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Alberta Sulphur Terminals Ltd.
Bruderheim Sulphur Forming and Shipping Facility

Volume IIC

1. Introduction

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Executive Summary

Alberta Sulphur Terminals Ltd. (AST), a division of HAZCO Environmental Services (HAZCO) which, in turn, is a division of CCS Income Trust (CCS), is applying to Alberta Environment (AENV) and the Natural Resources Conservation Board (NRCB) for approval to construct and operate a sulphur forming and shipping facility (the Project). The Project will be developed on a portion of Section 35, Township 55, Range 20, West of the 4th Meridian (35-55-20 W4M – the Site), approximately 2.2 km east of Bruderheim, Alberta, in the Industrial Heartland Area of Lamont County.

The Environmental Impact Assessment (EIA) study area comprises the Principal Development Area (PDA), Local Study Area (LSA) and Regional Study Area (RSA). The PDA is defined as the area within the Site that will contain the Project including:

- rail and road access for receiving molten sulphur
- molten sulphur unloading and transfer facilities
- sulphur forming facilities to produce sulphur pastilles
- loading and shipping facilities for formed sulphur

The LSA for the majority of disciplines assessed in the EIA is the Site (groundwater, historical resources, surface water quantity and surface water quality) or the Site plus a 200 m buffer zone (aquatics, biodiversity and fragmentation, land use and reclamation, soil, vegetation and wildlife). The RSA for the majority of disciplines is the Site plus a 500 m buffer zone (surface water quantity and surface water quality) or the Site plus a 1,000 m buffer zone (aquatics, biodiversity and fragmentation, soil, vegetation and wildlife).

The EIA will assist regulators and the public in understanding and evaluating the potential effects and benefits of the Project during its construction, operation and reclamation. The EIA identifies and assesses peak disturbance, residual impacts and cumulative effects associated with the Project. The EIA evaluates potential impacts to physical, biophysical and historical resources, in addition to potential socio-economic impacts. The EIA also identifies mitigative measures and adaptive management plans to reduce or eliminate potential adverse effects.

For each individual impact assessment, a qualitative, final evaluation rating is used where specific guidelines do not exist. This rating is a combination of quantitative analysis and professional judgment that takes into account the various descriptors for each attribute (direction, magnitude, geographic extent, duration, confidence and reversibility) and the potential effects of the specific impact. This rating is applied to residual impacts and cumulative effects. The following table lists the ratings applied and the level of action required for each.

Table ES-1: Final Impact Rating

Rating	Level of Action
Class 1	The predicted trend in an indicator under projected land use development could threaten the long-term sustainability of the quantity or quality of the indicator in the local and regional study areas. An action plan, developed jointly by regional stakeholders, could be developed to monitor the affected indicator, identify and implement further mitigation measures to reduce any impact, and promote recovery of the indicator, where appropriate. This class of impact might also be applicable to an exceedance of a regulatory guideline, or where the impact is expected to have long-term effects.
Class 2	The predicted trend in an indicator under projected land use development will likely result in a decline in the quantity or quality of the indicator. The decline could be to lower-than-baseline but stable levels in the local and regional study areas after closure and into the foreseeable future. In addition to responsible industrial operational practices, monitoring and recovery initiatives could be required if additional land use activities occur in the study area before closure of the projected land use development. This class of impact might also be applicable to an exceedance of a regulatory guideline, or where the impact is expected to have mid-term effects, but where recovery will take place shortly after closure of the projected land use development.
Class 3	The predicted trend in an indicator under projected land use development could result in a slight decline in the quantity or quality of the indicator in the local and regional study areas during the life of the projected land use development, but resource levels should recover to baseline after closure. In some cases, a short-term, low to moderate magnitude impact could occur, but recovery will take place within five years. No new resource management initiatives are necessary. Responsible industrial operational practices should continue. This class of impact could also be applicable where regulatory guidelines are not exceeded, but where a relative change in magnitude of an indicator occurs.
Class 4	The projected land use development results in no change and no contribution toward affecting the quantity or quality of the indicator in the local and regional study areas during the life of the projected land use development. Responsible industrial operational practices should continue. Therefore, no cumulative effects result from the Project.

Volume IIC – Terrestrial Ecosystems

Section 2: Soil

Soils in the PDA and Soil LSA were described and mapped using the methodology outlined in the Final Terms of Reference (TOR). A total of 20 site inspections were undertaken in the PDA; inspections were completed within 50 m of the PDA boundary because a final PDA location was not available at the time the field survey was completed. The resultant inspection intensity was approximately one inspection per 1.2 ha, slightly less than the expected SIL required (approximately 1 per ha). The LSA was surveyed at SIL 2 with one inspection per 6.8 ha. Soils in the LSA were mapped at a 1:20,000 scale (see Volume IIC, Section 2: Soil – Figure 2.5-3). For the Soil RSA, existing published soil mapping data for the region was used to evaluate potential effects of the Project on soil resources.

Soils in the LSA are primarily solonetzic and chernozemic. Solonetzic soils are formed on fine-textured till or glaciolacustrine deposits that are saline and sodic. Solonetzic subsoils have chemical exchange complexes dominated by sodium, are very hard when dry and swell to a sticky mass of low permeability when wet. Chernozemic soils are formed on a wide variety of parent materials, and are imperfectly to well-drained grassland soils having surface horizons darkened by accumulation of xerophytic and mesophytic grasses and forbs. Significant portions of the LSA (25.5%) and PDA (73.4%) are underlain by soils which are known to have been previously disturbed (i.e., stripped) and reclaimed during previous industrial activity at the Site. Reclaimed soils were interpreted to be derived from either chernozemic or solonetzic soils. Characteristics of both soil types were found in the reclaimed profiles investigated in the LSA. The reclaimed profiles have very little structure or lack structure in the horizons below the topsoil layer. Saline parent material is present in the majority of profiles. Reclaimed soils are associated with imperfectly to well-drained moisture regimes and a mix of vegetation types including: forage crops (hay), annual crops and improved pasture. Other key soil types in the LSA include Gleysols, soils formed under periodic or permanent flooding, and Organic soils, where the dominant soil matrix is decomposed vegetation.

Pre-disturbance soil capability classes were assessed using a classification system for agricultural capability. Soils in the LSA are classified as having agricultural capability classes ranging from Class 2 (having slight limitations that may restrict the growth of agricultural crops) to Class 7 (unsuitable for agriculture) with the majority of the LSA (56.5%) falling into Class 4 (Severe limitations that restrict the growth of crops). In addition to the pre-disturbance agricultural suitability classes, soils were also rated for sensitivity to wind and water erosion.

Pre-disturbance reclamation suitability of soils in the LSA was determined for both topsoil and subsoil. For areas of the LSA that were rated, topsoil reclamation suitability ratings are: Fair (43.9% of the LSA), Poor (39.9%) and Unsuitable (1.9%). Subsoil reclamation suitability is rated as Fair (14.4% of the LSA), Poor (6.2%) and Unsuitable (65.2%).

Sensitivity of soils to acid deposition in the LSA was evaluated using the guidelines set out in the TOR. Soils in the LSA were rated for sensitivity to acid deposition using currently accepted methodology. Mineral soils were rated with respect to sensitivity to base loss, acidification and aluminum solubilization. Organic soils were rated for overall sensitivity to acid deposition. Soils in the LSA are rated as having a low to moderate sensitivity to acid deposition. No sensitive soil units were identified in the LSA.

Modelled potential acid input (PAI) data were used to assess the baseline and application scenarios for the Project. For the baseline case, published data for the region indicates that the grid cell which includes the RSA and LSA, and all surrounding grid cells, have current levels of PAI below the critical load of 0.50 keq H^+/(ha•y) for soils which are moderately sensitive to acid input. For the application and cumulative effects cases, the predicted average PAI values associated emissions from the Project and the neighboring Canexus sodium chlorate plant are 0.04 keq H^+/(ha•y) at the Site boundary (see Volume IIA, Section 2: Climate and Air Quality – Figure 2.5-13), and are therefore, below the critical load of 0.50 keq H^+/(ha•y) for soils which are moderately sensitive to acid input.

An analysis of potential sulphur dry deposition effects of the Project on soil quality was also conducted. Based on the Project design and mitigation measures to limit aerial dispersal of elemental sulphur it is assumed that the majority of impacts to soil from dry deposition of elemental sulphur will occur within the PDA, where soils are rated as having a low sensitivity to acid deposition. Based on the sulphur deposition modelling data, the maximum average predicted annual deposition of sulphur at the Site boundary will be 1.11 kg/ha/y. This rate of deposition is expected to be negligible especially when compared with the acidifying effects of current agricultural practices of ammonia-based fertilizer application in the region. For soils within the PDA, where dry deposition effects are expected to be significant, changes to the chemical composition of the soils will occur within timescales (i.e., years) that allow for detection by a periodic soil monitoring program and the changes may be reversed by an appropriate soil treatment such as lime application.

Table ES-2 summarizes the potential impacts to soil from the Project and the proposed associated mitigation strategies.

Table ES-2: Potential Impacts to Soil and Proposed Mitigation Strategies

Potential Issue	Proposed Mitigation Strategies
Changes to Agricultural Land Capability	
Project Impacts to Agricultural Land Capability	Proper soil handing and storage as outlined in Volume IID, Section 2: Land Use and Reclamation – Appendix I – Conservation and Reclamation Plan
Potential effects on Soil Quality	
Soil admixing	Proper soil handing and storage as outlined in Volume IID, Section 2: Land Use and Reclamation – Appendix I – Conservation and Reclamation Plan and in Volume IIC, Section 2: Soils - Section 2.6.4.1
Soil compaction	Proper soil handing and storage as outlined in Volume IID, Section 2: Land Use and Reclamation – Appendix I – Conservation and Reclamation Plan and in Volume IIC, Section2: Soils - Section 2.6.5.1
Soil erosion	Proper soil handing and storage as outlined in Volume IID, Section 2: Land Use and Reclamation – Appendix I – Conservation and Reclamation Plan and in Volume IIC, Section 2: Soils - Section 2.6.6.1
Soil contamination	In the case of accidental releases of contaminants, conduct spill response, Site assessment and remediation activities in keeping with regulatory requirements. Implement spill prevention and waste management plans for the Site
Alteration of Soil Moisture Regime	
Project impacts to surface hydrology and shallow groundwater quantity	Install culverts and drainage controls as required for corridor facilities such as rail spurs to retain natural surface drainage and prevent water build-up
Soil Suitability for Reclamation	
Project impacts resulting in changes to soil reclamation suitability	Proper soil handing and storage as outlined in Volume IID, Section 2: Land Use and Reclamation – Appendix I – Conservation and Reclamation Plan and in Volume IIC, Section 2: Soils - Section 2.6.9.1
Soil Acidification	
Project impacts to soil resulting from dry and wet deposition of acidic compounds	• implement engineering controls on Project equipment to limit release of acidifying compounds • store soil stockpiles away from area of potential sulphur release • establish surface water management systems to limit surface water contact around the Project with surrounding soil • establish periodic soil monitoring for both the PDA and LSA

Section 3: Vegetation

The objectives of the vegetation assessment were as follows:

- satisfy the relevant section of the TOR
- conduct baseline vegetation and rare plant surveys of the Site for the proposed Project
- determine rare plant potential of the Site
- determine if plant communities of conservation concern are present on the Site

- evaluate the impacts of potential acid input to vegetation communities on the Site

Land unit classification using the Central Parkland Native Vegetation Inventory (CPNVI) indicated that 97% of the Vegetation LSA is human modified. The human modified polygon was further delineated using the Alberta Vegetation Inventory indicating that agricultural land classes cover 84.86% of the LSA and anthropogenic non-vegetated land classes cover 11.55% of the LSA.

The construction of the Project is anticipated to reduce the agricultural land classes by 6.10% and increase the following anthropogenic non-vegetated land classes: rights-of-way (4.05%), industrial facilities (1.53%), water reservoir (0.18%) and pipeline (0.34%).

Baseline vegetation surveys were conducted in June and August, 2006, as part of the rare plant surveys. The vascular and non-vascular species lists are reported in Volume IIC, Section 3: Vegetation - Appendix II and Appendix III, respectively. A range health assessment was conducted on the rough pasture in the northwest quarter of the Site.

The PDA will impact underlying agricultural lands during the construction and operation of the facility. Potential impacts that were assessed include surface disturbance, dust deposition, contaminant spills, introduction of non-native and invasive species, and air emissions. All impacts will affect the underlying agricultural lands negatively, however; the impacts are predicted to be local in extent, negligible to low-to-moderate in magnitude, short-term to mid-term in duration and reversible.

All potential impacts were determined to be local in geographic extent, therefore, the Project's contribution to regional cumulative pressures on biophysical resources is not expected to be significant.

One rare non-vascular plant, the lichen *Xanthoria fulva*, was identified in the shelterbelt running east to west along Township Road 560 in the northeast corner of the LSA. *X. fulva* is ranked as S1 in Alberta and is on the provincial tracking list. The rare lichen is not located within the PDA and is not expected to be impacted by the Project.

Five noxious weeds, eleven nuisance weeds and eleven non-native or agronomic invasive species were identified in the LSA. There is potential for weed encroachment to increase during the construction and operation of the Project. Weed management plans developed in conjunction with the railway right-of-way (ROW) holders are recommended. The nature of the potential acidifying emissions and their cumulative effects are described in Volume I: Project Description.

Vegetation in the potentially impacted area surrounding the PDA will be protected as a result of the proposed soil monitoring and mitigation program described in Volume IIC, Section 2: Soil. This will include regular monitoring of soil quality and treatment as required to buffer any pH impacts.

The results of the monitoring programs will be evaluated to determine if modifications to the mitigation plans are required to reduce impacts. The monitoring programs will be adjusted to address any issues that arise during the operation of the Project.

Section 4: Wildlife

The results of the baseline studies, impact, and cumulative effects assessment for wildlife are presented in Section 4. The issues assessed are:

- potential acid input (SO_2, NO_2 and sulphur dust)
- direct mortality
- habitat availability
- noise

- fragmentation and wildlife movements

The Project impacts from potential acid input to key wildlife indicators (amphibians and waterbirds) are predicted to be moderate. Monitoring of air, soil and water are required to detect changes in pH levels that may be detrimental to water dependent species. Increased traffic volumes may result in an increase in wildlife (primarily deer) mortality of up to 8%. The development will likely deflect deer movements away from the PDA, and deer are predicted to travel along areas adjacent to the development area. Impacts to highly suitable wildlife habitat due to surface disturbance will not occur.

Cumulative effects on availability of highly suitable wildlife habitats will not result in any loss. No impacts to Elk Island National Park are expected with regard to PAI.

Section 5: Biodiversity and Fragmentation

The results of the baseline studies and impact assessment for biodiversity are given in Section 5. The indicators assessed are:

- patch area and mean size
- patch anthropogenic edge to area ratio
- linear features and disturbances
- species diversity

The Project will have negligible to low impacts (Class 4 and Class 3) on landscape-level biodiversity indicators in the LSA. Impacts to biodiversity are expected to be minimal as a result of the high level of existing anthropogenic disturbance in the Biodiversity LSA and RSA. Patch indicators (patch area, mean patch size) and linear features will experience Class 3 impacts at application. Anthropogenic edge-to-area ratio will not change during application. Impacts to both vegetation and wildlife species diversity will be Class 3 impacts at application. Impacted areas will be reclaimed to their existing baseline conditions, therefore all indicators experience Class 4 impacts at closure.

Regionally, the cumulative effects scenario will cause minimal effects on biodiversity indicators. Patch area, mean patch size and linear features will experience Class 3 impacts in both application and cumulative effects. There will be no change (Class 4 impact) to the anthropogenic edge-to-area ratio in the RSA. Small changes in the RSA to annual and perennial forage crops lead to Class 3 impacts to species diversity for the cumulative effects scenario.

Table ES-3 summarizes the potential impacts to soil, vegetation, wildlife and biodiversity and fragmentation under the application scenario of the Project.

Table ES-3: Volume IIC Final Impact Summary Table for the Application Scenario of the Project

Potential Impact	Geographic Extent	Magnitude	Direction	Duration	Reversibility	Confidence	Rating
Soil							
Changes to Agricultural Land Capability							
Project impacts to agricultural land capability	Local	Low	Neutral to positive	Mid-Term	Reversible	High	3
Potential Effects on Soil Quality							
Soil admixing	Local – Confined to PDA	Low to moderate	Negative	Mid-Term	Reversible	High	3
Soil compaction	Local	Low to moderate	Negative	Mid-Term	Reversible	High	3
Soil erosion	Local	Low	Negative	Long-Term	Reversible	High	2
Soil contamination	Local	Moderate to high	Negative	Mid-Term	Reversible	High	2
Alteration of Soil Moisture Regime							
Project impacts to surface hydrology and shallow groundwater quantity	Local	Low	Negative	Mid-Term	Reversible	High	3
Soil Suitability for Reclamation							
Project impacts resulting in changes to soil reclamation suitability	Local	Low to moderate	Neutral to positive	Long-Term	Reversible	High	3
Soil Acidification							
Project impacts to soil resulting from dry and wet deposition of acidic compounds	Local	Moderate to high	Negative	Long-Term	Reversible	Moderate	2
Vegetation							
Surface disturbance	Local	Low to Moderate	Negative	Mid-term	Reversible	High	3
Dust deposition	Local	Low to Moderate	Negative	Mid-term	Reversible	Moderate	3
Contaminant spills	Local	Low to Moderate	Negative	Mid-term	Reversible	Moderate	3

Table ES-3: Volume IIC Final Impact Summary Table for the Application Scenario of the Project (Cont'd)

Potential Impact	Geographic Extent	Magnitude	Direction	Duration	Reversibility	Confidence	Rating
Vegetation (Cont'd)							
Introduction of non-native and invasive species	Local	Negligible	Negative	Short-term	Reversible	High	3
Air emissions	Local	Low to Moderate	Negative	Mid-term	Reversible	Moderate	3
Wildlife							
Potential acid input: air emissions	Local and Regional	Low to Moderate	Negative	Mid-term	Reversible	Moderate	3
Potential acid input: Waterbodies	Local and Regional	Low to Moderate	Negative	Mid-term	Reversible	Moderate	3
Potential acid input: Soils	Local and Regional	Low to Moderate	Negative	Long-term	Reversible	Moderate	3
Direct Mortality	Local and Regional	Low to Moderate	Negative	Mid-term	Reversible	Moderate	3
Habitat availability	Local	-	Neutral	-	-	Moderate	4
Fragmentation and Wildlife Movements	Local	Moderate	Negative	Mid-term	Reversible	Moderate	3
Noise	Local and Regional	Low to Moderate	Negative	Mid-term	Reversible	Moderate	3
Final Impact Rating Summary Table for the Cumulative Effects Scenario							
Habitat availability	Regional	-	Neutral	-	-	Moderate	4
Biodiversity and Fragmentation							
Impacts to Biodiversity Indicators in the LSA at Project Application							
Landscape Diversity							
Patch area	Local	Low	Negative	Mid-term	Reversible	Moderate	3
Patch size	Local	Low	Negative	Mid-term	Reversible	Moderate	3
Anthropogenic edge	Local	-	Neutral	-	-	High	4
Linear features	Local	Moderate	Negative	Mid-term	Reversible	Moderate	3
Species Diversity							
Vegetation Species Diversity	Local	Low	Negative	Mid-term	Reversible	Moderate	3
Wildlife Species Diversity	Local	Low	Negative	Mid-term	Reversible	Moderate	3

Table ES-3: Volume IIC Final Impact Summary Table for the Application Scenario of the Project (Cont'd)

Potential Impact	Geographic Extent	Magnitude	Direction	Duration	Reversibility	Confidence	Rating
Impacts to Biodiversity Indicators in the RSA at Project Application							
Landscape Diversity							
Patch area	Regional	Low	Negative	Mid-term	Reversible	Moderate	3
Patch size	Regional	Moderate	Negative	Mid-term	Reversible	Low	3
Anthropogenic edge	Regional	-	Neutral	-	-	High	4
Linear features	Regional	Moderate	Negative	Mid-term	Reversible	Moderate	3
Species Diversity							
Vegetation Species Diversity	Regional	Low	Negative	Mid-term	Reversible	Moderate	3
Wildlife Species Diversity	Regional	Low	Negative	Mid-term	Reversible	Moderate	3

Acronyms, Abbreviations and Defined Terms

Acronym	Definition
$(NH_4)_2SO_4$	ammonium sulphate
35-55-20-W4M	Section 35, Township 55, Range 20, West of the 4th Meridian (the Site)
A	symbol for hole area from the action leakage rate formula
A	cross-sectional area available for flow
A1	Agricultural Use Area 1
A2	Agricultural Use Area 2
AAAQO	Alberta Ambient Air Quality Objectives
AADT	average annual daily traffic
AAF	Alberta Agriculture and Food
AAFRD	Alberta Agriculture Food and Rural Development
abiotic	not biological; not involving or produced by organisms
ACD	Alberta Community Development
acid	molecule that is able to give up a proton (H^+) to, or accept electrons from, a base; gives a solution with a pH of less than 7
acidification	reduction of the pH of soil, waterways and lakes
adaptive planning	flexibility built into design and layout to accommodate future modifications required by changed standards, limits and guidelines
AENV	Alberta Environment
aerobic bacteria	bacteria that require oxygen to survive and grow
AET	areal evapotranspiration
AFSC	Agricultural Financial Services Corporation
AIH	Alberta Industrial Heartland: a large industrial centre in central Alberta including Edmonton, Fort Saskatchewan, Strathcona County, Sturgeon County and Lamont County
AII	industrial total
ALF	available labour force
ALR	action leakage rate – leakage expected to occur through a synthetic impermeable liner having 2 holes of 2 mm in diameter every 1-ha of area
alumina catalyst	medium used to regenerate and recycle amines used to adsorb hydrogen sulphide gas
amine units	process units used to remove hydrogen sulphide from a gaseous process stream using amine compounds
anaerobic bacteria	bacteria that do not require oxygen to survive and grow
ANC	acid-neutralizing capacity
ANHIC	Alberta Natural Heritage Information Centre
ANPC	Alberta Native Plant Council
AO	aesthetic objectives
APA	Agricultural Policy Area
API	American Petroleum Institute

Acronym	Definition
aquatics	aquatic resource conditions, including fish and benthic invertebrate habitat capability and their characteristics in waterbodies
aquifer	an underground porous geological formation that stores or carries water
ARET	accelerated reduction/elimination of toxics
ASIC	Alberta Soil Information Centre
ASL	ambient sound level
ASP	Alberta's Industrial Heartland Area Structure Plan/Lamont County
asphalt bulk sulphur storage pad	storage pad used to stockpile formed sulphur pastilles in preparation for shipment
ASRD	Alberta Sustainable Resource Development
ASRL	Alberta Sulphur Research Ltd.
AST	Alberta Sulphur Terminals Ltd.
ASWQ	Alberta Surface Water Quality
AVI	Alberta Vegetation Inventory
AWI	Alberta Wetland Inventory
BC MWLAP	British Columbia Ministry of Environment, Lands and Parks
bioavailability	the degree to which toxic substances or other pollutants present in the environment are available to potentially biodegradative microorganisms
bitumen upgrader	term used for a refining facility that converts bitumen (heavy oil) into a lighter grade synthetic oil that can be further refined to make useable products such as gasoline and diesel
BSL	basic sound level
BTEX	benzene, toluene, ethylbenzene and xylenes
buffer	a solution or liquid with a chemical constitution allowing it to neutralize acids or bases without a great change in pH
^{o}C	degrees Celsius
CA	annual crop total
Ca^{2+}	calcium ion
$CaCO_3$	calcium carbonate
CALPUFF	California Puff Model
camlock	fitting used to quick-connect pipes and hoses
CanSIS	Canadian Soil Information System
capital spending	expenditures by a company for plant and equipment
carbonate alkalinity	carbonate alkalinity is a measure of the amount of negative carbonate and bicarbonate ions in solution
CASA	Clean Air Strategic Alliance
CCME	Canadian Council of Ministers of the Environment
CCS	CCS Income Trust
CCS	Canadian Crude Separators

Acronym	Definition
CDWQG	Canadian Drinking Water Quality Guidelines
CEA	cumulative effects assessment
CEPA	Canadian Environmental Protection Act
CGCM3	Coupled Global Climate Model 3
Class II waste disposal facility	landfill facility that is designed and permitted to dispose of non-hazardous solid wastes in the Province of Alberta
clay soil liner	low permeability containment layer constructed using compacted clay soil
CLU	contemporary land use
cm	centimetre
cm y^{-1}	centimetres per year
CN	Canadian National Railway
CNR	Command Notification System
CO	carbon monoxide
CO_2	carbon dioxide
CO_3^{2-}	carbonate ion
COD	chemical oxygen demand – used to indirectly measure the amount of organic compounds in water
collection hopper	receptacle that collects formed sulphur pastilles and directs those pastilles onto a conveyor belt
Compliance Source Emissions Testing	testing implemented on sources of air emissions, such as combustion stacks, to verify that those emissions comply with regulated standards
conditioning unit	unit in the sulphur forming process that regulates the rate and temperature of the liquid sulphur that is fed into the process
COPC	chemicals of potential concern
COSEWIC	Committee on the Status of Endangered Wildlife
CP	perennial crop total
CPNVI	Central Parkland Native Vegetation Inventory
CPR	Canadian Pacific Railway
CPR1	cardiopulmonary resuscitation
CPR2	uncultivated pasture total
CPUE	catch per unit effort
CR	concentration ratio
CSA	Canada Standards Association
CSL	comprehensive sound level
CWQ	Canadian Water Quality
CWS	Canada-wide Standards
dBA	A-weighted decibel
dBC	C-weighted sound levels
degassed sulphur	sulphur that contains less than 10 ppm by weight of hydrogen sulphide

Acronym	Definition
DFO	Department of Fisheries and Oceans
DO	dissolved oxygen
DOC	dissolved organic carbon
double containment system	containment system for storing potentially hazardous liquids that includes two independent containment layers
draw down tube	tube used to control (reduce) fluid levels in a containment vessel
duplex filter	filter designed to remove two types of impurities, such as particulate and organic matter
dust suppression package	process component that suppresses dust that may be emitted to atmosphere at a material transfer point
EC	electrical conductivity
EC20	concentration that affects 20% of text organisms
EC50	concentration that affects 50% of test organisms
EIA	Environmental Impact Assessment
elemental	a pure substance that cannot be broken down into different kinds of matter
emergency response	the action taken after an event to minimize the consequences of an emergency
EMS	environmental management system
EMS	Emergency Medical Services
EOC	Emergency Operations System
EPEA	*Environmental Protection and Enhancement Act*
ER	exposure ratio
ERP	Emergency Response Plan
ESA	Environmental Significant Areas
EUB	Alberta Energy and Utilities Board
FAP	Fort Air Partnership
feed tank	tank at the beginning of the sulphur processing system that is used to control the rate of sulphur feed to the forming process
ferrous iron	iron with an oxidation number of +2
fish/trap-hour	fish catch rate; fish caught per hour
FMZ	Fur Management Zone
FOLC	The Friends of Lamont County for Responsible Industrial and Community Development
FONG	open, non-patterned graminoid dominated fen
formed sulphur	sulphur that has been formed into solid pastilles using the Rotoformer process
fugitive dust	dust that is not emitted from definable point sources
fugitive sulphur emissions	sulphur emissions that are not emitted from definable point sources
FWHIS	Fish and Wildlife Historical Information System
g	the gravitational constant (9.8 m/s^2)
$g\ s^{-1}$	grams per second

Acronym	Definition
GHG	greenhouse gases
GIS	geographic information system
GJ/mon	gigajoules per month
gm/t	grams per tonne
groundwater	water beneath the earth's surface in underground streams and aquifers
gypsum	a soft white mineral composed of hydrous sulfate of lime
H	Hour
H&S	Health and safety
H^+	hydrogen ion; the symbol for a proton
H_2CO_3	carbonic acid
H_2O	Water
H_2S	hydrogen sulphide
H_2SO_4	hydrogen sulphate
ha	hectare
HADD	harmful alteration, disruption, or destruction of fish habitat
HAZCO	HAZCO Environmental Services
HCO_3	bicarbonate
HDPE	high density polyethylene
HEC	human equivalent condition
HHRA	Human Health Risk Assessment
HNO_3	nitric acid
HP	horsepower
HRIA	Historical Resources Impact Assessment
HRV	historical resources value
hw	the symbol for liquid depth from the action leakage rate formula
hydraulic conductivity	the extent to which a given substance allows water to flow through it
hydrogen plant feedstock	plant that is used to generated hydrogen gas, which is in turn used in the heavy oil upgrading and/or oil refining process
hydrogeological	pertaining to the geology of ground water with emphasis on its chemistry and movement
i	hydraulic gradient in the surficial deposits
I/C	Industrial/Commercial District
ICS	Incident Command System
infrastructure	basic facilities, such as transportation, communications, power supplies and buildings, that enable an organization, project or community to function
interstitial water	subsurface water contained in pore spaces between grains of rock and sediment
IPCC	Intergovernmental Panel on Climate Change
ISQG	Interim Freshwater Sediment Quality Guidelines

Acronym	Definition
ITE	Institute of Transportation Engineers
K	hydraulic conductivity
K	degrees Kelvin
K^+	potassium ion
keq H^+/(ha•y)	kiloequivalents of hydrogen ions per hectare per year
kg	kilogram
kg s^{-1}	kilograms per second
kg/d	kilograms per day
kg/ha/y	kilograms per hectare per year
kg/t	kilograms per tonne
km	kilometres
km/h^{-1}	kilometres per hour
km^2	square kilometre
kPa	kiloPascals
kraft pulp	pulp produced by a process where the active cooking agent is a mixture of sodium hydroxide and sodium sulphide
Kw	kilowatt
L/min	litres per minute
L/s	litres per second
LCC	Lamont County Council
Le Chatelier’s Principal	used to predict the effect of changing the amount of reactants, products, temperature or system volume on the composition of a chemical system at equilibrium
leak detection layer	layer located between the primary and secondary containment layers that is used to monitor the integrity of the primary containment layer
LEK	local environmental knowledge
L_{eq}	energy equivalent sound level
Level I fire	minor fire that can be isolated or controlled and is not of a serious nature
Level II fire	fire that cannot be isolated or controlled, but can be managed by local fire and emergency response service
Level III fire	fire that cannot be isolated or controlled and cannot be managed by local fire and emergency response service
L_{max}	maximum sound level for a given time period
load out conveyor	conveyor used to transfer formed sulphur onto rail cars
LOAEL	lowest observed adverse effect level
LOS	level of service
LSA	Local Study Area
LST	local standard time
LUB	Land Use Bylaw
LZ	landing zone

Acronym	Definition
m	metre
m/m	metres per minute
m/s^{-1}	metres per second
m/y	metres per year
m^2	metres squared
m^2/day	metres squared per day
m^3	cubic metres
$m^3\ h^{-1}$	cubic metres per hour
m^3/day	metres cubed per day
m^3/s	metres cubed per second
m^3/y	metres cubed per year
MAC	maximum acceptable concentrations
Man-hours	number of workers multiplied by hours worked
masl	metres above sea level
mbgs	metres below ground surface
MDBP	Municipal Development Plan Bylaw
meq	milliequivalents
meq/L	milliequivalents per litre
metallic sulfides	compounds formed by metal elements bonding to sulphides
metering pump assembly	process unit that measures flow volumes and rates through a pump
mg/kg	milligrams per kilogram
mg/L	milligrams per litre
mg/m^3	milligrams per cubic metre
Mg^{2+}	magnesium ion
mitigation	any action taken to permanently eliminate or reduce the long-term risk to human life, property and function from hazards
mL	millilitre
mL/minute	millilitres per minute
mm	millimetre
mm day^{-1}	millimetres per day
mm/y	millimetres per year
MP	McElroy-Pooler dispersion coefficient
MPC	Municipal Planning Commission
MPOI	maximum points of infringement
MRL	minimal risk limit
MSDS	Material Safety Data Sheets

Acronym	Definition
MVC	motor-vehicle collisions
MWH/mon	power flux per month
N	Nitrogen
n	number of individuals
n.d.	not defined
n/a	not applicable
Na^+	sodium ion
NAAQO	National Ambient Air Quality Objectives
$NaHCO_3$	sodium bicarbonate
NCIA	Northeast Capital Industrial Association
Ne	effective porosity
neutralization sludge	sludge formed by the neutralization of sulphuric acid using either caustic soda or lime
NGO	non-governmental organizations
NH_4NO_3	ammonium nitrate
NIA	noise impact assessment
NO	nitric oxide
NO_2	nitrogen dioxide
NO_2^-	nitrite ion
NO_3^-	nitrate ion
NOAEL	no observed adverse effect level
NO_x	nitrogen oxides
NPRI	National Pollutants Release Inventory
NR CAER	Northeast Region Community Awareness and Emergency Response
NRC	Natural Regions Committee
NRCB	Natural Resources Conservation Board
NTU	nephelometric turbidity unit
O_2	oxygen
O_3	ozone
OEL	Occupational Exposure Limit
off-specification sulphur	sulphur that does not comply with shipping specifications either because of excessive mineral or organic content
OH^-	hydroxide ion
OM	organic matter
oxidation	the removal of electrons from an element or compound
ozone precursors	chemical compounds, such as carbon monoxide, methane, non-methane hydrocarbons and nitrogen oxides, which in the presence of solar radiation react with other chemical compounds to form ozone
PAH	polycyclic aromatic hydrocarbons

Acronym	Definition
PAI	potential acid input
PDA	Principal Development Area
PEL	probable effect levels
PEMS	Prairie Emergency Medical Systems
PET	potential evapotranspiration
PFRA	Prairie Farm Rehabilitation Administration
PG	Pasquill-Gifford dispersion coefficient or atmospheric stability class
pH	measure of the acidity or basicity (alkalinity) of a material when dissolved in water
piezometer	instrument which measures hydraulic pressures
PM_{10}	particulate matter with mean aerodynamical diameter less than 10 µm
$PM_{2.5}$	particulate matter with mean aerodynamical diameter less than 2.5 µm
PPE	personal protective equipment
ppb	parts per billion
ppm	parts per million
precipitate	separate as a fine suspension of solid particles
protons	positively charged particles forming part of atomic nuclei
psi	pounds per square inch
PSL	permissible sound level
pump hanger	device for vertically positioning a pump
PW	pumping well
Q	symbol for action leakage rate from the action leakage rate formula; groundwater contributions
QA	quality assurance
QC	quality control
R.R.	Range Road
radial stacking conveyor	conveyor that places formed sulphur in a radial pattern
rail transfer loop	rail line placed in an approximately circular pattern
RCMP	Royal Canadian Mounted Police
Rd	road
Receiving tank	tank used to receive liquid sulphur delivered by rail or truck
recirculation loop	water circulation loop that returns spent cooling water to the start of the cooling water circuit
reduction	addition of electrons to an element or compound
RELAD	Regional Lagrangian Acid Deposition
RfC	reference condition
RGDR	regional gas dosimetry ratio
Rotoform emissions	particulate sulphur emissions for the Rotoform process

Acronym	Definition
ROW	right(s) of way
RSA	Regional Study Area
runoff control system	system of ditches and culverts used to collect runoff from the sulphur processing area to the stormwater collection pond
S	Sulphur
s^{-1}	per second
S_2O_3	thiosulfate
SABA	supplied air breathing apparatus
Sandvik Rotoform process	sulphur forming process developed and patented by Sandvik and referred to as the Rotoform process
SAR	sodium adsorption ratio
SAR	species at risk
SARA	*Species at Risk Act*
saturated	most concentrated solution possible at a given temperature
SCA	soil correlation area
SCBA	self-contained breathing apparatus
SEIA	Socio-Economic Impact Assessment
SIL	survey intensity level
Site	Section 35-55-20 W4M
S^o	symbol for elemental sulphur
SO_2	sulphur dioxide
SO_4^{2-}	sulphate ion
sour gas	hydrogen sulfide gas; H_2S
SO_x	sulphur oxides
specific gravity	the ratio of the density of a material to the density of water
spontaneous combustion	self-ignition of combustible material through the chemical action of its parts
stakeholders	people or organizations with an interest or share in an undertaking, such as a commercial venture
sulphur acidification	lowering of pH in soils or water by sulphur dioxide
sulphur forming	process of converting liquid sulphur into solid sulphur particles
sulphur pastille	sulphur pastilles of uniform shape, stability and quality formed by the Sandvik Rotoform process
sulphur recovery	separation and recovery of sulphur from a hydrocarbon refining process
sulphur train	a train used to convey liquid or solid sulphur
sulphuric acid	a strong acid; H_2SO_4
surface water	water that flows in streams and rivers, natural lakes, in wetlands, and in reservoirs constructed by humans
surface water runoff	pond used to collect and contain surface runoff from the sulphur forming and handling

Acronym	Definition
collection pond	area
surge bin	bin used to collect and store surges in solid sulphur pastilles
sweet fuel gas	methane that is used as fuel and does not contain hydrogen sulphide
t/d	tonnes per day
t/y	tonnes per year
TDS	total dissolved solids
THE	total exactable hydrocarbons
temperature conditioned	sulphur that is conditioned and controlled to be in a specific temperature range
TIA	traffic impact assessment
TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TOR	Terms of Reference
totalizer	metering device that totals the volume of liquid passed through that meter
TP	total phosphorus
TPH	total petroleum hydrocarbons
TRV	toxicological reference values
TSS	total suspended solids; the weight of particles suspended in water
Twp	Township
UF	urban fringe
USEPA	United States Environmental Protection Agency
USGPM	US gallons per minute
USLE	universal soil loss equation
UTM	universal transverse mercator
V	Velocity
visible sheen	collection of hydrocarbons that is visible on the surface of a waterbody
VOC	volatile organic compounds
W4M	West of the 4th Meridian
vpd	vehicles per day
WA	*Water Act*
WCB	Workers' Compensation Board
wetland	area regularly saturated by surface water or groundwater and characterized by a prevalence of vegetation adapted for life in saturated soil conditions (e.g., swamps, bogs, fens, marshes and estuaries)
WHMIS	Workplace Hazardous Materials Information System – national chemical hazard communication system for regulation of information pertaining to hazardous materials
WMU	Wildlife Management Unit
WVC	wildlife-vehicle collisions
y	year

Acronym	Definition
µeq/L	microequivalents per litre
$\mu g\ m^{-3}$	micrograms per cubic metre
µm	microns (micrometres)
µS/cm	Microsiemens per centimetre

1. Introduction

The proponent, Alberta Sulphur Terminals Ltd. (AST), a division of HAZCO Environmental Services (HAZCO) which, in turn, is a division of CCS Income Trust (CCS), is applying to Alberta Environment (AENV) and the Natural Resources Conservation Board (NRCB) for approval to construct and operate a facility for sulphur receiving and forming, temporary sulphur pastille storage and shipment for export (the Project). The facility is to be developed on a portion of Section 35, Township 55, Range 20, West of the 4^{th} Meridian (35-55-20 W4M – the Site), approximately 2.2 km east of Bruderheim, Alberta, in the Industrial Heartland area of Lamont County (Figure 1.1-1).

