IN-SITU OIL SANDS EXTRACTION RECLAMATION AND RESTORATION PRACTICES AND OPPORTUNITIES COMPILATION

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PREFACE

The *Reclamation and Restoration Practices and Opportunities Compilation* document was prepared for Canada's Oil Sands Innovation Alliance (COSIA) to provide a summary of the current knowledge and practices that are being employed for reclamation of in-situ oil sands extraction facilities (in-situ facilities) and identify knowledge gaps, shortcomings and areas of improvement which are referred to as opportunities. The document is intended to direct COSIA and its member companies towards developing an action plan for in-situ reclamation to improve upon current practices in accordance with COSIA's reclamation and restoration goals.

Reclamation of in-situ facilities poses several unique challenges in comparison to conventional oil and gas and oil sands mining. In-situ results in a high density of relatively small scale (in comparison to mining) disturbances concentrated in an area which severely fragments a forest. Disturbances range widely in intensity, spatial and temporal scale and occur over many different forest types and ecosystems and there are considerable chances that a reclaimed facility will be redisturbed. Furthermore, construction of in-situ facilities occurs on a variety of forest types and ecosystems which can have variable levels of resiliency. Dry and nutrient poor ecosystems are inherently less resilient than wet and nutrient rich ecosystems. Similarly, due to the complex interactions of hydrology in fens and low productivity and growth in bogs, resiliency of these ecosystems may also be low. The interactions between different types of disturbances and ecosystems with different resiliencies are not well understood and historical and current practices may need to be altered to meet reclamation and restoration goals.

The term facilities used within the compilation document is meant to be wide ranging and includes all types of disturbances created for in-situ development. Practices and opportunities written for a specific stream within in-situ development (i.e. exploration or commercial) are clarified where required; the use of the term in-situ facilities without referencing exploration or commercial facilities means the practice or opportunity covers both types of facilities.

Current and past reclamation of in-situ facilities has focused primarily on exploration facilities (i.e. seismic lines, oil sands exploration (OSE) wellsites and associated access roads) which generally have a lower intensity of disturbance (e.g. minimal soil disturbance) and are active for only a short period of time. Individually they have a small footprint; however, at a landscape scale they consist of many interconnected linear disturbances resulting in a much greater area of disturbance compared to production facilities and fragmentation of forested areas. Minimal reclamation has currently been completed on production or commercial facilities (i.e. well pads and associated access roads, plant sites, borrow pits and pipelines); however, they will be the focus of future reclamation. Production facilities have high disturbance intensity, persist for years or decades and can have a relatively large individual footprint as well as collective footprint.

Prior to the development of the compilation document various COSIA members were interviewed to determine what areas of in-situ the study should focus on (i.e. exploration, production), key opportunities for the improvement of reclamation techniques (e.g. surface preparation, revegetation, soil salvage) and what type of document should come from the study (e.g. best management practices, guidelines, gap analysis). Interviews concluded the age of in-situ facilities varies widely among COSIA members with some members having exploration facilities dating back to the 1960s while others only have facilities dating back 5 to 10 years. This relates to the stage of development that each COSIA member is at which ranges from exploration and early production to mature facilities that are nearing the end of their life. Interests varied among COSIA members and it was determined the focus of the compilation document would be on both exploration and production facilities. There is considerable overlap between practices used on different types of facilities, and furthermore, including both facilities ensures that the needs of all COSIA members are met and that solutions to future challenges can be developed before the challenges become problems.

Information for the *Reclamation and Restoration Practices and Opportunities Compilation* document was obtained through literature review of government documents, industry studies, scientific literature, scientific reviews and interviews and field tours with individuals directly involved in in-situ reclamation. Information was also gathered during the *COSIA and Friends OSE Best Practices Fall 2013 Tour* which occurred between September 17, 2013 and September 18, 2013. A workshop conducted on November 13, 2013 attended by government representatives, academic researchers, consultants and industry members reviewed the document content and provided feedback and additional information that was incorporated into the final draft. A summary of observations from the *COSIA and Friends OSE Best Practices Fall 2013 Tour* as well as interviews pertaining to reclamation issues summarized by Natural Resources Canada are presented in Appendix A and B. Knowledge gaps, shortcomings and opportunities identified during the workshop are presented in Appendix C.

Several over-arching themes or opportunities were identified during interviews, tours and the workshop.

- Establish and clearly articulate reclamation goals; goals need to be defined for the industry, region (landscape), local area, facility (site) and project
- Improve training, communication (within and between companies) and awareness to facilitate communication and align the implementation of practices with COSIA. Standardized training should be provided for equipment operators, their supervisors and any other individual that works in the construction and reclamation/restoration of in-situ facilities
- Develop science-based but plain language guide book(s) for the construction, reclamation/restoration of in-situ facilities that will ultimately help in-situ operators achieve reclamation/restoration success faster and help standardize practices among COSIA members (applies to oil and gas industry in the boreal forest). The guide books should provide ecosite specific direction for each practice and should not provide prescriptions but instead help field personnel make decisions. Development of guide books can utilize existing documents or guide book(s) that have been proven to work in other industries (most notably silviculture practices in forestry; management interpretations from ecosystem classification)

These themes are echoed in many of the practices described in the *Reclamation and Restoration Practices and Opportunities Compilation* document.

The document does not present a comprehensive review of all current practices and details of their application but provides a snap-shot of each practice and references to applicable literature. The document is about reclamation and restoration and assumes remediation is complete. As much of the reclamation occurring on in-situ facilities is not described in readily available literature and not all individuals involved with in-situ reclamation could be interviewed, the document is to be considered a living document that can be updated as information is provided. The document is split into sections or practice areas which contain several practices. A general summary of each practice and its application is provided as well as a review of the practice and identification of opportunities.

SECTION I - PRE-DISTURBANCE DATA COLLECTION

1.0 PRE-DISTURBANCE SITE INFORMATION

Collecting pre-disturbance information and assembling this information optimizes timber harvest activities, conservation of woody material, soil and vegetation propagules to allow for the restoration of a functioning forest ecosystem on reclaimed in-situ facilities. During the initial stages of in-situ development, a large scale, low intensity survey may collect data on water, terrain, soils, vegetation, aquatics and wildlife at a broad level. The survey determines the potential environmental impact of development and gathers information for developing long-range Conservation and Reclamation Plans (CRPs). Increasingly detailed soil and vegetation data may be collected when the facility is constructed. Data collected in the field may provide knowledge that ultimately helps decrease the time required for the reestablishment of vegetation and the restoration of ecosystem processes (Ohio Department of Natural Resources 2005; Alberta Environment and Water 2012).

1.1 Rationale for Practice

1.1.1 Ecological

Documenting pre-disturbance site conditions confirms operators are taking appropriate steps toward understanding and preserving soil and vegetation resources for future reclamation. Therefore, this practice contributes to improved environmental outcomes and overall reclamation objectives (Alberta Environment and Water 2012).

1.1.2 Regulations and Guidelines

In-situ facilities regulated through *Environmental Protection and Enhancement Act* (EPEA) approvals require detailed soil and vegetation data collected in Pre-Disturbance Assessments (PDAs). The *Guidelines for Submission of a Pre-Disturbance Assessment and Conservation and Reclamation Plan* (Alberta Environment 2009) outline the accepted methodologies and parameters for completing PDAs. More information on collecting pre-disturbance data exists in the *Best Management Practices for Conservation of Reclamation Materials in the Mineable Oil Sands Region of Alberta* (Alberta Environment and Water 2012).

In-situ facilities outside the jurisdiction of EPEA approvals do not require pre-disturbance site assessments, although some operators choose to conduct less detailed PDAs or pre-construction assessments (PCAs). An Environmental Field Report (EFR) is used to complete the Enhanced Approval Process (EAP) that permits activity on public land in Alberta outside the jurisdiction of EPEA approvals and accounts for construction and reclamation planning. The EFR consists of a desktop review of aerial photographs, vegetation data, wildlife maps as well as field visits.

1.2 Application

1.2.1 Implementation Considerations

Collection of detailed pre-disturbance information for all in-situ facilities can lead to better reclamation outcomes. To determine the sampling intensity and data parameters to collect, the type (linear, non-linear), size, disturbance intensity, permanency and ecological location of the proposed facility must be considered.

1.2.2 Desktop Review

The desktop review process considers a broad range of information including, but not limited to, environmental impact assessments (EIAs), previous PDAs, conservation and reclamation business plans, soil surveys, Alberta vegetation inventory data, aerial photographs, LiDAR, rare plant data, ecosite classifications, ecoregion maps, and fish and wildlife maps. Stakeholder interviews provide additional information (Beckingham and Archibald 1996; Neville 2003; Alberta Environment 2009; Alberta Environment and Water 2012).

The desktop review may influence construction and reclamation planning. Information gathered during the review may prove useful for field visits. For example, a desktop review uncovers information for stratifying sites into ground assessment polygons based on similar vegetation and soil characteristics and determines an appropriate survey intensity level. Desktop reviews and site visits complement one another as site visits may also verify the accuracy of information collected during the desktop review.

1.2.3 Field Data

Existing guidelines provide methodological details and requirements for collecting pre-disturbance soil and vegetation data (Alberta Environment 2009; Alberta Environment and Water 2012). Although current reclamation guidelines do not require the analysis of borrow material for physical and chemical parameters, they do require consideration of the physical and chemical properties of padding material left in place. Additionally, field data collection could include identifying available resources for reclamation (e.g. seed trees, coarse woody material and areas to collect plant vegetative cuttings).

Data collected for PCAs is based on requirements of the operator and may include landscape information (e.g. surface and subsurface water flow and direction, riparian areas, soil stability, bare areas and woody material), vegetation information (e.g. rare plants, weeds, composition and plant cover) and soil horizon information (e.g. depth, texture, colour and structure).

1.3 Advantages and Disadvantages

Collecting pre-disturbance site information has many advantages as well as disadvantages for constructing and reclaiming in-situ facilities.

Advantages

Collecting pre-disturbance data has the following advantages:

- Aids in choosing a location for a facility that avoids sensitive areas and allows for construction with minimal disturbance
- Guides conservation and reclamation activities to a more timely closure
- Identifies potential natural recovery processes
- Provides reference data for management of reclamation and assessing reclamation success

Disadvantages

Collecting pre-disturbance site information has the following disadvantages:

- Sites can be difficult to access before development
- Current methods to meet regulatory requirements for PDAs are cumbersome. PDAs require significant time and effort although much of the information collected may not be used for constructing, reclaiming and monitoring facilities

1.4 Opportunities

The following are opportunities regarding the collection of pre-disturbance site information:

- Re-evaluate pre-disturbance data requirements for each type of facility. For example, facilities requiring minimal data may in fact require more data (e.g. exploration facilities). Moreover, it may not be beneficial to collect detailed information at a high intensity level for all facilities regulated under EPEA approvals – lower intensity or less detailed data may provide suitable information (i.e. data type and collection intensity should be consistent with site plans rather than regulatory requirements). A tool that determines which pre-disturbance parameters to assess and assessment intensity based on environmental factors and proposed construction techniques could be developed
- Develop a database to allow for sharing of pre-disturbance information among operators and as a tool for planning. The database could be used to supplement pre-disturbance information or reduce the need to collect the information if it is available
- Improve integration of ecological information into planning and management decisions
- Link pre-disturbance information with reclamation objectives and outcomes
- Determine the reclamation suitability of fill material used for padding prior to excavation
- Redefine the parameters in the *Soil Quality Criteria Relative to Disturbance* (SQC) (Alberta Soils Advisory

Committee 1987) as these parameters may require further investigation to determine the level of suitability of various types of reclamation material (e.g. surface soil, subsoil, peat). The parameters listed in Tables 8 and 9 in the SQC may not represent the overall quality of a particular reclamation material (e.g. suitability for forested vegetation, nutrients, organic matter).

2.0 PLANNING

Conservation and reclamation planning for in-situ oil sands extraction facilities guides construction and reclamation activities. Conservation and reclamation planning uses data from pre-disturbance information collection or the pre-disturbance assessment and regional management programs to develop woody material handling plans, rare plant and weed mitigation plans, soil salvage plans, operation and post-reclamation topography plans, soil replacement plans, revegetation plans, wildlife habitat protection plans and monitoring plans (Alberta Environment 2009). Pre-disturbance planning may also determine facility locations and boundaries.

2.1 Rationale for Practice

2.1.1 Ecological

Proper conservation and reclamation planning and implementation, along with adaptive management strategies, mitigate unnecessary disturbance in forest ecosystems (vegetation and wildlife), increase the chances of restoring a functional ecosystem and decrease the time required to restore a functional ecosystem.

2.1.2 Regulations and Guidelines

Planning is required by EPEA approvals in the form of CRPs. CRPs must be submitted prior to commencing facility construction. Detailed CRPs may not be required for exploratory facilities, although general plans are required for the EAP and EFR (Alberta Sustainable Resource Development 2008; Government of Alberta 2013).

2.2 Application

2.2.1 Implementation Considerations

Detailed conservation and reclamation planning is a necessary part of in-situ facility development and can occur at both the landscape level and site level. Planning is beneficial regardless of project scope. One benefit includes streamlining communication between multiple parties. CRPs reach their full potential when combined with best available practices, demonstrated stewardship and adaptive management strategies.

Conservation and reclamation planning is only beneficial when implemented correctly. A plan’s utility depends on the accuracy of the data collected for the plan. Clear communication, as well as education for involved stakeholders, will help align planning expectations and outcomes. Although considered difficult, planning disturbances with Forest Management Agreement (FMA) holder’s harvest plans is one way to integrate multiple disturbances at one time. Having experts in soil science, forestry, ecology and reclamation involved in all phases of implementation will contribute to successful conservation and reclamation planning (Osko and Glasgow 2010).

Documenting activities during the construction and operation of any facility is critical for the proper placement of reclamation materials used during the final reclamation stage (e.g. soil salvage practices, storage locations, woody material management, seeding practices, etc.). Transparent methods for storing and retrieving documents and transferring knowledge avoids the loss of potentially critical information over time.

2.2.2 Landscape

Landscape level planning requires consideration of regional land use frameworks and can include the use of various tools such as the Landscape and Ecological Assessment and Planning developed by the Oil Sands Leadership Initiative and Disturbance and Restoration Trajectories models being developed by Alberta Environment and Sustainable Resource Development to focus reclamation activities. It can also include integrating activities with other users in the area such as logging and traditional land uses and managing for wildlife (section 2.2.5).

2.2.3 Footprint Minimization

A CRP considers how to minimize the footprint of a facility. Footprint can refer to both the physical area that is directly disturbed or larger area directly or indirectly affected by the disturbance (e.g. wildlife population and forest fragmentation), and footprint minimization should focus on both of these aspects. Strategies include locating facilities in existing clearings, utilizing existing linear disturbances for access roads (Neville 2003; Government of Alberta 2013), avoiding disturbance in sensitive wildlife habitat and reducing the line of site along linear disturbances to reduce predation. Engaging multiple stakeholders reduces the potential for unnecessary disturbance duplication in the future, for example, using integrated land management tools available for all new disturbances.

The wide range of drilling technologies available can reduce the soil disturbance footprint. Examples include drilling pads built out of snow, wood mulch, using log fills and using self-leveling/jack-up drill rigs. Additionally, small rigs flown in for exploration could negate the need for road construction (Osko and Glasgow 2010).

Third party access restriction after facility construction may also decrease footprints. Restricting third party disturbance can be achieved by constructing fences and gates, or using bio-engineering techniques such as woody material and surface preparation (Government of Alberta 2013).

2.2.4 Landscape, Soil and Vegetation

Methods for avoiding topographical disturbance to areas prone to erosion or methods that may require cut and fill techniques are a consideration of the CRP (Ohio Department of Natural Resources 2005), as are methods for avoiding sensitive soils (Pedocan Land Evaluation Ltd. 1993) and forest vegetation that are difficult to re-establish (e.g. xeric sites or wetlands). The CRP typically follows engineering and geological decisions regarding the location and footprint of the disturbance. These decisions may constrain conservation and reclamation planning. Rounded or curved site boundaries may avoid sensitive areas and mimic natural clearing and disturbances (using a similar approach to cut block design that mimics fire disturbance) (Government of Alberta 2013). Knowledge about the site and surrounding area’s regeneration potential should guide soil salvage, propagule collection and revegetation practices. Involving an ecologist, forester or reclamation specialist, in addition to a surveyor, could increase the site’s regeneration potential.

2.2.5 Wildlife

Conservation and reclamation planning considers how to reduce the effect of disturbances on wildlife. Minimizing habitat fragmentation, reducing area traffic (e.g. third party access), reducing line of site on linear disturbances by using turns or curves and avoiding activity between February 15 and July 15 during calving are all potential strategies for minimizing disturbances to wildlife (Alberta Energy and Utilities Board 1994; West Central Producers Group 2003; Alberta Environment and Sustainable Resource Development 2012; Government of Alberta 2013).

2.3 Advantages and Disadvantages

Conservation and reclamation planning has the following advantages (research did not produce any disadvantages):

Advantages

Conservation and reclamation planning has the following advantages:

- Reduces impact on the forest ecosystem
- Improves conservation and reclamation success
- Aligns goals and expectations of multiple stakeholders

2.4 Opportunities

The following are opportunities regarding the application of conservation and reclamation planning:

- Improve transparency in conservation and reclamation requirements and best practices among multiple stakeholders
- Improve integration of reclamation specialists (e.g. engineers, planners and surveyors)
- Implement detailed landscape and site-level planning for all disturbances and including adaptive management scenarios into the planning
- Train equipment operators, supervisors and any other individual involved in the construction and reclamation/restoration of in-situ facilities

- Adopt more naturally shaped disturbances and matching disturbances to natural contours
- Determine if larger areas with lower disturbance are more effectively reclaimed than smaller facilities with greater disturbance (e.g. larger sites with greater storage area versus creating multiple sites with less area for material storage)
- Use ecological and pre-disturbance information to support planning and management decisions (e.g. disturbance and recovery trajectories)
- Plan for revegetation strategies that are consistent with natural disturbance recovery patterns specific to the forest type
- Investigate and incorporate the use of forest stand management, silviculture systems or integrating forestry cut-blocks into planning to improve revegetation on in-situ facilities (i.e. Having a young seral forest with an abundant and diverse propagule source surrounding a disturbance could improve revegetation of the disturbance)

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SECTION II - SITE CONSTRUCTION

1.0 MINIMAL DISTURBANCE

Minimal disturbance refers to the overall footprint of disturbance in various aspects; for instance, minimizing the size of in-situ oil sands extraction facilities, intensity and duration of disturbance and minimizing impacts to sensitive ecosystems. In recent years, operators have focused on minimizing the aerial extent of individual facilities, especially exploration wellsites. Temporary facilities such as OSE wellsites, access roads, seismic lines, portions of borrow pits and pipeline rights-of-way utilize no-strip construction practices which minimize the intensity of the disturbance. In-situ facilities initially surveyed on sensitive areas may be moved to less sensitive areas whenever practical (e.g. wetlands). Reduced and partial salvage construction techniques aim to minimize the area of soil disturbance during facility construction; for instance, salvaging surface soil on a portion of the facility (cut) and placing the cut material over the remainder of that facility that has intact surface soil (fill).

1.1 Rationale for Practice

1.1.1 Ecological

Minimal disturbance practices in the construction of in-situ facilities, if applied correctly, result in environmental protection and the increased establishment of desirable native plants. Minimal disturbance reduces the overall impact to soil quality and plant propagules.

1.1.2 Regulations and Guidelines

The Government of Alberta does not require minimal disturbance on forested sites; however, they do promote best practices and guidelines (Alberta Environment 2003; Government of Alberta 2011b).

1.2 Application

1.2.1 Implementation Considerations

Minimal disturbance techniques are best suited where there is a low risk of contaminating, admixing and compacting surface soil and on sites sensitive to disturbance (e.g. wetlands). Minimal disturbance can occur at different scales and should consider site and landscape levels. Ecological site conditions may dictate what level of disturbance is most appropriate. On sites constructed using no-strip methods with a low supply of viable propagules and thick LFH or duff (e.g. old growth forests) or on wet and nutrient rich sites (e.g. rich fens), some degree of surface disturbance may benefit revegetation because surface disturbance can lead to increased soil temperatures, improved nutrient cycling and more suitable surface conditions for tree seed germination (Welke and Fyles 2005).

1.2.2 No Strip

On sites were no soil salvage occurs (i.e. the site is level and accessed only in the winter), cutting trees and grinding stumps to the surface, rather than blading, minimizes soil disturbance. Sites should be frozen in before heavy equipment and equipment that could cause rutting or soil compaction arrive. A snow pad or logs and woody material could be used to level the site; snow could be obtained from the site, off-site or artificially made. No strip should be avoided on facilities accessed under non-frozen conditions due to the increased potential for admixing, damage to vegetative propagules and soil compaction (Renkema et al. 2009). Rig mats or low ground pressure equipment could be used on these sites. Revegetation on no strip sites could still benefit from surface scarification.

1.2.3 Reduced and Partial Stripping

Reduced or partial stripping involves salvaging surface soil from areas requiring contouring or leveling and surface soil is either stored in windrows or spread as temporary fill for site leveling. Soils not affected by contouring are left intact. The remainder of the material is distributed over top of the downslope area requiring fill. Storing salvaged surface soil in a windrow rather than using it for fill material minimizes the risk of admixing. Spreading woody material and snow in a thick layer segregating intact surface soil and fill material potentially reduces the risk of admixing. This method is recommended for temporary sites that will be reclaimed during the same winter season. Recontouring and final reclamation necessitate detailed as-built sites. Subsoil and underlying parent material should remain separate except where they are similar quality.

When applied correctly, the benefits of reduced or partial stripping include faster and better vegetation recovery, better environmental protection and reduced operational costs.

1.2.4 Drilling and Abandonment Technology

Using alternative drilling techniques or equipment such as directional drilling, self-leveling rigs, amphibious equipment and heli-portable rigs could reduce the need for site leveling, reduce area required for wellsites and reduce the need for access roads. Using alternative "cut and cap" methods such as water jet technology could reduce disturbance at well centre.

1.2.5 Timing

Winter has been considered the best time for minimal disturbance activities. Operating on frozen ground reduces the impact to soil quality and vegetative propagules. Planning activities for early winter also minimizes effects on wildlife breeding that may occur in early spring.

1.2.6 Planning

Pre-disturbance information collection helps determine whether to apply no-strip/no salvage, reduced/partial salvage or full salvage. Knowledge about the soils, vegetation, potential for aerial seed dispersal and propagule bank guides decisions toward the most appropriate construction method or silviculture system for vegetation regeneration.

Utilizing existing disturbed areas for winter road access minimizes spatial footprints. In general, utilizing existing disturbed areas for any type of future development is considered a best practice. Increasing the frequency of disturbance on former reclaimed sites could cause irreparable damage to the area previously reclaimed. Alternatively, imposing a light disturbance (e.g. vegetation clearing) on formerly reclaimed areas could help stimulate forest regeneration.

