change seasonally, interannually and spatially? What are the effects of multiple interacting stressors in atmospheric deposition (e.g. base cations, nitrogen compounds and sulphur compounds)? What are the differences in sensitivity to atmospheric deposition among ecosites? What spatial and temporal scale do we see impact from nitrogen deposition (in situ vs mining; near, mid and far-field)? What are the effects of different nitrogen species in different receiving environments?

The number of key questions about the effects of atmospheric deposition reflects the fact that currently, stack emissions and fugitive dust are the primary oil sands industry-related sources of contaminants of concern. The questions indicate a clear need for integration across Atmospheric Deposition, Terrestrial, and Surface Water/Aquatic Biology components, with assistance from Geospatial Science and Predictive Modelling components.

Recommendations Regarding Effects of Atmospheric Deposition

- Near-term (2019-2021):
  - Initial geospatial analysis: Data required to address these key questions should be compiled, evaluated by geospatial scientists for quality, appropriate resolution, and applicability and then used for initial exploration of the above questions by geospatial scientists in conjunction with specialists from the Atmospheric Deposition, Groundwater, Surface Water/Aquatic Biology and Terrestrial components. Data needs and sources were identified by Geospatial Science workshop participants as follows:
  - Soils - Government of Alberta
  - Deposition of N, S, and base cations –AEP and ECCC (modelled), WBEA (measured); EIAs
  - In situ vs surface mining (WBEA)
  - Impacts of wildfires (Government of Alberta, ECCC, academics)
  - Dustfall data and mapping
  - Improved understanding and quantification of base cation and N sources/emissions (both oil sands industry and natural fires)
  - Magnitude of sources of N, S and base cations
  - Particle size distribution (to improve estimates of dry particle deposition)
  - Leaf area index – can use airborne remote sensing
  - Vegetation responses to deposition
  - Soil inventory for the oil sands region

- Medium-term.
  - After the initial geospatial analysis, the atmospheric deposition, terrestrial, groundwater, surface water/aquatic biology and community-based monitoring components should produce an integrated workplan. A suggested approach is to start with pilot source-pathway-effects linkages, with a focus on areas where modelling has predicted exceedances of critical loads. Wetlands should be considered for these pilots because of their inherently integrated nature.
  - The integrated workplan should use the geospatial analysis results to identify critical data gaps, refine data resolution, and optimize monitoring to ensure appropriate co-location and timing of sampling, indicators, and measurement of co-variables.
- Subsequent workplans should be built upon iterations of geospatial analysis, modelling and monitoring.

Key Uncertainty: Fugitive dust sources and pathways for base cations and trace elements. Includes spatial uncertainty and seasonality.

Key Questions: What can vegetation data tell us about deposition of fugitive dust? What is the impact of reducing fugitive dust on human health versus the neutralization benefits? What is the mobility of base cations from terrestrial ecosystem deposition to aquatic ecosystems? What are the responses to the combination of base cations, nitrogen compounds and sulphur on receptors (plans, surface waters)? What is the relative contribution of fugitive dust to mercury deposition and transformation?

Recommendations Regarding Fugitive Dust

- Near-Term (2019-2021):
  - Design a focused monitoring program of fugitive dust. Include comparison of aircraft observations with surface observations. Integrate with terrestrial, surface water/aquatic biology, and community-based monitoring components in order to ensure appropriate co-location of deposition and effects monitoring, sample frequency and timing, and collection of supporting data. Include determination of the particle size distribution of dust with distance. Incorporate methods for source attribution. Include analysis of dust for contaminants of concern (including speciation). Include sites in the Cold Lake region as well as the AOSR. The design should be readily adjustable for application to the Peace River region.
  - Design a dust modelling program to complement the monitoring program and provide initial predictions.

Key Uncertainty: Long-term deposition trends for contaminants of concern produced by the oil sands industry.

Key Questions: on a chemical species-by-species basis, does the existing monitoring program adequately capture the spatial deposition? How far out do we need to measure before we get to no effects or background levels? Are we adequately measuring other oil sands regions such as Peace River, Cold Lake? Do we need to characterize other regions in the same way we have done for surface mining operations? Can we design a monitoring program that validates model predictions of long-range deposition? Are we monitoring the right things?

Recommendations Regarding Long-Term Deposition Trends

- See the recommendations for the Long-term Monitoring Program in an earlier section of this report.
- Provide input to the review of the OSM Long-term Monitoring Program by:
  - Assemble an integrated team of air quality and deposition, terrestrial, surface water/aquatic biology and community-based monitoring specialists to conduct a critical review of the current status of modelling and monitoring with respect to addressing the above key questions. Prepare a report which identifies critical gaps and limitations.
  - Use the results of the critical review and workshop to prepare an integrated workplan which addresses the key questions.
  - Clearly identify the long-term monitoring versus focused monitoring elements of the workplan.

Key Uncertainty: Definition, location and sensitivity of groundwater-dependent ecosystems (GDEs)

Key Questions: where are the groundwater-dependent ecosystems? Which GDEs would be impacts most seriously by changes in groundwater quantity and quality? Which are most sensitive? Has industry altered the rate of Devonian water discharge into the Athabasca River? What is "critical" alteration? How and to what extent does groundwater influence fens?

Recommendations Regarding Groundwater-Dependent Ecosystems

- Near-term (2019-2021):
  - Produce a preliminary map of GDEs (see information presented in the Workshop Summary Report, Geospatial Science section regarding data requirements and approaches).

