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REPORT ON

WETLANDS BASELINE

FOR THE

MUSKEG RIVER MINE PROJECT

Submitted to:

Shell Canada Limited
400 - 4 Avenue SW
Calgary, AB T2P 2H5

December 1997

972-2237

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January 28, 1998

Proj. No. 972-2237

Dr. Doug Mead
Senior Environmental Scientist
Safety and Environmental Resources
Shell Canada Limited.
400 - 4th Avenue SW
P.O. Box 100, Station M
Calgary, AB T2P 2H5

RE: Final report - Wetlands Baseline for the Muskeg River Mine Project

Dear Doug

Attached is the final report for the Wetlands Baseline for the Muskeg River Mine Project. This report provides details of wetlands within the Muskeg River Mine Project area identified using The Ecosites of Northern Alberta and Alberta Wetland Inventory wetlands classification system. It includes details on: a) inventory of lowland or wetland types within local and regional study area (LSA and RSA); b) wetlands diversity within the LSA and RSA; and c) the wetlands component to the Ecological Land Classification.

Should you have any questions about this report, please contact me at 299-5640.

Yours very truly,

GOLDER ASSOCIATES LTD.

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

attachment

cc. Judy Smith (Shell)
Ian Mackenzie (EIA Project Manager)

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EXECUTIVE SUMMARY

This document details the Wetlands Resources within the Local and Regional Study Areas for Shell Canada Limited's (Shell) Muskeg River Mine Project (the Project) 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 wetlands classifications in the Field Guide to Ecosites of Northern Alberta (Beckingham and Archibald 1996) and the Alberta Wetlands Inventory (AWI) (Halsey and Vitt 1996). Beckingham and Archibald's 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 local and regional study area (LSA, RSA) of the Project;
- 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.

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

- water
- fens and bogs
- marshes
- shallow open water
- deep open water.

For the LSA 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 Wetlands Inventory (AWI) criteria. Vegetation surveys were taken in July 1997 in some wetlands classes. The surveys typed the wetlands according to the Beckingham and Archibald (1996) classification system.

Community level biodiversity can be assessed by examining community richness, diversity, and polygon size. Changes in the ranges of these parameters are an expression of heterogeneity in ecosite phase polygons. A

reduction in the polygon size ranges, for example, could equate to a temporary loss in biodiversity.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.1 INTRODUCTION

This document details the wetlands within the Muskeg River Mine Project (Project) area 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 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:

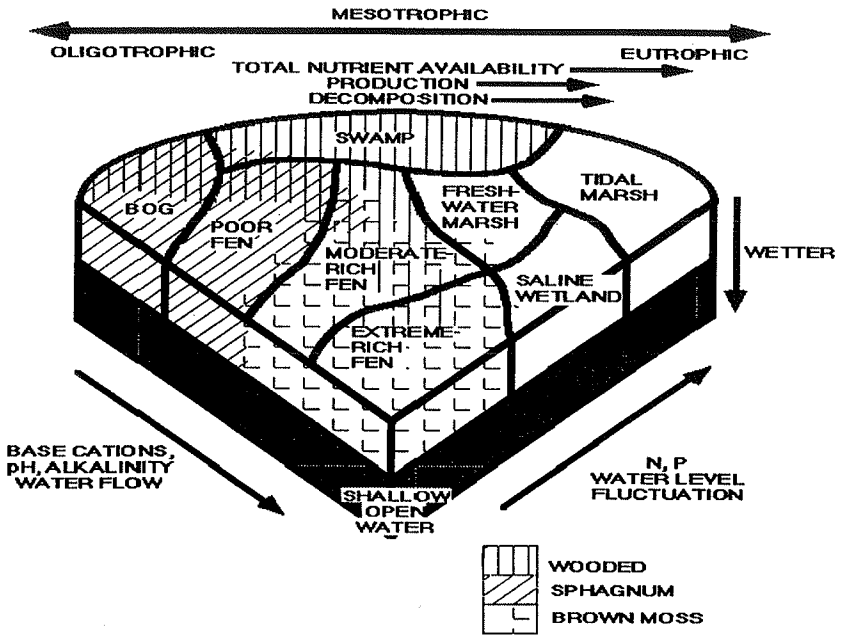
"land that is saturated with water long enough to promote wetland or aquatic processes as indicated by hydric soil, hydrophytic vegetation, and various kinds of biological activity which are adapted to the wet environment".

There are also 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 Muskeg River Mine Project 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 charateristics to be inventoried correctly. Beckingham and Archibald (1996) differentiates treed bogs, shrubby bogs, poor fens, treed poor fens, shrubby poor fens, rich fens, treed rich fens, shrubby rich fens, graminoid rich fens and marshes. This field guide classification system was used as a preliminary classification during the vegetation field survey; however; the Project area was also classified according to a more detailed system (Halsey and Vitt 1996) which differentiates shallow open waters, marshes, swamps, fens and bogs according to three wetlands classes, 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 local and regional study areas (LSA, RSA) of the Muskeg River Mine Project;
- 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 Muskeg River Mine Project area area shown in Figure 2.

6 350 000 N

6 345 000 N

6 340 000 N

460 000 E

465 000 E

470 000 E

475 000 E

LEGEND

- Local Terrestrial Study Area
- Lease 13
- Open Water

WETLANDS CLASSIFICATIONS

- Bog treed (Btnn)
- Fen patterned (Fopn)
- Fen treed > 6 - 70% (Ftnn)
- Fen treed > 70% (Ffnn)
- Fen shrub forest (Fons)
- Fen graminoid (Fong)
- Marsh graminoid (Mong)
- Swamp (coniferous > 70%) (Sfnn)
- Swamp (coniferous > 6-70%) (Stnn)
- Swamp (shrub) (Sons)
- Shallow open water (Wonn)
- Forest
- Cultural Features and Disturbed Lands

SOURCE:
VITT, D.H., Halsey, L.A., Thormann, M.N., and Martin, T., 1996.
Peatland Inventory of Alberta
Phase 1: Overview of peatland resource in the natural regions and subregions of the province.
The Forestry Corp.,
Golder Associates Ltd.

