



COSIA In-Situ Oil Sands Shared Practices for Working in and Around Wetlands

Prepared for:

Canada's Oil Sands Innovation Alliance
520 5th Avenue SW, Suite 1700
Calgary, AB T2P 3R7

Prepared by:

Terry Osko Ph.D., P.Ag., Circle T Consulting
Clayton Gillies RPF, RPBio, FPInnovations
Matthew Pyper M.Sc., Fuse Consulting

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Executive Summary

Background and approach

Wetlands are a critical and valued component of boreal landscapes in northeastern Alberta, and they comprise a significant proportion of operational tenures within the in-situ oil sands region. While companies have made progress on avoidance and mitigation strategies to reduce their impacts to wetlands, they also face many common challenges, including pad, road, and culvert settlement; culvert bowing and failure; and tree mortality or other vegetation changes in wetlands adjacent to roads. This document compiles a toolbox of shared practices currently in use by COSIA companies, or which have been used but were found to be unsuccessful.

Key foundations for environmentally responsible and cost effective practices

To inform this work, five foundational concepts related to working in or around wetlands are summarized to highlight opportunities to improve environmental and construction performance:

1. **Knowing your wetlands:** Identifying wetland types and applying this knowledge can improve environmental performance as well as road and pad performance.
2. **Maintaining wetland flow:** Operators that understand local flow conditions can make better site-specific decisions to accommodate wetland flow and reduce damming adjacent to roads and pads.
3. **Understanding peat bearing capacity:** Understanding the factors contributing to bearing capacity and how to manage them can help operators reduce peat failure during construction.
4. **Predicting settlement:** Peat consolidation graphs can be used to estimate the amount of settlement that is likely to occur and the timeframe for this settlement.
5. **Understanding additional environmental impacts of wetland development:** Alterations or compression of the natural hump and hollow microtopography on wetlands can have implications for both surface vegetation and methane emissions.

An inventory and evaluation of current practices

This report includes a **wetland shared practices ‘toolbox.’** This inventory of practices currently used by COSIA companies includes a factsheet for each practice and an evaluation of its relative effectiveness from both environmental and construction perspectives. This inventory is summarized in the following table, with a more comprehensive evaluation included within the larger document.

Observed Practice	How It Is Used
Planning tools for minimizing footprint	Multidisciplinary teams use desktop exercises to discuss route selection, construction alternatives, etc.
Measuring peat depth	Peat depth measurements are used to inform route selection and construction decisions.
Lab analysis of peat to predict strength	Peat samples are collected and sent for lab analyses to inform pad construction.

Observed Practice	How It Is Used
Oil sands exploration with a focus on protecting microtopography	The natural hump and hollow microtopography of peat is preserved by carefully managing freeze-in activities to avoid peat compression.
Culvert spacing to improve wetland flow	Culverts are placed at topographic lows as derived from LiDAR or at obvious flow channels.
Culvert foundations to maintain culvert effectiveness	Supports such as culvert pyramids and piles, and techniques such as providing sufficient time for settlement before placing final culverts, are used to improve culvert effectiveness.
Culvert materials to increase performance	Solid steel pipe has largely been adopted to reduce bowing and improve reliability.
Additional drainage and water flow solutions	Geosynthetic reinforced soil arches and jump span bridge technology are used to create a safe two-lane creek crossing while better managing sedimentation and other impacts of creek crossings.
Adjusting construction sequence to enable consolidation	Roads and pads are built during multiple seasons to accommodate primary and secondary consolidation.
Geosynthetics, such as geotextiles and geocells	Geosynthetics are used to increase bearing capacity and reduce fill requirements when building on wetlands.
Use of corduroy to increase bearing support and reduce fill	Whole logs are used below the road or pad to provide bearing strength.
Building on shallow peat	The amount of peat excavation is reduced by requesting variances from the Alberta Energy Regulator when variable peat depths are encountered.
Rock drains to increase water flow	Rock drains are installed to improve water flow below roads and pads.
Wick drains and drainage blankets to strengthen road and pad base	Small drains or blankets are installed in the road or pad base, using hydraulic conductivity to move water out of the base.
Erosion and sediment control	Straw wattles, fibrous matts, wood mulch and hydroseeding are regularly used to control erosion.
Ditches adjacent to wetland roads	Ditches are created adjacent to the road base to divert water.
Encouraging pad drainage using weeping tile	Weeping tile is installed at the toe of a pad berm to divert subsurface water and prevent saturation of the pad base.
Pad stabilization using soil cement or crushed limestone	Soil cement or limestone are used to improve pad strength and reduce gravel fill requirements.

Practices used by other sectors

Various techniques for operating in and around wetlands are common among in-situ oil sands and other industries. However, several practices that are not currently used (or used minimally) by in-situ oil sands operations may be of benefit:

- Log bundles
- Tire pressure control system
- Ground penetrating radar
- Lightweight fill
- Corduroy
- Permeable rock mattress
- Preload with a fill surcharge
- Raised drill platform

Opportunities to improve practices

The following opportunities for improvements to practices were identified as part of this study.

- Develop programs that train staff to identify different wetland types and use existing digital products that identify wetland types.
- Adopt a staged approach to constructing pads and roads to enable peat consolidation and encourage strengthening of the peat foundation.
- Increase the frequency of drainage structures, such as culverts, along roads.
- Develop an operational field guide for operating in and around wetlands.
- Develop a master drainage plan and determine how development may alter existing drainage patterns. Specifically, consider how pads and roads interact to block wetland flow on the landscape.
- Continue to identify opportunities to minimize footprint and/or improve the resilience of footprints that are placed on wetlands.
- Increase the use of bioengineering solutions to aid in erosion and sediment control.

Recommendations for future study

The following recommendations for future study were identified as part of this project:

- Develop a corduroy road or pad demonstration and research site.
- Develop a site to research soil stabilization applications and effectiveness.
- Develop a research site for geosynthetic application.
- Develop a research area for monitoring of landscape level wetland impacts (using drones and geophysical methods).
- Develop a better understanding of wetland flow and implications for road and pad development on wetlands.
- Inventory current geosynthetics in use by COSIA member companies and evaluate their current applications.
- Explore opportunities for new innovations in light weight fill that have a low life-cycle environmental impact and are cost effective.
- Identify new innovations or products that may help further reduce the cost of culvert installations.

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1.0 – Introduction

Background and context for this work

Wetlands are a critical and valued component of boreal landscapes in northeastern Alberta. They provide essential habitat for wildlife, house a unique set of plant species, and help regulate both water flow and carbon throughout the boreal forest. Wetlands also comprise a significant component of operational tenures within the in-situ oil sands region of Alberta. Many project tenures are composed of at least 25% wetlands, with many current and future projects occurring on landscapes composed of up to 75% wetlands.

Wetland avoidance is a priority for in-situ oil sands companies, yet the development of roads and operational infrastructure on wetlands is often required. Development on wetlands presents two core challenges for companies. First, development must be carefully managed to minimize environmental impacts on sensitive wetland ecosystems. Second, operations on wetlands are significantly more complex and costly than comparable developments on upland sites—as much as two to five times more expensive in some cases.

While considerable progress has been made by in-situ oil sands companies with respect to developing infrastructure on wetlands, companies have also noted many common challenges. These challenges include settlement of roads and operational pads; culvert settlement, bowing or complete failures; and tree mortality and other vegetation changes in wetlands adjacent to major roadways.

Canada's Oil Sands Innovation Alliance (COSIA) initiated this study through the Land Environmental Priority Area to summarize key learnings and identify future opportunities for environmental improvements and operational cost savings when working in and around wetlands.

Approach to the project

This project has capitalized on the extensive experience of COSIA member companies and their employees, relying heavily on information and perspectives from construction and field staff. Key personnel were interviewed about current practices and core challenges faced by companies when working in and around wetlands. These interviews were followed by a series of in-person field visits to in-situ oil sands operations. The field visits demonstrated the operational realities that companies face, and provided first-hand examples of how companies are constructing and maintaining their operations in or around wetlands. The final stage of this project was the synthesis of 1) additional practices used in other industries which may provide utility to in-situ oil sands operations when working in or around wetlands, 2) recommended improvements to current practices, and 3) future research opportunities.

What this document is

This document compiles a toolbox of shared practices currently in use by COSIA companies, including summaries of practices that were unsuccessful. By collating experiences of field staff from across the many diverse COSIA companies, this document will support idea sharing and generation of new applications for companies. It also represents an evaluation of current practices, recommendations for

future changes to practices, and opportunities to address key knowledge gaps. The document achieves the following objectives:

- Inventory existing practices into a wetland shared practices toolbox.
- Evaluate existing practices to identify opportunities to improve or further advance techniques.
- Identify practices from other industries which could help reduce environmental impacts and long-term costs for COSIA companies.
- Identify key knowledge gaps and future research opportunities to further advance discussion around wetland shared practices, assisting the continual shift towards more environmentally effective and cost-effective practices.

What this document is not

This document is not intended to prescribe practices for specific applications or serve as an exhaustive inventory of all current practices. It is also not intended to limit innovation in practices.

Core foundations for this study: Environmental performance and cost competitiveness

The pace of recent policy developments around wetlands has increased the level of uncertainty within the oil and gas industry. While this policy uncertainty can reduce clarity for companies, it also presents an opportunity. To overcome this uncertainty, companies can focus on what likely won't change as opposed to trying to predict what might change as result of these policy developments. The following realities are considered core principles that are unlikely to change, regardless of the policy environment:

1. Companies will continue to seek opportunities to minimize their environmental impacts on wetland ecosystems.
2. Companies will continue to seek opportunities to decrease life-cycle costs and increase their competitiveness.

These core principles have formed the foundation for this study. They have guided the authors' evaluations and interpretations of wetland practices and should help ensure the lasting utility of this work and the practices summarized within this study.

2.0 – Key Considerations for Environmentally Responsible and Cost-Effective Practices

Operating in and around wetlands presents unique challenges for in-situ oil sands companies in Alberta. However, by focusing on a few core principles related to wetland characteristics and processes, companies can significantly improve both environmental and construction outcomes.

Five foundational concepts for working in and around wetlands are reviewed here that can help improve environmental and construction performance. These concepts are used throughout this report to evaluate current techniques and recommend future practices or process improvements. While many of these five foundational concepts may be familiar to construction and environmental managers, it is always beneficial to revisit core principles. The five foundational concepts for operating in and around wetlands include:

1. Knowing your wetlands
2. Maintaining wetland flow
3. Understanding peat bearing capacity
4. Predicting settlement
5. Understanding additional environmental impacts of wetland development

Knowing your wetlands

Wetland characteristics can significantly affect the constructability and future performance of roads or pads. Four different wetland types are considered in this document to help match suitable construction techniques with the peat and water flow characteristics of each wetland type. The four wetlands considered in this report follow the wetland classes identified in the Alberta Wetland Classification System and definitions previously provided by FPIInnovations and Ducks Unlimited Canada (Partington et al., 2016; National Wetlands Working Group, 1997).

Bogs: Bogs typically contain trees that are less than 10 m tall and widely spaced (canopy cover generally <60%). Bogs are fed by rainwater, isolated from groundwater sources and have poor nutrient availability for trees. Trees are predominantly stunted black spruce. The peat is composed of poorly decomposed *Sphagnum* moss species. Water flows more slowly in bogs than other wetlands (such as fens) but can still be impacted by development.



Fens: Fens typically contain trees that are less than 10 m tall and are widely spaced (canopy cover generally <60%). Fens are fed by both groundwater and rainwater. This groundwater flow means that water is typically moving within a fen and contains more nutrients for trees. Trees are characterized by the presence of tamarack among stunted black spruce. Fens have deep organic soils that are composed of decomposing brown and *Sphagnum* mosses, as well as decomposed sedges.



Swamps: Swamps are typically characterized by trees that are greater than 10 m tall and are dense (canopy cover generally >60%). Peat depth is generally less than 40 cm, with mineral soils beneath this shallow peat layer. The water table is dynamic within swamps and fluctuates seasonally and after major rain or flooding events.



Marshes: Marshes are far less common in the boreal forest and generally have exposed or ponded water. They may dry up during drought years, during which time seeds within the marsh have a chance to germinate. Marshes are typically dominated by non-woody vegetation such as sedges, rushes, reeds, cattails and grasses.



Photos courtesy of FPInnovations.

Maintaining wetland flow

Each wetland type exhibits different water flow characteristics (i.e., flowing or seasonally fluctuating), with important implications for in-situ oil sands development. Different strategies can be used within different wetland types to enable successful construction and ensure wetland flow and health are maintained. The most common challenge with wetland flow is possible water ponding on one side of a

road and drying on the other side (Figure 1). Flooding, and subsequent death of trees and vegetation along roadways, can be caused by single flooding events such as beavers blocking culverts (Bocking, 2015), or they may be caused by general damming effects of the roadway. To prevent these issues, specific construction decisions can be made based on the anticipated wetland flow.



Figure 1. An example of a road acting as a barrier to water flow on a boreal wetland landscape. Note the ponding of water and dead trees on the left, with growth release on the right. Photo courtesy of Scott Nielsen (University of Alberta).

Failure to adequately address wetland flow can have negative environmental impacts and reduce road performance. To better address wetland flow during construction, it is helpful to understand how water moves within wetlands.

Water generally flows more quickly (i.e., material has higher hydrologic conductivity) through the living portion of the peat (acrotelm) than it does in the dead or decomposing layer of the peat (catotelm) where the peat layer is saturated with water (Figure 2) (Waddington et al., 2009). Furthermore, even though water generally flows more slowly in subsurface peat, large pores (>1 mm) and natural “pipes” (>10 mm or larger) can develop locally within the peat structure, allowing water to move more rapidly (Holden, 2005). These differences in flow rates emphasize the need to provide water passage and conduits for both surface and shallow subsurface flows.

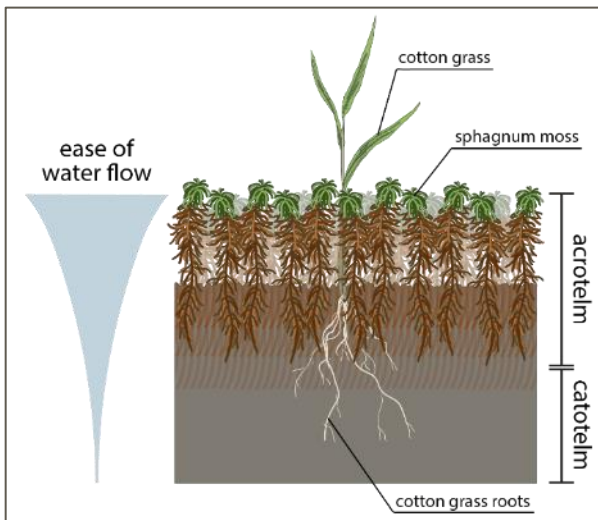


Figure 2. Examples of water flow rates within the living peat (acrotelm) and decomposing peat (catotelm).

In addition to peat characteristics, the texture of soil underlying wetlands can also influence water flow. Willier (2017) found that roads over wetlands had a lower impact where underlying soils were coarse (e.g., sand or gravel), while roads had a stronger impact on wetland flow where the underlying soils were fine (e.g., clay). Sandy and gravelly soils allowed water to move vertically from the peat into the soils, while fine-textured soils were less permeable and forced water to move laterally across the wetland.

Using this knowledge, operators can make site-specific decisions to accommodate wetland flow and reduce damming adjacent to roads and pads. This can be achieved, for example, by incorporating surficial geology into front-end planning tools. Specific approaches to maintain wetland flow, such as the frequency of culvert placement, will depend on the type of wetland.

Throughout this review these principles of wetland type and wetland flow are drawn on, and used to identify opportunities to adjust practices to better accommodate the flow requirements of different wetlands.

Understanding peat bearing capacity

When wetland avoidance is not possible and construction must occur over deep peat, bearing capacity is a primary point of concern. A soil's bearing capacity is its ability to support loads, and in the case of wetlands with deep peat, refers to the peat layer's ability to support loads. Where the load weight exceeds the peat's bearing capacity, it risks breaking through the peat surface.

Breaking through peat results in a long-term 'sore spot' in a road or a pad, and requires large volumes of fill as the road or pad is no longer able to float on the peat. Breaking through the peat surface also introduces the need to add significant volumes of fill material to the wetland, which can alter wetland flow and introduce foreign material into the peatland environment, thereby affecting wetland health.

The bearing capacity of a wetland depends on its peat characteristics. Bearing capacity is influenced by peat shear strength, tensile strength and compressibility, which are in turn influenced by the water content and fibre composition of the peat. Radforth (1969) identified three main types of peat: amorphous-granular peat (well decayed peat), fine fibrous peat and coarse fibrous peat, each of which vary in shear strength, tensile strength and compressibility. These peat characteristics may influence the integrity of roads or pads developed on wetlands.

