OPERATIONAL GUIDE

FOREST ROAD WETLAND CROSSINGS

LEARNING FROM FIELD TRIALS IN THE BOREAL PLAINS ECOZONE OF MANITOBA AND SASKATCHEWAN, CANADA

LP BUILDING PRODUCTS

Ducks Unlimited Canada

FPInnovations

SPL

SUSTAINABLE FORESTRY INITIATIVE

Weyerhaeuser

VERSION 1.0
MAY 2014

PURPOSE OF THIS GUIDE

The purpose of this guide is to provide forestry professionals and contractors with a general understanding of boreal wetlands, what to expect in terms of water movement between different types of wetlands and general considerations when planning, constructing, monitoring and decommissioning wetland crossings.

ACKNOWLEDGMENTS

The project team would like to extend our sincere gratitude and appreciation to the Sustainable Forestry Initiative Inc. (SFI) for their commitment to helping the forest industry and other organizations achieve sustainable forest management. SFI has recognized the importance of wetlands as an integral component of healthy forest landscapes through their financial support of this project. We applaud SFI for their continued support of projects like ours through the Conservation and Community Partnerships Grant Program that contribute to enhancement of current and future SFI forest certification standards.

The project team would like to thank all partners who were instrumental in assisting with the design, development and implementation of all aspects of this project: Ducks Unlimited Canada, FPInnovations, Louisiana-Pacific Canada Ltd., Weyerhaeuser Canada, and Spruce Products Ltd. In addition, we would also like to thank all of the staff and forestry contractors who participated in the workshops and implementation of the field trials in Manitoba and Saskatchewan.

TABLE OF CONTENTS

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INTRODUCTION

CANADA'S BOREAL FOREST IS RICH IN WATER RESOURCES

More than two-thirds of Canada's boreal forest is covered by aquatic ecosystems including wetlands, lakes, rivers and streams. Wetlands provide numerous benefits including water purification, flood moderation, carbon storage, fish and wildlife habitat and unique cultural values. Some forested wetlands can provide merchantable tree species, offering significant value to the forest industry.

Many boreal wetlands are highly connected systems that move water and nutrients slowly across the landscape making them vulnerable to road development that can potentially block water flow. This impedance of flow may result in the die off of trees or other long-term vegetation changes. This can be a very gradual process depending on the extent of damming and can sometimes take decades to see the full effects of these hydrologic changes.

Forest road development must consider multiple business needs which include harvesting, log hauling, forest renewal and safety while balancing numerous environmental considerations including impacts on aquatic systems. Resource managers are faced with numerous challenges when planning, constructing and maintaining roads that cross wetlands. These challenges include knowing where wetlands are located (i.e. mapping), identifying the different types of wetlands and understanding how and when water moves through these wetlands. Common operational problems associated with wetland crossings include soft road conditions, rutting, icing and safety concerns, all of which can result in increased maintenance costs.

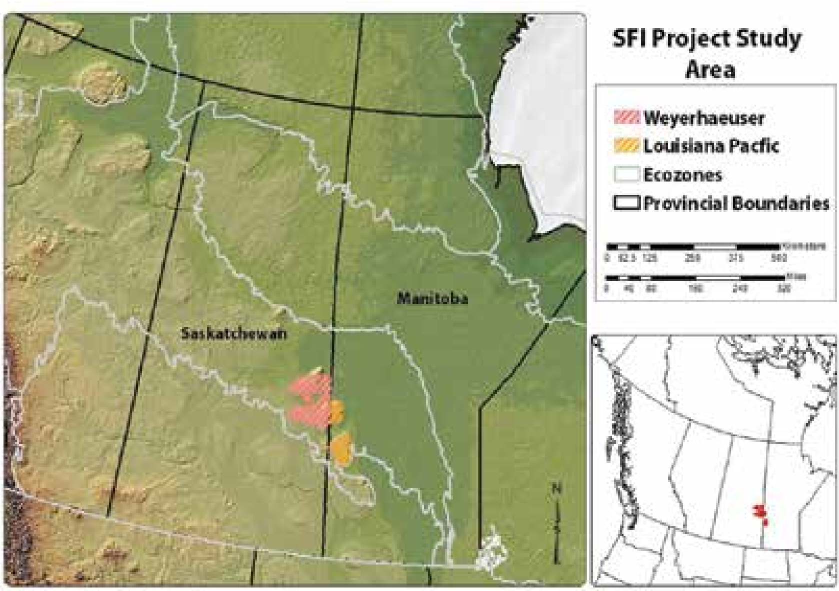
Knowing where wetlands are located and understanding how water flows through them can help ensure a successful road project, while minimizing impacts to wetland ecosystems.

To further examine these challenges a three-year project was undertaken with the support of a conservation grant from the Sustainable Forestry Initiative in partnership Ducks Unlimited Canada, FPInnovations, Louisiana-Pacific Canada Ltd., Weyerhaeuser Canada and Spruce Products Ltd.

Key components of this project included:

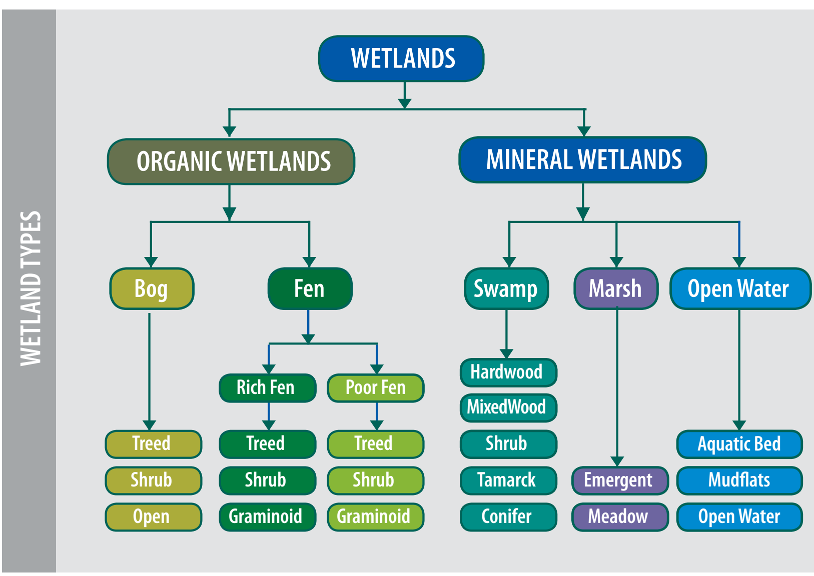
1. Generating an understanding of current state of knowledge on existing wetland crossing techniques
2. Workshops and field trips to exchange knowledge on boreal wetlands and associated crossing techniques and challenges
3. Field trials to test new wetland crossing techniques
4. Evaluation of effectiveness of these crossing techniques

The following is a synopsis of what was learned to enhance the location, design and construction of boreal wetland crossings to protect the integrity of these wetlands in the area of study.



WETLAND TYPES

There are five **major** classes of wetlands found in the boreal forest: bog, fen, swamp, marsh and shallow open water. These wetlands can be grouped into two categories based on soil type: organic wetlands and mineral wetlands.



ORGANIC WETLANDS

Includes bogs and fens typically located on flat, poorly drained terrain and characterized by deep organic deposits greater than 40 centimetres, often called peatlands or muskeg.