1 0 1 2
Kilometers

MAP PROJECTION: Universal Transverse Mercator Zone 12

DATUM: NAD 83

Golder Associates

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MUSKEG RIVER MINE PROJECT
WETLANDS CLASSIFICATION

09 Jan. 1998	Figure 2	PRODUCED BY: J. Shaw REVIEWED BY:

/data8/oilsands/972-2237/9700/9701/final/arcview/wet50.apr

1.2 REGIONAL STUDY AREA

The Regional Study Area (RSA) for the Project EIA is based on the RSA used for the Steepbank and Aurora Mine EIAs. It has an area of 1,051,411 ha (Suncor 1996, Bovar 1996). Boundaries for the RSA were selected based on ecoregions, watersheds and airsheds. The RSA is shown in Figure 3.

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 were assessed in the Peatlands of Alberta (Vitt et. al 1997) and will be discussed in this report.

1.3 LOCAL STUDY AREA

The Local Study Area (LSA) for the Project is located adjacent to the Athabasca River in Township 96, Ranges 9-11 and covers an area of 10,954 hectares (Figure 4). Boundaries were defined by the Project development area, with the exception of the south and east boundaries. Along these portions of the project development area the LSA extends a further 500 metres. The southern 500 m extension buffers the Project development. The eastern 500 m extension buffers any proposed development and includes the waters associated with the Muskeg River and Jackpine Creek. The 500 m buffer is based on previous studies in the area, and also includes buffer wetlands near the LSA boundary.

The LSA is a complex mosaic of glaciofluvial, lacustrine and organic plains. The vegetation is characterized by rapid transitions between dry, upland coniferous and deciduous communities to treed, shrub and graminoid wetlands. Wetlands, including bogs, fens, marshes, swamps and shallow open water, occupy approximately 61% of the LSA.

J:\1997\2237\7500\BASELINE\TERRAIN.DWG

LEGEND

- REGIONAL STUDY AREA
- Deciduous Forest (Closed)
- Mixedwood Forest (Closed)
- Coniferous Forest (Closed)
- Coniferous Forest (Open) / Muskeg
- Past Burn - Pine Regeneration
- Recent Burn
- Shrub / Young Regeneration
- Open Water
- Cloud

0 10 20 30 40km

SCALE 1:1,250,000

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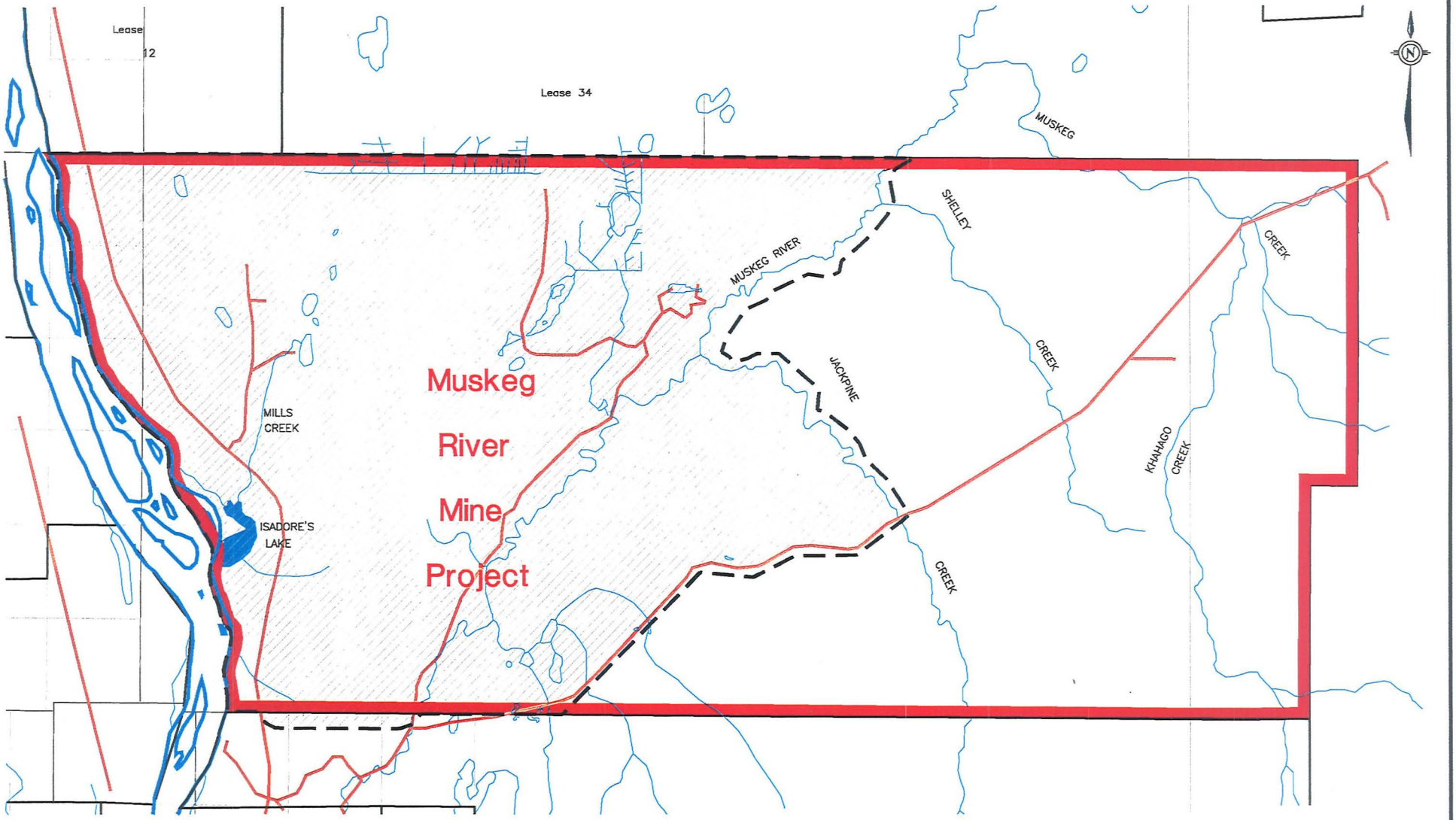
REGIONAL STUDY AREA FOR THE MUSKEG RIVR MINE PROJECT

