October 2013

SHELL CANADA ENERGY

Appendix 3.1: Assessment Methods

Submitted to:
Shell Canada Energy

REPORT

Project Number: 13-1346-0001

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TABLES

FIGURES

ATTACHMENT

Attachment A
Simulation of the Planned Development Case for the Regional Study Area of the Shell Jackpine Mine Expansion

1.0 INTRODUCTION AND APPROACH

1.1 Overview

Shell Canada Energy (Shell) submitted the Applications and supporting Environmental Impact Assessment (EIA) for the Jackpine Mine Expansion (JME) and Pierre River Mine (PRM) Project in December 2007. As part of the regulatory process for the PRM Application, the Joint Review Panel (JRP) provided Supplemental Information Requests (SIRs) dated October 25, 2012.

In the October 25, 2012 submission, the JRP requested a reassessment of impacts from those provided in the EIA, including:

- In JRP SIR 5, the JRP noted that the EIA, as amended, contains sections with assessment results combined for JME and PRM. They requested that Shell provide effects related to PRM alone, in isolation from JME, for specific components of the EIA.
- In JRP SIR 8, the JRP requested, among other items, an assessment of changes to the environment that have occurred since the initiation of major developments in the region, termed the Pre-Industrial Case (PIC), and an updated Planned Development Case (PDC) to account for foreseeable projects and activities publicly disclosed since the EIA for PRM was completed. Also, the JRP requested that Shell include updated forest harvesting information and the effects of past and future forest fires.

Appendix 1 contains the response to JRP SIR 5 and Appendix 2 contains the response to JRP SIR 8; however, detailed information describing the assessment methods used including assumptions in the assessments, confidence in the data and models used, and analysis to support the conclusions is provided in this appendix. Assessment methods for determining environmental significance are also presented in this appendix.

Appendix 3.1 is organized as follows:

- Section 2.0 – Assessment Methods;
  - Section 2.1 – Assessment Cases;
  - Section 2.2 – Temporal Boundaries;
  - Section 2.3 – Spatial Boundaries;
  - Section 2.4 – Projects Included in the Assessments;
  - Section 2.5 – Key Indicator Resources;
  - Section 2.6 – Integration of Traditional Ecological Knowledge;
  - Section 2.7 – Air Quality and Environmental Health;
  - Section 2.8 – Aquatic Resources;
  - Section 2.9 – Terrestrial Resources;
  - Section 2.10 – Traditional Knowledge and Land Use; and
  - Section 2.11 - Environmental Significance.

This appendix also provides a list of abbreviations (Section 4.0) and a glossary (Section 5.0) for Appendices 1 through 8 of this submission.

2.0 ASSESSMENT METHODS

The assessment methods for the October 2012 JRP SIRs are the same as those used for the EIA except where noted. The assessment methods comply with the requirements in *Cumulative Effects Assessment in Environmental Impact Assessment Reports Required Under the Alberta Environmental Protection and Enhancement Act* (AENV, EUB and NRCB 2000). The assessment meets the requirements of Section 19 of the *Canadian Environmental Assessment Act, 2012 (CEAA)* and the requirements of Alberta Environment and Water (now Alberta Environment and Sustainable Resource Development) and the Energy Resources Conservation Board (now the Alberta Energy Regulator [AER]) (AENV, EUB and NRCB 2000). The process for completing the cumulative effects assessment included consideration of guideline information as provided in the *Athabasca Oil Sands Cumulative Effects Framework Report* (Golder 1999), the *Cumulative Effects Assessment Practitioners Guide* (Hegmann et al. 1999) and the Canadian Environmental Assessment Agency's Operational Policy Statement, *Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012 (CEAA 2013)*.

2.1 Assessment Cases

The EIA, as amended, is based on three cumulative effects assessment cases, namely the EIA Base Case, EIA Application Case and EIA Planned Development Case (PDC). Each case represents a snapshot of the predicted condition of the environment, taking into account all developments occurring up to the snapshot date.

With the requests in JRP SIRs 5 and 8 for a Pre-Industrial Case (PIC), a revised PDC, and an Application Case for PRM without JME, Shell has developed terminology to assist the reader in understanding when Shell is referring to the existing EIA material or the additional cases developed as part of the responses to JRP SIRs 5 and 8. Specifically, cases from the EIA are referred to as "EIA" cases, whereas updated assessments addressing the information requests of the JRP are referred to as "2013" cases:

- The 2013 Base Case describes the environmental conditions resulting from the cumulative effects of existing and approved projects or activities within the study area and is updated from the EIA Base Case to consider projects that were approved as of June 2012, per the JRP Terms of Reference (JRP TOR). Approved projects are included so that PRM effects can be measured against the impacts associated with projects that are likely to be constructed. It was necessary to present an updated 2013 Base Case because JRP SIR 5 requested updated environmental consequences for PRM alone, and this requires identifying changes between the 2013 Base Case and the 2013 PRM Application Case (Appendix 1).
- The 2013 PRM Application Case, developed in response to JRP SIR 5, considers the effects of the 2013 Base Case projects in combination with the PRM.
- The 2013 PDC (Appendix 2) considers the 2013 Base Case projects in combination with the PRM and other planned projects and activities publicly disclosed as of June 2012, per the JRP TOR. The 2013 PDC assessment was completed for predicted residual effects rated greater than negligible due to the PRM (Appendix 1).

2.2 Temporal Boundaries

The temporal considerations for the October 2012 JRP SIRs are the same as those used for the EIA. They are based on the PRM operational development plan and include unique conditions that may affect environmental components differently. Details on the PRM description are provided in the EIA, Volume 2, as amended.

The Aquatic Resources components were examined under time snapshots at major changes in development phases or activities. The snapshot timing was offset by three years compared to the EIA to reflect a later startup date for the PRM. The new snapshots capture potential effects during each of the PRM phases described in the EIA, Volume 4A, Section 6.2.4. The snapshots considered for the October 2012 JRP SIRs were 2018, 2034, 2042, 2052 and Far Future.

The Terrestrial components were examined under six temporal conditions: the PIC, the 2013 Base Case, the 2013 PRM Application Case, the 2013 PDC, Closure (i.e., 80 years after the reclamation of PRM) and Far Future (i.e., 80 years after the reclamation of PRM and all other planned developments). Eighty years represents the estimated time required for the development of mature forest; consequently, it is an appropriate time to compare vegetation, wildlife and biodiversity values in the reclaimed landscape against the PIC and 2013 Base Case values. While there will be some phasing of both the disturbance and reclamation of terrestrial systems, phasing was not directly included in the assessments, which considered everything to be undeveloped, developed or reclaimed.

Potential effects of the PRM on terrestrial resources are assessed for construction, operations, and Closure (i.e., including reclamation). The temporal boundaries for the 2013 Base Case through to the 2013 PDC are the same as those used in the EIA.

The assessment of the effects of the PRM on terrestrial resources in the 2013 PRM Application Case and 2013 PDC assumes that all developments are 100% cleared during operations and then 100% reclaimed, even though developments will be cleared and reclaimed sequentially over different time periods. This approach analyzes the maximum possible disturbance to terrestrial resources and produces a conservative assessment in the sense that predicted effects are larger than will actually occur. Specific regional project developments included in the 2013 Base Case and 2013 PDC are derived from publicly available project disclosures, applications and approvals.

For the comparison between the 2013 Base Case and 2013 PRM Application Case prepared in response to JRP SIRs 5 and 7 (Appendix 1), the identification and assessment of the environmental consequences of residual effects for the PRM focused on residual effects prior to reclamation, although residual effects after Closure also were presented. For the 2013 PDC and the response to JRP SIR 8, located in Appendix 2, environmental consequences and significance are assessed prior to reclamation for soils and terrain, and wildlife because the information needed to predict the characteristics of the post-reclamation landscape is not available. Terrestrial vegetation, wetlands and forest resources assessed environmental consequences and significance in the 2013 PDC both prior to and after reclamation based on habitat ratios collated from publicly available reclamation plans.

2.3 Spatial Boundaries

Study areas were developed for each component of the EIA to focus analyses at relevant spatial scales. Typically, a Local Study Area (LSA) and a Regional Study Area (RSA) were defined for each EIA component. The LSA was used to focus on, and provide a detailed evaluation of, effects to areas that may be directly impacted by the PRM. The RSA was generally used to evaluate PRM effects in larger geographic and ecological contexts at an appropriate scale for a cumulative effects assessment.

Study areas were defined based on anticipated effects of the PRM and relevant ecological or social context. Study areas used by regional initiatives such as the Cumulative Environmental Management Association (CEMA), the Wood Buffalo Environmental Association and the Regional Aquatics Monitoring Program were also considered. Additional information and justification for study area boundaries are provided in the component sections of the EIA and as part of this Appendix (e.g., Terrestrial, Section 2.9).

The RSAs used in the 2013 Base Case, 2013 PRM Application Case and 2013 PDC were the same as those used in the EIA and are shown in the EIA, Volume 3, Section 1.3.4, Figures 1.3-1 and 1.3-2. The Traditional Land Use (TLU) RSA is based on the Terrestrial Resources RSA which is also discussed in the EIA, Volume 5, Section 1.3.4 and Section 7.2.4.

The LSAs for the following components were updated (Figure 2.3-1):

- The air quality LSA was revised to allow for a focused assessment of PRM.
- The Terrestrial Resources LSA was revised to incorporate the proposed South Redclay Lake.
- The Aquatics Resources LSA was updated to include the Redclay Creek watershed, because that watershed will be affected as a result of the updated south portion of South Redclay Lake and by the Teck Resources Limited (Teck) Frontier Oil Sands Mine Project, which is included in the 2013 PDC.
- The TLU LSA was updated to be the same as the Terrestrial Resources LSA. Using the Terrestrial Resources LSA allows for a direct consideration of effects on wildlife and vegetation resources, which are important components of TLU activities.

The rationale for selection of the LSA and RSA boundaries for each component is described in the EIA, Volume 3, Section 1.3.4.2. However, Section 2.3.1 presents additional rationale for the terrestrial LSA and RSA not described in the EIA, and Section 2.3.2 provides similar information for TLU.

The PRM footprint used in the responses to JRP SIRs 5 and 8 is the same as the footprint used in the EIA with the addition of the No Net Loss (NNL) lake and associated infrastructure that will be built to compensate for adverse effects to fish and fish habitat. The 2012 Draft No Net Loss Plan was submitted to the JME JRP on September 19, 2012. The updated PRM footprint is shown in Figure 2.3-1.

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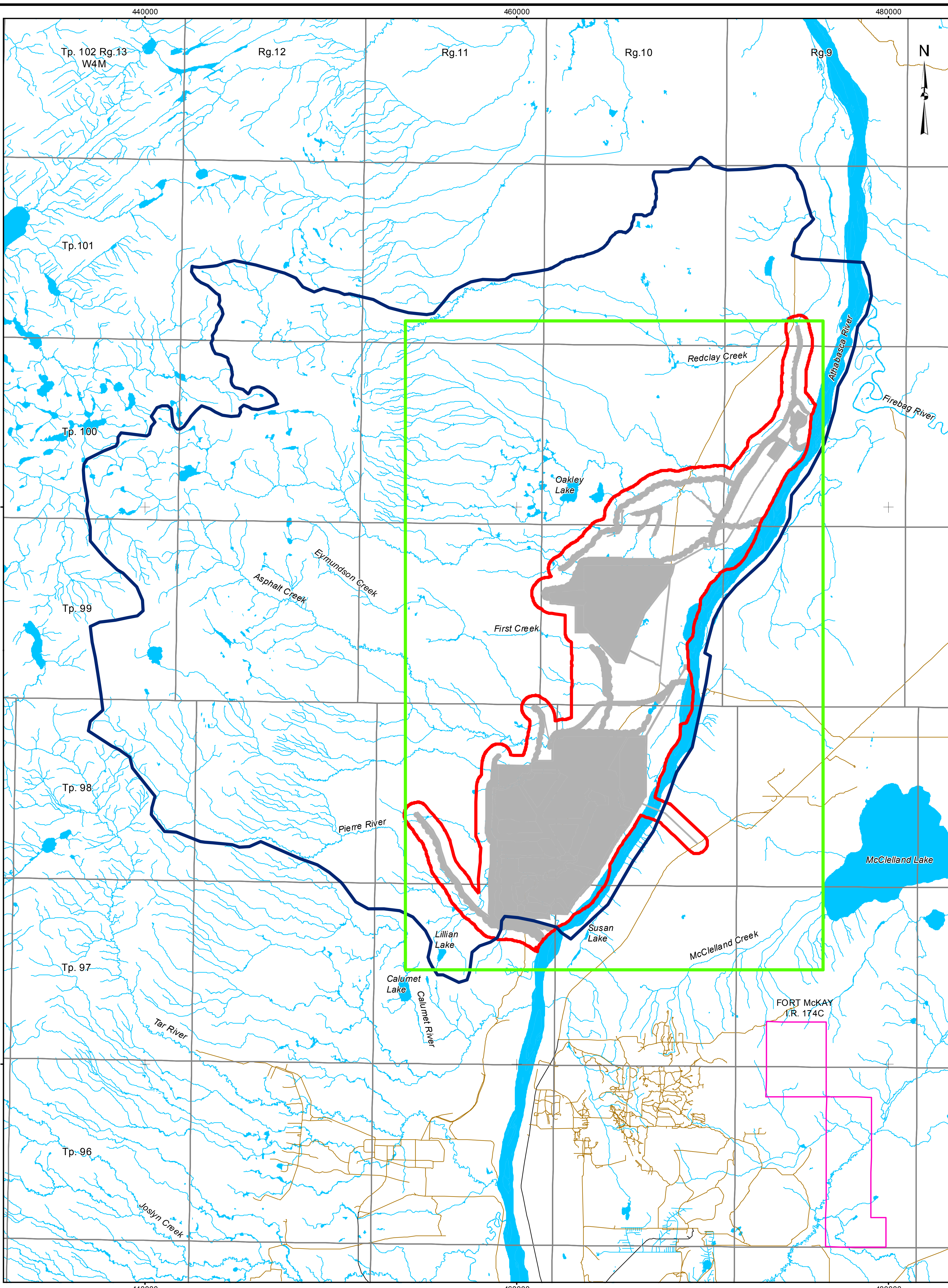


LEGEND

PAVED ROAD	AIR QUALITY LOCAL STUDY AREA
UNPAVED ROAD	AQUATICS LOCAL STUDY AREA
WATERCOURSE	PIERRE RIVER MINE TERRESTRIAL LOCAL STUDY AREA
INDIAN RESERVE	PROJECT FOOTPRINT
OPEN WATER	

8 0 8

SCALE 1:200,000 KILOMETRES

REFERENCE

ALBERTA DIGITAL BASE DATA OBTAINED FROM ALTALIS LTD. © GOVERNMENT OF ALBERTA 2013.
DATUM: NAD83 PROJECTION: UTM ZONE 12N

PROJECT

PIERRE RIVER MINE PROJECT

TITLE

TERRESTRIAL RESOURCES, AIR QUALITY AND AQUATICS LOCAL STUDY AREAS

Shell Canada Limited

PROJECT		13-1346-0001	FILE No.
DESIGN	CB	08 Jul 2013	SCALE AS SHOWN REV. 0
GIS	SB	08 Jul 2013	
CHECK	CY	18 Jul 2013	**FIGURE: 2.3-1**
REVIEW	DB	18 Jul 2013	

2.3.1 Terrestrial Spatial Boundaries

The terrestrial LSA was designed to include the PRM footprint including all associated infrastructure, plus a buffer averaging 500 m wide. The LSA was used to focus on and provide a detailed evaluation of effects to areas that may be directly affected by the PRM. This is an appropriate approach to defining an LSA and is consistent with direction provided by Alberta in the *Guide to Preparing Environmental Impact Assessment Reports in Alberta* (ESRD 2013a), which states, "*The Local Study Area is the area surrounding and including the Project Area where there is a reasonable potential for immediate environmental impacts due to ongoing project activities*". It is also an "*obvious and easily understood*" boundary in which "*mitigatable effects will occur*", as stated in the *Cumulative Effects Assessment Practitioner's Guide* (Hegmann et al. 1999). The focus of the LSA is on the specific effects of the PRM activities, not on the effects of activities that are associated with neighboring projects. It follows that inclusion of neighboring projects within the boundaries of the LSA would be inappropriate because it would not be possible to isolate and assess the effects of the PRM specifically. The environmental effects of the PRM in conjunction with other projects, including those immediately adjacent the PRM, are more appropriately assessed as part of a cumulative effects assessment at the RSA scale.

The LSA was defined using the PRM footprint and a buffer area to encompass the effects of PRM; it was not defined using ecological criteria, nor was it intended to encompass scales relevant to the conservation or management of terrestrial KIRs. To increase the LSA to a size that is ecologically relevant is to repeat the exercise of defining an RSA.

The terrestrial RSA was designed to evaluate impacts of the PRM at an ecologically relevant scale. For vegetation and wildlife especially, boundaries should be ecologically defensible, according to the *Cumulative Effects Assessment Practitioners Guide* (Hegmann et al. 1999). Consequently, RSA boundaries were based primarily on ecological parameters such as moose home range size and designated woodland caribou ranges. In addition to the application of ecological boundaries, the RSA is designed to capture the effects of most existing, approved, and planned development within the Oil Sands Region north of Fort McMurray. Given that terrestrial Key Indicator Resources (KIRs) include wide-ranging wildlife, such as woodland caribou and moose, and that the effects of oil sands development are also geographically widespread, a large RSA is appropriate to assess the cumulative effects of development on these wildlife KIRs. The RSA, therefore, is defined as a large area capturing the furthest potential measureable effects of the PRM in combination with approved and planned projects in an ecologically relevant region. A larger RSA would "dilute" the effects of the PRM and other oil sands projects, while a substantially smaller RSA would fail to appropriately account for cumulative effects at a scale relevant to the ecology, conservation, and management of many terrestrial KIRs. The use of a single terrestrial RSA allows for the comparison of cumulative effects across terrestrial disciplines.

The approach used to define the RSA is consistent with direction provided by Alberta in the *Guide to Preparing Environmental Impact Assessment Reports in Alberta* (ESRD 2013a), which states: *"The Regional Study Area is the area where there is the potential for cumulative and socio-economic effects and that will be relevant to the assessment of any wider spread effects of the project*". In addition, the *Cumulative Effects Assessment Practitioner's Guide* (Hegmann et al. 1999) states that the RSA "*includes the areas where there could be possible interactions with other actions*" and that boundaries should be set at a point which the project no longer contributes to cumulative effects. Further guidance is provided in the *Cumulative Effects Assessment in Environmental Impact Assessment Reports Required under the Alberta Environmental Protection and Enhancement Act* (AENV, EUB and NRCB 2000) which states that "*the spatial boundary of a cumulative effects* *assessment should consider the limit, if any, where a significant residual environmental effect can reasonably be expected*".

This approach to the designation of LSAs and RSAs has been used in many oil sands mining applications and accepted by several Joint Review Panels. For example, in the Joint Review Panel Decision Report for Canadian Natural Resources Limited's (Canadian Natural's) Horizon Project (EUB and CEAA 2004), the Panel considered the spatial and temporal boundaries that Canadian Natural used in its EIA and concluded that "*the boundaries were reasonable and reflect the ecological context of the project*". Shell's JME and PRM projects used the same RSA that was used for Canadian Natural, as well as other similar-sized oil sands mining projects north of Fort McMurray. In addition, by using the same RSA over a period of more than 10 years, regulators and stakeholders can compare and contrast the cumulative effects of development in the same area over time, a comparison that could not be made if RSAs were changed for each oil sands mining project application.

2.3.2 Traditional Land Use Spatial Boundaries

The Traditional Land Use assessment considers an RSA (Appendix 3.8, Figures 1.2-1) which is based on the Terrestrial Resources RSA. Traditional Land Use (TLU) areas primarily include land that is used to collect traditional resources, including hunted game, harvested berries or medicinal plants. The selection of the Terrestrial Resources RSA considers potential effects on wildlife and vegetation, which are important components of TLU activities. The potential effects on traditional fishing are also considered within the context of the TLU RSA.

2.4 Projects Included in the Assessments

The 2013 Base Case updates the EIA Base Case by including projects that have been approved since filing of the original EIA in 2007, and by updating previous Base Case projects to include approved changes since 2007. It includes existing and approved industrial projects and activities associated with land use and infrastructure as of the issuance of the JRP TOR in June 2012.

The 2013 PRM Application Case considers effects incremental to the 2013 Base Case from PRM alone. That is, incremental effects associated with Shell's proposed JME are not included in this case.

The 2013 PDC considers the effects of the PRM in combination with existing, approved and planned developments in the region that could reasonably be considered to have a combined effect. For the 2013 PDC, a "planned project" is any project or activity publicly disclosed as of the issuance of the JRP TOR in June 2012. Planned projects may or may not proceed; by including all planned projects, the 2013 PDC provides a conservative assessment of future social and environmental conditions. Shell's proposed JME is included in this 2013 PDC.

The existing, approved and planned developments included in the 2013 Base Case and the 2013 PDC are listed in Tables 2.4-1 and 2.4-2, respectively. The lists are categorized as follows:

- projects included in a specific case in the EIA and not changed in the 2013 case;
- projects included in the same case as the EIA, but updated based on new information such as recent approvals, amendments and EIAs; and
- projects not included in the same case as the EIA that have either been approved (i.e. new to 2013 Base Case) or publicly disclosed and awaiting approval (i.e. new to 2013 PDC) since the EIA.

Table 2.4-1 Projects Included in the 2013 Base Case

Developer	Projects Included in both the EIA Base Case and 2013 Base Case	Projects Included in the EIA Base Case but Updated in the 2013 Base Case	Projects New to 2013 Base Case (not included in EIA Base Case)
Shell Canada Limited	Jackpine Mine - Phase 1, Orion EOR Project	Muskeg River Mine and Muskeg River Mine Expansion	
Baytex Energy Corporation	–	–	Cold Lake
BlackPearl Resources Inc.	–	–	Blackrod SAGD Pilot Project
Brion Energy Corp.	–	–	Dover Pilot Project, MacKay River Pilot and Commercial Project
Canadian Natural Resources Limited	Burnt Lake Pilot Project	Horizon Oil Sands Project, Kirby In-Situ Oil Sands Project, Primrose East In-Situ Project, Primrose North In-Situ Project, Primrose South In-Situ Project, Wolf Lake In-Situ Project	–
Cenovus Energy	–	–	Grand Rapids SAGD Pilot Project
Cenovus FCCL Ltd.	–	Christina Lake Thermal Project, Foster Creek Thermal Project	Narrows Lake Project
Connacher Oil and Gas Limited	–	Great Divide Oil Sands Project	Algar Oil Sands Project
ConocoPhillips Canada	–	Surmont Pilot and Commercial SAGD Project	–
Devon Energy Corporation	–	Jackfish SAGD Project, Jackfish SAGD Project 2	Jackfish SAGD Project 3
E-T Energy	–	–	Poplar Creek In-Situ Pilot
Grizzly Oil Sands ULC	–	–	Algar Lake SAGD Project
Harvest Operations Corp.	–	–	BlackGold Oil Sands Project
Husky Energy Inc.	Sunrise Thermal Project, Tucker Thermal Project	–	Caribou Lake Thermal Demonstration Project, McMullen Thermal Pilot Project
Imperial Oil Resources Ventures Ltd.	Cold Lake In-Situ Project, Kearl Oil Sands Project	–	–
Japan Canada Oil Sands Ltd.	–	Hangingstone Pilot In-Situ Project	–
Laricina Energy Ltd.	–	–	Germain Phase 1, Saleski Pilot
MEG Energy Corp.	–	Christina Lake Regional Project - Pilot, Phases 2 and 2B	–
Nexen Inc.	Long Lake Pilot Project, Long Lake Commercial Project	–	Long Lake Project Phases 1 and 2
Southern Pacific Resources Corporation	–	–	MacKay River Project
Statoil Canada Ltd.	–	–	Kai Kos Dehseh SAGD Project
Suncor Energy Inc.	Dover SAGD Pilot and VAPEX Pilot, Firebag Enhanced Thermal Solvent (ETS) Pilot Project	Firebag SAGD Project, Lease 86/17, Steepbank & Millennium Mines, MacKay River In-Situ, MacKay River Expansion SAGD Project, Meadow Creek In-Situ, Millennium Coker Unit (MCU), Millennium Vacuum Unit (MVU), North Steepbank Extension Mine and Millennium Dump 9, South Tailings Pond, Upgrader Complex, Voyageur Upgrader, Fort Hills Oil Sands Project	–
Sunshine Oil Sands Ltd.	–	–	Harper Pilot, West Ells SAGD Project

Table 2.4-1 Projects Included in the 2013 Base Case (continued)

Developer	Projects Included in both the EIA Base Case and 2013 Base Case	Projects Included in the EIA Base Case but Updated in the 2013 Base Case	Projects New to 2013 Base Case (not included in EIA Base Case)
Syncrude Canada Ltd.	Aurora North Mine, Mildred Lake Upgrader	Aurora South Mine	–
Total E&P Canada Ltd.	–	Joslyn North Mine Project	–
Value Creation Inc.	–	–	Terre de Grace Pilot Project
Aggregate	Birch Mountain Resources Muskeg Valley Quarry, Birch Mountain Resources Hammerstone, Parsons Creek Resources Sand and Gravel Pit	–	–
Other	East Athabasca Aerodrome, Northland Forest Products Ltd. Sawmill, Williams Energy Chemical Plant, Gas Plants and Compressors, Pipelines, Roadways, East Athabasca Highway, Municipalities and Communities, Others	–	–

– = Not applicable.

Table 2.4-2 Projects Included in the 2013 Planned Development Case

Developer	Projects Included in the EIA PDC (no change in 2013 PDC)	Projects Included in the EIA PDC (Updated in 2013 PDC)	Projects New to 2013 PDC
Shell Canada Limited	Jackpine Mine - Phase 1*, Orion EOR Project*	Jackpine Mine Expansion & Pierre River Mine Project, Muskeg River Mine* and Muskeg River Mine Expansion*	
Alberta Oilsands Inc.	–	–	Clearwater West Pilot Project
Athabasca Oil Corp.	–	–	Dover West Clastics Phase 1, Dover West Leduc Carbonate Pilot, Hangingstone Experimental In-Situ Project, Hangingstone Project Phase 1, Birch Project
Baytex Energy Corporation	–	–	Cold Lake
BlackPearl Resources Inc.	–	–	Blackrod SAGD Pilot* and Commercial Project
Brion Energy Corporation	–	–	Dover Pilot Project*, Dover Commercial Project, MacKay River Pilot Project, MacKay River Commercial Project
Canadian Natural Resources Limited	Burnt Lake Pilot Project*	Birch Mountain East Project, Horizon Oil Sands Project*, Kirby In-Situ Oil Sands Project*, Primrose East In-Situ Project*, Primrose North In-Situ Project*, Primrose South In-Situ Project*, Wolf Lake In-Situ Project*	Grouse In-Situ Oil Sands Project, Kirby In-Situ Oil Sands Expansion Project, Gregoire Phase 1 In Situ Oil Sands Project
Cavalier Energy	–	–	Hoole Project
Cenovus Energy	–	Telephone Lake SAGD Project (formerly Borealis In-Situ Project)	Grand Rapids SAGD Pilot Project*, Narrows Lake Project*, Pelican Lake SAGD Project
Cenovus FCCL Ltd.	–	Christina Lake Thermal Project*, Foster Creek Thermal Project*	Christina Lake Thermal Project Expansion, Foster Creek Thermal Project Expansion

Table 2.4-2 Projects Included in the 2013 Planned Development Case (continued)

Developer	Projects Included in the EIA PDC (no change in 2013 PDC)	Projects Included in the EIA PDC (Updated in 2013 PDC)	Projects New to 2013 PDC
Connacher Oil and Gas Limited	–	Great Divide Oil Sands Project*	Algar Oil Sands Project*, Great Divide Oil Sands Expansion Project
ConocoPhillips Canada	–	Surmont Pilot and Commercial SAGD Project*	–
Devon Energy Corporation	–	Jackfish SAGD Project*, Jackfish SAGD Project 2*	Jackfish SAGD Project 3
Devon Energy and BP Canada	–	–	Pike Project, Walleye Project
E-T Energy	–	–	Poplar Creek In-Situ Pilot*
Grizzly Oil Sands ULC	–	–	Algar Lake SAGD Project
Harvest Operations Corp.	–	–	BlackGold Oil Sands Project* and Expansion
Husky Energy Inc.	Sunrise Thermal Project*, Tucker Thermal Project*	–	Caribou Lake Thermal Demonstration Project*, McMullen Thermal Pilot Project*
Imperial Oil Resources Ventures Ltd.	Cold Lake In-Situ Project*, Kearl Oil Sands Project*	–	–
Ivanhoe Energy Inc.	–	–	Tamarack Integrated Oil Sands Project
Japan Canada Oil Sands Ltd.	–	Hangingstone Pilot In-Situ Project*, Hangingstone SAGD Project	–
Koch Exploration Canada	–	–	Muskwa Oil Sands Project
Laricina Energy Ltd.	–	–	Germain Phase 1* and Expansion, Saleski Pilot* and Phase 1
Marathon Oil Corporation Canada	–	–	Birchwood Project
MEG Energy Corp.	–	Christina Lake Regional Project - Pilot*, Phases 2 and 2B*	Christina Lake Regional Project Phase 3, Surmont Project
Nexen Inc.	Long Lake Pilot Project*, Long Lake Commercial Project*	–	Long Lake Project Phases 1 and 2
Oak Point Energy Ltd	–	–	Lewis Pilot
OSUM Oil Sands Corp.	–	–	Taiga Project
Petrobank Energy and Resources Ltd.	–	–	May River Phase 1 Project and Expansion
Southern Pacific Resource Corporation	–	–	MacKay River Project and Expansion
Statoil Canada Ltd.	–	–	Kai Kos Dehseh SAGD Project
Suncor Energy Inc.	Dover SAGD Pilot and VAPEX Pilot*, Firebag Enhanced Thermal Solvent (ETS) Pilot Project*, Lewis SAGD Project, Voyageur South Project	Firebag SAGD Project*, Lease 86/17*, Steepbank & Millennium Mines*, MacKay River In-Situ*, MacKay River Expansion SAGD Project*, Meadow Creek In-Situ*, Meadow Creek Expansion SAGD Project, Millennium Coker Unit (MCU)*, Millennium Vacuum Unit (MVU)*, North Steepbank Extension Mine and Millennium Dump 9*, South Tailings Pond*, Upgrader Complex*, Voyageur Upgrader*, Fort Hills Oil Sands Project	Chard Project

Table 2.4-2 Projects Included in the 2013 Planned Development Case (continued)

Developer	Projects Included in the EIA PDC (no change in 2013 PDC)	Projects Included in the EIA PDC (Updated in 2013 PDC)	Projects New to 2013 PDC
Sunshine Oil Sands Ltd.	–	–	Harper Pilot*, Legend Lake SAGD Project Phase 1, Thickwood SAGD Project Phase 1, West Ells SAGD Project*
Surmont Energy Ltd.	–	–	Wildwood Project
Syncrude Canada Ltd.	Aurora North Mine*, Mildred Lake Upgrader*	Aurora South Mine*	–
Teck Resources Limited	–	–	Frontier Project
Total E&P Canada Ltd.	–	Joslyn North Mine Project*	Joslyn Mine Expansion
Value Creation Inc.	–	–	Terre de Grace Pilot and SAGD Project, TriStar Pilot Project, Advanced Tristar Commercial Project
Aggregate	Birch Mountain Resources Muskeg Valley Quarry*, Birch Mountain Resources Hammerstone, Parsons Creek Resources Sand and Gravel Pit*	–	Parsons Creek Resources Limestone Quarry
Other	East Athabasca Aerodrome, Northland Forest Products Ltd. Sawmill, Williams Energy Chemical Plant, Gas Plants and Compressors, Pipelines, Roadways, East Athabasca Highway, Municipalities and Communities, Others	–	–

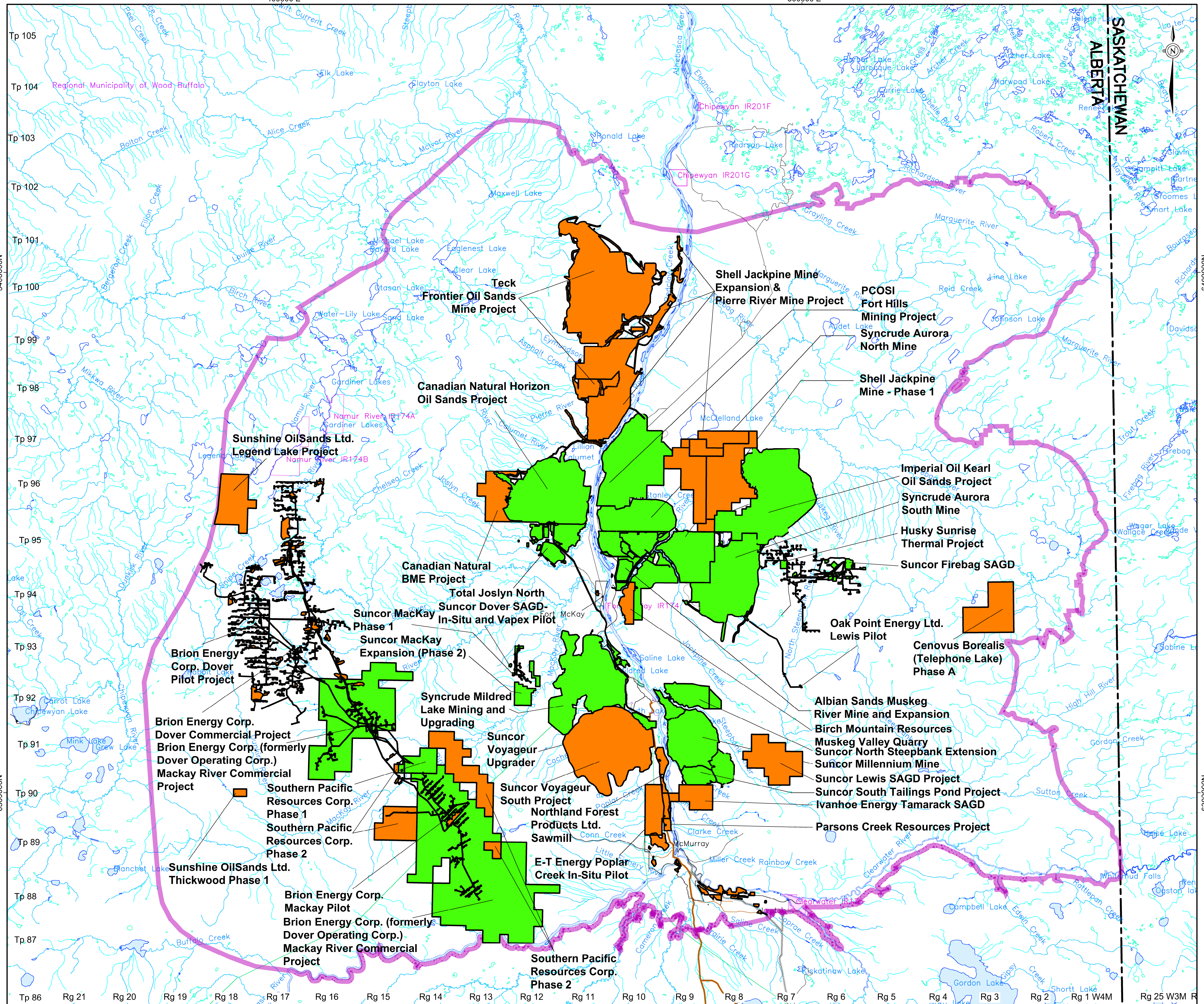
Note: The Total E&P Canada Ltd. Northern Lights Project (formerly owned by Synenco) was included in the EIA PDC; however, the project was put on hold and was not included in the 2013 PDC.

– = Not applicable.

* = project is existing or approved.

The locations of the existing, approved and planned projects used in the assessment are shown in Figure 2.4-1.

A project was not considered in a component if its potential effects had no measurable temporal and spatial overlap with those of the PRM. A list of projects included in the 2013 PDC broken down by assessment component is provided in Table 2.4-3.



LEGEND

- ROAD
- RAILWAY
- RIVER
- OPEN WATER
- EXISTING AND APPROVED DEVELOPMENT
- PLANNED DEVELOPMENT
- TERRESTRIAL REGIONAL STUDY AREA

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. © Government of Alberta SEPTEMBER 2004 and 2008. All rights reserved. USED UNDER LICENSE.
IHS TOWNSHIP OBTAINED FROM IHS ENERGY Inc.
DATUM: NAD83 PROJECTION: UTM ZONE 12. ALBERTA NTDB DIGITAL DATA OBTAINED FROM GEOMATICS CANADA, AUGUST 2001.

15 0 15
SCALE 1:750,000 KILOMETRES

PROJECT

PIERRE RIVER MINE PROJECT

TITLE

DEVELOPMENTS WITHIN THE TERRESTRIAL REGIONAL STUDY AREA

Shell Canada Limited

PROJECT	13.1346.0001.6103	FILE No. 131346000161O3A001	
DESIGN	CW	18 Jul. 2013	SCALE AS SHOWN REV. 0
CADD	PSR	19 Jul. 2013	
CHECK	CY	19 Jul. 2013	
REVIEW	DB	19 Jul. 2013	

FIGURE: 2.4-1

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Table 2.4-3 Projects Included and Environmental Components Considered in the 2013 Planned Development Case

Development	EIA Component							
	Air Quality	Hydrogeology	Aquatic Resources	Terrestrial Resources	Traditional Land Use	Resource Use	Historic Resources	Health
Shell Canada Limited								
Jackpine Mine Expansion & Pierre River Mine Project	●	●	●	●	●	●	●	●
Jackpine Mine - Phase 1	●	●	●	●	●	●	●	●
Orion EOR Project	●	–	–	–	–	–	–	●
Shell Canada Limited / Albian Sands Energy Inc.								
Muskeg River Mine and Muskeg River Mine Expansion	●	●	●	●	●	●	●	●
Alberta Oilsands Inc.								
Clearwater West Pilot Project	●	–	–	●	●	●	●	●
Athabasca Oil Corp.								
Dover West Clastics Phase 1	●	–	–	–	–	–	–	●
Dover West Leduc Carbonate Pilot	●	–	–	–	–	–	–	●
Hangingstone Experimental In-Situ Project	●	–	–	–	–	–	–	●
Hangingstone Project Phase 1	●	–	–	–	–	–	–	●
Birch Project	●	–	–	–	–	–	–	●
Baytex Energy Corporation								
Cold Lake	●	–	–	–	–	–	–	●
BlackPearl Resources Inc.								
Blackrod SAGD Pilot and Commercial Project	●	–	–	–	–	–	–	●
Brion Energy Corporation								
Dover Pilot Project	●	●	–	●	●	●	●	●
Dover Commercial Project	●	●	–	●	●	●	●	●
MacKay River Pilot Project	●	●	–	●	●	●	●	●
MacKay River Commercial Project	●	●	–	●	●	●	●	●
Canadian Natural Resources Limited								
Birch Mountain East Project (formerly Horizon In-Situ Project)	●	●	–	●	●	●	●	●
Burnt Lake Pilot Project	●	–	–	–	–	–	–	●
Grouse In-Situ Oil Sands Project	●	–	–	–	–	–	–	●
Horizon Oilsands Project	●	●	●	●	●	●	●	●
Kirby In-Situ Oil Sands Project	●	–	–	–	–	–	–	●
Kirby In-Situ Oil Sands Expansion Project	●	–	–	–	–	–	–	●
Primrose East In-Situ Project	●	–	–	–	–	–	–	●
Primrose North In-Situ Project	●	–	–	–	–	–	–	●
Primrose South In-Situ Project	●	–	–	–	–	–	–	●
Wolf Lake In-Situ Project	●	–	–	–	–	–	–	●
Gregoire Phase 1 In Situ Oil Sands Project	●	–	–	–	–	–	–	●
Cavalier Energy								
Hoole Project	●	–	–	–	–	–	–	●

Table 2.4-3 Projects Included and Environmental Components Considered in the 2013 Planned Development Case (continued)

Development	EIA Component							
	Air Quality	Hydrogeology	Aquatic Resources	Terrestrial Resources	Traditional Land Use	Resource Use	Historic Resources	Health
Cenovus Energy								
Telephone Lake SAGD Project (formerly Borealis In-Situ Project)	●	●	–	●	●	●	–	●
Grand Rapids SAGD Pilot Project	●	–	–	–	–	–	–	●
Narrows Lake Project	●	–	–	–	–	–	–	●
Pelican Lake SAGD Project	●	–	–	–	–	–	–	●
Cenovus FCCL Ltd.								
Christina Lake Thermal Project	●	–	–	–	–	–	–	●
Christina Lake Thermal Project Expansion	●	–	–	–	–	–	–	●
Foster Creek Thermal Project	●	–	–	–	–	–	–	●
Foster Creek Thermal Project Expansion	●	–	–	–	–	–	–	●
Connacher Oil and Gas Limited								
Algar Oil Sands Project	●	–	–	–	–	–	–	●
Great Divide Oil Sands Project	●	–	–	–	–	–	–	●
Great Divide Oil Sands Expansion Project	●	–	–	–	–	–	–	●
ConocoPhillips Canada								
Surmont Pilot and Commercial SAGD Project	●	–	–	–	–	–	–	●
Devon Energy Corporation								
Jackfish SAGD Project	●	–	–	–	–	–	–	●
Jackfish SAGD Project 2	●	–	–	–	–	–	–	●
Jackfish SAGD Project 3	●	–	–	–	–	–	–	●
Devon Energy and BP Canada								
Pike Project	●	–	–	–	–	–	–	●
Walleye Project	●	–	–	–	–	–	–	●
E-T Energy								
Poplar Creek In-Situ Pilot	●	●	–	●	●	●	●	●
Grizzly Oil Sands ULC								
Algar Lake SAGD Project	●	–	–	–	–	–	–	●
Harvest Operations Corp.								
BlackGold Oil Sands Project and Expansion	●	–	–	–	–	–	–	●
Husky Energy Inc.								
Caribou Lake Thermal Demonstration Project	●	–	–	–	–	–	–	●
McMullen Thermal Pilot Project	●	–	–	–	–	–	–	●
Sunrise Thermal Project	●	●	–	●	●	●	–	●
Tucker Thermal Project	●	–	–	–	–	–	–	●
Imperial Oil Resources Ventures Ltd.								
Cold Lake In-Situ Project	●	–	–	–	–	–	–	●
Kearl Oil Sands Project	●	●	●	●	●	●	●	●
Ivanhoe Energy Inc.								
Tamarack Integrated Oil Sands Project	●	●	–	●	●	●	●	●

Table 2.4-3 Projects Included and Environmental Components Considered in the 2013 Planned Development Case (continued)

Development	EIA Component							
	Air Quality	Hydrogeology	Aquatic Resources	Terrestrial Resources	Traditional Land Use	Resource Use	Historic Resources	Health
Japan Canada Oil Sands Ltd.								
Hangingstone Pilot In-Situ Project	●	–	–	–	–	–	–	●
Hangingstone SAGD Project	●	–	–	–	–	–	–	●
MEG Energy Corp.								
Christina Lake Regional Project - Pilot, Phases 2and 2B	●	–	–	–	–	–	–	●
Christina Lake Regional Project - Phase 3	●	–	–	–	–	–	–	●
Surmont Project	●	–	–	–	–	–	–	●
Koch Exploration Canada								
Muskwa Oil Sands Project	●	–	–	–	–	–	–	●
Laricina Energy Ltd.								
Germain Phase 1 and Expansion	●	–	–	–	–	–	–	●
Saleski Pilot and Phase 1	●	–	–	–	–	–	–	●
Marathon Oil Corporation Canada								
Birchwood Project	●	●	–	●	●	●	●	●
Nexen Inc.								
Long Lake Pilot Project	●	–	–	–	–	–	–	●
Long Lake Commercial Project	●	–	–	–	–	–	–	●
Long Lake Project Phases 1 and 2	●	–	–	–	–	–	–	●
Oak Point Energy Ltd.								
Lewis Pilot	●	●	–	●	●	●	●	●
OSUM Oil Sands Corp.								
Taiga Project	●	–	–	–	–	–	–	●
Petrobank Energy and Resources Ltd.								
May River Phase 1 Project and Expansion	●	–	–	–	–	–	–	●
Surmont Energy Ltd.								
Wildwood Project	●	–	–	–	–	–	–	●
Teck Resources Limited								
Frontier Project	●	●	●	●	●	●	●	●
Southern Pacific Resource Corporation								
MacKay River Project and Expansion	●	●	–	●	●	●	–	●
Statoil Canada Ltd.								
Kai Kos Dehseh SAGD Project	●	–	–	–	–	–	–	●
Suncor Energy Inc.								
Chard Project	●	–	–	–	–	–	–	●
Dover SAGD Pilot and VAPEX Pilot	●	–	–	●	●	●	●	●
Firebag Enhanced Thermal Solvent (ETS) Pilot Project	●	●	–	●	●	●	●	●
Firebag SAGD Project	●	●	–	●	●	●	●	●

Table 2.4-3 Projects Included and Environmental Components Considered in the 2013 Planned Development Case (continued)

Development	EIA Component							
	Air Quality	Hydrogeology	Aquatic Resources	Terrestrial Resources	Traditional Land Use	Resource Use	Historic Resources	Health
Lease 86/17, Steepbank & Millennium Mines, South Tailings Pond, North Steepbank Extension	●	●	●	●	●	●	●	●
Lewis SAGD Project	●	●	–	●	●	●	●	●
MacKay River In-Situ	●	–	–	●	●	●	–	●
MacKay River Expansion SAGD Project	●	–	–	●	●	●	–	●
Meadow Creek In-Situ	●	–	–	●	●	●	–	●
Meadow Creek Expansion SAGD Project	●	–	–	●	●	●	–	●
Millennium Coker Unit and Millennium Vacuum Unit	●	–	–	–	–	–	●	●
North Steepbank Extension Mine and Millennium Dump 9	●	●	●	●	●	●	●	●
Upgrader Complex	●	●	●	●	●	●	●	●
Voyageur South Project	●	●	●	●	●	●	●	●
Voyageur Upgrader	●	●	●	●	●	●	●	●
Fort Hills Oil Sands Project	●	●	●	●	●	●	●	●
Sunshine Oil Sands Ltd.								
Harper Pilot	●	–	–	–	–	–	–	●
Legend Lake SAGD Project Phase 1	●	–	–	–	–	–	–	●
Thickwood SAGD Project Phase 1	●	–	–	–	–	–	–	●
West Ells SAGD Project	●	–	–	–	–	–	–	●
Syncrude Canada Ltd.								
Aurora North Mine	●	●	●	●	●	●	●	●
Aurora South Mine	●	●	●	●	●	●	●	●
Mildred Lake Upgrader	●	–	●	●	●	●	●	●
Total E&P Canada Ltd.								
Joslyn North Mine Project	●	●	●	●	●	●	–	●
Joslyn Mine Expansion	●	–	–	–	–	–	–	●
Value Creation Inc.								
Terre de Grace Pilot and SAGD Project	●	●	–	●	●	●	●	●
TriStar Pilot Project	●	●	–	●	●	●	●	●
Advanced Tristar Commercial Project	●	●	–	●	●	●	●	●
Aggregate								
Birch Mountain Resources Muskeg Valley Quarry	●	–	–	●	●	●	●	●
Birch Mountain Hammerstone	●	–	–	●	●	●	–	●
Parson Creek Resources Sand and Gravel Pit	●	–	–	●	●	●	–	●
Parson Creek Resources Limestone Quarry	●	–	–	●	●	●	–	●

Table 2.4-3 Projects Included and Environmental Components Considered in the 2013 Planned Development Case (continued)

Development	EIA Component							
	Air Quality	Hydrogeology	Aquatic Resources	Terrestrial Resources	Traditional Land Use	Resource Use	Historic Resources	Health
Other								
East Athabasca Aerodrome	–	–	–	●	●	●	●	–
Forestry: Northland Forest Products Ltd. Sawmill	●	–	–	●	●	●	–	●
Williams Energy Chemical Plant	●	–	–	–	–	–	–	●
Municipal Growth	●	–	●	–	–	–	–	●
Gas Plants and Compressors	●	–	–	●	●	●	●	●
Major Pipelines, Utility Corridors, Roadways and Others	–	–	–	●	●	●	●	–

Note: ● = Included in the assessment; – = Not included in the assessment.