The purpose of this Environmental Impact Assessment (EIA) is to assess and report the potential environmental and socio-economic impacts of the Project. The EIA portion of this application has been organized into four sub-volumes:

Volume IIA – Air, Noise and Human Health

1. Introduction
2. Climate and Air Quality
3. Noise and Light
4. Public Health and Safety

Volume IIB – Water and Aquatic Resources

1. Introduction
2. Groundwater Quality and Quantity
3. Surface Water Quantity
4. Surface Water Quality
5. Aquatic Resources

Volume IIC – Terrestrial Ecosystems

1. Introduction
2. Soil
3. Vegetation
4. Wildlife
5. Biodiversity and Fragmentation

Volume IID – Land Use, Historical, Socio-Economics and Public Consultation

1. Introduction
2. Land Use and Reclamation
3. Historical Resources
4. Socio-Economic Assessment
5. Public Consultation Requirements

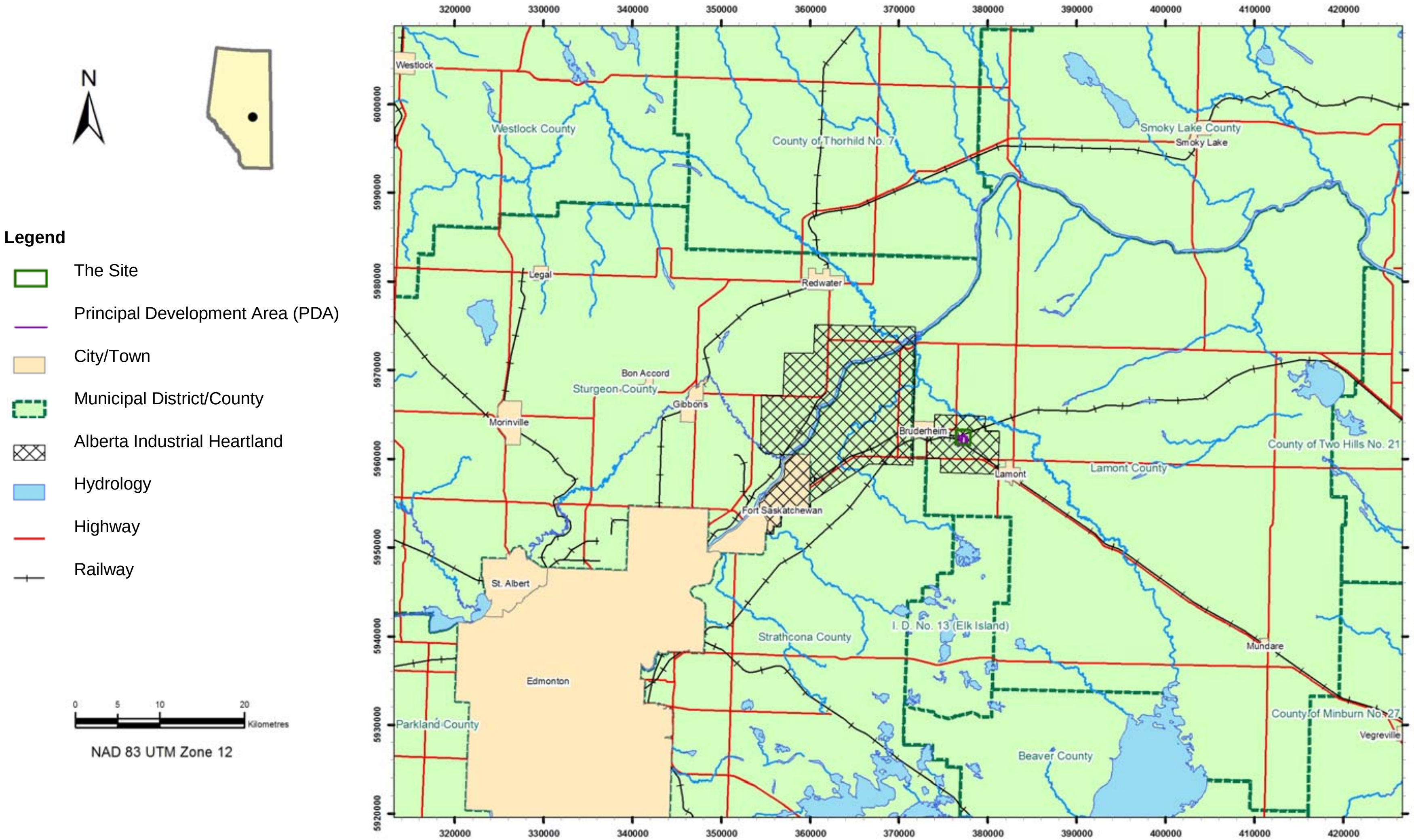

Figure 1.1-1: Regional Setting

This EIA forms part of the application for the Project submitted by AST and has been prepared according to the following requirements:

- AENV: *Environmental Protection and Enhancement Act* (EPEA 1993)
- AENV: Final Terms of Reference (TOR: AENV 2007)
- NRCB*: Natural Resources Conservation Board Act* (NRCB 2001)
- Permit to Divert Groundwater, to be issued by AENV under the Water Regulation of the *Water Act*: to provide up to 24,000 m^3 of cooling water per year to supply water during periods when the volume of water collected in the stormwater runoff control pond is not sufficient to operate the sulphur forming cooling system
- Development Permit issued by Lamont County under the *Municipal Government Act* (Government of Alberta 2000a) to allow construction of surface facilities associated with the Project
- authorization under the *Historical Resources Act* (Government of Alberta 2000b) for clearance to construct the Project

The concordance table that correlates the various clauses of the TOR to the application and EIA can be found in Volume I.

1.1 Project Description

The Project encompasses construction and operation of a facility for sulphur receiving and forming, temporary sulphur pastille storage and shipment for export. All infrastructure and activities will be confined to the lands owned by HAZCO. The Project includes:

- rail and road access for receiving molten sulphur
- molten sulphur unloading and transfer facilities
- sulphur forming facilities to produce sulphur pastilles
- loading and shipping facilities for formed sulphur
- sulphur pastilles temporary storage area

The Project will service oil and gas production and refining operations located in the Fort Saskatchewan area as well as northeastern Alberta. With increased applications, approvals and operation of bitumen upgraders and ongoing sulphur recovery initiatives, a shortage of sulphur forming facilities in Alberta is now apparent. AST will provide oil and gas producers in the area with a state-of-the-art sulphur forming, temporary pastille storage and shipping facility with design elements and monitoring programs that focus on environmental protection.

1.1.1 Sulphur Generation

The sulphur that would be accepted, formed and shipped by the Project is generated primarily by bitumen upgrading facilities located in the Fort Saskatchewan, Fort McMurray and Lloydminster areas. Amine units are part of the upgrader sulphur plant and remove H_2S from all upgrading gas streams, which produces sweet fuel gas (low sulphur content) and hydrogen plant feedstock. The plant consists of H_2S removal units (amine units) and sulphur recovery units, which convert H_2S to elemental sulphur.

The sulphur recovery units oxidize or burn part of the H_2S into SO_2, which then reacts with H_2S to form liquid elemental sulphur and water. The initial reaction takes place in the burners of a reaction boiler and in-line burners before the converters/condensers, known as sulphur "trains". First, second and third stage converters containing a (bauxite) alumina catalyst promote the reaction of H_2S with SO_2 at temperatures from 204–316°C. Modern processes reduce sulphur emissions and improve sulphur recovery.

Sulphur is recovered as a liquid by condensing sulphur vapour from the gases in the steam-generating heat exchangers of each sulphur train. The liquid sulphur is then gathered and stored, and entrained residual H_2S is removed from the stored sulphur.

Upgrading facilities at Lloydminster, Fort McMurray and Fort Saskatchewan currently generate sulphur at a rate of approximately 1 million tonnes/year (t/y). The rate of sulphur production in these areas is expected to rise to approximately 2 million t/y per year by 2008, and 3 million t/y by 2013 as upgrading operations are expanded to accommodate the increased production associated with heavy oil.

1.1.2 Project Components and Development Timing

The primary components of the proposed sulphur forming and shipping facility are:

- rail and road access for receiving and shipping sulphur
- liquid sulphur unloading and transfer facilities
- sulphur forming facilities to produce sulphur pastilles
- loading and shipping facilities for formed sulphur
- a sulphur pastille temporary storage area

1.1.2.1 Sulphur Reception

Liquid sulphur will be received at the facility by railcar, truck or (in future) pipeline. Only liquid sulphur that has been degassed to a maximum of 10 ppm H_2S will be accepted. Upon arrival, the liquid sulphur will be unloaded via a pumping station into insulated and heated receiving tanks. Liquid sulphur will then be pumped to a feed tank where it will be filtered and temperature conditioned prior to being formed.

1.1.2.2 Sulphur Holding

Storage will be provided for sulphur in its liquid form, prior to being formed, as well as in its pastille form, prior to being shipped. The sole purpose of this is to allow efficient operation of the forming facilities, while accommodating delivery and shipping. Liquid sulphur will be stored in 3,000 t, insulated and clad, steel tanks that meet the requirements of EUB Directive 55 (EUB 2001, Internet site) and API 650 (API 1998) modified. The initial development will include three 3,000 t tanks, rising to six – 3,000 t tanks at maximum capacity. Formed sulphur will be stored on a double-lined asphalt pad equipped with run-on and runoff controls. This pad will have the capacity to store 90,000 t of finished product, approximately half of which will be established as part of initial construction.

1.1.2.3 Sulphur Forming

After the sulphur is transferred to the receiving tanks, it will be pumped through a duplex filter and conditioning unit and cooled to an optimal forming temperature of 125°C. The sulphur will then enter a recirculation loop that will feed the Rotoform HS® drop forming equipment. The feed to the Rotoformer will use metering equipment and nozzles specifically designed to provide a continuous sulphur feed across a rotating stainless steel belt. The belt will be cooled by cold water jets sprayed against the underside of the rotating belt, causing the pastilles to cool and solidify above.

1.1.2.4 Transfer and Shipping Infrastructure

The solid pastilles will be deposited into a collection hopper, conveyed to a radial stacking conveyor and the asphalt bulk sulphur storage pad. A wind screen will be built upwind of the sulphur pastille stockpile. Initially, a front-end loader will transfer the stockpiled sulphur to a surge bin equipped with a dust suppression package. The dust treated product will then be deposited on a load-out conveyor equipped with weight measurements and totalizer and onto rail or trucks for shipment. An automated loading system will be introduced as part of future expansion to full production. In this instance, the formed sulphur will be transferred into vertical holding bins that will be used to directly load rail cars. The EIA is based on a forming capacity of 6,000 t/d, half of which will be associated with initial construction.

Water utilized by the Rotoform HS® equipment will be sent through a closed loop cooling tower which will provide filtration and temperature reduction. Make-up water for the cooling tower will be supplied from a runoff pond which is designed to collect and treat surface water from the Site and will also serve as the source of fire protection water. Additional make-up water will be provided by a groundwater supply well.

1.1.2.5 Development Schedule

The proposed facilities will be developed in stages to accommodate the rate of sulphur production generated by existing and proposed oil sands development programs as well as market conditions. The initial stage will include the development of all Project components with sufficient capacity to process approximately 3,000 t/d of sulphur. Subsequent expansions will occur to process approximately 6,000 t/d of sulphur. The anticipated timing for the initial stage of development is summarized in Table 1.1-1 and is dependent on the pace and outcome of the regulatory process.

Table 1.1-1: Initial Development Timing

Task	Anticipated Timeframe
Project disclosure	2005
EIA scoping	Early 2006
EIA implementation	2006
Application submission	Mid 2007
Detailed design	Late 2007
Construction	Early 2008
First operations	Mid 2008
Project lifespan	25 years

The receipt, forming, temporary storage and shipping of formed sulphur will occur continuously over the lifespan of the facility (estimated to be at least 25 years), assuming there is a viable international market for sulphur produced in Alberta.

Failure to meet the proposed timeline, or approve the Project in general, will result in the blocking of incremental volumes of sulphur produced by oil sands upgrading facilities, either in new locations or at existing facilities. For example, sulphur produced by Syncrude is currently being stored in above-ground blocks, and Suncor is considering this option for sulphur generated by its Voyageur upgrader. Sulphur forming facilities are currently not available to the independent upgraders that are scheduled to come on-line in the next few years.

1.2 Spatial Boundaries

1.2.1 Principal Development Area

The Principal Development Area (PDA) is located within a portion of Section 35-55-20 W4M (the Site) and comprises the area of disturbance and development as illustrated in Figure 1.1-1. The PDA contains the forming and shipping facility, located in the west-central portion of the Site, and rail transfer loop used to receive and ship sulphur.

1.2.2 Local Study Area

The LSA for the majority of disciplines assessed in the EIA is the Site (groundwater, historical resources, surface water quantity and surface water quality) or the Site plus a 200 m buffer zone (aquatics, biodiversity and fragmentation, land use and reclamation, soil, vegetation and wildlife).

1.2.3 Regional Study Area

The RSA incorporates the LSA into a larger geographical area where potential regional effects could occur. As with the LSA, the extent of the RSA for each EIA component was determined according to the indicators used. Where no impact (Class 4) is predicted within the LSA, no analysis of regional effects was undertaken.

1.2.3.1 Cumulative Effects Study Areas

Cumulative effects assessments (CEA) are only applicable when other announced, but yet-to-be approved, projects exist that would affect the same area. Cumulative effects were generally assessed within the RSA for each specific EIA component. Where no impact is predicted within the LSA, no analysis of cumulative effects was undertaken (see Section 1.5.3).

1.3 Temporal Boundaries

The Project schedule is preliminary and subject to modification in response to the receipt of regulatory approvals, business considerations and weather factors. Assuming favourable regulatory approval and market conditions, construction of the Project is scheduled to begin in early 2008 with initial sulphur processing starting in mid 2008. The Project is expected to operate for at least 25 years. A detailed schedule is provided in Volume I.

Temporal boundaries used in this assessment vary depending on the disciplines and the resource assessed. Temporal boundaries extend from the June 2006 for the baseline assessments to five years after reclamation of the Project for the Land Use and Reclamation assessment.

1.4 Assessment Criteria

The purpose of the EIA is to assess and report on the potential impacts associated with the construction and operation of the Project. This includes impacts to the biophysical landscape as well as socio-economic and cultural impacts to local communities and historical sites. The EIA also includes preventative, mitigative and compensatory actions to reduce impacts of the Project.

Impact assessments were based upon measured, predicted or reasonably expected changes in some attributes of a selected indicator. The choice of indicators was determined from reviewing other EIAs completed in the Alberta Industrial Heartland for applicability to this region through input from stakeholders and the professional judgment of scientists conducting the EIA.

For each identified indicator, an assessment of the potential residual impact was made using the attributes of:

- direction
- geographical extent
- magnitude
- duration
- confidence
- reversibility

The definition of each attribute used in the assessment is given below.

1.4.1 Direction

The direction of impact may be described as positive (beneficial), negative (detrimental) or neutral:

- Positive: measured or estimated impact represents a real or potential increase in abundance, quality or other attribute of the indicator
- Negative: measured or estimated impact represents a real or potential decrease in abundance, quality or other attribute of the indicator
- Neutral: a “neutral” direction indicates there is no impact to quantify; therefore, no quantitative assessment (e.g., extent, magnitude, duration) is possible; the confidence (based on an understanding of cause and effect relationship(s) and the quality and quantity of available data) in the assessment is discussed below

1.4.2 Geographic Extent

Impacts may be confined to small local areas, or may occur over a large geographic extent. Generally, impacts may be local or regional:

- Local: measured or estimated impact occurs only within the boundaries of the LSA
- Regional: measured or estimated impact occurs beyond the boundaries of the LSA and mainly within the boundaries of the RSA

1.4.3 Magnitude

Three levels of magnitude have been selected:

- Negligible: measured or estimated impact represents a 1% or less change in the indicator (quality, quantity or other attribute) from baseline conditions
- Low to Moderate: measured or estimated impact represents a greater than 1% to 10% change in the indicator (quality, quantity or other attribute) from baseline conditions
- Moderate to High: measured or estimated impact represents a greater than 10% change in the indicator (quality, quantity or other attribute) from baseline conditions

Some disciplines have specific threshold values (e.g., AAAQOs (AENV 2005, Internet site)) that determine the magnitude of the impact, rather than a combination of quantitative analysis and professional judgment that is used where specific guidelines and regulations do not exist.

1.4.4 Duration

Some impacts may persist for short periods of time, others may be virtually permanent. The following designations for duration are used:

- Short-term: measured or estimated impact persists for no longer than five years
- Mid-term: measured or estimated impact persists to the end of the operational life of the Project
- Long-term: measured or estimated impact is measurable beyond the end of the operational life of the Project

1.4.5 Confidence

All measurements or predictions of direction, magnitude, geographic extent and duration of an impact are made on the basis of available data and understanding of the Project. The confidence ratings used are:

- Low: no clear understanding of cause and effect is evident because of the lack of a relevant information base or directly relevant data. This generally applies to conditions relevant to the RSA where no data was collected or available, and no detail is available regarding other planned developments.
- Moderate: a good understanding of cause and effect is evident from the existing knowledge base; however, there is limited data or a lack of directly applicable data. This generally applies to conditions within the LSA where larger-scale data was collected, but the resource in question is very site-specific and could not be surveyed within this year's time frame or models were used but could not be validated.
- High: a good understanding of cause and effect is available from the existing knowledge base and good, directly-applicable data are available. This generally applies to conditions within the LSA where data was collected and information about the Project was available (e.g., footprint).

1.4.6 Reversibility

All disciplines provide basic explanation regarding whether or not the impact is reversible.

1.4.7 Final Impact Rating

For each individual impact assessment, a qualitative, final evaluation rating has been used where specific guidelines do not exist. This rating is a combination of quantitative analysis and professional judgment that takes into account the various descriptors for each attribute (direction, magnitude, geographic extent, duration, confidence and reversibility), and the potential effects of the specific impact. For some indicators, there are specific threshold values that will determine an indicator's ranking (e.g., for air quality, human health). Other indicators have no such threshold value and a combination of objective analysis and subjective professional judgment is used. Impact classification does not always relate directly to standard descriptors used to explain the impact occurring; this is often seen where a relative change of high magnitude is occurring, yet the impact is classified as Class 3 because the overall effect (e.g., impacts to one small stream within a watershed) may be unmeasureable.

The final impact rating is an aggregated, relative, numerical ranking determined by both the analysis of impact and the level of action the author recommends, as a professional, as necessary to address the impact. This ranking is applied to both the Project-specific impacts and cumulative effects residual impacts (see Table 1.4-1).

Table 1.4-1: Final Impact Rating

Rating	Level of Action
Class 1	The predicted trend in an indicator under projected land use development could threaten the long-term sustainability of the quantity or quality of the indicator in the local and regional study areas. An action plan, developed jointly by regional stakeholders, could be developed to monitor the affected indicator, identify and implement further mitigation measures to reduce any impact, and promote recovery of the indicator, where appropriate. This class of impact might also be applicable to an exceedance of a regulatory guideline, or where the impact is expected to have long-term effects.
Class 2	The predicted trend in an indicator under projected land use development will likely result in a decline in the quantity or quality of the indicator. The decline could be to lower-than-baseline but stable levels in the LSA and RSA after closure and into the foreseeable future. In addition to responsible industrial operational practices, monitoring and recovery initiatives could be required if additional land use activities occur in the study area before closure of the projected land use development. This class of impact might also be applicable to an exceedance of a regulatory guideline, or where the impact is expected to have mid-term effects, but where recovery will take place shortly after closure of the projected land use development.
Class 3	The predicted trend in an indicator under projected land use development could result in a slight decline in the quantity or quality of the indicator in the LSA and RSA during the life of the projected land use development, but resource levels should recover to baseline after closure. In some cases, a short-term, low to moderate magnitude impact could occur, but recovery will take place within five years. No new resource management initiatives are necessary. Responsible industrial operational practices should continue. This class of impact could also be applicable where regulatory guidelines are not exceeded, but where a relative change in magnitude of an indicator occurs.
Class 4	The projected land use development results in no change and no contribution toward affecting the quantity or quality of the indicator in the LSA and RSA during the life of the projected land use development. Responsible industrial operational practices should continue. Therefore, no cumulative effects result from the Project.

1.5 Assessment Scenarios

The assessment was based on three cases – baseline case, application case and cumulative effects case as required by the TOR (AENV 2007). Impacts of the Project were evaluated from a project-specific and cumulative perspective by undertaking comparisons of change within these cases. These generally included comparisons of the environmental characteristics occurring in the baseline case with environmental conditions predicted to occur in the application case and in the cumulative effects case (see Figure 1.5-1).

1.5.1 Baseline Case

The baseline case includes the existing environmental and socio-economic conditions and existing and approved projects and activities as of June, 2006.

1.5.2 Application Case

The application case includes the baseline case plus the Project within the LSA. Construction and operation of the Project will occur sequentially. A maximum worst-case disturbance case was assessed for the application case in which all construction and operation components of the Project were assumed to occur concurrently. This conservative, worst-case approach over-predicted the Project impacts. In some cases, impacts were evaluated at closure (decommissioning and reclamation) to determine residual effects at that time.

1.5.3 Cumulative Effects Case

The cumulative effects case includes baseline, application and existing projects or activities in combination with other planned projects or activities that could occur within the same geographic area (spatial) and within the same time (temporal). The Project Inclusion List in Table 1.5-1 shows existing and planned projects or activities.

Cumulative effects were evaluated where Class 1, 2 or 3 impacts were identified for that particular discipline (as per impact ratings explained in Section 1.4.7). Class 4 ratings indicate that no change would occur as a result of the Project. Therefore, a cumulative effects assessment was not undertaken for issues identified as Class 4.

1.5.3.1 Project Inclusion List

The Project Inclusion List (see Table 1.5-1) includes the various anthropogenic disturbances on the landscape that must be included in the applicable assessment case to effectively determine project and cumulative effects. As the study areas for each component vary, the project inclusion for a particular assessment also varies. Therefore, each component has modified the comprehensive project inclusion list for their assessment. The projects included for cumulative effects include other operators as well as facilities associated with the Project.

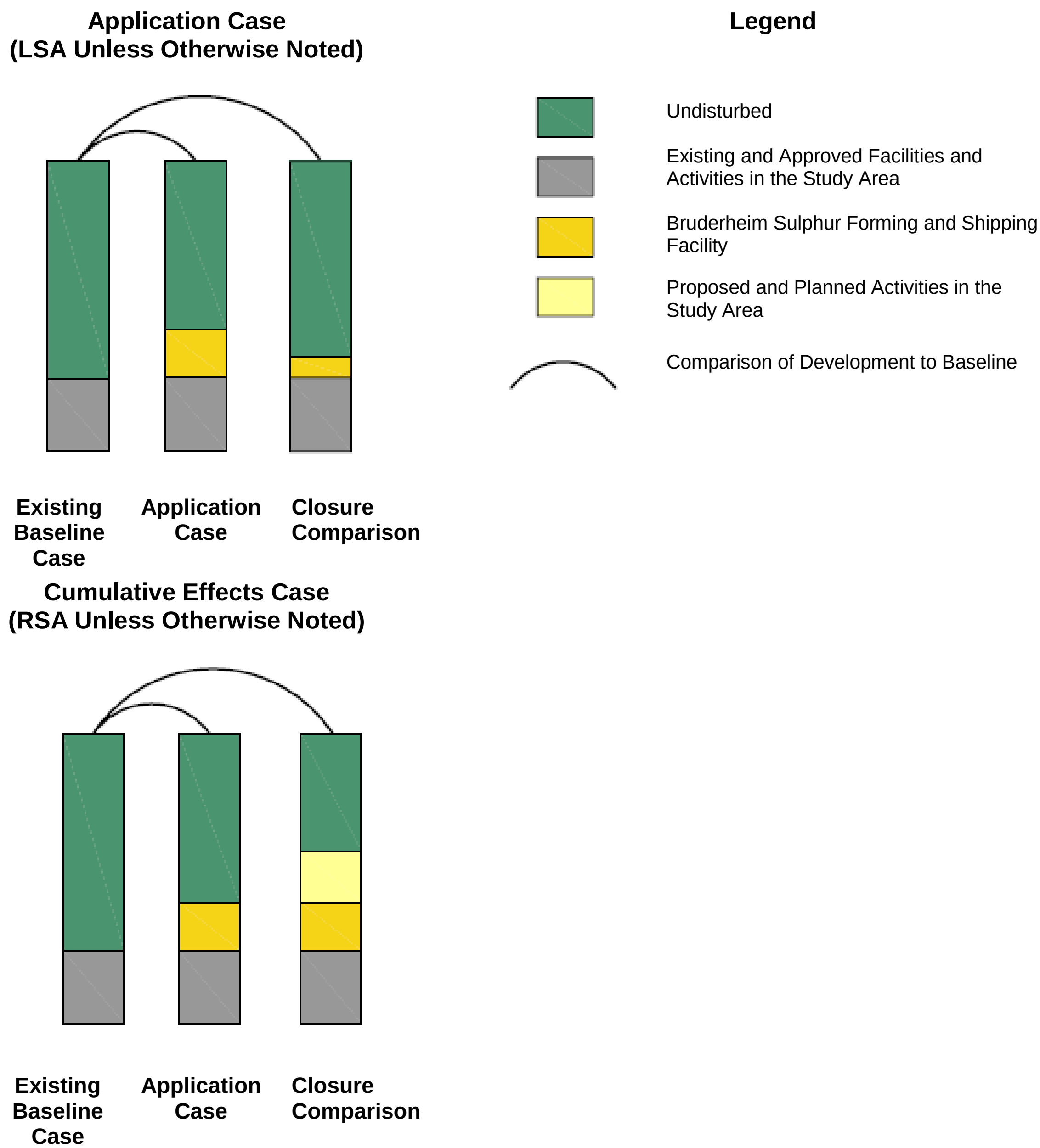

Figure 1.5-1: Comparisons of Change for Impact Assessment

Table 1.5-1: Project Inclusion List

Operator	Facility	Project Status		
		Existing	Approved (Not Operating)	Planned (Not Approved)
Access Pipeline	Redwater Trim Blending Facility		X	
Agrium Products Inc.	Fort Saskatchewan Fertilizer Plant	X		
Agrium Products Inc.	Redwater Fertilizer Plant	X		
Air Liquide Canada	Scotford Cogeneration Power Plant	X		
Alberta Sulphur Terminals	Bruderheim Sulphur Forming Facility			X
ARC Resources	Redwater Gas Conservation Plant	X		
ATCO Midstream	Fort Saskatchewan Sour Gas Plant	X		
Aux Sable Canada	Heartland Offgas Project			X
BA Energy	Heartland Bitumen Upgrader		X	
BP Canada Energy	Fort Saskatchewan Fractionation Plant	X		
Bunge Canada	Fort Sask. Oilseed Processing Plant	X		
Canexus Chemicals Canada	Bruderheim Sodium Chlorate Plant	X		
CE Alberta BioClean	Fort Saskatchewan Chemical Plant		X	
Degussa Canada Inc.	Gibbons Hydrogen Peroxide Plant	X		
Dow Chemical Canada	Fort Saskatchewan Chemical Plant	X		
ERCO Worldwide	Bruderheim Sodium Chlorate Plant	X		
Keyera Energy	Fort Saskatchewan Fractionation Facility	X		
Marsulex	Fort Saskatchewan Chemical Plant	X		
Newalta Corporation	Redwater Disposal Facility	X		
North West Upgrading Inc.	North West Upgrader Project			X
Petro-Canada Oilsands Inc.	Sturgeon Upgrader Project			X
Prospec Chemicals	Fort Saskatchewan Xanthate Plant	X		
Provident Energy Ltd.	Redwater Fractionation Facility	X		
Redwater Water Disposal Company	Redwater Waste Disposal Facility	X		
Shell Canada Limited	Scotford Upgrader	X	X expansion	
Shell Canada Products	Scotford Oil Refinery	X		
Shell Chemicals Canada	Scotford Styrene & MEG Plant	X		
Sherritt International Corporation	Fort Saskatchewan Fertilizer Plant	X		X
Synenco Energy Ltd.	Northern Lights Upgrader Project			X
Terasen Pipelines	Heartland Storage Tank Terminal			X
TransAlta Cogeneration	Fort Sask. Cogeneration Power Plant	X		
TransCanada Energy	Redwater Cogeneration Power Plant	X		

1.6 References

1.6.1 Literature Cited

Alberta Environment (AENV). 1999. *The Water Act.*

Alberta Environment (AENV). 2007. *Final Terms of Reference, Environmental Impact Assessment (EIA) Report for the Proposed Bruderheim Sulphur Forming and Shipping Facility.* March 13, 2007. Alberta Environment, Edmonton, AB.

Alberta Environmental Protection and Enhancement ACT (EPEA). 1993. Environmental Assessment Regulation 112/93.

American Petroleum Institute (API). 1998. *Welded Steel Tanks for Oil Storage*, 10th Edition. American Petroleum Institute, Washington, D.C.

Government of Alberta. 2000a. *Municipal Government Act,* RSA 2000, cM-26.

Government of Alberta. 2000b. *Alberta Historical Resources Act.*

Government of Alberta. 2001. *Natural Resources Conservation Board Act*.

1.6.2 Internet Sites

Alberta Energy and Utilities Board (EUB). 2001. Directive 055: Storage Requirements for the Upstream Petroleum Industry (2001-12). (Formerly Guide 55). December 2001. Available at: www.eub.ca\Docs\Documents\Directives. Accessed February 2007.

Alberta Environment (AENV). 2005. Existing Ambient Air Quality Objectives. Available at: http://www3.gov.ab.ca/env/air/OGS/objexisting. Accessed May 2006.

WorleyParsons Komex
resources & energy

Alberta Sulphur Terminals Ltd.
Bruderheim Sulphur Forming and Shipping Facility

Volume IIC – Terrestrial Ecosystems

2. Soil

Project Number 62720000
June 2007

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APPENDICES

Executive Summary

Alberta Sulphur Terminals Ltd. (AST), a division of HAZCO Environmental Services (HAZCO) which, in turn, is a division of CCS Income Trust (CCS), retained WorleyParsons Komex to complete a study of soil resources for the proposed Bruderheim Sulphur Forming and Shipping Facility (the Project) located on a portion of Section 35, Township 55, Range 20, West of the 4th Meridian (35-55-20 W4M - the Site). The objectives of the soil assessment were as follows:

- satisfy the relevant section of the Final Terms of Reference (TOR) of the Environmental Impact Assessment (EIA)
- assess the suitability of soils at the Site for the proposed Project

The study confirmed that the Site was suitable for siting the proposed Project. The TOR relevant to soil and the study's respective conclusions are summarized as follows.

a) *Describe and map the soil types and their distribution according to the Soil Survey Handbook, Vol. 1 (Agriculture Canada, 1987) and The Canadian System of Soil Classification Third Edition (Agriculture and Agri-Food Canada, 1998) including the following soil survey intensity levels;*

   i. *SIL (survey intensity level) 1 for the PDA area and any areas that may be subject to future disturbance by the Project such as borrows, rail spurs, access roads etc;*

   ii. *SIL 2 for the Local Study Area; and*

   iii. *appropriate level of detail to determine the effect of the Project on soil types and quality in the Regional Study Area.*

   The Principle Development Area (PDA) contains the Project's sulphur forming facilities, rail and road access, unloading facilities and temporary sulphur pastilles storage area. The PDA is located within the Site. The Soil Study Area (LSA) is defined as the Site plus a 200 m buffer area. The Soil Regional Study Area (RSA) is defined as the Site plus a 1,000 m buffer area.

   Soils in the PDA and LSA were described and mapped using the methodology outlined in the TOR. A total of 20 inspection sites were undertaken in the PDA; inspections were completed within 50 m of the PDA boundary because a final PDA location was not available at the time the field survey was completed. The resultant inspection intensity was approximately one inspection per 1.2 ha, slightly less than the expected SIL required (approximately 1/ha). The LSA was surveyed at SIL 2 with one inspection per 6.8 ha. Soils in the LSA were mapped at a 1:20,000 scale (Figure 2.5-3). For the RSA, existing published soil mapping data for the region was used to evaluate potential effects of the Project on soil resources.

b) *characterize the pre-disturbance morphological, physical and chemical properties of the soil types and assess the pre-disturbance soil capability classes;*

   Soils in the LSA are primarily solonetzic and chernozemic. Solonetzic soils are formed on fine-textured till or glaciolacustrine deposits that are saline and sodic. Solonetzic subsoils have chemical exchange complexes dominated by sodium, are very hard when dry and swell to a sticky mass of low permeability when wet. Chernozemic soils are formed on a wide variety of parent materials and are imperfectly to well-drained grassland soils having surface horizons darkened by accumulation of xerophytic and mesophytic grasses and forbs. Significant portions of the LSA (25.5%) and PDA (73.4%) are underlain by soils known to be previously disturbed (i.e., stripped) and reclaimed during earlier industrial activity at the Site. Reclaimed soils were interpreted to be derived from either chernozemic or solonetzic soils. Characteristics of both soil types were found in the reclaimed profiles investigated in the LSA. The reclaimed profiles had very little structure or lacked structure in the horizons below the topsoil layer. Saline parent material was present in the majority of profiles.

Reclaimed soils were associated with imperfectly to well-drained moisture regimes and a mix of vegetation types including forage crops (hay), annual crops and improved pasture. Other key soil types in the LSA included Gleysols, soils formed under periodic or permanent flooding, and Organic soils where the dominant soil matrix is decomposed vegetation.

As part of the inspection and assessment of soils in the LSA, soil samples were collected from the dominant soil map units and submitted for laboratory analyses of chemical and physical properties. Details of the chemical and physical characteristics of the dominant soil map units are presented in Appendix II.

Pre-disturbance soil capability classes were assessed using a classification system for agricultural capability developed by Agriculture and Agri-Food Canada. The Land Suitability Rating for Agricultural Crops uses rating classes that measure the capability of the soil to sustain crop production. Soils in the LSA were classified as having agricultural capability classes ranging from Class 2 (having slight limitations that may restrict the growth of agricultural crops) to Class 7 (unsuitable for agriculture) with the majority of the LSA (56.5%) falling into Class 4 (severe limitations that restrict the growth of crops).

c) *develop a soil conservation and reclamation plan for the PDA including re-vegetation and weed management plans. Describe the suitability and availability of soil materials within the Study Areas for reclamation. Outline the criteria to be used in salvaging and storing soils. Describe the procedures for soil handling storage and long-term management of soil intended for reclamation within the PDA. Provide siting criteria for and location of soil stockpiles and describe how they will be managed;*

Pre-disturbance reclamation suitability of soils in the LSA was determined for both topsoil and subsoil. For areas of the LSA that were rated, topsoil reclamation suitability ratings were:

- fair (44% of the LSA)
- poor (40%)
- unsuitable (2%)

The remaining 14% of the LSA was not rated for topsoil reclamation suitability as it was determined to be comprised of organic soils (3%) and non-terrain units (11%).

Subsoil reclamation suitability was rated as fair (14% of the LSA), poor (6%) and unsuitable (65%). The remaining portion of the LSA was not rated for subsoil reclamation suitability as it was determined to be comprised of organic soils (3%) and non-terrain units (11%).

Details of the specific measures to be used in soil salvage, storage, stockpiling and weed management are addressed in Volume IID, Section 2: Land Use and Reclamation – Appendix I: Conservation and Reclamation Plan.

d) *assess the sensitivity of local and regional soils to acidic deposition by: including baseline information as outlined in Appendix A-7 (Soil Monitoring Guidelines) of AENV's Air Monitoring Directive (1996);*

   i. *Discussing sensitivity of soils to wet and dry acidic deposition in the local and regional study areas for baseline, application and cumulative scenarios;*

   ii. *Explaining the methods used to assess sensitive soils and include information from grid cell sensitivity assessments that may be available for the study area;*

   iii. *Using modeled PAI for the baseline, application and cumulative scenarios, describe the soils that would exceed CASA's recommended critical loads in the Local and Regional Study areas, including maps showing their spatial distribution;*

iv. Outlining any existing monitoring information such as AENV's long term soil acidification study and any regional initiatives (NCIA) for acidic deposition.

Sensitivity of soils to acid deposition of soils in the LSA was evaluated using the guidelines set out in the TOR. The AENV Air Monitoring Directive – Appendix A-7 (Soil Monitoring Guidelines) sets out a baseline data collection framework which allows for future reference to baseline chemical and physical data. These data were collected for representative soils in the LSA and are summarized in Appendix V.

Soils in the LSA were rated for sensitivity to acid deposition using currently accepted methodology as described in Section 2.4.1.6. Mineral soils were rated with respect to sensitivity to base loss, acidification and aluminum solubilization. Organic soils were rated for overall sensitivity to acid deposition. Soils in the LSA were rated as having a low to moderate sensitivity to acid deposition. No sensitive soil units were identified in the LSA.

Published grid cell sensitivity data were used to evaluate the sensitivity of soil to acidification on a regional scale. Based on the most current data available, the LSA is within a low sensitivity grid cell.

Modelled potential acidifying input (PAI) data were used to assess the baseline and application cases for the Project. For the baseline case, published data for the region indicates the grid cell ,which includes the RSA and LSA and all surrounding grid cells, have current levels of acid input (PAI) below the critical load of 0.50 keq H^+/(ha•y) for soils moderately sensitive to acid input (Figure 2.5-13). For the application and cumulative effects cases, the predicted average PAI values associated with emissions from the Project and neighbouring Canexus sodium chlorate plant are 0.04 keq H^+/(ha•y) at the Site boundary (see Volume IIA, Section 2: Climate and Air Quality – Figure 2.5-13) and, are therefore, below the critical load of 0.50 keq H^+/(ha•y) for soils which are moderately sensitive to acid input.

