Summary of Resiliency of Reclaimed Boreal Forest Landscapes Seminar

M.P. Pyper and C.B. Powter, University of Alberta

T. Vinge, Alberta Environment and Sustainable Resource Development

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Oil Sands Research and Information Network

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The Oil Sands Research and Information Network (OSRIN) is a university-based, independent organization that compiles, interprets and analyses available knowledge about managing the environmental impacts to landscapes and water impacted by oil sands mining and gets that knowledge into the hands of those who can use it to drive breakthrough improvements in regulations and practices. OSRIN is a project of the University of Alberta's School of Energy and the Environment (SEE). OSRIN was launched with a start-up grant of $4.5 million from Alberta Environment and a $250,000 grant from the Canada School of Energy and Environment Ltd.

OSRIN provides:

- **Governments** with the independent, objective, and credible information and analysis required to put appropriate regulatory and policy frameworks in place
- **Media, opinion leaders and the general public** with the facts about oil sands development, its environmental and social impacts, and landscape/water reclamation activities – so that public dialogue and policy is informed by solid evidence
- **Industry** with ready access to an integrated view of research that will help them make and execute reclamation plans – a view that crosses disciplines and organizational boundaries

OSRIN recognizes that much research has been done in these areas by a variety of players over 40 years of oil sands development. OSRIN synthesizes this collective knowledge and presents it in a form that allows others to use it to solve pressing problems.

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

REPORT SUMMARY

Ecological resilience, first defined by Holling in 1973, can be broadly described as the capacity of an ecosystem to respond to a perturbation or disturbance by resisting damage and recovering quickly, but other authors have provided variations on this theme since 1973.

Ecological resilience is one potential measure of the goal of a self-sustaining ecosystem and is being considered for inclusion in the Cumulative Environmental Management Association's Criteria and Indicators Framework for assessing reclamation success in oil sands mines. For reclaimed lands to be considered self-sustaining they should respond to natural and anthropogenic disturbances in a similar manner to an analogous undisturbed landscape might respond to the same disturbances.

The University of Alberta's Department of Renewable Resources and the Oil Sands Research and Information Network jointly hosted a one-day seminar on January 22, 2013 at the University of Alberta to discuss the concept of ecological resiliency and how it can be applied to reclaimed landscapes. 108 people from a variety of organizations and technical interests attended the seminar.

There was general agreement amongst the presenters that resilience is a valuable topic to consider in reclamation planning. However, there was also agreement that implementing management systems based on resiliency would require a shift away from managing for consistency and single objectives (e.g., soil depth, stems/ha), to a system that embraces change and is focused on ensuring ecological processes are reintroduced to reclaimed landscapes (i.e., resiliency).

Some of the key ecological processes that were identified included: nutrient cycling and moisture availability; soil characteristics (e.g., pH, nutrient availability, propagules, soil biota, etc.); understory plant diversity (particularly when species are matched to the correct ecosite); presence of keystone species; and the proper construction of landforms which include slope, aspect and variability in their design.

The seminar was, by design, focused on providing information about the concept of ecological resilience and its potential application to land reclamation. The seminar participants recommended further sessions to bring the high-level concepts down to on-the-ground application.

There was also interest in holding a similar session in a year's time to provide more information and to focus on getting more technical detail, perhaps by focusing on specific research and implementation projects.

ACKNOWLEDGEMENTS

The Oil Sands Research and Information Network (OSRIN), School of Energy and the Environment (SEE), University of Alberta and the Department of Renewable Resources, University of Alberta provided funding for this project.

The authors are indebted to the members of the Seminar Committee and in particular to the speakers who volunteered their time to make the seminar a success. The authors are also grateful to Matthew Swallow who took notes during the presentations and question periods and Jeannine Goehing and Nilusha Welegedara who assisted with the registration desk.

The authors are grateful to the Alberta Land-use Knowledge Network for videotaping several of the presentations and making them available on their website at http://www.landusekn.ca/resource/resiliency-reclaimed-boreal-forest-landscapes-proceedings

1 INTRODUCTION

Ecological resilience, first defined by Holling (1973), can be broadly described as the capacity of an ecosystem to respond to a perturbation or disturbance by resisting damage and recovering quickly (Wikipedia), but other authors have provided variations on this theme since 1973.

Ecological resilience is one potential measure of the goal of a *self-sustaining* ecosystem and is being considered for inclusion in the Cumulative Environmental Management Association's Criteria and Indicators Framework for assessing reclamation success in oil sands mines (Poscente 2009, Poscente and Charette 2012). For reclaimed lands to be considered *self-sustaining* they should respond to natural and anthropogenic disturbances in a similar manner to an analogous undisturbed landscape might respond to the same disturbances.

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A Seminar Committee consisting of individuals from the University of Alberta and government developed the scope for the seminar and suggested presenters.

1.1 Information Sources

A Google Search for *ecological resilience* or *ecological resiliency* yields about 100,000 hits (Table 1)[1]. Many of these hits deal with the concept of ecological and social resilience[2]; removing records with either *socio* or *social* yields fewer results (Table 1) that are more directly focused on the ecological aspects of resilience. However, there are still many records that use the resilience concept and apply it to other issues, notably climate change, economics and public policy. A selection of references related to forests has been compiled in section 6.1.

Table 1. Results of Google search for ecological resilience and ecological resiliency

Term	All Hits	-Socio -Social
Ecological Resilience	100,000	19,000
Ecological Resiliency	100,000	1,030

[1] Search done January 21, 2013.

[2] See also Resilience Alliance at http://www.resalliance.org/ and Stockholm Resilience Centre at http://www.stockholmresilience.org/21/about-us.html

OSRIN has funded a project by Dr. Clive Welham to describe how the concept of ecological resilience can be applied to oil sands mine reclamation, and in particular describe reclamation and management practices necessary to generate ecological resilience in reclaimed oil sands mine upland landscapes. The project report will be available in Spring 2013.

1.2 Oil Sands Context

Ecological resilience is important for different reasons at different stages during the development and closure of oil sands projects:

- During development we are interested in the resilience of areas outside the immediate footprint – that is, those areas that may potentially be indirectly impacted by development from environmental stressors such as changes in groundwater regime, air emissions, water use, water releases, habitat fragmentation, etc. We are also interested in knowing where areas are not impacted as they can act as controls for research projects or reference areas for environmental monitoring.
- During reclamation we are interested in knowing what steps we can take to "add in" the characteristics of resilient landscapes, soils and vegetation.
- Following reclamation we are interested in knowing what characteristics of ecological resilience we should measure to determine if reclamation has been successful. The Cumulative Environmental Management Association has identified ecological resilience of both uplands and wetlands as a potential measure of reclamation success.

1.3 Organization of This Report

Section 2 of this report includes a brief abstract of each presentation, notes on key takeaway messages heard by the authors and a summary of the discussion period. This is not intended to be a verbatim transcript – rather it captures the key points made during the discussions. Slides from some of the presentations are used to illustrate key points.

A summary of the plenary discussion and recommendations for next steps are included in section 3.

The Report appendices include:

- Seminar committee members – Appendix 1.
- Agenda – Appendix 2.
- Presentation PowerPoints – Appendix 3.
- List of attendees – Appendix 4.

2 SEMINAR PRESENTATIONS

The seminar questions and associated presentations are noted below:

- What is resiliency?
  - Resilience: A Concept Worth Knowing – Clive Welham (3Green Tree Ecosystem Services Ltd.)
- How do we measure resiliency?
  - The Role of Plant Species Selection in the Functionality of Reclaimed Forest Landscapes – Simon Landhäusser (University of Alberta)
  - Ecological Resiliency of Alberta's Wetlands – Suzanne Bayley (University of Alberta)
  - Criteria and Indicators of Resilience – Ellen Macdonald (University of Alberta)
  - Ecological Resiliency: Measuring Degradation and Recovery – Jim Schieck (Alberta Biodiversity Monitoring Institute)
- How do we plan for resilient landscapes?
  - Landform Design for Resiliency – Elisa Scordo (BGC Engineering)
  - Changing Objectives for Oil Sands Reclamation: The Evolution of the Faster Forests Program – Terry Forkheim (Statoil Canada Ltd.)
  - Soil Management to Maintain Boreal Forest Resiliency – Dean Mackenzie (Navus Environmental Inc.)
  - Is Ecological Resiliency a Meaningful Concept for Reclamation Policy and Regulation: Considerations for the Management of Oil Sands Facilities – Brett Purdy (Alberta Innovates – Energy and Environment Solutions)

Videos of several of the presentations were prepared by the Alberta Land-use Knowledge Network and are available on their website at http://www.landusekn.ca/resource/resiliency-reclaimed-boreal-forest-landscapes-proceedings.

2.1 Why is Resiliency a Concept Worth Discussing?

Resilience: A Concept Worth Knowing – Clive Welham, 3GreenTree Ecosystem Services Ltd. and UBC Faculty of Forestry, Vancouver.

2.1.1 *Abstract*

Resilience is an emergent property of ecosystems, an outcome of their capacity for self-organization. As such, it is a challenging paradigm to interpret and implement because ecosystems cannot be easily 'deconstructed' with the aim of studying the behavior of each (simplified) part in isolation; in self-organized systems, the whole is indeed greater than the sum

of its parts. Nevertheless, the concept is as an important and useful paradigm in ecological management and by extension, reclamation.

Despite its presence in the common vernacular, a clear and precise ecological definition of ‘resilience’ has proven elusive[3]. Though not ideal from a scientific perspective, it is also not uncommon (think of how ‘ecosystem’ itself is defined, for example) and does not prevent its useful application. More problematic is a lack of appreciation for the two key components of resilience in ecological systems – structure and scale – both of which are necessary for the concept to be meaningful. Structure refers what’s there and in what amount (species, populations, ecosystem attributes, etc.). This component has received considerable attention. Less so for scale, which pertains to both space and time. Properties that confer resilience are not independent of the spatial scale under consideration, and resilience has no context unless we answer the question, over what time scale? In this respect, there are psychosocial, economic, and even geopolitical barriers that limit our ability to manage for resilience, and these should not be ignored.

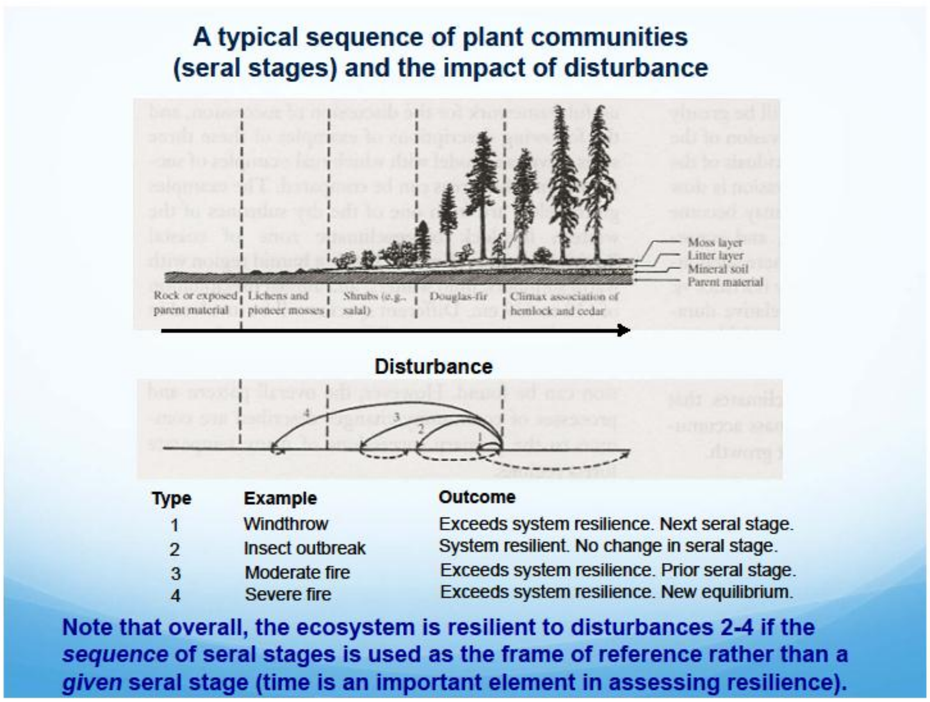

Figure 1. Resilience depends on the type and severity of disturbance.

Resilience in natural and reclaimed ecosystems are mirror images. Applying the concept in natural systems is to pose the question, how much can self-organizing capabilities be perturbed

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[3] See Plodinec (2009) for a discussion on the wide range of definitions used for different purposes in different disciplines.

and still achieve desired outcomes. In the case of reclamation the question becomes, how much of the self-organization capabilities of a system must be created to achieve desired outcomes.

2.1.2 *Takeaway Messages*

Change is an important consideration when thinking about resiliency and reclamation:

- Change occurs in natural systems over time and doesn't necessarily require a disruptive intervention (e.g., succession patterns).
- Change (disturbance) can be both negative and positive, can be either acute or chronic and can have biotic (e.g., insects, beavers[4]) or abiotic triggers (e.g., climate, wind, fire, industry).
- Change happens at several levels – individuals, populations, communities, and ecosystems.
- If we do nothing change will happen anyway, it just may not be the change we want.
- Systems in early stages of development are more susceptible to change than in later stages.

Resilience is a reflection of the inherent ability for systems to self-organize into stable states. Disturbances disrupt a system's self-organization and, if strong enough, can make it unstable. The system will eventually re-organize to the same state or a new stable state. Reclamation is an attempt to guide and/or speed up the pace of re-organization.

Manage for the journey, not the destination

Resilience is an emergent property of a natural or constructed system – therefore we can't manage for resilience itself; rather we can manage for change by trying to instill the capability for resilience to emerge and for the system to self-organize into a stable state. However our reclamation practices appear to ignore the potential for change, or even to design to avoid it.

Resilience arises from a combination of processes and functions – therefore managing for single objectives (e.g., wood fibre production) tends to destabilize systems. The challenge lies in determining the processes that need to be replicated to achieve the resilient system that we set out to create. It is important to factor in spatial connections (linkages) between areas and processes.

Early stages of reclamation are inherently unstable – stability will develop over time. However, reclamation can move the system into a stability domain that is desirable. To do this, reclamation should focus on reinstating natural processes (i.e., resiliency) rather than a collection

[4] OSRIN will be releasing a report on the potential impacts of beavers on reclaimed landscapes in Spring 2013.

of prescriptions (e.g., soil depth, seedlings/ha). Reclamation should also reduce stresses and increase buffering capacity against remaining stresses.

Natural systems have a *legacy bank* (seeds/propagules, litter/organic matter, nutrient capital) that provides resilience. In reclamation, replacement of salvaged soil (organic matter) is meant to replace this legacy bank.

Diversity within functional groups is key, however, diversity is not sufficient to impart resilience. Keystone species play a significant role in resilience and an impact to a keystone species has a much larger effect on resilience than an impact on other species. Keystone species may be very common (e.g., aspen) but do not have to be.

Resilience has both temporal and spatial scales. Resilience needs to be considered in terms of 200+ years to accommodate recurring change agents such as fire. Reclamation needs to develop resilience at several scales.

2.1.3 *Questions*

Q: What are the most important processes that one should manage for?
A: There are three key processes:

- Nutrient cycling and moisture availability
- Soil biology (e.g., mycorrhizae)
- Diversity in the understory community. Diversity is a good indicator of a transition to a litter based nutrient system.

Q: How important is hydrology in these reclaimed systems (mines)?
A: Hydrology is important but we need to start thinking at the scale of climate change influences on these systems; for example, in relation to level of nutrient cycling. We need to think about these systems in terms of future climate regimes. Think about outcomes and probabilities around what we do.

2.2 Measuring for Resilience – Vegetation

The Role of Plant Species Selection in the Functionality of Reclaimed Forest Landscapes – Simon M. Landhäusser, Renewable Resources, University of Alberta.

2.2.1 *Abstract*

Rapid expansion of resource extraction activities in boreal forests has occurred throughout the northern hemisphere. In Alberta, a significant portion of publicly owned land is currently subjected to industrial disturbance. Conditional to the licence to operate on these forested lands is the requirement that reclaimed and re-vegetated landforms and soils have the capability to support self-sustaining and locally common boreal forest types. That these novel ecosystems are locally common and functioning are key criteria of self-sustainability and indicative of the ability to withstand external or internal stresses (resistance) and/or are able to recover from natural and anthropogenic disturbances (resilience).

Over millennia, most natural boreal forest ecosystems (including their soils) have adapted well to a wide range of natural disturbance regimes created by fire, insect and diseases. Anthropogenic disturbances, specifically large scale surface mining operations that severely disrupt hydrological, physical and nutritional processes within soils, have created novel disturbance regimes that have few natural analogues. Recognizing the role of species being reintroduced during the recovery of severely disturbed areas is critical in determining trajectories along which reclaimed forest stands develop. As such, the autecology and life-history traits of these species and their abundance through time and space are critical to develop resistance and resiliency of these future ecosystems. Central ecosystem processes such as water, nutrient and carbon cycling, the maintenance of species and functional diversity, the development of propagule banks, and the interactions among these processes are important components of resiliency and resistance.

In this presentation I will give examples of some of the roles plants play in the development of resistance and resiliency in reclaimed novel ecosystems emphasizing linkages among plants and ecosystem processes.

2.2.2 *Takeaway Messages*

Reclamation has moved from an *agronomic approach* (focus on soils and crops) to a more *ecological approach* with an emphasis on functioning, sustainable ecosystems.

Landscape and landform decisions have a significant impact on ultimate reclamation options through their controls on slope, aspect and hydrology.

Spatial complexity (vertical and horizontal, above and below ground) is important. Need diversity in species and diversity in landforms, habitats, etc. Soil thickness (rooting zone) is a key attribute to achieve the desired goals.

Severely disturbed sites represent a special challenge in reclamation. For example, seed banks may be unavailable adjacent to sites or in salvaged soils.

Have to acknowledge we can’t replant all species in a complex ecosystem like a boreal forest therefore we need to select the important ones and hope (help) the others establish. We need to be aware of how different species react to their environment. Mixed stands build greater resiliency because if one species is impacted (e.g., by an insect outbreak) you still have the other species. Stress tolerance is a key characteristic of the keystone species we want to establish on the sites (e.g., aspen).

Although return of a naturally-occurring, self-sustaining boreal forest is our reclamation goal we may need to consider if we can live with alternate stable states.

2.3 Measuring for Resilience – Wetlands

Ecological Resiliency of Alberta's Wetlands – Dr. Suzanne Bayley, Dr. Rebecca Rooney, Matthew Wilson and Dustin Raab, Department of Biological Sciences, University of Alberta.

2.3.1 *Abstract*

Wetlands are commonly thought to be resilient to disturbance because their vegetative community is so responsive to changes in hydrology. However their resilience actually depends on a variety of factors, including the class of wetland, the timeframe of interest, the type, severity and frequency of disturbance and whether we are looking at an individual wetland or a wetland landscape. Even the definition of resilience can affect our judgment of whether a wetland is resilient. I present three different examples of how wetlands respond to disturbance: (1) change in regime state in shallow open water wetlands due to agricultural nutrients; (2) change in marsh biota and environmental conditions after restoration and creation of urban wetlands and (3) assessment tools to evaluate reclamation of oil sands marshes[5].

In each case I show criteria and indicators of disturbance and thresholds beyond which the wetland changed its structure and composition. If resilience is defined as the amount of disturbance that a wetland system can absorb without a change in structure and composition, then these Alberta wetlands did not demonstrate resilience to disturbance. If however, we want to incorporate social-ecological systems and societal goals, then these wetlands persisted in a changed state after disturbance and we need a broader definition of resilience.

Resilience of wetlands ecosystems constructed in the oil sands reclamation has not been achieved thus far but can be achieved by using appropriate design criteria and building a diversity of wetlands that can accommodate changing hydrology and climate.

[5] For more info see Rooney Productions, 2012. *Assessment Methods for Oil Sands Reclamation Marshes*. OSRIN Video No. V-1. 20 minutes. Also available on the University of Alberta You Tube Channel (recommended approach).

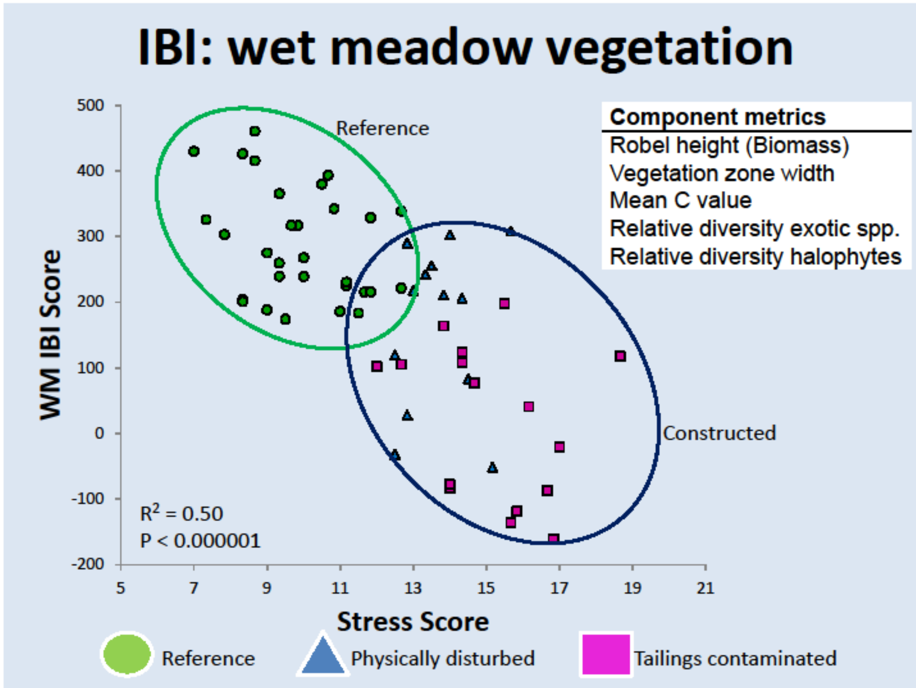

Figure 2. An index of biological integrity can be used to measure oil sands marsh resiliency. Here the wet meadow index of biological integrity component of the oil sands marsh evaluation system is shown.

2.3.2 *Takeaway Messages*

Resilience depends on wetland class and wetland functions. Time is an important factor, we see high variation in wetlands even in natural systems – for example, we can find both clear and turbid states, and algal- and vegetation-dominated states, in the same natural wetland over time.

Alternative stable (acceptable?) states can exist after a disturbance.

Peatlands are not resilient due to the time taken to build up organic matter and are hard to recreate. Marsh communities are the most appropriate reclamation goal for oil sands. When reconstructing wetlands we need to recreate a range of conditions. This will in turn produce a range of wetlands across the landscape. The range in size of wetlands was suggested to be 3 to 20 ha in size. It was also suggested that a range of depths be considered as well.

Indicators of resilience have to be responsive to the relevant stressors to be of use. Whether or not a wetland is resilient depends on timeframe and social goal. We have developed a stress gradient as a way to measure and compare whether a reclaimed wetland is within the 'natural variation' of surrounding wetlands.

2.3.3 *Questions*

Q: What about recreating peatlands in oil sands mines?
A: It is very expensive and takes a long period of time to try and recreate peatlands in reconstructed landscapes. We have to be careful with climate change as well. Peatlands may disappear because of increased temperatures at some point. The long term outlook is most important here.

2.4 Measuring for Resilience – Criteria and Indicators

Criteria and Indicators of Resilience **–** S. Ellen Macdonald, Department of Renewable Resources, University of Alberta.

2.4.1 *Abstract*

If we are to manage for resiliency in reclaimed boreal forest ecosystems and landscapes we must: define resilience; identify the factors that confer ecological resilience; and establish Criteria and Indicators (C & I) that can be used to determine whether we are achieving our objectives. Resilience is an emergent ecological property which is manifest by the ability of an ecosystem to reorganize following a perturbation (disturbance or stress). A reclaimed ecosystem could be considered to be resilient when it has regained – or is well along a pathway of recovery towards – a certain ecological structure and function. This could be defined by the pre-disturbance ecosystem, a locally representative ecosystem, or by an expected condition that relates to desired end land use. In a longer time frame, we might consider that the test of resilience will be the ability of the reclaimed ecosystem to reorganize following future disturbances and stresses.

Establishment of Criteria and Indicators for resilience is fraught with challenges:

- Which aspects of ecosystem structure and function should be considered?
- How do we apply relevant concepts of scale to these?
- How can we assess intangible and complex interactions among ecosystem components that may be critical to conferring resilience?
- Do we know which characteristics will be important for resilience in the face of disturbances and stresses that, in future, may be outside our current realm of experience?
- How do we establish targets for ecosystem structure and function, given that these are inherently highly variable and the characteristics required for resilience in future might be outside the range for which we have existing benchmarks?

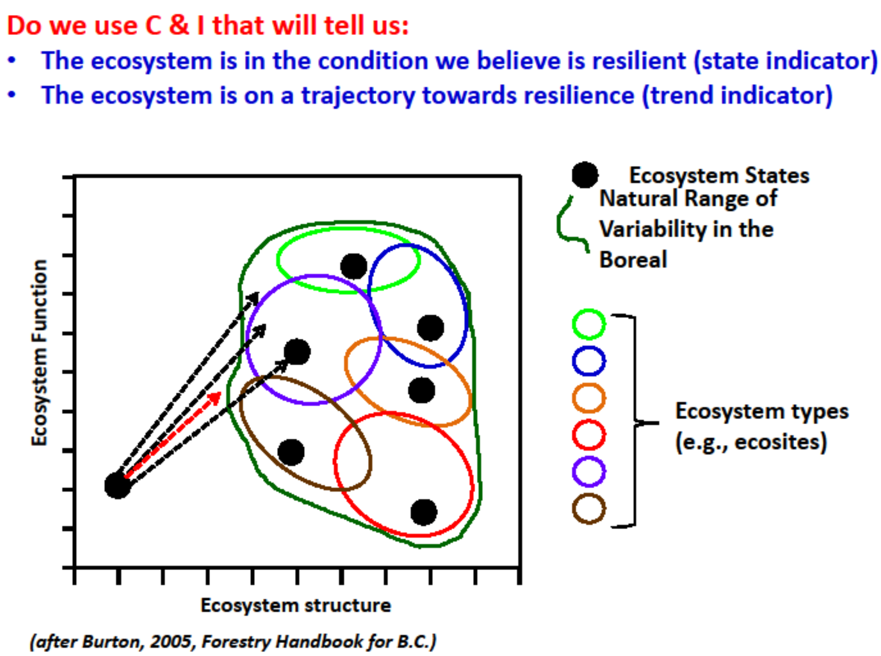

Figure 3. Options for selecting criteria and indicator measures

I will explore these questions and propose approaches to establishment of C & I for key aspects of ecosystem structure and function at appropriate spatial and temporal scales. Further, I will discuss how data derived from natural and managed forest landscapes could be used to inform establishment of C & I of resilience in reclaimed ecosystems.

2.4.2 *Takeaway Messages*

Resilience is a function of ecological structure and ecological functions (processes):

Structure	**Function**
Size, age	Primary productivity
Species diversity	Cycles
Forest floor diversity	Decomposition
Deadwood	
Spatial arrangement	

Need to consider broader landscape scale perspective as well.

Does *self-sustaining* (as required in *Environmental Protection and Enhancement Act* approvals) mean resilient?

Reclamation must ensure that the replaced soils and replanted vegetation are suitable for the site characteristics (slope, aspect, moisture, hydrology). Diversity of a system needs to be relevant – more is not always better; species need to be aligned with the reclamation goal, the ecosite and each other.

Criteria are categories or functions relative to achieving objectives. Indicators on the other hand are measurable attributes. CEMA criteria and indicators publication (Poscente and Charette 2012) refers to 3 objectives, 16 criteria and 44 indicators. Resilience is listed as a criterion for uplands and wetlands.

How do we know if we have achieved the reclamation objective? What makes an ecosystem "capable"? How far from the range of natural variability can a site be and still be "successful"?

- Start with the soil – landform and hydrology underlie this
- Nutrient availability – are nutrients flowing in the ecosystem
- Soil pH and salinity
- Soil depth
- Soil biodiversity

Financial analogy

Capability is like cash flow (supports day to day living)

Sustainability is like a bank account
(maintains through a recession or major disturbance)

Reclamation plan is like a budget
(allocates resources to achieve plan)

2.4.3 *Questions*

Q: If you reduce resiliency to criteria and indicators are we denying systems are self-organizing?
A: No, we are trying to find criteria and indicators that we hope will deliver emergent properties we desire in the ecosystem.

2.5 Measuring for Resilience – Degradation and Recovery

Ecological Resiliency: Measuring Degradation and Recovery – Dr. Jim Schieck, Alberta Biodiversity Monitoring Institute, Alberta Innovates – Technology Futures.