Bogs

- stagnant, non-flowing systems
- treed bogs have stunted black spruce less than 10 metres
- shrubby bogs contain ground level shrubs
- open bogs are dominated by grasses and moss

Fens

- slow flowing systems moving water across the landscape
- treed fens have stunted tamarack less than 10 metres
- shrubby fens have short bog birch less than 2 metres and
- open fens are dominated by grasses

MINERAL WETLANDS

Includes swamps, marshes and shallow open water and characterized by shallow organic deposits less than 40 centimetres.

Swamps

- fluctuating water tables, seasonally flooded
- treed swamps have tall dense canopy and greater than 10 metres
- shrub swamps have tall dense willow/alder greater than 2 metres

Marsh

- mostly flooded, periodically drying out
- marshes are dominated by rushes, sedges, grasses and cattails

Shallow Open Water

- inundated/flooded with water depth less than 2 metres generally permanently flooded but may fluctuate seasonally, exposing mudflats

More information on the different boreal wetland types is included in Appendix A.

FLOW CHARACTERISTICS

Wetlands are often connected and may be permanently or seasonally flooded. Water tables can rise and fall seasonally or after precipitation and may flow across the landscape, above or below the surface.

Understanding the flow characteristics of different wetland types provides significant insight into potential challenges if they are crossed with a road. To assist in predicting water flow, wetlands have been grouped into four main flow categories.

FLOW CHARACTERISTICS	STAGNANT	MOVING	INUNDATED/FLOODED
	• Open Bog • Shrubby Bog • Treed Bog • Treed Poor Fen • Conifer Swamp*	**Slow Lateral Flow** • Graminoid Poor Fen • Graminoid Rich Fen • Shrubby Poor Fen • Shrubby Rich Fen • Treed Rich Fen **Seasonally Fluctuating** • Mixedwood Swamp* • Tamarack Swamp • Hardwood Swamp* • Shrub Swamp*	• Emergent Marsh • Meadow Marsh • Open Water • Aquatic Bed *(may have significant water level fluctuations)*

** Often associated with flowing water systems, in which case increased water movement and water level fluctuations are expected.*

STAGNANT

Includes bogs, treed poor fens and conifer swamps.

- water source from rain or snow resulting in minor fluctuations
- often isolated from other wetland systems with minimal water flow
- water is often present at or below the surface and a defined stream channel is unlikely
- conifer swamps can have moving water if connected to a flowing water systems

MOVING - SLOW LATERAL FLOW

Includes graminoid (grassy) fens, shrubby fens and treed rich fens.

- receive water from precipitation, runoff and groundwater
- typically connected to adjacent wetlands
- slow moving flows at and below the surface, including continuous seepage

MOVING - SEASONALLY FLUCTUATING

Includes shrub/hardwood/mixedwood/tamarack swamps.

- receive water from precipitation, runoff and groundwater
- typically part of a flowing water system
- generally slow water movement at and below the surface
- water levels fluctuate seasonally or during runoff events, and may flood above the root mat

INUNDATED/FLOODED WETLANDS

Includes marshes, aquatic bed, and shallow open water.

- receive water from precipitation, runoff and ground water
- water levels may fluctuate seasonally or annually or may dry out

Meadow Marsh

PLANNING

Implementing Best Management Practices when developing roads in wetland rich environments can help mitigate environmental effects and ensure long-term road performance.

Through the use of effective road planning and construction techniques, forestry professionals and contractors can:

- maintain water quality and water flow through wetlands
- help minimize disturbance of the organic soil layer
- conserve the ecological integrity of wetland environments
- reduce forest road construction and maintenance costs
- enhance road and operator safety

When developing forest roads through wetland systems, planners need to address environmental and operational considerations prior to road construction. Forest planners typically locate forest roads to avoid sensitive water features, such as wetlands, as it makes ecological and economic sense to do so.

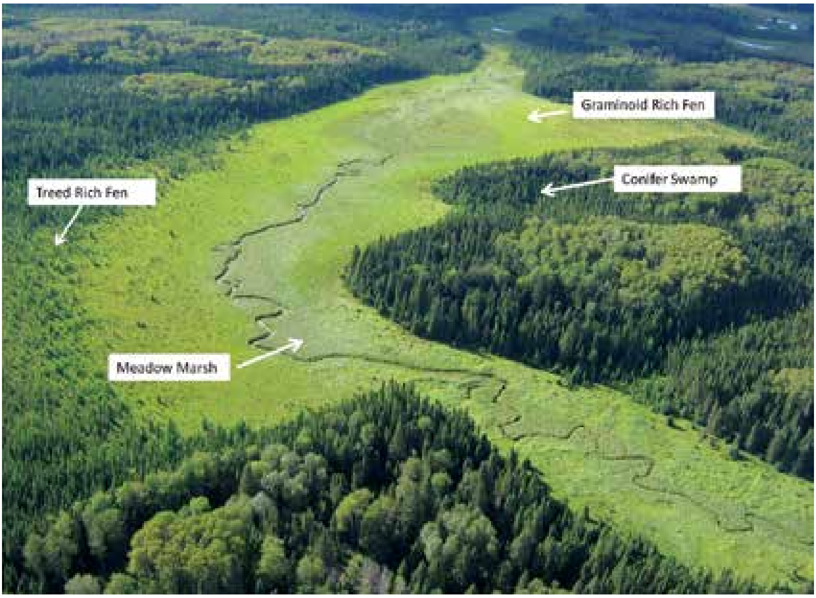
Where avoidance is not possible, forest planners should:

- identify the network of wetlands and associated water features using photo imagery and other GIS related information
- conduct spring/summer road location reconnaissance and collect information on wetland type, soil depth, wetland size and information on water flow (location, direction, and level of flow)

This information will help the forest planner better understand how water is moving through the wetland, and allow for the implementation of more informed road development strategies that help minimize disturbance to the wetland and reduce operational costs.

Once boreal wetlands are classified into specific wetland types, they can be categorized based on how water flows on the surface and/or subsurface through the wetland system. This information is important when making decisions on the road and crossing location, timing of construction, lifespan of crossing (i.e. long-term versus temporary roads) and in the selection of construction methods that best fit the conditions that occur on site.

Another important factor to consider is wetland complexity. Wetlands can occur as a single feature or as a series of wetland types across a larger expanse within the landscape, often referred to as a wetland complex. Water flow characteristics can be difficult to determine within a wetland complex, as a variety of wetland types are working together to move water across the landscape. When a wetland complex is encountered it is recommended that the crossing be designed to accommodate the most dynamic water flow conditions. This practice will reduce the risk of road and crossing related problems during high water flow events.



Wetland complex with various water flow characteristics (see page 9).

LOCATIONS

It is important that the design of a wetland crossing accommodate the anticipated flows at the location. As a general rule forest planners should anticipate water movement across the entire width of the wetland.

The functional groupings of wetlands will provide some insight to the water flow characteristics of different wetland types.

Wide Wetland Locations

- it is important to ensure that flows are not funneled through a single conduit creating a "pinch point" where flows may become impeded
- the use of multiple (e.g. spaced culverts) or continuous (e.g. corduroy) conduits allow water to flow through at various locations across the wetland and can help maintain natural hydrologic patterns
- providing numerous flow paths through the road at a wide wetland crossing location provides alternative routes for water to flow in the event that one of the conduit becomes blocked

Narrow Wetland Locations

- performance of a wetland crossing at a narrow location is significantly more important than a crossing at a wider location, as it may be the only conduit to maintain water flow
- the design should satisfy maximum flow events anticipated within the wetland type (indicated by functional groupings)
- depending on the width of the narrow crossing, there may only be room for a single conduit to accommodate for flow through the road

Wide wetland crossings should have multiple flow entry points.