26 JAN 98	Figure 3	DRAWN BY: CG

J:\1997\2237\7500\BASELINE\LOCTERR.DWG



REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA DIVISION
ALBERTA ENVIRONMENTAL PROTECTION, 1997.

0 1 2 3 4 5km

SCALE 1:100,000

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TERRESTRIAL LOCAL STUDY AREA FOR MUSKEG RIVER MINE PROJECT

26 JAN 98	FIGURE 4	DRAWN BY:

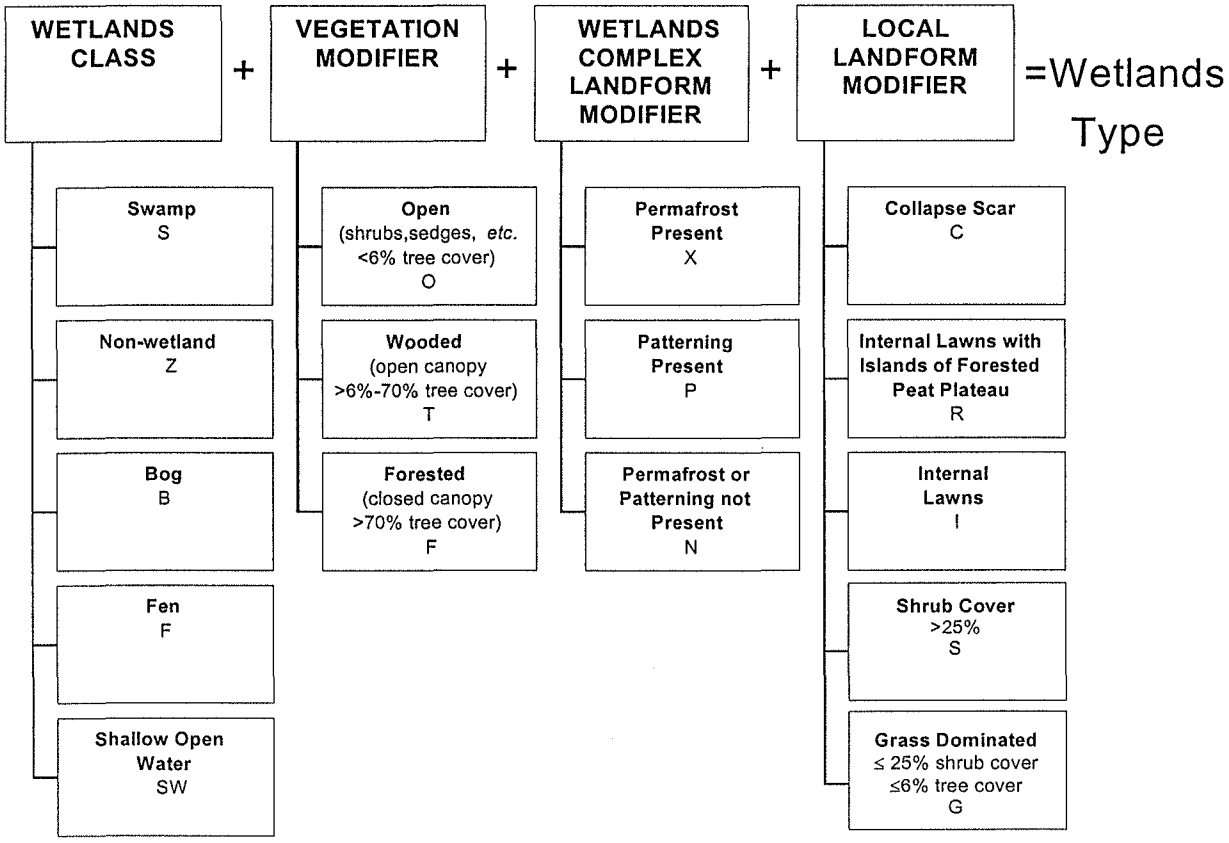
1.4 METHODOLOGY

1.4.1 Wetlands Classification Systems

The wetlands classification system developed by Halsey and Vitt (1996) uses variables that are distinguishable on aerial photographs (Figure 5). The Alberta Wetlands Inventory (AWI) classification system applied to the Project 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 classification system contains four levels: the wetlands class, the vegetation modifier, the wetlands complex landform modifier, and the local landform modifier (Figure 5). Approximately 14 of all the possible combinations typically occur in Alberta. This classification provides detailed information concerning the wetlands in the Project area.

Figure 5 Flow Chart Representation of Wetlands Classification Process



Source: Nesby 1997 (AVI Version 2.2)

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 mining 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 (Figure 6). The area covered by the image extends beyond the RSA boundaries.

