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REPORT ON

WETLANDS BASELINE

FOR PROJECT MILLENNIUM

Submitted to:

Suncor Energy Inc., Oil Sands

972-2205

Golder Associates Ltd.

10th Floor, 940 6th Avenue S.W.
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April 27, 1998

Proj. No. 972-2205

Mr. Martin Holysh
Senior Environmental Specialist
Sustainable Development
Suncor Energy Inc., Oil Sands
P.O. Box 4001
Fort McMurray, AB
T3H 3E3

RE: Final Report on Wetlands Baseline for Project Millennium

Dear Martin:

Attached are five copies of the Wetlands Baseline for Project Millennium. This report summarizes the following objectives:

- describe the lowland or wetlands types within the Project Millennium local and regional study areas (LSA, RSA);
- assess wetlands diversity within the LSA and RSA;
- provide a wetlands component to the Ecological Land Classification; and
- provide a basis for wetlands reclamation, research and monitoring.

If you have any additional questions about the report, please contact either Greg Sutor at 299-4655 or me at 299-5640.

Yours very truly,

GOLDER ASSOCIATES LTD.

Shawn McKeon

John R. Gulley, M.Sc., P. Biol.
Oil Sands Project Director

attachments (5)

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EXECUTIVE SUMMARY

This document details the Wetlands Resources within the Local and Regional Study Areas for Suncor Energy Inc. (Suncor) Project Millennium in support of an Environmental Impact Assessment. The National Wetlands Working Group (NWWG 1988) has defined wetlands as:

"... land that is saturated with water long enough to promote wetlands or aquatic processes as indicated by hydric soil, hydrophytic vegetation and various kinds of biological activity which are adapted to the wet environment".

This has been adopted as a working definition for the purposes of the current study.

The study area wetlands are described and classified using the methodology of the Alberta Wetlands Inventory (AWI) (Halsey and Vitt 1996). Beckingham and Archibald's wetlands classification system was used as the basis for the floristic analysis and initial classification of the wetlands types. The AWI was used for the final wetlands classification.

The objectives of this document are to:

- describe the lowland or wetlands types within the Project Millennium local and regional study areas (LSA, RSA);
- assess wetlands diversity within the LSA and RSA;
- provide a wetlands component to the Ecological Land Classification; and
- provide a basis for wetlands reclamation, research and monitoring.

For the RSA, Landsat Thematic Mapper (TM) Satellite imagery was used as a basis for mapping. This was augmented by a helicopter survey in July 1997. Based on these data, wetlands were classified into five classes:

- wet open and closed coniferous
- fens (shrubby and graminoid)
- bogs (sphagnum and shrub)
- marshes (emergent)
- open water

For the LSA, wetlands were identified on 1996, 1:10,000 scale black and white aerial photographs. The aerial photographs were pre-stratified according to the Alberta Vegetation Inventory (AVI), which included

Alberta Wetlands Inventory (AWI) criteria. Vegetation surveys were taken in July and August 1997. The surveys typed the wetlands vegetation according to the Beckingham and Archibald (1996) classification system: however, Project Millennium was also classified according to a more detailed system (Halsey and Vitt 1996) that differentiates bogs, fens, swamps, marshes and shallow open water.

Community level biodiversity was assessed by examining community richness, diversity and patch (map unit) size. The ranges of these parameters, or indices, are an expression of heterogeneity in wetlands within the LSA and RSA.

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1.1 INTRODUCTION

This document provides details on the Project Millennium (the Project) area wetlands that were identified using The Ecosites of Northern Alberta (Beckingham and Archibald 1996) and the Alberta Wetland Inventory (Halsey and Vitt 1996) wetlands classification system. The Ecosites of Northern Alberta classification provided the basis for the vegetation analysis; however, the Alberta Wetlands Inventory was used in the Ecological Land Classification of the Project Millennium area. A discussion on how these two classifications compare is provided in the following subsections.

While wetlands are difficult to define due in part to their variation in size, location and structure, the National Wetlands Working Group (NWWG 1988) has defined them as:

"land that is saturated with water long enough to promote wetland or aquatic processes as indicated by hydric soil, hydrophytic vegetation, and various kinds of biological activity which are adapted to the wet environment".

In Canada, wetlands are dominated by peatlands, representing about 14% of the land base (NWWG 1988). In Alberta, peatlands encompass 16.3% of the province. Peatlands are ecosystems which characteristically have >40 cm of accumulated organics and are subdivided into fens and bogs. Non-peat forming wetlands generally have <40 cm of accumulated organics and are sub-divided as shallow open water; marshes; and swamps. Peat accumulation occurs when water tables stabilize and plant production exceeds decomposition. Under these conditions, peat accumulates and gradually raises the peatland surface above the surrounding mineral soil (Vitt and Halsey 1997).

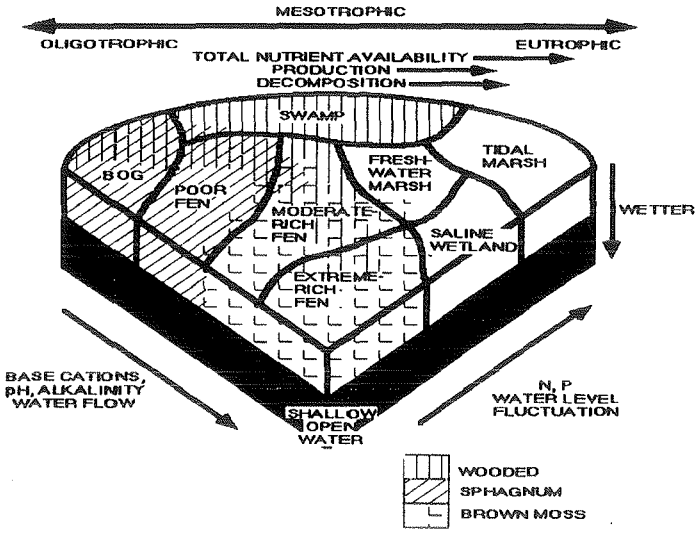
There are a variety of classification systems that can be used to delineate wetlands types, or classes. Wetlands are generally divided into five types: bogs, fens, marshes, swamps and shallow open water. The following, more detailed classification systems were used to identify wetlands in the Project Millennium area.

Wetlands identification and inventory compilation is dependent on the level of classification scheme adopted. A system that does not differentiate between the detailed features and functions of wetlands will not allow such characteristics to be inventoried correctly. Beckingham and Archibald (1996) differentiates treed bogs, shrubby bogs, treed poor fens, shrubby poor fens, treed rich fens, shrubby rich fens, graminoid rich fens and marshes. This field guide classification system was used for preliminary classification during the vegetation field survey; however the Project Millennium area was also classified according to a more detailed system (Halsey and Vitt 1996)

that differentiates bogs, fens, swamps, marshes and shallow open water to three vegetation modifiers, three wetlands complex landform modifiers and six local landform modifiers. These wetlands classes and their relation to the field guide system are discussed below.

The description of wetlands may be refined further through the definition of specific types, or classes of wetlands. The basis of wetlands classification systems is varied and includes combinations of water level, water chemistry, floristic composition, topographic location, geomorphic basin configuration and other environmental variables. Environmental parameters that provide the framework for the Alberta Wetlands Inventory system include chemical and biotic gradients (Figure 1).

Figure 1 Wetlands Classification Based on Chemical and Biotic Gradients

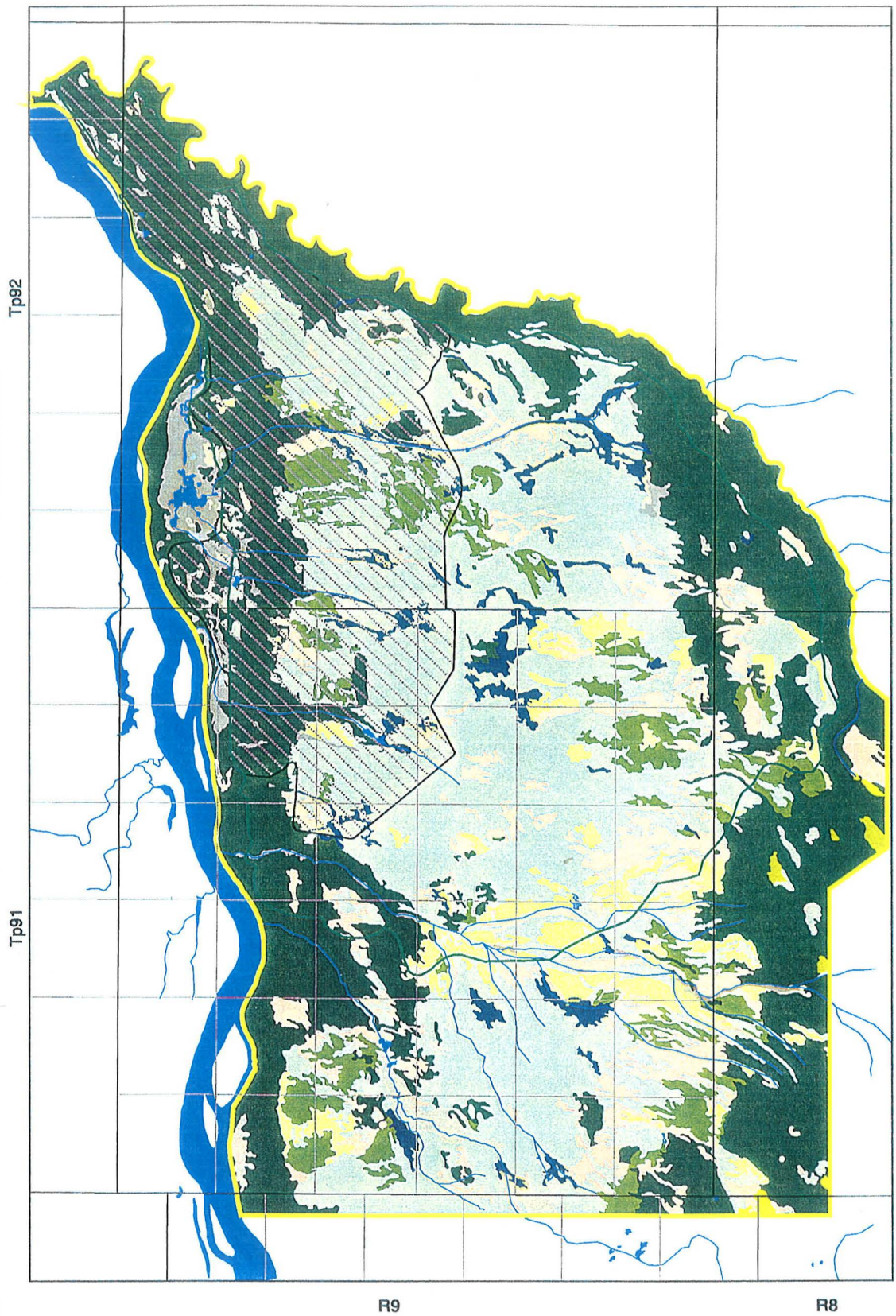


Source: Halsey and Vitt 1996, modified from Vitt 1994

The objectives of this document are as follows:

- to describe the lowland or wetlands types within the Project Millennium local and regional study areas (LSA, RSA);
- to assess wetlands diversity within the LSA and RSA;
- to provide a wetlands component to the Ecological Land Classification; and
- to provide a basis for wetlands reclamation, research and monitoring.

The results of the wetlands classification for the Project Millennium area are shown in Figure 2.