An analysis of potential dry deposition effects of the Project on soil quality was also conducted. Based on the Project design and mitigation measures to limit aerial dispersal of elemental sulphur, it is expected the majority of impacts to soil from dry deposition of elemental sulphur will occur within the PDA, where soils are rated as having a low sensitivity to acid deposition. Based on sulphur deposition modelling data presented in Volume IIA, Section 2: Climate and Air Quality – Figure 2.5-14, the maximum average predicted annual deposition of sulphur at the Site boundary will be 1.11 kg/ha/y. This rate of deposition is expected to be negligible, especially when compared to the acidifying effects of current agricultural practices of ammonia-based fertilizer application in the region. For soils within the PDA where dry deposition effects are expected to be significant, changes to the chemical composition of the soils will occur within timescales (i.e., years) that allow for detection by a periodic soil monitoring program and the changes may be reversed by an appropriate soil treatment such as lime application.

Regional soil monitoring initiatives are limited to Alberta Environmentally Sustainable Agriculture soil quality benchmark sites. No monitoring stations for this program are located in the LSA or RSA. However, data from the benchmark locations in the area may be used to provide additional baseline information for ongoing monitoring initiatives for the Project.

e) identify any activities associated with the Project, which may cause soil contamination or soil deterioration at the local and regional scale including acid deposition and discuss mitigation strategies to reduce potential impact; and

Table ES-1 summarizes the potential impacts to soil from the Project and the proposed associated mitigation strategies:

Table ES-1: Potential Impacts to Soil and Proposed Mitigation Strategies

Potential Issue	Proposed Mitigation Strategies
Changes to Agricultural Land Capability	
Project impacts to agricultural land capability	Proper soil handing and storage as outlined in Volume IID: Section 2: Land Use and Reclamation – Appendix I: C&R Plan
Potential effects on Soil Quality	
Soil admixing	Proper soil handing and storage as outlined in Volume IID: Section 2: Land Use and Reclamation and Appendix I: C&R Plan
Soil compaction	Proper soil handing and storage as outlined in Volume IID: Section 2: Land Use and Reclamation and Appendix I: C&R Plan
Soil erosion	Proper soil handing and storage as outlined in Volume IID: Section 2: Land Use and Reclamation and Appendix I: C&R Plan
Soil contamination	In the case of accidental releases of contaminants, conduct spill response, site assessment and remediation activities in keeping with regulatory requirements. Implement spill prevention and waste management plans for the site
Alteration of Soil Moisture Regime	
Project impacts to surface hydrology and shallow groundwater quantity	Install culverts and drainage controls as required for corridor facilities such as rail spurs to retain natural surface drainage and prevent water build-up
Soil Suitability for Reclamation	
Project impacts resulting in changes to soil reclamation suitability	Proper soil handing and storage as outlined in Volume IID, Section 2: Land Use and Reclamation – Appendix I: C&R Plan
Soil Acidification	
Project impacts to soil resulting from dry and wet deposition of acidic compounds	• implement engineering controls on Project equipment to limit release of acidifying compounds • store soil stockpiles away from area of potential sulphur release • establish surface water management systems to limit surface water contact around the Project with surrounding soil • establish periodic soil monitoring for both the PDA and LSA

f) *discuss the regulatory requirements for soil monitoring or soil management for potential impacts of the Project to soils in the development area and areas that may be potentially affected.*

It is expected that the Project will require the following soil monitoring programs to be implemented:

- a soil monitoring program every three years to assess the rate and locations of any increases in soil acidity compared to baseline data within and around the Site using established guidelines (AENV Air Monitoring Directive Appendix A–7: Soil Monitoring Guidelines)
- a soil monitoring program every three years for the PDA that complies with the Guideline for Monitoring and Management of Soil Contamination under Environmental Protection and Enhancement Act Approvals

2. Terrestrial Ecosystems – Soil

2.1 Introduction

This section presents the results of baseline studies and the impact assessment for soil resources as part of the EIA for the proposed Bruderheim Sulphur Forming and Shipping Facility Project (the Project). Existing information was reviewed and field studies were completed to classify, map and describe baseline soil conditions within the PDA, Soil Local Study Area (LSA) and Soil Regional Study Area (RSA). Section 2.6 presents the application case assessment with the potential Project-specific impacts on soil resources. Cumulative impacts on soil resources are considered in Section 2.7 and the impact summary is considered in Section 2.8. Mitigation measures are discussed within the application case.

2.2 Indicators and Issues

Based on the Terms of Reference (TOR) and stakeholder concerns and validated through a review of previous EIAs for the region, the following soils and terrain issues were considered in the impact assessment:

- soil and terrain alteration
- soil quality and land capability
- soil suitability for reclamation
- soil acidification resulting from acidifying emissions
- soil and terrain of restricted distribution

Soil resources will be directly and indirectly affected by the following issues associated with the Project:

- surface disturbance
- alteration of hydrogeology and hydrology
- dust deposition
- contaminant spills
- potential acid input

2.2.1 Terms of Reference

In addition to the issues provided above, the assessment also addressed issues identified in the TOR for the Project in Section 4.9.2 (Alberta Environment (AENV) 2007) as follows:

a) *Describe and map the soil types and their distribution according to the Soil Survey Handbook, Vol. 1 (Agriculture Canada, 1987) and The Canadian System of Soil Classification Third Edition (Agriculture and Agri-Food Canada, 1998) including the following soil survey intensity levels;*

   i. *SIL (survey intensity level) 1 for the PDA area and any areas that may be subject to future disturbance by the Project such as borrows, rail spurs, access roads etc;*

   ii. *SIL 2 for the Local Study Area; and* *iii. Appropriate level of detail to determine the effect of the Project on soil types and quality in the Regional Study Area.*

b) characterize the pre-disturbance morphological, physical and chemical properties of the soil types and assess the pre-disturbance soil capability classes;

c) develop a soil conservation and reclamation plan for the PDA including re-vegetation and weed management plans. Describe the suitability and availability of soil materials within the Study Areas for reclamation. Outline the criteria to be used in salvaging and storing soils. Describe the procedures for soil handling storage and long-term management of soil intended for reclamation within the PDA. Provide siting criteria for and location of soil stockpiles and describe how they will be managed;

Please note that this point of the TOR is addressed in Volume IID: Section 2: Land Use and Reclamation – Appendix I: C&R Plan.

d) assess the sensitivity of local and regional soils to acidic deposition by:

including baseline information as outlined in Appendix A-7 (Soil Monitoring Guidelines) of AENV's Air Monitoring Directive (1996);

i. Discussing sensitivity of soils to wet and dry acidic deposition in the local and regional study areas for baseline, application and cumulative scenarios;

ii. Explaining the methods used to assess sensitive soils and include information from grid cell sensitivity assessments that may be available for the study area;

iii. Using modeled PAI for the baseline, application and cumulative scenarios, describe the soils that would exceed CASA's recommended critical loads in the Local and Regional Study areas, including maps showing their spatial distribution;

iv. Outlining any existing monitoring information such as AENV's long term soil acidification study and any regional initiatives (NCIA) for acidic deposition.

e) identify any activities associated with the Project, which may cause soil contamination or soil deterioration at the local and regional scale including acid deposition and discuss mitigation strategies to reduce potential impact; and

f) discuss the regulatory requirements for soil monitoring or soil management for potential impacts of the Project to soils in the development area and areas that may be potentially affected.

2.3 Methods

2.3.1 Spatial and Temporal Boundaries

The EIA study areas comprise the spatial boundaries described below. Temporal boundaries include construction, operation and reclamation periods of activity.

2.3.1.1 <u>Principal Development Area (PDA)</u>

The proposed Project will be developed in the Principal Development Area (PDA), on a portion of Section 35-55-20 W4M (the Site), which comprises the area of disturbance and development. The PDA is equivalent to the Project footprint, which includes the direct footprint of the proposed facility and associated infrastructure and is 24.8 ha in size. All infrastructure and activities will be confined to the Site. The PDA, shown in Figure 2.3-1, consists of:

- rail and road access for receiving and shipping sulphur
- liquid sulphur unloading and transfer facilities
- sulphur forming facilities to produce sulphur pastilles
- loading and shipping facilities for formed sulphur
- a sulphur pastilles temporary storage area

2.3.2 Local Study Area

The Soil LSA includes the PDA and those areas that can reasonably expect to be affected by emissions associated with the proposed Project. The LSA has been established as the Site, plus a 200 m buffer, extending around the section (see Figure 2.3-1). The total geographic extent of the LSA is 407.4 ha (see Figure 2.3-1). Due to their common ecological relationships, the LSA is the same for the soil, vegetation, wildlife and biodiversity components (see Volume IIC, Section 3: Vegetation, Section 4: Wildlife and Section 5: Biodiversity and Fragmentation). For discussion specific to acidifying impacts to soil from air emissions, the results of air dispersion modelling (see Volume IIA, Section 2: Climate and Air) indicate that impacts are confined to the Site boundary.

2.3.3 Regional Study Area

The Soil RSA was identified and used to assess impacts on soils from a regional and cumulative effects perspective. The RSA is the Site plus a 1,000 m buffer (see Figure 2.3-1). The RSA is the same for the soil, vegetation, wildlife and biodiversity components (see Volume IIC, Section 3: Vegetation, Volume IIC, Section 4: Wildlife and Volume IIC, Section 5: Biodiversity and Fragmentation).

2.3.3.1 Temporal Boundaries

Three temporal boundaries are used in this assessment: baseline, application and closure. Baseline refers to the present conditions in the LSA and RSA as of November 2006. Application is assessed at maximum disturbance. This approach determines the impact of the Project as if all facilities were fully developed and operational at the same time. Therefore, impact predictions during the application case are considered worst case and conservative. Closure is considered when all Project facilities have been decommissioned and reclamation has taken place. The assumed lifetime of the Project is 25 years. It is assumed that closure occurs five years after decommissioning and reclamation, therefore, vegetation has been planted or seeded and has had time to establish.

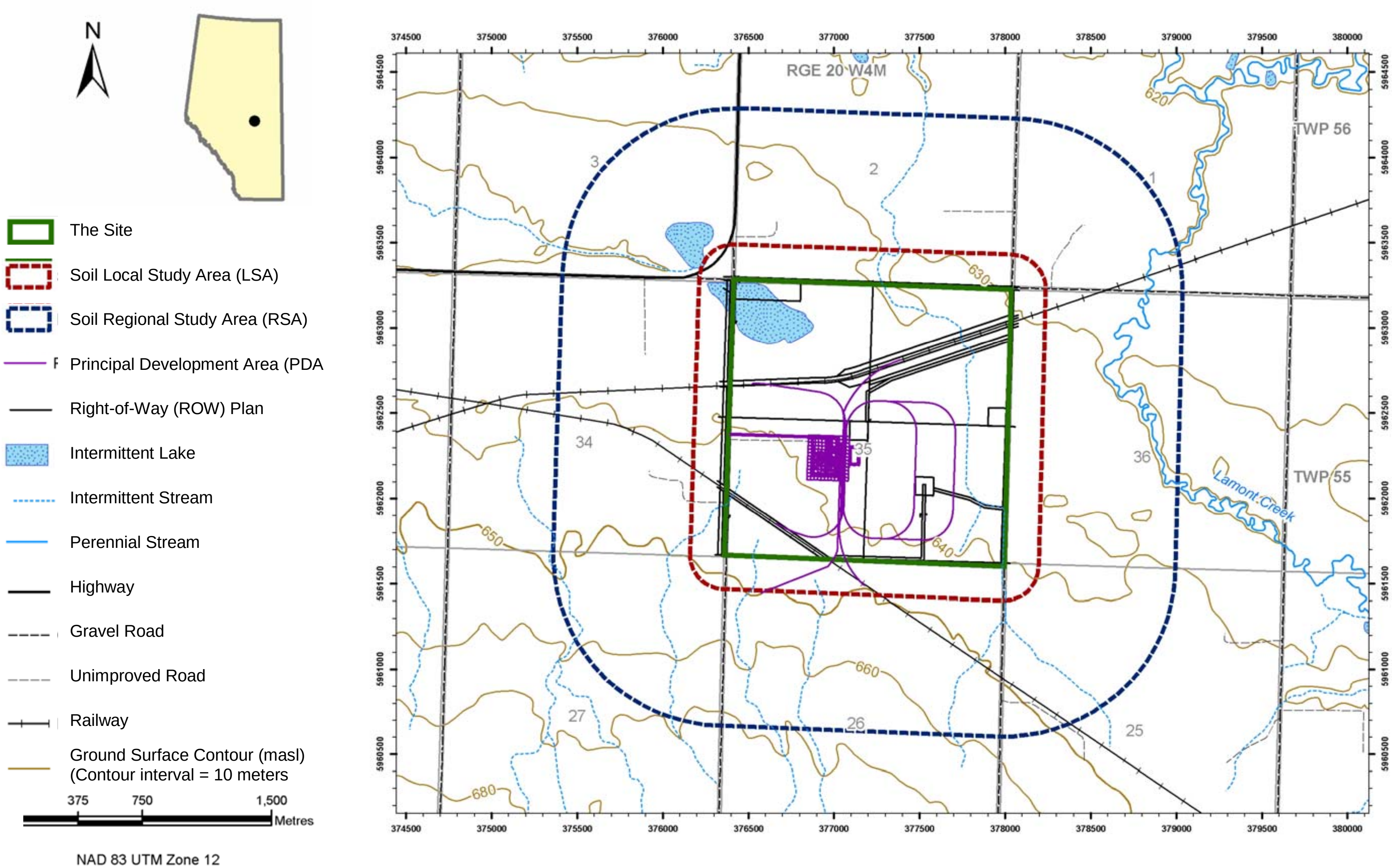

Figure 2.3-1: Soil PDA, LSA and RSA

2.3.3.2 Project Inclusion List

The project inclusion list includes the various anthropogenic disturbances on the landscape that must be included in each assessment case in order to effectively determine Project and cumulative effects. Table 2.3-1 provides the list of projects included in each case.

Table 2.3-1: Project Inclusion List

Status	Baseline Case	Application Case	Cumulative Effects Case
Existing and Approved	Canexus Chemicals	Canexus Chemicals	Canexus Chemicals
	ERCO Worldwide	n/a	n/a
	Triton	Triton	Triton
Project	n/a	Bruderheim Sulphur Forming and Shipping Facility	Bruderheim Sulphur Forming and Shipping Facility
Planned Projects and Activities	n/a	n/a	n/a

Note:
n/a – not applicable

2.4 Baseline Data Acquisition Methods

2.4.1 Soil Mapping and Classification

Prior to the field program, existing soil survey information for the area was reviewed, including existing regional soil survey data; a 1:100,000 scale map (ASIC 2001); a 1:126,720 scale map (Bowser et al. 1962) and a 1:126,000 scale map (Crown 1977). Available soil classification and mapping information from several EIAs in the area was also reviewed including the following:

- Agrium Products Inc. Northern Extension of the Existing Gypsum Storage Area (2003)
- BA Energy Heartland Upgrader (2004)
- Shell Canada Ltd. Scotford Upgrader Expansion Project (2005)
- North West Upgrading Inc. Northwest Upgrader Project (2006)
- Petro-Canada Oilsands Inc. Fort Hills Sturgeon Upgrader (2007)

Soil descriptions and mapping were conducted in accordance with the guidelines and procedures outlined by the Soil Survey Handbook, Vol. 1 (Agriculture Canada 1987) and The Canadian System of Soil Classification Third Edition (Agriculture and Agri-Food Canada 1998). Following soil classification to the subgroup level, soil series names were selected which conform to Soil Correlation Area (SCA) 10 of the soil names database of the Agricultural Region of Alberta Soil Inventory Database (ASIC 2001), Pedocan Land Evaluation (Pedocan 1993) and Alberta and the Alberta Soil Names File (ASIC 2006).

2.4.1.1.1 Field Program

The scope of work included field surveys encompassing the LSA conducted in October and November 2006 (for a summary of field methods, see Appendix I). A survey intensity level one (SIL 1) (Agriculture Canada 1983 and 1987), which comprises a minimum of one site per

1–5 ha, was used for the PDA, (i.e., area of planned soil disturbance). An expanded survey intensity level, SIL 2 (one site per 2–20 ha, Agriculture Canada 1987), was performed for the remaining LSA.

2.4.1.1.2 Soil Sampling and Laboratory Analysis

Soil samples were collected and analyzed at specific sites for the following purposes:

- to identify diagnostic horizons (i.e., Bnt) and confirm soil subgroup classification
- to verify soil series identified during the field inspection
- to provide data to assess soil quality for reclamation suitability
- to provide baseline information for soil monitoring in the PDA and LSA
- to provide data for land use interpretation

Specific soil sampling methods and analytical parameters are listed in Appendix II.

Site inspection data is provided in Appendix III.

2.4.1.1.3 Soil Map Development

The information collected, in combination with air photo interpretation, was used to extrapolate soil and terrain classifications onto map units for the LSA. Polygons were established through air photo interpretation. Although only one soil map unit is assigned to each polygon, it is possible that a polygon may consist of a dominant soil series with inclusions of other soil series; however, in order to create a clear and concise soil map of the LSA, only the dominant soil series was attributed to each polygon. For the RSA, existing regional mapping data (ASIC 2001, Bowser et al. 1962 and Crown 1977) was used.

2.4.1.2 Terrain Mapping

Terrain classification is an interpretation of landforms which is based on the attributes of parent geologic materials and surface expression. Terrain mapping integrated data from existing geologic sources with baseline survey information collected during the study. Geologic information applicable to terrain mapping included:

- Quaternary Geology, Central Alberta (Shetsen 1990)
- Geological Map of Alberta (Hamilton et al. 1999)
- Surficial Geology, Edmonton NTS 83H (Bayrock 1972)

Terrain map unit delineation of the LSA and RSA involved assigning a terrain map unit for each soil map unit based on parent geologic material. Terrain map units were queried from soil mapping data using GIS software, and where possible, merged into larger polygons. For example, all adjacent soil map units developed on glaciolacustrine sediments were merged into a single glaciolacustrine terrain map unit.

2.4.1.3 Soil Quality and Land Use Interpretations of Map Units

Based on the results of the soil and terrain survey of the LSA and RSA, land capability for agriculture and soil suitability for reclamation were interpreted and potential soil issues such as soil sensitivity to acidification and soil erosion were addressed.

2.4.1.3.1 Land Capability for Agriculture

Agricultural land capability was determined for the LSA. The agricultural capability of each agricultural soil series was rated according to the Land Suitability Rating System for Agricultural Crops (Agriculture and Agri-Food Canada 1995).

This agricultural rating system is based on an 'expert system' approach that uses available data, the knowledge of people involved with land science and the rating of land suitability from crop production throughout Canada. The system was initially designed for evaluating suitability of land to grow spring-seeded small grains (wheat, barley and oats) but can be used for all crop production. The system rates climate, soil and landscape factors independently as each factor can control the suitability of land for crops. Each factor is assigned a rating between 0–100 and the final rating is based on the most limiting of the three factors. The system has two categories: "Classes" based on the degree of limitation of land productivity and "Subclasses" based on the kind of limitations. There are seven Classes that reflect agricultural capability (see Table 2.4-1). The limitations associated with the subclasses are described in Table 2.4-2.

Table 2.4-1: Agricultural Capability Classes

Agricultural Capability Rating	Index Points	Degree of Limitation
Class 1	80-100	None to slight: land in this class has no significant limitations for production of the specified crop
Class 2	60-79	Slight: land in this class has slight limitation that may restrict the growth of the specified crops or require special management practices
Class 3	45-59	Moderate: land in this class has moderate limitations that restrict the growth of the specified crops or requires special management practices
Class 4	30-44	Severe: land in this class has severe limitations that restrict growth of the specified crops or require special management practice or both. This class is marginal for sustained production of the specified crops.
Class 5	20-29	Very Severe: land in this class has very severe limitations for sustained production of the specified crops. Annual cultivations using common cropping practices is not recommended.
Class 6	10-19	Extremely severe: land in this class has extremely severe limitations for sustained production of the specified crops. Annual cultivation is not recommended even on an occasional basis.
Class 7	0-9	Unsuitable: land in this class in not suitable for the production of the specified crops
Not rated	n/a	Forested areas were not rated for agricultural capability
Source: Agriculture and Agri-Food Canada (1995).		

Table 2.4-2: Agricultural Capability Subclasses

Agricultural Capability Subclass	Kind of Limitation
C – Climate	A general climatic restriction
H – Temperature	Indicates inadequate heat units for optimal growth of the specified crops
A – Moisture	Indicates inadequate moisture for optimal growth of the specified crops
S – Soils	A general soil restriction
M – Water holding capacity or texture	Indicates land areas where the specified crops are adversely affected by lack of water due to inherent soil characteristics
D – Soil structure	Indicates land areas where the specified crops are adversely affected by soil structure that limits the depth of rooting, or by surface crusting that limits the emergence of shoots. Root restriction by bedrock and high water table are considered separately (see Rock and Drainage)
F – Organic mater	Indicates mineral soil with a low organic matter content in the Ap or Ah horizon (often considered a fertility factor)
E – Depth of topsoil	Indicates mineral soil with a thin Ap or Ah horizon (often resulting from erosion)
V – Soil reaction	Indicates soils with a pH value either too high or too low for optimum growth of the specified crops
N – Salinity	Indicates soils with amounts of soluble salts sufficient to have an adverse effect on the growth of the specified crops
Y – Sodicity	Indicates soils having amounts of exchangeable sodium sufficient to have adverse effect on soil structure or on the growth of the specified crops – its use is restricted to reconstructed soils
O – Organic surface	Indicates mineral soils having a peaty surface layer up to 40 cm thick
W – Drainage	Indicates soils in which excess water (not due to inundation) limits the production of specified crops. Excess water may result from a high water table or inadequate soil drainage
Z – Organic soil temperature	This subclass recognizes the additional temperature limitation associated with organic soils – particularly where the regional climate has less than 1,600 Effective Growing Degree Days (EGDD)
R – Rock	Indicates that soils with bedrock sufficiently close to the surface have an adverse effect on production of the specified crops
B – Degree of decomposition or fibre content	Identifies organic soils in which the degree of decomposition of the organic material is not optimum for production of the specified crops
G – Depth and substrate	Indicates shallow organic soils with underlying material that is not optimum for production of the specified crops
L – Landscape	A general landscape restriction
T – Slope	Indicates landscapes with slopes steep enough to incur a risk of water erosion or limit cultivation
K – Landscape pattern	Indicates land areas with strongly contrasting soils and/or non-arable obstacles that limit production of the specified crops or substantially impact on management practices
P – Stoniness and coarse fragments	Indicates land that is sufficiently stony or gravely so as to hinder tillage or limit the production of specified crops

Source: Agriculture and Agri-Food Canada (1995).

2.4.1.4 Soil Suitability for Reclamation

Reclamation suitability ratings for the topsoil (i.e., A horizon(s)) and subsoil (i.e., B horizon(s) and upper portion of the parent material) of soils mapped for the LSA were determined using the method outlined in Soil Quality Criteria Relative to Disturbance and Reclamation (Macyk et al. 1987). These ratings identify information useful in formulating soil handling recommendations; however, as these criteria were developed strictly for mineral soils they are not applicable to organic soils. For this reason, suitability ratings for organic soils were not evaluated. Suitability ratings are determined by comparing the chemical and physical parameters of topsoil and subsoil to the suitability criteria as outlined in Table 2.4-3. A summary of reclamation suitability ratings is presented in Table 2.4-4.

Table 2.4-3: Criteria for Evaluating Suitability of Topsoil in the Plains Region

Property	Rating			
	Good (G)	**Fair (F)**	**Poor (P)**	**Unsuitable (U)**
Reaction (pH)	6.5–7.5	5.5–6.4 and 7.6–8.4	4.5–5.4 and 8.5–9.0	<4.5 and >9.0
Salinity (EC) (dS/m)	< 2	2–4	4–8	> 8
Sodicity (SAR)	<4	4–8	8–12	> 12[1]
Saturation (%)	30–60	20–30 or 60–80	15–20 or 80–120	< 15 or > 120
Stoniness class	S0, S1	S2	S3, S4	S5
Texture	FSL, VFSL, L, SL, SiL	CL, SCL, SiCL	LS, SiC, C[2], S, HC[3]	
Moist consistency	Very friable, friable	Loose	Firm, very firm	Extremely firm
Organic carbon (%)	>2	1–2	<1	
$CaCO_3$ equivalent (%)	<2	2–20	20–70	>70

Notes:

[1] Material characterised by an SAR of 12–20 may be rated as poor if texture is sandy loam or coarser and saturation % <100.

[2] C – may be upgraded – fair or good in some arid areas.

[3] HC – may be upgraded – fair or good in some arid areas.

Source: Macyk et al. 1987.

Table 2.4-4: Description of Reclamation Suitability Ratings for the Plains Region of Alberta

Reclamation Suitability Rating	Description
Good	None to slight soil limitations that affect plant growth
Fair	Moderate soil limitations; can be overcome by proper planning and good management
Poor	Severe soil limitations that make use questionable; careful planning and very good management are required
Unsuitable	Chemical or physical soil properties are so severe that reclamation is not possible or economically feasible

Source: Macyk et al. (1987).

2.4.1.5 Soil Erosion Risk

Water and wind erosion are naturally occurring, land forming processes but may be accelerated due to Project activities. Water erosion risk ratings were determined by applying the modified Universal Soil Loss Equation (USLE; Tajek et al. 1985). Soil water erosion risk classes and their potential annual soil loss are shown in Table 2.4-5. The erosion risk calculator provided in Tajek et al. (1985) was used to determine water erosion risk potentials for each soil map unit in the LSA. This rating system has also been applied by Pedocan (1993) by applying water erosion potentials to the Alberta Soil Inventory Database, which has since been updated (ASIC 2001).

Table 2.4-5: Water Erosion Risk Classes and Potential Annual Soil Losses

Water Erosion Risk Potential Class	Category	Potential Loss (t ha^{-1} yr^{-1})
1	Negligible	< 6
2	Slight	6–11
3	Moderate	11–22
4	Severe	22–33
5	Very severe	33–55
6	Extreme	> 55
Source: Tajek et al. (1985).		

Wind erosion risk ratings were assigned for each soil series mapped in the study based on the methodology described in Coote and Pettapiece (1989) and simplified by Pedocan (1993) by applying wind erosion potentials to the Alberta Soil Inventory Database, which has since been updated (ASIC 2001). The model predicts that sandy textured surface soil is the most susceptible to wind erosion, while silt textured soil is the least susceptible. Furthermore, soils which are moist or wet, or have a high surface stoniness, are at a low risk to wind erosion. Variables which could be affected by development and subsequently alter the risk of wind erosion on specific soils, have also been considered.

2.4.1.6 Soil Sensitivity to Acidification

The potential effects of soil acidification include:

- reduction of soil base saturation
- increase in the availability of aluminum (base cation:aluminum ratio) in the soil solution to levels that are toxic to plants
- change in soil fertility and nutrient cycling

Soils vary in terms of sensitivity to acidifying inputs depending on a range of related soil properties including pH, texture, organic matter content, carbonate content and cation exchange capacity (CASA and AENV 1999).

2.4.1.6.1 Potential Acid Inputs

The degree to which soils are affected by acid deposition is determined by the soil sensitivity as well as the degree of acid loading of the soil. CASA and AENV (1999) discuss acid loading rates in terms of Potential Acid Inputs (PAI). In this document, PAI is presented in keq H^+/(ha•y), the equivalent mass of hydrogen ions (acid) deposited on each hectare of land per year, and is calculated using the RELAD model, which simulates ground-level ambient concentrations and wet and dry deposition of SO_2, H_2SO_4, $(NH_4)_2SO_4$, NO_x (NO_2 and NO), HNO_3 and NH_4NO_3 (CASA and AENV 1999) using available ambient and point-source emissions data and meteorological inputs. CASA and AENV (1999) have established critical load guidelines for each soil sensitivity rating of Low (L), Moderate (M) or High (H). The critical load is a numerical expression of the maximum level of deposition that does not lead to long-term, harmful changes to a receptor. For Alberta, CASA and AENV (1999) established critical loads of 0.25, 0.5 and 1.0 keq H^+/(ha•y) for soils with H, M and L sensitivity ratings, respectively (see Table 2.4-6).

Table 2.4-6: Potential Acid Input Guidelines in Alberta

Air Emission	Alberta Environment Guidelines	
	Sensitivity	Critical Load keq H^+/(ha•y)
PAI deposition (annual)	Highly sensitive soils	0.25
	Moderately sensitive soils	0.50
	Low sensitivity soils	1.00

2.4.1.6.2 Mineral Soil Sensitivity

For mineral soils, sensitivity to acid deposition was rated using the criteria described by Holowaychuck and Fessenden (1987). This system establishes ratings of L, M and H for soil sensitivity to base saturation loss, acidification and aluminum solubilization based on the cation exchange capacity and pH of surface soils (see Table 2.4-7). For each soil map unit in the LSA, ratings for each individual acidification parameter and for overall sensitivity were calculated, based on soil analytical data and published soil chemical properties (ASIC 2001; Pedocan 1993).

Table 2.4-7: Criteria Rating the Sensitivity of Mineral Soils to Acidic Inputs

CEC[1]	pH	Sensitivity to:			Overall Sensitivity
		Base Loss	Acidification	Aluminium Solubilization	
<6	<4.6	H	L	H	H
	4.6–5.0	H	L	H	H
	5.1–5.5	H	M	H	H
	5.6–6.0	H	H	M	H
	6.1–6.5	H	H	L	H
	>6.5	L	L	L	L
6–15	<4.6	H	L	H	H
	4.6–5.0	M	L	H	M
	5.1–5.5	M	L–M	M	M
	5.6–6.0	M	L–M	L–M	M
	>6.0	L	L	L	L

Note:
[1] Cation Exchange Capacity (meq/100g).
Source: Holowaychuck and Fessenden (1987).

Table 2.4-7: Criteria Rating the Sensitivity of Mineral Soils to Acidic Inputs (Cont'd)

CEC[1]	pH	Sensitivity to:			Overall Sensitivity
		Base Loss	Acidification	Aluminium Solubilization	
>15	<4.6	H	L	H	H
	4.6–5.0	M	L	H	M
	5.1–5.5	M	L	M	M
	5.6–6.0	L	L–M	L–M	L
	>6.0	L	L	L	L

Note:
[1] Cation Exchange Capacity (meq/100g).
Source: Holowaychuck and Fessenden (1987).

2.4.1.6.3 *Organic Soil Sensitivity*

For organic soils, Turchenek et al. (1998) developed a rating system that provides overall ratings for sensitivity to acid deposition based on the trophic (i.e., nutrient) status of the peatland in which the organic soils have developed. The system rates extreme rich fens and moderate rich fen soils as having low sensitivity and critical loading PAI values greater than 0.5 keq H^+/(ha•y) and poor fen and bog soils as having moderate sensitivity and critical loading PAI values between 0.25–0.5 keq H^+/(ha•y).This rating system has been applied to organic soil map units in the LSA and RSA.

2.5 Baseline Scenario

2.5.1 Baseline Case

The baseline case describes surficial geology, soils and terrain and provides soil and landscape quality interpretations (land capability for agriculture, soil suitability for reclamation, soil acidification and soil erosion risk) for the LSA and RSA.

2.5.1.1 *Surficial Geology*

2.5.1.1.1 *Regional and Local Study Area*

The RSA and LSA are situated in the Central Parkland Natural Subregion of the Parkland Natural Region (Natural Regions Committee (NRC) 2006). A more detailed description of the Central Parkland Natural Subregion can be found in the vegetation report (see Volume IIC, Section 3: Vegetation). The RSA and LSA are located within the Daysland Plain and Leduc Plain districts of the Sullivan Lake Plain Section of the Eastern Alberta Plain physiographic region. The landforms are described as morainal (till) blankets and veneer deposits in addition to morainal deposits with a glaciolacustrine veneer, ranging in elevation from approximately 650–850 masl (Pettapiece 1986).

The main surficial geology units characterized for the RSA and LSA include stagnation moraine (till) modified by lake and stream erosion and of Pleistocene origin. A small area of organic deposits of recent origin also occurs in the LSA and RSA (Shetsen 1990 and Bayrock 1972). The stagnation moraine is described as till of uneven thickness, that was locally water sorted and is up to 30 m thick. The undulating topography reflects variation in till thickness. Organic deposits are described as peat occurring in wetland areas and are generally less then 1 m thick. The moraine is composed of approximately equal proportions of sand, silt and clay but generally contains less than 10% gravel. Where the recent organic deposits overlay the glaciolacustrine deposits, the organic thickness is less then 1 m. In some locations, glaciolacustrine and glaciofluvial deposits overlay the moraine. These deposits are generally less than 1 m thick and are composed of silts and clays (glaciolacustrine) or sands (glaciofluvial). More detailed information on surficial geology can be found in Volume IIB, Section 3: Surface Water Quantity and Section 4: Surface Water Quality.

The bedrock unit of the LSA is mainly of late Cretaceous age and is comprised of the Belly River Formation, Bearpaw Formation and Horseshoe Canyon Formation (Hamilton et al. 1998). Additional information on bedrock geology is available in Volume IIB, Section 2: Groundwater Quantity and Quality.

2.5.1.2 Soils

In the following sections, the type, geographic extent and area approximated to the nearest hectare of each soil series identified in the LSA and RSA based on field and existing mapping data, is described. However, the actual geographic extent of each soil series is expected to vary somewhat because soils are a continuum within the landscape.

2.5.1.2.1 Principal Development Area and Local Study Area

A total of 20 inspections sites were undertaken in the PDA. Inspections were completed within 50 m of the PDA boundary, because a final PDA location was not available at the time the field survey was completed. The resultant inspection intensity was approximately one inspection per 1.2 ha. A total of 60 inspection sites were undertaken throughout the LSA resulting in an inspection intensity of approximately one inspection per 7 ha (see Figure 2.5-1 and Figure 2.5-2). Three inspection plots were completed in the RSA, due to access restrictions in parts of the LSA. These locations were selected to be as representative as possible of conditions inside restricted portions of the LSA. A SIL 2 survey was undertaken within the LSA where possible and a SIL 1 was completed in the PDA. Field surveys were completed during October and November 2006.

Detailed descriptions of the soil series described in the LSA and soil inspection site data are provided in Appendix II and Appendix III. A summary of the soil series identified during the soil survey and associated characteristics is shown in Table 2.5-1.

A baseline soil series map of the LSA (1:20,000) is presented in Figure 2.5-3. The geographic extent and proportion of each soil series with respect to the LSA are presented in Table 2.5-2. Mineral soils (including reclaimed soils) constitute approximately 85.8% of the LSA, while 3.2% is comprised of organic soils. The remaining portion of the LSA (11.0%) is comprised of non-soil units (disturbed lands or water bodies). Mineral soils are comprised of Solonetzic (32.9% of LSA), Chernozemic (26.4%), Gleysolic (1.0%) and Mesisols (3.2%); 25.5% of the LSA was found to be previously reclaimed and soils in this area were classified as reclaimed soils.

Table 2.5-1: Soil Series Characteristics in the LSA

Soil Series	Series Code	Subgroup Classification	Parent Material	Soil Characteristics
Angus Ridge	AGS	Eluviated Black Chernozem	Morainal	Moderately fine textured, non-saline and moderately calcareous formed on Edmonton Formation Till
Camrose	CMO	Black Solodized Solonetz	Morainal	Moderately fine, moderately saline and calcareous formed on Edmonton Formation Till
Camrose-gleyed	CMOgl	Gleyed Black Solodized Solonetz	Morainal	Moderately fine, moderately saline and calcareous formed on Edmonton Formation Till, gleyed(gl)
Duagh-till, gleyed	DUGxtgl	Gleyed Black Solonetz	Glaciofluvial underlain by Morainal	Fine glaciolacustrine veneer, moderately saline and weak to moderately calcareous underlain by till (xt) within 99 cm of the surface, gleyed (gl)
Hobbema	HBM	Eluviated Black Chernozem	Glaciolacustrine underlain by Morainal	Medium textured glaciolacustrine veneer underlain by medium to fine textured till, non to weakly saline and moderately calcareous
Hobbema-gleyed	HBMgl	Gleyed Eluviated Black Chernozem	Glaciolacustrine underlain by Morainal	Medium textured glaciolacustrine veneer underlain by medium to fine textured till, non to weakly saline and moderately calcareous, gleyed (gl)
Haight	HGT	Orthic Humic Gleysol	Glaciolacustrine	Fine textured water-laid sediments that are non-saline and moderately calcareous
Hairy Hill	HYL	Rego Humic Gleysol	Morainal	Medium textured till sediments that are moderately saline and calcareous, this soil is associated with discharge areas
Manatokan-AA	MNTaa	Terric Mesisol	Organic (Fen Peat) underlain by glaciolacustrine	40–100 cm mesic fen peat developed on moderately fine textured sediments that are weakly calcareous
Peace Hills	PHS	Orthic Black Chernozem	Glaciofluvial	Moderately coarse textured, non-saline and weakly calcareous
Peace Hills-gleyed	PHSgl	Gleyed Black Chernozem	Glaciofluvial	Moderately coarse textured, non-saline and weakly calcareous, gleyed (gl)
Ponoka	POK	Eluviated Black Chernozem	Glaciolacustrine	Medium textured, non to weakly-saline and moderately calcareous

Note:
[1] Differs from the area of anthropogenic disturbance defined for other sections (e.g., Vegetation, Wildlife).

Table 2.5-1: Soil Series Characteristics in the LSA (Cont'd)

Soil Series	Series Code	Subgroup Classification	Parent Material	Soil Characteristics
Wetaskiwin	WKN	Black Solodized Solonetz	Glaciolacustrine	Fine textured, moderately saline and weakly calcareous
Wetaskiwin-till	WKNxt	Black Solodized Solonetz	Glaciolacustrine underlain by Morainal	Fine textured, moderately saline and weakly calcareous, underlain by till (xt) within 99 cm of the surface
Wetaskiwin-sand	WKNxs	Black Solodized Solonetz	Glaciolacustrine underlain by glaciofluvial	Fine textured, moderately saline and weakly calcareous underlain by sand (xs) within 99 cm of the surface
Reclaimed Area	RS	Reclaimed profiles	Morainal (90% of the area) with minor Glaciofluvial and Glaciolacustrine subunits	Fine to medium textured, non to weakly saline, weak to moderately calcareous
Non-soil Units[1]				
Disturbed	DL	Variable disturbed soils	Variable disturbed parent material	Anthropogenic activities resulting in variable soil material
Water	W	-	-	Open water bodies (ponds, creeks, rivers)

Note:
[1] Differs from the area of anthropogenic disturbance defined for other sections (e.g., Vegetation, Wildlife).

2.5.1.2.2 Reclaimed Soils – Local Study Area

Reclaimed soil profiles were investigated during the soil assessment in the area between the two existing rail lines (see Figure 2.5-3). The determination that these profiles were reclaimed came from a variety of historical sources and field observation and was confirmed in communication with area landowners. A historical air photo review of the LSA indicated that an area had been cleared for development and surface soils stripped prior to 1981 and then reclaimed before 1985.