Sampling peat and identifying peat characteristics is a key opportunity to predict potential weak points within wetlands and trigger steps to improve bearing capacity using corduroy, geotextiles, or other manufactured products. Sampling requirements can be minimized over time as personnel gain experience and operating conditions become documented and understood, eventually targeting expected problem or unknown areas.

Peat bearing capacity can increase over time and with added weight, and this property can be carefully managed to reduce instances of breaking through the peat during construction. When fill material is placed on top of peat, the additional weight expels water from the peat under compression, causing peat fibres to re-align and strengthening of the peat matrix as friction between peat fibres increases (Munro, 2004)—thus, reducing the probability of breaking through the peat. However, applying too great a load or applying the load too quickly can cause the peat to fail and cause peat displacement (Figure 3). Stability analyses based on bearing capacity or compressibility can indicate the general amount of fill that can be applied safely (Brawner and Tessier, 1969).

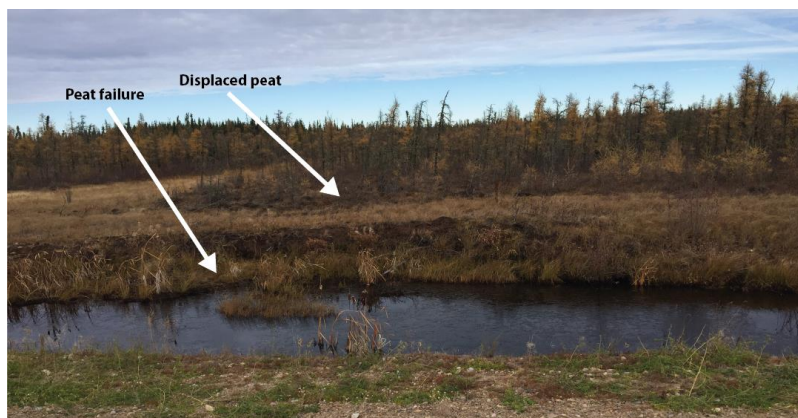


Figure 3. An example of peat failure and displacement adjacent to a road caused by the rapid increase of fill weight on a wetland. The peat shear face is evident above the open water and displacement has resulted in an elevated mound of peat behind it.

Predicting peat consolidation and settlement

Settlement is a key challenge when building in or around wetlands. It affects culvert placement and the volume of fill material required for construction, and can lead to long-term maintenance challenges. To address these challenges, a clear understanding of the process of peat consolidation and settlement is essential. Consolidation is the change in volume of peat under compression by a load, while settlement is the vertical elevation change in the peat resulting from consolidation (MacFarlane, 1969).

Peat settlement depends on peat physical characteristics, peat depth, and the applied load (MacFarlane, 1969; Munro, 2004); knowledge of these factors can be used to some degree to predict settlement. Construction operations can be adjusted in response to settlement predictions, avoiding situations where the amount of settlement exceeds the thickness of fill applied. For example, the predicted settlement of a section of the Burnaby Freeway in Vancouver during the 1960s was 2.8 m for just 0.9 m of fill (Brawner and Tessier, 1969). By understanding the factors affecting peat settlement, it is possible to anticipate when alternative practices such as lightweight fill (including corduroy) may be required (Sections 3 and 4).

Peat consolidation graphs can be used to estimate the amount of settlement that is likely to occur and the timeframe for this settlement (Figure 4). Most peat consolidation occurs within the first 30–50 days following placement of the fill material (i.e., primary consolidation). During this phase the free water is pushed out of the pore spaces within the peat and into the peat adjacent to the road or pad. During the second phase (secondary compression), trapped water exerts pressure within the peat structure and peat fibres re-align themselves into a denser matrix with reduced pore sizes. The two phases are dynamic and ongoing over time (MacFarlane, 1969). The degree of settlement also depends on the amount of fill material placed, as higher fill levels introduce greater weights onto the peat surface (Figure 5).

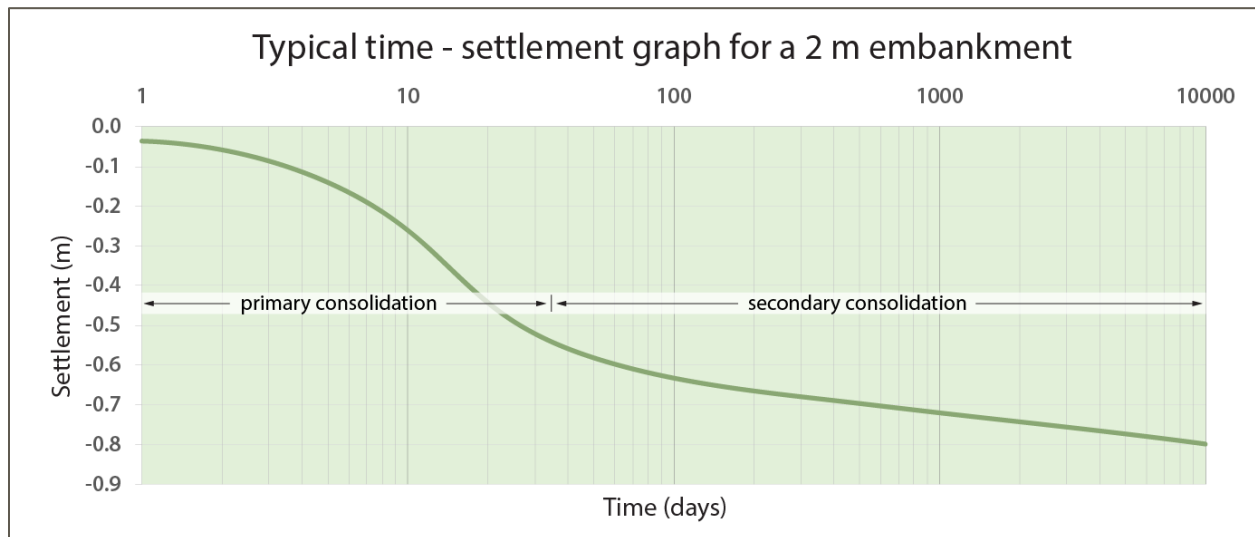


Figure 4. An example time-versus-settlement curve showing the rate at which peat can be expected to consolidate and compress for a 2 m floating road on peat (adapted from *The Muskeg Handbook (Chapter 4)*, National Research Council of Canada, 1969).

While peat settlement graphs cannot make exact predictions, they do provide a degree of guidance for estimated settlement. These graphs can assist with development on in-situ oil sands facilities by predicting the long-term settlement rate over the life of a project, allowing operators to adapt accordingly during construction.

Peat settlement graphs can also be used to estimate the surcharge required for preloading roads to reduce the time required to achieve secondary compression (see Section 4). Considering these applications, settlement graphs can be used to plan road developments in stages to increase road integrity.

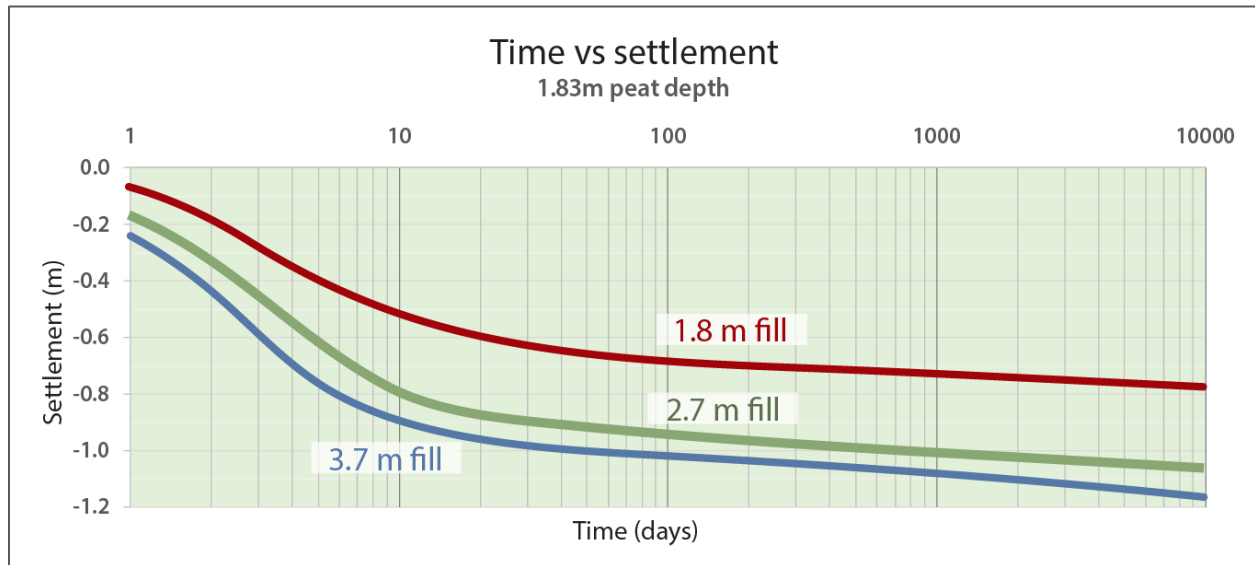


Figure 5. An example settlement curve from a site with 1.83 m deep peat, showing the rate at which peat consolidated with a range of fill depths (adapted from Manwaring et al., 2013).

Additional environmental impacts of in-situ oil sands development on wetlands

Two additional considerations for in-situ oil sands development on wetlands involve the natural hump and hollow microtopography within the wetland environment. Alteration or compression of these natural humps and hollows can have implications for both surface vegetation and methane emissions.

Surface vegetation within wetlands can be disturbed by equipment traffic, including compression or shearing of surface peat hummocks, resulting in reduced microtopographic variation (i.e., fewer humps and hollows in the peat surface). Reduced microtopographic variability reduces the number of elevated microsites, creates a higher apparent water table, and can lead to increased seasonal flooding. These effects in turn result in vegetation changes in favour of greater sedge abundance and fewer mosses and woody species (Caners and Lieffers, 2014). Maintaining this microtopography where possible during exploration and development, or recreating it after development, is therefore critical for vegetation establishment.

Maintaining microtopography is also important to reduce methane emissions from peatlands. Areas where peat has been compressed release more methane than areas with intact microtopography, thereby increasing the carbon footprint associated with oil sands exploration (Strack, 2016). Even low impact seismic lines can result in peat compression of up to 46 cm, with a direct reduction in the depth-to-water (Lovitt et al., 2018). This reduced depth-to-water increases the rate of methane release from peatland ecosystems. The full magnitude of this impact of low-impact seismic lines on methane release

is still under study but is believed to be significant enough to warrant the attention of oil sands companies (Greg McDermid, Personal Communication). Key opportunities to reduce the release of methane from peat following exploration activities include maintaining the natural hump and hollow microtopography of peat and making management choices during exploration activities that reduce peat compression.

3.0 – An Inventory and Evaluation of Current Practices

A core aspect of this document was creating a wetland shared practices toolbox. This included an evaluation of the relative effectiveness of current practices from both an environmental and construction perspective. This toolbox is not meant to be prescriptive but is intended to spark discussions and new ideas between planning, engineering, construction and environmental representatives.

To maximize the utility and applicability of the toolbox, each practice is summarized into a brief “fact sheet” (see Section 6). Each fact sheet includes a summary of the practice, examples and illustrations of its current use, and an evaluation of future opportunities and recommendations for improvements or adjustments to improve both environmental and construction performance. Each fact sheet is designed so it can be shared with construction and field crews, if desired.

Icons are used throughout the toolbox to depict whether practices apply to roads, pads, or both.



Roads











Pads

In addition to the factsheets, each practice was evaluated for its frequency of use within the in-situ oil sands and its consistency of implementation. The results are summarized below (Table 1). The first evaluation is a ranking of how frequently the practices are currently used in the in-situ oil sands. This ranking is based on interviews with company staff and reviews of company standard operating procedures. Where a practice is widely used among companies, the practice is ranked as green. Practices used by only a few companies are ranked yellow and those practices which are rarely used or not used at all are ranked orange.






The second evaluation focuses on how consistently or effectively each practice is being implemented by COSIA companies. These rankings were derived from a combination of the authors’ professional experience, how well current applications align with prevailing technical knowledge, and how consistently the practices are being implemented by COSIA companies. Green rankings indicate excellent and consistent application of the practice. Yellow rankings indicate that the execution of the practice is inconsistent between companies and improvements could be made. Orange rankings indicate when the current application of a practice needs improved. The intent of the ranking system is to highlight key opportunities for adjustments or improvements to practices, maximizing both environmental and economic objectives for COSIA companies.

The review of practices is based on interviews with eight different COSIA companies: Canadian Natural Resources, Cenovus Energy, ConocoPhillips Canada, Devon Canada, Imperial Oil, Nexen, Suncor Energy and Teck Resources.









Table 1. A summary of wetland techniques used by in-situ oil sands companies, including an evaluation of their current implementation.

Practice	Applicability	Current Approach	Frequency of In-Situ Oil Sands Use	Evaluation of Current Implementation	Rationale for Ranking & Recommendations
<u>Planning tools for minimizing footprint</u>	  Roads Pads	Multidisciplinary desktop exercises to discuss route selection, construction alternatives, etc.	Widely Used	Well Executed	Widespread use of desktop planning exercises. Broader use of project area wetland mapping and detailed wetland maps such as the Enhanced Wetland Classification could help improve construction reliability, identify wetlands with poor bearing capacity, and address wetland flow requirements.
<u>Measuring peat depth</u>	  Roads Pads	Peat depth measurements are used to inform route selection and construction decisions.	Widely Used	Inconsistent Execution	Use of peat depth sampling by a wider range of companies could improve construction reliability and reduce long-term maintenance and/or short-term bearing capacity concerns.
<u>Lab analysis of peat to predict strength</u>	  Roads Pads	Peat samples are collected and sent for lab analyses to inform construction of pads.	Used by a Few Companies	Well Executed	More companies may wish to adopt this technique as it provides increased reliability to construction practices and reduces concerns with bearing capacity.
<u>Oil sands exploration with a focus on protecting microtopography</u>	  Roads Pads	The natural hump and hollow microtopography of peat is preserved by carefully managing freeze-in activities to avoid peat compression.	Used by a Few Companies	Inconsistent Execution	Some companies reported a loss of microtopography and challenges with reclamation after exploration. Operators should prioritize using a careful, staged freeze-in approach and preserving the hump and hollow microtopography of exploration sites.







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Practice	Applicability	Current Approach	Frequency of In-Situ Oil Sands Use	Evaluation of Current Implementation	Rationale for Ranking & Recommendations
<u>Culvert spacing to improve wetland flow</u>	 Roads	Placed at topographic lows as derived from LiDAR or at obvious flow channels.	Widely Used	Execution Should be Improved	While watershed analyses based on surface topography are commonly used to inform culvert placement, complexities of wetland flow are not always considered. More frequent spacing or set spacing of culverts in some circumstances could improve environmental performance and road and pad quality, reducing water damming in wetlands.
<u>Culvert foundations to maintain culvert effectiveness</u>	 Roads	Supports such as culvert pyramids and piles, and techniques such as allowing time for settlement, are used to improve culvert effectiveness.	Used by a Few Companies	Inconsistent Execution	While all techniques are achieving the desired results, many companies stated that adjusting construction sequencing to enable consolidation before culvert placement has eliminated the need for culvert supports such as piles. Enabling consolidation prior to culvert placement is therefore a proven technique to improve the foundation for culvert support.
<u>Culvert materials used to increase performance</u>	 Roads  Pads	Solid steel pipe has largely been adopted to reduce bowing and improve reliability.	Widely Used	Well Executed	Most companies have shifted to using solid steel pipe in place of plastic or corrugated steel pipe culverts. This shift is increasing culvert consistency and installation efficiencies. A solid steel pipe also provides greater reliability at a welded connection as compared to a coupler used for traditional corrugated steel pipe.
<u>Additional drainage and water flow solutions</u>	 Roads	Geosynthetic reinforced soil arches and jump span bridge technology is used to create a safe two-lane creek crossing while better managing sedimentation and other impacts of creek crossings.	Widely Used	Well Executed	Use of geosynthetic reinforced soil arches (see Factsheet 6.3.5) is increasing within in-situ oil sands operations. These structures are enthusiastically endorsed by field crews because they can be constructed to any width, thereby ensuring safe two-way traffic can be accommodated, as well as enabling graders to prevent surface materials from falling off the bridge and entering water courses.




