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Alberta

Biodiversity assessment in the Oil Sands region, northeastern Alberta, Canada

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The Oil Sands region of northeastern Alberta contains the world's largest reserves of oil, in the form of tar-sand. In the Oil Sands region, a large number of environmental impact assessments (EIAs) have been completed for approximately 20 oil sands projects in the past two decades. The EIA process here is unique, in that stakeholders in the region (First Nations, industry representatives, scientists, and residents) have selected indicators of ecological health of the area, including biodiversity. This paper discusses the process of biodiversity assessment using the indicators selected by stakeholders in relation to the overall goals to maintain biodiversity in the region.

Keywords: Oil Sands; environmental impact assessment; cumulative effects; stakeholders; reclamation; closure; residual effects; biodiversity; mitigation

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THE OIL SANDS REGION is located in northeastern Alberta, in western Canada, between latitudes 55 and 58 degrees north (Figure 1). This region contains the world's largest reserves of oil, in the form of tar-sand or bitumen. Synthetic crude oil, processed from raw bitumen, is projected to account for 50% of Canadian crude oil output and 10% of North American output by 2005.

The area is covered by mixed wood boreal forest, part of the largest relatively intact forested area on earth, and contains extensive peatlands (bogs and fens). Biodiversity is tied closely to the pattern and distribution of natural processes (predominately fire), that is responsible for the present arrangement of vegetation types in the region.

Approximately 20 environmental impact assessments (EIAs) have been conducted for oil sands projects since 1997. This large number in one region in less than two decades is unique in Canada.

Oil Sands projects are of two main types — surface mines and in-situ production. Where bitumen occurs near the surface (at less than 40 metres depth) the resource is extracted from surface mines. Bitumen occurring at depths greater than 40 metres is pumped out through wells by injection of high-pressure steam (in-situ production). Surface mining projects are large open pits accompanied by tailings ponds and a processing plant that occupy areas of up to 40,000 hectares. In-situ projects consist of well pads, roads and pipelines and cover areas of 1,000–20,000 hectares. Within in-situ project areas, the forested portion of the landscape is largely retained. Figure 2 shows simplified footprints of a surface mine (2b) and an in-situ project (2c).

Because of the rapid pace of development in the Oil Sands region, stakeholders have become concerned

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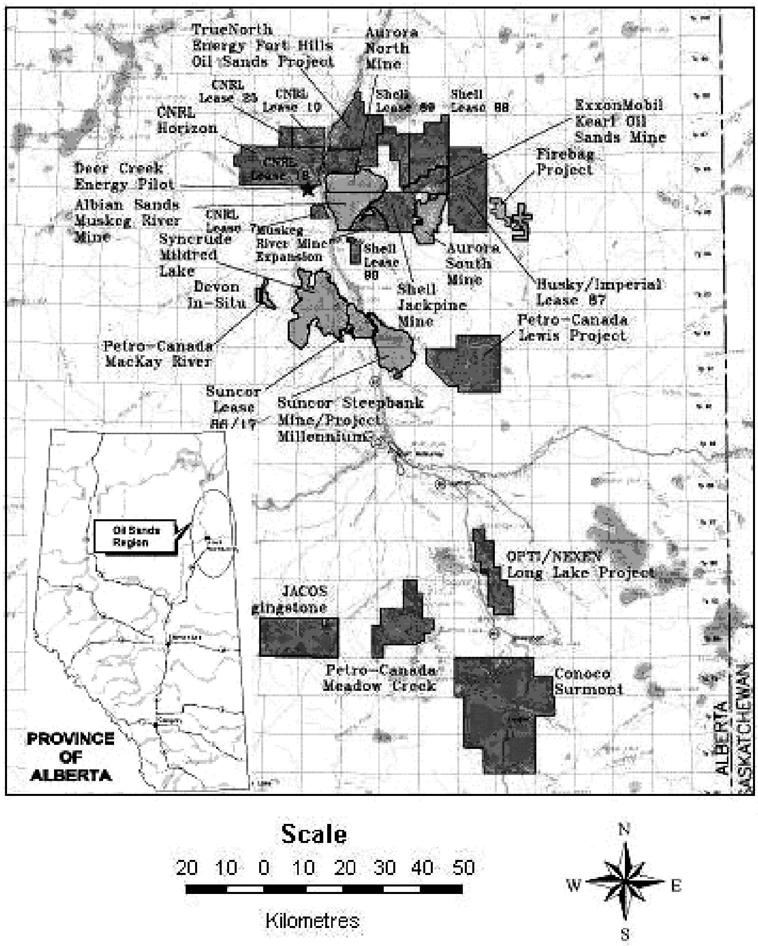