2.5.1 *Abstract*

Ecological resiliency encompasses concepts involving resistance to degradation and the estimation of ecosystem recovery. From a management perspective, these concepts are most

informative when applied to degradation at regional scales and recovery of natural systems at disturbed sites.

The Alberta Biodiversity Monitoring Institute[6] (ABMI) samples biota, habitat elements, landscape characteristics and human disturbance on a grid of 1,656 sites spaced 20 km apart, with each site re-surveyed once every five years. The program monitors changes in terrestrial biota (lichens, mosses, vascular plants, mites, birds, mammals), aquatic biota (vascular plants, benthic invertebrates), terrestrial and aquatic habitats (live and dead trees, shrubs, herbs, litter, soil, water physico chemistry, water basin characteristics) and landscape elements.

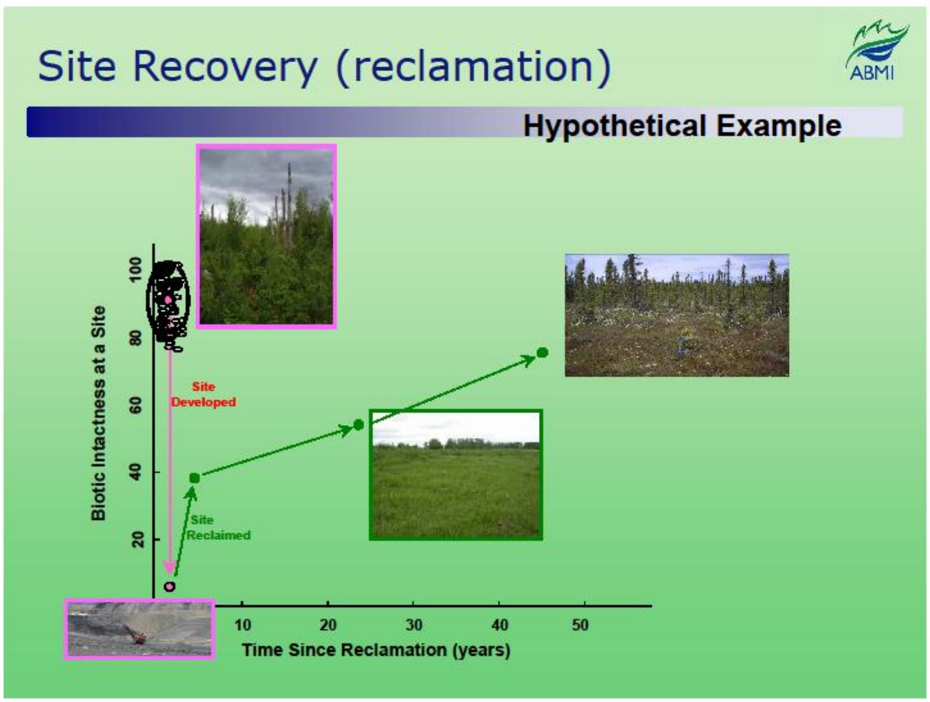

Figure 4. Hypothetical example using ABMI data to plot recovery trajectories.

ABMI information is used to assess ecological intactness – as a measure of ecosystem degradation / deviation from undisturbed condition – at the regional scale. In addition, ABMI has developed maximum likelihood models to describe the degree to which the biotic communities at target sites differ from those expected at undisturbed sites. Those relationships are used to create a framework under which recovery of disturbed sites can be evaluated. For both the regional- and site-level analyses, assessments are conducted at the species level and then combined among species to highlight biodiversity recovery and regional intactness. Since information at natural and human disturbed sites are required for both analyses, integrated data

[6] See http://www.abmi.ca/abmi/home/home.jsp

collection increases cost efficiencies. In addition, by focusing on compatible metrics at different spatial scales, it is possible to evaluate whether restoration and recovery at local scales (i.e., individual sites) results in increases in ecosystem health at the regional scale.

2.5.2 *Takeaway Messages*

Believe the terms *degradation* and *recovery* are more useful than resiliency. Focus on ability of a system to return to original conditions (recover from degradation). Note that as disturbed sites recover the regional degradation measures should decrease.

Lots of opinions but very little data available to actually measure resiliency. Need a test of whether our opinion is real – two scales to this, landscape and site level.

> *We can use Alberta Biodiversity Monitoring Institute protocols to evaluate the change in status of a disturbed site over time as it moves towards original conditions (recovery trajectory).*

Note that some disturbances are intended to be very long or permanent (e.g., roads, cities, agriculture) so there is no recovery.

2.5.3 *Questions*

Q: Why is % intactness a good measure of resilience?
A: Developed over 10 to 15 years, method includes all species and habitats – it worked best for our data.

Q: What is the role of dispersal in terms of resilience?
A: History of actions on the site are a key piece of the puzzle. Availability of undisturbed lands adjacent to disturbed areas will hasten recovery (conversely adjacent lands containing species that are not desired will slow recovery or change trajectory).

2.6 Planning for Resilience – Landform Design

Landform Design for Resiliency – Elisa Scordo, Jordana Fair and Gord McKenna, BGC Engineering Inc.

2.6.1 *Abstract*

Mining operations result in large-scale landscape disturbances. Reconstruction of the landscape involves re-establishment of topographic, surface water and groundwater systems disrupted by mining activities before terrestrial and aquatic communities can be established. The mining process in the oil sands region involves the stripping of soil and overburden to access the oil-bearing bitumen layer below and results in large mined-out pits, tailings storage facilities (in-pit and out-of-pit) and above ground overburden dumps comprised of saline-sodic soils and lean oil sands in the post-mining landscape.

Landform design is a holistic approach to the design and construction of mined landforms which uses a multidisciplinary structure to consider the implications to geotechnical, surface water, groundwater, soils, vegetation and wildlife on landscape performance. With this approach, the use of natural analogues is a key component of landform design and includes the replication of form and function to landform elements such as shallow wetlands, channels, pit lakes, plateaus and slopes. Natural features are the products of local conditions, such as climate, topography, and parent materials and processes that occur over thousands of years.

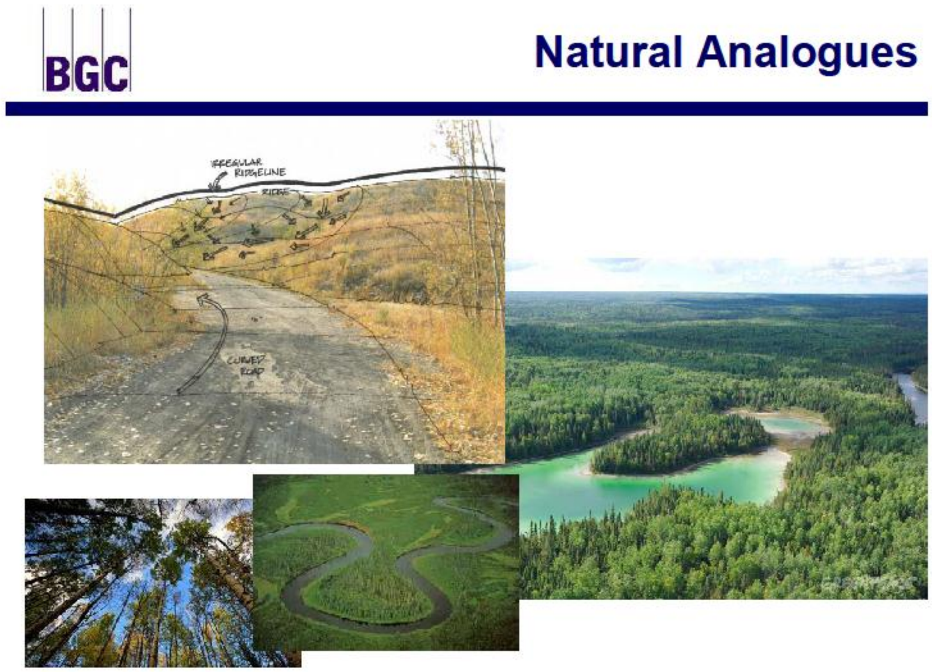

Figure 5. Natural analogues can provide templates for landscape reclamation plans.

As designers we cannot fully understand the intricacies and interactions of various landform elements (e.g., substrate, reclamation material, flora and fauna, climate), but a landform design approach can attempt to understand the implications of various failure modes or perturbations on the resiliency of reclaimed landforms over time.

2.6.2 *Takeaway Messages*

There are a variety of legacy landforms after mining, each of which poses challenges for reclamation.

Key aspects of landform design are geotechnical stability (both short term and long term) and water (surface water and groundwater). Landform design decisions impact slope, aspect, topography, etc. which are key parameters for ecological design and performance. There is increasing interest in landform "aesthetics" – are they "naturally appearing"?

> *In the end, the landform design approach should provide a stable foundation so functional ecosystems can be developed on them.*

Landform design must return both form and function over a variety of scales (regional down to micro). Natural analogues provide a template for landform design and give guidance on natural processes that should be re-established. Design must accommodate the range of natural variability in a region (e.g., stream design for both low flow and probable maximum flood). Proof of "success" will take a long time therefore models needed to predict performance.

2.6.3 *Questions*

Q: Where do we transition from engineering scale to ecological scale – is it at the landform?
A: The landform scale provides a definite opportunity to contribute ecological knowledge to landform design.

2.7 Planning for Resilience – Vegetation

Changing Objectives for Oil Sands Reclamation: The Evolution of the Faster Forests Program – Terry Forkheim, Statoil Canada Ltd.

2.7.1 *Abstract*

The development of Alberta's oil sands resource requires significant exploration activity before construction and operation of the facilities can occur. Oil Sands Exploration (OSE) sites are necessary to delineate the bitumen resource, thus enabling detailed planning of in-situ oil sands projects. Due to the large number of OSE sites required, they constitute a significant land disturbance in the Boreal forest. Prior to 2009 reclamation efforts for OSE sites focused on stabilizing the site and preventing erosion, and seeding the sites to native grasses was an accepted and common practice. Agronomic grasses and legumes were seeded prior to the native mixes becoming the standard.

These practices were not felt to be satisfactory in a Boreal forest setting, and plans were made to move towards more appropriate objectives. The first step was to move away from seeding sites to grass, and the initial focus was on planting trees.

The Faster Forests program[7] was initiated at OSLI (Oil Sands Leadership Initiative) in 2009, with three companies participating. The objective was to plant trees to accelerate the recovery to a forest trajectory for the site. One tree species (aspen poplar) was planted that year. While that was considered a success as the trees made it into the ground and survived, it was felt that there was much more that could be done. Every year since then the program has expanded and

[7] See http://www.osli.ca/projects/land/faster-forests

evolved considerably in terms of variety of species, numbers planted, planting techniques, ecological objectives, linkages to best construction and reclamation practices, and other OSLI projects. The findings are being applied to other disturbances to enhance and accelerate reclamation throughout the oil sands. This presentation describes the progress and evolution of the Faster Forests program.

2.7.2 *Takeaway Messages*

Several shifts in in-situ development reclamation practices over time have had an impact on resilience (though perhaps this was not the primary goal):

- Agronomic grasses to native grasses to trees to trees plus shrubs
- Single species to multi-species mixes
- Coarse woody materials viewed originally as a waste and now as an ecological resource[8]
- Greater "ownership" of planting stock development and methodology

> *The Faster Forests program was designed to get sites on a trajectory back to a forest quicker than traditional grass-based reclamation methods which seemed to "stagnate"*

Focus on number of trees planted as the metric changed to greater emphasis on diversity and site success. There is a lot of value in having field tours to look at what works and what doesn't – people *get it* better when seeing actual results as compared to tables and figures. However there is an important role for site documentation – what, when, how, why – to allow for learnings to be shared.

2.7.3 *Questions*

Q: Did the field implementation difficulties arise from attempts to plant to site characteristics or were they a result of logistical/planning issues?
A: They were due to logistical/planning issues – attempting to get the right mix of species delivered to the right site at the right time and planted.

[8] OSRIN will be releasing a field guide to using coarse woody materials for reclamation in early 2013.

2.8 Planning for Resilience – Soil Management

Soil Management to Maintain Boreal Forest Resiliency – Dean MacKenzie, Ph.D., P.Ag., Navus Environmental Inc.

2.8.1 *Abstract*

Conservation and management of forest surface soil is beneficial for the development of resilient boreal forest plant communities on post-disturbed land and can be used to target plant communities that will meet restoration/reclamation objectives[9]. Forest surface soil is an economical source of diverse and abundant biotic components such as native plant propagules (i.e., spores, seeds, vegetative propagules), soil fauna and microorganisms as well as abiotic components such as nutrients that are required for the development of resilient "future" forests. Biotic properties are among the most significant factors affecting resilience of the vegetation community on reclaimed land where salvaged forest surface soil has been placed.

Source location of donor soil, salvage depth, stockpiling and placement depth are factors that affect the availability and viability of propagules for regrowth. Salvage depth affects soil quality and potential for in situ propagules to emerge. Salvaging too deep will dilute the propagules and organic matter content of the forest floor with underlying mineral soil; however, salvaging too shallow may not provide sufficient root to soil contact for successful emergence of seeds or vegetative propagules. Optimal salvage depth will be impacted by various factors such as soil texture, source location and reclamation objectives.

Salvaged surface soil should be directly placed, as stockpiling surface soil for even short periods of time reduces viability of most boreal plant species and causes substantial changes to soil chemical properties. During salvage if too much mulch is incorporated with upland surface soil, viability of native propagules can be reduced. Optimal placement depth and distribution of surface soil is also dependent on many factors including salvage depth, substrate quality and reclamation objectives. Placement of coarse woody debris on the surface soil creates microsites that aid in reestablishment of native plants.

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[9] OSRIN will be releasing a review of the use of forest floor soils in reclamation in early 2013.

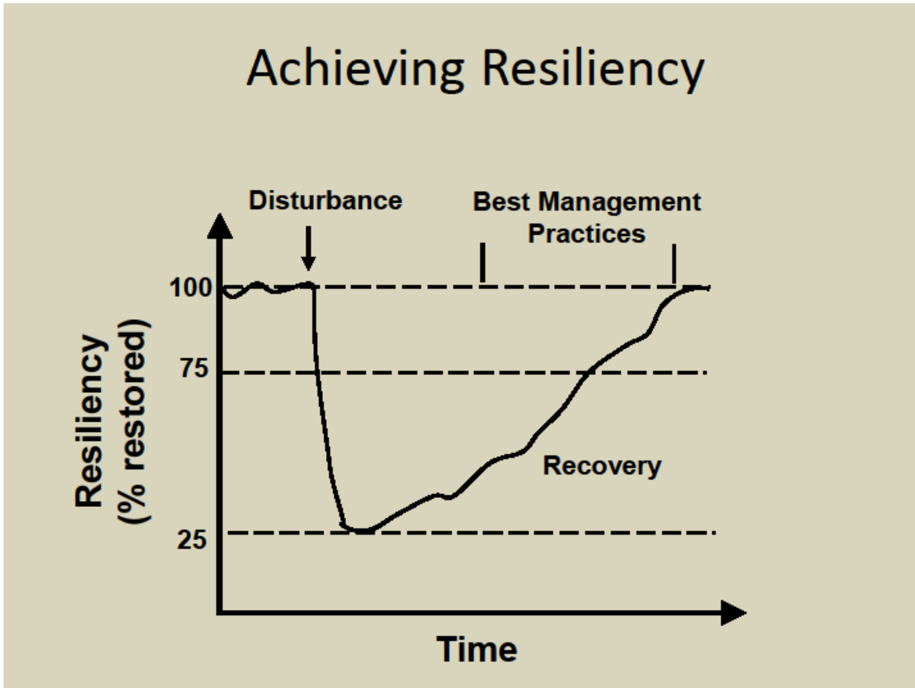

Figure 6. Achieving resiliency in reclaimed systems takes time and management. Using best management practices can potentially expedite the return to an original ecological state.

This presentation discusses how these factors affect vascular plant propagule and seed abundance, distribution and establishment towards diverse self-sustaining boreal forest plant communities. Various adaptive management practices developed from theory, research and operations to help reduce negative impacts on soil quality and viability of native propagules are also discussed.

2.8.2 *Takeaway Messages*

Soil provides valuable seeds and propagules to assist in increasing native species diversity on a reclaimed site. However, this value decreases with depth and storage time.

Soil handling/management has major impact on propagules and abiotic processes (seeds, like humans, lose viability over time).

Achieving resiliency is achieved by considering that:

- Salvaging soil beyond 30 cm reduces seed/propagule regeneration and will therefore require out planting

- Direct placing soils on sites with similar characteristics (i.e., upland salvaged soils should be placed on upland reclaimed sites) results in more, and more appropriate, regeneration
- Incorporating fine mulch into soil piles results in loss of all propagules; incorporating coarse woody debris may be acceptable
- Diversity is enhanced when surface left rough – microsites are created
- Diversity is greater with early seral stages than older seral stages

2.8.3 *Questions*

Q: What about adding stumps into surface soil salvage to increase microsites?
A: Yes, that is a valuable way to increase microsites.

Q: What are the operational challenges of thin lifts and direct placement?
A: Haul costs are the biggest challenge, and finding available space for storage, but the extra cost is worth it to have a viable seed/propagule bank for improved site recovery. The best option is to use direct placement.

2.9 Planning for Resilience – Resilience in Reclamation Policy and Regulation

Is Ecological Resiliency a Meaningful Concept for Reclamation Policy and Regulation: Considerations for the Management of Oil Sands Facilities **–** Brett Purdy, Alberta Innovates – Energy and Environment Solutions.

2.9.1 *Abstract*

The development of oil sands resources results in both extensive and intensive disturbance of the natural boreal landscape. Companies who receive approval to operate oil sands facilities are required to conserve and reclaim disturbed land as per the *Environmental Protection and Enhancement Act* (EPEA) and *Conservation and Reclamation Regulation*. Requirements detailed in EPEA Approvals are at times prescriptive such as those that govern soil salvage and placement, whereas others are outcome-based, such as the requirement that reclaimed lands be capable of supporting self-sustaining locally common boreal forest ecosystems. Due to the large temporal and spatial scales associated with oil sands operations, defining the measures of success in achieving outcomes-based reclamation objectives has at times been difficult in a regulatory context.

In response to this challenge, government requires companies to frequently update, and submit for regulatory approval, long-term operational planning documents such as life of mine closure plans. To assist with reclamation planning, reclamation operations, and assessment of performance, several guides, manuals and frameworks for reclamation specific to oil sands operations have been developed largely through multi-stakeholder forums. Annual reporting provides details of on-the-ground conservation and reclamation activities which reflect how the closure and reclamation plans are implemented. Whereas this process provides flexibility and adaptive management opportunities in developing acceptable reclamation and closure options

throughout the life of an oil sands facility, it can result in challenges in defining measures of reclamation success at the time of certification.

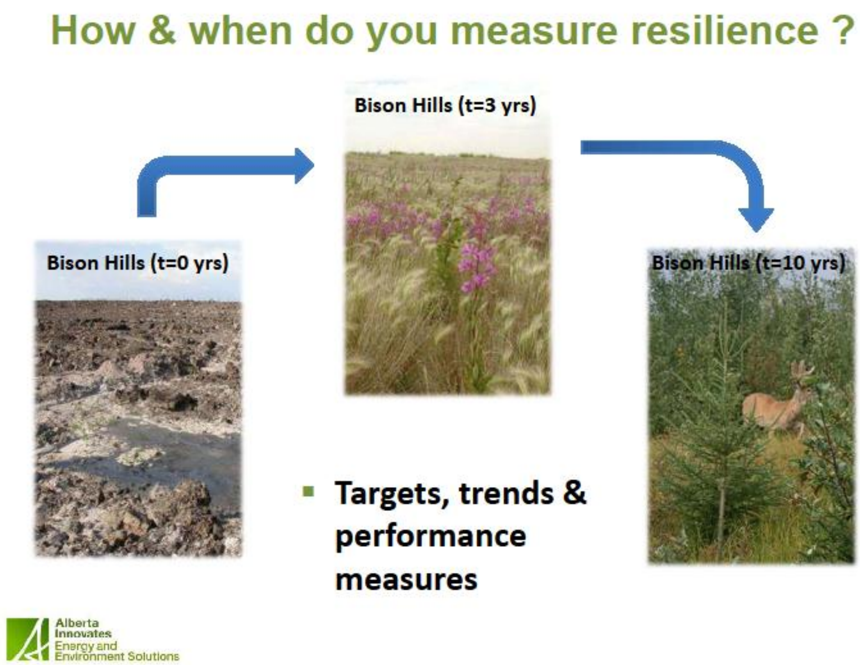

Figure 7. Measurement tools are required to evaluate development of resilience.

Extending regulatory consideration of the ecology and environment beyond the first generation of a reclaimed boreal forest ecosystem may seem to some unnecessary and overly complex. This presentation will introduce the conservation and reclamation context in which oil sands facilities operate, and attempt to discuss how long-term issues of sustainability, which incorporate concepts such as ecological resiliency, might be built into a regulatory system.

2.9.2 *Takeaway Messages*

The concept of resilience is complex but is still valuable in planning for and assessing reclamation. There are some policy barriers, but there are also opportunities to incorporate resilience into an adaptive management framework. The term *resilience* showed up regularly in current mine closure plans. We may need to vary expectations for pace of recovery on mines versus in-situ sites.

> *Resilience will likely be a checklist of reclamation and management strategies designed to ensure success rather than a measurement of ecological condition(s).*

While we may know what the individual components of a resilient system are we lack the tools to effectively and efficiently measure them. Resilience is built into monitoring to assess the *self-sustaining ecosystem* requirement in the approvals.

How and when do you measure resiliency? What would a checklist look like?

- Site level measurements
  - Look at soils
  - Landform design
  - Building the checklist
  - Establish targets based on natural systems
  - Form and function (wetlands, uplands)
  - Design landforms to sustain natural geomorphic processes
  - Natural appearance, hydrologic regimes
  - Best Management Practices for soils
  - Establish biodiversity
  - Stand level – establish more species
- Landscape level
  - Minimizing disturbance and progressive reclamation
  - Land disturbance limits
  - Legacies of secondary succession
  - Seed banks, propagules

Some resilience is emergent but some must also be designed/built early on (e.g., diversity of landforms, planting multiple species) to create the foundation for successful reclamation.

2.9.3 *Questions*

Q: So is the government coming up with two streams of regulations, one for mines one for in-situ?
A: Right now there is a hybrid system evolving independently of direction. The new Alberta Energy Regulator structure should get both groups in the room and focus on synergies.

Q: Is there more emphasis on progressive reclamation?
A1: Every closure plan submitted to the government has given rise to questions about the pace of reclamation.
A2: However it is important to note that there are not large blocks of land ready to

reclaim that industry is not addressing. They keep on top of reclamation as much as is practicable.
A3: Agree but interesting to note that a senior industry person indicated that changes in technology (especially for tailings management) may allow more land to become ready to reclaim quicker than current practices allow.

Q: Do regulations permit novel landscapes?
A: The goal for oil sands mines is locally common boreal forest landscape *regardless of the intended end land use*. There appears to be more flexibility for coal mines.

3 PLENARY DISCUSSION, WRAP-UP AND PATH FORWARD

3.1 Discussion

Need a timetable for when criteria for release of water will occur. Landform design can then flow from this (note current design impediments include debates about whether or not landforms should shed (geotechnical stability) or retain (ecology) water). To set timelines we need to develop criteria for chemicals not covered by existing documents.

We also need better models to understand hydrology under a changing climate. To build resilient landscapes, it will be fundamental to understand how uplands and lowlands interact, particularly their hydrology.

Resilience embraces uncertainty. What we often don't do is identify sources of uncertainty and identify which ones we can and can't control. More complex models don't always get us better results.

Do we need to establish natural range of variability at the landscape level and/or at the site level to set criteria? Yes, but also expand to ask where we derive natural range of variability from (i.e., what kinds of sites)? This has to be interpreted carefully. Not entirely certain what reference condition is because change is constant therefore need to resample reference sites to track their changes and reset reclaimed site performance expectations. Need to define these better. Reference conditions are based on past climate; climate is now changing so what exactly is an appropriate reference site? That's why we select both historic and contemporary natural range of variability and processes. Would making natural range of variability guidelines around ecosites be a reasonable approach?

Where within the range of natural variability do we want to have sites exist? Do we need to have threshold boundaries defined for when we move between alternate stable states?

Ecosite guides are misleading because boundaries are drawn. However, it is inevitable that you are in the field and you fall between two ecosites because nature doesn't do firm boundaries.

Particularly like the acknowledgement of spatial and temporal components. We heard a lot about plants and soil, but there was little discussion about interactions; need to spend more time here.

Future research: Look at reclaimed sites within major disturbance (e.g., fire) and see how they respond (Jay Woosaree – Alberta Innovates Technology Futures noted they have been doing post-fire recovery studies). Or do experimental studies with fire on reclaimed sites and see if they are resilient (suggested by more than one person).

3.2 Wrap-up Comments

Ellen Macdonald (University of Alberta) provided a summary of key points from the presentations.

When thinking of resilience we need to consider – of what, to what and for how long. There are important spatial and temporal aspects to resilience. The scale and intensity of disturbance impacts vary by activity type – mining vs. in-situ vs. upstream oil and gas[10].

Resilience can be thought of as the ability to deliver a desired suite of ecological goods and services in the future.

Resilience is not a static property – change happens naturally and resilience provides the system with capacity to resist or adapt to the change. Planning, regulation, policy and monitoring need to accept (ideally embrace) spatial and temporal variability.

The building blocks of resiliency are landscape, landform, hydrology, soils and species (arguably the same as the building blocks for successful reclamation). Reclamation planners must ensure that soil and vegetation are paired with the appropriate landform and hydrology. Analogues may serve as templates for reclamation planning.

We have a lot of existing knowledge from research and monitoring work on natural areas – just have to apply it to disturbed lands.

[10] Note there are also aggregate extraction sites and quarries in the oil sands region as well as infrastructure projects.

3.3 Additional Observations

The report authors offer the following additional observations.

Two key terms were variously defined during the presentations (more detailed definitions are provided in section 5.1):

- *Engineering resilience* or *Resistance* – the ability of a system to resist change by a stressor and stay more or less the way it was
- *Ecological resilience* – the ability of a system to recover to its original condition after a stressor

Resilience is imparted by a combination of structure (form) and process (function). Diversity (landforms and species) is necessary but not sufficient to impart resilience. Some components of a system may be more important for resilience than others (e.g., keystone species) and should therefore be given more emphasis in reclamation planning.

Table 2. Reclamation, diversity and resilience were commonly used terms in the seminar. Linkages between these key attributes adapted from comments by Simon Landhausser, Ellen Macdonald and Ken Foster.

Planning for resilience	If we build it will they come?
⇩	⇩
Monitoring for resilience	If they come will they stay?
⇩	⇩
Achieving resilience	If they stay will they thrive?

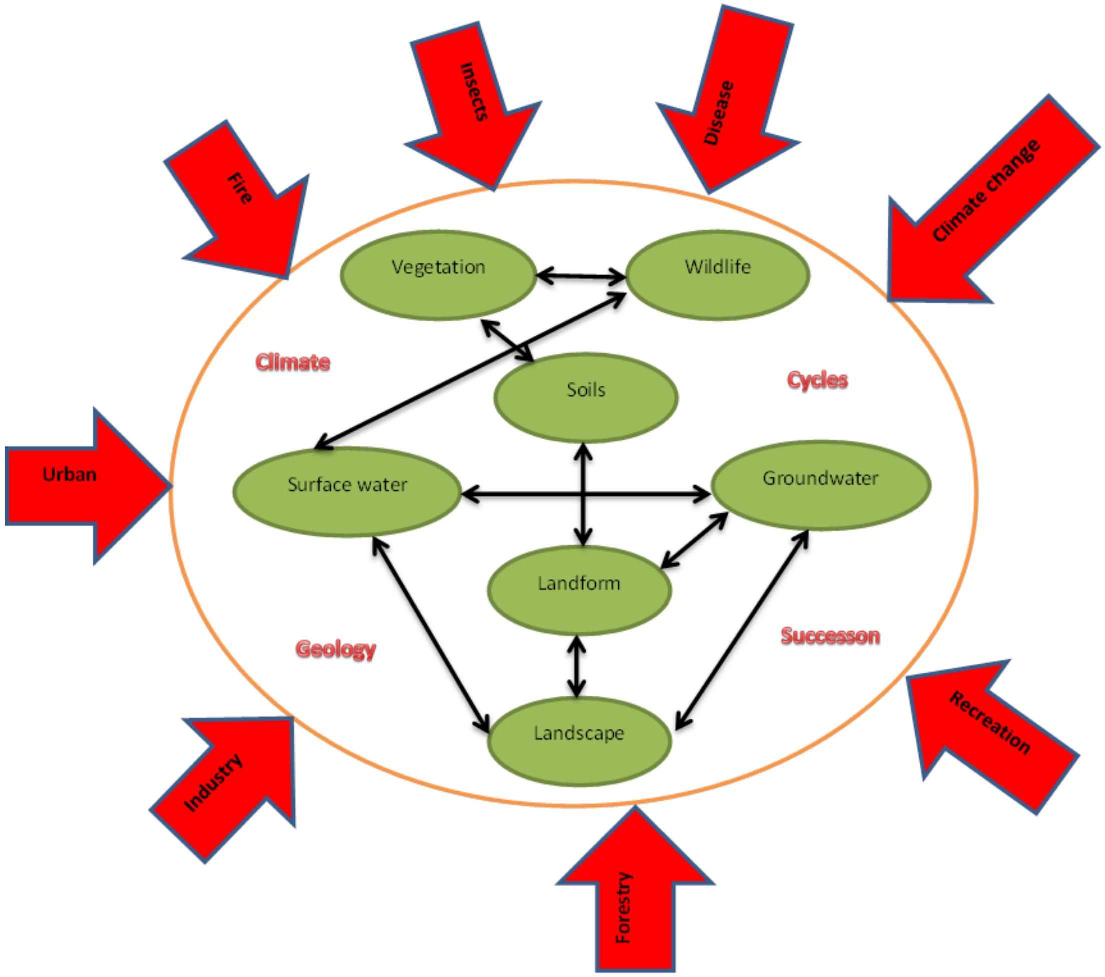

Figure 8. Resilience determines the fate of sites subjected to stress.
Resilience (brown circle) is a function of several key physical, chemical and biological components (green circles) that are inter-linked and large-scale processes (red text). Natural and manmade stressors act on a site (red arrows) at different times and different scales. The result may be no change, change and return to original condition, or change to a new stable state.