1.3 Advantage and Disadvantages

Minimal disturbance has many advantages as well as disadvantages for reclaiming in-situ facilities.

Advantages

Minimal disturbance has the following advantages:

- Cost effective and most effective method for restoration
- No-strip construction methods better preserve soil quality and the viability of in-situ propagules compared to soil stripping
- Reduces reclamation/restoration period
- Reduces exposure to bare ground, which reduces risk of weed invasion and erosion
- Plant establishment and composition is likely to be more predictable versus full disturbance

Disadvantages

Minimal disturbance has the following disadvantages:

- Minimizing the area of disturbance on each facility reduces the area available for soil storage, creating large stockpiles as opposed to small segregated stockpiles. Stockpiling is restricted by space allotments and subsoil might end up mixed with underlying parent material
- Vegetation growth on smaller sized facilities may be reduced due to decreased sunlight and lower temperatures
- May reduce the availability of exposed mineral soil and suitable sites for seed germination

1.4 Opportunities

The following are opportunities regarding the application of minimal disturbance:

- Clearly define minimal disturbance or degrees of minimal disturbance

- Determine an appropriate silviculture system guided by pre-disturbance information on no strip sites (e.g. ecosite type) to enhance woody plant establishment
- Develop an ecosite-specific propagule bank or aerial seed (i.e. identification of seed trees) classification guide or construction guide. Knowledge about the soil propagule bank prior to disturbance will allow revegetation planning and help determine optimal construction methods
- Determine when and where partial or full disturbance is more desirable than minimal disturbance. For example, if minimal disturbance results in the establishment of a high density of herbaceous plants that prevents woody species from establishing, imposing disturbance that reduces the competiveness of the herbaceous plants could be beneficial
- Implement more heli-drilling to reduce the area of disturbance required for access roads
- Determine if larger low-intensity disturbances with more area to segregate reclamation materials can improve revegetation success and out-weigh the benefits of a smaller footprint size

2.0 TIMBER CLEARING, GRUBBING AND WOOD MANAGEMENT

Removal and storage or disposal of timber and brush occur before soil salvage, drilling or infrastructure construction on an in-situ facility. The disposition or Forest Management Agreement holder collects salvaged, merchantable timber (Government of Alberta 2013). Non-merchantable timber, brush and slash generated from processing the merchantable timber may be piled and burned, mulched or maintained as whole/intact logs.

Merchantable timber is typically harvested with a feller buncher, then delimbed and skidded to a log storage area. The majority of other woody material (slash) remains on-site and is used for reclamation. Mulching reduces the volume of excess large woody material on a facility. Piled mulch may be used as fill for road building and to extend winter access by using it as insulation on snow or ice roads to prevent them from melting or otherwise spread across the site. In recent years there has been increased effort given to retaining coarse woody material on-site as a reclamation tool due to its beneficial properties in aiding vegetation establishment and creating biodiversity (Vinge and Pyper 2012). Coarse woody material is typically stockpiled, piled on soil windrows or used for interim reclamation prior to final reclamation (Alberta Sustainable Resource Development 2004, 2008).

2.1 Rationale for Practice

2.1.1 Ecological

Proper management of timber clearing, grubbing and woody materials during site construction increases the future success of facility reclamation by enhancing native species establishment, controlling erosion and providing a long term supply of nutrients and microorganisms (Alberta Environment and Water 2012). Furthermore, properly timing timber salvage activities reduces the impact of harvesting on the soil, surrounding vegetation communities and wildlife populations.

2.1.2 Regulations and Guidelines

The *Forest Act*, *Public Lands Act* and *Forest and Prairie Protection Act* dictate appropriate methods for timber clearing, grubbing and wood management. These Acts require the appropriate handling of residual wood materials to mitigate fire hazards. They also require the salvage of all merchantable timber according to forest management agreements and the *Alberta Timber Harvest Planning and Operating Ground Rules* (Alberta Environmental Protection 1994; Alberta Environment and Sustainable Resource Development 2012). The *Migratory Birds Convention Act* influences the timing of timber harvest.

2.2 Application

2.2.1 Timing

Clearing and grubbing timber in the fall or winter when soils are frozen minimizes rutting and compaction. It is ideal to harvest timber in frozen conditions yet dry conditions will also limit rutting and soil admixing (Alberta Environmental Protection 1994; Alberta Environment and Sustainable Resource Development 2012; Alberta Environment and Water 2012).

2.2.2 Timber Clearing and Grubbing

Timber clearing and grubbing requires appropriate equipment (e.g. hand felling, feller buncher, mulcher) based on clearing size, tree size and desired woody material type (e.g. whole logs, mulch, etc.). Reducing traffic across the facility limits soil disturbance. Desirable timber salvage outcomes include maximizing the amount of merchantable timber salvage and reducing the need for mulching (Alberta Sustainable Resource Development 2004). Some merchantable timber could be used for reclamation depending on the reclamation objectives of the site.

Desirable grubbing practices minimize the amount of LFH and surface soil mixed with woody material. Raking un-mulched brush is less harmful than bulldozing (Osko and Glasgow 2010). Leaving stumps in place until soil salvage reduces the loss of LFH and surface soil. If soil salvage is not required, grinding stumps to the soil level and leaving them in place also reduces the loss of LFH and surface soil. Grinding stumps on forested peatlands creates less surface disturbance than blading stumps; operators have had better success freezing the surface of organic soils on less disturbed sites.

2.2.3 Wood Management

Woody material is piled and burned, mulched, or left intact and stored or rolled back following the removal of merchantable timber. Piling and burning woody material eliminates the fire hazard associated with stored wood (Alberta Sustainable Resource Development 2008) and reduces the need for additional storage space. Burning woody material means it cannot be used for reclamation. Burning the slash piles may also sterilize the soil below and reduce the viability of propagules. Therefore, areas salvaged for surface soil make the best slash burning locations. Slash piles can become a fire hazard when there are improper buffers between the piles and the forest, they are left too long or are not closely monitored throughout the entire cycle of burning (i.e. from ignition to having the fire put out).

Mulching woody material may be an effective method for managing woody material provided it is spread in a thin layer and mixing with surface soil during salvage is minimized (Alberta Sustainable Resource Development 2009). Deep layers (>5 cm) of mulch prevent vegetation establishment (Alberta Sustainable Resource Development 2009; Vinge and Pyper 2012). Mixing mulch with forest surface soil and leaving windrows for a short period of time creates anaerobic conditions and reduces the viability of propagules (MacKenzie and Naeth 2011). Mulch left on wet sites promotes the growth of marsh reed grass, a competitive native grass species that reduces the establishment of desirable native species (Osko and Glasgow 2010).

Woody material in the form of intact logs (non-merchantable timber, slash and brush) can be used during reclamation to create suitable microsites for native vegetation establishment and growth, enhance biodiversity, provide wildlife habitat, control erosion and prevent human access (Vinge and Pyper 2012). Saving the tops of trees that contain seed bearing cones can provide seed sources for later revegetation efforts (Alberta Environmental Protection 1994; Alberta Environment and Sustainable Resource Development 2012). The availability of storage space and the flammability of storage piles create challenges for storing intact logs and therefore burning and transporting surplus material is a common practice; however, it may be possible to retain some merchantable timber on-site or transport limited quantities from new nearby disturbances (Alberta Environment and Water 2012). Woody material may be stored in windrows or piles, spread on the surface of soil stockpiles or on the surface of reclaimed areas. The maximum volume of woody material incorporated into surface soil without reducing the overall soil quality and viability of propagules is unknown. Vinge and Pyper (2012) recommend applying intact logs at volumes between 60 m^3/ha to 100 m^3/ha on upland sites and 30 m^3/ha to 50 m^3/ha on lowland sites. Other recommended application rates range between 10% to 20% maximum ground cover (Alberta Environment and Water 2012).

2.3 Advantages and Disadvantages

Timber clearing and/or grubbing are typically required for in-situ facilities; however, how the wood is managed has many advantages and disadvantages for reclaiming in-situ facilities.

Advantages

Grubbing, piling and burning, mulching and keeping intact logs have the following advantages:

Grubbing

- Reduces volume of material required for storage if disposed of off-site
- Provides a smoother surface for construction and drilling

Piling and Burning

- No space for storage required
- No negative effects on plant establishment caused by the physical barrier effect or preventing the soil from warming
- Reduces fire hazard potential
-

Mulching

- No space for storage required
- Mulch can be used in site levelling and road building
- Source of organic matter and nutrients for soil development

Intact logs

- Creates microsites for vegetation establishment
- Used to control erosion
- Can enhance biodiversity
- Source of organic matter and nutrients for soil development

Disadvantages
Grubbing, piling and burning, mulching and keeping intact logs have the following disadvantages:

Grubbing

- Removal of stumps ,roots and woody material can result in loss of organic matter and propagules
- Damage viable propagules
- Disturb surface of organic soils which can lengthen the freezing time for drilling equipment access

Piling and Burning

- Burn scars can result in reduced availability of propagules for plant establishment
- Can be a fire hazard
- Loss of organic matter

Mulching

- Can become a barrier to plant growth
- Difficult to fully remove from surface without disturbing soil
- Can reduce soil nutrient availability
- Create anaerobic conditions, reducing propagule viability if mixed and stored with surface soil

Intact logs

- Requires additional space for storage
- Can be a fire hazard

2.4 Opportunities
The following are opportunities regarding the application of timber clearing, grubbing and wood management:

- Determine if a timber harvest method that may allow for advanced growth/layering of black spruce or that leaves roots and stumps intact and promotes vegetation regeneration from roots can be used on minimal disturbance or disturbed sites
- Identify and maintain seed trees along the perimeter of the site
- Determine if grubbing or woody material removal be minimized on a site by constructing a snow/ice pad

- Improve handling/management of intact logs (coarse woody material), including centralized storage area and transportation between sites (i.e. reduce the need for storage on-site). Logs could be stored in ditches or used as fill material
- Develop techniques to better handle, distribute and remove mulch from a facility (the use of a "snow-blower" attachment to blow mulch into surrounding area has been unsuccessful) and to prevent leaving too much mulch on a facility or portion of a facility (e.g. geotextile below mulch)
- Use woody material as snags or wildlife trees
- Determine maximum threshold values of various types of woody material that can be mixed within surface soil during storage without reducing overall soil quality or propagule viability
- Determine what amount of forest floor disturbance on minimally disturbed sites is desirable to allow for improved regeneration of conifer forests

3.0 SURFACE SOIL SALVAGE

All in-situ facilities that are not padded or minimally disturbed undergo surface soil salvage. Operators utilize prescribed salvage depths based on pre-disturbance site information or field-fit methods that respond to changes in soil colour or texture. A qualified soil specialist may be on-site during salvage to monitor and provide guidance for salvage operations.

Salvage occurs mostly during winter months and frost may penetrate deep into the soil profile. Surface soils are typically salvaged using excavators and bulldozers. Bulldozers strip soil using the blade during a single pass or multiple passes and push soil into a pile or windrow. Excavators strip surface soil and place into a windrow or pile. Scrapers are used on larger sites.

During surface soil salvage the type of surface soil must be considered when determining salvage depths, timing and equipment. Surface soil can be divided into three categories: upland surface soil, shallow organics and deep organics. Upland surface soil consists of the L, F and H organic horizons and the underlying A mineral horizon (Government of Alberta 2005), also known as LFH mineral mix (Naeth et al. 2013). Shallow organic soil has organic layers up to 40 cm in depth and develops under forest locations with imperfect drainage or wetter conditions (Alberta Environment and Water 2012). Shallow organics have intermediate properties between upland and lowland surface soils. Deep organic soil develops in areas with imperfect to poor drainage. Peatlands are mostly comprised of deep organic soils that have organic layers greater than 40 cm (Quinty and Rochefort 2003; Alberta Environment and Water 2012).

3.1 Rationale for Practice

3.1.1 Ecological

Surface soil is a suitable growth medium containing organic matter and nutrients essential for plant growth and establishment. These qualities make surface soil an ideal material for reclamation (Osko and Glasgow 2010; Alberta Environment and Water 2012; MacKenzie 2013). If surface soil is salvaged properly (considering placement, timing and salvage depth), it provides an abundant source of plant propagules for native plant establishment.

3.1.2 Regulations/Guidelines

Salvaging surface soil has ecological benefits and is a regulatory requirement in many reclamation operations. EPEA, *Conservation and Reclamation Regulation*, *Code of Practice for Exploration Operations* and the *Integrated Standards and Guidelines of the Enhanced Approval Process* outline soil conservation regulations. EPEA and the *Code of Practice for Exploration Operations* require prevention and control of soil loss and degradation.

3.2 Application

3.2.1 Implementation Considerations

Surface soil may not need to be salvaged on all facilities. In cases where minimal disturbance/no strip or reduced/partial strip methods are possible, choosing these options may reduce the amount of time required for vegetation establishment and reduce the chances of erosion or weed establishment.

If surface soil salvage is necessary, proper planning ensures appropriate salvage techniques and equipment are used. Key considerations include: surface soil/horizon salvage depths and range of variability, soil chemical and physical properties, depth to root zone, volume estimates of salvageable surface soil, storage locations, potential losses (e.g. through erosion) and soil conditions that may require special consideration or handling techniques (MacKenzie 2013; Naeth et al. 2013). Detailed implementation considerations for upland surface soil salvage are described in various publications including Alberta Environment and Water (2012), Naeth et al. (2013) and MacKenzie (2013). Alberta Environment and Water (2012) and Rochefort et al. (2003) provide further detail on organic soil salvage.

3.2.2 Timing

The best time for surface soil salvage is when propagules are dormant and when direct placement can be maximized to reduce the loss of propagule viability (e.g. on exploration sites do not strip too far in advance of drilling). Salvaging surface soil under frozen ground conditions improves trafficability and reduces the potential for compaction. Winter salvage increases the risk of admixing if there is deep frost and soil comes out in lumps that contain surface soil and subsoil (Macyk and Drozdowski 2008; Alberta Environment and Water 2012). The time of year salvage activities occur affects the amount of damage to vegetative propagules. Plants capable of reproducing asexually are least likely to be damaged during fall and winter operations because they are dormant and the carbohydrate reserves in their root systems are highest. Most boreal plants have seeds that ripen in late summer or early fall and salvaging surface soil after seeds have ripened increases the total pool of viable seeds. The timing of upland surface soil salvage operations and its effects on propagules becomes less important if soils are stockpiled.

Salvage is restricted or suspended in adverse ground conditions or while prevailing weather conditions create an increased risk of soil loss, mixing or degradation (Government of Alberta 2005; Government of Alberta 2011a). For example, salvaging surface soil on large sites in windy conditions exposes the soil to wind erosion. Salvaging during wet conditions increases the risk of compaction, admixing, water erosion and degrades the soil structure (Ramsay 1986; EBA Engineering Consultants 2002; Osko and Glasgow 2010). Placement of wet surface soil into stockpiles further degrades the viability of propagules and quality of surface soil.

3.2.3 Salvage Depth

Salvage depth is important as it affects the physical, chemical and biological properties of the surface soil. The majority of propagules, organic matter and soil organisms in boreal forests are contained in the organic layer and upper few centimetres of mineral and organic soil (Alberta Environment and Water 2012; MacKenzie 2013). Generally, shallower salvage depths result in a greater abundance of native vascular and non-vascular plants re-establishing because shallow salvage depths concentrate the propagules, organic matter, nutrients and soil biota (Alberta Environment and Water 2012; Mackenzie 2013; Naeth et al. 2013). However, incorporating some mineral soil into the organic layer may improve root to soil contact once replaced, resulting in the improved plant establishment immediately after placement (MacKenzie 2006; Osko and Glasgow 2010; MacKenzie 2013).

Using a single prescribed salvage depth for all soil types may not optimize the potential of salvaged surface soil. For example, salvaging surface soil to greater depths (20 to 30 cm) increases the volume of material available for reclamation, although the increased depth limits the soil's suitability as a propagule source for revegetation and may reduce its organic matter content. Salvaging shallower depths of surface soils (10 to 15 cm) generally increases the proportion of viable propagules in these materials, but reduces the volume recovered for reclamation use. These examples demonstrate that there are different approaches for managing and using salvaged surface soil.

For upland surface soil, operators generally salvage the entire LFH layer and Ae mineral horizon. However, the optimal salvage depth considers how different types of soils and ecosites affect plant establishment and considers soil quality as well. Detailed reviews of the effects of salvage depth on plant establishment and soil quality can be found in Alberta Environment and Water (2012), MacKenzie (2013) and Naeth et al. (2013). Although the effect of salvage depth on shallow organic soils is not a well-researched topic, practitioners assume the effects are similar to those of upland surface soils.

On lowland areas, shallow and deep organic soils are salvaged to a minimum depth of 40 cm where pad materials will be left in place during reclamation. Additionally, locations with deep organics (i.e. peatlands) may be used as donor sites in reclamation operations (Quinty and Rochefort 2003; Sobze et al. 2012). As donor material, the upper 10 cm of living moss is salvaged and transferred to the reclaimed site. This shallow salvage increases the rate of vegetation establishment as most of the plant propagules are contained in the upper few centimetres of the salvaged organic soil.

A peat-mineral mix may be an alternative reclamation material as it provides physical and chemical characteristics of upland soil as well as high organic matter, excellent water holding capacity, sufficient infiltration and improved structure. Peat and peat-mineral mixes may be deficient in the macro- and micro-nutrients present in surface soil and shallow organics (Alberta Environment and Water 2012).

Salvage depth significantly affects the overall quality of soil; therefore, having qualified on-site monitors during salvage is critical to overall reclamation success.

3.2.4 Equipment

Salvage equipment is chosen carefully to enable accurate stripping of soil layers while adjusting to changes in surface soil depth (Ramsay 1986; EBA Engineering Consultants 2002). Bulldozers and excavators commonly carry out salvage activities. Using an excavator for surface soil salvage instead of a bulldozer minimizes the destruction of roots found within the surface soil-subsoil interface. These roots are often destroyed by equipment during surface soil salvage and when exposed to freezing and desiccation by the dozer blade (Osko and Glasgow 2010). Salvaging surface soil using a soil scraper often results in uneven stripping and admixing especially on uneven sites. It is difficult to adjust equipment position and cut depth to accommodate on-site variations in salvage depth.

Salvaging deep organics occurs during winter months due to trafficability issues. Excavators salvage deep organic soils and peat mineral mixes. Mulchers, rototillers and rotovators in combination with bulldozers, bobcats and excavators salvage the upper 10 to 30 cm of organic soils for use as a propagule source. For larger projects, mulchers are more effective at salvaging donor material. Salvage of organic soils during non-frozen conditions is more costly than salvaging during frozen conditions.

3.3 Advantages and Disadvantages

Surface soil salvage has many advantages as well as disadvantages for reclaiming in-situ facilities.

Advantages

Surface soil salvage has the following advantages:

- Essential for the development of a self-sustaining, diverse forest plant community, under most circumstances
- Reduces the timeframe to meet reclamation objectives
- Increases availability of native plant propagules and nutrients in the surface soil
- Reduces revegetation costs as the need for woody species planting and seeding is eliminated when surface soil is directly placed

Disadvantages

Surface soil salvage has the following disadvantages:

- Disturbs intact root systems and limits potential of vegetative reproduction (e.g. aspen suckering)
- Slows natural revegetation processes for certain species (e.g. low bush cranberry)
- Increase in operational costs depending on salvage technique and scenario (e.g. multiple surface soil lifts)
- Increased risk of soil degradation compared to no-strip operations (e.g. multiple handling, heavy equipment traffic, etc.)
- Direct placement of surface soil with an abundant seed bank of competitive species negatively affects reclamation progress and increases operational costs
- When salvaging all surface soil (Ae horizon and LFH), there may be poor plant establishment after placement if the Ae horizon is thick relative to a thin LFH or organic horizon which can dilute the propagules

3.4 Opportunities

The following are opportunities regarding the application of surface soil salvage:

- Develop construction techniques that can minimize the need for surface soil salvage (e.g. minimal disturbance)
- Share soils between sites to facilitate direct placement

- Undertake long term monitoring to assess outcome of various soil salvage practices such as the effect of ecosite specific salvage depths and soil segregation on vegetation establishment after placement
- Improve training for equipment operators involved in surface soil salvage and use of soil salvage monitors
- Explore the use of peat-mineral mix in different ratios to reclaim upland and transitional areas

4.0 SUBSOIL SALVAGE

Subsoil is salvaged from permanent in-situ facilities such as central processing facilities, borrow pits, well pads and access roads, as well as from temporary disturbances that require more intensive work, such as cut and fills. For certain facilities (e.g. pipelines), an upper lift of subsoil salvaged separately from the remainder of the mineral soil in the trench occurs when the quality of lower subsoil/spoil is poor or unsuitable. Soil data from the pre-disturbance assessment provides information enabling the planning and design of the soil salvage program, including salvage techniques, equipment and proposed horizon/salvage depths (Bell 2004; Alberta Environment 2009; Osko and Glasgow 2010; Alberta Environment and Sustainable Resource Development 2012). Subsoil is salvaged from developments on unsaturated mineral soils but not beneath deep organic soil or on wet mineral soils (e.g. gleysols). Where practical, suspend subsoil salvage to mitigate damage to soils by conditions such as wet materials, high winds or frost. Winter months increase accessibility for soil salvage. However, if access is not limiting, subsoil salvage occurs in summer and fall months as well. Equipment for subsoil salvage includes hoes, bulldozers and trucks and scrapers.

4.1 Rationale for Practice

4.1.1 Ecological

Subsoil is a valuable reclamation material. When replaced, subsoil provides a rooting zone that stores water and nutrients, a medium for root anchorage and creates a barrier to protect roots from unsuitable underlying material (Alberta Environment and Water 2012).

4.1.2 Regulations and Guidelines

Subsoil salvage is a regulatory requirement in reclamation operations. The *Conservation and Reclamation Regulation*, *Code of Practice for Exploration Operations* and the *Integrated Standards and Guidelines of the Enhanced Approval Process* outline soil salvage and segregation requirements. The *Code of Practice for Exploration Operations* and the *Conservation and Reclamation Regulation* require prevention and control of soil loss or degradation.

4.2 Application

4.2.1 Implementation Considerations

Subsoil salvage should occur prior to operating (drilling) on the site unless the subsoil is considered unsuitable according to Table 9 of the SQC (Alberta Soils Advisory Committee 1987); salvaging and replacing unsuitable subsoil could be detrimental to establishing a self-sustaining forest ecosystem. Subsoil is salvaged from upland landscapes with mineral soil, and to a lesser extent, from areas that have shallow organic soil. Subsoil is not typically salvaged under deep organic soil. Subsoil salvage may not be necessary on forested sites where infrastructure construction and drilling activities take place on the upper subsoil without degrading it (Pettapiece and Dell 1996; Government of Alberta 2013). For instance, traffic exposure may have less impact on the subsoil quality compared to salvage, storage and replacement activities. Additionally, remedial efforts to alleviate subsoil compaction on non-stripped subsoil (e.g. ripping) could result in less overall subsoil degradation compared to the impacts caused from salvage, storage and replacement. Factors considered while assessing the suitability of the no-strip method include risk of contamination, soil texture, season of construction and soil moisture.