A historical record search indicated that one reclamation certificate (Certificate 55-9806; Environmental Law Centre 2007) was issued within the LSA. The former wellsite located at 09-NE 35-55-20 W4M was certified in 1991. The historical search did not indicate any reclamation certification for the remainder of the LSA.

Field observation indicated a variety of characteristics that correspond to reclaimed soil profiles in the LSA. These observations include abrupt changes between topsoil and lower subsoil layers, admixing of topsoil and subsoil and lack of soil structure in the upper subsoil.

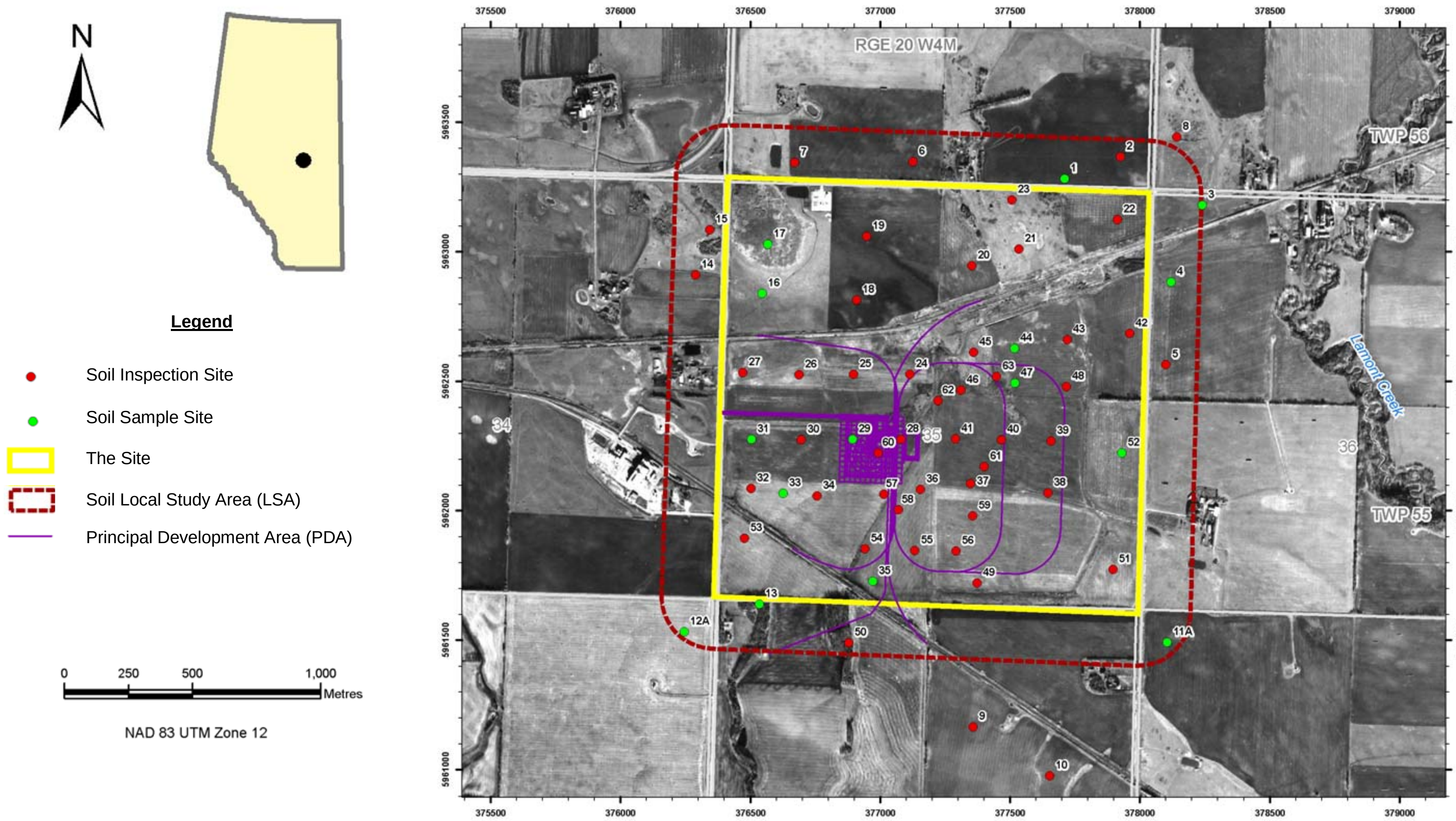

Figure: 2.5-1: Soil Inspection and Sampling Locations in the Soils LSA

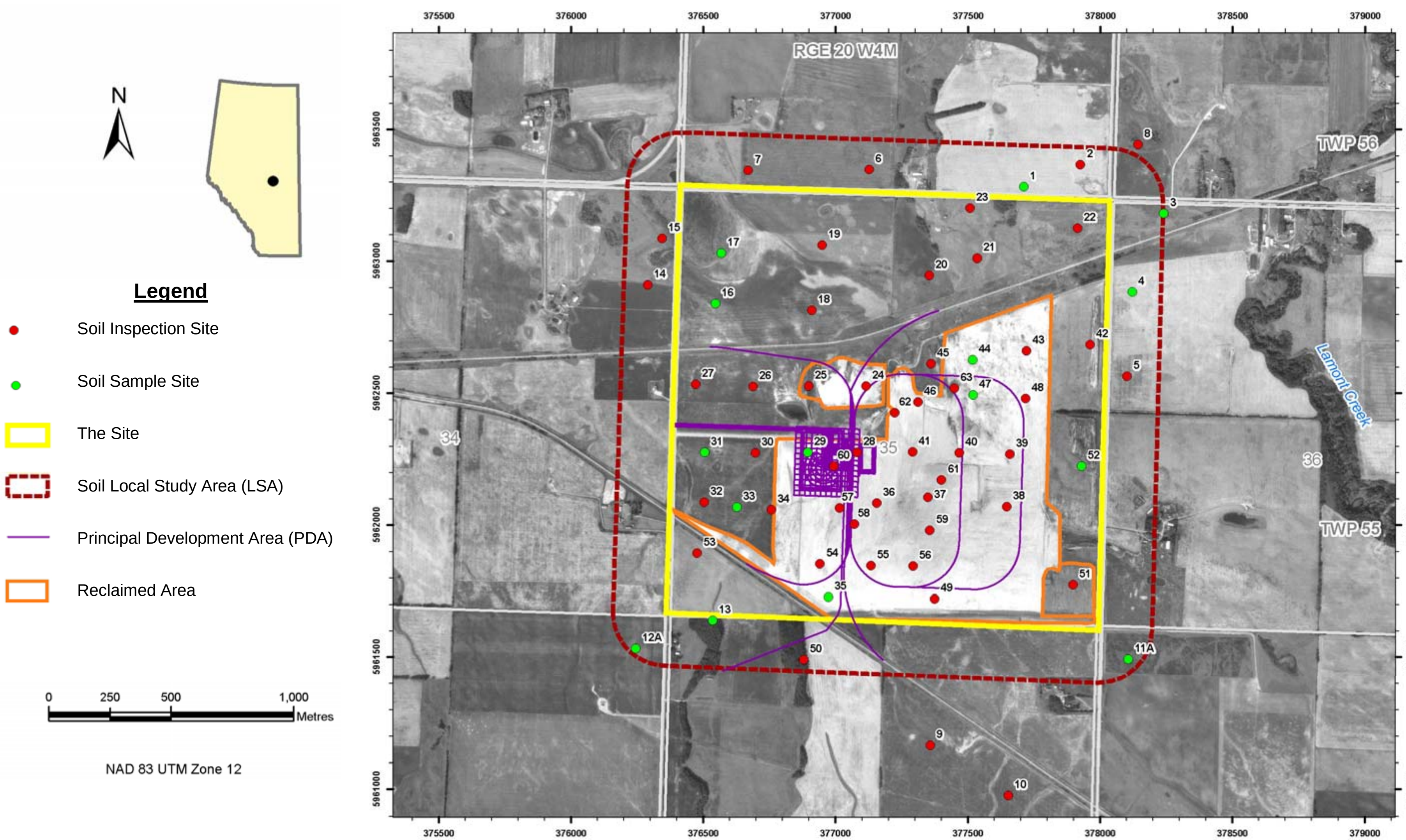

Figure 2.5-2: Soil Inspection and Sampling Locations with 1982 Air Photo Showing Previously Reclaimed Areas in the LSA

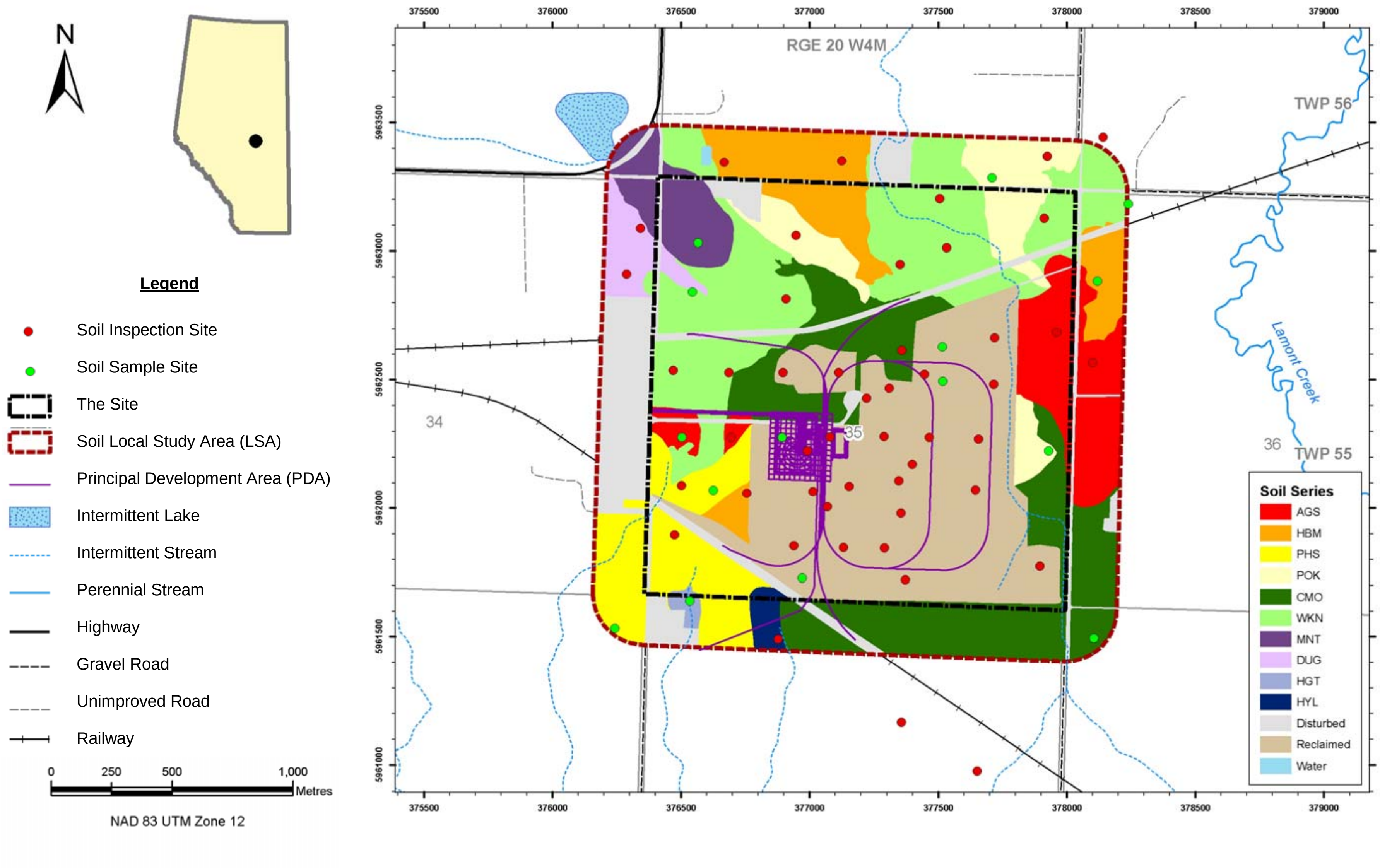

Figure 2.5-3: Soil Series in the LSA

Table 2.5-2: Extent of Soil Units in the LSA

Soil Unit[1]	Series or Variant Code	LSA	
		Area (ha)	% of LSA
Mineral Soils			
Angus Ridge	AGS	27.7	6.8
Camrose	CMO	58.9	14.5
Duagh	DUG	7.9	2.0
Hobbema	HBM	28.0	6.9
Haight	HGT	1.4	0.3
Hairy Hill	HYL	2.8	0.7
Peace Hills	PHS	29.3	7.2
Ponoka	POK	22.3	5.5
Wetaskiwin	WKN	67.3	16.5
Reclaimed Soils	RS	104.0	25.5
Organic Soils			
Manatokan-AA	MNT	12.9	3.2
Non-soil Units[2]			
Disturbed	DL	44.6	10.9
Water	W	0.3	0.1
Total		**407.4**	**100.0**

Notes:
[1] Includes all variants.
[2] Differs from the area of anthropogenic disturbance defined for other sections (e.g., vegetation, wildlife).

The dominant soil types in the LSA are Solonetzic and Chernozemic. Reclaimed soils are also present in the LSA. Solonetzic soils have formed on parent materials where the exchange complex is or was dominated by sodium. Solonetzic soils generally have B horizons that are very hard when dry and swell to a sticky mass of low permeability when wet. The solonetzic B horizon generally has a prismatic or columnar structure. They occur on saline parent materials in association with Chernozemic soils and to a lesser extent Luvisolic and Gleysolic soils. They are generally associated with a vegetative cover of grass. Chernozemic soils are imperfectly to well-drained grassland soils having surface horizons darkened by accumulation of decomposed xerophytic or mesophytic grasses and forbs. These soils are common across the cool subarid to subhumid interior plains of Western Canada (Agriculture and Agri-Food Canada 1998).

Reclaimed soils were interpreted to be derived from either chernozemic or solonetzic soils. Characteristics from both soil types were found in the reclaimed profiles investigated in the LSA. The reclaimed profiles had very little structure or lacked structure in the horizons below the topsoil layer. Saline parent material was present in the majority of profiles. Reclaimed soils were associated with imperfectly to well-drained moisture regimes and a mix of vegetation types including: forage crops (hay), annual crops and improved pasture.

Regional Study Area

Detailed descriptions of the soil series described in the RSA are presented in Table 2.5-3. A baseline soil map of the RSA at a scale of 1:30,000 is presented in Figure 2.5-4. This information is based on the Agricultural Region of Alberta Soils Inventory Database (ASIC 2001) and is mapped at a scale of 1: 100,000.

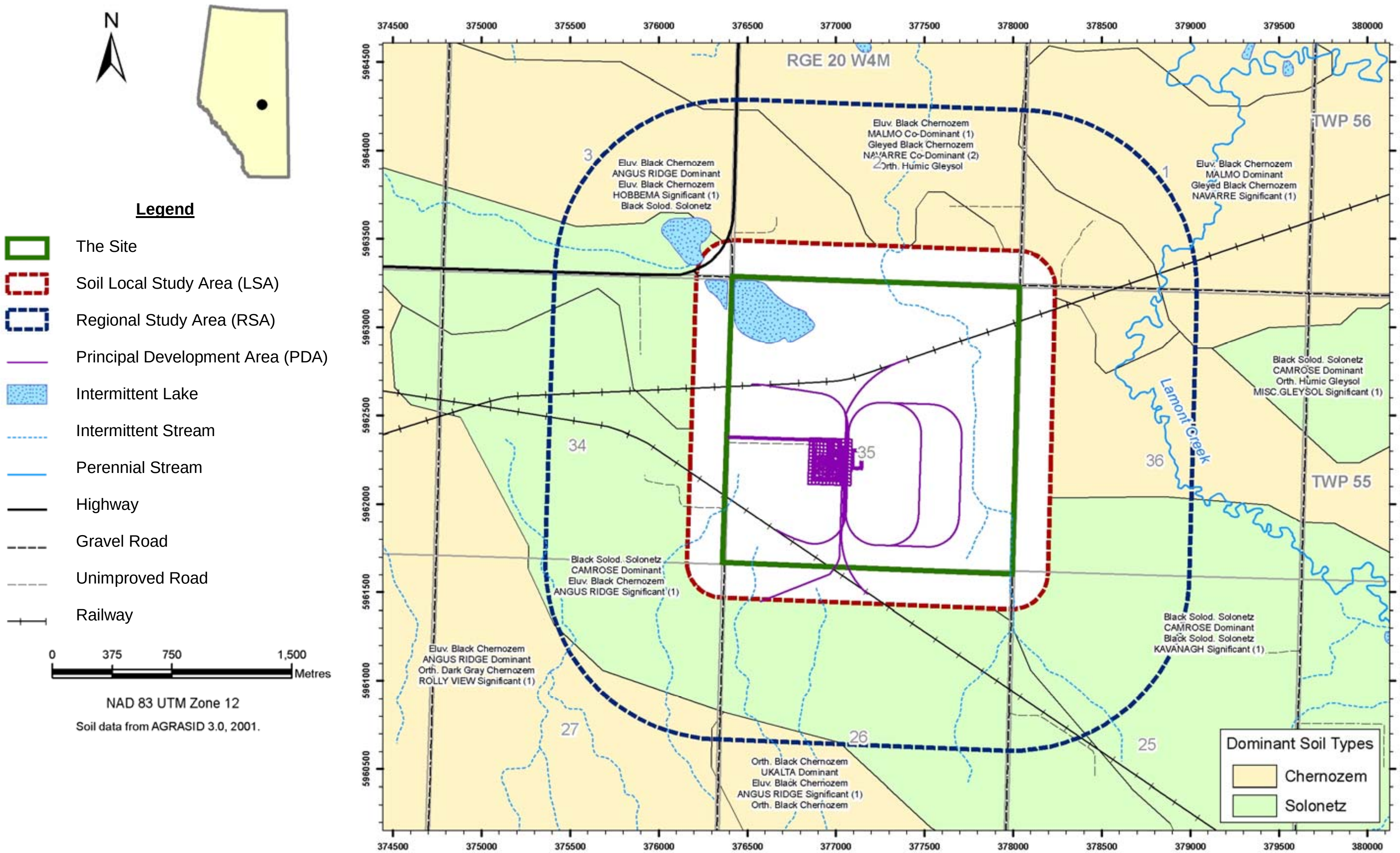

Figure 2.5-4: Soil Series in the RSA

Table 2.5-3: Soil Series Characteristics in the Project RSA

Soil Series	Series Code	Subgroup Classification	Parent Material	Soil Characteristics
Angus Ridge	AGS	Eluviated Black Chernozem	Morainal	Moderately fine textured, non-saline and moderately calcareous formed on Edmonton Formation Till
Camrose	CMO	Black Solodized Solonetz	Morainal	Moderately fine, moderately saline and calcareous formed on Edmonton Formation Till
Duagh-till, gleyed	DUGxtgl	Gleyed Black Solonetz	Glaciofluvial underlain by Morainal	Fine glaciolacustrine veneer, moderately saline and weak to moderately calcareous underlain by till (xt) within 99 cm of the surface, gleyed (gl)
Hobbema	HBM	Eluviated Black Chernozem	Glaciolacustrine underlain by Morainal	Medium textured glaciolacustrine veneer underlain by medium to fine textured till, non to weakly saline and moderately calcareous
Haight	HGT	Orthic Humic Gleysol	Glaciolacustrine	Fine textured water-laid sediments that are non- saline and moderately calcareous
Hairy Hill	HYL	Rego Humic Gleysol	Morainal	Medium textured till sediments that are moderately saline and calcareous, this soil is associated with discharge areas
Kavanagh	KVG	Black Solodized Solonetz	Weathered bedrock (Edmonton Formation)	Medium textured softrock, weakly saline and calcareous
Malmo	MMO	Eluviated Black Chernozem	Glaciolacustrine	Fine textured (C, SiC) water-laid sediments, non-saline and weakly calcareous
Manatokan-AA	MNTaa	Terric Mesisol	Organic (Fen Peat) underlain by Glaciolacustrine	40–100 cm mesic fen peat developed on moderately fine textured sediments that are weakly calcareous
Misc. Gleysol	HGT1	Orthic Humic Gleysol	Glaciolacustrine	Fine textured water-laid sediments that are non-saline and moderately calcareous
Misc. Solonetzic-ZBL	CMO or WKN1	Black Solodized Solonetz	Morainal or Glaciolacustrine	Moderately fine, moderately saline and calcareous formed on Edmonton Formation Till
Navarre	NVR	Gleyed Black Chernozem	Glaciolacustrine	Fine textured (C, SiC) water-laid sediments, non-saline and weakly calcareous
Peace Hills	PHS	Orthic Black Chernozem	Glaciofluvial	Moderately coarse textured, non-saline and weakly calcareous
Ponoka	POK	Eluviated Black Chernozem	Glaciolacustrine	Medium textured, non to weakly-saline and moderately calcareous
Rolly View	RLV	Orthic Dark Gray Chernozem	Morainal	Medium textured (L to CL) till, non-saline and moderately calcareous
Wetaskiwin	WKN	Black Solodized Solonetz	Glaciolacustrine	Fine textured, moderately saline and weakly calcareous

Note:

Interpreted Soil Series based on field observations in the LSA.

2.5.1.3 Terrain

2.5.1.3.1 Local Study Area

A total of five terrain units of Pleistocene and Recent (less than 10,000 years before present) origin were identified within the LSA. Morainal, glaciolacustrine and glaciofluvial materials are Pleistocene deposits; organic materials are recent deposits that have been deposited after glaciation. Terrain map units associated with each soil series are shown in Table 2.5-4 and detailed terrain unit descriptions are provide in Appendix IV.

Table 2.5-4: Terrain Unit Classification and Correlation with Soil Map Units

Soil Unit	Terrain Map Unit		
	Map Unit	Symbol	Geologic Age
Mineral Soils			
Angus Ridge	Morainal	M	Pleistocene
Camrose	Morainal	M	Pleistocene
Duagh	Glaciolacustrine underlain by Morainal	GLLC/M	Pleistocene
Hobbema	Glaciolacustrine underlain by Morainal	GLLC/M	Pleistocene
Haight	Glaciolacustrine	GLLC	Pleistocene
Hairy Hill	Morainal	M	Pleistocene
Peace Hills	Glaciofluvial	GF	Pleistocene
Ponoka	Glaciolacustrine	GLLC	Pleistocene
Wetaskiwin	Glaciolacustrine	GLLC	Pleistocene
Wetaskiwin	Glaciolacustrine underlain by Morainal	GLLC/M	Pleistocene
Reclaimed Soils (Angus Ridge, Camrose and Ponoka)	Morainal (90% of the area) with minor Glaciofluvial and Glaciolacustrine subunits	M, minor GF and GLLC	Pleistocene
Organic Soils			
Manatokan-AA	Fen Peat underlain by Glaciolacustrine	FNPT/GLLC	Recent underlain by Pleistocene

The terrain map of the LSA is presented in Figure 2.5-5 and a summary of the geographic areas of the terrain units is presented in Table 2.5-5. The LSA is dominated by morainal units (47.5%; including reclaimed), followed by glaciolacustrine over morainal (18.1%) terrain units. A number of other terrain units are present totaling 23.4% and non-terrain units (disturbed lands and water) comprise a smaller portion of the lease at 11.0%.

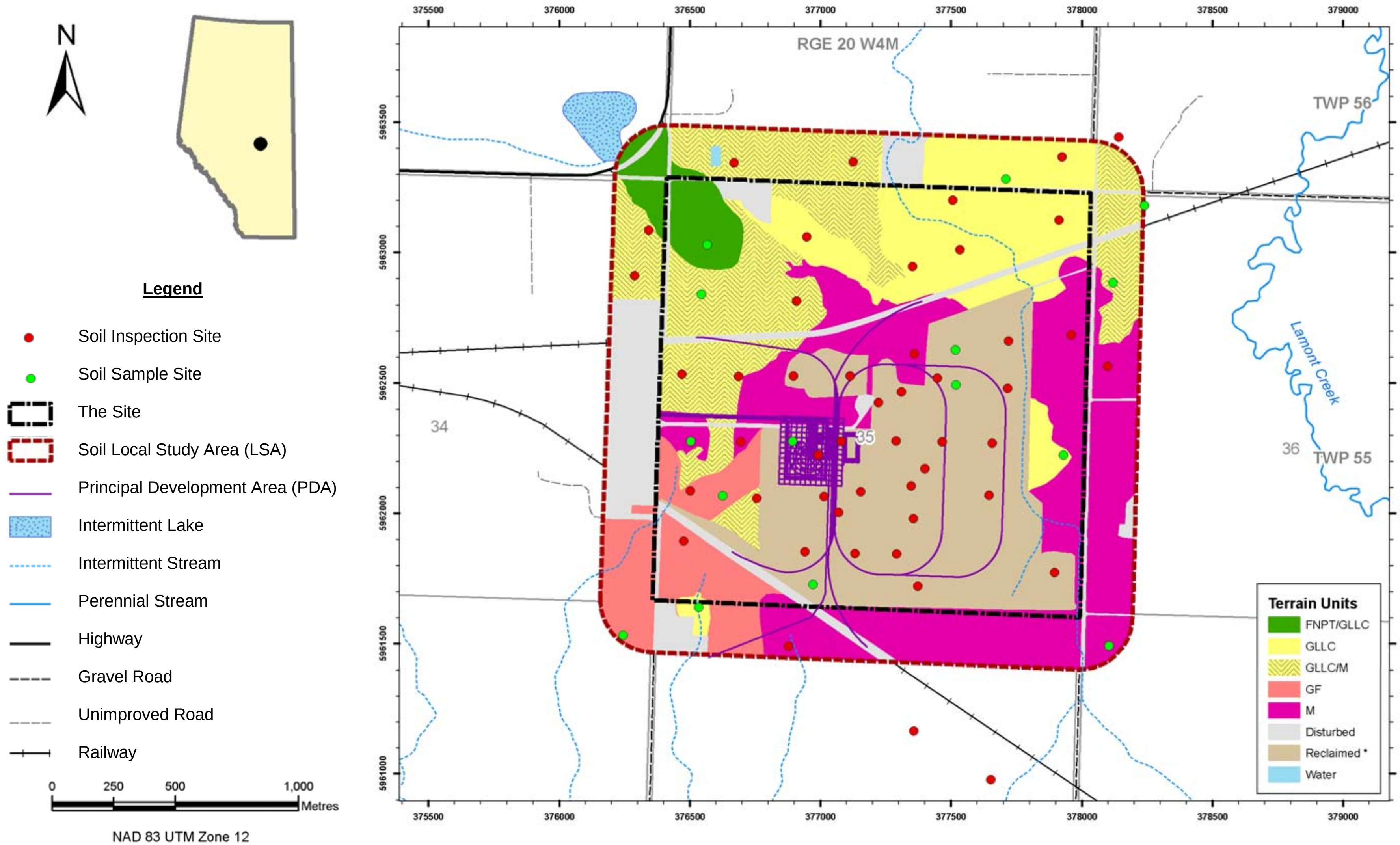

Figure 2.5-5: Terrain Units in the LSA

Table 2.5-5: Extent of Terrain Units in the LSA

Terrain Map Unit		LSA	
Map Unit	**Symbol**	**Area (ha)**	**% of LSA**
Fen Peat underlain by Glaciolacustrine	FNPT/GLLC	12.9	3.2
Glaciofluvial	GF	29.3	7.2
Glaciolacustrine	GLLC	53.3	13.1
Glaciolacustrine underlain by Morainal	GLLC/M	73.6	18.0
Morainal	M	89.5	22.0
Reclaimed (Morainal)	M	103.9	25.5
Non-terrain Units			
Disturbed	DL	44.6	10.9
Water	W	0.3	0.1
Total		**407.4**	**100.0**

2.5.1.4 Land Capability for Agriculture

Agricultural land capability ratings ranged from 2 (slight limitations to agriculture) to 7 (unsuitable for agriculture) in the LSA (see Figure 2.5-6; Table 2.5-6). Chernozemic soils (Angus Ridge, Hobbema, Peace Hills and Ponoka) had ratings from 2–3, with climate as the main limitation to agricultural production. In general, these soils are among the most productive in Central Alberta and can be used in traditional annual and perennial cropping systems in the Parkland region with few limitations. Solonetzic soils (Camrose, Wetaskiwin and Duagh) had ratings from 4–5, mainly due to climatic limitations and natural sodic properties. Subsoils of theses series are sodic, resulting in issues with tillage and admixing if appropriate management practices are not followed. These soils are generally limited in the types of crops they can produce. Gleysols and Organic soils were rated as having slight limitations (Hairy Hill) or being unsuitable (Haight, Manatokan). In all cases, these soils are periodically flooded and limitations arise from the degree to which the soil is seasonally affected by a high water table. In the case of the Hairy Hill soil, limitations are only temporary with a slight restriction on growing season, while in the other two soils limitations are severe and cropping or grazing is not possible. Areas of each agricultural suitability class are presented in Table 2.5-7.

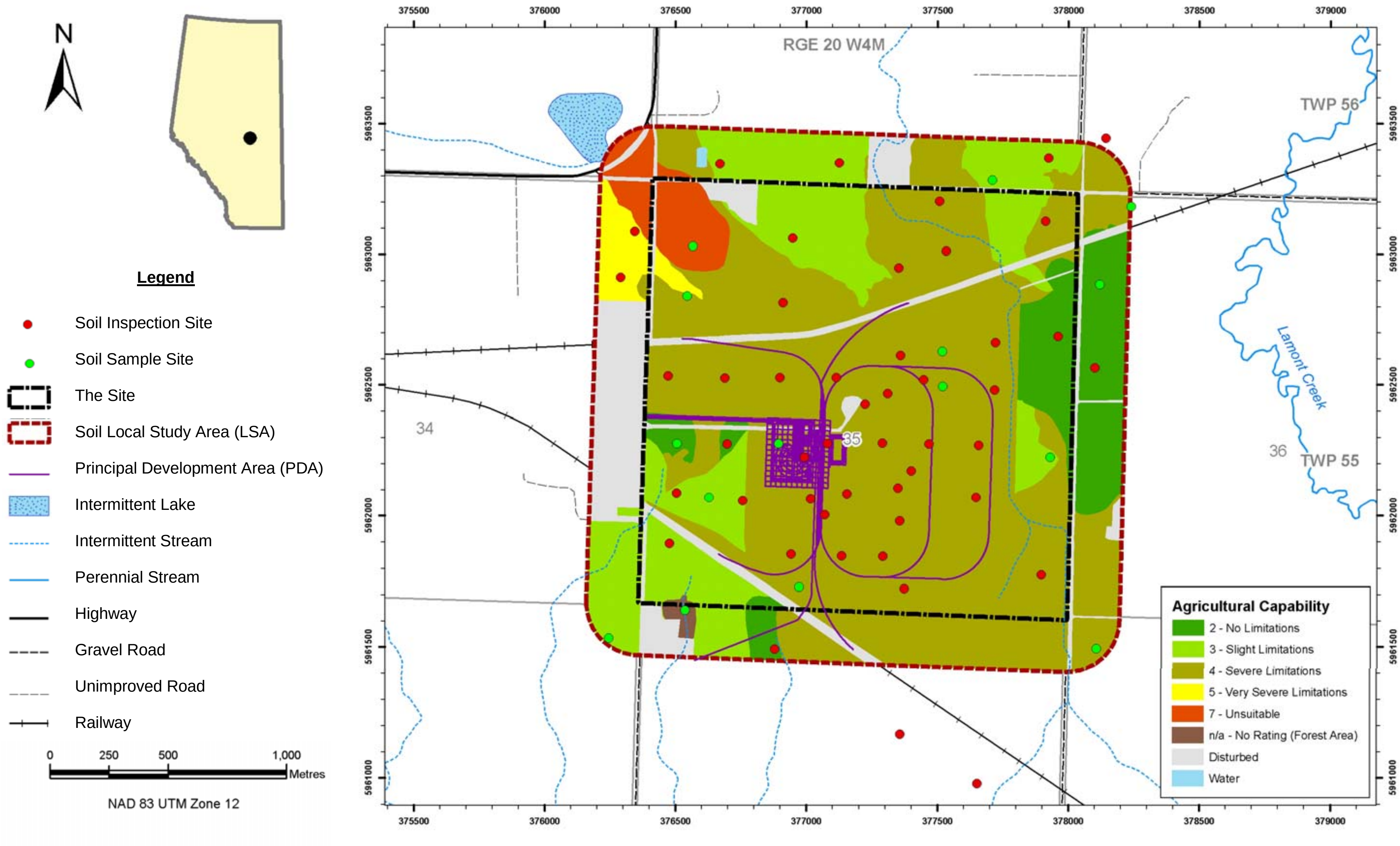

Figure 2.5-6: Agriculture Capability of Soils in the LSA

Table 2.5-6: Agricultural Capability Ratings LSA

Soil Series[1]	Soil Classification	Agricultural Capability Rating	Subclasses[2]
Angus Ridge	Eluviated Black Chernozem	2–3	H, D
Camrose	Black Solodized Solonetz, Gleyed Black Solodized Solonetz	4	H, D
Duagh	Gleyed Black Solonetz	5	H, D
Hobbema	Eluviated Black Chernozem, Gleyed Eluviated Black Chernozem	2–3	H, D
Haight	Orthic Humic Gleysol	7	H, W
Hairy Hill	Rego Humic Gleysol	2	H, W
Manatokan-AA	Terric Mesisol	7	H, Z, W
Peace Hills	Orthic Black Chernozem	3	H, M
Ponoka	Eluviated Black Chernozem	3	H, D
Wetaskiwin	Black Solodized Solonetz	4	H, D
Reclaimed soils (Angus Ridge, Camrose and Peace Ponoka)	Reclaimed profiles	4	H, Y, D

Notes:
[1] Includes all variants.
[2] See Table 2.4-1 and Table 2.4-2 for explanation of Agricultural Capability Classes and Subclasses.

Table 2.5-7: Extent of Agricultural Capability Classes in the LSA

Agricultural Capability Rating	LSA	
	Area (ha)	% of LSA
Class 1	0.0	0.0
Class 2	36.5	9.0
Class 3	73.8	18.1
Class 4	230.1	56.5
Class 5	7.9	1.9
Class 6	0.0	0.0
Class 7	12.8	3.2
Not rated[1]	1.4	0.3
Disturbed	44.6	10.9
Water	0.3	0.1
Total	**407.4**	**100.0**

Note:
[1] Forested area.

2.5.1.5 Soil Suitability for Reclamation

Soil suitability for reclamation ratings for agriculture was evaluated for topsoil (A horizon(s)) and subsoil (B horizon(s) if present, and the upper portion of the parent material) for each soil map unit based on the guidelines outlined by the Soil Quality Criteria Working Group (Macyk et al. 1987). For each soil map unit, a rating was derived based on field observations and analytical data collected. In map units for which analytical data were not available, Soil Layer File data (ASIC 2001) or published data from Pedocan (1993) were used. Reclamation suitability ratings for each mineral soil map unit are presented in Table 2.5-8. Ratings for organic soils were not calculated, as the reclamation suitability ratings have been derived for mineral soils only.

Approximately 100 ha of the LSA were described as having reclaimed profiles, due to previous disturbance (see Figure 2.5-7 and Figure 2.5-8). For this area, reclamation ratings were calculated for three locations where analytical data were obtained (see Table 2.5-8). Using this data, reclamation suitability ratings for the topsoil and subsoil across the entire previously disturbed area have been estimated. The estimated extent for each topsoil and subsoil reclamation suitability rating is provided in Table 2.5-9. A reclamation suitability rating of ‘poor’ or ‘unsuitable’ does not preclude the use of the material for reclamation. An acceptable reclamation outcome can be achieved by use of appropriate soil salvage and handling techniques as well as the use of appropriate soil amendments.

Table 2.5-8: Reclamation Suitability Ratings for Agriculture for Soil Map Units and Previously Reclaimed Areas in the LSA

Soil Series	Inspection Site Number(s)	Reclamation Suitability Rating[1]			
		Topsoil[2]	Main Topsoil Limitations	Subsoil[2]	Main Subsoil Limitations
Soil Map Units in the LSA					
AGS	Site 31	Fair	pH	Unsuitable	SAR
CMO	Site 11	Poor	pH	Unsuitable	SAR, consistence
DUG2	Site 15	Unsuitable	SAR	Unsuitable	SAR, EC
HBM	Site 4	Fair	pH	Fair	pH, texture, consistence
HGT	Site 13	Fair	pH	Fair	pH
HYL[3]	Site 50	Fair	pH	Poor	EC
MNTaa	Site 17	N/A[4]	N/A[4]	N/A[4]	N/A[4]
PHS	Sites 12 & 33	Fair	pH	Fair	Consistence
POK	Sites 1 & 52	Fair	pH	Poor	SAR
WKN	Sites 3 & 16	Fair	pH, SAR, saturation%	Unsuitable	pH, SAR, saturation%, consistence
Reclaimed Soils in the LSA					
Reclaimed	Site 29	Fair	pH, SAR	Unsuitable	pH, SAR, saturation%
Reclaimed	Site 35	Poor	SAR	Fair	SAR, consistence
Reclaimed	Site 44	Poor	SAR	Unsuitable	SAR, consistence

Notes:
[1] Macyk et al. 1987.
[2] See Table 2.4-4 for description of reclamation suitability ratings.
[3] Soil analytical data obtained from ASIC (2001) – Soil Layer Files; and Pedocan (1993).
[4] Organic soils have not been rated for reclamation suitability.

