Effects of Industrial Disturbance on the Traditional Resources of the Blueberry River First Nation

Prepared for

Blueberry River First Nation

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Prepared by

MSES

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Executive Summary

The Blueberry River First Nation (BRFN) is concerned about the rapid pace of development in their traditional territory. In order to fully understand how much of the BRFN's original traditional lands and resources have been impacted to date, and how impacts of further development will act in a cumulative fashion, measurements are needed to provide quantifiable information on past, present and future landscape disturbances. Therefore, the BRFN has requested that Management and Solutions in Environmental Science (MSES) undertake a time-series disturbance analysis of parts of their traditional lands. MSES compiled and reviewed data regarding past and present availability of undisturbed lands in the BRFN Consultation Area, hereafter referred to as the study area.

The rate of conversion from natural land surfaces to industrial ones between 1993 and 2011 in the study area was calculated by means of Landsat5 satellite imagery and SPOT image analysis. SPOT images are fine resolution satellite imagery but are not readily available for the area of interest prior to 2006 or after 2009. Hence, we first used the Landsat imagery to gain an understanding of the relative change in land cover from 1993 to 2011, and then we used the SPOT imagery to gain an understanding of how much the lower resolution Landsat imagery leaves undetected. The compiled data were used to calculate current and plausible future scenarios for traditional resource availability and use in the study area. Lastly, we have also included an analysis which looks at fragmentation effects that could lead to changes in the ecosystem. If the change in landcover moves the ecosystem to a different state, then First Nation traditional resource use may become unsustainable. The measurements and predictions in this report can be used as the foundation for future land management decisions and regional policy development.

The key findings of our analyses are:

1) The Landsat image analysis indicates that as of 2011, 59% of the land in the study area is either directly disturbed by industrial activities, or within 250 m of an industrial feature. However, the fine resolution SPOT image analysis indicates that the Landsat images underestimate the actual disturbance and that as of 2011, 66% of land cover in the BRFN study area was disturbed as a result of the high density of linear industrial features and land clearing.

2) The linear disturbance density in the study area is 1.58 km/km^2. Given the level of land disturbance and linear density, populations of traditional wildlife species could exist at low densities or may have ceased to be viable.

3) We estimated (multiplying the Landsat time series results by a correction factor based on the underestimation derived from the SPOT image analysis) that in the past 18 years, an average of 136 km^2 of undisturbed area has been removed each year from the BRFN study area as a result of industrial activity and development. At this rate, by the year 2060, there will be no land left in the BRFN study area that is farther than 250 m from any industrial feature.

4) The landscape disturbance process in the BRFN study area is likely approaching an asymptote of maximum fragmentation. Further development in the BRFN study area is anticipated and current

land management decisions will determine whether future regional landscapes will maintain functional ecosystems for the continued practice of Treaty rights.

5) Disturbed lands are unlikely to be reclaimed to pre-disturbance conditions. There is very little similarity in terms of species composition between reclaimed sites and natural stands. Reclaimed sites show an unnaturally low diversity of species.

6) Further analyses should be conducted to address management of specific traditional resources (e.g. moose, beaver, and waterfowl).

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ACRONYMS

BRFN	Blueberry River First Nation
C&R	Conservation & Reclamation
CEMA	Cumulative Environmental Management Association
EIA	Environmental Impact Assessment
LFH	Litter, Fermentation and Humus
MSES	Management and Solutions in Environmental Science
ZOI	Zone of Influence

1.0 Introduction

The Blueberry River First Nation (BRFN) is concerned about the rapid pace of development in their traditional territory. In order to fully understand how much of the BRFN's original traditional lands and resources have been impacted to date, and how impacts of further development will act in a cumulative fashion, measurements are needed to provide quantifiable information on past, present and future landscape disturbances. Therefore, the BRFN has requested that Management and Solutions in Environmental Science (MSES) undertake a time-series disturbance analysis of parts of their traditional lands. MSES compiled and reviewed data regarding past and present availability of undisturbed lands in the BRFN Consultation Area, hereafter referred to as the study area.

For the purpose of this report, we assume that natural land cover contains traditional resources, including the vegetation and the wildlife, required to exercise traditional resource use that are of concern to the BRFN. This is in contrast to industrial surfaces which do not provide opportunities for traditional resource use. The rate of conversion from natural land surfaces to industrial ones between 1993 and 2011 in the BRFN study area was calculated by means of Landsat5 satellite imagery. Additionally, several SPOT images were used to analyze recent land disturbance at a finer scale (see Appendix A, Sec. A1.3). The compiled data were used to calculate plausible future scenarios for traditional resource availability and use in the study area. Lastly, we also included an analysis which looks at fragmentation effects that could lead to changes in the ecosystem. If the change in landcover moves the ecosystem to a different state, then First Nation traditional resource use may become unsustainable. The measurements and predictions in this report can be used as the foundation for future land management decisions and regional policy development.

2.0 Study Area

The BRFN informed MSES that they would like to better understand potential development scenarios in what has been designated the BRFN Consultation Area (Figure 2-1 prepared by the BC Oil and Gas Commission and issued on April 14, 2011). However, this area does not necessarily represent all BRFN traditional lands, which actually extend into Alberta (Bouchard & Kennedy Research Consultants 2011a).

The BRFN have expressed concerns regarding the level of various development-related activities in their traditional territory and how the development continues to impact traditional land use activities (Bouchard & Kennedy 2011b). It should also be noted that the analysis completed in this report only examines levels of industrial footprint disturbance in the BRFN Consultation Area and does not consider specific traditional use activity, such as hunting, trapping, fishing, gathering areas, camping, meeting areas and travel routes that have been presented, in part, elsewhere (e.g., Bouchard & Kennedy 2011b). MSES understands that BRFN have concerns with BC Hydro's proposed Site C Clean Energy Project, a dam and hydroelectric generating station on the Peace River located approximately 7 km southwest of Fort St. John, B.C. These concerns include effects from increased access by non-Aboriginal peoples for hunting and fishing; increased disturbance to the land, wildlife, vegetation and water; and social impacts (Bouchard & Kennedy 2011b). The analysis presented in this report is the first step in quantifying land use change and the resulting potential impacts to traditional land use activities from further development in the BRFN Consultation Area.