On temporary facilities, such as OSE wells, subsoil is not always salvaged. Storage space is often limited and subsoil blending with underlying parent material during the construction contouring phase could occur. Mixing subsoil with underlying parent material should be avoided unless the chemical and physical properties of the underlying parent material are similar and will not degrade the quality of subsoil after mixing and replacement.

4.2.2 Chemical and Physical Constraints

Chemical and physical constraints, either natural or anthropogenic (e.g. contamination), affect revegetation and plant establishment. Constraints may include: very fine or very coarse textured soils, coarse fragment content, pH, salinity, sodicity, aluminum toxicity, high calcium carbonate equivalency and calcium deficiency (Ramsay 1986; Bell 2004; Rodrigue and Burger 2004). Pre-disturbance data, qualified soil monitors and on-site testing minimize the salvage of soil with these chemical and physical constraints (Ramsay 1986; Alberta Environment and Water 2012). Salvaging soil with high coarse fragment content or low pH is possible given the surrounding soil is comparable. Typical salvage depths are 30 cm. At this depth, the operator is unlikely to encounter unsuitable material.

4.2.3 Timing

Salvaging subsoil under frozen ground conditions enhances trafficability and reduces compaction (Macyk and Drozdowski 2008; Alberta Environment and Water 2012). Adverse ground or weather conditions such as wind and precipitation increase the risk of soil loss, mixing or degradation and therefore operators should restrict or suspend salvage operations (Government of Alberta 2011a). For example, salvaging in wet conditions increases the risk of water erosion, compaction and destruction of soil structure (i.e. through smearing in fine-textured soils) (Ramsay 1986; EBA Engineering Consultants 2002).

4.2.4 Pads

Should chemical or physical constraints within pad material (for pads to remain in place) limit future vegetation establishment, additional subsoil salvaged from the associated borrow pit or other nearby facilities may be used in reclamation or padding material can be removed and placed back into the borrow pit.

4.2.5 Equipment

Careful selection of subsoil salvage equipment accommodating variation in salvage depth minimizes soil degradation. The salvage plan identifies the proper type of equipment (Bell 2004; Alberta Environment 2009; Osko and Glasgow 2010).

Excavators and bulldozers primarily carry out salvage activities. Larger sites may use scrapers where salvage depths are deep. One drawback of the scraper is the equipment blade does not easily adjust to accommodate variations in salvage depth, especially on uneven areas. Compaction also occurs when the scraper makes multiple passes over the stockpile when dumping.

4.3 Advantages and Disadvantages

Subsoil salvage has many advantages as well as disadvantages for reclaiming in-situ facilities.

Advantages

Subsoil salvage has the following advantages:

- Subsoil is a valuable reclamation material and provides plants with a rooting zone that stores nutrients and water, a medium for anchorage and a barrier between roots and potentially deleterious elements
- Subsoil may contain greater amounts of nutrients and organic matter than underlying parent material

Disadvantages

Subsoil salvage has the following disadvantages:

- Subsoil salvage may be costly and logistically difficult depending on type and size of facility being constructed and volume of subsoil required for salvage
- Salvaging subsoil may not benefit plant growth if the underlying material is of similar quality
- There is increased risk of degrading subsoil quality when conditions force operators to salvage during less than ideal conditions (e.g. multiple handling, heavy equipment traffic, etc.)

4.4 Opportunities

The following are opportunities regarding the application of subsoil salvage:

- Develop field trials to determine the additional environmental gain of salvaging subsoil versus using subsoil mixed with suitable underlying parent material or overburden. Trails should be conducted under various conditions (e.g. frozen, unfrozen, wet, dry).

- Use pre-disturbance data to determine suitability of subsoil below 30 cm and salvaging greater than 30 cm if it is suitable. Deeper salvage and a greater volume of subsoil can be used to place on areas where existing mineral soil is less suitable or not available (e.g. pads)
- Consider revising the parameters listed in Tables 8 and 9 in the SQC as they may not represent the overall quality of subsoil. For instance, when subsoil is compared to the underlying parent material many of the parameters are of equal value. The tables, however, do not include other factors (e.g. nutrients, organic matter and roots) that might otherwise identify greater value in the subsoil
- Develop improved salvage practices during non-frozen conditions

5.0 SOIL STOCKPILING AND STOCKPILE MAINTENANCE

Salvaged surface soil and subsoil are stored and segregated on in-situ facilities prior to drilling or extraction operations. Operators place stockpiles on stable, accessible and retrievable areas (i.e. minimal erosion and flooding potential). The size of stockpile is proportional to the size of disturbance and generally the number of stockpiles per facility is limited to one stockpile for surface soil and one for subsoil. On large facilities, it is not uncommon to have stockpiles several metres high and tens or hundreds of metres long. The stockpiles are often graded with 3:1 (H:V) slopes and seeded with a regulator-approved native seed mix. Older stockpiles may have been planted with non-native grasses. Recently constructed stockpiles may have woody material placed on the surface to help control erosion and promote native plant establishment, and trees may be planted on the stockpiles. Weeds are controlled on stockpiles as part of stockpile maintenance and management. Soils may be stockpiled for decades, therefore, stockpile maintenance and management is ongoing during operations prior to soil replacement.

On temporary facilities, such as wellsites and access roads, soil is temporarily stockpiled in windrows or blended into the surface of the facility. On these facilities, soil is stockpiled for a few weeks up to a few months typically during winter.

5.1 Rationale for Practice

5.1.1 Ecological

Storing reclamation materials conserves the soil's physical, chemical and biological properties for future reclamation (Alberta Environment and Water 2012). Soil segregation helps to prevent admixing and preserve soil quality for each soil type (Ramsay 1986; Bell 2004; Alberta Environment and Water 2012; MacKenzie 2013).

Stockpile maintenance minimizes soil loss, preserves soil quality, ensures geotechnical stability and helps to control weeds (Ramsay 1986; Thurber Consultants Ltd. et al. 1990; Alberta Environment and Water 2012). Properly managed stockpiles may promote more successful vegetation establishment when replaced. Stockpiles where propagules are preserved may also be used as seed banks for future reclamation and enhance the establishment of native species.

5.1.2 Regulations and Guidelines

EPEA, *Conservation and Reclamation Regulation* and the *Code of Practice for Exploration Operations* require that soil conservation during operations occurs without degrading the soil. EPEA approvals regulate stockpile construction and maintenance. Soil stockpiles are therefore managed continuously to maintain quality and minimize loss. Weeds on stockpiles are also regulated under the *Weed Control Act*.

5.2 Application

5.2.1 Implementation Considerations

Direct placement of salvaged soil minimizes the need for soil storage and allows the soil to become a propagule source. After several months of storage, viability of propagules in stockpiled surface soil declines significantly for propagules that are deeper than 1.0 m below the surface of the stockpiles (MacKenzie 2013). Constructing temporary stockpiles (i.e. less than one year) during frozen months potentially prolongs propagule viability. When stockpiles thaw, seed viability rapidly declines. Where the aim is to maximize establishment of native species from vegetative propagules, stockpiling is not a good option and direct placement is preferable.

5.2.2 Segregation

Surface soil and subsoil are segregated. Nevertheless, segregating different types of surface soil (e.g. upland surface soil and shallow organics) or soils with different textures is not a common practice because of space limitations on-site. However, segregation may advance the restoration of post-disturbed facilities toward the same ecosite type that existed prior to disturbance. The inherent value of selectively stockpiling soil based on texture and fertility is a major factor affecting water and nutrient dynamics of reconstructed soil (Alberta Environment and Water 2012).

Several options are available to further segregate different soil types if space is limited. Geotextile material or woody material segregate stockpiles stored close to each other or stockpiles that overlap. Detailed surveys and documented construction methods showing the exact dimensions of stockpiles and can guide future soil replacement.

5.2.3 Timing

Prevailing weather and field conditions determine the appropriate time for soil salvage and consequentially storage operations. Surface soil and subsoil are mostly salvaged under frozen, and in some cases, dry conditions. Limiting stockpile operations to such conditions improves stockpile workability and minimizes the risk of compaction. Adverse ground or weather conditions restrict stockpile operations, for example, those operations restricted by wind and precipitation to minimize the risk of erosion, admixing and loss of quality (Government of Alberta 2005, 2011a).

5.2.4 Stockpile Construction, Location and Size

Stockpile construction technique, location and size may influence the survival of plant propagules, soil quality and ease of operations (Thurber Consultants Ltd. et al. 1990). Stockpiles placed on areas protected from saturation, unnecessary compaction and contaminants that reduce soil quality are best. A planned location in easily accessible, well-drained areas on the edge of site clearings ensures minimal handling (Alberta Environment and Water 2012). Incorporating snow into the stockpile should be avoided. Shallow stockpiles are best for the long-term allowing the survival of plant propagules through the regeneration of new shoots which can continually disperse seeds on the surface. Stockpiles should be constructed to maximize surface area (MacKenzie 2013) such as by creating a rough surface. Rough surfaces may also promote rapid revegetation.

5.2.5 Documentation

Documentation is critical to stockpile maintenance, ensuring the stockpiles are not mistakenly used or degraded during facility operations. Documenting the locations, properties (e.g. soil type(s), volumes, salvage date) and management methods of each stockpile is necessary for effective soil handling, reclamation planning and for determining reclamation material balances. Documentation is also important for asset sales.

5.2.6 Equipment

Equipment is carefully selected to reduce handling and operations over the soil stockpiles. Excavators and bulldozers are preferred to scrapers. Scrapers increase compaction by making multiple passes over the stockpile during construction (Ramsay 1986).

5.2.7 Maintenance

Stockpiles constructed from upland surface soil or shallow organics may not require seeding as there may be sufficient quantities of desired, native plant propagules. Soils without sufficient quantities of desired, native plant propagules require seeding. Subsoil stockpiles are slow to revegetate and an alternative revegetation method may include directly placing a shallow layer of surface soil containing an abundant density of viable plant propagules over top of the subsoil stockpile or adding other amendments (see 7.0 in the Landscape and Soil Reclamation Section). This method helps retain seed viability in surface soil and is the soil is re-salvageable for final reclamation.

Seeding often prevents weed establishment. Refer to the Seeding practices (see 2.0 in the Revegetation Section) and Weed Control practices (see 2.0 in the Monitoring and Site Maintenance section) for more detail.

To prevent stockpile erosion, refer to the Erosion Control practices (see 1.0 in the Monitoring and Site Maintenance Section) for more detail. Leaving surfaces rough and applying coarse woody material can help reduce erosion.

5.3 Advantages and Disadvantages

Soil stockpiling and maintenance has many advantages as well as disadvantages for reclaiming in-situ facilities.

Advantages

Soil stockpiling and maintenance has the following advantages:

- Stockpiling conserves soil for future reclamation
- Segregating different soil types helps preserve different soil type's inherent physical properties for future restoration and prevents admixing and soil quality loss
- Stockpiles can be managed and used as a seed bank for future revegetation

Disadvantages

Soil stockpiling and maintenance has the following disadvantages:

- Segregation increases operational costs due to multiple operations in a given area
- Additional space is required for storage which results in larger disturbance
- Soils are temporarily prone to erosion until revegetated
- Stockpiling leads to changes in soil physical properties (e.g. increased bulk density and reduced aggregate stability) (McQueen and Ross 1982; Ramsay 1986; Alberta Environment and Water 2012)
- Stockpiling, even for short periods of time, reduces propagules/seed viability (Alberta Environment and Water 2012; MacKenzie 2013)
- Stockpiling may impact the biological and chemical properties of soil (e.g. increased anaerobic conditions below the surface, reduction of total available nitrogen and organic carbon, and reduced microbial activity) (Schuman and Power 1981; Ramsay 1986; Alberta Environment and Water 2012; MacKenzie 2013)

5.4 Opportunities

The following are opportunities regarding the application of soil stockpiling and maintenance:

- Direct place surface soil on subsoil stockpiles to reduce the degradation of surface soil and in-situ propagules and establish native plants on subsoil stockpiles
- Explore other segregation options (e.g. segregating reclamation material from different ecosites and using it to reclaim different site types and diverse ecosystems)
- Plant shrubs and trees on surface soil and subsoil stockpiles for future re-salvage of the propagules and use during final reclamation
- Construct surface soil stockpiles with increased surface area (e.g. spread surface soil on top of subsoil stockpiles or creating rough surfaces) to allow for growth and maintaining the viability of the propagules contained in the stockpile
- Apply organic amendments to subsoil stockpiled to facilitate vegetation establishment

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SECTION III - LANDSCAPE AND SOIL RECLAMATION

1.0 SITE RECONTOURING

Integration of meso- and macro-contours with adjacent offsite landscape features during reclamation of in-situ facilities retains the character of the area's relief and restores comparable water drainage patterns. In the past, contours were often field fitted, more recent methods include surveying pre-existing elevations to guide contouring operations. Recontouring has also adopted the use of more natural features (e.g. rolling contours, additional relief and micro-topography, irregular shaped borrow pits), rather than engineered features (e.g. flat, smooth contours and rectangular shape).

1.1 Rationale for Practice

1.1.1 Ecological

Site recontouring creates physiographic and edaphic conditions that impact vegetation establishment and influence wind and water erosion (DePuit 1984). Properly recontoured sites will therefore promote stable soils, establishment of vegetation and reduce any negative impacts to surrounding land (e.g. blocked drainage, sedimentation).

1.1.2 Regulations and Guidelines

Recontouring is necessary to achieve equivalent land capability from reclaimed sites as required in EPEA and to meet the *2010 Reclamation Criteria for Wellsites and Associated Facilities on Forested Land* (Alberta Environment and Sustainable Resource Development 2013). Furthermore, the *Code of Practice for Exploration Operations* requires that contours are backfilled to conform with the surrounding topography (Government of Alberta 2005).

1.2 Application

1.2.1 Implementation Considerations

Using minimal disturbance practices and alternate drilling practices can reduce the need to recontour a site. Where construction, operation or reclamation of a facility alters a site's topography in relation to the surrounding landscape, the site requires recontouring. Contours must match the surrounding area but do not necessarily have to be identical to pre-disturbance conditions; however, matching pre-disturbance conditions may allow for restoring drainage patterns and establishing comparable vegetation. The post-disturbed landscape should be evaluated at the stand-level and regional scale (e.g. integrated resource management).

Measures for approximating pre-disturbance contours and drainage features include pre-disturbance data, historical photos and field assessments (Bielich et al. 2011). Recontouring requires consideration of available materials, groundwater levels, settlement of any underlying fill, erosion hazards, slope criteria, aspects, microclimates and drainage (Ramsay 1986).

1.2.2 Altered Landscapes

Facilities that significantly alter the topography of a landscape (e.g. plant sites, multi well pads and borrow pits) require recontouring to match natural features in the surrounding area but might not match pre-disturbance conditions. Incorporating meso and macro topographical relief creates a more diverse landscape that is more likely to establish diverse plant communities than a uniform landscape. Considerations for reclaiming borrow pits to wetlands include how slope, design and bottom contours will affect the functions of the reconstructed wetland (Alberta Environment 2008). Irregular edge and bottom contours develop diverse habitats and reduce the risk of channeling and slumping. Borrow pits designed with natural and irregular shapes are more aesthetic and functional than engineered shapes.

1.2.3 Subsidence

Avoiding subsidence is difficult in recontouring winter constructed facilities, in particular well centres. Other areas that may commonly become subsided included sites constructed using cut and fill techniques, cement pits and drilling sumps. Subsidence can affect drainage and could lead ponding and increased erosion; however, depending on the degree of subsidence its effect on site productivity and land use may be minimal. Mixed-in frost and snow increase the potential to miscalculate fill material specifications. The amount of fill required for a cut and capped well centre varies depending on the depth of excavation and type of material used. Ideal fill material has a texture matching soil present on site and is good quality. Backfilling with peat on peatlands might be more suitable than using heavy fill material that may compress the underlying edges of the peat and result in subsidence. The edges of cuts are often built higher (up to 1 m) than the surrounding topography to allow for settlement. Subsidence can occur anywhere within the first year or two of recountouring. Large subsided areas require surface soil stripping and subsoil or spoil replacement to regrade the subsided area. The amount of snow mixed in with subsoil and fill material should be minimized to help reduce the risk of subsidence.

1.3 Advantages and Disadvantages

Site recontouring has many advantages as well as disadvantages for reclaiming in-situ facilities.

Advantages

Site recontouring has the following advantages:

- Creates conditions that are favourable for vegetation establishment leading to a successful reclamation process
- Proper recontouring reduces costs associated with erosion control

Disadvantages

Site recontouring has the following disadvantages:

- Increased operational costs are associated with diversifying landscape features

1.4 Opportunities

The following are opportunities regarding the application of site recontouring:

- Compile information from all members on what works best for backfilling well centres and cut and fills resulting in minimal subsidence
- Determine whether subsided areas can be left subsided (i.e. not filled in) to meet alternative land use goals (e.g. wildlife habitat) and what level of effort is required to ensure success. Filling in subsided areas often requires re-disturbance of a facility and can be detrimental to the long-term trajectory of the vegetation.
- Involve reclamation specialists in the reclamation contour design
- Obtain fill from older, existing borrow pits that have engineered appearances to allow for the creation of more natural appearing constructed wetlands (i.e. redesign older reclaimed borrow pits so they have a more natural appearance)
- Collect pre-disturbance contour information for exploration sites to improve success in restoring natural drainage patterns and reducing the need to re-access the site to improve drainage

2.0 PAD RECLAMATION

Constructing permanent in-situ facilities on wetlands is commonly completed on 1 to 2 m of mineral padding (fill) over deep peat. Corduroy and/or geotextile liner may be placed between the peat and pad. The padding raises the surface of the facility above the surrounding peatland, stabilizes the facility to allow for drilling and construction of infrastructure, and creates access for the life cycle of the facility (Vitt et al. 2011). Padded access roads typically have culverts installed to prevent water backing up and flooding adjacent peatlands.

Reclaiming in-situ facilities that utilize padding material within wetland environments has received little attention in the past and is a relatively new concept from a scientific perspective. The most common reclamation practice has been to leave padding material in place and revegetate the padded facility to an upland or transitional forest. Success reclaiming facilities with padding left in place varies; diverse, young to mid seral forests may establish or only herbaceous vegetation may establish. Facilities constructed with poor or unsuitable quality padding material may have areas devoid of vegetation for decades following abandonment.

An alternative practice is removing padding material from in-situ facilities on peatlands. This method of restoring peatlands; however, lacks the scientific understanding of the long term effects of pad removal. A few experimental wellsites have had padding removed or partially removed. Where padding is removed, the pad material is put back into the borrow pit. Little is known about how restoration practices affect peatland hydrology, making the restoration success of disturbed peatland difficult to predict. One restoration practice involves complete removal of the padding, corduroy and geotextile (if present) followed by fluffing the compacted peat to an elevation similar to the peat surface on the adjacent land. Another method involves inverting the padding material (NAIT 2013). After the removal or partial removal of padded materials from peatlands, live moss propagules collected from donor sites may be spread on-top of the “dead” peat that was exposed after pad removal. Other research shows a potential for wetland plants to establish on padded facilities that have had padding material leveled to appropriate elevations (i.e. to a level where mineral soils become saturated with water) and establishing nurse species (e.g. water sedge) that create conditions favorable for the natural recovery of mosses (Vitt et al. 2011).

2.1 Rationale for Practice

2.1.1 Ecological

Peatlands dominate the northern Alberta landscape. Globally, peatlands are extremely important ecosystems due to their ability to sequester carbon and regulate the water cycle. Stewardship principles indicate preference for restoring peatlands, potentially facilitated by pad removal over the reclamation of wetlands to upland sites (Graf 2009).

2.1.2 Regulations and Guidelines

Provincial regulations do not require the removal of all padding materials upon final reclamation. However, recent EPEA approvals and reclamation guidelines suggest considering pad removal during wetland reclamation. Growing public and government interest for conserving and restoring wetlands (Osko 2010) may indicate that future social license to operate will require pad removal and site restoration. Leaving padding in place currently requires written release from the landowner prior to reclamation certification (Alberta Environment and Sustainable Resource Development 2013).

2.2 Application

2.2.1 Implementation Considerations

It is not always practical or economically efficient to restore a padded facility to pre-disturbance conditions. Investing in pad removal presents a risk given that the outcomes of removing pads from peatlands are not yet known and there is a lack of clearly defined goals for peatland restoration and reclamation. These challenges present the largest opportunities for reclamation and restoration research. Collaboration between industry and government creates an opportunity to facilitate the proactive empirical investigation of wetland reclamation/restoration priorities toward desirable outcomes (Osko 2010).

Determining whether or not padding material is left in place requires consideration of the integrated land management approach. Leaving padding in place on access roads allows access to sensitive peatland areas. Local communities, trappers and conservationists may find this decision undesirable. Barriers to access could limit traffic on access roads left in place. Quickly establishing dense stands of trees or using coarse woody material reduces the need for engineered barriers. However, leaving padding in place can also create rare, desirable habitat types within a particular region.

2.2.2 Padding Left in Place

Reclaiming facilities with padding left in place warrants a number of considerations, including end land use goals, quality of fill material used for construction, type of peatland, proximity to other upland areas, target plant community, species selection utilizing adjacent seed source and potential impacts to local and regional hydrology. The quality of fill material used for padding will largely determine the future potential of the disturbed area as it affects the reclamation practices required to establish and sustain vegetation, the future development of self-sustaining forests and target plant communities. Unsuitable padding material (i.e. inappropriate electrical conductivity or pH) may not sustain a forest plant community; these cases may require partial removal, amendments or capping with suitable material. Highly compacted padding material may restrict root growth and could require alleviation. Desired deep rooting trees and shrubs may not establish successfully or have poor growth rates (Kozlowski 1999).

Knowledge regarding the capability of surrounding peatland to facilitate reclamation and revegetation of a facility is incomplete. Nevertheless, vegetation on padded sites established within fens is more likely to benefit from a nutrient rich environment than bogs if the nutrients are available to plants. Depending on the quality of padding material, padded sites within bogs may require additional fertilization, amendments or nitrogen fixing species to establish a forested plant community in an appropriate time frame.

Factors such as adjacent forest plant communities, quality of padding material (i.e. the nutrient regime) and soil moisture regime guide the establishment of target plant communities, species selection and natural recovery processes. Facility proximity to suitable and desirable seed sources greatly influences the length of time required to establish desirable vegetation on the facility and influences the reliance on out-planting and seeding. *The Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region, 2nd Edition* (Alberta Environment 2010) and the *Field Guide to Ecosites of Northern Alberta* (Beckingham and Archibald 1996) provide details on how to select target plant communities based on soil moisture regime and nutrient regime in north eastern Alberta (these guidelines apply throughout Northern Alberta).