2.5 Key Indicator Resources

The selection of Key Indicator Resources (KIRs) is described in the EIA, Volume 3, Section 1.3.5. All KIRs used in the EIA were considered for the 2013 Base Case, 2013 PRM Application Case and 2013 PDC. For Terrestrial Resources, all federally listed wildlife species at risk that may occur in the LSA were added as KIRs as part of the updated 2013 assessment. A list of species at risk considered in this assessment is presented in Table 1.3-2 of the *May 2011, Submission of Information to the Joint Review Panel, Appendix 2*.

2.6 Integration of Traditional Ecological Knowledge

The EIA, Volume 5, Section 8.4.4, Table 8.4-2 discusses how Traditional Ecological Knowledge (TEK) was integrated into the assessment. The EIA TOR included specific requirements for the information that must be addressed within the EIA, including the use of TEK. The TEK considered for inclusion in the EIA was gathered from the following sources:

- literature review for the Traditional Land Use (TLU) RSA;
- previous impact assessments;
- interviews with trapline holders in the LSA; and
- consultation with and documentation from the Community of Fort McKay including the Fort McKay First Nation (FMFN) and Fort McKay Métis, Athabasca Chipewyan First Nation (ACFN) and Mikisew Cree First Nation (MCFN) on their traditional uses within the LSA.

The TEK made available to Shell since the EIA has been reviewed and incorporated into the updated assessment (Appendix 1 and Appendix 2) as well as in the Cultural Assessment (Appendix 7).

A detailed description of the assessment methods used to collect the TEK considered in the EIA can be found in the TLU Environmental Setting Report (ESR; Golder 2007a) and in the TLU Environmental Setting Report Update (Appendix 3.8, Section 1.0).

The TEK was integrated into the EIA based on the following approach:

- The TLU component lead segregated the TLU ESR information into land use information and TEK.
- The EIA technical components reviewed the TEK and identified items relevant to each technical component.
- The TEK was incorporated as part of the analysis quantitatively or qualitatively, where possible.
- A discussion outlining the relevant TEK information, how the TEK was integrated and where the integrated TEK can be found within the EIA was prepared for each EIA technical component.

Traditional Ecological Knowledge played an important role in the EIA assessment methods and analysis. Each component of the EIA presents a "TEK Integration" section outlining how TEK was integrated. Some examples include:

- KIRs selected for the Fish and Fish Habitat assessment;
- presence/absence information in local watercourses and waterbodies were used in the Conceptual Compensation Plan;
- KIRs selected for the Traditional Use Plant Potential assessment based on food, ceremonial or medicinal uses; and
- information on wildlife habitat associations, seasonal movements, hunting pressure, wildlife distribution and relevant abundance, and the KIRs selected for the Wildlife Assessment.

The Closure and Reclamation Plan assessed in the EIA was based on Shell's objectives for their revegetation program and include end land uses consistent with traditional resource use and TEK.

Traditional Ecological Knowledge provided by the various Aboriginal groups was considered as baseline information by the various components, and incorporated into the assessment using a weight-of–evidence approach.

2.7 Air Quality and Environmental Health

The air quality modelling assessment methods used for the 2013 Base Case, 2013 PRM Application Case and 2013 PDC are the same as was used for the EIA. The Alberta Ambient Air Quality Objectives (AAAQOs) for sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and particulate matter with a mean aerodynamic diameter of 2.5 µm or smaller ($PM_{2.5}$), and the Texas Commission on Environmental Quality (TCEQ) Effects Screening Levels (ESLs) for several trace compounds have been revised since the EIA (ESRD 2013b; TCEQ 2013); therefore, the air quality predictions are compared to the 2013 AAAQOs and the 2013 TCEQ ESLs.

Criteria Air Compounds

Criteria air compounds are common emissions from industrial developments and include SO_2, NO_2, carbon monoxide (CO) and $PM_{2.5}$. They are regulated using criteria developed based on their effects on human health and the environment.

The AAAQOs, the Federal Government Air Quality Objectives and the Canada-Wide Standards for criteria air pollutants used in this assessment are shown in Table 2.7-1. These criteria have been updated from the EIA based on the most recent AAAQOs.

Table 2.7-1 Alberta and National Air Quality Criteria

Parameter	Ambient Air Quality Objectives[a]	Canada-Wide Standards[b]	National Ambient Air Quality Objectives[c]			Lower Athabasca Regional Plan Trigger Levels and Limits
			Desirable	Acceptable	Tolerable	
SO_2 [µg/m³]						
1-Hour	450	–	450	900	–	31 / 63 / 94[f]
24-Hour	125	–	150	300	800	–
30-Day	30	–	–	–	–	–
Annual	20	–	30	60	–	8 / 13 / 20
NO_2 [µg/m³]						
1-Hour	300	–	–	400	1,000	57 / 118 / 176[f]
24-Hour	–	–	–	200	300	–
Annual	45	–	60	100	–	15 / 30 / 45
CO [µg/m³]						
1-Hour	15,000	–	15,000	35,000	–	–
8-Hour	6,000	–	6,000	15,000	20,000	–
$PM_{2.5}$ [µg/m³]						
24-Hour	30	30[e]	–	–	–	–
Annual	–	–	–	–	–	–

(a) Source: ESRD 2013.

(b) Source: Canadian Council of Ministers of the Environment (CCME) 2000.

(c) Source: Health Canada 2006.

(d) Compliance with the Canada-Wide Standard (CCME 2000) is based on the fourth highest 8-hour measurement annually averaged over three consecutive years.

(e) Compliance with the Canada-Wide Standard (CCME 2000) is based on the 98th percentile of the annual monitored data averaged over three years of measurements.

(f) The hourly trigger levels are based on the 99^{th} percentile of the hourly data over a year.

– = No criteria available.

Lower Athabasca Regional Plan

The Air Quality Management Framework of the *Lower Athabasca Regional Plan* (LARP; Government of Alberta 2012) sets air quality triggers and limits for hourly and annual SO_2 and NO_2 to aid in long-term decision-making and management of air quality in the Lower Athabasca Region. Under this framework, ambient SO_2 and NO_2 data from Wood Buffalo Environmental Association and Lakeland Industrial and Community Association monitoring stations will be evaluated annually. If the monitoring values exceed any trigger or limit, an appropriate management response will be initiated under the framework. The trigger levels and limits are shown in Table 2.7-1.

While the management response is triggered by monitored ambient air quality data, the framework also recognizes that air dispersion modelling can be a valuable tool in response planning and future development planning. However, any SO_2 or NO_2 predictions provided in EIAs that are above the air quality triggers do not prompt a management response under the framework. Rather, the predictions in the EIA can provide useful information in the planning and management of the air quality in the Lower Athabasca Region under the framework.

Trace Air Compounds

Industrial and residential activities in the modelling domain can result in the release of numerous trace air compounds. Although a thorough evaluation of the potential health effects associated with air emissions in the region has been provided in Appendix 3.3, the air quality assessment provides a screening-level evaluation for the compounds that have air quality criteria. The air quality criteria for the trace compounds are provided in the EIA, Volume 3, Section 3.2.3.7. The updated TCEQ ESLs are provided in Appendix 3.2.

The trace air compounds evaluated in the air quality assessment include:

- Total Reduced Sulphur (TRS) compounds;
- Volatile Organic Compounds (VOCs);
- Polycyclic Aromatic Hydrocarbons (PAHs); and
- airborne metals.

2.8 Aquatic Resources

The assessment methods applied to the Aquatics assessment were broadly consistent with those applied in the EIA, described in the EIA, Volume 4B, Appendix 4-1 and 4-2. Some changes were made to the water quality and aquatic health assessments to align with current practice and regional frameworks.

2.8.1 Water Quality

The 2013 PRM Application Case (Appendix 1, Section 3.4), and the 2013 PDC include changes to the operational and closure drainage plans for oil sands mines in the PRM LSA and the RSA. Planned projects and drainage plan integration will result in different water chemistry and flow rates of mine-affected water releases and natural flows from undisturbed areas (Table 2.8-1). The changes in amounts and chemistry of water releases may affect constituent concentrations in receiving watercourses and waterbodies.

The modelling methods in the 2013 PDC are identical to those described in the EIA, Volume 4B, Appendix 4-2, Section 2.1, with the following exceptions:

- The Golder Pit Lake Model was used to assess the water quality in pit lakes.
- Naphthenic acids were modelled according to the rates described in the *End Pit Lakes Guidance Document 2012* (CEMA 2012).
- The Athabasca River Model was calibrated (Appendix 1, Section 3.4.1) to include natural saline groundwater inflows between Fort McMurray and Embarras.

In this submission, the list of modelled water quality constituents was revised to be in alignment with the *Lower Athabasca Region Surface Water Quality Management Framework* (Government of Alberta 2012). Constituents with a water quality limit under the Framework were included in the modelling. Finally, water quality guidelines were revised to include updates by the Canadian Council for Ministers of the Environment (CCME 2012).

Table 2.8-1 Mine-Related Water Releases Used for Modelling

Node	Source	Muskeg Drainage[(a)] [m³/s]	Overburden Dewatering [m³/s]	In-pit Tailings Consolidation Release [m³/s]	Mature Fine Tailings Consolidation Release [m³/s]	Process-Affected Seepage [m³/s]
2018						
Athabasca River between Pierre River and Big Creek	Shell PRM	0.14	-	-	-	-
Eymundson Creek	Shell PRM	0.2	0.007	-	-	-
Big Creek	Teck Frontier	0.0041	-	-	-	-
Redclay Creek	Teck Frontier	0.00091	-	-	-	-
2034						
Athabasca River between Pierre River and Big Creek	Shell PRM	0.14	0.081	-	-	-
Athabasca River between Pierre River and Big Creek	Teck Frontier	0.0042	-	-	-	-
Big Creek	Teck Frontier	0.0069	-	-	-	-
2052						
Athabasca River between Pierre River and Big Creek	Shell PRM	-	-	-	-	0.02
Pierre River	Shell PRM	-	-	-	-	0.0000083
Shell's Treatment Lake	Shell PRM	-	-	-	-	0.000032
Shell's Treatment Wetland	Shell PRM	-	-	-	-	0.0023
Pierre North Pit Lake	Shell PRM	-	-	0.00052	0.012	0.0043
Pierre South Pit Lake	Shell PRM	-	-	0.00014	0.02	0.0023
2152						
Athabasca River between Pierre River and Big Creek	Shell PRM	-	-	-	-	0.011
Pierre South Pit Lake	Shell PRM	-	-	0.00014	0.00022	0.00097
Pierre North Pit Lake	Shell PRM	-	-	0.00052	0.00013	0.00087
Pierre River	Shell PRM	-	-	-	-	0.0000014
Shell's Treatment Lake	Shell PRM	-	-	-	-	0.0000024
Shell's Treatment Wetland	Shell PRM	-	-	-	-	0.0011
Teck Frontier's Closure Lake 3	Teck Frontier	-	-	-	-	0.0059
Teck Frontier's South Pit Lake	Teck Frontier	-	-	-	-	0.0007
Teck Frontier's Closure Lake 2	Teck Frontier	-	-	-	-	0.031
Teck Frontier's South Central Pit Lake	Teck Frontier	-	-	-	-	0.016
Big Creek	Teck Frontier	-	-	-	-	0.0002
OPTA Seepage Pond[(b)]	Teck Frontier	-	-	-	-	0.014
Teck Frontier's Central Pit Lake	Teck Frontier	-	-	-	-	0.0046
Athabasca River downstream of Redclay Creek[(b)]	Teck Frontier	-	-	-	-	0.0064
Athabasca River upstream of Big Creek[(c)]	Teck Frontier	-	-	-	-	0.0043

(a) Muskeg drainage release occurs at the rate shown during the open-water period.

(b) OPTA = Out of Pit Tailing Area.

- = no discharge.

Assessment methods used to screen and assess the results of water quality model predictions in this submission are also consistent with those used in the EIA, Volume 4A, Section 6.5.5.3. Predictions for the 2013 PDC were compared to water quality guidelines and PIC concentrations. The 2013 PDC predictions are accompanied by these reference values in the results tables in this section.

Assessment nodes used for assessing changes to water quality in the PRM LSA under the 2013 PDC were generally consistent with those used for the 2013 PRM Application Case. However, some nodes were moved because their physical locations are proposed to change as part of stream diversions and construction of compensation lakes. In snapshots 2034 and 2042, Pierre River and the upper watershed of Eymundson Creek and its tributaries will be diverted south to the Pierre River diversion channel. For these snapshots, water quality for both nodes was assessed at the mouth of the Pierre River diversion channel.

In the 2013 PDC, Redclay Creek will be diverted around the Frontier Mine, and then through Teck's compensation lake and the South Redclay Lake. Therefore, the South Redclay Lake will receive inflows from Big Creek and Redclay Creek. In 2018, the South Redclay Lake will not yet exist, and thus the water quality for that node was assessed at the mouth of Redclay Creek, upstream of the confluence with the Athabasca River. For the remaining snapshots after construction of the Frontier Mine Compensation Lake, water quality was assessed at the South Redclay Lake. In 2018, Big Creek was assessed at the mouth of Big Creek, upstream of the confluence with the Athabasca River. In other snapshots, Big Creek was assessed upstream of the South Redclay Lake.

2.8.1.1 Small Streams

The small streams assessment approach is consistent with that described in the EIA, Volume 4B, Appendix 4-2, Section 2.1. To include Teck's Frontier Mine in this submission, the LSA boundary was updated, for the following two reasons: 1) to include the entire Redclay Creek watershed, because that watershed will be affected by the Frontier Mine, which is included in the 2013 PDC; 2) in the 2013 PRM Application Case, Redclay Creek will be diverted to South Redclay Lake.

For this assessment, the Hydrological Simulation Program-Fortran (HSPF) water quality model was recalibrated to include additional data that have been collected since submission of the EIA in 2007. Calibration, application and assumptions of the HSPF model used for predicting constituent concentrations are consistent with the EIA (Volume 4, Appendix 4-2, Section 2.1). Mine-related inputs to the model were updated as presented in Table 2.8-2.

Assessment methods used to screen and assess the results of the water quality model predictions in this submission are consistent with those described in the EIA, Volume 4A, Section 6.5.6.3. Predictions for the 2013 PRM Application Case were compared to water quality guidelines, PIC concentrations (Appendix 2, Section 2) and 2013 Base Case concentrations.

The nodes for assessing the effects of PRM in the LSA are consistent with the EIA, with an additional node added at Redclay Creek to evaluate effects of the South Redclay Lake and the northern extent of the Teck Frontier Project. The assessment nodes in the RSA were updated to capture the effects of both Shell PRM and Teck Frontier projects, and are located at the following locations on the Athabasca River:

- downstream of Redclay Creek (Node AR1); and
- upstream of the Embarras River (Node A4).

Table 2.8-2 2013 PRM Application Case Mine-Related Water Releases Used for Modelling

Node	Muskeg Drainage[(a)] [m³/s]	Overburden Dewatering [m³/s]	In-pit Tailings Consolidation Release [m³/s]	Mature Fine Tailings Consolidation Release [m³/s]	Process Affected Seepage [m³/s]
2018					
Athabasca River between Pierre River and Big Creek	0.14				
Eymundson Creek	0.20	0.007	-	-	-
2034					
Athabasca River between Pierre River and Big Creek	0.14	0.081	-	-	-
2052					
Athabasca River between Pierre River and Big Creek	-	-	-	-	0.020
Pierre River	-	-	-	-	0.0000083
Shell's Treatment Lake	-	-	-	-	0.000032
Shell's Treatment Wetland	-	-	-	-	0.00230
Pierre North Pit Lake			0.00052	0.012	0.00430
Pierre South Pit Lake			0.00014	0.02	0.0023
2152					
Athabasca River between Pierre River and Big Creek	-	-	-	-	0.011
Pierre South Pit Lake	-	-	0.00014	0.00022	0.00097
Pierre North Pit Lake			0.00052	0.00013	0.00087
Pierre River	-	-	-	-	0.0000014
Shell's Treatment Lake	-	-	-	-	0.0000024
Shell's Treatment Wetland	-	-	-	-	0.0011
Athabasca River downstream of Redclay Creek	-	-	-	-	0.0064
Athabasca River upstream of Big Creek	-	-	-	-	0.0046

[(a)] Muskeg drainage waters discharge at the rate shown during the open water period.

Due to changes to the configuration of watersheds throughout operations, some assessment nodes are located at different points during different snapshots. Node locations change during some snapshots in response to diversions of streams or creation of lakes, and are situated to capture the effects of sensitive conditions such as low background flows or high mine water inputs. For the 2034, 2042, 2052 and 2152 snapshots, water quality results are predicted at the South Redclay Lake, whereas for the first snapshot (2018), water quality results are assessed at the mouth of Redclay Creek because the South Redclay Lake will not exist yet. In 2018, Big Creek was assessed at the mouth of Big Creek, just upstream of the confluence with the Athabasca River. In other snapshots, Big Creek was assessed upstream of South Redclay Lake. In both 2052 and 2152, Eymundson Creek was assessed at the South Pit Lake.

2.8.1.2 Athabasca River Model

Water quality of the Athabasca River was predicted for each assessment snapshot under the PIC, 2013 Base Case, 2013 PRM Application Case and 2013 PDC. General information such as the modelling equations used in the Athabasca River Model (ARM) and a description of the model inputs are provided in the EIA, Volume 4B, Appendix 4-2, Section 2.1.3. For this assessment, the ARM setup was consistent with the EIA with the following exceptions:

- additional constituents which have limits in the LARP were added to the model;

- an input source representing natural saline groundwater inputs between Fort McMurray and Embarras was added; and
- a loading source was added for constituents that were initially under-predicted at Embarras.

Additional details regarding these updates are provided below.

Additional Constituents

The LARP is the Government of Alberta's regional plan, which specifies environmental limits and triggers in the Lower Athabasca River (Government of Alberta 2012). Among water quality constituents that have limits and triggers in LARP, four of them were not included in previous assessments. These constituents are nitrate, lithium, thallium and uranium. Using the assessment methods described in the EIA, Volume 4B, Appendix 4-2, Section 2.1.4, input data were derived for these constituents for the Clearwater and Athabasca rivers upstream of Fort McMurray, natural tributaries, mine waters, as well as output from the small stream and pit lake models. In cases where observed data were unavailable for a given input, concentration profiles from a similar water input were applied.

Time series of concentrations for Big Creek, Eymundson Creek, Pierre River and Redclay Creek were obtained from the small streams model for each applicable snapshot. In the case of tributaries outside of the LSA, for which small streams models have not been completed for the additional constituents, the change in concentration for each constituent in Big Creek under each assessment scenario was used as proxy data for those streams. Specifically, loadings during each snapshot were calculated based on natural observed data and ratios between background and other predicted snapshots in Big Creek.

Water quality profiles for pit lakes outside of the LSA that are input to ARM were also updated for the additional constituents. Similar to the proxy method applied to small stream model inputs, pit lakes outside of the LSA were assumed to have similar concentrations of nitrate, lithium, thallium and uranium as PRM South Pit Lake.

Natural Saline Groundwater Input

The presence of natural, saline groundwater discharges to the Lower Athabasca River has been known for some time, but its influence on river chemistry has not been quantified until recently. In a mass-balance exercise, Jasechko et al. (2012) used chloride as a conservative tracer to estimate the rate of discharge of these waters to the river between Fort McMurray and Old Fort (which is near the Embarras assessment node). The saline groundwater has high concentrations of chloride, sodium and Total Dissolved Solids (TDS), which cause measureable changes to concentrations downstream in the Athabasca River. To improve the ARM calibration and better understand the contribution of saline groundwater to the Lower Athabasca River, saline groundwater input was added to the ARM, and the model was iteratively calibrated to observed sodium and chloride concentrations in the Athabasca River near Embarras.

In this calibration, saline groundwater seepage input was added to ARM by way of a two-step process:

- calibration was completed with chloride from a single groundwater input to arrive at initial estimates; and
- calibration was completed with other ions at three different locations to refine that estimate.

The input data used in the first step of calibration were derived from measured groundwater chloride concentrations, which were used in the mass balance study by Jasechko et al. (2012). The raw data, provided by the author (Jasechko 2012, pers. comm.), are presented in Table 2.8-3. This dataset was used to create a stochastic time-series of input chloride concentration from 1960 to 2005 using the assessment methods described in the EIA, Volume 4B, Appendix 4-2, Section 2.1.4. The upper bound of the chloride time-series was set as the maximum measured concentration (65,200 mg/L).

In the first step, only one input node, located directly downstream of Fort McMurray, was added to the model. It is recognized that this input node does not match the actual location of saline seepages, but it was considered appropriate for arriving at an initial estimate of overall loadings. The saline groundwater input flow estimated by Jasechko et al. (2012) ranged from 0.5 to 3.4 m^3/s with a mean value of 1.08 m^3/s. These values were used as initial inputs in the iterative simulations. The output node at the Embarras location was used for comparison with observed values collected from the Athabasca River. The saline groundwater discharge rate was determined by iterative simulation to match the observed cumulative probability distributions, as well as best overall correlation with mean, median and peak values (99.91% percentile).

In the second step of calibration, a more detailed groundwater datasheet including eight constituents and three source locations was assembled based on Hitchon (1991) and Hakbarth (1977), as listed in Table 2.8-4. Concentrations of calcium, chloride, sulphate, potassium, sodium, magnesium and TDS were included in the groundwater quality datasheet. Input time-series of ions and TDS were created based on ratios with the chloride time-series used in the first step of calibration. The simplifying assumption that all groundwater seepages will have ion ratios defined by the three water types was necessary based on the limited data available.

For each of three discharge points along the Athabasca River, individual input time-series were created and entered into ARM. Inputs were created for each ion for the following water types: saline brine, hypersaline brine and Basal Aquifer. The discharge points were assumed to be located at 40, 50 and 75 km downstream of Fort McMurray, respectively, based on assumed hydrostratigraphy. An approximate flow rate at each input node was determined through iterative simulations. The ARM was simulated first without saline groundwater input. Then, in-stream model results with different discharge rates were compared with measured data at Embarras to find the best match in probability distributions, with emphasis on matching mean, median and peak values. Initial values for each input location were obtained by apportioning the rates estimated by the first step into three sources, then refining each of the three apportionments iteratively.

Sodium and chloride are the two main ions which contribute to most of the TDS in saline groundwater (Table 2.8-4), and the ARM model results without a saline groundwater input under-predicted these two constituents in the Athabasca River. Therefore, the calibration focused on sodium and chloride. Even without a saline water input, the model over-predicted potassium and sulphate concentrations at the downstream node of the Athabasca River. Therefore these constituents were not re-calibrated with the saline groundwater input. Additionally, calcium concentrations in saline groundwater were so low that they did not affect the calibration, so a calibration with calcium was excluded. Total dissolved solids were also calibrated, but it only changed slightly after calibration.

Based on the iterative calibration, the best match between predicted and observed data was achieved when the input flow rates of 0.015, 0.18 and 0.003 m^3/s, respectively were entered at the three input nodes, for a total saline groundwater input of 0.198 m^3/s. Cumulative probabilities and correlations between predicted and observed data are plotted in Figure 2.8-1.

Table 2.8-3 Chloride Concentration in Saline Groundwater

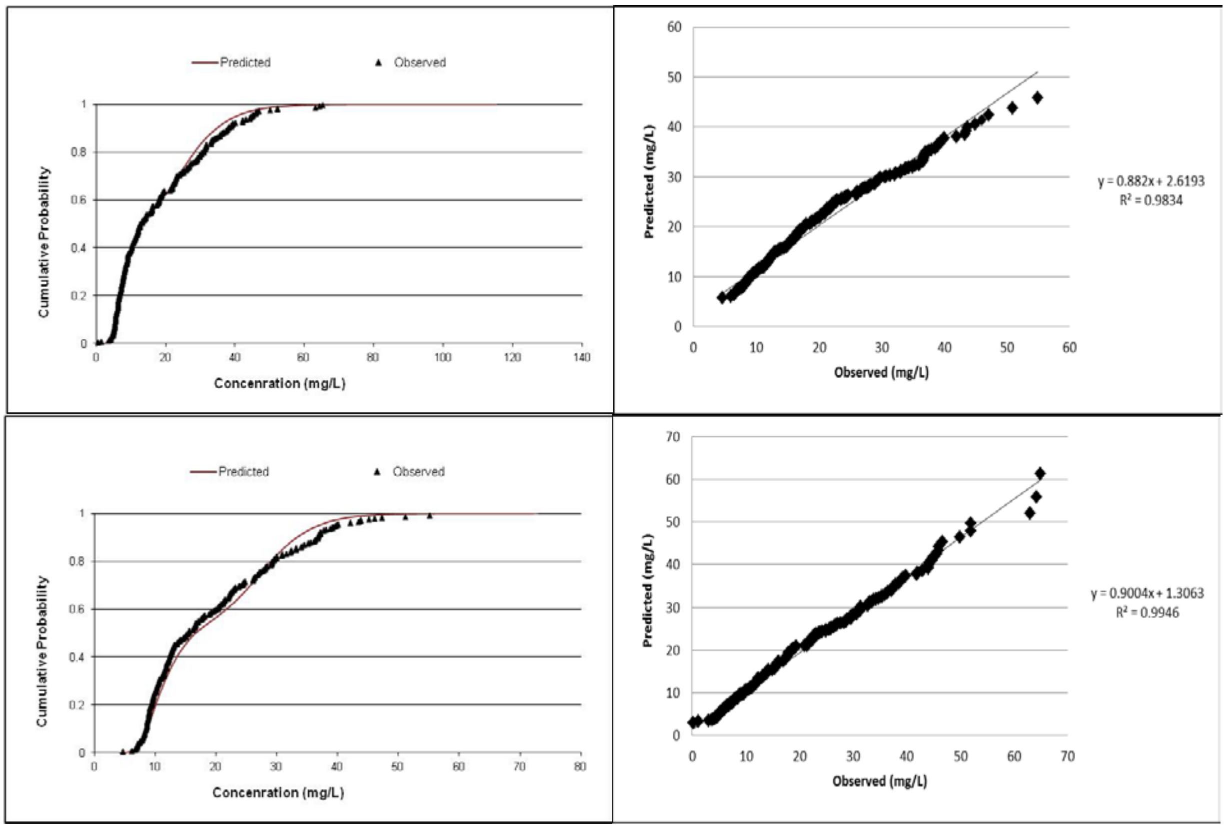
Chloride [mg/L]	System	Ref
554	Basal McMurray	Fennell (2010)
563	Basal McMurray	Fennell (2010)
587	Basal McMurray	Fennell (2010)
621	Basal McMurray	Fennell (2010)
629	Basal McMurray	Fennell (2010)
1,500	K-D	Gibson et al. (2011)
1,778	Basal McMurray	Fennell (2010)
2,147	Basal McMurray	Fennell (2010)
2,223	Basal McMurray	Fennell (2010)
2,590	K-D	Gibson et al. (2011)
2,710	K-D	Gibson et al. (2011)
2,900	Wabiskaw	Lemay (2002)
3,180	Clearwater	Lemay (2002)
3,694	Basal McMurray	Fennell (2010)
3,709	Basal McMurray	Fennell (2010)
3,744	Basal McMurray	Fennell (2010)
3,864	Basal McMurray	Fennell (2010)
3,919	Basal McMurray	Fennell (2010)
3,952	Basal McMurray	Fennell (2010)
4,030	K-D	Gibson et al. (2011)
4,049	Basal McMurray	Fennell (2010)
4,130	Basal McMurray	Fennell (2010)
4,660	Wabiskaw	Lemay (2002)
5,200	McMurray	Lemay (2002)
6,013	Basal McMurray	Fennell (2010)
6,200	Basal McMurray	Fennell (2010)
6,398	Basal McMurray	Fennell (2010)
6,971	Basal McMurray	Fennell (2010)
7,182	Basal McMurray	Fennell (2010)
8,600	Clearwater	Lemay (2002)
10,153	McMurray	Lemay (2002)
11,200	Clearwater	Lemay (2002)
12,569	McMurray	Lemay (2002)
14,200	K-D	Gibson et al. (2011)
14,979	McMurray	Lemay (2002)
16,045	Basal McMurray	Fennell (2010)
16,561	McMurray	Lemay (2002)
17,104	Basal McMurray	Fennell (2010)
17,245	Basal McMurray	Fennell (2010)
18,881	Basal McMurray	Fennell (2010)
19,413	Basal McMurray	Fennell (2010)
26,000	K-D	Gibson et al. (2011)
65,200	K-D	Gibson et al. (2011)

Source: Raw data from Jasechko et al. (2012) provided by the author.

Table 2.8-4 Saline Groundwater Quality and Location

Name	Reference	Location [km]	TDS [mg/L]	Na [mg/L]	K [mg/L]	Ca [mg/L]	Mg [mg/L]	Cl [mg/L]	SO_4 [mg/L]
Saline brine	Hitchon (1991)	40	73,000	25,600	64	1,830	456	40,200	4,780
Basal aquifer	Hakbarth (1977)	50	7,000	2,550	24	21	59	3,440	62
Hypersaline brine	Hakbarth (1977)	75	280,000	120,313	108	1,084	380	160,000	4,150

Figure 2.8-1 Cumulative Probabilities and Correlation Between Predicted and Observed Data (Top: Chloride; Bottom: Sodium)



After the calibration was completed, the three input nodes were recombined and added directly downstream of Fort McMurray. A full suite of chemistry was applied to this source so that the contribution of saline groundwater discharge to concentrations of other constituents in the river would be accounted for. The water quality profiles for other constituents which were not calibrated were adopted from observed basal water quality (EIA, Volume 4B, Appendix 4-2, Table 34).

Unknown Loading Sources

For some of the total metals, the model underestimated concentrations compared to observed data in the Athabasca River near Embarras. The underestimated constituents are arsenic, cadmium, chromium, copper, iron, lead and manganese. Because the model was calibrated to existing conditions, and accounts for inputs from upstream sources, natural tributaries, saline groundwater and licensed discharges, the additional load of these constituents is thought to derive from some other source.

To identify other potential loading sources, a literature review was completed on available studies of Athabasca River water quality. This review included AWC (2011, 2012), Glozier et al. (2009), Hebben (2009), Squires et al. (2009) and RAMP (2012). These studies examined water quality in the Athabasca River, each with a different scope and focus. Most studies included comparisons of concentrations over time or by location (e.g., upstream and downstream of oil sands developments). While these studies did note high concentrations of these constituents, they did not determine the source or cause of the increased loads at the downstream location. Therefore, to ensure that the model does not under predict concentrations, an input load was added to the model to account for unknown loading sources. The load of each constituent, listed in Table 2.8-5, was determined iteratively such that the best fit between modelled and observed data were obtained. The load was added as a constant source, distributed across the river, downstream of the mineable Oil Sands Region.

Table 2.8-5 Load of Metals in Calibration Input Water

Name	Load [kg/day]
Arsenic	8.4
Cadmium	4.0
Chromium	50
Copper	49
Iron	13,744
Lead	27
Manganese	540

2.8.1.3 Pit Lakes

Two pit lakes will be created during the Closure phase of PRM. These lakes are the North Pit Lake and South Pit Lake. The South Pit Lake will be separated by a submerged dyke into an Upstream Cell and Downstream Cell. The downstream cell will contain no tailings and will provide final polishing of pit lakes water prior to release to the receiving environment. The lake configurations are described in the EIA, Volume 4A, Appendix 4-2, Section 2.1.3, and have not been updated since 2007. As in previous submissions, the water in the pit lakes will originate from Non Segregated Tailings (NST) pond runoff, natural watershed runoff, reclaimed overburden runoff and tailings sand seepage. In the EIA, the pit lake models assumed that the lakes would be filled with inflows from Asphalt and Eymundson creeks, whereas in this submission, Athabasca River water is assumed to be used to fill the lakes. The configuration of the lakes and source waters are summarized in Table 2.8-6. Updates to the pit lakes since 2007 include a change in timing of the mine plan and a larger dataset of background and mine-related waters that include data collected since 2007 by Shell and Teck.

The pit lake modelling approach in this assessment is the same as the approach described in the EIA, Volume 4B, Appendix 4-2, Section 2.1.3, except that, to minimize model run times, the Golder Pit Lake Model (GPLM) was used to model water quality instead of CE-QUAL-W2 (Cole and Wells 2008). Previous work (Golder 2007b) has shown that these models produce similar water quality predictions, provided that CE-QUAL-W2 is run first and the hydrodynamic conditions predicted by CE-QUAL-W2 are entered as inputs to GPLM.

Inputs to the model were consistent with the previous pit lakes modelling, except where additional data have become available since 2007. Pit lakes water quality was modelled from the time of initial filling, through the time of connection to the surrounding watershed, in 2052, and continuously for one hundred years post-closure. North Pit Lake and South Pit Lake Upstream Cell are assumed to start filling in 2043; South Pit Lake Downstream Cell is scheduled to start in 2051 because it receives water mainly from the discharge of South Pit Lake Upstream Cell.

Separate GPLM models were set up for each Pit Lake to predict constituent concentrations. The models were constructed with influent streams, precipitation and evaporation rates, lake volume and influent water quality and mixing characteristics of each lake. The mixing characteristics of lakes were estimated by the hydrodynamic model completed in CE-QUAL-W2 and presented in the EIA. Inflow rates were set to the rates generated by the HSPF model for small streams.

Table 2.8-6 Characteristics of Pit Lakes

Description	North Pit Lake	South Pit Lake Upstream Cell	South Pit Lake Downstream Cell
Total volume [Mm^3]	118	294	26
Water volume [Mm^3]	17	131	26
Surface elevation [m]	280	250	250
Surface area [km^2]	2.7	10.6	0.9
Mean water depth [m]	6.3	12	29
Filling begins	2043	2043	2051
Bottom material	MFT	MFT	overburden
Discharge begins	2044	2052	2052
Discharge receptor	South Pit Lake Upstream Cell	South Pit Lake Downstream Cell	Athabasca River
Mean Far Future outflow [m^3/s]	0.63	0.57	0.57
Mean residence time [yr]	0.9	7.3	1.4
Source waters [Mm^3/annum]	Natural and reclaimed landscape runoff: 0.69, 0.89 Tailing sand seepage: 0.14, 0.028 CT flux and runoff from cell 1 & 3: 1, 0.03 Athabasca River: 13.3, 0 Precipitation: -0.4, -0.4	Natural and reclaimed landscape runoff: 1.4, 2.1 Tailing sand seepage: 0.07, 0.03 CT Flux and runoff from Cell 2: 0.29, 0.004 Precipitation: -1.3, -1.3 North Pit Lake: 0.56, 0.63	Athabasca River: 28, 0 Precipitation: -0.1, -0.1 South Pit Lake Upstream Cell: 0, 0,57

Notes: Values in last row refer to inflow volumes during filling period and post-filling.
Precipitation values are shown as net precipitation/evaporation (i.e., negative value indicates net evaporation).

2.8.2 Aquatic Health

2.8.2.1 Chronic Effect Benchmarks and Bioaccumulation Factor Updates

The Chronic Effects Benchmarks (CEBs) used in the 2013 assessment are revised values that incorporate additional data for several substances and apply the CCME (2007) species-sensitivity-distribution approach, where appropriate, as discussed in Appendix 3.6. The CEBs represent concentrations beyond which changes to aquatic health could occur on the scale of individual organisms within populations of sensitive species. Although the benchmarks are less conservative than generic water quality guidelines, the evaluation of community-level effects and population-level effects for derivation of the benchmarks is still considered protective and consistent with accepted practice (i.e., CCME, 2007) which allows for consideration of the resiliency and redundancy in natural communities. In some cases, the CEBs have also been developed based on consideration of toxicity modifying factors within the Oil Sands Region. Consequently, the benchmarks are considered to be appropriately conservative thresholds by which potential effects on aquatic health can be assessed. The revised CEBs that were used in the aquatic health assessment are listed in Appendix 3.6, Section 2.9, Table 2.9-1. For comparison purposes, the original CEBs that were used in the EIA are also presented.

Consistent with the current state of the science of selenium toxicology, and recognizing that selenium elicits effects on reproduction due to maternal transfer (Chapman et al. 2010), a water-based CEB was not developed for selenium. Rather, the potential for effects to aquatic health due to predicted selenium concentrations were assessed only through fish tissue effects assessment.

Chronic effects benchmarks have not been developed for calcium, lithium, and sodium; these substances are trace elements for which water guidelines for protection of aquatic life are unavailable from CCME. However, the Surface Water Quality Management Framework for the Lower Athabasca River (SWQMF) screening values were available for these parameters. The SWQMF was prepared by Alberta Environment and Sustainable Resource Development (ESRD) for the LARP (Government of Alberta 2012). The objective of the LARP is to balance existing development with environmental protection by utilizing a cumulative effects management approach. Therefore, the SWQMF screening values were considered appropriate for determining whether or not calcium, lithium and sodium were Substances of Potential Concern (SOPCs).

The potential for effects related to fish tissue quality was previously assessed in the EIA, Volume 4A, Section 6.6.5.3. At the time of the EIA, the parameters for which tissue-based toxicological benchmarks could be derived were assessed, and included the following:

- aluminum;
- antimony;
- arsenic;
- cadmium;
- chromium;
- copper;
- lead;
- mercury;
- nickel;
- selenium;
- vanadium; and
- zinc.