Awareness of the range of natural variability helps in understanding how resilient a system is. It is also a useful concept in assessing reclamation success. However, the scale of assessment is important – a site could be deemed to *fail* because it falls outside the range of natural variability for the expected site conditions but could *pass* in the context of a larger area (mine, region) because the range of natural variability is much broader.

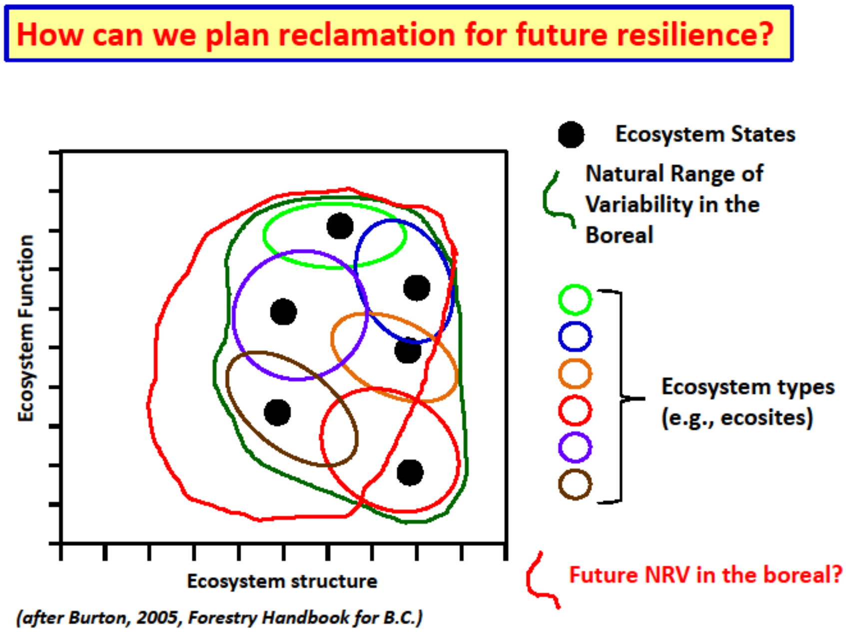

Figure 9. Reclamation planning and assessment must take into account variation in the range of natural variability with scale and time.

We must consider the linkages between reclaimed landforms – e.g., what happens in uplands affects what happens in the lowlands – and remember that managing for resilience in one landform may change the stressors, and therefore the resilience, of another.

We may not need to measure resilience; rather we may want to focus on the planning and management strategies that will impart resilience characteristics to a reclaimed landscape. Examples include diversity of landforms, diversity of species (planted and emergent), and soils appropriate to the landform and ecological outcome (ecosite).

> *Resilience may need to be moved from a criterion to an objective in the Cumulative Environmental Management Association's Criteria and Indicators system because it is a function of so many parameters that are already listed as criteria.*

3.4 Post-Seminar Feedback

The following comments were provided by seminar attendees after the event:

- The seminar emphasis was on the ability to withstand or recover from disturbance/change. There would be value in discussing the types and nature of changes/stresses we can expect reclaimed sites to experience. As noted by a number of presenters change can be both acute and chronic. A starting point might be the Failure Modes diagram shown by Elisa Scordo (Figure 10).

- There is need for more guidance/advice on reclamation design principles that will help tie together the important lessons we have learned in individual disciplines. The seminar made it very clear that resiliency is dependent on linkages within the landscape components.
- Most of the discussions focused on the traditional landscape, soils and vegetation metrics. It would be helpful to discuss other aspects such as wildlife. Some species need specialized habitats which will require careful planning.
- Much of the discussion focused on resiliency to a sudden event. We also need to discuss stresses – not a single event which impacts an ecosystem, but a series of events that over time that affect the resiliency of a system.

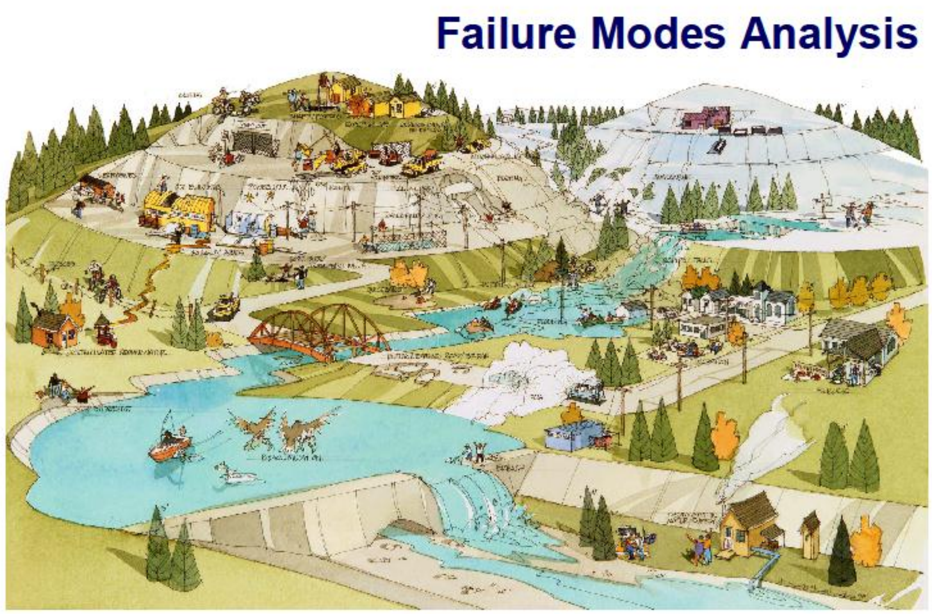

Figure 10. Potential places where landscapes and reclamation can "fail".

3.5 Path Forward

There was interest in holding a similar session in a year's time to provide more information. This seminar was, by design, focused on providing information about the concept of ecological resilience and its potential application to land reclamation. There was interest in getting more technical detail, perhaps by focusing on specific research and implementation projects – there is a need to see more practical advice in terms of how to apply these concepts on the ground.

A session on how to create and monitor recovery (reclamation) trajectories would be helpful.

It would be good to hear from other disciplines that have tracked adaptations to change (e.g., fire, volcanic eruptions, glaciation, abandoned farmland, unreclaimed lands, etc.).

Similarly it would be useful to get a better understanding of the predicted stresses that will result from climate change.

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5 GLOSSARY

5.1 Terms

Alternative Stable State

An ecological condition that is different than the original (or desired) condition but is nonetheless stable (there is a balance in system processes).

[Wikipedia] In ecology, the theory of alternative stable states (sometimes termed alternate stable states or alternative stable equilibria) predicts that ecosystems can exist under multiple "states" (sets of unique biotic and abiotic conditions). These alternative states are non-transitory and therefore considered stable over ecologically-relevant timescales. Ecosystems may transition from one stable state to another, in what is known as a state shift (sometimes termed a phase shift or regime shift), when perturbed. Due to ecological feedbacks, ecosystems display resistance to state shifts and therefore tend to remain in one state unless perturbations are large enough. Multiple states may persist under equal environmental conditions, a phenomenon known as hysteresis. Alternative stable state theory suggests that discrete states are separated by ecological thresholds, in contrast to ecosystems which change smoothly and continuously along an environmental gradient.

Ecological Elasticity

The proportionate change in environmental impact which will result from a change in the driving (in this case, anthropogenic) factors.

Ecological Resilience(y) – assumes multiple stable states are possible

The ability of a system to absorb impacts before a threshold is reached where the system changes into a different state (alternate stable state).

The magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behaviour.

The amount of disturbance that can be sustained [by an ecosystem] before a change in system control or structure occurs.

A measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables.

The capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity.

The capacity of an ecosystem to return to the pre-condition state following a perturbation, including maintaining its essential characteristics taxonomic composition, structures, ecosystem functions, and process rates.

Engineering Resilience(y) – assumes one stable state is possible (also called Resistance)

The capacity of a system to return to its pre-disturbance state.

The time required for a system to return to an equilibrium point following a disturbance event.

Latitude

The maximum amount a system can be changed before losing its ability to recover (before crossing a threshold which, if breached, makes recovery difficult or impossible).

Range of Natural Variability

The temporal and spatial distribution of ecological processes and structures.

The ecological conditions, and the spatial and temporal variation in these conditions, that are relatively unaffected by people, within a period of time and geographical area appropriate to an expressed goal.

Ecologists and natural resource managers use the term range of natural variability to recognize that the environment and its characteristics vary in space and time. Variations outside the expected range may indicate a problem.

Recovery

The return to a pre-existing condition.

Resilience(y)

The ability of an ecosystem to respond to disturbance by resisting damage and recovering quickly.

The ability to recover from or adjust easily to a disturbance or change.

Resistance

The capacity of the ecosystem to absorb disturbances and remain largely unchanged.

The capacity of an ecosystem (e.g., a forest) to resist minor disturbances over time, such as the death of a few trees or a chronic level of herbivory by insects.

The ease or difficulty of changing the system (i.e., how “resistant” it is to being changed).

Stability

The capacity of an ecosystem to remain more or less in the same state within bounds, that is, the capacity to maintain a dynamic equilibrium in time while resisting change.

Trajectory

The steps or path from one state to another state (e.g., disturbed to reclaimed). Trajectories are helpful in developing plans by setting our expected stages of development over time; these in turn help identify characteristics that should be incorporate into the plan. Similarly they are helpful in monitoring success by allowing us to compare a site’s current status with its expected status – when deviations are spotted their cause can be determined and remedial/adaptive measures taken, or a new end state can be predicted.

5.2 Acronyms

ABMI	Alberta Biodiversity Monitoring Institute
C & I	Criteria and Indicators
CEMA	Cumulative Environmental Management Association
EPEA	*Environmental Protection and Enhancement Act*
OSE	Oil Sands Exploration
OSLI	Oil Sands Leadership Initiative
OSRIN	Oil Sands Research and Information Network
RWG	Reclamation Working Group
SEE	School of Energy and the Environment

APPENDIX 1: Seminar Committee Membership

Tim Vinge	Alberta Environment and Sustainable Resource Development
Matthew Pyper	Department of Renewable Resources, University of Alberta
Chris Powter	Oil Sands Research and Information Network, University of Alberta
Kate Lindsay	Alberta Energy
Brett Purdy	Alberta Environment and Sustainable Resource Development
Caroline Bampfylde	Alberta Environment and Sustainable Resource Development
Carol Bettac	Alberta Innovates – Technology Futures
Scott Nielsen	University of Alberta

APPENDIX 2: Seminar Agenda

8:30am - 8:45am Opening remarks and context – Chris Powter (OSRIN)

8:45am - 9:30am Keynote

- Why is resiliency a concept worth discussing? – Clive Welham (3Green Tree Ecosystem Services Ltd.)

9:30am - 10:30am How do we measure resiliency?

- The importance of plant species selection in reclaimed forest landscapes – Simon Landhausser (University of Alberta)
- Suzanne Bayley (University of Alberta)

10:30am - 11:00am Coffee break

11:00am - 12:00pm How do we measure resiliency? *continued*

- Criteria and indicators of resiliency – Ellen Macdonald (University of Alberta)
- Measuring ecological/biodiversity recovery – Jim Schieck (Alberta Biodiversity Monitoring Institute)

12:00pm - 1:00pm Lunch

1:00pm - 3:00pm How do we plan for resilient landscapes?

- Elisa Scordo (BGC Engineering)
- Changing objectives in oil sands reclamation – Terry Forkheim (Statoil Canada Ltd.)
- Soil management to maintain boreal forest resiliency – Dean Mackenzie (Navus Environmental Inc.)
- Is ecological resiliency a meaningful concept for reclamation policy and regulation? – Brett Purdy (Alberta Innovates Energy and Environment Solutions)

3:00pm - 3:20pm Coffee break

3:20pm - 4:00pm What are our needs moving forward?

- Open discussion and question period

4:00pm - 4:15pm Closing Remarks

APPENDIX 3: Seminar Presentations

The following PowerPoint presentations were delivered at the seminar.

Context for the Day – Chris Powter (Oil Sands Research and Information Network, University of Alberta)

Resilience: A Concept Worth Knowing – Clive Welham (3Green Tree Ecosystem Services Ltd.)

The Role of Plant Species Selection in the Functionality of Reclaimed Forest Landscapes – Simon Landhausser (University of Alberta)

Ecological Resiliency of Alberta's Wetlands – Suzanne Bayley (University of Alberta)

Criteria and Indicators of Resilience – Ellen Macdonald (University of Alberta)

Ecological Resiliency: Measuring Degradation and Recovery – Jim Schieck (Alberta Biodiversity Monitoring Institute)

Landform Design for Resiliency – Elisa Scordo (BGC Engineering)

Changing Objectives for Oil Sands Reclamation: The Evolution of the Faster Forests Program – Terry Forkheim (Statoil Canada Ltd.)

Soil Management to Maintain Boreal Forest Resiliency – Dean Mackenzie (Navus Environmental Inc.)

Is Ecological Resiliency a Meaningful Concept for Reclamation Policy and Regulation: Considerations for the Management of Oil Sands Facilities – Brett Purdy (Alberta Innovates – Energy and Environment Solutions)

Seminar Wrap-up Notes – Ellen Macdonald (University of Alberta)

Context for the Day

Chris Powter (Oil Sands Research and Information Network, University of Alberta)

Ecological resilience is important for different reasons during the development and closure of oil sands projects:

- During development we are interested in the resilience of areas outside the immediate footprint – that is, those areas that may potentially be indirectly impacted by development from environmental stressors such as changes in groundwater regime, air emissions, water use, water releases, habitat fragmentation, etc. We are also interested in knowing where areas are not impacted as they can act as controls for research projects or reference areas for environmental monitoring.
- During reclamation we are interested in knowing what steps we can take to "add in" the characteristics of resilient landscapes, soils and vegetation
- Following reclamation we are interested in knowing what characteristics of ecological resilience we should measure to determine if reclamation has been successful (the Cumulative Environmental Management Association has identified ecological resilience of both uplands and wetlands as a potential measure of reclamation success)

Resiliency of Reclaimed Boreal Forest Landscapes

CONTEXT FOR THE DAY

Chris Powter
Executive Director
Oil Sands Research and Information Network
School of Energy and the Environment
University of Alberta

OSRIN Oil Sands Research and Information Network

www.osrin.ualberta.ca

Not Rocket Surgery

No amount of resilience will protect against direct disturbance like a mine, tailings pond, well pad or CPF

http://environment.alberta.ca/apps/osip/

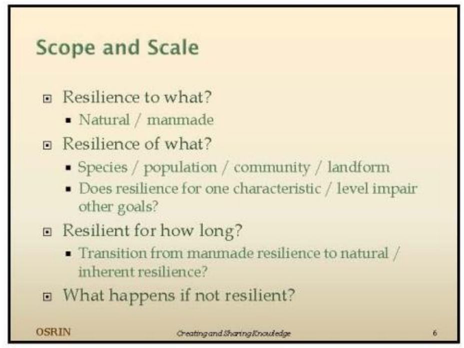
Application to Adjacent Lands

Are offsite lands resilient to change? Which components? How much?
Put another way – where are your controls or reference areas?

Application to Reclaimed Landscapes

How do we build resilience into reclaimed landscapes?
What physical and biological characteristics are critical?


CEMA Criteria & Indicators
CEMA RWG Criteria and Indicators project includes "ecological resilience" as potential measure for uplands and wetlands mine site certification
OSRIN
Creating and Sharing Knowledge
5


Scope and Scale
Resilience to what?
Natural / manmade
Resilience of what?
Species / population / community / landform
Does resilience for one characteristic / level impair other goals?
Resilient for how long?
Transition from manmade resilience to natural / inherent resilience?
What happens if not resilient?
OSRIN
Creating and Sharing Knowledge
6


Questions?
OSRIN
Creating and Sharing Knowledge
7

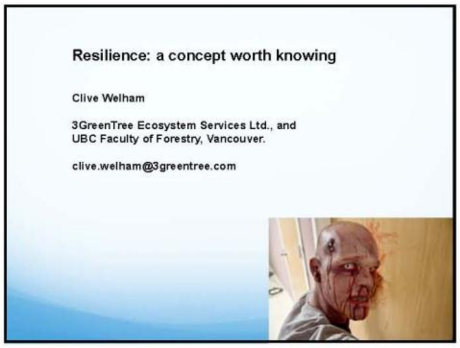
Resilience: A Concept Worth Knowing

Clive Welham (3Green Tree Ecosystem Services Ltd.)

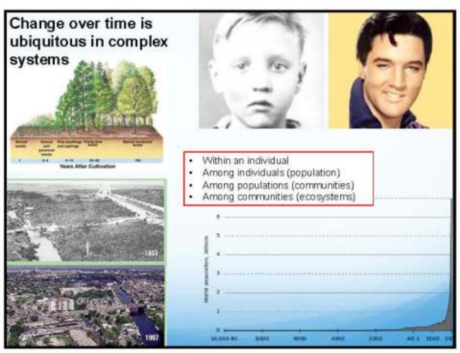
Resilience is an emergent property of ecosystems, an outcome of their capacity for self-organization. As such, it is a challenging paradigm to interpret and implement because ecosystems cannot be easily ‘deconstructed’ with the aim of studying the behavior of each (simplified) part in isolation; in self-organized systems, the whole is indeed greater than the sum of its parts. Nevertheless, the concept is as an important and useful paradigm in ecological management and by extension, reclamation.

Despite its presence in the common vernacular, a clear and precise ecological definition of ‘resilience’ has proven elusive. Though not ideal from a scientific perspective, it is also not uncommon (think of how ‘ecosystem’ itself is defined, for example) and does not prevent its useful application. More problematic is a lack of appreciation for the two key components of resilience in ecological systems – structure and scale – both of which are necessary for the concept to be meaningful. Structure refers what’s there and in what amount (species, populations, ecosystem attributes, etc.). This component has received considerable attention. Less so for scale, which pertains to both space and time. Properties that confer resilience are not independent of the spatial scale under consideration, and resilience has no context unless we answer the question, over what time scale? In this respect, there are psychosocial, economic, and even geopolitical barriers that limit our ability to manage for resilience, and these should not be ignored.

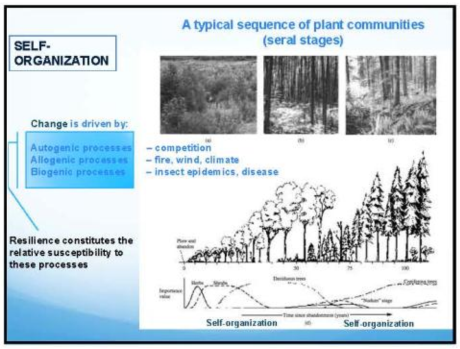
Resilience in natural and reclaimed ecosystems are mirror images. Applying the concept in natural systems is to pose the question, how much can self-organizing capabilities be perturbed and still achieve desired outcomes. In the case of reclamation the question becomes, how much of the self-organization capabilities of a system must be created to achieve desired outcomes.

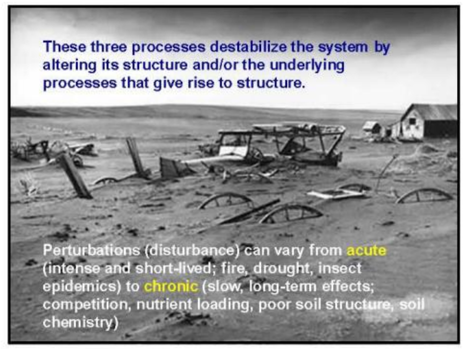

Resilience: a concept worth knowing
Clive Welham
3GreenTree Ecosystem Services Ltd., and
UBC Faculty of Forestry, Vancouver.
clive.welham@3greentree.com

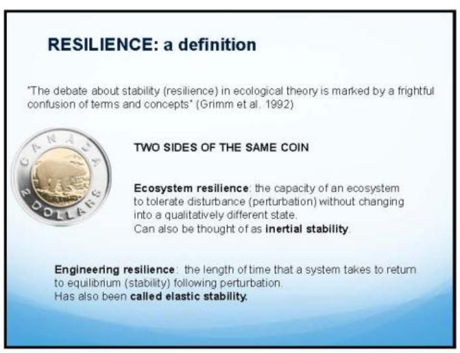

3 KEY POINTS
Complex systems arise in nature through an inherent capacity for self-organization
Self-organization is the interaction between structure and process that leads to system development
Resilience is an emergent property of complex systems, an outcome of their capacity for self-organization

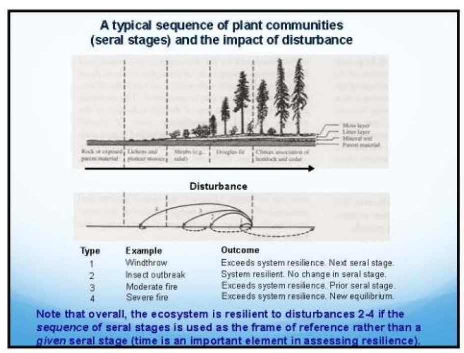

Change over time is ubiquitous in complex systems
Within an individual
Among individuals (population)
Among populations (communities)
Among communities (ecosystems)

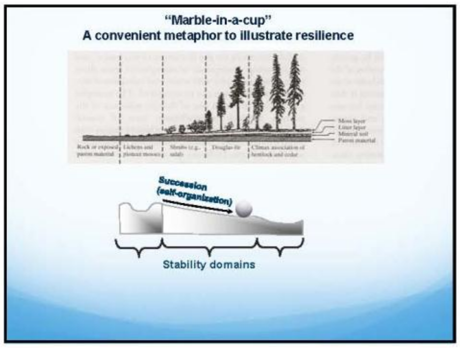

Change is ubiquitous in complex systems, and resilience theory helps us learn, adapt, and manage for change, instead of against change.
Resilience theory suggests that complex systems can exist in fundamentally different regimes (states), and resilience is the property that mediates transitions among those regimes.

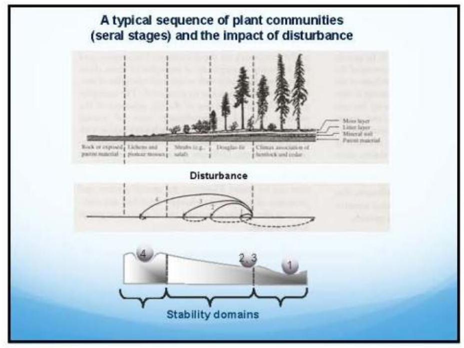

A typical sequence of plant communities
(seral stages)
SELF-
ORGANIZATION
Change is driven by:
Autogenic processes
Allogenic processes
Biogenic processes
– competition
– fire, wind, climate
– insect epidemics, disease
Resilience constitutes the relative susceptibility to these processes
Self-organization
Self-organization

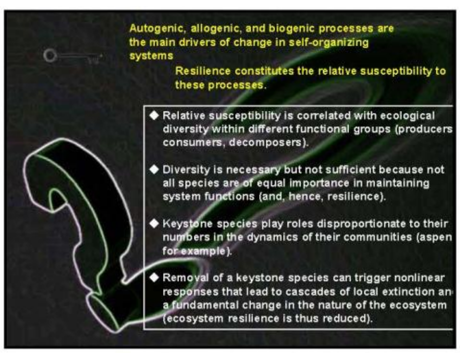

These three processes destabilize the system by altering its structure and/or the underlying processes that give rise to structure.
Perturbations (disturbance) can vary from acute (intense and short-lived; fire, drought, insect epidemics) to chronic (slow, long-term effects; competition, nutrient loading, poor soil structure, soil chemistry)


RESILIENCE: a definition
"The debate about stability (resilience) in ecological theory is marked by a frightful confusion of terms and concepts" (Grimm et al. 1992)
TWO SIDES OF THE SAME COIN
Ecosystem resilience: the capacity of an ecosystem to tolerate disturbance (perturbation) without changing into a qualitatively different state.
Can also be thought of as inertial stability.
Engineering resilience: the length of time that a system takes to return to equilibrium (stability) following perturbation.
Has also been called elastic stability.

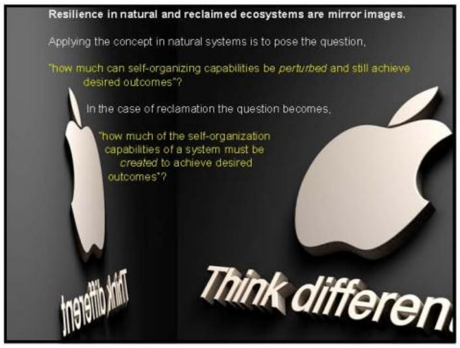

A typical sequence of plant communities
(seral stages) and the impact of disturbance
Disturbance
Type
Example
Outcome
1 Windthrow Exceeds system resilience. Next seral stage.
2 Insect outbreak System resilient. No change in seral stage.
3 Moderate fire Exceeds system resilience. Prior seral stage.
4 Severe fire Exceeds system resilience. New equilibrium.
Note that overall, the ecosystem is resilient to disturbances 2-4 if the sequence of seral stages is used as the frame of reference rather than a given seral stage (time is an important element in assessing resilience).

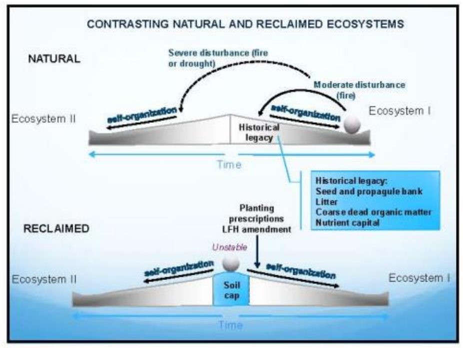

"Marble-in-a-cup"
A convenient metaphor to illustrate resilience
Succession
(self-organization)
Stability domains

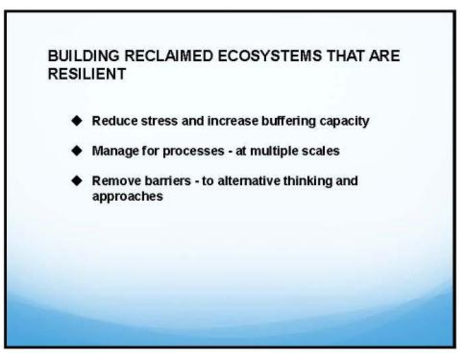

A typical sequence of plant communities
(seral stages) and the impact of disturbance
Disturbance
4
2, 3
1
Stability domains

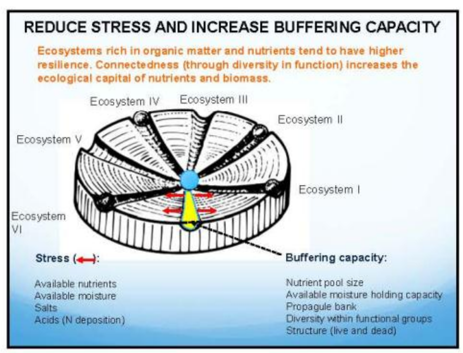

Autogenic, allogenic, and biogenic processes are the main drivers of change in self-organizing systems
Resilience constitutes the relative susceptibility to these processes.
◆ Relative susceptibility is correlated with ecological diversity within different functional groups (producers consumers, decomposers).
◆ Diversity is necessary but not sufficient because not all species are of equal importance in maintaining system functions (and, hence, resilience).
◆ Keystone species play roles disproportionate to their numbers in the dynamics of their communities (aspen for example).
◆ Removal of a keystone species can trigger nonlinear responses that lead to cascades of local extinction an a fundamental change in the nature of the ecosystem (ecosystem resilience is thus reduced).