LEGEND

- Terrestrial Local Study Area
- Steepbank Mine
- East Bank Mining Area
- Open Water

Wetland Classification

- Bog treed (Btnn)
- Bog treed > 70% (Bfnn)
- Fen treed > 6-70% (Ftnn)
- Fen treed > 70% (Ffnn)
- Fen shrub forest (Fons)
- Fen graminoid (Fong)
- Marsh graminoid (Mong)
- Marsh shrub (Mons)
- Swamp (coniferous > 70%) (Sfnn)
- Swamp (coniferous > 6-70%) (Stnn)
- Swamp (shrub)
- Shallow open water
- Forest

West of Fourth Meridian

N

1000 0 1000 2000 3000

Metres
Scale 1:100,000

SOURCES: Suncor
Golder
Vitt, D.H., Halsey, L.A., Thormann, M.N., and Martin, T., 1996.

Map Projection: UTM 12
Datum: NAD 83

SUNCOR ENERGY

Project Millennium

LOCAL STUDY AREA WETLANDS CLASSIFICATION

02 Apr. 1998	Figure 2	PRODUCED BY: JS REVIEWED BY:

/data14/suncor/local/9700/9701/arcview/wetlands.apr

1.2 REGIONAL STUDY AREA

The Regional Study Area (RSA) for the Project EIA has an area of 2,428.645 ha. Boundaries for the RSA were selected based primarily on airsheds, although ecoregions and watersheds were also considered. The RSA is shown in Figures 3a, 3b, 3c and 3d.

The RSA for the Project is situated in the Central Mixedwood Natural Subregion, formerly known as the Mixed Boreal Ecoregion. Although uplands were primarily used to characterize the Boreal Ecoregion, wetlands have a large aerial extent in the region. Wetlands represented in the RSA include bogs, fens, swamps, marshes and shallow open water. Specific wetlands types represented in each Ecoregion as assessed in the Peatlands Inventory of Alberta (Vitt et al. 1997), will be discussed in this report.

1.3 LOCAL STUDY AREA

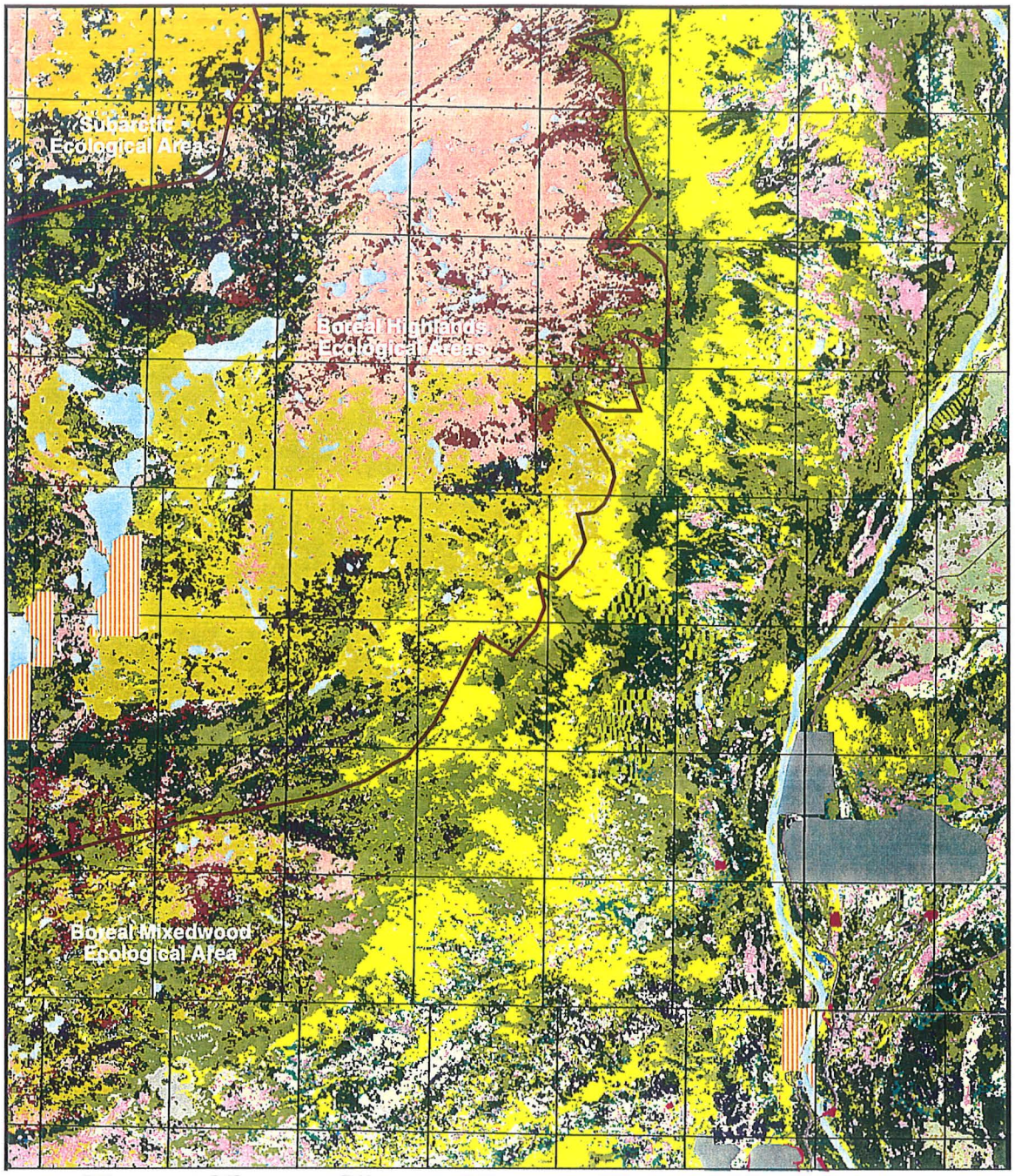
The Local Study Area (LSA) for Project Millennium is located adjacent to the Athabasca River in Township 91 and 92, Ranges 8 and 9 west of the fourth Meridian and covers an area of 16,181 hectares (Figure 4). Boundaries were defined by Project Millennium development area.

The LSA is characterized by thin ground moraine composed of loamy Kinosis till in the north and thick, bedded glaciolacustrine sands and silts to the south. The Athabasca and Steepbank river valleys are classed as erosional or slumping on the slopes with alluvial deposits along the floodplains. There are two classes of soils within the LSA; those which have developed on organic deposits; and those formed from mineral parent materials. The vegetation is characterized by rapid transitions between dry upland deciduous, mixedwood and coniferous communities to treed, shrub and graminoid wetlands. Wetlands including wooded bogs, fens, marshes, swamps and shallow open water, occupy approximately 62% of the LSA. In general the topography is level to undulating except along the river and stream channels.

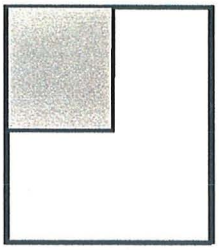
1.4 METHODOLOGY

1.4.1 Wetlands Classification Systems

The Alberta Wetland Inventory Classification contains four levels that include: 1) wetland classes; 2) vegetation modifier; 3) wetland complex landform modifier; and 4) local landform/vegetation modifier (Nesby 1997) (Figure 5). For example, a wetland designated as MONG, refers to a graminoid marsh which is open, without permafrost or patterning.



West of Fourth Meridian



SOURCES: Suncor, Syncrude, Petro-Canada, Golder, Landsat TM Satellite Image Classification, Larkspur Biological, Conor Pacific

Scale 1:500,000

5 0 5 10 15 20

Kilometres

LEGEND

- Regional Study Area
- Linear Disturbances
- Open Water
- Forestry
- Existing Open Pit Mines
- Other Disturbances
- Municipalities
- Indian Reserves

VEGETATION CLASSIFICATION

- Open Pine Lichen
- Mixed Deciduous (Aw Dom.)
- Mixedwood (Sw-Aw Dom.)
- Mixed Coniferous (Sw Dom.)
- Mixed Coniferous (Sw-Pj/Pl Dom.)
- Mixed Coniferous (Pj/Pl Dom.)
- Mixed Coniferous (Sb-Lt Dom.)
- Wet Closed Coniferous (Sb Dom.)
- Wet Open Coniferous (Sb Dom.)
- Pine Regeneration (Pine<2m)
- Shrubland
- Bog (Sphagnum Dom.)
- Bog (Shrub Dom.)
- Shrubby Fen
- Graminoid Fen
- Marsh Emergents
- Barren Ground / Bedrock Exposure
- Unclassified

N

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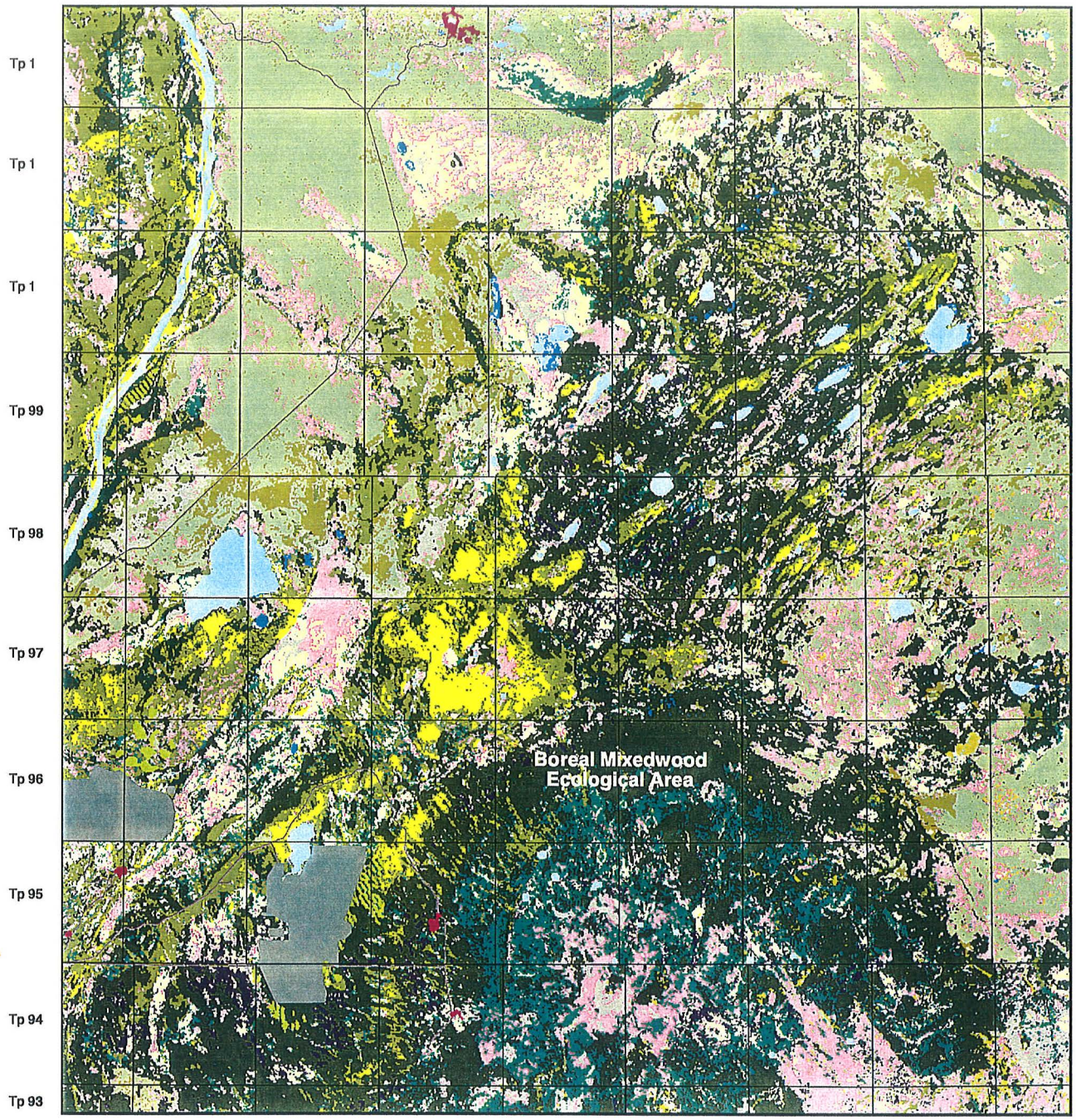
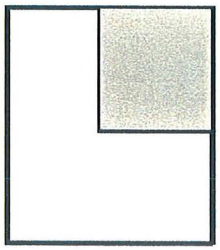
Project Millennium