Egg and ovary tissue selenium concentrations were estimated by applying the recently developed integrated lotic bioaccumulation model developed for westslope cutthroat trout (*Oncorhynchus clarki lewisi*) (Orr et al. 2012). This model approach was considered a more technically robust approach to evaluating selenium bioaccumulation potential than using a linear Bioaccumulation Factor (BAF) for several reasons:

- The relationship between selenium concentrations in water and tissues is not linear (Orr et al. 2012).
- The empirical BAF for selenium used in the EIA, Volume 4A, Section 6.6.2.12 was calculated using a data set with a high frequency of non-detected data and with an elevated detection limit. The calculation using this data set resulted in an elevated, overly conservative BAF relative to other sites for which higher precision data sets are available.
- Improved models for selenium accumulation are available (e.g., Orr et al. 2012) and were applied to provide a more realistic assessment.

The selenium tissue benchmark in the EIA, Volume 4, Appendix 4-2 was converted to a wet weight to be consistent with the tissue benchmarks presented by Jarvinen and Ankley (1999). However, in the 2013 assessment, the selenium tissue BAF and corresponding tissue benchmark were revised to align with recent work by DeForest et al. (2011) and Orr et al. (2012), and as such are expressed on a dry weight (dw) basis throughout this document. Accordingly, the selenium tissue benchmark of 2.3 mg/kg wet weight (ww) has been updated to the value in DeForest et al. (2011) of 20 mg/kg dw.

The tissue-based toxicological benchmark for mercury was updated from 0.8 mg/kg ww in the EIA to 0.5 mg/kg ww based on an updated understanding of the tissue residue threshold for potential chronic effects in fish (Appendix 3.6).

The remaining tissue benchmarks and BAFs used for prediction of fish tissue metals concentrations remained the same as those used in the EIA, Volume 4A, Section 6.6.

2.8.2.2 Effects Classification

Environmental consequences associated with predicted peak levels of chronic or acute toxicity that exceeded the recommended guidelines, or individual SOPCs that exceeded CEBs, were classified considering the findings of risk-based effects assessment and the classification approach described in the EIA, Volume 3, Section 1.4, and Volume 4, Section 6.6.2.12. Considerations included:

- the magnitude of the potential effects to aquatic health relative to both PIC conditions and relevant CEBs;
- the frequency at which the predicted change is expected to occur;
- expected duration of predicted changes;
- geographical extent of change; and
- the reversibility of the potential effect.

Classification involved first considering the potential magnitude of aquatic health effects that could result from predicted changes to water quality and tissue chemistry. Where magnitude was predicted to be negligible, then the overall environmental consequence rating was also concluded to be negligible. Where magnitude was non-negligible, then the remaining considerations were classified and an overall environmental consequence rating was reached following the approach in the EIA, Volume 3, Section 1.4.

The approach to classifying magnitude generally followed the approach described in the EIA, Volume 4, Section 6.6.2.12 with some updates. Considerations included:

- If predicted peak levels of chronic or acute toxicity exceeded the recommended guidelines of 1 Chronic Toxicity Unit (TUc) or 00.3 Toxic Unit – Acute (TUa) (AEP 1995), respectively, then the magnitude of potential effects to aquatic health were ranked as high, without consideration of PIC conditions. If the predicted peak levels of chronic or acute toxicity were below the guidelines, then the magnitude was ranked as low or negligible.
- The potential aquatic health effects under the 2013 PRM Application Case were considered to be negligible if either peak concentrations were less than the CEB; or the frequency of exceedance of the CEB was either the same as, or lower than, that predicted to occur under the PIC.
- If predicted peak concentrations were greater than the associated CEB then the risk based effects assessment was applied to estimate whether the magnitude of potential effects was negligible or non-negligible. Where potential effects were considered non-negligible, then a low magnitude rank was assigned to the affected SOPCs. As discussed in the EIA, Section 6.6.2.12, the assessment is considered protective because:
  - CEBs are often derived based in dissolved substance concentrations whereas the aquatic health assessment applied total substance concentrations, a proportion of which would not be bioavailable;
  - additional layers of conservatism are inherent in the BAFs applied for fish tissue assessment and setting CEBs where the underlying toxicity information is uncertain (i.e., estimated exposure estimates and toxicity threshold err on the side of caution; refer to Appendix 3.6); and
  - comparison of predicted peak concentrations to CEBs is inherently protective because the peak predicted concentrations would occur for approximately 1 day every 3 years, whereas for aquatic life, chronic exposure is typically on the order of 7 days or greater.

  Thus, unless CEBs are exceeded by a large degree with a high frequency, and the certainty of effects associated with the CEB is high, the potential for actual aquatic health effects remains at a low level. A moderate magnitude ranking was not used in the aquatic health assessment, because greater weight is given to whole effluent toxicity predictions (i.e., magnitude is high if whole effluent toxicity predictions exceed benchmarks, but low if it doesn't), and because this would have required the use of an arbitrary decision point to differentiate low from moderate (EIA, Volume 4A, Section 6.6.2.12).

2.9 Terrestrial Resources

The 2013 Base Case, 2013 PRM Application Case and 2013 PDC address information requests from the JRP. The approaches used for these assessments are the same as the approaches used in the EIA with the following exceptions:

- As described in Section 2.5, federally listed wildlife species at risk that had not previously been identified as KIRs are included as KIRs in the updated submissions.
- The effects of development on wildlife movement were not previously explicitly assessed for Canadian toad, barred owl, black-throated green warbler and western toad, but are assessed for the comparison between the 2013 Base Case, the 2013 PRM Application Case, and the 2013 PDC.
- A PIC using the year 1955 as a snapshot was applied to represent conditions before substantial development occurred in the region, permitting a more comprehensive and quantitative assessment of cumulative effects for all assessment cases.
- The magnitude of residual effects is determined using % of resource (e.g., % of the 2013 Base Case amount) rather than % of study area (i.e., % of RSA). The % of resource is calculated as a percentage of the areal extent of each resource in the 2013 Base Case in Appendix 1 and Section 3 of Appendix 2. The % of resource is calculated as a percentage of the areal extent of each resource in the PIC in Sections 2, 4 and 5 of Appendix 2.
- A Landscape Cumulative Effects Simulator (ALCES®) model was used to simulate forest fire and forest harvest to more realistically estimate cumulative effects in the 2013 PDC. ALCES® was used to simulate the spatial configuration and extent of forest fire and forest harvest in the RSA given the spatial distribution of existing, approved and planned industrial developments. Simulations were projected forward over a 60-year period from the 2013 Base Case. The resulting maps of burns and cutblocks were applied to the 2013 Base Case, the 2013 PRM Application Case and the 2013 PDC.
- Updated Alberta Biodiversity Monitoring Institute (ABMI), Alberta Conservation Management Information System (ACIMS), and Fisheries and Wildlife Management Information System (FWMIS) were incorporated into the updated assessment of the effects of the PRM.
- An updated disturbance layer was applied to all components of the terrestrial assessment, and was incorporated into predictive models. Updated linear feature data were obtained from the Government of Alberta in February 2013. Access features including roads and cutlines were updated as of October 2010 and May 2011 (depending on the location in the RSA). Updates are based on interpretation of linear features from satellite imagery. Pipelines and well site updates were obtained from IHS Energy in February 2013 and are current as of November 2012. Within the LSA, both linear and non-linear disturbances were updated by Golder Associates Ltd. (Golder) based on August 2011 high-resolution satellite imagery.
- Assumptions around time to reclamation were adjusted to be more accurate and to be consistent with other components.
- Significance of adverse environmental effects was not determined as part of the EIA submission, but is identified for terrestrial resources as part of the response to JRP SIR 8 (Appendix 2). Assessment methods for the determinations of environmental significance are described in Section 2.11 of this appendix.

These changes in assessment methods are discussed in the following subsections and in Section 2.11 (environmental significance), with the exception of the assessment methods used to develop and apply the PIC, which are described in Appendix 2. Detailed information on the use of ALCES® models is provided in Attachment A to this Appendix.

2.9.1 Simulation of Forest Harvest and Forest Fire

For the purposes of assessing cumulative effects, it is important to consider the effects of forest fire and forest harvest. Although these effects can be incorporated using simple assumptions, Shell utilized the services of the ALCES Group to conduct complex and realistic landscape simulations to estimate the distribution of burns and forest harvest cutblocks over the life of PRM. The ALCES Group previously simulated forest fire and forest harvest as a component of the *Terrestrial Ecosystem Management Framework (TEMF) for the Regional Municipality of Wood Buffalo* (CEMA 2008) and for the JME. The simulations used for JME were also used for this assessment. The ALCES Group simulations are summarized below and a detailed report is provided in Attachment A.

The first step in the simulation process was to identify forested areas within the RSA. Data describing the land cover types currently present in the RSA were assembled by the CEMA, as described by Wilson et al. (2008). Land cover in the CEMA data set is based on the Alberta Vegetation Inventory and the Alberta Ground Cover Classification inventory, as well as on disturbance data from a variety of geospatial inventories. Simulations of forest harvest and forest fire were conducted only in areas classified by CEMA as forested. Forested polygons with stand age expressed as 20-year seral stages are divided into nine classes:

- hardwood;
- mixedwood;
- white spruce;
- jack pine;
- closed black spruce;
- black spruce lichen moss;
- riparian;
- open black spruce fen; and
- open fen.

The original CEMA landscape composition data set is current to 2005, but was updated to incorporate fires that occurred between 2006 and 2011 using historical wildfire perimeter data (ASRD 2011).

An area accounting for 6% of the RSA lies outside the extent of the CEMA land cover data. Land cover for the portion outside the CEMA land cover data was defined using the current Golder Regional Land Cover Classification (RLCC) data set and available disturbance data. The RLCC data do not include forest age; therefore, stand ages for the RLCC data were assigned in such a way as to be representative of the age class distribution of that forest type elsewhere in the RSA, based on the CEMA land cover data.

Forest fires and forest harvest patterns were then simulated within forest classes using the ALCES® and ALCES Mapper® computer programs. The ALCES® program was used to simulate the effects of forest fire, forest harvest, and industrial development in the RSA over a 60-year period. The ALCES Mapper® program was used to simulate the potential spatial configuration of forest fire and forest harvest. Details about the assumptions made for the simulations are provided in Attachment A.

The effects of forest fire were simulated using a mean annual burn rate of 1.25% of each land cover type, as assumed by CEMA for northeastern Alberta, with burn events drawn randomly from a lognormal probability distribution, irrespective of stand age. The maximum annual burn rate was set at 10% of the RSA (i.e., 2,277,376 ha) as a realistic limit. Although the Richardson Fire in the Spring of 2011 was considered to be an abnormally large fire, the approximately 221,821 ha of the RSA that it burned are still slightly less than the 10% maximum annual burn rate set in the ALCES® model.

Unlike the simulated effects of forest fires, the simulated effects of forest harvest depended on forest class, stand age, and stand volume. The effects of forest harvest were simulated using annual allowable cuts defined for hardwood and softwood forest by forest management units and adjusted for the areal extent of each forest management unit in the RSA. The assumptions described below regarding future timber supply and harvest in the RSA were developed in co-operation with Alberta-Pacific Forest Industries Inc. (Al-Pac), and approved by Al-Pac as “reasonable and defendable” (Cheyne 2012, pers. comm.).

Forest harvest simulations were conducted by first partitioning forest stands into white spruce, pine, mixedwood or hardwood classes, and reducing their areal extent under the assumptions that 10% of forested areas are inaccessible, and 3% are on slopes too steep for harvest. Stand volumes were calculated using growth and yield equations provided by Al-Pac. Harvest was simulated assuming that oldest stands are harvested first, with minimum stand ages of 80 years for hardwood and 100 years for softwood, and a minimum volume of 50 m^3/ha. Cutblocks were assumed to be contiguous where possible to reflect Al-Pac’s (2008) aggregated harvest strategy, and were assumed to regenerate to their original forest type. When and where fires or human developments occurred, forest salvage was ranked and applied against the annual allowable cut using the same volume constraints as for non-salvage harvest. In addition, wood that could be salvaged was assumed to make up no more than 33% of in situ mining development footprints and 100% of surface mining footprints. Only 25% of wood within the perimeters of burns was assumed to be both accessible and salvageable.

The footprints of planned developments present in the 2013 PDC were simulated to develop at a constant rate over time from the start of construction to project completion, using the best information available regarding project schedules. In situ developments were simulated to be fully constructed 10 years before project completion because the average productive lifespan of in situ wells is 10 years (Wilson et al. 2008). Progressive reclamation of developments was not considered in the 2013 PDC, resulting in a more conservative and precautionary assessment by assuming that areas disturbed by industrial development remained disturbed for the purpose of the 2013 PDC cumulative effects assessment. However, these areas also were no longer considered habitat that could be burnt in the simulations.

Under these assumptions, 200 stochastic simulations were run to provide information on a range of potential landscape burn trajectories and the effects of those trajectories on forest harvest and the distribution of land cover types in the RSA. From those 200 simulations, specific examples were selected to represent a low (i.e., 5^{th} percentile), mean (i.e., 50^{th} percentile), and high (i.e., 95^{th} percentile) scenario of average forest ages in the RSA after 60 years.

The purpose of the EIA for PRM is to determine the direct and indirect effects of changes due to different human development scenarios. Future landscape disturbances will occur in all assessment cases and must, therefore, be represented in all assessment cases to avoid introducing differences between cases that are not due to changes in human developments. Therefore, the forest fires simulated in the 2013 PDC were also represented in RSA for the PIC, 2013 Base Case, and 2013 PRM Application Case. Forest harvest cutblocks simulated in the 2013 PDC were represented in the RSA for the 2013 Base Case and 2013 PRM Application Case. Forest harvest cutblocks were not represented in the PIC because industrial-scale logging was not occurring at that time.

2.9.2 Application of Updated Alberta Wildlife and Vegetation Data

Updated ABMI, ACIMS, and FWMIS were incorporated into the 2013 Base Case, 2013 PRM Application Case and 2013 PDC assessments.

Breeding bird survey data from the ABMI was downloaded on December 15, 2011 and analyzed to estimate the relative density of each species per plot. The ABMI data include habitat associations, but not spatially explicit survey locations to compare with model outputs. Consequently, model verification was only possible by comparing the relative densities of Canada warbler, olive-sided flycatcher, rusty blackbird and black-throated green warbler in the ABMI habitat data to habitat suitability scores for each ecosite phase and wetland types in the Habitat Suitability Index models used for each species (Appendix 3.7; *May 2011, Submission of Information to the Joint Review Panel*, Appendix 2). Results of this comparison generally support the assumptions of the species-specific habitat suitability index models (Appendix 3.7), and therefore increase the confidence in the ability of the models to accurately predict habitats where these species are most abundant.

Updated FWMIS data were requested in 2012 to confirm that no rare species believed to be absent from the LSA were observed in proximity to the LSA (e.g., Eskimo curlew, northern leopard frog, woodland caribou) (Skilnick 2012, pers. comm.). The FWMIS data confirm that all federally listed wildlife species believed to be absent from the LSA were not reported in or near the LSA between the EIA submission and the updated search in 2012.

Rare plants in Alberta are represented by those species listed on the ACIMS tracking and watch lists (ACIMS 2011). Species of high priority are placed on the tracking and watch lists because they are rare or there is a conservation concern (Kemper 2009). Updated ACIMS data were combined with ABMI data to update and inform the number of occurrences of rare plants in the RSA. These data were used so that all rare plants confirmed to occur in the RSA are included in the assessment of the effects of the PRM, and existing, approved and planned developments.

2.10 Traditional Knowledge and Land Use

The 2013 PDC undertakes both quantitative and qualitative assessments in determining cumulative effects to potentially affected Aboriginal groups.

Effects to Traditional Land Use include effects to traditional hunting, trapping, fishing, and plant and berry gathering. Within this assessment, each of these elements of TLU has been addressed separately for each of the directly affected Aboriginal groups.

The assessment undertakes both quantitative and qualitative assessments in determining cumulative effects to potentially affected Aboriginal groups. Quantitative approaches include a comparison of the amount of 2013

Base Case, 2013 PRM Application Case and 2013 PDC disturbance to the RSA, LSA, First Nations' traditional territories (or preferred use areas) within the RSA, the Fort McKay Culturally Significant Ecosystems (CSEs), and affected Registered Fur Management Areas (RFMAs). The assessment also includes a qualitative approach that considers the results of the wildlife and wildlife habitat, terrestrial vegetation, wetlands and forestry, and fish and fish habitat assessments to determine effects on the abundance of traditional resources used by Aboriginal groups for harvesting activities, and areas of preferred harvesting, changes in access to these preferred harvesting areas, air, noise, and odour impacts to TLU, human health, and individual and/or community responses to observed environmental effects.

2.10.1 Pathways

Activities in the 2013 Base Case, 2013 PRM Application Case and 2013 PDC are predicted to influence Traditional Land Use within the region for affected Aboriginal groups. Potential effects on TLU are evaluated in consideration of the following pathways:

- traditional hunting opportunities;
- traditional trapping opportunities;
- traditional fishing opportunities;
- traditional berry and plant harvesting opportunities;
- noise, visual and odour effects to traditional land use;
- effects on human health in relation to traditional land use; and
- socio-economic effects on the traditional use of lands.

2.10.2 Effects Classification

For each pathway identified in Section 2.10.1, an effects classification was conducted for each traditional activity and for all potentially affected Aboriginal groups.

Pathways that reflect the opportunities to undertake traditional activities consider:

- availability of the underlying resources (e.g., wildlife, fish, plants);
- disturbance to preferred harvesting areas within the RSA; and
- the ability to access preferred areas.

The assessment of effects to the resources base and disturbance to preferred harvesting areas follow the EIA assessment methods put forward in Volume 3, Section 1.3, where appropriate. The assessment of effects to traditionally used resources relied upon the conclusions of the effects assessment for each respective component (e.g., wildlife, fish, and vegetation assessments). Effects to access, while a product of disturbance, are assessed through qualitative assessment methods, and generally determine whether disturbance will affect access to or within preferred harvesting areas.

The criteria used in the assessment of magnitude of effects to opportunities for traditional hunting, trapping, fishing, and plant and berry harvesting are both qualitative and quantitative. Where disturbances to preferred harvesting areas are quantified, the assessment criteria are consistent with those used for other land base assessments (e.g., terrestrial, resource use) as follows:

- Negligible: less than 1% impact on the measurement point;
- Low: less than 10% impact on the measurement end point;
- Moderate: greater than 10% and less than 20% impact on the measurement end point; and
- High: greater than 20% impact on the measurement end point.

The following qualitative criteria are used to assess the magnitude of change in non-quantified changes, such as access to preferred harvesting areas:

- Negligible: indicates no discernible change to access to preferred areas;
- Low: indicates a discernible change, but the effect is not expected to materially affect access to preferred areas;
- Moderate: indicates a noticeable and potentially detrimental or beneficial change to access to preferred areas; and
- High: indicates that the effect is expected to substantially interfere with or enhance people's access to preferred areas.

The assessment further considered the duration of an effect to be long duration if the effect lasted 25 years or longer (i.e., the length of a generation). Effects were also considered irreversible if they lasted 25 years or longer because effects of this duration can interrupt the transmission of Traditional Knowledge between generations.

To provide an assessment of the effects to traditional harvesting activities, the effects to the TLU opportunity pathway are combined with other relevant pathways that may impact the TLU activity. Other relevant pathways (e.g., odour, noise and visual effects, human health and other effects) are not easily quantifiable with regard to their effects on TLU and no agreed-upon thresholds exist. Therefore, these pathways are not assigned a magnitude, but are assessed as existing or not and then considered on a qualitative basis in conjunction with the conclusions from other pathways.

2.11 Environmental Significance

For all environmental disciplines, a determination of environmental significance is provided in Appendix 2 to answer JRP SIR 8, part a) iii). The determination of significance considers PRM in light of the cumulative effects of previous, existing and planned developments.

This section describes the assessment methods used to identify environmental significance. The assessment methods described in this section apply to all environmental and social KIRs. The general approach to significance determination is similar for all disciplines, but the details vary depending on discipline-specific requirements. Where the approach applied to a particular discipline varies from the general approach described in Section 2.11.1, the assessment methods are presented in a discipline-specific sub-section. For example, additional detail concerning significance assessment for terrestrial KIRs is presented in Section 2.11.2, and for Traditional Land Use and Aboriginal Rights and Interests in Section 2.11.3.

2.11.1 General Approach

The general approach elaborates on the approach presented in PRM Round 1, Appendix B, Section 5. The Canadian Environmental Assessment Agency (CEAA) states that "*the Responsible Authority must make the final determination and decide whether the project is likely to cause significant adverse environmental effects*" (CEAA 2012, internet site). A project can proceed where significant adverse effects are identified if the Governor in Council determines that the project can be justified to be in the public interest (Government of Canada 2012).

For environmental disciplines, EIA practitioners can contribute to the determination of significance by discussing environmental significance from a scientific perspective and in an ecological context. Values placed on resources beyond a scientific or ecological context can vary greatly among individuals or groups and were not considered when determining significance as part of the assessments for these disciplines; however, as part of their decision-making process, agencies responsible for making public interest decisions on development applications should be aware of the value placed on these resources by people. Impacts of the project for social disciplines are more closely tied to human perspectives and these perspectives can be incorporated by EIA practitioners into significance determination. For example, significance determination for the Traditional Land Use component considered viewpoints or values placed upon resources by traditional harvesters (Section 2.11.3).

2.11.1.1 The Concept of Environmental Significance

A review of assessment methods and criteria for determining significance by Roussouw (2003) indicated that the concept of significance related to environmental impact assessment "remains largely undefined and there is no international consensus on a single definition".

The CEAA (2012, internet site) states that "*deciding whether a project is likely to cause significant adverse environmental effects is central to the concept and practice of environmental assessment*" but does not provide a definition of environmental significance. The CEAA further states that "*the concept of significance cannot be separated from the concepts of adverse and likely*" and outlines a three-step framework for determining the likelihood of significant adverse environmental effects:

- Step 1: Deciding whether the environmental effects are Adverse.
- Step 2: Deciding whether the adverse environmental effects are Significant.
- Step 3: Deciding whether the significant adverse environmental effects are Likely.

For the purposes of this submission, the concept of environmental significance is consistent with CEAA's concept of likely significant adverse environmental effects and the CEAA framework has been followed. The definitions of adverse, significant and likely effects developed for use in this exercise follow.

Adverse Effects

Adverse effects are considered changes in the environment with harmful effects, such as negative effects on health, threats to endangered species, loss of or damage to habitats, or discharges of toxic or persistent chemicals, microbiological agents or nutrients (CEAA 2012, internet site). Effects are considered either Adverse or Non-adverse.

Significant Effects

All adverse effects are evaluated to determine whether or not they are significant. Adverse effects are classified either as Significant or Not Significant. A Significant adverse effect is defined as:

- an adverse effect resulting in a sustained, irreversible effect with unacceptable environmental consequences on a regional resource, population or community; or
- an adverse effect resulting in a sustained, irreversible effect with unacceptable environmental consequences on a unique localized resource, population or community; or
- an adverse effect resulting in an unacceptable health risk.

An irreversible effect is one where the resource element cannot be restored to pre-impact conditions within the long-term (EIA, Volume 3, Section 1.3.6.1). Acceptability of an effect is considered from a scientific basis and in an ecological context based on available peer-reviewed literature and other data.

Likely Effects

As with all predictions, significance determinations are associated with varying degrees of uncertainty. Significant adverse effects were therefore identified as either Likely or Unlikely. A Likely effect is a significant adverse environmental effect with a high probability to occur (CEAA 2012, internet site). Consideration is given to the likelihood of the project activity resulting in, or contributing to, the effect as well as the scientific uncertainty associated with the information used to identify the effect.

2.11.1.2 Environmental Consequence Ratings

For the environmental components, the EIA and this assessment present information on the potential effects of the PRM in terms of environmental consequence ratings. The environmental consequence ratings were calculated using an objective system based on the following components:

- Residual effects: the impacts of development activities with mitigation in place. The CEAA states that significance should be determined only after taking into account any appropriate mitigation measures (CEAA 2012, internet site).
- Impact criteria: based on CEAA criteria for determining impact significance (i.e., direction, magnitude, geographic extent, duration, reversibility and frequency). The criteria were assigned numeric scores as outlined in the EIA, Volume 3, Section 1.3.6.1, Table 1.3-4.

The residual effects for each resource identified in the EIA, Volume 3, Section 1.3.6.1, Table 1.3-4 (e.g., Air Quality) were scored against the applicable impact criteria and the resulting totals were the environmental consequence ratings presented in the EIA. Volume 3, Section 1.3.6.2 of the EIA outlines the four environmental consequence categories included in the EIA: negligible, low, moderate and high.

As discussed in the EIA, Volume 3, Section 1.3.6.2, the purpose of the environmental consequence rating system was to allow the effects from different technical components to be compared using a common rating so that areas of greatest potential concern across disciplines might be identified. Although environmental consequence and significance are related concepts, the environmental consequence rating system was not developed to translate directly into an assessment of significance. However, environmental consequence, and especially the absolute values from the criteria used to calculate it such as number of hectares of habitat loss or the number of days over which air quality might decline, provide central context for a determination of significance. The relationship between environmental consequence and significance can generally be defined as follows:

- negligible or low environmental consequence ratings were unlikely to produce significant effects; whereas
- moderate or high environmental consequence ratings could result in effects that are either Significant or Not Significant and require careful consideration prior to making a final determination.

2.11.1.3 Significance Determination

The framework identified by CEAA (2012, internet site) was followed to determine environmental significance, as outlined in the following sections, below. The objective of the original environmental significance determination (May 2009 PRM SIRs, Volume 2, Appendix B, Section 5) was to provide an environmental significance assessment for the predicted Project impacts, as described in the EIA Application Case. To respond to JRP SIR 8, part a) iii), this submission provides an environmental significance determination for the predicted impacts of cumulative effects, as described in the 2013 PRM Application Case and the 2013 PDC relative to the PIC.

Assessment of Adverse Effects

The environmental consequence rating system used in the EIA included a “direction” criterion that was categorized as positive, negative or, in some cases, neutral. The direction criterion takes into account whether the nature of the effect on a parameter will be adverse or not, consistent with the CEAA guidance.

Based on this system, effects on parameters categorized with a negative direction are considered to be Adverse effects and were carried forward for significance determination, whereas effects on parameters with a positive or neutral direction are considered to be Non-Adverse effects.

Assessment of Significant Effects

For Adverse effects, CEAA suggests that significance be based on the following criteria: direction, magnitude, geographic extent, duration, reversibility, frequency and ecological context (CEAA 2012, internet site). All of these criteria were included in the environmental consequence rating system, except ecological context.

In discussing ecological context, CEAA (2012, internet site) states “effects of projects may be significant if they occur in areas or regions that have already been adversely affected by human activities and/or are ecologically fragile and have little resilience to imposed stresses”. Although not included in the scoring criteria for environmental consequence, the concept of ecological context is considered and discussed throughout the EIA and the updated assessments provided as responses to SIRs. The consideration of ecological context in the determination of significance is discussed in detail in Section 2.11.2.2 below.

Using the concepts of magnitude, geographic extent, duration, reversibility, frequency and ecological context, the significance of adverse effects was determined for each KIR using appropriate ecological thresholds or resource management criteria. Ecological thresholds are exceeded when ecosystem function is seriously impaired or when plant or animal populations are no longer viable. An example of an ecological threshold is the point at which a wildlife population is no longer self-sustaining or ecologically effective. Resource management criteria are acceptable levels of change set by regulators to protect the environment or human health. Examples of resource management criteria are air and water quality limits. The ecological thresholds or resource management criteria used to help define significance for each KIR are identified and presented in the appropriate sections of the EIA or Appendix 2 and in the discipline-specific assessment methods in the following sections of this Appendix.

Where uncertainty was present with respect to whether an ecological threshold or resource management criterion has been exceeded, the source(s) of uncertainty were described and significance was determined using a weight of evidence approach. That is, significance was determined by carefully evaluating the scientific evidence indicating that an effect exceeds an ecological threshold or resource management criterion compared with the scientific evidence indicating the effect does not exceed the threshold or limit, using a reasoned narrative where data, assumptions, and interpretations are clearly stated. A precautionary approach was applied when determining significance in the face of uncertainty, and where a weight of evidence analysis presented equivocal results, effects were considered significant.

Assessment of Effect Likelihood

For those effects identified as being adverse and significant, effect likelihood is based on the probability of the activities actually resulting in the predicted effect. Significant adverse effects were identified as either Likely or Unlikely.

When determining likelihood, consideration was given to the scientific uncertainty associated with the information used to identify the effect. In some cases an effect may be identified as significant because of uncertainty about whether or not an ecological threshold or resource management criterion has been exceeded, but the chance that the significant effect would occur may be unlikely. Information about scientific uncertainty with respect to the assessment is provided throughout the EIA, as amended.

2.11.2 Significance Determination for Terrestrial Resources

Although CEAA provides a framework for significance determination, the application of the framework is flexible and little specific direction is given other than the expectation that effects are more likely to be significant if they are high magnitude, cover a broad geographic extent, occur over a long duration, and are irreversible. A common approach to determining significance is to set thresholds or limits beyond which changes in these criteria are considered significant. As noted in Section 2.11.1.3, such limits are often set using either ecological thresholds or resource management criteria. Both concepts can be applied to terrestrial KIRs.

The JME EIA (*May 2012, Submission of Information to the Joint Review Panel*) used an approach for significance that was based on ecological thresholds. However, the Shell JME Joint Review Panel Decision Report reassessed the effects of JME using a resource management criteria approach as advocated by CEMA's Terrestrial Ecosystem Monitoring Framework (AER and CEAA 2013). The application of ecological thresholds and resource management criteria do not necessarily produce identical significance determinations for all KIRs. To reflect potential differences between the approaches, in this assessment significance for the terrestrial disciplines was determined for each KIR using both ecological thresholds and the resource management criteria applied by the JRP for JME. These parallel approaches to significance determination were based on exactly the same data inputs, as described in Section 2.11.2.1. The assessment methods used to determine significance for ecological thresholds and resource management criteria based on these inputs are described in Sections 2.11.2.2 and 2.11.2.3, respectively. Section 2.11.2.4 describes the advantages and disadvantages of each approach.

2.11.2.1 Data Inputs

As noted in Section 2.11.1.3, significance of adverse residual effects should be based on magnitude, geographic extent, duration and frequency, reversibility, and ecological context (CEAA 2012, internet site). Raw data for each criterion are presented for each KIR, and these data form the basis of the significance determination using both ecological threshold and resource management criteria approaches. For example, the magnitude of an effect in terms of the number of hectares of habitat lost and the percent of resource lost in the LSA or RSA are presented. Similarly, duration of effects is described in years, and so on. Ecological context is provided based on available data and a review of the literature for each KIR. Ecological context considers provincial and federal species status and identified threats. For species at risk, the primary causes of decline are identified. Ecological context presented as part of the results also includes information about the population of each KIR in the RSA as well as the adaptability and resilience of the species.

Information is presented without reference to any value judgements. For example, magnitude is presented numerically but is not classified as low, moderate, or high. Consequently, the data and ecological context included in this presentation of results provide an objective and common foundation for different possible approaches to significance determination.

2.11.2.2 Ecological Thresholds

Ecological thresholds are used to identify boundaries that can be applied to facilitate effective conservation and management of species and ecosystems. For the terrestrial disciplines, cumulative effects were considered significant if:

1) an animal or plant population is no longer self-sustaining;

2) an animal or plant population is no longer ecologically effective; or

3) ecosystem function has been lost at the community, ecosystem, or landscape scales.

A self-sustaining population is one that will be maintained into the future with a low risk of extirpation. Long-term population persistence is the outcome of maintaining viable populations, and maintaining or achieving self-sustaining populations is frequently applied as a conservation target by conservation biologists and resource managers (Fahrig 2001; Nicholson et al. 2006; Ruggiero et al. 1994; With and Crist 1995). By definition, self-sustaining populations are not populations at the brink of extirpation; they are healthy, robust populations capable of withstanding environmental change and accommodating stochastic population processes (Reed et al. 2003).

However, a self-sustaining population does not always suffice to achieve conservation objectives for assemblages of biodiversity values that might interact with the species being evaluated (Soule et al. 2005). For KIRs that have strong effects on ecosystem structure and function (i.e., highly interactive species), the concept of ecologically effective populations also was used (Soule et al. 2003). An ecologically effective population differs from the smallest possible self-sustaining population if the number of individuals needed to maintain ecological function is greater than the number required to maintain a viable population for the long-term.

Ecosystem function can be lost due to changes in the population of a highly interactive species but can also be lost due to changes in the amount and composition of habitats representing communities, ecosystems and landscapes. Loss of ecosystem function or ecosystem shifts due to changes in vegetation community KIRs such as wetlands or old growth forests are also considered significant.

The determination of whether or not self-sustaining and ecologically effective populations or ecological function of each terrestrial KIR were maintained at the RSA scale was based on available data from the regional population considered in light of ecological context, specifically using the concepts of adaptability and resilience. Adaptability refers to the ability of an ecological system to accommodate disturbance and remain more or less unchanged. For example, animal and plant populations often can accommodate loss of some individuals without a change in overall population status or trajectory (known as compensatory mortality, Krebs 2009), or can adjust their behaviour to accommodate disturbance (e.g., Pedevillano and Wright 1987; Sawaya et al. 2013; Sheperd and Whittington 2006). Ecosystems often have inertia and will continue to function after disturbance up to the point where the disturbance becomes severe enough that the system changes. Resilience is the ability of an ecological system to recover from a disturbance (Holling 1973; Levin et al. 1998). Highly resilient KIRs have the potential to recover quickly after disturbance and reclamation, whereas KIRs with low resilience will recover more slowly or may not recover. The ability to absorb or accommodate disturbance is a property of the KIR within the RSA and is not necessarily related to its provincial or federal status. For example, a species that is highly threatened provincially or federally may also have low adaptability and resilience in the RSA or it may have a robust population within the RSA that is both adaptable and resilient.

Whether or not a KIR was predicted to maintain a self-sustaining, ecologically effective population or maintain ecological function was determined using a weight of evidence approach, as described in Section 2.11.1.3. Part of the ecological context applied in this evaluation includes an analysis of existing trends (e.g., in populations) to facilitate predictions of future trends. This is consistent with the *Cumulative Effects Assessment Practitioner's Guide*, which states that "when an actual capacity level cannot be determined, analysis of trends can assist in determining whether goals are likely to be achieved or patterns of degradation are likely to persist" (Hegmann et al. 1999).

In cases where a population may no longer be self-sustaining or ecologically effective but the ultimate cause of decline is not related to PRM or other developments in the oil sands region, the cumulative effect of those developments for that KIR may not be significant. For example, if a species is declining in Alberta or across its North American range, but the cause of the decline is not associated with the PRM or cumulative effects of other projects in the region, then the contribution of PRM and other associated developments at the scale of the regional cumulative effects assessment would not be considered significant. Little brown myotis (Appendix 2, Section 4.3.4.2.12), northern myotis (Appendix 2, Section 4.3.4.2.13) and western toad (Appendix 2, Section 4.3.4.2.19) are primarily limited by disease unrelated to the effects of development in the RSA, and therefore the cumulative effects of development in the RSA are likely not significant for these species according to the ecological thresholds approach to determining significance.

Choosing an appropriate spatial scale for a significance assessment is critical for identifying whether ecological thresholds have been exceeded. In their decision report for the JME, the JRP indicated that "*the Panel is of the opinion that the significance of project effects needs to be considered at the LSA and RSA scales*" (AER and CEAA 2013). However, determining significance at the LSA scale using ecological thresholds is not possible without considering the broader regional context. This is because most vegetation, wildlife and biodiversity resources in northeastern Alberta function at ecological scales much larger than the LSA (e.g., the range of a caribou herd). Assessing ecological thresholds at the LSA scale is akin to attempting to determine whether a person is sick by only assessing their foot, or evaluating the extent of flood damage to a city by examining only one impacted house or neighbourhood. Assessments at these scales are important, but they do not provide sufficient information if one is ultimately interested in the heath of a person or estimating the total cost of flood damage. The highly interactive characteristics of ecosystems require that boundaries of assessment are sufficiently large to encapsulate the processes that are primarily responsible for population viability and ecosystem function. Significance determination for KIRs that are wide ranging, highly interactive or contiguous at broad spatial scales should be conducted at the RSA scale.

The LSA was defined using the PRM footprint and a buffer area to encompass the effects of PRM; it was not defined using ecological criteria, nor was it intended to encompass scales relevant to the conservation or management of terrestrial KIRs. To increase the LSA to a size that is ecologically relevant is to repeat the exercise of defining an RSA. Consequently, significance of adverse cumulative effects was determined at the RSA scale for all terrestrial KIRs when applying ecological thresholds.

2.11.2.3 Resource Management Criteria

Resource management criteria are also sometimes called environmental standards and are commonly applied to concentrations of hazardous agents, such as chemicals or radioactive materials. When applied to terrestrial resources, resource management criteria are similar to ecological thresholds in that they are defined to facilitate conservation of existing ecological conditions, but these criteria are not as strictly tied to a particular ecological outcome or response. Instead, resource management criteria represent the amount of change deemed acceptable by resource managers and regulators. Recent JRP decision reports for oil sands mines (Joint Review Panel for the Joslyn North Mine Project 2011, Joint Review Panel for the Shell Canada Energy Jackpine Mine Expansion Project 2013) have identified the following criteria to determine significance for effects to terrestrial resources:

- an adverse effect that exceeds 20% of a resource at the LSA and RSA scales is determined to be significant; and
- any adverse effect to federally listed species at risk is determined to be significant.

Using the resource management criteria approach, these criteria were applied to each terrestrial KIR to determine whether a significant effect was present. In cases where habitat was used as a surrogate for populations when evaluating the 20% loss criterion, only high and, occasionally, moderate-high quality habitats were considered. The loss of a single individual or any high quality habitat for federally-listed species at risk was identified as a significant effect based on the second criterion above. These criteria were applied at both the LSA and RSA scales.

2.11.2.4 Comparison of Ecological Threshold and Resource Management Criteria for Terrestrial Significance Determination

Both the ecological threshold and resource management criteria approaches have strengths and weaknesses; these are summarized in Table 2.11-1 and then discussed in the text that follows. These strengths and weaknesses should be considered when evaluating and interpreting significance determinations with respect to whether or not a project may be in the public interest.

Table 2.11-1 Comparison of Ecological Threshold and Resource Management Criteria for Determining Significance for Terrestrial Resources

Ecological Thresholds		Resource Management Criteria	
Strengths	**Weaknesses**	**Strengths**	**Weaknesses**
▪ Accounts for differences in adaptability and resilience among KIRs ▪ Provides a significance determination that is based on ecological outcomes ▪ Unlikely to produce spurious significant effects	▪ Thresholds have not been precisely defined ▪ Application requires a detailed weight of evidence approach	▪ Transparent because limits are set by regulators ▪ Easily applied ▪ Conservative for most KIRs ▪ May reflect societal values	▪ Fails to account for differences in adaptability or resilience among KIRs ▪ Produces significant effects that may be not be ecologically important (i.e., overly conservative)

The ecological thresholds approach to significance determination is advantageous because it addresses each KIR individually and applies ecological concepts important for conservation and management of terrestrial resources. This approach acknowledges differences in resilience and adaptability among KIRs and recognizes that KIRs that cannot adapt and have low resilience will experience significant adverse effects after less disturbance, as compared with more adaptive and resilient KIRs. Ecological thresholds may also vary depending on local and regional context and an ecological threshold approach can account for that variability. Where significant adverse effects are identified using this approach, they have serious implications for conservation and management of KIRs, and results identified as significant but that are ecologically unimportant are unlikely.

A central challenge of using the ecological threshold approach is that thresholds beyond which a population fails to be self-sustaining or ecologically effective or where ecological function is lost at higher levels of biological organization have not been precisely defined for most KIRs. In the absence of precisely defined thresholds, the amount of change in each measurement endpoint on which the PRM had an adverse effect (e.g., habitat quantity, quality and connectivity, survival and reproduction, and relative abundance and distribution) must be considered together in light of ecological context using a weight of evidence approach. Such an approach is excellent where scientific literature for a KIR is extensive and data are abundant, but can be limited where scientific information is scarce and few data are available about populations and their trends in the RSA. Where data are extremely limited such that uncertainty is very high, it may not be appropriate to apply an ecological threshold approach to significance determination.

A key strength of resource management criteria is their simplicity; they are easy to understand and easy to apply. Losses of 20% to a resource or any adverse effects to a federally listed species are easily identified using data that are readily available for all KIRs. Both values are also likely very conservative and protective of the environment in most cases. For example, many studies have indicated that abrupt and non-linear, negative changes in ecological or population function occur at levels of 40% to 90% habitat loss (Andren 1994; Monkkonen and Reunanen 1999; Rompre et al. 2010; Swift and Hannon 2010). The 20% resource management criteria applied by the JRP is well below those levels and likely provides a large margin of safety for most KIRs. In addition, resource management criteria can be set by responsible authorities to reflect consultative processes involving stakeholders and regulators. They can also be informed by regional landscape objectives such as LARP. In this regard, they can be appropriate measures for “what society is willing to lose”.

However, the resource management criteria approach applied for this assessment also has several substantial disadvantages. The consistent application of a single, ecologically arbitrary, limit (e.g., 20% of a resource) is a generic approach which could assign inappropriate significance determinations because the single value does not take into account both variations in adaptability and resilience of different KIRs and how the PRM may affect KIRs differently. For example, species that are highly sensitive to development may no longer maintain a self-sustaining or ecologically effective population prior to a loss of 20% of high quality habitat, and the application of this resource management criterion would fail to identify such an effect as significant. Conversely, the loss of greater than 20% of habitat for a KIR that is both adaptable and resilient, currently considered secure by regulatory agencies, and whose numbers are primarily affected by human hunting, would be identified as a significant effect even if the population continues to be self-sustaining and ecologically effective (i.e., moose, Appendix 2, Section 4.3.4.2.8).

A second important weakness of the resource management criteria approach is that it will identify large numbers of significant adverse environmental effects, some of which may be ecologically irrelevant. For example, the second criterion concerning federally listed species at risk results in a significant adverse effect based on the loss of a single individual or hectare of high quality habitat for those KIRs. The relevance of such a loss for management and conservation will depend on ecological context. For example, the effect of the loss of a single individual for an endangered species with fewer than 10 individuals left in the wild may be catastrophic, whereas the loss of an individual from a robust population of thousands from a different species at risk may be compensated for through increased survival or fecundity of other individuals such that there is no net effect on the population. Even though there are vast differences in the relative importance of the above effects to the population of these hypothetical KIRs they are both classified as significant using resource the management criteria. If significance determinations are intended to be used by regulators and governments to allocate resources to those KIRs in most need of management actions, an approach that produces large numbers of significant adverse effects (many of which may be ecologically irrelevant) is less useful than an ecological threshold approach.