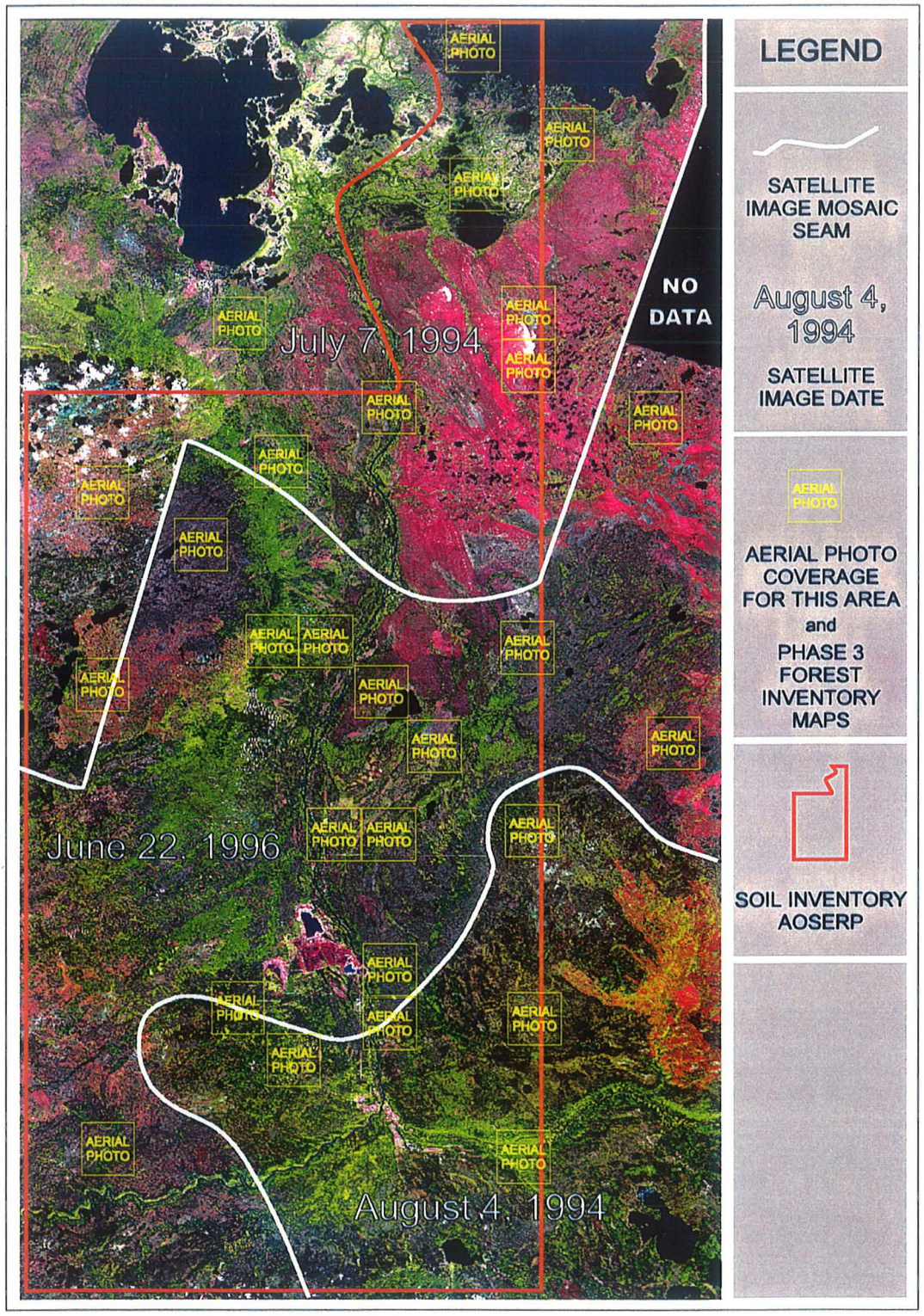
A supervised classification of the Landsat imagery was performed prior to field surveys. Information sources that assisted this classification included: 1:40:000 scale, black and white photographs; Alberta Phase 3 Forest Inventory Maps (Alberta Energy and Natural Resources 1983); the Alberta Wetland 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 four classes, including:

- water
- fens and bogs
- marshes
- shallow open water
- deep open water

Figure 6 Satellite Imagery and Aerial Photo Coverage for RSA



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 September 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 1:10,000 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 1997 in some wetlands classes. 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 1997) 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 on the shore, and some heights were measured near the shore. Beyond the shore, only visual estimates were provided. Herb plots were omitted, and the percent cover of herbs was visually estimated within a 10 x 10 m plot. The heights of the herbs were measured at the shore, and visually estimated beyond the shore. The wetlands types and number of vegetation surveys conducted per type is presented in Table 1.

Table 1 Common Cover Types, with Associated Ecosites and Associated Ecosites Sampled[a]

Forest Types (AVI)	Associated Ecosite Phase	Number Surveyed for Muskeg River Mine	Number Surveyed for Aurora Mine
SbLt/LtSb	j1 (poor fen)	5	14
	j2 (shrubby poor fen)	0	8
Sb	i1 (bog)	4	10
Riparian/Swamp	none	4	
Lt	k1 (rich fen)		21
	k2 (shrubby rich fen)	0	36
	k3 (graminoid fens)	0	4
Marsh	l1 (marsh)	2	0
The following cover types were not common (1-2 polygons), and had no associated ecosites: Pb, PbSb, PbSbLt, PbAwSw, SbLtPj, SbSwPb, SbSwLt, PjAwSw, AwPbSw, AwSwPb, LtSbPb, LtSbPj, SwPb, SwBw, LtPj, PbPjSb, PbLt, PjLt, AwSw, LtPb.			

[a] Muskeg River Mine Project wetlands sampled by Golder; Aurora Mine wetlands sampled by BOVAR (1996)

Wetlands field surveys, which were conducted in September 1997 as part of the AVI field investigation, provided field validation of wetlands types.

A measure of wetlands diversity is patch (or polygons) size (Table 2). The most extensive wetlands type, the Wooded Fens and Bogs, have an average patch size of 386 ha. Recently burned Wooded Fens and Bogs have an average patch size of 1.6 ha. Graminoid fens (k3) and marsh (11) wetlands have average patch sizes of 35.2 ha and 0.6 ha, respectively.