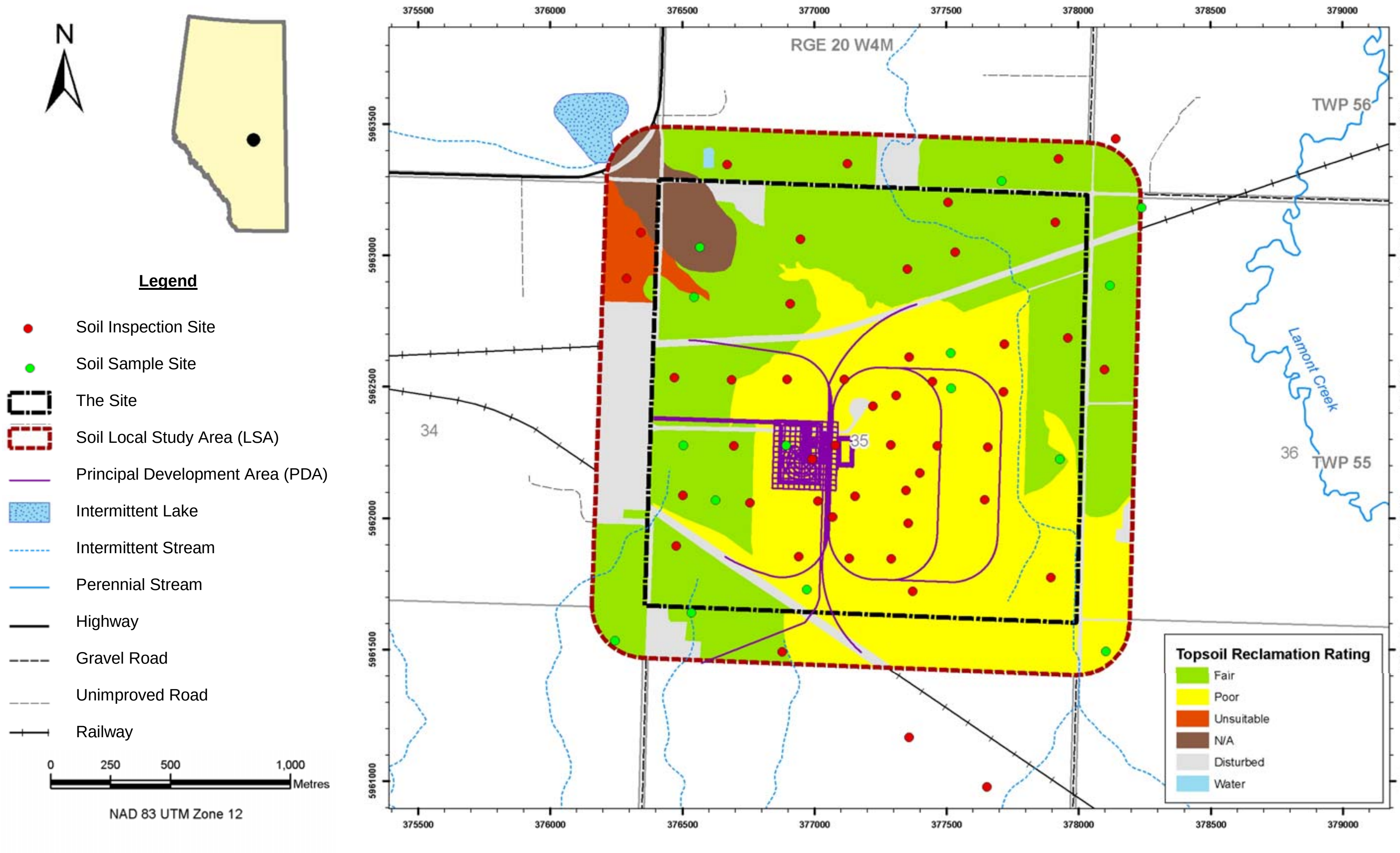

Figure 2.5-7: Topsoil Reclamation Suitability in the LSA

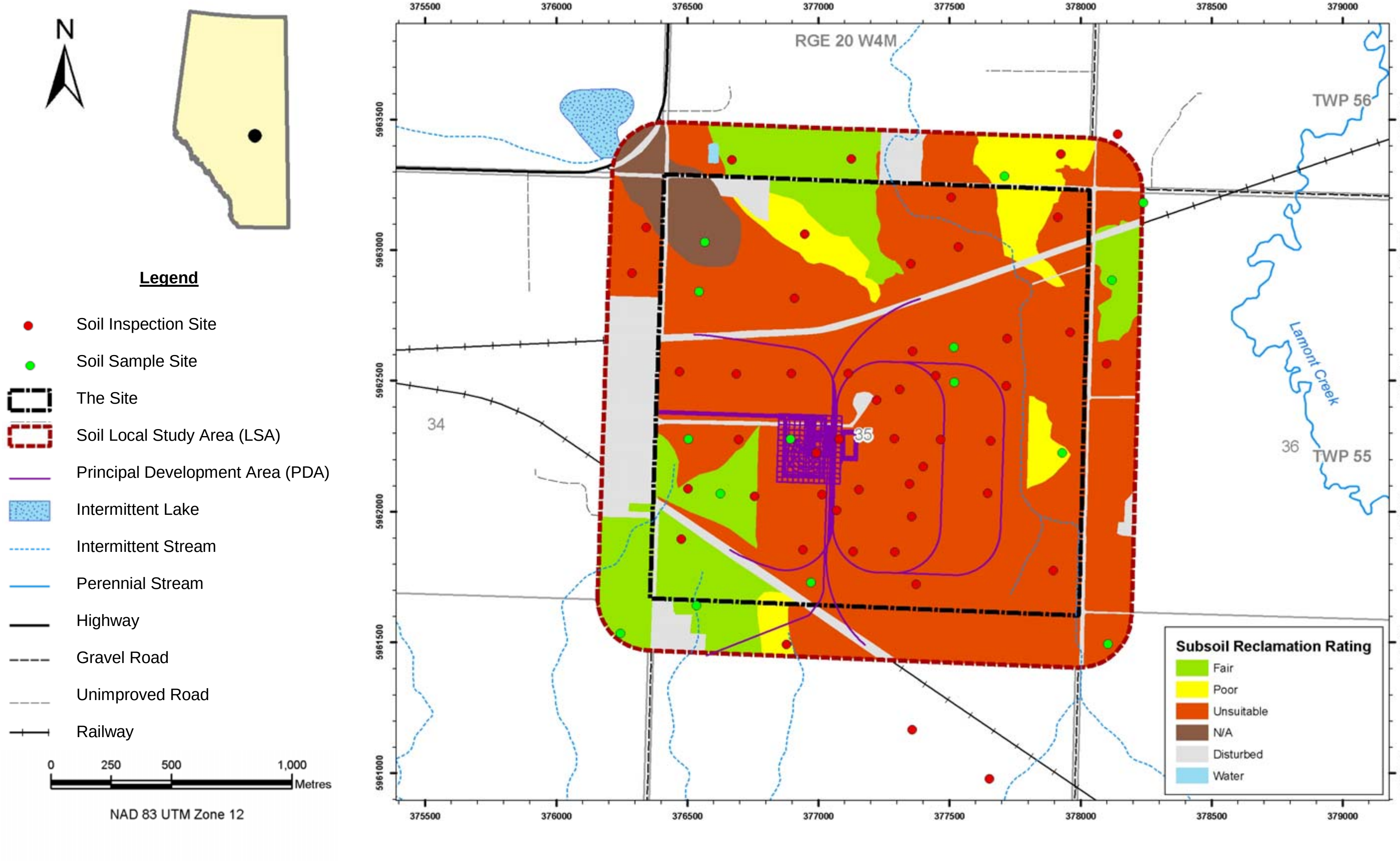

Figure 2.5-8: Subsoil Reclamation Suitability in the LSA

Table 2.5-9: Extent of Reclamation Suitability Classes within the LSA

Reclamation Suitability Rating	Extent within the LSA (ha)	
Soil Series in the LSA	**Topsoil**	**Subsoil**
Good	0.0	0.0
Fair	178.9	58.7
Poor	58.9	25.2
Unsuitable	7.9	161.8
Not rated (organic soils)	12.9	12.9
Subtotal	258.6	258.6
Previously Reclaimed Areas in the LSA		
Good	0.0	0.0
Fair	0.0	0.0
Poor	103.9	0.0
Unsuitable	0.0	103.9
Subtotal	103.9	103.9
Non-terrain Units		
Disturbed	44.6	44.6
Water	0.3	0.3
Total	**407.4**	**407.4**

Note:
[1] Based on average ratings from three detailed plots obtained from the reclaimed area.

2.5.1.6 Soil Sensitivity to Water and Wind Erosion

Water and wind erosion risk ratings for mapped soil units are presented in Table 2.5-10. The geographic extents of water and wind erosion risk ratings within the LSA are presented on Figure 2.5-9 and Figure 2.5-10. Water erosion ratings were based on data from Tajek et al. (1985) and Pedocan (1993). Wind erosion ratings were based on mapped for wind erosion risk data from Coote and Pettapiece (1989).

A significant portion of the LSA consists of reclaimed soil profiles for which no specific rating classes exist. For these areas, interpretation of the field data indicated that topsoil likely originated from Camrose, Ponoka or Angus Ridge soils. Therefore, wind and water erosion risk ratings for these soils have been applied to the reclaimed area.

Ratings were not generated for slopes above 9%. Based on topographic map interpretation, all slopes in the LSA are below this value.

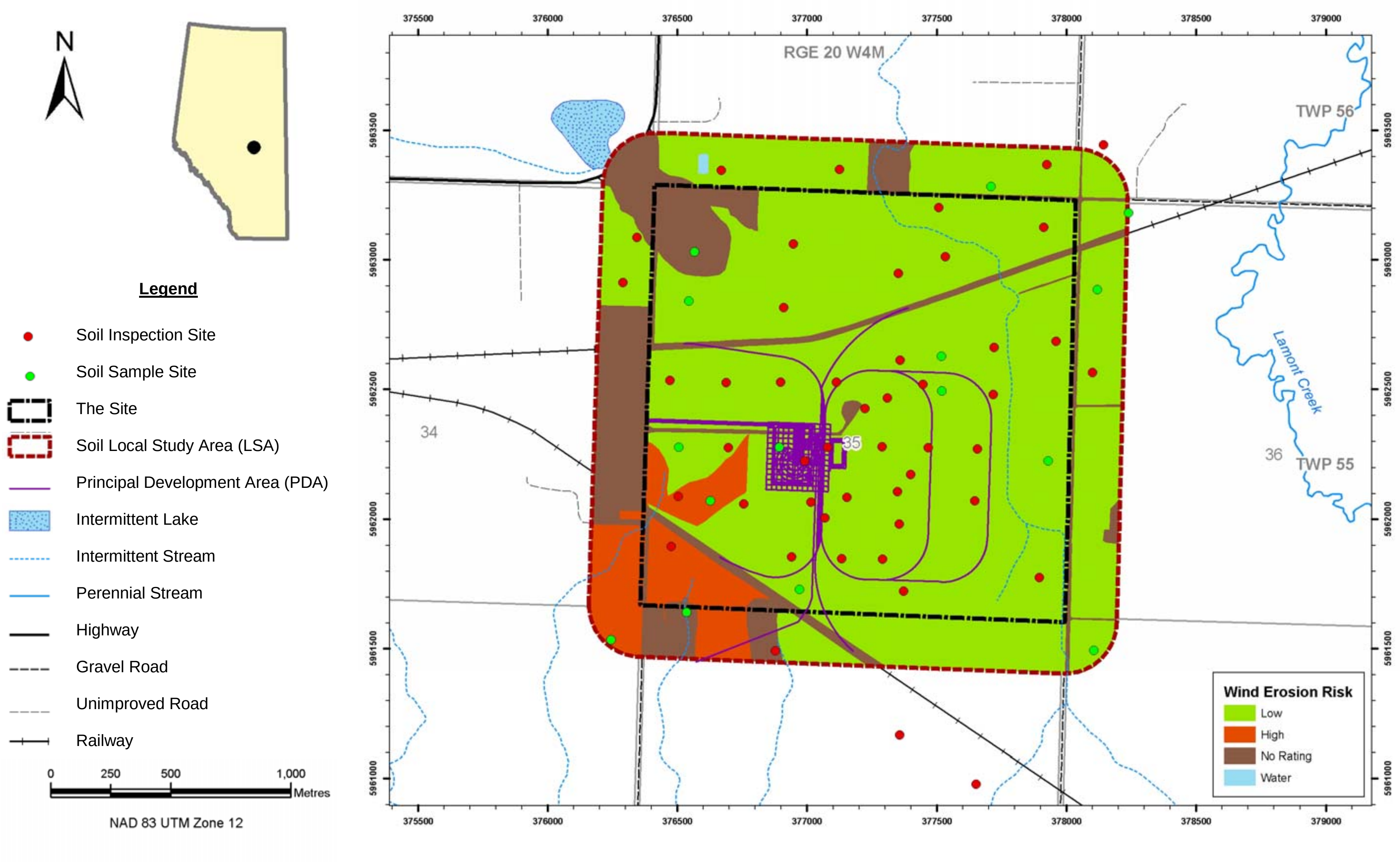

Figure 2.5-9: Wind Erosion Risk in the LSA

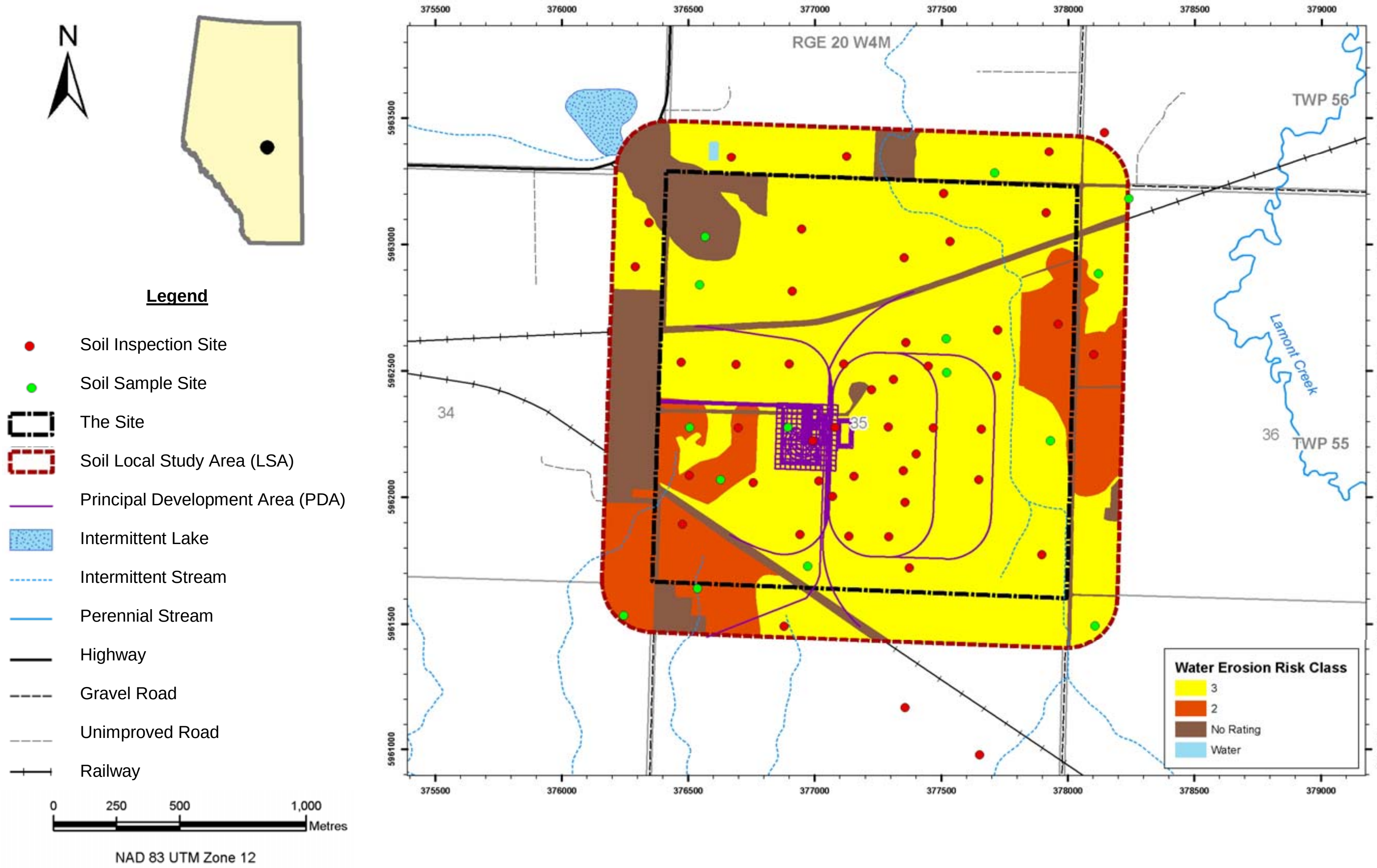

Figure 2.5-10: Water Erosion Risk in the LSA

Table 2.5-10: Summary of Wind and Water Erosion Risk Ratings for Soil Units in the LSA

Soil Series	Soil Code	Area (ha)	Wind Erosion Risk*	Water Erosion Risk*		Water Erosion Risk Class**
				Slope <5%	Slope 5–9%	
Angus Ridge	AGS	27.7	Low	Low	Low	2
Camrose	CMO	59.0	Low	Low	Moderate	3
Duagh	DUG	7.9	Low	Low	Moderate	3
Hobbema	HBM	28.0	Low	Low	Moderate	3
Haight	HGT	1.4	N/R[1]	N/R	N/R	2
Hairy Hill	HYL	2.8	N/R	N/R	N/R	3
Manatokan-AA	MNT	12.9	N/R	N/R	N/R	N/R
Peace Hills	PHS	29.3	High	Low	Low	2
Ponoka	POK	22.3	Low	Low	Moderate	3
Wetaskiwin	WKN	67.3	Low	Low	Moderate	3
Reclaimed profiles	RS	103.9	Low[2]	Low[2]	Moderate[2]	3
Subtotal		362.5				
Non-soil units	n/a	44.9	N/R	N/R	N/R	N/R
Total		**407.4**				

Notes:
[1] NR – Not rated – Gleysols, organic soils and non-soil units have not been rated for wind or water erosion.
[2] Ratings for reclaimed profiles were estimated based on textures for observed profiles in the reclaimed area indicating that source soils for the reclaimed area were AGS, CMO or POK.
n/a – not applicable.
Source: * Pedocan (1993); ** Tajek et al. (1985).

2.5.1.7 Soil Sensitivity to Acidification

2.5.1.7.1 Baseline Soil Quality

Soil quality data were obtained from soils in the LSA to fulfill the TOR with respect to baseline data gathering (see Appendix V, Figure V-1). Soils were analyzed for the following chemical parameters as outlined in the AENV Air Monitoring Directive Appendix A-7 (AENV 1989):

- pH
- sulphur concentrations (total sulphur, elemental sulphur, sulphate sulphur)
- electrical conductivity (EC)
- cation exchange capacity (CEC)
- major soluble anions and cations
- bulk density

The data collected is summarized in Appendix V. These data may serve as a baseline for future monitoring for the Project as discussed in Section 2.6. Additional baseline data from Alberta Environmentally Sustainable Agriculture Soil Quality Monitoring Initiative for Alberta (Cannon and Leskiw 1999) was reviewed. No monitoring stations for this program are located in the LSA or RSA. However, data from the benchmark locations in the area may be used to provide additional baseline information for ongoing monitoring initiatives for the Project.

2.5.1.7.2 Soil Sensitivity Ratings

Regional Grid Cell Receptor Sensitivity Ratings

Published regional receptor sensitivity data (including soil and surface water) to acidifying input are available for the region which includes the RSA and LSA (CASA and AENV 1999). The study assumes the intersection of the 1° longitude x 1° latitude grid cells represent the centre of the grid. Based on this, the region as receptors are classified as being within a high sensitivity grid cell. Since the preparation of the 1999 document, AENV has updated their 1° longitude x 1° latitude modelling using 1° longitude x 1° latitude grid cells that have been shifted by a half degree (Cheng 2006). The 1° longitude x 1° latitude grid cells now represent the corners of the grid. Based on this, the region is now within a low sensitivity grid cell (see Figure 2.5-11). The grid cell sensitivity data is intended to provide a regional overview and the data may not be directly applicable to smaller areas like the LSA within a grid cell.

Soil Sensitivity Ratings for the LSA and RSA

In addition to the grid cell sensitivity analysis, soil sensitivity to acidification was evaluated for soils in the LSA and RSA using analytical data collected from representative inspection locations and/or using published soil chemical data (ASIC 2001). A significant area of the LSA was described as having reclaimed profiles, due to previous disturbance (see Figure 2.5-2). For this area, sensitivity ratings were calculated for three locations where analytical data were obtained. Mineral and organic soils in the LSA and RSA were rated as having low to moderate overall sensitivity to acid deposition (see Table 2.5-11, Table 2.5-12 and Figure 2.5-12).

Table 2.5-11: Sensitivity Ratings for Soil Map Units in the LSA

Soil Map Unit	Inspection Site Number	pH	CEC (meq/100g)	Sensitivity Ratings[1]			Overall Sensitivity[1]
				Base Loss	Acidification	Aluminum Solubilization	
AGS	31	6.2	24.0	L	L	L	L
CMO	11	5.0	22.7	M	L	H	M
DUG[2]	15	5.11	4,111.0	M	L	M	M
HBM	4	6.0	20.9	L	L–M	L–M	L
HGT	13	6.2	34.4	L	L	L	L
HYL2	50	7.7	211.0	L	L	L	L
MNT	17	n/a	n/a	L–M	L	n/a	L
PHS	12	5.7	13.1	M	L–M	L–M	M
PHS	33	5.6	16.4	L	L–M	L–M	L
POK	1	6.3	26.9	L	L	L	L
POK	52	7.2	21.6	L	L	L	L
WKN	3	5.8	24.5	L	L–M	L–M	L
WKN	16	6.8	24.0	L	L	L	L
Reclaimed	29	7.6	17.9	L	L	L	L
Reclaimed	35	7.6	19.6	L	L	L	L
Reclaimed	44	7.9	21.9	L	L	L	L

Notes:
[1] Sensitivity ratings were determined using the methods outlined in Holowaychuck and Fessenden (1987) for mineral soils or Turchenek et al. (1998) for organic soils.
[2] Analytical data obtained from AGRASID (ASIC 2001) Soil Layer File.
n/a – parameter is not applicable or not used for rating organic soils (Turchenek et al. 1998).

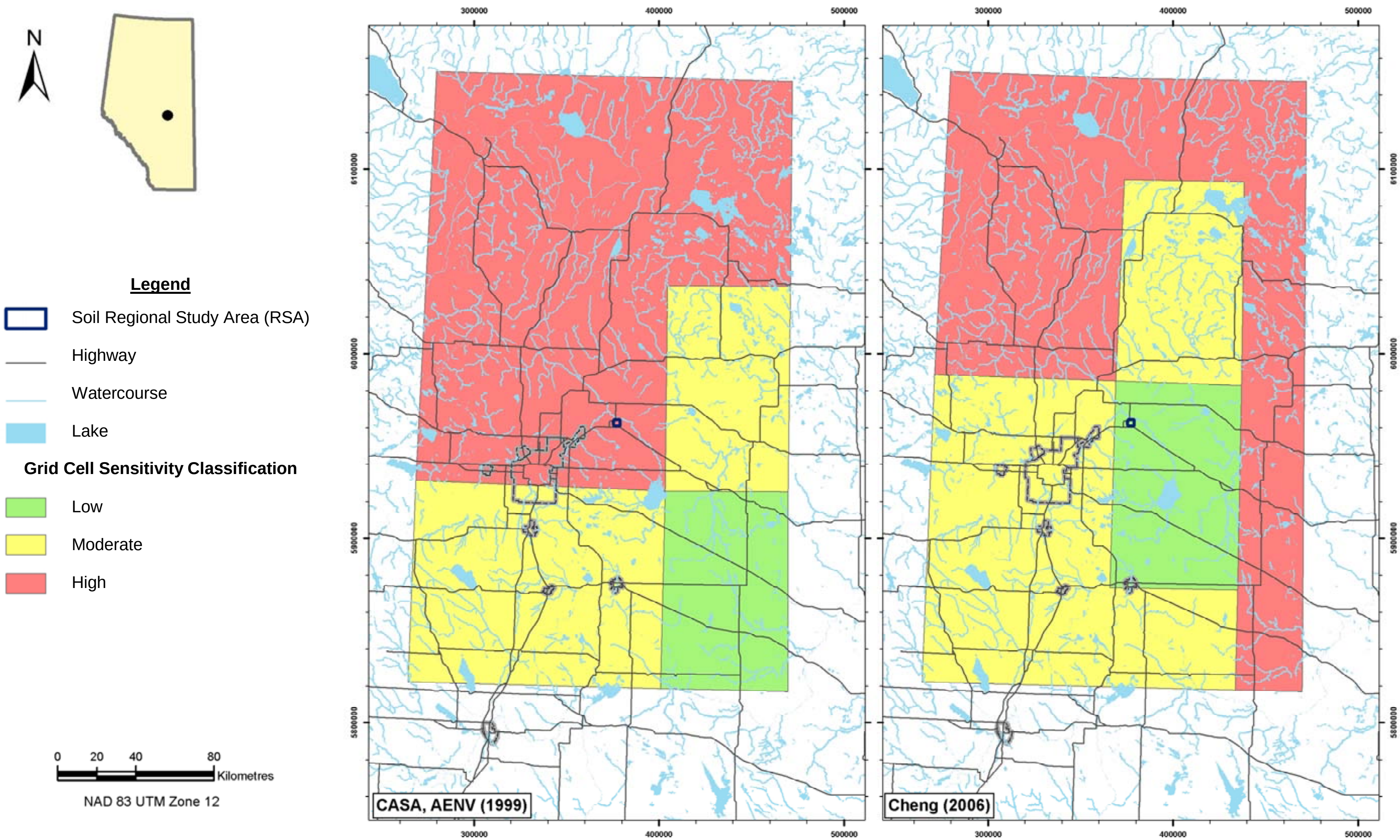

Figure 2.5-11: Acidification Grid Cell Sensitivity

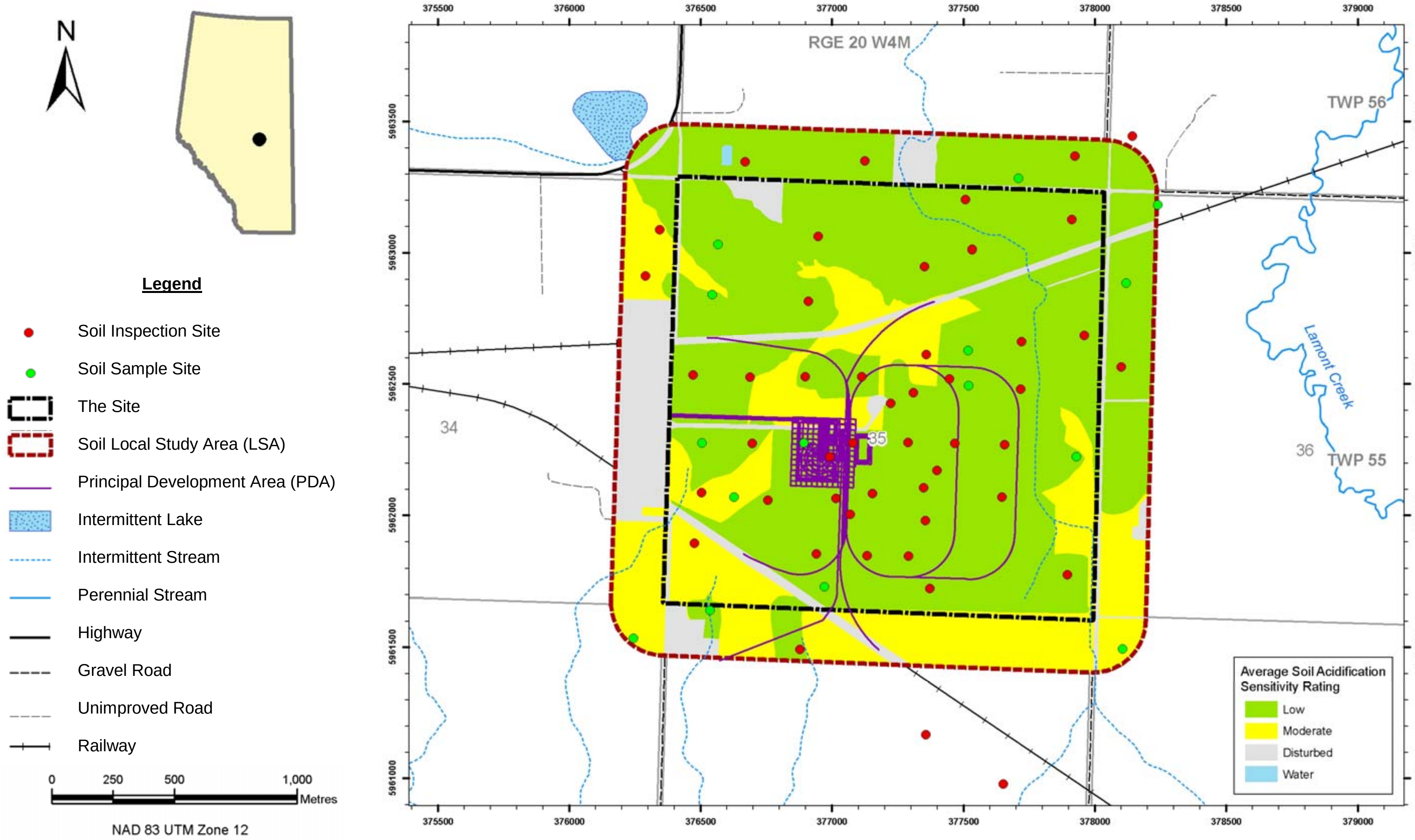

Figure 2.5-12: Overall Soil Acidification Sensitivity Rating in the LSA

Table 2.5-12: Sensitivity Ratings for Soil Map Units in the RSA

Soil Series	Sensitivity Ratings[1]			Overall Sensitivity[1]
	Base Loss	Acidification	Aluminum Solubilization	
AGS	L	L	L	L
CMO	L–M	L–M	L-H	M
HBM	L	L–M	L–M	L
KVG	M	L	M	M
MMO	M	L	M	M
Misc. Gleysols[2]	L	L	L	L
NVR	L	L–M	L–M	L
Misc. Solonetz[3]	M	L–M	L–M	M
PHS	M	L–M	L–M	M
RLV	L	L	L	L

Notes:

[1] Sensitivity ratings determined using the methods outlined in Holowaychuck and Fessenden (1987) for mineral soils or Turchenek et al. (1998) for organic soils.

[2] Miscellaneous Gleysols (may include HYL and HGT soil units).

[3] Miscellaneous Solonetzic Soils (may include WKN and DUG soil units).

2.5.1.7.3 Soil Acidification – Baseline Case

Comparison of the baseline PAI case with grid cell data published by CASA and AENV (1999) indicates that the grid cell, which includes the RSA and LSA and all surrounding grid cells, have current levels of acid input (PAI) below the critical load of 0.50 keq H^+/(ha•y) for soils which are moderately sensitive to acid input (see Figure 2.5-13).

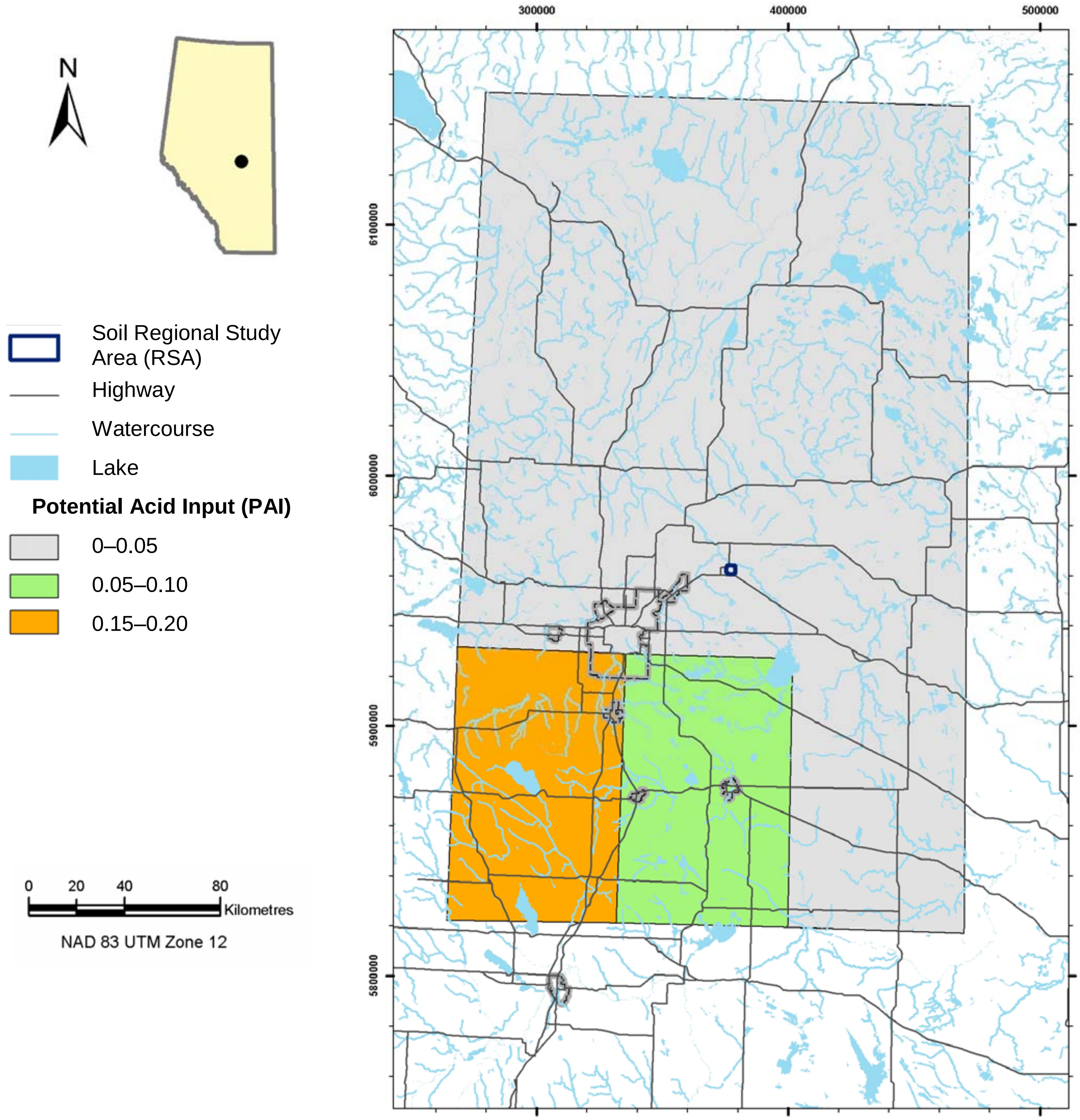

Figure 2.5-13: Current Level of Acid Deposition in Alberta, PAI in Grid Cells Measuring 1° Latitude by 1° Longitude in Alberta

2.6 Application Case

The Project includes the construction and operation phase for the sulphur forming and shipping facility. These activities are expected to be confined to the PDA. The application case assesses potential impacts to soil resources additively with the baseline case findings.

2.6.1 Soil and Terrain Alteration

Only mineral soils are present within the PDA, with the majority of soil being from the previously reclaimed soils. Table 2.6-1 and Table 2.6-2 provide a summary of expected disturbance for each soil unit and each terrain unit in relation to the total area of the PDA and LSA.

Table 2.6-1: Soils Series Disturbance in the LSA

Soil Unit[1]	Series or Variant Code	LSA	
		Area (ha)	% of LSA
Mineral Soils			
Angus Ridge	AGS	0.2	0.05
Camrose	CMO	3.1	0.8
Hairy Hill	HYL	0.2	0.05
Peace Hills	PHS	0.4	0.1
Wetaskiwin	WKN	0.9	0.2
Reclaimed soils	n/a	18.2	4.5
Non-soil Units[2]			
Disturbed	DL	1.8	0.4
Total		**24.8**	**6.1**

Notes:
[1] Includes all variants.
[2] Differs from the area of anthropogenic disturbance defined for other sections (e.g., vegetation, wildlife).
n/a – not applicable.

Table 2.6-2: Terrain Unit Disturbance in the LSA

Terrain Map Unit		LSA	
Map Unit	**Symbol**	**Area (ha)**	**% of LSA**
Glaciofluvial	GF	0.4	0.1
Glaciolacustrine underlain by Morainal	GLLC/M	0.9	0.2
Morainal	M	3.5	0.9
Reclaimed (Morainal)	M	18.2	0.4
Non-terrain units			
Disturbed	DL	1.8	4.5
Total		**24.8**	**6.1**

When final reclamation is complete for the Project, it is expected there will be no net loss in mineral soils. The Project is not expected to have an effect on distribution of terrain units, as soil disturbance will be limited to the topsoil and upper subsoil.

2.6.1.1 *Mitigation*

The primary mitigation strategy to restore soil and terrain disturbances is the reclamation of disturbed areas in accordance with regulations at that time. The current objective is to achieve equivalent land capability, defined as the ability of the land to support various land uses after reclamation similar to that which existed prior to disturbance while recognizing that individual land uses will not necessarily be equal after reclamation (Powter 2002). Details of proposed soil handling and reclamation activities to minimize soil loss and alteration are outlined in Volume IID, Section 2: Land Use and Reclamation.

2.6.2 Change in Agricultural Land Capability

Proper soil handling as outlined in Volume IID, Section 2: Land Use and Reclamation, is expected to minimize any negative effects to the agricultural land capability within the LSA. During Project construction and operation, it is expected that soils within the PDA will be removed from agricultural production. However, the goal of conservation and reclamation practices will be to conserve soil resources and to achieve the equivalent land capability upon Project decommissioning as existed prior to Project initiation. Table 2.6-3 summarizes the expected changes in agricultural land capability as a result of the Project.

Table 2.6-3: Summary of Predicted Disturbance of Agricultural Capability Classes in the LSA

Land Capability Class	Extent Within Each Capability Class					
	Baseline Case		Application Case		Closure[1]	
	(ha)	% of LSA	Expected Reduction in Area (ha)	Change Relative to Baseline (%)	(ha)	Change Relative to Baseline (%)
Class 1	0.0	0.0	0.0	n/a	0.0	0.0
Class 2	36.5	9.0	0.4	1.1	36.5	0.0
Class 3	73.8	18.1	0.4	0.5	73.8	0.0
Class 4	230.1	56.5	22.2	9.6	230.1	0.0
Class 5	7.9	1.9	0	n/a	7.9	0.0
Class 6	0.0	0.0	0.0	n/a	0.0	0.0
Class 7	12.8	3.2	0.0	n/a	12.8	0.0
Not Rated	1.4	0.3	0.0	n/a	1.4	0.0
Subtotal	362.5	89.0	23.0	n/a	362.5	0.0
Disturbed[2]	44.6	10.9	1.8	4.0	44.6	0.0
Water	0.3	0.1	0	n/a	0.3	0.0
Subtotal	44.9	11.0	1.8	n/a	44.9	0.0
Total	**407.4**	**100.0**	**24.8**	**n/a**	**407.4**	**n/a**

Notes:
[1] Assumes reclamation will return equivalent capability for all Class 2, 3 and 4 soils.
[2] When possible, baseline case disturbed areas will be returned to agriculture lands resulting in a possible increase in Class 2, 3 or 4 areas in the closure.
n/a – not applicable.