COSIA In-Situ Oil Sands Shared Practices
for Working in and Around Wetlands

Practice	Applicability	Current Approach	Frequency of In-Situ Oil Sands Use	Evaluation of Current Implementation	Rationale for Ranking & Recommendations
<u>Rock drains to increase water flow</u>	  Roads Pads	Rock drains (also called French Drains) are installed to improve water flow below roads and pads. They are generally built using aggregate stones to improve water flow.	Used by a Few Companies	Well Executed	Companies using this technique have seen excellent results and rock drains have the added benefit that they do not attract beavers. They can be used alone or in combination with culverts to address surface and subsurface flows. More companies could explore this technique.
<u>Adjusting construction sequence to enable consolidation</u>	  Roads Pads	Roads and pads are built during multiple seasons to accommodate primary and secondary consolidation.	Used by a Few Companies	Well Executed When Used	Companies that are using this approach have found significant reductions in road maintenance issues and with culvert settlement. However, budget and timing considerations may constrain the application of this practice.
<u>Geosynthetics, such as geotextiles and geocells</u>	  Roads Pads	Geosynthetics are used to increase bearing capacity and reduce fill requirements when building on wetlands.	Widely Used	Inconsistent Execution	Geosynthetics are being used at various locations in the road and pad profile which may not be consistent with manufacturer recommendations. Use of a separation layer between peat and geogrid is also strongly recommended.
<u>Use of corduroy to increase bearing support and reduce fill</u>	  Roads Pads	Whole logs are used below the road or pad to provide bearing strength.	Rarely Used	Well Executed When Used	Many company engineers are hesitant to use this technique, however those that are using corduroy are seeing excellent results. More companies could explore this technique.

COSIA In-Situ Oil Sands Shared Practices
for Working in and Around Wetlands

Practice	Applicability	Current Approach	Frequency of In-Situ Oil Sands Use	Evaluation of Current Implementation	Rationale for Ranking & Recommendations
<u>Building on shallow peat</u>	  Roads Pads	Companies that encounter variable peat depths are requesting variances from the Alberta Energy Regulator to reduce peat excavation.	Widely Used	Well Executed	In cases where roads or pads traverse areas with varying peat depths (i.e., <40 cm and >40 cm), leaving peat in place can likely cause less severe long-term environmental impacts. This can also improve the construction integrity and reliability of pads and roads.
<u>Wick drains and drainage blankets to strengthen the road base</u>	  Roads Pads	Small drains or blankets are installed in the road or pad base, using hydraulic conductivity to move water out from under the base.	Rarely Used	Inconsistent Execution	Most companies are not satisfied with the performance of wick drains and are no longer using them. However, drainage blankets should be investigated as they provide an important opportunity to move water out from under the road base and provide a capillary break.
<u>Ditches adjacent to wetland roads</u>	 Roads	Ditches are created adjacent to the road base to divert water from road base.	Rarely Used	Not Recommended	Deep ditches adjacent to roads can interrupt water flow, or may result in saturation of the road or pad base decreasing long term integrity. Ditches are also hard to maintain and may slough in after the first frost cycle. Ditches should be avoided where possible.
<u>Pad stabilization using soil cement or crushed limestone</u>	 Pads	To reduce gravel fill requirements, soil cement or limestone have been used to improve pad strength.	Used by a Few Companies	Inconsistent Execution	Few companies found positive results using soil cement. However, companies using soils with high silt content did have positive results. Using crushed limestone worked well for one company. These products are likely to be beneficial in case-specific applications.

COSIA In-Situ Oil Sands Shared Practices
for Working in and Around Wetlands

Practice	Applicability	Current Approach	Frequency of In-Situ Oil Sands Use	Evaluation of Current Implementation	Rationale for Ranking & Recommendations
<u>Encouraging pad drainage using weeping tile</u>	 Pads	Weeping tile has been installed at the toe of a pad berm to divert subsurface water and prevent saturation of the pad base.	Used by a Few Companies	Well Executed	This innovative technique may prove beneficial where sites transition from an upland swamp/marsh to a lowland site and subsurface water flow is causing issues in the road or pad base.
<u>Erosion and sediment control</u>	 Roads  Pads	Straw wattles, fibrous matts, wood mulch and hydroseeding are used to control erosion. Bioengineering solutions also exist.	Widely Used	Inconsistent Execution	Many erosion control products require regular, ongoing maintenance, which may not always be performed. Maintenance should be performed more frequently. Companies should investigate bioengineering solutions (i.e., willows and other woody vegetation) to increase vegetative cover and reduce erosion. Capping subsoil stockpiles with topsoil and keeping them vegetated may also be a valuable practice for reducing erosion, minimizing stockpile space, and maintaining soil nutrients while stockpiled.

4.0 – Practices Used by Other Sectors

Sectors and industries other than in-situ oil sands companies have used various techniques for operating in and around wetlands. While many techniques have either been tested or are in regular use by in-situ oil sands companies, there remain several which may yet benefit in-situ oil sands operations. These are captured in Table 2 and subsequently described in greater detail. This is not an exhaustive list of practices, but rather a compilation of those which may be relevant and easily adopted. Some practices may not be cost-effective at this time but are provided to highlight future innovation opportunities. In addition, some practices may already be used by in-situ oil sands companies, although their use is not common.

Table 2. Inventory of wetland practices in use by other industries for possible use in the in-situ oil sands. *NOTE: Some practices are currently used by in-situ oil sands companies, but not widely.*

Practice used by other industries	Phase of application	Why is it used?	How is it used?	How could it help in-situ oil sands operators?
Log bundles	Construction	Provides a conduit for flow, like a culvert.	Logs placed below the road surface.	Provides a pathway for water flow without attracting beavers.
Tire pressure control system	Operations	Reduces contact pressure of tires on roads and increases traction.	Tire pressure is manipulated from the cab when crossing wetlands.	Reduce maintenance for wetland crossings.
Ground penetrating radar	Planning	Measure depth and thickness of soil/peat, assess peat quality.	Peat thickness can be interpreted; road behavior can be monitored.	Measure accurate peat depths across wetlands; long-term monitoring reference.
Lightweight fill	Construction	Used for its light weight and as an alternative to soil. Reducing weight of fill reduces settlement.	Placed as fill.	An alternative source of fill where in-situ soils are lacking; reduces weight of fill; reduces borrow pit requirements.
Corduroy	Construction	Provides increased bearing capacity, distributed loading, and water flow capacity below the road.	Logs placed along the surface of the peat before any fill is placed; a separation layer between the logs and fill is key to promoting flow through the corduroy logs.	Provides an alternative bearing improvement option coupled with water flow opportunities. Reduces fill requirements. Uses natural resources and avoids the need for imported mineral aggregates.
Permeable rock mattress	Construction	Reinforces the subgrade and provides a conduit for water flow.	Placed below the road surface.	Provides a reliable foundation for long-lasting performance. It could contribute to a dispersed pathway for water flow below the road.

Practice used by other industries	Phase of application	Why is it used?	How is it used?	How could it help in-situ oil sands operators?
Preload with a fill surcharge	Construction	A means to manage or prevent long term road settlement.	A fill surplus is added to the road during construction. A portion of the fill is then removed once settlement has been achieved.	Can eliminate issues of road grade and culvert settlement over time and reduce the need for additional fill to maintain road grade.
Raised drill platform	Construction	Provides a raised working surface above the wetland.	Mats are supported by piles.	For site specific locations where it is considered necessary to elevate operations above the wetland.

Log bundles

Only one company used a log bundle to allow for water flow through a road. Like corduroy, log bundles can be used to promote flow through the voids between logs. The log bundle is not as extensive as corduroy and could be considered as an alternative to a culvert (Figure 6). Logs placed two or three layers high, with a separation layer to keep the spaces between logs clear of sediment, will allow water to pass through the structure. The use of a log bundle is appropriate for a wetland road crossing (Gillies, 2011a). As well, logs in water are protected from fungal decay in part by maintaining a high moisture content and limited exposure to oxygen. The rate of decay is greatly reduced in the absence of oxygen; log bundles will continue to be monitored for the application of balancing water levels for wetland applications.



Figure 6. An example of a log bundle used to enable water flow along a long-term forestry road.
Photo courtesy FPIInnovations.

Tire pressure control system

It is uncertain how many companies have used variable tire pressure technology specifically for wetlands and wetland crossings. Tire pressure control systems are a technology that allows a vehicle operator to reduce the inflation pressure of a truck's tires while traveling over soft, wet areas with slippery weak soils. At reduced tire pressures a larger contact footprint is developed, reducing contact pressure and increasing the tractive ability of the tires. The result is improved soft ground mobility and less road damage (Bradley 1997). Keller et. al (2011) illustrated how the use of reduced tire pressures by all vehicles allowed resource road bases to be reduced by up to 50%.

Ground penetrating radar

Ground penetrating radar is not widely used among COSIA companies, but its use within the natural resources sector has been increasing over recent years. Boundaries and depths of soil/peat horizons can be plotted and used to enhance construction across the wetland. The precise peat depths for any given section allow for the development of section-specific construction plans and plans to address possible weak points with poor bearing strength. Peat depth thresholds (i.e., depths at which certain construction practices may pose a higher risk to breaking through or otherwise damaging the peat surface) could also be established through this technique and correlated to construction practices.

Lightweight fill

The use of lightweight fill was mentioned by only two companies during our interviews, with one being a trial which did not go ahead. The second scenario was the use of wood fibre/chips. Lightweight fill can benefit wetland construction practices by reducing the weight of the fill, and in turn, the forces acting on weak wetland soils. The use of lightweight fill could result in the reduced settlement of the constructed surface due to the overall reduced weight (see Section 2). For roads this could result in reduced maintenance and/or reduced ongoing fill delivery. The most commonly used form of lightweight fill for civil engineering applications is expanded polystyrene (i.e., geofoam) (Figure 7). However, COSIA member companies have expressed concerns about both the cost and the reclamation feasibility of this material. Wood fibre, as used by some COSIA member companies, has been well documented (see Blinn et al., 1998). Novel sources of lightweight fill can be found in the literature but are not considered appropriate or cost effective for the oil and gas industry in Canada.

While the above highlights current constraints to adoption of lightweight fill, there exist opportunities for innovation and entrepreneurship to drive new and more efficient lightweight fill products. Finding an environmentally responsible and economical solution for lightweight fill could dramatically reduce the time, equipment, and disturbance required for obtaining large quantities of fill material. The consequent reduction in borrowed fill required could also have substantial environmental and economic benefits.



Figure 7. Example of the use of expanded polystyrene showing typical dimensions of the blocks. Note that expanded polystyrene can be used as a lightweight fill as well as for other engineered specifications, such as void forms. Photo courtesy of Tembec.

Corduroy

Corduroy has been used by other natural resource industries for bearing improvement and load distribution during construction on and across wetlands. A few companies interviewed suggested they had used corduroy in the past, and a few more companies suggested they had internal discussions regarding its use and possibly trying it as an alternate construction method to the use of geosynthetics. The main reasons for embracing traditional geosynthetic products were identified as: uniform and standardized properties; standard installation; theoretical technical advantages backed up by engineering and scientific resources; and aggressive marketing by the manufacturers and suppliers. Corduroy does not have standardized properties like manufactured products, but this should not undermine its potential utility. Corduroy is a natural product and has the potential to reduce environmental footprints from borrow pits and significantly reduce costs for operations.

Corduroy can be used strictly for bearing improvement and load distribution. In this case the logs are entirely covered with fill and there is no exposure of the logs to air, UV, or weather. It is suggested that if the logs are completely covered the corduroy structure should remain sound indefinitely (MacFarlane, 1969).

Logs placed as corduroy are often laid side by side, one or two logs high, perpendicular to the direction of travel. One of the companies interviewed said that at times they would also lay two rows of logs with

the lower row at 90 degrees to the upper row, and each row made up of continuous logs. Other industries have used a similar method but with fewer logs used in the lower row (non-continuous) acting more like abutments. Where logs are scarce or at a premium, there may be an advantage to constructing the lower row with non-continuous logs. A variation of this method is shown in various reports and text books; examples include “Dealing with bearing capacity problems on low volume roads constructed on peat” (Munro, 2004) and the Muskeg Handbook (MacFarlane, 1969).

Corduroy has more recently been used in wetlands to promote water passage. Partington et al. (2016) provide detailed considerations for various flow regimes by wetland type and report that corduroy is appropriate for all flow regimes. Gillies (2011b) previously suggested that opportunities to use corduroy to promote water flow may need to be explored further, and has since collaborated in field trials utilizing corduroy for both bearing and flow capacity. Because of the voids left between logs and the lineal nature of a log, corduroy better addresses both bearing and hydrologic function. Given that corduroy should be laid parallel to the direction of flow to promote drainage, understanding wetland function and the direction of flow is critical to the success of the design (The Forestry Corp., 2004). Two main considerations during construction for the use of corduroy as a conduit are the need to leave the ends of the logs open so that water can pass through the structure, as well as the need to prevent the structure from infilling with fill material. A separation layer is used to ensure fill material does not occupy the spaces between logs, allowing water to pass through the corduroy surface.

Permeable rock mattress

Only one company used coarse angular aggregate to facilitate water passage through roads. A permeable rock mattress or seam provides flow through the angular aggregate, and the structure can be built with additional conduits incorporated into it such as corrugated culverts or steel pipe. The use of permeable rock mattresses (both with and without culverts) is described by Keller and Sherar (2003), Partington et al. (2016), and Gillies (2014). Rock mattresses are typically constructed on top of the peat surface above a separation layer (geotextile) where peat is shallower or otherwise competent enough to bear the weight of the mattress without failing. They can also be constructed on the underlying mineral surface where shallow peat has been removed, rather than using clay fill as a road base (Figure 8).



Figure 8. Permeable rock mattress used beneath a resource road in a wetland. Photo courtesy of FPIInnovations.

Pre-loading with a surcharge

Peat continues to compress after the initial consolidation phase, which can lead to additional settlement of the road grade and culverts over time. Pre-loading the peat with fill exceeding the desired road height is a means of eliminating (or partially eliminating) this long-term compression. This approach improves the predictability of the road grade over time and reduces the need to raise the road grade with additional fill. The principle is to use the excess fill to cause the peat to compress to the long-term settlement expected from the designed road grade over the duration of construction rather than over multiple years post construction. Once the desired settlement is achieved, the surplus fill is removed and used in construction elsewhere.

Caution is advised, as the peat can sometimes rebound once the surplus fill is removed and still be subject to future settling. In addition, pre-loading with a surcharge only compresses the peat and not the underlying soil. Structures may still settle considerably over time if soils below the peat are very soft. Finally, the amount of surcharge that can be applied will depend on the stability of the peat and pre-loading with a surcharge may not be feasible on very deep peat or areas with poor bearing capacity.

Consolidation curves such as those introduced in Section 2 can be used to determine the duration required for a certain pre-load surcharge or the amount of surcharge required to achieve settlement within a specific time period. For example, Figure 9 shows the expected time settlement curve for 1.8 m of fill on a peat of given characteristics, as well as the expected settlement time for several increments of fill in surplus of the target. In these cases, settlement is achieved in days to weeks instead of years.