REGIONAL STUDY AREA VEGETATION CLASSIFICATION IMPACT ASSESSMENT BASELINE

14 Apr. 1998	Figure 3a	PRODUCED BY: K.K.O. REVIEWED BY:



West of Fourth Meridian



SOURCES: Suncor, Syncrude, Petro-Canada, Golder, Landsat TM Satellite Image Classification, Larkspur Biological, Conor Pacific

Scale 1:500,000

5 0 5 10 15 20

Kilometres

LEGEND

- Regional Study Area
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- Graminoid Fen
- Marsh Emergents
- Barren Ground / Bedrock Exposure
- Unclassified

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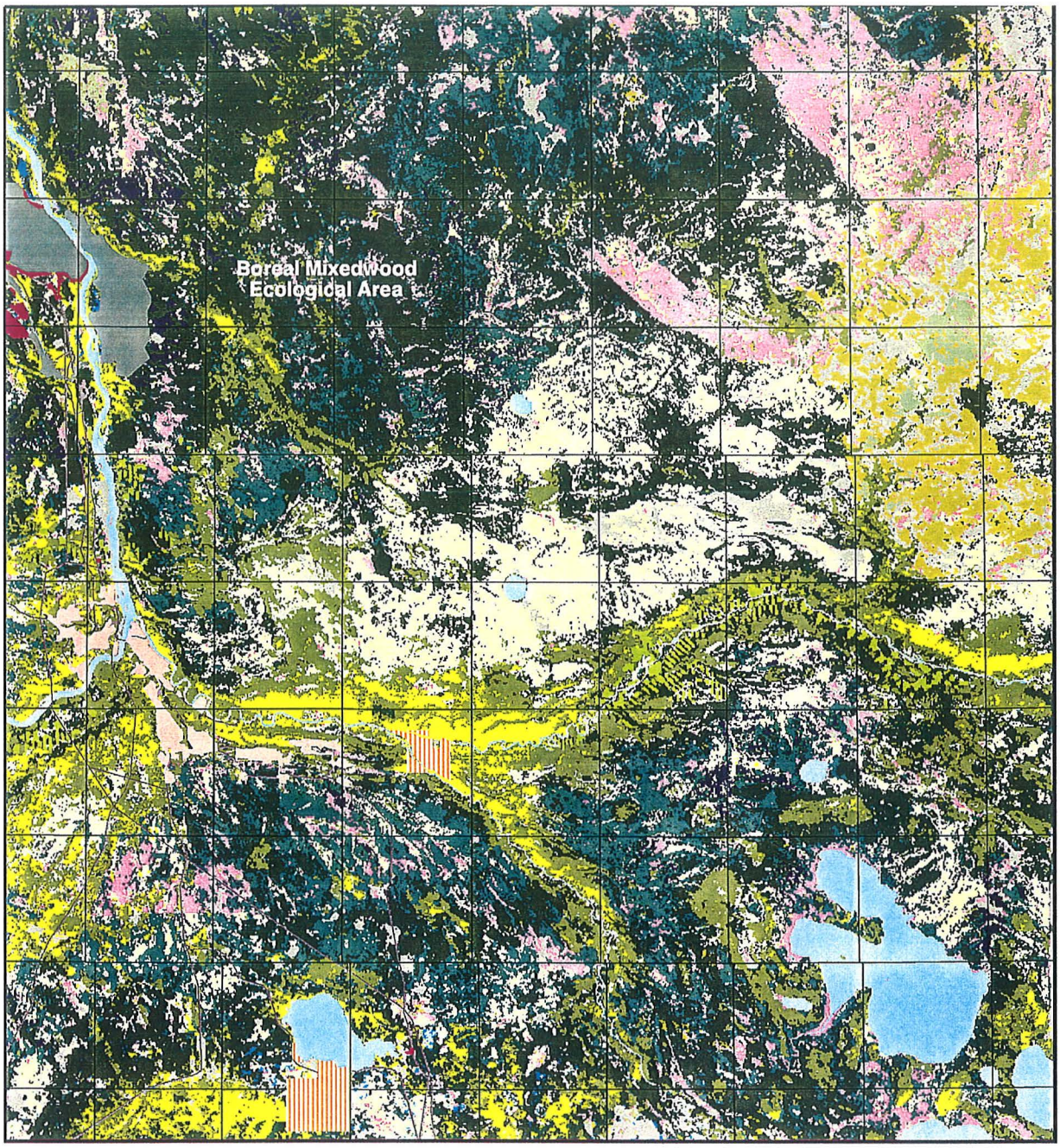
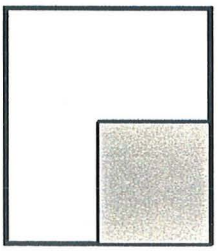
REGIONAL STUDY AREA VEGETATION CLASSIFICATION IMPACT ASSESSMENT BASELINE

14 Apr. 1998	Figure 3b	PRODUCED BY: K.K.Q. REVIEWED BY:



West of Fourth Meridian



SOURCES: Suncor, Syncrude, Petro-Canada, Golder, Landsat TM Satellite Image Classification, Larkspur Biological, Conor Pacific

Scale 1:500,000

5 0 5 10 15 20

Kilometres

LEGEND

- Regional Study Area
- Linear Disturbances
- Open Water
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- Unclassified

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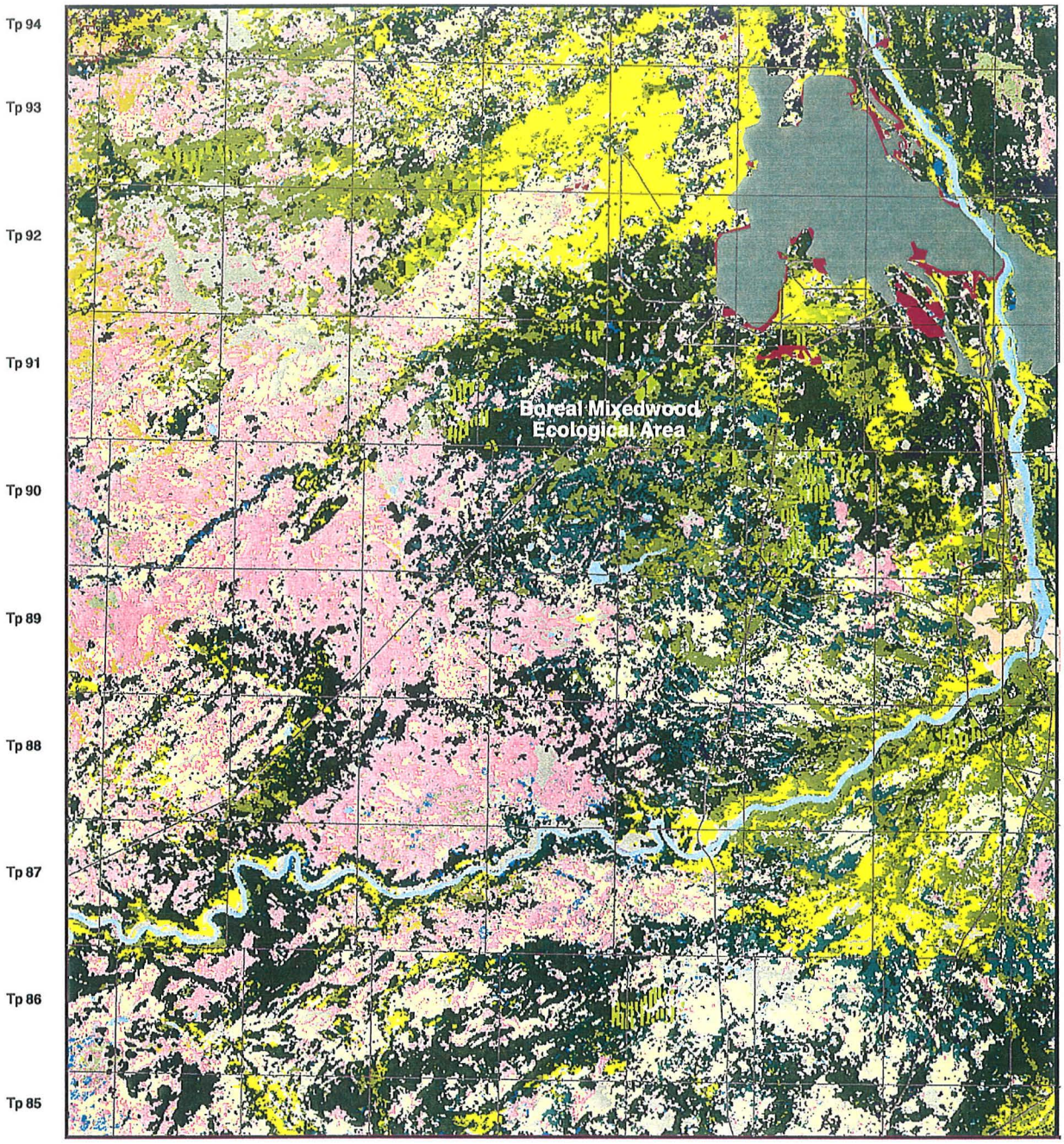
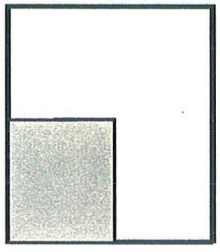
REGIONAL STUDY AREA VEGETATION CLASSIFICATION IMPACT ASSESSMENT BASELINE

14 Apr. 1998 | Figure 3c | PRODUCED BY: K.K.Q. REVIEWED BY:

/data1/4/suncor/regional/9700/9701/arcview/vegrsa.apr



West of Fourth Meridian



SOURCES: Suncor, Syncrude, Petro-Canada, Golder, Landsat TM Satellite Image Classification, Larkspur Biological, Conor Pacific

Scale 1:500,000

5 0 5 10 15 20

Kilometres

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- Bog (Shrub Dom.)
- Shrubby Fen
- Graminoid Fen
- Marsh Emergents
- Barren Ground / Bedrock Exposure
- Unclassified