2.6.2.1 *Mitigation*

The objective of soil reclamation activities is to achieve equivalent land capability to what existed prior to the disturbance. The overall impact of the Project to land capability for agriculture is expected to be neutral or increased capacity. In order to achieve this result, mitigation measures must be adopted to preserve soil quality. Details of proposed reclamation activities are discussed further in Volume IID, Section 2: Land Use and Reclamation.

2.6.3 Changes in Soil Quality

Surface disturbance from the Project may affect soil quality. Key soil physical and chemical properties are identified to assess the impact of the Project on soil quality. Specific potential impacts of the Project on soil quality include:

- soil admixing, which may change the organic matter content, available water holding capacity, texture, or nutrient status of salvage material to be used in reclamation
- soil compaction, which alters soil structure and reduces soil permeability and aeration
- soil erosion, which can result in soil volume losses and organic matter and nutrient losses
- soil contamination, which can have an effect on soil chemical and physical properties

2.6.4 Soil Admixing

Admixing of topsoil and subsoil materials can occur during the soil salvage and reclamation phases of the Project. Overstripping (salvaging topsoil and subsoil as one-lift) and understripping (salvaging only a portion of the topsoil) can alter the chemical and/or physical properties of the reclaimed topsoil, which can compromise the quality of the soil. Overstripping is most likely to occur if the A horizon depth is highly variable or if the A horizon thickness is less than the depth prescribed for salvage. Admixing of topsoil and subsoil from solonetzic soils can result in an increase in sodicity and soluble salt concentrations in the topsoil. Both chernozemic and solonetzic soils within the PDA would have reduced topsoil quality ratings if significant admixing were to occur. There is evidence, based on soil inspections and analytical data that some admixing of topsoil and subsoil has occurred previously in the area of reclaimed soil that dominates the southern portion of the LSA. Further admixing of this material would have a negative effect on topsoil quality.

2.6.4.1 <u>Mitigation</u>

The following measures will be implemented to prevent admixing of topsoil and subsoil and prevent further admixing of previously reclaimed profiles:

- develop a site-specific soil salvage plan in accordance with pre-disturbance assessment requirements
- use experienced supervisors to oversee soil salvage operations to ensure quality control
- conduct on-site meetings to brief all construction personnel involved of the site-specific soil salvage plan
- use equipment operators experienced in soil salvage operations
- document soil salvage activities (e.g., stripping depths and soil characteristics) for use later during site reclamation

2.6.5 Soil Compaction

Soil compaction refers to the force applied by equipment traffic on the soil, which results in a pore volume reduction. When soil is compacted, the total porosity is reduced at the expense of the macropores which inhibits aeration and water movement through the soil profile. In addition, the susceptibility of soil to water erosion increases as the infiltration rate decreases. The LSA soils developed on glaciolacustrine and morainal material are most susceptible to compaction. These include Angus Ridge, Camrose, Duagh, Hobbema, Hairy Hill, Haight, Ponoka and Wetaskiwin soils. In particular, solonetzic soils and their variants such as Camrose, Duagh and Wetaskiwin are particularly susceptible to subsoil compaction, due to the dispersive effects on clay of excess sodium in the profiles. Gleysols in the LSA such as Hairy Hill and Haight are also susceptible to subsoil compaction. The reclaimed profiles observed in the LSA are also considered to be at risk for subsoil compaction because they were generally found to be fine-textured and sodic.

2.6.5.1 Mitigation

To reduce the risk and adequately ameliorate soil compaction, the following mitigation activities will be practiced:

- plan construction activities during dry periods when soil moisture content is lower
- minimize the number of passes over soils prone to compaction, recognizing that compaction will occur during construction, but this will occur after topsoil is removed
- limit repetitive traffic to designated areas
- where compaction is an issue, use low ground pressure vehicles (e.g., wide pad tracked equipment) rather than vehicles with conventional tires to reduce the load on the soil
- use one or both of the following reclamation techniques:
    - deep-ripping, disking or cultivating compacted subsoil
    - mix nutrient-rich amendment into topsoil during spreading where required

2.6.6 Soil Erosion

The primary soil erosive agents are wind and water erosion. The impacts of soil erosion include:

- loss of organic matter and nutrients
- alteration of soil texture
- available water holding capacity and degradation of structure due to particle removal

Under conservative agronomic practices, wind and water erosion of soil is low, however, if soil is exposed to wind and water with minimal surface cover, erosion risk increases.

Soils in the LSA were all rated as having slight to moderate water erosion risk and generally low wind erosion risk. Slopes in the LSA were generally less than 5%, resulting in low water erosion risk for all soil units (see Table 2.5-10). The Peace Hills soil unit was rated as having a high wind erosion risk due to a coarse-textured topsoil texture. This soil unit is present in the western part of the PDA and may require mitigation measures during stripping and storage to ensure that wind erosion is minimized.

2.6.6.1 Mitigation

The following measures will be practiced to minimize soil erosion for the Project:

- contour and grade slopes during site restoration to maintain the natural surface drainage pathways
- construct temporary drainage ditches and berms, where required, to control and direct surface runoff
- utilize temporary erosion control materials such as erosion mats, fences, nets or mulches, where required
- apply an organic or synthetic tackifier or use hydroseeders for soil stability during stockpiling
- promptly re-vegetate exposed surfaces to a quick-establishment seed-mix depending on erosion risk potential
- drill seed, harrow or otherwise cover broadcasted seed to ensure a high degree of re-vegetation

2.6.7 Soil Contamination

Soil contamination might occur during the construction and operational phases of the Project. These conditions are generally the result of accidental events and could result in negative effects to soil quality. Upset conditions and potential changes to soil quality during the construction and operation phase of the Project could result from:

- spillages arising during refueling of construction equipment (i.e., heavy equipment)
- events such as a train crash, vehicle crash on site, or leak of heated sulphur storage tank giving rise to uncontrolled spillage or leakage of deleterious substances
- accidental release or spillage of process-affected water or other chemicals such as dust suppression agents (Dustbind S5) and proprietary sulphur release aid (IPAC SRB Plus)
- uncontrolled release of deleterious substance during a fire fighting incident
- uncontrolled emission from the plant stack giving rise to increased deposition of acidifying compounds
- uncontrolled release from the runoff collection pond taking place prior to neutralization, testing and sampling

If soil contamination occurs, it is expected to be localized. The primary means of reducing the impact of soil contamination will be adopting a management plan that emphasizes prevention of contamination and immediate response to an accidental spill, leak or discharge. Spill and release contingency plans are discussed in greater detail in Volume I: Project Description. The construction and operational phases of the Project will comply with the Guideline for Monitoring and Management of Soil Contamination under EPEA Approvals (AENV 1996).

The products of greatest concern, in terms of affecting soil quality in the PDA, are expected to be acidifying substances such as sulphur dust, liquid sulphur and related products. Potential soil acidification from these substances is discussed in Section 2.5.17.

Soils in the PDA that are most susceptible to mobile chemicals (e.g., salts, low-molecular-weight hydrocarbons) are medium-textured soils of glaciofluvial origin (Peace Hills). These soils have less sorption capacity than fine-textured soils of glaciolacustrine and/or morainal origin (Angus Ridge, Camrose, Duagh, Hobbema, Hairy Hill, Ponoka, Wetaskiwin and the reclaimed soil units).

2.6.7.1 Mitigation

Specific measures to mitigate or minimize the potential impacts of spilled waste or chemicals include the following:

In the case of an accidental spill resulting in a release of acidifying liquids, the following mitigation procedures will be conducted:

- acidifying compounds (i.e., acidic water, liquid sulphur or uncontrolled releases of elemental sulphur): A site assessment will be conducted including soil sample collection and analysis of the affected area according to appropriate regulatory criteria. Suitable remediation options may include amendments (e.g., calcium), containment and disposal of affected soil by "flushing" soil with fresh or calcium-amended water.

All wastes generated during the construction and operation phases (e.g., oils, filters, chemicals and garbage) that cannot be recycled will be handled appropriately, as outlined in the Waste Management section of the Application (see Volume I: Project Description).

2.6.8 Alteration of Soil Moisture Regime

Project impacts to surface hydrology and shallow groundwater quantity may affect soil moisture regimes. The extent of soils where the upper groundwater zone is expected to be seasonally within 1 m of the soil surface is limited in extent to the organic and gleysolic soil units and to some gleyed subunits of other soil series (e.g., Duagh, Manatokan-AA, Haight and Hairy Hill) which constitute less than 5% of the LSA. Hairy Hill soils are located in the southern part of the PDA and this soil is expected to be disturbed during construction/ operation of a rail spur in this area. The wetland to the northwest of the PDA, where Manatokan soils were observed, will not be disturbed as part of the Project.

Gleyed subunits of the Camrose, Hobbema and Peace Hills soils that were observed during the site inspections are interpreted as being seasonally wet due to limited subsurface drainage and, therefore, unlikely to be affected by Project-related hydrologic disturbance. All other soil units are considered to be freely drained and would not be affected by Project-related hydrologic disturbances.

2.6.8.1 Mitigation

Mitigation measures will not be required at the majority of the Site. However, mitigation to limit the effects on the Hairy Hill soil unit in the south of the PDA may include:

- installation of culverts as required for corridor facilities such as rail spurs to retain natural surface drainage and prevent water build-up
- installations are constructed using appropriate methods, including proper camber, slope, length and compaction

2.6.9 Soil Suitability for Reclamation

Soil salvage plans that identify materials suitable for reclamation and include adequate storage measures will preserve the quality of the material to be used for reclamation of surface disturbances in the PDA. Generally, topsoil is rated as fair for reclamation, while topsoils from Camrose and reclaimed soil units are rated as poor, and topsoil from the Duagh soil was rated as unsuitable (see Table 2.5-8). Duagh soils were observed in the northwest corner of the LSA, outside of the PDA and are not expected to be disturbed for the Project. Subsoil suitability was rated fair to unsuitable, generally due to pH and sodicity**.** Subsoil salvage for the Project is expected to be limited. Reclamation suitability ratings of 'poor' or 'unsuitable' do not preclude the use of the material for reclamation. An acceptable reclamation outcome can be achieved by use of appropriate soil salvage and handling techniques, as well as appropriate soil amendments. Specific soil salvage information and volume estimates are discussed in greater detail in Volume IID, Section 2: Land Use and Reclamation.

Based on the site investigation data, the majority of the PDA is underlain by reclaimed soil units where topsoil was previously stripped and replaced. These profiles are readily identifiable because of an abrupt transition between topsoil and subsoil and are generally rated as poor for topsoil reclamation suitability and unsuitable for subsoil reclamation suitability. Field observations of these profiles also indicated that some admixing of topsoil and sodic subsoil has already taken place during the previous disturbance. The reclamation objective for these profiles would be to minimize further admixing and attempt to return these soils to their current productivity, or improved if possible.

Stripping solonetzic soils such as Camrose must be accomplished with great care to minimize admixing the topsoil and subsoil, which can further reduce topsoil reclamation suitability.

Project impacts that are predicted to affect soil quality also have the potential to affect soil suitability for reclamation. Stockpiling salvaged material for reclamation at a later date can impact soil quality and its suitability for use in reclamation. Although some studies have indicated that topsoil storage does not have any severe or long-term effects on soil quality, potential impacts to soil quality can be mitigated by minimizing soil handling by stockpiling once and allowing re-vegetation of the pile until it can be used. Changes to chemical properties are short-term and can be rectified by incorporating a nutrient (e.g., fertilizer) or organic amendment following use of the topsoil for reclamation. Soil physical changes are negligible relative to the changes which can take place during salvage and placement operations. The viability of native seeds and plant propagules in stored topsoil decreases quickly if materials are stored longer than two or three years (Abdul-Kareem and McRae 1984, Stark and Redente 1987, Thurber Consultants Ltd. et al. 1990).

The impact from Project activities to soils suitable for reclamation is predicted to be minimal with mitigation of soil quality issues during the salvage, storage and site restoration phases. Based on the studies mentioned previously, storage of salvaged soil is expected to have little impact on soil quality and its use as reclamation material.

2.6.9.1 Mitigation

To preserve the quality of material to be used as reclaimed topsoil, the following actions are proposed (see Volume IID, Section 2: Land Use and Reclamation):

- place stockpile locations away from areas of potential erosion and in well-drained landscape positions to prevent saturation (either surface water runoff or groundwater) where practical. Saturation of the stockpile results in anaerobic conditions which may have an adverse effect on soil biota, seed viability and nutrient availability (Thurber Consultants Ltd. et al. 1990).
- to prevent soil erosion occurring at stockpiles, the following practices are recommended

- base slope length and gradient selected on the wind and water erosion risk guidelines (i.e., Universal Soil Loss Equation)
- utilize erosion control materials (e.g., mats, mulches, nets) as required
- promptly re-vegetate constructed stockpiles for sufficient ground surface cover
- incorporate vegetation species into the seed mix that will not only protect soil from erosion, but also promote biological activity (e.g., mycorrhizae) and nutrient cycling
- utilize steps to prevent and mitigate soil contamination of soil stockpiles including acid deposition or dry deposition of elemental sulphur

2.6.10 Soil Acidification

Soils within the LSA and RSA are rated as low to moderate with respect to acid sensitivity. For the application case, the predicted average PAI values associated emissions from the Project and neighboring Canexus sodium chlorate plant are 0.04 keq H^+/(ha•y) at the Site boundary (see Volume IIA, Section 2: Climate and Air Quality Figure 2.5-13). Predicted PAI values at the Site are less than 10% of the critical load of 0.50 keq H^+/(ha•y) for soils which are moderately sensitive to acid input (CASA-AENV 1999).

A potential Project effect may be soil acidification from the dry deposition of elemental sulphur within the PDA and within the Site. Acidification by dry deposition of elemental sulphur takes place when sulphur is converted to sulphuric acid by microbial oxidation. The rate at which this process takes place is regulated by several factors including the presence of an appropriate microbial population, soil temperature, soil moisture, sulphur particle size, soil properties, soil contact, soil aeration and the quantity of sulphur present (Janzen and Bettany 1987a and 1987b; Fox et al. 1964; Li and Caldwell 1966 and others). Because of these many factors, the relation between the acidification of soil by dry deposition and the deposition quantity of elemental sulphur is generally not a linear one.

Based on the Project design and mitigation measures to limit aerial dispersal of elemental sulphur, it is assumed that the majority of impacts to soil from dry deposition of elemental sulphur will occur within the PDA, where soils are rated as having a low sensitivity to acid deposition. Based on the sulphur deposition modelling data presented in Volume IIA, Section 2: Climate and Air Quality – Figure 2.5-14, the maximum average predicted annual deposition of sulphur at the Site boundary will be 1.11 kg/ha/y. The effect of this rate of deposition on agricultural soils of moderate-to-low acid sensitivity may be small in comparison to localized soil acidification that generally occurs due to the current agricultural practice of ammonia-based fertilizer application. For agricultural soils, changes to the chemical composition of the soils will occur within timescales (i.e., years) that allow for detection by a periodic soil monitoring program and the changes may be reversed by an appropriate soil treatment such as lime application. Forest and organic soils in the LSA (i.e., Manatokan and Haight) are rated as having low sensitivity to acid deposition and both will have considerable buffering capacity to limit the effects of dry dust acid deposition. However, these soils will be periodically monitored to ensure acidification effects are minimal. Acidification is expected to be reversible by liming.

2.6.10.1 <u>Mitigation</u>

In addition to the Project design, which will limit emissions and releases of elemental sulphur to soil; the following measures will be implemented:

- store topsoil and any subsoil stockpiles away from areas of potential sulphur release and in locations where aerial deposition of elemental sulphur will be limited (see Volume IID, Section 2: Land Use and Reclamation)
- establish surface water management systems to limit surface water contact around the Project with surrounding soil
- establish a periodic soil monitoring program to assess the rate and locations of any increases in soil acidity compared to baseline data within the Site using established guidelines (AENV Air Monitoring Directive Appendix A–7: Soil Monitoring Guidelines; AENV 1989)
- establish a periodic soil monitoring program for the PDA that complies with Guideline for Monitoring and Management of Soil Contamination under EPEA Approvals (AENV 1996)

2.7 Cumulative Effects Assessment Case

There are currently no other planned projects located within the RSA with the potential to affect soil quality with respect to operations at the Site. Similarly, the potential of the Project to affect soil quality at other nearby projects is negligible due to the localized effects. As such, the application case for the Project is expected to encompass all the anticipated effects to soil resources in the LSA and RSA.

2.8 Summary of Impacts

Table 2.8-1: Final Impact Assessment Summary Table for Application Phase

Issue	Direction	Magnitude	Geographic Extent	Duration	Confidence	Reversibility	Impact Class
Changes to Agricultural Land Capability							
Project impacts to agricultural land capability	Neutral to positive	Low	Local	Mid-term	High	Reversible	3
Potential effects on Soil Quality							
Soil admixing	Negative	Low to moderate	Local – confined to PDA	Mid-term	High	Reversible	3
Soil compaction	Negative	Low to moderate	Local	Mid-term	High	Reversible	3
Soil erosion	Negative	Low	Local	Long-term	High	Reversible	2
Soil contamination	Negative	Moderate to high	Local	Mid-term	High	Reversible	2
Alteration of Soil Moisture Regime							
Project impacts to surface hydrology and shallow groundwater quantity	Negative	Low	Local	Mid-term	High	Reversible	3
Soil Suitability for Reclamation							
Project impacts resulting in changes to soil reclamation suitability	Neutral to positive	Low to moderate	Local	Long-term	High	Reversible	3
Soil Acidification							
Project impacts to soil resulting from dry and wet deposition of acidic compounds	Negative	Moderate to high	Local	Long-term	Moderate	Reversible	2

2.9 Reference List

2.9.1 Literature Cited

Abdul-Kareem, A.W. and S.G. McRae. 1984. The Effects on Topsoil of Long-Term Storage in Stockpiles. *Plant and Soil.* 76: 357-363.

Agriculture and Agri-Food Canada. 1995. *Land Suitability Rating System for Agricultural Crops: 1*. Spring-seeded small grains. W.W. Pettapiece (Ed.). Tech. Bull. 1995-6E. Agronomic Interpretations Working Group, Centre for Land and Biological Resources Research, Ottawa, ON. 90 pp.

Agriculture and Agri-Food Canada. 1998. *The Canadian System of Soil Classification.* Expert Committee on Soil Survey. 3rd Edition. Publication 1646. National Research Council Canada. Ottawa, ON.

Agriculture Canada. 1983. *Manual for Describing Soils in the Field.* Expert Committee on Soil Survey. The Canadian Soil Information System (CanSIS). 1982 Revised. J.H. Day (Ed.) LRRI No. 82-52, Research Branch, Agriculture Canada. Ottawa, ON.

Agriculture Canada. 1987. *Soil Survey Handbook*. Expert Committee on Soil Survey. Volume 1. G.M. Coen (ed.). Contribution No. 85-30. Tech. Bulletin 1987-9E. Research Branch. Edmonton, AB.

Agrium Products Inc. 2003. *Environmental Impact Assessment – Northern Extension to the Existing Gypsum Storage Area, Redwater, AB*.

Alberta Environment (AENV). 1989. *Air Monitoring Directive.* Monitoring and Reporting Procedures for Industry. Alberta Environment, Standards and Approvals Division. Edmonton, AB. June 1989.

Alberta Environment (AENV). 1996. *Guideline for Monitoring and Management of Soil Contamination under EPEA Approvals.* Chemical Assessment and Management Division, Environmental Regulatory Services. Edmonton, AB. May 1996.

Alberta Environment (AENV). 2007. *Final Terms of References for an Environmental Impact Assessment (EIA*) Report for the Proposed Bruderheim Sulphur Forming and Shipping Facility. March 13, 2007. Alberta Environment, Edmonton, AB.

Alberta Soil Information Centre (ASIC). 2006. *Alberta Soil Names File* (Generation 3); *User's Handbook.* Land Resource Unit, Research Branch, Agriculture and Agri-Food Canada.

Alberta Soil Information Database (ASIC). 2001. ASIC 3.0: *Agricultural Region of Alberta Soil Inventory Database* (Version 3.0). (Eds.) J.A. Brierley, T.C. Martin and D.J. Spiess. Agriculture and Agri-Food Canada, Research Branch; Alberta Agriculture, Food and Rural Development, Conservation and Development Branch. Edmonton, AB.

BA Energy Inc. 2004. *Volume 2: Environmental Impact Assessment, BA Energy Heartland Upgrader.* Calgary, AB.

Bayrock L.A. 1972. *Surficial Geology of the Edmonton Map Sheet* NTS 83H; Res. Coun. Alberta map (scale 1:250,000).

Browser, W.E., A.A. Kjearsgaard, T.W. Peters and R.E. Wells. 1962. *Soil Survey of Edmonton Sheet (83-H).* Canada Department of Agriculture.

Canadian Council of Ministers of the Environment (CCME). 2006. *Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines.* Winnipeg, MB.

Cannon, K. and L. Leskiw. 1999. *Soil Quality Benchmarks in Alberta.* In: Proceedings of 36th Annual Alberta Soil Science Workshop, February 16-18, 1999, Calgary, AB.

Cheng, L. 2006. *Acid Deposition Modelling using RELAD*. Presented at Emerging Issues in Air Quality Modelling for Canada. AWMA Conference. Calgary, AB. October 3–5, 2006. As referenced in Petro-Canada Oilsands Inc. 2007, Fort Hills Sturgeon Upgrader. Volume 2 Environmental and Socio-Economic Impact Assessment.

Clean Air Strategic Alliance (CASA)/Alberta Environment (AENV). 1999. *Application of Critical, Target and Monitoring Loads for the Evaluation and Management of Acid Deposition.* Target Loading Subgroup, CASA and Environmental Service, Environmental Sciences Division, Alberta Environment. Publication No. T/472. Edmonton, AB.

Coote, D.R. and W.W. Pettapiece. 1989. *Wind Erosion Risk – Alberta. Canada-Alberta Soil Inventory*, Land Resource Research Centre, Research Branch, Agriculture Canada.

Crown. P.H. 1977. *Soil Survey of Elk Island National Park Alberta.* Agriculture Canada Research Branch. Soil Research Institute Soil Survey, Edmonton. Alberta Institute of Pedology S-77-38.

Environmental Law Centre. 2007. *Wellsite Historical Search for Legal Location: 35-55-20-W4M.*

Fox, R.L., H.M Atesalp, D.H. Kampbell and H.F. Rhoades. 1964. Factors influencing the availability of sulfur fertilizers to alfalfa and corn. *Soil Sci. Soc. Am. Proc.* 28:406-408.

Hamilton, W.N., M.C. Price and C.W. Langenberg (compilers). 1999. *Geological Map of Alberta.* Alberta Geological Survey, Alberta Energy and Utilities Board. Edmonton, AB. Map No. 236, Scale 1:1,000,000.

Holowaychuck, N. and R.J. Fessenden. 1987. *Soil Sensitivity to Acid Deposition and the Potential of Soils and Geology in Alberta to Reduce the Acidity of Acidic Inputs*. Prepared for Alberta Environment by Natural Resources Division, Terrain Sciences Department, Alberta Research Council. Earth Sciences Report 87-1. Edmonton, AB.

Janzen, H.H. and J.R. Bettany. 1987a. Measurement of sulfur oxidation in soils. *Soil Sci.* 143:444-452.

Janzen, H.H. and J.R. Bettany. 1987b. The Effect of Temperature and Water Potential on Sulfur Oxidation in Soils. *Soil Sci*. Vol 144, No. 2. August 1987.

Li, P. and A.C. Caldwell.1966. The oxidation of elemental sulphur in soils. *Soil Sci. Soc. Am. Proc*. 30:370-372.

Macyk, T.M., L.K. Brocke, J. Fujikawa, J.C. Hermans and D. McCoy. 1987. *Soil Quality Criteria Relative to Disturbance and Reclamation*. Prepared by Soil Quality Criteria Working Group. Soil Reclamation Subcommittee. Alberta Agriculture. Edmonton, AB.

Natural Regions Committee (NRC). 2006. *Natural Regions and Subregions of Alberta*. Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. I/005.

North West Upgrading Inc. 2006. *Northwest Upgrading Integrated Application for Approval.,* Volume II and III, Environmental Reports. Calgary, AB.

Pedocan Land Evaluation Ltd. (Pedocan). 1993. *Soil Series Information for Reclamation Planning in Alberta.* Alberta Conservation and Reclamation Council Report No. RRTAC 93-7.

Petro-Canada Oilsands Inc. 2007. *Fort Hills Sturgeon Upgrader*. Volume 2 Environmental and Socio-Economic Impact Assessment.

Pettapiece, W. 1986. *Physiographic Subdivisions of Alberta* 1:1,500,000. Land Resource Centre, Research Branch. Ottawa, ON.

Powter, C.B. (Compiler). 2002. *Glossary of Reclamation and Remediation Terms Used in Alberta* – 7th Edition. Alberta Environment, Science and Standards Branch. Edmonton, AB.

Shell Canada Limited. 2005. *Scotford Upgrader Expansion Project.* Environmental Impact Assessment.

Shetsen, I. 1990. *Quaternary Geology, Central Alberta* 1: 500,000. Map 213, Alberta Geological Survey and Energy Utility Board.

Stark, J.M. and E.F. Redente. 1987. Production Potential of Stockpiled Topsoil. *Soil Science* 144: 72-76.

Tajek, J. W.W. Pettapiece and K.E. Toogood. 1985. Water erosion potential of soils in Alberta: estimates using a modified USLE. *Agriculture Canada Technical Bulletin No. 1985-29*. Ottawa, ON.

Thurber Consultants Ltd., Land Resources Network Ltd. and Norwest Soil Research Ltd. 1990. *Review of the Effects of Storage on Topsoil Quality.* Alberta Land Conservation and Reclamation Council Report No. RRTAC 90-5.

Turchenek, L.W., S.A. Abboud, U. Downey. 1998. *Critical Loads for Organic (Peat) Soils in Alberta.* Prepared for Target Loading Subgroup Clean Air Strategic Alliance.

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Appendix I: Summary of Field Methods

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1. Summary of Field Methods

The Principal Development Area (PDA), Local Study Area (LSA) and Regional Study Area (RSA) were traversed primarily by pick-up truck and by foot where access was limited. Inspection locations were chosen based on existing soil survey data and air photo analysis. Inspections consisted of using a Dutch hand auger and shovel to examine mineral and organic soils. Soil inspections were conducted in accordance with the guidelines and procedures outlined in Agriculture and Agri-Food Canada (1983, 1987 and 1998) including the Canadian Soil Information System (CanSIS). Sampling sites are inspection sites that included collection and laboratory analysis of soil horizons. Mineral soils were examined to a depth of greater than 100 cm, unless excessive stoniness precluded further examination. Organic soils were examined to a maximum depth of 200 cm using an extension auger.

1.1 Soil Inspections

Soil inspections were conducted in accordance with the guidelines and procedures outlined in Agriculture and Agri-Food Canada (1983, 1987 and 1998) including the Canadian Soil Information System (CanSIS).

At each soil inspection location, the horizon description included the following:

- subgroup classification
- horizon name
- depth
- colour
- texture
- structure
- consistence
- coarse fragments
- mottles
- presence of carbonates or salts
- rooting description

1.2 Site Description

At each soil inspection location, information was collected on the following:

- parent geologic material
- slope class
- slope position
- aspect
- drainage
- approximate water table depth

- erosion
- stoniness class
- present land use
- vegetation cover (if present)
- Universal Transverse Mercator (UTM) coordinates of NAD 83, Zone 12 north

1.3 Pre-disturbance Soil Capability Classes

Pre-disturbance soil capability was estimated in the field based on the Agricultural Capability Rating Classes as outlined in the Land Suitability Rating System for Agricultural Crops (Agriculture and Agri-Food Canada 1995). See Table I–1 for descriptions of each Class. Subclasses were not determined during the field survey.

Table I–1: Agricultural Capability Classes

Agricultural Capability Rating	Degree of Limitation
Class 1	None to slight: no significant limitations for production of the specified crop
Class 2	Slight: land in this class has slight limitation that may restrict growth of specified crops or require special management practices
Class 3	Moderate: land in this class has moderate limitations that restrict the growth of the specified crops or require special management practices
Class 4	Severe: land in this class has severe limitations that restrict growth of the specified crops or require special management practise or both. This class is marginal for sustained production of the specified crops.
Class 5	Very severe: land in this class has very severe limitations for sustained production of the specified crops and annual cultivations using common cropping practices not recommended
Class 6	Extremely severe: land in this class has extremely severe limitations for sustained production of the specified crops and annual cultivation is not recommended even on an occasional basis
Class 7	Unsuitable: Land in this class in not suitable for the production of the specified crops

Source: Agriculture and Agri-Food Canada (1995).

1.4 Soil Classification

Soils were classified to the subgroup level according to the guidelines of the Canadian System of Soil Classification (Agriculture and Agri-Food Canada 1998) and then classified to soil series in accordance with ASIC (2001), Pedocan (1993), as well as previous soil survey reports and Environmental Impact Assessments (EIAs) in region. The soil and site descriptions collected in the survey were used to assess pre-disturbance soil capability according to the land suitability rating system in Agriculture and Agri-Food Canada (1995).

1.5 Survey Intensity

A Survey Intensity Level (SIL) 1 (Agriculture and Agri-Food Canada 1987) was used for the Principal Development Area (PDA). A SIL 1 is defined as one inspection per 1–5 ha; the actual survey inspection intensity for the PDA was one inspection per 1.2 ha. This SIL provides an adequate data set from which to map the PDA. The remainder of the LSA was mapped at SIL 2, which is defined as one inspection point for every 2–20 ha. The actual survey inspection intensity for the Local Study Area (LSA) was one inspection per 6.8 ha.

For the purposes of the soil study, the PDA is approximately 24.8 ha in size, while the remainder of the LSA is approximately 382.6 ha in size. A total of 60 inspections points within the LSA and PDA were completed. Three inspections were completed in the Regional Study area (RSA) and due to access restrictions in a portion of the RSA, additional information on the soils in the RSA was compiled from AGRASID (2001).

1.6 Soil Sampling and Analysis

Composite soil samples of individual horizons were collected to a maximum depth of 150 cm, kept in plastic bags and stored in a cool environment until they could be shipped to ETL Laboratories in Edmonton, Alberta for subsequent chemical and physical analyses.

Soil samples were analyzed for all, or a portion, of the following:

- particle size analysis (texture)
- salinity/sodicity parameters including electrical conductivity (EC), sodium adsorption ratio (SAR), pH, saturation percentage, and main soluble ions
- elemental sulphur and total sulphur
- total organic carbon (TOC), organic matter (OM), total inorganic carbon, total Kjeldahl nitrogen (TKN)
- plant available nutrients (nitrogen, phosphorus, potassium and sulphur)
- calcium carbonate equivalent
- major and trace metals using inductively coupled plasma/mass spectroscopy, including mercury and hot-water-soluble boron
- bulk density measured from an oven-dried sample of known volume

1.7 References

1.7.1 Literature Cited

AGRASID. 2001. *Agricultural Region of Alberta Soil Inventory Database,* Version 3.0 released on CD-ROM. Available from Alberta Agriculture, Food and Rural Development.

Agriculture and Agri-Food Canada. 1983. *The Canadian Soil Information System* (CanSIS). Manual for Describing Soils in the Field. Expert Committee on Soil Survey. 1982 Revised. J.H. Day (Ed.) LRRI No. 82-52, Research Branch, Agriculture Canada. Ottawa, ON, p. 97.

Agriculture and Agri-Food Canada. 1987. *Soil survey handbook.* Expert Committee on Soil Survey. *Volume 1.* G.M. Coen (Ed.). Contribution No. 85-30. Tech. Bulletin 1987-9E. Research Branch, Agriculture Canada. Edmonton, AB.

Agriculture and Agri-Food Canada. 1995. *Land Suitability Rating System for Agricultural Crops: 1.* Spring-seeded small grains. W.W. Pettapiece (Ed.). Tech. Bull. 1995-6E. Agronomic Interpretations Working Group, Centre for Land and Biological Resources Research, Agriculture and Agri-Food Canada, Ottawa, ON. 90 pp., 2 maps.

Agriculture and Agri-Food Canada. 1998. *The Canadian System of Soil Classification.* 3rd Edition. Expert Committee on Soil Survey. Agriculture and Agri-Food Canada. Publication 1646. National Research Council Canada. Ottawa, ON, p. 187.

Alberta Soil Information Centre (ASIC). 2006. *Alberta Soil Names File* (Generation 3); *User's Handbook.* Land Resource Unit, Research Branch, Agriculture and Agri-Food Canada.

Pedocan Land Evaluation Ltd. (Pedocan). 1993. *Soil Series Information for Reclamation Planning in Alberta.* Alberta Conservation and Reclamation Council Report No. RRTAC 93-7.

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Appendix II: Detailed Soil Series Descriptions

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1. Detailed Soil Series Descriptions

The dominant soil series identified in the soil mapping of the LSA are described below. The soils are described in terms of their morphological, physical and chemical attributes. Soil data from other sources was incorporated (and referenced), where available, if a modal soil series was not sampled.

1.1 Abbreviations

The following abbreviations are used in the tables below.

"---" - not applicable, or not analyzed

The following abbreviations pertain to soil structure descriptions, which describe grade (distinctness) – class (size) – kind (shape). For example, strong, medium, platy is shown as s-m-pl.

Grade (Distinctness)

vw	–	very weak
w	–	weak
m	–	moderate
s	–	strong

Class (Size)

f	–	fine
m	–	medium
c	–	course

Kind (Shape)

cl	–	columnar
pl	–	platy
pr	–	prismatic
sg	–	single grain
sbk	–	subangular blocky

The following abbreviations pertain to soil chemical and physical parameters:

Chemical Parameters

TOC	–	total organic carbon
TN	–	total nitrogen
NO_3-N	–	nitrate nitrogen
PO_4-P	–	phosphate phosphorus
K	–	potassium
SO_4-S	–	sulphate sulphur
$CaCO_3$	–	calcium carbonate equivalent
EC	–	electrical conductivity
SAR	–	sodium adsorption ratio

Physical Parameters

D_b	–	bulk density
Sat	–	percent saturation

1.2 Detailed Soil Series Descriptions

1.2.1 Angus Ridge Soil Map Unit (AGS)

Soil Subgroup Classification: Eluviated Black Chernozem

Parent Geologic Material: Morainal (Edmonton Formation Till)

Topography (Slope Class/%): Class 2 to 3/>0.5 to 5 % slope

Slope Position: Middle slope

Drainage Class: Moderately well to well drained.

Land Use Cropland

Comments: Modal Angus Ridge soil series are Eluviated Black Chernozems developed on moderately fine textured till (Clay Loam) according to the Alberta Soil Information Centre (ASIC) soil names file. They are typically moderately stoney soil occupying blanket, undulating and hummocky landforms. Usual soil moisture conditions are moderately well to well drained. Topsoil thickness ranges from 20–40 cm. Soils are non-saline and moderately calcareous. These soil series are considered very good for agriculture.

Table II–1: Physical and Chemical Characteristics of the Angus Ridge Map Unit

Horizon	Depth (cm)	Colour	Texture	Sand (%)	Silt (%)	Clay (%)	CF (%)	Structure	Consistence
Site 31									
Ap	0-26	10YR 3/2	L	32	46	22	---	granular	Friable
Bt	26-65	10YR 6/3	L	41	34	26	few	s- m to c- sbk	Moderately firm
Csk	65-1.20	10YR 6/2	L	37	38	25	few	massive	Firm

Note:
* For all detailed soil descriptions, the texture classification presented is the laboratory-determined texture class unless otherwise noted.

Horizon	TOC (%)	TN (%)	pH	Available Nutrients (mg/kg)				D_b (kg/m^3)	$CaCO_3$ (%)
				NO_3-N	PO_4-P	K	SO_4-S		
Site 31									
Ap	3.1	0.28	6.2	11.0	14	120	15	1,050	<0.7
Bt	---	---	7.3	---	---	---	---		---
Csk	---	---	7.9	---	---	---	---	---	2.4

Horizon	Sat (%)	EC (dS/m)	SAR	Soluble Ions – Paste Extract (mg/L)					
				Ca	Mg	K	Na	Cl	SO_4
Site 31									
Ap	52	0.5	1.9	51	13	3	59	30	74.5
Bt	51	0.7	2.8	60	21	3	99	15	113
Csk	61	1.4	14.8	33	12	5	391	29	341

1.2.2 Camrose Soil Map Unit (CMO)

Soil Subgroup Classification: Black Solodized Solonetz

Variants or Modifiers: Gleyed Subgroup (Gleyed Black Solodized) (gl)

Parent Geologic Material: Moranial (Edmonton Formation Till)

Topography (Slope Class/%): Class 2 to 3/>0.5 to 5 % slope

Slope Position: Lower, middle and upper slope

Drainage Class: Well to imperfectly drained

Land Use: Cropland, natural grazing, improved pasture and forage

Comments: Modal Camrose soil series are Black Solodized Solonetzs developed on moderately fine till according to the ASIC soil names file. They are typically soils occupying well to imperfectly drained lower to upper slope landscape positions on blanket landforms. Gleyed phases are common. Topsoil depths range from 15–35 cm. Soils are typically moderately saline and calcareous.

Table II–2: Physical and Chemical Characteristics of the Camrose –Map Unit

Horizon	Depth (cm)	Colour	Texture	Sand (%)	Silt (%)	Clay (%)	CF (%)	Structure	Consistence
Site 11A									
Ap	0-32	10YR 3/2	SiL	31	52	17	---	f-granular	Friable
Ae	32-38	10YR 7/2	SiL	37	56	7	Very Few	s-pl	Friable
Bntgj	38-70	10YR 7/4 and 10YR 4/3	L	40	33	27	Few	s-pr	Dry Hard
Ckg	70-120	10YR 6/8	SiCL	9	58	33	Few	massive	Very Firm

Horizon	TOC (%)	TN (%)	pH	Available Nutrients (mg/kg)				D_b (kg/m^3)	$CaCO_3$ (%)
				NO_3-N	PO_4-P	K	SO_4-S		
Site 11A									
Ap	3.6	0.33	5.0	8.0	13	114	22	---	<0.7
Ae	0.3	0.05	7.0	---	---	---	---	1,220	<0.7
Bntgj	---	---	7.5	---	---	---	---	---	<0.7
Ckg	---	---	8.0	---	---	---	---	1,100	1.5

Horizon	Sat (%)	EC (dS/m)	SAR	Soluble Ions – Paste Extract (mg/L)					
				Ca	Mg	K	Na	Cl	SO_4
Site 11A									
Ap	46	0.6	3.0	35	9	2	77	53	160
Ae	30	0.7	6.6	20	7	1	134	67	140
Bntgj	48	0.7	10.7	9	3	<1	151	31	96.9
Ckg	73	1.0	14.8	11	5	<1	236	26	202

1.2.3 Manatokan-AA Soil Map Unit (MNT-aa)

Soil Subgroup Classification: Terric Mesisol

Parent Geologic Material: Glaciolacustrine

Topography (Slope Class/%): Class 1/0 to 0.5% slope

Slope Position: Lower, depressional

Drainage Class: Poorly drained

Land Use: Wetland marsh

Comments: The home Soil Correlation Area (SCA) for the Manatokan soil series is 12. Modal Manatokan-AA soils are Terric Mesisols developed on moderately fine textured glaciolacustrine sediments according to the ASIC soil names file. They occupy depressional slope positions with characteristic fen (sedges) and/or marsh (cattails) vegetation. These soils are typically non-saline and non-calcareous, but in the Bruderheim Sulphur Forming and Shipping Facility Project area (the Project) they are weakly saline and calcareous.