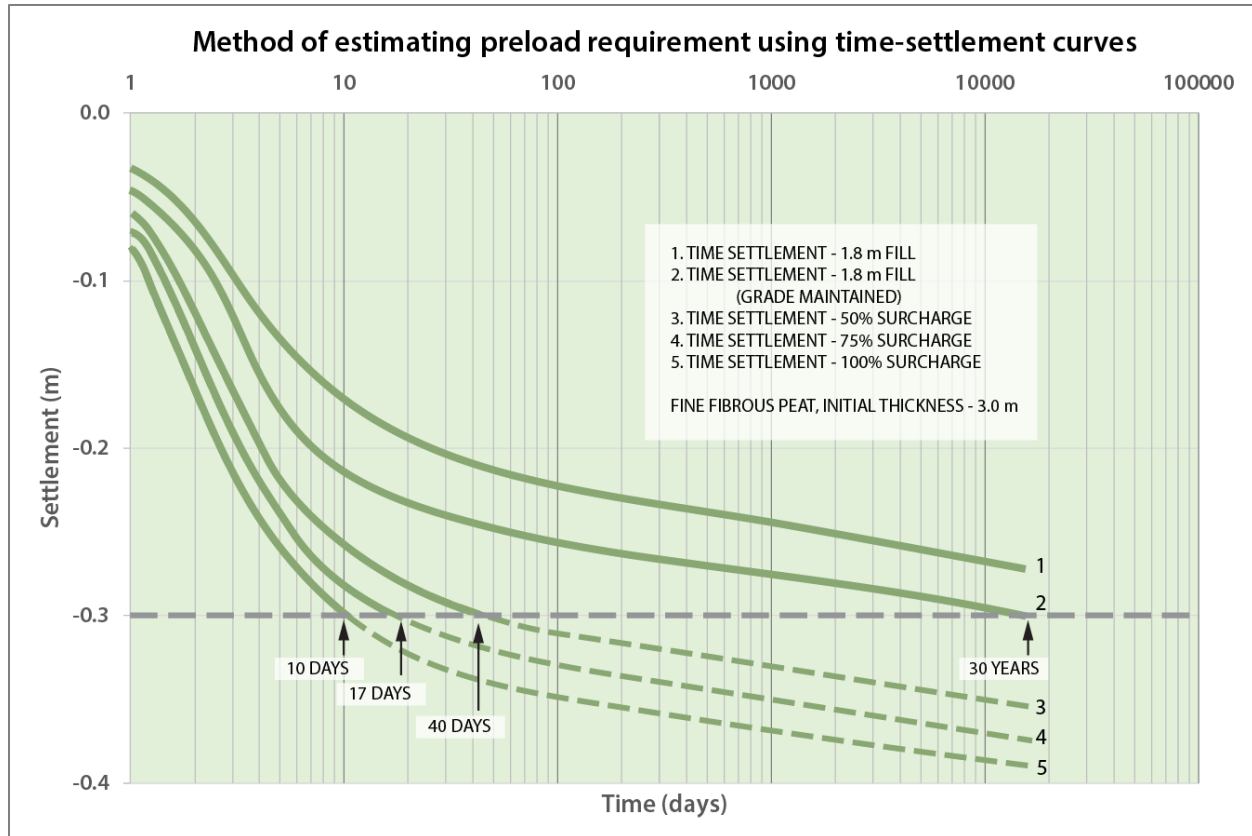


Figure 9. Graph showing the effects of applying a surcharge on long-term settlement (adapted from *The Muskeg Handbook* (Chapter 4), National Research Council of Canada).

Raised drill platforms

The use of raised drill platforms is a novel approach for constructing operating areas that are above the natural ground surface. Several companies provide such products and have demonstrated their utility providing high bearing capacity for weak soils. The mats are designed for use in challenging areas including wetlands and environmentally sensitive areas.

Raised drill platform panels are modular and made from Fiberglass Resin Polymer. The panels are supported on steel beams, which are supported on piles. The entire drilling operation, including trucks and equipment (drilling rig), does not come into contact with the ground. The final pile size and frequency of placement will vary according to site-level soil characteristics. Pile caps are placed on the piles to facilitate the bolting of the steel beams to the piles; these connections also allow for thermal expansion / contraction of the beams. The mats are designed to allow for containment of spills and have a carbon veil in the surface for static dissipation. The composite raised drilling platform requires almost no site preparation and, if needed, the mats are light enough to be delivered in place by a helicopter.

The cost to implement this system is high. Companies may be inclined to consider this system where there is a need to eliminate any impact to a wetland or fragile ecosystem.

5.0 – Opportunities to Improve Practices and Recommendations for Future Study

Summary of opportunities to improve practices

Opportunity for Improvement	Issue Addressed
Wetland identification training	Improves staff understanding of how different wetland types can impact wetland flow and peat bearing capacity.
Adopt a staged approach to constructing pads and roads	Staged construction allows peat to consolidate and encourages strengthening of the peat foundation during construction. Staged construction also minimizes the potential for peat shearing, which significantly compromises road integrity over the life of the project.
Increase the frequency of culverts and other drainage structures	Increased use of culverts, or set culvert spacing, increases opportunities for water flow beyond just the lowest points and should reduce the damming impacts of roads.
Develop a field guide for operating in and around wetlands	Company field staff indicated a visual guide would be helpful to encourage rapid adoption of new practices or improve the use and understanding of current practices.
Consider how pads and roads interact to block wetland flow	Pads can alter wetland flow, and broader consideration of these impacts can help prevent pads from forcing water into roaded areas with poor drainage.
Continue to identify opportunities to minimize footprint and improve resilience of footprints	Reducing footprints, where feasible, dramatically reduces potential wetland impacts and, in many cases, can improve economic efficiencies. Carefully managing wetland footprints and ensuring that careful freeze-in techniques are used can also help maintain the natural hump and hollow topography of wetlands.
Knowledge sharing about minimizing OSE footprints on wetlands	Most companies stated they aim to carefully preserve the natural hump and hollow peatland surface when freezing in wetland sites, however the results appear to vary widely. Some companies state that they have no issues and reclamation goals are quickly achieved, while others stated issues with ponding and loss of the humps and hollows characteristic of the peatland surface. Sharing information could help address this variability in outcomes.
Increase the use of bioengineering solutions to aid in erosion and sediment control	Manufactured erosion control products require regular maintenance which is not always performed. Growing woody vegetation, or other vegetation, can improve erosion control and soil stability.
Explore opportunities for new innovations in light weight fill	Current options for light-weight fill (such as polystyrene) are not currently cost effective and pose challenges at reclamation. New innovations could significantly reduce the need for fill material and borrow pits.
Identify new innovations or products for culverts	Opportunities to further reduce the cost of culvert installations could facilitate their more frequent use in wetland areas.

Develop programs that train staff to identify different wetland types and use existing digital products that identify wetland types

Wetland identification is an essential step for operating in and around wetlands (See Section 2). Knowledge of the different wetland types within an operational area can be used to improve mitigation measures to ensure water flow, and to anticipate and adapt to peat integrity and constructability on wetlands. Field staff who are familiar with wetland identification will better understand the soil moisture, nutrient regime, pH, and water flow of the wetland. They may also understand the importance of assessing peat depth and properties, and how these measures may be correlated to expected bearing capacity. A strong understanding of all these factors will improve the choice of construction method and attention to flow requirements.

One option to increase field staff and contractor awareness about wetland types is to provide field training programs on identification. Various agencies have already developed courses for forestry practitioners that could easily be adapted for an in-situ oil sands audience.

A second option is to invest in the current Enhanced Wetland Classification developed by Ducks Unlimited Canada and its partners. This inventory identifies wetlands at both a coarse scale (bogs, fens, marshes, swamps) or at finer scales (rich fen, poor fen, treed bog, open bog etc.). Companies therefore have the option of using the level of detail that best suits their operations. The data resolution of the Enhanced Wetland Classification is 30 m x 30 m with mapping to 1 ha (Smith et al., 2007), so it will require field verification and/or finer scale mapping to support operational scale decisions related to pad or road placement. It nonetheless provides a landscape level picture of wetland types and characteristics.

Adopt a staged approach to constructing pads and roads to enable peat consolidation and encourage strengthening of the peat foundation

Some companies have substantially improved their operations on wetlands by shifting to a staged approach to construction. This approach entails placing an initial lift and temporary drainage features, then allowing settlement and peat consolidation before placing additional lifts. In many cases one lift was applied in one season, with subsequent lifts and permanent drainage features applied in later seasons (e.g., winter then summer). These companies reported fewer issues with culvert settlement, better road integrity, and limited experiences with breaking through peat during construction.

The addition of a settlement period into the construction schedule extends the timeline for building roads and pads. In most cases this shift in scheduling will require longer planning horizons and budget decisions earlier in the planning cycle. While this may prove challenging, companies that have made this shift in their construction schedules have found fewer long-term maintenance and reliability issues on their sites. For example, final culverts placed after a road has undergone settlement are likely to experience fewer issues and are less likely to require culvert piles or other solutions designed to reduce culvert settlement. As described in Section 2, building roads and pads in multiple phases also allows time for the peat fibres to consolidate, providing additional long-term strength to floating roads over wetlands.

Increase the frequency of drainage structures, such as culverts, along roads

Maintaining water flow on wetlands intersected by roads and other features has long been a challenge in the in-situ oil sands region of Alberta. Older roads with dammed water on one side are common, but damming continues to be a challenge on modern roads as well. During field visits, sparing use of culverts was observed along most roads. Generally, culverts were placed at topographical lows or where obvious drainage channels were observed by field staff. However, drainage can also be required in areas other than obvious topographical lows and it plays an important role in balancing water and maintaining flow in wetlands.

By strategically increasing the use of culverts, or other conduits such as rock drains or log bundles, companies are likely to more effectively mitigate their impacts on wetland health. Road performance will also likely be improved by reduced pooling of water next to roads, which can saturate and negatively impact the road base and negatively affect wetland health. COSIA member companies should evaluate the feasibility of set culvert spacing or, at a minimum, increased use of culverts when operating on wetlands (see Table 3 in Factsheet 6.3.1).

Develop an operational field guide for operating in and around wetlands

During our field visits for this project, field personnel expressed significant interest in the outcomes of this project. This COSIA study and the resulting toolbox of wetland shared practices could therefore be viewed as the first in a series of projects that raise awareness about preferred practices when operating in and around wetlands. While this COSIA study focused on *why* practices for operating in and around wetlands are beneficial and *what* they look like when applied, an operational field guide could increase knowledge sharing between field staff within COSIA member companies and focus on more of the construction specifics in terms of *how* to apply the practices. The guide could focus on specific practices such as winter freeze-in techniques, various approaches to seasoning roads and enabling settlement, culvert installation techniques, installation of corduroy, and more. Field staff endorsed the development of such a guide, suggesting it could be a useful training tool.

Consider how pads and roads interact to block wetland flow on the landscape

A key opportunity identified during field visits was to encourage companies to consider how pads and roads may interact to impact wetland flow, and to alleviate these impacts with more strategic placement of culverts. A specific example arose when a company had placed a pad within a wetland and the angle of the pad, combined with the lack of conduits along the access road, resulted in significant ponding of water adjacent to the road and pad (Figure 10).

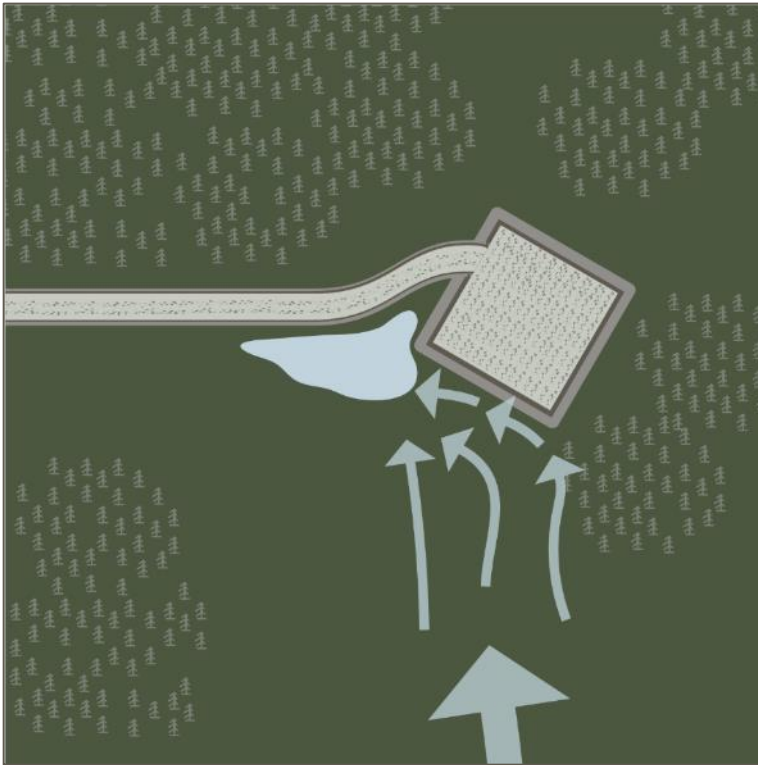


Figure 10. A schematic of a pad that altered water flow in a wetland and caused ponding. This issue could have been mitigated by more frequent culvert placement.

This example highlights an important consideration that is broadly applicable. Water flow within wetlands is a common process that must be accommodated not only to ensure road and pad integrity, but also to maintain wetland health. To mitigate the combined impacts of pads and roads, effects on flow should be assessed and additional drainage structures (e.g., culverts) should be considered to permit flow and reduce water ponding adjacent to these features. This needs to be completed with consideration of the master drainage plans for the area so that additional issues are not created by addressing a single, local problem.

Continue to identify opportunities to minimize footprint and/or improve the resilience of footprints that are placed on wetlands

Minimizing footprint has been a key priority for COSIA member companies for some time, however it warrants emphasis again as part of this study. The best way to mitigate the impacts of in-situ oil sands footprints on wetlands is to minimize the number of footprints that occur. It is important to consider opportunities to re-use existing footprints, use smaller rigs to enable smaller oil sands exploration well sites, or reduce the number of roads throughout an operational area when working in or around wetlands.

In addition to reducing the physical size or number of in-situ oil sands footprints, better identification of wetland types and a careful, well planned, and staged approach to freezing-in pads can all help increase the resilience of wetlands after footprints are removed and limit the long-term impacts of in-situ oil

sands footprints on wetlands. Where appropriate techniques are used to maintain microtopography of the peat, fewer ecological impacts will be observed post-development.

Increase the use of bioengineering solutions to aid in erosion and sediment control

Sedimentation and erosion control measures are often a key focus for COSIA companies in and around their operating areas. Erosion control by COSIA member companies mainly consists of straw wattles, fibrous matting and other ground coverage techniques. Many companies also use hand seeding as they have had poor success with hydroseeding. Seeding can attract wildlife, which must be carefully managed with respect to forage quality and safety of the animals. Bioengineering solutions (e.g., planting willow or poplar cuttings) are infrequently used by COSIA companies for erosion control, although these solutions are increasingly gaining acceptance in the oil and gas industry for erosion control and slope stabilization (Lewis, 2000; Polster, 2013).

Materials for cuttings are readily available on most sites, and they generally prevent erosion and slow water flow in drainage areas more effectively than many of the mat products for stabilizing slopes. While somewhat labour intensive, this solution makes use of naturally occurring local vegetation and can also provide opportunities to partner with local communities for labour resources. Utilizing compost-based erosion control blankets or wattles (rolls) also may be an effective means for promoting both natural growth and planted vegetation where erosion control is needed.



Figure 11. An example of a perimeter berm for an in-situ oil sands pad that would benefit from additional erosion control measures. Photo courtesy of FPIInnovations.

Recommendations for more specific study

Study	Issues Addressed	Description	Benefits
Corduroy road or pad demonstration	Engineering, Bearing Capacity, Hydrology	Incorporate corduroy into a planned road. Document engineering properties, bearing capacity, and hydrologic flow compared to conventional road.	Demonstrate engineering soundness and hydrologic performance to increase industry adoption.
Soil stabilization applications and effectiveness	Engineering	Test a range of soil stabilization options, such as soil cement, limestone, etc., to evaluate effectiveness.	Clarify when and where various products provide the most utility.
Erosion control study	Erosion Control	Complete a study which compares a range of erosion control options, including manufactured products and bioengineering solutions, such as the planting of woody vegetation.	Help identify which practices work best over the long-term and increase worker familiarity with the use of bioengineering solutions that can improve soil stability and reduce erosion.
Geosynthetic applications	Engineering, Bearing Capacity	Set up a trial, or multiple trials, to test different geosynthetic products and where and when they provide the most utility.	Improve awareness of product strengths; can be used to train staff in optimal use and placement of geosynthetic products.
Study and monitor landscape level wetland impacts	Hydrology, Engineering	Use drones, other geophysical methods to monitor landscape level impacts and/or changes because of in-situ oil sands development.	Provide a broader perspective than simply local studies and identify areas of opportunity for reducing wetland impacts.
Develop a better understanding of wetland flow and implications for road and pad development	Hydrology, Engineering	Study how wetland flow occurs across the landscape and throughout various wetland types. Will help improve awareness of areas that may require additional drainage structures to reduce ponding around roads and pads.	Fill a major knowledge gap with respect to complex wetland flow regimes on boreal landscapes. Could reduce wetland impacts and improve integrity of roads and pads.
Inventory current geosynthetics in use and evaluate applications	Engineering, Bearing Capacity	Complete an inventory of how various companies are using geosynthetic products and where in the road/pad profile the products are being used.	Clarify inconsistencies in application of products and ensure products are being used to maximum benefit.
Borrow pits	Ecology, Hydrology	Understand how borrow pits adjacent to wetlands contribute to wider wetland ecology.	Increase the level of understanding of how borrow pits impact local ecology.

Develop a corduroy road or pad demonstration and research site

Some companies view corduroy as an outdated technique. However, its widespread use in the forest industry and its use by some COSIA member companies demonstrates its ongoing utility in the construction of roads and pads for in-situ oil sands facilities. Corduroy paired with geotextiles can significantly reduce the amount of fill required and improve overall road performance, resulting in notable environmental and economic cost reductions. However, significant resistance to using corduroy remains within COSIA member companies. The potential value and reduced environmental footprint of corduroy warrants additional demonstrations and research to showcase this approach and promote its wider adoption.