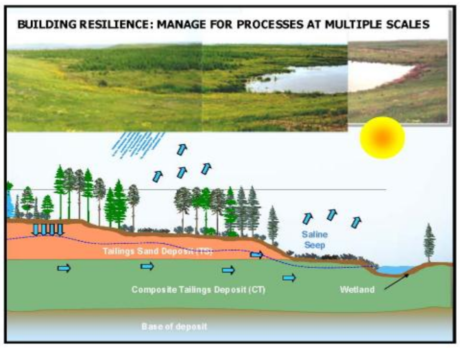

Part II. Resilience applied to reclamation
◆ Reclamation strives to move a system from an undesired state to a more desirable one.
◆ Resilience thinking is a major departure from the conventional approach to natural resources management, which is typically focused on maximizing one, or a small number of, ecosystem services (e.g., wildlife habitat) or goods (e.g., timber volume).
◆ A focus on resilience means that reclamation should also seek to restore natural processes.
◆ This approach has two key virtues. First, reinstating natural processes will require less ongoing, human management. At least equally important, restoring natural processes will allow ecosystems to evolve over time, just as they did before the occurrence of mining.
Think differen


Resilience in natural and reclaimed ecosystems are mirror images.
Applying the concept in natural systems is to pose the question,
"how much can self-organizing capabilities be *perturbed* and still achieve desired outcomes"?
In the case of reclamation the question becomes,
"how much of the self-organization capabilities of a system must be *created* to achieve desired outcomes"?
Think different
Think differen

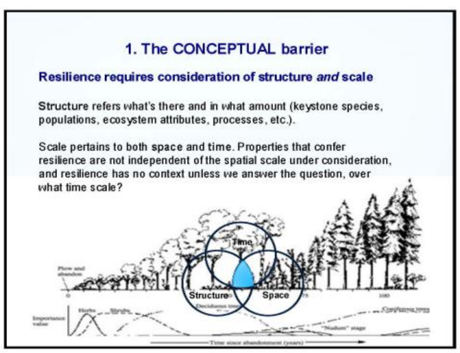

CONTRASTING NATURAL AND RECLAIMED ECOSYSTEMS
NATURAL
Severe disturbance (fire or drought)
Moderate disturbance (fire)
Ecosystem II
self-organization
self-organization
Ecosystem I
Historical legacy
Time
Historical legacy:
Seed and propagule bank
Litter
Coarse dead organic matter
Nutrient capital
RECLAIMED
Planting prescriptions
LFH amendment
Unstable
Ecosystem II
self-organization
self-organization
Ecosystem I
Soil cap
Time

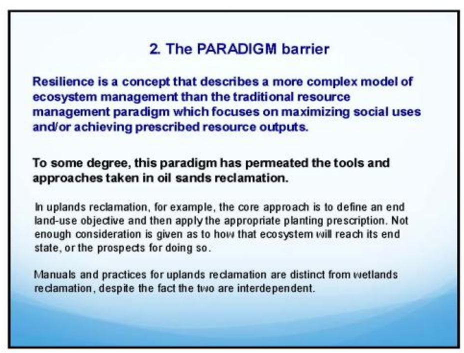

BUILDING RECLAIMED ECOSYSTEMS THAT ARE RESILIENT
◆ Reduce stress and increase buffering capacity
◆ Manage for processes - at multiple scales
◆ Remove barriers - to alternative thinking and approaches


REDUCE STRESS AND INCREASE BUFFERING CAPACITY
Ecosystems rich in organic matter and nutrients tend to have higher resilience. Connectedness (through diversity in function) increases the ecological capital of nutrients and biomass.
Ecosystem IV
Ecosystem III
Ecosystem II
Ecosystem V
Ecosystem I
Ecosystem VI
Stress (⟷):
Available nutrients
Available moisture
Salts
Acids (N deposition)
Buffering capacity:
Nutrient pool size
Available moisture holding capacity
Propagule bank
Diversity within functional groups
Structure (live and dead)

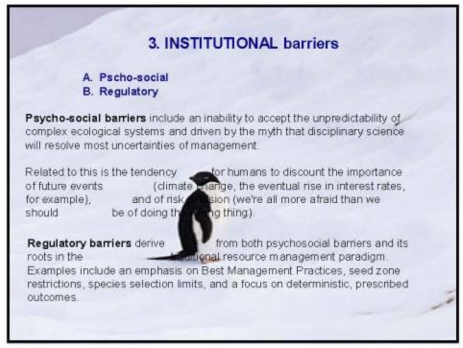

BUILDING RESILIENCE: MANAGE FOR PROCESSES AT MULTIPLE SCALES
Saline Seep
Tailings Sand Deposit (TS)
Composite Tailings Deposit (CT)
Wetland
Base of deposit

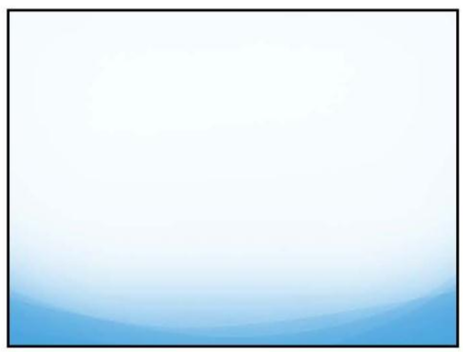

BARRIERS TO MANAGING FOR RESILIENCE IN RECLAMATION
1. Conceptual
2. Paradigm
3.A. Psychosocial
3.B. Regulatory

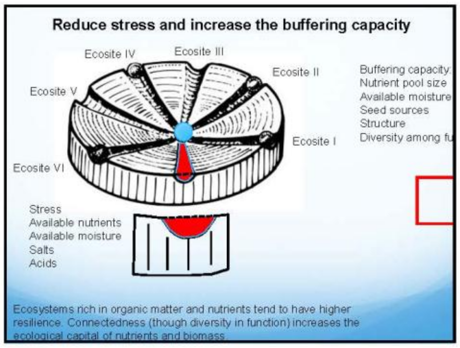

1. The CONCEPTUAL barrier
Resilience requires consideration of structure *and* scale
Structure refers what's there and in what amount (keystone species, populations, ecosystem attributes, processes, etc.).
Scale pertains to both space and time. Properties that confer resilience are not independent of the spatial scale under consideration, and resilience has no context unless we answer the question, over what time scale?
Time
Structure
Space


2. The PARADIGM barrier
Resilience is a concept that describes a more complex model of ecosystem management than the traditional resource management paradigm which focuses on maximizing social uses and/or achieving prescribed resource outputs.
To some degree, this paradigm has permeated the tools and approaches taken in oil sands reclamation.
In uplands reclamation, for example, the core approach is to define an end land-use objective and then apply the appropriate planting prescription. Not enough consideration is given as to how that ecosystem will reach its end state, or the prospects for doing so.
Manuals and practices for uplands reclamation are distinct from wetlands reclamation, despite the fact the two are interdependent.

Management-oriented	Resilience-oriented
Focus on end targets	Focus on process targets
Narrow scale (stands)	Broad scale (stands to landscapes)
Specificity (focus on target tree species)	Diversity (focus on keystone species)
Avoid change	Accept change
Constancy of relationships	Dynamic relationships
Deterministic outcomes	Uncertain outcomes
Best Management Practices	Adaptive Management





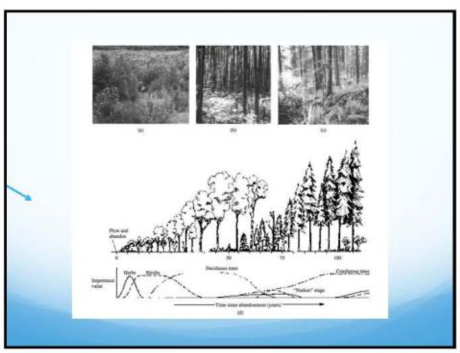


Change over time is ubiquitous in nature

The first is the emerging system property of resilience, a concept that describes a more complex model of change and restoration than typical resource management goals related to maximizing social uses and achieving optimum yields of resource out- puts.

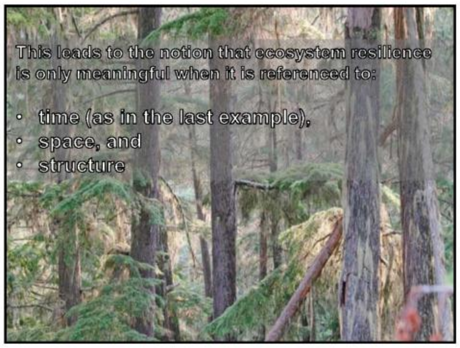
A resilience approach helps to focus attention on the specific attributes or drivers of complex social-ecological systems and to craft guiding principles for human intervention to improve the long-term performance of the systems.

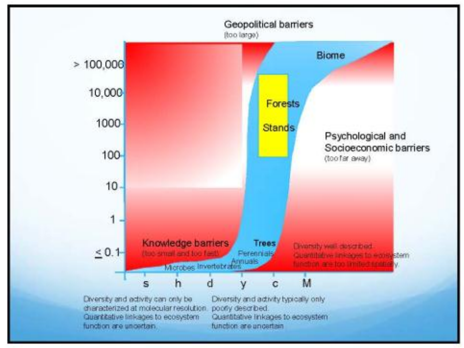
Ironically, resilience is likely to increase over time thereby making it increasingly difficult to mitigate a shift in state, if outcomes are not desirable.

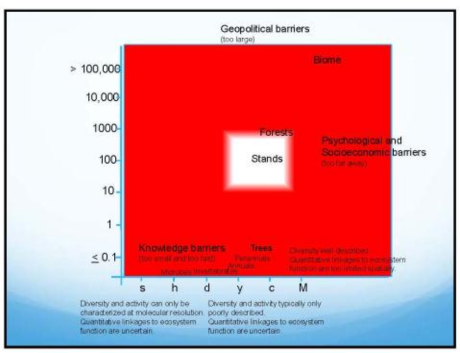


Gunderson paper. In order to add resilience to managed systems, at least three strategies are employed: increasing the buffering capacity of the system, managing for processes at multiple scales, and removing institutional barriers to implementation.

Resilience theory suggests that complex systems can exist in fundamentally different regimes, and resilience is the property that mediates transitions among those regimes. **Hence resilience must be overcome when undertaking objectives that involve regime changes, such as an ecological restoration or a social transformation**


This leads to the notion that ecosystem resilience is only meaningful when it is referenced to:
• time (as in the last example),
• space, and
• structure


Geopolitical barriers
(too large)
Biome
> 100,000
10,000
1000
100
10
1
≤ 0.1
Forests
Stands
Psychological and
Socioeconomic barriers
(too far away)
Knowledge barriers
(too small and too fast)
Trees
Perennials
Annuals
Microbes
Invertebrates
Diversity well described.
Quantitative linkages to ecosystem
function are too limited spatially.
s
h
d
y
c
M
Diversity and activity can only be characterized at molecular resolution. Quantitative linkages to ecosystem function are uncertain.
Diversity and activity typically only poorly described. Quantitative linkages to ecosystem function are uncertain


Geopolitical barriers
(too large)
Biome
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Diversity and activity can only be characterized at molecular resolution. Quantitative linkages to ecosystem function are uncertain.
Diversity and activity typically only poorly described. Quantitative linkages to ecosystem function are uncertain.

The Role of Plant Species Selection in the Functionality of Reclaimed Forest Landscapes

Simon Landhausser (University of Alberta)

Rapid expansion of resource extraction activities in boreal forests has occurred throughout the northern hemisphere. In Alberta, a significant portion of publicly owned land is currently subjected to industrial disturbance. Conditional to the licence to operate on these forest lands is the requirement that reclaimed and re-vegetated landforms and soils have the capacity to support self-sustaining and locally common forest types. That these novel ecosystems are locally common and functioning are key criteria of self-sustainability and indicative of the ability to withstand external or internal stresses (resistance) and/or are able to recover from natural and anthropogenic disturbances (resilience).

Over millennia, most natural boreal forest ecosystems (including their soils) have adapted well to a wide range of natural disturbance regimes created by fire, insect, and diseases. Anthropogenic disturbances, specifically large scale surface mining operations that severely disrupt hydrological, physical and nutritional processes within soils, have created novel disturbance regimes that have few natural analogues. Recognizing the role of species being reintroduced during the recovery of severely disturbed areas is critical in determining trajectories along which reclaimed forest stands develop. As such, the autecology and life-history traits of these species and their abundance through time and space are critical to develop resistance and resiliency of these future ecosystems. Central ecosystem processes such as water, nutrient and carbon cycling, the maintenance of species and functional diversity, the development propagule banks, and the interactions among these processes are important components of resiliency and resistance.

In this presentation I will give examples of some of the roles plants play in the development of resistance and resiliency in reclaimed novel ecosystems emphasizing linkages among plants and ecosystem processes.

The role of plant species selection in the functionality of reclaimed forest landscapes

Simon Landhäusser
Department of Renewable Resources

The new disturbances

Natural analogues

Ólafur Ingólfsson

www.meteorcrater.com/Fun-Science

Challenge

To date the most successful reported restoration efforts had the advantage of natural assemblages nearby…

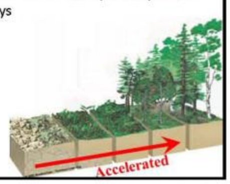
…if appropriate colonists are not available, new ecosystems will likely be created; however, neither the stability, the capability of self maintenance, nor the functional attributes of these new systems will be known beforehand. (Cairns 2000)

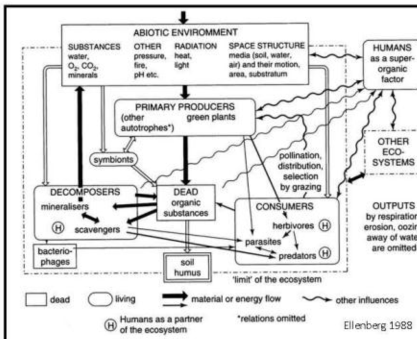
Reclamation objectives

- There is a legacy of sites where reclamation strategies were mostly driven by very few objectives, often with an "agricultural perspective"
    - Stabilization of site
    - Soil centered approach
    - Crop (tree) centered approach
- Evolution to reclaiming disturbed sites to fully functioning and sustainable ecosystems … with the idea that nature will provide the services and humans are a passive recipient

Restored ecosystems should be

- Composed of native species, common to the area, persistent without continuing maintenance and without soil and landscape limitations (e.g. capability of water, nutrients, carbon cycling etc.)
- Resilient to disturbances (present and future) and capable of natural successional pathways

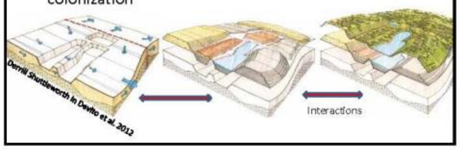




Ellenberg 1988

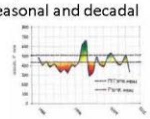
Complexity of forest ecosystem restoration

- [illegible] soils and the appropriate rooting zone (depth) for plants
- Species and genotype selection appropriate for climate and conditions and by taking into account future anticipated disturbance regimes, seedbank, re-colonization



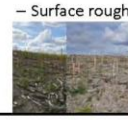
Climate

Large scale climate
- Initiation of vegetation will likely occur at different points of the climate cycle (seasonal and decadal wet and dry cycles) (Devito et al 2012)



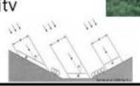
Meso scale climate
- Topographical positions

Micro scale climate
- Surface roughness, CWD



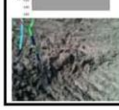
Landscape forms and Topography

Conditions driven by
- Overburden materials and their variability and functioning in water transport and storage
- Landscape position
- Slope and Aspect
- Connectivity



Rooting zone

- Materials and Thickness
  - appropriate for the short-term and long-term water and nutrient supply of plants (active rooting zone): soil texture, organic content, nutrition etc.
- Barriers
  - chemical and/or physical barriers: compaction, salt etc.
- Variability (meso- and micro-scale)
  - at soil surface (roughness, CWD, material types)
  - below ground (thickness and materials)



Vegetation structure

Intimately connected with climate, topography and rooting zone

- Appropriate species and genotype selection and their interaction
- Diversity
  - Richness and abundance (species, functional groups)
  - Patterns and distribution (spatial complexity)
  - Genetic variety
  - Habitat complexity (vertical complexity)
- Adapted to natural disturbance regimes

Plants as drivers of ecosystem function and service

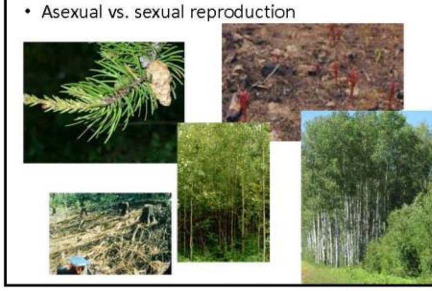
Ecosystem regulation

- Life history traits (reproduction, pollination system, stress tolerance, habitat, life span, life form, growth strategies, productivity etc.)
- Soil development (nutrient carbon cycling, soil microbial community, seedbank)
- Hydrological cycling (hydraulic redistribution, root distribution)
- Their interactions and more…

- **Habitat and productivity**
  - Food and other products
  - Refugia
  - Nursery
- **Others socioecological**
  - Aesthetic
  - Recreation
  - Cultural and spiritual
  - Educational and scientific

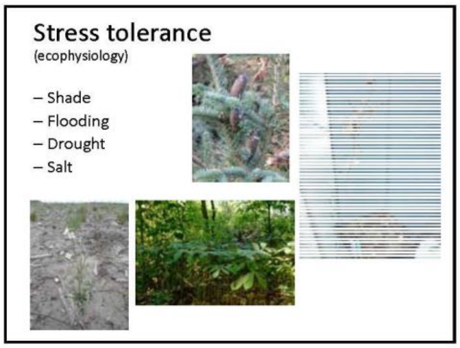
Reproduction

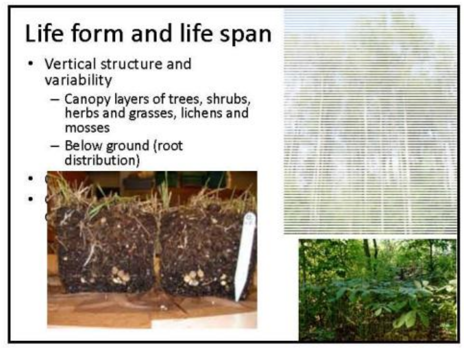
- Asexual vs. sexual reproduction

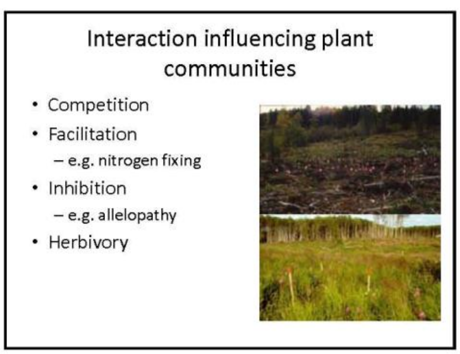


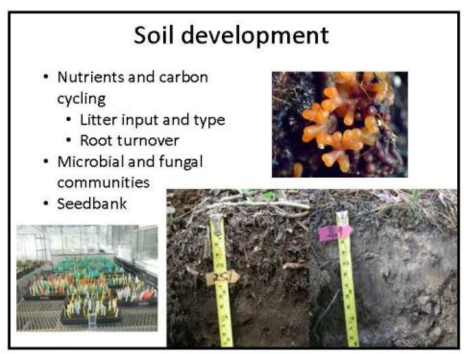
Pollination

- Animal
  - Timing and synchronization
- Wind
- Self
- Propagation and fruits
- Dispersal

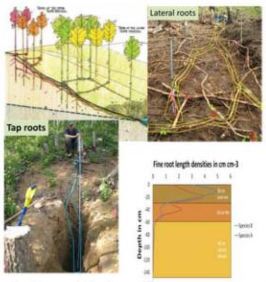

Stress tolerance
(ecophysiology)
– Shade
– Flooding
– Drought
– Salt


Life form and life span
• Vertical structure and variability
– Canopy layers of trees, shrubs, herbs and grasses, lichens and mosses
– Below ground (root distribution)


Interaction influencing plant communities
• Competition
• Facilitation
– e.g. nitrogen fixing
• Inhibition
– e.g. allelopathy
• Herbivory


Soil development
• Nutrients and carbon cycling
• Litter input and type
• Root turnover
• Microbial and fungal communities
• Seedbank

Hydrological Cycling



- Hydraulic redistribution and hydraulic lift
- Linkages between slope positions
- Root architecture
- Leaf area development and transpiration
- Mycorrhizae

Snedden unpublished

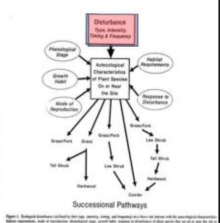
Fraser et al. 2006

Resiliency

A dynamic property of ecosystems that describe the capability or degree to which an ecosystem can absorb perturbation and allows it to remain within the functional boundaries that characterized it by retaining the same structures, functions & feedbacks (Holling 1973)

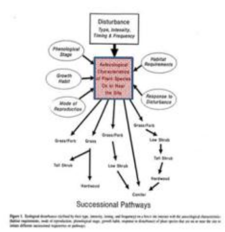
Disturbances

- Fire
- Insects and diseases
- Wind
- Climate change
- Pollution
- Invasive species



Wagner and Zasada 1991

Selecting species for resiliency



- Autecological knowledge of species is imperative
- Identifying key species based on function not on original abundance (ecosite classification)
- Diversity (mixing), hedging your bets
- Weighing options (one can't plant them all)
- If we build it, they will come... will they?

Selecting ecosystems for resiliency

- Landscape designs that allow for the development of a range of different ecosystems
- Knowledge of stability, capability of self maintenance, and functional attributes of these new ecosystems
- Identifying key ecosystems based on the new landscape
- Weighing our options (one can't do it all)
- If we build them, will they stay... ?

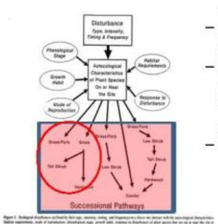
Risks

Resiliency of ecosystems can change in time and with disturbance type and frequency and therefore ecosystem trajectories and also outcomes could be altered (Thompson et al. 2009)

Are there possibly alternate stable states of ecosystems?

Will these different outcomes be considered a success or a failure?

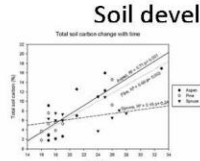
Outcomes

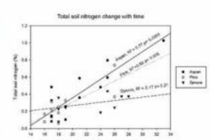


Wagner and Zasada 1991

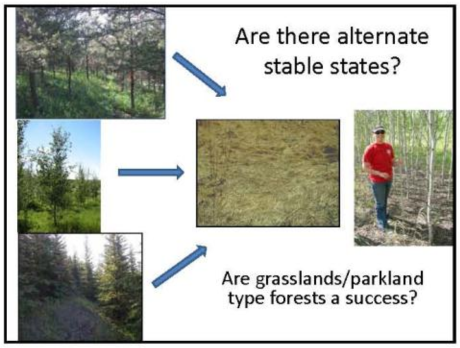
- Type of disturbance (size, seasonality, severity)
- Age of ecosystem (resiliency in time)
- Species presence, seedbank at the time of disturbance, and distance to nearest seed source
- Site and soil development

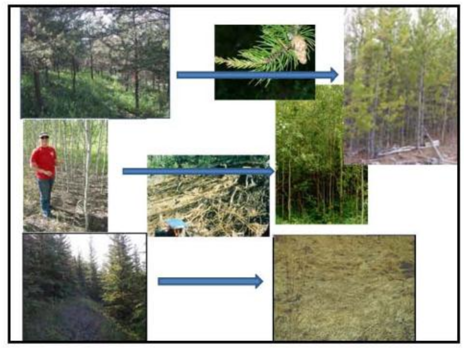
Soil development

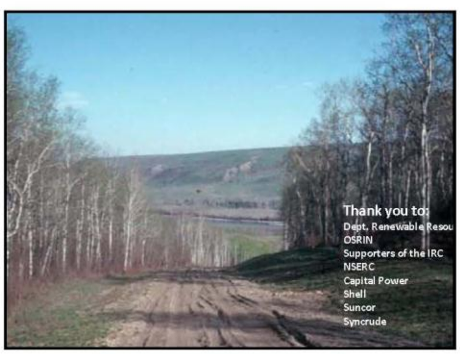




Sorenson et al. 2011


Are there alternate stable states?
Are grasslands/parkland type forests a success?

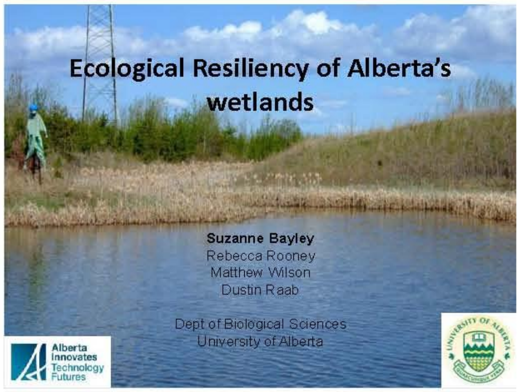



Thank you to:
Dept. Renewable Resou
OSRIN
Supporters of the IRC
NSERC
Capital Power
Shell
Suncor
Syncrude

Ecological Resiliency of Alberta's Wetlands

Dr. Suzanne Bayley, Dr. Rebecca Rooney, Matthew Wilson and Dustin Raab
Department of Biological Sciences, University of Alberta

Wetlands are commonly thought to be resilient to disturbance because their vegetative community is so responsive to changes in hydrology. However their resilience actually depends on a variety of factors, including the class of wetland, the timeframe of interest, the type, severity and frequency of disturbance and whether we are looking at an individual wetland or a wetland landscape. Even the definition of resilience can affect our judgment of whether a wetland is resilient. I present three different examples of how wetlands respond to disturbance: (1) change in regime state in shallow open water wetlands due to agricultural nutrients; (2) change in marsh biota and environmental conditions after restoration and creation of urban wetlands and (3) assessment tools to evaluate reclamation of oil sands marshes. In each case I show criteria and indicators of disturbance and thresholds beyond which the wetland changed its structure and composition. If resilience is defined as the amount of disturbance that the wetland system can absorb without a change in structure and composition, then these Alberta wetlands did not demonstrate resilience to disturbance. If however, we want to incorporate social-ecological systems and societal goals, then these wetlands persisted in a changed state after disturbance and we need a broader definition of resilience. Resilience of wetlands ecosystems constructed in the oil sands reclamation has not been achieved thus far but can be achieved by using appropriate design criteria and building a diversity of wetlands that can accommodate changing hydrology and climate.



Resilience of Alberta wetlands?

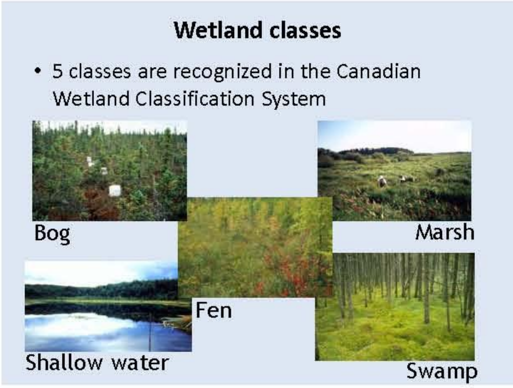
- Do wetlands in Alberta show resilience to disturbance?
  - Peatlands
  - Shallow open water affected by agriculture
- Can restored or created wetlands achieve the same structure and composition as undisturbed (natural) wetlands?
  - Permanent marshes in white zone and oil sands
  - Future marshes in the oil sands

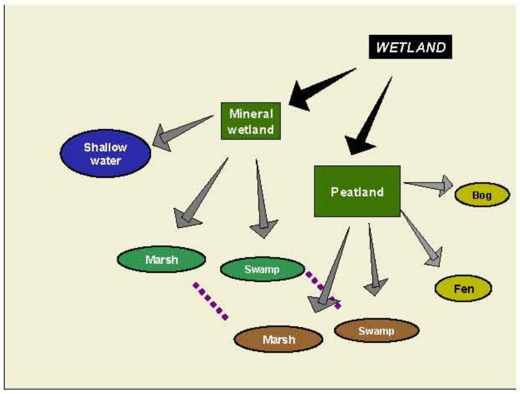
Do wetlands in Alberta show resilience to disturbance?