- Produce an integrated workplan which targets groundwater-dependent habitats in streams, ponds and lakes. Integration of groundwater and surface water/aquatic biology specialists will be required, including fish and amphibian habitat specialists.

- Medium-term:
  - Implement wetland workplans. Incorporate community-based monitoring and earth observation/remote sensing tools.
  - Implement workplans for groundwater-dependent habitats in streams, ponds and lakes. Incorporate community-based monitoring and earth observation/remote sensing tools.
  - Update and refine the maps of GDEs as information is generated.

Key Uncertainty: Reclamation Success

Key Questions: does the local reclaimed system fit with the surrounding system? What are the desired conditions and uses of the reclaimed landscape? Is different monitoring required to understand sub-regional success vs local success (on lease)?

Reclamation is not within the scope of the OSMP.

Notwithstanding the fact that reclamation is outside the OSMP Scope, understanding the role of reclamation in stressor-pathway-receptor linkages and subsequent effects is critical. On-lease reclamation can substantially influence sources and pathways, as well as the presence of receptors. As the spatial and temporal effects of reclamation expand, an understanding of operations-related versus reclamation-related environmental responses will be required. Otherwise, decision-makers will not be equipped with sufficiently clear results with which to judge the effectiveness of operational and reclamation requirements.

Coordination between the OSMP and agencies/industry/academics currently investigating reclamation is highly recommended in order that both the current environmental conditions as well as possible future environmental conditions can be adequately and appropriately evaluated.

Key Uncertainty: Effects of climate change.

Key Questions: Do the time scales used in current climate change models predict changes in the oil sands region with respect to groundwater? Can predictive modelling be used to test the resiliency of reclamation scenarios given potential climate change impacts? How does climate change affect the overall water balance in the oil sands region? How are changes in climate affecting location, timing, chemistry of surface and groundwater? Can the effects of groundwater withdrawals be distinguished from climate change and at which spatial scale?

Predictive modelling within the OSMP has already incorporated climate change in some cases (e.g. hydrologic and water quality modelling). However, there has been no integration of models across the OSMP components.

Recommendations Regarding Effects of Climate Change

- Near-term (2019-2021):
  - As part of the integrated development of conceptual models, produce conceptual models of climate change-related effects on source-pathway-receptor linkages. Identify potential critical changes caused by climate change that may significantly alter the fate and transport and/or the effects of contaminants of concern. Identify potential critical climate-change alterations of habitat.
  - Incorporate the conceptual models of climate change into all workplans for addressing critical pathways through predictive modelling (see list of the top five critical pathways in Annex 2).
- Medium-term:
  - Based on initial modelling results for critical pathways under climate change scenarios, produce long-term monitoring workplans to be incorporated into the long-term monitoring program.

Key Uncertainty: The spatial and temporal scales required to define conditions and allow removal of "footprint".

Key Questions: How do temporal and spatial scales vary with respect to effects on ecosystem structure versus ecosystem function? When is a footprint no longer a footprint?

This uncertainty with associated key questions was identified by Terrestrial Biological Monitoring workshop participants; however, the key questions presented above apply to aquatic ecosystems as well, including groundwater and surface water flow systems and aquatic community structure and function.

Recommendations Regarding Spatial and Temporal Scales Relevant to Ecosystem Effects and "Footprint"

- Near-term (2019-2021):
  - These key questions are related to key questions about causation; these questions should be included in the review information provided to the SIKIC regarding source attribution and causation (see above).
  - The definition of "footprint" was controversial at the integration workshops; therefore, it is recommended that a consensus-based definition of "footprint" be developed. A draft definition should be submitted to the SIKIC for review.

- Medium-term:
    - Implement approved workplans for addressing the above key questions.

Recommendations for Specific OSMP Components

Some key questions produced by workshop participants are specific to individual components. The specific key questions are identified by yellow highlights in Annex 2.

Although the workshops were productive and successful in terms of identifying priority uncertainties and key questions, there will undoubtedly be additional key questions proposed. Additional key questions should be evaluated according to how well they address the OSMP Objective, the OFA Objectives, and the three Core Outcomes.

What It Will Take to Achieve Integration

The following points summarize guidance provided in the literature regarding collaborative science and integrated scientific teams.

Leadership

Integration of OSMP programs will require strong, focused and dedicated leadership from within the OFA structure.

> *"I suppose leadership at one time meant muscles; but today it means getting along with people"* M Ghandi

Applicable leadership characteristics are:

- Foresight
    - Anticipating change and challenge
    - Adaptability
- Commitment
    - Committed to promises, duties and tasks, working alongside the rest and showing them challenges can be met
    - Persistent

- Authenticity
  - Clear intentions and consistency
  - Embracing diversity in all forms, being unique by displaying strengths and areas of weakness, understanding their own identity and knowing how to delegate while making their own contribution towards success
  - Trustworthiness
  - Understanding and owning up to personal drawbacks
- Skilled Communication
  - Effective communication which creates a sense of ease and understanding
  - Offer recognition for effort and achievement
  - Effective listening skills
  - Sense of humour
- Ability to delegate back to the OSMP teams and/or other OFA committees
  - Recognize when it's not the committee's job
  - Reinforce successful processes
  - Give constructive feedback
- Ability to inspire
  - Strong sense of purpose
  - Optimistic
  - Create a culture of inclusion
  - Demonstrate integrity
  - Show genuine interest in the integration teams – gets to know team members as individuals in the context of the work
  - Champion change

Adequate Resources

Long-term, sustained support for the existing analytics team within the OSMP is vital to integration. There must also be sustained and adequate resources provided for the support of administrative and communication functions provided by the OSM Program Office; these functions will be key to the success of integrated teams.