Natural drainage patterns may be altered around padded facilities, potentially leading to flooding in some areas and draining in others. Pad removal is a consideration where a facility constrains the natural drainage, causing a change in adjacent plant communities. Improper local and regional drainage around facilities with padding left in place necessitates alterations to padding material left in place. The effect of padding material on water quality of the surrounding peatland should also be considered. *The Restoration of Alberta's Boreal Wetlands Affected by Oil, Gas and In Situ Development* provides a comprehensive review of the best practices for reducing hydrological impacts (Graf 2009).

2.2.3 Padding Removed

Removing padded material from peatlands and initiating peatland restoration is at the forefront of research and application. Only a handful of facilities have had pads removed. Trials established in the Peace River and Cold Lake regions evaluated the complete removal of padding, partial removal of padding and inversion of padding material. Ongoing challenges include cost, hydrological restoration, obtaining suitable donor material and establishing peatland species.

The cost of removing padded material and backfilling into the original borrow pit is often a concern. Recycled padding material is typically very wet and therefore unsutiable for reuse from an engineering perspective. Nevertheless, there are alternative uses for recycled padding material. Recycled padding material could fill excavations on contaminated sites and may reduce overall reclamation costs, offsetting the cost of padding removal.

Restoring the surface hydrology is a key element of restoring peatland vegetation, yet it is the least understood aspect of peatland restoration (Osko 2010). Successful moss establishment occurs when water levels are near the surface and uniform (Rochefort et al. 2003). Drought or oversaturated conditions (i.e. free standing water) inhibit moss establishment and promote the establishment of vascular species such as birch, cattails or sedges. The establishment of a uniform water table relative to the surface of freshly exposed peat is unlikey and unnecessary for all peatland types in Western Canda; a rough or uneven surface produces moisture conditions that help establish moss and other wetland species.

Spreading living moss fragments across newly exposed peat helps establish moss after pad removal. Live moss collection from suitable donor sites produces propagules from desireable moss species required for restoration. The ideal salvage depth for moss collection is 5 to 10 cm from the surface (Rochefort et al. 2003; Graf 2009) which should comprise the majority of the acrotelm layer. The donor material collection typically occurs at a 1:10 donor to restoration site ratio (5 to 10 cm of donor material salvaged from 1 ha is needed to restore 10 hectares of peatland). The moss transfer technique was only recently implemented in Western Canada. Therefore, the optimal salvage to placement ratios, placement thickness of donor material and the resilience of the donor peatland after harvesting material are still undetermined. Nevertheless, peat harvesting operations in Western Canada have proven the technique to be successful (Graf 2009; Graf et al 2009).

2.3 Advantages and Disadvantages

Pad reclamation has many advantages as well as disadvantages for reclaiming in-situ facilities.

Advantages

Pad reclamation has the following advantages:

Padding removed

- Potential for restoring original ecosystem and drainage patterns
- Pad material may be salvaged for future use

Padding left in place

- Upland vegetation typically establishes quicker than bog or fen vegetation and there is more knowledge regarding establishing upland vegetation
- Potential to restore locally rare upland habitats

Disadvantages

Pad reclamation has the following disadvantages:

Padding removed

- Costly
- Original substrate below padding may be severely degraded (e.g. compacted)
- Difficult to re-establish hydrology
- Requires a suitable place for disposal which may create additional disturbance

Padding left in place

- Pad material may not be suitable for vegetation establishment
- Lack of nearby suitable sources of propagules for natural infill of vegetation to occur
- Not representative of predisturbance ecosystem

2.4 Opportunities

The following are opportunities for pad reclamation:

- Develop land management plans that include consideration for pads to be left in place or removed
- Determine if constructing pads to have more naturally shaped landforms versus squares and rectangles enhances interim and final reclamation
- Find solutions to recycle padding rather than using new material (e.g. treating recycled pads to meet engineering specifications)
- Develop a process to determine a facility's viability for peatland restoration (e.g. padding removal)
- Research the cumulative effect of multiple pads within a peatland
- Continue monitoring reclaimed padded sites to determine common elements of success and investigate pad removal occurring in conventional oil and gas practices
- Use legacy sites to assess site-specific constraints that make leaving pads in place more desirable
- Determine how the proximity of other upland or transitional forests affect the natural recovery of facilities with padding left in place
- Investigate whether pads left in place alter the water quality and hydrology of the adjacent peatland to the extent adjacent land plant communities are affected.
- Determine if desirable forested plant communities can develop on pads left in place
- Research the types of amendments, soil applications and site preparation activities that can enhance plant establishment on pads left in place
- Research whether organic matter and other chemical constraints (e.g. pH, EC) limit plant establishment and whether mixing pad material with underlying peat alleviates these constraints

3.0 SUBSOIL REPLACEMENT

Salvaged subsoil is replaced on in-situ facilities during reclamation. Where subsoil was not salvaged, the substrate may be a mixture of subsoil and parent material used for leveling during construction or subsoil obtained from a borrow pit. Subsoil replacement depth often depends on initial salvage volume; however, the common placement depth is 30 cm. Dry or frozen conditions are ideal times to redistribute subsoil.

3.1 Rationale for Practice

3.1.1 Ecological

Subsoil is a valuable reclamation material. When replaced, subsoil provides a rooting zone that stores water and nutrients, a medium for root anchorage and creates a barrier to protect roots from unsuitable underlying material (Alberta Environment and Water 2012).

3.1.2 Regulations and Guidelines

Replacement of subsoil to provide equivalent land capability to pre-disturbance land is a regulatory requirement as per EPEA approvals and the *Code of Practice for Exploration Operations*.

3.2 Application

3.2.1 Implementation Considerations

All sites where subsoil was salvaged require it to be replaced. When replacing subsoil the landform, surrounding landscape, reclamation material and underlying substrates should be considered as they can affect the depth of subsoil required, quality of subsoil required and end plant community that can be established. Assessing the potential constraints prior to construction of the facility increases the potential establishment of the desired plant community as a suitable volume of subsoil can be salvaged.

3.2.2 Timing

Where practical, subsoil should be replaced within a reasonable time after salvage to prevent long term stockpiling and subsequent erosion (Government of Alberta 2013). Subsoil replacement should occur under dry weather conditions and during winter to reduce the risk of compaction and loss of soil quality (EBA Engineering Consultants 2002; Alberta Environment and Water 2012). Movement of wet subsoil should be avoided to prevent compaction and rutting.

3.2.3 Placement depth

Generally, subsoil is placed at a uniform depth across the site similar to the depth of salvage (approximately 30 cm). However, considering the quality of the substrate, the annual average effective precipitation, soil quality, topographic positions and species requirements (Hargis and Redente 1984; Merrill et al. 1998) could allow for better use of the subsoil to achieve a self-sustaining forest ecosystem. Soil placement depth requirements generally increase as the severity of the adverse properties of the underlying substrate material increase (Hargis and Redente 1984). EPEA approvals require a minimum placement depth of 1 m of suitable material over unsuitable material. Certain parameters (e.g. coarse fragments and percent saturation) classified unsuitable may not have deleterious effects for plants as similar constraints could exist on adjacent undisturbed areas. Compaction is one of the key factors limiting plant productivity when replacing considerable depths of soil (Bell 2004). Increased traffic and/or soil handling required to replace thicker depths can increase compaction and limit root growth.

3.2.4 Equipment

Subsoil replacement equipment is selected carefully to minimize compaction and loss of soil quality during handling. Excavators and bulldozers are commonly used in subsoil replacement. Scrapers and equipment with rubber tires increase the risk of soil compaction and should be avoided (McRae 1989; EBA Engineering Consultants 2002).

3.3 Advantages and Disadvantages

Subsoil replacement has many advantages and disadvantages for reclaiming in-situ facilities.

Advantages

Subsoil replacement has the following advantages:

- Subsoil is a valuable reclamation material and can increase plant establishment compared to overburden
- Subsoil provides plants with a rooting zone that stores nutrients and water, a medium for anchorage and a barrier between roots and potentially deleterious elements

Disadvantages

Subsoil replacement has the following disadvantages:

- Knowledge of how the various subsoil placement techniques impact forest establishment on in-situ facilities is limited
- Conditions forcing operators to salvage during less than ideal conditions increases the risk of degrading subsoil quality (e.g. multiple handling, heavy equipment traffic, etc.)

3.4 Opportunities

The following are opportunities regarding subsoil replacement:

- Determine whether 30 cm of subsoil replacement depth is sufficient if there are limiting factors to plant growth below 30 cm depth (e.g. high pH, low nutrient status, high water table)
- Define subsoil (B horizon or suitable material below the A horizon) and determine if subsoil needs to be salvaged from all sites or if using a parent material and subsoil mix is equivalent
- Determine if variable subsoil replacement depths and surfaces enhance plant establishment in targets areas
- Determine practices that allow wet subsoil stockpiles to dry prior to placement
- Determine if rough and loose placement and use of different textures can be used to create different hydrology and ecosite regimes

4.0 SURFACE SOIL REPLACEMENT

Salvaged surface soil is replaced on in-situ facilities during reclamation. In some cases, surface soil is imported if there are deficiencies (e.g. legacy sites and padded sites). On temporary disturbances, surface soil replacement occurs during the season of salvage. On permanent disturbance sites, including areas receiving interim reclamation, surface soil replacement occurs throughout the year depending on access. To minimize the risk of compaction, reclamation personnel attempt to minimize handling of wet surface soil. Site access limitations and timing constraints restrict optimal handling conditions. The surface soil is uniformly distributed across the site and the surface is left rough. On approval-regulated facilities, on-site monitors check surface soil depths to ensure the replacement depth is equal to or greater than 80% of the average depth of surface soil present prior to disturbance. On temporary disturbances, on-site monitors may or may not be present.

4.1 Rationale for Practice

4.1.1 Ecological

Replaced surface soil provides a source of growth medium, organic matter and nutrients essential for plant growth and establishment (Osko and Glasgow 2010; Alberta Environment and Water 2012; MacKenzie 2013). It can also contain an abundant source of plant propagules that are used to establish native vegetation during reclamation when placed directly (MacKenzie and Naeth 2009; MacKenzie 2013). Woody material present in surface soil provides microsites necessary for vegetation establishment (Alberta Environment and Water 2012). Surface roughness and appropriate placement depth allows establishment by a wider variety of plant species (Government of Alberta 2004; Osko and Glasgow 2010).

4.1.2 Regulations and Guidelines

Replacement of surface soil to provide equivalent land capability to pre-disturbance land is a regulatory requirement as per EPEA approvals and the *Code of Practice for Exploration Operations*. Surface soil depths must be redistributed to meet minimum replacement depths as stated within the EPEA approval and the *2010 Reclamation Criteria for Wellsite and Associated Facilities on Forest Land*.

4.2 Application

4.2.1 Implementation Considerations

All sites where surface soil was salvaged require it to be replaced. Replacement should take into account reclamation objectives (e.g. target ecosites and plant species), pre-disturbance conditions, material volume balance and operational constraints. For example, upland surface soil should be replaced on upland areas and organic soil replaced on lowland areas. To obtain the most value from direct placement of upland surface soil or transitional surface soil (i.e. shallow organic soil) each type of surface soil should be replaced on post-disturbance landscapes at locations where the predicted soil moisture regime and soil nutrient regime are similar to the salvage site (Alberta Environment and Water 2012).

4.2.2 Direct Placement

Direct placement of surface soil containing viable propagules is one of the most economical ways of ensuring re-establishment of the diversity of species that exist in native ecosystems (Leck et al. 1989). Direct placement of surface soil is effective at establishing native plants in both upland and peatland environments. However, if undesirable species are present in the seed bank (i.e. noxious weeds, competitive native or introduced species) and are anticipated to out-compete desired species, direct placement will not be as effective (MacKenzie and Naeth 2011). Direct placement is preferred to stockpiling because seed viability, nutrients, organic matter and soil biota are difficult and costly to replenish once degradation occurs in stockpiles (MacKenzie 2013). Direct placement preserves viable propagules making them available for revegetation. Typical shrub densities obtained from upland surface soils salvaged from mid-seral deciduous stands in the boreal forest, replaced at depths greater than 10 to 20 cm range between 20,000 to over 100,000 stems per ha (MacKenzie 2006, 2013). The number of plants emerging from direct placed surface soil depends on numerous factors such as salvage depth, stand age and type, disturbance history, variations in year-to-year seed production and precipitation. Few native plants will establish from the soil propagule bank if there are few propagules to begin with. Older forested stands with a sparse understory and low abundant soil propagule bank will not establish many plants from natural recovery, unless there is a nearby source of propagules.

Operators should look for alternative opportunities to directly place salvaged surface soil if the facility is not available for permanent reclamation. For example, direct placement of surface soil on facilities without surface soil (e.g. older reclaimed sites, padded sites) would improve the establishment of diverse self-sustaining native ecosystems (MacKenzie and Naeth 2011). Although this method might seem counterintuitive, research suggests that this is a better alternative to stockpiling. Surface soil should not be placed on former reclaimed areas that are or will be prone to soil quality degradation or on areas that would accelerate the loss of viable propagules (e.g. flooded areas). Additionally, placing upland surface soil on substrates that already have a viable propagule bank of species should be avoided where possible.

4.2.3 Timing

Surface soil replacement should be restricted in adverse weather or ground conditions (i.e. wet or windy conditions) to reduce the risk of soil loss and compaction (EBA Engineering Consultants 2002; Darmody et. al. 2009; Alberta Environment and Water 2012; Government of Alberta 2013). However, direct placement under less than ideal conditions is more desirable than stockpiling surface soil.

4.2.4 Placement Depth

The thickness of the replaced soil depends on multiple factors such as the quality of the subsoil or overburden to be covered, soil quality, species requirements and topographic position (Hargis and Redente 1984; Merrill et al. 1998). Where the underlying subsoil/substrate material has adverse characteristics for root growth, the depth of soil replaced (which must be applied to achieve long-term productivity) depends on the characteristics of the subsoil/substrate material. Soil placement depth requirements generally increase as the severity of the adverse properties of the subsoil/substrate material increase (Hargis and Redente 1984). Thicker depths on higher topographic positions that have moisture constraints would increase water holding capacity. Replacement depth may be varied within the site to promote establishment of a diverse and dynamic vegetation community (Buchanan et al. 2005).

It is important to note that when replacing a considerable depth of soil, compaction is one of the key factors limiting plant productivity (Bell 2004). Increased traffic and/or soil handling required to replace thicker depths can increase compaction and limit root growth. Placement with an excavator rather than a bulldozer can reduce compaction and increase surface roughness and the availability of different microsites.

4.3 Advantages and Disadvantages

Surface soil replacement has many advantages as well as disadvantages for in-situ oil sands extraction facilities.

Advantages

Surface soil replacement has the following advantages:

- Returns essential organic matter, nutrients and microorganisms required for healthy forest establishment
- Reduces operational costs as the need for herbaceous, shrub and tree planting is eliminated when surface soil contains a propagule bank of desired species
- Improves soil texture, structure and thus rooting suitability when A horizon is mixed with overlying LFH or organic surface soil during salvage

Disadvantages

Surface soil replacement has the following disadvantages:

- Competitive species contained in propagule bank may out complete desired woody plants
- Loose surface soil composed of only organic matter can become very dry preventing native plant establishment

4.4 Opportunities

The following are opportunities regarding improvement regarding surface soil replacement:

- Improve training for equipment operators
- Use soil placement monitors
- Direct place surface soil on subsoil stockpiles to reduce the volume stockpiled in larger piles and also help revegetate the subsoil stockpile, reducing the need to seed and fertilize
- Research different replacement depths to address the shortage of reclamation material
- Enhance variation in reclaimed landscapes through varying surface soil depths
- On facilities with several different plant communities or ecosites, Replace surface soil on the same landform form where it was salvaged to enhance reestablishment of pre-disturbance plant communities
- Investigate the use of rough surfaces to increase diversity of microsites and water infiltration
- Determine if benefits of moving soil between locations to be used for direct placement outweigh negative effects – cost, regulatory restrictions, movement of genetic material and potential weed propagules – and the results can be used to overcome current regulatory restrictions

5.0 SOIL TILLING AND DECOMPACTION

Alleviating soil compaction prevents poor vegetation growth and establishment. Compaction alleviation is generally restricted to the reclamation of permanently constructed facilities, temporary facilities that have had frequent traffic under unfrozen conditions or padded facilities. Compaction can be alleviated by soil tilling and contouring leveled materials. Minimizing the loss of surface soil during decompaction requires the consideration of suitable equipment and methods. Common implements used to alleviate compaction include rippers, RipPlows®, a hoe with bucket or bucket implements, rakes and discs. Ideal conditions to alleviate subsoil compaction occur when soils are frozen or moist.

5.1 Rationale for Practice

5.1.1 Ecological

Soil compaction commonly reduces the growth of young trees and severe soil compaction can reduce the growth of shrubs and herbaceous plants. Compacted soils have a high bulk density which limits water infiltration, reduces nutrient availability and impedes or restricts root penetration and development (McRae 1989; Arnup 1998; Sweigard et al. 2007). Porosity is also reduced in compacted soils as a result of macro-pore reduction and this can create anaerobic environments. Alleviating compaction may be necessary to improve soil aeration, infiltration, hydraulic conductivity, nutrient uptake and root penetration.

5.1.2 Regulations and Guidelines

There are no specific regulatory requirements for alleviating compaction. EPEA approvals require avoiding soil handling and placement operations during conditions that could result in soil degradation. Facilities with severely compacted soil that restricts the establishment and growth of forest vegetation might require alleviating compaction to meet the *2010 Reclamation Criteria for Wellsite and Associated Facilities on Forest Land*.

5.2 Application

5.2.1 Implementation Considerations

Using construction and reclamation techniques that minimize soil compaction such as minimal disturbance construction techniques, accessing the site under frozen conditions, limiting the handling of the soil and limiting traffic on the soil can reduce the need for decompaction. Knowledge about the construction, operations and reclamation history helps evaluate the severity of compaction and provides information to determine whether alleviating compaction is nessessary and worth while. Alleviating compaction on a site that does not require decompaction potentially negatively affects a site's hydrology and soil quality. Most padded facilities require some form of decompaction depending on the nature of construction. Older facilities (i.e. legacy sites) exposed to decades of freeze-thaw cycles and minimal traffic after construction may not require decompaction if bulk densities compare to undisturbed upland forest stands.

5.2.2 Assessing Soil Compaction

Applying moderate foot pressure on a spade in a rocking motion to assess ease of penetration is a subjective method to determine the severity of compaction (Sweigard et al. 2007). The severity of compaction may also be determined through root depths and orientation observations; however, this method may not be suitable to determine the depth of compaction. Assessing penetration resistence or bulk density provide more objective results. Penetration resistance is highly variable due to its relationship with soil moisture and pentrometer interpretations therefore requires caution (Taylor and Gardner 1963). Comparing bulk density measurements to pre-disturbance or control values may determine when ripping may be warranted.

5.2.3 Soil Moisture

Wet soils that have high clay content are most susceptible to compaction. Many areas within the boreal forest have high clay content and are moist to wet throughout the year. Alleviating compaction should be avoided when soils are wet or very dry because the soil will not fracture properly. The use of certain implements under wet conditions may however create large voids in the subsurface that allow freeze-thaw cycles to alleviate further compaction (McNabb 2012).

Decompacting extremely dry soils increases wear on equipment and may increase admixing and disrupt surface soil (Jansen and Hooks 1988; Raper and Sharma 2004; Sweigard et al. 2007). Frozen soils are difficult to till due to the resistance created by the frost in the surface although surface soil compaction is minimized. Tilling in the earlier part of winter avoids deep frost penetration.

5.2.4 Methods and Equipment

Properly selecting methods and equipment for decompaction and tillage ensures reaching the appropriate decompaction depth in the subsoil while forgoing irreparable, negative changes to surface soil quality. Any method used to alleviate subsoil compaction should minimize the loss and admixing of surface soil. An advantage to alleviating subsoil compaction on facilities that have surface soil replaced is the creation of a rough surface. Mesic (moist) sites with a lot of available surface soil are likely more resilient to admixing compared to xeric (dry) sites that have little available surface soil. Decompacting subsoil prior to surface soil replacement minimizes the surface soil loss and admixing. The benefits of decompacting the subsoil prior to surface soil replacement may be negated should surface soil replacement result in additional compaction; decompaction could occur when soils are not frozen and surface soil replacement could occur on decompacted and frozen soil.

Tillage and mounding techniques effectively alleviate compaction and each has its own advantages and limitations. Corns and Annas (1986) describe a wide variety of equipment for alleviating compaction. The most commonly used equipment to alleviate deep subsoil compaction include dozers pulling rippers and ripper plows. Rippers and other rigid shank equipment may have less effect beyond 0.5 m (Jansen and Hooks 1988). The RipPlow® is a recent innovation combining the benefits of a plow and ripper to alleviate compaction deep within the subsoil while minimizing the admixing of surface soil (McNabb 2012). Vibration rippers effectively alleviate compaction deep within the profile (Nadeau and Pluth 1997). Tilling perpendicular to steep slopes prevents erosion. Tilling parallel with gentle slopes improves drainage. Increasing the number and intensity of passes increases the potential for admixing and additional compaction.

Mounding is another method for alleviating subsoil compaction. Mounding is more common for scarification of surface soil to create microsites and expose mineral soil for improved germination of tree seeds (Londo and Mroz 2001). For alleviating subsoil compaction, a tracked excavator (backhoe) digs into the subsoil and creates large mounds of mixed, loosened surface and subsurface material. Mounding compacted sites that do not have surface soil alleviates compaction and creates microsites that assist in native seed catchment, germination and establishment. Alternatively, excavators fitted with brush rakes or rippers are used to alleviate compaction, although these methods are slower than those using a dozer. Bucket mounding may be most effective on compacted peatland sites, padded sites or sites that do not have surface soil.

5.3 Advantages and Disadvantages

Soil tilling and decompaction has many advantages as well as disadvantages for reclaiming in-situ facilities.

Advantages

Soil tilling and decompaction has the following advantages:

- Creates a suitable rooting medium for vegetation
- Allows for water infiltration
- May increase the diversity and number of microsites

Disadvantages

Soil tilling and decompaction has the following disadvantages:

- Can result in admixing
- May not fully alleviate compaction or could cause additional compaction
- Can disturb existing or re-established vegetation (depending on when the treatment is applied)

5.4 Opportunities

The following are opportunities regarding soil tilling and decompaction:

- Determine if soil tilling and decompaction should be a standard practice on all severely disturbed facilities or legacy sites or only suspect locations
- Investigate if the benefits of soil tilling and decompaction outweigh the negative impacts of admixing
- Determine if it is beneficial for minimally disturbed sites that have been heavily trafficked to have their soils decompacted
- Determine if a combination of decompaction and surface preparation treatments enhances microsites

6.0 SURFACE PREPARATION

Surface preparation treatments are applied to in-situ facilities to promote the establishment of forest vegetation. Surface preparation can include the application of a number of different techniques that that move or displace surface soil or woody and organic material. These techniques expose mineral soil, create suitable microsites (or seedbed) for the establishment and growth of native forest vegetation (BC Ministry of Forests ND) and reduce surface soil compaction (McNabb 2012). Most surface preparation techniques have been adopted from forestry applications. Historically, surface preparation typically occurred on sites that have had surface soil replaced, on sites that are compacted or have a dense cover of grass.