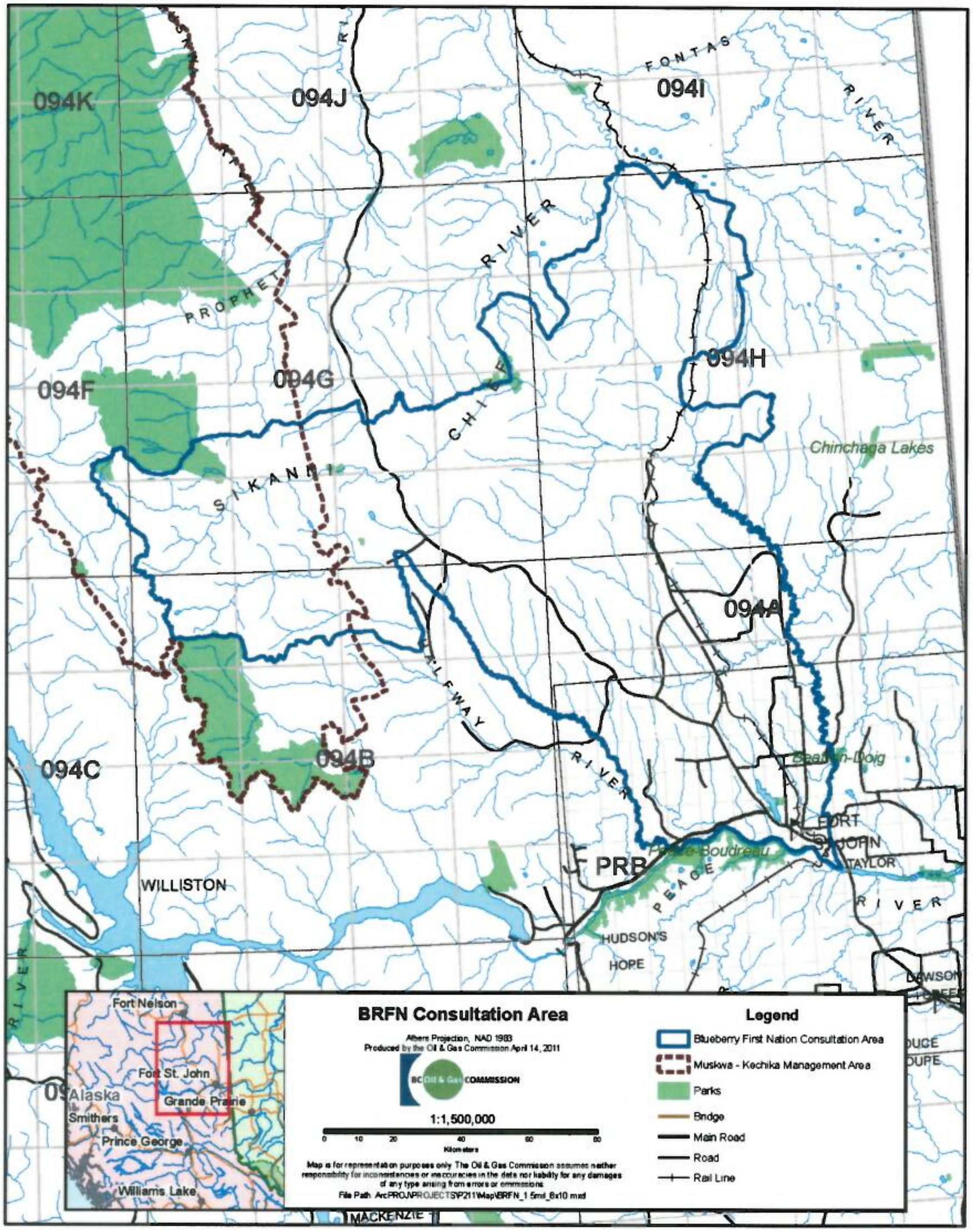

Figure 2-1 Location of the BRFN Consultation Area

3.0 Industry Impacts on Conditions Supporting Traditional Resources

Key Finding: The Landsat image analysis indicates that as of 2011, 59% of the land in the study area is either directly disturbed by industrial activities, or within 250 m of an industrial feature. However, the fine resolution SPOT image analysis indicates that the Landsat images underestimate the actual disturbance and that as of 2011, 66% of land cover in the BRFN study area was disturbed as a result of the high density of linear industrial features (1.58 km/km^2 linear disturbance) and land clearing.

This section focuses on the "deprivation of traditional lands". "Traditional lands" refers to the natural land surfaces and resources, including the vegetation and the wildlife, required to exercise traditional resource use, as opposed to industrial surfaces which do not provide traditional resources. Here, we view the ability to use traditional resources as a service provided by the ecosystem to human society (see discussion by Schindler and Lee 2010).

3.1 Past and Current Disturbances

3.1.1 Identifying the Industrial Footprint

The rate of converting natural land surfaces to industrial/disturbed ones was calculated by means of satellite imagery. Using a series of satellite Landsat5 images we calculated the yearly rate of converting natural surfaces to industrial ones from 1993 to "present" (as captured in the satellite image of 2011). We applied a change analysis using data processing based on the image algebra method which allows one to compute the change in each pixel between two images of different dates (see Appendix A for detailed methods). Both linear and non-linear disturbances were included in the disturbance analyses. The disturbance analysis does not include damage from natural disturbances such as fire or wind storms.

For linear disturbances that may not be detected by the 30 m resolution of Landsat images, we used cloud-free SPOT images of the same area from 2006 to 2009 (Appendix A, Sec. A1.3). SPOT images are fine resolution satellite imagery with a resolution of 10 m. However, SPOT imagery is not readily available for the area prior to 2006 or after 2009. Therefore, we first used the Landsat imagery to gain an overall understanding of the relative changes to the landscape from 1993 to 2011. Although we do not have 2011 SPOT data available, we were able to use the SPOT images from 2006 to 2009 to calculate any additional disturbances on the landscape that may have gone undetected with the Landsat images. The difference between the SPOT analysis and Landsat analysis provided us with a correction ratio that could be used to "correct" the Landsat data.

3.1.2 Identifying the Zone of Influence

In our ecological research and evaluations, we typically find that animals avoid the area near industrial activities. This area is typically called a "zone of influence" (ZOI). Based on our experience working with First Nations, we understand that traditional land users also avoid the areas near industrial activities. Consequently, in addition to analyzing the effects of direct vegetation clearing and the simple length of linear corridors, we have applied a ZOI around each disturbance footprint and each linear industrial feature.

Both the Alberta and the British Columbia provincial resource management agencies have adopted a 250 m buffer (zone of influence) when developing land use plans relating to industrial activities (ASRD 2009, Thiessen 2009).

The distance of 250 m was chosen for several reasons, including the following:

- hunting is not permitted within 100 m of an occupied church, school, playground, park, dwelling house or farm/ranch building (BC Government 2012);
- moose presence near roads is reduced within 200 m (Rolley and Keith 1980) to 500 m (Laurian *et al.* 2008);
- moose suffer higher mortality from wolf predation near trails (median distance of kills was 209 m, compared to random sites at 470 m, Kunkel and Pletscher 2000);
- caribou avoid industrial features within about 250 m (Dyer *et al.* 2001);
- the viability of caribou populations could be compromised when more than 61% of the landscape is within 250 m of industrial features (Sorensen *et al.* 2008);
- other mammals avoid industrial features within about this distance (Forman *et al.* 2003);
- birds in woodlands avoid roads, power lines and seismic lines by up to about 300 m, depending on species and ecological context (Kroodsma 1982, Bayne *et al.* 2008, Machtans 2006); and
- comprehensive reviews of edge responses show that "abiotic and plant responses are generally reported to extend up to 50 m into patches, invertebrate responses up to 100 m, and bird responses 50–200" (Ries *et al.* 2004, p. 510).

Clearly, the ZOI differs widely between the species, the type of industrial features and related activities, and the ecological context (i.e., species, reproductive cycle, hunting or predation regimes, habitat structure and quality). However, it appears that, in absence of detailed information on any of the situations, the 250 m distance is a reasonable approximation for a zone within which the abundance of wildlife and the land use by humans may be altered.

3.1.3 Results

Landsat Image Analysis

Assuming that the disturbance includes a ZOI of 250 m from any industrial feature, of the 19, 691 km^2 BRFN study area, Figure 3.1-1 shows the progression of disturbance (linear and non-linear) as follows:

- as of 1993, 48% was disturbed;
- as of 2001, 54% was disturbed; and
- as of 2011, 59% was disturbed.

This analysis indicates that currently, 59% of the land in the study area is either directly disturbed by industrial activities, or within 250 m of an industrial feature. Overall, the total land disturbance from 1993 to 2011 in the study area has increased by 11% according to Landsat imagery.

SPOT Image Analysis

When including the more detailed SPOT image analysis, it appears that the results shown in the Landsat analysis underestimates the amount of disturbance in the study area by approximately 11%. Using this information, we can calculate a correction factor based on the underestimation derived from the SPOT image analysis and use it to 'correct' the 2011 Landsat information. Figure 3.1-2 shows how much disturbance is underestimated between Landsat versus SPOT imagery. Using the correction factor from the SPOT image analysis (1.12), the results show that 66% of the land cover in the study was on or within 250 m of an industrial feature (as compared to 59% calculated from Landsat images in 2011). This SPOT correction factor was used in all predictions of future development scenarios (see Section 3.2.1 below).

In terms of linear disturbance, we calculated that from 1993 to 2011 (Landsat plus SPOT), there was a grand total of 31, 089 km of linear corridors in the study area, representing a linear disturbance density of 1.58 km/km^2. To put this density into perspective, density thresholds of linear corridors as low as 0.3 to 0.8 km/km^2, depending on the ecological context, have been shown to exclude wildlife populations such as caribou from an area (Weclaw & Hudson 2004). Likewise, moose have been shown to avoid roads and trails (Laurian *et al.* 2008, Kunkel and Pletscher 2000) or have decreased occurrence in association with increasing linear density (Snaith *et al.* 2002).

Consequently, with 66% of land on or near industrial features and 1.58 km/km^2 linear disturbance, wildlife species, such as moose, can likely only persist at very low densities under these land disturbance conditions, if at all.