Suggested Principles for Integration of OSMP Programs

Integration requires teamwork. Some guiding principles for successful multidisciplinary research and monitoring teams are provided by Bennett et al. 2010, Bennett and Gadlin 2012, Lustig et al. 2015, and Roncaglia 2016. These are presented (with adaptations to the OSMP) below.

- All team members must be familiar with the OFA, including its governance structure, principles, and objectives. The OFA provides the shared Vision and Mission for integration teams.
- Make operational plans for each integrated team.
    - Define the role of each party
    - Define the objectives of each party
    - Plan for training of researchers
    - Strategies to be used to address problems with the project and personnel
    - Address intellectual property issues
    - Identify timelines, plan for different timelines of each group's contribution. Plan for how milestones and expectations are managed
- Make provisions for appropriate recognition and credit.
    - Develop a system to provide appropriate credit to all researchers
    - Rules for authorship
    - Responsibility for writing manuscripts
    - Extend credit to trainees in addition to PIs
- Develop agreements for how financial resources are shared.
    - Agreement from the onset how PIs share the financial resources
    - Avoid a single "lead PI" who decides to control all the funding rather than share from the onset
- Budget plan – for who does what and for how much.
- Build in practical limits and contingencies.
- Implement effective project and time management.
    - Develop a master project plan
    - Objectives for each facet of the project

- Long and short-term goals'
- Procedures
- Tangible milestones and deliverables
- Identify each researcher's activities
- Allow subprojects to be evaluated during the course of the bigger project
- Allow modification of goals as the project evolves
- Realistic timelines
- Identify potential issues with respect to work sequence and timeliness of meeting deliverables in the planned sequence

- Encourage open team communication through a variety of methods.
    - Be fair and respectful
    - Hold yearly integration workshops
    - Hold quarterly team web meetings
    - Hold monthly or bimonthly progress/tactical meetings
- Conference calls, web mtgs).
- Short activity report to be circulated electronically prior to each mtg.
- Standard agenda for regular mtgs.
    - Provide opportunity for all team members to participate in meetings – not just PIs; e.g. invited presentation at monthly mtg; attendance at semi-annual in-person team mtgs

Managing and Mitigating Risks to Effective Integration

<u>Communication Barriers</u>

"…scientists would rather be doing science than concerning themselves with discussions about how they are all getting along"

Recommended Risk Mitigation

- Learn the language and understand context: define jargon and terms; address differences in understanding of the same terms.
- Create an environment that is collegial and non-threatening.
- Openly recognize strengths of all team members and discuss how these different strengths contribute to advancing the project.

- Take a few minutes at regularly scheduled group meetings to do a check-in. Ask how everyone is doing.
- Encourage open and honest discussion by establishing trust.
- Jointly develop a process for bringing issues and disagreements forward for early resolution.
- Assure than when decisions are being made that require everyone's input that each person has an opportunity and understand the process for providing input.
- Schedule periodic assessments and feedback – including opportunities for collaboration to discuss what is going well, what is not, and what needs to be improved.
- Recognize and manage alliances and coalitions against others.

<u>Inadequate Resources: Accessibility and Availability</u>

Financial and organizational constraints can lead to fragmented work patterns and working off sides of desks. Staff turnover can interrupt work flow and create delays in reaching milestones.

Recommended Mitigation

- Prepare a financial plan with clear financial requirements for each critical element of integration. The plan should present the consequences of funding shortfalls in terms of schedule and deliverables.
- Plan for contingencies such as staff turnover by identifying training and mentoring requirements and responsibilities.

<u>Lack of Trust, Disagreement and Conflict</u>

Issues of boundaries and territory may arise when group members feel that they are treading on each other and there is a lack of clarity and productivity. Acceptance of the lead professional from a different discipline can be an issue. Some team members may be uncomfortable with group decision-making. There may be disconnects between the goals of the team and the aspirations and career needs of team members.

Recommended Mitigation

- The Integration Director is provided with training in leading diverse (and potentially large) teams.
- Develop collaborative agreements for all integrated projects which stipulate:
    - Roles and responsibilities;
    - Processes for allocation of funds;
    - Processes for sharing of data and materials;

- Publication standards and processes;
- Decision-making processes; and
- Conflict resolution procedures.

- Establish and maintain a focus on effective communication (see above recommendations).
- If one of the collaborative members feel there is inequality, deal with this immediately.
  - Communication hierarchy:
- Issues with funding or problems with personnel – PIs should discuss.
- Issues with specific project – all researchers on the team discuss.
- Protocol for conflict among PIs or PIs not respecting the PI who is making decisions with respect to a particular project – refer to the Integration Director.
- Disclose financial and competing interests.
- Establish a procedure for dealing with conflict.
  - Outside mediator
  - Oversight Committee
  - Etc.
- Create a safe environment for discussion of hot button and controversial issues.
  - Focus on the issues, not the people
  - Keep discussion centred on ideas
- Understand how trust is built in scientific teams.
  - Calculus-based – engendered when we interact with people who keep their word, meet deadlines and fulfill expectations agreed upon in our communications with them. Such trust is not dependent on a deep personal understanding but over time in can contribute to personal bonds.
  - Competence-based – the confidence we have in the capabilities and skills of another person. Can also lead to more personal trust.
- Promote team awareness.
  - Personalities, tendencies, strengths and weaknesses of team members.
  - Shared understanding of the most effective and efficient modes of working together.