Figure 1. Oil Sands leases in north-east Alberta

about cumulative effects. This has led to the formation of the Cumulative Effects Management Association (CEMA), a stakeholder group consisting of First Nations, industry representatives, and the scientific community. This group has the vision of managing the cumulative effects of development within environmental limits (thresholds).

In support of this vision, CEMA has identified general areas of concern and information gaps in environmental protection in the region, and has set up a landscape and biodiversity subgroup within the Sustainable Ecosystems Working Group (SEWG) to address issues regarding vegetation, soil and landforms, watershed integrity and biodiversity. The long-term goal of SEWG is to “sustain the natural range of vegetation communities, species diversity and natural disturbance patterns, and the ecological processes at multiple scales” (Olson, 2001).

SEWG has worked with the provincial government regulators to determine which indicators of biodiversity should be addressed in EIAs in order to assess whether project-specific and cumulative effects will cause residual effects to biodiversity once the reclamation and closure of oil sands projects has occurred.

Regulatory context for EIAs in Alberta

The biodiversity component of EIAs for oil sand projects evaluates the potential impacts to biodiversity (among many other disciplines) on a project-by-project basis using biodiversity indicators. There are

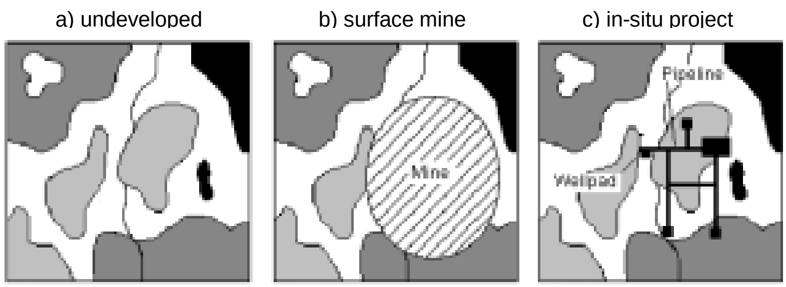

Figure 2. Comparison of a surface mine project footprint to an in-situ project footprint

three scenarios in the environmental assessments that use these indicators: project-specific, regional context, and cumulative effects (CEA). The project-specific assessment looks at the direct effects on habitat from project development. The regional assessment looks at the effect of the project in relation to a regional context. The cumulative effects assessment looks at the main biodiversity issues, such as landscape fragmentation, species movement and ecosystem health, where multiple projects over time are considered.

Project-specific and CEAs for oil sands projects are subject to review by the provincial environmental regulatory body, Alberta Environment, as part of the project-evaluation process pursuant to Sections 38 and 47 of the Alberta Environmental Protection and Enhancement Act (AEPEA), provincial legislation that includes evaluation of the assessment of biodiversity issues. The assessment of biodiversity in EIA is evaluated under AEPEA. The public, stakeholder groups and First Nations can submit supplemental questions for the biodiversity, wildlife and vegetation assessment sections of the EIA, requesting clarification of existing information or further information from the discipline-specific scientists (consultants) in the EIA process.