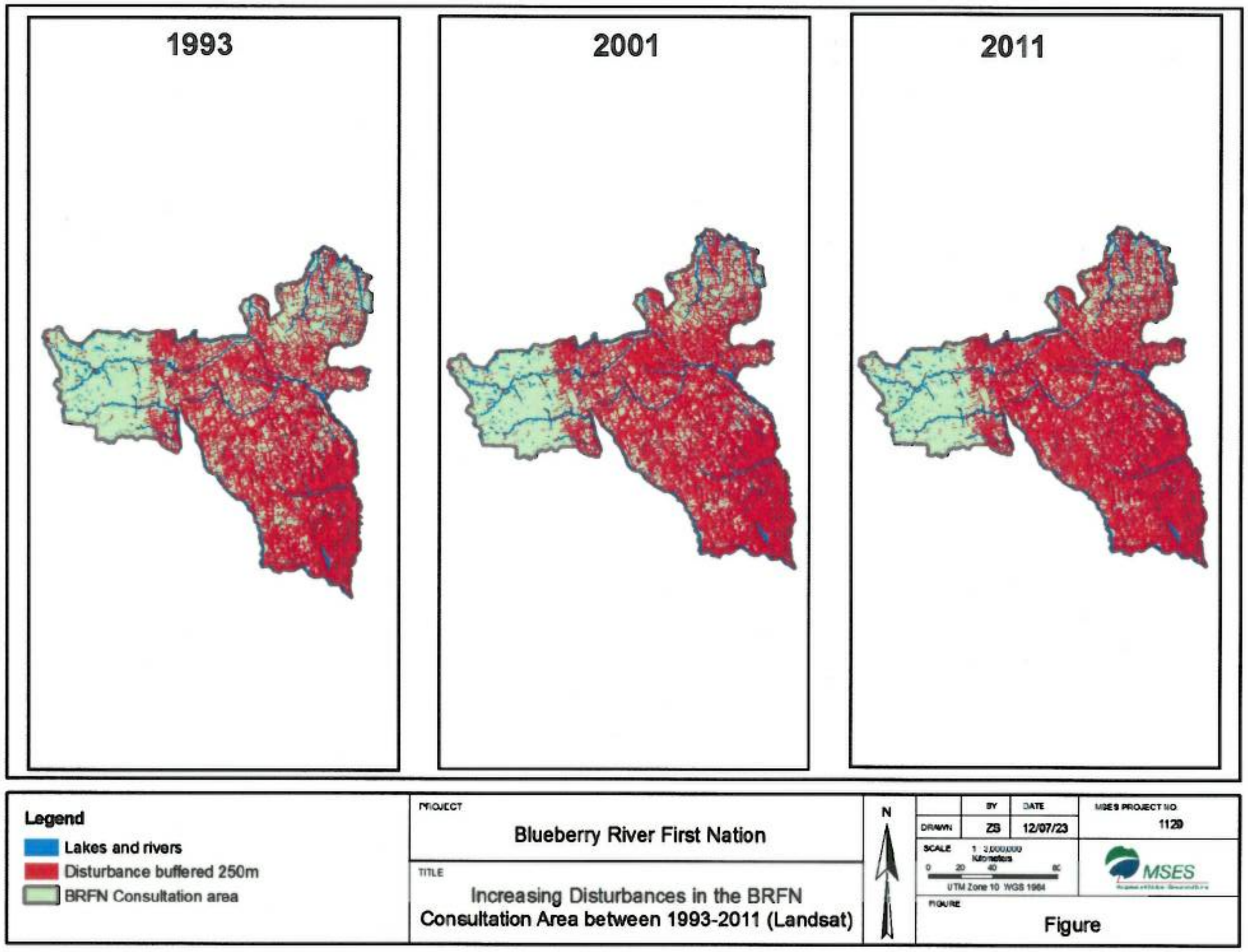

Figure 3.1-1: Increasing conversion of natural surfaces (green) to industrial ones (red) in BRFN study area. (Includes 250 m ZOI around all industrial features and is based on Landsat image analysis.)

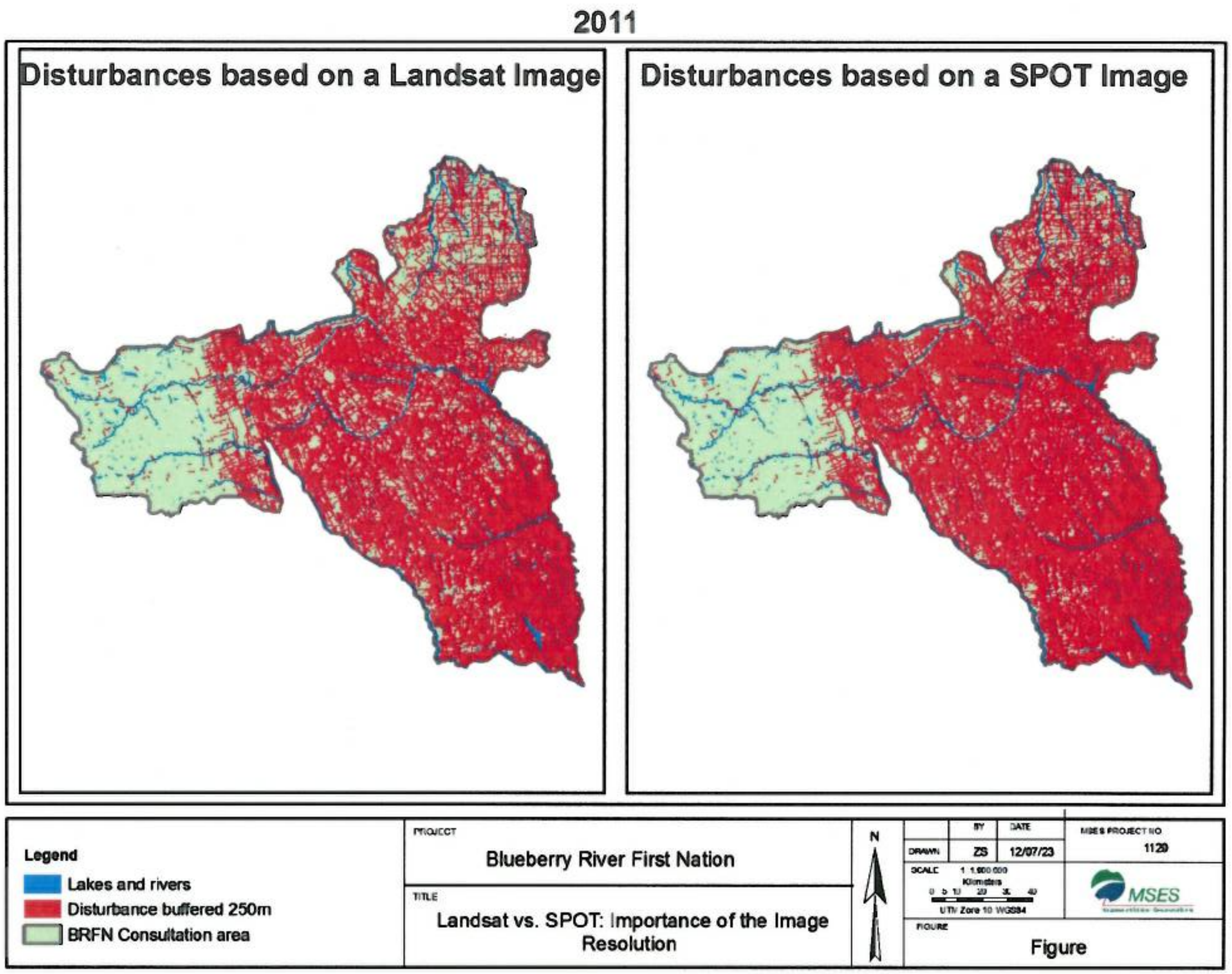

Figure 3.1-2: Most recent disturbances in the BRFN Consultation Area using Landsat plus SPOT data (right panel) compared to only Landsat data (left panel).

3.1.4 Conservative Use of Data

A major challenge in obtaining data detailed enough to capture all disturbance data lies in the fact that Landsat images do not capture small human caused changes. However, although we were able to determine and apply a correction factor to the Landsat data based on the SPOT image analysis, it is very likely that we are still underestimating the level of disturbance in the BRFN study area because we were unable to obtain SPOT images after 2009.

While the analysis of SPOT images enables us to capture linear disturbance with high accuracy, we were unable to apply the same level of detail to the analysis of non-linear developments. For example, well pads are difficult to capture on satellite images and we believe that we may have omitted numerous well pads in the analysis of disturbance of the BRFN study area. Other small disturbances such as staging areas, sumps, or workers camps may not have been detected as a disturbance.

3.2 Projected Decrease of Natural Surfaces

Key Finding: We estimated (multiplying the Landsat time series results by a correction factor based on the underestimation derived from the SPOT image analysis) that in the past 18 years, an average of 136 km^2 of undisturbed area has been removed each year from the BRFN study area as a result of industrial activity and development. At this rate, by the year 2060, there will be no land left in the BRFN study area that is farther than 250 m from any industrial feature.

3.2.1 Rate of Disturbance and Future Projections

Landsat image analysis indicates that over the past 18 years, the study area saw an average annual addition of 121 km^2 (0.6% of the study area) of new disturbance. However, analysis of SPOT images shows that the Landsat images leave an approximate 11% of the disturbance undetected. We can therefore estimate (multiplying the Landsat results by a correction factor of 1.12) that the actual yearly disturbance was on average 136 km^2 (0.7%). To gain an understanding of potential disturbance levels in the future, we assumed that the rate of change will remain constant and we applied trend lines to the data. Whether or not our assumption regarding a constant rate of change is accurate will depend upon future land management decisions. However, we are aware that development in the BRFN study area is growing, including new energy projects and supporting activities such as exploration and infrastructure (B.C. Government 2011 website http://www.energyplan.gov.bc.ca/bcep/default.aspx?hash=9) which supports our assumption that the rate of disturbance will not likely slow anytime soon. Therefore, if the rate of change remains constant, the conversion of natural land cover to industrial surface will be 100% in the study area by approximately 2060 (Figure 3.2-1). In other words, after 2060, there will be no area left in the study area where a person could go to be farther than 250m away from an industrial feature.