Although not necessarily a strength or weakness of either approach, a key difference between the ecological threshold and resource management approaches is the scales at which significance can be assessed. Resource management criteria can be applied at both the LSA and RSA scales, although applying the 20% criterion at the LSA scale is almost certain to produce a significant result because the LSA is defined specifically to encompass immediate effects of the PRM. In contrast, determining significance at the LSA scale using ecological thresholds is not possible without considering the broader regional context, ultimately constraining assessments of significance to ecologically relevant scales, such as the RSA.

Based on the above discussion, while the ecological threshold and resource management criteria approaches each have strengths and weaknesses, ecological thresholds produce a more appropriate and meaningful assessment of significance, provided available data and knowledge are sufficient to implement this assessment method.

2.11.2.5 Uncertainty

Uncertainty in the data inputs, including results of modelling, amount of data available, and knowledge of the resilience and adaptability of each KIR, was considered in the determination of significance for terrestrial resources for both ecological thresholds and resource management criteria. Where uncertainty was high and an effect was near an ecological threshold or approaching a resource management criterion cut-off, the assessment conservatively determined the effect to be significant.

An important source of uncertainty for terrestrial KIRs is error in the models used to estimate habitat suitability or biodiversity potential. Such uncertainty is particularly important when using resource management criteria, which are based entirely on the percent habitat lost. The importance of model error for ecological thresholds will vary by KIR and will be dependant on the extent to which change in population or ecological function is driven by habitat loss and the extent to which other factors such as direct mortality affect those populations.

Model accuracy and predictive power were evaluated in several ways (Appendix 3.7). Resource selection functions and habitat suitability indices were validated for some KIRs. Validation results were explicitly considered as part of the determination of significance. In addition, error rates in the Regional Land Cover Classification (RLCC), which forms the basis of regional habitat models for terrestrial disciplines, were determined in September 2013 by comparing predicted habitat types with habitat types observed in the field. Errors in the RLCC could lead to over- or under-estimates in the amount of predicted habitat present in the RSA for each KIR. Such error rates were calculated and accounted for when determining significance, reducing uncertainty and permitting refined significance determinations.

Errors may also affect predicted vs. actual spatial distribution of habitat and may result in an under- or over estimation of the proportion of a particular habitat affected by development. However, the direction of these errors could not be calculated from available field data. Where classification success for a particular habitat type was low and substantial uncertainty present, a precautionary approach was applied and effects were more likely to be identified as significant.

2.11.2.6 Application to Assessment Cases

For the comparison between the 2013 Base Case and 2013 PRM Application Case (i.e., incremental effects of PRM), significance was determined for construction and operations only, using maximum disturbance footprints as described in Section 2.3. Significance for this case was determined at the LSA scale using only resource management criteria. A single project considered in isolation generally will not be sufficient to exceed an ecological threshold at ecologically relevant scales, so the significance of the incremental effects of PRM were not assessed at the LSA scale using the ecological threshold assessment method.

For the PIC to 2013 PRM Application Case and PIC to 2013 PDC, significance of cumulative effects was determined using both ecological thresholds and resource management criteria at the RSA scale and resource management criteria at the LSA scale. Terrestrial vegetation, wetland and forest resources and biodiversity were assessed for environmental consequences and significance in the 2013 PDC both prior to and after reclamation based on habitat ratios collated from publicly available reclamation plans. Significance prior to reclamation during construction and operations represents the period when the PRM makes its largest contribution to adverse cumulative effects to terrestrial resources. Such an assessment is appropriate given the long time horizon for the PRM. Significance after reclamation considers the residual effects of the PRM after all mitigation has been implemented. For wildlife, significance was only assessed before reclamation because the data needed to predict the characteristics of the post-reclamation landscape spatially at the RSA scale are not available.

2.11.3 Significance Determination to Aboriginal Traditional Land Use

For the purposes of the TLU assessment the overall effects to traditional harvesting were determined to be either significant or not significant based on the expected result at the Aboriginal group level. This is not to suggest that effects that may be experienced by some individuals are not important, or even critical, to their traditional use of land and resources. Where this is the case, the effect is discussed and Shell will implement mitigation measures in response to those effects. However, the determination of significance considered the magnitude of effects, duration and reversibility of the effects based on effects to the group as a whole. Generally, significant effects were considered to be high magnitude effects of long duration and affecting the group as a whole. The determination of significance also considered the following:

- perceptions and values of affected Aboriginal groups;
- qualitative data and interpretation, and observations of patterns of Aboriginal traditional use of land and resources of a project area.

Furthermore, for traditional land and resource use there are no established thresholds or standards. Although it may be possible to set thresholds for purposes of an EIA, it often cannot be demonstrated that there is any consensus on a specific threshold value or what such a threshold means in terms of significance of an effect. As a result, professional judgement (as opposed to the use of quantitative tools such as decision trees or valued matrices) is often used in reaching conclusions on the significance for effects on Aboriginal traditional use of land and resources.

The following definitions were used in this assessment to determine the significance of adverse effects for Traditional Land Use and Aboriginal rights:

- Not Significant: the effects are experienced only by individuals and are not expected to have a substantial effect on the larger group, or the effects may be experienced at the Aboriginal group level but are not likely to result in substantial changes in the overall patterns of traditional land and resource use.
- Significant: the overall effect is experienced at the Aboriginal group level, and results in substantial changes in the overall patterns of traditional land and resource use.

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4.0 ABBREVIATIONS

°	degree
°C	degrees Celsius
#	number
%	percent
<	less than
>	greater than
±	plus or minus
≤	less than or equal to
≥	greater than or equal to
7Q10	lowest 7-day consecutive flow that occurs, on average, once every 10 years
95%UCLM	95% upper confidence limit the mean
a1	lichen jack pine
AAAQG	Alberta Ambient Air Quality Guidelines
AAAQO	Alberta Ambient Air Quality Objectives
AAC	Annual Allowable Cuts
ABMI	Alberta Biodiversity Monitoring Institute
ACB	Alberta Cancer Board
ACFN	Athabasca Chipewyan First Nation
ACIMS	Alberta Conservation Information Management System (formerly Alberta Natural Heritage Information Centre)
ACR	Acute to Chronic Ratio
AEE	Air Emissions Effects
AENV	Alberta Environment (now Alberta Environment and Sustainable Resource Development)
AEP	Alberta Environmental Protection (now Alberta Environment and Sustainable Resource Development)
AER	Alberta Energy Regulator
AEW	Alberta Environment and Water (now Alberta Environment and Sustainable Resource Development)
Ag	silver
$AgNO_3$	silver nitrate
AGP	Above-Ground Pipelines
Al	aluminum
$Al(OH)_4^-$	tetrahydroxoaluminate ion

ALCES	A Landscape Cumulative Effects Simulator
Al-Pac	Alberta-Pacific Forest Industries Inc.
amsl	above mean sea level
AMV	Aquatic Maximum Value
ANC	Acid Neutralizing Capacity
AOSA	Athabasca Oil Sands Area
AOSCEHEP	Alberta Oil Sands Community Exposure and Health Effects Assessment Program
AOSERP	Alberta Oil Sands Environmental Research Program
ARM	Athabasca River Model
As	arsenic
As/L	arsenic per litre
ASRD	Alberta Sustainable Resource Development
ASTM	American Society for Testing and Materials
atm-m^3/mol	atmosphere cubic metre per mole
ATSDR	Agency for Toxic Substances and Disease Registry
AVI	Alberta Vegetation Inventory
AWI	Alberta Wetlands Inventory
b1	blueberry jack pine-aspen
b2	blueberry aspen (white birch)
b3	blueberry aspen-white spruce
b4	blueberry white spruce-jack pine
BAF	Bioaccumulation Factors
bbl/cd	barrels per calendar day
BBS	Breeding Bird Survey
BC MWLAP	British Columbia Ministry of Water, Land and Air Protection
$Be[OH]_2$	solid beryllium hydroxide
BFNN	forested bog
BLM	Biotic Ligand Model
BONN	open bog
BTEX	benzene, toluene, ethylbenzene, xylene
BTNI	wooded bog with internal lawn
BTNN	wooded bog
BTNR	wooded bog with internal lawn with islands of forested peat plateau
BTXC	wooded bog with collapsed scars

BUu	burned uplands
BUw	burned wetlands
c1	Labrador tea-mesic jack pine-black spruce
Ca	calcium
Ca^{2+}	calcium base cation (particle)
CAC	Criteria Air Contaminant
$CaCO_3$	calcium carbonate
CASA	Clean Air Strategic Alliance
$CaSO_4$	calcium sulphate
CC&R	Closure, Conservation and Reclamation
CCC	Criterion Continuous Concentration
CCCSN	Canadian Climate Change Scenario Network
CCME	Canadian Council of Ministers of the Environment
Cd	cadmium
CEAA	Canadian Environmental Assessment Act
CEB	Chronic Effects Benchmark
CEMA	Cumulative Environmental Management Association
Cl	Chlorine
cm	centimetre
cm^3/molec/s	cubic centimetres per molecule per second
CMC	Criterion Maximum Concentration
CO	carbon monoxide
$CoCl_2$	cobalt chloride
COPCs	Chemicals of Potential Concern
COPD	Chronic Obstructive Pulmonary Disease
COS	carbonyl sulphide
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CoZMo-POP	Coastal Zone Model for Persistent Organic Pollutants
Cr	chromium
CRISP	Comprehensive Regional Infrastructure Sustainability Plan
CS_2	carbon disulphide
CSE	Culturally Significant Ecosystem
CTV	Critical Toxicity Value
Cu	copper

CWS	Canada-Wide Standards
d	day
d1	low-bush cranberry aspen
d2	low-bush cranberry aspen-white spruce
d3	low-bush cranberry white spruce
dam^3	cubic decametre (thousand cubic metres)
dB	decibels
DC	Disturbance Coefficients
DEM	Digital Elevation Model
DIS	disturbance
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DQRA	Detailed Quantitative Risk Assessment
dw	dry weight
E	east
e.g.	for example [Latin exempli gratia]
e1	dogwood balsam poplar-aspen
e2	dogwood balsam poplar-white spruce
e3	dogwood white spruce
EC	Effective Concentration
EC_{50}	Median Effective Concentration
Eco-SSLs	Ecological Soil Screening Levels
EDI	Estimated Daily Intake
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
ELS	Early Life Stage
ENN_MN	Euclidian Nearest Neighbour distance
ERA	Ecological Risk Assessment
ERCB	Energy Resources Conservation Board (now the Alberta Energy Regulator)
ESL	Effects Screening Level
ESR	Environmental Setting Report
ESRD	Alberta Environment and Sustainable Resource Development
et al.	and others [Latin et alia]
ETMF	Environmental Toxicity Modifying Factors

EUB	Alberta Energy and Utilities Board (predecessor to the Energy Resources Conservation Board [ERCB])
f2	horsetail balsam poplar-white spruce
f3	horsetail white spruce
FAV	Final Acute Value
Fe	iron
FEC	Field Effect Concentration
FFNN	forested fen
FM468	Fort McMurray First Nation
FMA	Forest Management Agreement
FMFN	Fort McKay First Nation
FMSA	Fort McKay Specific Assessment
FMU	Forest Management Unit
FONG	graminoid fen
FONS	shrubby fen
FOPN	open patterned fen
FTIR	Fourier Transform Infrared spectroscopy
FTNI	wooded fen with internal lawns
FTNN	wooded fen
FTPN	wooded patterned fen
FWMIS	Fisheries and Wildlife Management Information System
g	grams
g $C/m^2/yr$	grams carbon per square metre per year
g/cm^3	grams per cubic centimetre
g/m^3	grams per cubic metre
g/mol	grams per mole
g1	Labrador tea-subhygric black spruce-jack pine
GCM	General Circulation Model
GEI	GEI Consultants
GIR	Government and Industry Relations
GIS	Geographic Information System
GMAV	Genus Mean Acute Value
Golder	Golder Associates Ltd.
GPLM	Golder Pit Lake Model

GPS	Global Position System
h1	Labrador tea/horsetail white spruce-black spruce
H_2S	hydrogen sulphide
ha	hectare
HC	hydrocarbons
HC_5	hazard concentration to 5% of the tested species, or the concentration that protects 95% of the tested species
HCO^{3-}	bicarbonate
Hg	mercury
HHRA	Human Health Risk Assessment
HNO_3	nitric acid (gas)
HQ	Hazard Quotient
HRSG	Heat Recovery Steam Generator
HS	Habitat Suitability
HSI	Habitat Suitability Index
HSPF	Hydrological Simulation Program-Fortran
i.e.	that is [Latin id est]
IC	Inhibiting Concentration
IC_{25}	25% Inhibiting Concentration
IDNR	Iowa Department of Natural Resources
IHDA	Interactive Health Data Application
ILCRs	Incremental Lifetime Cancer Risks
IPCC	Intergovernmental Panel on Climate Change
IR	Indian Reserve
IRC	Industry Relations Corporation
ISQG	Interim Sediment Quality Guidelines
IUCN	International Union for the Conservation of Nature
J/mol•K	Joule per mole per Kelvin
JME	Jackpine Mine Expansion
JRP	Joint Review Panel
K	degrees kelvin
K	potassium
keq H^+/ha/yr	kiloequivalent of hydrogen per hectares per year
keq N/ha/yr	kiloequivalent of nitrogen per hectares per year

keq/ha/yr	kiloequivalent per hectares per year
keq/ha/yr H^+	kiloequivalent per hectares per year hydrogen ion
kg N ha/yr	kilograms of nitrogen per hectare per year
kg/day	kilograms per day
KIR	Key Indicator Resource
kJ/mol	kilojoules per mole
km	kilometre
km^2	square kilometre
K_{oc}	soil organic carbon-water partitioning coefficient
K_{ow}	n-octanol/water partition coefficient
kt/y	kilotonnes per year
L	litre
L/ha/yr	litres per hectare per year
L/s	litres per second
LARP	Lower Athabasca Regional Plan
LC	Lethal Concentration
LC_{10}	Lethal concentration to 10% of organisms
LC_{50}	Lethal concentration to 50% of organisms
Li	lithium
LOAEL	Lowest Observed Adverse Effect Level
LOEC	Lowest Observed Effect Concentration
Log	Base 10 logarithm
Log_{kaw}	Base 10 logarithm of the air-water partition coefficient
Log_{koa}	Base 10 logarithm of the octanol-air partition coefficient
Log_{kow}	Base 10 logarithm of the octanol-water partition coefficient
LRSYA	Long Run Sustained Yield Average
LSA	Local Study Area
LT_{50}	median lethal time, i.e., the exposure time that is estimated to be lethal to 50% of test organisms for a given concentration of test material
LZA	Linkage Zone Analysis
m	metre
m/h	metres per hour
m/h	metres per hour
m/s	metres per second

m^2	square metres
m^2/g	square metres per gram
m^2/g	square metres per gram
m^2/h	square metres per hour
m^3	cubic metres
m^3/h	cubic metres per hour
m^3/ha	cubic metres per hectare
m^3/m^3	cubic metres per cubic metre
m^3/s	cubic metres per second
m^3/yr	cubic metres per year
MAI	Mean Annual Increment
MATC	Maximum Allowable Toxicant Concentration
MCFN	Mikisew Cree First Nation
Me	meadow
MFT	Mature Fine Tailings
mg	milligram
Mg	magnesium
mg/kg	milligrams per kilogram
mg/kg/yr	milligrams per kilogram per year
mg/L	milligrams per litre
mm	millimetre
mm/a	millimetres per annum
Mm^3	mega metres (million cubic metres)
mmBtu/lb	million British Thermal Units per pound
mmBtu/yr	million British Thermal Units per year
Mn	manganese
Mo	molybdenum
mol/m^3	moles per cubic metre
MONG	graminoid marsh
MPOI	Maximum Point of Impingement
MPS	Mean Patch Size
MRDA	Muskeg River Diversion Alternative
MRL	Minimal Risk Level
MRME	Muskeg River Mine Expansion

MW	megawatt
N	north
N	nitrogen
n	sample size
n.d.	no date
N/ha/yr	nitrogen per hectare per year
Na	sodium
NAD	North American Datum
NAs	naphthenic acid
NEPL	Northeast Pit Lake
ng/L	nanograms per litre
NH_3	ammonia
Ni	nickel
Nichols	Nichols Applied Management
NLHR	Northern Lights Health Region
nm	nanometre
NNLP	No Net Loss Plan
NO	nitric oxide
No.	number
NO_2	nitrogen dioxide (gas)
NO_3^-	nitrate (particle)
NOAEL	No Observed Adverse Effect Level
NOEC	No Observed Effect Concentration
NO_x	oxides of nitrogen (NO, NO2) (gas), or all nitrogen species (e.g., NOX, N2O, N3O)
NP	Number of Patches
NPRI	National Pollutant Release Inventory
NRBS	Northern River Basin Study
NREI	Northern River Ecosystem Initiative
NST	Non Segregated Tailings
NWPL	Northwest Pit Lake
O_3	ozone
OBDA	Overburden Disposal Area
OH^-	hydroxide
OMOE	Ontario Ministry of the Environment

OSDG	Oil Sands Developers Group (formerly the Athabasca Regional Issues Working Group [RIWG])
p.	page
PAC	Polycyclic Aromatic Compounds
PAD	Peace-Athabasca Delta
PAH	Polycyclic Aromatic Hydrocarbons
PAI	Potential Acid Input
PDC	Planned Development Case
PEF	Potency Equivalency Factors
pg/g	picograms per gram
PIC	Pre-Industrial Case
Pj-Lt	jack pine-tamarack complex
PM	particulate matter
$PM_{2.5}$	particulate matter with a mean aerodynamic diameter of 2.5 microns (µm) or smaller
POC	Particulate Organic Carbon
POP	Persistent Organic Pollutants
ppb	parts per billion
ppm	parts per million
ppmv	parts per million by volume
PQRA	Preliminary Quantitative Risk Assessment
PR	Patch Richness
PRM	Pierre River Mine
PVA	Population Viability Analysis
r^2	Coefficient of determination
RAMP	Regional Aquatics Monitoring Program
RCMP	Royal Canadian Mounted Police
RELAD	Regional Lagrangian Acid Deposition Model
RfC	Reference Concentration
RFMA	Registered Fur Management Area
RLCC	Regional Land Cover Classes
RMWB	Regional Municipality of Wood Buffalo
RPP	Rare Plant Potential
RQ	Risk Quotient
RSA	Regional Study Area

RSF	Resource Selection Function
S	south
SAGD	Steam Assisted Gravity Drainage
SAR	Species at Risk
Sb	antimony
SCI	Stream Condition Index
SCPL	South Central Pit Lake
Sh	shrubland
Sh2	reclaimed shrubland type 2
Sh3	reclaimed shrubland type 3
SHEI	Shannon’s Evenness Index
Shell	Shell Canada Energy
SI	Suitability Index
SIR	Supplemental Information Request
SK	Saskatchewan
SLWHRA	Screening Level Wildlife Health Risk Assessment
SMCV	Species Mean Chronic Values
SO_2	sulphur dioxide
SO_4	sulphate
SO_4^{2-}	sulphate (particle)
SONS	shrubby swamp
SOPC	Substances of Potential Concern
sp.	species
SPL	South Pit Lake
spp.	multiple species
SQC	Sediment Quality Criteria
Sr	strontium
SSD	Species Sensitivity Distribution
STNN	wooded swamp
Suncor	Suncor Energy Inc.
SWQMF	Surface Water Quality Management Framework for the Lower Athabasca River
t/cd	tonnes per calendar day
t/d	tonnes per day
t/sd	tonnes per stream day

TASA	Terrestrial Resources Air Emissions Effects Study Area
TCEQ	Texas Commission on Environmental Quality
TCU	True Colour Unit
TDI	Tolerable Daily Intake
TDS	Total Dissolved Solids
Teck	Teck Resources Limited
TEK	Traditional Ecological Knowledge
the Panel	Joint Review Panel
TLM	Target Lipid Model
TLU	Traditional Land Use
TMAC	Trace Metal and Air Contaminant
TN	Total Nitrogen
TOR	Terms of Reference
TP	Total Phosphorus
TPP	Traditional Plant Potential
TPR	Timber Productivity Rating
TPU	Tainting Potential Unit
TRS	Total Reduced Sulphur
TRVs	Toxicity Reference Values
TSS	Total Suspended Solids
t-TEL	Tissue Threshold-Effect Level
TU	Toxic Unit
TU_a	Toxic Unit – Acute
TU_C	Chronic Toxicity Unit
U.S. EPA	United States Environmental Protection Agency
US	United States
UTM	Universal Transverse Mercator
UV	ultraviolet
V	vanadium
VHF	Very High Frequency
VOC	Volatile Organic Compound
W	west
WALIC	Water Act Licence
WBEA	Wood Buffalo Environmental Association

WDS	Water Data System
WHO	World Health Organization
WHRA	Wildlife Health Risk Assessment
WMU	Wildlife Management Unit
WNS	White-Nose Syndrome
WONN	shallow open water
WQG	Water Quality Guidelines
WRLIC	Water Resource Licence
WSAR	West Side of the Athabasca River
WSC	Water Survey Canada
ww	wet weight
yr	year
Zn	zinc
ZOI	Zones of Influence
λ	rate of increase
µeq/L	microequivalent per litre
µg/g	micrograms per gram
µg/L	micrograms per litre
$\mu g/m^3$	micrograms per cubic metre
$\mu g/m^3/yr$	micrograms per cubic metre per year
µS/cm	microsiemens per centimetre
µm	micron or micrometre

5.0 GLOSSARY

Abiotic	Non-living factors that influence an ecosystem, such as climate, geology and soil characteristics.
Acid Neutralizing Capacity (ANC)	The equivalent capacity of a solution to neutralize strong acids. Acid Neutralizing Capacity can be calculated as the difference between non-marine base cations and strong anions. This is the principal variable used to quantify the acid-base status of surface waters. Acidification is often quantified by decreases in ANC, and susceptibility of surface waters to acidic deposition impacts is often evaluated on the basis of ANC.
Acid Pulse	A rapid drop in pH in surface waters over a short period. Acid pulse (or episodic acidification) typically occurs in the spring, and may result from: (1) dilution of base cations in surface waters by large volumes of runoff from snow melt; and/or (2) release of acids stored in the snowpack that originated from industrial emissions.
Acidification	The decrease of acid neutralizing capacity in water, or base saturation in soil, caused by natural or anthropogenic processes. Acidification is exhibited as the lowering of pH.
Acute	A stimulus severe enough to rapidly induce an effect; in aquatic toxicity tests, an effect observed in 96 hours or less is typically considered acute. When referring to aquatic toxicology or human health, an acute effect is not always measured in terms of lethality.
Advection	The transport mechanism of a substance by a fluid due to the fluid's bulk motion.
Airshed	The geographic area requiring unified management to achieve air pollution control.
Alberta Ambient Air Quality Objective (AAAQO)	Levels established for several air compounds under Section 14 of the *Environmental Protection and Enhancement Act* (EPEA). The AAAQOs form an integral part of the management of air quality in the province, and are used for reporting the state of the environment, establishing approval conditions, evaluating proposed facilities with air emissions, assessing compliance near major air emission sources and guiding monitoring programs.

Alberta Environment and Sustainable Resource Development (ESRD) Provincial ministry that establishes policies, legislation, plans, guidelines and standards for environmental management and protection; allocates resources through approvals, dispositions and licenses, and enforces those decisions; ensure water infrastructure and equipment are maintained and operated effectively; and prevents, reduces and mitigates floods, droughts, emergency spills and other pollution-related incidents. The ministry was formed in May 2012 to bring together the former departments of Environment and Water, and Sustainable Resource development; ESRD's predecessors were Alberta Environment and Water (from October 2011 to May 2012), and Alberta Environment.

Alevin A newly hatched fish in the larval stage, dependent upon a yolk sac for nutrients while their digestive system develops.

Alkalinity A measure of water's capacity to neutralize an acid. It indicates the presence of carbonates, bicarbonates and hydroxides, and less significantly, borates, silicates, phosphates and organic substances. Alkalinity is expressed as an equivalent of calcium carbonate. Its composition is affected by pH, mineral composition, temperature and ionic strength. However, alkalinity is normally interpreted as a function of carbonates, bicarbonates and hydroxides. The sum of these three components is called total alkalinity.

Ambient Air The air in the surrounding atmosphere.

Amphibian Any of the class of cold-blooded vertebrates such as frogs, toads, and salamanders intermediate between fishes and reptiles; they have gilled aquatic larva and air-breathing adults.

Anion An ion or group of ions having a negative charge.

Anoxia Little to no dissolved oxygen in the water sample. Waters with less than 2 mg/L of dissolved oxygen experience anoxia.

Anthropogenic Caused by human activity.

Application Case The Environmental Impact Assessment (EIA) case including the project that is the subject of the application, existing environmental conditions, and existing and approved projects or activities.

Aquifer	A body of rock or soil that contains sufficient amounts of saturated permeable material to yield economic quantities of water to wells or springs. Any water-saturated body of geological material from which enough water can be drawn at a reasonable cost for the purpose required. An aquifer in an arid prairie area required to supply water to a single farm may be adequate if it can supply 1 m^3/d. This would not be considered an aquifer by any industry looking for cooling water in volumes of 10,000 m^3/d. The term aquifer is commonly used to indicate the water-bearing material in any area from which water is most easily extracted.
Area Source	A two-dimensional source of diffuse air pollutant emissions (e.g., forest fire).
Asphaltene	Any of the dark, solid constituents of crude oils or other bitumens that are soluble in carbon disulphide but insoluble in paraffin naphthas. They hold most of the organic constituents of bitumens.
Bankfull Depth	The maximum depth of a channel within a rifle segment when flowing at a bank-full discharge.
Bankfull Discharge	The flow rate that fills the channel of an undisturbed stream with a wide floodplain up to the top of its banks prior to flooding.
Basal Aquifer	A water-bearing strata located at the lowest portion of a stratigraphic unit.
Base Case	The EIA assessment case that includes existing environmental conditions as well as existing and approved projects or activities.
Baseline	A surveyed or predicted condition that serves as a reference point to which later surveys are coordinated or correlated.
Basin	A geographic area drained by a single major stream; consists of a drainage system comprised of streams and often natural or artificial (constructed) lakes.
Bedrock	The body of rock that underlies gravel, soil or other subregion material.
Benthic Invertebrates	Invertebrate organisms living at, in or in association with the bottom (benthic) substrate of lakes, ponds and streams. Examples of benthic invertebrates include some aquatic insect species (such as caddisfly larvae) that spend at least part of their lifestages dwelling on bottom sediments in the waterbody. These organisms play several important roles in the aquatic community. They are involved in the mineralization and recycling of organic matter produced in the water above, or brought in from external sources, and they are important second and third links in the trophic sequence of aquatic communities. Many benthic invertebrates are major food sources for fish.

Bioaccumulation	When an organism stores within its body a higher concentration of a substance than is found in the environment. Bioaccumulation is not necessarily harmful. For example, freshwater fish must bioaccumulate salt to survive in intertidal waters. Many toxicants, such as arsenic, are not included among the dangerous bioaccumulative substances because they can be handled and excreted by aquatic organisms.
Bioavailability / Bioavailable	The amount of chemical that enters the general circulation of the body following administration or exposure.
Biochemical Oxygen Demand (BOD)	An empirical test in which standardized laboratory procedures are used to determine the relative oxygen requirements of wastewaters, effluents and polluted waters.
Biodiversity	The variety of plant and animal life in a particular habitat (e.g., plant community or a country). Biodiversity includes all levels of organization, from genes to landscapes, and the ecological processes through which these levels are connected.
Biodiversity Potential	Biodiversity potential (high, moderate or low) represents the relative contribution of a land cover type or regional land cover class to the overall biological diversity of an area.
Biota	The plant and animal life of a particular region
Biotic	The living organisms in an ecosystem.
Bioturbation	The displacement and mixing of sediment particles (i.e., sediment reworking) and solutes (i.e., bio-irrigation) by benthic fauna (animals) or flora (plants).
Bitumen	A highly viscous, tarry, black hydrocarbon material having an American Petroleum Institute (API) gravity of about 9 (specific gravity about 1.0). It is a complex mixture of organic compounds. Carbon accounts for 80% to 85% of the elemental composition of bitumen, hydrogen 10%, sulphur 5%, and nitrogen, oxygen and trace elements form the remainder.
Bog	Sphagnum or forest peat materials formed in an ombrotrophic environment due to the slightly elevated nature of the bog, which tends to disassociate it from the nutrient-rich groundwater or surrounding mineral soils. Characterized by a level, raised or sloping peat surface with hollows and hummocks. Mineral-poor, acidic and peat-forming wetlands that receives water only from precipitation.
Boreal Forest	The northern hemisphere, circumpolar, tundra forest type consisting primarily of black spruce and white spruce with balsam fir, birch and aspen.

Bryophyte	Sphagnum or forest peat materials formed in an ombrotrophic environment due to the slightly elevated nature of the bog, which tends to disassociate it from the nutrient-rich groundwater or surrounding mineral soils. Characterized by a level, raised or sloping peat surface with hollows and hummocks. Mineral-poor, acidic and peat-forming wetlands that receives water only from precipitation.
Calendar Day	Stream day multiplied by a service factor for planned and unplanned downtime.
CALPUFF	A non-steady Lagrangian Gaussian Puff Model containing modules for complex terrain effects, overwater transport interaction effects, building downwash, wet and dry removal, and simple chemical transformation.
Canopy	An overhanging cover, shelter or shade. The tallest layer of vegetation in an area.
Carcinogen	An agent that is reactive or toxic enough to act directly to cause cancer.
Carnivore	Any of an order of mammals that feed chiefly on flesh or other animal matter rather than plants.
Carrying Capacity	The maximum population size that can be supported by the available resources.
Catchment Area	The area of land from which water finds its way into a particular watercourse, lake or reservoir. Also termed river basin or watershed.
Cation	An ion or group of ions having a positive charge.
Channel	The bottom of a flowing body of water that may be eroded into the underlying bedrock. The bed of a stream or river.
Chemical of Potential Concern	A chemical that is emitted or released into the environment and poses a potential risk of exposure to humans.
Chlorophyll *a*	One of the green pigments in plants. It is a photo-sensitive pigment that is essential for the conversion of inorganic carbon (e.g., carbon dioxide) and water into organic carbon (e.g., sugar). The concentration of chlorophyll a in water is an indicator of algal concentration.
Chlorosis	A yellowing of leaf tissue due to a lack of chlorophyll. Possible causes of chlorosis include poor drainage, damaged roots, compacted roots, high alkalinity, and nutrient deficiencies in the plant.

Chronic The development of adverse effects after extended exposure to a given substance. In chronic toxicity tests, the measurement of a chronic effect can be reduced growth, reduced reproduction or other non-lethal effects, in addition to lethality. Chronic should be considered a relative term depending on the life span of the organism.

Class Area The total area of each patch type.

Coefficient of Variation Standardized index of the variability of a value relative to the mean value.

Collapse Scar Areas where permafrost has melted, causing the ground above to slump below the surrounding area, often with "ripped" edges.

Concentration Quantifiable amount of a chemical in environmental media.

Conductivity A measure of the capacity of water to conduct an electrical current. It is the reciprocal of resistance. This measurement provides an estimate of the total concentration of dissolved ions in the water.

Conifer Trees in the division Pinophyta of the plant kingdom. These are cone-bearing trees with no true flower (e.g., white spruce, black spruce, balsam fir, jack pine and tamarack).

Coniferous Bearing cones or strobili (a cone-like cluster).

Country Foods Dietary items from the local region which are used for sustenance. Country food items include: fruit, vegetables, herbs, medicinal plants, fish and game.

Critical Load A quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge. For waterbody acidification, the critical load represents an estimate of the amount of acidic deposition below which significant adverse changes are not expected to occur in a lake's ecosystem.

Cubic metres per second (m^3/s) The standard measure of water flow in rivers (i.e., the volume of water in cubic metres that passes a given point in one second).

Cutblock Previously forested area that has been harvested for timber and is presently regenerating at various stages of regrowth.

Decibel (dB) The standard unit of measure, in acoustics. A logarithmic ratio of the measured pressure fluctuation and reference pressure.

Deciduous Falling off at maturity or tending to fall off. This term is used in reference to trees, shrubs, and ultimately a forest of this primary vegetation type, that loses their leaves seasonally.

Depressurization The process of reducing the pressure in the Basal Aquifer, by withdrawing water from it.

Detection Limit (DL) The lowest concentration at which individual measurement results for a specific analyte are statistically different from a blank (that may be zero) with a specified confidence level for a given method and representative matrix.

Dew Point Dew point temperature is a measure of atmospheric moisture. It is the temperature to which air must be cooled in order to reach saturation (assuming air pressure and moisture content are constant).

Dewatering Removal of groundwater from surficial aquifers or deposits using wells or drainage ditch systems.

Digital Elevation Model (DEM) A three-dimensional grid representing the height of a landscape above a given datum.

Dissolved Organic Carbon (DOC) The dissolved portion of organic carbon water; made up of humic substances and partly degraded plant and animal materials.

Dissolved Oxygen (DO) Measurement of the concentration of dissolved (gaseous) oxygen in the water, usually expressed in milligrams per litre (mg/L).

Disturbance An event that causes a sudden change from the existing pattern, structure and/or composition in an ecological system or habitat.

Diversity The variety, distribution and abundance of different plant and animal communities and species within an area.

Drainage Basin A region of land that eventually contributes water to a river or lake.

Drawdown Lowering of water level caused by pumping. It is measured for a given quantity of water pumped during a specified period, or after the pumping level has become constant.

Dry Bitumen Bitumen froth is treated to remove sands and fine clay, producing clean, "dry" bitumen.

Echolocation	High frequency sounds (25 to 120 kHz) produced by bats that are beyond the range of human hearing (20 to 25 kHz). These sounds are produced with great intensity. Echoes resulting from sound returning from objects in the bat's environment provide information to the bat.
Ecodistrict	A broad subdivision of the landscape based on differences in landscape pattern, topography and dominant soils.
Ecosite	Ecological units that develop under similar environmental influences (climate, moisture and nutrient regime). Ecosites are groups of one or more ecosite phases that occur within the same portion of the moisture/nutrient grid. Ecosite is a functional unit defined by the moisture and nutrient regime. It is not tied to specific landforms or plant communities, but is based on the combined interaction of biophysical factors that together dictate the availability of moisture and nutrients for plant growth.
Ecosite Phase	A subdivision of the ecosite based on the dominant tree species in the canopy. On some sites where the tree canopy is lacking, the tallest structural vegetation layer determines the ecosite phase.
Ecosystem	An integrated and stable association of living and non-living resources functioning within a defined physical location. A community of organisms and its environment functioning as an ecological unit. For the purposes of assessment, the ecosystem must be defined according to a particular unit and scale.
Edge	Where different plant communities meet in space on a landscape; and where plant communities meet a disturbance. An outer band of a patch that usually has an environment significantly different from the interior of the patch.
Effect Concentration	The effect concentration (EC_x) refers to a reduction of a sublethal endpoint, such as growth or reproduction by x percent, often expressed relative to reference or control.
Effluent	Stream of water discharging from a source.
Elution	Process whereby a component of a solution (usually attached to a solid phase, such as ice crystals) is extracted by movement of a solvent.
Environmental Impact Assessment (EIA)	A review of the effects that a proposed development will have on the local and regional environment. Typically completed in accordance with a defined Terms of Reference (TOR).

***Environmental Protection and Enhancement Act* (EPEA) (Alberta)**	The purpose of the act is to support and promote the protection, enhancement and wise use of the environment.
Ericaceous	Plant species belonging to the heath family (Ericaceae) and typically prefer acid soil.
Eutrophic	The nutrient-rich status (amount of nitrogen, phosphorus and potassium) of an ecosystem.
Eutrophication	The over fertilization of a body of water, which generally results in increased plant growth and decay. This ultimately leads to an increase in simple algae and plankton over more complex plant species, resulting in a decrease in water quality. Causes of eutrophication can be anthropogenic or natural.
Evaporation	The process by which water is changed from a liquid to a vapour.
Evapotranspiration	A measure of the capability of the atmosphere to remove water from a location through the processes of evaporation and water loss from plants (transpiration).
Evenness	The relative abundance of land cover types; measured using the Shannon's Evenness Index.
Exposure	The contact reaction between a chemical and a biological system, or organism. Estimated dose of chemical that is received by a particular receptor via a specific exposure pathway (e.g., ingestion, inhalation); expressed as the amount of chemical received, per body weight, per unit time (i.e., mg/kg/day).
Far Future	Defined as 80 years following final reclamation.
Fen	The over fertilization of a body of water, which generally results in increased plant growth and decay. This ultimately leads to an increase in simple algae and plankton over more complex plant species, resulting in a decrease in water quality. Causes of eutrophication can be anthropogenic or natural.
Fish	Fish as defined in the *Fisheries Act*, includes parts of fish, shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals and the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals.
Fish Habitat	Fish habitat, as defined in the *Fisheries Act*, includes the spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly to carry out their life processes.

Fluvial	Relating to a stream or river.
Footprint	The proposed development area that directly affects the soil and vegetation components of the landscape.
Fragmentation	The process of breaking into pieces or sections. For example, dividing contiguous tracts of land into smaller and less connected sections through site clearing (e.g., for roads).
FRAGSTATS	A spatial pattern analysis software program used to quantify the areal extent and spatial configuration of patches within a landscape. The analysis is done using categorical spatial data (e.g., plant communities).
Fry	The early stage of development for the fish from hatching until it is one year old.
Fugacity	Identical to partial pressure in ideal gases and logarithmically related to chemical potential, useful as a measure of the escaping tendency of a substance from a heterogenous system.
Fugitive Emissions	Substances emitted from any source except those from stacks and vents. Typical sources include gaseous leakage from valves, flanges, drains, volatilization from ponds and lagoons, and open doors and windows. Typical particulate sources include bulk storage areas, open conveyors, construction areas or plant roads.
Fugitive Emissions	Substances emitted from any source except those from stacks and vents. Typical sources include gaseous leakage from valves, flanges, drains, volatilization from ponds and lagoons, and open doors and windows. Typical particulate sources include bulk storage areas, open conveyors, construction areas or plant roads.
Fumigation	Exposure to potentially toxic substances such as sulphur dioxide (SO_2) or nitrogen dioxide (NO_2) in gaseous form.
Furbearers	Mammals that have traditionally been trapped or hunted for their fur.
Geographic Information System (GIS)	Computer software designed to develop, manage, analyze and display spatially referenced data.
Global Positioning System (GPS)	A system of satellites, computers and receivers that is able to determine the latitude and longitude of a receiver on Earth by calculating the time difference for signals from different satellites to reach the receiver.
Graminoid	Grasses and grass-like plants such as sedges and rushes.

Groundtruth	Visiting locations in the field to confirm or correct information produced from remote sources such as interpreted aerial photographs or classified satellite imagery.
Groundwater	That part of the subsurface water that occurs beneath the water table, in soils and geologic formations that are fully saturated.
Groundwater Discharge	The volumetric flow of groundwater from an aquifer to ground surface (springs or seeps) or a surface waterbody.
Habitat	The place or environment where a plant or animal naturally or normally lives or occurs.
Habitat Fragmentation	Occurs when extensive, continuous tracts of habitat are reduced by habitat loss to dispersed and usually smaller patches of habitat. Generally reduces the total amount of available habitat and reduces remaining habitat into smaller, more isolated patches.
Habitat Patches	Isolated patches of habitat.
Habitat Suitability Index (HSI) Model	Analytical tools for determining the relative potential of an area to support individuals or populations of a wildlife species. They are frequently used to quantify potential habitat losses and gains for wildlife as a result of various land use activities.
Hardness	Calculated mainly from the calcium and magnesium concentrations in water; originally developed as a measure of the capacity of water to precipitate soap. The hardness of water is environmentally important since it is inversely related to the toxicity of some metals (e.g., copper, nickel, lead, cadmium, chromium, silver and zinc).
Heterogeneity	Consisting of parts that are unlike each other. For example, the variety and abundance of ecological units (e.g., ecosite phases and wetlands types) comprising a landscape mosaic.
Hibernacula	A protective cave, covering, or structure, such as a plant bed, in which an organism remains dormant for the winter.
Historic/Heritage Resources	Works of nature or of humans, valued for their palaeontological, archaeological, prehistoric, historic, cultural, natural, scientific or aesthetic interest.
Home Range	The area within which an animal normally lives, and traverses as part of its annual travel patterns.
Human Health Risk Assessment	The process of defining and quantifying risks and determining the acceptability of those risks to human life.

Humus	Organic matter that has reached a point of stability and will not degrade further. Humus has a characteristic dark brown/black colour due to an accumulation of black carbon. Humus is so well decomposed that the original sources cannot be identified.
Hydrogeology	The study of the factors that deal with subsurface water (groundwater) and the related geologic aspects of surface water. Groundwater as used here includes all water in the zone of saturation beneath the earth's surface, except water chemically combined in minerals.
Hydrological Simulation Program – Fortran (HSPF)	A comprehensive, conceptual, continuous watershed simulation model designed to simulate the water quantity and water quality processes that occur in a watershed. The model can reproduce spatial variability by dividing the basin in hydrologically homogeneous land segments and simulating runoff for each land segment independently, using segment-specific meteorological input data and watershed parameters.
Hydrology	The science of waters of the earth, their occurrence, distribution, and circulation; their physical and chemical properties; and their reaction with the environment, including living beings.
Hygric	Water is removed slowly enough to keep the soil wet for most of the growing season; permanent seepage and mottling are present and possibly weak gleying.
Hyper-Eutrophic	Trophic state classification for lakes characterized by high primary productivity and high nutrient inputs (particularly total phosphorus). Hyper-eutrophic lakes are characterized by abundant plant growth, algal blooms and oxygen depletion.
Incremental Lifetime Cancer Risk (ILCR)	The risk associated with daily exposure to a carcinogenic chemical that is separate from the risk associated with assumed background exposures.
Instar	A development stage of arthropods, such as insects, between each moult (ecdysis), until sexual maturity is reached.
Internal Lawn	Wet depressional area within bog or fen wetlands types that are absent of trees and contain species adapted to wetter conditions than the surrounding wooded habitat. In bogs, internal lawns contain wet *Sphagnum* species and sedges and represent previous areas of permafrost that have degraded in the past. In fens, internal lawns contain wetter species of *Sphagnum* or brown moss.
Invertebrate Drift	The downstream movement of invertebrates by floating through or on top of the water column. Benthic invertebrates may enter the water column and drift due to accidental dislodgement or active release from the substrate in response to food availability or changes in environmental conditions.