Table 2 Patch Size Change for Wetlands in the LSA

Map Code	Ecosite Phase	Baseline Patch Size (ha)		
		Min	Max	Avg
j1,j2,k1,k2 and limited i1,i2	Wooded Fens and Bogs	<0.0001	239,044	386.0
j1,j2,k1,k2 with recent burn	Wooded Fens and Bogs (recently burned)	<0.0001	146	1.6
k3	Graminoid Fens	0.001	7,923	35.2
l1	Marsh	<0.0001	89	0.6

1.5 CLASSIFICATION SYSTEMS

The Field Guide to Ecosites of Northern Alberta (Beckingham and Archibald 1996) and the Alberta Wetland Inventory (AWI - Halsey and Vitt 1996) describe bogs, fens and marshes. The AWI however, also classifies swamps and shallow open water. Table 3 compares the two classification systems with wetlands types represented in the LSA.

1.5 CLASSIFICATION SYSTEMS

The Field Guide to Ecosites of Northern Alberta (Beckingham and Archibald 1996) and the Alberta Wetland Inventory (AWI - Halsey and Vitt 1996) describe bogs, fens and marshes. The AWI however, also classifies swamps and shallow open water. Table 3 compares the two classification systems with wetlands types represented in the LSA.

Table 3 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	n/a	n/a
Marsh (M)	n/a	n/a	Marsh (l1)
Swamp (S)		Coniferous swamp (Stnn and Sfnn)	Wetter end of horsetail (f)
		Deciduous Swamps (Sons)	any upland ecosites phases
Fen (F)	Open fen (≤10% tree cover)	Patterned fen (Fop)	
		Non-patterned shrubby fen (Fons)	Shrubby poor fen (j2) and shrubby rich fen (k2)
		Non-patterned graminoid fen (Fong)	Graminoid rich fen (k3)
	Wooded fen (>10% - ≤70% tree cover)	No internal lawns (Ftnn)	Treed poor fen (j1) and treed rich fen (k1)
Bog (B)	Wooded bog (>10%, ≤70% tree cover)	No internal lawns (Btnn)	Treed bog (i1) and shrubby bog (i2

[a] Haley and Vitt 1996.
(b) Beckingham and Archibald 1996.
n/a = not applicable.

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.

The two classification system do share a number of wetlands properties, which are outlined in Table 4.

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) and shrubby rich fens (k2). Distinctions between wetlands types is largely based on nutrient and moisture regime and the dominant plant species present.

Table 4 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) served as the primary classification system for the wetlands of the Muskeg River Mine Project. The AWI 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.

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

1.7.1 Field Guide to the Ecosites of Northern Alberta - Wetlands Classification System

Tthe number and distribution of wetlands types in the LSA is detailed in Table 5. A map highlighting the Ecosites of Northern Alberta is included in the Terrestrial Vegetation Baseline for the Muskeg River Mine Project (Golder 1997).

Table 5 Distribution of Wetlands Plant Community Types According to Ecosites

Wetlands Type		Baseline	
Map Code	Ecosite Phases	Area (ha)	% LSA
i2	Shrubby Bog	20	0.18
j1	Treed Poor Fen	356	3.25
j1/g1 complex	Lt/Sb-Pj	27	0.25
j1/h1 complex	Sb/Sw-Lt	74	0.68
j2	Shrubby Poor Fen	1,182	10.79
j2/h1 complex	Sw/Sb-Fen Complex	2	0.02
k1	Treed Rich Fen	1,370	12.51
k2	Shrubby Rich Fen	2,136	19.50
k3	Graminoid Rich Fen	51	0.47
l1	Marsh	85	0.78
Stnn, Sfnn Sons	Swamp (coniferous, deciduous and shrub)	708.5	6.47
Sons	Riparian Shrub Complex	650.5	5.91
Wonn	Shallow Open Water	57	0.52
WETLANDS TOTAL		**6,719**	**61.00**
NON-WETLANDS		**4,235**	**39.0**
TOTAL		**10,954**	**100.0**

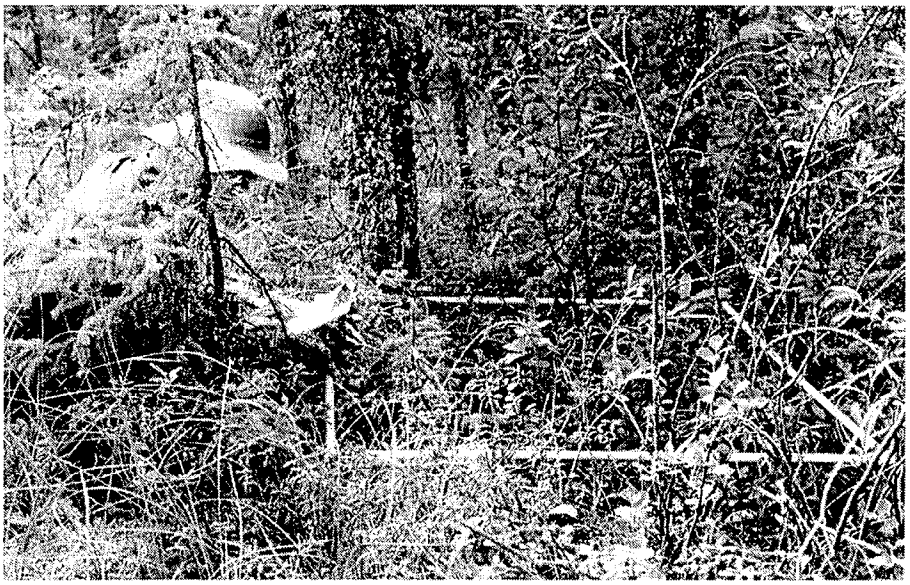
1.7.1.1 Bog Ecosite (B)

Bog ecosites generally have poor to very poor drainage, leading to a hydric to hygric moisture regime. The water is stagnant, and the nutrients are poor to very poor. Bogs can occur in depressions or in level areas where there is a high accumulation of peat and organic matter. The two ecosite phases identified in bogs include treed bogs (i1) and shrubby bogs (i2).