An immediate option would be to host a field tour for key engineering and environmental staff within companies. The proposed focus could be on Canadian Natural Resources Limited's use of corduroy for in-situ oil sands operations and examples of recent applications of corduroy on forestry roads. Devon Canada is also currently developing a research program around a corduroy road which again would provide opportunity for staff to see corduroy in use and better understand the potential benefits of this technique. The proposed field tour would increase knowledge sharing between companies and allow company planners, engineers, and construction staff to develop a greater understanding of its use and potential while increasing comfort with this technique.

A second opportunity is for COSIA to establish a corduroy demonstration and research site, developed on a future road or pad and designed to showcase the corduroy technique to a range of stakeholders. It could additionally serve as a field trial equipped with instrumentation to monitor road characteristics and estimate the mechanical contribution of corduroy in wetland roads.

FPIInnovations has envisioned a trial of this kind to model a corduroy road as a stiff layer on an elastic base and use the model to estimate stress, strain and surface deflection. The model would then be calibrated after measured responses to the variable of interest. An important variable is the height of the required embankment, considering the potential cost savings associated with reduced fill requirements. Another important variable is the performance of the logs, therefore a corduroy road could be constructed with variable log quality, uniform high-quality logs, and different log species. It could then be tested using balanced vs unbalanced truck loading and vehicles of various weight. The values obtained from the trial can be used to continuously calibrate the model and predict the short-term and long-term integrity of corduroy roads.

Similarly, if the long-term integrity of corduroy roads is a point of concern for companies, historic roads that were built using corduroy could be tested for their integrity to assess their long-term reliability. This could include excavating sections of corduroy roads and sampling the logs for integrity and decomposition.

Finally, if companies are interested in using corduroy in the immediate term, then developing a short pamphlet or guide that highlights key considerations and showcases schematics for handling logs and building with corduroy could prove highly beneficial.

Develop a broader understanding of landscape level implications of development on wetlands

This COSIA study focused largely on the site-specific impacts of developments on wetlands. However, the landscape perspective is without question of equal or greater importance to overall wetland health. A key first step companies can take in considering the landscape level impacts of in-situ oil sands operations is to know the wetland type they are operating in and to use specific techniques to address wetland flow (see Section 2).

However, investing in a landscape level study could help determine the immediate, local scale impacts of in-situ oil sands developments as well as broader landscape level impacts. By understanding the broader complexities of wetland flow and impacts of in-situ oil sands developments on wetland health, a study could provide relevant guidance for mitigating impacts to wetlands during construction. The study could also inform why trees may be observed dying on opposite sides of a road within a span of only 100–200 metres (Figure 16) and provide guidance for managing similarly complex patterns of water flow. Finally, studying the broader landscape level impacts of in-situ oil sands operations and finding ways to mitigate these impacts connects well with recent requests by the Alberta Energy Regulator for project level conservation and reclamation plans from in-situ oil sands operators.

It is our understanding that a landscape level study like the one described here is under consideration by some COSIA companies, and the findings contained in this report provide further support to the importance of undertaking such a research program.

Develop a better understanding of wetland flow rates and implications for road and pad development on wetlands

Wetland flow is variable and often depends on the underlying parent material and wetland type. However, recent studies on the effects of roads on wetlands suggest water flow is more difficult to predict than presently acknowledged (Strack, 2016; Willier, 2017). Some sources also describe bog hydrologic regimes as “stagnant,” which can be misleading and is inconsistent with other literature (e.g., MacKenzie and Moran, 2004). Field observations of water ponding along roads that cross bogs, sometimes more frequently than along roads that cross fens, indicate that water in bogs may not be stagnant. This presents an opportunity to further synthesize existing information and conduct new research on water flow to fill knowledge gaps. For example, piezometers may be used to track variation in water levels that may be correlated to lateral and vertical water migration. This information could then be used to improve practices for operating on wetlands.

Chemical tracers have been used to verify conceptual peatland hydrologic flow models, whereby flow within wetlands is “mapped” by following the tracers as they flow through the peatland (Siegel and Glaser, 2006). Such technology could be used in local studies to improve understanding of wetland flow within wetlands typically encountered by Alberta in-situ oil sands operators to inform field programs and help identify opportunities for improved drainage structures or design. Natural variations and blockages to flow could also be observed for comparison with artificial blockages (i.e., roads and pads).

Evaluation of current geosynthetic use by COSIA member companies

This COSIA study has highlighted that geosynthetics are a critical product when operating in and around wetlands. However, it has also demonstrated that the specific products used, and the placement of these materials in the road or pad profile, vary by company and by field staff. While a comprehensive evaluation of all products currently in use was beyond the scope of this study, it may be a useful follow-up study for companies.

Specifically, evaluating how the products are being used, and where in the road or pad profile the products are being placed, could possibly lead to innovative solutions. Through our discussions with field staff, it was clear that products are not being applied consistently between companies, and in some cases their placement in the road or pad profile is not consistent with manufacturer recommendations. While geotextile companies already collate their products into an inventory of recommended use, we see value for COSIA companies in collating this information on these manufactured products and highlighting their use by various companies.

The proposed study would help ensure that companies achieve the maximum benefit from geosynthetics during construction. It would also help ensure that the use of products used outside of their recommended applications is documented and evaluated for effectiveness. An additional opportunity would be the development of a field guide for the application of geosynthetics in wetland construction.

6.0 – COSIA Toolbox of Wetland Shared Practices

Detailed guide to the COSIA toolbox of wetland shared practices

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6.1 – Planning

Planning Tools for Mitigating Wetland Impacts

Planning is a key stage in the construction process. While all companies interviewed have a planning process in place, the detail and sophistication of planning approaches vary widely. Most companies have adopted a desktop planning exercise where they bring together a multi-disciplinary team to review target locations, access routes, and pad locations. They then work to adjust routes and locations to balance many competing interests (e.g., geology, access length, etc.) as much as possible. There are also a wide range of unique approaches being used by companies. These include capitalizing on wetland inventories such as the enhanced wetland classification, developing wetland risk categories based on peatland depth, and completing detailed hydrological studies prior to development.

What are companies doing?

The desktop planning exercise that most companies have adopted involves staff from environmental, planning, construction, reclamation and geology departments. Some companies also include key stakeholders such as Indigenous community members. The process typically starts with LiDAR data and target locations provided by geological departments. Staff then work collaboratively to improve environmental performance and reduce operating costs. Key outcomes from this process include re-routing roads, deciding on initial culvert locations, preserving overall drainage patterns, and thinking holistically about opportunities to reduce costs.

These planning processes also involve avoiding wetlands where possible. Many companies aim to minimize wetland footprints by reducing the length of road crossings on wetlands or placing pads on uplands. Some companies also provide their staff field-ready maps that identify wetland types and preferred access routes (Figure 12). When wetlands cannot be avoided, companies select operating locations based on wetland value, constructability, and reclamation potential. Where possible, reducing the overall disturbance or exploration footprint by increasing the number of Oil Sands Exploration (OSE) wells that are drilled from a single top-hole location is also a key planning approach.

Figure 12. A wetland avoidance map modelled after a COSIA member company. The map classifies wetland types and access routes to ensure avoidance of wetlands.



What is unique?

Detailed hydrologic studies and updated master drainage plans for the proposed development areas, beyond those required for Environmental Impact Assessments, are helping companies better understand existing drainage patterns and potential alterations to these patterns by the intended development. These more detailed studies focus on improving operations and can be used to inform culvert and other drainage spacing. Hydrologic reports can make recommendations to accommodate various storm return intervals, such as 25- to 100-year events. The company using this approach cited the lowest number of problems with environmental impacts and road maintenance.

Additionally, a ‘cold eyes review’ of a construction plan by an outside contractor or consultant provides an impartial evaluation of the integrity of the construction plan and the accommodation of wetland flow requirements. The review also allows the third-party contractor to suggest reasonable alternatives or identify possible omissions from the plan. Finally, an enhanced wetland classification (Figure 13) can be used to characterize all wetlands into a range of wetland types. This layer is used to better plan for construction activities and to better anticipate the water flow requirements for different wetland types encountered during the construction activities.

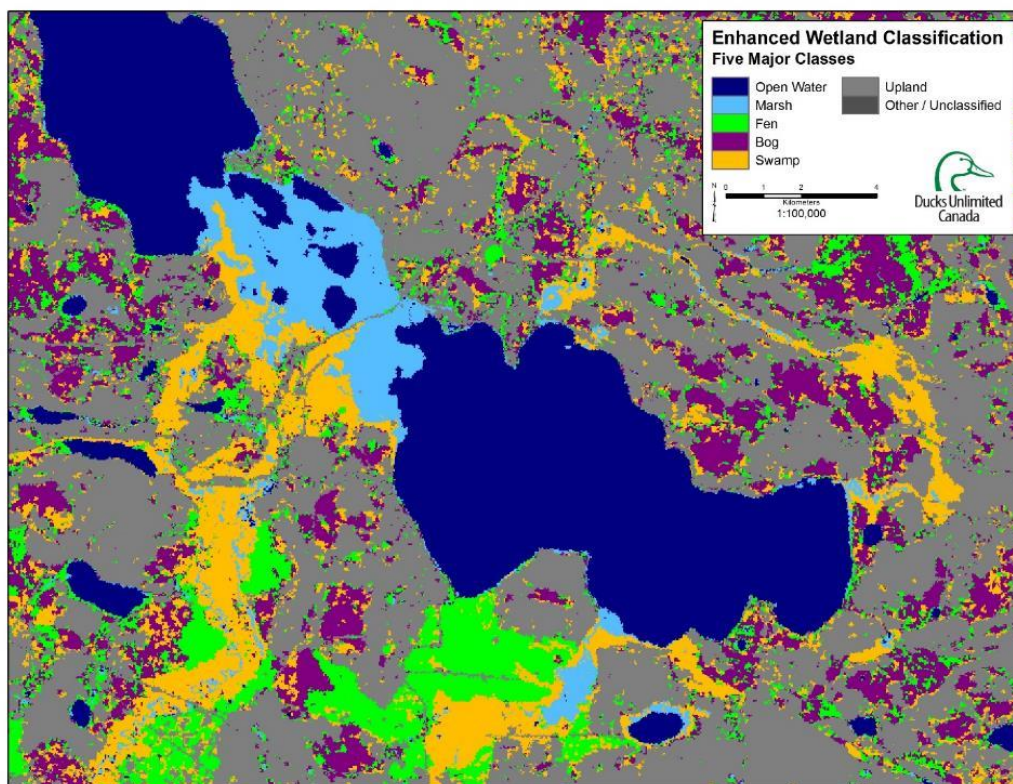


Figure 13. GIS planning tools, such as the enhanced wetland classification, can be used to enhance planning practices and identification of wetland types. Photo courtesy of Ducks Unlimited Canada and partners.

Other unique practices covered a wide range of goals and outcomes including:

- Recording knowledge about wetlands every year and building a database of local knowledge.
- Consulting with local Indigenous communities to map important wetlands.
- Using in-house risk evaluation protocols for wetlands, wherein different wetland types are characterized using a green, yellow, and red risk rating system based on wetland depth.
- Developing an in-house wet area mapping product (compared to the more broadly used provincial wet areas mapping layers).

Key considerations and opportunities

Companies that have a clear process for planning construction on wetlands, and that have invested in data collection and third-party expertise during the planning stage, reported more consistent control over costs and reduced maintenance concerns. Thus, despite the cost and time required for up-front planning, it is clearly a valuable practice.

There is significant variation between companies with respect to the types of information included in the planning process. Developing a more consistent process between companies may be one option for improving collective outcomes related to environmental performance and costs.

Very few companies are purchasing or using the Enhanced Wetland Classification produced by Ducks Unlimited Canada and its partners, yet it may be useful during planning stages. For example, the data layer could be used as an input layer during multi-disciplinary team planning meetings. The detailed wetland classifications within the product could also help companies better predict the type of wetland flow they may encounter in their operations. As described in Section 2.0 of this report, knowledge of wetland types and wetland flow characteristics can and should be a driver for design considerations for flow requirements.

Measuring Peat Depth

Measuring peat depth prior to development, in addition to any general information collected during Environmental Impact Assessment (EIA) or Pre-Disturbance Assessment (PDA) procedures, is an approach that is providing value to some companies. The information is proving helpful in making decisions about route locations and informing detailed decisions about construction techniques. Techniques that have been used include avalanche probes, peat augers, and ground penetrating radar.

What are companies doing?

While general information about peat depth is often obtained during EIA and PDA, additional sampling of peat depths increases potential identification of problem areas associated with deep peat.

The simplest approach to sampling peat depth includes use of an avalanche probe or soil auger. The avalanche probe can sample at deeper depths, while the soil auger more generally informs companies whether the peat is deeper than 2 m.

Ground penetrating radar has also been used by some companies to map out peat depths. However, companies note that ground penetrating radar is more easily collected once the location is cleared and therefore may not be available soon enough in the planning process to make good use of the information. Although geophysical methods (e.g., ground penetrating radar) are increasingly used by companies, the most popular means of measuring peat depth remains physical probing.

Key considerations and opportunities

Peat depth can be an indicator of water content. It can also impact construction procedures, such as determining whether peat excavation is reasonable. Peat characteristics can change with depth, often becoming more amorphous and less fibrous (more decayed) with depth. Bearing capacity may increase with depth, but this varies with peat type and moisture content (MacFarlane, 1969). Peat depth also has an obvious impact on expected settlement in combination with very soft or high moisture peat, with possible settlement exceeding the depth of fill applied as indicated in Section 2.0 of this report. Knowledge of peat properties as they change with depth can be used to predict where deep peat may have low bearing capacity, thereby allowing preventive measures to be undertaken to ensure the integrity and performance of developments constructed on peat.

Unmanned Aerial Vehicles (UAVs, commonly known as drones), are increasingly available for commercial use. A potential application for this technology includes scanning existing ground conditions in otherwise impossible to access areas by flying close to the ground (made possible by the typically low, sparse vegetation characteristic of deep peat).

Lab Analysis to Predict Peat Strength Characteristics

Peat characteristics vary within wetlands, affecting the integrity and reliability of roads and pads. Areas of peat with low bearing capacity may fail during construction, compromising long-term performance, requiring additional fill, and affecting wetland health and hydrology. To identify peat with lower bearing capacity, some COSIA companies are calculating the engineering properties of peat samples and successfully adjusting construction practices in response to their results.

What are companies doing?

Peat sampling is not a common practice, but it provides value to the companies using it. Sampling is often focused in areas where wetland maps indicate potential weak points or areas of concern to engineers (usually deep peat). Field staff collect samples at areas of concern across pads. Sampling methods are specific to the analysis technique, but they generally involve collecting a sample from up to 40 cm below the peat surface and sealing it in a container or bag to prevent any moisture loss.

Lab analyses assess fibre characteristics and moisture content of the peat. Bearing capacity decreases as peat moisture increases, therefore high moisture content could indicate a potential point of failure for a pad or road. Specific strategies to increase bearing capacity at these locations can prevent pad or road failures. This may include the addition of corduroy or use of additional geotextiles to provide sufficient bearing capacity.

Lab analysis can be used to identify spatial variation and lack of uniformity of peat characteristics across a site. This technique can thus be used to identify weak areas and fault locations that are hard to reinforce and need to be “bridged” through separate construction techniques.

Key considerations and opportunities

Using peat sampling to inform construction approaches can clearly improve the reliability of pads, and potentially roads, built on wetlands. Many field staff provided examples where ‘weak points’ in the peat either sheared during construction, or where companies had ongoing maintenance concerns on roads with constant requirements for additional fill. Peat sampling may provide a low-cost option to mitigate these issues and ensure peat integrity is preserved through all stages of construction, including on potential weak points. Sampling peat to assess for potential weakness is particularly important on deep peat as it carries the highest risk.

6.2 – Exploration Programs

Oil Sands Exploration Programs

Oil Sands Exploration (OSE) programs are the main source of temporary footprints within in-situ oil sands. One of the key goals of companies during exploration programs is to preserve the natural hump and hollow microtopography of the peat surface, which helps expedite reclamation and recovery following the temporary developments. To achieve this, companies are using a range of techniques including the following:

- Carefully managing clearing operations to avoid shearing the peat surface and to preserve the natural peat microtopography.
- Using woody materials and snow to fill in the natural hollows in the peat surface.
- Starting the freezing-in process with very light equipment, such as snowmobiles.
- Carefully managing weight during freeze-in by using half-loads of water on trucks with high flotation tires.