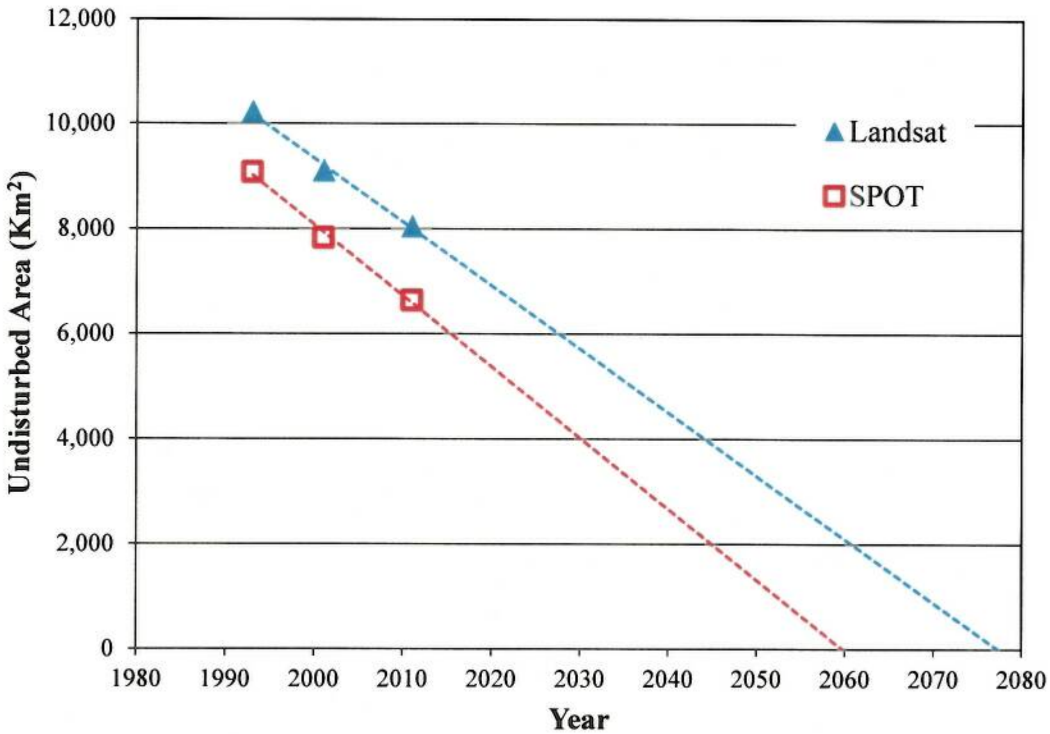

Figure 3.2-1: Projected disturbance in the BRFN study area, based on Landsat and SPOT image analysis, including ZOI. Linear best fit trend lines were calculated in excel. Solid blue symbols = measurements from Landsat imagery; Open red symbols = derived from the ratio of Landsat:SPOT correction factor.

Although reclamation is the main mitigation for habitat loss from industrial development, we have not included reclamation in our analysis because there does not appear to be any data showing that the continued addition of new disturbance is currently countered by reclamation. Our experience with reviewing Conservation and Reclamation plans (C&R) for various projects in B.C. and Alberta indicate that not all vegetation types are targeted for reclamation and those that are show little similarity with pre-disturbance conditions (see Section 4.0 below, and Johnson and Miyanishi 2008). For example, a report presenting the history of reclamation on Suncor leases in the Alberta oil sands region (Golder 2007) showed that the communities which develop in reclamation sites are not comparable to pre-disturbance communities:

> "It was found that areas seeded with agronomic species continued to be dominated by these species, even on reclamation sites over 20 years old, thus producing a very different ground cover species composition than on adjacent forest areas. Native species were only common in areas that had not been seeded with agronomic species (AGRA 1996b). Forest growth after 100 years on reclaimed sites at Suncor was predicted to be slightly lower (i.e., trees slightly smaller) than on adjacent natural forest areas (AGRA 1996b)." (p.32)

> "Winter tracking surveys conducted in 1999 and 2000 identified 15 wildlife species groups on the Suncor lease areas including: mice and voles, red squirrels, snowshoe hares, fishers, martens, weasels, minks, river otters, lynx, coyotes, wolves, foxes, deer (white-tail and mule), moose and grouse (including ptarmigan) (Suncor 2000c, 2001a). Wildlife use was observed to be higher in undisturbed areas than reclaimed areas, with reclaimed areas being used mainly by coyote, small mammals and grouse." (p.48).

The concern that reclamation may not re-create pre-disturbance habitats needs to be addressed by collecting scientifically rigorous data and comparing such data with established thresholds or targets to demonstrate the effectiveness of the mitigation efforts. Given that the reclamation methods are standard (whether the project is in Alberta or B.C.), the same issues apply to the BRFN study area where data has shown that the current reclamation practices (i.e. planting trees and shrubs, seeding with grasses, natural recovery) do not return the full suite of pre-disturbance plant species and vegetation types (i.e. ecosite phases and wetland types) to the reclaimed landscape.

3.3 Ecosystem Process

Key Finding: The landscape disturbance process in the BRFN study area is likely approaching an asymptote of maximum fragmentation. Further development in the BRFN study area is anticipated and current land management decisions will determine whether future regional landscapes will maintain functional ecosystems for the continued practice of Treaty rights.

Ecosystem shifts occur when external forces alter a system so that its organization shifts from one set of processes to another (Gordon *et al.* 2008). Folke *et al.* (2003, p.354) define ECOLOGICAL RESILIENCE as "the magnitude of disturbance that can be experienced before a system moves into a different state and different set of controls". These researchers argue that natural and human systems are combined as one social-ecological system and that ecosystems need to be managed to sustain the social systems. They define SOCIAL RESILIENCE as "the ability of human communities to withstand external shocks to their social infrastructure, such as environmental variability or social, economic, and political upheaval". If the environmental variability represents a great shock to the social infrastructure, then the social structure will break down. If the environmental variability moves the ecosystem to a different state then the First Nation traditional resource use will be unable to sustain that shock and will need to change.

Given the amount of natural land cover converted to industrial areas (see Section 3.1.3) in the BRFN study area, it is plausible that the ecosystem in the BRFN study area may have already shifted to a different state; that is, a landscape made up of very many, very small and isolated patches of natural surfaces. To visualize the effect of vegetation clearing on natural surfaces in a real landscape, we used township data from the Alberta Oil Sands region, an area that is heavily disturbed by oil and gas activity to generate a data set that includes the number of patches and mean patch size by township. Township data was not readily available for the BRFN study area. We calculated the number of patches of natural surfaces and the average patch size for each of the 34 townships in the mineable Oil Sands Region using Patch Analyst, ArcGIS 9. We also calculated the amount of natural surface disturbed in each township. Results are shown in Figures 3.3-1 and 3.3-2 (represented by blue diamond symbols).

These calculations show that fragmentation of natural surfaces increases exponentially with the amount of natural surface conversion (see Appendix B for methodology). The results are consistent with theoretical predictions in landscape ecology (Andrén 1994, Hargis *et al.* 1998). Therefore, we can use these findings in a comparison with snapshots of the entire BRFN study area in 1993, 2001, and 2011 (including SPOT corrected Landsat for 2011). Based on the SPOT corrected Landsat data and the best fit regression model from the Oil Sands region data, the number of patches in the landscape in the BRFN study area appears to be nearing its maximum (Figure 3.3-1) indicating that patches of undisturbed habitat could be on a trajectory of being entirely removed from the landscape. Furthermore, the average size of patches in the BRFN study area appears to be nearing its minimum (Figure 3.3-2). Therefore, the required travel distance from one patch to another could be nearing a maximum where, even if any patch is reached, it is small and likely isolated.

Based on landscape ecology theory and the calculated elimination of natural surfaces, the landscape in the BRFN study area may have already entered a new state of configuration of natural vegetation patches that could lead to a new scheme of ecological processes (Scheffer *et al.* 2001; Gordon *et al.* 2008). Open spaces and habitat edges or ecotones could now dominate the landscape and areas large enough to be considered intact expanses of boreal forests may no longer exist (Potapov *et al.* 2008 defined intact forests as areas of at least 500 km^2 without significant human activity). Concurrently, if the BRFN study area becomes dominated by disturbed edges and smaller patches, core wildlife habitat will eventually disappear or become rare. The advancement of disturbance can also lead to the invasion by other species, including deer and magpies (Dawe and Boutin 2009; BC Ministry of Environment, Lands and Parks 2000). Invading deer change wolf-prey dynamics (Latham et al. 2011), and the invasion of natural vegetation communities by invasive plant species is believed to be a considerable impact caused by disturbance (White *et al.* 1993, ASRD 2004). Early warning signals for ecological transition, such as increasing variance of environmental parameters (natural variability), may well be accessible and measurable (Landres *et al.* 1999; Carpenter and Brock 2006, Scheffer *et al.* 2009), but the system controls in the BRFN study area are not sufficiently known to quantify the change.