6.1 Rationale for Practice

6.1.1 Ecological

Surface preparation has numerous ecological benefits as it helps promote the establishment and rapid recovery and growth of many boreal forest species by improving microsite availability, soil temperatures, soil aeration, nutrient availability and reducing the risk of vegetation desiccation and drowning, competition from non-native vegetation and insect attacks (BC Ministry of Forests ND). Surface preparation also makes it difficult for third party access and increased disturbance.

6.1.2 Regulations and Guidelines

Surface preparation is not required but is beneficial and may be needed to meet vegetation requirements in EPEA approvals and the *2010 Reclamation Criteria for Wellsite and Associated Facilities on Forest Land*.

6.2 Applications

6.2.1 Implementation Considerations

Applying surface preparation techniques to all facilities may not be beneficial and the construction method used and ecological conditions of the site and desired plant species should be considered. On facilities constructed with minimal disturbance practices, surface preparation could damage the intact forest root network which is capable of vegetative reproduction. Damage to the root system of tree and shrub species could result in decay and death of the root network negating its ability for regeneration (Renkema et al. 2009). However, minimal disturbed sites may have a thick litter or organic layer that may inhibit vegetation establishment and growth and reducing or partially removing the layer may outweigh the benefit of keeping the root system intact. Creating microsites can enhance the establishment of undesired plant species where large weed populations are located nearby (MacKenzie and Naeth 2009).

6.2.2 Technique

Several different techniques and equipment are available for applying surface preparation treatments. The techniques are briefly summarized below:

- Surface Roughness – Soil is left rough by placing soil in small mounds (can be <30 cm in height) and not "track-packing the soil" during soil replacement
- Drag Scarifying – Chains, barrels or other objects are dragged over the surface of the ground to move organic material and expose mineral soil
- Mounding – An excavator or an attachment mounted to a bulldozer is used to flip the soil and create a "mound" and a "hole"
- Ripping or Cultivating – Ripper teeth on a bulldozer or an implement attached to a bulldozer is pulled through the soil to loosen it
- Disc Trenching – An implement attached to a bulldozer creates a continuous trench as well as mounds or windrows along the trench
- Scalping – A bulldozer blade or implements attached to a bulldozer push organic matter and surface soil to the side in small areas

Surface preparation techniques can be applied to various depths or to create mounds or windrows of varying height. The techniques can also be at a narrow or wide spacing (e.g. mounds at a spacing of 1 m or a spacing of 5 m) and in one direction or multiple directions (e.g. ripping). Using a forest ecosystem classification framework along with soil survey information can help determine appropriate surface preparation techniques that minimize soil degradation and enhance forest establishment (Corns and Annas 1986).

6.2.3 Timing

Surface preparation techniques are best applied under conditions that minimize compaction and unintended admixing. Techniques can be applied under frozen and unfrozen conditions (McNabb 2012). Preparing the surface under wet conditions will create compaction and smearing and excessive admixing can occur if frost is deep.

6.3 Advantages and Disadvantages

Applying surface preparation treatments has many advantages as well as disadvantages for reclaiming in-situ facilities.

Advantages

Surface preparation has the following advantages:

- Can improve vegetation establishment and growth and decrease competition of undesirable species
- Exposed mineral soil creates opportunity for directly seeding conifers
- Reduces site accessibility to third parties and wildlife predators
- Reduces erosion potential

Disadvantages

Surface preparation has the following disadvantages:

- Can result in significant loss of organic matter
- Can lead to water ponding and water saturated soils

6.4 Opportunities

The following are opportunities regarding the application of surface preparation treatments:

- Determine benefits of applying surface preparation/silviculture techniques on in-situ facilities. A detailed review of silviculture systems used in forestry applications would provide guidance on how to integrate practices with the reclamation/restoration of in-situ facilities. Application methods for surface preparation could be adapted from forestry where an intact or partially intact forest floor is still present. On reclaimed in-situ facilities a forest floor may not be present and the benefits of surface preparation techniques are not known
- Develop guidelines for surface preparation techniques and intensity based on ecosite and site conditions (e.g. upland vs. lowland facilities). Determining correlations of aerial seed dispersal potential and soil propagule bank species composition and abundance with ecosites would further help determine site resilience to various site preparation techniques
- Determine if surface preparation should be applied as an adaptive management technique or applied to all in-situ facilities

7.0 AMENDMENTS

Surface and soil amendments may be applied to in-situ facilities during reclamation to improve the biological, chemical and physical properties of the soil, to promote vegetation establishment and enhance growth. Amendments are applied due to loss of soil organic matter, nutrients and other soil properties during soil salvage, storage and placement (Land Resources Network Ltd. 1993; Naeth and Wilkinson 2003). Amendments may include wood fibre and woody material, sewage waste, pulp sludge, manure, compost and many other carbon containing materials and mixtures. These amendments can be applied or broadcast over the surface of the soil or they can be incorporated into the soil to different depths. Currently, amendment application is not a common practice.

7.1 Rationale for Practice

7.1.1 Ecological

Applying surface and soil amendments creates microsites, increases soil organic matter and nutrient content, improves soil chemical and physical characteristics, enhances biological activity and provides erosion control (Alberta Environment and Water 2012). Improvement in soil conditions due to amendment application can improve the establishment and growth rate of vegetation (Land Resources Network Ltd. 1993).

7.1.2 Regulations and Guidelines

Amendment application is not required but is beneficial and may be needed to meet regulatory vegetation and soil requirements in EPEA approvals and the *2010 Reclamation Criteria for Wellsite and Associate Facilities on Forest Land*. Reclamation certification is delayed two years after application of amendments.

Application of amendments should follow government guidelines such as the *Standards and Guidelines for the Land Application of Mechanical Pulp Mill Sludge to Agricultural Land* (Alberta Environmental Protection 1999) and the *Management of Wood Chips on Public Land* (Government of Alberta 2009).

7.2 Application

7.2.1 Implementation Considerations

In most circumstances proper salvage, storage and placement of surface soil can negate the need to apply amendments, although the application of coarse woody material has been shown to be a beneficial regardless of surface soil handling techniques (Vinge and Pyper 2012). If there is surface soil loss, minimal or no surface soil (e.g. padded sites) or on subsoil stockpiles that require revegetation then application of an amendment may be appropriate but it should be recognized that amendment may have detrimental effects such as lowering soil temperature, introducing non-native propagules, creating nutrient imbalances or adding harmful chemical elements.

7.2.2 Types

There are numerous amendments that can be applied to soil. The following are common amendments applied to soils to improve their fertility: livestock manure, green manure or crop residue (e.g. straw), compost, fertilizer, peat, wood waste (e.g. mulch and coarse woody material), pulp sludge, sewage sludge, coal ash, lime and gypsum.

Details on the chemistry, effect on soil fertility and application methods for the majority of common amendments can be found in *Organic Materials as Soil Amendments in Reclamation: A Review of the Literature* (Land Resources Network Ltd. 1993). Recent literature on role of various types of organic amendments can be found in *The Role of Organic Amendments in Soil Reclamation: A Review* (Larney and Angers 2012).

Less common amendments or new amendments that may have potential for reclamation include biochar and mycorrhizae inoculation.

7.2.3 Rate

Choosing an appropriate amendment and application method needs to consider the existing physical and chemical properties of the soil and amendment, and the effect that the amendment may have on soil properties. On forested lands, there are guidelines for coarse woody material and mulch (e.g. Vinge and Pyper 2012; Pyper and Vinge 2013). Other guidance documents apply mainly to oil sands mining or agriculture (e.g. Land Resources Network Ltd. 1993; Alberta Environmental Protection 1999; Alberta Environment and Water 2012).

Pulp sludge trials have been conducted to determine their potential for forestry reclamation (Smartsludge.com ND). On reclaimed forest sites sludge applications of 60 to 100 t/ha can reduce soil bulk density and increase water holding capacities which improves vegetation establishment and growth (Macyk 1999).

7.3 Advantages and Disadvantages

Applying amendments has many advantages as well as disadvantages for reclaiming in-situ facilities.

Advantages

Amendment application has the following advantages:

- Improved soil physical properties
- Increase soil nutrients
- Increased vegetation diversity, establishment and growth

Disadvantages

Amendment application has the following disadvantages (Land Resources Network Ltd. 1993):

- Can result in nutrient release off-site (leaching)
- For high carbon to nitrogen ratio amendments, some soil nutrients may become immobilized
- Can contain heavy metals and other toxic compounds
- Benefits of the amendment can be lost over time
- May benefit a single species and reduce diversity
- Coarse woody material can be ground into mulch if repeatedly driven over

7.4 Opportunities

Currently amendments are not commonly used but increased development and continued construction of pad sites may create a need for amendment use. The following are opportunities regarding amendments:

- Determine the benefits of amendment application on pad sites that do not have surface soil
- Determine the benefits for revegetating subsoil stockpiles
- Develop application guidelines for reclamation of forested lands
- Research potential for new amendments: biochar, incorporation of wood mulch into soil, composting wood waste and camp waste (e.g. sewage sludge and food waste) and green crops planted on facilities in-situ facilities (native and cultivated species)
- Determine effect on plant community composition and changes overtime

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SECTION IV - REVEGETATION

1.0 PROPAGULE COLLECTION

Propagules are collected for planting native and local species on in-situ facilities. The collected propagules are either propagated in a greenhouse prior to outplanting or directly distributed or planted on a facility. Propagules are collected for herbaceous, shrub and tree species. Collection occurs by hand or with mechanical equipment (Graf 2009). Propagules are gathered from pre-disturbance facilities or from nearby areas. Collected propagules are cleaned, processed and tested for viability.

1.1 Rationale for Practice

1.1.1 Ecological

Collecting propagules from local and native species ensures the re-established vegetation is adapted to local climate conditions and that genetic diversity is preserved (Alberta Environment and Water 2012) and supports the growth of nursery stock for reclamation and restoration.

1.1.2 Regulations and Guidelines

Propagules may need to be collected to meet revegetation requirements in EPEA approvals and the *2010 Reclamation Criteria for Wellsite and Associate Facilities on Forest Land* (Alberta Environment and Sustainable Resource Development 2013a). The *Alberta Forest Genetic Resource Management and Conservation Standard* require that propagules are collected from within specified seed zones to establish native species (Alberta Sustainable Resource Development 2009). For shrubs, propagules should be collected from similar ecoregions (Oil Sands Research and Information Network 2013). All collection, transportation, storage and deployment must follow the *Alberta Forest Genetic Resource Management and Conservation Standard* (Alberta Sustainable Resource Development 2009) and *Timber Management Act and Regulations* (Government of Alberta 2013b). Requirements are summarized by Smreciu (2011).

1.2 Application

1.2.1 Implementation Considerations

Promoting the infill of native species either from the soil propagule bank or aerially dispersed seed by creation of a suitable seed bed reduces the necessity for propagule collection and enhances establishment and growth of planted propagules. When anticipating the facility will require native and local plants to be propagated from seed, collection plans should be made well in advance of revegetation (two to three years) to allow for propagation and growth in a nursery (Alberta Agriculture, Food and Rural Development 2001). Advanced planning also allows collection from certain species that produce seed crops periodically or produce a limited seed crops (Mihajlovich and Wearmouth 2012; Alberta Environment and Water 2012). Seeds collected well in advance of disturbance can be stored. Seedlings from certain tree species may be obtained from the FMA holder and therefore it may not be necessary to collect seeds (Mihajlovich and Wearmouth 2012). Propagating from plant cuttings requires less advanced planning. Cuttings can often be collected in the same year as planting; however, they cannot be stored for significant lengths of time (MacKenzie and Renkema 2011).

1.2.2 Propagule Type

Propagule types may include seeds, spores, seed containing (native) hay, sod, plugs and cuttings (Alberta Agriculture, Food and Rural Development 2001). Suitable or best propagule types for establishing vegetation vary by species. Refer to the Species Fact Sheets in the *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region* (Smreciu et al. 2013) to help determine suitable propagules for species. Considerations for propagule selection depend on: length of available time for planning and collection, the limited availability of seeds and the germination process of seeds for tree and shrub species (MacKenzie and Renkema 2011).

1.2.3 Timing

There are seasonal considerations for propagule collection in addition to previously discussed timelines for seed and cutting collection. Many species have a very short window during which they can be collected (AMEC 2001; Smreciu 2011). General guidelines for timing propagule collection include: harvesting cones when they are ripe but prior to opening, harvesting fleshy fruits when they are ripe, taking hardwood cuttings when the plant is dormant and taking softwood cuttings while the plants are growing. The Species Fact Sheets in the *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region* (Alberta Environment 2010) outline the time horizons for specific species. Early preparation and close monitoring ensures propagules are collected when they are available (e.g. seed masting years) and at the correct time when they are mature and viable. Monitoring also ensures propagules are collected before dispersed.

1.2.4 Collection

Collection techniques vary depending on species and whether or not the harvesting areas are disturbed. The following guidelines summarized from the *Native Plant Revegetation Guidelines for Alberta* should be followed when collecting propagules from undisturbed areas (wild harvest) *(*Alberta Agriculture, Food and Rural Development 2001):

- Collect propagules from abundant species
- Avoid rare or fragile habitats
- Leave 50% of the seed and greater than 50% of vegetative propagules in place in areas that are frequented for collection or browsing
- Do not collect from the same area in consecutive years
- Minimize collection disturbance by using non-mechanical methods

Local diversity is preserved by collecting propagules nearby the planting site (Alberta Sustainable Resource Development 2009; Government of Alberta 2013a).

1.2.5 Storage

Propagules may need to be stored if not immediately propagated. Propagules should be stored at a licensed facility. Seeds can be stored for longer period of time while cuttings generally lose their viability over a shorter period of time. Seeds should be dried and frozen. Green cuttings should be kept moist. Dormant cuttings can be frozen until deployed (Smreciu 2011). Extensive studies are underway at University of Saskatchewan to determine optimal storage conditions for individual shrub species; however, results are not yet available.

1.3 Advantages and Disadvantages

Propagule collection has many advantages as well as disadvantages for reclaiming in-situ facilities.

Advantages

Propagule collection has the following advantages:

- Preserves local and native genetic diversity
- Plants are adapted to local conditions
- Propagules from numerous species can be collected
- Certain seeds of species can be stored for long periods of time
- In seed masting years, collection can be extremely efficient

Disadvantages

Propagule collection has the following disadvantages:

- Low germination rate of seeds from some species and poor establishment from cuttings
- Logistically challenging
- Not feasible for small sites

1.4 Opportunities

The following are opportunities regarding the application of propagule collection:

- Develop seed banks or co-ops to make collecting more efficient and increase the number of species available for propagation (COSIA's Oil Sands Vegetation Cooperative for mine sites – http://www.cosia.ca/initiatives/land/oil-sands-vegetation-cooperative – can serve as a model)
- Collect and develop propagation methods for a more diverse range of species

2.0 SEEDING

Tree, shrub and herbaceous species may be established by spreading or sowing seeds. Most seed mixes are composed of herbaceous species. Grasses in particular are readily available and have high germinations rates. Grass mixes provide seed for various and diverse combinations of species adaptable to different environmental conditions. Mixes may contain native and non-native species. Seed mixes used in forested areas in Alberta require forest officer approval (Government of Alberta 2013c). Currently, the majority of in-situ facilities are left to recover naturally without seeding.

2.1 Rationale for Practice

2.1.1 Ecological

Seeding species on in-situ facilities located in forested areas, in particular native herbaceous species, can be beneficial as seeded species can establish rapidly and prevent erosion caused by wind and water (Langdale et al. 1991). Herbaceous species can produce litter which can reduce soil moisture loss from the soil and the decomposing litter can add to soil organic matter (Alberta Environment 2010). Herbaceous species also decrease the amount of exposed soil where weed species may germinate (Alberta Environment 2003) and provide browse for wildlife. Nonetheless, seeded herbaceous species can slow or prevent succession and do not provide comparable wildlife habitat and are typically considered undesirable in a forest setting.

2.1.2 Regulations and Guidelines

EPEA requires land be returned to equivalent land capability; this may require establishing a functioning forest ecosystem which requires herbaceous, shrub and tree species. Seeded species contribute toward the vegetation requirement of EPEA approvals and the *2010 Reclamation Criteria for Wellsite and Associated Facilities for Forest Lands*.

2.2 Application

2.2.1 Implementation Considerations

Prior to seeding a site, it should be determined whether or not seeding will be beneficial. Seeding grasses can reduce the natural infill of native herbaceous, shrub and tree species due to the density of grass and the amount of litter that it can produce. The roots and litter can act as a barrier to seed germination and plant growth (Osko and Glasgow 2010). Seeding may be a suitable option for sites where the risk of erosion is high, there is potential for weed establishment or there is minimal natural infill (i.e. the site is bare of vegetation) or minimal potential for natural infill (Alberta Environment 2003; Government of Alberta 2013a). Seeding of native non-grass species may be beneficial for restoring forest ecosystem function; however, availability of seeds is currently limited or there has been minimal germination from seed in field trials (Naeth and Wilkinson 2003).

2.2.2 Species Selection

Restoration of forest ecosystems heavily relies on the right selection of species used for seeding. Tables 4-15 and 4-22 in the *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region* outline criteria for species selection (Alberta Environment 2010). Sowing seed mixes rather than single species promotes infill and biodiversity (Younkin and Martens 1987). Seeds for certain grass species and legumes, along with the techniques for establishing them, are more readily available than other species (Naeth and Wilkinson 2003).

The proper selection of seeded species ideally leads to a successional pathway allowing similar vegetation to establish on- and off-site (Government of Alberta 2013c). Considerations toward this aim include competitiveness and duration of the species. Competitive native species such as *Calamagrostis canadensis* should not be seeded.

Seed mixes with a variety of species, growth forms and rooting characteristics help mitigate erosion, minimize weed establishment and provide maximum soil stabilization (Alberta Environment 2003).

Cover crops (e.g. annual grasses) may create microsites and establish native species. Seeding cover crops requires knowledge about their appropriate densities and proper management (e.g. litter management) as cover crops may be competitive.

Seeding of spruce and pine has been widely researched for forestry applications. Germination and establishment has had mixed results but recent a review suggests that white spruce can be successfully seeded provided suitable substrates exist (Gartner et al. 2011).

2.2.3 Seeding Rates

Seeding rates may influence the success of the seeding program. Low rates do not allow vegetation to perform their desired role. High rates may prevent natural succession and the establishment of a forest ecosystem. When choosing a seed mix or seeding rate, seed size, weights, germination rate and landscape characteristics should all be considered. Seed weights vary greatly between species and can influence the number of seeds that are sown.

2.2.4 Seeding Methods

Seeds may be sown by broadcast seeding, drill seeding, hydro-seeding and aerial seeding. Drill seeding produces better soil to seed contact and germination rates than broadcast seeding (Alberta Environment 2003). Drill seeding often results in a dense root system that is beneficial for controlling erosion and preventing weed invasion. This dense root system may prevent the infill of native species. Facilities on certain forested landscapes are not suited to drill seeding or there may be access limitation, these areas may be more suited for broadcast seeding or aerial seeding. Aerial seeding or other broadcast seeding methods is also appropriate for large disturbances (e.g. plant sites). Aerial and other broadcast seeding methods are likely the most logistically efficient methods of seeding in-situ exploration sites. Hydro-seeding is typically used on slopes and may benefit a variety of areas given the ability of this method to incorporate fertilizer and other materials into the hydro-seed mix.

2.3 Advantages and Disadvantages

Seeding has many advantages as well as disadvantages for reclaiming in-situ facilities.

Advantages

Seeding has the following advantages:

- Increases soil stability
- Reduces invasion of weeds
- Rapid establishment of vegetation cover
- Increases soil organic matter
- Economical and simple practice

Disadvantages

Seeding has the following disadvantages:

- Seeded grasses may prevent infill of more desirable native species, stagnate succession and reduce growth of woody species
- Can attract wildlife which results in increased damage to vegetation caused by herbivory
- Can support invasive wildlife (e.g. white tailed deer) at the expense of other wildlife species (e.g. caribou)

2.4 Opportunities

The following are opportunities regarding seeding:

- Develop techniques for seeding
- Generate a commercially available supply of non-graminoid native species (e.g. hydro-seeding forbs, shrubs and trees)
- Research seed bed requirements for various species and how to create these seed beds on minimal disturbance sites

- Determine seed treatments and sowing techniques for shrub and tree species
- Develop standardized seeding mixtures and seeding rates that are specific to individual ecosites
- Increase the availability of seeds and seed mixes for native non-competitive grasses (e.g. hairy wild rye, wheat grasses, rice grasses) and sedges typically observed in the boreal forest
- Develop a guide for seeding; seeding should be used for specific species and to achieve a specific purpose and it should not be used uniformly

3.0 TREE AND SHRUB PLANTING

Transplanting tree and shrub seedlings, cuttings or plugs containing trees and shrubs onto in-situ facilities is the most common method for establishing woody forest vegetation. It typically involves obtaining 1 to 2 year old seedlings from a nursery and hand planting them on the facility. Seed may need to be provided to the nursery for growing the seedlings or seedlings can often be obtained from the FMA holder. A variety of woody species can be grown by nurseries. Seedlings must be carefully handled, transported and stored after being removed from the nursery. They must be kept cool and moist and planted as soon as possible after removing them from the nursery. Planted seedlings must be healthy, planted in a suitable microsite, at an appropriate depth and density and backfilled to ensure good root to soil contact to prevent desiccation and dislodging. Planting tree and shrub seedlings requires planning to obtain stock and may require consultation with AESRD (AMEC 2001; Mihajlovich and Wearmouth 2012).

An alternative or supplemental method to planting seedlings to establish woody forest vegetation is to plant tree and shrub cuttings. Several tree and shrub species can establish from cuttings (refer to *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region* (Alberta Environment 2010)). Cuttings are collected from living vegetation (see Propagule Collection Practice). Depending on the species, the cuttings may vary in size and may be rooted or un-rooted whips, softwood cuttings and the cuttings may be taken from the basal or terminal ends of healthy stems (Naeth and Wilkinson 2003). Guidelines for planting are provided by AMEC (2001). Plugs containing trees and shrubs can be transplanted using a similar method to cuttings (MacKenzie and Renkema 2011) but contain multiple species that can be difficult to establish by other means.