Companies have reported a range of success in their approaches and key successes appear to be linked to carefully following the above noted practices.

What are companies doing?

The Oil Sands Exploration footprint is not as permanent as commercial footprints but it is more extensive, contributing to habitat fragmentation on in-situ oil sands operations. Surface vegetation can be disturbed by equipment traffic, including compression or shearing of surface peat hummocks, resulting in reduced microtopographic variation (i.e., humps and hollows) after development. This shearing can reduce availability of elevated microsites, raise the apparent water table and increase seasonal flooding. This results in vegetation changes in favour of greater sedge abundance and fewer bryophytes and woody species (Caners and Lieffers, 2014). Warmer conditions on temporary roads and 3-D seismic can also result in increased greenhouse gas emissions (e.g., methane) (see Section 2).

To maintain the natural hump and hollow microtopography of the peat surface, several common techniques are being used by companies. These include the following:

- Re-using existing footprints as much as possible
- Using directional drilling to reduce the number of oil sands exploration well locations
- Targeting the narrowest points when crossing wetlands

A focus of most companies is to preserve the natural hump and hollow microtopography on wetland sites to expedite the reclamation phases after temporary development. To achieve this, companies are using a range of practices including the following:

- Supporting roads and exploration well sites using onsite woody materials, snow and ice.
- Carefully placing woody materials in hollows within the peat to preserve microtopography.

- Using a phased approach to freezing-in sites, often starting with snowmobiles, followed by snow cats, and then progressing to larger equipment such as small dozers.
- Using half-loaded water trucks with high flotation tires to reduce compression of peat, followed by full loads of water once a solid pad base has been established.

Companies are, however, experiencing varying levels of success. Some companies report that reclamation on wetlands is straightforward because they can preserve hump and hollow microtopography during operations. Meanwhile, other companies have reported that peat is still being compressed on exploration well sites requiring additional reclamation measures to re-establish the natural microtopography of the peat.

One company was also experimenting with exploration drilling from frozen water bodies to reduce their long-term exploration footprint and capitalize on frozen conditions.

Key considerations and opportunities

While some companies reported good results after development on their oil sands exploration sites, not all companies are consistently avoiding peat surface disturbance and compression. Improved communication among companies in this area would help all operators achieve more desirable results.

The companies that reported positive results from their exploration programs had a clear focus on maintaining the natural hump and hollow microtopography of the peat throughout the lifecycle of their temporary developments. This includes ensuring that peat is not sheared during construction of temporary disturbances, using very lightweight machines (e.g., snowmobiles) to initiate the freeze-in phase, and carefully managing weight during freeze-in by using half-loads of water transported by trucks with high flotation tires. Companies experiencing peat compression or loss of microtopography during their exploration operations should consult these practices and evaluate their possible use in their own operations. Companies may also wish to increase the adoption of frost penetration measurements prior to operating on temporary footprints.

The size of exploration footprints is also often limited by the drilling rigs available. In some cases, footprints of exploration wells could be reduced if smaller rigs were available. If possible, encouraging investment in smaller rigs could result in general reduction of exploration footprint. Reducing the number of exploration well locations by using directional drilling where possible could also result in a reduced exploration footprint.

6.3 – Managing Water Flow

Culvert Spacing to Improve Wetland Flow

Culverts are used as a conduit for water along roads and operational pads at in-situ oil sands operations. They are primarily used to provide water flow through a road and reduce any ponding. Current practices typically target culvert placement at flow channels or topographical lows derived from LiDAR imagery. This can result in long stretches of road with no culverts. By placing culverts more frequently, companies are likely to see fewer environmental impacts and improved road integrity.

What are companies doing?

Most culverts are placed at topographical lows along roads or clearly visible flow channels identified via LiDAR and field observation. Companies also commonly install culverts near intersections with other roads or at the ends of roads. Culverts are not commonly placed at regular intervals along roadways. As a result, the observed distance between culverts can range from 350 m to 750 m (Figure 14).



Figure 14. Example of a road where culverts were only placed at topographic lows, resulting in this 500-m stretch of road with a single culvert. Dead trees and trees with reduced vigour were observed beside the road on the ponded side; trees showing increased vigour are found on the drier side.

Key considerations and opportunities

Standardized spacing or increased frequency of culverts

The current reliance on culvert placement only at topographic lows along roads has resulted in several noticeable impacts that can be mitigated. First, when large volumes of water are forced to move through a limited number of culverts the water can form channels on the downstream side of roads. These channels can alter the wetland environment and can also cause localized road settlement if water is drawn from the underlying peat (Scottish National Heritage, 2010) (Figure 15). Reliance on a single culvert leaves no contingency for water flow should it become plugged by beaver activity or some other cause (Bocking, 2015).



Figure 15. An example crossing where concentrated flow has created flow channels at the exit point of the culverts, even though multiple culverts were used. Photo courtesy of FPIInnovations.

Second, trees adjacent to roads may exhibit mortality where wetland flow is limited by insufficient or blocked culverts. Observations from field visits also demonstrated that the direction of wetland flow is not always easy to predict. For example, rather than tree mortality consistently observed on one side of a road with no culverts, patches of dying trees were observed on alternating sides of the road with as little as 200 m separating them. Not only did the presence of dying trees demonstrate that water flow was not addressed, but the alternating pattern of their occurrence clearly illustrates the meandering nature of wetland flow direction over even short distances (Figure 16) and, thus, challenges in predicting flow direction.

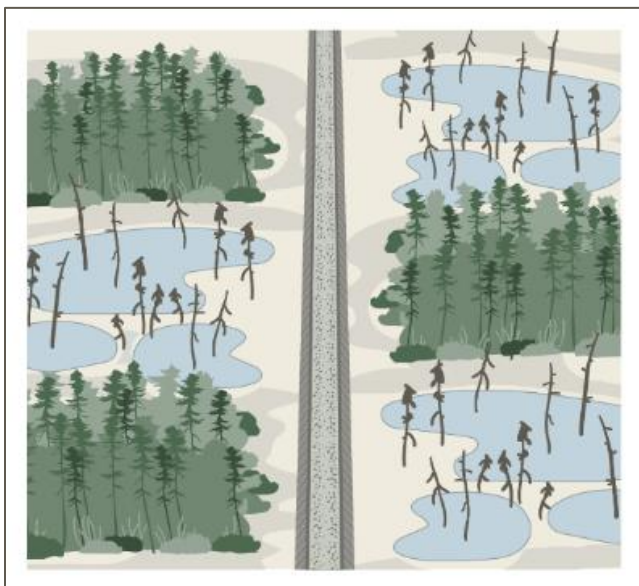


Figure 16. Schematic showing observed changes in flow direction along a short stretch of road through a wetland. Applying culverts more frequently can help address these issues by establishing water balance over the entire distance of road and preventing the damming effect.

One option to address this challenge is to reduce culvert spacing. Installing more culverts will increase road construction costs, but many field managers indicated they would support such an approach. The cost of additional culvert installations is low relative to road maintenance associated with water issues wherein the road base becomes saturated. From an ecological perspective, installing more culverts could dramatically increase water flow and help reduce impacts to wetlands adjacent to roads.

Culvert spacing decisions could follow a simple three-phase process:

1. Determining the wetland type and its water flow capabilities (see Section 2)
2. Defining the permanence of the road
3. Assigning culvert spacing based on these conditions

As an example, FPInnovations and Ducks Unlimited Canada suggested the following spacing considerations in their Resource Roads and Wetlands Guide (Table 3). These recommendations present an opportune starting point for culvert spacing, which could be adjusted with additional assessment of wetland conditions or experience in an operating area.

Table 3. Suggested culvert spacing based on road and wetland type (Partington et al., 2016).

Culvert Spacing	Bogs: Widely Spaced	Fens: Moderately to Widely Spaced	Marshes: Closely Spaced
Maximum spacing for a permanent road	200 m	150 m	100 m
Maximum spacing for a temporary road	250 m	200 m	150 m

In areas where high flow is apparent within the wetland, companies could consider placing multiple culverts spaced closely together. This approach builds redundancy into the culverts such that if one culvert freezes or otherwise impairs flow, other culverts are available to permit flow within the wetland.

Culvert Foundations to Maintain Surface and Subsurface Flow

Culverts which have settled below design elevation are a frequent challenge on in-situ oil sands operations. Companies have devised several solutions to better support culverts and avoid the need to replace sunken culverts. In general, three approaches have been used: culvert pyramids, culverts on piles, and culverts placed after the road has settled. The road settlement approach has had consistent positive results among COSIA companies. Companies that use this approach report very few culvert failures and better overall road performance.

What are companies doing?

Installation and Support – Floating Roads and Pads

Settlement of culverts and sinking culverts represent major challenges on wetland roads and pads as they can reduce the effectiveness of the culverts as conduits for surface and sub-surface water flow. Three observed approaches to address these challenges are culvert pyramids, culverts on piles, or culverts placed after the road has had a chance to settle/season (Figure 17).

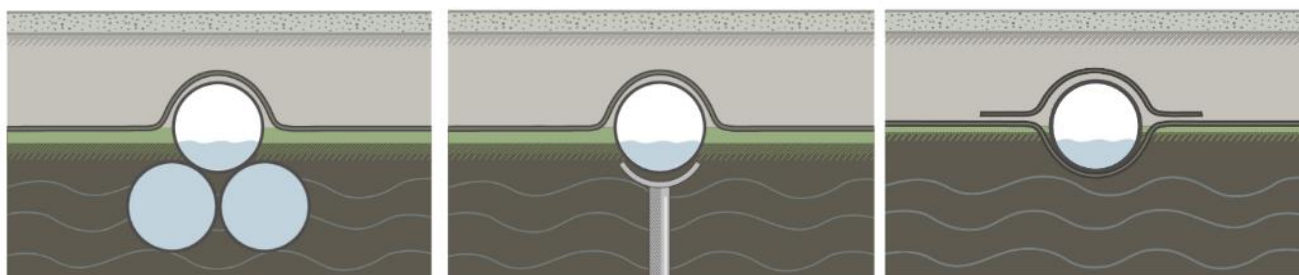


Figure 17. Three schematics of culvert installations. Culvert pyramids (left), culverts on piles (centre) and culverts installed after road seasoning (right).

On deep peat, culverts are generally installed on the surface, although some companies identified instances where a shallow trench was excavated for the culvert in the peat to allow for partial embedment (Figure 18). In cases where a geotextile layer is used as a separation layer, the culvert is generally placed on top of the geotextile, which can provide additional bearing capacity if the material is put under tension.

Figure 18. Example of a partially embedded culvert. Photo courtesy of FPIInnovations.



Installation and Support – Excavated (Shallow Peat) Roads

On shallow peat, the culvert is placed on parent material exposed by excavating the peat. The culvert may be bedded on sand, aggregate or a rock drain in the excavation (Figure 19). Rock drains provide a secure support for the culverts and can also help address both surface flow (through the culvert) and subsurface flow (through the rock drain).

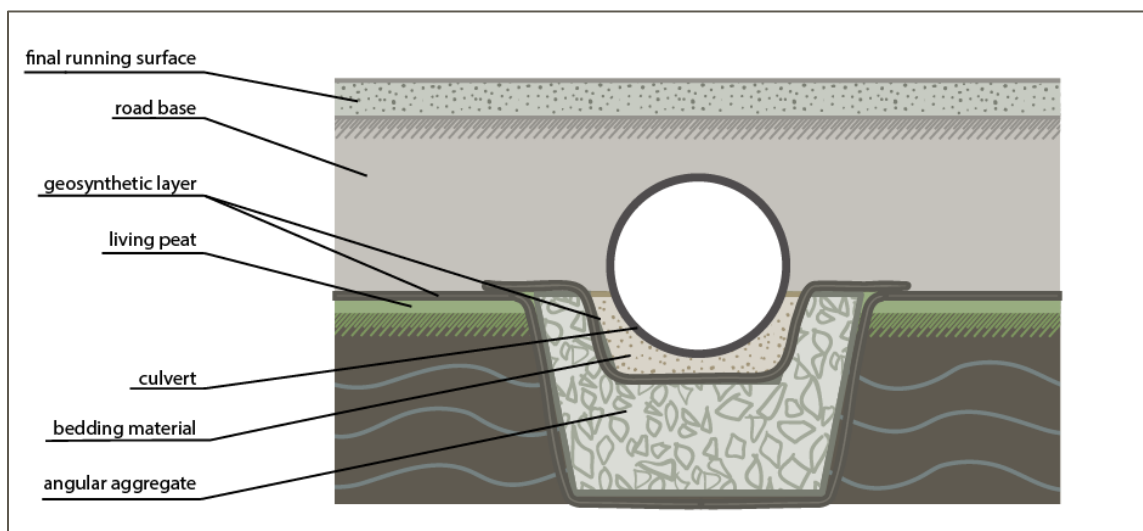


Figure 19. Schematic of a culvert installed on top of a rock drain.

Key considerations and opportunities

Delaying culvert installation

Delayed culvert placement is one of the most successful approaches to reduce or prevent culvert settlement when building floating roads over deeper peat. Temporary culverts are initially placed and after the peat has undergone primary consolidation, they are replaced with permanent culverts (see Section 2), reducing issues associated with culvert settlement and deformation.

The road can settle for a period of time (80–90% of peat consolidation frequently occurs within 30 to 50 days), after which final (permanent) culverts are installed prior to road use. While this technique incurs additional time investment in the short term, companies using this approach have reported better long-term performance of culvert installations, with few reported issues of settlement or deformation. This aligns with the settlement graphs described in Section 2 (Figures 4, 5). Waiting for the peat to consolidate prior to final culvert installation may help to mitigate many of the settlement challenges faced by companies.

Supporting culverts

There are several under-used products that could provide additional support to culverts, such as high strength geosynthetics. When placing culverts directly on the peat surface during road construction, companies should consider using high strength geosynthetics under the culvert to capitalize on their

‘hammocking effect’ (Scottish Natural Heritage, 2010). High strength geosynthetic can be used to achieve this hammocking effect when culverts are placed after road settlement or during initial construction. Where hammocking techniques are used, careful attention should be focused on proper installation.

Companies have also reported success using piles with prefabricated saddles to support culverts (Figure 17). The piles provide elevational support and the saddles hold the culvert in place. Efficiencies are gained by installing the piles (6-inch pipe) with a vibrating attachment on an excavator, eliminating the need for a pile driver or specialized equipment. This technique may prove particularly beneficial for companies that are exclusively using corrugated steel pipe (CSP) culverts in their operations.

Replacing sunken culverts

Companies typically reported replacing culverts that have sunk below the peat surface with another culvert. However, in some cases the additional culvert was placed beside the sunken culvert, exposing it to a similar settlement risk. Instead, it is recommended that operators place the new culvert on top of the sunken one, using it as a foundation for the new culvert; this approach may provide the additional benefit of providing subsurface and surface water flow.

Culvert Materials Used to Increase Performance

Culvert materials have historically been limited to either high density polyethylene culverts (HDPE) or corrugated steel pipe (CSP). COSIA companies have reported challenges installing plastic culverts and often experience bowing or buckled culverts when using CSP. Most companies are now using solid steel pipe for their culverts. These pipes have more strength to resist bowing, are able to be welded together on site, and residual steel pipe is often available from onsite projects. Companies have reported success using solid steel products and most have now adopted this material as standard for culverts.

What are companies doing?

Corrugated steel pipe (CSP) and solid steel pipe are the most frequent materials being used for culverts. Diameters of 600 mm were by far the most common: companies indicated that this size balances water flow needs with settlement observations. Increasingly, solid steel pipes are the preferred culvert material (Figure 20). Solid steel pipes have higher resistance to deformation during installation and do not bow as readily under road settlement. Solid steel pipe sections can be welded to length, although welding pipe is more difficult and expensive than using couplers with CSP. The solid steel culverts are either derived from re-used steel piping, residual steel from pipeline installations, or in some cases rejected new pipe. Most companies noted that CSP culverts are more difficult to install and tend to bow once installed under roads. The main limitation with solid steel pipes is their diameter: they are not readily available in sizes greater than 762 mm (30 inches). Although 600 mm is a very common prescribed diameter, where larger diameters are required, CSP is preferred. Costs for solid steel pipe culverts can range from \$2,000–\$4,000 per pipe; the approximate costs for a 600 mm diameter CSP is \$86 per lineal metre, and for an 800 mm diameter it is \$114 per lineal metre.



Figure 20. View of a solid steel pipe used as a culvert. Note the pipe is higher than the water surface, indicating the need for precise elevation controls during construction. Partial embedment is a common practice in the forestry sector.