Recommended Team Performance Metrics

The overarching purpose of a measurement system should be to help the team gauge its progress (Meyer 1994). While the need for collaboration has increased, the way researchers are evaluated is still lagging (Lindsay et al. 2015). This can disadvantage scientists who collaborate. This must be avoided in the OSMP.

A balanced set of metrics which reflect important contributors to team performance is recommended (Goring et al. 2014).

The following performance metrics are suggested:

- Internal team communication and collaboration: team in-person and on-line meetings; workshops (including field visits), tracking of issues and the resolution of those issues.
- Knowledge generation: # of team publications; publications with interdisciplinary authorship; mentoring and training of team members.
- Policy and management outcomes: compliance with OFA principles and objectives; on-time and on-budget performance.
- Innovation: improved or new methods, products, approaches and analyses.
- Public outreach: common language publications and other accessible products such as maps and visualizations; participation in community meetings, panel discussions, public seminars.

Suggested Topics for Future Workshops

In order to build and maintain momentum towards integration, the following workshops are recommended.

1. Workshops on Integration of Traditional Knowledge and Western Science. The first workshop occurred on June 6-7, 2019. See above recommendation for referring to the key questions developed at the Integration Workshops and identifying those which lend themselves to integration with community-based monitoring and traditional knowledge.
    - A second workshop is recommended for fall or early winter.
    - NOTE: it is recommended that integration of work in the Peace Athabasca Delta receive specific attention, with the goal of achieving a suite of jointly-designed and implemented projects aimed at discriminating oil sands-related effects from other effects (such as the effect of upstream dams).
2. Inaugural Cumulative Effects Program Workshop. To be led by the team currently working on the Master Conceptual Model and Cumulative Effects Framework. The workshop goals will be to achieve consensus on foundational aspects of the cumulative effects program.

- Geospatial science and predictive modelling will be central to the cumulative effects assessment program; the roles to be played by these two disciplines will be stipulated in the draft Cumulative Effects Framework.

- Recommendations produced by the TK/WS workshops regarding work on the Peace Athabasca Delta should be discussed in light of requirements of the assessment of cumulative effects in the Delta.

3. Wetland Integration Workshop. This workshop will identify the best opportunities for integration across groundwater, surface water, terrestrial, and aquatic biology disciplines with the support of Geospatial Science as well as modelling.

4. Causation workshops: one for Terrestrial and one for Aquatic. One or two-day workshops to develop methods for investigating the cause of observed effects on terrestrial and aquatic biota in order to discriminate the relative contribution of oil sands operations to the effects.

5. Integrated Long-term Monitoring Workshop. This workshop will be based on a critical review of how well current long-term monitoring addresses OSMP objectives. Opportunities for improvement will be identified. Ideas such as “super sites” and “representative watersheds” will be discussed.

6. Cumulative Effects Program Workshop #2. The goal of this workshop would be constructing a set of projects within the Cumulative Effects Framework to test the effectiveness of the Framework.

7. Risk-based Benchmarks workshop. This workshop will focus on the approaches for development of risk-based benchmarks required to establish change and, in turn, effects in the context of monitoring.

Recommended Workshops Beyond 2020

- Yearly Integration Workshops which continue to use and refine the Master Conceptual Model as well as theme-specific conceptual models to help identify the top priority uncertainties with associated key questions which require integration. (See Annex 1 for specific recommendations for each priority uncertainty).

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Annex 2: Compiled List of Priority Uncertainties and Key Questions

Introduction

This Annex presents the key uncertainties (in order of priority) and associated key questions developed at the Terrestrial Biological Monitoring, Groundwater, Surface Water and Aquatic Biology, Atmospheric Deposition and Mercury workshops. Key uncertainties were identified at each workshop using a prioritization process which produced 5-6 key uncertainties. A set of key questions was then developed for each of the key uncertainties.

This Annex lists the top 5 key questions for application of geoscience tools and approaches which were selected by Geospatial Science workshop participants from the compiled list of key questions produced by earlier workshops.

This Annex lists the top 5 critical pathways for application of predictive modelling which were selected by Predictive Modelling workshop participants based upon conceptual models produced for previous workshops.

Highlighted key questions are those which pertain to one component only. All other key questions require integration among components in order to obtain a fulsome answer which meets OSMP objectives. All key questions related to source attribution and causation have been included in recommendations for an integrated approach to these two important issues.

Terrestrial Biological Monitoring

Key Uncertainty: Quality/ quantity/safety, availability of traditional resources

Key Questions:

- General: all questions relate to quantity and quality of things you eat.
- What species should we focus on?
- How do we build trust in communities?
- Do studies need to be done more regionally, reflecting concerns of several communities? Or should we work with individual communities? (regional approach could be challenging because concerns vary among communities).
- Are we monitoring an appropriate range of spatial scales to answer communities' questions? (e.g. localized depletion of mammals).

Key Uncertainty: What are the levels of uncertainty related to predicted (and observed) effects on terrestrial biota including rare species

Key Questions

- What is an acceptable level of uncertainty when evaluating species (this is a science-informed policy decision)?
- What pathways should be priorities for understanding effects on receptor species? (some taxonomic groups have less developed understanding).
- Is the current approach for setting priorities sufficient to predict future states? What approaches needed to address this?