Narrow wetland crossings should accommodate high flow events.

TIMING OF CONSTRUCTION

The timing or season of construction is an important factor to consider when crossing wetlands. For example during summer months, conditions for road building can be highly unpredictable based on the number and severity of wet weather events.

Most often, construction activities are postponed during wet weather to avoid unnecessary damage to soil and drainage areas. During wet conditions, the use of low ground pressure equipment that distributes the weight of the machinery over a larger surface area can help prevent soil compaction or disturbance to the area.

Construction of wetland crossings during the winter is common in northern boreal forest environments, where operational costs may be reduced and where construction can occur with minimal soil disturbance due to frozen conditions.

LIFESPAN

Determining the lifespan of a wetland crossing will help guide the crossing design and water management options used to maintain the water movement of the wetland.

Long-Term Crossings

- typically crossings that are active for five years or longer
- implement designs and construction materials that provide for the anticipated road use and providing for the greatest flow events that may be expected

Short-Term or Temporary Crossings

- are active for less than five years
- must be durable and maintain flow capacity
- modifications to the design and construction material can be made to account for a shorter period of use such as biodegradable geotextiles or corduroy

The following section provides an overview of the various construction methods and materials that were used during the implementation of field trials conducted in Manitoba and Saskatchewan.

CONSTRUCTION METHODS

Once the crossing design is determined the next step is to determine the construction method.

Construction methods should be selected based on:

- season of construction and proposed lifespan of the crossing
- costs associated with the purchase of off-site materials or the procurement of on-site materials
- activities planned for future decommissioning and rehabilitation

The following section provides a description of the various construction methods that were established in support of the field trials conducted in Manitoba and Saskatchewan.

GEOSYNTHETICS

Geosynthetics are comprised of a number of products and materials used for road/crossing and erosion control purposes.

Geotextile is a geosynthetic material manufactured in woven and non-woven types and is available in various levels of tensile strength. Woven geotextile is generally stronger and more durable than the non-woven type.

The type of geotextile used should be selected based on the function it is meant to serve at the wetland crossing. Geotextile fabric can be used to separate construction layers, provide for road reinforcement, and contain road fill material.

Separation

- geotextile used between construction layers of the road prevents mixing of material
- woven and non-woven types can be used

Geotextile used as a separation layer.

Reinforcement

- woven geotextiles can be effective when used for road reinforcement purposes
- for increased road reinforcement, place geotextile on top of the remnant root mat and tree stumps along right of way
- placing geotextile over an uneven road base creates tension across the layer of the geotextile reducing the sinking of road fill material into the wetland and from mixing with underlying material

Photo credit: FPInnovations

Geotextile placed over uneven road surface.

Containment

- geotextile can be used to contain fill material
- when using corduroy crossings, extending the geotextile beyond the ends of the corduroy helps to prevent sediment and other road surface materials from entering into waterways
- an alternate approach is to construct a curb log by wrapping logs lying parallel to both sides of the road with geotextile which helps to contain road fill material once it is in place
- this practice may be effective for road decommissioning activities where the logs can be pulled back allowing for the removal and disposal of the material

Extending geotextile helps prevent sediment from entering waterways.

Photo credit: LP Canada

Curb logs can help contain road fill.

Biodegradable Geotextiles

- biodegradable geotextile such as woven jute can also be used in crossing designs
- may be more suitable for temporary crossings as materials naturally break-down more rapidly
- the average lifespan of a biodegradable geotextile is approximately two years
- an advantage of biodegradable geotextile is this material can be left in place to decompose, lending itself to be operationally cost effective and environmentally friendly

Photo credit: LP Canada

Use of biodegradable geotextile is suitable for temporary crossings.

CORDUROY

Corduroy (tree length logs) when properly installed, can effectively increase the road bearing capacity and facilitate water flow through the base of the road.

Corduroy applications are often operationally cost-effective as materials can be found on site and considered to be environmentally friendly as it can be left on site to decompose over time.

When planning for a corduroy crossing:

- consider the lifespan of the crossing, the type of tree species, tree diameter and length

- typically smaller diameter conifer logs are selected, although other species can be used
- use more than one layer of corduroy to accommodate for the movement of water
- corduroy that has branches and/or branch stubs remaining may create spaces between the adjacent logs providing more opportunity for water flow through the crossing

Corduroy can increase road bearing capacity and facilitate water flow.

Photo credit: LP Canada

Corduroy with branches can help facilitate water movement.

- consider the timing or season of construction for corduroy crossings
- frozen soil conditions provide more strength for the roadbed and help prevent damage or sinking that may occur from the use of heavy equipment during construction *(Gillies 2011)*

Use of corduroy in combination with geotextile.

- corduroy is often used in combination with geotextile, whereby geotextile is placed below the corduroy, above the corduroy or both to provide for a separation layer between the logs and the road fill *(Gillies 2011)*
- geotextile prevents the road material from moving into the spaces between the logs allowing for unobstructed water flow or seepage and also prevents sediment from being deposited into the wetland

CULVERTS

Plastic and metal culverts are commonly used to allow surface or subsurface water flow from one side of the road to the other.

Culverts are manufactured in a variety of diameters, lengths, corrugations, thicknesses and coatings. They can be cost effective and environmentally friendly if the appropriate size specifications have been determined, the installation is done properly and regularly scheduled inspections and maintenance are completed while the structure is in place.

Metal Culverts

- metal culverts provide greater strength and durability and are considered to be lightweight relative to other crossing types such as portable bridges
- forest operators suggest metal culverts are more prone to freeze-up during winter operations, causing water to back-up, eventually flooding over the road resulting in road damage and safety issues

Plastic Culverts

- plastic culverts are suggested to have higher thermal properties and are not as conducive to freezing-up
- plastic culverts are lightweight, durable and well suited to road construction projects that require pipe flexibility
- to prevent uplifting of plastic culverts securing a straight log parallel to the culvert will help maintain its shape and orientation

Photo credit: Spruce Products Ltd.

Plastic culverts have higher thermal properties and may help reduce freezing up and ice blockage.

Culvert Sizing and Spacing

- for long term crossings (5 or more years), culvert sizing should accommodate the potential for a high flow event
- for short term crossings (less than 5 years), the use of smaller diameter culverts may be more appropriate
- installing culverts so that a portion of the culvert is embedded (buried) into the wetland to provide for the movement of subsurface water flow, as well as, surface water flow *(Phillips 1997)*. This technique may prevent culverts from becoming perched
- where the wetland crossing spans a large distance, the use of multiple culverts, spaced along the length of the forest road will assist with maintaining water flow
- it is recommended to space culverts 15-100 metres apart depending on the length of crossing *(Phillips 1997)*

Culverts Used with Other Materials

- the use of geotextile beneath a culvert can help provide additional road bearing capacity and prevent the culvert from sinking
- the use of corduroy in combination with a culvert can increase water flow capacity of the structure, and provides for additional support for the culvert
- corduroy, extended out to the ends of the culvert, may help to reduce the amount of road fill that may spill over and block the culvert as result of road maintenance activities
- when using a combined culvert/corduroy crossing, logs should extend out to the ends of the culvert to help prevent material from being deposited into culvert openings from road maintenance activities

Example of culvert used in combination with corduroy.

Culverts should be embedded.

SNOW AND ICE CROSSINGS

Snow and ice crossings are often used to reduce forest road development costs and to minimize disturbance to sensitive areas, such as wetlands.