Key considerations and opportunities

Most companies have adopted solid steel pipe as their conduit of choice and are finding success with the product, increasing both installation efficiency and providing more reliable water balancing. However, some company engineers hesitate to use solid steel pipe as it is not purpose-built for culverts and may not conform to required standards for this use.

This presents an opportunity to perform appropriate testing to determine whether solid steel pipe meets the necessary standards for use in engineered designs, thus broadening its potential applications to include culverts. The use of this alternate conduit also suggests a window for the introduction of innovative new products that do not yet exist or those which have not been well adopted. A product that could achieve the benefits of solid steel pipe at a lower cost could provide additional benefits to COSIA companies. There are conduits which can conform to the meander of a stream and provide an open bottom for improved environmental performance; these features are especially favourable for fish-bearing water courses.

Rock Drains to Increase Water Flow, Avoid Impacts of Beavers

Rock drains are used to allow both shallow subsurface and surface water to flow from one side of a road to the other. They are suitable for excavated roads on wetlands and they have been used in deeper peatlands by some companies. The angularity and size profile of the aggregate is critical to help ensure that flow is maintained over time and not blocked by fine soil particles. A primary benefit of rock drains is that they permit flow that is characteristic of the wetland; unlike culverts, they are not affected by icing or beavers. Rock drains are typically used in flow channels or in road sections where high flow requirements are anticipated.

What are companies doing?

Three ways in which rock drains have been used to promote wetland flow by in-situ oil sands companies are shown in Figure 21. They have been used as a base below culverts, used with a 100–150 mm perforated pipe, and/or wholly comprised of large aggregate.

Some companies noted that rock drains are a relatively new practice; however, one company has used the technique in combination with culverts since 2010, with high success in ensuring both surface and subsurface flow through the wetlands.

Key considerations and opportunities

Rock drains permit high water flow when initially constructed but this flow rate should be expected to diminish over time as the rock drain establishes. Experience suggests that at the point of lowest flow, the rock drain should still be equivalent to the typical flow rates within wetlands. To maximize flow potential, however, Class 1 rock or ‘gabion rock’ that is 50 mm to 400 mm in size should be used to limit the clogging or filling of fines within the rock drain. Drain rock with 80 mm to 125 mm sizing does not perform as well as Class 1 rock.

Perforated pipes can also be placed among the aggregate through the rock drain to provide an additional opening for flow. The perforated pipe does not have to be large considering the rock drain is also acting to promote flow: a smaller 150 mm diameter pipe is sufficient and resists clogging by fine sediment particles. Some smaller-diameter perforated pipe can be purchased with a ‘sock’ covering to act as a separation layer that keeps the pipe from infilling with fine material.

Rock drains may cause localized settling within roads if they draw water from the adjacent under-road peat. Companies using rock drains have suggested that multiple rock drains with close spacing can address this issue. In cases where isolated rock drains are installed, they should be monitored for signs of localized settlement issues.

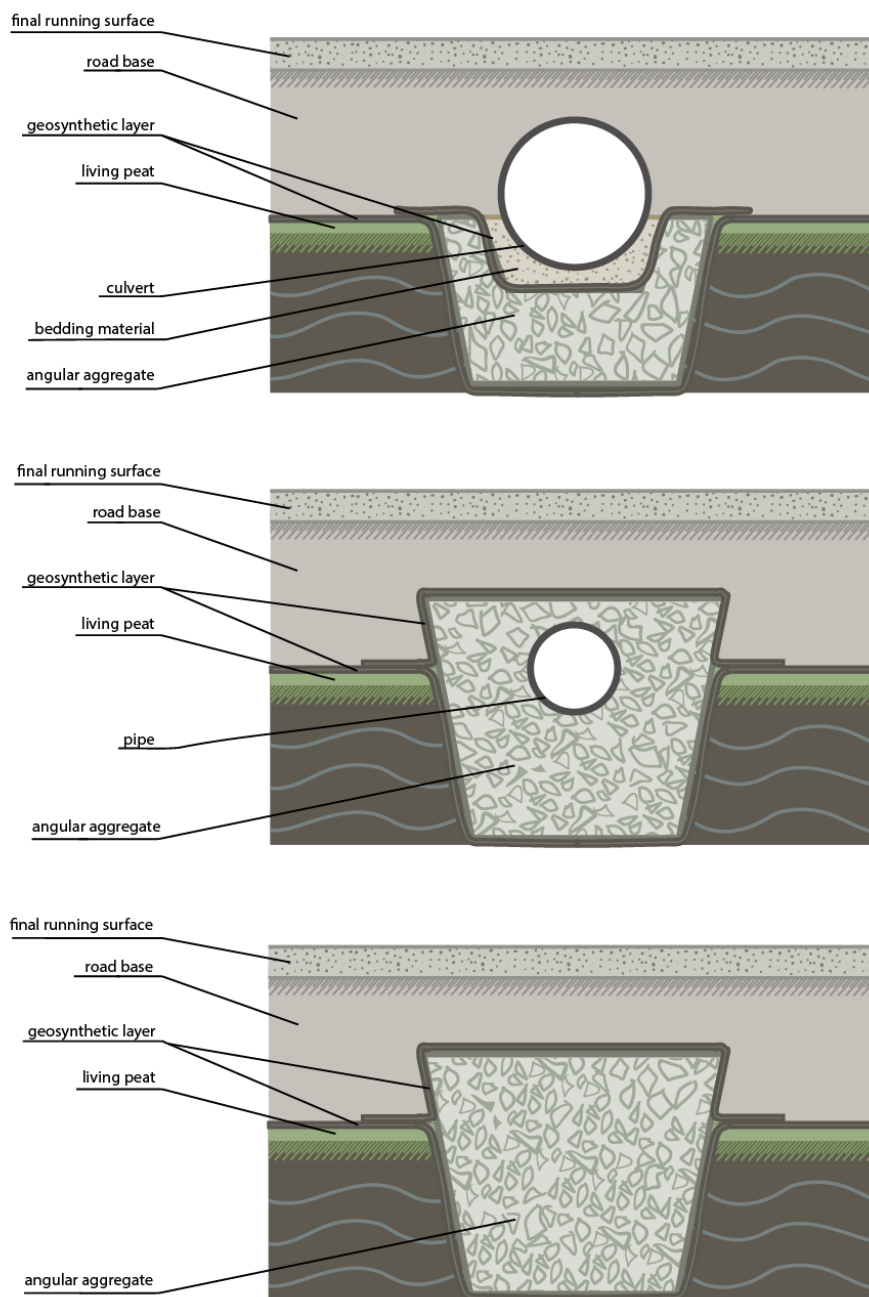


Figure 21. Schematics of different rock drain installations.
Top: Rock drain as a base for a culvert.
Centre: Rock drain with a perforated pipe.
Bottom: Rock drain composed of aggregate stones.

Additional Drainage and Water Flow Solutions

When companies encounter creek crossings, a recent approach has been to build a geosynthetic reinforced soil (GRS) arch as an alternative to a conventional bridge. Companies have reported effective results from the structures, which achieve safety considerations by allowing for two lanes of traffic while also helping to reduce sedimentation into water bodies. A pile supported jump span structure has also been used by one company when an open wetland was encountered.

What are companies doing?

Use of GRS arches is increasing within in-situ oil sands operations and are enthusiastically endorsed by field crews. Key advantages of the GRS arch include:

- Provides efficient two-lane crossings over creeks
- Limits sedimentation into creeks by reducing material pushed into the creek in winter during snow clearing
- Achieves movement criteria for navigable waters

One company has also used a pile supported GRS jump span bridge to cross a sensitive wetland habitat (Figure 22). This option again achieves safety requirements of a two-lane crossing while also reducing the amount of fines and sediments that enter via the crossing, as compared to conventional bridges.



Figure 22. A geosynthetic reinforced soil (GRS) arch used as an alternative to a bridge over a defined water course (left) and a pile supported GRS jump span bridge crossing a sensitive wetland habitat.

Key considerations and opportunities

GRS arches and pile supported jump spans are flexible products that can be built to a range of widths and purposes, thereby enabling safe two-lane traffic. The surfaces are easier to grade and keep clear of snow than bridges and reduce aggregate build up and sediment deposition into water courses and crossings. For these reasons, they are both effective options for achieving environmental and operational objectives. The requirement for specified aggregate (engineered fill) for use with GRS

structures can result in a cost-prohibitive structure due to lack of suitable fill material. Costs and specified fill material also play a role in determining the feasibility of pile supported jump span designs.

The use of concrete box culverts has been suggested as an alternative to an arch culvert for use in wetland crossings. The concrete box culvert does not require specified fill and is well suited (robust) for heavy haul routes.

6.4 – Construction of Roads and Pads

Adjusting Construction Sequence to Enable Settlement

The sequence and timing of road and pad construction are potentially the most important variables that can be managed to reduce long-term maintenance and road settlement. Companies that build their roads or pads in two phases—allowing time for the road to settle and season—reported far fewer issues with both their culverts and their roads in general. They also reported few to no issues with peat displacement, which occurs on peatlands when rapid weight application alters the local hydrology or causes peat failure resulting in weak points in the road. Building roads or pads over multiple seasons aligns with foundational knowledge about peat characteristics and should be implemented whenever possible.

What are companies doing?

While some COSIA companies continue to build roads and pads over a single season, the majority have shifted their operations (wherever possible) to occur over multiple seasons to permit settlement. Companies that build roads over a single season typically cited budget or timing restrictions as key drivers behind this choice. However, these companies also cited issues with peat displacement, peat shearing, culvert settlement and long-term settlement on their roads.

Other COSIA companies initiate construction in winter with the first lift of road base applied during frozen conditions or during the previous summer. Initial lifts thaw and settle through spring with roads completed in the summer. Allowing the road to settle through the spring season provides the peat matrix a chance to consolidate and gain strength before applying additional lifts (see Section 2). This reduces the instances of peat shearing or displacement, which can cause long-term issues for the road and wetland health. Several companies noted they would ‘never go back’ to completing their road over a single season.

Key considerations and opportunities

While timing and budgeting of construction activities can be logistically challenging within companies, those that build roads and pads over several seasons to allow peat to consolidate regularly reported better performance (i.e., less long-term settlement and maintenance issues). These companies also found far better reliability of culvert installations. In contrast, companies that used a ‘just in time’ delivery model, where roads were constructed over a single season, often cited issues with their roads or changes to the local hydrology as evidenced by peat displacement adjacent to the roads.

Identifying opportunities within an organization to conduct road and pad construction over several seasons, thus maximizing consolidation of the underlying peat, is one of the most effective ways to increase settlement predictability, improve road performance, and minimize long-term issues.

Geosynthetics to Provide Bearing Support

Geosynthetics are being used by all companies during road development to increase bearing capacity while building over wetlands. Some companies are using non-woven geosynthetics as a separation layer with the peat surface and using geogrids to provide additional bearing capacity for roads. Other companies are using a combination grid which integrates a non-woven geotextile and a biaxial geogrid into a single product. Placement of geosynthetics within the road and/or pad profile is highly variable among companies. For example, some companies do not apply a separation layer between the peat surface and the road base to prevent mixing of clay material with the underlying organic peat. This mixing of materials will compromise road integrity and reduce reclamation efficiencies.

What are companies doing?

Companies used a variety of geosynthetic products, produced by a range of manufacturers, and placed the product at different layers during road and pad construction.

Three main products are primarily used: non-woven geotextiles as a separation layer, woven geotextiles to provide both flow capabilities and bearing capacity, and geogrids to increase bearing capacity through interlocking and to reduce the amount of fill required (Figure 23). The reduced fill can result in less environmental footprint for fill material and lower construction costs. High strength reinforcement geosynthetics can increase the bearing capacity of road fill and thereby reduce the depth of fill required.

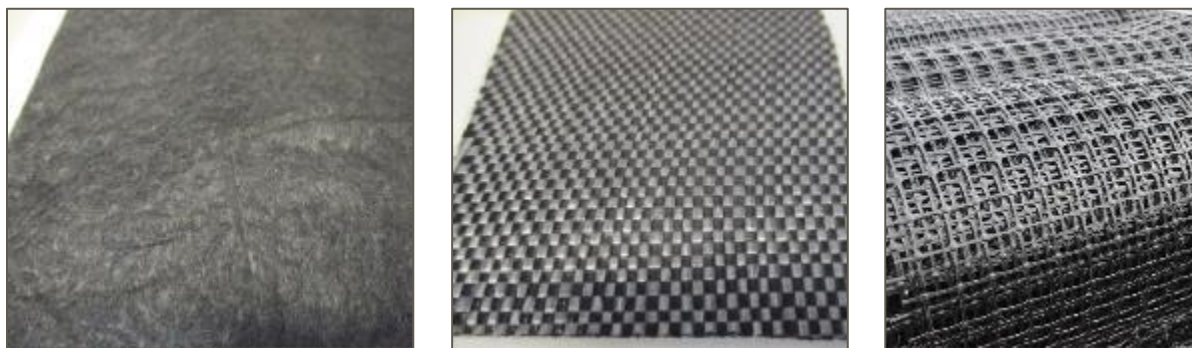


Figure 23. An example of non-woven geotextile (left), a woven geotextile (centre) and a geogrid (right).

Some companies use two layers of geosynthetics: a non-woven fabric on top of the peat surface and a geogrid placed either directly on top of the non-woven fabric or higher in the road base profile. Other companies have moved towards a single-layer product because of increased installation efficiency and reduced tripping and safety concerns. These single-layer products include woven high flow geotextiles, a non-woven separation geotextile with a biaxial grid (e.g., combi-grids), or high strength reinforcement geotextiles (Figure 24). The companies using the combi-grids have reported more consistency in product applications and better overall road performance.



Figure 24. Example of a non-woven separation geotextile with a biaxial geogrid (e.g., combi-grid) combined into a single product.

There is also wide variation in how companies are placing products within the road base or pad base profile. Companies using a combination grid were placing it between the peat layer and the road base fill. Companies using both a geogrid and a non-woven geotextile sometimes placed the non-woven geotextile between the peat and the road base fill, with geogrid placed higher in the base profile. Last, some companies were placing only a geogrid between the peat and the road base fill with no separation layer.

Geocells have been used by a range of companies. Geocells require clean sand to work effectively, and most field staff found this requirement difficult to accommodate in the field. Some companies also reported a lack of lateral permeability of the water, while others noted that the product did not reduce the amount of gravel required as much as they had expected. However, geocells should not be discounted entirely. There are positive reviews of the product from other companies and like most products, geocells may be superior in specific situations but perform poorly in others—especially in cases where manufacturing recommendations are not followed. The suitability of geocells should be assessed for specific applications and conditions.

What is unique?

Only one company is using a combination grid, but they reported good value from the product and good improvement of bearing capacity for roads. The combi-grid has been found to significantly reduce installation time and safety hazards, such as tripping, associated with applying two different products.

A second unique application was that some companies are not using a separation layer between the peat and the road fill. Rather, these companies are simply using a geogrid to provide support for the road base. These applications may be inconsistent with the intentions of the product designs and should be investigated further if companies continue to use this approach. For example, a geogrid alone, without a separation layer or the specified aggregate to achieve interlocking (as per manufacturer suggested use), may not be useful for specific sites and may be unlikely to succeed.

Key considerations and opportunities

Geogrid use by COSIA member companies was not consistent with other industries. The main discrepancy between oil and gas industry use and use in other industries was geogrid being used without the placement of angular aggregate directly on top of it. Geogrid is designed to have angular aggregate, sized to match the geogrid opening size, placed directly on top of it. This results in the aggregate penetrating the geogrid openings to firmly interlock with the geogrid. The aggregate is then laterally and vertically fixed in place by the geogrid (Figure 25). The geogrid stiffens the road base and, when placed at the peat surface, the reinforced layer creates a stable foundation on which to build. It can also provide a road base reinforcement (above the peat layer interface) that allows for a reduced fill thickness, resulting in a lighter road fill. The aggregate and geogrid combination reduce subgrade strain, which would eventually lead to accelerated deterioration, differential settlement, and increased maintenance or repair. While many companies have opted not to use geogrid interlocked with aggregate due to high cost and limited product availability, companies may wish to substitute a separation layer in combination with the geogrid to reduce clay movement through the geogrid.

Similarly, when clay material was placed on top of geogrids, some companies opted to not include a separation layer between the peat layer and the geogrid. When geogrid is thus placed directly on the peat surface without a separation layer below it, the product will not achieve its full performance. The absence of a separation layer below the geogrid also results in fill loss from the road base and/or contamination of the peat below the road.

This consideration highlights the importance of a separation layer between the peat layer and the road fill. Use of such a separation layer will provide many benefits including:

- Preventing loss of road fill into the peat
- Preventing longer-term contamination of the road fill through upward movement of organics and fines
- Creates a visible lower boundary of road materials for reclaiming and decommissioning roads.