Key Uncertainty: What spatial and temporal scales are required to define conditions and allow removal of "footprint"

Key Questions

- General Questions:
  - What is the appropriate scale with respect to oil sands-related effects?
  - How do temporal and spatial scales vary with respect to effects on ecosystem structure versus ecosystem function?
  - When is a footprint no longer a footprint? Need to consider and define temporal scale – historic and future.
- Specific Questions:
  - Which species are most sensitive to habitat fragmentation?
- Include habitat fragmentation from in situ oil sands operations.
  - What is the rate of spatial change in conditions which affect caribou populations?
- And how much of this change is due to oil sands activities?
  - How do oil sands-related effects on terrestrial biota compare to effects from other anthropogenic stressors (at specific spatial or temporal scales)?

Key Uncertainty: State, trend, cause-effect relationship for mammal and plant communities

Key Questions

- Raw Workshop notes do not contain recognizable key questions.

Key Uncertainty: Effects of atmospheric deposition

Key Questions

- Divide AD into key classes that manifest themselves differently in terms of effects.
  - PACs, Hg, Metals.
  - Acidifying and nitrifying.
  - What are the levels of mercury in foods consumed by Indigenous people?
  - What are the effects of enhanced nitrogen deposition on vegetation communities?
  - What are the effects of sulphur deposition on vegetation communities?

Key Uncertainty: Knowledge held by indigenous communities

Key Questions

- NOTE: Questions must be developed via engagement with communities.
- In general, the concerns focus on impacts of oil sands development on quality and quantity of traditional resources.
- Need alignment regarding what is "safe" or "healthy" and what is not.
- Require integration of community knowledge and knowledge generated by others (e.g. Parks Canada).
- Explicit links between Parks Canada work (which includes working with communities) and OSM include:
  - Abundance of muskrat – link to fur-bearers and contaminants in fur-bearers
  - Macroinvertebrates in delta areas
  - Amphibians – Parks Canada scientist is in the community and working with community members
- Need to formalize entry point for people who want to work with communities and also need communication protocols.
- Work with communities has to be long-term, reciprocal and beneficial.

Groundwater

Key Uncertainty: Baseline and range of variability for groundwater quality and quantity

Key Questions

- What is the natural range of variability?
    - Seasonal variability
    - Long-term trends aren't easy to demonstrate
- Where would we expect to see water balance changes?
    - System scale
    - Vulnerability
- How do monitored changes compare to model predictions?
    - Need conceptual model for baseline (outside area of impact)
- What is a suitable control or reference area?
- Can proxy data be used to help understand past conditions?

Key Uncertainty: What are critical GDEs, GW/SW Interaction rates, mass flux?

Key Questions

- Where are the Groundwater Dependent Ecosystems?
    - Modelling effort to map the GDEs and the connectivity
- Which ecosystems would be impacted most seriously by changes in GW quantity & quality? Which are most sensitive?
    - First Nations will have different answers to this question
    - McKay River – potential flow reversals – important to FN
    - Studies estimate GW input to various tributaries – those with minimal GW input are a lower risk (from dewatering?) – working at the watershed scale

- Has industry altered the rate of Devonian water discharge into the Athabasca River?
  - What is "critical"? Susceptible to change? High consequence from change (to water balance)? Timing aspect as GW input into e.g. tributaries must be considered in definition of critical, even though overall GW input in SW is minimal.
- How and to what extent does GW influence Fens?
  - Timing? Chemistry?
  - Influence = hydro function

Key Uncertainty: Hydrogeological Conceptual Model: Sub regional; flow paths

NOTE: this is more of a general requirement rather than an uncertainty. Therefore, the following presents the thoughts of the break-out group regarding requirements for construction of the Conceptual Model.

- Must understand the geology – need to establish sufficient level of confidence in the knowledge of the geological setting at the appropriate spatial scale for OSM.
- Agreement that there are sufficient data spatially distributed to give a good picture of the hydrogeological framework.
- Model would be for a disturbed landscape.
  - Would be a different model. Need to understand the predevelopment
  - What is the model post development?
  - Have we sufficiently considered the implications of land disturbances on flow system dynamics?
  - Do we know enough about what we are doing on the land now that alter the flow systems to affect the future
- Focus should be shallow groundwater.
  - Some debate about this:
- Ultimately, it's the shallower systems that concern the communities, and affect the ecosystems.
- We need to know the fluxes into shallow systems. Which means you have to understand the deeper system as well.
- Structural influences on deeper water on the system. It is a big concern for the communities.

- How does that concern the community, because of the high-water level and the quantity?
- Hydrogeological model: need knowledge of:
  - geology
  - geochemistry
  - fluid flow
  - flow patterns
  - recharge and discharge
- Be clear about the stressors.
- Determine the boundary condition. Design some monitoring to determine the boundary positions; e.g. groundwater divides. Is there a long-term divide?
- Use the model to inform monitoring.
  - including geophysics
- Divide the model into mine and in situ.
- Uncertainties:
  - Water level data or geochemistry data
  - Have we sufficiently identified the flow paths, structurally to support a regional monitoring system?
  - Influence of surface water on groundwater
- Could modelling done by oil sands operators be scaled up spatially and temporally?

Key Uncertainty: Effects of climate change on groundwater quantity and quality

Key Questions:

- Modelling:
  - Do the time scales used in current climate change models predict changes in the oil sands region?
  - Can predictive modelling be used to test the resiliency of reclamation scenarios given potential climate change impacts on groundwater flows?

- How does climate change affect the overall water balance in the oil sands region? Do climate models predict increased or decreased precipitation flux and groundwater discharge?
- How are changes in climate affecting location, timing, chemistry of groundwater systems?