Snow and Ice Crossings

- recommended for crossing inundated/flooded wetland types
- constructed from clean snow found on site or transported in from nearby locations (depending on snow availability)
- the crossing is filled with snow and compacted to create a stable driving surface capable of carrying heavy loads
- when required, water will be used to flood the surface of the snow crossing to enhance the bearing capacity and extend the longevity of the crossing to spring break-up
- construct when temperatures are warmer as colder temperatures create a *sugary* snow condition which does not allow for layers of snow to compact
- road fill material may be used on the road surface
- when the site is decommissioned much of the fill material should be removed prior to thaw
- snow and ice crossings can be used in combination with culverts and/or corduroy in areas where increased water flows are present or may occur
- before spring melt or flows develop, trenching the crossing at various locations will facilitate water flow during this period

Photo credit: FPInnovations

Snow and ice crossings are ideal when crossing inundated/flooded wetlands.

DECOMMISSIONING

Decommissioning of crossings should be considered during the planning phase to ensure that surface and subsurface water flow is maintained post-construction.

It is important to consider the time of year and equipment required to deactivate the site, disposal of materials that are no longer required and rehabilitation techniques that will stabilize and restore the crossing location back to near natural conditions.

Some decommissioning techniques may involve:

- re-contouring of road approaches to near natural slope conditions
- removal and disposal of geotextile
- removal and/or disposal of corduroy
- removal of road fill material from snow and ice crossing
- trenching snow and ice crossings to facilitate water flow during spring melt
- use of soil stabilization techniques, for example, grass seeding and placement of erosion control blankets

Photo credit: LP Canada

Example of decommissioned crossing site where culvert was removed and use of erosion control matting.

MONITORING AND INSPECTION

Crossing sites should be monitored on an ongoing basis to determine if they are performing as intended.

The following are indicators that will help determine if a wetland crossing is not accommodating water flow. Sometimes problems are not immediately apparent since subtle changes can be difficult to detect over the short term.

Ecological Indicators

Blockage of flow often results in changes in native vegetation:

- presence of aquatic vegetation such as cattails growing on one side of the road
- vegetation die-back, reduced vigor and/or tree stress such as brown needles and/or leaves resulting from an increase in water table
- more vigorous tree growth on one side of the crossing such as black spruce and tamarack resulting from a lowered water table
- an increase presence of snags on one side of the crossing as a result of tree death from flooding

Other signs of blockage:

- water ponding on one side of the crossing
- beaver activity at the crossing site

Cattails and dead trees.

Water ponding.

Operational Indicators

- perched culverts that prevent the natural flow of water
- sunken culverts that block natural water flow
- soft road surface and rutting due to wet sub grade as a result of blockage of flow through the crossing
- deposition of road fill material into exposed corduroy and into the wetland which can result in the blockage of flow
- flooding or icing on road surface

Photo credit: LP Canada

Perched culvert.

Photo credit: FPInnovations

Sunken culverts can block flow.

Photo credit: FPInnovations

Soft road surface and rutting can be caused by blockage of flow.

WETLAND CROSSING DESIGNS

A variety of wetland crossing methods and techniques can be used and/or adapted to suit wetland type and water flow conditions.

The following schematics provide guidance for constructing wetland crossings under three flow conditions:

- stagnant (bogs, treed poor fens and conifer swamps)
- slow lateral flow (graminoid (grassy) fens, shrubby fens and treed rich fens)
- seasonally fluctuating (shrub/ hardwood/mixedwood/tamarack swamps)

These schematics will help inform crossing design and minimize the potential risk of effects on the wetland over the lifespan of the crossing.

Proposed Wetland Best Practices

Water flow characteristics: Stagnant Culvert amongst corduroy

! Crossings needs to accommodate minimal fluctuating water levels below the surface.

Hydrology

- A stagnant water flow regime includes **open bogs, shrubby bogs, treed bogs, treed poor fens and conifer swamps.**
- Water source for most of these wetland types is typically from rain or snow resulting in minor fluctuations.
- Conifer Swamps are sometimes associated with flowing water systems, in which case increased water movement and water level fluctuations can be expected.
- Can be considered dryer than most other wetland types. For this reason relatively small culverts placed along the undisturbed forest floor / root mat will provide a conduit for water when flooded conditions do occur.
- Pools of water may be present during periods of high water.
- Unlikely to encounter a defined stream channel.

Suggested construction notes

Culvert diameter: 150 –300 mm.

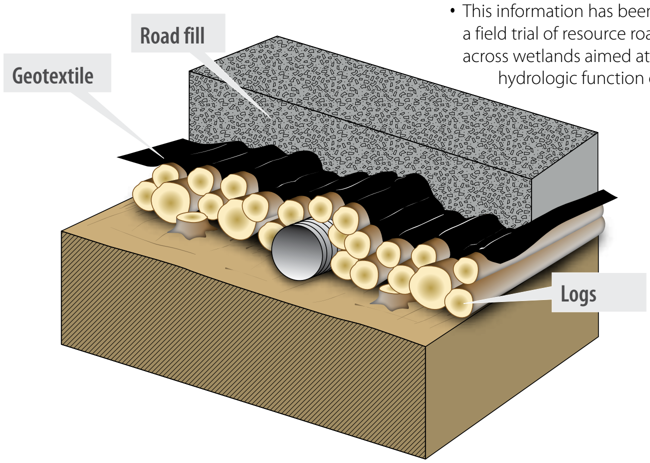
Culvert spacing: 20 – 100 m (site specific). Key is that culvert is placed amongst continuous length of corduroy which also provides for water flow.

Culvert location: attempt to place in low lying area(s) of the crossing. Where length of crossing requires more than one culvert, place culverts at equal spacing to one another.

Geotextile

- To be placed above the corduroy to provide a separation layer between the road fill material and the logs; it will also help to stabilize the corduroy by reducing movement.
- Extend geotextile to cover ends of corduroy and where overlapping is needed place downstream layer first.
- Where a curb log is used to contain road fill the geotextile can be wrapped around the curb log and not extend to the end of the corduroy.

- This information has been prepared to support a field trial of resource road building practices across wetlands aimed at maintaining the hydrologic function of the wetland.



FPInnovations Ducks Unlimited Canada LP Weyerhaeuser SPL

Proposed Wetland Best Practices

Water flow characteristics: Moving - lateral

Culvert amongst continuous corduroy

Crossing needs to accommodate slow but continuous below surface water movement.

Hydrology

- Wetland types with theses flow characteristics include **graminoid poor fen, graminoid rich fen, shrubby poor fen, shrubby rich fen, treed rich fen** (all slow lateral flow).
- Slow moving flows at and below the surface, including continuous seepage.
- Because fens are often connected to other wetlands, the entire system can be considered sensitive with respect to disrupting the flow of water. This promotes the need to not break through the forest floor / root mat and to protect the peat columns from disturbance.
- Local sites can be saturated and / or flooded; watertable is typically at or just below the surface with little seasonal fluctuation. Small culverts (less than 300 mm) are not suggested for use with Fen wetlands due to the continuous water passage required.