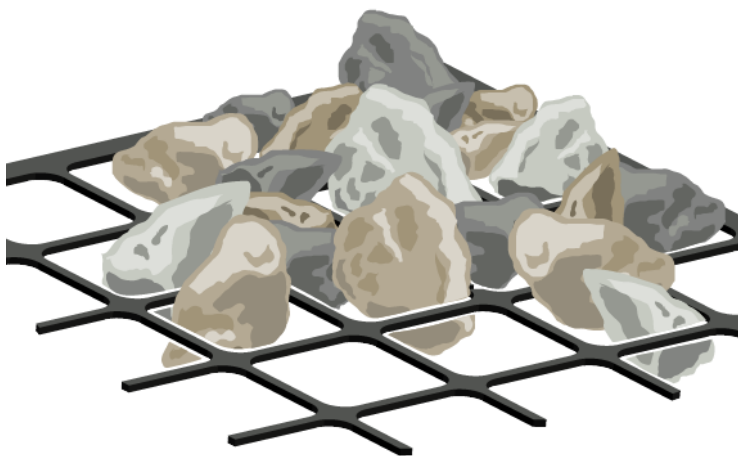


Figure 25. Schematic of the 'locking' effect when an angular fill is used in combination with a geogrid product.

Using Corduroy to Provide Bearing Support and Reduce Fill Requirements

Corduroy utilizes whole logs to construct the foundation for a road or a pad when building over deep peat. While corduroy is used regularly in the forest industry, its use is limited in the in-situ oil sands industry. COSIA member companies using corduroy report reduced fill requirements by up to 50% and increased long-term reliability of roads and pads. The increased bearing capacity provided by logs reduces fill requirements and total road weight, thereby reducing settlement. Where possible, COSIA member companies are encouraged to use corduroy in their operations and explore wood purchase/exchange agreements between companies if appropriately sized logs are in short supply for specific companies.

What are companies doing?

Many COSIA companies stated an interest in the use of corduroy to support roads and pad development, but two common barriers were identified: 1) hesitance among road design engineers within companies because corduroy lacks standardized and uniform properties, as well as standardized installation guidelines and quality control common to alternatives such as geosynthetic products; and 2) a lack of whole logs of sufficient size to form a competent road or pad base. Nevertheless, one company has been actively using corduroy on both roads and pads for many years, reporting no issues with long-term reliability or structural integrity. Furthermore, they reported using up to 50% less fill than would be required if corduroy was not used, thereby reducing the overall environmental footprint. These benefits justify considering corduroy use in road and pad construction.

Corduroy is applied in one or two layers. Logs are either hauled to site using a skidder or transported to the working area via haul trucks and placed with an excavator (Figure 26). A geotextile layer is then placed on top of the corduroy, followed by fill material (Figure 27). Ends of the logs are covered with road fill to slow rotting, avoid log bowing, and address potential safety concerns with exposed log ends.



Figure 26. Logs are generally brought to site using a skidder and placed with an excavator.



Figure 27. Corduroy placement on an in-situ oil sands road, with a geotextile separation layer on top of the corduroy logs.



Figure 28. An example of road (left) and pad (right) construction at an in-situ oil sands facility using corduroy as a base foundation.

Logs for corduroy installations are currently obtained from clearing programs for current facilities. Merchantable logs are harvested and may be stored on site for a period of up to two years to ensure availability on an as-needed basis. In the case of one in-situ oil sands operation, aspen logs are generally used for the corduroy roads because of their lower market value.

It should be noted that although corduroy has many technical benefits, it will take time for operators to develop an efficient process for log handling and placement. Approximately 120 truckloads of logs are required to develop a single pad. The process challenges are considered minor because of the benefit

provided by lower fill requirements. In addition, practices utilized in the forest industry can help facilitate the uptake of this construction practice in the in-situ oil sands industry.

What is unique?

Historically, forestry operations have tended to use large diameter spruce or pine logs for corduroy roads (Partington et al., 2016). These logs are known to have higher strength and to resist flexing when loads are applied. Aspen logs have been successfully used for in-situ oil sands construction. This practice has enabled companies to achieve a beneficial use with aspen logs that otherwise command a low return when sold to local mills.

Key considerations and opportunities

Corduroy represents a key opportunity for in-situ oil sands operators and warrants a closer look from engineering and construction teams. While hesitance from engineers was a common point of concern within COSIA companies, corduroy has a long history of use in other fields and modern approaches have substantially improved its utility. One of the significant potential advantages of corduroy is the reduced fill requirements and associated reductions in environmental footprint and costs by using less fill material from borrow pits. Second, less fill material results in a lower total weight for roads built over wetlands. Reduced road weight reduces the overall settlement and associated loss of water passage capabilities.

Burying the log ends is a practice that has been associated with the use of corduroy when improved bearing capacity has been the sole intention. Log butts that are buried can improve road integrity by preventing logs from bowing, which can cause safety concerns or road toe slope erosion. By eliminating air exposure, burying logs also prevents rot that could affect road integrity. However, water flow can continue through the voids between logs if log ends are left exposed. Companies are encouraged to experiment with exposed log ends to provide multiple conduits for water flow. Corduroy also has the benefit of being a relatively low maintenance crossing and does not attract beavers which can dam traditional larger conduit openings.

More generally, COSIA companies are encouraged to look for opportunities to increase their use of corduroy where possible. Many companies have access to a sufficient volume of logs from their operational clearings that could be put to highly functional and economic use as corduroy roads. Companies that have log size limitations on their tenures may wish to explore the use of wood purchase agreements with neighboring companies to gain access to appropriately sized wood for corduroy installations.

Building on Shallow Peat

In-situ oil sands operations have a standard approval condition that requires the excavation of shallow peat (i.e., peat <40 cm deep). However, situations often occur where variable peat depths are encountered along the length of a road or under a pad location. Several companies are exploring variances to reduce the amount of peat excavation required when peat excavation might compromise the integrity of the road or pad development.

What are companies doing?

While current operating approvals for in-situ oil sands facilities include a standard clause to excavate peat that is <40 cm deep, many companies have found that variations in peat depth along roads or pads means that meeting this approval condition can compromise the integrity of the road or pad. Companies are therefore applying for variances under the AER Bulletin 2014-32. These variances may improve environmental performance by reducing peat storage requirements and maintaining the integrity of the in-situ peat. They also have the potential to save time and reduce costs for operators.

In practice, this means that companies building roads or pads over deep peat will continue to float their pads or roads over sections of shallow peat (Figure 29). This approach can help reduce environmental risks associated with road failure and produce a better road structure with fewer failures and less repairs due to differential settlement and/or drainage issues. Additionally, it can reduce project footprints by eliminating the need to stockpile peat for future reclamation. This reduces the amount of forest clearing required for peat stockpiling and avoids potential changes to local hydrology arising from in-situ peat compression caused by peat storage stockpiles.

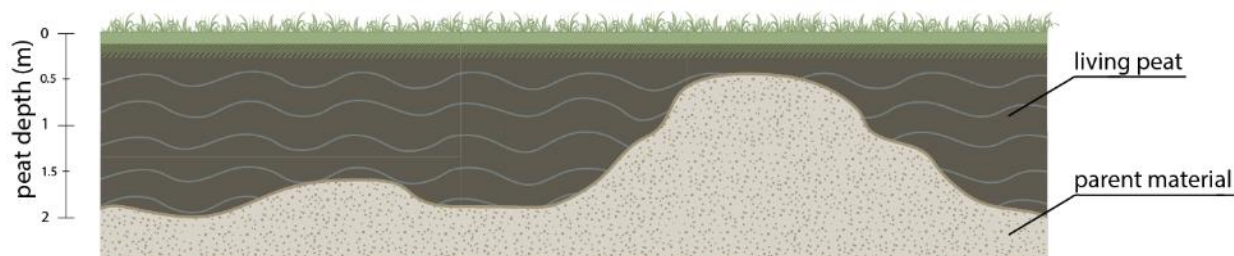


Figure 29. Schematic showing fluctuations in peat depth that can be encountered during road or pad development.

Key considerations and opportunities

Companies that encounter varying depths of peat on their operations should consider applying for variances on requirements for shallow peat removal and storage. This can improve construction reliability and potentially improve environmental performance by reducing road maintenance issues and reducing the additional footprint required for long-term storage of excavated peat. Improved environmental performance may also be realized by keeping the peat in place (although compacted) as compared to having it removed and stored, which may alter the peat properties.

Wick Drains and Drainage Blankets to Protect the Road Base

Wick drains and geocomposite drainage blankets are manufactured products that are used to encourage water flow from the road or pad base out to a drain. The intent is to encourage the uniform lateral flow of water out of the road or pad base. This approach helps to preserve uniform moisture levels within the peat and road base and can help reduce instances of differential settlement on roads and pads. This in turn better preserves the quality and integrity of the road base. While many companies have tried wick drains, few have found long-term reliability and success. Most companies report that wick drains quickly become clogged with fines and become non-functional. However, more recent designs of drainage blankets are reported to have good success and have achieved the goals of encouraging lateral water movement out of the road base.

What are companies doing?

Most companies interviewed as part of this project had experience with wick drains on their operations. An example of their application was showcased during the field visit component of this project (Figure 30). Even though water was observed moving through these wick drains during the field visit, most companies reported low long-term reliability of these products. Most companies noted that they quickly filled with fine-grained materials and become non-functional.



Figure 30. An example of field application of wick drains on a roadway (left) and a geocomposite drainage blanket (right).

Drainage blankets are reported to be a more reliable and useful alternative for encouraging lateral water flow below the road base. Drainage blankets are composed a high-strength, non-woven geotextile; the geotextile is fully bonded to the dimpled drainage core (Figure 30). The high compressive strength of the centre geosynthetic provides a reliable opening for water to move laterally through the road base and to the road edges.

What is unique?

Drainage blankets are a relatively new product on the market but positive reviews from company engineers and construction staff suggest that drainage blankets have a clear role to play in helping preserve the integrity of road bases.

Key considerations and opportunities

Because some companies noted positive performance of wick drains, and this was observed during our field visits, companies are encouraged to investigate various product designs to determine the best products for specific applications. Nevertheless, drainage blankets may be a preferred product over wick drains.

Ditches Used Adjacent to Roads and Pads

Ditches are generally not advised when constructing roads on peatlands, yet some companies referred to roadside ditches in their standard operating procedures. Deep ditches near the roadside on wetland roads can intercept flow in the wetland and could lower the water table. This can reduce the buoyancy of the peat and lead to increased compression and settlement. Ditches should be avoided when building roads on wetlands and preference should be given to preserving the integrity of the peat adjacent to roads.

What are companies doing?

While not common, the use of ditches adjacent to roads was mentioned in the interviews of COSIA companies and in one company's best practice documents. This practice referred to placing the ditch up to three times the depth of the organic layer away from the edge of the road fill. However, ditches are known to have negative impacts on the local wetland environment and can also saturate the sub-base and sub-grade of roads. FPInnovations and Ducks Unlimited Canada have previously shown that in some cases, ditches can interrupt lateral water movement in the wetland and negatively impact road performance (Partington et al., 2016).

Key considerations and opportunities

If roads are constructed properly in wetlands, ditches should not be required in most cases. While ditches play a role in upland sites, they will typically result in the pooling of water adjacent to the road, and will reduce the integrity of the adjacent peat fibres where ditch excavations occur. If necessary, ditches should be shallow, only removing the living layer of the peat (acrotelm) and not disturbing the underlying peat fibres (catotelm) (Scottish Natural Heritage, 2010). Ditches should also be placed far from the road base (Scottish Natural Heritage, 2010). This will help preserve the integrity of the peat surface and avoid ponding of water adjacent to the road base. Wherever possible, however, ditches should not be constructed on wetlands.

Pad Surface Stabilization Using Soil Stabilizers

Two primary tools have been used to quickly improve surface stability of pads: soil cement and crushed limestone. While soil cement has been used by most companies, only one company had positive experiences with it. Most companies did not get the expected results, or could not reduce gravel fill levels to the extent they had hoped. Incorporation of limestone into the subsurface or surface fill material provided a suitable substitute for gravel by one company.

What are companies doing?

Soil cement used for soil stabilization is a tool that has been used by most companies, but few companies had positive enough results to warrant the additional cost of the product. Most companies stated that soil cement was not performing as expected and that it was too costly, but one operation with high silt content in their fill material found positive results from the soil cement. It was noted, however, that soil cement can contaminate pad surface runoff, which may require hauling contaminated water off-site for treatment, increasing effort and cost required for water management.

Crushed limestone has also been used by one company to improve lateral strength and prevent rutting on the running surface of the pads.

Although soil cement is a general term, numerous specific products from various suppliers have been tried by COSIA companies. The newest products claim to be “environmentally friendly,” although these products have not been widely used to date.

Key considerations and opportunities

If available, limestone may be used for pad surface layers instead of or in conjunction with gravel. Structured trials for soil cement on pads may help determine which soil types or applications it works well with, refining parameters for its utility in improving pad surface structure. Such a trial could also help determine whether variable effectiveness of soil cement is due to differences in soil types, manufacturer, application experience, or any number of other factors.

Such a research project will be very beneficial for both the suppliers and the potential users. There seems to be a gap between the two sides at present. Soil stabilizers have the added value effect of dust suppression, which is always a costly safety mitigation, and many companies would like to have a “tool” that would address both dust control and soil stabilization.

Encouraging Pad Drainage by Using Weeping Tile

In one instance, a COSIA company had a pad where there was significant groundwater flow from an uphill slope area to a pad. Weeping tile was installed at the toe of the pad berm to intercept the subsurface water and prevent saturation of the pad base. The technique was successful, with few long-term issues with water management on the pad and no reports of saturation of the pad base.

What are companies doing?

Containment berms are a standard design consideration of operational pads for in-situ oil sands facilities; however, one company installed weeping tile outside of the berm to divert large volumes of groundwater flow from an adjacent transitional upland. The pad was cut and fill construction on mineral soil and the tile drain consisted of a plastic weeping tile pipe wrapped in a synthetic sock (Figure 31).



Figure 31. An example of a cut and fill pad with significant groundwater flow and weeping tile installed to divert water from the pad, preventing saturation of the pad base.

Key considerations and opportunities

Products like weeping tile may be a valuable tool for companies that face unique situations such as high groundwater flow from adjacent upland or transitional forests.

6.5 – Erosion and Sediment Control

Erosion and Sediment Control to Preserve Wetland Health

Erosion control is a high priority for companies working within wetlands. Runoff is a potential source of contaminants and sediment, and erosion is carefully monitored on sites. Sedimentation can also interfere with drainage products; thus, erosion control has both environmental and maintenance benefits. Typical products include straw wattles, silt fencing, fibrous matting, and wood mulch. While these products can help reduce short-term erosion, they quickly collect silt and require regular maintenance. Increased use of vegetation as erosion control, such as planted poplar and willow cuttings/stakes, could help improve erosion control outcomes. Hydroseeding is also an option for establishing vegetation cover, however many companies indicated it was not a cost-effective strategy.

What are companies doing?

Several different practices are currently in use by companies, including:

- Runoff collection ditches on pads
- Coconut mats
- Stone armor (rip rap) on discharge points.
- Straw wattles
- Hydro seeding
- Wood mulch



Figure 32. Straw wattles and coconut matting erosion control measures used by COSIA companies.

Key considerations and opportunities

Most of the products being used to slow water flow on sites will collect silt quickly. They require frequent maintenance (e.g., wattles and fences) or they will cease to function and increase erosion. Regular maintenance is, therefore, a key best practice. Vegetation is usually the best erosion and silt control measure and should be employed as often as possible. While many companies were seeding

grasses or native vegetation, companies should also consider bioengineering solutions such as planting poplar and willow cuttings/stakes (Lewis, 2000; Polster, 2013).

Many companies are encouraged by the regulators to place the salvaged topsoil and/or peat over the sides and bottom of drainage ditches (i.e., 'dressing up' the ditches), thus promoting vegetation and natural sediment and erosion control. There is a debate, however, about the effectiveness of this measure and whether it results in more soil displacement while the vegetation is established.

This represents an additional research opportunity to compare the results from bare surface ditches, 'dressed up' ditches, and lined ditches over a period of three years and determine which is the most environmentally-effective measure. There are also erosion control blankets with pre-seeded or pre-vegetated sockets, which could likewise be tested. The benefit of this product is that the grass growth is expedited and the initial soil displacement until it is established is eliminated.

Recently, a few compost-based erosion control products have been developed and offered on the market. The intention and expectation is likewise that they would expedite vegetation growth.

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