The treed 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 and slender hair-cap moss. Reindeer lichen is also present in bogs (Figure 7).

Only four treed/shrubby bog ecosites (i2) were identified in the Muskeg River Mine Project LSA. Treed bogs represent less than 1% of the LSA (20 ha; Table5).

Figure 7 Shrubby Bog With a Variety of Understory Species



1.7.1.2 Poor Fen Ecosite (j)

Poor fens are midway between bogs and rich fens in terms of nutrients and species composition. Drainage is poor to very poor, although there is some slowly flowing water through the soil/organic layers. The moisture regime is subhygric to hydric. The nutrient regime is very poor to medium or rich. Poor fens occur in depressions or on level surfaces. There is an accumulation of peat moss and other organic matter such as sedges. There are two ecosite phases, treed poor fens and shrubby poor fens.

Stunted black spruce and tamarack are the dominant trees in the canopy (Figure 8). In addition to those species that occur in the treed bog, the shrub layer in treed poor fens also include willow, tamarack and dwarf birch, while the herb layer also includes common horsetail and sedges. Mosses include peat moss, golden moss, stair-step moss, Schreber's moss, tufted moss and slender hair-cap. Reindeer lichen is also present in this ecosite.

Shrubby poor fens lack the canopy layer; however, they have a similar species composition to the treed poor fen. The proportion of peat moss is higher in shrubby poor fens than in treed poor fens.

There were 1,641 ha of poor fen ecosites identified in the Muskeg River Mine Project LSA (Table 5). Poor fens represent 24 % of the LSA.

Figure 8 Poor Fen With Black Spruce and Shrubby Understory

1.7.1.3 Rich Fen Ecosite

Rich fens have very poor to poor drainage, leading to a hydric to hygric moisture regime. The water is flowing, which results in a medium to very rich nutrient regime. Rich fens occur in level areas or depressions. Water is near at or the surface of the fen for part of the year. There are three ecosite phases, treed rich fens (k1), shrubby rich fens (k2) and graminoid rich fens (k3).

Treed rich fens have a canopy layer composed of tamarack and stunted black spruce. Dwarf birch and tamarack dominate the shrub layer, while willow, Labrador tea, bog rosemary and black spruce are also present. The herb layer may include three-leaved Solomon's seal, buck-bean, marsh cinquefoil and marsh marigold. Sedges and marsh reed grass are also present. The dominant mosses include tufted moss, golden moss and peat moss. Brown moss and Schreber's moss are also present.

The canopy layer is lacking in the shrubby rich fen. The shrub layer is dominated by willow and dwarf birch, river alder and tamarack are also present. The herb layer may include marsh marigold, sweet gale and buck-

bean. Sedges and marsh reed grass are prominent in this ecosite. Mosses present include brown moss, tufted moss and golden moss.

Graminoid rich fens are dominated by sedges. Forbs that may be present include marsh cinquefoil, buck-bean and marsh skullcap. Grasses may include marsh reed grass and northern reed grass. Ragged moss and brown moss may also be present.

There were 3,557 ha of rich fen ecosites identified in the Muskeg River Mine Project LSA (Table 5). Rich fens represent 53% of the LSA.

1.7.1.4 Marsh Ecosite

Marshes have poor to very poor drainage, and have a hydric to subhydric moisture regime. The nutrient regime is medium to very rich due to occasional slow-moving water. Marshes occur in level areas near the edges of lakes or rivers. Water is above the level of the rooting zone of the plants for all or part or the year. There is only one ecosite phase, the marsh.

Marshes are dominated by sedges, cattail and other emergent vegetation (Figure 9). The herb layer may also 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. Marshes often are associated with the margins of streams and lakes.

Eighteen marsh ecosites were identified in the Muskeg River Mine Project LSA. Marshes represent approximately 1% of the LSA (85 ha; Table 5).

Figure 9 Marsh Dominated by Sedges, Rushes and Cattails

1.7.2 Alberta Wetlands Inventory

Table 6 and the Wetlands Map (Figure 2) detail the AWI wetlands identified in the LSA. Descriptions of each wetlands type is summarized below.

1.7.2.1 Bogs (Btnx)

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 et al. (1994). Examples of bog locations include drainage divides, stagnation zones of peatland areas and small isolated basins.

Table 6 AWI Wetlands Represented in the LSA

AWI Class	AWI Subclass	Number of Wetland Types	LSA (ha)
Shallow Open Water **(Wonn)**	Shallow Open Water **(SW)**	17	**57**
Marsh **(M)**	Marsh **(M)**	18	**85**
Swamps **(S)**	Coniferous swamp **(Stnn)**	163	702
	Coniferous swamp **(Sfnn)**	4	7
	Deciduous swamps **(Sons)**	72	651
Subtotal	***Swamps***		**1360**
Fens **(F)**	Open patterned fen **(Fop)**	3	2
	Open non-patterned shrubby fens **(Fons)**	162	1,376
	Open non-patterned graminoid fen **(Fong)**	6	51
	(Ffnn)		26
	Wooded fen, no internal lawns **(Ftnn)**	612	3,742
Subtotal	***Fens***		**5197**
Bogs **(B)**	Wooded bog (>10%, ≤ 70% tree cover) not internal lawns **(Btnn)**		20
Total Wetlands			**6,719**
Non-Wetlands			**4,235**
Total			**10,954**

Bogs also can be found in a broad, poorly-defined depression near drainage divides. Wooded bogs (Btnx) 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. Peat moss and lichens dominate the ground cover (Halsey and Vitt 1996).

Wooded bogs without internal lawns were the only bogs observed in the Project LSA. The 20 ha of bogs (Table 6) represent less than 1% of the LSA. The largest bog occurs between the Muskeg River and Jackpine Creek and is associated with a marsh fen complex. The three other small bogs occur in association with fen complexes east of the Muskeg River.