- Does loading of salts change over time due to climate change?
    - How would impact of climate change on vegetation affect groundwater?
- Compare existing vegetation with 50 year out reclamation plan.
    - What should be measured on the ground to calibrate and verify models? (what is measurable – recharge isn't measurable)
    - NOTE: see the most recent EIA to check predictions made.
- Spatial Trends:
    - How far-reaching are climate-change related effects on groundwater systems? Do we see trends in water level change in a range of different locations inside and outside of the oil sands region and do those trends show a relationship with climate change?
    - Can the effects of groundwater withdrawals be distinguished from climate change and at which spatial scale?
- Groundwater-Dependent Ecosystems:
    - Where would we expect to see changes in water levels due to climate change?
    - Would climate change cause effects on water temperatures in streams/wetlands with significant proportion of inflow coming from groundwater?

Key Uncertainty: Reclamation Success

Key Questions

- Does the local reclaimed system fit with the surrounding system?
    - Key parameters:
    - Interaction with regional system
    - Interaction with GDE (scale (time), Steady state, transition)
    - Flow system
    - Water quality

- Is different monitoring required to understand sub regional success vs local success (on lease)?
- Integration need with surface water, geospatial, diversity.

Surface Water Quality and Aquatic Biology

Key Uncertainty: Separation of different anthropogenic and natural stressors (in situ, surface mining, natural bitumen, forestry sewage treatment, etc.). Includes cumulative effects.

Key Questions:

<u>Null Hypotheses</u>

1 There are no observed differences in biological responses between different sites within a tributary (upstream, within, and downstream of the McMurray Formation and industrial development).

2 There are no identifiable source inputs that could explain observed differences in biological responses within a tributary.

3a Isolated chemical mixtures from identified source inputs of interest between sites in a tributary do not elicit responses in laboratory bioassays that are consistent with the original field observations.

3b Isolated chemical mixtures from identified source inputs of interest between sites in a tributary do not differ in chemical profile (qualitative and quantitative).

- What are the differences in contaminant signatures from upper reaches to lower reaches in tributaries (Firebag (reference) vs Steepbank)? Design based on JOSM observations.
- What are the differences in source and loads of inputs among sites?
  - Groundwater and overland flow
  - Fugitive dust/ pet coke
  - Bank erosion
- What is the contribution of the source input differences to ecological effects?
  - Field observations (JOSM)
  - Toxicity tests (Effects Directed Analysis)
  - Interannual variation in key environmental drivers (e.g. flow)

- Role of nutrient - contaminant interaction in modifying toxicity

- Remaining Issues:
    - Gaps in field observations across tributaries – spatial extent
    - Role of geology
    - Role and contributions of groundwater
- Recommendation:
    - 2-day workshop to develop focussed studies on investigation of cause

Key Uncertainty: How much atmospheric deposition of contaminants reaches the Athabasca watershed. Quantification of emissions and loading distributions.

Key Questions:

- What is the temporal (seasonal, interannual) and spatial variability in contaminant “x” deposition across the landscape?
- How does the type of land cover, topography, etc. affect the mass of contaminant “x” deposited and accumulated?
- What is the spatial and temporal variability in the hydrological connection between the depositional areas and regional waterbodies? What are the key drivers of spatial and temporal variability in the hydrological connection between depositional areas and the waterbody?
- What is the fate of contaminant “x” once it is deposited to the landscape?
- What proportion of contaminant “x”, once deposited, is delivered to the waterbody and how does this change seasonally, interannually and spatially?
- Recommendation:
    - A fully instrumented representative basin (s)
    - Align deposition monitoring with NADP protocol

Key Uncertainty: Fate of oil sands organic and inorganic contaminants in downstream receiving habitats/food webs

Key Questions:

- H0: Oil sands inorganic and organic contaminants are not changing food webs in downstream receiving environments.
    - Approaches for addressing this hypothesis:
- Source attribution: spatial distribution of loads, mass balance, sediment finger printing, multi-variate statistics, chemical fingerprinting, isotope analysis.
- Bioavailability in food web and uptake – tissue (plants) analysis, metal speciation, water chemistry, modelling tools, sediment chemistry, passive sampling.
- Transport: high frequency turbidity data, suspended sediment sampling.
    - Increase longitudinal spatial assessment from M1 to PAD with respect to:
- Contaminant sources (air, overland, groundwater).
- Transport, deposition, remobilization, transformation, uptake.
    - Include wetlands
- How does an altered food web impact bioaccumulation of contaminants (or vice versa)?

Key Uncertainty: Lack of knowledge of higher order ecological effects

Key Questions:

- What are the impacts of oil sands development on aquatic habitat connectivity at large spatial scales?
    - Focus on:
        - How can we separate oil sands mining contribution from other development (forestry, urban etc.)?
        - What are the implications to populations of sensitive/valued fish species?
- Require sufficient information to assess fish habitat quality, access and utilization at a large spatial scale.

Key Uncertainty: Uncertainty that selection of measurement endpoints reflects community concerns and values

Key Questions:

- What are the commonalities between existing OSM work and communities and how do you maximize exposure of OSM programs in these communities in response to community needs?
- Can the existing OSM program integrate with community-based monitoring?
  - Gaps:
    - Cold Lake area
    - Sites and indicators relevant to communities
  - Confirm that endpoints are relevant to communities
- What are some effective approaches to building capacity in the communities?
  - Capacity can't be bought, it must be built

Key Uncertainty: Do we have the correct indicators of natural versus anthropogenic change?