Invertebrates	Any animal lacking a backbone, including all species not classified as vertebrates.
Isopleth	A line on a map connecting places sharing the same feature (e.g., ground-level concentrations).
ISQG (Interim Sediment Quality Guideline)	Recommended maximum concentration of a chemical in sediment, intended to be protective of aquatic organisms.
Key Indicator Resources (KIRs)	Environmental attributes or components identified as a result of a social scoping exercise as having legal, scientific, cultural, economic or aesthetic value.
Kinetic rate constant	A value that quantifies the speed at which a chemical reaction proceeds
Labile	Susceptible to alteration or destruction.
Land cover type	Ecosite phases, wetlands types, disturbance and other land cover types; used to describe land cover in the LSA.
LANDSAT 5	A specific satellite or series of satellites used for earth resource remote sensing. Satellite data can be converted to visual images for resource analysis and planning.
Landscape	A heterogeneous land area with interacting ecosystems that are repeated in similar form throughout. From a wildlife perspective, a landscape is an area of land containing a mosaic of habitat patches within which a particular “focal” or “target” habitat patch is embedded.
Landscape Structure	The spatial relations among a landscape’s component parts including composition; the presence and amount of each patch type without being spatially explicit; and landscape configuration, the physical distribution or spatial character of patches within a landscape.
Lentic	Of or relating to or living in still waters (as lakes or ponds).
Lenticular Patterned Fen	A patterned fen with uncharacteristic lens-like patterning, the nature of which is affected by its landscape position at both an area of groundwater discharge and a surface water drainage divide. The character of a lenticular patterned fen is expressed by “lens” or “island” like patterning rather than the more typical linear string and flark type patterning.
Lethal Concentration	The lethal concentration (LC_x) refers to mortality rate of 10 percent, often expressed relative to reference or control.

Lichen	Any complex organism of the group Lichenes, composed of a fungus in symbiotic union with an alga and having a greenish, grey, yellow, brown, or blackish thallus that grows in leaflike, crustlike, or branching forms on rocks, trees and other surfaces.
Linear Disturbance	Cutlines, pipelines, rights-of-ways, and transmission lines (but not roads).
Littoral Zone	The zone in a lake that is closest to the shore. It includes the part of the lake bottom, and its overlying water, between the highest water level and the depth where there is enough light (about 1% of the surface light) for rooted aquatic plants and algae to colonize the bottom sediments.
Local Study Area (LSA)	Defines the spatial extent directly or indirectly affected by Pierre River Mine.
Long Run Sustained Yield Average (LRSYA)	The sum of Mean Annual Increments (MAI) for all forest cover types in a study area. The LRSYA is an estimate for the sustained yield or expected annual growth of the coniferous and deciduous fibre in a study area.
Lotic	Flowing water.
Lowest Observed Adverse Effect Level (LOAEL)	In toxicity testing, the lowest concentration at which adverse effects on the measurement end point are observed.
Lowest Observed Effect Concentration (LOEC)	The lowest concentration in a medium that causes an effect that is a statistically significant difference in effect compared to controls.
Macrophytes	Plants large enough to be seen by the unaided eye. Aquatic macrophytes are plants that live in or near water.
Mainstem	The main portion of a watercourse extending continuously upstream from its mouth, but not including any tributary watercourses.
Marsh	Non-peat-forming, nutrient-rich wetlands characterized by frequent flooding and fluctuating water levels.
Mature Fine Tailings (MFT)	Thin fine tailings that have dewatered to a level of about 30% solids over a period of about three years after deposition. The rate of consolidation beyond this point is substantially reduced. Mature fine tailings behave like a viscous fluid.
Mean Annual Increment (MAI)	The measure of cubic metres of fibre that accumulates per year from each hectare of forest. Calculated MAI for each stand is summed by forest cover type, and multiplied by its area to derive expected fibre accumulation for that forest cover type.

Mean Patch Size	The average size of habitat patches within the study area.
Merchantable Forest	A forest area with potential to be harvested for production of lumber/timber or wood pulp. Forests with a timber productivity rating of moderate to good.
Mesic	A moderate soil moisture regime value whereby water is removed somewhat slowly in relation to supply; neither wet nor dry. Available soil water reflects climatic inputs.
Mesotrophic	Trophic state classification for lakes characterized by moderate productivity and nutrient inputs (particularly total phosphorus).
Mineral Soil	Soils containing low levels of organic matter. Soils that have evolved on fluvial, glaciofluvial, lacustrine and morainal parent material. The A, B, and C horizons and underlying parent material.
Mixedwood	A stand containing both deciduous and coniferous trees. Defined in this report as stands where the primary species is deciduous and the secondary species totals ≥30% coniferous species, or vice-versa. Also, multistory stands of an “A” density with a deciduous primary overstorey species, and the dominant understorey species is coniferous, or vice-versa.
Modelling	A simplified representation of a relationship or system of relationships. Modelling involves calculation techniques used to make quantitative estimates of an output parameter based on its relationship to input parameters. The input parameters influence the value of the output parameters.
Moisture Regimes	The relative moisture supply at a site available for plant growth.
Muskeg	A soil type comprised primarily of organic matter. Also known as bog peat.
Naphthenic Acids	Generic name used for all the organic acids present in crude oils.
Narcosis	A state of unconsciousness caused by a chemical compound or lack of oxygen.
Necrosis	Death of cells or plant parts, usually resulting in the tissue turning brown or black due to oxidation of phenolics.
Nitrogen Dioxide	One of the component gases of oxides of nitrogen which also includes nitric oxide. In burning natural gas, coal, oil and gasoline, atmospheric nitrogen may combine with molecular oxygen to form nitric oxide, an ingredient in the brown haze observed near large cities. Nitric oxide is converted to nitrogen dioxide in the atmosphere. Cars, trucks, trains and planes are the major source of oxides of nitrogen in Alberta. Other major sources include oil and gas industries and power plants.

Nitrogen Oxides (NO_x)	Oxides of nitrogen (NO_x) include gaseous compounds such as nitrogen oxide (NO) and nitrogen dioxide (NO_2), but may also include additional nitrogen species (e.g., N_2O, N_3O). Oxides of nitrogen are the primary precursor for tropospheric ozone.
Nival Flow Regimes	A flow regime that is dominated by spring and summer snowmelt, and is consequently characterized by spring or early summer high flows, and lower late summer and fall flows.
No Net Loss Plan	A working principle which strives to balance unavoidable habitat losses with habitat replacement on a project by project basis so that reductions to fisheries resources due to habitat loss or damage may be prevented.
No Observed Adverse Effect Level (NOAEL)	In toxicity testing, the highest concentration at which no adverse effects on the measurement end point are observed.
No Observed Effect Concentration (NOEC)	The highest concentration in a medium that does not cause a statistically significant difference in effect as compared to controls.
Node	Location along a river channel, lake inlet or lake outlet where flows, sediment yield and water quality have been quantified.
Non-Carcinogen	A chemical that does not cause cancer and has a threshold concentration, below which adverse effects are unlikely.
Non-Segregating Tailings (NST)	Tailings formed from a mixture of cycloned sand tailings and thickened fine tailings in a non-segregating stream. These consolidate relatively rapidly upon placement in tailings disposal areas to form a trafficable surface. Consolidated tailings are one type of NST.
Nutrients	Environmental substances (elements or compounds) such as nitrogen or phosphorus, which are necessary for the growth and development of plants and animals.
Oil Sands	A sand deposit containing a heavy hydrocarbon (bitumen) in the intergranular pore space of sands and fine grained particles. Typical oil sands comprise approximately 10 wt% bitumen, 85% coarse sand (>44 µm) and a fines (<44 µm) fraction, consisting of silts and clays.
Oil Sands Process Water	Water that has come into contact with oil sands tailings and has become elevated in a number of constituents, including TDS and naphthenic acids.
Oil Sands Region	The Oil Sands Region includes the Fort McMurray – Athabasca Oil Sands Subregional Integrated Resource Plan (IRP), the Lakeland Subregional IRP and the Cold Lake – Beaver River Subregional IRP.

Old Growth Forest	An ecosystem distinguished by old trees and related structural attributes. Old growth encompasses the later stages of stand development that typically differ from earlier stages in a variety of characteristics which may include tree size, accumulations of large dead woody material, number of canopy layers, species, composition, and ecosystem function. Old growth forests are those forested areas where the annual growth equals annual losses, or where the mean annual increment of timber volume equals zero. They can be defined as those stands that are self-regenerating (i.e., having a specific structure that is maintained).
Oligotrophic	Trophic state classification for lakes characterized by low productivity and low nutrient inputs (particularly total phosphorus).
Organic Soil	A soil order that have developed primarily on organic deposits. Soils containing high percentages of organic matter (fibric and humic inclusions).
Organics	Chemical compounds, naturally occurring or otherwise, which contain carbon, with the exception of carbon dioxide (CO_2) and carbonates (e.g., $CaCO_3$).
Outlier	A data point that falls outside of the statistical distribution defined by the mean and standard deviation.
Overburden	The soil, sand, silt or clay that overlies a mineral deposit and must be removed before mining (material below the soil profile and above the bituminous sand).
Overstorey	Those trees that form the upper canopy in a multi-layered forest.
Particulate Matter	A mixture if small particles and liquid droplets, often including a number of chemicals, dust and soil particles.
Patch	An area that is different from the area around it (e.g., vegetation types, non-forested areas). This term is used to recognize that most ecosystems are not homogeneous, but rather exist as a group of patches or ecological islands that are recognizably different from the parts of the ecosystem that surround them but nevertheless interact with them.
Patch Richness (PR)	A measure of the number of different patch types that occur within a study area or landscape unit within a study area. The patch types used here are vegetation units.
Patterned Fen	Peatlands that display a distinctive pattern due to alterations between open wet areas (flarks) and drier shrubby to wooded areas (strings).
Peat	A material composed almost entirely of organic matter from the partial decomposition of plants growing in wet conditions.

Peatland	Areas where there is an accumulation of peat material at least 40 cm thick. These areas are represented by bog and fen wetlands types.
Pedogenic Development	The process of soil development as a result of inter-related factors of climate, living organisms, parent materials, topography and time.
Perched Basin	A tributary area or sub-watershed that is elevated above the main watershed.
Petrogenic	Of or relating to the origin or formation of rocks.
pH	The degree of acidity (or alkalinity) of soil or solution. The pH scale is generally presented from 1 (most acidic) to 14 (most alkaline). A difference of one pH unit represents a ten-fold change in hydrogen ion concentration.
Phytotoxic	Toxic or poisonous to plants or plant tissue.
Phytotoxic Metals	Metals in concentrations toxic to plants.
Pit Lake	An artificial lake located in a mine pit upon closure into which tailings may be discharged. Pit lakes are typically filled with waters pumped from adjacent rivers, or from runoff waters from reclamation areas.
Planned Development Case (PDC)	The Planned Development Case includes the Application Case components and planned developments that have been publicly disclosed at least six months prior to submission of the Environmental Impact Assessment, or as otherwise directed in the Terms of Reference.
Plant Community	An association of plants of various species found growing together.
Point Count	A circular plot survey where observers spend a prescribed time looking and listening for birds or toads.
Point Source	Any single identifiable source of pollution from which pollutants are discharged (e.g., a stack).
Polishing Pond	Pond where final sedimentation takes place before discharge.
Polycyclic Aromatic Hydrocarbon (PAH)	Aromatics are considered to be highly toxic components of petroleum products. PAHs, many of which are potential carcinogens, are composed of at least two fused benzene rings. Toxicity increases along with molecular size and degree of alkylation of the aromatic nucleus.
Polygon	The spatial area delineated on a map to define one feature unit (e.g., one type of ecosite phase).

Population A collection of individuals of the same species that potentially interbreed.

Population Viability Analysis (PVA) A modelling process that uses estimates of landscape changes, demographic rates and environmental variation to calculate the probability of species extinction within a given period of time and space.

Porewater Water between the grains of a soil or rock.

Porosity The percentage of the bulk volume of a rock or soil that is occupied by interstices (minute openings or crevices), whether isolated or connected.

Potential Acid Input (PAI) A composite measure of acidification determined from the relative quantities of deposition from background and industrial emissions of sulphur, nitrogen and base cations.

Probable Effects Level Concentration of a chemical in sediment above which adverse effects on an aquatic organism are likely.

Process Affected Water Any water that has come in contact with oil sands through an industrial process, and may contain hydrocarbons and other chemicals.

Rare Plant A native plant species found in restricted areas, at the edge of its range or in low numbers within a province, state, territory or country.

Rare Plant Potential A ranking system used to determine and map the likelihood of finding rare plants or the relative abundance of rare plant species among different vegetation types or land cover classes within the landscape.

Raster A graphic structure where the data is divided into cells on a grid. An example would be a computer screen where an image is represented by horizontal lines of coloured pixels. Shapes are represented by cells of the same colour or content adjacent to each other

Reach A comparatively short length of river, stream channel or shore. The length of the reach is defined by the purpose of the study.

Receptor The person or organism subjected to exposure to chemicals or physical agents.

Recharge The infiltration of water into the soil zone, unsaturated zone and ultimately the saturated zone. This term is commonly combined with other terms to indicate some specific mode of recharge such as recharge well, recharge area, or artificial recharge.

Reclamation The restoration of disturbed land or wasteland to a state of useful capability. Reclamation is the initiation of the process that leads to a sustainable landscape (see definition), including the construction of stable landforms, drainage systems, wetlands, soil reconstruction, addition of nutrients and revegetation. This provides the basis for natural succession to mature ecosystems suitable for a variety of end uses.

Redox Potential A measure of the tendency of a chemical species to undergo reduction through acceptance of electron(s).

Refractory Materials or compounds able to retain strength and structure at high temperatures.

Region The Region includes the Fort McMurray – Athabasca Oil Sands Subregional Integrated Resource Plan (IRP), the Lakeland Subregional IRP and the Cold Lake – Beaver River Subregional IRP.

Regional Aquatics Monitoring Program (RAMP) A monitoring program established to determine, evaluate and communicate the state of the aquatic environment in the Athabasca Oil Sands Region.

Regional Land Cover Class (RLCC) Terrestrial classes, wetlands classes, disturbance and other land cover classes; used to describe land cover in the RSA.

Regional Study Area (RSA) Represents the area of study for the assessment of cumulative (combined) effects of Pierre River Mine and other past, existing or planned developments.

Relative Humidity The ratio of the amount of water vapour in the atmosphere to the amount necessary for saturation at the same temperature. Relative humidity is expressed in terms of percent and measures the percentage of saturation.

Resource Selection Function A model of how animals select resources. These estimate the relative probability that a resource will be selected.

Riparian Terrain, vegetation or a position next to or associated with a stream, floodplain or standing waterbody.

Riparian Areas The vegetated areas adjacent to a watercourse or waterbody that directly contributes to fish habitat by providing shade, cover and food production areas. Riparian areas are also important to vegetation and wildlife, and because they stabilize stream banks and shorelines. To minimize disturbance to fish habitat and prevent bank erosion, it is important to retain as much riparian vegetation as possible, especially the vegetation directly adjacent to the watercourse or waterbody.

Risk The likelihood or probability that the toxic effects associated with a chemical or physical agent will be produced in populations of individuals under their actual conditions of exposure. Risk is usually expressed as the probability of occurrence of an adverse effect, i.e., the expected ratio between the number of individuals that would experience an adverse effect at a given time and the total number of individuals exposed to the factor. Risk is expressed as a fraction without units and takes values from 0 (absolute certainty that there is no risk, which can never be shown) to 1.0, where there is absolute certainty that a risk will occur.

Rough Broken An area having steep slopes and many intermittent drainage channels, but usually covered with vegetation.

Runoff The portion of water from rain and snow that flows over land to streams, ponds or other surface waterbodies. It is the portion of water from precipitation that does not infiltrate into the ground, or evaporate.

Saline Water Water with total dissolved solids concentration ranging from 10,000 to 100,000 g/m^3.

Scale Level of spatial resolution.

Scavenging Removal of a contaminant from the air through chemical or physical processes such as dry deposition or washout by precipitation.

Sedge Any plant of the genus *Carex*, perennial herbs, often growing in dense tufts in marshy places. They have triangular jointless stems, a spiked inflorescence and long grass-like leaves which are usually rough on the margins and midrib. There are several hundred species.

Sediment Solid material that is transported by, suspended in, or deposited from water. It originates mostly from disintegrated rocks; it also includes chemical and biochemical precipitates and decomposed organic material, such as humus. The quantity, characteristics and cause of the occurrence of sediment in streams are influenced by environmental factors. Some major factors are degree of slope, length of slope soil characteristics, land usage and quantity and intensity of precipitation.

Seepage Slow water movement in subsurface. Flow of water from constructed retaining structures. A spot or zone, where water oozes from the ground, often forming the source of a small spring.

Seral Stage In an ecological succession, the series of biotic communities that follow one another on the way to the stable stage, or climax community.

Shannon's Evenness Index (SHEI) Distribution of area among or within patch types in the landscape.

Soil	The naturally occurring, unconsolidated mineral or organic material at least 10 cm thick that occurs at the earth's surface and is capable of supporting plant growth.
Solar Radiation	The principal portion of the solar spectrum that spans from approximately 300 nanometres (nm) to 4,000 nm in the electromagnetic spectrum. It is measured in W/m^2, which is radiation energy per second per unit area.
Species	A group of organisms that actually or potentially interbreed and are reproductively isolated from all other such groups; a taxonomic grouping of genetically and morphologically similar individuals; the category below genus.
Species Abundance	The number of individuals of a particular species within a biological community (e.g., habitat).
Species Composition	The number and abundance of species found within a biological community.
Species Diversity	A description of a biological community that includes both the number of different species and their relative abundance. Provides a measure of the variation in number of species in a region.
Species Richness	The number of different species occupying a given area.
Stand	A group of trees occupying a specific area and sufficiently uniform in composition, age, arrangement and condition so that it is distinguishable from trees in adjoining areas.
Stand Age	The number of years since a forest has been affected by a stand-replacing disturbance event (e.g., fire or logging) and has since been regenerating.
Standard Deviation (SD)	A measure of the variability or spread of the measurements about the mean. It is calculated as the positive square root of the variance.
Stream Day	Maximum daily rate (design capacity for equipment).
Subhygric	Soil moisture conditions where water is removed slowly enough to keep the soil wet for a significant part of the growing season. There is some temporary seepage and possible mottling below 20 cm.
Sulphur Dioxide (SO_2)	A colourless gas with a pungent odour. In Alberta, natural gas processing plants are responsible for close to half of the emissions of this gas. Oil sands facilities and power plants are also major sources. Others include gas plant flares, oil refineries, pulp and paper mills and fertilizer plants.

Surfacant	Compounds that lower the surface tension of a liquid because they contain both a polar and non-polar functional group.
Surrogate	The chemical selected to represent a group of related chemicals.
Swamp	Land having soils that are saturated with water for at least part of the year and which usually occur next to waterbodies or in areas in association with fluctuating water levels such as along peatland margins.
Tailings	A by-product of oil sands extraction typically comprised of water, sands and clays, with minor amounts of residual bitumen.
Tailings Ponds	Constructed impoundment structures required to contain tailings. Tailings ponds are enclosed dykes made with tailings and/or overburden materials to stringent geotechnical standards.
Terrestrial Vegetation	Land where the soils are very rapidly to imperfectly drained and not saturated for extended periods of the year.
Thermal Regime	The range in water temperature typically observed in a given waterbody.
Timber Productivity Rating (TPR)	The potential timber productivity of a stand based on height and age of dominant and co-dominant trees of the leading species. The TPR reflects factors affecting tree growth including soil, topography, climate, elevation and moisture.
Total Core Area (TCA)	A core area is an interior of a patch type that is within a given distance from the patch edge. This is the distance from a disturbance edge used to represent isolation from disturbance. It is used to represent the central portion of the natural area that is not part of the ecotone.
Total Dissolved Solids (TDS)	The total concentration of all dissolved compounds solids found in a water sample. See *filterable res*idue.
Total Metals	Metallic elements which have been digested in strong acid before analysis. Includes suspended, dissolved and colloidal forms.
Total Organic Carbon (TOC)	Total organic carbon is composed of both dissolved and particulate forms. Total organic carbon is often calculated as the difference between Total Carbon (TC) and Total Inorganic Carbon (TIC). Total organic carbon has a direct relationship with both biochemical and chemical oxygen demands, and varies with the composition of organic matter present in the water. Organic matter in soils, aquatic vegetation and aquatic organisms are major sources of organic carbon.

Total Recoverable Hydrocarbons	Groups of petroleum hydrocarbons recovered using a solvent-specific extraction procedure. Hydrocarbons may include a wide range of fuels, oils and greases.
Total Reduced Sulphur (TRS)	A term used to collectively describe hydrogen sulphide and mercaptans.
Total Suspended Solids (TSS)	The amount of suspended substances in a water sample. Solids, found in wastewater or in a stream, which can be removed by filtration. The origin of suspended matter may be artificial or anthropogenic wastes or natural sources such as silt.
Toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.
Toxicity Assessment	The process of determining the amount (concentration or dose) of a chemical to which a receptor may be exposed without the development of adverse effects.
Toxicity Reference Value (TRV)	For a non-carcinogenic chemical, the maximum acceptable dose (per unit body weight and unit of time) of a chemical to which a specified receptor can be exposed, without the development of adverse effects. For a carcinogenic chemical, the maximum acceptable dose of a chemical to which a receptor can be exposed, assuming a specified risk (e.g., 1 in 100,000). May be expressed as a Reference Dose (RfD) for non-carcinogenic (threshold-response) chemicals or as a Risk Specific Dose (RsD) for carcinogenic (non-threshold response) chemicals. Also referred to as exposure limit.
Traditional Knowledge	Knowledge and understanding of traditional resource and land use, harvesting and special places.
Traditional Land Use (TLU)	Activities involving the harvest of traditional resources such as hunting and trapping, fishing, gathering medicinal plants and travelling to engage in these activities. Land use maps document locations where the activities occur or are occurring.
Traditional Use Plant Potential	A ranking system used to determine and map the relative abundance of traditional use plant species among different vegetation types or land cover classes within the landscape.
Traditional Use Plants	Plants used by aboriginal people of a region as part of their traditional lifestyle for food, ceremonial, medicinal and other purposes.
Trophic	Pertaining to part of a food chain, for example, the primary producers are a trophic level just as tertiary consumers are another trophic level.

Trophic State	Eutrophication is the process by which lakes are enriched with nutrients, increasing the production of rooted aquatic plants and algae. The extent to which this process has occurred is reflected in a lake's trophic classification or state: oligotrophic (nutrient poor), mesotrophic (moderately productive) and eutrophic (very productive and fertile).
Turbidity	An indirect measure of suspended particles, such as silt, clay, organic matter, plankton and microscopic organisms, in water.
Ungulate	Belonging to the former order Ungulata, now divided into the orders Perissodactyla and Artiodactyla, and composed of the hoofed mammals such as horses, cattle, deer, swine and elephants.
Uplands	Areas where the soil is not saturated for extended periods as indicated by vegetation and soils.
Vagile Species	Species that are able to move about in a given environment.
Vascular Plant	Plants possessing conductive tissues (e.g., veins) for the transport of water and food.
Vector	A graphic structure where the data is partitioned into polygons. Shapes are created by drawing a line around data of the same content.
Vegetation Community	See "Plant Community".
Volant Species	Species that are able to fly.
Volatile Organic Compounds (VOC)	Volatile Organic Compounds include aldehydes and all of the hydrocarbons except for ethane and methane. VOCs represent the airborne organic compounds likely to undergo or have a role in the chemical transformation of pollutants in the atmosphere.
Water Table	The shallowest saturated ground below ground level - technically, that surface of a body of unconfined groundwater in which the pressure is equal to atmospheric pressure.
Waterbody	Any location where water flows or is present, whether or not the flow or presence of water is continuous seasonal, intermittent, or occurs only during a flood.
Watercourse	Riverine systems such as creeks, brooks, streams and rivers.

Watershed	The area of land bounded by topographic features that drains water to a larger waterbody such as a river, wetlands or lake. Watershed can range in size from a few hectares to thousands of kilometres.
Wetlands	Land where the water table is at, near or above the surface or that is saturated for a long enough period to promote such features as wet-altered soils and water tolerant vegetation. Wetlands include organic wetlands or peatlands, and mineral wetlands or mineral soil areas that are influenced by excess water but produce little or no peat.
Wildlife	Under the *Species at Risk Act*, wildlife is defined as a species, subspecies, variety or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus that is wild by nature and is native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Yearling	An animal in its second year.
Young of the Year (YOY)	Fish at age 0, within the first year after hatching
Zooplankton	Small (often microscopic) aquatic animals suspended or weakly swimming in water.

ATTACHMENT A

Simulation of the Planned Development Case for the Regional Study Area of the Shell Jackpine Mine Expansion

Simulation of the Planned Development Case for the Regional Study Area of the Shell Jackpine Mine Expansion

Prepared for Golder Associates Ltd. and Shell Canada Energy

Prepared by the ALCES Group

ALCES Group

December 20, 2011

Disclaimer

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1. INTRODUCTION

Under the Canadian Environmental Assessment Act, the environmental impact assessment for the Shell Jackpine Mine Expansion Project requires an assessment of the cumulative effects of reasonably foreseeable disturbance in the regional study area (RSA) over the lifespan of the proposed project. The major disturbances that are likely to occur in the region include industrial footprint associated with the Jackpine mine expansion and other bitumen projects, timber harvest, and fire. To assess potential future changes to landscape composition in the RSA, the ALCES Group was contracted to simulate the following disturbances, as directed by Golder Associates: an 80-year fire cycle, future timber harvest, and future insitu and mining project polygons included in the RSA's planned development case (PDC). Two models were applied when exploring potential future changes in landscape composition: ALCES® and ALCES Mapper®. ALCES simulated disturbance trajectories and ensuing regional changes in landscape composition, while ALCES Mapper distributed the simulated disturbances spatially to create maps of potential future landscape composition. The models are described in greater detail in Appendix 1.

This report presents the methods used when simulating fire, timber harvest, and the PDC in the RSA, and the results of the analysis.

2. METHODS

2.1 INITIAL LANDSCAPE COMPOSITION

Parameterization of ALCES requires that the RSA's landscape composition be assessed, including its current land cover and anthropogenic footprint. Landscape composition was estimated using data assembled by the Cumulative Environmental Management Association's (CEMA) as described by Wilson et al. (2008). The data set, which was created to populate the ALCES model for the Regional Municipality of Wood Buffalo, is geospatial and includes 23 land cover types and 16 footprint types. Age is provided by 20-year seral stages for nine forest types (hardwood, mixedwood, white spruce, pine, closed black spruce, black spruce lichen moss, riparian, open black spruce fen, and open fen). Non-forest types were given an initial seral stage of 1. Land cover in the CEMA data set is based on the Alberta Vegetation Inventory and the Alberta Ground Cover Classification Inventory, and footprint is based on a variety of geospatial footprint inventories.

The south-western edge of the RSA, accounting for 6.1% of the total area, lies outside of the CEMA region (Figure 1). Land cover for this portion of the study area was defined using a regional land cover classification (RLCC) data set provided by Golder and a variety of footprint inventories. The relationship between land cover types from the RLCC and CEMA data sets is outlined in Table 1. The RLCC data set included a small number of polygons classified as "burn", accounting for 851 ha or 0.04% of the RSA; these polygons were re-classed to their dominant neighbouring vegetated RLCC class (i.e., according to longest shared border).

Forest age is not included in the RLCC data set. Instead, age was applied to forest polygons in a manner that is consistent with the age-class composition of the remainder of the study area. To do this, the age-class distribution (i.e., percent area by 20-year seral stage) of each forest type was calculated for the portion of the RSA overlapping with the CEMA data set. Then, in the portion of the RSA not overlapping with CEMA, the first seral stage was randomly assigned to a forest type's polygons until the percent area for that seral stage (i.e., according to the CEMA portion of the RSA) was reached. Subsequent seral stages were then randomly assigned to the forest type's polygons until the percent area by seral stage approximated that of the CEMA portion of the RSA.

Table 1. Relationship between CEMA and RLCC land cover classes (prior to updating with reclassed burn polygons and adding in footprint).

CEMA class (and area of RSA in ha)	Associated RLCC classes (and are in ha)
Closed black spruce forest (188,881)	Coniferous jack pine-black spruce (517)
Pine (363,002)	Coniferous jack pine (4,789)
White spruce (143,811)	Coniferous white spruce (2,265)
Mixedwood (169,560)	Mixedwood aspen-white spruce (12,507)
	Mixedwood aspen-jack pine (5,667)
Hardwood (317,048)	Deciduous aspen-balsam poplar (4,628)
Open black spruce fen (431,106)	Treed fen (13,273)
	Treed bog/poor fen (70,422)
Riparian forest (22,116)	
Black spruce lichen moss (732)	
Beach dune (85)	
Open Fen (115,483)	Non-treed wetland (22,704)
Bog1 (114,275)	
Shrubby swamp (64,556)	
Natural herbaceous (59,570)	
Tall shrub (9,617)	
Low shrub (10,454)	
Non-natural herbaceous (133)	
Rock ice (493)	
Water; incorporates lentic, lotic small, and lotic large (67,013)	Water (765)

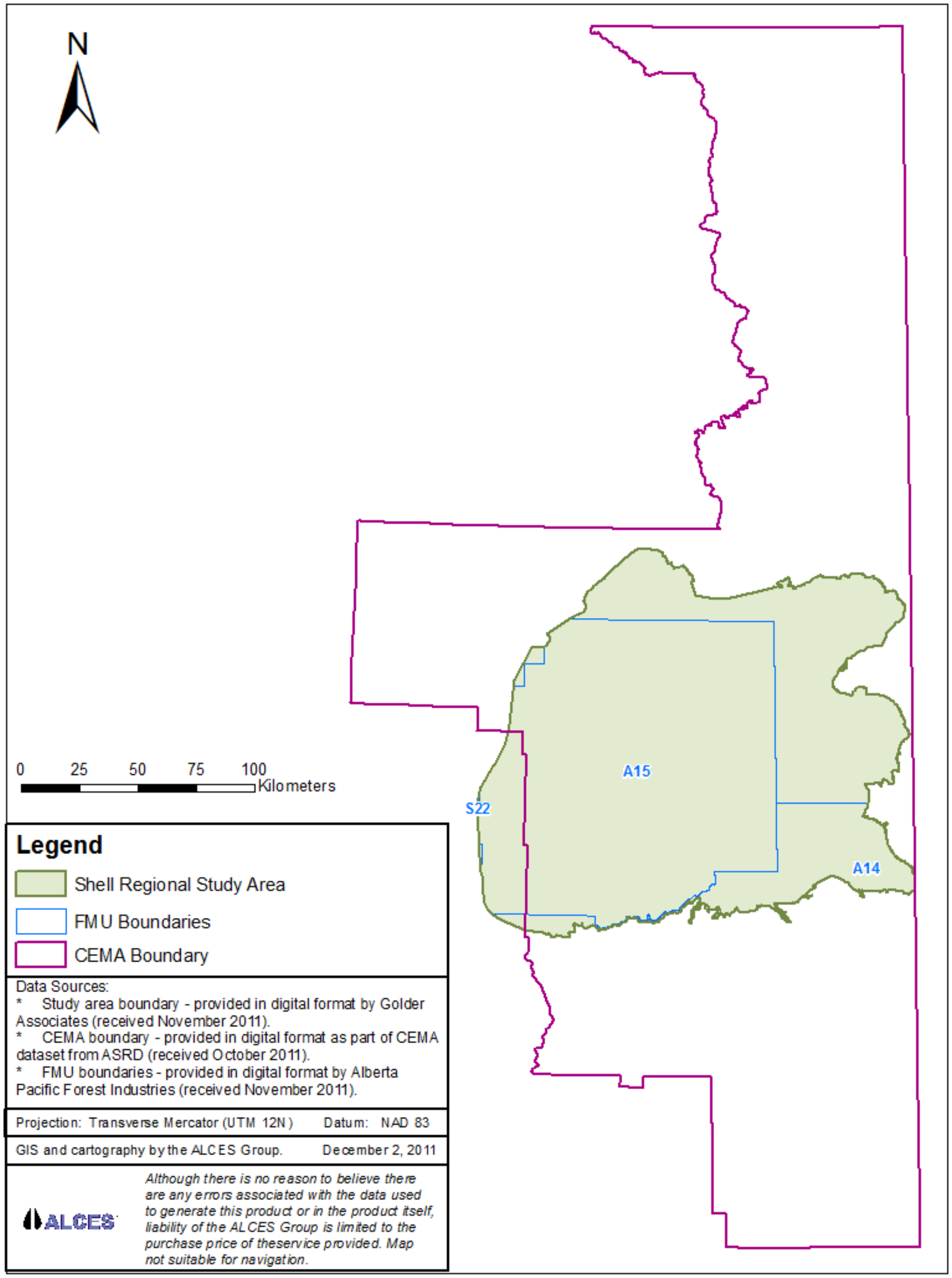

Figure 1. Shell RSA relative to the CEMA boundary.

The CEMA landscape composition data set is current to 2005. To incorporate natural disturbances that have occurred since 2005, forest age (Figure 2) was updated to reflect the location of fires occurring between 2006 and 2010 according to Historical Wildfire Perimeter Data: 1931 to 2010 available from Alberta Sustainable Resource Development.

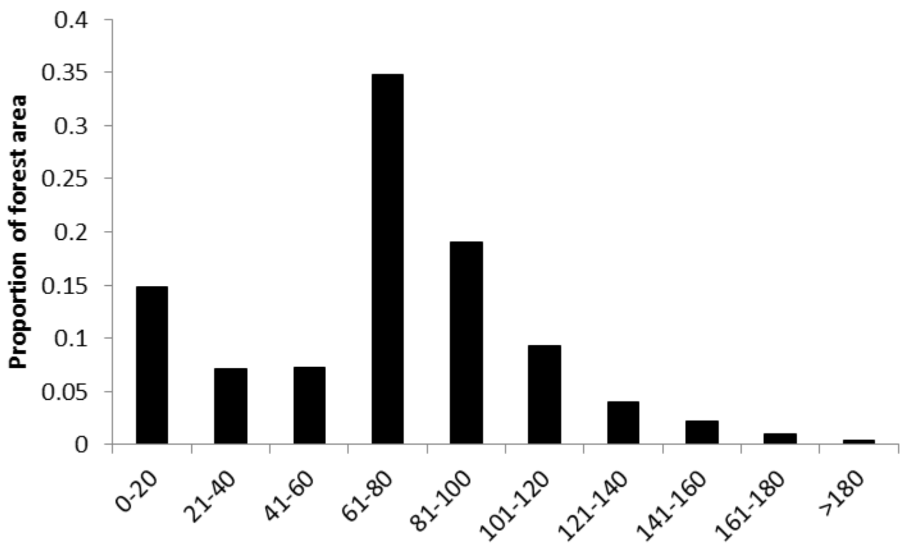

Figure 2. Initial age-class composition of forested land cover in the regional study area.

2.2 ALCES SIMULATIONS

ALCES was applied to simulate the cumulative effects of fire, timber harvest, and bitumen development in the RSA over a 50-year period, as per assumptions described below.

2.2.1 Fire Assumptions

Fire, the dominant natural disturbance in the study area, has a large influence on the composition of boreal landscapes. Fire was included in simulations to incorporate its effect on forest age. The fire regime is temporally variable, and was simulated as a random draw from a lognormal distribution (Armstrong 1999). The mean annual burn rate was 1.25%, the rate assumed by CEMA for northeastern Alberta. The standard deviation of the lognormal distribution equalled 2.853, based on the variation in annual burn area for a region in northeastern Alberta (Armstrong 1999). When simulating fire using a lognormal distribution, it is necessary to impose a maximum annual burn rate to avoid unrealistically large fire years. A maximum annual burn rate of 10% was applied to each landscape type; i.e., if a random draw from the lognormal was greater than 10%, it was truncated to 10%. An implication of imposing a maximum burn rate is that the average simulated burn rate under-represents the mean of the distribution prior to truncation (Armstrong 1999). The mean of the lognormal distribution was inflated to ensure that the mean of a series of simulated fire rates approximated 1.25%.

Due to the stochasticity of fire, each simulation differs with respect to area burned per year and forest age dynamics. As a consequence, the age of the forest at the end of a simulation can differ substantially among runs. Two hundred simulations were completed to incorporate a range of burn trajectories and better reflect the resulting forest demography.

2.2.2 Timber Harvest Assumptions

The timber harvest net-down assumptions adopted in these analyses are based on previous ALCES analyses for CEMA (Cumulative Environmental Management Association). The annual allowable cut (AAC) for hardwood and softwood in relevant FMUs were provided by Mr. Dave Cheyne (Management Forester, R.P.F.) of Alberta-Pacific Forest Industries (Table 2). These values include both the harvest volumes of Alberta-Pacific Forest Industries and those allocated to all embedded softwood quota holders. These values were then area-corrected to account for those portions of each FMU found within the RSA. For A15, we chose to base AAC on both primary and secondary (incidental) volume. The area-adjusted AAC values for both hardwood and softwood in the RSA have been reviewed by Dave Cheyne of Alpac and have been ratified as "reasonable" values to be used for strategic-level assessments. It should be emphasized that an actual AAC value would be recomputed downward if the gross landbase were reduced by a value in excess of 3% (Dave Cheyne, pers. comm.).

Table 2. Area adjusted hardwood and softwood AAC for the Regional Study Area. Original values were extracted from the 2006 Alberta-Pacific Forest Industries Approved AAC for Forest Management Plan.

Forest Management Unit	Hardwood (m^3)	Softwood (m^3)
A15	516,088	393,210
A14	50,508	61,959
S22	712	344
Total	567,308	455,513

A detailed description of the timber supply module and equations in ALCES is provided in the ALCES Users Manual (www.alces.ca). The key components within the ALCES model used to compute wood harvest include:

- Size and age class of the forest landbase
- The forest landbase was stratified into the following merchantable forest types:
    - White spruce
    - Pine
    - Mixedwood
    - Hardwood

- Size of the gross and net forest landbase. The net landbase is smaller than the gross landbase by a factor determined by the following netdown factors:
  - Inaccessibility (10.0%)
  - Steep Slopes (3.0%)
- Growth and Yield Equations. Values of hardwood and softwood density (m^3/ha) for each seral stage (ten 20 year intervals between Year 0 and 200) were provided by Mr. Dave Cheyne of Alberta-Pacific Forest Industries
- Cutblock harvest scheduling was based on a sequence based on forest age and wood density that can best be described as an "oldest-first" constraint where maximum wood density is given highest priority
- Eligible forest stands included those seral stages greater than 80 years for hardwood and 100 years for softwood
- Minimum wood harvest volume of 50 m^3/ha
- Harvested cutblocks were subjected to silvicultural treatments that returned all cutblocks to their original forest type.

Where direct footprints (surface mining, wellsites, pipelines, access roads) or fire was simulated in ALCES on the RSA, wood salvaging was simulated using the same piece size and volume constraints as followed for non-salvaged logging. In terms of area, 33% of area affected by insitu was eligible for wood salvage and 100% of area from surface mining was eligible for salvage. In terms of salvage access to wood volume within fire perimeters, only 50% of the area is accessible, and only 50% of the volume within the access area was salvaged (values provided by Dave Cheyne of Alberta-Pacific Forest Industries). Hence only 25% (50% x 50%) of the merchantable volume was recoverable following fires. Salvage wood from fires and oilsand footprints was applied against the annual allowable cut in a compensatory manner.

2.2.3 Bitumen Development Assumptions

The rate of bitumen development was dictated by the size and timing of current, approved, and planned development case (PDC for insitu and surface bitumen projects. The spatial extent of each project (Figure 3) and its start and finish date was provided by Golder. Prior to calculating bitumen development trajectories, the spatial extents of projects were adjusted to exclude existing footprint and overlap between projects. The area of new bitumen footprint per year (Figure 4) was then calculated by assuming that creation of each project's footprint is evenly spread out over its lifespan, except for the final 10 years of insitu projects during which no new footprint was created. The completion of insitu footprint expansion 10 years prior to project completion is because the average productive lifespan of insitu wells is 10 years (Wilson et al. 2008); i.e., new infrastructure will not be needed after the last set of wells is developed. For both insitu and mining development, simulations assumed that the entire spatial extents of project polygons were converted to footprint. Simulations also assumed that new bitumen development footprint is permanent in the context of a 50-year simulation. No footprint outside of the future bitumen projects was simulated. No footprint associated with either insitu or mining of bitumen reserves were allowed to reclaim during the simulation period.

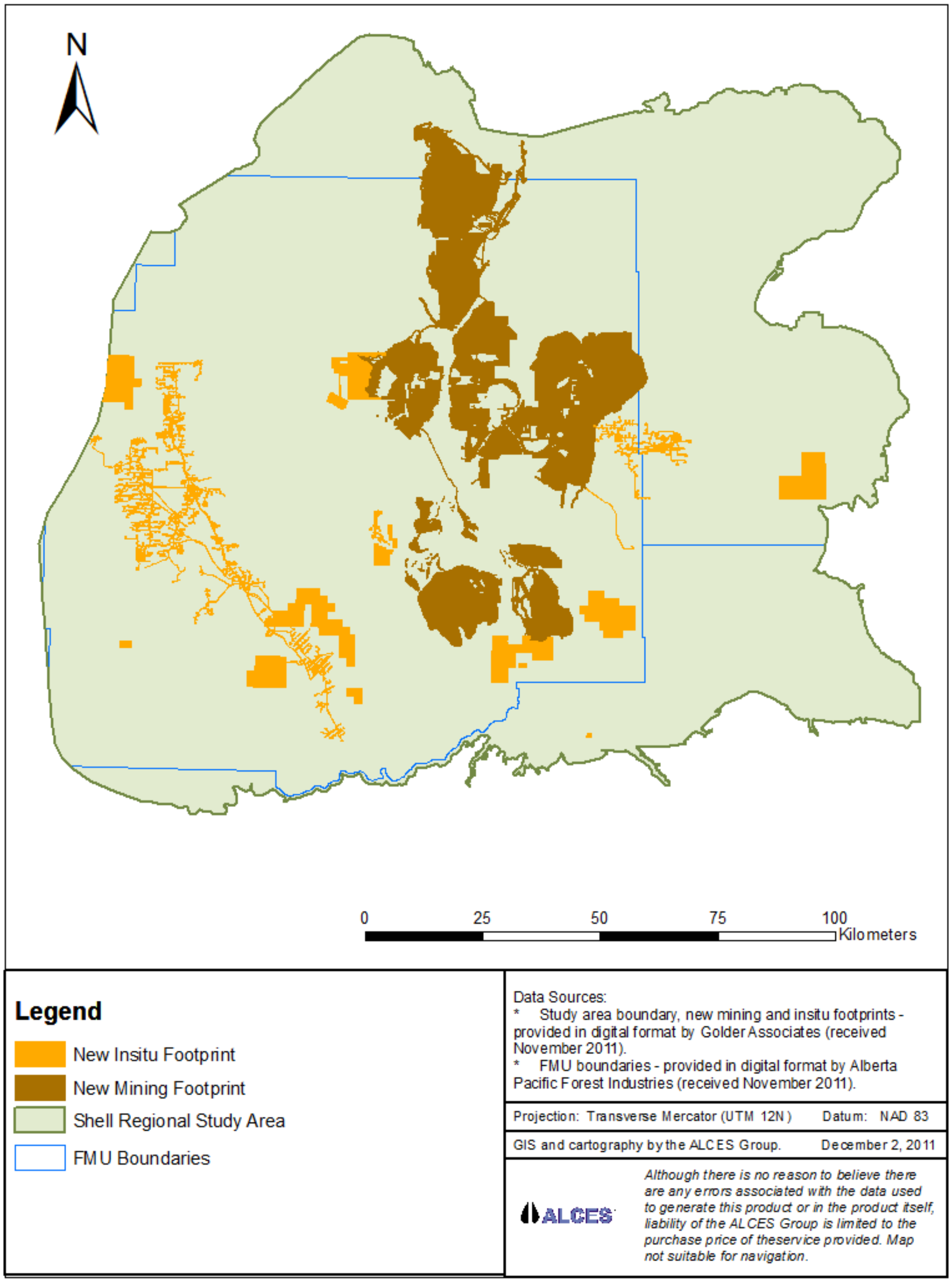

Figure 3. The location of new insitu and mineable bitumen projects included in simulations.