Table II–3: Physical Characteristics of Manatokan-AA Map Unit

Horizon	Depth (cm)	Colour	Texture	Sand (%)	Silt (%)	Clay (%)	CF (%)	Structure	Consistence
Site 17									
Om	0-60	10YR 2/2	---	---	---	---	---	---	---
Cg	60-120	10YR 6/1	SiC	6	45	49	---	massive	Moderately Soft

Horizon	TOC (%)	TN (%)	pH	Available Nutrients (mg/kg)				D_b (kg/m^3)	$CaCO_3$ (%)
				NO_3-N	PO_4-P	K	SO_4-S		
Site 17									
Om	19.5	2.04	7.2	13.0	4	444	1,350	440	3.2
Cg	---	---	7.7	---	---	---	---	---	8.2

Horizon	Sat (%)	EC (dS/m)	SAR	Soluble Ions – Paste Extract (mg/L)					
				Ca	Mg	K	Na	Cl	SO_4
Site 17									
Om	103	2.8	---	---	---	---	---	---	---
Cg	125	1.3	2.8	106	38	24	132	6	532

1.2.4 Duagh Soil Map Unit (DUG)

Soil Subgroup Classification: Black Solonetz

Variants or Modifiers: Gleyed Subgroup (Gleyed Black Solonetz) (gl); and modifier xt indicates till within 30-99 cm.

Parent Geologic Material: Glaciolacustrine underlain by till

Topography (Slope Class/%): Class 1 to 2/0 to 2% slope

Slope Position: Level and lower

Drainage Class: Imperfectly drained

Land Use: Improved pasture and forage

Comments: Modal Duagh soil series are Black Solonetzs developed on fine glaciolacustrine sediments according to the ASIC soil names file. They occupy level (gl variant) to lower slope positions with natural shrub vegetation (willows), and pasture grasses or forage crops. Soils are typically moderately saline and weak to moderately calcareous. Top soil depths range from 10–20 cm. The solonetzic B horizon make this soil undesirable for cropland.

Table II–4: Physical and Chemical Characteristics of the Duagh Map Unit

Horizon	Depth (cm)	Colour	Texture*	Sand (%)	Silt (%)	Clay (%)	CF (%)	Structure	Consistence
Site 15									
Ap	0-16	10YR 3/1	L	---	---	---	---	f-granular	Friable
Bntj	16-50	10YR 6/2 In-ped/10YR 3/2 Ex-ped	SiCL	---	---	---	---	m-pr/cl	Hard to firm
Ckg	50-65	10YR 6/2	SiCL	---	---	---	few	massive	Firm
II Ckg	60-150	10YR 5/2	C	---	---	---	few	massive	Firm

Note:
* field texture.

Horizon	TOC (%)	TN (%)	pH	Available Nutrients (mg/kg)				D_b (g/cm^3)	$CaCO_3$ (%)
				NO_3-N	PO_4-P	K	SO_4-S		
Duagh									
Ap	4.0	---	5.7	---	---	---	---	1.10	0
Bnt	1.8	---	5.2	---	---	---	---	1.50	0
Bnt	1.5	---	5.4	---	---	---	---	1.50	0
Csakgj	0.0	---	7.6	---	---	---	---	1.35	7
Cskgj	0.0	---	7.8	---	---	---	---	1.30	5

Source: Data from AGRASID (2001).

Horizon	Sat (%)	EC (dS/m)	SAR	Soluble Ions – Paste Extract (mg/L)					
				Ca	Mg	K	Na	Cl	SO_4
Duagh									
Ap	65	0	---	---	---	---	---	---	---
Bnt	73	0	---	---	---	---	---	---	---
Bnt	83	1	---	---	---	---	---	---	---
Csakgj	99	15	---	---	---	---	---	---	---
Cskgj	99	10	---	---	---	---	---	---	---
Source: Data from AGRASID (2001).									

1.2.5 Hobbema Soil Map Unit (HBM)

Soil Subgroup Classification: Eluviated Black Chernozem

Variants or Modifiers: Gleyed Subgroup (Gleyed Eluviated Black Chernozem) (gl)

Parent Geologic Material: Glaciolacustrine underlain by till

Topography (Slope Class/%): Class 3/2 to 5 % slope

Slope Position: Lower to middle slope

Drainage Class: Well

Land Use: Cropland

Comments: The Hobbema soil series are well drained Eluviated Black Chernozems developed on a veneer of medium textured glaciolacustrine deposits underlain by fine textured till according to the ASIC soil names file. Hobbema soils have the same characteristics as Ponoka but develop when the depth to till is considered shallow (31–99 cm). Topsoil depths range from 20–40 cm and soils are non to very weakly saline and moderately calcareous.

Table II–5: Physical and Chemical Characteristics of the Hobbema Map Unit

Horizon	Depth (cm)	Colour	Texture*	Sand (%)	Silt (%)	Clay (%)	CF (%)	Structure	Consistence
Site 4									
Ap	0-28	10YR 3/2	SiL/L	36	50	14	---	m-granular	Friable
Ae	28-38	10YR 7/2	L	39	48	14	---	v s-m-pl	Friable
Bt	38-80	10YR 6/3	SiL	21	53	26	---	s-m-sbk	Friable
C	80-120	10YR 5/3	SiCL	14	53	33	5	massive	Firm

Note:
* field hand texture.

Horizon	TOC (%)	TN (%)	pH	Available Nutrients (mg/kg)				D_b (kg/m^3)	$CaCO_3$ (%)
				NO_3-N	PO_4-P	K	SO_4-S		
Site 4									
Ap	3.2	0.35	6.0	10.0	99	872	27	960	<0.7
Ae	1.5	0.15	6.4	---	---	---	---	---	<0.7
Bt	---	---	6.5	---	---	---	---	---	<0.7
C	---	---	6.4	---	---	---	---	---	<0.7

Horizon	Sat (%)	EC (dS/m)	SAR	Soluble Ions – Paste Extract (mg/L)					
				Ca	Mg	K	Na	Cl	SO_4
Site 4									
Ap	54	0.8	0.8	73	12	115	30	68	188
Ae	44	0.6	1.0	77	12	17	36	33	177
Bt	47	0.5	1.8	48	7	6	50	25	122
C	58	1.0	3.1	87	14	7	119	258	289

1.2.6 Haight Soil Map Unit (HGT)

Soil Subgroup Classification: Orthic Humic Gleysol

Parent Geologic Material: Fine glaciolacustrine

Topography (Slope Class/%): Class 1/0 to 0.5 % slope

Slope Position: Level

Drainage Class: Imperfectly

Land Use: Woodland

Comments: The Haight soil series are imperfectly drained Orthic Humic Gleysols developed on level fine textured glaciolacustrine (water-laid sediment) landforms according to the ASIC soil names file. Topsoil depths are from 15–60 cm and the soils are non-saline and moderately calcareous. In the project area the vegetation associated with this soil series is aspen woodland.

Table II–6: Physical and Chemical Characteristics of the Haight Map Unit

Horizon	Depth (cm)	Colour	Texture	Sand (%)	Silt (%)	Clay (%)	CF (%)	Structure	Consistence
Site 13									
LF	-10-0	---	---	---	---	---	---	---	---
Ah	0-15	10YR 2/1	Loam	34	42	25	---	m-granular	Friable
Bg	15-38	10YR 4/1	Loam	34	41	25	---	f-sbk	Friable
Cg	38-150	10YR 7/2	Loam	38	40	23	few	massive	Moderately Firm

Horizon	TOC (%)	TN (%)	pH*	Available Nutrients (mg/kg)				D_b (kg/m^3)	$CaCO_3$ (%)
				NO_3-N	PO_4-P	K	SO_4-S		
Site 13									
LF	28.0	1.91	6.8*	65.0	31	913	53	380	3.3
Ah	4.1	0.37	6.2	4.2	8	523	14	970	<0.7
Bg	---	---	6.1	---	---	---	---	---	---
Cg			6.7	---	---	---	---	---	<0.7

Notes:
* pH and EC determined from 1:1 soil to water solution, not by saturated paste method.

Horizon	Sat (%)	EC*(dS/m)	SAR	Soluble Ions – Paste Extract (mg/L)					
				Ca	Mg	K	Na	Cl	SO_4
Site 13									
LF	303	1.0	---	---	---	---	---	---	---
Ah	63	0.6	1.3	65	17	34	46	22	55.0
Bg	44	0.4	2.0	36	10	16	54	33	55.3
Cg	54	0.3	2.0	24	9	4	45	20	54.4

Notes:
* pH and EC determined from 1:1 soil to water solution, not by saturated paste method.

1.2.7 Hairy Hill Soil Map Unit (HYL)

Soil Subgroup Classification: Rego Humic Gleysol

Parent Geologic Material: Morainal (till)

Topography (Slope Class/%): Class 3/2 to 5 %

Slope Position: Lower

Drainage Class: Imperfectly

Land Use: Cropland

Comments: The Hairy Hill series are Rego Humic Gleysols developed on moderately fine till sediments in discharge areas according to the ASIC soil names file. Topsoil depth ranges from 10–35 cm and soils are typically moderately saline and calcareous.

Table II–7: Physical and Chemical Characteristics of the Hairy Hill Map Unit

Horizon	Depth (cm)	Colour	Texture*	Sand (%)	Silt (%)	Clay (%)	CF (%)	Structure	Consistence
Site 50									
Ap	0-26	10YR 3/2	SiCL	---	---	---	few	v w- sab	Friable
Ah	26-65	10YR 4/3	SiCL	---	---	---	few	f- granular	Friable
Cg	65-120	10YR 6/3	CL	---	---	---	very few	massive	Firm
Note: * field texture.									

Horizon	TOC (%)	TN (%)	pH	Available Nutrients (mg/kg)				D_b (g/cm^3)	$CaCO_3$ (%)
				NO_3-N	PO_4-P	K	SO_4-S		
Hairy Hill									
Ahks	2.9	---	7.9	---	---	---	---	1.20	6
ACksg	2.0	---	8.5	---	---	---	---	1.40	7
Ccasg	0.0	---	8.6	---	---	---	---	1.35	15
Source: Data from AGRASID (2001).									

Horizon	Sat (%)	EC (dS/m)	SAR	Soluble Ions – Paste Extract (mg/L)					
				Ca	Mg	K	Na	Cl	SO_4
Hairy Hill									
Ahks	99	4	---	---	---	---	---	---	---
ACksg	99	8	---	---	---	---	---	---	---
Ccasg	99	10	---	---	---	---	---	---	---
Source: Data from AGRASID (2001).									

1.2.8 Peace Hills Soil Map Unit (PHS)

Soil Subgroup Classification:	Orthic Black Chernozem
Soil Variants or Modifiers:	Gleyed Subgroup (Gleyed Black Chernozem) (gl)
Parent Geologic Material:	Moderately coarse glacial fluvial or eolian
Topography (Slope Class/%):	Class 3/2-5 % slopes
Slope Position:	Middle to upper
Drainage Class:	Moderately well to well drained
Land Use:	Cropland
Comments:	The Peace Hills soil series are moderately well to well drained Orthic Black Chernozems developed on blanket landforms of glacial fluvial or eolian sediments according to the ASIC soil names file. Topsoil depths range from 20–40 cm and soils are considered non-saline and weakly calcareous.

Table II–8: Physical and Chemical Characteristics of the Peace Hills Map Unit

Horizon	Depth (cm)	Colour	Texture	Sand (%)	Silt (%)	Clay (%)	CF (%)	Structure	Consistence
Site 12A									
Ap	0-25	10YR 2/2	SL	56	32	12	---	f-granular	Friable
Ae/Ahe	25-35	10YR 4/4	SL	62	27	11	---	w- f- pl	Friable
Btg	35-53	10YR 6/2	SL	64	22	14	---	s-m-sbk	Dry to moderately hard
C	53-150	10YR 6/4	LS	82	10	9	5	sg	Loose
Site 33									
Ap	0-31	10YR 3/2	L	50	38	12	---	granular	Friable
Ae	31-35	10YR 7/2	L	48	34	17	---	m-pl	Firm
Bm	35-70	10YR 6/4	L	45	36	19	---	m-sbk	Moderately Firm
C	70-120	10YR 7/4	SL	68	18	14	---	massive	Moderately Firm

Horizon	TOC (%)	TN (%)	pH	Available Nutrients (mg/kg)				D_b (kg/m^3)	$CaCO_3$ (%)
				NO_3-N	PO_4-P	K	SO_4-S		
Site 12A									
Ap	2.2	0.15	5.7	13.0	8	132	6	1,130	<0.7
Ae/Ahe	0.3	0.06	6.5	---	---	---	---	1,190	<0.7
Btg	---	---	6.7	---	---	---	---	1,200	---
C	---	---	7.5	---	---	---	---	1,330	<0.7
Site 33									
Ap	5.0	0.42	5.6	23.0	35	280	12	930	<0.7
Ae	---	---	7.0	---	---	---	---	---	<0.7
Bm	---	---	7.2	---	---	---	---	---	---
C	---	---	6.5	---	---	---	---	1,200	<0.7

Horizon	Sat (%)	EC (dS/m)	SAR	Soluble Ions – Paste Extract (mg/L)					
				Ca	Mg	K	Na	Cl	SO_4
Site 12A									
LF	303	1.0	0.7	---	---	---	---	---	---
Ah	63	0.6	0.7	65	17	34	46	22	55.0
Bg	44	0.4	0.6	36	10	16	54	33	55.3
Cg	54	0.3	0.8	24	9	4	45	20	54.4
Site 33									
Ap	57	0.6	2.0	57	9	16	60	47	63.9
Ae	39	0.5	0.9	62	13	3	28	17	45.5
Bm	37	0.5	0.8	68	16	3	28	18	54.2
C	34	0.4	1.4	33	11	3	36	20	69.3

1.2.9 Ponoka Soil Map Unit (POK)

Soil Subgroup Classification: Eluviated Black Chernozem

Parent Geologic Material: Fluvial, lacustrine and glaciolacustrine

Topography (Slope Class/%): Class 3/2–5 % slope

Slope Position: Lower, middle

Drainage Class: Well drained

Land Use: Cropland

Comments: Modal Ponoka soil series are Eluviated Black Chernozems developed on medium textured glaciolacustrine sediments according to the ASIC soil names file. Topsoil depths range from 20–40 cm and soils are typically non-saline and moderately-calcareous. Ponoka soils are considered excellent for agriculture.

Table II–9: Physical and Chemical Characteristics of the Ponoka Map Unit

Horizon	Depth (cm)	Colour	Texture	Sand (%)	Silt (%)	Clay (%)	CF (%)	Structure	Consistence
Site 1									
Ap	0-26	10YR 3/2	SiL	35	53	12	---	f-gr	Friable
Aej	26-30	10YR 5/3	L	40	39	21	---	w-f- sbk	Friable
Bt	30-65	10YR 6/4	L	34	43	23	---	m-pr	Moderately Firm
Ck	65-120	10YR 7/3	SCL	49	26	25	---	massive	Friable
Site 52									
Ap	0-19	10YR 3/2	L	49	34	17	---	f-gr	Friable to moderately firm
Aej	19-24	10YR 6/2	SiL[1]	---	---	---	---	v w- pl	Friable
Bt	24-66	10YR 7/3	L	46	33	21	very few	m-pr	Friable
Ck	66-120	10YR 7/4	SL	69	14	17	---	massive	Moderately Firm

Note:
[1] Field texture.

Horizon	TOC (%)	TN (%)	pH	Available Nutrients (mg/kg)				D_b (kg/m^3)	$CaCO_3$ (%)
				NO_3-N	PO_4-P	K	SO_4-S		
Site 1									
Ap	3.8	0.31	6.3	6.4	4	102	15	1,020	<0.7
Aej	---	---	7.0	---	---	---	---	---	---
Bt	---	---	7.4	---	---	---	---	1,100	<0.7
Ck	---	---	7.5	---	---	---	---	---	8.6
Site 52									
Ap	2.9	0.24	7.2	5.0	27	511	8	1,030	<0.7
Aej	---	---	---	---	---	---	---	---	---
Bt	---	---	7.9	---	---	---	---	1,080	<0.7
Ck	---	---	7.6	---	---	---	---	---	<0.7

Horizon	Sat (%)	EC (dS/m)	SAR	Soluble Ions – Paste Extract (mg/L)					
				Ca	Mg	K	Na	Cl	SO_4
Site 1									
Ap	51	0.6	1.1	74	12	3	40	40	96.0
Aej	41	0.7	0.6	108	20	3	26	28	129
Bt	43	0.6	0.7	75	15	3	25	23	60.0
Ck	45	0.6	0.5	96	21	3	19	17	26.0
Site 52									
Ap	46	0.6	0.8	79	13	44	29	27	37.2
Aej	---	---	---	---	---	---	---	---	---
Bt	37	0.9	6.4	42	7	36	172	64	104
Ck	38	1.6	9.7	87	16	>5	376	12	394

1.2.10 Wetaskiwin Soil Map Unit (WKN)

Soil Subgroup Classification: Black Solodized Solonetz

Variants or Modifiers: Modifier xt indicates till within 30–99 cm, modifier xs indicates sand within 30–99 cm.

Parent Geologic Material: Fine glaciolacustrine; glaciolacustrine underlain by till or glaciofluvial (sand)

Topography (Slope Class/%): Class 1-3/0-5 % slope

Slope Position: Lower, middle, crest

Drainage Class: Moderately well to well drained

Land Use: Cropland and native grazing

Comments: Modal Wetaskiwin soil series are Black Solodized Solonetzs developed on blanket landforms of fine textured glaciolacustrine sediments according to the ASIC soil names file. Topsoil depths range from 15–25 cm and soils are typically moderately-saline and weakly-calcareous. Wetaskiwin soils are considered fair for agriculture use, but are limited by Solonetzic B horizons that are sodic.

Table II–10: Physical and Chemical Characteristics of Wetaskiwin- XT Map Unit

Horizon	Depth (cm)	Colour	Texture	Sand (%)	Silt (%)	Clay (%)	CF (%)	Structure	Consistence
Site 3									
Ap	0-15	10YR 3/2	L	48	39	13	---	f-gr	Friable
Bnt	15-45	10YR 4/1	L	51	36	14	---	s-m-cl	Very firm
C	45-80	10YR 6/3	L	50	32	17	---	massive	Moderately firm
Ck	80-120	10YR 6/3	SL	64	18	17	---	massive	Moderately firm
II Ck	120-140	10YR 5/3	SCL	47	26	27	v few	massive	Very firm
Site 16									
Ap	0-23	10YR 3/2	L	48	37	15	---	f-gr	Friable
Bnt	23-48	10YR 7/3 In-ped and 10YUR 5/1 Ex-ped	L	46	28	26	---	s-cl	Hard
Csk	48-100	10YR 6/3	SL	65	16	19	---	massive	Hard
II Csk	100-120	10YR 4/2	SiC/C	10	39	50	v few, v fine	massive	Hard

Horizon	TOC (%)	TN (%)	pH	Available Nutrients (mg/kg)				D_b (kg/m^3)	$CaCO_3$ (%)
				NO_3-N	PO_4-P	K	SO_4-S		
Site 3									
Ap	4.3	0.39	5.8	3.4	13	144	20	890	<0.7
Bnt	2.6	0.22	6.5	---	---	---	---	1,000	<0.7
C	---	---	7.7	---	---	---	---	---	<0.7
Ck	---	---	8.3	---	---	---	---	1,040	3.5
II Ck	---	---	7.9	---	---	---	---	1,100	6.1
Site 16									
Ap	4.2	0.41	6.8	6.0	132	1,130	15	1,010	<0.7
Bnt	---	---	8.4	---	---	---	---	1,050	---
Csk	---	---	9.5	---	---	---	---	---	7.6
II Csk	---	---	9.4	---	---	---	---	---	8.0

Horizon	Sat (%)	EC (dS/m)	SAR	Soluble Ions – Paste Extract (mg/L)					
				Ca	Mg	K	Na	Cl	SO_4
Site 3									
Ap	64	0.9	7.2	36	13	4	198	80	98.7
Bnt	102	1.2	15.0	25	7	2	332	124	194
C	86	2.3	28.8	25	5	1	605	103	708
Ck	84	4.6	43.0	53	14	<1	1,360	14	2,560
II Ck	107	5.9	28.3	234	55	<1	1,850	45	3,940
Site 16									
Ap	57	1.1	0.9	87	25	188	35	43	59.8
Bnt	49	3.1	19.4	48	52	110	816	155	748
Csk	89	3.4	58.3	7	11	26	1,090	71	1,360
II Csk	252	3.2	117	<2	3	4	938	25	1,410

1.2.11 Reclaimed Soil Map Units

Soil Subgroup Classification: n/a

Variants or Modifiers: n/a

Parent Geologic Material: Glaciolacustrine, till and glaciofluvial (sand)

Topography (Slope Class/%): Class 1-3/0-5 % slope

Slope Position: All

Drainage Class: Moderately well to well drained

Land Use: Cropland and improved pasture and forage

Comments: Topsoil depths range from 11–90 cm and soils are typically non to moderately-saline and non to moderately-calcareous. These reclaimed soils are composed mostly of the previous soil series of Angus Ridge, Camrose, Peace Hills and Ponoka and are considered fair to good for agriculture use, but in some cases are limited by solonetzic horizons that are sodic.

Table II–11: Physical and Chemical Characteristics of Reclaimed Soil Map Unit

Horizon	Depth (cm)	Colour	Texture	Sand (%)	Silt (%)	Clay (%)	CF (%)	Structure	Consistence
Site 29									
Ap	0-18	10YR 3/2	SL	57	29	14	---	gr	Friable
B	18-35	10YR 7/4	SL	54	29	17	---	massive	Friable
II Bb	35-65	10YR 4/2	SL	54	29	17	---	m-sbk	Firm
Ck	65-120	10YR 7/4	SCL	46	26	27	Few	massive	Firm
Site 35									
Ap	0-16	10YR 3/2	SL	76	16	9	Very few	gr	Friable
C	16-150	10YR 7/3	L	51	29	20	---	sg	Moderately firm
Site 44									
Ap	0-14	10YR 4/3	SiL	29	53	18		f-gr	Friable
Ap/B	14-29	10YR 6/3	CL	---	---	---	5	admixed 50/50	Moderately soft
I Ck	29-37	10YR 6/2	CL	---	---	---	5	m-sbk	Firm
II Ck	37-120	10YR 6/2	L/CL	37	35	27	5	massive	Very firm

Horizon	TOC (%)	TN (%)	pH	Available Nutrients (mg/kg)				D_b (kg/m^3)	$CaCO_3$ (%)
				NO_3-N	PO_4-P	K	SO_4-S		
Site 29									
Ap	2.0	2.8	7.6	2.8	5	77	20	1,190	0.8
B	2.0	---	6.8	---	---	---	---	---	0.7
II Bb	2.0	---	6.8	---	---	---	---	---	0.7
Ck	2.0	---	9.0	---	---	---	---	---	8.0
Site 35									
Ap	---	3.0	7.6	3.0	2	182	20	940	---
C	---	---	7.5	---	---	---	---	1,090	1.5
Site 44									
Ap	4.2	0.41	7.9	5.6	35	196	10	---	2.2
Ap/B	---	---	---	---	---	---	---	---	---

Horizon	TOC (%)	TN (%)	pH	Available Nutrients (mg/kg)				D_b (kg/m^3)	$CaCO_3$ (%)
				NO_3-N	PO_4-P	K	SO_4-S		
I Ck	---	---	---	---	---	---	---	---	---
II Ck	---	---	8.3	---	---	---	---	---	6.7

Horizon	Sat (%)	EC (dS/m)	SAR	Soluble Ions – Paste Extract (mg/L)					
				Ca	Mg	K	Na	Cl	SO_4
Site 29									
Ap	37	1.1	3.7	120	29	3	172	26	132
B	43	1.5	1.3	274	48	4	89	22	330
II Bb	43	1.5	1.3	274	48	4	89	22	330
Ck	204	2.8	Incalculable	<2	<1	3	847	20	1,150
Site 35									
Ap	50	0.6	5.5	21	6	5	112	11	86.1
C	49	1.2	4.4	101	27	11	194	46	72.1
Site 44									
Ap	50	0.8	7.4	24	10	5	172	29	36.9
Ap/B	---	---	---	---	---	---	---	---	---
I Ck	---	---	---	---	---	---	---	---	---
II Ck	67	1.6	14.2	12	17	4	326	34	465

2. References

Alberta Soil Information Centre. 2006. Alberta Soil Names File (Generation 3); User's Handbook. Land Resource Unit, Research Branch, Agriculture and Agri-Food Canada.

Alberta Soil Information Database (ASIC). 2001. ASIC 3.0: *Agricultural Region of Alberta Soil Inventory Database* (Version 3.0). (Eds.) J.A. Brierley, T.C. Martin, and D.J. Spiess. Agriculture and Agri-Food Canada, Research Branch; Alberta Agriculture, Food and Rural Development, Conservation and Development Branch. Edmonton, AB.

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Appendix III: Site Inspection Data

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1. Site Inspection Data

Soil inspection data from a total of 63 inspection locations are summarized below. Soils information was collected to a minimum of 100 cm for mineral profiles unless excessive stoniness precluded further examination and to 200 cm for organic profiles. Hand augers and shovels were used in the investigation.

Soils information collected during the inspection conformed to the criteria outlined in the Canada Soil Information System (CanSIS; Agriculture and Agri-Food Canada 1983, 1987, 1998) and included: subgroup classification, horizon, depth, colour, texture, structure, consistence, coarse fragments, mottles, presence of carbonates and/or salts and rooting description. Site description information collected included: parent geologic material, slope class, slope position, drainage, aspect, approximate water table depth, erosion, stoniness, vegetation cover (if present) and Universal Transverse Mercator (UTM) coordinates of NAD 83, Zone 12 north. Pre-disturbance soil capability was estimated in the field based on the Agricultural Capability Rating Classes as outlined in the Land Suitability Rating System for Agricultural Crops (Agriculture and Agri-Food Canada 1995). An explanation of the classes for each parameter investigated is presented below.

1.1 Soil Series

- AGS – Angus Ridge
- CMO – Camrose
- DUG – Duagh
- HBM – Hobbema
- HGT – Haight
- HYL – Hairy Hill
- POK – Ponoka
- PHS – Peace Hills
- WKN – Wetaskiwin
- Reclaimed

1.2 Soil Series Modifiers or Variants

- gl – gleyed
- xt – till within 99 cm of the soil surface
- xs – sand within 99 cm of the soil surface

1.3 Soil Subgroup Classifications

1.3.1 Chernozemic Order

- O.BLC – Orthic Black Chernozem

- E.BLC – Eluviated Black Chernozem
- GL.BLC – Gleyed Black Chernozem
- GLE.BLC – Gleyed Eluviated Black Chernozem

1.3.2 Gleysolic Order

- O.HG – Orthic Humic Gleysol
- R.HG – Rego Humic Gleysol

1.3.3 Solonetzic Order

- BL.SZ – Black Solonetz
- GLBL.SZ – Gleyed Black Solonetz
- BL.SS – Black Solodized Solonetz
- GLB.SS – Gleyed Black Solodized Solonetz

1.3.4 Organic Order

- T.M – Terric Mesisol

1.4 Parent Materials

- FNPT/GLLC – Glaciolacustrine sediments overlain by fen peat
- GF – Glaciofluvial
- GLLC – Glaciolacustrine
- GLLC/M – Glaciofluvial overlain by glaciolacustrine
- M – Morainal (till)

1.5 Topsoil/ A Horizon or Organic

- Depth of topsoil, A Horizon or O Horizons for organic soil profiles

1.6 Subsoil Texture

- soil texture of subsoil (Horizon overlain by A Horizon, if present), of mineral soil profiles, or texture of underlying mineral material of organic soil profiles

1.7 Slope Class

Class	Percent Slope	Terminology
1	0–0.5	Level
2	>0.5–2	Nearly level
3	>2–5	Very gentle slopes
4	>5–9	Gentle slopes
5	>9–15	Moderate slopes
6	>15–30	Strong slopes
7	>30–45	Very strong slopes
8	>45–70	Extreme slopes
9	>70–100	Steep slopes
10	>100	Very steep slopes

1.8 Slope Position

- C – Crest
- U – Upper slope
- M – Middle slope
- L – Lower slope
- D – Depression
- V – Level

1.9 Drainage

- R – Rapidly drained
- W – Well drained
- MW – Moderately well drained
- I – Imperfectly drained
- P – Poorly drained
- VP – Very poorly drained

1.10 Water Table Depth

- approximate depth of surface groundwater table (m)

1.11 Erosion

- the presence of erosion was noted by the agent and amount of erosion that had occurred

1.11.1 Water Erosion

- N – None
- W1 – Slightly eroded land
- W2 – Moderately eroded land
- W3 – Severely eroded
- W4 – Gullied land

1.11.2 Wind Erosion

- D1 – Slightly wind-eroded
- D2 – Severely wind-eroded
- D3 – Blown-out land

1.12 Stoniness

Rock fragments on the surface of the soil or those protruding above ground have important effects on soil use and management. The limitations they impose are related to their number, size and spacing at the surface. Class limits are defined in terms of the approximate amount of stones and boulders and their spacing. Stoniness classes were estimated for each site inspection.

- S0 – Nonstony
- S1 – Slightly stony
- S2 – Moderately stony
- S3 – Very stony
- S4 – Exceeding stony
- S5 – Excessively stony

1.13 Present Land Use

- C – Cropland
- IP – Improved Pasture
- NG – Natural grazing
- WF – Fen
- WP – Productive woodland

1.14 Estimated Soil Capability Class

Pre-disturbance soil capability was estimated in the field based on the Agricultural Capability Rating Classes as outlined in the Land Suitability Rating System for Agricultural Crops (Agriculture and Agri-Food Canada 1995).

- 1 – Class 1
- 2 – Class 2
- 3 – Class 3
- 4 – Class 4
- 5 – Class 5
- 6 – Class 6
- 7 – Class 7
- NR – Not Rated – Forested area

Table III– 1: Site Inspection Data

Site Number	GPS Coordinates		Reclaimed Profile	Series	Soil Series Modifier 1	Soil Series Modifier 2	Subgroup	Parent Material	Topsoil/A Horizon/Organic		Subsoil Texture	Slope Class	Slope Position	Aspect	Drainage	Water Table (m)	Erosion	Stoniness Class	Present Land Use	Vegetation Cover	Estimated Agriculture Capability Rating	Comments
	Easting	Northing							Depth (cm)	Texture												
1	5963283	377709	N	POK			E.BLC	GLLC	26	L	SiL	3	M	W	W	> 1.20	N	S0	C	Wheat /weeds	2	
2	5963368	377924	N	POK			E.BLC	GLLC	22	SiL	L	3	L	NE	W	> 1.2	N	S0	C	Wheat	2	
3	5963181	378239	N	WKN	xt		BL.SS	GLLC/M	15	SiL	SiL	3	L	E	MW	> 1.4	N	S0	IP	Grass, Foxtail	4-5	
4	5962884	378119	N	HBM			E.BLC	GLLC/M	28	SiL	CL	3	U	S	W	> 1.2	N	S0	C	Wheat	2	
5	5962565	378100	N	AGS			E.BLC	M	25	L	SiCL	3	M	W	W	> 1.2	N	S0	C	Wheat canola	2	
6	5963349	377125	N	HBM	gl		GLE.BC	GLLC/M	30	L	CL	3	L	W	W	>1.0	N	S0	C	Wheat/ weeds	2	
7	5963345	376669	N	HBM			E.BLC	GLLC/M	23	SiL	SiCL	3	M	SE	W	> 1.1	N	S0	C	Wheat/ weeds	2	
8	5963443	378142	N	CMO			GLBL.SS	M	16	SiL	CL	2	L	Level	MW	> 1.1	N	S0	NG	Shrubs/ grass	4-5	
9	5961165	377357	N	CMO			BL.SS	M	21	L	SiCL	2	M	NE	W	> 1.2	N	S0	C	Barley weeds	3	
10	5960977	377652	N	CMO			BL.SS	M	23	SiL	SiL	2	M	NE	MW	>1.2	N	S1	C	Barley	2	
11A	5961493	378105	N	CMO	gl		GLBL.SS	M	32	L	SiCL	3	M	NNW	I	> 1.2	W1	S2	C	Canola stubble	4	
12A	5961533	376244	N	PHS	gl		GL.BLC	GF	25	Si	CL	3	M	SE	MW	>1.5	W1	S0	C	Barley	3	
13	5961639	376535	N	HGT			O.HG	GLLC	15	CL	CL	1	L	Level	I	>1.5	N	S0	WP	Aspen	NR	LF depth 10 cm.
14	5962911	376289	N	DUG	xt	gl	GLBL.SZ	GLLC/M	32	SiL	CL	2	V	NE	I	> 1.2	N	S0	IP	Timothy Alfalfa	6	
15	5963086	376343	N	DUG	xt	gl	BL.SZ	GLLC/M	16	L	SiCL	1	L	Level	I	>1.1	N	S0	IP	Grass, C. Thistle	6	
16	5962841	376544	N	WKN	xt		BL.SS	GLLC/M	23	SiL	SiCL	1	L	Level	MW	>1.2	N	S0	IP	Grass	5	
17	5963031	376566	N	MNT			T.M	FNPT/GLLC	60	n/a	CL	1	D	Level	P	0.8	N	S0	WF	Sedges	7	
18	5962815	376909	N	WKN	xs		BL.SS	GLLC/GF	26	CL	CL	2	L	S	W	>1.4	N	S1	C	Cultivated	3-4	
19	5963060	376947	N	POK			E.BLC	GLLC	23	SiL	SiCL	3	M	SW	W	>1.3	N	S0	C	Cultivated	1	
20	5962948	377352	N	WKN			BL.SS	GLLC	12	SiL	CL	3	C	NE	W	>1.2	N	S0	C	Recently Harvested	3-4	
21	5963012	377533	N	WKN			BL.SS	GLLC	10	SiCL	SiCL	2	L	SW	MW	> 1.2	N	S0	NG	Grass	6	
22	5963125	377913	N	WKN			BL.SS	GLLC	23	SiCL	CL	3	M	NE	MW	>1.2	N	S0	C	Hay	3-4	
23	5963202	377507	N	WKN			BL.SS	GLLC	27	SiL		3	C	SW	W	>1.2	N	S0	NG	Grass	3-4	
24	5962527	377113	Y	n/a			n/a	M	15	L	SiCL	2	M	NE	W	>1.2	N	S1	C	Alfalfa/Timothy	4	
25	5962527	376897	Y	n/a			n/a	GLLC	15	L	L	3	U	N	W	>1.2	N	S1	C	Alfalfa/Timothy	4	
26	5962526	376687	N	WKN	xt		BL.SS	GLLC/M	18	L	SiCL	3	M	N	W	>1.2	N	S0	C	Alfalfa/Timothy	4	
27	5962534	376470	N	WKN	xt		BL.SS	GLLC/M	80	SiL	CL	2	M	NW	MW	>1.2	N	S0	C	Alfalfa/Timothy	4	
28	5962277	377079	Y	n/a			n/a	M	18	SiCL	CL	2	D	Level	W	>1.2	N	S0	C	Cultivated	4	
29	5962276	376893	Y	n/a			n/a	M	18	SiL	L	2	L	N	W	>1.2	N	S0	C	Cultivated	4	
30	5962275	376696	N	AGS			E.BLC	M	18	SiL	CL	3	M	E	W	>1.2	N	S0	C	Cultivated	4	
31	5962276	376504	N	AGS			E.BLC	M	26	SiL	CL	2	M	N	MW	>1.2	N	S0	C	Cultivated	4	
32	5962087	376502	N	PHS			O.BLC	GF	22	L	SiL	3	M	NE	W	>1.3	N	S0	C	Cultivated	4	
33	5962069	376626	N	PHS			O.BLC	GF	31	SiL	SiCL	3	U	NW	W	>1.2	N	S0	C	Cultivated	3	
34	5962058	376756	N	HBM	gl		GL.BLC	GLLC/M	36	SiL	SiCL	3	L	NW	W	>1.2	N	S0	C	Cultivated	3	
35	5961727	376971	Y	n/a			n/a	GF	16	CL	SL	3	D	W	W	>1.5	N	S0	C	Cultivated	3	

Notes:
n/a – not applicable.
All soil textures are field values and may differ from laboratory analysis.
Estimated Agricultural Capability Rating may differ from values presented in report.
NR – not rated.
LF – Organic Soil Horizon

Table III–1: Site Inspection Data (Cont'd)

Site Number	GPS Coordinates		Reclaimed Profile	Series	Soil Series Modifier 1	Soil Series Modifier 2	Subgroup	Parent Material	Topsoil/A Horizon/Organic		Subsoil Texture	Slope Class	Slope Position	Aspect	Drainage	Water Table (m)	Erosion	Stoniness Class	Present Land Use	Vegetation Cover	Estimated Agriculture Capability Rating	Comments
	Easting	Northing							Depth (cm)	Texture												
36	5962084	377154	Y	n/a			n/a	M	24	SiCL	C	1	M	SW	W	>1.2	N	S0	C	Cultivated	3-4	
37	5962106	377348	Y	n/a			n/a	M	25	SiCL	CL	1	V	NE	W	>1.2	N	S0	C	Stubble	3-4	
38	5962070	377646	Y	n/a			n/a	M	22	SiCL	CL	1	C	NE	MW	>1.2	N	S0	C	Stubble	3-4	
39	5962269	377657	Y	n/a			n/a	M	24	SiCL	C	1	V	NW	MW	>1.2	N	S1	C	Stubble	3-4	
40	5962275	377466	Y	n/a			n/a	M	25	SiCL	CL	1	L	NE	MW	>1.2	N	S0	C	Stubble	3-4	
41	5962279	377289	Y	n/a			n/a	M	12	SiL	SiCL	1	U	E	W	>1.2	N	S1	C	Stubble	3-4	
42	5962684	377960	Y	n/a			n/a	M	24	SiCL	CL	2	M	NW	W	> 1.2	N	S0	C	Canola	3-4	
43	5962661	377720	Y	n/a			n/a	M	11	SiCL	CL	2	M	SW	W	> 1.5	N	S1	C	Canola	3-4	
44	5962627	377517	Y	n/a			n/a	M	14	SiCL	CL	2	L	SW	MW	>1.2	N	S0	C	Barley	3-4	
45	5962612	377359	N	CMO			BL.SS	M	20	SL	CL	2	U	S	MW	1.3	N	S0	IP	Brome weeds	3-4	
46	5962466	377310	Y	n/a			n/a	M	18	SiCL	CL	3	U	N	MW	> 1.2	N	S0	IP	Brome weeds	3-4	
47	5962493	377519	N	CMO			BL.SS	M	16	SiCL	CL	3	M	S	MW	> 1.0	N	S1	C	Barley	3	
48	5962480	377717	Y	n/a			n/a	M	20	SiCL	C	2	L	SW	MW	> 1.2	N	S0	C	Barley	3	
49	5961721	377372	Y	n/a			n/a	GF	16	SiCL	L	2	L	N	W	> 1.2	N	S1	C	Canola	3	
50	5961490	376878	N	HYL			R.HG	M	20	SiCL	CL	3	M	SW	I	>1.1	N	S0	C	Wheat	2	
51	5961773	377896	Y	n/a			n/a	M	85	SiCL	CL	3	M	NE	W	> 1.4	N	S0	C	Canola	2-3	
52	5962224	377929	N	POK			E.BLC	GLLC	19	SiCL	CL	3	M	SW	W	> 1.2	N	S0	C	Canola	2	
53	5961894	376476	Y	PHS			O.BLC	GF	34	SiL	SiL	3	U	W	W	> 1.2	N	S0	C	Cultivated	3	
54	5961853	376940	Y	n/a			n/a	M	20	CL	SCL	2	M	N	W	> 1.2	N	S0	C	Wheat	3	
55	5961846	377133	Y	n/a			n/a	M	23	CL	SiC	2	L	N	W	> 1.2	N	S0	C	Wheat	3	
56	5961844	377291	Y	n/a			n/a	M	16	L	C	2	L	N	W	> 1.2	N	S0	C	Canola	2	
57	5962064	377014	Y	n/a			n/a	M	18	L	SiCL	2	M	NE	MW	> 1.2	N	S0	C	Barley	3	
58	5962004	377069	Y	n/a			n/a	M	18	SiC	SiC	2	M	N	W	> 1.2	N	S0	C	Barley or Wheat	3	
59	5961980	377355	Y	n/a			n/a	M	20	SiC	SCL	2	M	N	W	> 1.2	N	S0	C	Canola	2	
60	5962224	376991	Y	n/a			n/a	M	15	L	SiC	3	M	NE	W	> 1.2	N	S0	C	Barley	3	
61	5962171	377399	Y	n/a			n/a	M	29	L	SiC	2	U	N	W	> 1.2	N	S0	C	Wheat	3	
62	5962426	377222	Y	n/a			n/a	M	15	L	SiC	2	L	W	W	> 1.1	N	S0	C	Wheat	3	
63	5962519	377447	Y	n/a			n/a	M	90	SiL	SC	3	U	SE	MW	> 1.2	N	S0	IP	Grasses	4	

Notes:
n/a – not applicable.
All soil textures are field values and may differ from laboratory analysis.
Estimated Agricultural Capability Rating may differ from values presented in report.
NR – not rated.
LF – Organic Soil Horizon

1.15 References

Agriculture and Agri-Food Canada. 1983. The *Canadian Soil Information System* (CanSIS). *Manual for Describing Soils in the Field.* Expert Committee on Soil Survey.1982 Revised. J.H. Day (ed.) LRRI No. 82-52, Research Branch, Agriculture Canada. Ottawa, ON, p. 97.