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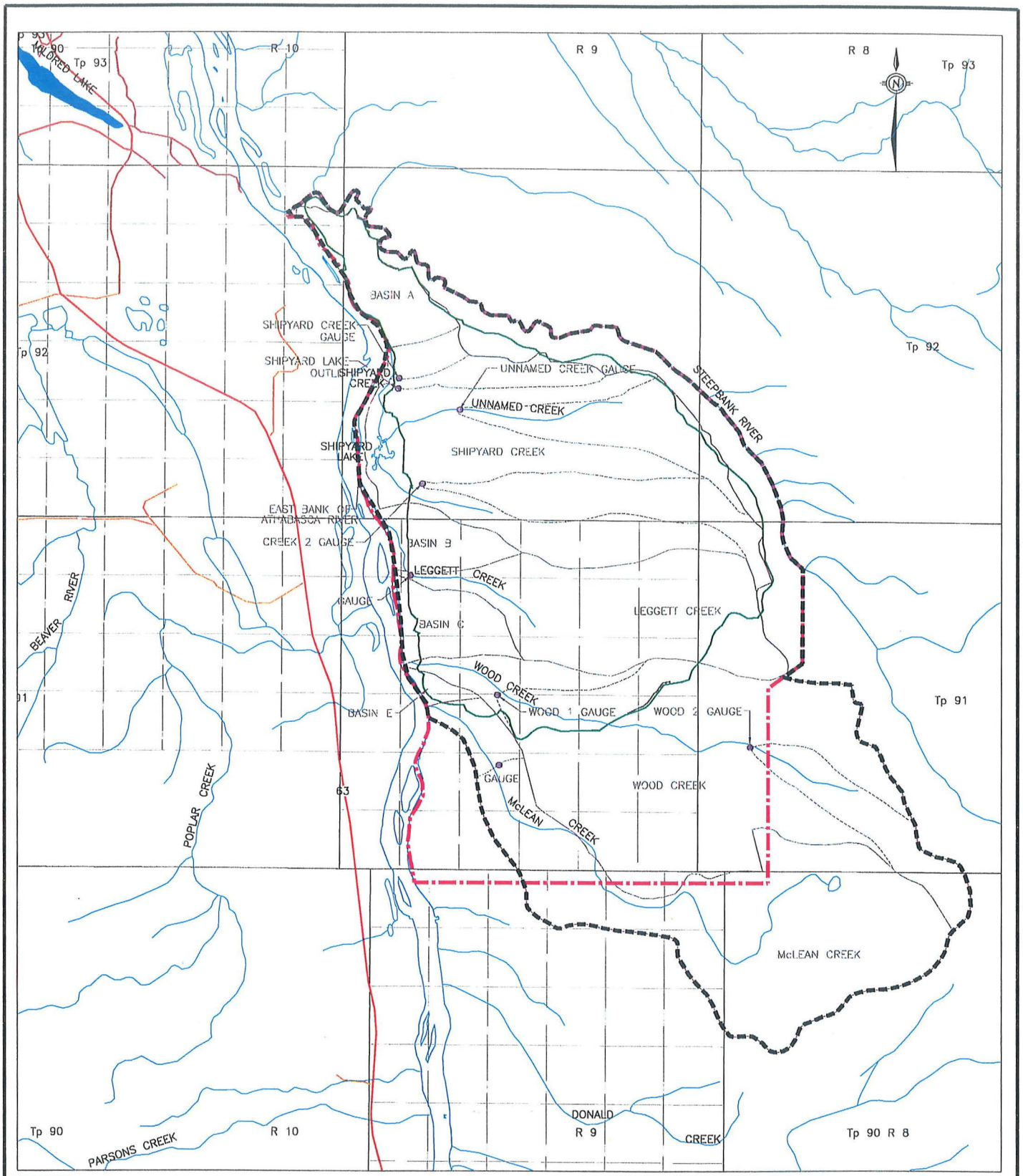
REGIONAL STUDY AREA VEGETATION CLASSIFICATION IMPACT ASSESSMENT BASELINE

14 Apr. 1998 | Figure 3d | PRODUCED BY: K.K.O. REVIEWED BY:

J:\1997\2205\7500\TERBLINE.dwg



LEGEND

- EAST BANK MINING AREA
- LOCAL DRAINAGE BASIN
- LOCAL DRAINAGE SUB BASIN
- LOCAL BASIN GAUGE
- LOCAL STUDY AREA FOR TERRESTRIAL
- LOCAL STUDY AREA FOR AQUATICS

REFERENCE

DIGITAL DATA SETS 74D AND 74E RESOURCE DATA DIVISION, ALBERTA ENVIRONMENTAL PROTECTION, 1997.
MINE PLAN SUPPLIED BY SUNCOR ENERGY, MAR 1998.
DATUM IS IN NAD83 UTM

0 1 2 3 4 5km

SCALE 1:150,000

SUNCOR ENERGY

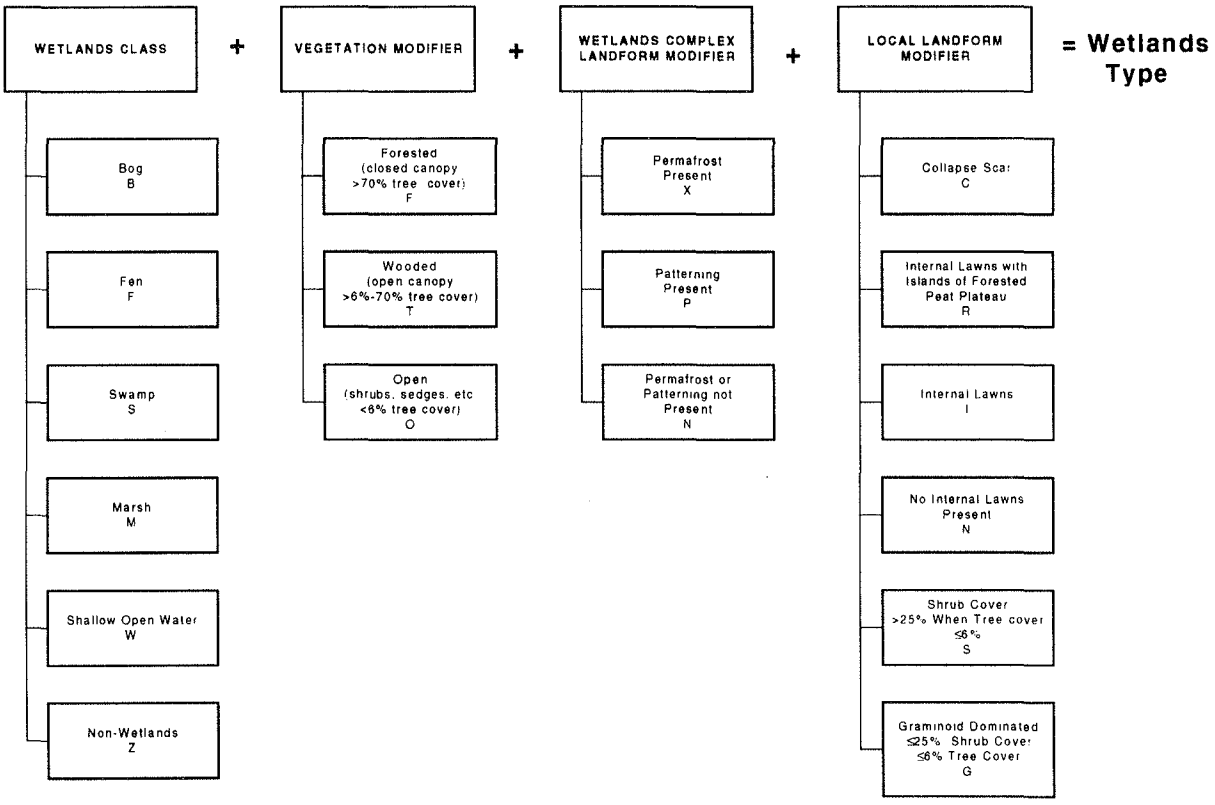
Project Millennium
Taking Suncor into the 21st Century

LOCAL STUDY AREA FOR PROJECT MILLENNIUM TERRESTRIAL VEGETATION AND WETLANDS BASELINE

03 Apr. 1998	Figure 4	DRAWN BY: CG/TM

The wetlands classification system developed by Halsey and Vitt (1996) uses similar variables that are distinguishable on aerial photographs. The Alberta Wetlands Inventory (AWI) classification system applied to Project Millennium uses similar classes to those developed by the NWWG (1988). However, the subdivision of these classes follows a more simplified scheme than that of NWWG (1988). The wetlands classification system has been sanctioned by the Alberta Vegetation Inventory Standards Development Group and incorporated into the Alberta Vegetation Inventory (AVI 2.2) as the Alberta Wetland Inventory Classification Standards (Nesby 1997).

Figure 5 Flow Chart Representation of Wetlands Classification Process Used for Project Millennium



Source: Nesby 1977 (AVI Version 2.2)

Approximately 14 of all the possible combinations typically occur in Alberta. This classification provides detailed information concerning the wetlands in the Project area.

1.4.2 Wetlands Mapping

1.4.2.1 Regional Study Area

Landsat Thematic Mapper (TM) Satellite imagery that included two full scenes (180 by 180 km) and a single-quarter scene (90 by 90 km) was utilized to classify wetlands and vegetation in the RSA. The oil sands development area is almost entirely covered by the 1996 imagery, while to the north and south, it is covered by 1994 imagery. Due to cloud cover constraints, imagery acquired for these time periods were merged to form the RSA. The area covered by the image extends beyond the RSA boundaries.

A supervised classification of the Landsat imagery was performed prior to field surveys. Information sources that assisted this classification included: 1:40,000 scale, black and white photographs; Alberta Phase 3 Forest Inventory Maps (Alberta Energy and Natural Resources 1983); the Alberta Wetland Classification Maps (Halsey and Vitt 1996), and Soils Inventory of the Alberta Oil Sands Environmental Research Program (AOSERP) Study Area (Turchenek and Lindsay 1982).

A helicopter survey of the RSA was undertaken in July 1997. Video coverage with continuous Global Positioning System (GPS) datum was collected to allow refinement of the Landsat classification and provide information for an accuracy assessment.

Wetlands were classified into five classes, including:

- wet open and wet closed coniferous
- fens (shrubby and graminoid)
- bogs (sphagnum and shrub)
- marshes (emergent)
- open water

1.4.2.2 Local Study Area

Wetlands were identified on 1:10,000 scale, black and white aerial photographs. The aerial photographs were pre-stratified according to the Alberta Vegetation Inventory (AVI), which included Alberta Wetland Inventory (AWI) criteria. Field investigations were undertaken in July and August 1997 to refine the preliminary classification. Wetland classes (Halsey and Vitt 1996) and Ecosite Phases (Beckingham and Archibald 1996) were assigned to AVI polygons. Linda Halsey provided the final AWI wetlands classification.

Once the aerial photograph interpretation was complete, polygons were transferred to a 1:20,000 orthophotograph and digitized in Geographic Information System (GIS) software (ARCINFO). Associated attributes for each wetlands class were entered into a database, and linked to the digitized map.

1.4.3 Wetlands Field Surveys

Vegetation surveys were undertaken in July and August 1997. The surveys typed the wetlands according to the Beckingham and Archibald (1996) classification system. The same methodology used in the assessment of terrestrial vegetation (Golder 1998) was applied to the wetlands, with a few exceptions, as reviewed below.

The marsh ecosite was not as accessible due to water depth constraints: therefore the methodology used in the assessment of marshes was adjusted. The 20 x 20 m tree plot was omitted due to the absence of a tree canopy. The 10 x 10 m shrub plot was systematically placed on the side of the marsh that was closest to the shore. The percent cover of shrubs was estimated within the plot, as well as heights. Beyond the shore, only visual estimates were provided. The percent cover of herbs was estimated within a 1 x 1 m plot within the 10 x 10 m plot. The heights of the herbs were measured within the plot and visually estimated beyond the shore.

Wetlands field surveys, which were conducted in July and August 1997, provided field validation of wetland types.