3.1 Rationale for Practice

3.1.1 Ecological

Tree and shrub planting on in-situ facilities has numerous ecological benefits. Tree planting can accelerate the establishment of tree canopy cover as natural infill can often be slow or may not occur (Geographic Dynamics Corp 2006; Graf 2009). Trees and shrubs provide cover and browse for wildlife (Oil Sands Vegetation Reclamation Committee 1998), reduce forest fragmentation, encourage infill of native understory species, suppress the growth of weeds and grassy species and facilitate the development of forest floor layers through the input of litter (Macdonald et al. 2012).

3.1.2 Regulations and Guidelines

Tree and shrub planting is beneficial and may be needed to meet regulatory requirements on in-situ facilities. EPEA requires land to be returned to equivalent land capability, this may require establishing a functioning forest of which trees and shrubs are an important component. Furthermore, the facility may have to meet woody stem densities in EPEA approvals and the *2010 Reclamation Criteria for Wellsites and Associated Facilities for Forest Lands* or Alberta forest regeneration standards (e.g. *Alberta Regeneration Standards for the Mineable Oil Sands* (Alberta Environment and Sustainable Resource Development 2013b).

3.2 Application

3.2.1 Implementation Considerations

Prior to deciding to plant trees or shrubs, determining whether or not there is potential for natural infill or recovery of native woody species should be considered; planting can be costly and logistically challenging and naturally established species may have greater survival than planted species (Naeth and Wilkinson 2003). Suitable conditions for the infill of native species promote their establishment. Potential for infill should take into account size of disturbance, intensity of disturbance, surrounding vegetation, vegetation currently growing on the site and microtopography of the site (AMEC 2001; Macyk and Drozdowski 2008). Furthermore, infill of species and survival of planted trees and shrubs is dependent upon soil handling (e.g. if the surface soil was salvaged properly (not admixed) or stockpiled only for a short time (Alberta Environment 2010; MacKenzie 2013)). Common species that naturally infill (at least on oil sands mines) include trembling aspen, balsam poplar, wild raspberry and Saskatoon (Geographic Dynamics Corp. 2006). Planting can still be used to augment natural infill or in instances where the desired woody species is not regenerating.

3.2.2 Species Selection

Selecting species to be planted on a site is important for survival of the planted species and making sure that an equivalent forest cover to the predisturbance forest is obtained. Guidelines for selecting species to be planted for each ecosite are provided in Tables 4-5 to 4-14 in the *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region* (Alberta Environment 2010).

In selecting species, natural successional pathways should be considered. Planting a mixture of early successional and later successional species can be beneficial (Osko and Glasgow 2010; MacDonald et al. 2012). Later successional species could be under-planted at a later date. Suitable pioneer species that have been identified for upland sites include balsam poplar, trembling aspen, white birch, jack pine and lodgepole pine. Later successional species may include white spruce and black spruce (MacDonald et al. 2012). Another approach would be to plant fast-growing nurse trees to help create microsites that may favour the establishment of crop trees (or shrubs) (Burger and Zipper 2002). Poplar has been identified as a valuable nurse species or pioneer species due to its competitiveness with herbaceous species (Osko and Glasgow 2010; NAIT 2011).

Species selection on linear disturbances should take into account the reduced sunlight due to shading (MacFarlane 1999) and later successional species may be more suitable.

3.2.3 Propagule Type

A suitable propagule type or method of establishing tree and shrub species should be selected. Tree and shrub seedlings obtained from a nursery may be containerized or bare root (AMEC 2001) and they may also be different ages or sizes. Small seedlings may be more cost effective but may be less likely to survive compared to larger seedlings (Mihajlovich and Wearmouth 2012). The root characteristics of the seedlings should also be considered (Landhäusser et al. 2012); larger root systems with higher energy reserves are preferred.

Shrubs and some tree species may be propagated by cuttings. Cutting considerations may vary by species and requirement for some species are summarized in *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region* (Alberta Environment 2010).

3.2.4 Planting Density

The density that trees and shrubs are planted can affect canopy closure and tree productivity. Recommended tree planting densities range from 500 stems/ha to 5,000 stems/ha (Alberta Environment 2010) with trees planted 0.5 to 2 metres apart (Government of Alberta 2003; Naeth and Wilkinson 2003). Target densities for shrubs range from 1 to 2 plants/m^2 (Government of Alberta 2003). The *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region* prescribe several planting densities for trees and shrubs for various ecosites (Alberta Environment 2010). For sites to be returned to commercial forestry use the tree planting densities should be consistent with the timber supply analysis for the area (Government of Alberta). More general recommendations include allowing flexibility in plant spacing so that the best microsites can be targeted and comparable to distribution of trees off-site (Alberta Agriculture, Food and Rural Development 2001; Mihajlovich and Wearmouth 2012); areas of high density may provide better cover for wildlife.

Additional trees and shrubs may need to be planted at a later date due to mortality or to promote succession.

3.2.5 Timing

Timing of planting needs to consider the time of year when planting occurs and when in the reclamation process planting is completed. It is typically recommended to plant during the time of year when there is the greatest moisture (Alberta Agriculture, Food and Rural Development 2001; Macyk and Drozdowski 2008). Planting should be avoided in early spring when there is a chance for frost. It is also possible that timing of seedling planting does not significantly affect the survival of planted propagules (Naeth and Wilkinson 2003) and it may be possible to plant in the winter on facilities that are difficult to access (e.g. Winter Wetland Planting Trial). Cuttings likely have greater survival when planted in early spring when they are dormant (Alberta Sustainable Resource Development 2009).

Osko and Glasgow (2010) suggest planting immediately after soil replacement (e.g. conifer seedlings) and prior to herbaceous species establishment. Others recommend establishing a cover species to prevent weed establishment first and then planting trees and shrubs approximately 1 to 3 years later (Government of Alberta 2003; Macyk and Drozdowski 2008). It may also be beneficial to under-plant certain species (e.g. shrubs, later successional species) after a tree canopy has established due to more favourable conditions (MacKenzie and Renkema 2011).

3.2.6 Competition

Competition with trees and shrubs especially from herbaceous species can negatively affect tree survival and growth (AMEC 2001; Naeth and Wilkinson 2003); as well, herbaceous species can result in an increase in herbivory by rodents (Macyk and Drozdowski 2008). Controlling competition from herbaceous species can be done in many ways including site preparation and using an appropriate seed mix or not seeding. The use of herbicides to kill herbaceous plants (Burger and Zipper 2002; Naeth and Wilkinson 2003) or brush mats to reduce competition are also potential methods.

3.3 Advantages and Disadvantages

Planting shrub and trees has many advantages as well as disadvantages for reclaiming in-situ facilities.

Advantages

Tree and shrub planting has the following advantages:

- Establishes tree and shrub species on a facility often faster than allowing for natural infill
- Allows for establishment of a competitive target species
- More predictable results than allowing for natural infill
- Well-developed systems exist for tree planting
- A tree and shrub canopy can facilitate the establishment of native forest species and prevent the establishment of weeds
- Provides cover for wildlife and can reduce the line of site

Disadvantages

Tree and shrub planting has the following disadvantages:

- Technical and logistical challenges in obtaining desired species from nurseries and arranging for shipping and planting
- Unpredictable survival of transplanted seedlings (Alberta Agriculture, Food and Rural Development 2001). A 10% mortality rate was used in the Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region (Alberta Environment 2010); however, it might be much higher. Infill species often have better survival and growth (Naeth and Wilkinson 2003)
- Lack of available plant material
- Due to access limitations, it may not be possible to plant during optimal times

3.4 Opportunities

The following are opportunities regarding the application of tree and shrub planting:

- Develop tools for better predicting when a site should be tree planted
- Determine if earlier or later successional species should be targeted as many exploration disturbances are small and have reduced sunlight
- Investigate the use of nurse trees
- Investigate use of alternate tree planting spacing
- Develop an end land use goal (i.e. commercial forestry, wildlife habitat, recreational use) so that it can be targeted with an appropriate planting prescription

- Undertake long-term monitoring of tree planting projects to increase knowledge and observe trends
- Monitor the sustainability, health, successional pathway and resiliency of sites that have had trees planted
- Determine the most effective density and distribution of planted trees that will result in a sustainable forest that mimics the species composition off-site
- Incorporate successional theory in species selection and use it to determine the success of revegetation (e.g. successional advancement)
- Develop a seed co-op and education or guidance materials
- Develop propagation methods for more shrub species (summarized in Naeth and Wilkinson 2003)
- Look at interactions between surface preparation and growth and establishment of planted trees and shrubs
- Research optimal seedling stock types for reclaimed facilities
- Determine what species should be planted to restore function

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SECTION V - MONITORING AND SITE MAINTENANCE

1.0 EROSION CONTROL

Erosion, the loss of soil due to wind or water, may lead to gullies and channels and cause soil loss that negatively impact use of the in-situ facility for operational purposes, reclamation efforts and surrounding land and water. Facilities most prone to erosion may have steep slopes and exposure to high winds. It is possible to manage erosion through construction practices, engineered products (e.g. silt fences, coconut matting) and bioengineering methods (e.g. revegetation, organic amendments) (Government of Alberta 2013).

1.1 Rationale for Practice

1.1.1 Ecological

Erosion depletes beneficial soil microorganisms, organic matter and nutrients. When managed or controlled improperly, vegetation establishment and cover is potentially reduced (Bell 2004). Erosion may also lead to sediment build-up on adjacent land and in nearby water bodies, creating the potential for aquatic habitat loss and the destruction of aquatic ecosystems (Ghose and Sampurna 2004).

1.1.2 Regulations and Guidelines

EPEA and the *Water Act* regulate erosion prevention. The *2010 Reclamation Criteria for Wellsite and Associated Facilities for Forest Lands* (Alberta Environment and Sustainable Resource Development 2013a) requires that all reclaimed lands must be stable.

1.2 Application

1.2.1 Implementation Considerations

Proper planning, facility placement and construction techniques help minimize the need for erosion control methods. Factors to consider when choosing a facility location to minimize erosion include: topography, slope, soil conditions, exposure to wind and water, proximity to nearby water bodies and sensitive ecosystems, methods reducing soil disturbance and appropriate soil stockpile design and location. Where facilities are necessarily located in erosion prone areas, erosion control methods should be considered in the planning stage.

Other proactive measures that prevent the need for erosion control include leaving the forest understory vegetation or root network intact, leaving organic matter on the soil surface, loosening the soil and leaving the soil surface rough to allow for water infiltration (Alberta Environment and Water 2012). Additionally, constructing drainage channels around the facility to minimize surface runoff (Graf 2009) and proper water crossing construction also prevent the need for future erosion control.

1.2.2 Permanency

Erosion control methods are temporary or permanent. Temporary measures control erosion during periods of increased risk (e.g. high winds, melt water run-off in spring, limited vegetation cover) or while establishing more permanent methods. Permanent control methods are left in place indefinitely (Norman et al. 1997). Facilities built on erosion prone areas would benefit from the immediate application of temporary erosion control methods, even if erosion is not observed.

1.2.3 Methods

Several techniques are available to control or prevent erosion if erosion occurs or will likely occur on a facility.

Vegetative/organic material techniques include: seeding herbaceous species that are fast growing and form a dense root network (Naeth and Wilkinson 2003; Osko and Glasgow 2010), live staking or wattles (cuttings), rolling back organic material over a facility, applying coarse woody material, wood mulch or straw (Alberta Environment and Water 2012). These techniques reduce the rate of run-off, protect the soil surface from wind and water and help hold soil particles in place (Alberta Sustainable Resource Development 2004a).

Mechanical structural techniques include: silt fences, coconut matting, geotextiles, berms, rocks and synthetic chemical tackifiers used to shield the soil from erosive forces, divert water flow or slow its rate of flow (Alberta Sustainable Resource Development 2004a). Some mechanical structures used to control erosion may require removal to obtain reclamation certification or government approval to leave in place.

Landscape modification techniques include: reducing slope angles or creating complex slopes or loose mounds that reduce the flow rate of water and promote infiltration rather than surface run-off (EBA Engineering Consultants 2002).

1.3 Advantages and Disadvantages

Applying erosion control techniques has many advantages as well as disadvantages for reclaiming in-situ facilities.

Advantages

Erosion control techniques have the following advantages:

- Prevents sedimentation in water bodies and on surrounding land
- Stabilizes land
- Minimizes loss of surface soil, organic matter and vegetation propagules needed for revegetation

Disadvantages

Erosion control techniques have the following disadvantages:

- May reduce the establishment of native vegetation
- Certain erosion control products can introduce undesired plant species
- Various products are not biodegradable
- May require routine maintenance
- Costs for materials and installation

1.4 Opportunities

The following are opportunities regarding erosion control:

- Develop specific guidelines for construction and reclamation to help reduce erosion through planning
- Develop species selection (cuttings and seed mix) and planting and seeding rate guidelines specifically for erosion control yet also suitable for establishing native forest vegetation

2.0 WEED CONTROL

Weed control methods are applied to eliminate or control the abundance of plants on in-situ facilities that are designated as prohibited noxious or noxious by the Weed Control Regulation (Government of Alberta 2010). Application of weed control methods may also eliminate or reduce the abundance of plants that compete with targeted species for growth on a site. Weed control methods include manual methods (e.g. hand-picking), mechanical methods, (e.g. mowing or cultivation), chemical methods (e.g. herbicide application) and biological methods (e.g. the introduction of insect pests or fungal disease). Chemical methods are the most commonly used. Weeds may also be controlled by using competing vegetation that can prevent weed establishment or limit its growth.

Most in-situ developments have a weed management plan. Weed management plans are used to address weed inventory, control, education, stakeholder involvement and prevention measures. Weed management plans will provide details on different control methods and types of herbicides used.

2.1 Rationale for Practice

2.1.1 Ecological

With increasing disturbance and traffic around in-situ facilities there is a high chance of weed species introduction and proliferation which increases the need for weed control. Weed control has several ecological benefits. Weeds are typically competitive species and can prevent the establishment of a diverse community of native species or affect their growth (Neville 2003; Alberta Environment 2010) which in turn can affect the function of ecosystems (i.e. providing wildlife habitat and browse and nutrient cycling) and prevent natural succession from occurring (Alberta Sustainable Resource Development 2001; Alberta Environment and Sustainable Resource Development 2010).

2.1.2 Regulations and Guidelines

Prohibited noxious weeds must be eliminated and noxious weeds must be controlled according to the *Weed Control Act* and control is required under several other regulations pertaining to in-situ facilities including the *Public Lands Act*. Furthermore, EPEA approvals require weed control and the *2010 Reclamation Criteria for Wellsite and Associated Facilities for Forest Lands* requires that prohibited noxious weeds are eliminated and the density and distribution of noxious weeds are comparable on-site and off-site.

2.2 Application

2.2.1 Preventative Measures

Reducing the need to implement weed control methods can be done by using preventative measures. Preventative measures can reduce costs and allow for native vegetation to establish more rapidly. Preventative measures include:

- Controlling existing populations to prevent the spread on new disturbances
- Limiting soil disturbance which should reduce sites for weed seed germination (Alberta Agriculture, Food and Rural Development 2001; Alberta Sustainable Resource Development 2001)
- Cleaning equipment prior to arrival on-site (Alberta Sustainable Resource Development 2001; Neville 2003)
- Ensuring all seed mixes and amendments used are free of weeds and have seed certificates (Government of Alberta 2010, Government of Alberta 2013)
- Minimizing exposed or bare soil by seeding a cover crop and implementing interim reclamation immediately in areas that have known weed populations

Historically, wellsites and associated facilities were seeded with agronomic grasses and forbs which can still prevent forest vegetation establishment. Common undesired species include smooth brome, Kentucky blue grass, timothy, creeping red fescue, alsike clover, red clover, alfalfa and sweet clover. Controlling non-native species on older reclaimed sites will allow for forest establishment on them and prevent further proliferation of these species.

2.2.2 Control Methods

Weed population size and type, site conditions and desired end plant community must be considered when selecting a control method to ensure that the weeds are controlled and there is not a detrimental effect on desired vegetation (Alberta Agriculture, Food and Rural Development 2001). Common control methods include manual control, mechanical control, chemical control and cultural control. Using an integrated weed management approach is suggested as being the most effective control method and applying it for several years may be required (Alberta Agriculture, Food and Rural Development 2001). Applying weed control methods to weed populations as quickly as possible after establishment will help limit their distribution (Alberta Sustainable Resource Development 2001). Details on species specific control methods are available from Alberta Agriculture and Rural Development (note: many of these control methods apply to agriculture systems and not forest ecosystems). Additional information on recommended practices for weed control methods are summarized in the following documents: *Weed Management in Forestry Operations* (Alberta Sustainable Resource Development 2001) and *Weeds on Industrial Development Sites* (Alberta Environment 2003a).

Manual weed control typically refers to hand-picking. Hand-picking is best suited for small populations of annual or biennial weeds or prompt response to newly establishing populations. Hand-picking should be done prior to seed set, if done after seed set all plants should be bagged and disposed of off-site. For perennial weeds with deep roots or extensive roots; control through hand-picking may be difficult as the entire root system will likely not be removed; however, if continuous picking is done, it may eventually result in deterioration of the root system (Alberta Sustainable Resource Development 2001).

Mechanical weed control refers to cultivation or mowing. Cultivation may be used to reduce aggressive and non-native grass species but is typically not used to eliminate weed species in forested areas. Mowing is more commonly used to control weed species; however, it is typically not employed on sites where native forest vegetation is targeted as it is non-selective and affects all vegetation on the site. Nonetheless, mowing can be an effective control method for perennial species; it should be done prior to seed set and may need to be completed several times to deplete the resources within the weeds root system (AMEC 2001; Alberta Sustainable Resource Development 2001). Mowing may be a suitable option where there is a large weed population and a high risk of erosion as the root system is maintained for a period of time allowing for soil stabilization while other species are establishing (Alberta Sustainable Resource Development 2001).

Chemical weed control involves the application of herbicides. Herbicides must be applied in accordance with the *Environmental Code of Practice for Pesticides, Pesticide Regulation* and the *Pesticide Sales, Handling, Use and Application Regulation*. Herbicide application must take into account species, physiology, density and distribution as well as the existing vegetation and desired vegetation on-site. The weed characteristics will help dictate the appropriate herbicide type and application method (spot-spraying, site-wide application, selective control – broad leaf or complete control) (Alberta Environment 2003b). Use of persistent residual herbicides should be avoided because these herbicides can accumulate in the soil and prevent growth of desirable species.

Cultural weed control methods include seeding and planting competitive species or encouraging the growth of existing species on-site to out-compete weed species. Herbaceous species or a cover crop can be seeded and trees and shrubs can be planted to prevent the establishment of weeds (Osko and Glasgow 2010). A dense cover of herbaceous species is thought to be the most effective method to reduce weed population sizes (Naeth and Wilkinson 2003). Planting fast growing woody species at a high density can help establish a canopy cover that may shade-out weed species. Using species with a variety of different growth forms will be most beneficial in out-competing weed species. Furthermore, mulches and mats can be used to cover exposed soil to prevent weed establishment or to act as a barrier to weed growth and the spread of weeds.

Biological weed control methods involve the introduction of insects, arthropods, fungal diseases and other weed pests to attack and kill a targeted species (Alberta Sustainable Resource Development 2001; Government of Saskatchewan 2004). While not a common control method it has been employed in agriculture settings and has the potential to be a viable control method. Applying it in forest ecosystems may have several ecological implications that must be considered.

Stockpiling soil is known to rapidly reduce seed viability if seeds are buried below the surface (MacKenzie 2013). Weed seed viability could be reduced or eliminated if the soil containing the weed seeds is stockpiled and weeds are controlled on the surface. Although stockpiling has not been considered a method for controlling weeds, if implemented correctly, stockpiling could help control the spread of future weed populations by reducing weed seed viability. This method may be most effective if there is a high population of weed seeds in the soil. The effectiveness of reducing seed viability will depend on species seed characteristics, storage time, burial depth, soil organic matter content and soil moisture content.

2.2.3 Monitoring

Monitoring is an important component of a weed control program. Monitoring allows for weeds to be detected prior to widespread establishment so that weed control methods can be promptly implemented (Oil Sands Vegetation Reclamation Committee 1998; Neville 2003; Alberta Environment 2003a). Pre-disturbance assessment can be valuable in documenting existing weed levels, allowing the opportunity to alert the land manager to establish baseline and target control levels. Pre-reclamation monitoring can also be important to detect potential weed problems that may have to be dealt with (i.e. stockpiles are infested with weeds or nearby area has a large weed population).

A weed management program is only as good as the frequency and time frame weeds are monitored. Annual monitoring on all disturbed sites for weed establishment and weed control effectiveness until weeds are considered controlled or eliminated would help identify the majority of weed populations and help identify which control methods are effective in a particular in-situ development area. Having all field personnel trained in weed identification of common problem weeds can help assist in identifying weeds throughout the year.

2.3 Advantages and Disadvantages

Current weed control programs have many advantages as well as disadvantages for use on active and reclaimed in-situ facilities.

Advantages

Current weed control programs have the following advantages:

- Typically successful in ensuring compliance with relevant legislation and approvals
- Effectively reduce weed population sizes
- Encourages establishment of desired plant communities
- May protect native species diversity

Disadvantages

Current weed control programs have the following disadvantages:

- High costs associated with weed control, especially for remote sites with limited access
- Weed control may affect desirable plant species and alter vegetation composition, structure and successional patterns (Alberta Sustainable Resource Development 2004b)
- Public concerns about herbicide use (Lautenschlager and Sullivan 2002)
- Moss and lichen abundance and species richness decreases after herbicide treatments (Newmaster et al. 1999; Lautenschlager and Sullivan 2002)

2.4 Opportunities

The following are opportunities regarding the application of weed control programs:

- Limit threats to biodiversity through effective control
- Consider the role of surface soil/subsoil stockpile design in making weed seeds less viable

- Better define what it means to have a controlled weed population in a forest ecosystem and if a small weed population can have a detrimental effect on biodiversity
- Use fast growing native shrub and tree species to outcompete weed species, including planting at high densities
- Research the efficiencies, costs and accuracy of unmanned aerial vehicles for monitoring weeds and weed control effectiveness
- Develop herbicide application guidelines for forest ecosystems
- Develop a cooperative weed management group to share resources and track weed control costs, magnitude of weed control programs and effectiveness of the programs
- Train all field personnel in weed identification and awareness (e.g. make a mandatory portion of on-site training dedicated to identification of common weeds)
- Determine if the costs equal the benefits of using “targeted” or species specific herbicides which are currently considered expensive

3.0 FERTILIZATION

Fertilization of in-situ facilities increases vegetation growth or seed germination and off-sets a nutrient deficiency in the soil that reduces vegetation growth or establishment. Fertilizers can include organic materials (e.g. compost) and mineral materials. Fertilization in forest ecosystems is not a common practice and is generally discouraged as it may result in the growth of non-native species or allow competitive early successional species to dominate (Alberta Sustainable Resource Development 2004a, 2008; Alberta Environment and Water 2012). Mineral soils low in organic matter and requiring erosion control are most likely to receive fertilizer applications. Soil and plant tissue analyses can be used to tailor fertilizer requirements and a general prescription is not recommended.