- **Broader definition:** The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure and feedbacks, and therefore identity, that is, the capacity to change in order to maintain the same identity. (Folke et al 2010)
- **Narrower definition:** Ecological resilience in aquatic and wetland systems is defined as the amount of disturbance that the system can absorb without a change in structure and composition (Holling 1973, Carpenter et al. 2001).

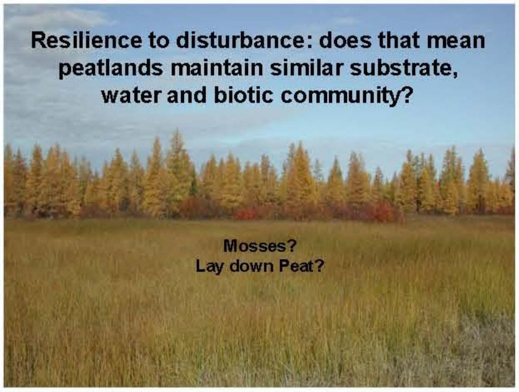
Resilience may vary depending on:

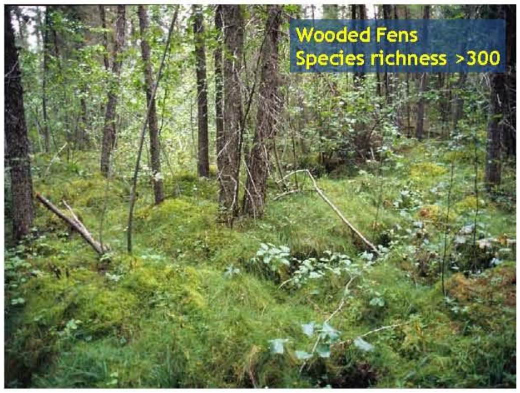
- How you define resilience
- Wetland class
  - How you define wetland functions
- Type, severity and frequency of disturbance: large drastic, frequent small etc
- Individual wetlands vs wetlands as part of landscape
- Time lags: recovery time since disturbance


Wetland classes
• 5 classes are recognized in the Canadian Wetland Classification System
Bog
Marsh
Fen
Shallow water
Swamp


WETLAND
Mineral wetland
Shallow water
Peatland
Bog
Marsh
Swamp
Fen
Marsh
Swamp


Peatland disturbance in the boreal zone
▪Agricultural Expansion
▪Peat Mining
▪Logging
▪Oil Sands
▪Roads
▪Seismic Lines
▪Pipelines
▪Climate warming

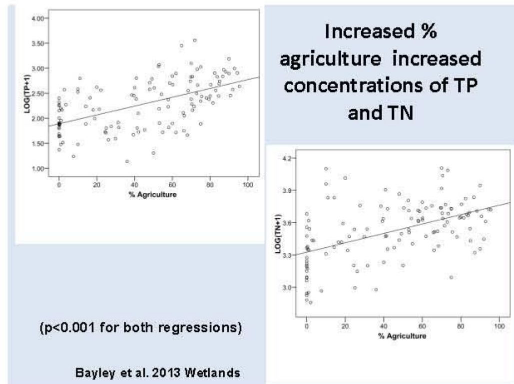

Resilience to disturbance: does that mean peatlands maintain similar substrate, water and biotic community?
Mosses?
Lay down Peat?

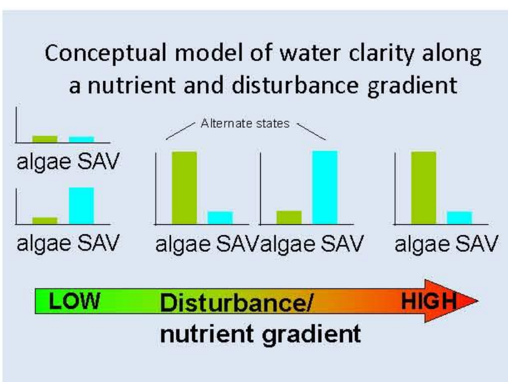


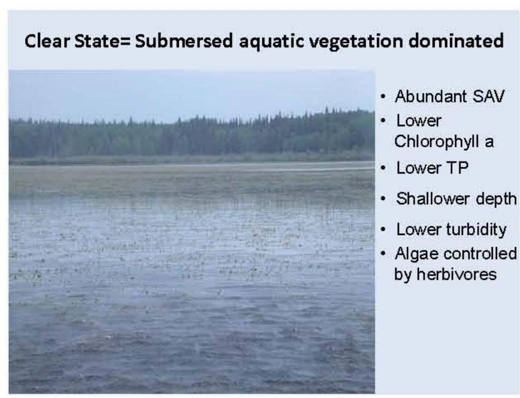
How do we measure resilience?

- Measure the structure, composition & condition of :
  - Biotic community (marsh vegetation, SAV, birds, invertebrates)
  - Substrate – organic or mineral matter characteristics and depth
  - Water- hydroperiod and chemical characteristics
- Establish the threshold whereby the system changes from one state (regime) to another
  - **Regime-** The set of system states within a stability landscape
  - **Regime shift** A change in a system state from one regime or stability domain to another


Does amount of agriculture in buffer zone change
the ecosystem state in shallow wetland lakes


Increased %
agriculture increased
concentrations of TP
and TN
LOG(TP+1)
% Agriculture
LOG(TN+1)
% Agriculture
(p<0.001 for both regressions)
Bayley et al. 2013 Wetlands

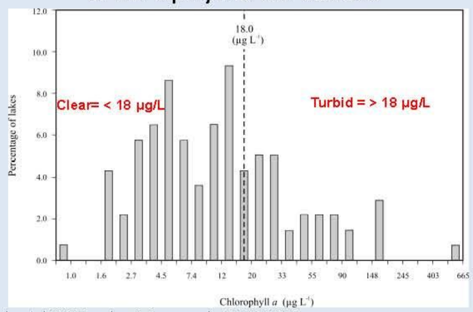

Conceptual model of water clarity along
a nutrient and disturbance gradient
Alternate states
algae SAV
algae SAV
algae SAV
algae SAV
algae SAV
LOW
Disturbance/
HIGH
nutrient gradient


Clear State= Submersed aquatic vegetation dominated
• Abundant SAV
• Lower Chlorophyll a
• Lower TP
• Shallower depth
• Lower turbidity
• Algae controlled by herbivores

Turbid state= algae dominated

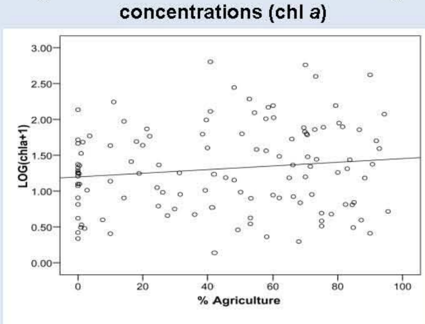
- Sparse or no SAV
- Higher chlorophyll a
- Higher total phosphorus
- Deeper depth
- Higher turbidity
- Algae not controlled by herbivores

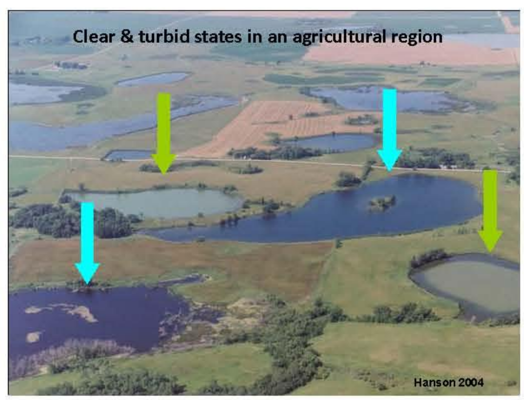
Chlorophyll *a* threshold



Bayley et al. 2007 Limnology & Oceanography 52: 2002-2012

Increased nutrients associated with agriculture did not lead to increased algal concentrations (chl *a*)





Number of switches of alternative trophic states in 23 lakes from 2000-2007

	# of Lakes	% of Lakes
Stable clear	**1**	**4**
Stable turbid	**0**	**0**
1 switch	**6**	**26**
2 switches	**9**	**39**
3 switches	**2**	**9**
4 switches	**4**	**17**
5 switches	**1**	**4**

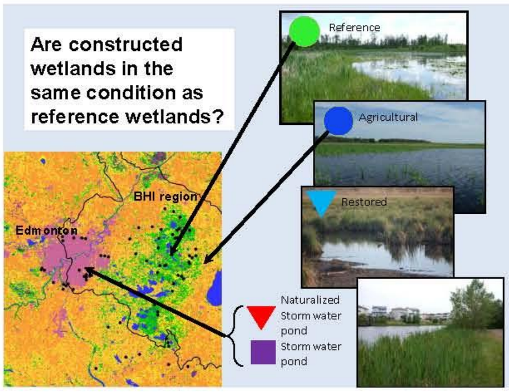
Are shallow open water wetlands resilient to increases in phosphorus?

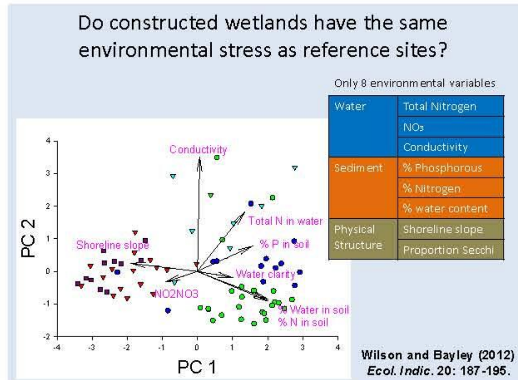
- **No:** not resilient if definition means that remain with similar algal or SAV dominated state across a range of conditions
- **Yes:** are resilient because they easily change from back and forth from one regime to another as conditions change
- So depends on **social goal** (clear with SAV or turbid with algae), and **time frame** of the definition

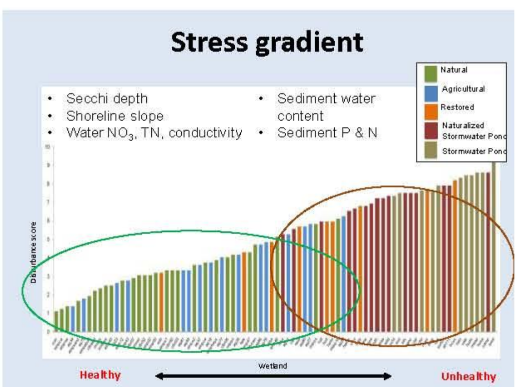
Are our created or restored wetlands resilient? How do you measure it?

Can constructed wetlands achieve similar abiotic and biotic characteristics as natural wetlands?

- Reference condition approach: Uses natural minimally disturbed sites to explain the natural variability of biota and then compare constructed or disturbed sites with the natural sites
- Resiliency- if the created/restored wetlands achieve the same "scores" as the natural sites, then they are resilient. Assumes that the natural wetlands are resilient
  - Physio-chemical disturbance gradient (Stress gradient)
  - Plant community (veg IBI)
  - Wetland dependent song bird community (bird IBI)


Are constructed wetlands in the same condition as reference wetlands?
Reference
Agricultural
Restored
BHI region
Edmonton
Naturalized Storm water pond
Storm water pond


Do constructed wetlands have the same environmental stress as reference sites?
Only 8 environmental variables
Water
Total Nitrogen
NO3
Conductivity
Sediment
% Phosphorous
% Nitrogen
% water content
Physical Structure
Shoreline slope
Proportion Secchi
Conductivity
Total N in water
% P in soil
Shoreline slope
Water clarity
NO2NO3
Water in soil
% N in soil
PC 2
PC 1
Wilson and Bayley (2012)
Ecol. Indic. 20: 187-195.


Stress gradient
Secchi depth
Shoreline slope
Water NO3, TN, conductivity
Sediment water content
Sediment P & N
Natural
Agricultural
Restored
Naturalized Stormwater Pond
Stormwater Pond
Disturbance score
Wetland
Healthy
Unhealthy


Six main bioindicator assemblages
Open water veg
Emergent veg
Wet meadow veg
Inverts
Waterfowl
Songbirds
Rooney and Bayley (2012) Ecol. Indic. 20: 42-50.

All 6 bioindicators affected by same environmental variables

Most important environmental variables	Abundance and diversity of biological communities
• Area of wet meadow zone	• Open-water vegetation
• Area of emergent zone	• Emergent vegetation
• Shoreline slope	• Wet meadow vegetation
• Water TDN, DOC, & K conc	• Macro-invertebrates
• Sediment water content	• Waterfowl
• Sediment C &N conc	• Wetland-dependent songbirds

Rooney and Bayley (2012) *Ecol. Indic.* 20: 42-50.

Field-based tools: biota

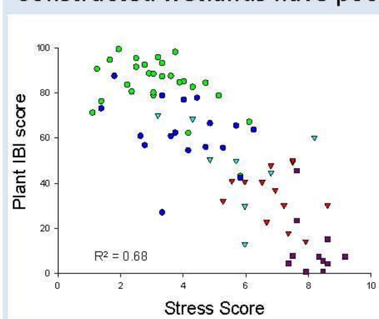
- If all 6 bioindicators are sensitive to the same environmental variables, can we use biota to evaluate wetland health?
  - Plant-based Index of Biotic Integrity (IBI)
  - Bird-based Index of Biotic Integrity (IBI)

Plant-based IBI uses 4 metrics to estimate biological health

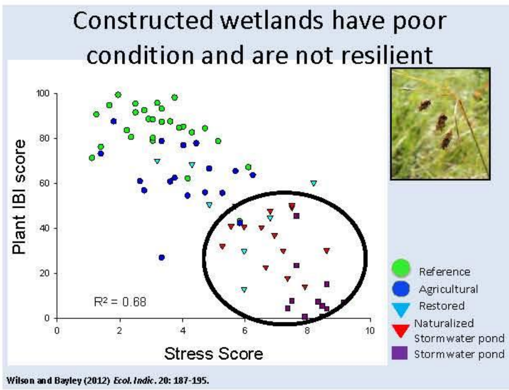
Metrics	R^2
Vegetation width of wet meadow	0.65
Floristic Quality Index	0.43
% Carex spp.	0.44
% Native perennials	0.42

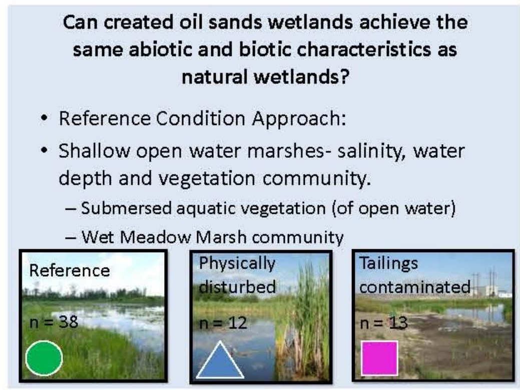
} IBI score

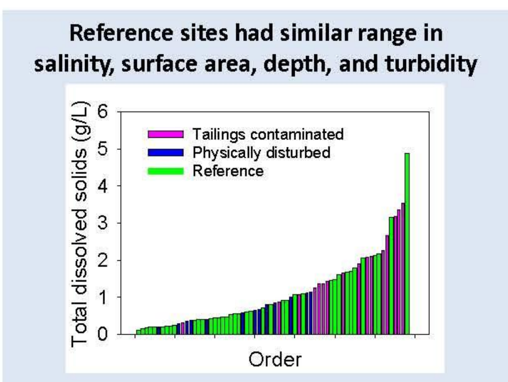
Constructed wetlands have poor condition

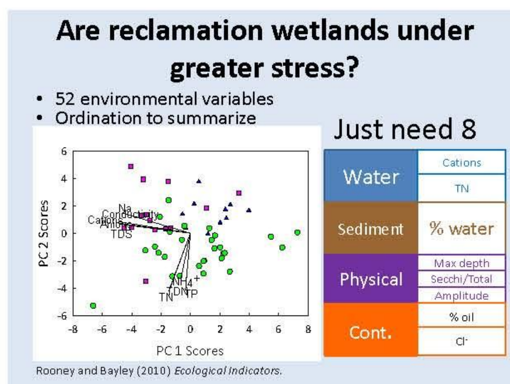


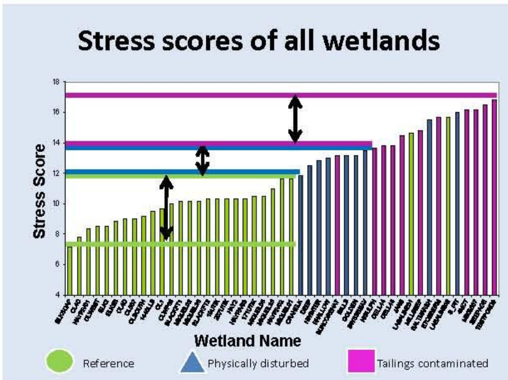
Wilson and Bayley (2012) *Ecol. Indic.* 20: 187-195.

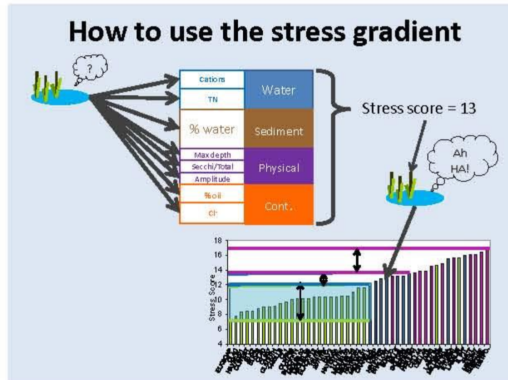

Constructed wetlands have poor condition and are not resilient
Plant IBI score
100
80
60
40
20
0
0
2
4
6
8
10
Stress Score
R² = 0.68
Reference
Agricultural
Restored
Naturalized Stormwater pond
Stormwater pond
Wilson and Bayley (2012) Ecol. Indic. 20: 187-195.

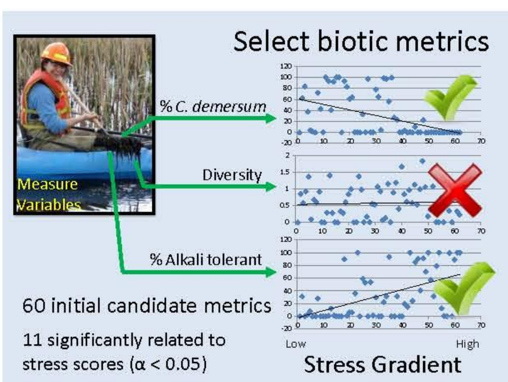

Can created oil sands wetlands achieve the same abiotic and biotic characteristics as natural wetlands?
• Reference Condition Approach:
• Shallow open water marshes- salinity, water depth and vegetation community.
– Submersed aquatic vegetation (of open water)
– Wet Meadow Marsh community
Reference
n = 38
Physically disturbed
n = 12
Tailings contaminated
n = 13

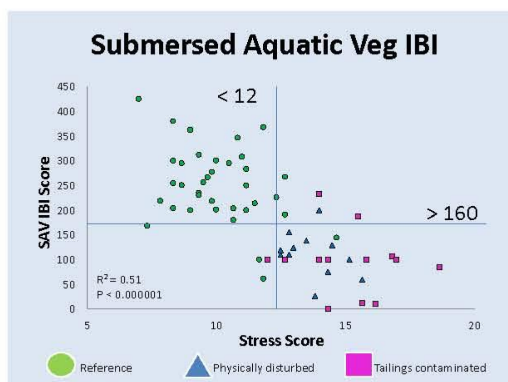

Reference sites had similar range in salinity, surface area, depth, and turbidity
Total dissolved solids (g/L)
6
5
4
3
2
1
0
Tailings contaminated
Physically disturbed
Reference
Order

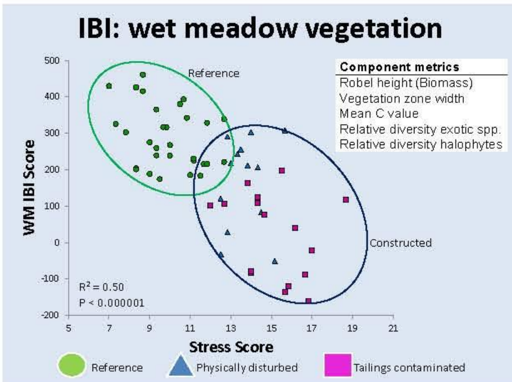

Are reclamation wetlands under greater stress?
• 52 environmental variables
• Ordination to summarize
Just need 8
PC 2 Scores
PC 1 Scores
TDS
TN
TP
Water
Cations
TN
Sediment
% water
Physical
Max depth
Secchi/Total
Amplitude
Cont.
% oil
Cl⁻
Rooney and Bayley (2010) Ecological Indicators.

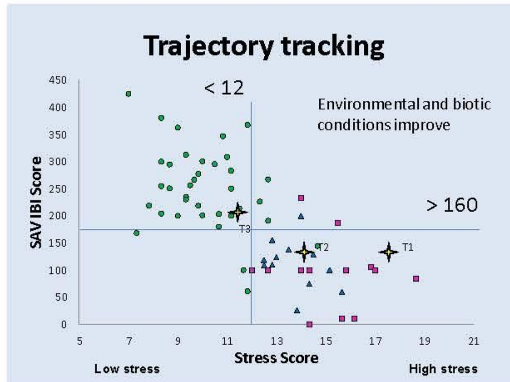

Stress scores of all wetlands
Stress Score
Wetland Name
Reference
Physically disturbed
Tailings contaminated


How to use the stress gradient
Water
Sediment
Physical
Cont.
% water
Stress score = 13
Ah
HA!


Select biotic metrics
% C. demersum
Diversity
% Alkali tolerant
Measure
Variables
60 initial candidate metrics
11 significantly related to
stress scores (α < 0.05)
Low
High
Stress Gradient

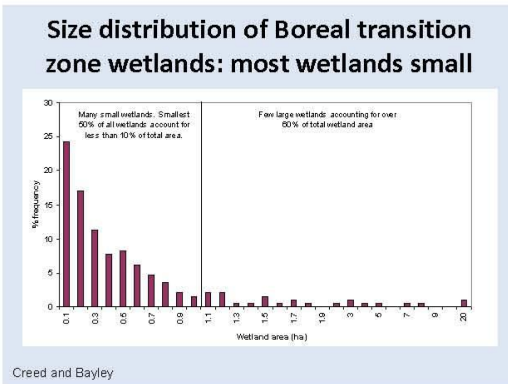

Submersed Aquatic Veg IBI
< 12
> 160
SAV IBI Score
Stress Score
R2 = 0.51
P < 0.000001
Reference
Physically disturbed
Tailings contaminated

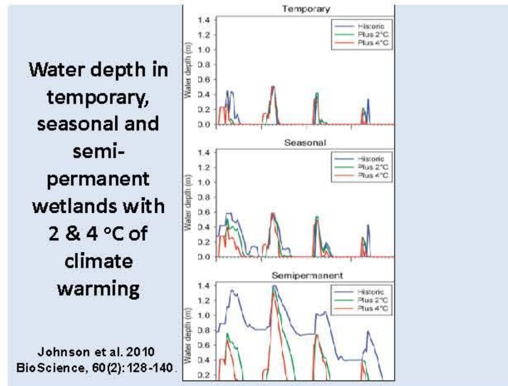

IBI: wet meadow vegetation
Component metrics
Robel height (Biomass)
Vegetation zone width
Mean C value
Relative diversity exotic spp.
Relative diversity halophytes
Reference
Constructed
$R^2 = 0.50$
$P < 0.000001$
WM IBI Score
Stress Score
Reference
Physically disturbed
Tailings contaminated


Trajectory tracking
< 12
Environmental and biotic conditions improve
> 160
SAV IBI Score
Stress Score
Low stress
High stress
T1
T2
T3


Can we achieve resiliency in constructed oil sands wetlands?
Boreal Transition Zone marshes


Can we achieve resiliency in constructed oil sands wetlands?
Yes, but we need good wetland designs and we need to construct our wetland landscapes to include a diversity of wetland types with a range of salinities, water depths and adaptation to changing climate
Boreal Transition Zone marshes


Size distribution of Boreal transition zone wetlands: most wetlands small
Many small wetlands. Smallest 50% of all wetlands account for less than 10% of total area.
Few large wetlands accounting for over 60% of total wetland area
% frequency
Wetland area (ha)
Creed and Bayley


Water depth in temporary, seasonal and semi-permanent wetlands with 2 & 4 °C of climate warming
Johnson et al. 2010
BioScience, 60(2): 128-140.
Temporary
Seasonal
Semipermanent
Historic
Plus 2°C
Plus 4°C
Water depth (m)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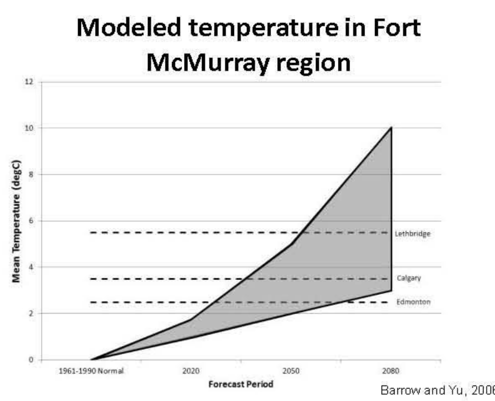
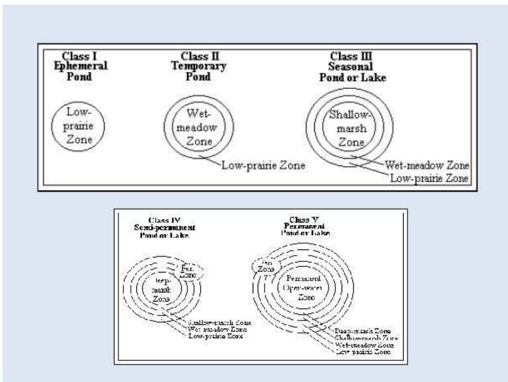
Killam Trusts
NSERC CRSNG
Alberta Innovates Technology Futures
Syncrude
SUNCOR ENERGY
ACA grants in biodiversity
OSRIN


Modeled temperature in Fort McMurray region
Mean Temperature (degC)
Lethbridge
Calgary
Edmonton
1961-1990 Normal
2020
2050
2080
Forecast Period
Barrow and Yu, 2006


Class I
Ephemeral
Pond
Low-
prairie
Zone
Class II
Temporary
Pond
Wet-
meadow
Zone
Low-prairie Zone
Class III
Seasonal
Pond or Lake
Shallow-
marsh
Zone
Wet-meadow Zone
Low-prairie Zone
Class IV
Semi-permanent
Pond or Lake
Shallow-marsh Zone
Low-prairie Zone
Class V
Permanent
Pond or Lake
Wet-meadow Zone

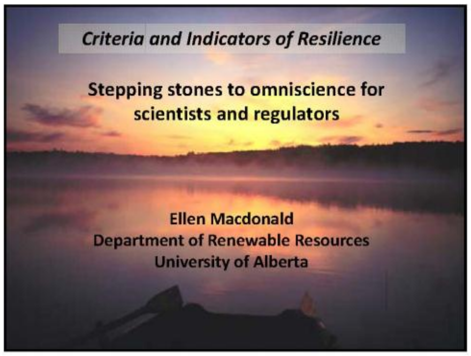
Criteria and Indicators of Resilience

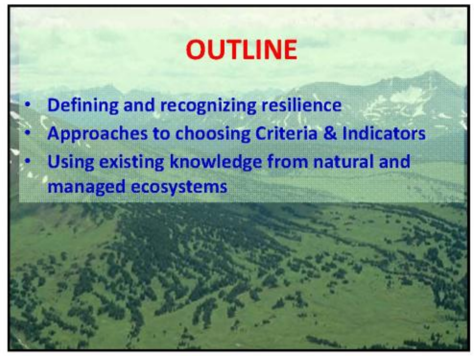
S. Ellen Macdonald
Department of Renewable Resources, University of Alberta

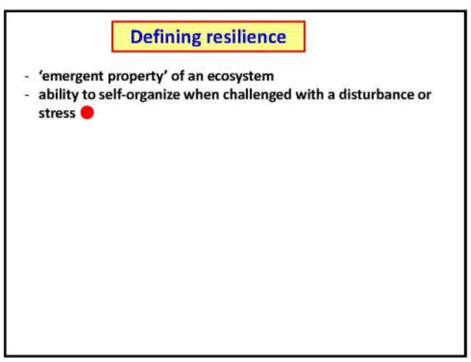
If we are to manage for resiliency in reclaimed boreal forest ecosystems and landscapes we must: define resilience; identify the factors that confer ecological resilience; and establish Criteria and Indicators (C & I) that can be used to determine whether we are achieving our objectives. Resilience is an emergent ecological property which is manifest by the ability of an ecosystem to reorganize following a perturbation (disturbance or stress). A reclaimed ecosystem could be considered to be resilient when it has regained – or is well along a pathway of recovery towards – a certain ecological structure and function. This could be defined by the pre-disturbance ecosystem, a locally representative ecosystem, or by an expected condition that relates to desired end land use. In a longer time frame, we might consider that the test of resilience will be the ability of the reclaimed ecosystem to reorganize following future disturbances and stresses.