A measure of wetlands diversity is patch (or polygons) size (Table 1). The most extensive wetlands type, the wooded fens (FTNN), have a mean patch size of 35 ha. Bogs (BTNN/BFNN) have a mean patch size of 5 ha. Graminoid marshes (MONG) and shrubby marshes (MONS) have mean patch sizes of 6 ha and 8 ha, respectively. Coniferous (STNN) and deciduous (SONS) swamps have mean patch sizes of 9 ha and 7 ha. Graminoid fens (FONG) and shrubby fens (FONS) have mean patch sizes of 2 ha and 10 ha, respectively.

Table 1 Mean, Minimum and Maximum Wetlands Patch Size

Map Code	AWI Class	Patch Count	Baseline Patch Size (ha)		
			Min	Max	Mean
FTNN	Wooded Fen	172	<1	4,667	35
FFNN	Forested Fen	46	1	116	21
FONG	Graminoid Fen	2	1	3	2
FONS	Shrubby Fen	41	1	64	10
BTNN	Wooded Bog	4	2	12	5
BFNN	Forested Bog	5	1	12	5
STNN	Coniferous Swamp	153	<1	100	9
SFNN	Forested Swamp	51	<1	93	13
SONS	Shrubby Swamp	24	<1	33	7
MONG	Graminoid Marsh	18	<1	67	6
MONS	Shrubby Marsh	27	1	85	8
WONN	Shallow Open Water	16	<1	3	1

1.5 CLASSIFICATION SYSTEMS

The Alberta Wetland Inventory (AWI - Halsey and Vitt 1996) and the Field Guide to Ecosites of Northern Alberta (Beckingham and Archibald 1996) both describe bogs, fens and marshes. The AWI however, also classifies swamps and shallow open water. Table 2 compares the two classification systems with wetlands types represented in the LSA. The LSA was mapped according to the Alberta Wetlands Inventory Classification System (Halsey and Vitt 1996), whereas the RSA used a generalized classification scheme that utilized some of Beckingham and Archibald (1996) and the AWI (Halsey and Vitt 1996).

The classification systems are comparable, at times; however, the distinction between poor and rich fens are not easily distinguishable in the field. In addition, there is no equivalent ecosite classification for patterned fens.

Table 2 Comparison of Alberta Wetlands Inventory (AWI) Forest Classification and the Field Guide to Ecosites of Northern Alberta

ALBERTA WETLANDS INVENTORY[a]			FIELD GUIDE ECOSITES[b]
CLASS	SUBCLASS		
Shallow open water (SW)	n/a[c]	Shallow open water (WONN)	n/a
Marsh (M)	n/a	Graminoid/shrub Marsh (MONG and MONS)	Marsh (l1)
Swamp (S)	Combination of black spruce and tamarack at > 70% cover	Wooded and Forested Swamp (STNN and SFNN)	Wetter end of horsetail (f)
	Shrub cover > 25%	Shrubby Swamps (SONS)	any upland ecosites phases
Fen (F)	Shrub cover > 25% when tree cover ≤ 6%	Non-patterned shrubby fen (FONS)	Shrubby poor fen (j2) and shrubby rich fen (k2)
	Graminoid dominated with shrub cover ≤ 25% and tree cover ≤ 6%	Non-patterned graminoid fen (FONG)	Graminoid rich fen (k3)
	Wooded fen (>10% - ≤70% tree cover)	Non-patterned wooded fen with no internal lawns (FTNN)	Treed poor fen (j1) and treed rich fen (k1)
	Wooded fen > 70% tree cover	Non-patterned forested fen with no internal lawns (FFNN)	n/a
Bog (B)	Wooded bog (>10%, ≤70% tree cover)	No internal lawns (BTNN)	Treed bog (i1) and shrubby bog (i2)

[a] Halsey and Vitt 1996.
[b] Beckingham and Archibald 1996.
[c] n/a = not applicable.

The two classification system do share a number of wetlands properties, which are outlined in Table 3.

Table 3 Summary of General Wetlands Types and their Properties

Properties	Bogs	Fens	Marshes	Swamps	Shallow Open Water
Peat-forming	yes (*Sphagnum*)	yes (sedges, brown moss)	no	no	no
pH	strongly acidic	acidic to neutral	neutral to slightly alkaline	neutral to moderately acidic	variable
Water Level	at or near surface	at or near surface	fluctuates seasonally	at or near surface	intermittent or permanently flooded
Flowing Water	no	yes	yes	yes	yes
Nutrients	low	medium to high	high	high	variable
Minerals	low	medium to high	medium	medium	high
Dominant Vegetation	*Sphagnum*, ericaceous shrubs	sedges, grasses, reeds, brown moss	emergent sedges, grasses, rushes, reeds, submerged and floating aquatics	deciduous or coniferous trees or shrubs, herbs, some mosses	emergent vegetation

The Alberta Wetland Inventory (AWI) classification system (Halsey and Vitt 1996) is based on the interpretation of aerial photographs. There are four levels of classification in the AWI, including wetlands class, vegetation modifiers, wetlands complex landform modifier and local landform modifier. There are five wetlands classes that may be distinguished based on their vegetation composition; bog, fen, swamp, marsh and shallow open water. The vegetation modifier describes the amount of vegetation cover. The presence of permafrost and/or patterning is indicated by the wetlands complex landform modifier. The local landform modifier describes the type of internal lawn, if present, and the amount of shrub and graminoid cover.

The Field Guide to the Ecosites of Northern Alberta (Beckingham and Archibald 1996) includes some wetlands ecosites. This relatively general classification system was used as a preliminary classification of wetlands. The Ecosites are distinguished into treed bogs (i1), shrubby bogs (i2), treed poor fens (j1), shrubby poor fen (j2), treed rich fens (k1), shrubby rich fens (k2), graminoid rich fen (k3) and marsh (l1). Distinctions between wetlands types is largely based on nutrient and moisture regime and the dominant plant species present.

1.6 WETLANDS DIVERSITY

The same methodology (species richness and species diversity) for assessing vegetation diversity was applied to wetlands. Compositional biodiversity is commonly described using measures of richness (species number), and eveness (relative abundance). Species richness is the total number of species present in an area (Krebs 1989). Species richness was calculated for herb, shrub and tree layers in each plot surveyed. Community richness was calculated by averaging the species richness recorded for each community type. Species diversity was measured using the Shannon Index, which describes both species richness and eveness (Krebs 1989). Similar to species richness, diversity was measured at the species and community levels.

1.7 RESULTS AND DISCUSSION

The wetlands classes and types provide critical information for the description and inventory of wetlands. The current wetlands assessment was conducted using the AWI classification system (Halsey and Vitt 1996). The AWI approach (Halsey and Vitt 1996) recognizes six types of fens, four of which are recognized in the Project Millennium LSA. Also, Halsey and Vitt (1996) differentiate five types of bogs, two of which are recognized in Project Millennium LSA

1.7.1 Local Study Area Wetlands

Table 4 and the Wetlands Classification Map (Figure 2) detail the AWI wetlands identified in the LSA. Summary descriptions of each wetlands type are provided below.

1.7.1.1 Bogs (BFNN, BTNN)

Bogs are peatlands that have low surface water flow. The only water available for bogs is from precipitation; consequently, bogs are generally acidic, with a pH of less than 4.5. Bogs are dominated by acid-loving plant species such as peat moss, feathermoss and lichens. Bogs are subdivided into categories based on the percentage and type of forest cover, and on the presence of permafrost and internal lawns following Vitt (1994). Examples of bog locations include drainage divides, stagnation zones of peatland areas and small isolated basins.

Bogs also can be found in a broad, poorly-defined depression near drainage divides. Wooded and forested bogs (BTNN, BFNN) without internal lawns have a flat, uniformly wooded, homogenous surface. Bogs without internal lawns appear as islands or peninsulas within large fens or are confined to small basins associated with hummocky terrain or in broad, poorly defined depressions as well as along drainage divides.

The wooded bog is composed of stunted black spruce in the canopy. Black spruce is also present as tall and low shrubs, although the low shrubs are dominated by Labrador tea, with bog cranberry and small bog cranberry also present. Typical herbs include cloudberry and three-leaved Solomon's seal. Mosses are dominant and include peat moss, Schreber's moss, stair-step moss, knight's plume moss, slender hair-cap moss and reindeer lichen. A picture taken from a wooded bog within the Muskeg River Mine Project (Golder 1997q) is shown in Figure 6.

Figure 6 Wooded Bog with a Variety of Understorey Species

Wooded bogs without internal lawns were the only bogs observed in the Project LSA. The 46 ha of bogs (Table 4) represent less than <1% of the LSA. The largest bog occurs along the southeastern edge of the LSA and is associated with a graminoid fen complex. The other bogs occur in association with swamp complexes south of the Steepbank River.

Table 4 Distribution of Wetlands Plant Community Types According to AWI Class

Wetlands Type		LSA	
Level Code	**AWI Class**	**Area (ha)**	**%**
Shallow Open Water **(W)**	Shallow Open Water **(WONN)**	15	< 1
Marsh **(M)**	Marsh **(MONG)**	107	1
	Marsh **(MONS)**	211	1
Subtotal	***Marsh***	***333***	
Swamps **(S)**	Wooded swamp **(STNN)**	1,359	8
	Forested swamp **(SFNN)**	687	4
	Shrubby swamps **(SONS)**	161	1
Subtotal	***Swamps***	***2,207***	
Fens **(F)**	Open non-patterned shrubby fens **(FONS)**	426	3
	Open non-patterned graminoid fen **(FONG)**	4	< 1
	Wooded fen, no internal lawns **(FTNN)** (tree cover >10% and ≤70%)	6,012	37
	Forested fen, no internal lawns (tree cover >70%) **(FFNN)**	966	6
Subtotal	***Fens***	***7,407***	
Bogs **(B)**	Wooded bog (>10%, ≤ 70% tree cover) not internal lawns **(BTNN)**	20	< 1
	Forested bog, >70% tree cover **(BFNN)**	26	< 1
Subtotal	***Bogs***	***46***	-
Total Wetlands		**9,994**	-
Non-Wetlands		**5,856**	-
Existing, Disturbances and Water		**331**	-
Total Area		**16,181**	-

1.7.1.2 Fens

Fens are peatlands or wetlands where peat accumulates because the rate of plant decomposition is slower than plant production. Fens are also characterized by water flow (i.e., they have inflow and outflow). Fens can be open and dominated by sedges, rushes and cotton grasses; shrubby and dominated by willow or birch; or, wooded and dominated by black spruce, tamarack and/or willow.

The water level of typical fens is at or near the surface. Fens can be relatively rich in mineral elements. The number of indicator vegetation species present can be used to subdivide fens based on acidity: poor fens are acidic (pH of 4.5 to 5.5) with few indicators, while moderately rich fens are slightly acidic to neutral (pH of 5.5 to 7.0) and have more indicator species. Extremely rich fens are basic (pH >7.0) and have a high number of indicator species. As rich and poor nutrient levels cannot be differentiated by air

photo interpretation, the AWI classification uses vegetation and patterning to distinguish between treed, patterned, shrubby and open fens (Halsey and Vitt 1996).

1.7.1.3 Open Fens (FONS and FONG)

Non-patterned fens can be dominated by either shrubs (FONS) or grasses (FONG). In shrub-dominated fens, shorter birch and willow are common, with >25% cover (Figure 7). Conifers may have ≤6% cover. Shrub-dominated fens are located in small isolated basins, and in areas sloping gently in the direction of drainage. Shrub dominated fens occupy 426 ha or 3% of the Project LSA (Table 4).