Oil and gas development proponents often state that their disturbance (which in our view cause ecosystem shifts) can be reversed. However, as discussed below (Section 4.0) there is no verifiable evidence of successful re-establishment of natural vegetation communities to pre-disturbance conditions which would allow for traditional land use to resume. In fact, future development could push the ecosystem into a substantial and long-term reorganization which is understood by many as an ecosystem or regime shift (Scheffer *et al.* 2001; Carpenter and Brock 2006; Gordon *et al.* 2008; Scheffer *et al.* 2009; Gamerstani *et al.* 2009).

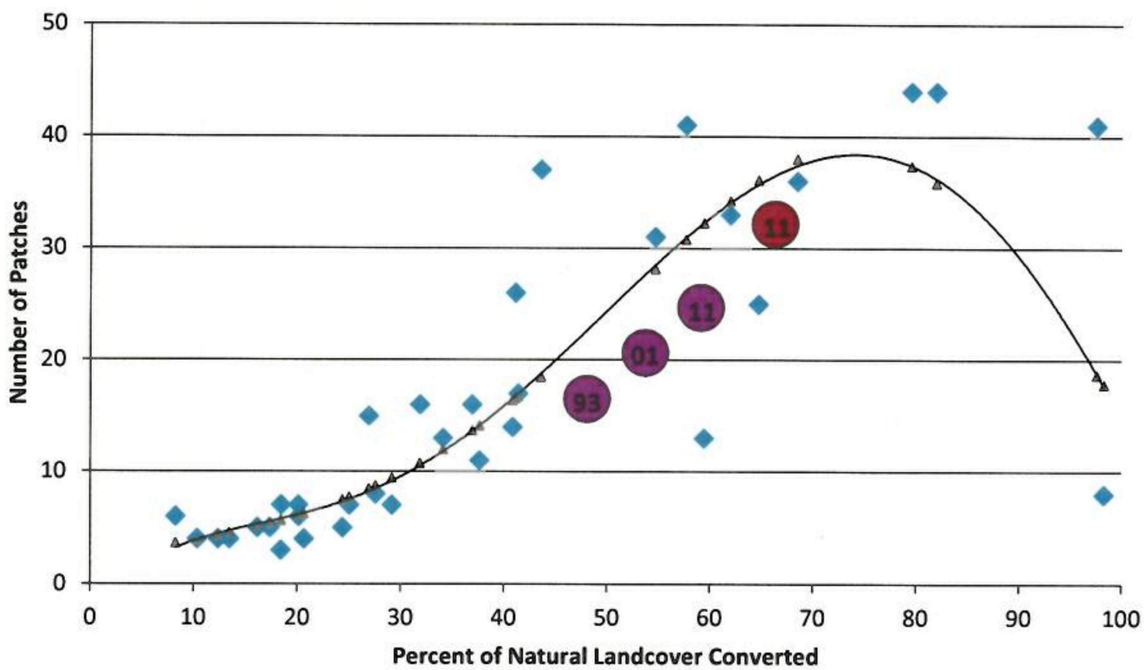

Figure 3.3-1: The number of patches of natural land cover in the BRFN study area related to the amount of land cover conversion in a real landscape (exemplified by townships within the Alberta Oil Sands region).

The best fit regression model is a 3rd order polynomial (n=34, R^2=0.80, P<0.0001) with a natural log transformation (triangles and gray line). The R^2 value is 0.80, indicating that 80% of the variation in the data is represented by the regression line. The purple circles indicate the situation in the BRFN study area in 1993, 2001 and 2011, based on Landsat images, and the red circle indicates 2011 conditions based on SPOT image correction.

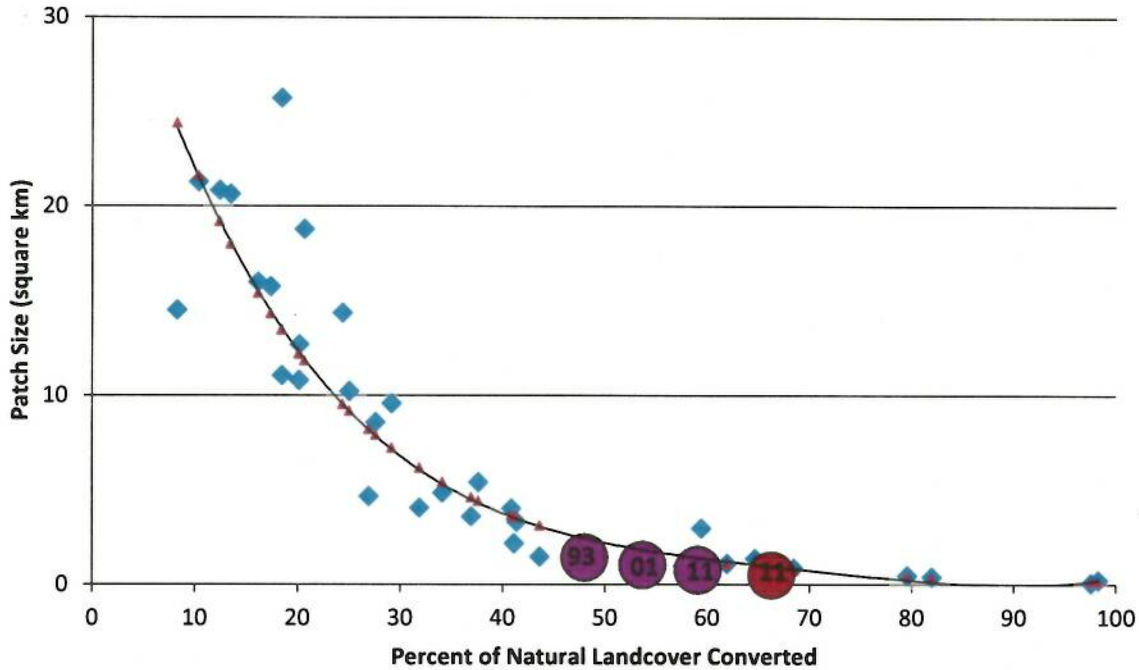

Figure 3.3-2: The average size of patches of natural land cover in the BRFN study area related to the amount of land cover conversion in a real landscape (exemplified by townships within the Alberta Oil Sands region).

The best fit regression model is a linear model (n=34, R^2=0.94, P<0.0001) with a natural log transformation (triangles and red line; backtransformed). R^2 value is 0.94 (thus 94% of variation in the data is represented by the regression line). Purple circles show placement of the BRFN study area in 1993, 2001, and 2011 based on Landsat images. The red circle shows placement of the BRFN study area in 2011 based on SPOT image correction.

4.0 Re-establishing Traditional Resources

Key Finding: The disturbed areas are unlikely to be reclaimed to pre-disturbance conditions. There is very little similarity in terms of species composition between reclaimed sites and natural stands. Reclaimed sites show an unnaturally low diversity of species.

4.1 Natural Forest Stands

Under natural conditions within the boreal forest, the plant species present within each stand (i.e., ecosite phase) is determined primarily by the soil moisture and nutrient regime of a site (e.g., Bridge and Johnson 2000) and by the availability of seeds or viable asexual stems/roots soon after wildfire (e.g., Greene *et al.* 2004). Most plant species in the boreal forest appear to establish within the first few years after forest fire (Chipman and Johnson 2002). The establishment of most sexually reproducing plant species occurs where the litter, fermentation and humus (LFH) layers have been consumed by fire, leaving either a very thin layer of humus or exposed mineral soil (e.g., Charron and Greene 2002, Hesketh *et al.* 2009). Where LFH is consumed by fire, conditions for establishment and growth are ideal: there is adequate moisture, space, and light, allowing plants to thrive. Soon after fire, these sites become covered with plants and as a result there is little or no further establishment. Thus, in contrast to what is often believed, a succession of plant species does not establish over long periods of time in these stands (see Appendix C for further detail). At least one study has shown that as boreal forest stand age increases, the number of vascular plant species actually decreases (Chipman and Johnson 2002).