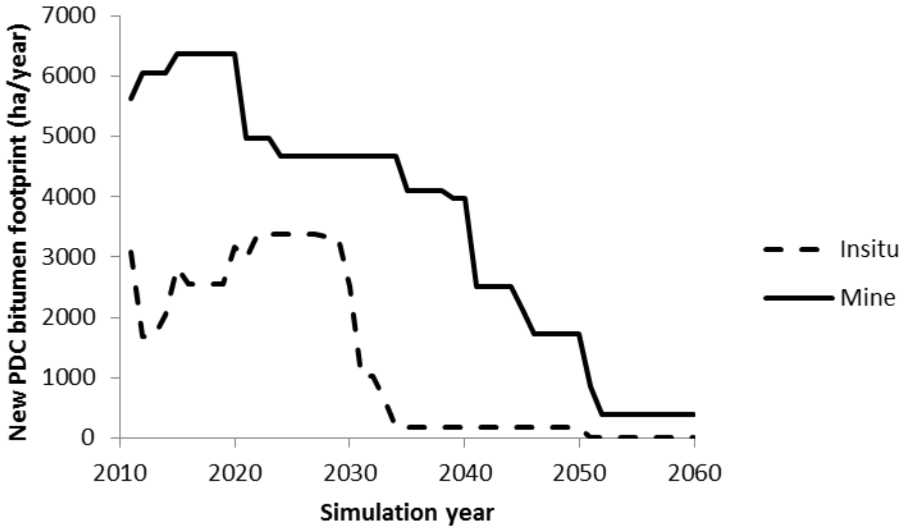

Figure 4. New bitumen footprint simulated each year in ALCES to reflect the planned development case.

2.3 MAPPER SIMULATIONS

ALCES Mapper is a companion tool to ALCES that creates maps illustrating the plausible future condition of a landscape under scenarios simulated by ALCES. The tool is raster based, and tracks the composition of each cell by combining ALCES outputs regarding landscape change with rules regarding the spatial distribution of future anthropogenic and natural disturbances. For each cell, Mapper tracks percent coverage and age by land cover and footprint type. To initialize Mapper, composition and average age by cover type was calculated for each 0.5 km^2 cell using the initial landscape coverage. The relatively small grid cell size was selected so that a cell could be treated as the smallest disturbance size (i.e., for fire, harvest, or bitumen development); i.e., Mapper was set to disturb entire cells.

Mapper disturbed land cover at rates dictated by ALCES simulations (i.e., ha/year of each land cover type disturbed by fire, nonsalvage timber harvest, and bitumen development). Due to the stochasticity of the simulated burn rate, each simulation differed with respect to ha disturbed each year by fire and non-salvage timber harvest. Three of 200 ALCES simulations were selected as examples of simulations resulting in low, average, and high forest age after 50 years. Mapper was applied to create maps of future landscape composition that were consistent with each of the three selected ALCES simulations. Selection of the simulations was based on the average forest age (across forested cover types) at the end of the simulation. The low, average, and high simulations were those whose final forest age were in proximity to the 5^{th} percentile, mean, and 95^{th} percentile of final average forest age across the 200 simulations.

Mapper incorporates stochasticity into the mapping of future disturbances in recognition that the location of future events is uncertain. However, the randomness is constrained by user-defined rules that dictate where disturbance types can occur, the size distribution of disturbance events, and whether disturbance is contiguous (i.e., aggregated) or dispersed. Rules guiding the mapping of simulated fire, harvest, and bitumen development were as follows:

1. Fires were distributed across the study area and location was insensitive to stand age. Fire events followed the size distribution assumed by CEMA (Wilson et al. 2008). The size classes were organized into multiples of 50 ha's for compatibility with the grid cell size used in Mapper. Fires tended to burn cells in their entirety but, similar to post-fire residuals, portions of cells were sometimes left unburned. The fire size distribution was: 87.53% of fires as 1 cell events, 8.18% as 2 cells, 2.94% as 3 to 20 cells, 0.74% as 21 to 200 cells, and 0.61% as 201 to 2000 cells[1].
2. Simulated timber harvest was limited to Alberta Pacific Forest Industry's Forest Management Units occurring in the regional study area (A14, A15, and S22), and to forest exceeding the minimum harvest age. Only planned (i.e., non-salvage) harvest was mapped. To avoid double counting salvage harvest, planned harvest was restricted from future bitumen footprints. Future timber harvest was contiguous to reflect the aggregated harvest strategy adopted by the primary tenure holder (Alberta-Pacific Forest Industries 2008). Aggregated harvest was implemented in Mapper by harvesting adjacent cells in a given simulation year. This does not imply, however, that year's harvest was simulated as a very large cutblock. Rather, harvest across adjacent cells was fragmented by non-merchantable land cover types and young forest.
3. The location of simulated bitumen development was dictated by the location and timing of insitu and mining projects that are part of the current, approved, and the planned development case (PDC). Projects were sequenced temporally so that, on average, footprint was fully developed by a project's completion year[2] (or 10 years before in the case of insitu). Bitumen development converted entire cells to insitu or mine footprint[3]. The spatial pattern of bitumen development was intermediate between dispersed and contiguous to approximate the pattern of multiple dispersed projects at any one time, but contiguous development within any given project.

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[1] CEMA assumed that burn area is distributed across size classes as follows: 1% as 0-10 ha, 2% as 11-100 ha, 4% as 101-1000 ha, 10% as 1001-10000 ha, and 83% as 10000 to 100000 ha. This distribution was converted to % of fire events across size classes, and adjusted to accommodate slightly different size classes (i.e., increasing the first size class from 0-10 to 0-50 ha to match the grid cell size).

[2] To temporally sequence bitumen footprint, polygons of future projects were grouped into 5 categories based on their completion year (2020, 2030, 2040, 2050, and 2060). Footprint for a given category of projects was then distributed equally across relevant decades. For example, total footprint for projects completed by 2020 occurred during the first decade of the simulation whereas total footprint for projects completed by 2030 was equally divided between the first and second decade of the simulation.

[3] As a consequence of converting entire cells to footprint, simulated footprint may occasionally exceed the PDC footprint polygons if a cell is only partially within one of the polygons.

For each simulation, Mapper created two personal geodatabases[4]: landscape composition and landscape age. Combined, the geodatabases indicate the composition and age of each grid cell through time, and when a cell was last disturbed by fire, harvest, or bitumen development. Although Mapper tracks the effect of annual disturbances created during ALCES simulations, composition and age outputs are created only every 10 years in order to conserve computing time. For every 10th simulation year, the following outputs are exported to the personal geodatabases:

1. For each cell, the area (ha) of each land cover and footprint type, and the length5 (km) of each footprint type. Changes in composition for this project are limited to expansion of insitu and mining footprint at the expense of land cover.
2. For each cell, the average age of each vegetated land cover type. Age increases during simulations unless land cover within a cell is disturbed by fire or timber harvest, both of which cause age to revert to 0. Age is reported as 20-year seral stages.
3. For each cell, the time since fire, harvest, and bitumen development. Time is reported as 10-year periods (i.e., a 2 is interpreted as a disturbance occurring 10- 20 years ago).

3. RESULTS

3.1 ALCES

ALCES simulations showed natural land cover (Figure 5) and average forest age (Figure 6) to decline in the coming decades at the scale of the RSA. The decrease in natural land cover was due to the expansion of bitumen projects which accounted for 240,920 ha of new footprint during the simulation period. Forest age declined primarily in response to timber harvest; the influence of timber harvest is demonstrated by the increase in simulated age of non-merchantable forest types in contrast to the decline in simulated age of merchantable forest types (Figure 7). Non-salvage timber harvest was highly variable across simulations as shown by the wide 90% confidence intervals in Figure 8. The high variability was in response to the stochastic fire regime. The simulated burn rate was highly variable across simulation years (Figure 9) and simulations (Figure 10), with the consequence that any given simulation was unique with respect to the area of merchantable forest burned through time. As a result, the area of salvage and therefore nonsalvage harvest was highly variable.

[4] These are Microsoft Access databases that contain the landscape composition and age data created by Mapper along with the geometry data used in the GIS. They can be viewed, queried, or analyzed in ArcGIS as well as in Microsoft Access.

[5] Footprint length is assessed as length of centreline for linear footprints and perimeter for polygonal footprints.

Variation in fire and therefore harvest and forest age is perhaps better illustrated by results from individual simulations (i.e., as opposed to averages across simulations). The simulated burn rate varied temporally for any given simulation, and the series of burn rates varies from simulation to simulation (Figure 11). As a result, non-salvage harvest was also highly variable, declining to zero during very high fire years during the first half of the simulations (Figure 12). By the second half of the simulations, however, nonsalvage harvest became less variable because a lower percent of burnt forest was salvageable due a decline in the abundance of merchantable-age forest. Average forest age also fluctuated in response to the variable fire regime (Figure 13).

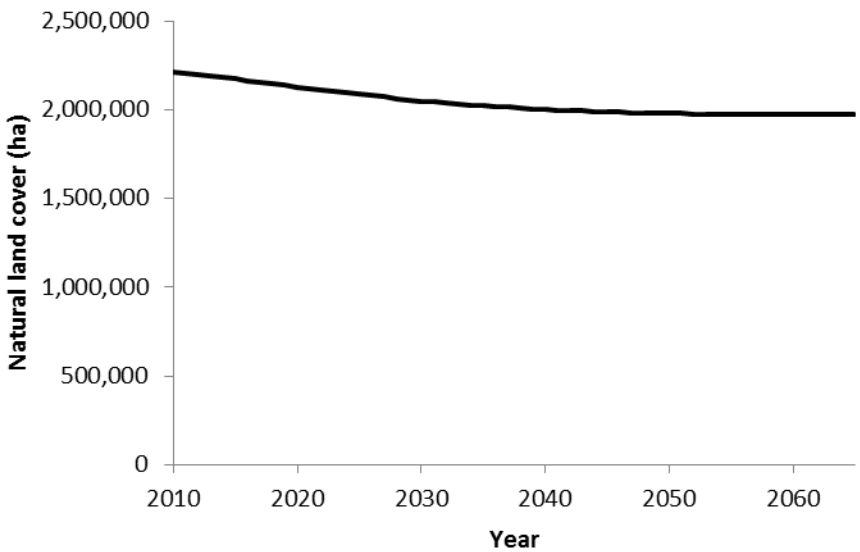

Figure 5. Simulated response of natural land cover (including cut blocks and burns) to the PDC.

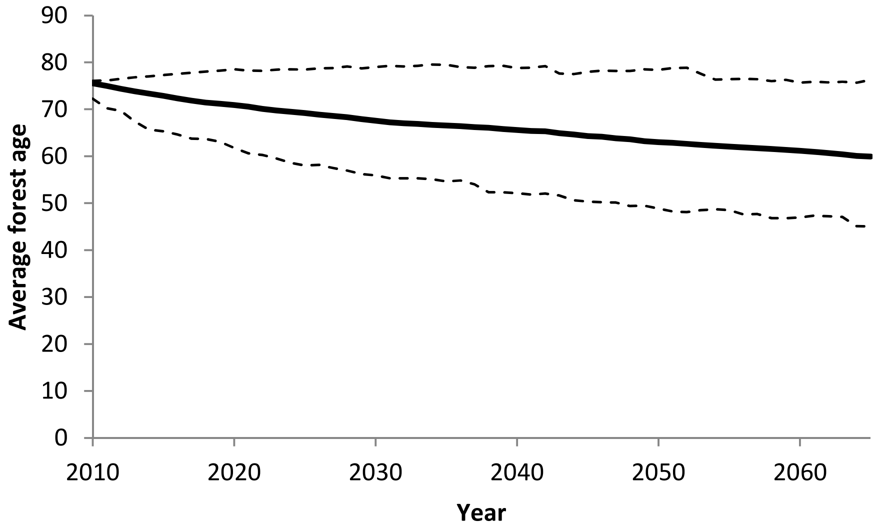

Figure 6. Response of average forest age (i.e., across forested cover types) to simulated disturbances. The solid line is the average response across 200 simulations, while the dashed lines bound the 90% confidence interval.

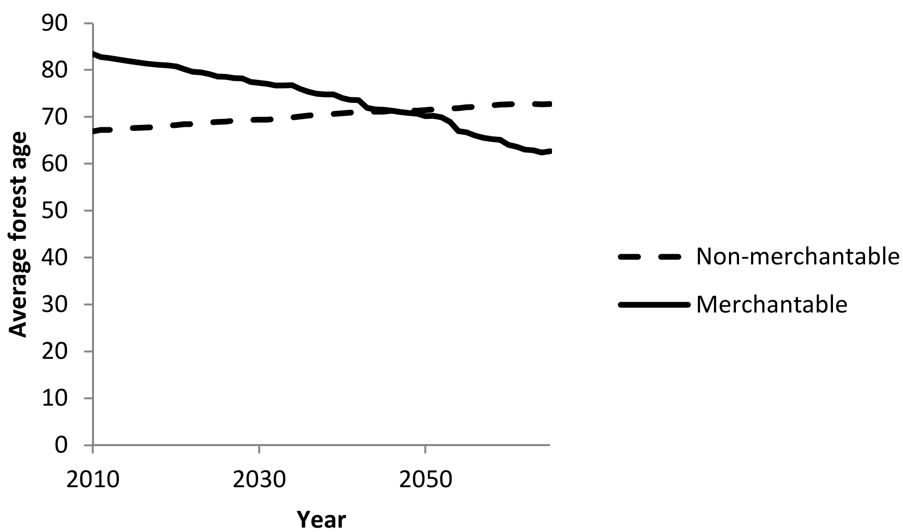

Figure 7. Response of average forest age to simulated disturbances across non-merchantable and merchantable forest types. The response surfaces are the average response across 200 simulations.

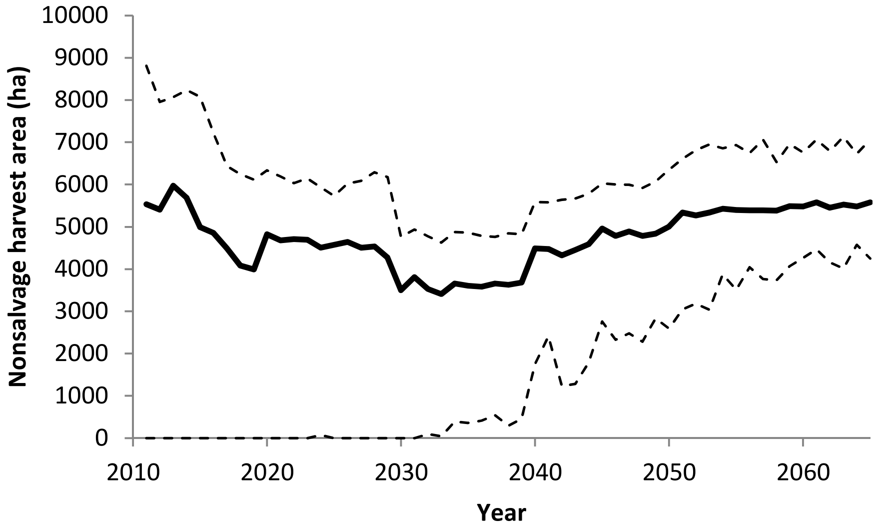

Figure 8. Simulated response of non-salvage harvest area. The solid line is the average response across 200 simulations, while the dashed lines bound the 90% confidence interval.

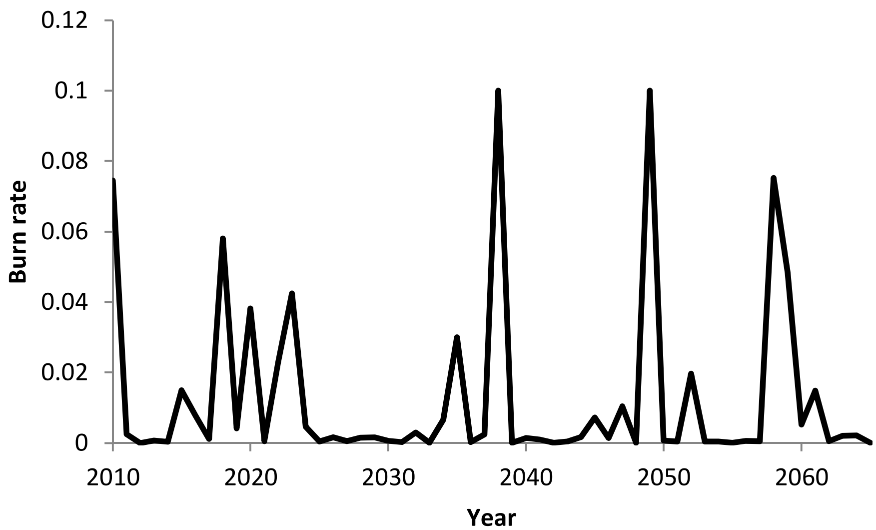

Figure 9. Simulated annual burn rate from a run that resulted in a final forest age that was in proximity to the mean across all runs.

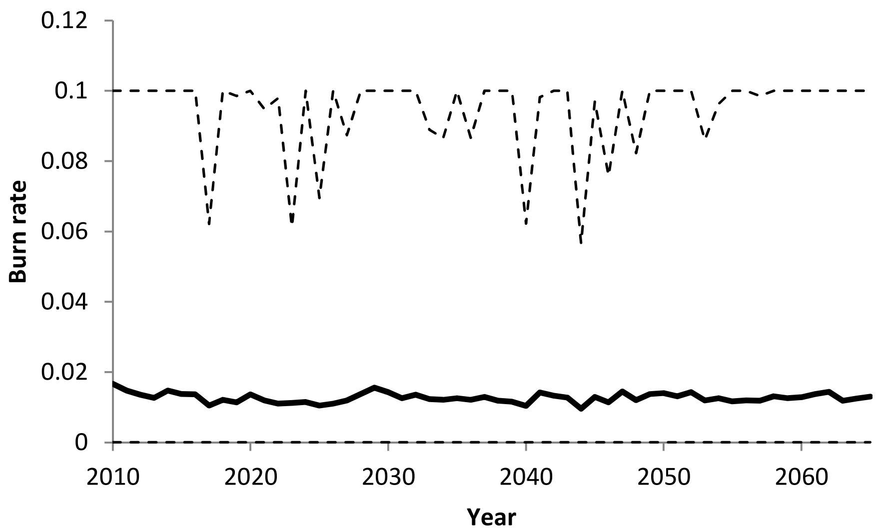

Figure 10. Average simulated burn rate across 200 simulations (solid line) and 90% confidence interval (dashed lines).

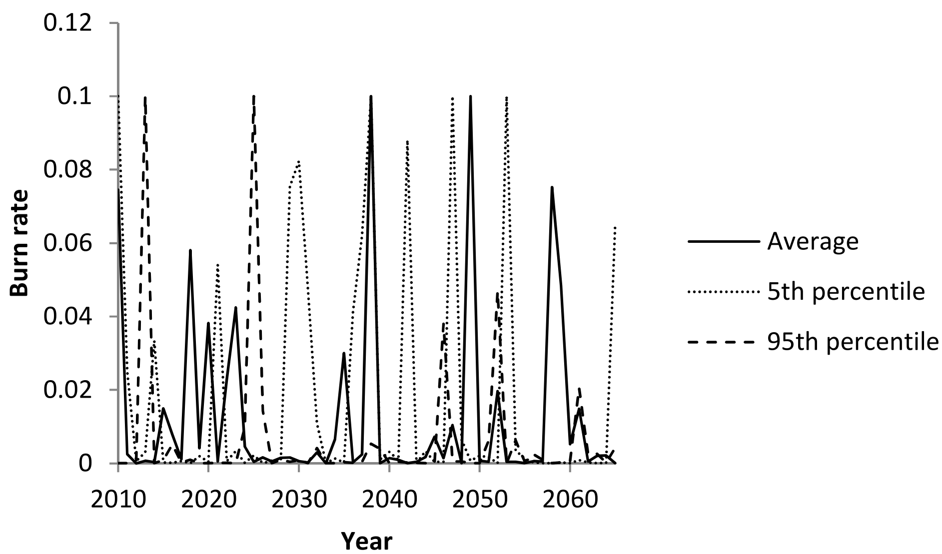

Figure 11. Simulated burn rate from three simulations selected such that the final average forest age was in proximity to the mean, 5th percentile, and 95th percentile across 200 simulations.

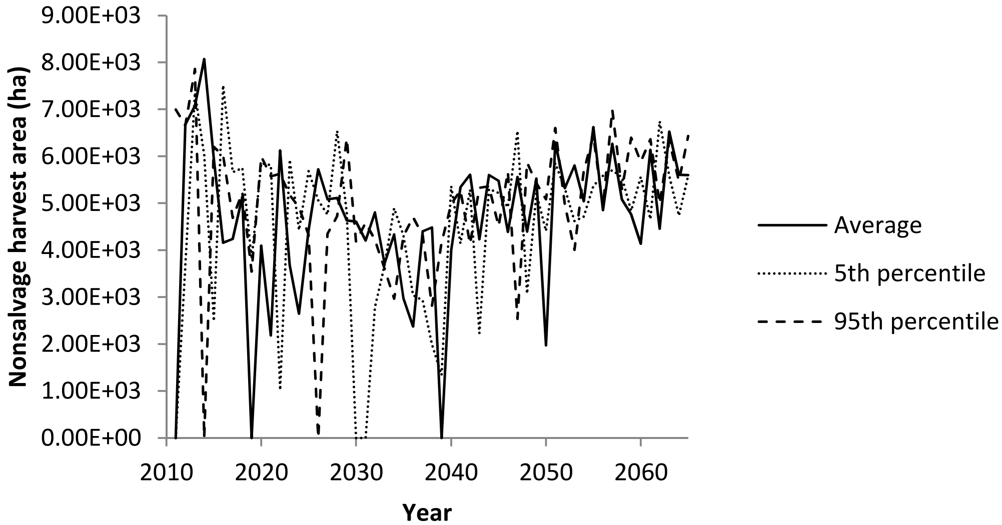

Figure 12. Simulated non-salvage harvest area (ha) from three simulations selected such that the final average forest age was in proximity to the mean, 5th percentile, and 95th percentile across 200 simulations.

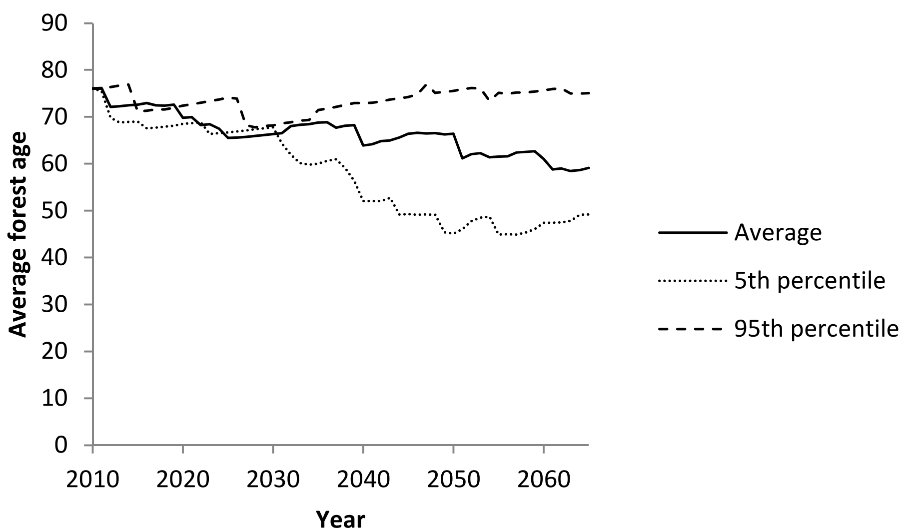

Figure 13. Simulated average forest age from three simulations selected such that the final average forest age was in proximity to the mean, 5th percentile, and 95th percentile across 200 simulations.

3.2 MAPPER

Three map sequences are presented for a simulation that was selected as having an average outcome; i.e., the forest age at the end of the simulation was in proximity to the mean across the 200 simulations. The first map sequence presents cumulative disturbance by 10-year reporting period. The second map sequence presents fire and timber harvest over 10-year periods as well as cumulative bitumen development, and the third map sequence presents average forest age across merchantable forest types. Due to the temporal and spatial variability incorporated in simulations, the maps should be viewed as just one of many potential futures that are consistent with the scenario settings. Map sequences for simulations whose final forest age was in proximity to the 5th and 95th percentiles are provided in Appendix 2.

Four disturbance types are presented in the disturbance map sequence: future surface mine, future insitu footprint, timber harvest, and fire. By the end of the simulation, the cumulative disturbance had affected the majority of cells in the RSA, although some cells are only partially disturbed. Bitumen footprint expanded rapidly in the first and second decades (Figure 14), with the rate of expansion decreasing substantially in subsequent decades (Figure 15-Figure 16). The new bitumen footprint occurred in the PDC project polygons, with projects with nearer-term completion dates receiving proportionally more footprint in early decades of the simulation. For example, the most southwestern surface mine project has a completion date within the first decade of the simulation and, as a result, receives its entire footprint during the first reporting period. Timber harvest also accumulated during the simulation. Each year's harvest was aggregated, although aggregation declined through time as a result of there being fewer large patches of merchantable age forest across forest types. i.e., as the simulation proceeds, merchantable age forest became rarer which limited the options available for aggregating harvest (Figure 17-Figure 19). Fire (i.e., burns) accumulated during the simulation, and the rate of accumulation was variable across reporting periods due to the temporally variable burn rate. As per the fire size distribution described in the methods, most fires were single cell events but the majority of burn area was associated with a few large burns.

The maps depicting the age class structure of the forest communities in the RSA reflect the spatial location of the 2 major disturbance regimes (fire, logging) that affect forest demography (Figure 20-Figure 23). It is important to note that the bitumen sector does cause significant mortality of forests, but does not affect forest demography directly because none of the bitumen footprint was allowed to reclaim and as such none of this footprint was converted back to a forest trajectory.

The color coding of forest age class structure reflected the average age of the combined forests (or individual forest types) and does not contain information on the fraction of an individual cell that is comprised of forests. As such, a cell may contain forests that comprise between 0 and 100% cover. This explains the relatively few small patches (individual cells) of older forests found embedded within the broader bitumen development matrix. These cells likely contain a relatively small patch of residual trees and these trees are unlikely to experience either logging or fire once they are affected by the bitumen development event.

The forest age maps effectively convey the importance of non-salvage logging in determining forest age class structure in those forest types that are merchantable. Unlike fire, non-salvage logging will only occur on those stands that are of merchantable age. In contrast, fire can occur on any forest or non-forest type and is insensitive to forest age; as such, a 15 year old forest has the same probability of fire as does a 115 year old forest. In terms of salvage logging, only stands removed by bitumen activities that were of merchantable age were considered eligible for salvage logging. Young forests, or those with low forest volumes, were not salvaged.

A key pattern revealed by the forest age time series was that the merchantable forest matrix becomes progressively younger. This shift in forest age class structure reflects the high combined perturbation rate of both logging (~80-100 year cycle) and fire (80 year cycle). The shift in forest age class is somewhat less pronounced non-merchantable forest types are considered (Figure 24-Figure 27).

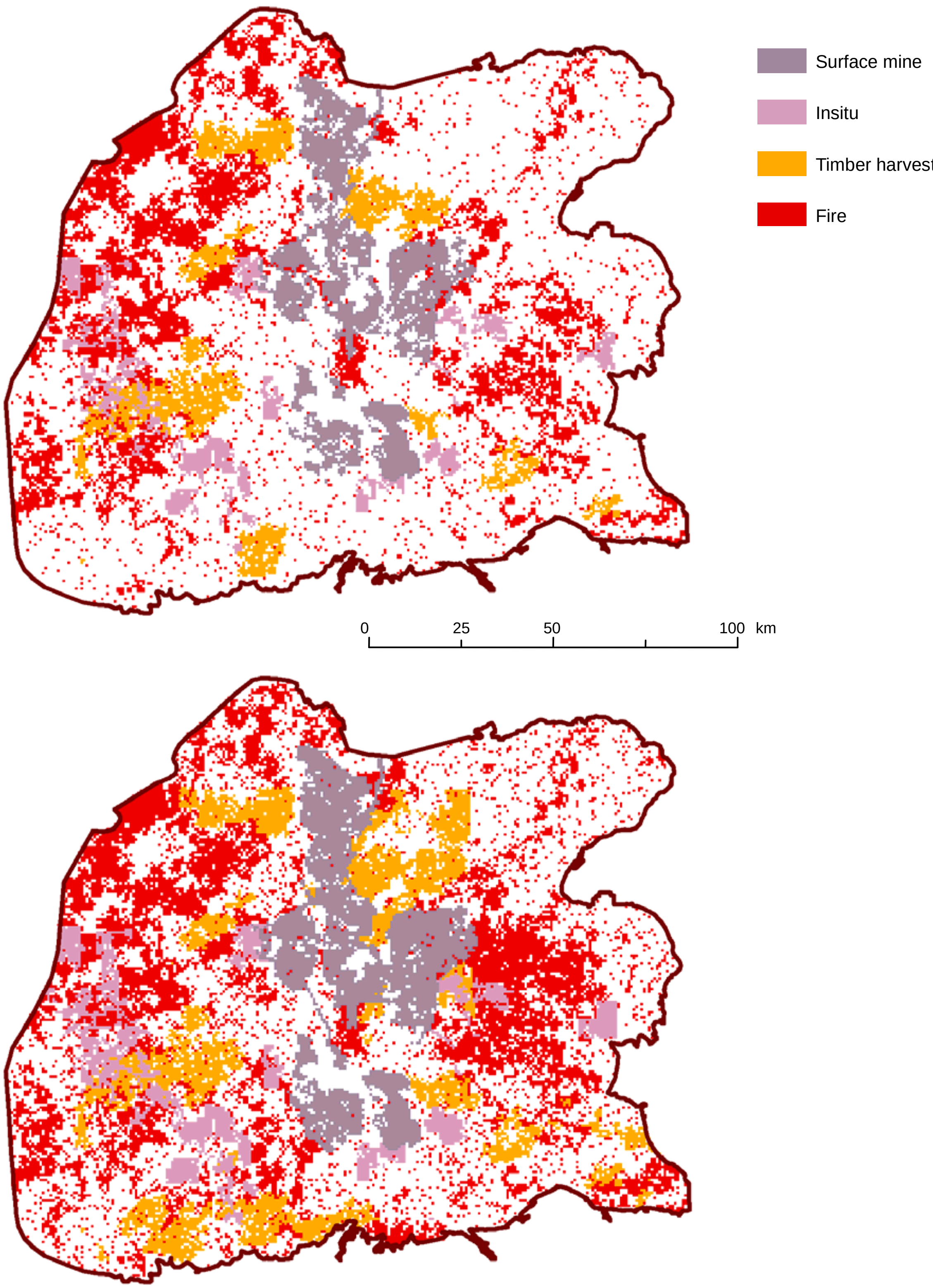

Figure 14. Potential cumulative fire, harvest and bitumen development in 2020 (top) and 2030 (bottom).

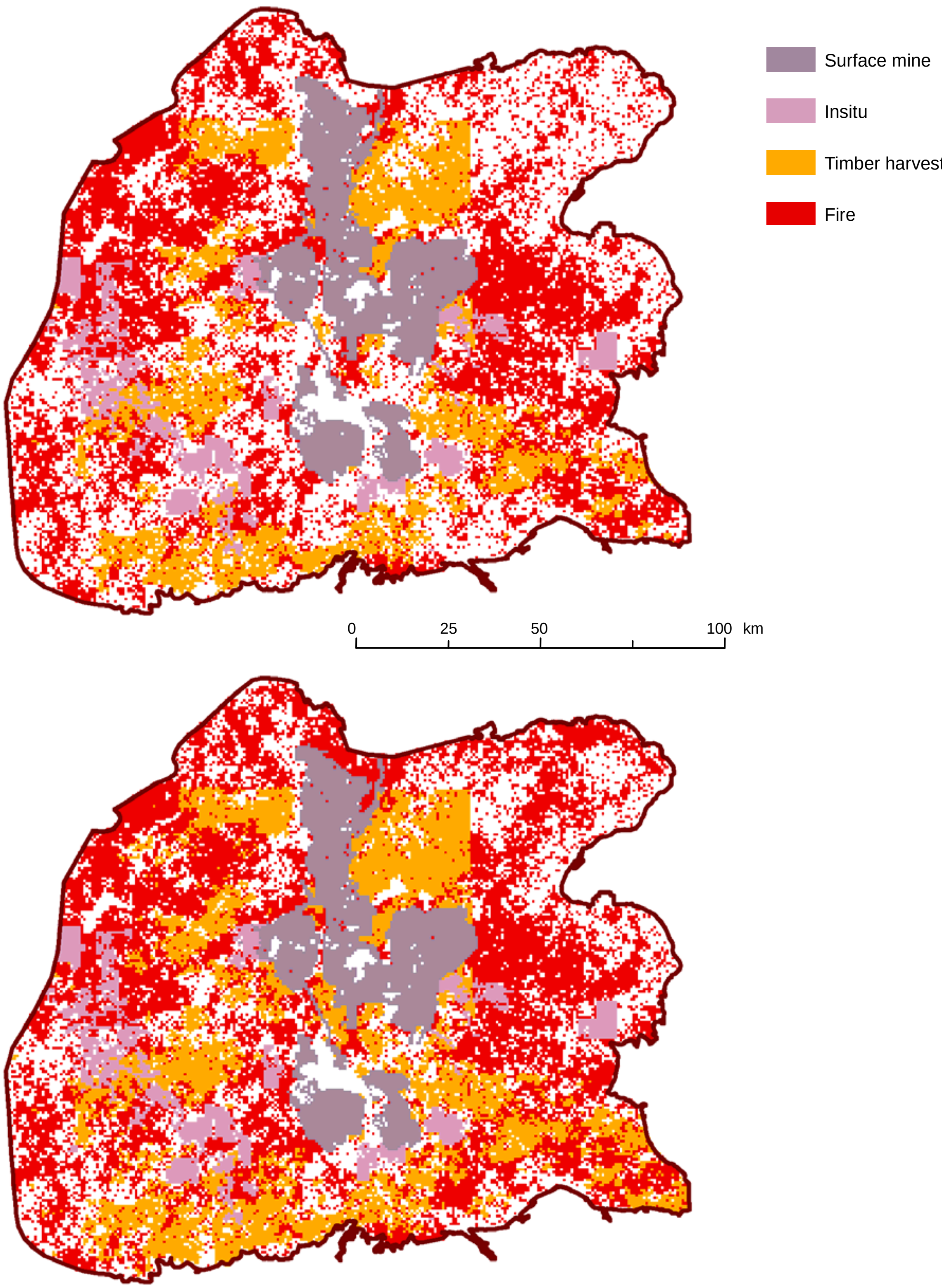

Figure 15. Potential cumulative fire, harvest and bitumen development in 2040 (top) and 2050 (bottom).

Figure 16. Potential cumulative fire, harvest and bitumen development in 2060 (top) and 2070 (bottom).

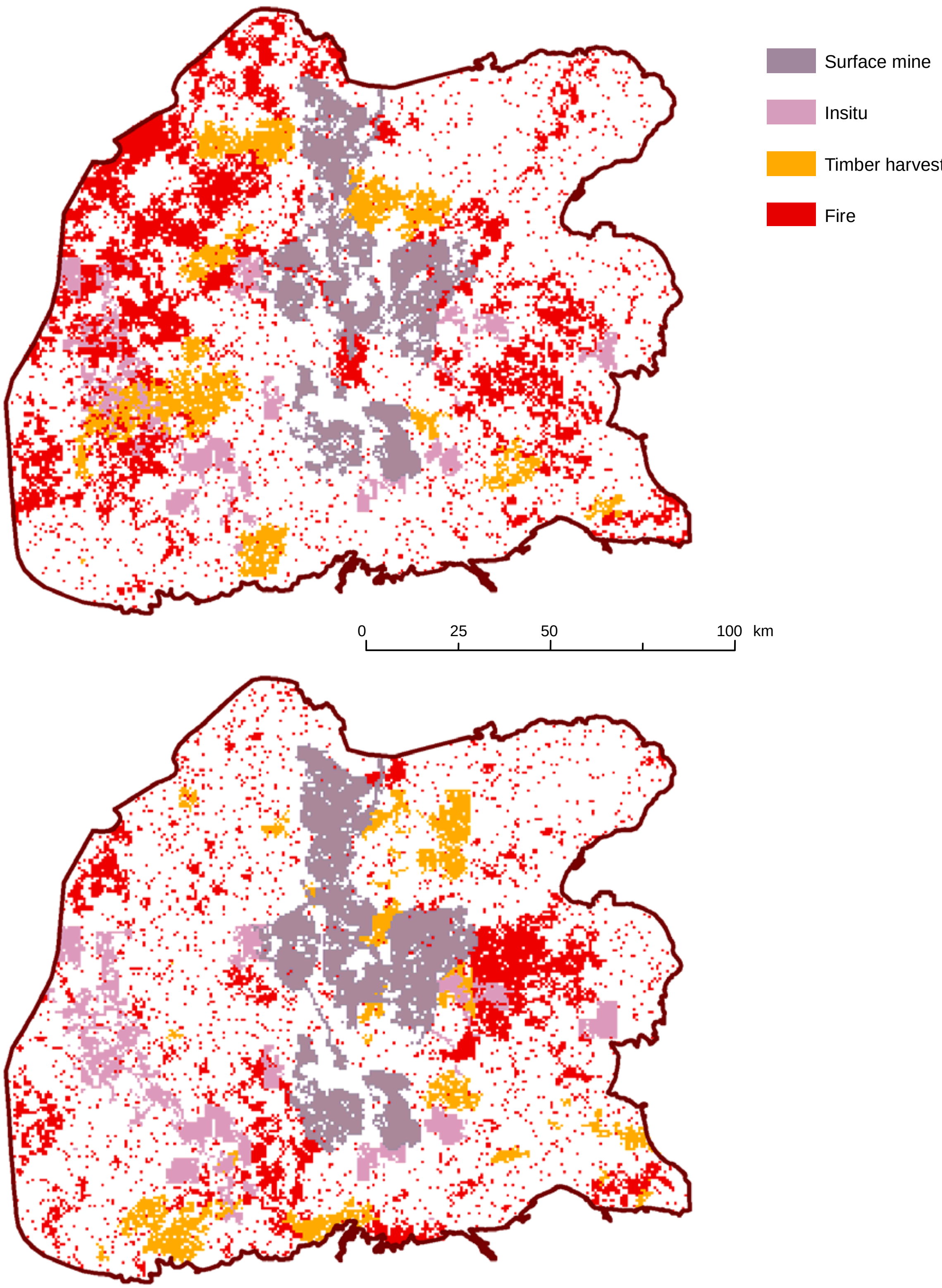

Figure 17. Potential fire and timber harvest for the 10-year period ending 2020 (top) and 2030 (bottom) and cumulative bitumen development.

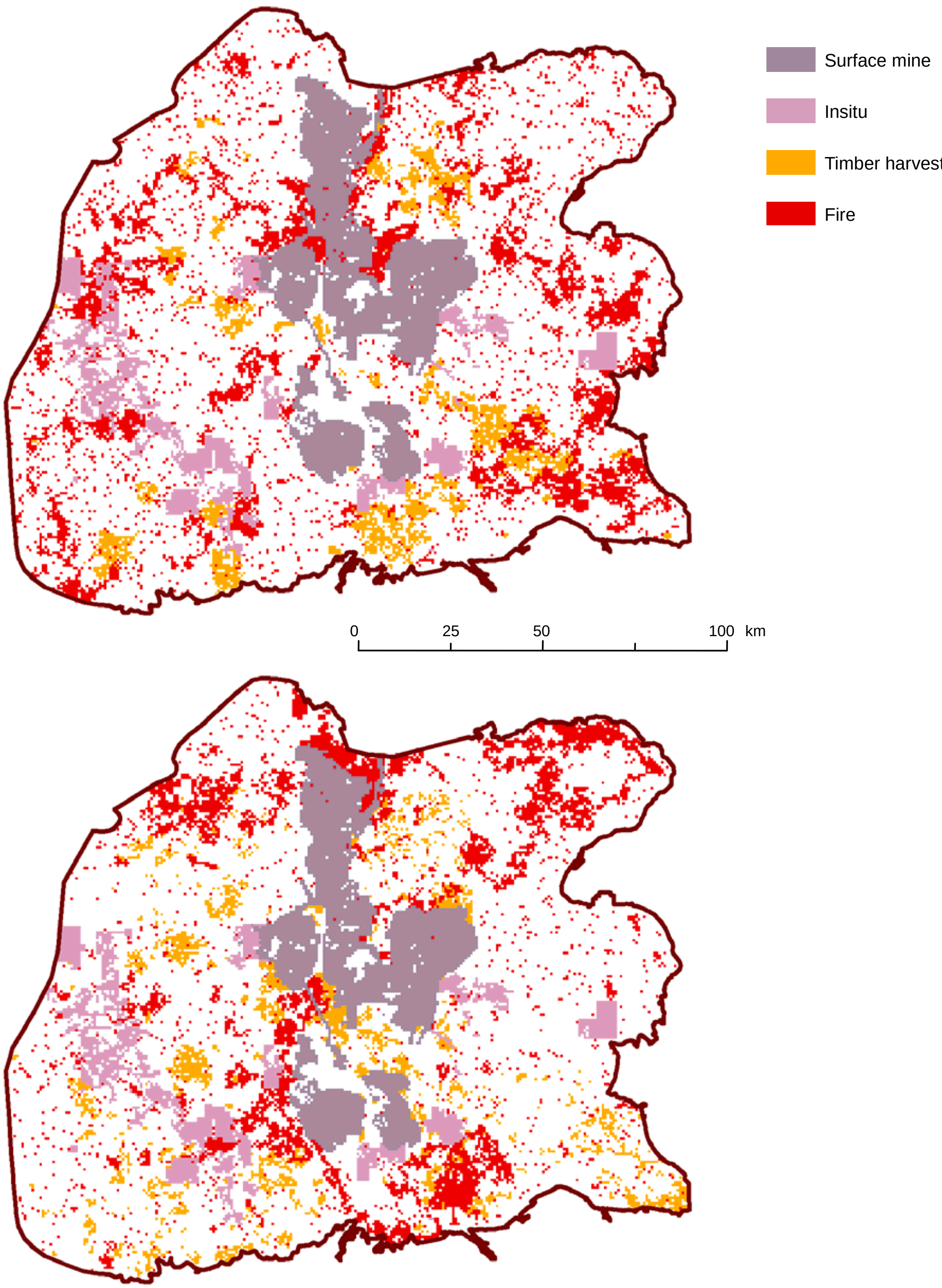

Figure 18. Potential fire and timber harvest for the 10-year period ending 2040 (top) and 2050 (bottom) and cumulative bitumen development.