Key Questions:

- Indicators must be sensitive and scalable and must provide a signal early enough to prevent irreversible harm.
- Which indicators can be extrapolated from individual to population level?
- What indicators would show a response to natural and anthropogenic stressors?
  What focussed research is required to identify indicators of most utility with respect to distinguishing natural and anthropogenic stressors?
- Metabolomics: for both long-term and short-term – can be used for fitness, reproduction, survival – linked as an early warning indicator.
  - How do you make metabolomics relevant?
  - Would need focussed studies in references areas
  - See if metabolomics works to distinguish upstream vs downstream
- What environmental markers can be used to identify the downstream Fort McMurray effects in order to allow for unconfounded assessment of oilsands activities on the mainstem Athabasca River?

Atmospheric Deposition

Key Uncertainty: Fugitive dust sources and pathways for base cations, trace elements. Includes spatial uncertainty and seasonality. Includes large particle modelling.

Key Questions:

- What size fraction distribution dominates base cations? Where (distance and windspeed)?
- What is the speciation and size distribution of fugitive dust?
- What are the sources of fugitive dust and what is the magnitude and speciation of sources?
- What can vegetation data tell us about deposition of fugitive dust?
- What is the seasonal variability (e.g. with respect to snow)?
- What are the meteorological drivers for fugitive dust emissions? Vs mechanical sources. Wind-blown origin from pet coke?
- Can the aircraft and ground-based observations of fugitive dust be linked to source types?
- What is the impact of reducing fugitive dust on human health versus neutralization benefits?
- What is the mobility of the base cations from terrestrial ecosystem deposition to aquatic ecosystems (e.g. lakes)?
- What are the chemical transformations affecting fugitive dust and how do they affect downwind deposition?
- What is the combined response of base cations, N and acidity on receptors (plants, surface waters)?
- What is the resulting spatial distribution of fugitive dust and its components?
- Can model-measurement fusion be used/improved to get better spatial maps?
- How will the in situ facilities and other projected emissions change fugitive dust and neutralization?
- Design Issues
    - Focussed study for surface monitoring of fugitive dust
    - PCA of aircraft fugitive dust linked to surface observations (and other means of source attribution)

- Need to choose sites on the surface carefully.
- What is the size distribution of fugitive dust much further downwind (50-200 km)?

Key Uncertainty: Deposition trends: long-term, for those constituents of concern which are produced by oil sands. Includes timescale to effects and temporal variability.

Key Questions:

- On a chemical species by species basis, does the existing monitoring program adequately capture the spatial deposition?
  - How far out do we need to measure before we get to no effects or background levels?
  - Are we adequately measuring other oil sands regions such as Peace River, Cold Lake, CHOPS.
  - Do we need to characterize these other regions in the same way we have done for surface mining operations?
  - Can we design a monitoring program that validates model predictions of long-range deposition?
- Are we monitoring the right things?
  - We need validations from all stakeholders to choose the chemical species to model
  - Uncertainty around temporal measurements – stakeholders might specify requirements on what needs to be measured
- Designs equal super sites?
  - New monitoring approach
  - Passive
  - Models

Key Uncertainty: Sources and deposition of total nitrogen, including spatial distribution and critical loads

Key Questions:

- What are major sources of NH_3 – oil sands vs non-oil sands (50 km from fence line)?
- What are major sinks of NH_3 (50km from fence line). At what distance negligible?

- What fraction of total N deposition is attributable to oil sands?
    - What is the spatial variability: 0-50 km;50-100 km; > 100 km from facility fence lines
- Are critical loads for acidification being exceeded (lakes/aquatic vs terrestrial)? Near, mid and far-field? What are the critical loads?
- What is the difference in total N deposition between in situ and mineable areas (near, mid and far-field)?
- What are the differences in effects in receiving environments?
- What is the spatial variability in critical loads (by receiving environment)?
- What are levels of unknown N species by receiving environment? Are these levels important?
- Is observed N deposition around oil sands mines within values predicted by EIAs?
- What spatial and temporal scale do we see impact from N deposition in receiving environments
    - In situ vs mining
    - Near, mid and far-field
- What distances are near. Mid and far field? Is this dependent on oil sands type (in situ vs mining)? At what distances do oil sands emissions become negligible?
- What are the effects of different N species in different receiving environments? NH3 vs NO3 vs NH4

Key Uncertainty: Source attribution – oil sands vs non-oil sands. Mercury and trace elements; others as needed (PACS)

Key Questions:

- Mercury:
    - Is the oil sands industry a source of mercury?
    - What are the oil sands processes that could contribute to methylation of mercury?
    - What are the co-occurring pollutants with mercury? (there are tools available that measure this)
    - What are the mercury emissions outside of the oil sands region?

- Trace Metals/ PACs
    - Can we distinguish oil sands sources of trace elements from natural sources?
    - Do isotopes and con-contaminants (REEs) help identify the sources?
- Recommendations:
    - Ongoing monitoring of multiple pollutants in air (active/passive, snow), lichens, tree cores, lake sediments.
    - Need precipitation measurement of trace elements (should be combined with existing collections of PACs).
    - Combine all of the various multi-contaminant geospatial data to understand current status.