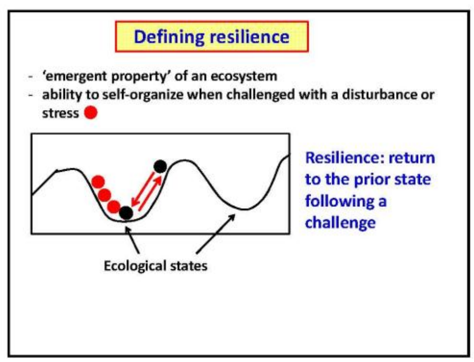
Establishment of Criteria and Indicators for resilience is fraught with challenges. Which aspects of ecosystem structure and function should be considered? How do we apply relevant concepts of scale to these? How can we assess intangible and complex interactions among ecosystem components that may be critical to conferring resilience? Do we know which characteristics will be important for resilience in the face of disturbances and stresses that, in future, may be outside our current realm of experience? How do we establish targets for ecosystem structure and function, given that these are inherently highly variable and the characteristics required for resilience in future might be outside the range for which we have existing benchmarks? Do we use C & I that assess condition or trajectory?

I will explore these questions and propose approaches to establishment of C & I for key aspects of ecosystem structure and function at appropriate spatial and temporal scales. Further, I will discuss how data derived from natural and managed forest landscapes could be used to inform establishment of C & I of resilience in reclaimed ecosystems.


Criteria and Indicators of Resilience
Stepping stones to omniscience for scientists and regulators
Ellen Macdonald
Department of Renewable Resources
University of Alberta

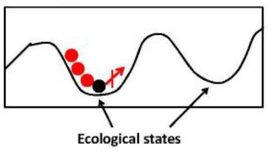

OUTLINE
• Defining and recognizing resilience
• Approaches to choosing Criteria & Indicators
• Using existing knowledge from natural and managed ecosystems


Defining resilience
- 'emergent property' of an ecosystem
- ability to self-organize when challenged with a disturbance or stress


Defining resilience
- 'emergent property' of an ecosystem
- ability to self-organize when challenged with a disturbance or stress
Resilience: return to the prior state following a challenge
Ecological states

Defining resilience

- 'emergent property' of an ecosystem
- ability to self-organize when challenged with a disturbance or stress

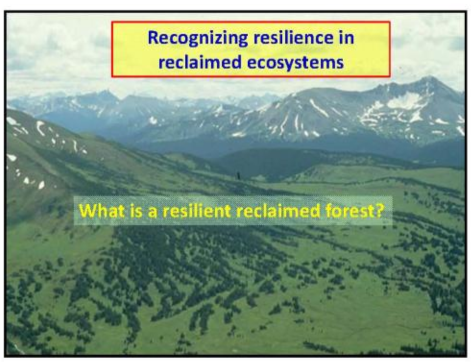


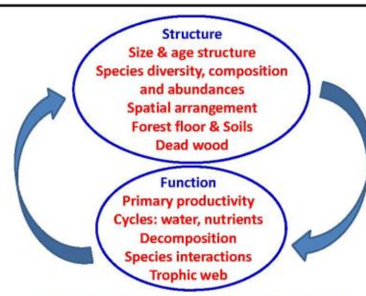
Resistance: little or no change when challenged

Defining resilience for reclaimed ecosystems: How do we know we're there?

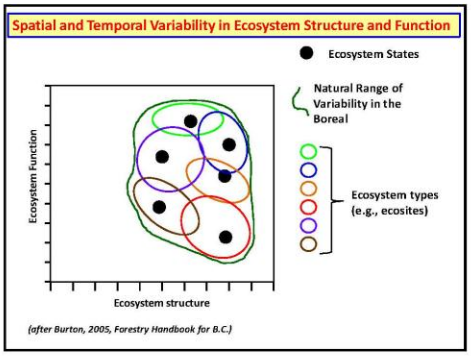
Ecosystem has returned to the pre-disturbance state: then it should be resilient - presuming the 'undisturbed' forest was resilient

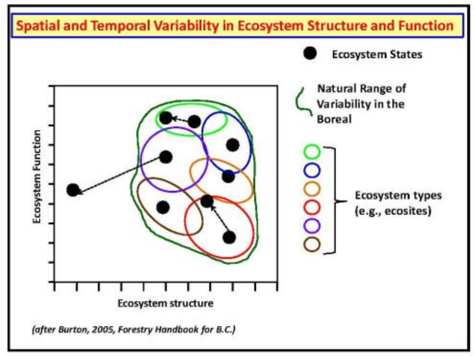
Ecosystem has the capacity for resilience when challenged with future disturbance or stress:
- Can return to it's current (reclaimed) state
- Can return to a desired state

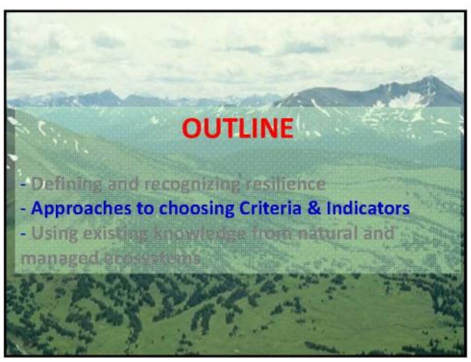




Spatial and temporal variability in these
Scale dependent





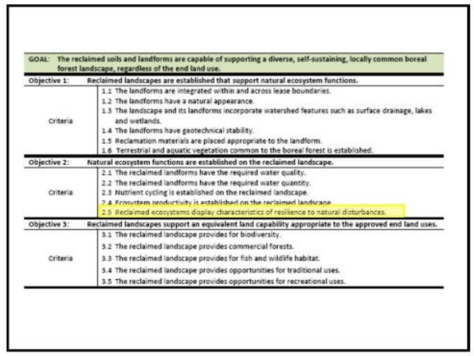


Defining Criteria and Indicators

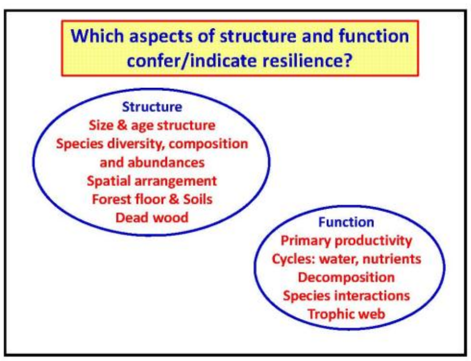
Criteria: Categories of structure or function relevant to achieving the objective (ecosystem resilience); need to know your objective

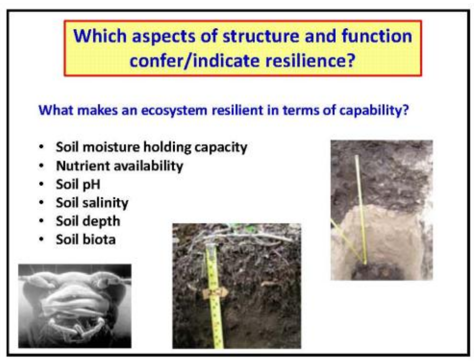
Indicators: Measureable attributes that allow us to determine if a criterion has been met; need a standard/benchmark

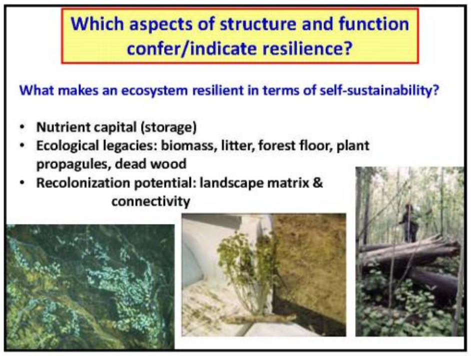
From EPEA mine approval conditions: "The reclaimed soils and landforms are capable of supporting a self-sustaining, locally common boreal forest…"….that is resilient…..

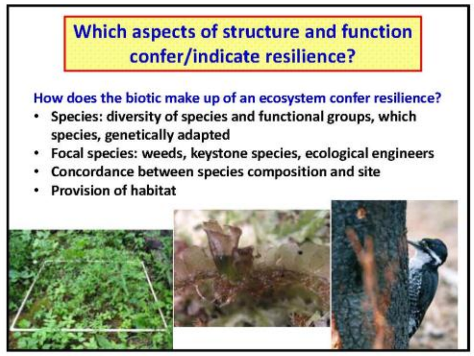


GOAL:	The reclaimed soils and landforms are capable of supporting a diverse, self-sustaining, locally common boreal forest landscape, regardless of the end land use.
Objective 1:	Reclaimed landscapes are established that support natural ecosystem functions.
Criteria	1.1 The landforms are integrated within and across lease boundaries. 1.2 The landforms have a natural appearance. 1.3 The landscape and its landforms incorporate watershed features such as surface drainage, lakes and wetlands. 1.4 The landforms have geotechnical stability. 1.5 Reclamation materials are placed appropriate to the landform. 1.6 Terrestrial and aquatic vegetation common to the boreal forest is established.
Objective 2:	Natural ecosystem functions are established on the reclaimed landscape.
Criteria	2.1 The reclaimed landforms have the required water quality. 2.2 The reclaimed landforms have the required water quantity. 2.3 Nutrient cycling is established on the reclaimed landscape. 2.4 Ecosystem productivity is established on the reclaimed landscape. 2.5 Reclaimed ecosystems display characteristics of resilience to natural disturbances.
Objective 3:	Reclaimed landscapes support an equivalent land capability appropriate to the approved end land uses.
Criteria	3.1 The reclaimed landscape provides for biodiversity. 3.2 The reclaimed landscape provides commercial forests. 3.3 The reclaimed landscape provides for fish and wildlife habitat. 3.4 The reclaimed landscape provides opportunities for traditional uses. 3.5 The reclaimed landscape provides opportunities for recreational uses.









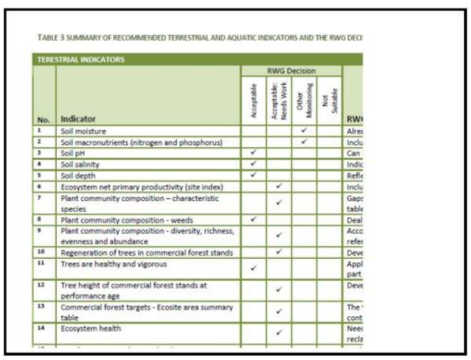
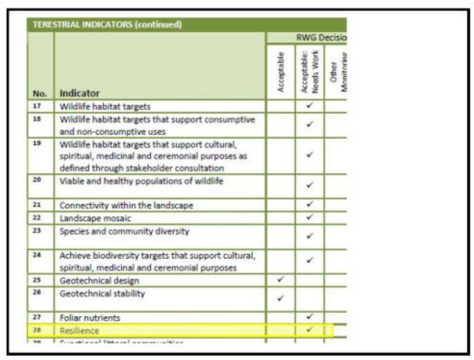


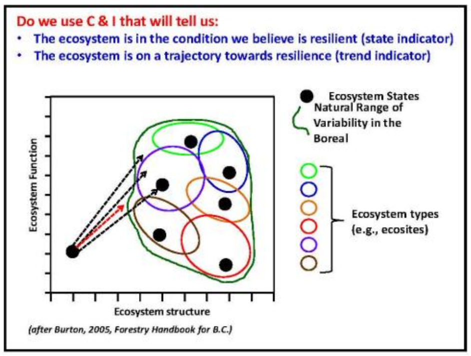
TABLE 3 SUMMARY OF RECOMMENDED TERRESTRIAL AND AQUATIC INDICATORS AND THE RWG DECI

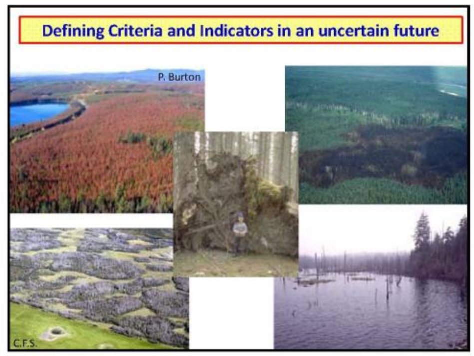
TERESTRIAL INDICATORS

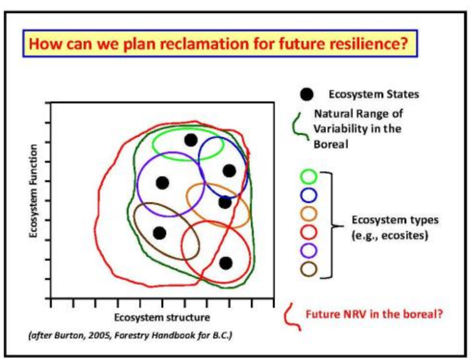
No.	Indicator	RWG Decision: Acceptable	RWG Decision: Acceptable: Needs Work	RWG Decision: Other Monitoring	RWG Decision: Not Suitable	RW
1	Soil moisture			✓		Alre
2	Soil macronutrients (nitrogen and phosphorus)			✓		Inclu
3	Soil pH	✓				Can
4	Soil salinity	✓				Indic
5	Soil depth	✓				Refle
6	Ecosystem net primary productivity (site index)		✓			Inclu
7	Plant community composition – characteristic species		✓			Gaps table
8	Plant community composition - weeds	✓				Deal
9	Plant community composition - diversity, richness, evenness and abundance		✓			Acco refer
10	Regeneration of trees in commercial forest stands		✓			Deve
11	Trees are healthy and vigorous	✓				Appl part
12	Tree height of commercial forest stands at performance age		✓			Deve
13	Commercial forest targets - Ecosite area summary table		✓			The cont
14	Ecosystem health		✓			Neec recla

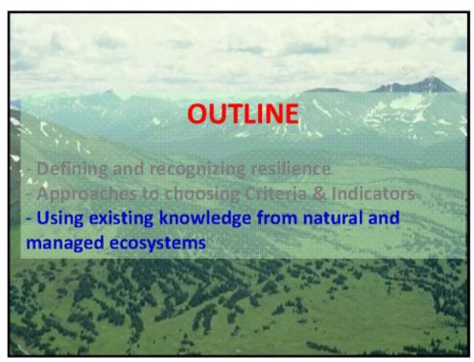

TERESTRIAL INDICATORS (continued)

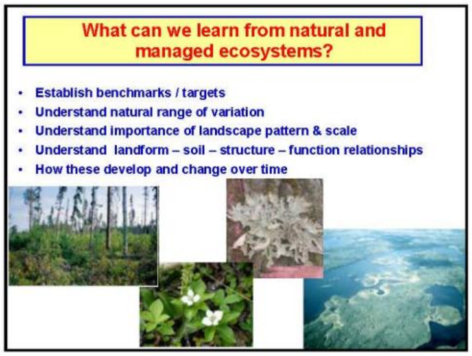
No.	Indicator	RWG Decisio: Acceptable	RWG Decisio: Acceptable: Needs Work	RWG Decisio: Other Monitoring
17	Wildlife habitat targets		✓	
18	Wildlife habitat targets that support consumptive and non-consumptive uses		✓	
19	Wildlife habitat targets that support cultural, spiritual, medicinal and ceremonial purposes as defined through stakeholder consultation		✓	
20	Viable and healthy populations of wildlife		✓	
21	Connectivity within the landscape		✓	
22	Landscape mosaic		✓	
23	Species and community diversity		✓	
24	Achieve biodiversity targets that support cultural, spiritual, medicinal and ceremonial purposes		✓	
25	Geotechnical design	✓		
26	Geotechnical stability	✓		
27	Foliar nutrients		✓	
28	Resilience		✓	

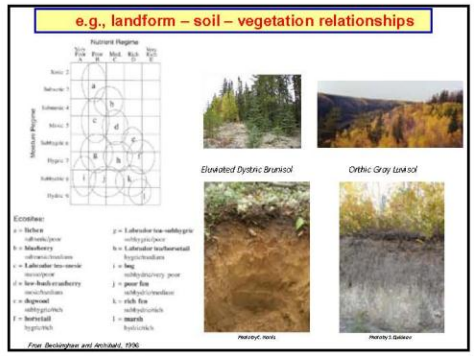

Do we use C & I that will tell us:
• The ecosystem is in the condition we believe is resilient (state indicator)
• The ecosystem is on a trajectory towards resilience (trend indicator)
Ecosystem States
Natural Range of Variability in the Boreal
Ecosystem types (e.g., ecosites)
Ecosystem Function
Ecosystem structure
(after Burton, 2005, Forestry Handbook for B.C.)

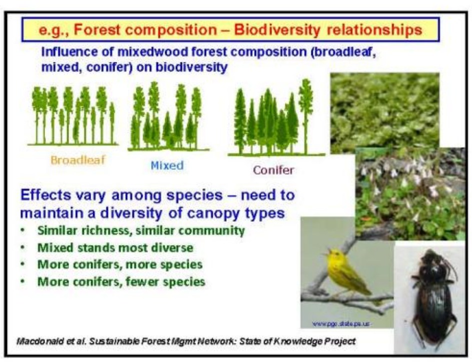

Defining Criteria and Indicators in an uncertain future
P. Burton
C.F.S.

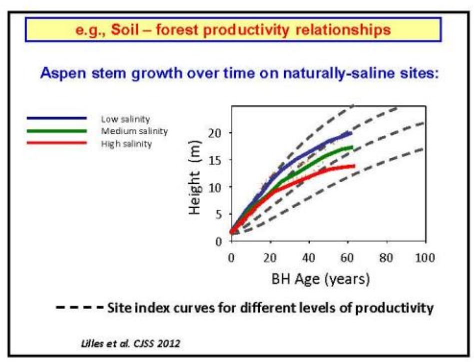

How can we plan reclamation for future resilience?
Ecosystem States
Natural Range of Variability in the Boreal
Ecosystem types (e.g., ecosites)
Ecosystem Function
Ecosystem structure
Future NRV in the boreal?
(after Burton, 2005, Forestry Handbook for B.C.)


OUTLINE
- Defining and recognizing resilience
- Approaches to choosing Criteria & Indicators
- Using existing knowledge from natural and managed ecosystems


What can we learn from natural and managed ecosystems?
Establish benchmarks / targets
Understand natural range of variation
Understand importance of landscape pattern & scale
Understand landform – soil – structure – function relationships
How these develop and change over time


e.g., landform – soil – vegetation relationships
Elevated Dystric Brunisol
Orthic Gray Luvisol
From Beckingham and Archibald, 1996


e.g., Forest composition – Biodiversity relationships
Influence of mixedwood forest composition (broadleaf, mixed, conifer) on biodiversity
Broadleaf
Mixed
Conifer
Effects vary among species – need to maintain a diversity of canopy types
Similar richness, similar community
Mixed stands most diverse
More conifers, more species
More conifers, fewer species
Macdonald et al. Sustainable Forest Mgmt Network: State of Knowledge Project


e.g., Soil – forest productivity relationships
Aspen stem growth over time on naturally-saline sites:
Low salinity
Medium salinity
High salinity
Height (m)
0
5
10
15
20
0
20
40
60
80
100
BH Age (years)
Site index curves for different levels of productivity
Lilles et al. CJSS 2012

e.g., Forest response to disturbance

EMEND experiment

Summary

Understand future challenges facing reclaimed ecosystems

Know what ecological features will confer resilience

Re-establish key components of structure & function

Measure and Monitor

Be patient

Ecological Resiliency: Measuring Degradation and Recovery

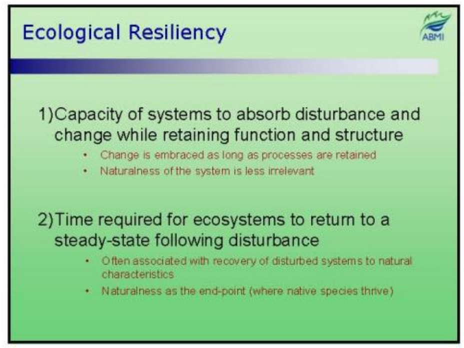
Dr. Jim Schieck
Alberta Biodiversity Monitoring Institute, Alberta Innovates – Technology Futures

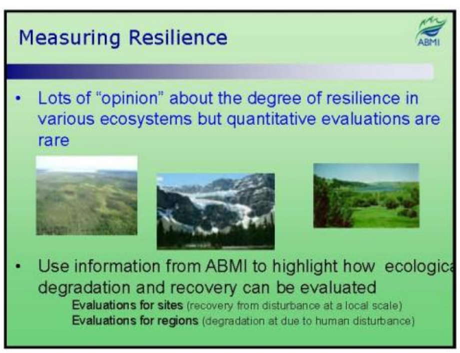
Ecological resiliency encompasses concepts involving resistance to degradation and the estimation of ecosystem recovery. From a management perspective, these concepts are most informative when applied to degradation at regional scales and recovery of natural systems at disturbed sites.

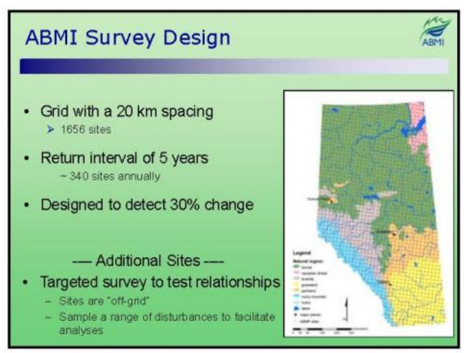
The Alberta Biodiversity Monitoring Institute (ABMI) samples biota, habitat elements, landscape characteristics and human disturbance on a grid of 1,656 sites spaced 20 km apart, with each site re-surveyed once every five years. The program monitors changes in terrestrial biota (lichens, mosses, vascular plants, mites, birds, mammals), aquatic biota (vascular plants, benthic invertebrates), terrestrial and aquatic habitats (live and dead trees, shrubs, herbs, litter, soil, water physicochemistry, water basin characteristics) and landscape elements.

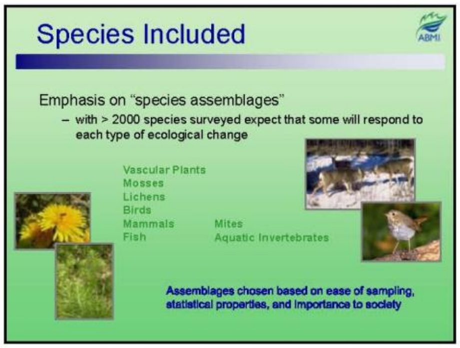
ABMI information is used to assess ecological intactness – as a measure of ecosystem degradation / deviation from undisturbed condition – at the regional scale. In addition, ABMI has developed maximum likelihood models to describe the degree to which the biotic communities at target sites differ from those expected at undisturbed sites. Those relationships are used to create a framework under which recovery of disturbed sites can be evaluated. For both the regional- and site-level analyses, assessments are conducted at the species level and then combined among species to highlight biodiversity recovery and regional intactness. Since information at natural and human disturbed sites are required for both analyses, integrated data collection increases cost efficiencies. In addition, by focusing on compatible metrics at different spatial scales, it is possible to evaluate whether restoration and recovery at local scales (i.e., individual sites) results in increases in ecosystem health at the regional scale.


Ecological Resiliency:
Measuring Degradation & Recovery
Jim Schieck
January 22, 2013
ALBERTA
BIODIVERSITY
MONITORING INSTITUTE

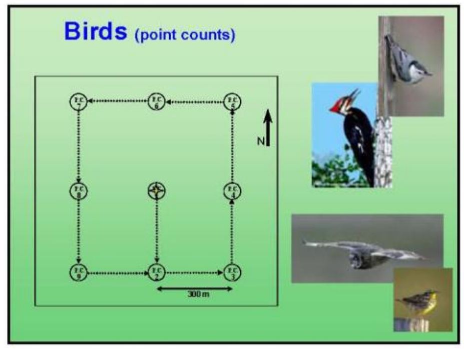

Ecological Resiliency
ABMI
1)Capacity of systems to absorb disturbance and change while retaining function and structure
• Change is embraced as long as processes are retained
• Naturalness of the system is less irrelevant
2)Time required for ecosystems to return to a steady-state following disturbance
• Often associated with recovery of disturbed systems to natural characteristics
• Naturalness as the end-point (where native species thrive)


Measuring Resilience
ABMI
• Lots of "opinion" about the degree of resilience in various ecosystems but quantitative evaluations are rare
• Use information from ABMI to highlight how ecologica degradation and recovery can be evaluated
Evaluations for sites (recovery from disturbance at a local scale)
Evaluations for regions (degradation at due to human disturbance)

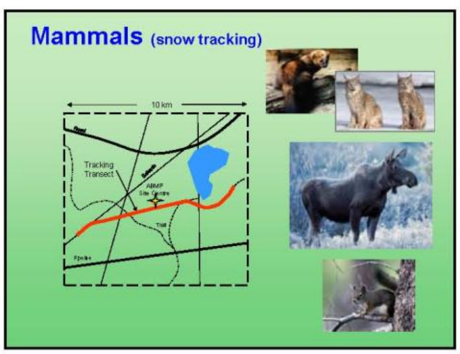

ABMI Survey Design
ABMI
• Grid with a 20 km spacing
➤ 1656 sites
• Return interval of 5 years
~340 sites annually
• Designed to detect 30% change
---- Additional Sites ----
• Targeted survey to test relationships
– Sites are "off-grid"
– Sample a range of disturbances to facilitate analyses



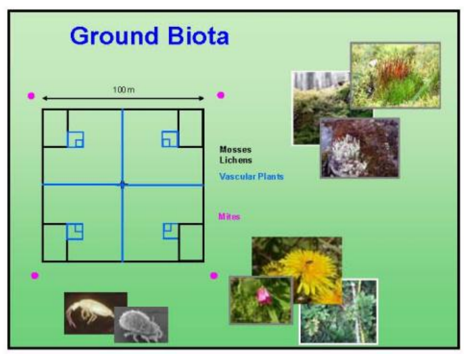
Species Included
ABMI
Emphasis on "species assemblages"
– with > 2000 species surveyed expect that some will respond to each type of ecological change
Vascular Plants
Mosses
Lichens
Birds
Mammals
Fish
Mites
Aquatic Invertebrates
Assemblages chosen based on ease of sampling, statistical properties, and importance to society



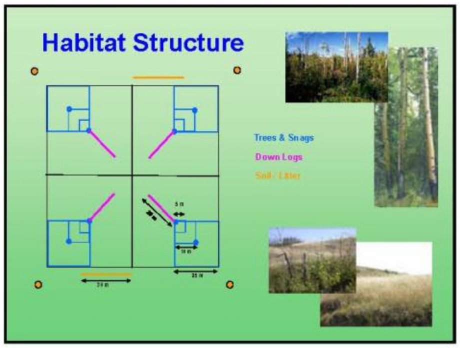
Birds (point counts)
N
300 m



Mammals (snow tracking)
10 km
Tracking Transect
ABMP Site Centre
Trail
Pipeline

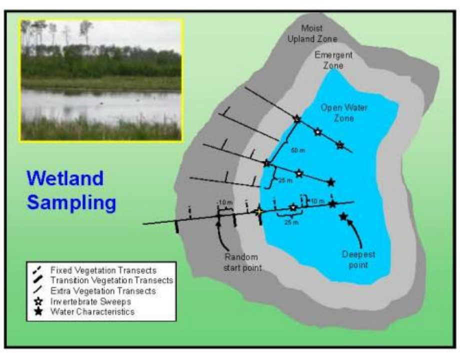


Ground Biota
100 m
Mosses
Lichens
Vascular Plants
Mites

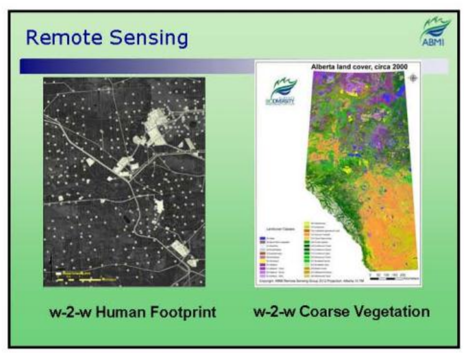


Habitat Structure
Trees & Snags
Down Logs

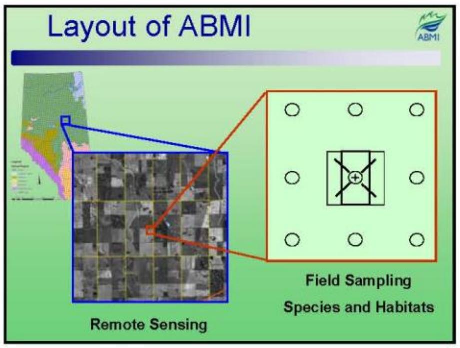
Wetlands
ABMI
Choose closest wetland to each ABMI site