4.2 Reclaimed Sites

In a reclaimed site, salvaged surface organic material (LFH) or a peat-mineral mix is put onto the site and a small number of tree and shrub species are planted. The presence of a relatively thick surface organic layer precludes most sexually reproducing species from successfully establishing. Therefore, these sites will consist of mainly planted species that survive and species that can sprout from underground stems or roots and spread from adjacent, intact forests. They may also contain species that have emerged from viable seeds or vegetative structures within the salvaged LFH layers replaced on a site. However, the emergence of species from the LFH appears to occur only if the LFH is replaced within 12 months of it being salvaged (MacKenzie and Naeth 2007). Unfortunately, such rapid replacement is rare in reclamation. Only a small number of species are planted in reclamation sites because it is believed that a succession of species will establish over time, eventually leading to high diversity sites similar to naturally occurring boreal forest stands. Unfortunately, this view is not supported by evidence in the scientific or gray literature.

Evidence for the above arguments of a lack of succession can be seen in peer-reviewed publications (e.g., Gutsell and Johnson 2002) and in an example from the Alberta oil sands region using Suncor and Syncrude's long-term reclamation data (as seen in Appendix F of Guidelines to Reclaim Forest Vegetation in Alberta (OSVRC 1998)). Notably, Syncrude and Suncor's results, after 40 or more years of reclamation, substantiate the arguments that there is a short establishment period in reclaimed sites and no succession thereafter (and contradict the Guidelines' own recommendations that revegetation of reclaimed sites will occur by natural successional processes). The relevant results from their reclaimed sites are detailed below (text in italics are quotes from page F-14, OSVRC 1998):

On the oldest reclaimed sites, where peat amendment was incorporated and a legume/grass mix applied, grass and legume cover ranged from 50-100%. These vegetation communities have *persisted for over 20 years* and have *resisted the establishment of native species either through natural invasion* or planting programs. Reclaimed sites that were not seeded or only seeded to annual barley have typically become dominated by a variety of herbaceous species that provide *close to 100% total cover within a few years after reclamation* (incidentally, none of these herbaceous species were present in natural stands). These herbaceous species *maintain their control in the following years*. Trembling aspen, balsam poplar and a variety of native shrubs *invade* the sites within *a few years* of reclamation.

4.3 Differences Between Natural Stands and Reclaimed Sites

The methods that are often proposed by oil sands operators to reclaim disturbed areas have been shown to result in reclaimed sites that have very low or no similarity, in terms of species composition, to natural stands, with a low diversity of species unlike any post-fire boreal forest stands. The reasons for this can be seen by examining what we know about the post-fire regeneration dynamics in the boreal forest and comparing it with the methods that are often proposed in oil sands reclamation plans.

Comparisons between reclaimed sites and natural stands show that there is very little similarity in terms of species composition between any of the reclaimed areas with natural stands. The oldest reclaimed sites seeded to grasses and legumes typically had ≤10% similar species. Sites seeded to native grasses and sites not seeded had similarity values between 0.1 and 0.29. In most cases, the *species that were common between the sites were the trees and shrubs planted as part of the reclamation program*. These results clearly show that it is incorrect to assume that re-vegetation will be augmented by natural vegetation species ingress and reclaimed areas will evolve into ecosystems similar to those found naturally. Clearly, if a particular set of plant species is desired within a reclaimed site then they will need to be planted within the first few years of reclamation. Within these reclaimed sites at least some patches of thin humus or exposed mineral soil will be needed to ensure early plant survival.

There is a relatively small number of plant species in the planting mix for reclaimed sites because it is also believed that shrubs, graminoids, and forbs will establish from seeds or propagules in the LFH layers that are placed back onto reclamation sites. However, as noted above, recent studies in the oil sands (MacKenzie 2006, MacKenzie and Naeth 2007, MacKenzie 2009) have found that when soils are stockpiled for more than one year, there are no viable seeds or root stocks remaining in the LFH. Furthermore, if the LFH was a productive source of seeds then one would expect to see the emergence of plant species found in natural stands from soils salvaged from natural areas (pre-disturbance stands). Instead, Suncor and Syncrude's reclaimed sites have plants that are "virtually absent" in natural stands (OSVRC 1998). Two of the plants found to be dominant in reclaimed sites, fireweed (a native species) and sow thistle (a non-native species), which are known to be good at dispersing quickly into disturbed areas, were not found in adjacent natural stands. Trembling aspen, balsam poplar, a variety of willows and other native shrubs *invaded* the sites (likely from asexual stems) within a few years of reclamation (OSVRC 1998). Given that none of the herbaceous species that dominated reclaimed sites were present in natural stands and that tree and shrub species apparently invaded the sites from adjacent intact stands, it does not appear that there has been emergence of individuals from the LFH.

The information presented above is important to understanding how successful reclamation might be achieved. Unfortunately, the belief that the emergence of plants from the LFH and "successional processes" will supplement any early reclamation efforts (i.e., planting/seeding) means that not enough will be done in the critical early period of reclamation to ensure that a variety of plant species will establish successfully and lead to the high diversity of forested stands seen in the pre-disturbance landscape.

5.0 Next Steps

MSES understands that it is important to First Nations that regional landscapes maintain functional ecosystems and that First Nation communities wish to have input in how the traditional resources on those landscapes will be managed and protected for the continued practice of Treaty rights. There are a number of further steps that can be taken with the data that MSES has generated for this report. We recommend that in order to gain a deeper understanding of how development has already and will continue to impact the ecosystems that support BRFN traditional resources use, analyses be conducted to address the management of specific resources such as vegetation and wildlife species but also intact forest and wetland complexes.

5.1 Ground-truthing of Non-linear Disturbances

An important step in the spatial analysis process is conducting an accuracy analysis which determines the quality of the information derived from remotely sensed data (Congalton and Green 1999). For the BRFN disturbance change analysis, we used black and white SPOT images from 2006 to 2009 which have finer, 10 m resolution to identify and reconcile linear disturbances with our Landsat data set. However, an accuracy assessment of the non-linear disturbances (which was not conducted under the current scoped budget) would require site visits to ground-truth data points. We recommend completing a non-linear disturbance accuracy assessment to determine whether the disturbed versus undisturbed classes were correctly assigned by comparing the class extracted from the imagery with what is seen on the ground.

5.2 Patch Analysis with B.C. Township Data

In our first analysis, we show how much land is left undisturbed in the BRFN study area in total. It is a logical conclusion that most of the remaining undisturbed land is now largely divided up into small and isolated patches of natural vegetation. Many small patches of undisturbed land may exist between major developments, but these isolated patches may not be useful for traditional resource use and should be subtracted from the total "undisturbed" land calculations. Therefore, we conducted a patch analysis that shows the degree of fragmentation of the remaining natural surfaces by calculating the number of remaining patches of natural surfaces and the average patch size in the BRFN study area. For discussion purposes, we compared the patch analysis data for the BRFN study area to patch analysis data for 34 townships in the Alberta oil sands region because township data for B.C. was not available. Our calculations show that fragmentation of natural surfaces in the Oil Sands region data increases exponentially with the amount of natural surface conversion and that landscape disturbance process in the BRFN study area is likely approaching an asymptote of maximum fragmentation. Although the data from the Alberta oil sands region supports what is seen in landscape ecology literature, the BRFN may wish to re-analyze the fragmentation effects with township data from B.C.

5.3 Habitat Analysis for Key Traditional Resources

The BRFN may wish to explore how current and proposed disturbances affect specific Traditional Resources such as moose, beaver, waterfowl or old growth forests and wetland complexes. As mentioned in Section 3.1.3, the results of the linear disturbance analysis suggest that populations of traditional wildlife species may only exist at low densities or possibly cease to be viable at this disturbance density. Trends in changes to traditional resources, especially changes that are detrimental, should be better understood in order to develop mitigation and protection measures.

6.0 References

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Appendix A

Change of Land Cover Analysis

A1.0 Change of Land Cover Analysis

We estimated the change in the landscape based on the:

1) digitized linear disturbances that are visible on the Landsat5 images at a 1:50,000 scale;
2) change analysis of the Landsat images which extracts areas that have been changed between two consecutive images.

Linear disturbances that were visible on the Landsat images were digitized and used as a separate layer of lines. We did not have any reliable information on the width of linear disturbances because they do not have a footprint per se, unless they were buffered by 250 m (see below), so as a result, the change analysis only addresses footprints of non-linear developments such as clearings, facilities, mining operations, etc.

Due to the size of the BRFN Consultation Area, three Landsat images were needed to cover the entire area. The main central image that covers the majority of the BRFN Consultation Area were images from 1993, 2001 and 2011 while for a small portion of the western section and the southeastern section of the area, we were unable to obtain the same date range. The dates of the images used for the analysis are as follows:

Image "049020"
September 19, 1993
August 16, 2001
June 1, 2011

Image "050020" – representing the western portion of the area
September 10, 1987
August 2, 1999
Aug 5, 2009

Image "048021" – representing the southeastern portion of the area
August 24, 1992
August 4, 1999
August 7, 2009

The image resolution was 30 x 30 m and all images were orthorectified using geodetic and elevation control data to correct for positional accuracy and relief displacement. Large blocks of Landsat data were adjusted through a patented procedure that uses pixel correlation to acquire tie-points within the overlap area between adjacent Landsat images (USGS 2008). Ground control points were fixed, and images were projected to the Universal Transverse Mercator map projection. All bands were individually re-sampled, using a nearest neighbour algorithm. The result is a final product with a Root Mean Square Error of better than 50 m in positional accuracy (USGS 2008). To estimate the disturbances other than linear, we performed a change analysis using data processing based on the image algebra method (Wickware and Howarth 1981, Singh 1989, Stanojevic *et al.* 2006).