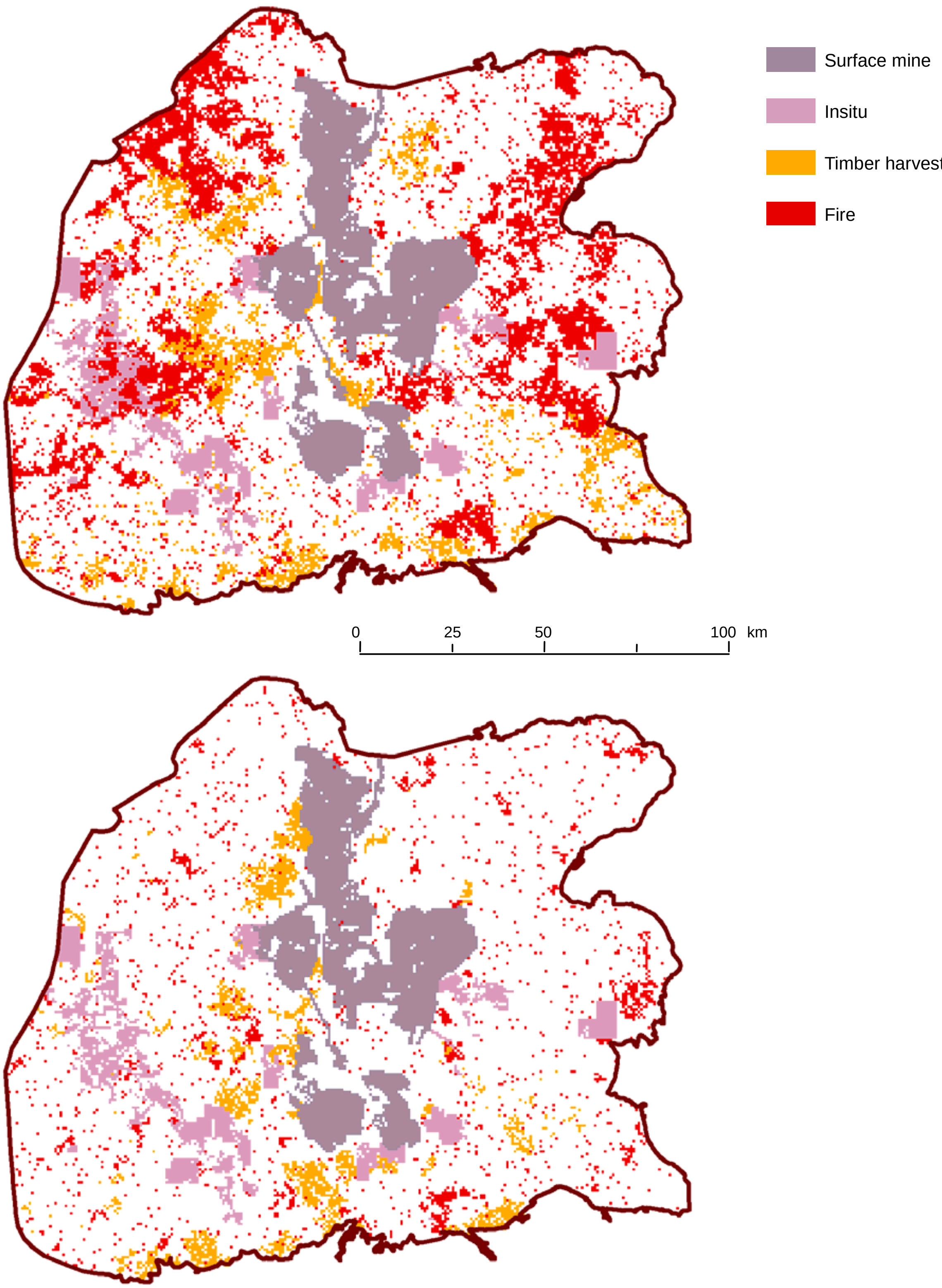

Figure 19. Potential fire and timber harvest for the 10-year period ending 2060 (top) and 2070 (bottom) and cumulative bitumen development.

Figure 20. Initial (2010 - top) and potential future (2020 - bottom) average forest seral stage (hardwood, mixedwood, pine and white spruce).

Figure 21. Potential future average forest seral stage (hardwood, mixedwood, pine and white spruce) 2030 (top), 2040 (bottom).

Figure 22. Potential future average forest seral stage (hardwood, mixedwood, pine and white spruce) 2050 (top), 2060 (bottom).

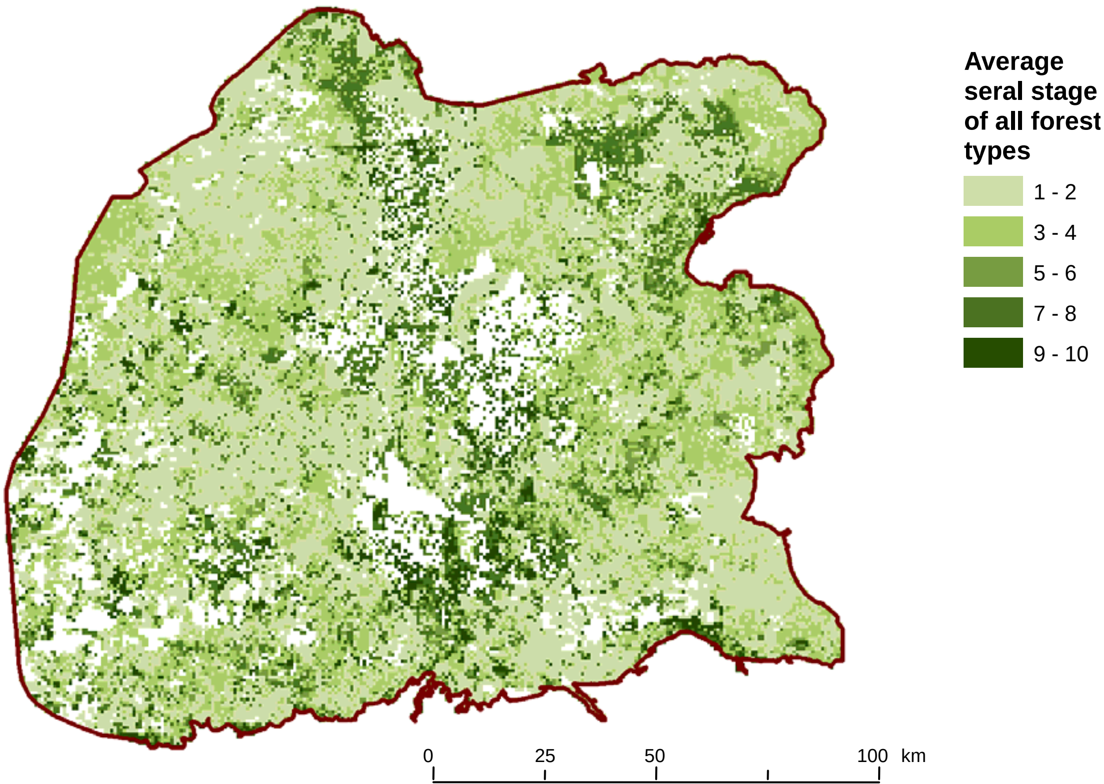

Figure 23. Potential future average forest seral stage (hardwood, mixedwood, pine and white spruce) 2070.

Figure 24. Initial (2010 - top) and potential future (2020 - bottom) average forest seral stage (hardwood, mixedwood, pine, white spruce, closed black spruce forest, riparian, open black spruce fen, open fen and black spruce lichen moss).

Figure 25. Potential future average forest seral stage (hardwood, mixedwood, pine, white spruce, closed black spruce forest, riparian, open black spruce fen, open fen and black spruce lichen moss) 2030 (top) and 2040 (bottom).

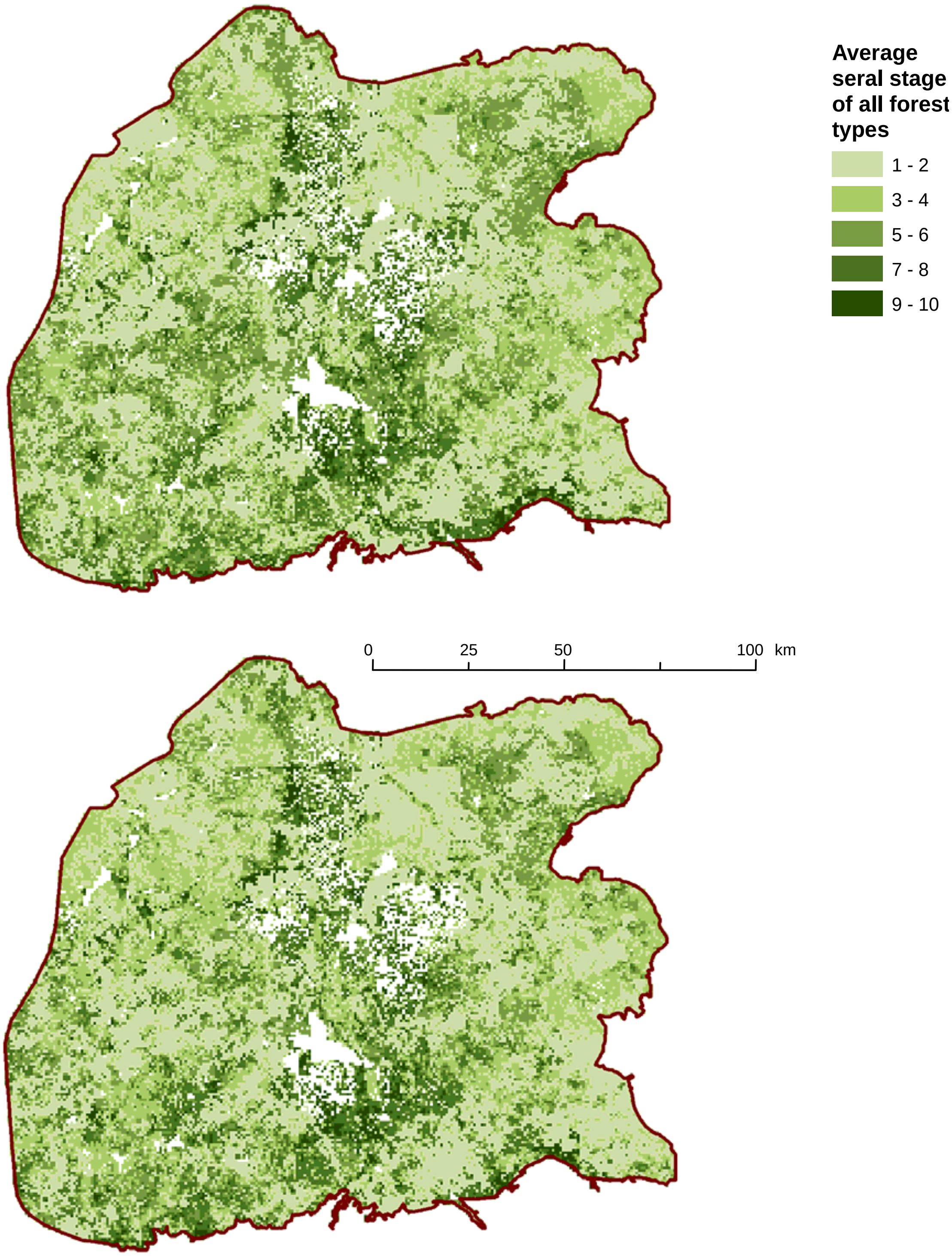

Figure 26. Potential future average forest seral stage (hardwood, mixedwood, pine, white spruce, closed black spruce forest, riparian, open black spruce fen, open fen and black spruce lichen moss) 2050 (top) and 2060 (bottom).

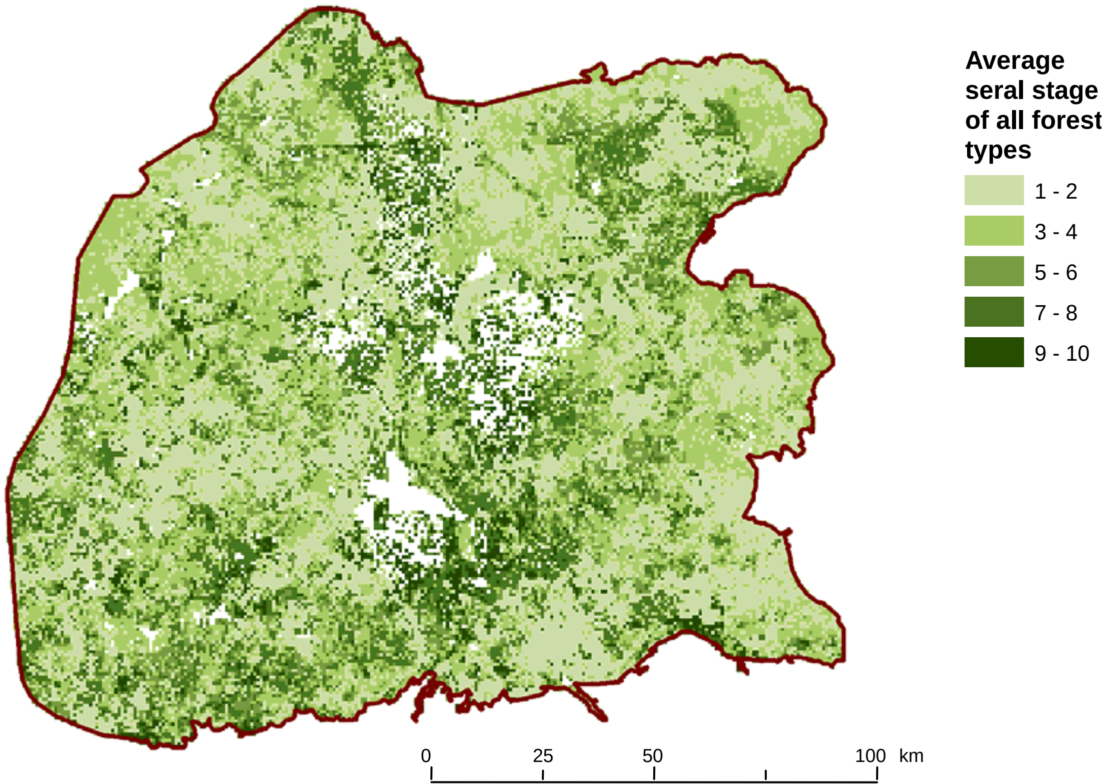

Figure 27. Potential future average forest seral stage (hardwood, mixedwood, pine, white spruce, closed black spruce forest, riparian, open black spruce fen, open fen and black spruce lichen moss) 2070.

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Appendix 1

Overview of ALCES

Appendix 1: Overview of ALCES

ALCES and its companion mapping tool (ALCES Mapper) provide strategic land use planning guidance by examing inter-relationships among the full range of relevant land-use sectors and natural disturbances, and exploring their environmental and socioeconomic consequences at large temporal and spatial scales. ALCES is a stock and flow model built using the Stella modelling platform (www.iseesystems.com). The model was first developed by Dr. Brad Stelfox in the mid 1990's and has gradually expanded in scope to meet the needs of various regional planning initiatives in western North America. The following description provides an overview of ALCES structure and function. More details can be found on the ALCES Group website (www.alces.ca).

To achieve a synoptic view of regional cumulative effects, a wide-range of land uses and ecological processes are incorporated into the model as drivers. The various land uses and ecological processes can be turned on or off depending on the needs of the scenario analysis. For each land use operating in a region, the user defines development rates, the portion of the landscape available for development, and management practices such as the intensity and lifespan of associated industrial footprints. The influence of natural disturbances (fire and insects) and plant succession on landscape composition are also tracked. Hydrological processes are addressed with surface and groundwater modules, and climate change effects can be incorporated by defining temporal changes in natural disturbances rates, successional trajectories, landcover, meteorology and hydrology.

The first-order effects tracked by ALCES are landscape composition and resource production/supply. Using an annual time-step (although monthly time steps can be used for the meteorology module) the model modifies the area and length of up to 20 landcover and 15 anthropogenic footprint types in response to natural disturbances, succession, landscape conversion, reclamation of footprints, and creation of new footprints associated with simulated land-use trajectories. ALCES is a spatially stratified model, meaning that it tracks the area, length, and quantity of each footprint separately for each landscape type. ALCES does not, however, track the explicit geographic location of these features (e.g., latitude and longitude), a feature that greatly speeds up processing time (less than 1 second per simulation year) relative to a spatially explicit modelling approach. ALCES also tracks resource production and supply using approaches that are typical of sector-specific models such as forestry timber supply models. By tracking resource supply, ALCES can reduce or stop the expansion of a land use if resource supply becomes inadequate. Changes to water quantity can also be tracked by applying water use coefficients associated with each land use.

By applying ALCES Mapper, ALCES tabular and graphical output can be augmented with maps illustrating the plausible future condition of landscapes and indicators. ALCES Mapper is a companion tool to ALCES developed as an ArcGIS application. The tool divides the study area into grid cells of user-defined size, and calculates the initial landscape and footprint composition within each cell. Footprint growth and reclamation, landcover change, natural disturbances, and other variables as reported by ALCES are then applied to each cell, tracked, and displayed spatially. ALCES Mapper allows users to specify the general location (i.e., where specified land-use footprints can or cannot occur) and pattern (e.g., dispersed versus contagious) of future development. This feature provides flexibility to map transformations of landscapes through time according to different spatial rules, and is useful for visualizing the implications of different zoning or resource utilization strategies. Maps of future landscape condition can then be analyzed to evaluate the spatial response of indicators such as wildlife habitat to potential future landscapes associated with land-use scenarios.

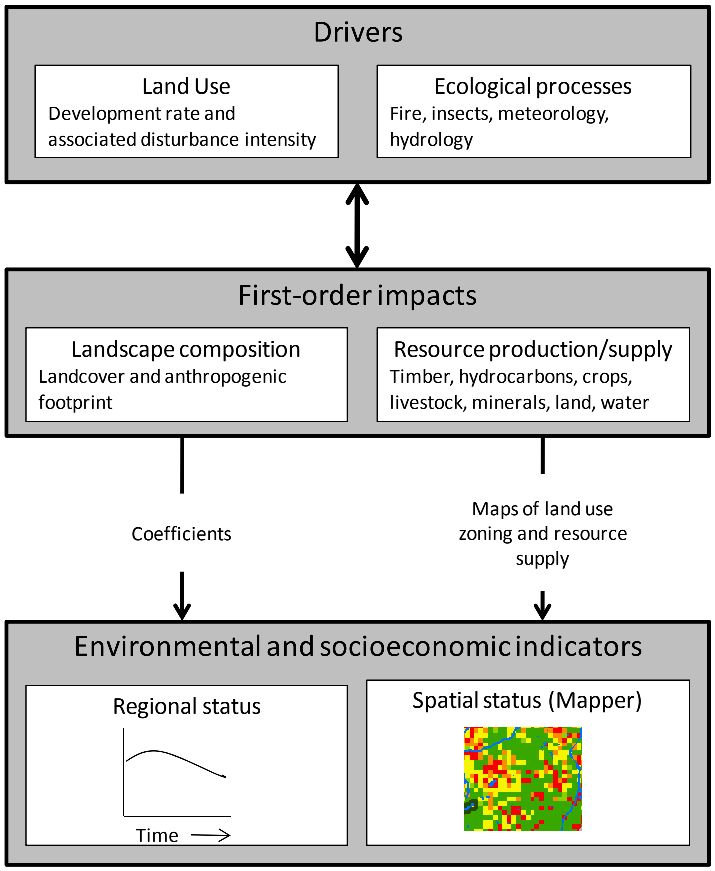

Figure 1. Overview of the ALCES land use simulation tool.

Appendix 2

Maps of 95th and 5th Percentile Simulations

Map sequences for a run where the final average forest age was in proximity to the 95th percentile across 200 simulations.

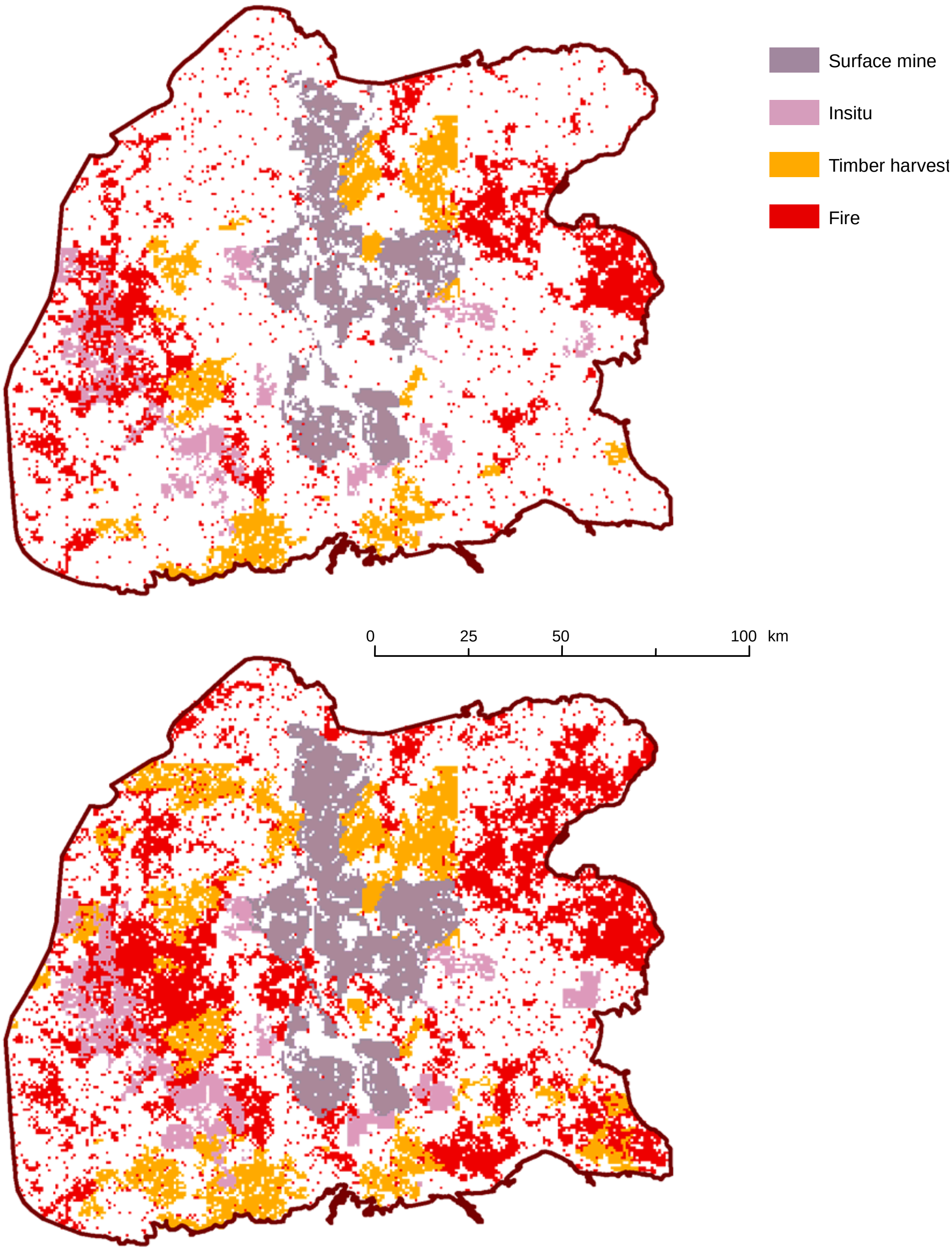

Figure 1. Potential cumulative fire, harvest and bitumen development in 2020 (top), 2030 (bottom).

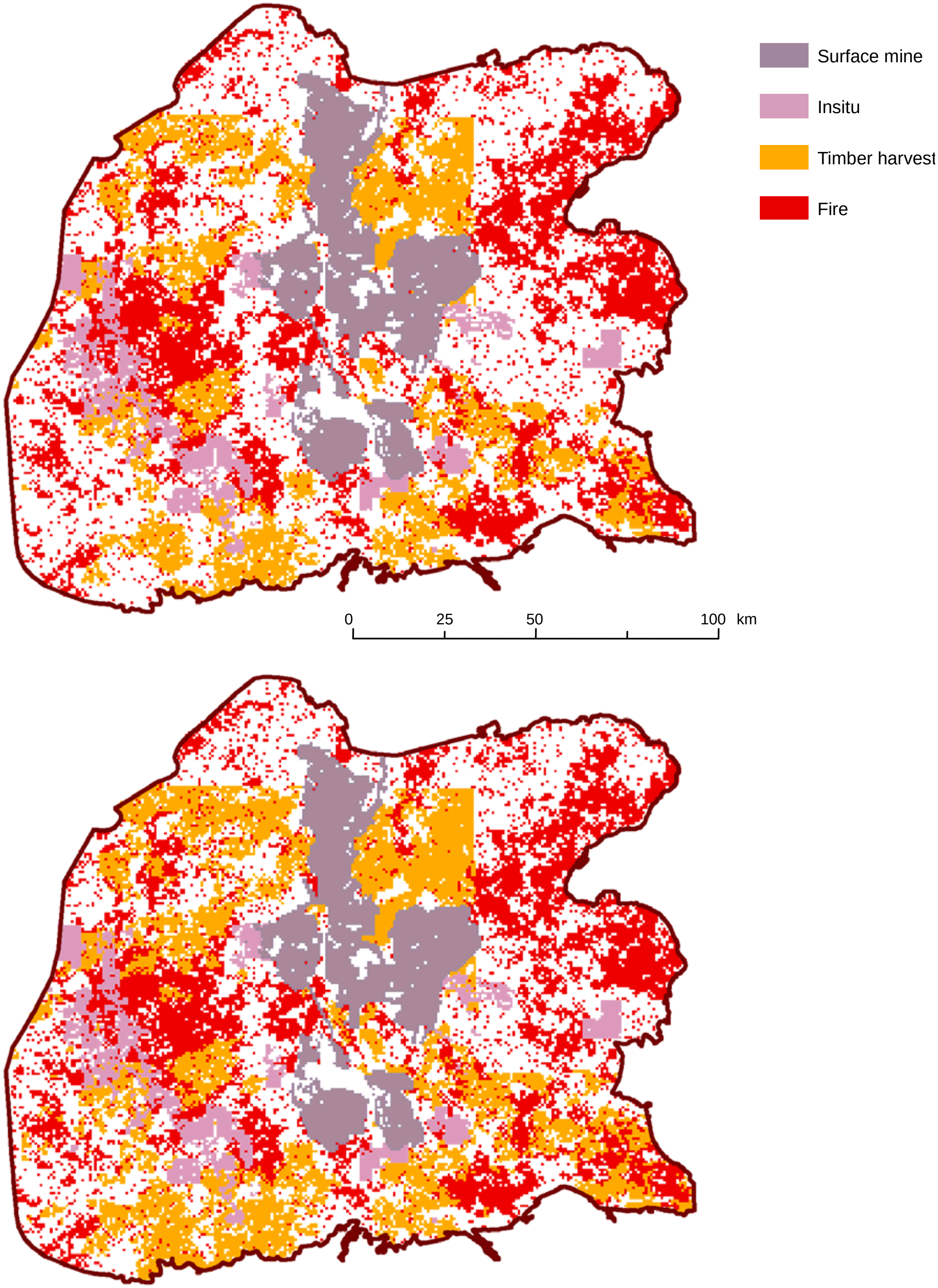

Figure 2. Potential cumulative fire, harvest and bitumen development in 2040 (top), 2050 (bottom).

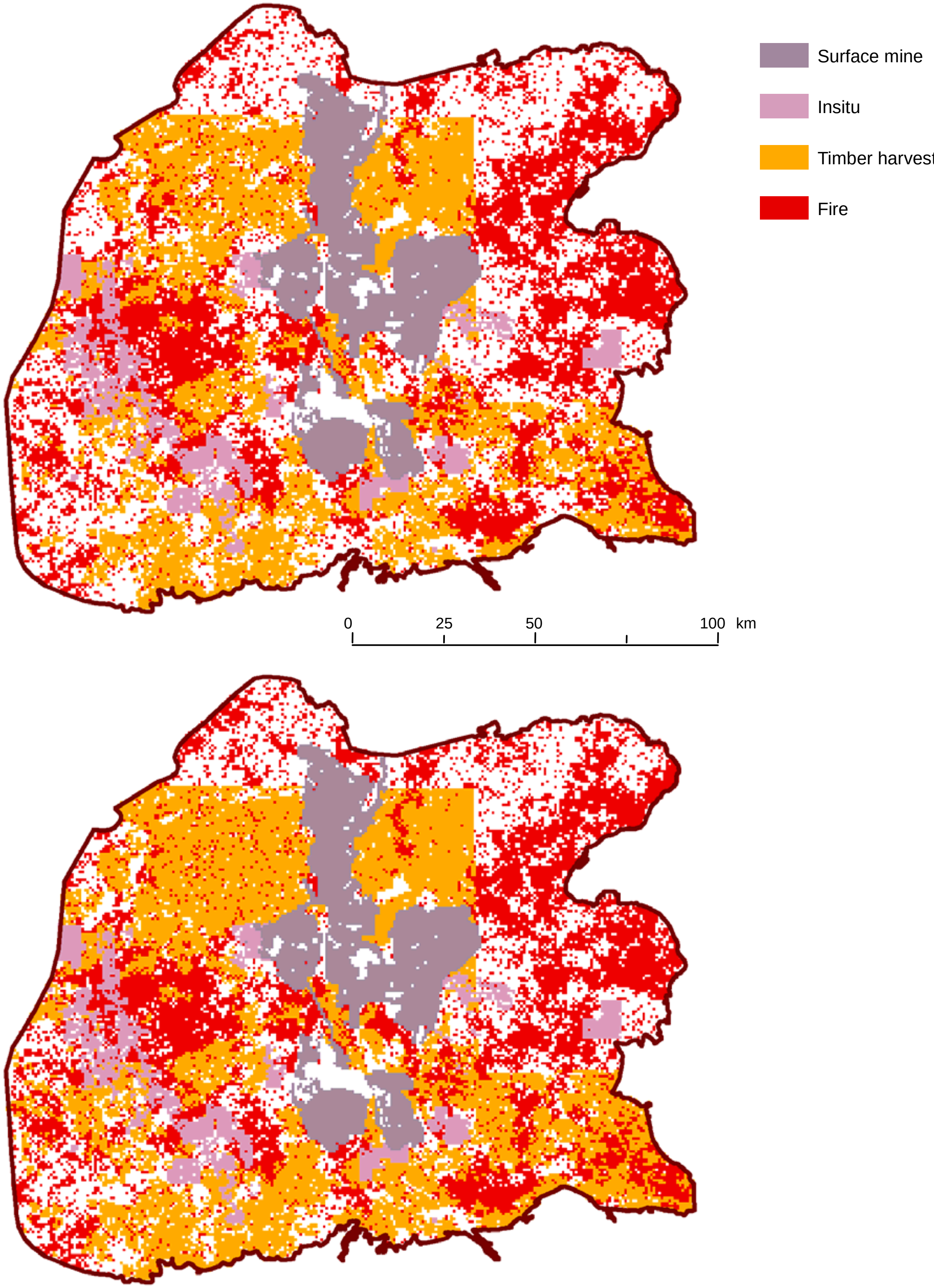

Figure 3. Potential cumulative fire, harvest and bitumen development in 2060 (top) 2070 (bottom).

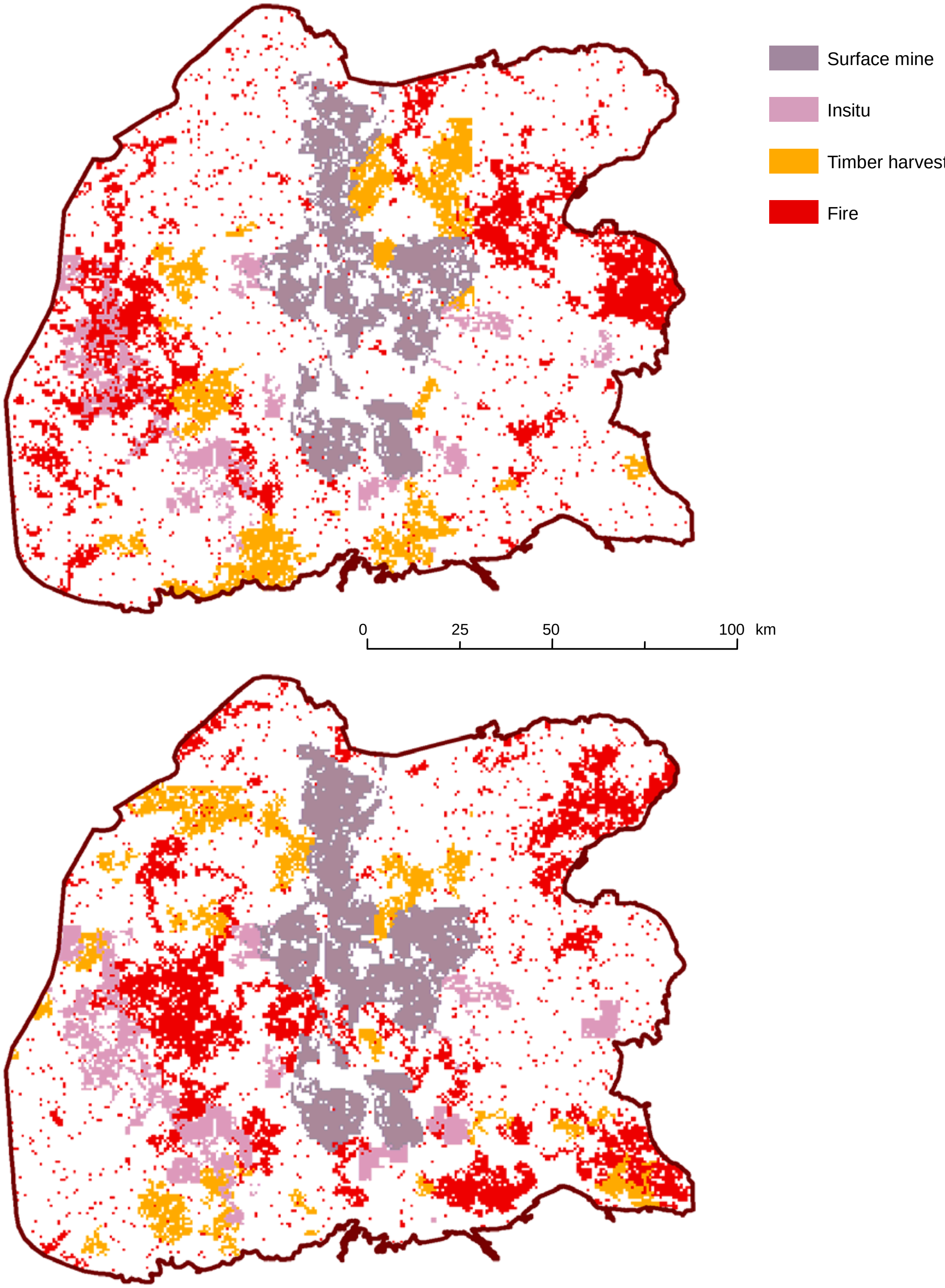

Figure 4. Potential fire and timber harvest for the 10-year period ending 2020 (top) and 2030 (bottom) and cumulative bitumen development.

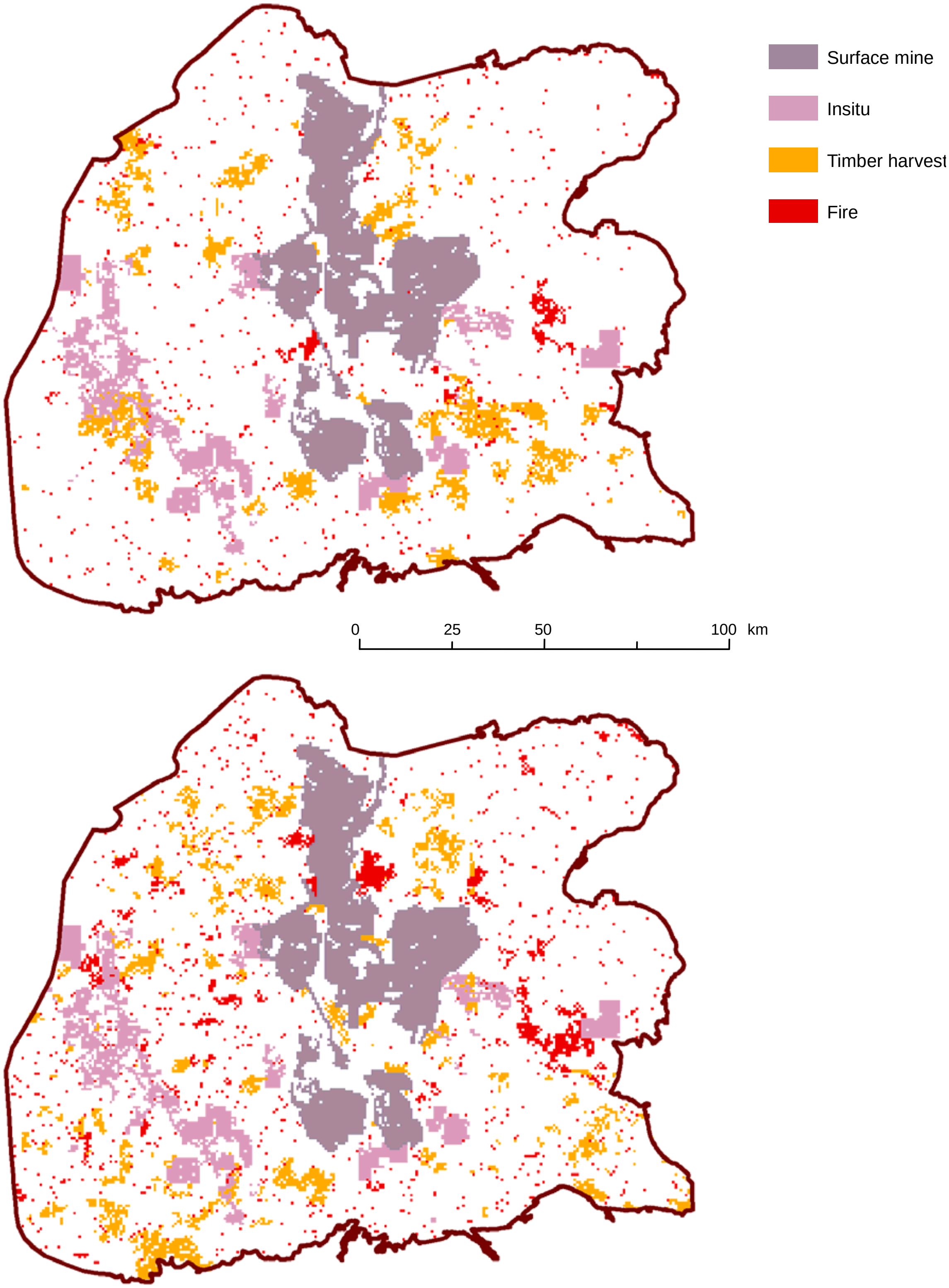

Figure 5. Potential fire and timber harvest for the 10-year period ending 2040 (top) and 2050 (bottom) and cumulative bitumen development.

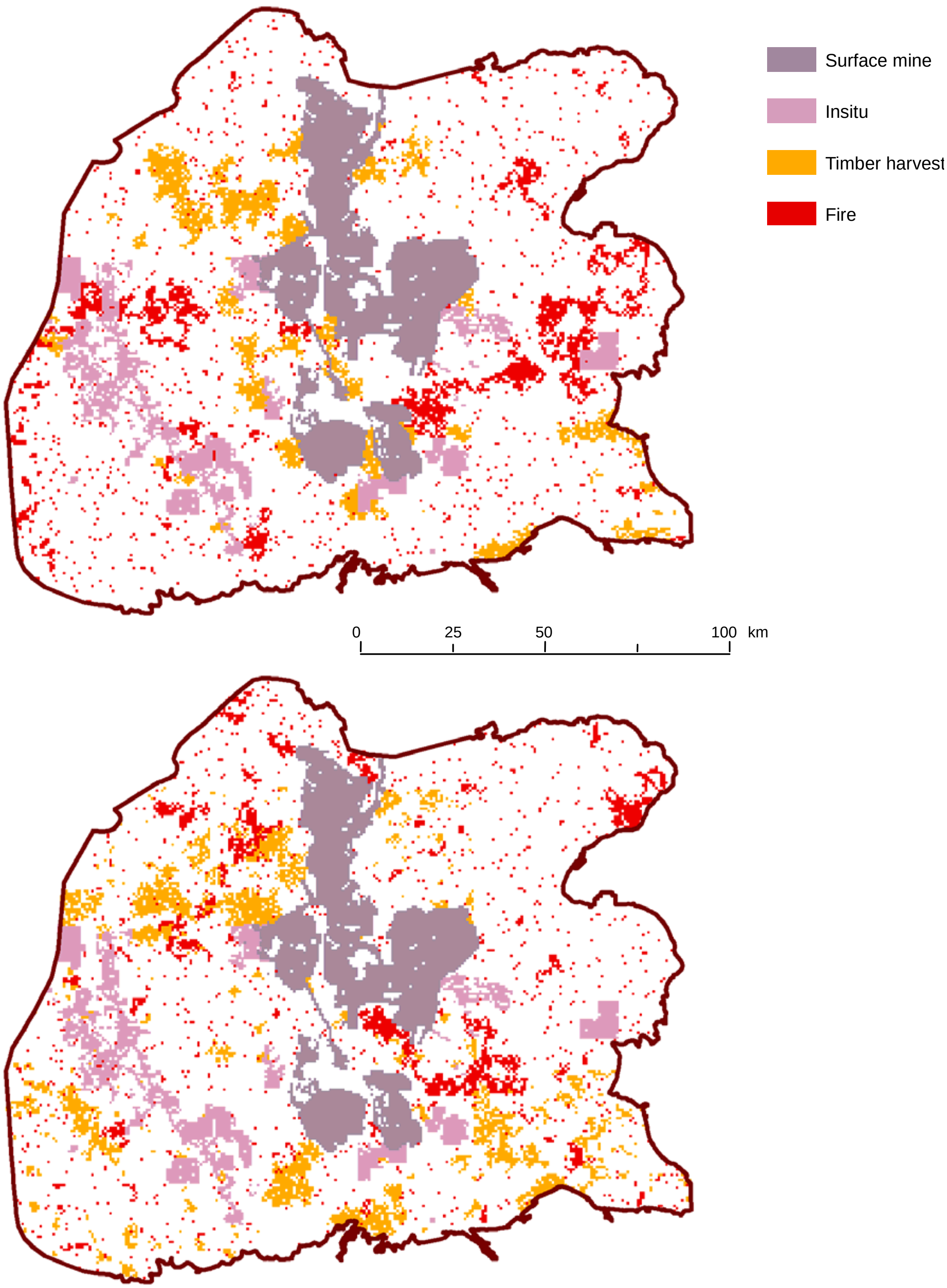

Figure 6. Potential fire and timber harvest for the 10-year period ending 2060 (top) and 2070 (bottom) and cumulative bitumen development.