1.7.2.2 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 may 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).

1.7.2.3 Open Fens (Fpon, Fons and Fong)

The surface of patterned fens alternates between open, wet areas (flarks), and drier shrubby to wooded areas (strings). The pattern of flarks and strings results from the perpendicular orientation of the direction of water flow to the landforms. Depending on whether strings or flarks dominate, a patterned fen can be considered wooded or open. The vegetation cover on the strings may be any combination of tamarack, black spruce, birch and willow. Potential ground cover varies, ranging from species of peat moss in poor fens; to golden moss and associated brown mosses, which require mid-levels of nutrients, in moderately rich fens; to scorpion feathermoss and associated brown mosses in extremely rich fens.

Only three patterned fens, open and without internal lawns (Fopn) were identified in the Project LSA. They represent 1.9 ha or <0.1% of the LSA, (Table 6).

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. Conifers may have ≤6% cover. Shrub-dominated fens are located in small isolated basins, and in areas sloping gently in the direction of drainage. The equivalent ecosite in the Field Guide encompasses both the shrubby poor fen and shrubby rich fen. Shrub dominated fens occupies 1,336.3 ha or 12.3% of the Project LSA (Table 6).

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. 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, such as Isadore's Lake, and in areas that slope gently in the direction of drainage such as the Athabasca escarpment. Open fens occurs in <1 % of the Project LSA (Table 6).

1.7.2.4 Wooded Fens (Ftnn)

Wooded fens have greater than 10% tree cover and are classified into three 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 overstory is composed of >6% black spruce and/or tamarack, while birch and willow may be found in the understory. The ground cover of wooded fens can be dominated by peat moss or brown moss. Wooded fens are found only in level areas of land, distinguishing them from the upland wooded regions, which may be found in sloped areas.

The only nonpatterned wooded fen in the LSA is 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. Nonpatterned wooded fens are the most dominant wetland type in the Project LSA. They occupy an area of 3,768 ha or 34.5% (Table 6). The wooded fens are situated throughout the entire LSA.

1.7.2.5 Marshes (Mong)

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 9). 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 the large bog west of the Muskeg River. Marshes occur on 84.6 ha of the Project LSA, or <1% of the LSA (Table 5).

1.7.2.6 Swamps (S)

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-peaty 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.

Two types of swamps, coniferous and deciduous, are recognized by the AWI classification system (Halsey and Vitt 1996).

Coniferous (Sfnn and Stnn) swamps exist near floodplains and streams associated with peatland areas. They have a dense tree cover (>70%) of black spruce and tamarack. Deciduous 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. Coniferous swamps occur on 713 ha in the Muskeg River Mine Project, LSA representing 6.5% of the LSA (Table 6). Deciduous swamps occur on 651 ha of the Project LSA, representing 6% of the LSA.Both swamp types occur along riparian areas associated with the Muskeg River and Jackpine Creek drainages. More shrubby swamps are associated with a disturbance area along the northern boundary of the LSA.

1.7.2.7 Shallow open water (Wong)

Shallow open waters are waters that are less than 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.

The aforementioned wetlands classes and types provide critical information for the description and inventory of wetlands. The current wetlands assessment was conducted using a less detailed, but generally equivalent, classification approach (Beckingham et al. 1996) as the previously described AWI classification system (Halsey and Vitt 1996) was not fully completed at the time of the field survey. The marsh classes, are equivalent

between the two approaches (Table 3). The AWI approach (Halsey and Vitt 1996) recognizes six types of fens, three of which have equivalent classifications in the Field Guide (Beckingham et al. 1996). Also, Halsey and Vitt (1996) differentiate five types of bogs, for which one equivalent class is provided in the Field Guide (Beckingham et al. 1996). The AWI classes will ultimately be used to reclassify the RSA, thus providing information on the relative abundance of the various wetlands types.

Shallow open water occurs in <1% of the LSA (Table 6). Most of this wetlands type occurs along the northern edge of Isadore's Lake.

1.7.3 Wetland 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 7 show the total number of wetlands plots surveyed, data from which was the basis of the richness and diversity assessment.

The number and distribution of wetlands type surveyed are indicated in Table 6.

Table 7 Wetlands Plots Surveyed in the LSA

AWI	Ecosite Phase	Class Name	Number of Plots
Btnn	i1	Treed Bog	10
Ftnn/Ffnn	j1	Treed Poor Fen	14
Fons	j2	Shrubby Poor Fen	8
Ftnn/Ffnn	k1	Treed Rich Fen	21
Fons	k2	Shrubby Rich Fen	36
Fong	k3	Graminoid Rich Fen	4
		Total Plots	**93**

The wetlands exhibited a similar level of species richness to the upland ecosite phases (Table 8). Also, species richness was greatest in the low

shrub layer, as was observed in both the riparian and upland ecosite phases. However, all of the wetlands, the treed poor fens were the most species rich.

Table 8 Species Richness for Surveyed Wetlands

AWI	Eco-Phase	Total Species Richness Class Name	Total Species			Herb-Layer			Shrub-Layer			Tree-Layer		
			Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Btnn	i1	Treed Bog	7.3	5	10	1.9	0	4	4.6	4	6	1.0	1	1
Ftnn/FfnnFf	j1	Treed Poor Fen	12.9	6	25	6.0	2	14	5.9	3	11	1.6	1	2
Fons	j2	Shrubby Poor Fen	11.3	7	18	4.8	3	7	6.1	3	11	0.5	0	1
Ftnn/Ffnn	k1	Treed Rich Fen	12.0	6	23	6.6	3	16	4.6	2	8	1.3	1	2
Fons	k2	Shrubby Rich Fen	8.7	2	23	5.4	1	16	3.3	1	7	0.1	0	1
Fong	k3	Graminoid Rich Fen	3.0	1	5	2.3	1	3	0.8	0	2	0.0	0	0

Composition

Table 8 also shows the total number of different species present in all wetlands plots in six ecosite phases and four AWI classes, as well as the total number of species present in each of three structural layers (tree, shrub and herb). No plot surveys were undertaken in marsh (Mong), shallow open water (Wonn), patterned fens (Fopn) or swamps.