The image algebra method is a relatively simple change detection technique, also known as the band differencing method. The reasons for using the image algebra method versus other methods, such as classifications are:

1) The image algebra method is highly accepted and widely used in the remote sensing research community (Jensen 2005).
2) Jensen (1981) and Jensen and Toll (1982) report that this method is among the most accurate change detection algorithms.
3) The image algebra method was reported to have an overall accuracy near 90% for standardized differencing (Bauer et al. 1994). In the Fort McMurray region, the image algebra method was also found to be near 90% accuracy and is believed to be better than other methods when the focus is quantifying change, without defining the categorical nature (e.g. type of vegetation classes) of the change (Alsadat et al. in press).
4) The image algebra method is cost effective as it does not require as much time as image classification methods.
5) While classification methods provide information of the categorical nature of the change, these methods are not as effective at detecting anthropogenic change over large areas. Because of its effectiveness, the image algebra method has been used by Global Forest Watch Canada to detect changes in very large regions (Stanojevic et al. 2006).

The image algebra method employs an equation for the differencing of a common band of imagery for two image dates as shown below (Jensen 2005):

$$Dijk = BVijk(1) - BVijk(2) + c$$

where: $Dijk$ = change in pixel value
$BVijk(1)$ = brightness value at time 1
$BVijk(2)$ = brightness value at time 2
c = constant
i = line number
j = column number
k = band number

The image algebra method allows the analysts to define the level of change that they are interested in describing. In our analysis, we specified that the change in pixel value had to be at least 10%. We compared the satellite image from 1993 to the images from 2001, and the image from 2001 to the image from 2011, in order to detect changes caused by anthropogenic disturbances between these periods of time.

The 4th or 5th image bands were used for differencing within the image pairs. These were used to minimize the atmospheric effects on the spectral signature of any given land cover type. A raster file was created based on the output of this image differencing. The output raster file depicted all pixel changes greater than (approximately) 10% between the two dates. In some cases, the bands being compared were evaluated for minor differences in reflectance unrelated to changes in cover type. Discrepancies were treated by evaluating and matching the histograms of the bands used in the analysis. This process aided in the reduction of in-between scene variability as a result of potential differences in atmospheric conditions.

All of the raster files depicting change were compared with the image pairs to ensure that the appropriate data were captured. In order to reduce the data "noise" that resulted from the processing routine, the initial processed data set was re-processed using a filter to eliminate the smaller, scattered clusters of pixels that were less than 0.27 ha in size (3 pixels). Upon visual inspection of the image pairs, the vast majority of these small, scattered clusters of pixels appeared to indicate "natural" and/or phenological changes, such as varying water levels in wetlands and lakes, or varying leaf colour and cover. In some cases, the filter eliminated linear disturbances such as roads, seismic line, etc., but these were manually re-inserted into our "anthropogenically-disturbed" data layer during the visual checking stage.

An unsupervised isodata clustering process was also applied to the image files in order to provide an additional dataset to assist in determining whether specific identified changes were anthropogenically-caused disturbances. Clusters which fell into both classes were identified as "crossovers" and these pixels were subjected to another round of isodata clustering (with a greater number of specified classes) and then classified accordingly. This complementary data layer was especially useful in identifying areas affected by wildfire.

In addition to the classification of pixel clusters in the differencing output raster files, the analyst manually "cleaned" the borders of some of the detected changes. Some of the changes that were eliminated by the "noise" filter that was performed were manually recovered and added back into the data set of anthropogenically-disturbed clusters. The pixels classified as "anthropogenically-disturbed" were used to create a digital disturbance layer.

A1.1 Disturbance Buffer (Zone of Influence)

A disturbance buffer or zone of influence of 250 m around the footprints of developments and the centerlines of linear corridors was applied based on the potential for reduced animal activity and hunting and trapping activity near industrial features. The distance of 250 m was chosen for many reasons, for example, hunting is not permitted within 100 m of an occupied building (BC Government 2012). Other examples include: moose sign was found to be reduced within 200 m of roads (Rolley and Keith 1980); caribou avoid industrial features within about 250 m (but avoidance could be greater or smaller for some features during some seasons, Dyer *et al.* 2001); and other mammals have been observed to avoid industrial features within this distance (Forman *et al.* 2003). Birds in woodlands have also been observed to avoid roads, power lines and seismic lines by up to about 300 m depending on species and ecological context (Kroodsma 1982, Belisle *et al.* 2001, Machtans 2006).

Clearly, the zone of influence differs widely between the species, the type of industrial features and related activities, and the ecological context (reproductive cycle, hunting or predation regimes, habitat structure and quality). However, it appears that, in absence of detailed information on any of the situations, the 250 m distance is a reasonable approximation for a zone within which First Nations could not effectively exercise their rights.

A1.2 Atmospheric Correction

The solar spectrum electromagnetic radiation signals that satellites collect are affected by aerosols and gases in the atmosphere. Performing atmospheric correction on the satellite images can account for this modification and lead to improvements in classification and detection, and therefore, atmospheric correction problems have received considerable attention from researchers in remote sensing who have devised a number of solution approaches. Sophisticated approaches are computationally demanding and have only been validated on a very small scale (Tucker and Sellers 1986), and, in fact, some researchers have determined that atmospheric correction is unnecessary in many cases (Tucker *et al.* 2004).

We addressed the issue of atmospheric influence in our study by first creating a cloud-water mask and then performing differencing using only spectral band 4 or 5, because these are less influenced by atmospheric conditions. Other studies also dropped the bands most influenced by atmospheric effects from their analyses (Skole and Tucker1993, Collins and Woodcock 1994, Foody *et al.* 1996).

A1.3 Accuracy Analyses

Accuracy assessments determine the quality of the information derived from remotely sensed data (Congalton and Green 1999). Quantitative assessments attempt to identify and measure remote sensing-based error such as misclassification. There are two main types of common errors including omission (underestimation) and commission (overestimation). Processes that use medium and low resolution images produce larger errors than high resolution images. For the assessment, we compared data derived from Landsat images with reference data. For linear disturbances that may not be detected by the 30 m resolution of Landsat images, we used cloud-free SPOT images of the same area that ranged from 2006 to 2009 (http://www.geobase.ca/geobase/en/browse.do?produit=imr&decoupage=image&map=canada). SPOT images are fine resolution satellite imagery with a resolution of 10 m. However, SPOT imagery is not readily available for the area prior to 2006 or after 2009. . Therefore, we first used the Landsat imagery to gain an overall understanding of the relative changes to the landscape from 1993 to 2011, and then we used the SPOT imagery to determine of how much the Landsat imagery leaves undetected. All visible linear disturbances were digitized and these were then compared with Landsat linear disturbances. The difference between the SPOT analysis and Landsat analysis provided us with a "correction ratio" to be used to "correct" the Landsat data.

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Appendix B

Class Metric Regression Analysis

B1.0 Class Metric Regression Analysis

The two class-level metrics, number of patches (NUMP) and mean patch size (MPS), were regressed against the percent of natural landcover converted in each of the 34 townships analyzed in the oil sands region to assess whether these metrics followed the expected patterns based on simulations (Gustafson and Parker 1992, Hargis et al. 1998). Simple linear, quadratic polynomial, and cubic polynomial regression models were fit to the data using Systat software (Systat Software Inc. 2004) and compared using AICc values (Burnham and Anderson 1998). The response variable NUMP was square root transformed and the response variable MPS was natural log transformed to satisfy assumptions of normality and heteroscedasticity. Estimated response variables were backtransformed for the purposes of presentation and calculation of slopes at 66% disturbance (corresponds to 2011 conditions based on SPOT image correction).

The cubic polynomial model was the best model for describing the relationship between NUMP of landcover and the percent of natural landcover converted. The linear model was the best model for describing the relationship between landcover MPS and the percent of natural landcover converted (Table B1-1).

Table B1-1: Regression results and AICc values for landcover class metrics versus the percent of natural landcover converted.