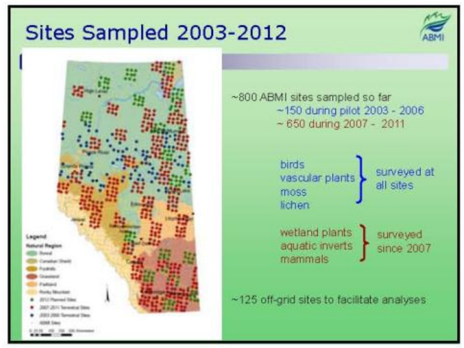


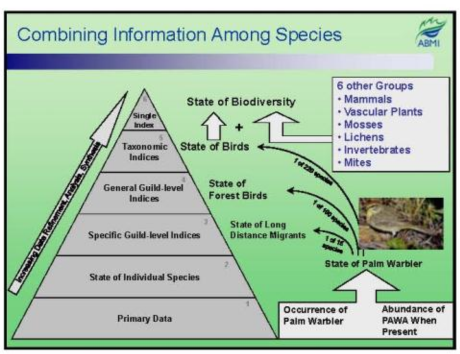
Wetland Sampling
Moist Upland Zone
Emergent Zone
Open Water Zone
50 m
25 m
10 m
25 m
Random start point
Deepest point
Fixed Vegetation Transects
Transition Vegetation Transects
Extra Vegetation Transects
Invertebrate Sweeps
Water Characteristics

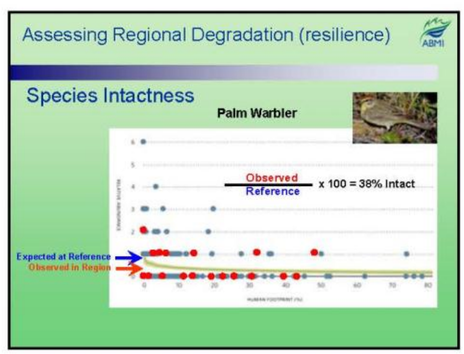


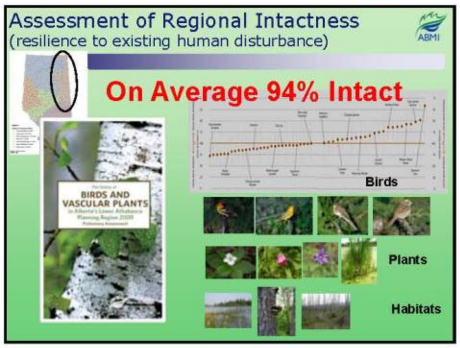
Remote Sensing
ABMI
Alberta land cover, circa 2000
w-2-w Human Footprint
w-2-w Coarse Vegetation

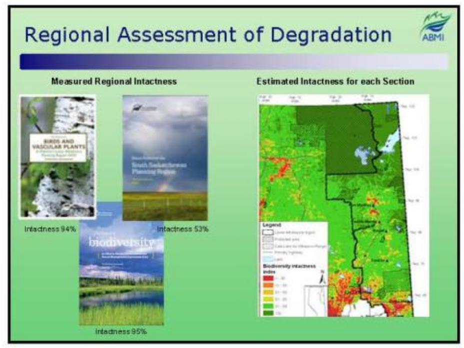

Layout of ABMI
ABMI
Field Sampling
Species and Habitats
Remote Sensing

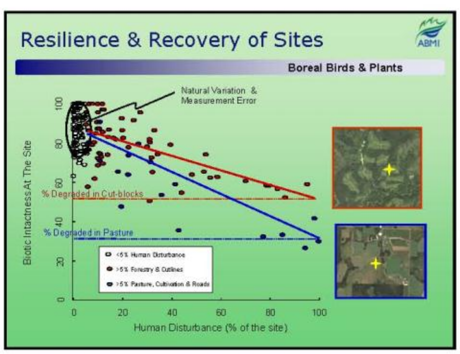

Sites Sampled 2003-2012
ABMI
~800 ABMI sites sampled so far
~150 during pilot 2003 - 2006
~ 650 during 2007 - 2011
birds
vascular plants
moss
lichen
surveyed at all sites
wetland plants
aquatic inverts
mammals
surveyed since 2007
~125 off-grid sites to facilitate analyses

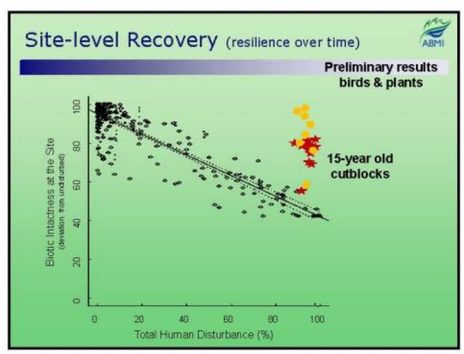

Combining Information Among Species
ABMI
State of Biodiversity
6 other Groups
• Mammals
• Vascular Plants
• Mosses
• Lichens
• Invertebrates
• Mites
Single Index
Taxonomic Indices
State of Birds
General Guild-level Indices
State of Forest Birds
Specific Guild-level Indices
State of Long Distance Migrants
State of Individual Species
State of Palm Warbler
Primary Data
Occurrence of Palm Warbler
Abundance of PAWA When Present

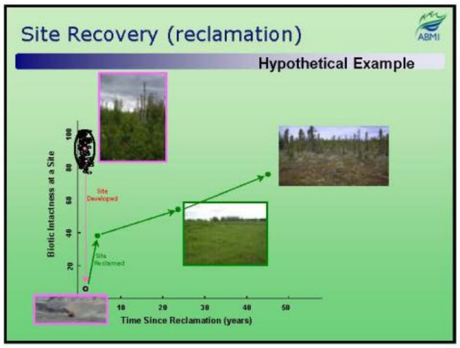

Assessing Regional Degradation (resilience)
ABMI
Species Intactness
Palm Warbler
Observed
Reference
x 100 = 38% Intact
Expected at Reference
Observed in Region

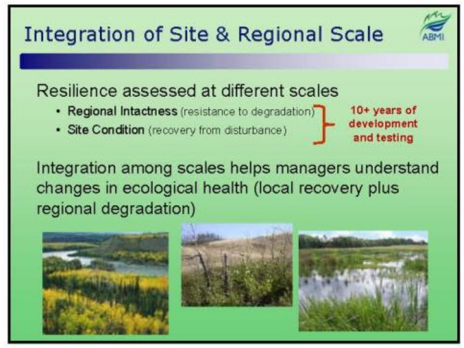

Assessment of Regional Intactness
(resilience to existing human disturbance)
ABMI
On Average 94% Intact
BIRDS AND VASCULAR PLANTS
Birds
Plants
Habitats

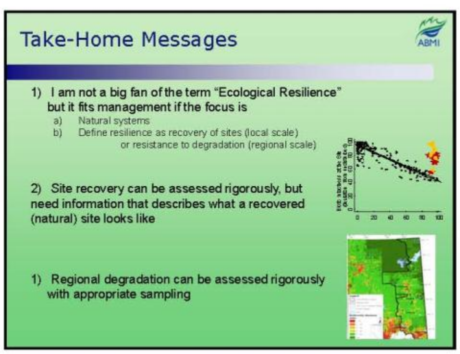

Regional Assessment of Degradation
ABMI
Measured Regional Intactness
Estimated Intactness for each Section
Intactness 94%
Intactness 53%
Intactness 95%


Resilience & Recovery of Sites
ABMI
Boreal Birds & Plants
Natural Variation & Measurement Error
% Degraded in Cut-blocks
% Degraded in Pasture
Biotic Intactness At The Site
Human Disturbance (% of the site)


Site-level Recovery (resilience over time)
ABMI
Preliminary results
birds & plants
15-year old cutblocks
Biotic Intactness at the Site
Total Human Disturbance (%)


Site Recovery (reclamation)
ABMI
Hypothetical Example
Biotic Intactness at a Site
100
80
60
40
20
Site Developed
Site Reclaimed
10
20
30
40
50
Time Since Reclamation (years)


Integration of Site & Regional Scale
ABMI
Resilience assessed at different scales
• Regional Intactness (resistance to degradation)
• Site Condition (recovery from disturbance)
10+ years of development and testing
Integration among scales helps managers understand changes in ecological health (local recovery plus regional degradation)


Take-Home Messages
ABMI
1) I am not a big fan of the term "Ecological Resilience" but it fits management if the focus is
a) Natural systems
b) Define resilience as recovery of sites (local scale) or resistance to degradation (regional scale)
2) Site recovery can be assessed rigorously, but need information that describes what a recovered (natural) site looks like
1) Regional degradation can be assessed rigorously with appropriate sampling

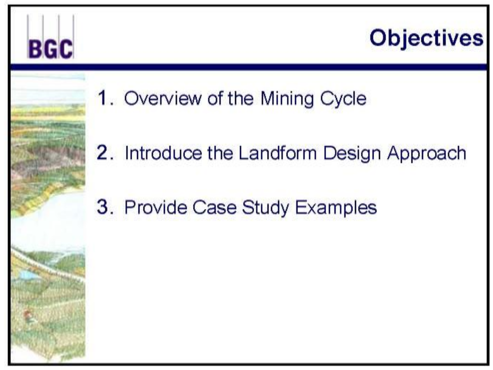
Landform Design for Resiliency

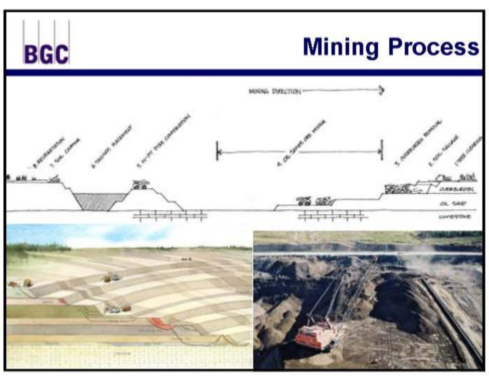
Elisa Scordo, Jordana Fair and Gord McKenna
BGC Engineering Inc.

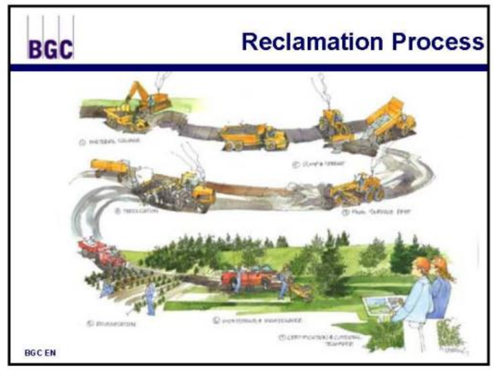
Mining operations result in large-scale landscape disturbances. Reconstruction of the landscape involves re-establishment of topographic, surface water and groundwater systems disrupted by mining activities before terrestrial and aquatic communities can be established. The mining process in the oil sands region involves the stripping of soil and overburden to access the oil-bearing bitumen layer below and results in large mined-out pits, tailings storage facilities (in-pit and out-of-pit) and above ground overburden dumps comprised of saline-sodic soils and lean oil sands in the post-mining landscape.

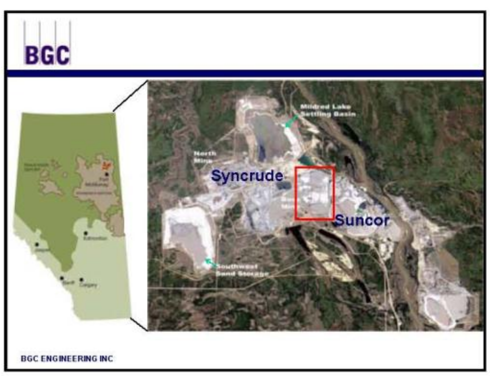
Landform design is a holistic approach to the design and construction of mined landforms which uses a multidisciplinary structure to consider the implications to geotechnical, surface water, groundwater, soils, vegetation and wildlife on landscape performance. With this approach, the use of natural analogues are a key component of landform design and includes the replication of form and function to landform elements such as shallow wetlands, channels, pit lakes, plateaus and slopes. Natural features are the products of local conditions, such as climate, topography, and parent materials and processes that occur over thousands of years. As designers we cannot fully understand the intricacies and interactions of various landform elements (e.g., substrate, reclamation material, flora and fauna, climate), but a landform design approach can attempt to understand the implications of various failure modes or perturbations on the resiliency of reclaimed landforms over time.

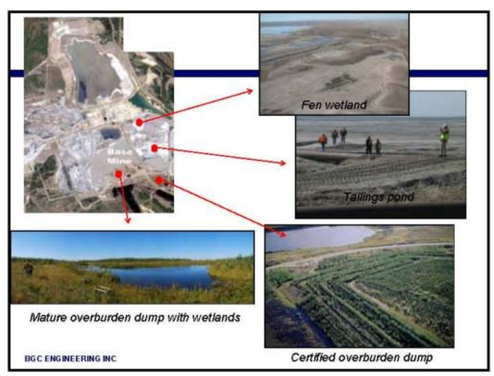

BGC
Resiliency of Reclaimed Boreal Forest Landscapes Workshop
Landform Design for Resiliency
Elisa Scordo, Jordana Fair and Gord McKenna
BGC Engineering
January 22, 2013 – Edmonton, Alberta
University of Alberta
BGC ENGINEERING INC

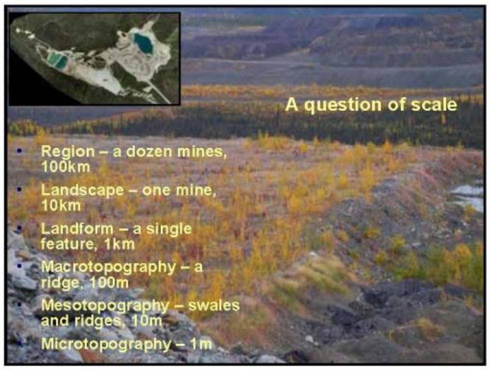

BGC
Objectives
1. Overview of the Mining Cycle
2. Introduce the Landform Design Approach
3. Provide Case Study Examples

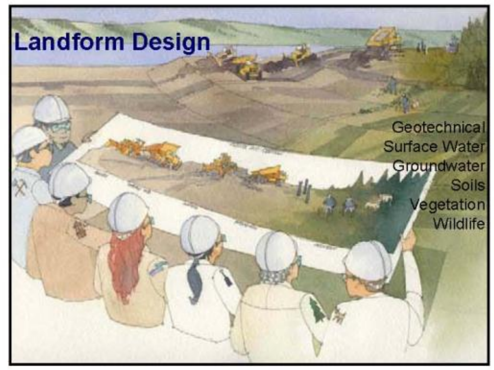

BGC
Mining Process

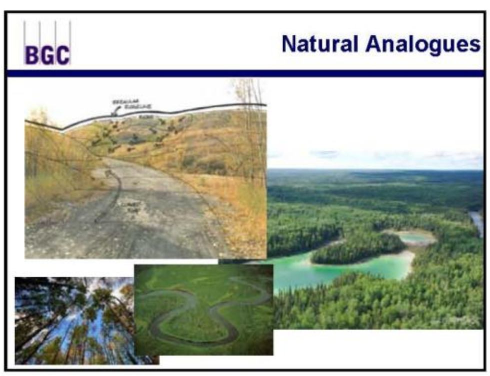

BGC
Reclamation Process
BGC EN

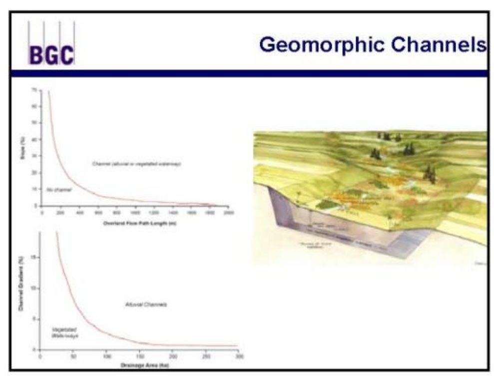

BGC
Syncrude
Suncor
BGC ENGINEERING INC

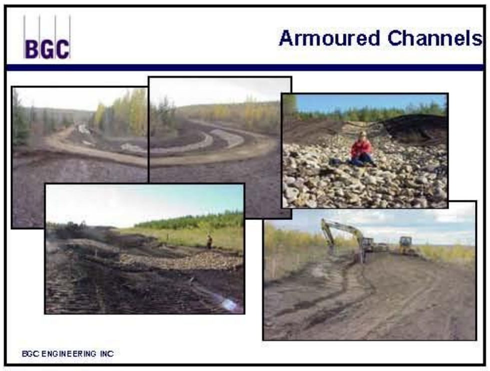

Fen wetland
Tailings pond
Mature overburden dump with wetlands
Certified overburden dump
BGC ENGINEERING INC


A question of scale
Region – a dozen mines, 100km
Landscape – one mine, 10km
Landform – a single feature, 1km
Macrotopography – a ridge, 100m
Mesotopography – swales and ridges, 10m
Microtopography – 1m


Landform Design
Geotechnical
Surface Water
Groundwater
Soils
Vegetation
Wildlife


BGC
Natural Analogues


BGC
Geomorphic Channels


BGC
Armoured Channels
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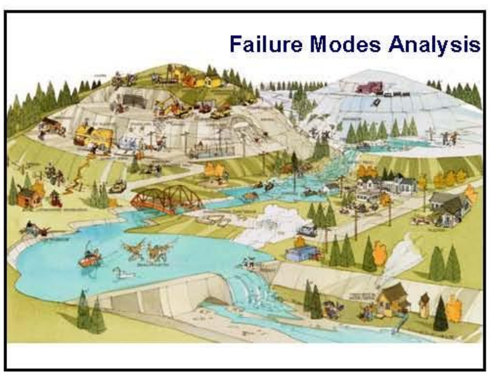
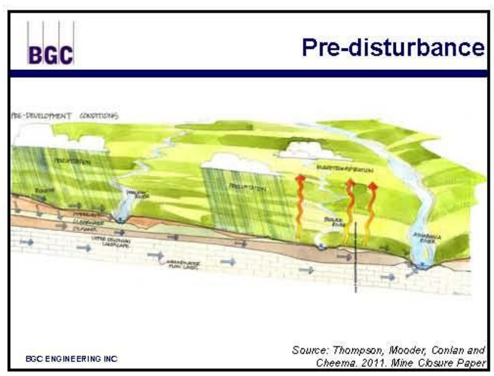

Failure Modes Analysis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Pre-disturbance
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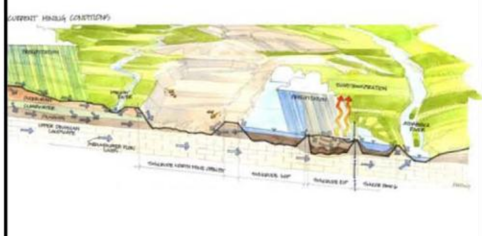
Source: Thompson, Mooder, Conlan and Cheema. 2011. Mine Closure Paper

Mining

BGC



Source: Thompson, Mooder, Conlan and Cheema. 2011. Mine Closure Paper

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Closure

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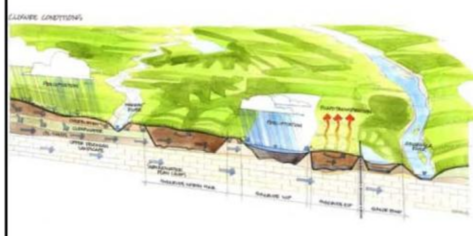

Source: Thompson, Mooder, Conlan and Cheema. 2011. Mine Closure Paper

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A note on time…

BGC

…natural landscapes represent **geomorphic processes and patterns** that have evolved over significant periods of time and at slow rates…

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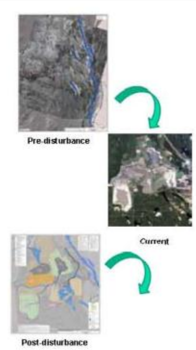
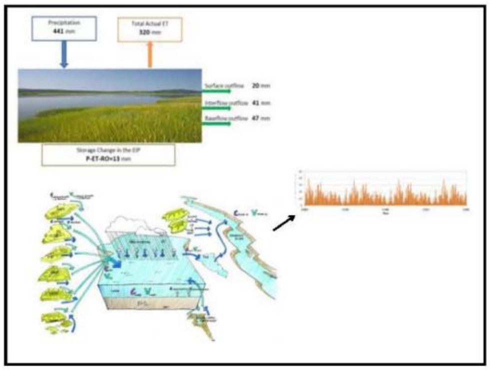
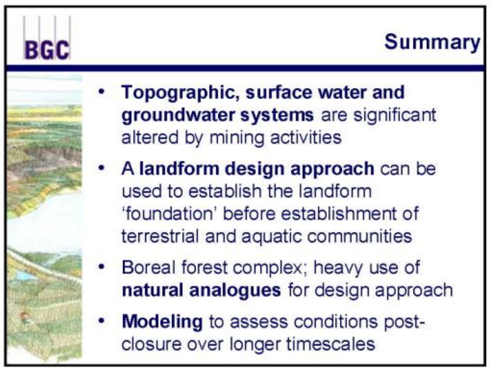



Precipitation
441 mm
Total Actual ET
320 mm
Surface outflow 20 mm
Interflow outflow 41 mm
Baseflow outflow 47 mm
Storage Change in the EIP
P-ET-RO=13 mm


BGC
2007
BGC ENGINEERING INC
Source: www.suncor.com


BGC
2010
BGC ENGINEERING INC
Source: www.suncor.com


BGC
2012
BGC ENGINEERING INC
Source: www.suncor.com


BGC
Summary
Topographic, surface water and groundwater systems are significant altered by mining activities
A landform design approach can be used to establish the landform 'foundation' before establishment of terrestrial and aquatic communities
Boreal forest complex; heavy use of natural analogues for design approach
Modeling to assess conditions post-closure over longer timescales


Thanks!

Changing Objectives for Oil Sands Reclamation:
The Evolution of the Faster Forests Program

Terry Forkheim
Statoil Canada Ltd.

The development of Alberta's oil sands resource requires significant exploration activity before construction and operation of the facilities can occur. Oil Sands Exploration (OSE) sites are necessary to delineate the bitumen resource, thus enabling detailed planning of in-situ oil sands projects. Due to the large number of OSE sites required, they constitute a significant land disturbance in the Boreal forest. Prior to 2009 reclamation efforts for OSE sites focussed on stabilizing the site and preventing erosion, and seeding the sites to native grasses was an accepted and common practice. Agronomic grasses and legumes were seeded prior to the native mixes becoming the standard.

These practices were not felt to be satisfactory in a Boreal forest setting, and plans were made to move towards more appropriate objectives. The first step was to move away from seeding sites to grass, and the initial focus was on planting trees.

The Faster Forests program was initiated at OSLI (Oil Sands Leadership Initiative) in 2009, with three companies participating. The objective was to plant trees to accelerate the recovery to a forest trajectory for the site. One tree species (aspen poplar) was planted that year. While that was considered a success as the trees made it into the ground and survived, it was felt that there was much more that could be done. Every year since then the program has expanded and evolved considerably in terms of variety of species, numbers planted, planting techniques, ecological objectives, linkages to best construction and reclamation practices, and other OSLI projects. The findings are being applied to other disturbances to enhance and accelerate reclamation throughout the oil sands. This presentation describes the progress and evolution of the Faster Forests program.

Changing Objectives for Oil Sands Reclamation; the evolution of the Faster Forests Program

Terry Forkheim, Statoil Canada

January 2013

OUTLINE

- OSLI (Oil Sands Leadership Initiative) introduction
- In-situ development impacts
- OSLI LSWG (Land Stewardship Working Group)
- Faster Forests
- Evolution of the program, and changing objectives
- Value added component, including other OSLI LSWG projects
- Monitoring
- Wrap up

2

The Oil Sands Leadership Initiative

Five founding companies:

- *ConocoPhillips Canada*
- *Nexen Inc.*
- *Statoil (Canada)*
- *Suncor Energy Inc. (with former Petro-Canada)*
- *Total E&P Canada*

A sixth company joined OSLI within a year of its creation:

- *Shell Canada Ltd.*

Alberta Environment, Alberta Energy and Alberta Sustainable Resource Development participate as observers

OSLI Vision:
Achieving world-class environmental, social and economic performance in developing this world-scale oil sands resource.

OSLI is complementary to industry groups such as CAPP and the Oil Sands Developers Group. We are a leadership group with a "laser focus" on performance improvement.

3

LSWG Vision and BHAGs

LSWG Vision (Draft)

- Protect ecological integrity and assure sustainable landscapes to manage environmental and economic risk in the Oil Sands region.

LSWG BHAGs

1. Oil sands development will have less landscape footprint than Canadian conventional oil
2. Reverse the decline of listed wildlife species of concern in Northeast Alberta

4

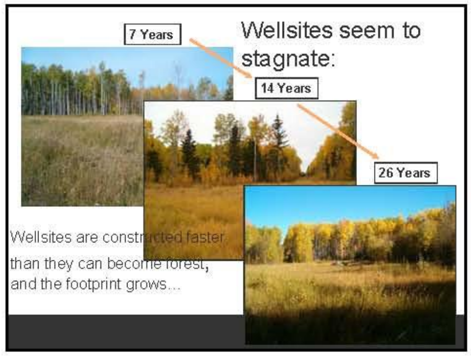
In-situ Impacts

- Exploration – coreholes and 3-D seismic results in fragmentation and land disturbance.

  Aggressive reclamation, trials and research. Examples – CWD manual, Algar restoration, BMPs, Faster Forests

- Production – CPF, pads, roads, AGPs

  Planning tools, avoid, minimize, mitigate. Studies and research – wetland reclamation, AGP impacts and design, monitoring.



Faster Forests

- Member companies pledge to adopt an on-lease policy of replanting both historic and current disturbances when they are no longer in active use
- Planting program, land treatments and best practices, encouragement of natural regeneration, monitoring and dissemination of best practices.
- Started in 2009 – planted one species of trees – Aspen poplar
  - ~30,000 stems were planted. We all scrambled to get locations that were ready to go. The planters were planting just in time.
  - Full page CAPP advertisements occurred country-wide; tree planting resonates very well with the public

Faster Forests next few years…

- 2010 - it was not difficult to improve on 2009,
- we received four species that year – white spruce, jack pine, balsam poplar and white birch.
- We started moving towards prescriptions and matching sites with species. This would prove to be challenging!
- Also started that fall was shrub seed collection as we felt that shrubs would be a valuable addition to the program. Numbers planted went up significantly and became a focus, and the key performance indicator.
- Tours, questions, coarse woody material rollback, construction practices, linkages to other projects were all started in earnest at this time.

Faster Forests next few years…

- 2011 – the first year of shrub planting, with seven shrub species and four tree species – a cornucopia!
- We were still challenged by matching available stock with the right sites, microsite planting, planning ahead far enough, among other things. The wheels were in motion though, to make some real improvements.
- A closer look at our construction and reclamation practices and how they affect outcomes allowed us to make changes that we would see the results of the next summer
- Curiouser and curiouser we were…

Faster Forests today

- 2012 – this was the first year of "Boutique Planting", with "buckets" to choose from for different site types.
- A large variety of trees and shrubs were available.
- New for 2012 were dedicated planting crews trained specifically for our needs. This along with a stronger focus on planting and stock handling QA/QC resulted in another improvement to the program.
- We also welcomed a new industry partner to the program.
- We found that due to a large number of variables that affect the program, detailed planning for each site is not feasible. This was a valuable learning.




The value added component

- Informal tours and questioning – curiousity!!
- Tours with industry partners and regulators, discussing best practices, sharing our experiences, good, bad, and not so pretty. All sorts of trials and experimentation on a small scale.
- Follow-up and documentation. This is critical for long term success.
- Immensely valuable collaboration and sharing was occurring between companies and regulators.
- Things like the CWM manual were incubated here.
- Linkages to LEAP, Algar, winter planting.
- Discussion moved towards things like caribou habitat, line of sight, berry patches. Ecological functionality had replaced the numbers game as the prime objective, without conscious thought towards this outcome.