CEA is legislated under Section 47 of the AEPEA. For biodiversity impacts it evaluates the significance of impacts in consideration of other than just direct, local effects over a regional area. The magnitude, geographical extent, duration and frequency, degree to which the effects are reversible or irreversible, and the ecological context are evaluated.

The EIA review for biodiversity has been limited to the provincial process to date. The trigger for federal process in EIA is Section 35-2, the Fisheries Act, under the Canadian Environmental Assessment Agency (CEAA). However, the Fisheries Act applies only to rivers and lakes supporting fish species. Therefore, the federal process does not apply to terrestrial biodiversity.

Terms of reference for individual EIAs are formulated by the provincial regulatory body, Alberta Environment, with input from stakeholder groups, including CEMA. Figure 3 shows the relationship among the stakeholders, SEWG and CEMA, the regulatory body (Alberta Environment) and the EIA practitioners (environmental consultants). These interactions add value to the EIA process through ensuring that terms of reference evolve to reflect issues affecting biodiversity as identified by stakeholders in the Oil Sands region.

In the future, stakeholders may identify biodiversity components that are currently not measured, for instance, invertebrate species, to be incorporated into baseline data collection, and then evaluated in the biodiversity assessment. Changes that have occurred to the terms of reference in the past five years include a requirement to collect non-vascular plant species and aquatic macrophyte data, where previously only vascular plant species collection was required.

Biodiversity assessment process

Selection of key issues and questions

The key issues identified by SEWG relating to biodiversity conservation goals in the region are formulated

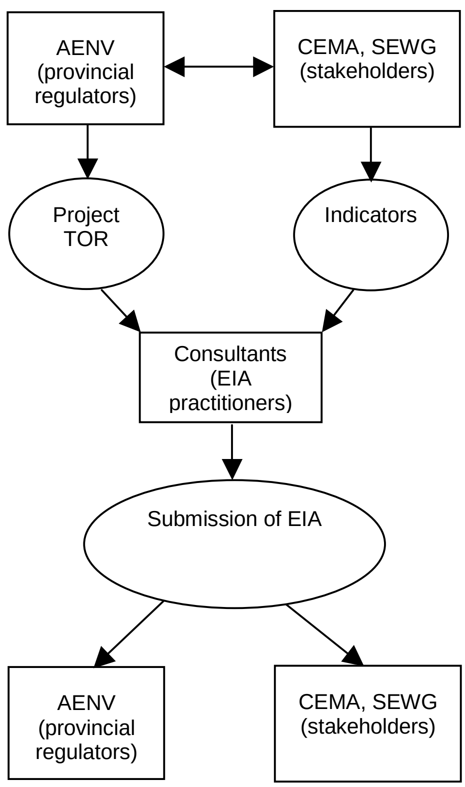

Figure 3. Alberta Oil Sands EIA process

Table 1. Project-specific key issues and questions

Level	Key issue	Key question
Landscape	Effects of a project on landscape-level biodiversity in the local study area and regional study areas	What are the effects of a project on landscape-level biodiversity in the local study area and regional study areas?
Ecosystem	Effects of a project on ecosystem-level biodiversity in the local study area and regional study areas	What are the effects of a project on ecosystem-level biodiversity in the local study area and regional study areas?

Table 2. Agreed biodiversity indicators

Level	SEWG indicators	Key issues
Landscape	Landscape structure[a] (distribution and patterns of vegetation classes)	Effect of disturbance and reclamation on the arrangement of vegetation classes on the landscape Changes to wildlife habitat, abundance and diversity
Ecosystem	Diversity and abundance of vascular and non-vascular plants and vertebrates Occurrence of listed (rare) plants and vertebrates Specificity of species to habitat Number of niches in an ecosystem	Changes in the diversity and abundance of vascular and non-vascular plants and vertebrates in reclamation ecosystems Changes in the occurrence of listed (rare) plants and vertebrates in reclamation ecosystems Changes in the specificity of species to habitat in reclamation ecosystems Changes in the number of niches in reclamation ecosystems