Figure 7 Shrubby Fen Composed of Dwarf Birch and Willow

Four of the plots surveyed are shrub-dominated fens. Within one shrub-dominated fen, the vegetation was dominated by shrubs composed of willow, dwarf birch and river alder. In the herb layer, marsh cinquefoil, Labrador bedstraw, yellow marsh-marigold, western dock and water-hemlock are the most dominant, with northern green bog-orchid, northern willowherb and small bedstraw being less common. Water sedge, beaked sedge, northern bog sedge, two-stamened sedge and golden sedge are abundant and characteristic.

In another shrub-dominated fen composed of willow and dwarf birch, other shrubs observed are red bearberry, Labrador tea, fly honeysuckle, small bog cranberry and sweet gale. The herb layer is characterized by dwarf scouring-rush, three-leaved false Solomon's-seal, common horsetail, round-leaved sundew, northern grass-of-parnassus, northern bastard toadflax, small bedstraw, Siberian yarrow, northern goldenrod, purple paintbrush, fringed aster, water-parsnip, hooded ladies'-tresses and northern green bog-orchid. Tufted hair grass, slender wheatgrass, field wood-rush, water sedge, hair-like sedge and northern bog sedge are the graminoids observed.

Figure 8 Graminoid Fen With Continuous Sedge Layer

Open, non-patterned, grass and grass-like dominated peatlands may be poor, moderately rich, or extremely rich in nutrients (Vitt and Chee 1990, Nicholson and Gignac 1995). They are characterized by a continuous sedge layer (Figure 8). Tree cover in these fens is ≤6%, and shrub cover is <25%. Open, grass and grass-like dominated poor fens occur as collapse scars (low, wet areas) in association with peat plateaus (Halsey and Vitt 1996). They also have ground cover characterized by drier, species of peat moss that can withstand nutrient-poor conditions. Open, graminoid-dominated fens are also found in small isolated basins, and in areas that slope gently in the direction of drainage and may be poor, moderate-rich, or extreme-rich. Open fens (FONS and FONG) occur in <3 % of the Project Millennium LSA (Table 4).

1.7.1.4 Wooded and Forested Fens (FFNN)

Wooded and forested fens have greater than 10% tree cover and are classified into two categories, based on the presence of permafrost. Non-patterned, wooded fens with no internal lawns, or lower wet areas, vary in nutrients from poor, to moderately rich, to extremely rich. The overstorey is composed of 6 and 70% black spruce and/or tamarack, while birch and willow may be found in the understorey (Figure 9). For forested fens, the overstorey is composed of greater than 70% black spruce and/or tamarack.

The ground cover of wooded fens can be dominated by peat moss or brown moss. Wooded and forested fens are found only in level areas of land, distinguishing them from the upland wooded regions, which may be found in sloped areas.

Figure 9 Wooded Fen Tamarack and Black Spruce Canopy

Only the non-patterned wooded fens in the LSA are without internal lawns. Internal lawns contain standing, dead trees and are dominated by grasses and wet-tolerant species of peat moss or brown moss. A woody debris layer is present at a depth of 20 to 40 cm within internal lawns. Plants, such as feathermoss or golden moss, have been found in this woody debris layer, usually growing under drier conditions. Non-patterned wooded fens are the most dominant wetland type in the Project Millennium LSA. They occupy an area of 6,977 ha or 43% (Table 4). The wooded and forested fens are situated throughout the entire LSA.

A plant survey was completed on a non-patterned, wooded fen within the LSA. The overstorey was composed of tamarack (70%) and black spruce (30%), with a combined cover of 20%. Willow, river alder and larch are the most dominant shrub species. The herb layer is characterized by dwarf raspberry, marsh cinquefoil, yellow marsh-marigold, water-hemlock, Labrador bedstraw, three-leaved false Solomon's-seal, common pink wintergreen, northern willowherb, small bedstraw and blunt-leaved bog-orchid. Two-seeded sedge, water sedge, rough hair grass and marsh reed grass are the characteristic graminoids. There is a moss layer with approximately 70% ground coverage. It is dominated by mnium moss. Old man's beard, horsehair and powdered sunshine was observed as well.

Another non-patterned, wooded fen within the LSA was dominated by tamarack (95%). Black spruce was also present in the canopy but at a smaller coverage (5%). The shrub layer contains dwarf birch, sweet gale, Labrador tea and hoary willow. Three-leaved Solomon's-seal, Labrador bedstraw, marsh willowherb, western dock, yellow marsh-marigold, marsh aster, sheathed cotton-grass and tall cotton-grass characterize the herb layer,

along with water sedge, Dewey's sedge and Sartwell's sedge. Old man's beard, horsehair and Monk's hood lichen was observed on the tamarack and black spruce. Leafy bark lichen was also observed on the dwarf birch.

1.7.1.5 Marshes (MONG, MONS)

Water levels fluctuate in marshes during the course of the year and they have a relatively high water flow (Halsey and Vitt 1996). While high concentrations of nitrogen and phosphorus allow for a high plant productivity in marshes, decomposition rates are also high. For this reason, little peat accumulates in these wetlands, and mosses and lichens are uncommon. They are dominated instead by sedges, rushes and cattails (Figure 10). The herb layer may be composed of northern willowherb, water smartweed, wild mint, reed grass, marsh reed grass, creeping spike-rush, bulrush and rush. Brown moss may also be present.

Figure 10 Marsh Dominated by Sedges, Rushes and Cattails

Marshes often are associated with the margins of streams and lakes. Graminoid marshes in the LSA are restricted to a few small areas. The most extensive marsh system is found in association with Shipyard Lake and McLean Creek. Marshes occur on 318 ha of Project Millennium LSA, or <2% of the LSA (Table 4).

A series of three marshes occur on McLean Creek (east of the Athabasca River). Water sedge, two-stamened sedge and common cattail along with marsh reed grass occur around the marshes edge. Grey-leaved willow, pussy willow and river alder surround the marshes. Other species observed along the marshes edge include water arum, marsh skullcap, yellow water-crowfoot, Labrador bedstraw, water-hemlock, western dock and water-parsnip. Wool-grass was also observed along the edge of the marsh. Wool-grass is rare in Alberta and is on the ANHIC (1996) tracking list.

1.7.1.6 Swamps (SFNN, STNN, SONS)

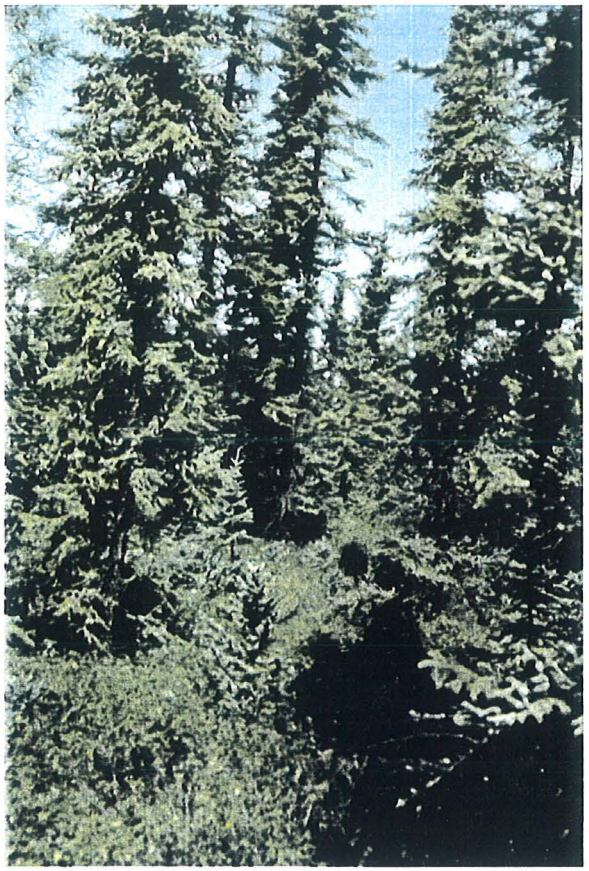
Swamps often exist where there are bodies of water that flood frequently or where water levels fluctuate (e.g., along peatland margins). They are non-peat wetlands that can be forested, wooded, or shrubby. Few mosses and lichens grow in swamps due to the fluctuating water levels. Peat accumulation is low due to high decomposition rates. Common species within swamps include tamarack, birch, willow, alder and black spruce.

Three types of swamps, wooded, forested and shrubby are recognized by the AWI classification system (Halsey and Vitt 1996).

Wooded and forested (STNN and SFNN) swamps (Figure 11) exist near floodplains and streams associated with peatland areas. Forested swamps have a dense tree cover (>70%) of black spruce and tamarack. Wooded swamps have 6 to 70% tree cover of black spruce and tamarack. Shrubby swamps (SONS) are associated with floodplains, stream terraces and peatland ridges. They are dominated by willow. Shrub cover is >25%, with few bryophytes (i.e., liverworts, mosses) present due to fluctuating water levels. Wooded and forested swamps occur on 2,046 ha in Project Millennium LSA, representing 13% of the LSA (Table 4). Shrubby swamps occur on 161 ha in Project Millennium LSA, representing 1% of the LSA. Both swamp types are associated with the Wood Creek and McLean Creek drainages. More shrubby swamps are associated along the central portion of the LSA.

A plant survey was completed on a wooded swamp within the LSA. The tree canopy was dominated by black spruce (70%) and tamarack (30%), with a percent cover of <70%. Dwarf blueberry, dwarf birch and bog cranberry are dominant in the shrub layer. The herb layer is characterized by dewberry, dwarf scouring-rush, woodland horsetail, arrow-leaved coltsfoot, blunt-leaved bog-orchid, northern green bog-orchid, wild strawberry and fringed aster. Hair-like sedge, northern bog sedge and marsh reed grass are the characteristic graminoids observed. Ground coverage by sphagnum was 90%.

Figure 11 Coniferous Swamp With Black Spruce and Tamarack Canopy



1.7.1.7 Shallow Open Water (WONN)

Shallow open waters are waters that are < 2 m in depth during midsummer, but do not function as an aquatic system. Submergent and/or floating vegetation is present, representing the middle ground between terrestrial and aquatic systems. This wetlands class often is associated with other wetlands types such as marshes in the south, or thermokarst basins in the north associated with peat plateaus.

Shallow open water occurs on 15 ha or < 1% of the LSA (Table 4). Most of this wetlands type occurs in Shipyard Lake, McLean Creek, Wood Creek and Leggett Creek.

1.7.1.8 Riparian

Riparian areas are wetlands associated with running water systems found along rivers, streams and drainageways. Riparian areas are bounded on the landward side by upland, by the channel bank, or by wetlands. Water is usually, but not always, flowing in the Riparian area. They are dominated by willow and river alder in the shrub layer and swamp horsetail in the herb layer.

A plant survey was conducted on a riparian shrub complex (Figure 12) located within the Athabasca Floodplain. The shrub complex was located along the Athabasca River. Flat-leaved willow and river alder are the most dominant shrub species. Other shrubs observed are low-bush cranberry, red-osier dogwood, alder-leaved buckthorn, wild red currant, Labrador tea, bracted honeysuckle and twin-flower. The herb layer is characterized by wild sarsaparilla, wild lily-of-the valley, dewberry, bunchberry, bishop's cap, marsh violet, wild strawberry and yellow marsh-marigold. Mud sedge and marsh reed grass are the characteristic graminoids observed. There is a moss layer with approximately 30% ground coverage. Powdered sunshine and hair lichens were observed as well.