CLASS METRIC	TYPE	P VALUE	R^2	AICC	Δ AICC (X – SMALLEST)
NUMP = % of natural landcover (n=20)	Linear	<0.0001	0.59	-35.63	18.22
	Quadratic	<0.0001	0.78	-53.47	0.38
	Cubic*	<0.0001	0.80	-53.85	0
MPS = % of natural landcover (n=20)	Linear*	<0.0001	0.94	-59.59	0
	Quadratic	<0.0001	0.94	-57.04	2.56
	Cubic	<0.0001	0.94	-55.17	4.42

* best models describing relationship

B1.1 References

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Appendix C

Background on Forest Succession and Reclamation through Natural Succession

C1.0 Reclamation in Environmental Impact Assessments

The reclamation process is typically based on the Cumulative Environmental Management Association's (CEMA) guidance and the general belief described in environmental impact assessments (EIAs):

> "Successful reclamation requires the reestablishment of ecosystem functions based on natural successional processes."
>
> "While specific ecosite phases will be targeted within various landscapes, natural processes will ultimately determine the progression and eventual ecosite phase. Revegetation will be augmented by natural vegetation species ingress and successional processes, providing an opportunity for reclaimed areas to evolve into ecosystems similar to those found naturally in the region under similar environmental conditions."

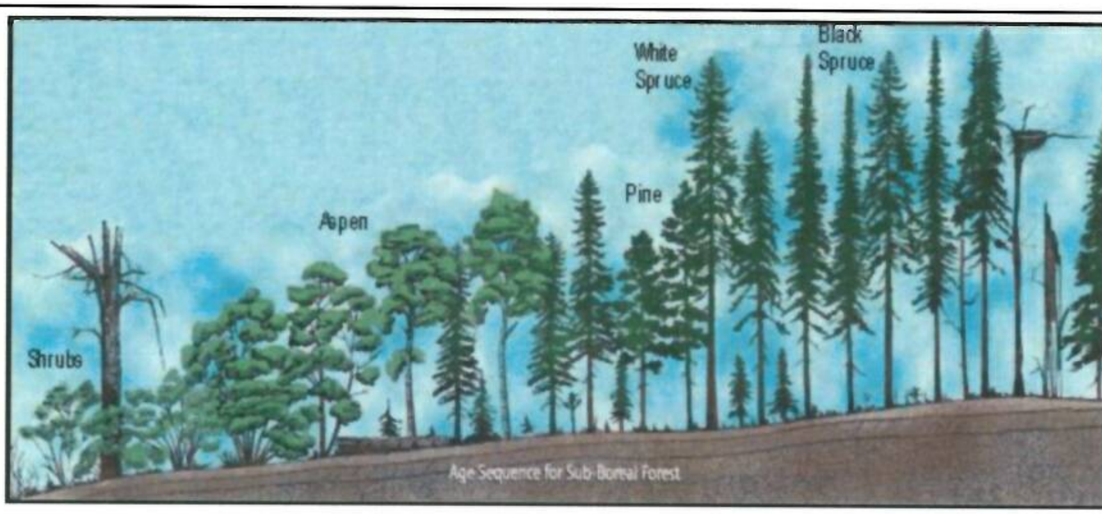
As the above and similar such statements from EIAs indicate, an important part of any reclamation plan involves believing that "a succession of species" will become established on their own within reclaimed sites. This means that only a few species may be planted/seeded initially in the reclamation site with the expectation that a series of plant species will become established on their own over time. However, *direct* evidence from both Suncor and Syncrude data and scientific studies in the Alberta oil sands region shows that in the boreal forest most plant species become established within the first few (~five) years of reclamation or after forest fires. The only species that we are aware of that can establish after this initial period are trembling aspen (*Populus tremuloides*), which can sprout from underground stems, and white birch (*Betula papyrifera*) which can sprout asexually from the base of the tree, usually after the tree is damaged or dies. However, both species have high mortality rates.

C1.1 Background about Forest Succession

Definitions of forest succession may include only tree species or all plant species that exist in a forest. The concept of succession with only trees or all plants came about using what is called a chronosequence approach. This approach is described below for only tree species, but the same approach has been used to develop successional arguments for all plant species.

Forest succession is hypothesized to be a result of differences among tree populations in establishment time and growth and death rates. Some populations establish, mature, and decline when a community is young, while others do so when the community is middle aged, or older. Hence, there is a succession of tree species replacing each other. It is often believed that the early successional species make the environment unsuitable for recruitment of their own species such that as they die, space is made available for the next species in the successional sequence.

For example, Figure C1-1 below shows a *hypothesized* pattern of forest succession in the boreal forest, with different tree populations establishing and dominating at different times. In early succession, aspen (*Populus tremuloides*) establishes and dominates the community. In mid-succession, as aspen dies, white spruce (*Picea glauca*) and pine (*Pinus banksiana*) establish and dominate the community. Finally, in late succession, when aspen and pine have died, black spruce (*Picea mariana*) establishes and dominates the community (with some white spruce).



Aspen dominates	White Spruce/Pine dominate	Black Spruce dominates
Early Succession	→Mid-Succession →	Late-Succession (Old-growth)

Figure C1-1: Hypothesized pattern of forest succession in the boreal forest

The theory of forest succession is widely accepted as an accurate description of nature, but there is actually little *direct evidence* that tree populations succeed each other. Direct evidence is lacking because the long life span of trees (>100 years) makes it impossible to follow several generations of tree species populations long enough to see the replacement of tree species in the canopy.

Because showing forest succession directly is difficult, ecologists have tried to document succession indirectly (e.g., Cowles 1899 and Cooper 1923 are examples of two classic studies). They have attempted this by finding a series of forest sites that are believed to be similar in all respects except age. This series of sites is called a chronosequence. For example, Figure C1-2 below shows the same diagram as above but it is divided into a chronosequence of sites, separated by vertical black lines. On the left is a young site dominated by aspen, in the middle is a middle-aged site dominated by white spruce and pine, and on the right is an old site dominated by black spruce.

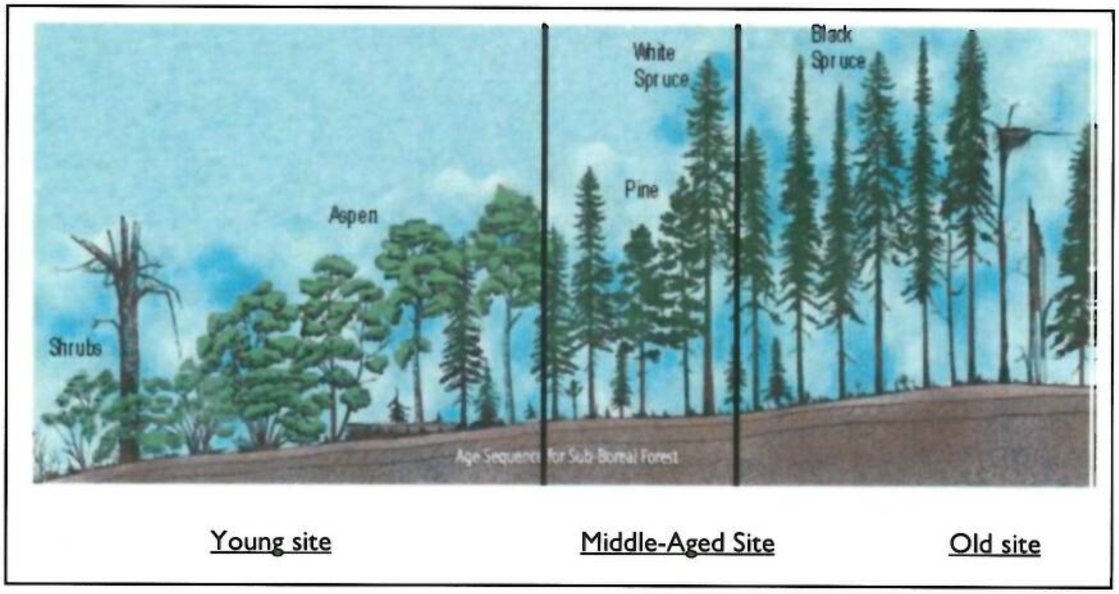


Figure C1-2: Chronosequence for sub-boreal forest

It is *assumed* that the different tree populations dominating the different-aged sites represent a sequence over time that occurred (and is occurring) at each site. Unfortunately, studies advocating succession seldom test the assumption that different aged sites experience the same developmental sequence. In fact, the few studies that have examined this assumption have found that plant populations do not succeed each other over time (e.g., Jackson *et al.* 1988; Fastie 1995).

Succession, as described above (or some form of the above) is a widely-believed concept. Therefore, it is surprising to most people that there is actually no *direct* evidence of succession in the boreal forest, or in other forests. More recent studies have shown that forest dynamics are actually much simpler than succession theory suggests. The recruitment of plant species after forest fires or during initial reclamation of oil sands sites is rapid and occurs until all available sites are occupied by plants (e.g., Gutsell and Johnson 2002, OSVRC 1998). After this initial period, the number of species within sites actually decreases such that older stands are less diverse than younger stands (Chipman and Johnson 2002).

C1.2 References

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