Note: [a] The landscape structure approach has been applied elsewhere in North America in gap analysis, where biodiversity potential for vegetation types is extrapolated from biodiversity plots in the same vegetation type (Scott et al, 1996) and used to identify gaps in land use systems to protect biodiversity

into key questions in the biodiversity assessment. These key questions are addressed in the EIA to determine the direction, magnitude, geographic extent, duration or active disturbance, frequency, and reversibility of individual effects in relation to the project and to the region as a whole, and to determine whether the project will result in residual effects (ecological effects remaining following mitigation) in the region (Table 1). There are two levels of biodiversity assessment: landscape and ecosystem.

Application of indicators

Agreed biodiversity indicators have been developed that relate to the key issues and questions and enable assessments to be focused to address these. The landscape-level and the ecosystem-level indicators (Table 2) were assessed by an independent consulting firm to determine how well they related to ecological function (flows of animals, plants, water in ecosystems) and structure (the relationship of species and abiotic components to landscape composition and arrangement) (Olson, 2001).

Indicators were also evaluated for sensitivity to development, measurability in a field setting, and applicability to the scale of investigation (for instance, a one hectare development would not be assessed using a regional scale fragmentation). The Olson (2001) report concluded that biodiversity indicators were good surrogates or measures for biodiversity.

The indicators developed by SEWG have been adopted by Alberta Environment and have been incorporated into biodiversity assessment since 2001. Consistent criteria to measure biodiversity are designed to ensure the impact assessment approach followed by EIA practitioners will allow regulators to compare the impacts among separate projects such that the long-term goal of maintaining ecosystem function in the region is realized.

The landscape level is a broad-scale view of the overall boreal forest (forest area, arrangement of vegetation types), whereas the ecosystem level looks at plant community species diversity, occurrence of rare species, and habitat specificity of species. Landscape-level and ecosystem-level SEWG indicators are sensitive to changes in the extent and distribution of vegetation types when coupled with information on other 'stressors', such as development (Scott, 1993; Scott *et al*, 1996). By using such indicators "as measurable surrogates for biodiversity" (Noss, 1990), the direct loss to vegetation classes in the biodiversity assessment in EIA at a project level ties back to the regional conservation initiatives and goals of SEWG.

Consistent criteria to measure biodiversity are designed to ensure the impact assessment approach followed by EIA practitioners allows regulators to compare the impacts among separate projects such that the long-term goal of maintaining ecosystem function in the region is realized

Table 3. Data sources for basic vegetation units for project-specific landscape-level biodiversity assessment

Data source	Description of data source
Alberta Vegetation Inventory (AVI)	Medium-scale mapping with forest stand attributes such as tree height, density and age, is obtained from the Forest Management Unit (FMU) holder in the area of interest
Field Guide to Ecosites of Northern Alberta (Beckingham and Archibold, 1996)	Classification of vegetation types in northern Alberta using plant community composition and site characteristics (that is, moisture regime, nutrient regime)
Alberta Wetlands Inventory (AWI) (Halsey *et al*, 2003)	Classification of non-peatland and peatland wetlands using features identifiable using large-scale aerial photography

Indicators of biodiversity, both landscape level and ecosystem level, are applied in a project-specific (local) study area (LSA) and a broader regional study area (RSA). The LSA (from 800 to 50,000 ha in area) is used to evaluate the direct project effects (that is, forest clearing) on biodiversity. It also includes areas where indirect effects, such as groundwater drawdown, are predicted to occur.

The RSA (from 1 million to 2 million ha in area) is used to evaluate project-specific effects in relation to other existing projects and cumulative effects from other projects planned, over a broad area. The RSA should be large enough to address effects on potentially unique or sensitive ecosystems. To address these effects, RSAs are defined using broad-scale landforms (for instance, ecodistricts) and wildlife home ranges. Important wildlife habitat for endangered species (for instance, woodland caribou home ranges) are also used to determine the RSA size and boundaries.