Figure 12 Riparian Shrub Complex Dominated by Willow and Alder

1.7.2 Wetlands Species Richness and Diversity

The indices used were species richness, expressed as the number of species present, and species diversity, which was calculated using the Shannon Index. The Shannon Index, H, can be expressed as

$$H = \sum_{I=1}^{k} P_i \log P_i$$

where k is the number of categories (i.e., species) and P_i is the proportion of the observations found in category i. In this case, the percent coverage of the plot area, expressed as a decimal, was used to approximate P_i. Extensive recalculations to account for incomplete coverage and overlapping would be required to find the true values of P_i. Table 5 show the total number of wetlands plots surveyed, data from which was the basis of the richness and diversity assessment.

Table 5 Wetlands Plots Surveyed in the LSA

AWI Class	Class Name	Number of Plots
FTNN/FFNN	Wooded and Forested Fen	23
FONG	Graminoid Fen	3
FONS	Shrubby Fen	8
MONG/MONS	Marshes	8
SONS	Shrubby Swamp	1
STNN	Wooded Swamp	1
	Total Plots	**44**

1.7.3 Total Richness and Diversity

Total richness is the total number of species found in each AWI Class surveyed. Likewise, total diversity is the Shannon Index value calculated with total richness and average cover per plant species. Community diversity and richness was calculated for vascular plants only because these were the only plant types completely surveyed at any site. Total diversity and richness were determined from the combined set of sites which were classed within the same AWI Class. However, each AWI Class phase did not have the same number of sample sites. The number of species will likely increase with the number of sites sampled. Thus, total richness for undersampled AWI Classes is a conservative estimate of the total species richness.

The highest number of total species found in each wetlands site are in the wooded fen (FTNN) and the shrubby fen (FONS) (Table 6) The lowest number of total species found in each wetlands site are the wooded swamp (STNN). The highest number of species in the shrub layer are in the wooded fen (FTNN) and shrubby fen (FONS); in the herb layer it is also the wooded (FTNN) and shrubby fen (FONS). Total shrub species are high among wetlands sampled. Total tree species are low among wetlands sampled, particularly among graminoid fens (FONG), marshes (MONG/MONS) and shrubby swamp (SONS).

Table 6 Richness for Wetlands Surveyed

	Richness				
Phase	Trees	Shrubs	Herbs	Total	Number of Sampled Sites
FFNN	2	19	18	37	3
FONG	0	3	26	29	3
FONS	2	25	52	77	8
FTNN	2	35	51	86	20
MONG	0	4	35	39	5
MONS	0	6	26	32	3
SONS	0	11	11	22	1
STNN	2	5	4	10	1

Table 7 Total Diversity for Wetlands Surveyed

	Diversity				
Phase	Trees	Shrubs	Herbs	Total	Number of Sampled Sites
FFNN	0.18	1.02	1.18	1.03	3
FONG	0.00	0.40	0.99	1.07	3
FONS	0.18	1.18	1.34	1.56	8
FTNN	0.26	1.14	1.31	1.34	20
MONG	0.00	0.55	1.05	1.09	5
MONS	0.00	0.64	1.11	1.22	3
SONS	0.00	0.92	0.73	1.13	1
STNN	0.14	0.45	0.36	0.78	1

The highest diversity was found within the shrubby fen (FONS) and wooded fen (FTNN) among all surveyed wetlands (Table 7). The wooded swamp (STNN) has the lowest diversity among all surveyed wetlands. The highest diversity for the shrub layer was found in the shrubby fen (FONS) and wooded fen (FTNN) among all surveyed wetlands. The highest diversity for the herb layer was also found in the shrubby (FONS) and wooded (FTNN) fens. The highest diversity among all surveyed wetlands was in the herb layer. The lowest diversity among all surveyed wetlands was in the tree layer.

1.7.3.1 Composition

Composition is assessed by examining the total number of different species present in all of the plots in each of the ecosite phases (Table 8), as well as the total number of species present in each of three structural layers (tree, shrub and herb). These data represent overall species richness in each AWI Class when taken as a whole. The sum of the species present in each of the layers does not necessarily equal the total for the ecosite phase because of species duplications between layers. Using the Shannon Index, the SONS (shrubby swamp) and FFNN (forested fen) wetlands class exhibits the greatest species richness both overall and in the shrub layer. The highest herb species richness, is in the MONG/MONS (marshes) and SONS (shrubby swamp) wetlands class. Overall, shrub and herb species comprise the most species for individual plots within the wetlands classes surveyed. In addition, all wetlands classes sampled have few species in the tree layer. No plot surveys were undertaken in the WONN (shallow open water) and BTNN/BFNN (wooded/forested bogs) wetlands classes.

Table 8 Average Richness for Surveyed Wetlands

Phase	Total Vascular Species			Tree Layer			Shrub Layer			Herb Layer		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
FFNN	19.7	18	22	2.0	2	2	12.0	9	15	6.7	3	9
FONG	10.0	8	14	0.0	0	0	1.3	0	3	8.7	5	13
FONS	15.9	9	25	0.8	0	2	5.8	2	8	9.9	5	18
FTNN	14.6	6	23	1.5	1	2	7.6	3	14	6.5	1	12
MONG	10.8	3	16	0.0	0	0	0.6	0	2	10.2	3	14
MONS	15.0	11	21	0.0	0	0	3.0	2	4	12.0	7	19
SONS	22.0	22	22	0.0	0	0	11.0	11	11	11.0	11	11
STNN	10.0	10	10	2.0	2	2	5.0	5	5	4.0	4	4

1.7.3.2 Structure

In terms of structure, species richness is highest in the shrub and herb layer and lowest in the tree layer for wetlands classes surveyed. Structurally, both mean and maximum richness are lowest in the tree layer in each wetlands class. Generally, mean and maximum richness are higher in the herb layer than in the shrub layer. The differences in relative species richness among wetlands classes, may result from differences in internal compositional variability among wetlands classes surveyed.

The use of structure also aids in describing the appearance of the community. Structure relates to the vertical spacing and height of the plants making up the community. Table 9 shows the percentage of stands with multilayered structure (i.e., overstorey and understorey). BTNN/BFNN (wooded/forested bogs), FONS (shrubby fens), FONG (graminoid fens), MONG (marshes) and SONS (deciduous swamps) have only single layered structured stands. The FTNN/FFNN (wooded/forested fens) and STNN/SFNN (wooded/forested swamps) have multilayered structured stands.

Table 9 Percentage of AWI Classes in the LSA With Multilayered Structure (Overstorey and Understorey)

Phase	Multilayered Stand Percentage	Single Layer Stand Percentage
BFNN	0.0	100.0
BTNN	0.0	100.0
FFNN	13.0	87.0
FONG	0.0	100.0
FONS	0.0	100.0
FTNN	39.0	61.0
MONG	0.0	100.0
MONS	1.8	98.2
SFNN	8.3	91.7
SONS	0.0	100.0
STNN	52.1	47.9
WONN	00.0	100.0

1.7.3.3 Diversity

Diversity refers to the numbers of species in given areas, the ecological roles that these species play, the way that the composition of species changes as we move across a region and the groups of species (ecosystems) that occur in particular areas, together with the processes and interactions that take place within and between these systems (UNEP 1995).

The Shannon Index is used to measure species diversity. This index combines the number of types (species) and the frequency distribution of these types. The more types and the more evenly distributed they are, the higher the index value. The index is generally used on random samples drawn from a large community, where there is a less likely chance to randomly select the same sample twice.

Table 10 gives the mean and range of species diversity values for individual plots within the wetlands classes. The SONS (shrubby swamp) and MONS (marsh) wetlands classes have the highest mean diversity among wetlands surveyed. The highest mean diversities for the shrub layer are in the SONS (shrubby swamp) and the FFNN (forested fen). The highest mean diversity for the herb layer is in the MONS (marsh). The lowest mean diversity among all wetlands surveyed was in the MONG (marsh). The lowest mean diversity in the shrub layer is in the MONG (marsh). The lowest mean diversity in the herb layer is in the STNN (wooded swamp). Overall, mean diversity is highest in the herb layers for individual plots of the wetlands surveyed. Mean diversity is lowest in the tree layer for all wetlands classes.

Table 10 Species Diversity for Surveyed Wetlands

	Total Vascular Species			Tree Layer			Shrub Layer			Herb Layer		
Phase	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
FFNN	0.91	0.85	0.99	0.14	0.02	0.27	0.88	0.81	0.99	0.72	0.48	0.90
FONG	0.84	0.64	1.15	0.00	0.00	0.00	0.13	0.00	0.40	0.77	0.45	1.11
FONS	0.93	0.69	1.21	0.03	0.00	0.28	0.53	0.22	0.72	0.75	0.53	1.14
FTNN	0.89	0.50	1.06	0.09	0.00	0.27	0.68	0.27	0.97	0.65	0.00	0.95
MONG	0.68	0.16	0.93	0.00	0.00	0.00	0.06	0.00	0.30	0.65	0.16	0.89
MONS	0.98	0.89	1.09	0.00	0.00	0.00	0.41	0.28	0.54	0.85	0.63	1.11
SONS	1.13	1.13	1.13	0.00	0.00	0.00	0.92	0.92	0.92	0.73	0.73	0.73
STNN	0.78	0.78	0.78	0.14	0.14	0.14	0.45	0.45	0.45	0.36	0.36	0.36

Total Cover

Cover is defined as the vertical projection of the crown or shoot area of a plant species to the ground surface expressed as a fraction or percent of a reference area. Cover is generally evaluated separately for each height layer or vegetation stratum. Nearly all plant lifeforms, from trees to mosses, can be evaluated by cover and thereby expressed in comparable terms (Mueller-Dombois and Ellenberg 1974).

Table 11 gives total cover for the tree layer, shrub layer and herb layer within the wetlands classes. The highest total mean for the tree layer are in the FTNN/FFNN (wooded fen) and STNN (coniferous swamp) wetlands classes. The highest total mean for the shrub layer are in the SONS (deciduous swamp) and FTNN/FFNN (wooded fen) wetlands classes. The highest total mean for the herb layer are in the MONG/MONS (marshes) wetlands classes. The minimum total cover in the shrub layer is in the MONG (marsh) and FONG (graminoid fen) wetlands classes and for herb layer it is in the FTNN/FFNN wetlands classes.

The highest mean for total vascular species are in the SONS (shrubby swamp) and FTNN/FFNN (wooded/forested fen) wetlands classes. The maximum total cover of vascular species for individual plots within the wetlands classes are 300 and 292% cover for FTNN (wooded fen) and FONS (shrubby fen). The minimum total cover of vascular species for individual plots within the wetlands classes are 14% cover for FONG (graminoid fen). These are additive covers for each species in each vegetative layer. The analysis was not constrained to 100%, which is why the totals can be greater than 100%.

Table 11 Total Cover for Vascular Species in Surveyed Wetlands

Phase	Total Vascular Species			Tree Layer			Shrub Layer			Herb Layer		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
FFNN	209	196	233	86	79	100	98	80	124	25	9	38
FONG	59	14	97	0	0	0	6	0	17	53	13	80
FONS	163	86	292	0	0	2	80	13	155	82	38	137
FTNN	207	115	300	37	20	70	128	75	213	42	5	106
MONG	110	77	125	0	0	0	3	0	10	107	77	120
MONS	177	111	245	0	0	0	63	25	90	113	86	155
SONS	218	218	218	0	0	0	141	141	141	77	77	77
STNN	172	172	172	50	50	50	67	67	67	55	55	55

1.7.4 Tree Measurements

The weighted mean heights by wetlands classes occurring in the LSA are shown in Table 12. The means and standard deviation were weighted by stand area. The wetlands class with the highest mean height was the coniferous swamp (STNN). The shrubby fen (FONS) wetlands class has the lowest mean height. The maximum height of standing trees was found in the wooded fen (FTNN) wetlands class. The graminoid fen (FONG), marsh (MONG) and shallow open water (WONN) wetlands classes did not have a mean height recorded.