Suggested construction notes

Culvert diameter: 300 –800 mm

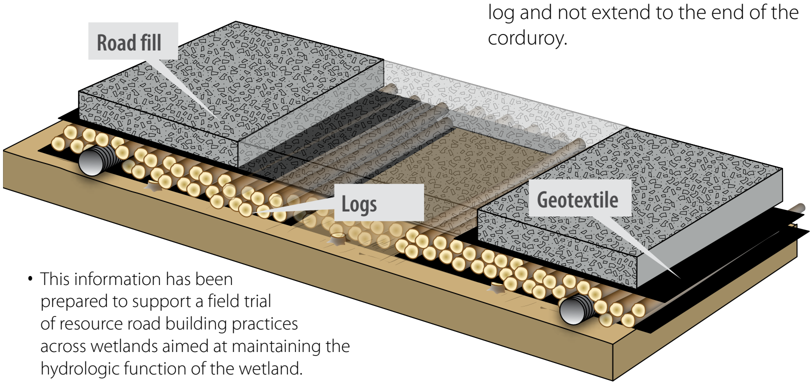
Culvert spacing: 20 – 100 m (site specific). Key is that culvert is placed amongst continuous length of corduroy which also has a water passing capability.

Culvert location: attempt to place in low lying area(s) of the crossing. Where the length of the crossing requires more than one culvert, place culverts at equal spacing to each other. Transition areas into and out of this group of wetlands may offer a shallow depth to mineral soil, providing support for a culvert.

Culvert placement: on top of forest floor/root mat to preserve natural bearing capacity. Some embedment will occur over time. Remove stumps only to promote alignment and placement.

Geotextile:

- place below culvert to provide additional bearing capacity, and placed above the corduroy to provide a separation of road fill material from the logs as well as to help stabilize the corduroy by reducing movement.
- Extend top layer to cover ends of corduroy and where overlapping is needed place downstream layer first.
- Where a curb log is used to contain road fill the upper layer of geotextile can be wrapped around the curb log and not extend to the end of the corduroy.



- This information has been prepared to support a field trial of resource road building practices across wetlands aimed at maintaining the hydrologic function of the wetland.

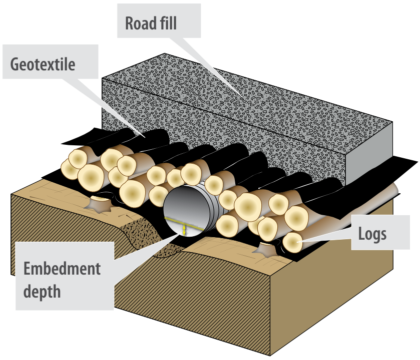
Proposed Wetland Best Practices

Water flow characteristics: Moving - fluctuating
Embedded culvert amongst corduroy

! **Crossing needs to accommodate seasonally fluctuating water levels and ongoing below surface flows**

Hydrology

- Wetland types with these flow characteristics include **mixedwood swamp, tamarack swamp, hardwood swamp, shrub swamp** (all seasonally fluctuating and typically part of a flowing system).
- Water level will fluctuate seasonally or semi-annual, and may fluctuate widely flooding above the root mat. This is followed by continuous slow lateral water movement at and below the surface from adjacent areas.
- Often sites will have hummocky terrain with pools of water present.
- Water table is typically maintained below the surface requiring the need for continued subsurface flows through a road. Embedded / countersunk culverts can help maintain subsurface flows.



Suggested construction notes

Culvert diameter: 400 – 800 mm

Culvert spacing: 20 – 100 m (site specific). Key is that culvert is placed amongst continuous length of corduroy which also has a water passing capability.

Culvert location: attempt to place in low lying area(s) of the crossing. Where length of the crossing requires more than one culvert, place culverts at equal spacing to one another. Where a defined stream channel is present, an appropriate sized culvert or bridge crossing may be required.

Embedment / countersunk depth of culvert: 25 – 40 % of culvert diameter (see yellow arrow). Excavation (for culvert placement) through the natural forest floor / root mat should be kept to a minimum width; the undisturbed areas provide greater strength / bearing capacity.

Geotextile:

- Place below culvert to provide additional bearing capacity, and placed above the corduroy to provide a separation of road fill material from the logs as well as to help stabilize the corduroy by reducing movement.
- Extend top layer to cover ends of corduroy and where overlapping is needed place downstream layer first.
- Where a curb log is used to contain road fill the upper layer of geotextile can be wrapped around the curb log and not extend to the end of the corduroy.

- This information has been prepared to support a field trial of resource road building practices across wetlands aimed at maintaining the hydrologic function of the wetland.

SUMMARY

Wetlands are prominent aquatic features across the boreal forest and provide a multitude of benefits to society.

Many of these wetlands are connected systems that move water slowly across the landscape which make them vulnerable to road development that can potentially block this natural flow. This can result in negative ecological consequences on these wetland systems and also operational challenges for the forest industry.

Knowing where wetlands are located, being able to identify the different types of wetlands, and understanding associated flow characteristics provide forestry professionals with valuable tools for planning road networks and for designing/constructing individual wetland crossings.

The purpose of this guide is to provide forestry professionals and contractors with a general understanding of boreal wetlands, what to expect in terms of water movement between different types of wetlands and general considerations when planning, constructing, monitoring and decommissioning wetland crossings.

This operational guide was compiled based on the results of a three year project which included a combination of workshops, field visits and operational field trials to test alternate wetland crossing techniques for stagnant and moving wetland systems.

Key findings from this work provide forestry professionals with:

- a general overview of the different types of boreal wetlands
- a practical approach to predicting water movement within these different wetlands based on four different groupings (stagnant, moving – lateral, moving – fluctuating and inundated/flooded)
- recommended practices for wetland crossing locations, timing of construction, construction methods, decommissioning, monitoring and inspection, and
- three wetland crossing techniques based on field trials

The information contained in this guide is not exhaustive and is a reflection of lessons learned from this project. The information and crossing techniques presented is intended to provide general guidance on the construction of forest road wetland crossings and may not be necessarily be applicable to all field situations.

Forestry professionals and contractors are encouraged to provide feedback on the information contained in this report and to offer alternate approaches that can be incorporated in future revisions.

GLOSSARY OF TERMS

aquatic - related to water including lakes, ponds, rivers, streams and wetlands

best management practices - methods or techniques found to be the most effective and practical means of achieving an objective

biodegradable geotextile - is a woven material made from natural fibers, often used as a product for erosion control projects

decommissioning - to deactivate or shutdown

dynamic water flow - the tendency for flowing water that fluctuates widely both vertically and horizontally from dry conditions to flooding

ecosystem - a community of living organisms in conjunction with the nonliving components of their environment, interacting as a system. These living and non-living components are regarded as linked together through nutrient cycles and energy flows

environmental effects - a community of living organisms in conjunction with the nonliving components of their environment, interacting as a system. These living and non-living c components are regarded as linked together through nutrient cycles and energy flows as any change to the environment, whether adverse or beneficial, resulting from a development or activity

high water flow events - high flow resulting from spring runoff or significant rainfall

hydrologic changes - changes in water quantity, depth and flow

landscape - is the area beyond, and surrounding the specific site

non-woven geotextile - arrangement of fibers either oriented or randomly patterned in a sheet, resembling felt

tensile strength - the resistance of a material to a force tending to tear it apart, measured as the maximum tension the material can withstand without tearing

tree stress - visual cues that a tree is not healthy including browning of leaves and yellowing of needles

vegetation die-back - a condition in a plant in which the branches or shoots die from the tip inward, caused by any of several bacteria, fungi, or viruses or by certain environmental conditions

water table - the highest underground level at which the rocks and soil in a particular area are completely wet with water

wetland: areas which are seasonally or permanently waterlogged and characterized by vegetation that is adapted for life in saturated / flooded soil conditions

woven geotextile - a fabric made of two sets of parallel strands systematically interlaced to form a thin, flat fabric

woven jute - a long, soft, shiny vegetable fiber that can be spun into coarse, strong threads and can be woven into long rolls of biodegradable material

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Ducks Unlimited Canada. 2014. Boreal Wetlands A Guide for Determining Wetland Classes in the Boreal Plains Ecozone of Western Canada.