Vegetation types represent the basic units of landscape structure for project-specific biodiversity assessment in the LSAs. The plants and vertebrate species occurring in each vegetation type are used to determine whether a high, moderate or low level of biodiversity is present relative to other vegetation types in the LSA and RSA.

This ecosystem-level information is translated to the landscape level by using indicator measures on the ranked vegetation types to determine changes in the arrangement of these types in the LSA and RSA as a result of development. Changes in the arrangement of vegetation types ranked for biodiversity potential will also be measured for reclaimed lands following development. The mapping used for project-specific assessment in the LSA is derived from the data sources listed in Table 3.

At the RSA level, the landscape-level biodiversity indicators, selected by SEWG, are used to measure changes in landscape structure (for instance, number of patches of land-cover classes, number and area of forest patches) of the regional land-cover classes. The regional land-cover classes are determined from a supervised classification of Landsat Thematic Mapper (TM) satellite imagery with field checks. Supervised classification is a procedure in remote sensing where an analyst familiar with an area selects representative areas of known land-cover types on imagery and these are then used to classify the remainder of the imagery into the land-cover classes.

Biodiversity indicator measures

In the biodiversity assessments, landscape structure, species diversity and abundance in ecosystems (the agreed indicators listed in Table 2) are quantified using measures selected by SEWG (see Table 4). The biodiversity indicators are used in project-specific

Table 4. Biodiversity measures selected by SEWG

Level	SEWG indicator measures
Landscape level	The abundance and area of vegetation communities Distribution and arrangement of vegetation communities Level of fragmentation, edge, and vegetation connectivity Distribution and area of forest age classes Area, size and density of human-caused disturbance including density and distribution of linear features (seismic lines and roads) Area converted from forested to non-forested land (and vice-versa) Area of ecosystems that are regionally representative and ecologically viable (protected areas)
Ecosystem level	Abundance of vegetation types: uniqueness of regional vegetation classes based on relative abundance in the RSA Total species richness: total number of vascular (eg, herbs and forbs) and non-vascular plant species (eg, bryophytes and lichens), terrestrial and aquatic vertebrates in each vegetation type Species overlap: proportion (%) of plant species and terrestrial vertebrate species shared with other vegetation types (> 4 habitats shared) Rare species potential: potential for ecosystems to support listed plant species and wildlife species of special concern (ANHIC, 2002; COSEWIC, 2003) Structural complexity: measure of the number of layers comprising each vegetation type The number and distribution of native and non-native plant species

assessment to compare the landscape pre-project (baseline), and the landscape predicted to be present once mitigation has been completed (closure landscape). The relative level of biodiversity for each vegetation type at baseline is ranked high, moderate and low through combining plant, wildlife species, and aquatic species richness and diversity data.

To estimate the total number of species of terrestrial vertebrates (mammal, bird, amphibian and reptile), for each vegetation type, the wildlife species potential was based on regional field surveys and literature review. The habitat preferences for each species group are categorized according to the regional vegetation classes identified from remote sensing imagery (TM supervised classification).

The biodiversity potential is ranked according to scores for the SEWG ecosystem-level metrics by regional vegetation class. The biodiversity ranking for regional vegetation classes is applied to the ecosite phases and wetlands types that fall within the broader-scale regional land-cover classes (that is, these are ranked high, moderate, and low). The biodiversity potential for the regional vegetation classes is scaled to the ecosite phases and wetlands types using the proportional area of each ecosite phase and wetlands types within the broader regional class. Combining ecosystem-level species data from over ten oil-sands projects by EIA practitioners, has increased the confidence level in describing the biodiversity in each vegetation community compared to seven years ago when few project EIAs had been completed in the region, and vegetation, wildlife and aquatic species datasets were less complete.