Table 12 Weighted Mean Heights by Wetlands Classes From AVI Data

Ecophase	Number of Stands	Mean Height	Standard Deviation	Minimum Height	Maximum Height
BFNN	5	2.9	0.4	2	5
BTNN	4	4.1	2.0	2	5
FFNN	66	4.9	5.6	2	10
FONG	2	0.0	0.0	0	0
FONS	45	1.5	0.6	1	6
FTNN	620	6.0	11.5	1	22
MONG	21	0.0	0.0	0	0
MONS	43	2.9	9.3	0	16
SFNN	63	8.2	7.1	3	16
SONS	31	2.6	2.1	0	5
STNN	228	12.3	23.4	3	29
WONN	16	0.0	0.0	0	0

The mean stand ages by wetlands classes are shown in Table 13 (raw age data was determined by subtracting vegetation sample year (1997) from year

of origin classes. consequently all raw values end in the digit 7). The wetlands class with the highest mean age was the coniferous swamp (STNN). The wetlands class with the lowest mean age was the wooded bog (BFNN). The "oldest" trees were found in the coniferous swamp (STNN/SFNN) and the wooded fen (FTNN) wetlands classes. There was no recorded mean stand age data the graminoid fen (FONG); the shrubby fen (FONS); the marsh (MONG); and shallow open water (WONN). This is because these wetlands classes usually do not have standing trees in their communities.

Table 13 Mean Stand Ages by Wetlands Classes

Phase	Number of Stands	Mean Age	Standard Deviation	Minimum Age	Maximum Age
BFNN	5	65	15	57	67
BTNN	4	84	283	57	97
FFNN	66	74	376	17	117
FONG	0	0	0	0	0
FONS	0	0	0	0	0
FTNN	618	84	742	0	147
MONG	0	0	0	0	0
MONS	5	4	323	0	117
SFNN	63	89	496	57	147
SONS	0	0	0	0	0
STNN	228	109	821	67	207
WONN	0	0	0	0	0

The mean canopy closure by wetlands classes are shown in Table 14 (determined from the total stand area representing each class within each ecosite phase). The wetlands class with the highest percentage (71-100%) of ground area covered was the coniferous swamp (SFNN). This means that the SFNN wetlands class have closed stands and are very dense. The wetlands class with the lowest percentage (6-30%) of ground area covered was the coniferous swamp (SFNN) and the marsh (MONS). However. thirty percent of the wooded fens (FTNN) and coniferous swamp (STNN) occurring within the LSA are in the A (6-39%) crown closure class. This means that the FTNN and STNN wetlands classes are open and not very dense.

Table 14 Mean Canopy Closure by Wetlands Class

Phase	A (6 - 30 %)	B (31 - 50 %)	C (51 - 70 %)	D (71 - 100 %)	Open (0 - 5 %)
BFNN	0.0	0.0	16.9	83.1	0.0
BTNN	0.0	0.0	92.0	8.0	0.0
FFNN	13.0	0.0	3.8	83.2	0.0
FONG	0.0	0.0	0.0	0.0	100.0
FONS	0.0	0.0	0.0	0.0	100.0
FTNN	30.4	16.4	50.5	2.6	0.2
MONG	0.0	0.0	0.0	0.0	100.0
MONS	4.7	0.8	0.0	0.0	94.5
SFNN	3.4	4.9	0.0	91.7	0.0
SONS	0.0	0.0	0.0	0.0	100.0
STNN	33.8	19.7	41.3	5.1	0.0
WONN	0.0	0.0	0.0	0.0	100.0

1.7.5 Regional Study Area

Wetlands occurring within the RSA were determined through Landsat classification (Table 12). Regional wetlands were classified to the Beckingham and Archibald system, as described in the 1996 Field Guide to Ecosites of Northern Alberta and to the Alberta Wetlands Inventory (AWI) classification system (Halsey and Vitt 1996). The majority of wetlands are wet open and closed coniferous, shrubby fens and graminoid fens. Approximately <1% of the RSA are bogs (sphagnum around edges of graminoid fens). Marshes occur in association with shallow open water in the RSA.

Table 15 Regional Vegetation Classification

Land Cover Classes	Boreal Mixedwood	Boreal Highlands	Subarctic	AWI	Area (ha)	% RSA
Open Pine Lichen	Lichen (Pj) a1	Bearberry/lichen a1	Bearberry (Pl) a1	-	130,960	5
Mixed Deciduous (Aspen Dominant)	Blueberry Aw (Bw) b2 Low-bush cranberry (Aw) d1 Dogwood (Pb-Aw) e1 <10% Horsetail (Pb-Aw) f1 <10%	Blueberry Aw (Bw) b2 Low-bush cranberry (Aw) d1	Bearberry (Aw) a3 Canada buffalo-berry (Aw) b2 Horsetail (Pb-Bw) d1 <10%	-	180,410	7
Mixedwood (White Spruce-Aspen Dominant)	Blueberry (Aw-Sw) b3 Low-bush cranberry (Aw-Sw) d2 Dogwood (Pb-Sw) e2 <10% Horsetail (Pb-Sw) f2 <10%	Low-bush cranberry (Aw-Sw-Sb) d2	Canada buffalo-berry (Aw-Sw-Sb) b3 Horsetail (Aw-Sw) d2	-	323,026	13
Mixed Coniferous (White Spruce Dominant)	Low-bush cranberry (Sw) d3 Dogwood (Sw) e3<10% Horsetail (Sw) f3<10%	Low-bush cranberry (Sw) d3	Canada buffalo-berry (Sw) b4 Horsetail (Sw) d3	-	113,366	5
Mixed Coniferous (White Spruce- Pine Dominant)	Blueberry (Sw-Pj) b4	Blueberry (Sw-Pj) b3	Labrador tea - hygric (Pl-Sb) e1	-	18,811	1
Mixed Coniferous (Pine Dominant)	Blueberry (Sw-Pj) b4 Labrador tea -mesic (Pj-Sb) c1 Labrador tea-subhygric (Sb-Pj) g1	Blueberry (Sw-Pj) b3 Labrador tea -mesic (Pj-Sb) c1 Labrador tea-subhygric (Sb-Pj) g1	Labrador tea - mesic (Pl-Sb) c1 Labrador tea - hygric (Pl-Sb) e1	-	15,081	1
Pine Recolonization (Pine <2m)	shrubland dominated by Pine	shrubland dominated by Pine	shrubland dominated by Pine	-	87,475	4
Mixed Coniferous (Black Spruce-Tamarack)	Non-wetlands Sb-Lt	Non-wetlands Sb-Lt	Non-wetlands Sb-Lt	-	95,190	4
Wet Closed Coniferous (Black Spruce)	Treed poor fen j1 Treed rich fen k1 Treed bog i1	Treed poor fen i1 Treed rich fen j1 Treed bog h1	Treed bog f1 Treed poor fen g1 Treed rich fen h1	FTNN/FFNN	519,401	21
Wet Open Coniferous (Black Spruce)	Treed poor fen j1 Treed rich fen k1 Treed bog i1	Treed poor fen i1 Treed rich fen j1 Treed bog h1	Treed bog f1 Treed poor fen g1 Treed rich fen h1	FTNN/FFNN	137,847	6
Shrubby Fen	Shrubby poor fen j2 Shrubby rich fen k2	Shrubby poor fen i1 Shrubby rich fen j2	Shrubby poor fen g2 Shrubby rich fen h2	FONS	294,532	12
Graminoid Fen	Graminoid rich fen k3	Graminoid rich fen j3	Graminoid rich fen h3	FONG/MONG	226,625	9
Low Shrub wetlands (bog)			Shrubby bog f2	BONS	64,818	3
Bog (sphagnum around edges of graminoid fens)	Shrubby l2 bog	Shrubby bog h2	Shrubby bog f2	BTNN, BTNI	3,334	<1
Marsh emergent	marsh l1	marsh	marsh	MONG	5,805	<2
Shrubland (low shrub recolonization no pine)	-	-	shrubland (upland dry-mesic moisture regime)	-	16,668	1
Forestry Cutblocks	-	-	-	-	14,905	1
Natural or Human Disturbance	-	-	-	-		
Water	-	-	-	WONN, NWL, NWF, NWR	65,309	3

1.8 CLOSURE

We trust that this report presents the information that you require. Should any portion of the report require clarification, please contact the undersigned.

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1.9 REFERENCES

Alberta Energy and Natural Resources. 1983. Phase 3 Forestry Inventory Maps. Resource Evaluation and Planning Division.

ANHIC (Alberta Natural Heritage Information Centre). 1996. Alberta Natural Heritage Information Centre Plant Species of Concern. Alberta Natural Heritage Information Centre. Edmonton. Alberta.

Beckingham, J.D. and J.H. Archibald. 1996. Field Guide to Ecosites of Northern Alberta. Northern Forestry Centre. Forestry Canada, Northwest Region. Edmonton, Alberta. Spec. Rep. 5.

Golder. 1996. Impact Analysis of Terrestrial Resources Associated with the Steepbank Mine. Report for Suncor Inc., Oil Sands Group, fort McMurray, Alberta.

Golder (Golder Associates Ltd.) 1998. Terrestrial Vegetation Baseline for Project Millennium. Report for Suncor Energy Inc., Oil Sands. Fort McMurray. Alberta.

Halsey, L. and D.H. Vitt. 1996. Alberta Wetlands Inventory Standards - Version 1.0. *In* Nesby, R. (ed.). Alberta Vegetation Inventory Standards Manual. 1997. Alberta Environmental Protection Resource Data Division.

Krebs, C.J. 1989. Ecological Methodology. Harper and Row, New York.

Mueller-Dombois, Dieter and Heinz Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley & SONS, New York.

Nesby, R. 1997. Alberta Vegetation Inventory Standards Manual Final Draft. Alberta Protection Resource Data Division.

Nicholson, B.J. and L.D Gignac. 1995. Ecolyse Dimensions of Peatland Bryophyte Indicator Species Along Gradients in the MacKenzie River Basin. Canada. The Bryologist 98(4):437-451.

NWWG (National Wetlands Working Group) 1988. Wetlands of Canada. Ecological Land Classification Series No. 24. Sustainable Development Branch. Environment Canada. Ottawa, Ontario.

Turchenek, L.W. and J.D. Lindsay. 1982. Soils Inventory of the Alberta Oil Sands Environmental Research Program Study Area. Alberta Oil Sands Environmental Research Program (AOSERP). Report 122 & Appendix 9.4. Alberta Environment, Research Management Division.

United Nations Environmental Programme. 1995. Global Biodiversity Assessment. University Press, Cambridge.

Vitt, D.H. 1994. An Overview of Factors that Influence the Development of Canadian Peatlands. Memoirs of the Entomological Society of Canada. 169:7-20.

Vitt. D.H., L.A. Halsey, M.N. Thormann and T. Martin. 1997. Peatland Inventory of Alberta. Phase 1: Overview of Peatland Resources in the Natural Regions and Subregions of the Province. Report for the Alberta Peat Task Force. Edmonton.

Vitt. D.H. and W.I. Chee. 1990. The Relationships of Vegetation to Surface Water Chemistry and Peat Chemistry in Fens of Alberta, Canada. Vegetation 1989:87-106.