Gillies, C. 2011 Water management techniques for resource roads in wetlands: a state of practice review. FPInnovations,Vancouver, B.C. Contract Report CR-652. 81 pp

Phillips, M.J. 1997. Chapter 28, forestry best management practices for wetlands in Minnesota. Pages 403-409 in C. C. Trettin, M. F. Jurgensen, D. F. Grigal, M. R. Gale, and J. K. Jeglum, editors. Northern forested wetlands: ecology and management. Lewis Publishers, New York, N.Y.

SUGGESTED READING

In addition to the above literature, the following are suggested reading. These are available at Louisiana-Pacific Canada Ltd. and Spruce Products Ltd. in Swan River Manitoba, Weyerhaeuser Canada, Timberlands in Hudson Bay Saskatchewan and Ducks Unlimited Canada in Edmonton Alberta.

Partington, M. 2006. A guide for temporary stream crossings in Quebec. FPInnovations, Pointe-Claire Que. (Guide) 20pp

Sustainable Forestry Initiative, Ducks Unlimited Canada, FPInnovations and Louisiana-Pacific Canada Ltd. 2011. Resource Roads and Wetlands, Learning From the Operator. SFI Forestry Roads and Wetlands Workshop May 25-27, 2011. 65pp

Boreal Wetlands

- 85 per cent of Canada's wetlands are located in the boreal forest.
- Canada's boreal forest is water dominated. More than two-thirds is covered by wetlands.

What are Boreal Wetlands?

- Seasonally or permanently water-saturated or flooded areas
- Plants and trees adapted to wet conditions
- Areas can be covered with trees, shrubs, grass, sedge or moss
- Highly connected moving water and nutrients over long distances, making them vulnerable to development that blocks their natural flow

"Land that is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation and various kinds of biological activity which are adapted to a wet environment."

(official definition: Canadian Wetland Classification System)

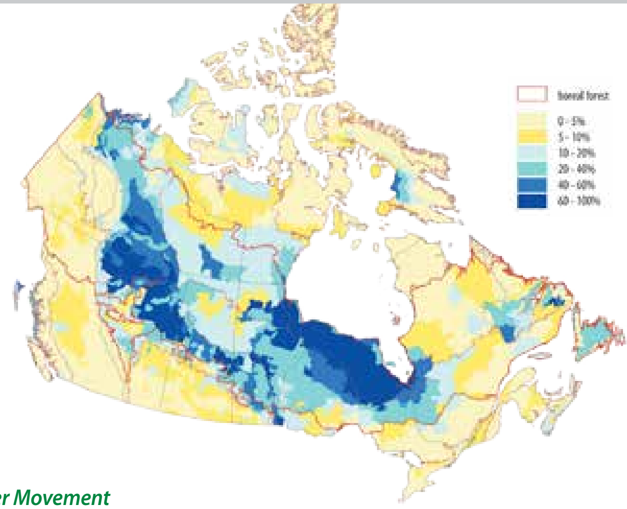
Types of Boreal Wetlands

Organic wetlands (bogs, fens)

- Deep organic deposits (>40cm) slowly build up due to limited amounts of oxygen
- Referred to as *peatlands* and are sometimes called *muskeg*
- Vegetation: open (no woody vegetation), shrubby or treed (stunted trees)
- Most common wetlands in Canada's boreal forest

Mineral wetlands (swamps, marshes, open water)

- Shallow organic deposits (<40cm)
- Contain nutrient-rich soils and water
- Vegetation: ranges from open water to trees



Water Movement

- Organic and mineral wetlands are often interconnected
- Water flow fluctuates
- Water may flow laterally across the landscape, at or below the surface
- Water tables may rise and fall seasonally or after precipitation
- Infrastructure such as roads may block the movement of water, causing water to dam and potential damage

Environmental & Social Benefits

- Vital habitat to thousands of species of Canadian wildlife, such as ducks, songbirds, beaver and the endangered woodland caribou
- Store large amounts of carbon and help moderate climate change
- Minimize soil erosion
- Filter, store and transport large amounts of water and nutrients
- Act like sponges
  - Absorb precipitation and run-off to help prevent flooding
  - Release water during droughts
- Important locations for hunting, fishing and other cultural activities
- Offer tremendous learning opportunities for people of all ages

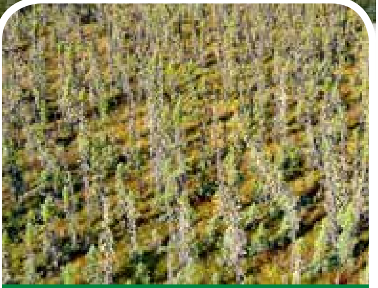
Resources

- Ducks Unlimited Canada in the Boreal Forest – borealforest.ca
- Ducks Unlimited Canada Natural Values Fact Sheet Series – ducks.ca/learn-about-wetlands/what-wetland
- North American Wetlands Conservation Council: WetlandNetwork – wetlandnetwork.ca

Bogs

Fen Complex

Bogs are peatlands that have deep deposits (>40 cm) of poorly decomposed organic material (referred to as peat). They are elevated above the surrounding terrain and receive water and most nutrients from precipitation. Bogs are the most nutrient-poor wetlands in the eastern boreal forest.



Treed Bog

Shrubby Bog

Open Bog

Identifying Characteristics

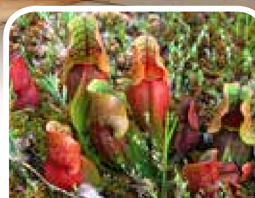
Vegetation

- Low plant diversity due to lack of nutrients
- Tree and ground lichens can be abundant
- *Treed Bog:* stunted black spruce (25- 60% canopy closure) with sphagnum moss ground cover (>20%)
- *Shrubby Bog:* low-lying shrubs (e.g. Labrador tea, bog cranberry >25%) with sphagnum moss (>20%) tree cover <25%
- *Open Bog:* sphagnum moss dominated with scattered herbs/forbs, such as cotton grass and sedges; tree and shrub cover <25%

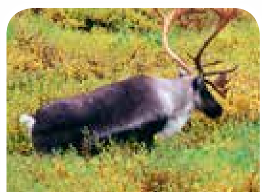
Hydrology

- *Water source:* precipitation from snow and rain
- Stagnant, non-flowing systems isolated from surface run-off and groundwater/ nutrients
- Capillary action of sphagnum moss maintains the water table at or below the ground surface

Treed Bog (note 25-60% canopy closure)



Pitcher Plant



Woodland Caribou

Soil

- Peat deposits (> 40 cm) accumulating over long periods of time because decomposition is very slow in the wet, cool, anoxic (oxygen deprived) environment
- Two distinct peat layers *(above)*:
  - Acrotelm - living top layer (30-50 cm)
  - Catotelm - lower, non-living layer

Ecological Benefits

- Due to deep organic deposits, bogs store large amounts of carbon and help to moderate climate change
- Important habitat for the threatened woodland caribou
- Important water storage/recharge areas on the landscape that release water in dry periods and store water in wet periods

Types of Bogs

- *Treed Bog:* Sparsely vegetated and stunted (<10 m) black spruce with sphagnum moss and low-lying shrubs
- *Shrubby Bog:* Low-lying shrubs and sphagnum moss
- *Open Bog:* sphagnum moss dominated with sparse non-woody vegetation

Fens

Fens are peatlands with deep organic (peat) deposits (>40 cm) and are influenced by slow, lateral water movement. Water sources have been in contact with nutrient-rich surface and/or groundwater making fens more productive and biologically diverse than bogs. Fens can be treed, shrubby or open.