The data represent overall species richness in each ecosite phase (AWI) 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 this index, the k2 (Fons) ecosite phase exhibits the greatest species richness both overall and in the herb layer. The k3 ecosite phase has the fewest species overall and in each of the layers.

The mean and range of species richness values for individual plots within wetlands is also presented in Table 8. These data provide an indication of the species richness that is characteristic of small areas within ecosite phases. The highest mean and maximum of total species richness are in the j1 (Ftnn/Ffnn) wetlands. The highest mean richness in the herb layer is in d1 and d2; in the shrub layer it is in d2 and e1; and in the tree layer it is in b3. Mean richness is lowest in k3 (Fong) overall and in the shrub and tree layers. The lowest mean richness in the herb layer is in the treed bog (i1).

Structure

In terms of structure, species richness is highest in the herb layer and lowest in the tree layer for all ecosite phases except i1. Structurally, both mean and maximum richness are lowest in the tree layer in each ecosite phase.Mean and maximum richness are higher in the herb layer than in the shrub layer ecosite phases, respectively. The differences in relative species richness among ecosite phases or AWI may result from differences in internal compositional variability among ecosite phases.

Diversity

Wetlands diversity exhibited similar patterns to richness in that treed poor fens were the most diverse (Table 9). Diversity was highest in the herb layer which was also the most rich. The treed poor fen ecosite phase is the most rich and diverse of the wetlands, but not richer or more diverse than the riparian ecosite phase.

Table 9 gives the mean and range of species diversity values for individual plots within the ecosite phases. The Ftnn/Ffnn and Fons treed and shrubby fens have the highest mean overall diversities and have the highest mean diversities in the herb layer. Mean diversity is lowest in graminoid fens (FONG) overall and also in the shrub and herb layers. There is little difference in mean diversity between the shrub and herb layers in many of the wetlands and there is no discernible overall trend to higher diversity in either layer. Mean diversity is lowest in the tree layer for all wetlands.

Table 9 Species Diversity for Surveyed Wetlands

	Total Species Diversity	Total Species			Herb-Layer			Shrub-Layer			Tree-Layer		
AWI	Class Name	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Btnn	Treed Bog	0.57	0.41	0.74	0.13	0.00	0.49	0.39	0.1	0.51	0.00	0.00	0.00
Ftnn/Ffnn	Treed Poor Fen	0.69	0.48	1.06	0.42	0.20	0.79	0.44	0.0	0.67	0.13	0.00	0.29
Fons	Shrubby Poor	0.66	0.55	0.78	0.43	0.35	0.54	0.50	0.3	0.70	0.00	0.00	0.00
Ftnn/Ffnn	Treed Rich Fen	0.72	0.37	1.09	0.47	0.16	0.97	0.41	0.0	0.69	0.07	0.00	0.30
Fons	Shrubby Rich Fen	0.58	0.15	1.03	0.39	0.00	0.86	0.29	0.0	0.69	0.00	0.00	0.00
Fong	Graminoid Rich	0.22	0.00	0.54	0.16	0.00	0.43	0.08	0.0	0.30	0.00	0.00	0.00

Diversity can be measured by assessing the number of individual wetlands, their size and shape. Species level assessment of diversity examines species richness and rare plant potential lost to the mine development.

1.7.4 Regional Study Area

Wetlands occurring the RSA are as determined through the Landsat classification are presented in Table 10. The majority of wetlands are fen/bogs. Marshes occur in association with shallow open water and deep open water in the RSA.

Table 10 Baseline Wetlands in the RSA

Wetlands Types		Baseline	
Map Codes	**Ecosite Phases**	**(ha)**	**(%)**
j1,j2,k1,k2 and limited i1,i2	Wooded and Shrubby Fens and Bogs	639,004	60.8
j1,j2,k1,k2 with recent burn	Wooded and Shrubby Fens and Bogs (recently burned)	10,131	1.0
k3	Graminoid fens	31,906	3.0
l1	Marsh	3,408	0.3
	Sub-Total (Wetlands)	**684,449**	**65.1**
	Sub-Total (Terrestrial Vegetation)	**293,353**	**27.9**
	Anthropogenic Disturbances	30,941	2.9
	Forestry Disturbance	13,443	1.3
	Reclaimed Unit	3,600	0.3
	Sub-Total (Disturbances)	**47,984**	**4.6**
	Water	19,216	1.8
	Unclassified	6,409	0.6
	Total	**1,051,411**	**100.0**

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.

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.

Beckingham, J.D., D.G. Nielsen and V.A. Futoransky. 1996. Field Guide to Ecosites of the Mid-Boreal Ecoregions of Saskatchewan. Nat. Resource. Can., Can. For. Serv., Northwest Reg., North. For. Cent., Edmonton, Alberta. Spec. Rep. 6.

BOVAR Environmental Ltd. 1996. Environmental impact assessment for the Syncrude Canada Limited Aurora Mine. Report prepared for Syncrude Canada Limited.

Golder Associates Ltd. 1997. Terrestrial vegetation baseline for the Muskeg River Mine Project. Report for Shell Canada Limited, Calgary, Alberta. December 1997.

Halsey, L. and D.H. Vitt. 1996. Alberta Wetland 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.

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.

Suncor Inc., Oil Sands Group. 1996. Steepbank Mine application. April 1996.

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.

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.

Vitt, D.H., L.A Halsey and S.C. Zoltai. 1994. The bog landforms of Continental Canada in relation to climate and permafrost patterns. Arctic and Alpine Research 26:1-13.