Adaptive management approach

The assessment of biodiversity baseline is a snapshot of the ecological conditions that exist prior to a project. However, the ongoing monitoring of the plant, wildlife and aquatic species (that is required for all oil-sands projects) is anything but a snapshot in time. Species monitoring data is added into databases, cumulatively, so comparisons to baseline conditions from project operations and reclamation stages can be made. The parameters compared are the biodiversity indicators selected by SEWG. Only through monitoring of the SEWG indicators over time in the EIA process, from project inception to closure, will resource managers in the region know whether the long-term goals of SEWG, to maintain ecosystem function and biodiversity, have been realized.

The EIA terms of reference for project-specific biodiversity assessments are reviewed periodically by stakeholders and the academic community to ensure the assessment process is not static, but continually strives to meet regional conservation goals.

Cumulative effects assessment of biodiversity

Issues and key questions Cumulative effects occur when human-caused disturbance increases incrementally in an area over time. Cumulative effects is a challenge that must be addressed through continuing monitoring of ecosystems using indicator measures to meet SEWG's long-term goal for ecosystem function.

From the cumulative effects perspective, the key issues related to biodiversity and key questions posed in the EIA are presented in Table 5.

Challenges in CEA The practical challenges in the assessment of cumulative effects (the CEA case) are to measure biodiversity such that it meets the project-specific biodiversity assessments (the local scale) and the broader-scale regional conservation objectives as identified by SEWG, within the budget and timelines of the oil-sands operators (the clients of EIA practitioners).

One of the practical challenges faced by ecological EIA practitioners (environmental consultants) in the Oil Sands region is how to assess most accurately the cumulative effects resulting from multiple, large-scale projects occurring simultaneously on the landscape. The cumulative effects are a result of the combined oil-sands developments, forestry industry logging, conventional oil and gas development and transportation infrastructure (roads).

The accurate representation of disturbance as an indicator measure is desirable for stakeholders and regulators to present a clear picture of the cumulative effects in the region. With the overall goal of SEWG being to determine the effects of cumulative disturbance on biodiversity in the region, accurate information is essential.

The cumulative effects case assessed in EIA consists of the existing, approved, and planned project footprints. One constraint in CEA is that accurate boundaries of planned projects are not usually available at early stages of projects. Also, projects are confidential prior to public announcements, with little information available on project layout. In the CEA, the areas leased by proponents are typically used as

Table 5. Cumulative effects issues and key questions

Level	Key issue	Key question
Landscape	Changes to ecological land units (soil, terrain, wetlands and forest resources), both project-specific and regional in scope	What are cumulative effects of a project on landscape-level biodiversity in the LSA and RSAs?
Ecosystem	Changes to plant species and wildlife habitat, abundance and diversity	What are the cumulative effects of a project on ecosystem-level biodiversity in the LSA and RSAs?

a potential project footprint. Where the proponent develops only a portion of the land leased from the provincial government, the cumulative effects are overestimated. As a rule, to be conservative in landscape-level biodiversity assessment is preferable to underestimating cumulative effects.

Ecological effects and mitigation

Prior to large-scale oil-sands development (pre-1970), the landscape of the Oil Sands region comprised continuous forest and peatland areas with large burned areas from forest fires. The boreal forest landscape of NE Alberta is now characterized by surface mines, seismic lines from oil and gas exploration, wellpads, pipeline corridors and forestry cutblocks. The primary goal of the stakeholders in the region is to maintain ecosystem function in the face of this development and closely monitor ecosystem changes using the indicators already discussed.

Site reclamation and control of vehicle access are the main forms of mitigation for landscape-level effects on biodiversity. Reclamation of linear disturbance (that is, roads and seismic lines) required under provincial regulatory approval conditions, is a key mitigation measure to decrease human and other predator access to endangered species such as the woodland caribou.

Reclamation of disturbance to facilitate species movement through key habitat, such as peatlands and marshes, is a mitigation measure intended to restore species flow essential to ecosystem function and overall biodiversity following project operations. The ecosystem-level biodiversity indicators that are used to measure ecosystem function (such as species flow) indirectly are the diversity and abundance of vascular, non-vascular plants and vertebrates, the occurrence of listed (rare) plants and vertebrates. These indicators are measured on reclaimed landscapes in regional monitoring programmers funded by project proponents.