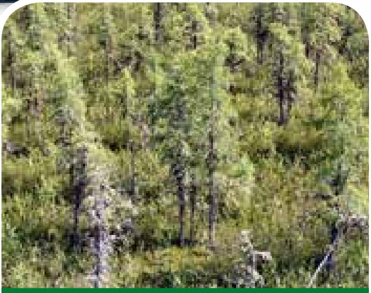
Identifying Characteristics

Vegetation

- Plant species reflect nutrient and moisture gradients
- The plant communities of nutrient-poor fens more closely resemble those of bogs, while rich fens have more diverse and robust vegetation
- *Treed Fens:*
  – trees (<10 m) make up 25-60% of surface area
  – dominated by tamarack although black spruce can occur
- *Shrubby Fens:*
  – shrubs (<2 m) dominate (>25%) with less than 25% tree cover
  – common species are dwarf birch and sweet gale
- *Graminoid (open) fens:*
  – dominated by sedges, mosses and buckbean

Hydrology

- Complex hydrology with surface, subsurface and groundwater interactions
- High water table (at or slightly below the surface) with lateral water flow often connecting wetland systems over vast distances

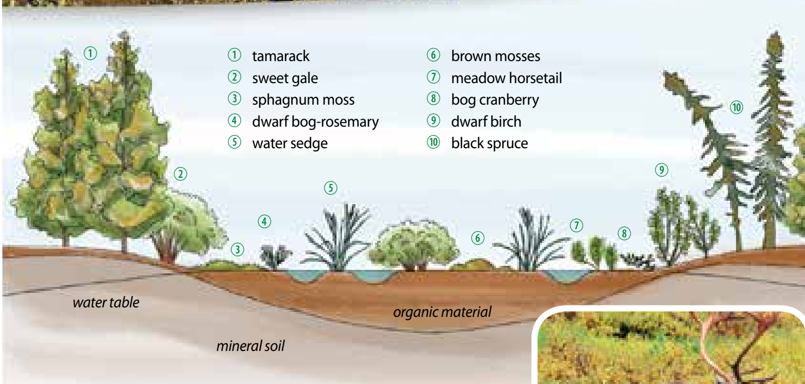


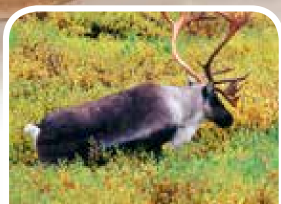
Treed Fen

Shrubby Fen

Graminoid Fen

Patterned Fen complex with treed, shrubby and open graminoid components





Woodland Caribou

Soil

- Deep peat deposits (>40 cm)
- Similar to bogs but with greater composition of sedge peat
- Decomposition is slow due to the wet, cool, anoxic (oxygen-deprived) environment, resulting in the accumulation of deep organic deposits
- Depending on water sources and nutrient availability, fens can be either nutrient rich or nutrient poor
- Two distinct layers *(right)*:
  – *Acrotelm:* the living layer, top 30-50 cm
  – *Catotelm:* the lower, non-living layer

Ecological Benefits

- Known as the "green rivers" of the boreal, fens transport large volumes of water and nutrients across the landscape; help to regulate water flow
- Help prevent downstream flooding by absorbing precipitation and run-off
- Due to deep organic deposits, fens store large amounts of carbon and help to moderate climate change
- Provide important habitat for several species of scoters

Types of Fens

- *Treed fens:* Sparsely vegetated and stunted (<10 m) tamarack, sometimes mixed with black spruce, shrubs, sedges and mosses
- *Shrubby fens:* sparse to medium density; short (<2 m) shrubs (e.g. dwarf birch and willow) mixed with sedges and mosses
- *Graminoid (open) fens:* dominated with sedges, mosses and herbs (e.g. buckbean) often interspersed with open water

Swamps

Treed (Hardwood) Swamp

Treed (Conifer) Swamp Fringe

Swamps are a common, diverse group of wetlands occurring in a variety of landscapes. Soils are predominantly mineral based although the presence of peat can occur in some settings. They are often transition areas between upland forest and other wetland areas and typically have hummocky ground that may contain pools of water. Most commonly recognized as shoreline areas of streams, lakes and floodplains, swamps are either treed or shrubby.

Treed (Tamarack) Swamp

Identifying Characteristics

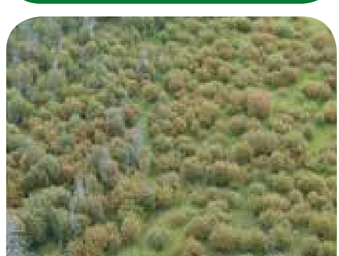
Vegetation

- *Treed swamp species:* black spruce and tamarack (conifer swamps), white birch, balsam poplar (hardwood swamps) or combinations of conifer and hardwood species (mixed wood swamps)
- *Shrub swamp species:* willow, redosier dogwood and speckled alder with sedges and grasses

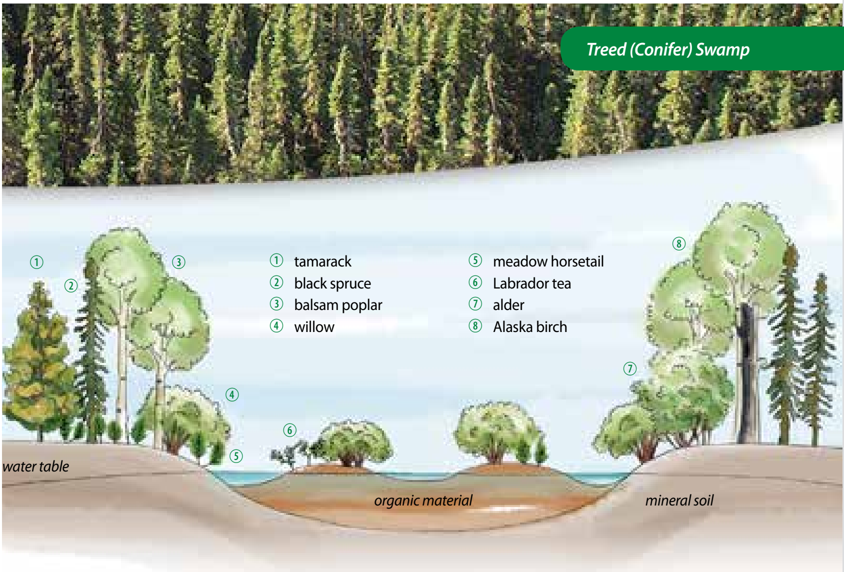
Treed (Mixed Wood) Swamp

Hydrology

- *Water source:* run-off, precipitation, groundwater and flooding from adjacent wetlands
- Seasonally flooded, fluctuating water levels
- Hummocky terrain with pools of water



Shrub Swamp



Soil

- *Nutrient levels:* range from poor to rich, with conifer swamps being poor to medium and other swamps ranging from medium to rich
- Typically, less than 40 cm of peat; primarily composed of decaying shrubs and trees (unlike sphagnum-dominated peat in bogs and fens)
- Most soil is aerated, but water availability is still high in lower portions of the root zone
- Typically gleysols with mottling (signs of temporary flooding) in the upper horizons and gleying (signs of permanent saturation) in the lower horizons


Common Yellowthroat

Ecological Benefits

- Moderate floods by slowing water flow
- Fertile soils support a diversity of trees, shrubs and other plants
- Vegetation protects shoreline areas from erosion and sedimentation
- The variety of swamp wetlands provide a high diversity of habitat for many species of wildlife


Moose

Types of Swamps

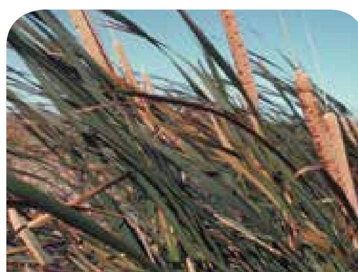
- *Treed swamp:*
  - dense (>75% canopy closure) tall trees (>10 m)
  - may be conifer dominated, hardwood dominated or mixed wood
- *Shrub swamp:* dominated by tall shrubs (>2 m) such as willow and alder

Marshes

Sedge

Marshes in the western boreal forest are often found as a transition between open water and shorelines.