Figure 7. Initial (2010 - top) and potential future (2020 - bottom) average forest seral stage (hardwood, mixedwood, pine and white spruce).

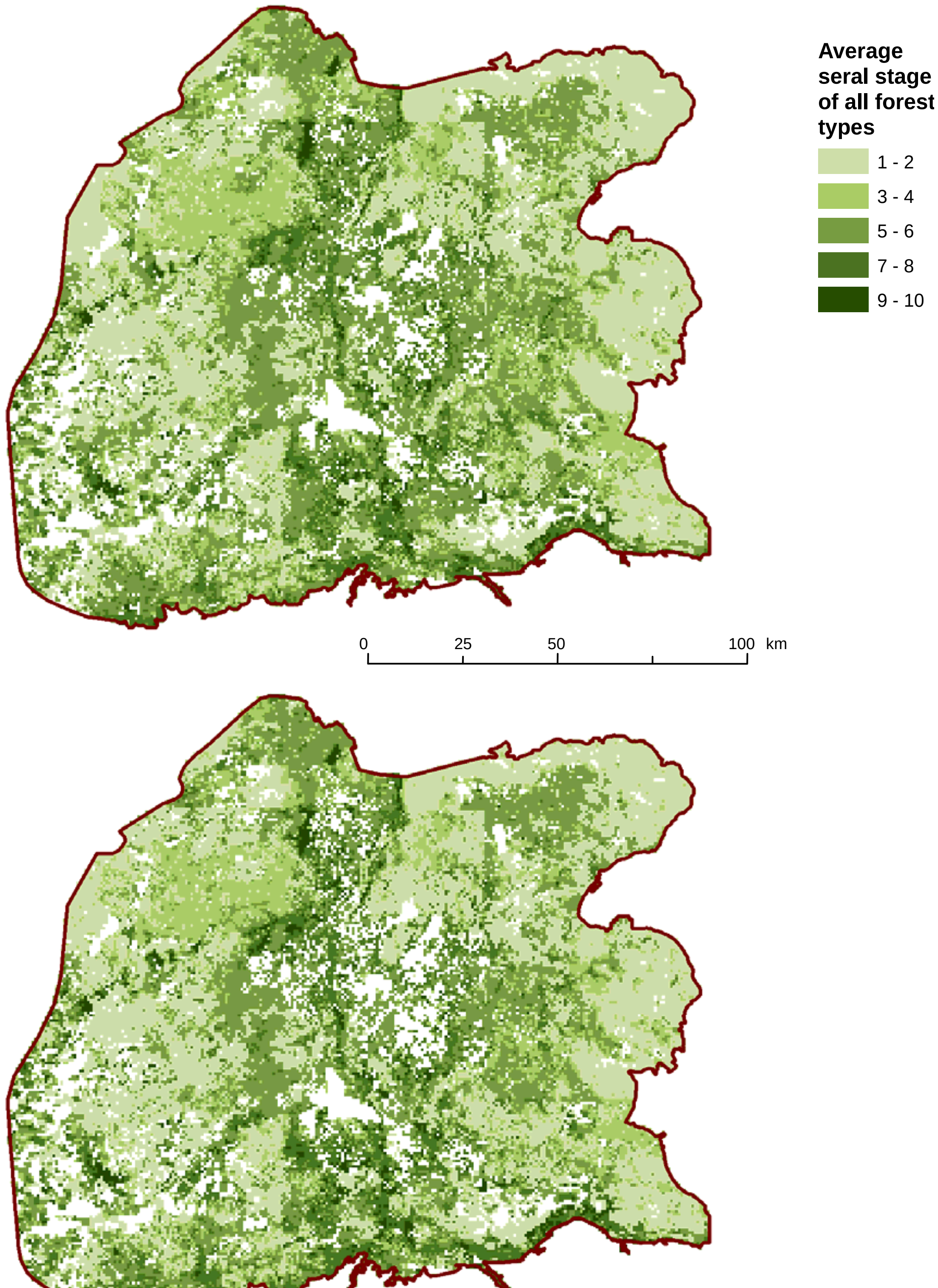

Figure 8. Potential future average forest seral stage (hardwood, mixedwood, pine and white spruce) 2030 (top), 2040 (bottom).

Figure 9. Potential future average forest seral stage (hardwood, mixedwood, pine and white spruce) 2050 (top), 2060 (bottom).

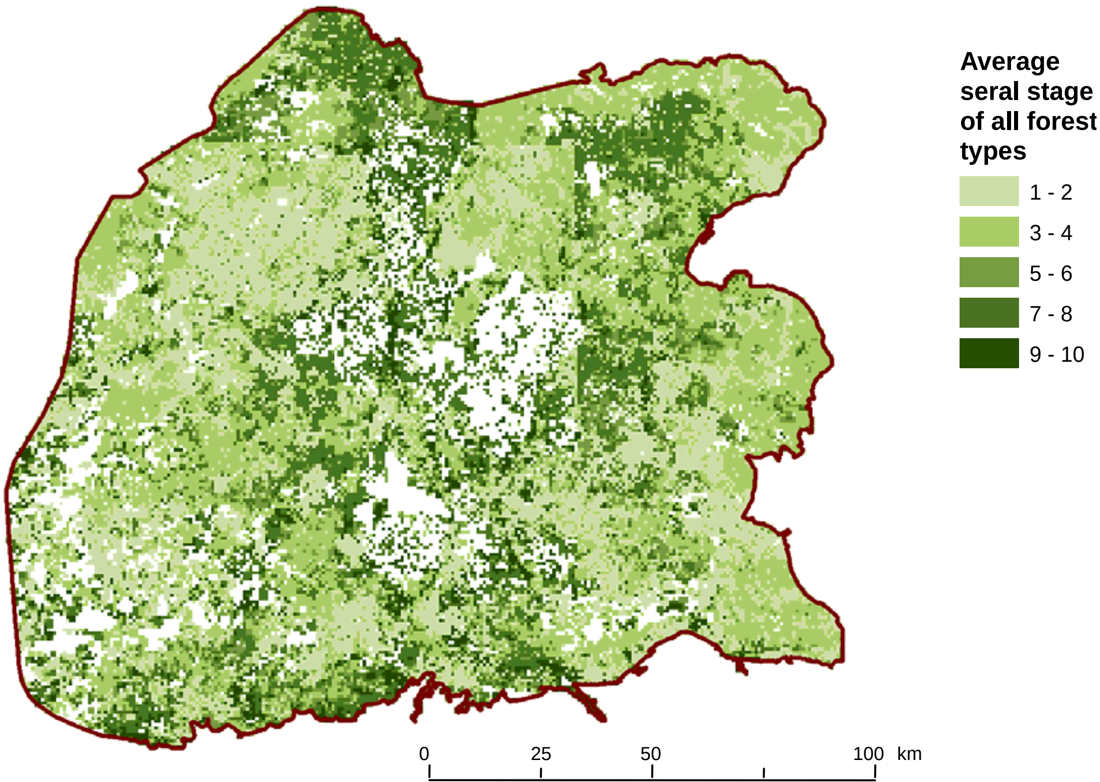

Figure 10. Potential future average forest seral stage (hardwood, mixedwood, pine and white spruce) 2070.

Figure 11. Initial (2010 - top) and potential future (2020 - bottom) average forest seral stage (hardwood, mixedwood, pine, white spruce, closed black spruce forest, riparian, open black spruce fen, open fen and black spruce lichen moss).

Figure 12. Potential future average forest seral stage (hardwood, mixedwood, pine, white spruce, closed black spruce forest, riparian, open black spruce fen, open fen and black spruce lichen moss) 2030 (top), 2040 (bottom).

Figure 13. Potential future average forest seral stage (hardwood, mixedwood, pine, white spruce, closed black spruce forest, riparian, open black spruce fen, open fen and black spruce lichen moss) 2050 (top), 2060 (bottom).

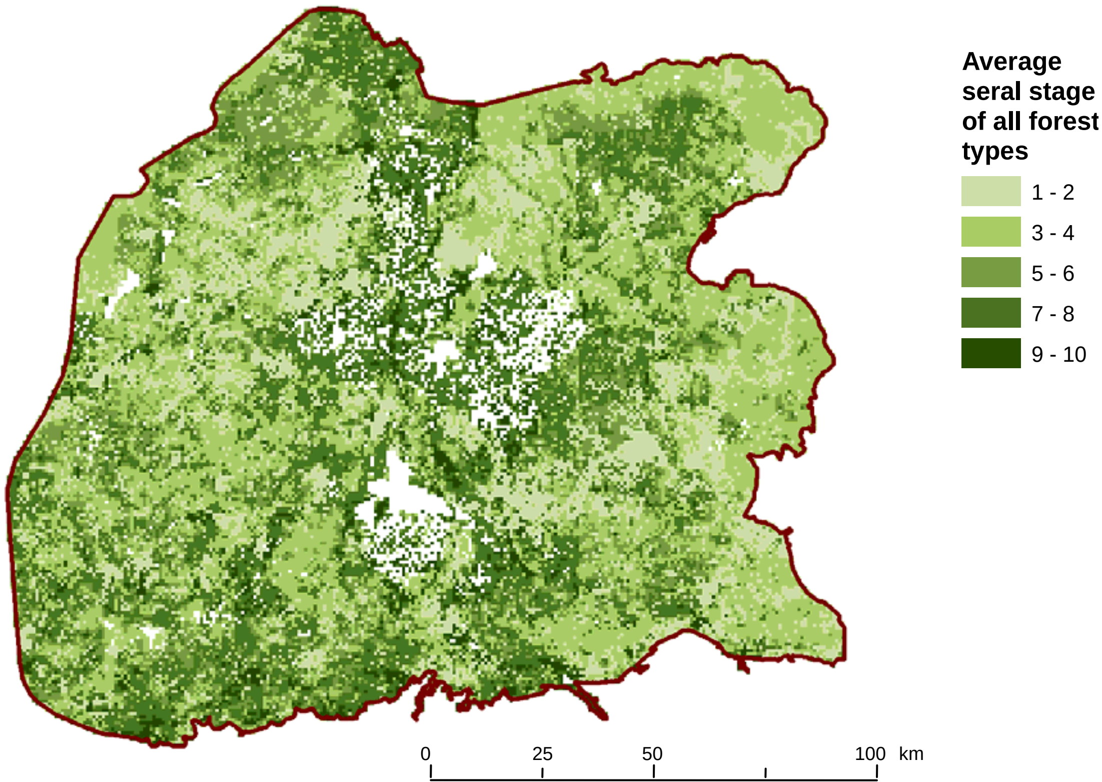

Figure 14. Potential future average forest seral stage (hardwood, mixedwood, pine, white spruce, closed black spruce forest, riparian, open black spruce fen, open fen and black spruce lichen moss) 2070.

Map sequences for a run where the final average forest age was in proximity to the 5th percentile across 200 simulations.

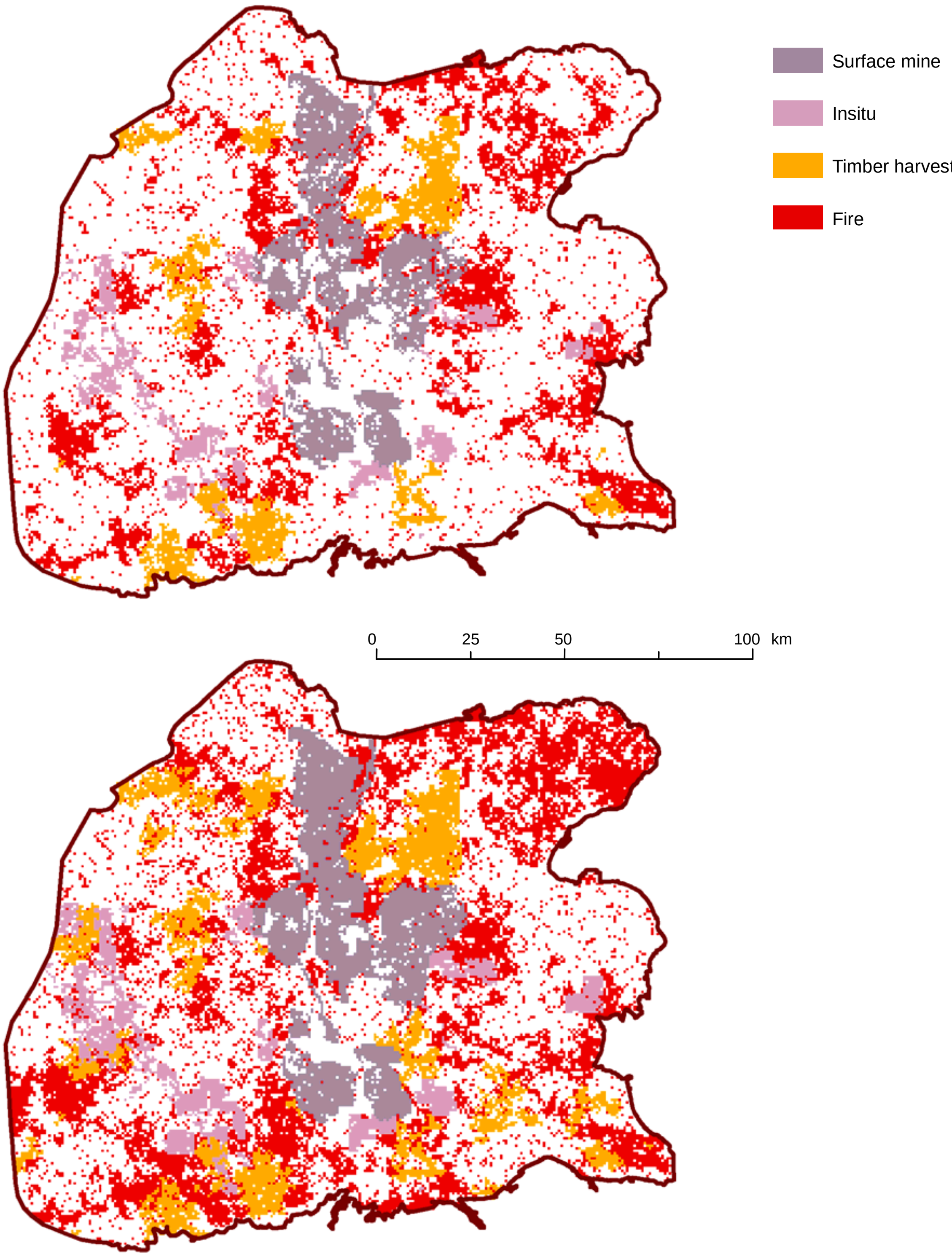

Figure 15. Potential cumulative fire, harvest and bitumen development in 2020 (top), 2030 (bottom).

Figure 16. Potential cumulative fire, harvest and bitumen development in 2040 (top), 2050 (bottom).

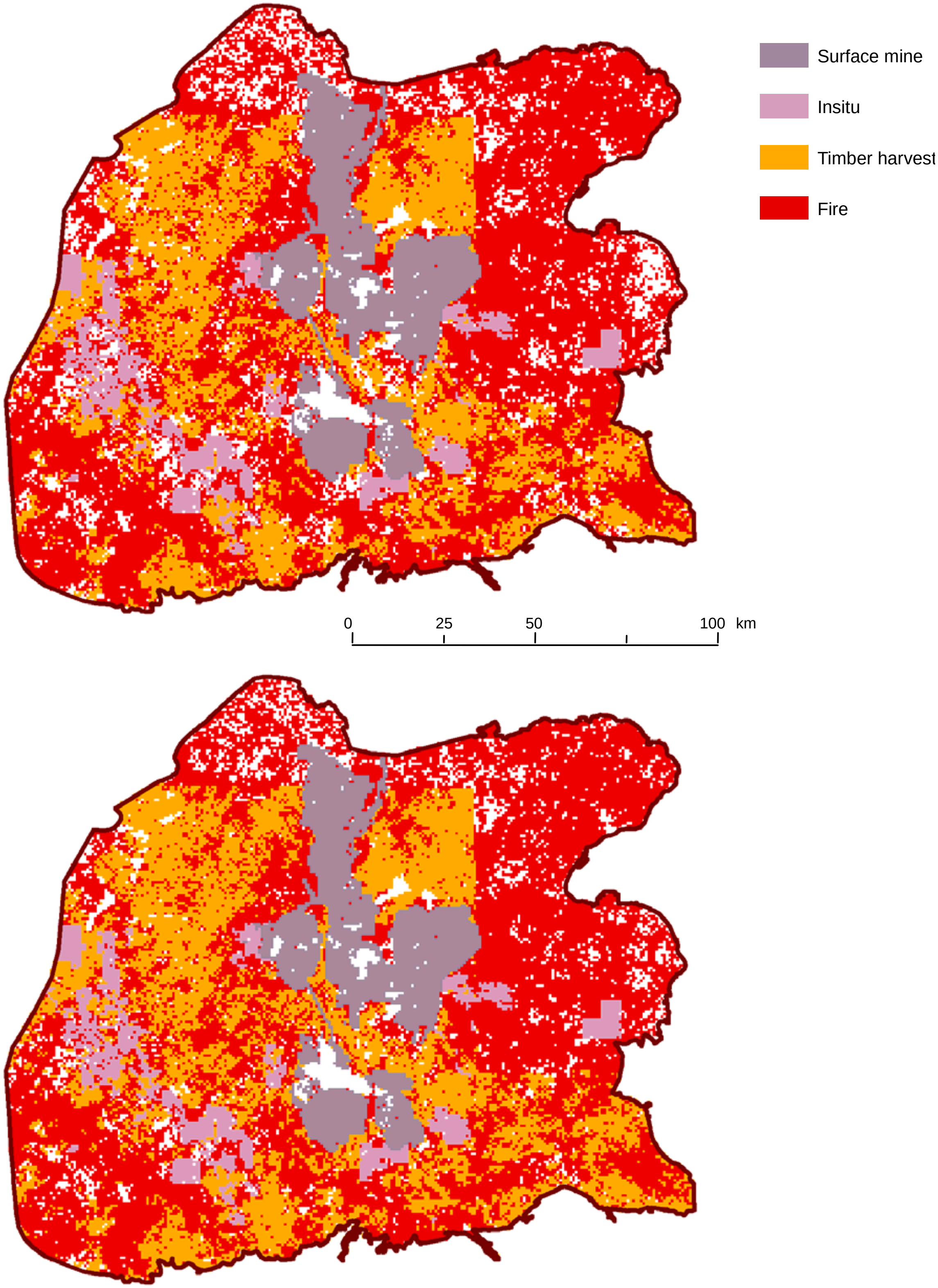

Figure 17. Potential cumulative fire, harvest and bitumen development in 2060 (top) 2070 (bottom).

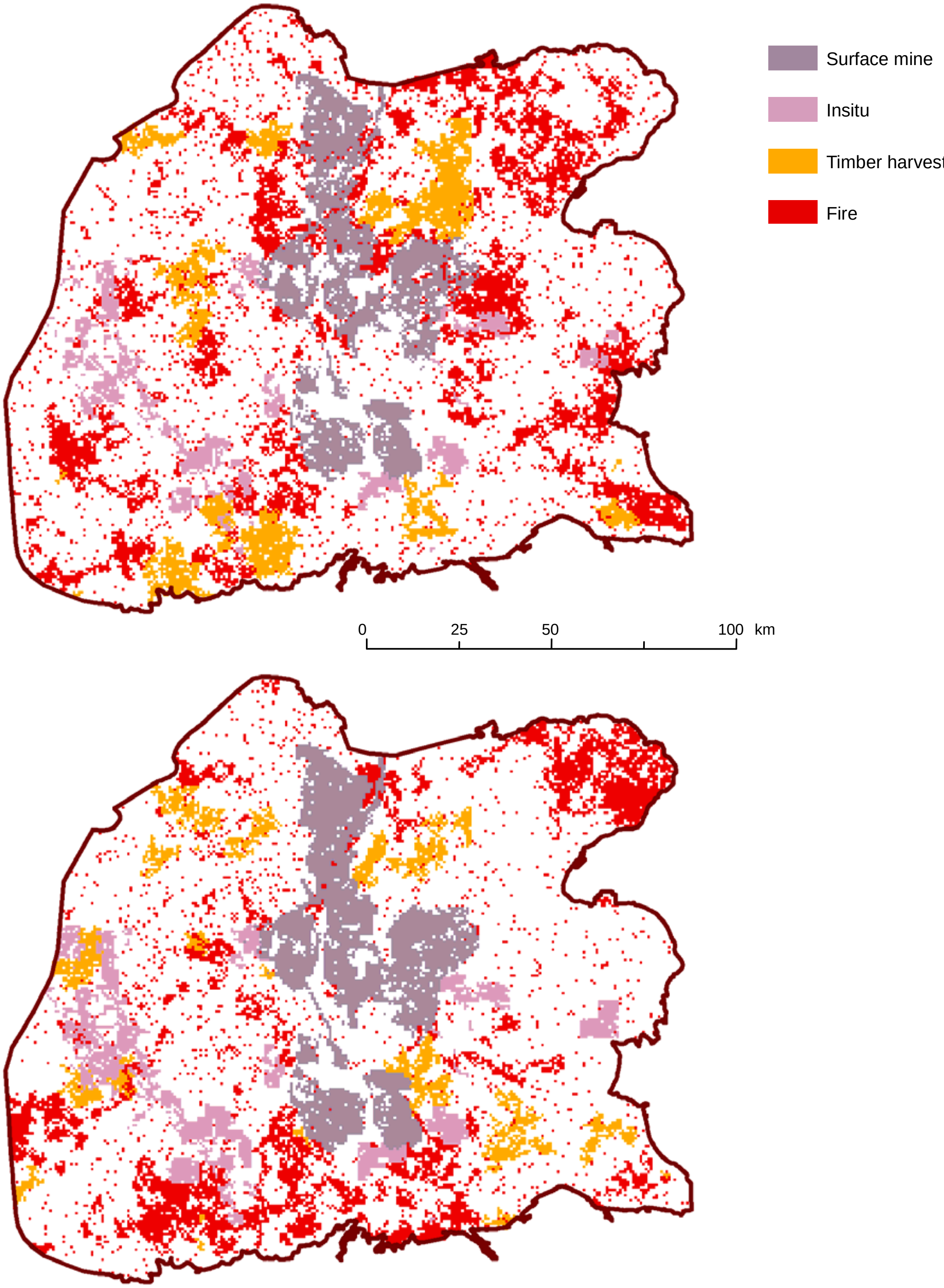

Figure 18. Potential fire and timber harvest for the 10-year period ending 2020 (top) and 2030 (bottom) and cumulative bitumen development.

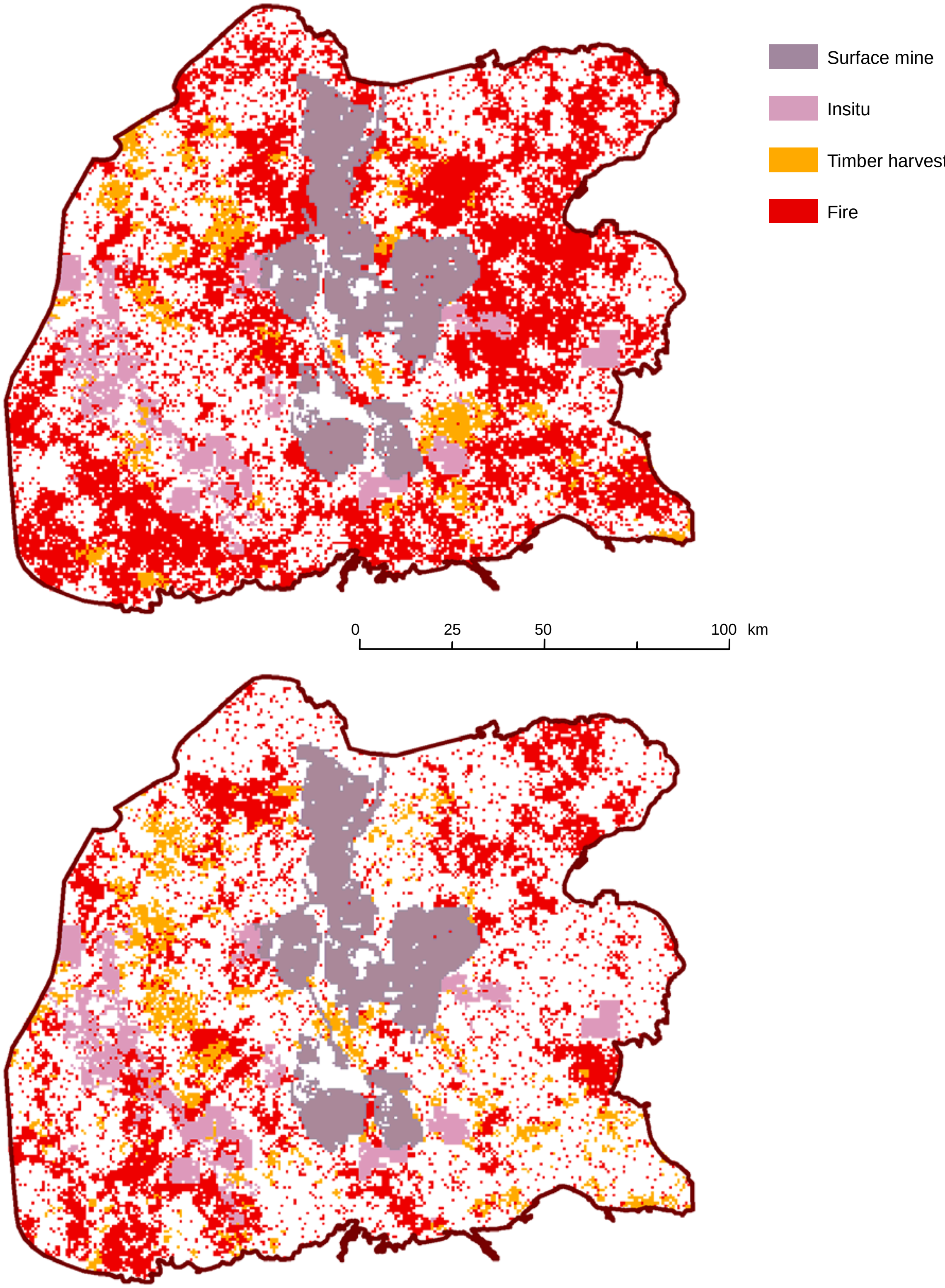

Figure 19. Potential fire and timber harvest for the 10-year period ending 2040 (top) and 2050 (bottom) and cumulative bitumen development.

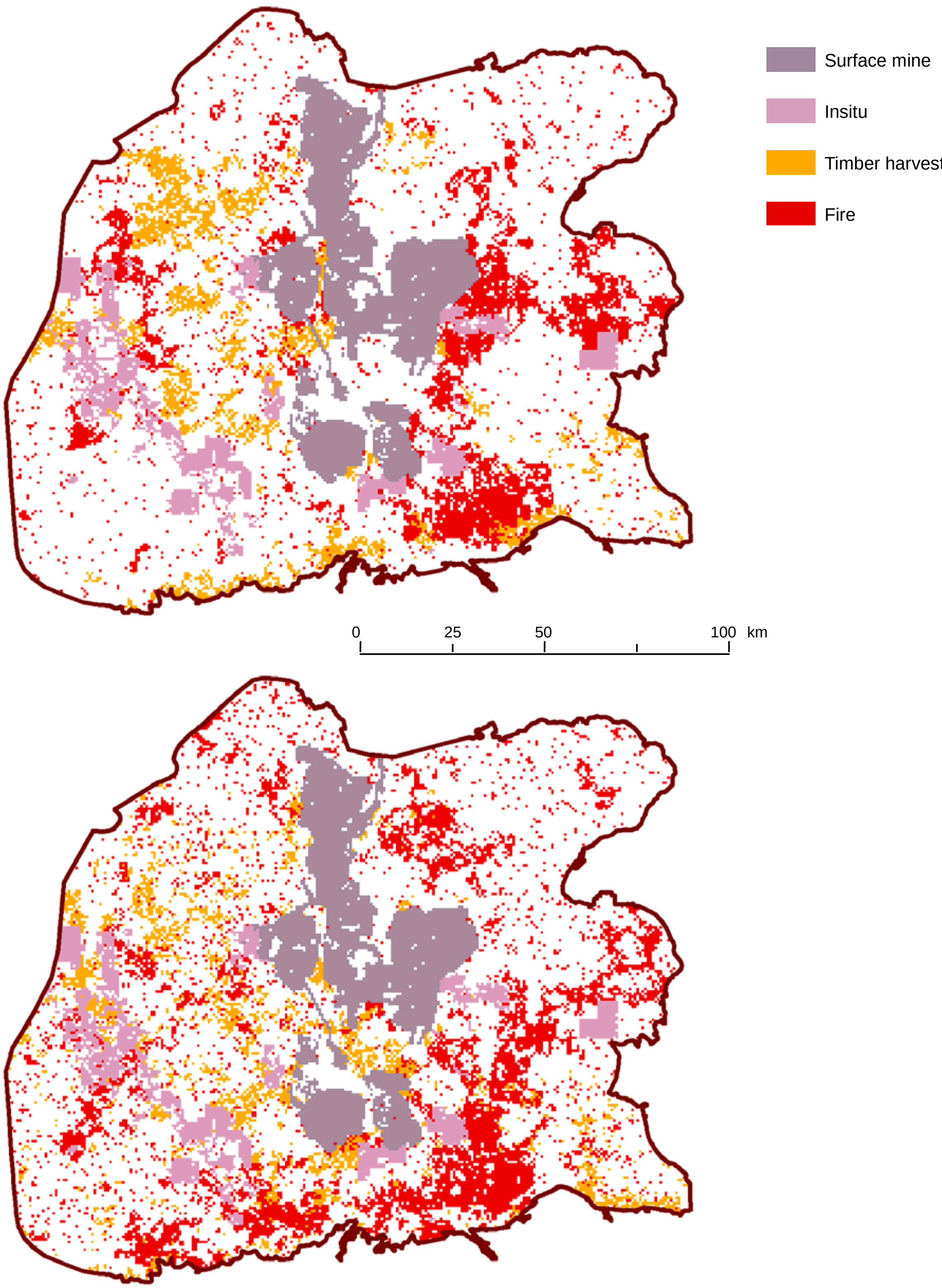

Figure 20. Potential fire and timber harvest for the 10-year period ending 2060 (top) and 2070 (bottom) and cumulative bitumen development.

Figure 21. Initial (2010 - top) and potential future (2020 - bottom) average forest seral stage (hardwood, mixedwood, pine and white spruce).

Figure 22. Potential future average forest seral stage (hardwood, mixedwood, pine and white spruce) 2030 (top), 2040 (bottom).

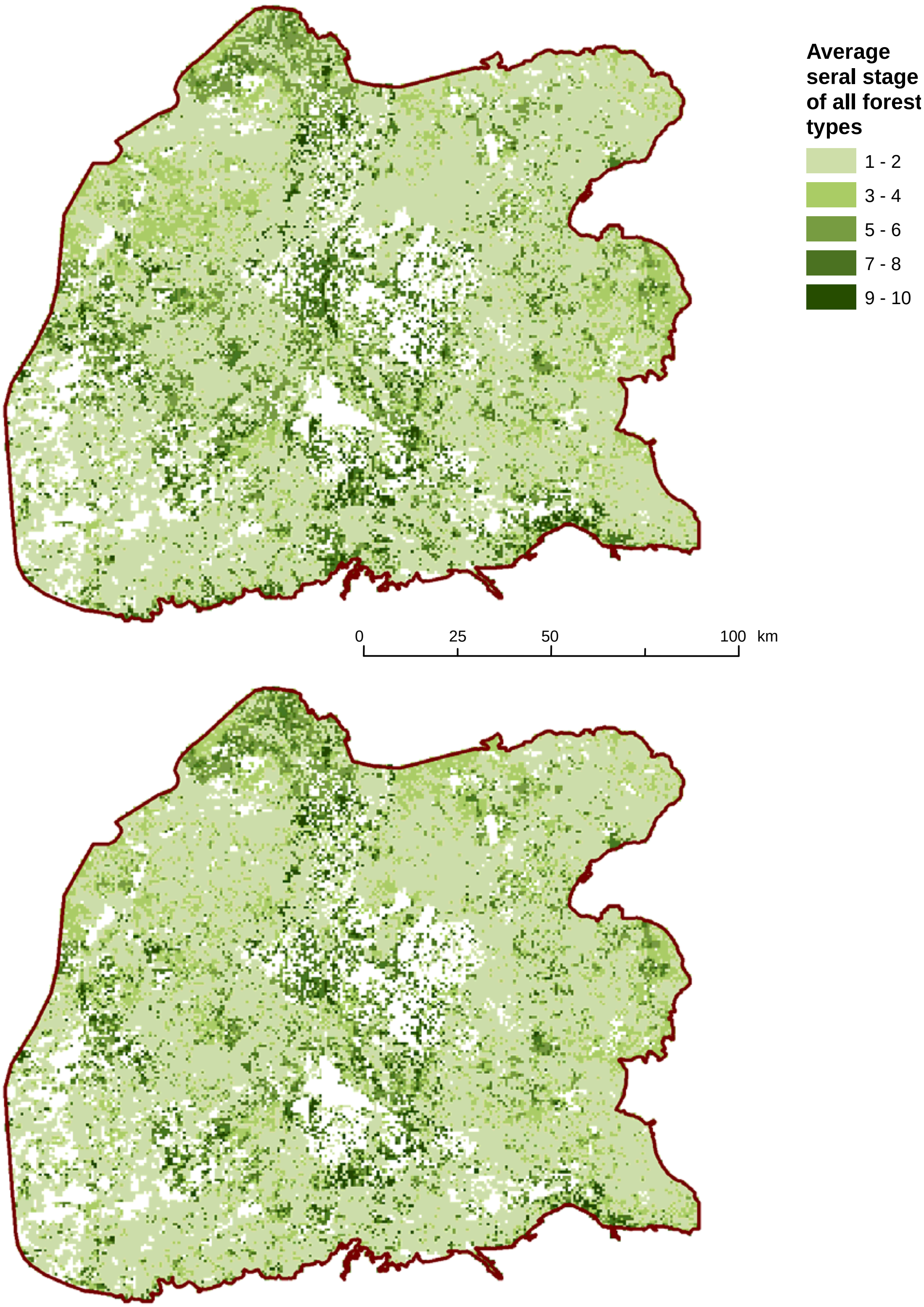

Figure 23. Potential future average forest seral stage (hardwood, mixedwood, pine and white spruce) 2050 (top), 2060 (bottom).

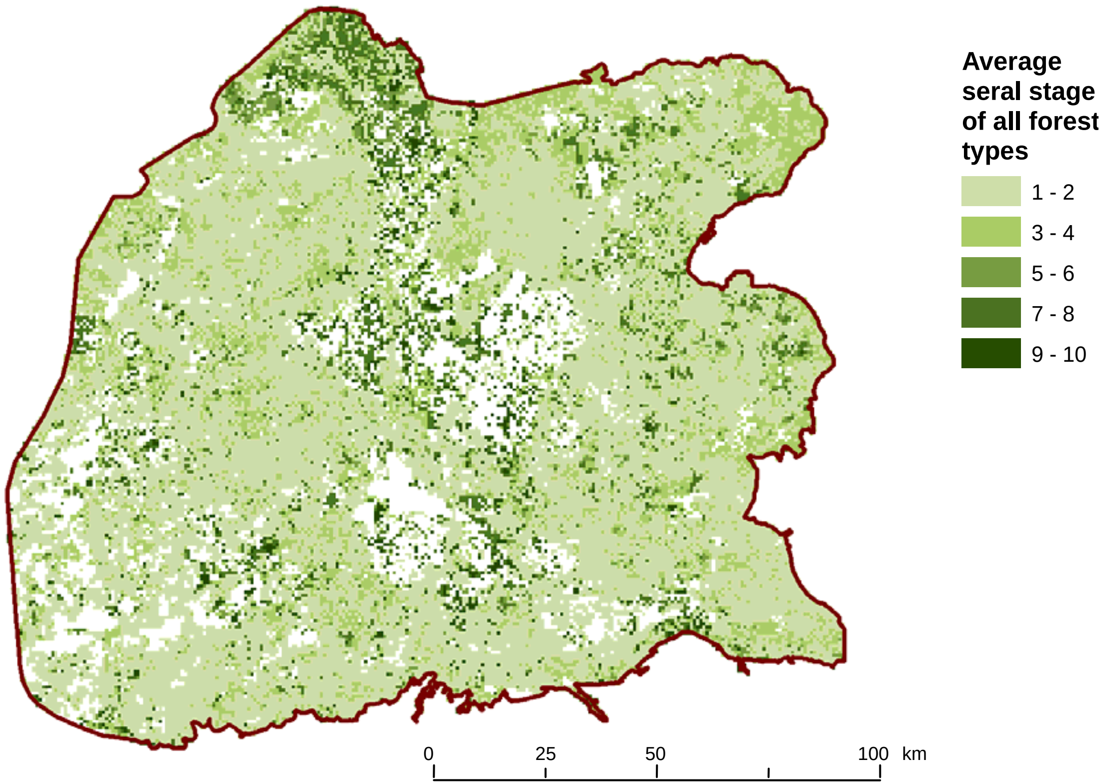

Figure 24. Potential future average forest seral stage (hardwood, mixedwood, pine and white spruce) 2070

Figure 25. Initial (2010 - top) and potential future (2020 - bottom) average forest seral stage (hardwood, mixedwood, pine, white spruce, closed black spruce forest, riparian, open black spruce fen, open fen and black spruce lichen moss).

Figure 26. Potential future average forest seral stage (hardwood, mixedwood, pine, white spruce, closed black spruce forest, riparian, open black spruce fen, open fen and black spruce lichen moss) 2030 (top), 2040 (bottom).

Figure 27. Potential future average forest seral stage (hardwood, mixedwood, pine, white spruce, closed black spruce forest, riparian, open black spruce fen, open fen and black spruce lichen moss) 2050 (top), 2060 (bottom).

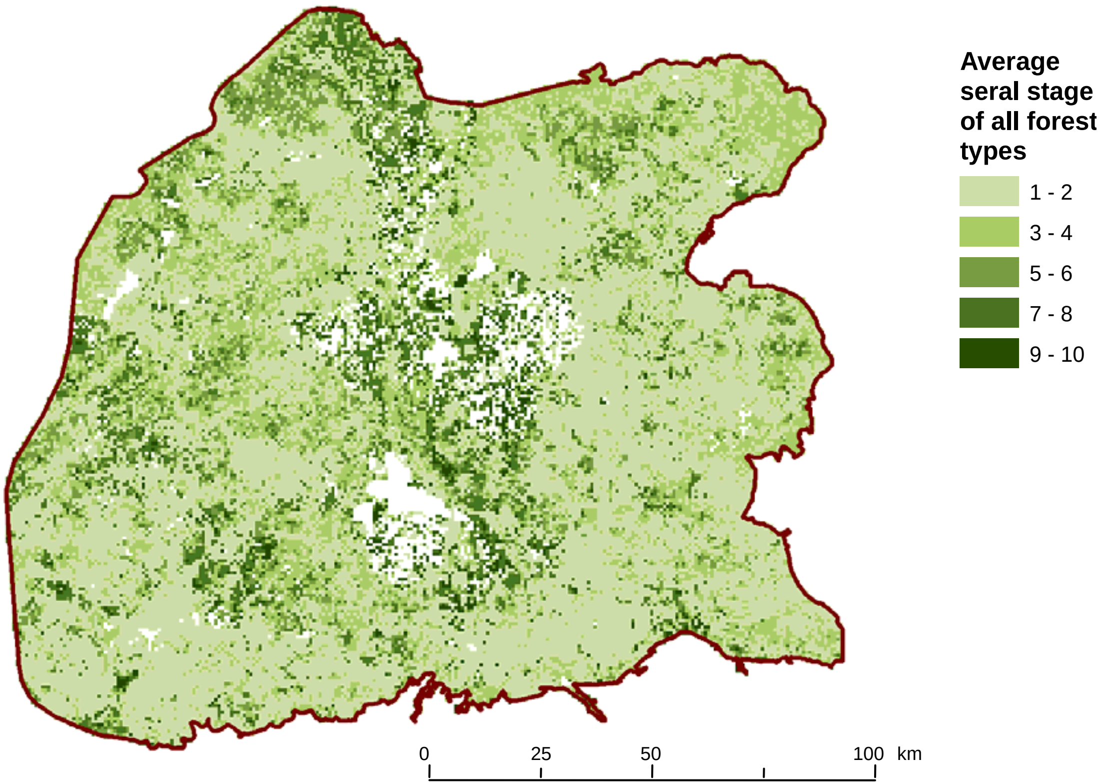

Figure 28. Potential future average forest seral stage (hardwood, mixedwood, pine, white spruce, closed black spruce forest, riparian, open black spruce fen, open fen and black spruce lichen moss) 2070.

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For more information, visit golder.com

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
102, 2535 - 3rd Avenue S.E.
Calgary, Alberta, T2A 7W5
Canada
T: +1 (403) 299 5600

Golder Associates