Key Uncertainty: Ecological impacts of base cations – multiple interacting stressors (Base cations/N/S)

Key Questions:

- H1: There are differences in patterns of spatial distribution of base cations and S/N.
    - which leads to differences in how they combine across the landscape and this changes over time (e.g. emissions from in in situ vs mining area in terms of dust/base cations vs N and perhaps S.
- H2: Ecosites will show a range of sensitivities.
    - E.g. low CEC/base saturation site types will be most sensitive.
    - To verify ecological effects, need co-location of deposition monitoring and ecological effects monitoring.
- Issues and Opportunities
    - Other data or samples (provincial soils data base, ABMI soil samples)
    - A reference from outside the region
    - Scale and resolution need to be suitable for developing a terrestrial monitoring program (township scale won't work)
    - Controlled experiments might be useful (e.g. critical load questions)
    - Deposition close to mining is mostly relevant for impacts on reclaimed ecosystems

Mercury

Key Uncertainty: Oil sands mercury sources and speciation.

Key Questions

- What is the characterization of mercury emissions from stacks and land disturbance (including speciation)?
- What emissions other than mercury impact mercury accumulation and methylation?
- Can we collect fugitive dust and understands its characteristics in order to understand its relative contribution to mercury deposition and transformation?
- What is the level of mercury deposition in the oil sands region during the rest of the year (outside of snow seasons)?

Key Uncertainty: Mercury in Traditional Foods and Subsequent Effects on Traditional Resources and Human Health

Key Questions

Does the oil sands industry contribute to an incremental increase of mercury in traditional foods?

- What has been done to date to measure mercury in traditional foods? Where? How?
- Do the food items that have been measured encompass the full range of subsistence foods? Are the sampled at the right place and time?
- How are the traditional foods prepared and what is eaten?
- Are mercury concentrations now and in the past higher in the oil sands regions than elsewhere (near and far?)
- Can we attribute mercury present in subsistence foods to oil sands sources?
- What has/is changing in the environment that affects mercury biogeochemistry, methylation and biomagnification?
- Are there historical samples which could be accessed and analysed for mercury?

Are there effects from mercury on traditional resources and human health? THIS QUESTION IS ON HOLD UNTIL MERCURY SOURCE ATTRIBUTION HAS BEEN CONFIRMED

- Does the perception of pollution from oil sands development affect use of subsistence foods?

- Are mercury concentrations above threshold levels that would result in consumption advisories?
- What advisories have been issued?
- Do the advisories affect use of subsistence foods?
- Have there been direct effects of mercury on health (humans and fish/wildlife)?
- Have there been indirect effects on human health?

Key Uncertainty: Quantify and understand mercury inputs from natural and anthropogenic sources (oil sands, compensation lakes, non-oil sands such as hydroelectric dams)

Key Questions

- What are the natural versus anthropogenic sources of mercury in the oil sands region?
- What is the relative contribution of natural and anthropogenic sources in the Athabasca River and the PAD?
- What is the spatial and temporal variation of source contributions?

Key Uncertainty: (a) Mechanisms of transport of methylmercury from near-field to far-field downstream systems (b) Mass balance of mercury and methylmercury source contributions to the Athabasca River.

THE FOLLOWING QUESTIONS ARE ON HOLD UNTIL MERCURY SOURCE ATTRIBUTION HAS BEEN CONFIRMED

Key Questions

- Where are mercury methylation sites within the AOSR all the way to the PAD? (riverine wetlands, lakes, tributaries).
- Can we model sites and conditions that lead to methylmercury in order to understand its spatial and temporal distribution?
- What conditions are required for methylation? Mercury load? Effect of other emissions? Are these conditions changing over time?
- What are mercury sediment concentrations in the Athabasca River upstream and downstream of the oil sands region?
    - How does this sediment mobilize if it contains mercury?

- Which sediments contain mercury? Which horizons? What is the range and scale of mercury with respect to source?

- What are non-atmospheric mercury sources? Sediments? Soils? Other?
- What are non-atmospheric transport mechanisms? Model these?
  - Overland flow
  - Groundwater
  - Tributaries
  - Mainstem
- What is the fate of mercury deposited on the land surface? What is transported vs retained/ accumulated?
- What is the fate of mercury deposited/transported in the Athabasca River?
  - How much is bioaccumulated?
  - How much settles in depositional areas?
- Where are the depositional areas?
- Are these sites of methylation
- How do these change temporally and spatially?
- Are there spatial or temporal patterns in total and methylmercury concentrations in biota?
  - Have any spatial trends been confirmed with abiotic and biotic samples? With source-tracking tools such as stable isotopes?

Geospatial Science

The Geospatial Science Workshop participants voted on the top 5 key questions for application of geospatial science in the near-term.

The top 5 key questions in order of priority were:

1. Mapping community knowledge of the quality and quantity of traditional resources .
2. What is the spatial and temporal variability in hydrologic connectivity between depositional areas and surface water bodies? What are the key drivers of this variability?
3. Where are groundwater-dependent ecosystems?
4. Which species are the most sensitive to habitat fragmentation?

5. What are the effects of enhanced N, S and base cation deposition on vegetation communities?

Predictive Modelling

The Predictive Modelling Workshop participants voted on the top 5 critical pathways to be addressed using modelling.

The top 5 critical pathways were:

1. Groundwater connectivity with surface water quality and baseflow inputs.
2. Natural, oil sands and non-oil sands stressors -> surface water quality, groundwater quality and sediment quality ->fish health and human health.
3. The causal linkage between surface water quality and ecological effects (monitored changes in benthic invertebrates and fish health). Coupled water quality-quantity. Link to air deposition.
4. Atmospheric deposition links to terrestrial effects and surface water quality.
5. Contaminant exposure and effects on terrestrial species persistence, biodiversity, productivity. Includes comparison to habitat effects.