Water levels fluctuate seasonally and water sources come from precipitation and associated run-off, groundwater and stream inflow.



Cattail

Identifying Characteristics

Vegetation

- Emergent vegetation (e.g. cattail, bulrush and sedges) occupies more than 25% of the area interspersed with open water
- Floating vegetation (e.g. pondweeds and milfoil) occupies open water

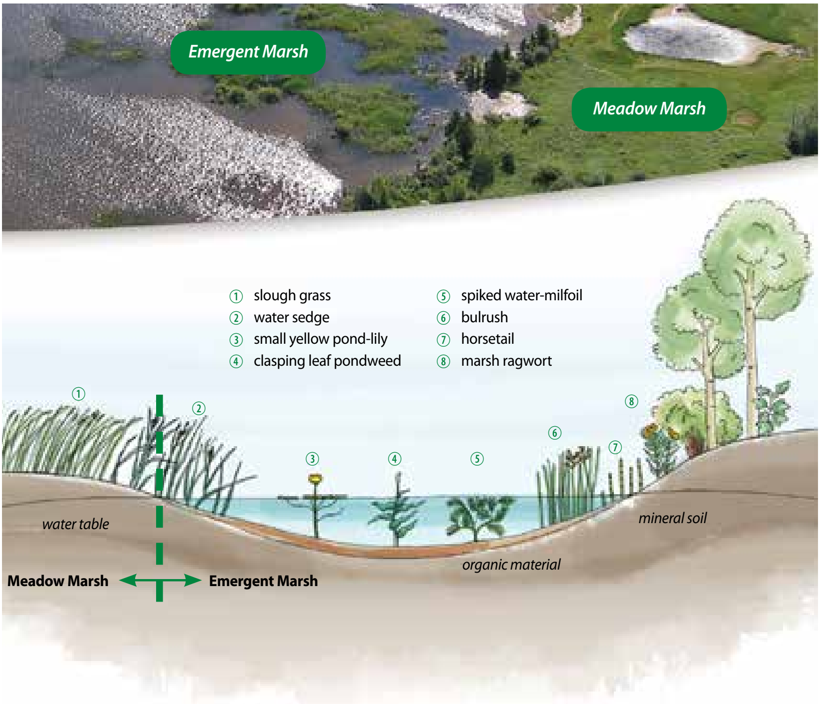
Hydrology

- *Water levels:* fluctuate seasonally and can periodically dry out
- *Water sources:* precipitation, run-off, groundwater and streams

Soil

- Mineral based soils with shallow organic deposits (< 40 cm)
- Nutrient rich soils resulting from periodic drying out and exposure to oxygen

Hard-stem Bulrush



Ecological Benefits

- Most biologically diverse but the least common boreal wetland
- Marshes moderate flooding and minimize soil erosion
- Filter and trap nutrients and neutralize a number of contaminants
- Vital habitat for many wildlife such as waterfowl, moose, beaver and muskrat

Type of Marshes

- *Emergent marshes:* dominated by flood tolerant cattail and rushes; located between deeper open water and meadow marshes
- *Meadow marshes:* dominated by sedges and grasses; less flood tolerant and occupy shallow water areas

Muskrat

Trumpeter Swan

Open Water

Aquatic Bed

Open Water wetlands have water depths less than two metres, yet are too deep for emergent marsh vegetation to establish. Visually, these wetlands appear to be shallow lakes, although floating-leaved and submerged aquatic vegetation are common in more nutrient-rich settings.

Identifying Characteristics

Vegetation

- Submerged aquatic (e.g. water-milfoil) and floating vegetation (e.g. pond lily)
- Too deep for emergent plants like cattails and rushes to establish

Hydrology

- *Water sources:* precipitation, run-off, groundwater and streams
- *Water levels:* generally permanent but may fluctuate seasonally, exposing mudflats

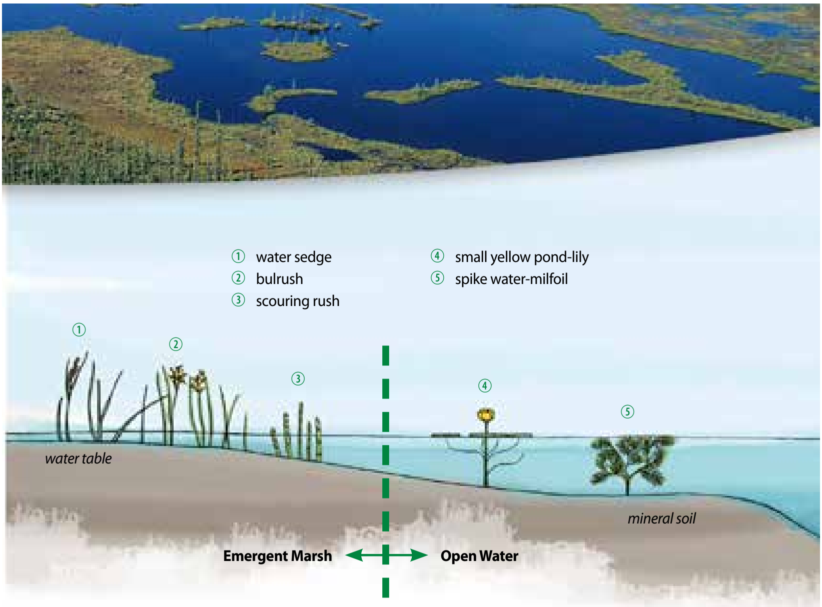
Soil

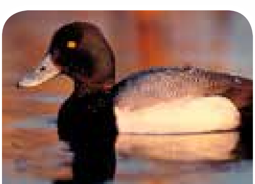
- Soil is poorly developed because of high water levels and lack of oxygen
- *Substrate:* silt, gravel or combinations of organic deposits

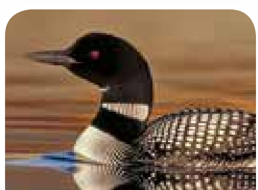
Open Water

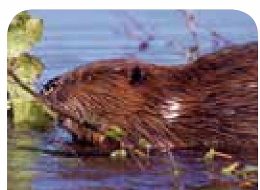
White-winged Scoter

Pond Lily




Lesser Scaup


Common Loon


Beaver

Ecological Benefits

- Retain and store water helping to moderate flooding, recharge groundwater and maintain stream flows
- Productive for many plants and animals in nutrient-rich environments

Types of Open Water Wetlands

- *Open water:* <25% aquatic vegetation on the water
- *Aquatic bed:* >25% aquatic vegetation on the water
- *Mudflat:* a temporary condition when water levels are low (drawdown)

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