3.1 Rationale for Practice

3.1.1 Ecological

Fertilization improves the growth rate of vegetation and encourages vegetation establishment on substrates with low nutrient concentrations.

3.1.2 Regulations and Guidelines

Fertilization is not a regulatory requirement and is typically discouraged in forest settings (Alberta Sustainable Resource Development 2004a, 2008). Stressed vegetation and nutrient deficient communities may require fertilization to meet requirements in EPEA approvals and the *2010 Reclamation Criteria for Wellsite and Associated Facilities for Forest Lands*. Additionally, use of amendments such as fertilizers can result in a regulatory delay in achieving reclamation certification.

3.2 Rationale for Practice

3.2.1 Implementation Considerations

Past and current site moisture and nutrient regimes should be considered before applying fertilizer as some vegetation species are adapted to low nutrient conditions. Research is underway to assess the impact of fertilization on plant community establishment on upland surface soils. As more upland surface soils become used in reclamation, soil and plant nutrient analysis continue to verify whether or not fertilization is required.

While the use of fertilizer is generally not recommended, it may beneficial to apply fertilizer when:

- Attempting to establish native seedlings on sandy soils as these may benefit by applying phosphorus (Alberta Sustainable Resource Development 2004a)
- Establishing cover crops (Alberta Environment and Water 2012)
- Establishing vegetation on facilities where there is no surface soil (Osko and Glasgow 2010)
- Establishing vegetation on exposed peat as it may benefit from phosphorus application (Quinty and Rochefort 2003; Alberta Environment 2008)
- On erosion prone areas where rapid establishment of vegetation is needed (Burger and Zipper 2002)
- There are obvious nutrient deficiencies in plants

Native nitrogen fixing plants provide an alternative to fertilizers (Alberta Sustainable Resource Development 2004a), as do amendments such as LFH and woody material. Fertilizer applications may require approval from the regulator.

3.2.2 Type, Frequency and Rate

When applying fertilizer, determine the application rate and fertilizer type (i.e. NPKS 14-14-14-5) by collecting soils and plant tissue for nutrient analysis. These samples illuminate nutrient deficiencies in the plant and/or soil and therefore the rate and type of fertilizer to apply (Alberta Sustainable Resource Development 2004a; Alberta Environment and Water 2012). This method helps ensure the area is not over-fertilized which may lead to run-off impacting water and the potential establishment of undesired species. Currently, nutrient requirements are available for commercial forestry trees but not understory species. Forestry grade fertilizer is preferable to agriculture grade fertilizer due to coarser particles and slower release rates (Government of British Columbia 1995). Mineral fertilizer as opposed to an organic fertilizer allows for one to tailor the nutrient blend specific to the site.

3.2.3 Methods and Timing

There are various methods for applying fertilizer. Access restrictions and the current state of vegetation on the site will likely dictate the chosen method. Application methods include: broadcasting from the ground or aerially or incorporating into the soil and applying as an inoculant to planted trees and shrubs (Alberta Environment and Water 2012). Seasons and vegetation stages will affect the application method chosen. It is best to apply fertilizer in the fall or early spring when temperatures are cooler (Government of British Columbia 1995; Alberta Environment and Water 2012). Applying fertilizer after the establishment of woody vegetation on forested sites is best so that fertilization does not increase herbaceous growth and prevent woody vegetation infill (Alberta Environment and Water 2012).

3.3 Advantages and Disadvantages

Fertilization has many advantages as well as disadvantages for reclaiming in-situ facilities.

Advantages

Fertilization has the following advantages:

- Increased growth rate of vegetation
- Encourage vegetation establishment
- Allow for vegetation establishment and growth on less suitable substrates

Disadvantages

Fertilization has the following disadvantages:

- Result in establishment of undesired species and prevent growth of desired species
- Costly and may not significantly benefit overall vegetation establishment and growth
- Run-off can affect water quality

3.4 Opportunities

The following are opportunities regarding fertilization:

- Develop clear fertilization guidelines and research method to target only desired vegetation
- Develop alternative fertilization techniques – e.g. inoculation
- Determine economic and reclamation benefits

4.0 FOREST STAND MANAGEMENT/STAND TENDING

Forest stand management or stand tending on in-situ facilities involves the application of silviculture-related practices to the developing forest after the establishment of woody species. Practices include identification and retention of desirable stand attributes (e.g. seed trees, rare plant communities), stem thinning through hand-felling until a desired density remains, decreasing the cover of understory species (brushing, applying a herbicide or tilling the soil), fertilizing to improve tree growth, under-planting tree and or shrub species to increase diversity and establish commercial/crop tree species and infill or fill planting to establish species on areas with poor woody species growth.

4.1 Rationale for Practice

4.1.1 Ecological

Depending on land management goals, forest stand management/stand tending can be used to promote quicker successional advancement, increase woody species (tree) growth or create a full and diverse canopy cover that improves understory vegetation establishment.

4.1.2 Regulations and Guidelines

Regulations may require forest stand management/stand tending for in-situ oil sands extraction facilities on forested land. The re-establishment of a functioning forest and a minimum woody stem density may be required by EPEA approvals, the *2010 Reclamation Criteria for Wellsite and Associated Facilities for Forest Lands* (Alberta Environment and Sustainable Resource Development 2013a) or the Alberta regeneration standards (e.g. *Alberta Regeneration Standards for the Mineable Oil Sands* (Alberta Environment and Sustainable Resource Development 2013b)).

4.2 Application

4.2.1 Implementation Considerations

Proper construction, reclamation and revegetation of a site may eliminate any requirement for forest stand management/stand tending. Vegetation establishing on a facility may require close monitoring to determine if a forest stand management technique is necessary. The potentially high cost of forest stand management at times is unnecessary for meeting site-specific reclamation criteria or the restoration of a functioning ecosystem.

4.2.2 Attribute Retention

Retention of seed trees or patches of trees for wildlife cover and understory protection is a common practice in commercial forestry. Seed trees provide a propagule source to help regenerate trees on the area after logging. Other areas that are not logged can be seed sources for understory species.

For in-situ disturbances, facilities could be located so that they are near potential seed sources or the potential seed sources could be retained along the perimeter of the facility.

4.2.2 Thinning and Brushing

Thinning (pre-commercial and commercial) is often applied to stands used for commercial forestry. Thinning reduces the density of trees and therefore reduces competition. Thinning improves forest growth and stand development (Alberta Sustainable Resource Development 2006) and is typically applied to young and dense stands approximately 10 to 15 years of age.

On reclaimed facilities, naturally established tree densities and planted stems typically have a low density (<5,000 stems/ha) and thinning is likely not required. On minimally disturbed sites, natural establishment may lead to high densities but natural thinning may occur. Thinning dominant, undesirable woody species may benefit the establishment of desired species and promote end land use goals (e.g. high density willows on a site may crowd out desired white spruce). Nurse species may also require thinning to allow for the growth of a crop species. Thinning could also be conducted in the area around the facility to improve light or temperature conditions on the facility as well as to stimulate propagule production in the surrounding area (i.e. creating canopy gaps in a spruce dominated forest stand with a moss understory to facilitate the establishment of a more diverse understory and propagule source).

Brushing typically involves the removal of competitive woody understory species and secondary tree regeneration. A modified approach to brushing may benefit reclaimed facilities. Brushing on reclaimed facilities would remove competitive herbaceous species and undesired woody species. Brushing is labour intensive and may also affect desired vegetation; therefore, the decision to brush requires close consideration.

4.2.3 Under-Planting

Under-planting later successional, shade tolerant species and crop tree species under an early successional nurse species improves the survival and growth of the crop tree species (Lieffers and Grover 2004). Moreover, the initial establishment of fast-growing, deciduous pioneer/nurse species may lead to faster crown closure and create suitable conditions for the development of a native vegetation understory and wildlife habitat. Deciduous species can naturally establish into a crop species through seed dispersion and planting may not be required.

4.2.4 Infill Planting and Fill Planting

Facilities with poor initial woody plant establishment may require infill/fill planting. Determining the cause of poor initial establishment prior to infill planting proactively mitigates limitations. Limitations include soil characteristics (physical and chemical) and competing vegetation as well as light and climate conditions.

4.3 Advantages and Disadvantages

Applying forest stand management/stand tending has many advantages as well as disadvantages for reclaiming in-situ facilities.

Advantages

Applying forest stand management/stand tending has the following advantages:

- Improved tree growth and appropriate species composition
- Improved abundance and diversity of propagule sources
- Increase tree canopy and understory diversity
- Ensure canopy cover across the facility

Disadvantages

Applying forest stand management/stand tending has the following disadvantages:

- Can damage existing vegetation or lead to increased damage to remaining vegetation (i.e. increased sunlight or forest exposure to remaining vegetation)
- Improves tree growth but may not improve understory growth and establishment
- May not benefit restoration of a functioning ecosystem or establishment of other goals such as wildlife habitat

4.4 Opportunities

The following are opportunities regarding forest stand management/stand tending:

- Identify how forest stand management benefits revegetation of in-situ facilities
- Develop forest stand management techniques specific to in-situ facilities (e.g. how to adapt knowledge from the forest industry) based on stand and eco-site type
- Develop methods to manage forest stands on a landscape scale (i.e. location of in-situ and surrounding areas) to improve restoration on in-situ facilities and manage wildlife habitat and other land uses (e.g. Integrated land use)

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SECTION VI - ASSESSMENT

1.0 RECLAMATION ASSESSMENT

Reclamation assessments collect data on the landscape, soil and vegetation parameters of an in-situ facility once the vegetation establishes to determine whether reclamation achieves equivalent land capability. Reclamation certification requires reclamation assessments. Oil sands exploration programs use the Coal and Oil Sands Exploration Reclamation Requirements to guide assessment (Alberta Sustainable Resource Development 2010). In-situ facilities regulated under EPEA approvals do not have a set requirement for determining reclamation success. Instead, each operator submits a proposed reclamation monitoring program. Existing wellsite reclamation criteria provide a conceptual framework for determining reclamation success.

Criteria outline whether assessed parameters on facilities meet reclamation certification standards. Adaptive management addresses facility deficiencies should the assessed parameters on the facility fail to meet the criteria. Assessment of the landscape, vegetation and soil parameters occur independently at separate times or together at once. Criteria require landscape, vegetation and soil parameter assessments within less than one to two years after reclamation to determine the necessity of follow-up measures.

1.1 Rationale for Practice

1.1.1 Ecological

Reclamation assessments determine whether the ecological integrity of a reclaimed facility is comparable to adjacent land or pre-disturbance conditions. Reclamation assessments are an important step toward meeting end land use objectives and contribute to the establishment of healthy ecosystems.

1.1.2 Regulations and Guidelines

Reclamation assessments are required to obtain reclamation certificates and determine whether sites meet EPEA requirements. Reclamation assessments are to be completed by qualified personnel. Sites that do not meet reclamation criteria cannot receive reclamation certification and the lease owner remains liable for the facility. Requirements for the reclamation assessment vary by facility type and land use. The following guidelines outline requirements for forested land: the *2010 Reclamation Criteria for Forested Lands* (Alberta Environment and Sustainable Resource Development 2013), (including the *Coal and Oil Sands Exploration Reclamation Requirements*), *Land Capability Classification System for Forest Ecosystems in the Oil Sands, 3rd Edition* (Alberta Environment 2006) and the *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region, 2nd Edition* (Alberta Environment 2010). Regulators are currently updating peatland site criteria found in the *Reclamation Criteria for Wellsites and Associated Facilities – 1995 Update* (Alberta Environment 1995).

1.2 Rationale for Practice

1.2.1 Implementation Considerations

The current reclamation criteria for upland forests utilize parameters based on current knowledge to determine whether facilities will become self-sustaining forests. The criteria likely accounts for the contribution from adjacent seed sources and propagule inputs from newly established vegetation toward mitigating future (minimal) disturbances. It is less likely the criteria accounts for the abundance and composition of the propagule bank within reclaimed soils and the size of the disturbance. Although larger facilities may meet current reclamation requirements, larger facilities with a limited propagule bank or a propagule bank composed of less than desirable species are less likely to develop into a desired forest after disturbance, unless specific management tools, such as direct placement of LFH or tree planting, are implemented.

1.2.2 Time and Frequency

It may be beneficial to conduct reclamation assessments in stages (interim) to note and quickly correct deficiencies. A landscape and soil assessment completed within the year soil is replaced is a proactive approach to mitigate deficiencies. Vegetation monitoring is essential to determine what management actions, if any, are required. Monitoring vegetation on permanent plots is rare. Frequent monitoring using a standard assessment approach utilizing the permanent plots may provide accurate trends and data for various parameters such as cover, stem densities, plant height and erosion, leading to better management decisions (e.g. tree planting density, seeding rates, natural recovery).

1.3 Advantages and Disadvantages

Current reclamation assessment methods have advantages as well as disadvantages for assessing in-situ facilities.

Advantages

Reclamation assessments have the following advantages:

- Determine if a facility meets government criteria
- Helps guide further work that may be required to meet government criteria

Disadvantages

Reclamation assessments have the following disadvantages:

- Current reclamation criteria used to evaluate a facility reclamation success may not determine if a functioning forest ecosystem has been re-established and if successional advancement will occur

1.4 Opportunities

The following are opportunities regarding reclamation assessments:

- Determine if current reclamation criteria will result in sites becoming functioning forest ecosystems and improving or developing a new industry standard if the current criteria are found to be deficient
- Determine if there should be different criteria for vegetation parameters for facilities reclaimed using direct placed soil or that have been minimally disturbed versus facilities reclaimed using stockpiled soil
- Develop and implement a reclamation status tracking system similar to that which exists for oil sands mines to improve public understanding of development and reclamation status
- Establish reclamation requirements for seismic lines
- Determine what successful reclamation is for caribou ranges
- Determine parameters and criteria for successful peatland reclamation or restoration
- Link reclamation and restoration goals with climate change and adaptive management
- Develop assessment methods for borrow pits
- Manage reclamation assessment data so that they can be stored, shared and analyzed

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APPENDIX A: COSIA AND FRIENDS OSE BEST PRACTICES 2013 FALL TOUR TOPIC SUMMARY

1.0 INTRODUCTION

A fall field tour of reclaimed oil sands exploration (OSE) facilities was held between September 17, 2013 and September 18, 2013 in the Conklin, Alberta area. Attendees were provided with a dialogue primer which was a summary of the practices contained within the *Reclamation and Restoration Practices and Opportunities Compilation* document prepared by Navus Environmental Inc. The field tour provided an opportunity to view current OSE reclamation practices and their outcomes as well as discuss the contents of the dialogue primer.

2.0 DISCUSSION TOPICS

The following provides of summary of the discussion topics and themes observed during the field tour as well as points for further consideration and discussion. The summary was prepared by Anna Dabros of Natural Resources Canada.

- Better knowledge exchange and integration of ecological knowledge with operational practices could help in optimization of [in-situ] oil sand operations in terms of minimizing the disturbance and thus, the need for reclamation. Ecosystem Management Emulating Natural Disturbance (EMEND) (e.g. http://www.emendproject.org/) research could be valuable in that respect.
- How to connect and apply silvicultural knowledge and forest logging knowledge and practices to reclamation? How to learn from its long experience, and avoid potentially making similar mistakes? In which situations are logging practices comparable to in-situ disturbances requiring reclamation? Oil Exploration Sites (OSE) are probably closer to logging sites than fully stripped, soil-compacted sites or old legacy sites (these may have a closer resemblance to logging access roads).
- There is a potential for transferring the existing scientific (ecological) knowledge and applying it to reclamation. How to do it? Where to begin? If reclamation starting points are different, it is difficult to provide general guidelines of how to proceed with reclamation, and how the existing CFS research and knowledge can be applied to facilitate reclamation efforts.
- Pre-disturbance assessment: regulations around what exactly should be recorded prior to disturbance. Presence and abundance of different species of vegetation, mosses and lichens, soil properties – type, pH, nutrient levels, topography, water table level etc. Using Field Guide to Ecosites? This could be crucial for re-establishing the pre-disturbance habitat.
- Edge effects and pre-disturbance planning: could be minimized with thoughtful choice of locations of operational sites. In that respect, pre-disturbance planning is crucial. Existing ecological knowledge could help in determining where the operational sites should be located to minimize disturbance effects of habitats on a larger scale. Tree retention levels and disturbance shapes could be determined based on maximization of habitat resilience. A consideration could be given to combining [in-situ] oil sand operations with harvesting activities, i.e. “shooting two birds with one stone”, or locating [in-situ] oil sand operations on already disturbed (harvested or burned) sites. Also, better coordination among oil sand companies may further optimize operation locations and thus minimize disturbance footprint.
- The effects of linear disturbances on wildlife in general (seismic lines, access roads etc.). Caribou habitat, wolf populations were mentioned briefly. What about other, less visible, non-charismatic species?
- Habitat fragmentation: forests surrounding disturbance patches are often so fragmented and affected by edge effects that they may likely not support the same biodiversity and abundance of insects, arthropods, herbs, forbs, and songbirds etc. as intact forests. If these are absent, or if their populations are diminished in the forests

surrounding disturbance patches, there is little chance that they will recolonize the recovering disturbance patches and thus lead to re-establishment of a healthy forest ecosystem. That is, the potential for recolonization is diminished, if the source is affected. Current reclamation practices seem to focus largely on re-establishment of trees and shrubs. While these are an essential part of any forest, forest ecosystem is much more complex than that. It is an organism functioning through multiple and complex interactions of biotic and abiotic factors, all of which need to be taken into consideration.

- Invasive species: while weed problems were often addressed and considered, potential invasion of other species was not. [In-situ] oil sand disturbances involve development of complex infrastructures, including access roads, campsites etc. Transportation of equipment and other construction material etc. creates potential for introducing non-native and possibly invasive species of not only plants, but also insects, pathogens etc. In particular, introduction of earthworms may have profound effects on soil composition, structure, texture, and by extension, other insect and plant species.
- More holistic approach: Oil sand operations should be considered on per-patch disturbance scale, but also on a landscape scale. More holistic and thus multidisciplinary approach is needed: silviculture, ecology, mycology, entomology, hydrology, ornithology, meteorology, pedology, etc. are some of the main disciplines that could to inform reclamation practices.
- Ecosystem resilience: i.e. how quickly can ecosystem ‘bounce back’ to pre-disturbance state? The University of Alberta held a workshop on resilience and reclamation. This knowledge could be useful in reclamation practices in terms of re-establishing functioning ecosystems. See OSRIN resiliency reports - http://hdl.handle.net/10402/era.30360 and http://hdl.handle.net/10402/era.31714 .
- Underground disturbance at in-situ sites: in-situ infrastructure is left underground, even at fully reclaimed sites (e.g. pipes from Steam-Assisted Gravity Drainage (SAG-D) operations). What are the effects of this on soil structure, hydrology, water table, potential soil and water contamination, root systems, microbial activity, etc.). What effect does injecting steam underground have on soil properties and the organisms associated with it? What effects does underground disturbance have on freezing/thawing cycles?
- Climate change: planning for the future. Re-establishment of a given ecosystem should be put in the larger context of continuously changing climatic trends. Could the concept of assisted migration be useful in planning what to species to plant on a given site when reclaiming a site? (refer to Forestry Chronicle, vol. 87, 2011, special issue on assisted migration).

APPENDIX B: IN-SITU OIL SANDS EXTRACTION: RECLAMATION ISSUES

Natural Resources Canada conducted interviews of several key industry members, suppliers, academic researchers and consultants in the fall of 2013 to gather opinions on the key issues currently surrounding reclamation of facilities associated with oil and gas or oil sands extraction. Excerpts of the reclamation issues, summarized by Anna Dabros of Natural Resources Canada are presented in the following section.

Planning and Goals

- Lack of continuity through site selection, development, and reclamation processes. Involving geologists, field scout personnel, construction group and reclamation group early in the planning process can be beneficial to the project outcome, and potentially save dollars and time… The use of LiDAR should be promoted as a scouting tool
- Lack of assessment prior to disturbance. Sites need to be assessed for reclamation potential. Many of the sites …have been aggressively addressed by planting the entire site early. Was this necessary on all sites when considering the success of the natural regeneration? The failure to assess can also result in creation of site conditions following disturbance that can make it very difficult to achieve the current reclamation criteria
- Site selection…select sites to eliminate or minimize cut and fill construction and to avoid extremely wet or extremely dry soils, where surface disturbance is likely [required]
- Lack of realistic planning, commitment and knowledge transfer from the PDA stage to final reclamation
- One size fits all approach combined with lack of follow up after reclamation. This is changing, but for a long time, practitioners would come across a practice that worked well in a given situation and then apply it everywhere assuming it would work well in all situations without following up to confirm later
- Lack of holistic planning and communication…Industry and regulators are often fixated on specific disturbances while ignoring the bigger environmental picture. In addition, within energy sector corporations, there seems to be little holistic management in terms of how they operate
- A lack of clear, robust higher level plans for the forest landscape on a regional basis. Without a clearly defined higher level plans, lower level plans and site level plans have nothing to align with. As a result, we get the lack of clear conclusions on the most appropriate guidelines and best practices at the site level (i.e. are we reclaiming for maximum biodiversity on the site? similar ecological function to previous? sustained timber yield? caribou habitat?
- Lack of clarity on the goal(s) of reclamation: What is the goal of reclamation? Biodiversity (slower?) or forest cover (faster) ...and are they mutually exclusive?
- Spatial bias in assessment of impact and in management decisions. There are many analysis, models, metrics, etc. out there that are used to measure and judge the impact of oil sands development. By and large, all of these are biased by an emphasis only on hectares disturbed, hectares reclaimed. This 'binary' approach misses the perhaps the most important point, that it is the ecological function of lands that support the key forest values (biodiversity, resilience, fiber production, water and air quality, etc.) expressed cumulatively at the landscape scale
- Conflicting objectives…caribou habitat or biodiversity or fastest growth to reduce line of sight
- Lack of clarity on the reason(s) for reclamation: Why are we reclaiming? Is Caribou the only reason? Others? What is the ethical [reason]? Political [reason] (government wants to appease aboriginal demands relating to caribou)? and business [reasons] (need to go beyond compliance to support our need for social license/market access)?