Generally, an important measure of landscape-level structure, connectivity, for species, increases as landscape fragmentation decreases. For example, pine marten, a fur-bearing mammal adapted to old forest habitat, does not cross cleared areas that are more than 50 metres wide between forest patches (Hargis *et al*, 1999). Reclamation of disturbance, a mitigation strategy required by regulators, is a concrete step that works toward the SEWG goal of maintaining species flow in ecosystems.

Seismic lines and roads can lead to an increase in human access compared to pre-development, underscoring the importance of reclamation and access management (that is, limiting employees use of off-road vehicles at oil-sands projects and timing project operations to avoid spring calving season). Species sensitive to such disturbance are those adapted to older forest stands and more open treed peatlands. At-risk species, such as the woodland caribou, can decline where wolves use human disturbance to access previously undisturbed areas (Dyer *et al*, 2001), thus encouraging regeneration of disturbance and designing projects to minimize disturbance is of prime importance. Mitigation of fragmentation supports the SEWG goal of maintaining species movement essential to ecosystem function.

Mitigation of disturbance is most cost-effective and ecologically beneficial when incorporated into project design at the project planning stages when project disturbance can be reduced by using existing linear disturbance and techniques such as low-impact seismic

Mitigation of disturbance is most cost-effective and ecologically beneficial when incorporated into project design at the project planning stages. At that time, the level of project disturbance can be reduced through re-use of existing linear disturbance and application of techniques such as low-impact seismic (a procedure where forest clearing is minimized) through the use of narrow, sinuous lines. Mitigation at this stage of in-situ projects can prevent irreversible effects to ecosystems though avoidance of peatlands.[1]

The relocation of wellpads for bitumen extraction away from peatlands onto upland vegetation classes that can be reclaimed can be an option with improving technology, such as directional drilling techniques. Baseline disturbance used for project-specific infrastructure will be reclaimed, thus reducing overall forest fragmentation in the landscape where baseline disturbance is common. On-going monitoring of seismic line regeneration using SEWG indicator measures is supported by industry, as it allows changes in forest fragmentation to be tracked in the region.

Closure of large surface mines, a process described in detail in the closure and reclamation plans, will result in a change in the arrangement of vegetation types of the landscape, with fewer peatlands, a larger proportion of upland vegetation types and large lakes. This process is being measured and monitored with the SEWG indicator measures for landscape structure in the region. Interspersed marshlands and uplands established after closure (with active reclamation and natural succession) will support functional ecosystems over time on reclaimed mine sites.

Peatlands are vegetation communities established on organic soils over several thousand years and cannot be reclaimed in the 80–100 year time period considered for reclamation in the Oil Sands region. Marshes, ponds and swamps, which regenerate relatively quickly, are expected to replace the peatlands that are removed for development.

It is important for regional biodiversity that peatlands be protected outside of development areas in the Oil Sands region because of the irreplaceable nature of these vegetation types as plant and wildlife habitat for species with high habitat specificity. The inability to reclaim peatland ecosystems — specifically tree-poor fens, and bogs — following disturbance has a negative effect on these moderate to high biodiversity potential ecosystems in the RSA, and thus is recorded as a residual effect in EIA from Oil Sands projects.

A central question directly related to changes in landscape structure, is whether or not the reclaimed mines will support a comparable level of biodiversity to that existing prior to disturbance. Biodiversity of the baseline vegetation classes compared to the vegetation types after reclamation and closure will change where peatlands are reclaimed to non-peatlands such as swamps, riparian areas and marshes.