LSWG Projects

Baseline and Benchmarking – Landbase Modelling

- Creating a benchmarked landbase to conduct ecological and spatial modeling for the member companies
- Covers 350 townships, will get historic footprint and with AVI data enable us to erase the footprint and look at the pre-disturbance forest
- We can then use it to guide us as to the best places to plant trees to maximize habitat restoration and intactness (when other practices are included), also to predict where caribou food source (lichen) will occur, and ultimately, could provide a mechanism for large-scale (OSLI) on-lease restoration and habitat preservation

19

LSWG Projects

Algar Disturbance Reclamation

- Restoration of historical disturbances in the Algar area.
- Initial program will cover 8 townships, long-term program will consider 25 townships or more.
- Line inventory and field validation will be complete in January 2011by Matrix Solutions
- Development of a restoration plan underway - plans expected mid-spring 2011 with potential for limited summer planting in 2011
- SRD is leading the consultation program (underway)

20

LSWG Projects

Best Practices and Knowledge Gathering

- Treatment Effectiveness (Phase 1 Complete)
  - Retrospective analysis of linear corridor site preparation treatments used in the Little Smokey area by ConocoPhillips and Suncor
  - Results will inform the design of a pilot program to test site preparation treatments for re-establishing ground vegetation, shrubs and trees on linear corridors
- Coarse Woody Debris Management
  - Developing with SRD a debris management guide to better manage woody debris during construction and reclamation, the guide will aim to develop best management practices through: consultation with resource managers and operators, consideration of economic and ecological requirements, and synthesis of the most relevant and current scientific evidence.

21

LSWG Projects

Best Practices and Knowledge Gathering

- Caribou Diet and Lichen Mapping Project

  Completion of a woodland caribou diet and lichen mapping program designed to identify the relationship between the diet, nutrition, and habitat choices of woodland caribou and to develop a classification model to delineate lichen habitats in the Athabasca oil sands area.
- Winter Planting – late 2011 trial, was implemented in Algar if successful

22

And for dessert - Monitoring

- Not everyone felt the program was worthwhile, our regulatory obligations were lower than what we were achieving.
- Leave for natural was and still is a good practice when your C&R techniques are top drawer. Could this be our ultimate goal?
- What exactly were the objectives of the Faster Forests program?
- Monitoring proposal now being completed.
- Evaluation sites being selected.
- Can we see a difference, and can it be measured? Anecdotally we saw proof.

Statoil

Thanks to many…

- Folks from ConocoPhillips, Nexen, Statoil, Cenovus, MEG Energy
- Terry Osko
- Folks from AESRD – Kevin Ball, Ken Greenway, Tim Vinge, Erin Fraser, Isaac Amponsah
- Andrew Carpenter (Reclaimit)
- Folks from U of A – Matthew Pyper

Statoil


There's never been a better
time for good ideas
QUESTIONS?
Terry Forkheim
Senior Regulatory Advisor
tefor@statoil.com
Tel: +587 233 0560
www.statoil.com
Statoil

Soil Management to Maintain Boreal Forest Resiliency

Dean MacKenzie, Ph.D., P.Ag.
Navus Environmental Inc.

Conservation and management of forest surface soil is beneficial for the development of resilient boreal forest plant communities on post-disturbed land and can be used to target plant communities that will meet restoration/reclamation objectives. Forest surface soil is an economical source of diverse and abundant biotic components such as native plant propagules (i.e., spores, seeds, vegetative propagules), soil fauna and microorganisms as well as abiotic components such as nutrients that are required for the development of resilient "future" forests. Biotic properties are among the most significant factors affecting resilience of the vegetation community on reclaimed land where salvaged forest surface soil has been placed.

Source location of donor soil, salvage depth, stockpiling and placement depth are factors that affect the availability and viability of propagules for regrowth. Salvage depth affects soil quality and potential for in situ propagules to emerge. Salvaging too deep will dilute the propagules and organic matter content of the forest floor with underlying mineral soil; however, salvaging too shallow may not provide sufficient root to soil contact for successful emergence of seeds or vegetative propagules. Optimal salvage depth will be impacted by various factors such as soil texture, source location and reclamation objectives. Salvaged surface soil should be directly placed, as stockpiling surface soil for even short periods of time reduces viability of most boreal plant species and causes substantial changes to soil chemical properties. During salvage if too much mulch is incorporated with upland surface soil, viability of native propagules can be reduced. Optimal placement depth and distribution of surface soil is also dependent on many factors including salvage depth, substrate quality and reclamation objectives. Placement of coarse woody debris on the surface soil creates microsites that aid in reestablishment of native plants.

This presentation discusses how these factors affect vascular plant propagule and seed abundance, distribution and establishment towards diverse self-sustaining boreal forest plant communities. Various adaptive management practices developed from theory, research and operations to help reduce negative impacts on soil quality and viability of native propagules are also discussed.

Resiliency

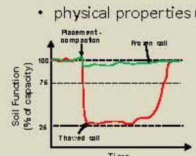
- Degree to which initial (or target) plant community characteristics are restored
- Biological communities, both above and below ground, are among the most significant factors affecting resilience – "propagules"

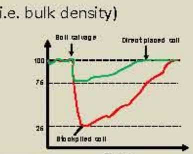
Soil Management and Resiliency

- Managing for **biotic (propagules)** and abiotic properties
- Source location of donor soil, season, salvage depth, stockpiling and placement depth affect
  - species composition of propagules
  - propagule density
  - propagule distribution

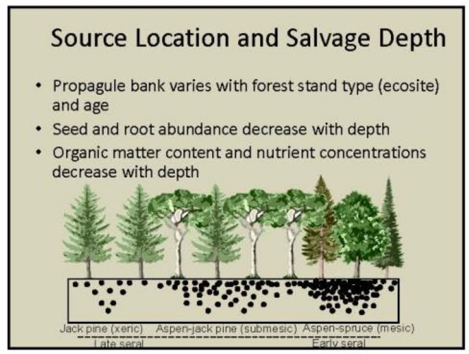
Soil Management and Resiliency

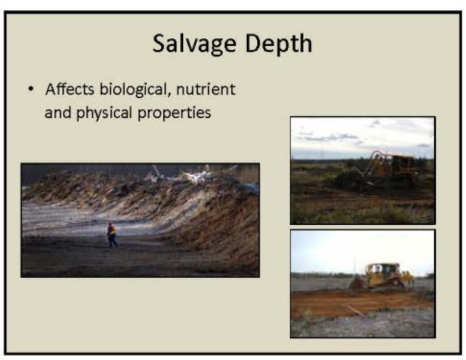
- Managing for biotic (propagules) and **abiotic** properties
- Source location of donor soil, season, salvage depth, stockpiling and placement depth affect
  - organic matter content and quality
  - nutrient forms and concentrations
  - physical properties (i.e. bulk density)

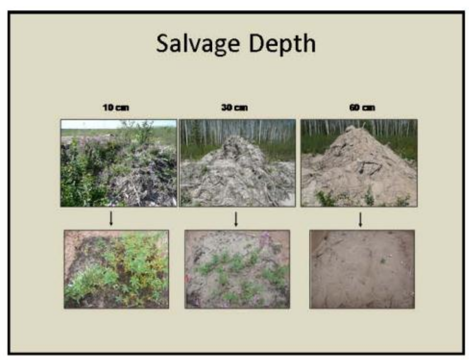





Salvage
Storage
Resiliency
Placement


Source Location and Salvage Depth
• Propagule bank varies with forest stand type (ecosite) and age
• Seed and root abundance decrease with depth
• Organic matter content and nutrient concentrations decrease with depth
Jack pine (xeric)
Aspen-jack pine (submesic)
Aspen-spruce (mesic)
Late seral
Early seral


Salvage Depth
• Affects biological, nutrient and physical properties


Salvage Depth
10 cm
30 cm
60 cm

Salvage

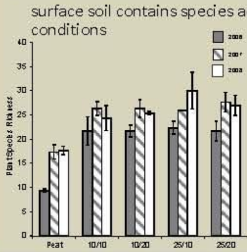
- Woody debris (WD) is beneficial but excessive amounts can be detrimental

Placement

- Seed germination occurs near surface
- Establishment success from plant vegetative parts decreases with increasing burial depth
- Species establishment is successful if adapted to the new environment

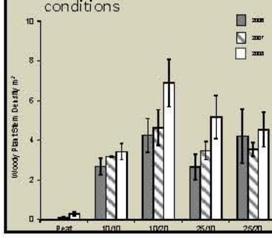
Source Location of Donor Soil

- Plant establishment and diversity are enhanced when surface soil contains species adapted to placement conditions



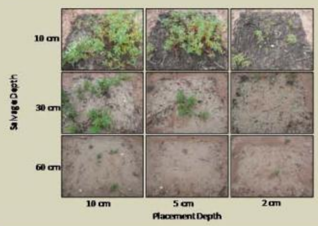
Source Location of Donor Soil

- Plant establishment and diversity are enhanced when surface soil contains species adapted to placement conditions



Placement Depth

- Placement depth has more influence on plant productivity versus number of species emerging



Placement

- Plant establishment and diversity are enhanced when surface is left rough

Placement

- Amendments can be beneficial or detrimental

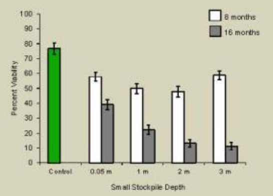
Stockpiling

Stockpiling effects

- Physical properties
- Chemistry
- Fauna
- Gases
- Seed viability, germination

Stockpiling

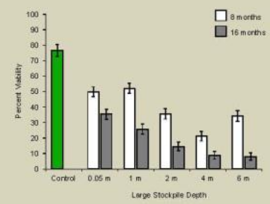
- Stockpiling quickly reduces seed and root viability, regardless of stockpile size



Viable Seed

Stockpiling

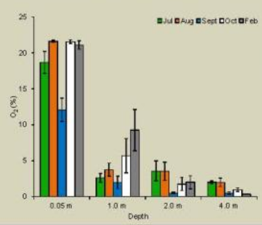
- Stockpiling quickly reduces seed and root viability, regardless of stockpile size



Dead Seed

Stockpiling

- Stockpiling quickly changes soil chemistry due to constant anaerobic activity



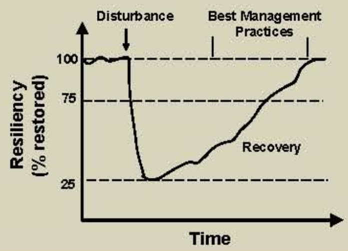
Stockpiling

- Maintaining seed viability may only be achieved in the upper 1.0 m of surface soil within stockpile
- Maximize surface area to retain some viability and handle upper 1.0 m separately
- Free dump on top of stockpiles to increase surface area
- Find alternative stockpile locations if space is a constraint

Achieving Resiliency

- Direct placed surface soil containing desired species is the most effective method establishing diverse native plant communities
- All stages of soil handling methods will influence success

Achieving Resiliency



Maintaining Resiliency

- Select donor soils with native species adapted to environmental conditions on post-disturbed landscapes
- Place select donor soils throughout post-disturbed landscape to maximize dispersal

References

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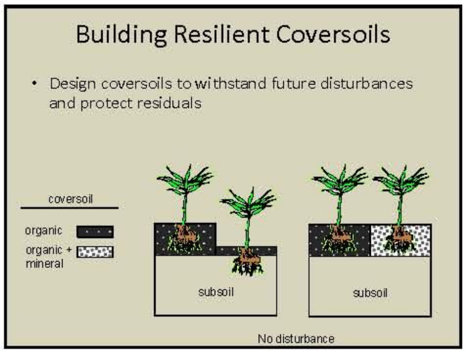
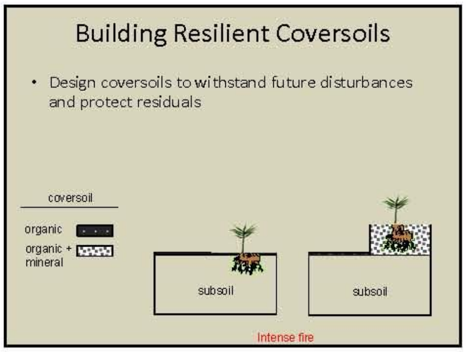
Thank You


Building Resilient Coversoils
• Design coversoils to withstand future disturbances and protect residuals
coversoil
organic
organic + mineral
subsoil
subsoil
No disturbance


Building Resilient Coversoils
• Design coversoils to withstand future disturbances and protect residuals
coversoil
organic
organic + mineral
subsoil
subsoil
Intense fire

Is Ecological Resiliency a Meaningful Concept for Reclamation Policy and Regulation: Considerations for the Management of Oil Sands Facilities

Brett Purdy
Alberta Innovates – Energy and Environment Solutions

The development of oil sands resources results in both extensive and intensive disturbance of the natural boreal landscape. Companies who receive approval to operate oil sands facilities are required to conserve and reclaim disturbed land as per the *Environmental Protection and Enhancement Act* (EPEA). Requirements detailed in EPEA Approvals are at times prescriptive such as those that govern soil salvage and placement criteria, whereas others are outcome-based, such as the requirement that reclaimed lands be capable of supporting self-sustaining locally common boreal forest ecosystems. Due to the large temporal and spatial scales associated with oil sands operations, defining the measures of success in achieving outcomes-based reclamation objectives has at times been difficult in a regulatory context.

In response to this challenge, government requires companies to frequently update and submit for regulatory approval long-term operational planning documents such as life of mine closure plans. To assist with reclamation planning, reclamation operations, and assessment of performance, several guides, manuals and frameworks for reclamation specific to oil sands operations have been developed largely through multi-stakeholder forums. Annual reporting details on-the-ground conservation and reclamation activities which reflect how the closure and reclamation plans are implemented. Whereas this process provides flexibility and adaptive management opportunities in developing acceptable reclamation and closure options throughout the life of an oil sands facility, it can result in challenges in defining measures of reclamation success at the time of certification.

Extending regulatory consideration of the ecology and environment beyond the first generation of a reclaimed boreal forest ecosystem may seem to some unnecessary and overly complex. This presentation will introduce the conservation and reclamation context in which oil sands facilities operate, and attempt to discuss how long-term issues of sustainability, which incorporate concepts such as ecological resiliency, might be built into a regulatory system.

Is ecological resiliency a meaningful concept for reclamation policy and regulation ?

Brett Purdy
Reclamation research specialist (ESRD)
Director, Restoration ecology and ecosystem management (AI-EES)

Alberta Innovates Energy and Environment Solutions

Alberta

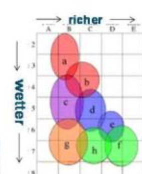
Outline

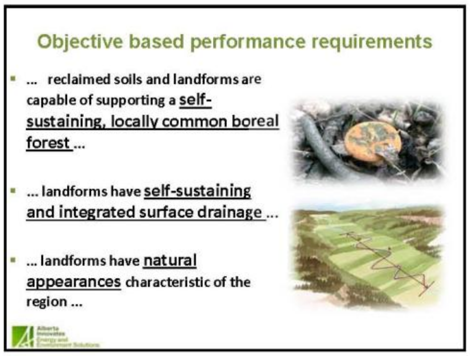
- Current system
- Evolving expectations
- Best practices
- Capability / functionality
- Target, trend, checklist
- Research ideas

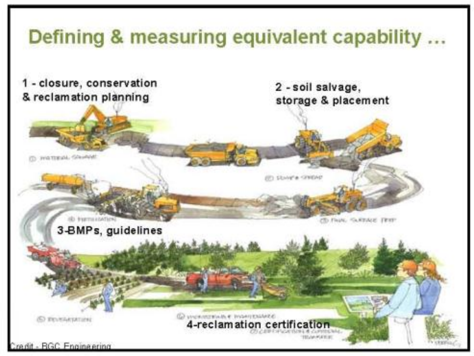
Current system

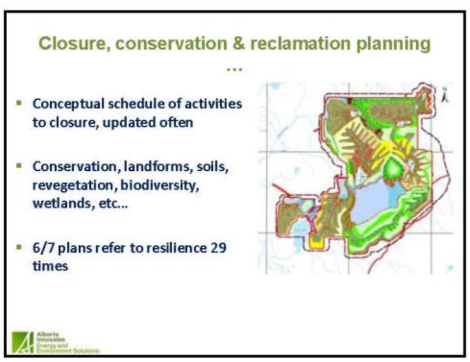
- **... regs, APPROVALS – establish requirements, standards, procedures, thresholds, research**
- **Key components**
  - **Planning & reporting**
  - **Conservation & reclamation**
  - **Monitoring & certification**
- **Objective of reclamation ...**
  Equivalent Land Capability

Prescriptive reclamation standards - soil management, some revegetation

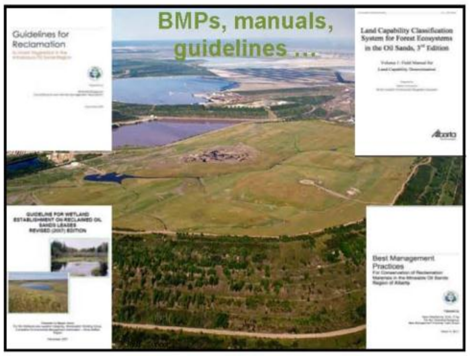


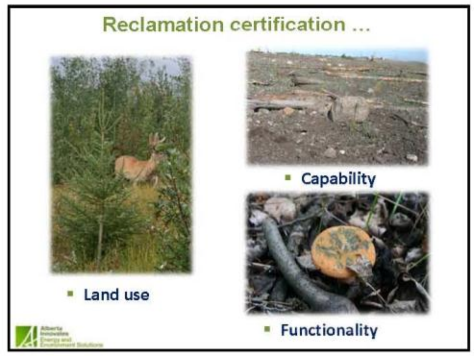

Objective based performance requirements
… reclaimed soils and landforms are capable of supporting a self-sustaining, locally common boreal forest …
… landforms have self-sustaining and integrated surface drainage …
… landforms have natural appearances characteristic of the region …

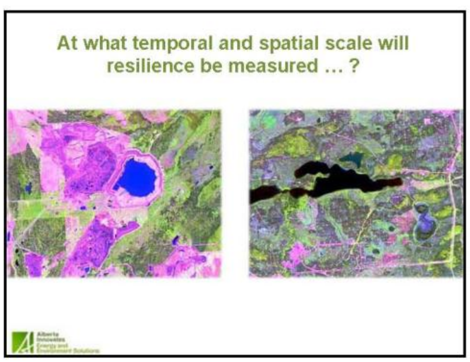

Defining & measuring equivalent capability …
1 - closure, conservation & reclamation planning
2 - soil salvage, storage & placement
3-BMPs, guidelines
4-reclamation certification
Credit - BGC Engineering


Closure, conservation & reclamation planning …
Conceptual schedule of activities to closure, updated often
Conservation, landforms, soils, revegetation, biodiversity, wetlands, etc…
6/7 plans refer to resilience 29 times


Soil salvage, storage & placement …

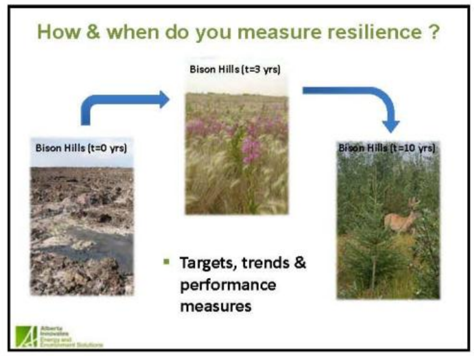

BMPs, manuals, guidelines …
Guidelines for Reclamation
Land Capability Classification System for Forest Ecosystems in the Oil Sands, 3rd Edition
Volume 1: Field Manual for Land Capability Determination
GUIDELINE FOR WETLAND ESTABLISHMENT ON RECLAIMED OIL SANDS LEASES REVISED (2007) EDITION
Best Management Practices
For Conservation of Reclamation Materials in the Mineable Oil Sands Region of Alberta


Reclamation certification …
Capability
Land use
Functionality
Alberta Innovates Energy and Environment Solutions

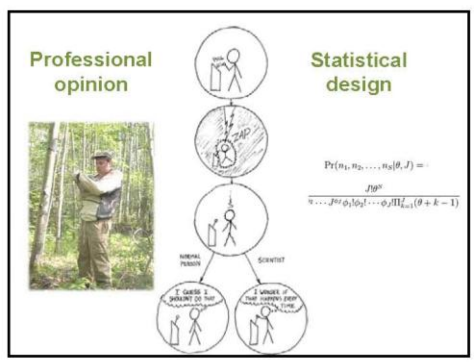

At what temporal and spatial scale will resilience be measured … ?
Alberta Innovates Energy and Environment Solutions


Will expectations or measures of resilience be the same … ?
Alberta Innovates Energy and Environment Solutions


Suncor Pond 1 - 2005
What milestones during reclamation and closure can be managed to address resiliency ?
Suncor Pond 1 - 2009
Suncor Pond 1 - 2011
Dewater
Remediation
Landform design
Capping
Soil placement
Revegetation
Monitoring


How & when do you measure resilience ?
Bison Hills (t=0 yrs)
Bison Hills (t=3 yrs)
Bison Hills (t=10 yrs)
Targets, trends & performance measures


What would a checklist look like ?
Credit – BGC Engineering


Professional opinion
Statistical design
ZAP
NORMAL PERSON
SCIENTIST
I GUESS I SHOULDN'T DO THAT
I WONDER IF THAT HAPPENS EVERY TIME

Establish targets based on natural systems

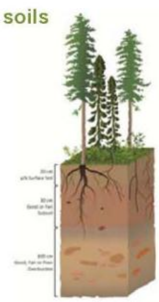
- Form and function (Wetlands, uplands)

Design landforms to sustain natural geomorphic processes

- Natural appearance, hydrologic regime

BMPs for soils

- Total nutrient pools
- Nutrient cycling
- Soil organisms
- Dead wood



Establish biodiversity

- stand level
- landscape


Minimizing disturbance and progressive reclamation
Land disturbance limits
Legacies of 2° succession


Research

Seminar Wrap-up Notes

Ellen Macdonald
University of Alberta

Resiliency of reclaimed boreal forest landscapes

Resilience of what? To what? For how long?

Resilience = ability to deliver desired suite of ecological goods and services in the future (stand, landscape = multiscale)

Resilience ≠ static, resilient could = capacity to change

Is 'naturalness' important/relevant? As analog or template?

The "Field of Dreams" dream ...they will come...and also take care of themselves

Resiliency of reclaimed boreal forest landscapes

Building blocks: landform, hydrology, soils, species, landscape
We heard details on these, how to encourage and assess recovery

Existing knowledge from research and monitoring:

- Dynamic interplay of structure – function - process
- Response to disturbance
- Ability to 'recover'

Temporal and spatial variability in these

- Because that's natural
- Because it reduces risk

Resiliency of reclaimed boreal forest landscapes

Planning, regulation, policy and monitoring need to accept (embrace!) spatial and temporal variability

- Uncertainty (risk?)
- Prescriptive *vs.* outcomes or objective-based

Mining vs. *in situ* vs. upstream vary:

- Intensity / scale of disturbance
- Landscape context

We have a gradient of disturbance and recovery trajectories/objectives

PROPOSED Alberta Centre for Reclamation and Restoration Ecology (ACRRE)

Mission: Providing science and policy to guide the renewal of disturbed lands and ecosystems.

Vision:

- World-class Centre at the University of Alberta
- Bringing together scientists and facilitate research and collaboration
- Science focused on solving real-world problems
- Go-to-place for scientists, students, managers and policy makers
- Translation and application of scientific knowledge
- Training the next generation of problem solvers

Ellen.macdonald@ualberta.ca

APPENDIX 4: Seminar Attendees

Doug Ambedian	Woodlands North Inc.
Karen Anderson	Alberta Tourism, Parks & Recreation
Robert Anderson	FORCORP
Anthony Anyia	Alberta Innovates - Technology Futures
Kevin Ball	Environment & Sustainable Resource Development
Caroline Bampfylde	Environment & Sustainable Resource Development
Suzanne Bayley	Department of Biological Sciences
John Begg	Environment & Sustainable Resource Development
David Bergstrom	
Atty Bressler	AMEC Environment & Infrastructure
David Bruinsma	The Pembina Institute
Alfred Burk	Cenovus Energy
Andrew Carpenter	Reclaimit Ltd.
Shauna-Lee Chai	Alberta Innovates - Technology Futures
David Chanasyk	Department of Renewable Resources - University of Alberta
Virginia Chavez	Alberta Innovates - BioSolutions
Chi Chen	
Dave Cheyne	Alberta-Pacific Forest Industries
Allisson Cohen	Stantec
Mike Collie	Alberta Tourism, Parks & Recreation
Michelle Cotton	Solstice Canada Corp.
Phyllis Dale	Canadian Forest Service
Andrea Dechene	
Dani Degenhardt	Alberta Innovates - Technology Futures
Mark Dewey	NAIT
Gordon Dinwoodie	
Craig Dockrill	Environment & Sustainable Resource Development
Margaret Donnelly	Alberta-Pacific Forest Industries
John Doornbos	Canadian Forest Service

Natasha Downes	Alberta Tourism, Parks & Recreation
Catrina Duffy	Solstice Canada Corp.
Brian Eaton	Alberta Innovates - Technology Futures
Lynette Esak	Esak Consulting Ltd.
Jordana Fair	BGC Engineering
Lee Foote	Devonian Botanic Garden
Terry Forkheim	Statoil Canada Ltd.
Ken Foster	Owl Moon Environmental Inc.
Erin Fraser	Environment & Sustainable Resource Development
Chris Godwin	Owl Moon Environmental Inc.
Jeannine Göhing	Department of Renewable Resources - University of Alberta
Joyce Gould	Alberta Tourism, Parks & Recreation
Robert Grant	Department of Renewable Resources - University of Alberta
Ken Greenway	Environment and Sustainable Resource Development
Sheldon Helbert	Polymath Environmental Consulting Ltd.
Guillermo Hernandez-Ramirez	Department of Renewable Resources - University of Alberta
Gray Jordan	Nexen Inc.
Al Kalantry	
Justine Karst	Department of Renewable Resources - University of Alberta
Jillian Kaufmann	Millennium EMS Solutions
Barb Kishchuk	Canadian Forest Service
Richard Krygier	Canadian Forest Service
Dieter Kuhnke	Canadian Forest Service
Simon Landhausser	Department of Renewable Resources
Janine Lemire	WorleyParsons Canada
Rae Lett	Alberta Tourism, Parks & Recreation
Vic Lieffers	Department of Renewable Resources
Marcus Ma	Beckingham Environmental
Neil MacAlpine	Land Use Knowledge Network
Beth MacCallum	Bighorn Wildlife Technologies Ltd.

Ellen Macdonald	Department of Renewable Resources
Dean Mackenzie	Navus Environmental Inc.
Anne McIntosh	Alberta Biodiversity Monitoring Institute
David McNabb	Forest Soil Science Ltd
Marge Meijer	Alberta Tourism, Parks & Recreation
Carl Mendoza	Department of Earth & Atmospheric Sciences
Marco Mogollon	
Anjum Mullick	Worley Parsons
Romi Oshier	Canadian Forest Service
Terry Osko	Circle T Consulting Inc.
Shane Patterson	Environment and Sustainable Resource Development
John Peters	The Silvacom Group
Brad Pinno	Canadian Forest Service
Taras Pojasok	Environment & Sustainable Resource Development
Mark Polet	Klohn Crippen Berger
Chris Powter	Oil Sands Research and Information Network
Brett Purdy	Alberta Innovates Energy & Environment Solutions
Matthew Pyper	Department of Renewable Resources - University of Alberta
Kevin Renkema	Navus Environmental Inc.
Tanya Richens	Environment & Sustainable Resource Development
Delinda Ryerson	Alberta Biodiversity Monitoring Institute
Soung Ryu	Department of Renewable Resources - University of Alberta
Jim Schieck	Alberta Biodiversity Monitoring Institute
Amanda Schoonmaker	NAIT Boreal Research Institute
Elisa Scordo	BGC Engineering
Ann Smreciu	Wildrose Consulting
John Spence	Department of Renewable Resources - University of Alberta
John Stadt	Environment & Sustainable Resource Development
Karen Stals	Environment & Sustainable Resource Development
Alan Stewart	Agriculture and Agri-food Canada

Robert Stokes	Environment & Sustainable Resource Development
Mathew Swallow	Department of Renewable Resources - University of Alberta
Lauren Thillman	Navus Environmental Inc.
Barb Thomas	Department of Renewable Resources - University of Alberta
Kyle Tieulie	Navus Environmental Inc.
Douglas Turner	
Stephen Tuttle	Canadian Natural Resources Limited.
Andrew Vandenbroeck	The Silvacom Group
Rob Vassov	
Tim Vinge	Environment & Sustainable Resource Development
Ksenija Vujnovic	Alberta Tourism, Parks & Recreation
Jaime Walker	Millennium EMS Solutions
Nilusha Welegedara	Department of Renewable Resources - University of Alberta
Clive Welham	3Green Tree Ecosystem Services Ltd.
Barry White	Environment & Sustainable Resource Development
Richard Wiacek	Canadian Wildlife Service
Robert Wirtz	WorleyParsons Canada
Jay Woosaree	Alberta Innovates - Technology Futures
Jayde Young	Beckingham Environmental

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