Communication and Collaboration

- Creating an environment of innovation is important. If we keep doing the same things "by the book" as per prevailing regulations – we are unlikely to advance/accelerate best management practices or improve our environmental performance. Most people are working to implement beyond compliance but are sometimes hesitant due to lack of confirmation from the regulator that it'll be accepted
- Better industry collaboration and sharing to avoid duplication of effort and duplication of implementing practices that do not work. These tours and our COSIA project are a good step in this direction and much better than everyone working in isolation on the same issues
- [Improved] knowledge network information sharing…In other parts of Canada [people are] working on issues that, given some thought, may provide engaging or avoidance learning's that we may all benefit from. Littoral Zones in wetland areas was a topic of interest…how mining operations in Ontario and Quebec are working on it
- Avoidance of the research re-do. Essentially, sometimes research appears 're-invented, slightly modified or re-dressed'
- Corporate willingness to adopt new practices, make changes, move away from the tried and true
- Compendium of construction techniques. Every company seems to do things slightly differently. The minor differences in approach may be the key to successful reclamation. Techniques that appear to successfully promote a more natural early successional response should be catalogued for general review by any oil sands company. This is especially true for mesic, very nutritious sites, where early establishment of difficult to control highly competitive species (e.g. Calamagrostis) is likely. What construction and reclamation techniques are most successful on these sites?
- Streamlining and improving communication/mindset between the reclamation planners and the construction crews…Improvements have been happening recently and [it is] where the major innovation will take place e.g. drilling rigs designed to drill on a slope
- Internal and external communication amongst construction and reclamation groups to enable consistent long term performance
- Communications…we understand best practices for reclamation, but are they getting through to the group that constructs? …Companies are structured in a way that keeps these activities separate
- Education…How do we best communicate evolving best practices within our companies and between our companies or even to NGO's

Regulatory

- Alignment of policies to encourage/incent behavior in a consistent direction (e.g. caribou are thought to be sensitive to disturbance and fragmentation of habitat). A habitat fragmentation target of 65% intact was set by federal government, but the Government of Alberta policy requires lease holders to "drill at least one section every five years" (approximately) essentially guaranteeing that far future development areas are disturbed perpetually during the life of the surface lease rather than allowing some areas of the lease to be managed purely for habitat as a "refugia" while other parts of the lease are developed
- Inconsistent regulatory system on the forest landscape. The regulations for reclamation/reforestation on disturbed forest vary widely between i) forest industry, ii) EPEA approved oil and gas project lands, and iii) oil and gas exploration…Each of these would have a totally distinct regulatory process and resultant, highly variable reforestation practice, and resultant great differences in outcomes on the site (we saw a partial example of this at our second last site). How can this be possible in a properly managed landscape?

- Regulatory Direction. The in-situ region appears to be being held to the same criteria that were designed for a different purpose with a different set of practices and disturbances
- Regulatory acceptance or encouragement of [industry] initiatives rather than "go ahead, looks good" but no guarantee of acceptance in the future. An example of this is [industry's] caribou recovery strategy and the lack of response from provincial and federal regulators
- Clarity and education amongst the front line government employees who enforce the regulations. They can be focused on a particular practice to meet a short term management objective, for example, burning all woody material because it creates fire hazards, rather than taking the long view in that we understand how woody material is useful for wildlife habitat, access management and in use as an aid in faster reclamation, and there are ways of dealing with woody materials so that it does not pose a fire risk and the resource is not lost
- Lack of trust between project proponents and regulators. Not always the case either, but regulators may not trust proponents to do what is right for the resource, which discourages proponents from innovating. On the other hand, proponents are reluctant to innovate or push envelopes for fear regulators will hold them to ever increasing standards. In this way, both sides push for status quo

Revegetation

- Limited understanding among practitioners of adaptive genetic variation within species used in reclamation and its importance, and limited information on adaptive genetic variation for many species used in reclamation.…If the appropriate DNA isn't available and matched to the reclamation site, all other best reclamation practices can be a waste of resources and effort
- Limited access to suitable adapted sources of seed and propagules for use in reclamation
- [Use of] other plant species that may provide ecological benefit - *Equisetum* spp. and *Geum* spp.
- Vegetative resource availability…having seeds or cuttings in sufficient quantities from the appropriate area. The Oil Sands Vegetation Cooperative is one entity addressing this [issue]
- Limiting weed spread. Is there really anything that can be done?
- Availability of abundant, diverse mix of native propagules for revegetating intensively disturbed sites. There are few shrub species that are commercially available and shrubs, like aspen are quite expensive to purchase relative to cheaper species such as pine, spruce and alder…Coniferous trees [are] being planted on larger intensely disturbed sites and the problem with this method is conifers do not recycle the nutrients as fast as deciduous trees leaving the site stagnant for a while compared to sites planted with deciduous plants. [Exploration] and short term disturbances [may be] relatively easy to reclaim; however, the more intense disturbances that are longer term are difficult simply due to the fact there is not an abundance of propagules for a diverse array of native boreal species
- Trembling aspen are under-utilized as a way to capture a site with canopy closure, improve resiliency and reduce invasion chances
- Structural layering and diversity are not in the forefront of reclamation yet but they set the stage for "with the same function" a goal of current practices
- Vegetation management…companies have regulatory obligations to spray for weeds (which may or may not truly hinder the establishment of native plants) yet are being told to reclaim a native plant community. Unless they are strictly spot-spraying or can get away with a single herbicide application (which is unusual), doing both these things is contrary
- Lack of information in terms of alternative methods to herbicide spraying that might be employed (e.g. cover crop use)

- Access to many native plant species...currently there is only the oil sands seed coop in Northeastern Alberta where some oil and gas companies have combined their efforts in seed collection. Otherwise, companies are left to collect seeds independently if they want to establish anything but commercial tree species
- Establish a shrub seed/seedling source for reclamation companies to establish the three layers of vegetation

Wetlands

- Wetlands...[there is not] a very good understanding of how to reclaim these or minimize the effects of our activities on them
- Wetland Construction and Design. Relative to terrestrial systems, natural wetland systems are difficult to restore after disturbance, especially into a self-sustaining fen or bog. Constructed wetland systems are also important as they will treat process affected water before release. Reclaimed and constructed wetlands need more focused effort
- Removal of pads and reclamation of pads left in place (for wellsite and access roads). There is a huge liability with the development of pads if these cannot be reclaimed to diverse self-sustaining boreal forests. Additionally, their impacts on the hydrology of adjacent peatlands is not well understood
- Peatlands…we simply can’t restore them on a large scale...We are conducting peatland restoration research in Peace River, and there is funding for other wellpad-level peatland restoration work...but we are in the infancy of that research
- Peatland restoration too…restoring the hydrologic functions of the site (i.e. succeeding to establish a saturated but not inundated substrate on which peatland species such as mosses can grow)

Drilling Technologies

- Alterative Drilling Technologies to minimize land footprint. Concepts such as “Slant Drilling” can have a profound effect on reducing the number of OSE wells by drilling 7+ wells from one pad location. In addition, companies like Devon Canada have developed “trenchless” pipelines where drilling rigs can drill shallow (2 to 5m below surface) horizontal pipelines without the need to remove vegetation or excavate soil. Another concept worth pursuing are “self-leveling” drilling rigs that are able to safely operate on uneven ground surfaces which would eliminate the need to clear a flat well pad from which to drill
- In-situ technologies that maximize recovery, while minimizing project land footprint by reducing the area of well pads, roads, borrow pits and plant sites

Monitoring and Assessment

- Evaluation of success. It seems there are mixed opinions of what success means. Some consider successful reclamation when a certificate is granted, others when EPEA conditions are met, others when ecological conditions are similar to offsite comparisons.
- Monitoring...few sites are revisited in the exploration phase. Success might be easily achieved on small disturbances, but some minimal monitoring is necessary to learn from current techniques and create a timeline for site recovery. As well, longer term monitoring can help identify which characteristics are best predictors for success and how they can be quantified

APPENDIX C: IN-SITU OIL SANDS EXTRACTION: RECLAMATION AND RESTORATION OPPURTUNITIES AND OUTCOMES WORKSHOP SUMMARY

1.0 INTRODUCTION

A workshop was held on November 13, 2013 at the Northern Forestry Centre, Edmonton, Alberta to review the *Reclamation and Restoration Practices and Opportunities Compilation* document prepared by Navus Environmental Inc (Navus). The document was written to provide a summary of the current knowledge and practices that are being employed for reclamation of in-situ oil sands extraction facilities (in-situ facilities) and identify knowledge gaps, shortcomings and areas of improvement which are referred to as opportunities. The workshop was attended by federal and provincial government representatives, academic researchers, industry members and consultants.

The main objectives of the workshop were to:

- Approve the content of the *Reclamation and Restoration Practices and Opportunities Compilation* document
- Align understanding of the state of the art in in-situ reclamation
- Chart a path for the next steps that are consistent with Canada's Oil Sands Innovation Alliance's (COSIA) goals

The workshop was organized into two discussion periods and participants were split between four groups. Discussion questions or points were provided for each discussion period and each of the four groups used those questions to review different sections of the *Reclamation and Restoration Practices and Opportunities Compilation* document.

Discussion questions or points for each of the discussion periods included:

- Discussion period 1
    - Does the compilation document capture all of the practices?
    - Is industry using all of the practices?
    - Would industry start using the practices?
- Discussion period 2
    - Identify opportunities in the compilation document or previous discussion that could be readily applied or acted upon
    - Identify opportunities in the compilation document or previous discussion that are less likely to be applied or acted upon. Are there limitations associated with the opportunities due to cost, lack of knowledge or uncertainty of success?
    - What needs to be done to allow for industry to apply or act upon the opportunities?

The section(s) of the *Reclamation and Restoration Practices and Opportunities Compilation* document reviewed by each of the four groups is as follows:

- Group 1 – Pre-Disturbance Data Collection (Section I) and Revegetation (Section IV)
- Group 2 – Site Construction (Section II)
- Group 3 – Landscape and Soil Reclamation (Section III)
- Group 4 – Monitoring and Site Maintenance (Section V) and Assessment (Section VI)

Discussion items and opportunities identified by each group are summarized in the following sections of Appendix B and overarching themes identified during the workshop are included in a separate section. Discussions often strayed from the discussion period questions; however, the information from these discussions was considered relevant to the objectives for the workshop and is valuable for charting a path for COSIA's next steps.

2.0 PRE-DISTURBANCE DATA COLLECTION

The following points were discussed regarding pre-disturbance data collection:

Pre-Disturbance Site Information

- Pre-disturbance data that are collected should be linked or be relevant to conservation and reclamation objectives and should be specific to construction methods and terrain type
- Pre-disturbance data should be used by monitoring programs to link pre-disturbance conditions with reclamation outcomes. Pre-disturbance data must include relevant data to be able to accomplish this objective
- Increased pre-disturbance hydrology and drainage data should be collected
- Soil physical and chemical data that are appropriate to their intended use should be collected
- A tool specific to ecosite type that can be used to determine pre-disturbance data collection requirements could be developed to prevent the collection of irrelevant or not useful data and help collect more useful data
- Development or increased use of landscape level tools that allow planners to link pre-disturbance data to reclamation objectives or level of effort that will be required to meet the reclamation objectives
- Rationalize and improve upon current practices regarding differential requirements for pre-disturbance information between exploration facilities and production facilities
- Standardized pre-disturbance data collection and reporting to allow it to be shared, made accessible and used in the production of geographical information system layers and maps

Planning

- Planning, monitoring and assessment should be linked to the *Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region*
- Greater attention is required at vegetation transition zones regarding pre-disturbance site information collection and reclamation planning as well as improved understanding of the processes occurring at these zones
- Broader use of different tools for planning and construction purposes especially in wetlands or peatlands (e.g. Wet Area Mapping Tool)
- Development of a tool to link ecosite type to appropriate reclamation (and silviculture) techniques to aid in planning
- Compilation and assessment of currently available landscape planning tools
- Planning should consider wetland avoidance, mitigation and reclamation
- Planning should incorporate or consider edge effects and ecological effects of forest fragmentation
- Exploration wellsite boundaries could be matched to landscape contours which can reduce disturbance intensity (e.g. Requirement for cut and fill) and there should be flexibility to move facility locations for ecological purposes
- Consider the impacts of road construction across wetlands – proper water movement must be maintained
- Reclamation planning should be completed for minimal disturbance sites to support their development to target vegetation (e.g. Stand tending, site preparation)

- Improved planning and coordination between land-users and regulators to manage disturbance footprints
- Incorporating adaptive management into planning considerations
- Improved planning for end land uses of borrow pits can facilitate a more natural final appearance and allow for reclamation of a natural habitat
- Management or reclamation objectives need to be refined, clarified and clearly communicated during planning and construction
- All aspects of in-situ development and the personnel involved must be linked: pre-disturbance information collection, planning, construction, reclamation and revegetation and feedback loop must be available
- Forest stand management should be integrated with caribou management plans and integrated with in-situ life cycle planning

3.0 SITE CONSTRUCTION

The following points were discussed regarding pre-disturbance data collection:

Timber Clearing, Grubbing and Wood Management

- Retain forest stand attributes surrounding facilities and determine which attributes should be retained that could enhance revegetation
- Fine mulch and coarse mulch have different properties and effects on revegetation
- Non-merchantable timber can be “walked” down and then frozen and mulching may not be required
- Reallocation of coarse woody material between facilities could benefit revegetation efforts and reduce the storage space required
- Mulch could be used by the forestry industry as fuel or as an insulation layer to prevent winter roads from thawing and extend winter access
- Mulch could be distributed into an adjacent forest using a “snow” blower attachment (past use has had minimal success)
- Driving over coarse woody material can crush and compact and the resulting material may have similar negative impacts on vegetation establishment as mulch
- Coarse woody material could be preserved or stored by using it for erosion control on soil stockpiles or in ditches

Minimal Disturbance

- A clear definition of minimal disturbance is required as the term has been applied to various construction methods and degrees of disturbance
- Low impact seismic methods can reduce disturbance footprint
- Use of rig matting can minimize site leveling requirements and thus soil disturbance as well as the use of snow or log fills. Snow can be obtained from the site or can be made
- Larger facilities that allow storage and segregation of reclamation materials could improve reclamation success. Evidence or research is necessary to support this claim
- Increased use of boring to install pipelines could reduce the need to remove vegetation
- Directionally drilling wells can reduce the wellsite and access road footprint
- Disturbance during abandonment of wells (“cut and cap”) could be reduced by using new technology (e.g. Water jet)

- Irregularly shaped facilities could be constructed to mimic natural “lines”

Surface Soil and Subsoil Salvage

- Equipment for soil salvage should be specific to site parameters (i.e. size and type of equipment and size of site)
- Examine the need for soil monitors during soil salvage
- Examine the use of ecosite specific soil salvage and segregation to help future establishment of an ecosite comparable to the pre-disturbance condition
- Soil salvage depths can be used to manipulate vegetation species that re-establish from directly placed material (i.e. propagule banks can be diluted to prevent establishment of a high density of competitive species)
- Use of forest floor protection in cut and fill construction methods can result in successful revegetation (i.e. the upper slope soil is flipped onto the lower slope and soil is not stripped from the lower slope, during reclamation the upper slope soil is flipped back and the lower slope soil is left undisturbed)

Soil Stockpiling and Stockpile Maintenance

- Organic soils could be preserved in stockpiles by putting them in a depression created in a topsoil or subsoil stockpile and then cover with mineral soil

4.0 LANDSCAPE AND SOIL RECLAMATION

The following points were discussed regarding landscape and soil reclamation:

Site Recontouring

- To avoid or repair subsided well centres a consistent and successful approach is required; various methods should be tested. Requirements for subsided well centres need to be consistent. Subsided well centres can be considered acceptable habitat
- Restoration of drainage patters on a facility typically uses a “field fit” method and plans that may be provided are often modified in the field. Pre-disturbance drainage information is often not collected

Pad Reclamation

- Pad material cannot be re-used due to changes in its structure; returning pad material to borrow pit requires potentially disturbing a functioning wetland habitat
- Reclaim or construct larger pads to have gentle slopes if they are to be left in place to allow for establishment of a transitional zone between the wetland and upland vegetation to be established on the pad
- Pad removal should take into consideration that a portion of the pad may be removed during remediation activities
- Research is needed into methods and success of pad removal and creating functional ecosystem on pads
- Determine if hydrology can be restored after pad removal, or if pads are left in place, how do they affect hydrology of the surrounding area
- Wetland reclamation should consider the following points: compaction of substrate, restoration of hydrology, placement of soil (organics) and revegetation

Subsoil and Surface Soil Replacement

- Subsoil is important part of the root zone and suitable material is required to restore a functioning ecosystem
- Different subsoil material and textures could be used to create areas with different drainage patterns and could support different vegetation communities
- Sources outside of in-situ could provide valuable knowledge on subsoil replacement requirements (e.g. Syncrude Aurora Soil Capping Study)
- Direct placement of soil currently has limited opportunity for in-situ facilities and is restricted by regulations

Soil Tilling and Decompaction

- Determine when it is beneficial to apply decompaction treatments and what techniques are most successful (current research is being conducted by Nova NAIT)
- Decompaction treatments could be used to incorporate surface amendments

Surface Preparation

- Surface preparation could be used as an alternative to coarse woody material application
- Determine if surface preparation is effective and economical. Need a trial to determine if results are repeatable
- On minimally disturbed facilities is surface preparation beneficial or detrimental to revegetation and is the success of the treatment ecosite specific
- Mounding should be used as an adaptive management practice if revegetation of a site is not successful

Amendments

- Amendments may be valuable for left in place pad material
- Dehydrated camp food waste could be used as amendments
- Local sources can be used as amendments (pulp sludges, biosolids, peat, biochar, etc.)

5.0 REVEGETATION

The following points were discussed regarding revegetation:

Propagule Collection and Planting

- A broader range of species should be collected, propagated and planted and methods developed for species that cannot be successfully propagated
- Increase focus on establishing native understory species (especially herbaceous species) and on species “function” and importance
- Improved knowledge and practices for reforestation of treed wetlands
- Promote natural recovery through proper construction, soil reclamation and silviculture techniques
- Examine the role of natural disturbance (fire) in the recovery of vegetation
- Improve understanding of species adaptation and genetic diversity in relation to collection and deployment of

propagules

- Develop and apply best management practices for tree and shrub establishing including handling, planting and site preparation
- Establish that a seed co-op that has the following roles:
    - Collect, store and clean propagules as well as propagate and deploy the seedlings
    - Develop handling and deployment methods
    - Educate field staff

Seeding

- Re-evaluate seeding of topsoil stockpiles; the stockpiles could revegetated naturally with native species allowing the stockpiles to preserve or be a source of native propagules when the soil is replaced. Coarse woody material could be used to control erosion instead of grasses
- Evaluate seed mixes and rates in relation to reclamation objectives (e.g. erosion, traditional plants, nitrogen fixing)
- Proper use of cover crops to support succession and establish function
- Seeding should be used for specific species for specific purposes (i.e. A general seed mix should not be applied to all facilities)

6.0 MONITORING AND SITE MAINTENANCE

The following points were discussed regarding monitoring and site maintenance:

Erosion Control

- Expanded use of bioengineering techniques for erosion control such as woody cuttings, LFH and non-traditional species (e.g. horsetail)
- Succession and end plant community must still be considered when applying erosion control techniques

Weed Control

- Clearly define what is meant to have a “controlled” weed population in a forest ecosystem
- Determining liability for weed infestations can be difficult and it is a nationwide issue
- Develop a weed management co-op to track the costs and efficacy of weed control programs, improve upon current methods and share resources
- Determine benefits of using more costly targeted or species specific herbicides and develop application guidelines

Forest Stand Management/Stand Tending

- Examine the use of forest harvesting as a tool to “re-set” an area surrounding in-situ facility development
- Currently there is limited use of forest stand management or stand tending by the in-situ industry with the exception of tree felling along seismic lines to reduce access and improve site conditions
- Forest stand management should be integrated with caribou management plans and integrated with in-situ life cycle planning

7.0 ASSESSMENT

The following points were discussed regarding assessment:

- Improved management and communication of data collected during reclamation assessments (i.e. the data can be used to inform practices)
- Development of peatland assessment methods and reclamation requirements
- Determine if meeting current reclamation criteria will allow for the development of functioning forest ecosystems
- Improved or new reclamation criteria for exploration facilities (e.g. seismic lines)
- Determine how borrow pits should be assessed or reclamation criteria for the borrow pits (e.g. areas that are holding water)

8.0 WORKSHOP THEMES

Several over-arching themes were evident during the workshop. The over-arching themes apply to the majority of the specific practice areas. The themes were summarized by the workshop moderator, Chris Powter of the Oil Sands Research and Information Network and are provided below.

- Current regulatory rules (whether real or perceived) are hindering adoption of practices that would improve environmental outcomes. An example is restrictions against moving salvaged soil to a new location to facilitate direct placement (even though the newest EPEA approval encourages direct placement).
- Some of the terms we use when discussing enhancing environmental performance are restricting open dialogue because of the baggage associated with them. For example, terms like criteria, guidelines and Best Management Practices invoke specific connotations for some participants even if they are merely intended to convey their common language interpretation. We need to find some mechanism to overcome this hurdle so we can talk freely about change.
- There is a need to establish and clearly articulate the goal(s) for environmental performance. This is the first step, before any technical discussions are held. Once the goal is determined the technical options available to achieve the goal will often be narrowed; this makes discussions and decisions easier, but it also reduces flexibility. We also need to recognize that goals have changed over time, and that today's goals will very likely be different from the goals when today's new footprint is to be reclaimed. This means we need a clearly articulated policy for how industry is to adapt to changes in goals – are changes applied retroactively or only to new footprint or … Note that in the discussions goal was sometimes used interchangeably with land use and outcome.
- There is a need to establish and clearly articulate the scale at which goals are expected to be achieved. Goals, and the plans to achieve them, will be very different if the scale is a pad vs. an entire in-situ operation vs. a sub-region (e.g. SAOS) vs. a region (e.g. LARP). The latter two scales will require cooperation and coordination amongst operators and regulators.
- Training, awareness and communication are critical for implementing sound environmental management practices. This is particularly true when looking to adopt new practices.
- Staff, contractors and regulators all need to be willing to adopt new practices, methods and tools to achieve more complex environmental outcomes such as ecological function and biodiversity. Old ways of thinking and doing, no matter how successful in the past, may not achieve new goals. People who cannot change may need to be shifted to other duties.
- Frequent staff turnover in industry and government means that there is an increasing need to document actions, decisions and rationale for these long-lived sites (the mining community calls these site biographies). Too often a

new staff member will make (or require, in the case of a regulator) changes to plans without being aware of the rationale for the current plan (or even the plan itself). Change in itself is not bad; uninformed change is.

- Good ecological practices that will meet the new goals will have costs (e.g., money, time, extra land). The balance between outcomes and costs should be described and the trade-off should be explicitly acknowledged by all parties.
- We don't necessarily have to run out and create new practices. There is lots of opportunity to synthesize and publish/communicate existing knowledge. We need to be open to the idea that the knowledge can come from other industries (forestry being the one most referenced), or other parts of our industry (e.g., conventional wells, mining).
- We are likely going to need different solutions for legacy footprint than for new footprint. While the legacy footprint may be problematic because it was created with old practices, we are able to implement solutions now and see immediate environmental improvements. New site development footprint will not be reclaimed for many years so the benefit of new practices will not be evident for a long time.