The guidelines for the reclamation of terrestrial vegetation in the Oil Sands region (Oil Sands Vegetation Reclamation Committee, 1998) suggest strategies to attain ranges of biodiversity similar to pre-disturbance values. One approach is that closure landforms should be "spatially variable" such that a range of ecosystems becomes established. Other strategies are preservation of refugia within mining areas and ensuring species native to the area are used in reclamation. Monitoring of reclamation, as detailed in EIA, incorporate indicators (vascular plant composition) sensitive to long-term stressors, such as climate change, and those sensitive to short-term disturbance (landscape-level indicators).

At present there are several monitoring programs in the region related to project approval conditions (for instance, monitoring of water table drawdown in wetlands, seismic line reclamation, caribou population monitoring).

Individual project life times for surface mines range from 25 to 40 years, with reclamation and closure extending for an additional 60 years. Therefore ecosystem processes over these areas of the Oil Sands region will have low levels of function until the reclamation of the sites and establishment of the vegetation types detailed in the closure and reclamation plans in the mitigation stage.

The landscape at closure, more than 100 years from project start-up, is planned through a multi-stage process starting with the EIA and collection of detailed baseline data, multi-disciplinary development of the closure and reclamation plans, and monitoring of reclamation by the operators and government regulators over time. The process of restoring biodiversity to areas affected by in-situ projects is expected to be more rapid than areas with mining, since, with in-situ projects, most forest remains in place, acting as a source for species recolonization on linear disturbance (for instance, reclaimed roads).

The landscape in the Oil Sands region is affected by linear disturbance features (for instance, seismic lines, roads) and contiguous features (for instance, mines, forestry cutblocks). In a biodiversity context, the landscape structure affects connectivity between habitats through affecting wildlife species' movement (specifically foraging and reproduction). The aim of stakeholders is to ensure that changes in number of species, and species adapted to reclaimed vegetation types and disturbance are closely monitored using the ecosystem-level indicator measures (SEWG) to ensure that 'threatened' or 'at risk' species, adapted to the boreal forest are not lost over time.

Summary and conclusions

In the Oil Sands region, an integrated approach to resource management, where stakeholders and regulators have worked together in the selection of biological indicators to measure the potential ecosystem effects from cumulative development, has been developed quite recently and integrated with biodiversity assessment in EIA. Ongoing involvement of SEWG, a stakeholder group consisting of First Nations, the scientific community, industry representatives and provincial regulators, is essential to maintain linkage among the scientific community, resource management policy, and the people using the land for traditional uses.

EIA practitioners in the region must continue to collect terrestrial and aquatic biodiversity data from ecosystem field monitoring programs throughout the reclamation and closure phases of the oil sands projects, to provide current information on biodiversity to resource managers throughout the reclamation and closure stages of the multiple projects. Adaptive management in reclamation procedures may be necessary in response to ecosystem data collected in the terrestrial and aquatic monitoring programs in order to move towards SEWG's long-term goal of sustainability of species of flora and fauna.

The measurement and monitoring of ecosystem indicators selected to meet regional conservation objectives, as specified in the approval conditions from regulators, is designed to ensure the landscape continues to function in such a way as to protect biodiversity over time. Particular attention should be given to species interaction with the landscape (for instance, changes in predator–prey relationships, changes in abundance of exotic or invasive species, and occurrence of rare species) as these are important indicators of potential landscape-scale ecosystem changes that could occur as a result of incremental development in the region.

Biodiversity is tied closely to the pattern and distribution of natural processes such as fire frequency, which have regenerated the boreal forest for thousands of years. SEWG and the scientific community is closely monitoring the changes in the area of forested land compared to disturbance from oil-sand mining operations, to determine whether fire frequency will change over the next century as a result of the cumulative area occupied by oil-sands operations in various stages of reclamation. SEWG has been working toward determining thresholds for measured indicators (such as fire frequencies) to provide guidance on the ultimate level of development the regional ecosystems can accommodate without widespread loss in ecosystem function.

Note

1. Peatlands are wetlands characterized by the accumulation of sphagnum mosses that decompose slowly and incompletely over thousands of years to form organic deposits greater than 0.4 metres and up to 10 metres deep in places.

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