Agriculture and Agri-Food Canada. 1987. *Soil Survey Handbook*. Volume 1. Expert Committee on Soil Survey. G.M. Coen (Ed.). Contribution No. 85-30. Tech. Bulletin 1987-9E. Research Branch, Agriculture Canada. Edmonton, AB.

Agriculture and Agri-Food Canada. 1998. *The Canadian System of Soil Classification*. 3rd Edition. Expert Committee on Soil Survey. Publication 1646. National Research Council Canada. Ottawa, ON, p. 187.

Natural Region Committee (NRC). 2006. *Natural Regions and Subregions of Alberta.* Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. I/005.

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Appendix IV: Soil and Terrain Unit Descriptions

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1. Soil and Terrain Unit Descriptions

1.1 Soil Unit Descriptions, Local Study Area

1.1.1 Soils of Mineral Parent Materials

A large portion of the LSA consists of soils developed on mineral deposits consisting of till, glaciolacustrine and glaciofluvial sediments. The mineral soil series recognized in the soil survey include:

1.1.1.1 Soil Series Developed on Morainal (till) parent material

- Angus Ridge series
- Camrose series
- Hairy Hill series
- Reclaimed areas

1.1.1.2 Soil Series Developed on Glaciolacustrine Parent Material

- Ponoka series
- Wetaskiwin series
- Hobbema series
- Duagh series
- Haight series

1.1.1.3 Soil Series Developed on Glaciofluvial Parent Material

- Peace Hills series

1.2 Soils of Organic Parent Materials

A small portion of the LSA consisted of soils developed on recent (post-glacial) organic parent material overlying mineral deposits. The mineral deposits were glaciolacustrine. The organic soil series recognized in the soil survey includes:

1.2.1.1 Soil Series Developed on Shallow Fen underlain by Glaciolacustrine Parent Material

- Manatokan-AA series

1.3 Terrain Unit Descriptions, Local Study Area

1.3.1 Shallow Fen (FNPT/GLLC map unit)

Fens are peat-filled wetlands comprised of moderately to well decomposed sedge, grass and reed material, generally with a water table at or above the surface (Agriculture and Agri-Food Canada 1983). Fens have a range of nutrient regimes from poor to very rich; however, those that are situated within depressions that receive surface runoff and/or groundwater recharge from surrounding mineral soil sources (minerotrophic) are generally nutrient-rich (eutrophic) environments. Peat depth within the Shallow Fen map unit can vary from 0.4 m to 1 m in thickness. This conforms to the landform surface expression of a veneer (Agriculture and Agri-Food Canada 1983). The underlying mineral material in the LSA is generally glaciolacustrine.

1.3.2 Glaciofluvial (GF map unit)

Glaciofluvial deposits consist of materials moved by a glacier and later sorted and re-deposited by streams or rivers flowing from melting ice. They are generally coarse-textured sands and gravels resulting in relatively high hydraulic conductivities. Their occurrence is predominantly in the southwest portion of the LSA (see Figure 2.5-5 of main report). Glaciofluvial (GF) deposits are associated with the well drained Peace Hills soil map units.

1.3.3 Glaciolacustrine (GLLC map unit)

Glaciolacustrine deposits consist of suspended material transported by meltwater streams of a glacier flowing into lakes bordering the glacier. The sediments are generally fine-textured silt and clay material. Till-like features are also present (i.e., stones/pebbles) derived from ice-rafting and mud flows (Browser et al. 1962, Bayrock 1972, and Shetsen 1990).

Glaciolacustrine deposits are documented mainly in the northern portion of the study area (see Figure 2.5-5 of main report). Their occurrence is either as a blanket (>1 m) (GLLC) or as a veneer (<1 m) underlain by till (GLLC/M). The surface form of the glaciolacustrine deposits is generally level to gently undulating with low relief. The hydraulic conductivity of these materials is low due to the increased clay proportion. In some cases, soil indicators (i.e., mottles/gleying) are present in the LSA suggesting periodic or seasonal wet conditions. The Hobbema, Ponoka, and Wetaskiwin soil map units are associated with moderately well to well drained, upland slope positions, and the gleyed variant is associated with imperfectly drained glaciolacustrine material. Poorly and very poorly drained glaciolacustrine deposits are associated with the Manatokan and Duagh soil map units that generally occupy the lower and depressional slope positions.

1.3.4 Morainal (M map unit)

Morainal (till) deposits are the dominant mineral terrain unit and they occur in the central and southeast portion of the LSA. The morainal material in the LSA is locally derived from bedrock material (disintegrated Cretaceous sandstones and betonitic shales with coal and sidertic ironstone fragments), and is comprised roughly of equal parts of sand silt and clay, with pebbles and boulders (Bowser et al. 1962, Bayrock 1972, and Shetsen 1990). The surface form of the till deposits is generally gently undulating with low relief (see Photo IV-1).

2. References

Agriculture and Agri-Food Canada. 1983. The Canadian Soil Information System (CanSIS). *Manual for describing soils in the field.* Expert Committee on Soil Survey 1982 Revised. J.H. Day (ed.) LRRI No. 82-52, Research Branch, Agriculture Canada. Ottawa, ON, p. 97.

Bayrock L.A. (1972) Surficial Geology of the Edmonton Map Sheet NTS 83H; Res. Coun. Alberta map (scale 1:250,000).

Browser, W.E., A.A. Kjearsgaard, T.W. Peters and R.E. Wells. Soil Survey of Edmonton Sheet (83-H). Canada Department of Agriculture. 1962.

Shetsen, I. 1990. Quaternary Geology, Central Alberta 1: 500,000. Map 213, Alberta Geological Survey and Energy Utility Board. 1990

Photo IV-1: Morainal Terrain Unit – Gently Undulating Terrain

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Appendix V: Baseline Soil Monitoring Information, Analytical Data and Laboratory Reports

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LIST OF ATTACHMENTS

1. Baseline Soil Monitoring

Field studies were completed to classify, map and describe baseline soil conditions within the Principal Development Area (PDA) and Local Study Area (LSA). The soil analytical data obtained from the Siting Investigation (Komex 2005), Limited Soil Investigation (Komex 2006) and the soil resources surveys from the Environmental Impact Assessment (EIA) may be used as baseline information for future monitoring programs at the Bruderheim Sulphur Forming and Shipping Facility Project (the Project). The baseline monitoring locations are presented in Figure V–1. Analyzed baseline soil quality parameters included:

- pH
- electrical conductivity (EC)
- total sulphur
- elemental sulphur
- sulphate sulphur (available sulphur)
- soluble sulphate
- calcium carbonate equivalent

These parameters were selected based on the requirements of Alberta Environment's Air Monitoring Directive Appendix A-7 (Alberta Environment 1989). The baseline analytical data is summarized in Table V–1, Table V–2 and Table V–3.

2. Analytical Data and Laboratory Reports

All additional analytical data analyzed to establish baseline soils conditions are presented in the original laboratory data reports (see Attachment V-1: Laboratory Reports).

3. Reference

3.1 Literature Cited

Alberta Environment. 1989. *Air Monitoring Directive.* Monitoring and Reporting Procedures for Industry. Alberta Environment, Standards and Approvals Division. Edmonton Alberta June 1989.

Komex International Ltd. (Komex). 2005. *Siting Investigation Report, Proposed Sulphur Forming Facility, Bruderheim, Alberta.* Unpublished report prepared for Hazco Environmental Services Ltd. C62720000. October 2005.

Komex International Ltd. (Komex). 2006. *Limited Soil Investigation – Proposed Sulphur Facility, Section 35-55-20 W4M, Bruderheim, AB.* Unpublished report prepared for CCS Energy Services. C62720000. January 20, 2006.

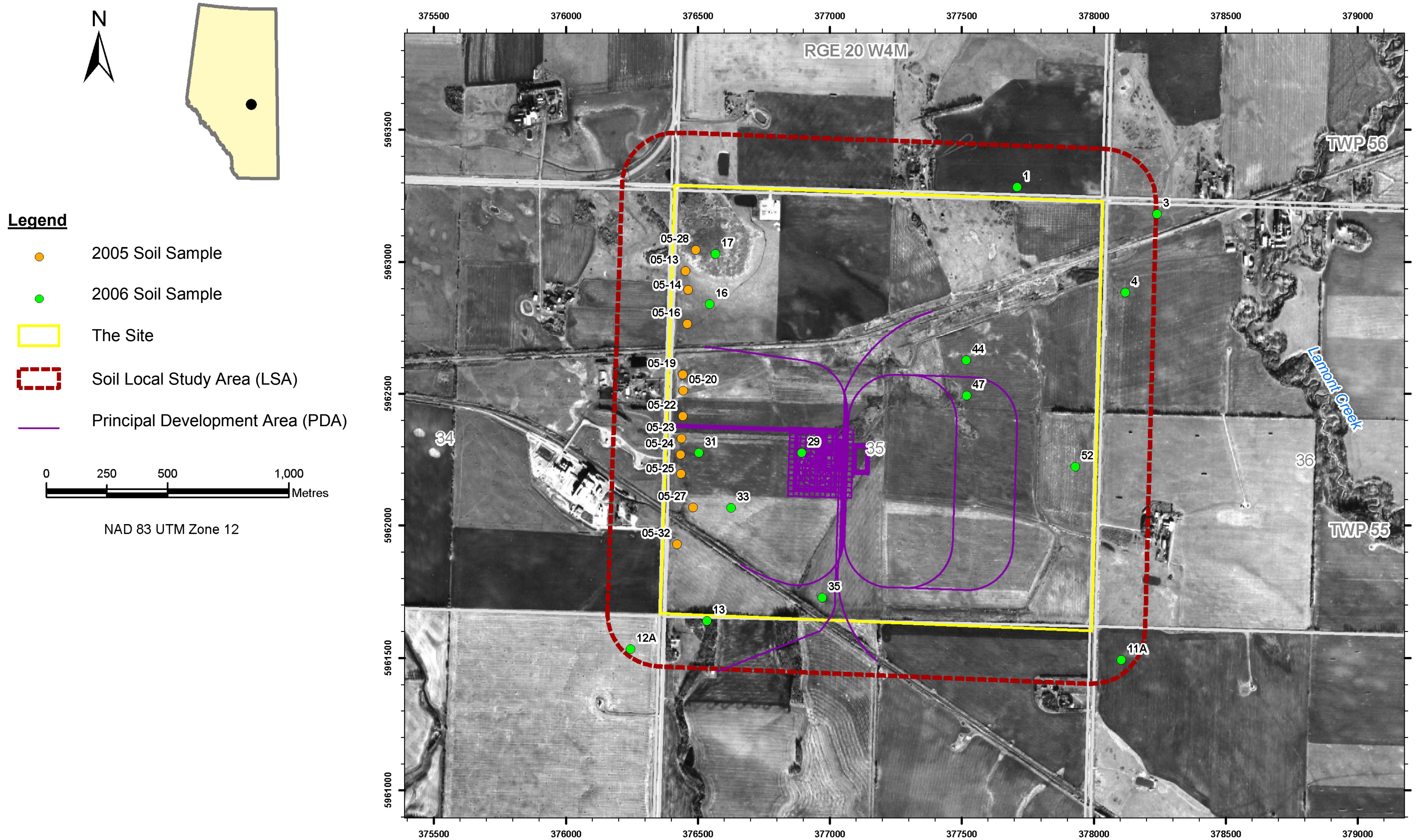

Figure V-1: Baseline Soil Quality Data

Table V–1: Salinity/Sodicity Data for Soil Samples

			Salinity										CEC & Extractable Cations					
Sampling Location	Soil Depth	Date	Saturation %	EC	pH - Saturated Paste	Sodium Adsorption Ratio	Soluble Ca	Soluble Mg	Soluble K	Soluble Na	Soluble Cl	Soluble SO_4	CEC	Calcium	Magnesium	Potassium	Sodium	$CaCO_3$ Equivalent
	(m)	(d-m-y)	(%)	(dS/m)	(units)	(ratio)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(meq/100 g)	(meq/100 g)	(meq/100 g)	(meq/100 g)	(meq/100 g)	(%)
05-13	(0.00–0.30 m)	21-Dec-05	76.1	5.97	7.7	9.8	534	328	6	1,170	40	4,480	–	–	–	–	–	–
05-16	(0.00–0.30 m)	21-Dec-05	61.6	1.15	7.8	7.0	82	28	4	288	40	399	–	–	–	–	–	–
05-19	(0.60–1.00 m)	21-Dec-05	99.3	2.68	8.7	21.0	39	40	6	780	<20	1,490	–	–	–	–	–	–
05-20	(0.00–0.30 m)	21-Dec-05	69.8	1.19	9.0	13.9	19	19	3	356	40	309	–	–	–	–	–	–
05-22	(0.00–0.30 m)	21-Dec-05	57.6	0.64	8.1	3.3	52	20	4	109	<20	87	–	–	–	–	–	–
05-23	(0.00–0.30 m)	21-Dec-05	43.2	1.12	7.9	5.8	74	25	4	229	<20	417	–	–	–	–	–	–
05-25	(0.00–0.30 m)	21-Dec-05	48.4	1.00	5.5	2.5	107	21	7	108	80	106	–	–	–	–	–	–
05-27	(0.00–0.30 m)	21-Dec-05	49.3	1.11	8.0	7.5	59	15	6	249	110	200	–	–	–	–	–	–
05-28	Surface	21-Dec-05	184	12.3	7.5	21.8	549	602	247	3,100	910	7,580	–	–	–	–	–	–
05-32	(0.00–0.30 m)	21-Dec-05	37.8	0.44	7.6	0.6	66	13	6	22	<20	41	–	–	–	–	–	–
1	(0.00–0.20 m)	12-Oct-06	51	0.6	6.3	1.1	74	12	3	40	40	96.0	26.9	22.7	3.6	0.3	0.2	<0.7
	(0.25–0.30 m)	12-Oct-06	41	0.7	7.0	0.6	108	20	3	26	28	129	17.6	15.2	3.2	0.3	<0.2	–
	(0.35–0.50 m)	12-Oct-06	43	0.6	7.4	0.7	75	15	3	25	23	60.0	–	–	–	–	–	<0.7
	(0.80–1.00 m)	12-Oct-06	45	0.6	7.5	0.5	96	21	3	19	17	26.0	–	–	–	–	–	8.6
3	(0.00–0.15 m)	12-Oct-06	64	0.9	5.8	7.2	36	13	4	198	80	98.7	24.5	12.6	4.4	0.4	1.7	<0.7
	(0.20–0.40 m)	12-Oct-06	102	1.2	6.5	15.0	25	7	2	332	124	194	–	–	–	–	–	<0.7
	(0.60–0.80 m)	12-Oct-06	86	2.3	7.7	28.8	25	5	1	605	103	708	–	–	–	–	–	<0.7
	(1.00–1.20 m)	12-Oct-06	84	4.6	8.3	43.0	53	14	<1	1,360	14	2,560	–	–	–	–	–	3.5
	(1.20–1.40 m)	12-Oct-06	107	5.9	7.9	28.3	234	55	<1	1,850	45	3,940	–	–	–	–	–	6.1
4	(0.00–0.20 m)	17-Oct-06	54	0.8	6.0	0.8	73	12	115	30	68	188	20.9	13.7	2.1	2.6	<0.2	<0.7
	(0.30–0.35 m)	17-Oct-06	44	0.6	6.4	1.0	77	12	17	36	33	177	–	–	–	–	–	<0.7
	(0.50–0.70 m)	17-Oct-06	47	0.5	6.5	1.8	48	7	6	50	25	122	–	–	–	–	–	<0.7
	(0.80–1.00 m)	17-Oct-06	58	1.0	6.4	3.1	87	14	7	119	258	289	–	–	–	–	–	<0.7
11A	(0.00–0.32 m)	13-Oct-06	46	0.6	5.0	3.0	35	9	2	77	53	160	22.7	10.2	2.4	0.3	0.6	<0.7
	(0.32–0.38 m)	13-Oct-06	30	0.7	7.0	6.6	20	7	1	134	67	140	–	–	–	–	–	<0.7
	(0.38–0.70 m)	13-Oct-06	48	0.7	7.5	10.7	9	3	<1	151	31	96.9	20.1	11.4	6.1	0.3	3.0	<0.7
	(0.70–1.20 m)	13-Oct-06	73	1.0	8.0	14.8	11	5	<1	236	26	202	–	–	–	–	–	1.5
12A	(0.00–0.25 m)	13-Oct-06	34	0.4	5.7	0.7	53	8	8	21	29	34.2	13.1	9.4	1.2	0.3	<0.2	<0.7
	(0.25–0.35 m)	13-Oct-06	26	0.7	6.5	0.7	92	15	6	26	22	25.8	–	–	–	–	–	<0.7
	(0.35–0.53 m)	13-Oct-06	34	0.3	6.7	0.6	40	8	7	15	16	15.7	–	–	–	–	–	–
	(1.30–1.50 m)	13-Oct-06	27	0.3	7.5	0.8	28	6	6	17	10	8.97	–	–	–	–	–	<0.7

Note:
– in detail data row(s) denotes parameter not analyzed.

Table V–1: Salinity/Sodicity Data for Soil Samples (Cont'd)

			Salinity										CEC & Extractable Cations					
Sampling Location	Soil Depth	Date	Saturation %	EC	pH - Saturated Paste	Sodium Adsorption Ratio	Soluble Ca	Soluble Mg	Soluble K	Soluble Na	Soluble Cl	Soluble SO_4	CEC	Calcium	Magnesium	Potassium	Sodium	$CaCO_3$ Equivalent
	(m)	(d-m-y)	(%)	(dS/m)	(units)	(ratio)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(meq/100 g)	(meq/100 g)	(meq/100 g)	(meq/100 g)	(meq/100 g)	(%)
13	LF	13-Oct-06	303	1.0	6.8	–	–	–	–	–	–	–	114	81.3	15.2	3.0	0.5	3.3
	(0.00–0.15 m)	13-Oct-06	63	0.6	6.2	1.3	65	17	34	46	22	55.0	34.4	22.7	6.3	1.5	0.3	<0.7
	(0.15–0.30 m)	13-Oct-06	44	0.4	6.1	2.0	36	10	16	54	33	55.3	–	–	–	–	–	–
	(0.80–1.00 m)	13-Oct-06	54	0.3	6.7	2.0	24	9	4	45	20	54.4	–	–	–	–	–	<0.7
16	(0.00–0.23 m)	13-Oct-06	57	1.1	6.8	0.9	87	25	188	35	43	59.8	24.0	18.8	4.3	3.1	0.3	<0.7
	(0.23–0.48 m)	13-Oct-06	49	3.1	8.4	19.4	48	52	110	816	155	748	–	–	–	–	–	–
	(0.80–1.00 m)	13-Oct-06	89	3.4	9.5	58.3	7	11	26	1,090	71	1,360	–	–	–	–	–	7.6
	(1.00–1.20 m)	13-Oct-06	252	3.2	9.4	117	<2	3	4	938	25	1,410	–	–	–	–	–	8.0
17	(0.30–0.40 m)	13-Oct-06	103	2.8	7.2	–	–	–	–	–	–	–	76.6	77.3	13.3	1.6	2.4	3.2
	(0.70–0.90 m)	13-Oct-06	125	1.3	7.7	2.8	106	38	24	132	6	532	–	–	–	–	–	8.2
29	(0.00–0.20 m)	16-Oct-06	37	1.1	7.6	3.7	120	29	3	172	26	132	17.9	18.8	4.1	0.2	0.7	0.8
	(0.20–0.50 m)	16-Oct-06	43	1.5	6.8	1.3	274	48	4	89	22	330	–	–	–	–	–	0.7
	(0.80–1.00 m)	16-Oct-06	204	2.8	9.0	Incalculable	<2	<1	3	847	20	1,150	–	–	–	–	–	8.0
31	(0.00–0.20 m)	16-Oct-06	52	0.5	6.2	1.9	51	13	3	59	30	74.5	24.0	17.7	4.5	0.3	0.3	<0.7
	(0.30–0.50 m)	16-Oct-06	51	0.7	7.3	2.8	60	21	3	99	15	113	–	–	–	–	–	–
	(0.80–1.00 m)	16-Oct-06	61	1.4	7.9	14.8	33	12	5	391	29	341	–	–	–	–	–	2.4
33	(0.00–0.20 m)	16-Oct-06	57	0.6	5.6	2.0	57	9	16	60	47	63.9	16.4	21.4	2.9	0.9	0.4	<0.7
	(0.31–0.35 m)	16-Oct-06	39	0.5	7.0	0.9	62	13	3	28	17	45.5	–	–	–	–	–	<0.7
	(0.40–0.60 m)	16-Oct-06	37	0.5	7.2	0.8	68	16	3	28	18	54.2	–	–	–	–	–	–
	(1.00–1.20 m)	16-Oct-06	34	0.4	6.5	1.4	33	11	3	36	20	69.3	–	–	–	–	–	<0.7
35	(0.00–0.16 m)	16-Oct-06	50	0.6	7.6	5.5	21	6	5	112	11	86.1	19.6	13.6	5.3	1.6	2.2	–
	(1.30–1.50 m)	16-Oct-06	49	1.2	7.5	4.4	101	27	11	194	46	72.1	–	–	–	–	–	1.5
44	(0.00–0.10 m)	17-Oct-06	50	0.8	7.9	7.4	24	10	5	172	29	36.9	21.9	24.3	7.6	0.6	1.6	2.2
	(0.80–1.00 m)	17-Oct-06	67	1.6	8.3	14.2	12	17	4	326	34	465	17.2	24.3	12.0	0.4	3.3	6.7
47	(0.00–010 m)	17-Oct-06	43	1.1	7.7	4.1	90	24	5	169	64	156	20.1	23.0	5.3	0.4	1.1	–
	(0.30–0.40 m)	17-Oct-06	55	1.0	7.9	13.7	14	4	3	226	34	177	–	–	–	–	–	–
	(0.80–1.00 m)	17-Oct-06	84	2.4	8.2	26.2	24	10	4	607	25	995	–	–	–	–	–	–
52	(0.00–0.10 m)	17-Oct-06	46	0.6	7.2	0.8	79	13	44	29	27	37.2	21.6	19.3	3.1	1.6	<0.2	<0.7
	(0.30–0.50 m)	17-Oct-06	37	0.9	7.9	6.4	42	7	36	172	64	104	–	–	–	–	–	<0.7
	(0.80–1.00 m)	17-Oct-06	38	1.6	7.6	9.7	87	16	>5	376	12	394	–	–	–	–	–	<0.7

Note:
– in detail data row(s) denotes parameter not analyzed.

Table V–2: Regulated Metal and Inorganic Data for Soil Samples

Sampling Location	Soil Depth	Date	Metals																		Sulphur	
			Arsenic	Barium	Beryllium	Boron-Hot Water Soluble	Cadmium	Chromium	Cobalt	Copper	Lead	Manganese	Mercury	Molybdenum	Nickel	Selenium	Strontium	Thallium	Vanadium	Zinc	Elemental Sulphur	Sulphur:T
	(m)	(d-m-y)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
1	(0.00–0.20 m)	12-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	300
	(0.35–0.50 m)	12-Oct-06	8.2	169	<1	0.4	<0.5	21.6	12	13	11	390	<0.05	<1	29	0.3	26	<1	34	66	–	–
	(0.80–1.00 m)	12-Oct-06	6.8	167	<1	0.3	<0.5	21.5	10	15	10	360	<0.05	<1	30	0.1	49	<1	36	53	–	–
3	(0.00–0.15 m)	12-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	500
	(1.00–1.20 m)	12-Oct-06	5.2	135	<1	0.2	<0.5	17.3	8	13	7	250	<0.05	<1	22	<0.1	44	<1	29	45	–	–
	(1.20–1.40 m)	12-Oct-06	6.9	188	<1	0.3	<0.5	22.5	11	18	10	370	<0.05	<1	30	<0.1	69	<1	36	62	–	–
4	(0.00–0.20 m)	17-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	300
	(0.80–1.00 m)	17-Oct-06	9.6	161	<1	0.4	<0.5	26.1	12	24	12	380	0.07	<1	32	0.6	30	<1	41	73	–	–
11A	(0.00–0.32 m)	13-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	300
	(0.70–1.20 m)	13-Oct-06	8.6	259	<1	0.3	<0.5	25.0	10	20	12	320	0.06	<1	34	<0.1	54	<1	40	74	–	–
12A	(0.00–0.25 m)	13-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	200
	(1.30–1.50 m)	13-Oct-06	4.3	46	<1	0.2	<0.5	6.4	4	7	<5	200	<0.05	<1	12	0.1	11	<1	12	20	–	–
13	(0.00–0.15 m)	13-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	600
16	(0.00–0.23 m)	13-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	500
	(0.80–1.00 m)	13-Oct-06	3.8	93	<1	1.0	<0.5	9.8	4	7	<5	160	<0.05	<1	13	0.3	121	<1	19	24	–	–
	(1.00–1.20 m)	13-Oct-06	9.1	291	1	2.0	<0.5	30.7	13	26	14	390	<0.05	<1	34	0.3	139	<1	50	89	–	–
17	(0.70–0.90 m)	13-Oct-06	5.2	426	<1	1.1	<0.5	26.8	11	22	13	230	<0.05	<1	31	0.4	100	<1	38	86	–	–
29	(0.00–0.20 m)	16-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	300
	(0.20–0.50 m)	16-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	300
	(0.80–1.00 m)	16-Oct-06	7.1	232	<1	1.2	<0.5	23.8	10	20	11	510	<0.05	<1	28	0.2	105	<1	41	66	<0.01	600
31	(0.00–0.20 m)	16-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	300
	(0.80–1.00 m)	16-Oct-06	7.2	287	<1	0.6	<0.5	21.8	12	23	10	290	<0.05	<1	29	<0.1	84	<1	32	84	–	–
33	(0.00–0.20 m)	16-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	500
	(0.40–0.60 m)	16-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	–
	(1.00–1.20 m)	16-Oct-06	4.4	87	<1	0.2	<0.5	10.8	7	9	5	230	<0.05	<1	17	<0.1	21	<1	19	29	–	–
35	(0.00–0.16 m)	16-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	200
	(1.30–1.50 m)	16-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	–
44	(0.00–0.10 m)	17-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	200
	(0.80–1.00 m)	17-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	–
47	(0.00–0.10 m)	17-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	300
	(0.30–0.40 m)	17-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	<100
	(0.80–1.00 m)	17-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	300
52	(0.00–0.10 m)	17-Oct-06	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	<0.01	200

Note:
– in detail data row(s) denotes parameter not analyzed.

Table V–3: Physical Properties, Carbon and Nutrient Data for Soil Samples

			Physical Properties					Carbon				Nutrients				
Sampling Location	Soil Depth (m)	Date (d-m-y)	Clay (%)	Sand (%)	Silt (%)	Texture Class (units)	Bulk Density (kg/m^3)	Organic Matter (%)	Carbon:T (%)	Inorganic Carbon (%)	TOC (%)	TKN (%)	Available NO_3 (mg/kg)	Av PO_4 as P (mg/kg)	Available K (mg/kg)	Available SO_4 (mg/kg)
1	(0.00–0.20 m)	12-Oct-06	12	35	53	Silt loam	1,020	9	3.8	<0.1	3.8	0.31	6.4	4	102	15
	(0.25–0.30 m)	12-Oct-06	21	40	39	Loam	–	–	–	–	–	–	–	–	–	–
	(0.35–0.50 m)	12-Oct-06	23	34	43	Loam	1,100	–	–	<0.09	–	–	–	–	–	–
	(0.80–1.00 m)	12-Oct-06	25	49	26	Sandy clay loam	–	–	–	1.01	–	–	–	–	–	–
3	(0.00–0.15 m)	12-Oct-06	13	48	39	Loam	890	10	4.3	<0.1	4.3	0.39	3.4	13	144	20
	(0.20–0.40 m)	12-Oct-06	14	51	36	Loam	1,000	6	2.6	<0.09	2.6	0.22	–	–	–	–
	(0.60–0.80 m)	12-Oct-06	17	50	32	Loam	–	–	–	<0.09	–	–	–	–	–	–
	(1.00–1.20 m)	12-Oct-06	17	64	18	Sandy loam	1,040	–	–	0.40	–	–	–	–	–	–
	(1.20–1.40 m)	12-Oct-06	27	47	26	Sandy clay loam	1,100	–	–	0.71	–	–	–	–	–	–
4	(0.00–0.20 m)	17-Oct-06	14	36	50	Silt loam/Loam	960	7	3.2	<0.1	3.2	0.35	10.0	99	872	27
	(0.30–0.35 m)	17-Oct-06	14	39	48	Loam	–	4	1.5	<0.09	1.5	0.15	–	–	–	–
	(0.50–0.70 m)	17-Oct-06	26	21	53	Silt loam	–	–	–	<0.09	–	–	–	–	–	–
	(0.80–1.00 m)	17-Oct-06	33	14	53	Silty clay loam	–	–	–	<0.09	–	–	–	–	–	–
11A	(0.00–0.32 m)	13-Oct-06	17	31	52	Silt loam	–	8	3.6	<0.1	3.6	0.33	8.0	13	114	22
	(0.32–0.38 m)	13-Oct-06	7	37	56	Silt loam	1,220	2	0.3	<0.1	0.3	0.05	–	–	–	–
	(0.38–0.70 m)	13-Oct-06	27	40	33	Loam	–	–	–	<0.09	–	–	–	–	–	–
	(0.70–1.20 m)	13-Oct-06	33	9	58	Silty clay loam	1,100	–	–	0.15	–	–	–	–	–	–
12A	(0.00–0.25 m)	13-Oct-06	12	56	32	Sandy loam	1,130	5	2.2	<0.1	2.2	0.15	13.0	8	132	6
	(0.25–0.35 m)	13-Oct-06	11	62	27	Sandy loam	1,190	2	0.3	<0.1	0.3	0.06	–	–	–	–
	(0.35–0.53 m)	13-Oct-06	14	64	22	Sandy loam	1,200	–	–	–	–	–	–	–	–	–
	(1.30–1.50 m)	13-Oct-06	9	82	10	Loamy sand	1,330	–	–	<0.09	–	–	–	–	–	–
13	LF	13-Oct-06	–	–	–	–	380	65	28.4	0.4	28.0	1.91	65.0	31	913	53
	(0.00–0.15 m)	13-Oct-06	25	34	42	Loam	970	11	4.1	<0.1	4.1	0.37	4.2	8	523	14
	(0.15–0.30 m)	13-Oct-06	25	34	41	Loam	–	–	–	–	–	–	–	–	–	–
	(0.80–1.00 m)	13-Oct-06	23	38	40	Loam	–	–	–	<0.09	–	–	–	–	–	–
16	(0.00–0.23 m)	13-Oct-06	15	48	37	Loam	1,010	10	4.2	<0.1	4.2	0.41	6.0	132	1,130	15
	(0.23–0.48 m)	13-Oct-06	26	46	28	Loam	1,050	–	–	–	–	–	–	–	–	–
	(0.80–1.00 m)	13-Oct-06	19	65	16	Sandy loam	–	–	–	0.89	–	–	–	–	–	–
	(1.00–1.20 m)	13-Oct-06	50	10	39	Silty clay / Clay	–	–	–	0.94	–	–	–	–	–	–
17	(0.30–0.40 m)	13-Oct-06	–	–	–	–	440	41	19.9	0.4	19.5	2.04	13.0	4	444	1,350
	(0.70–0.90 m)	13-Oct-06	49	6	45	Silty clay	–	–	–	0.96	–	–	–	–	–	–
29	(0.00–0.20 m)	16-Oct-06	14	57	29	Sandy loam	1,190	6	2.0	<0.1	2.0	0.17	2.8	5	77	20
	(0.20–0.50 m)	16-Oct-06	17	54	29	Sandy loam	–	6	2.0	<0.1	2.0	0.19	–	–	–	–
	(0.80–1.00 m)	16-Oct-06	27	46	26	Sandy clay loam	–	–	–	0.93	–	–	–	–	–	–

Note:
– in detail data row(s) denotes parameter not analyzed.

Table V–3: Physical Properties, Carbon and Nutrient Data for Soil Samples (Cont'd)

			Physical Properties					Carbon				Nutrients				
Sampling Location	Soil Depth	Date	Clay	Sand	Silt	Texture Class	Bulk Density	Organic Matter	Carbon:T	Inorganic Carbon	TOC	TKN	Available NO_3	Av PO_4 as P	Available K	Available SO_4
	(m)	(d-m-y)	(%)	(%)	(%)	(units)	(kg/m^3)	(%)	(%)	(%)	(%)	(%)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
31	(0.00–0.20 m)	16-Oct-06	22	32	46	Loam	1,050	8	3.1	<0.1	3.1	0.28	11.0	14	120	15
	(0.30–0.50 m)	16-Oct-06	26	41	34	Loam	–	–	–	–	–	–	–	–	–	–
	(0.80–1.00 m)	16-Oct-06	25	37	38	Loam	–	–	–	0.26	–	–	–	–	–	–
33	(0.00–0.20 m)	16-Oct-06	12	50	38	Loam	930	13	5.0	<0.1	5.0	0.42	23.0	35	280	12
	(0.31–0.35 m)	16-Oct-06	17	48	34	Loam	–	–	–	<0.09	–	–	–	–	–	–
	(0.40–0.60 m)	16-Oct-06	19	45	36	Loam	–	–	–	–	–	–	–	–	–	–
	(1.00–1.20 m)	16-Oct-06	14	68	18	Sandy loam	1,200	–	–	<0.09	–	–	–	–	–	–
35	(0.00–0.16 m)	16-Oct-06	9	76	16	Sandy loam	940	–	–	–	–	–	3.0	2	182	20
	(1.30–1.50 m)	16-Oct-06	20	51	29	Loam	1,090	–	–	0.16	–	–	–	–	–	–
44	(0.00–0.10 m)	17-Oct-06	18	29	53	Silt loam	–	6	2.0	0.2	1.8	0.17	5.6	35	196	10
	(0.80–1.00 m)	17-Oct-06	27	37	35	Loam / Clay loam	–	–	–	0.78	–	–	–	–	–	–
47	(0.00–0.10 m)	17-Oct-06	20	40	40	Loam	1,140	–	–	–	–	–	12.2	27	158	18
	(0.30–0.40 m)	17-Oct-06	22	45	33	Loam	–	–	–	–	–	–	–	–	–	–
	(0.80–1.00 m)	17-Oct-06	25	41	34	Loam	1,150	–	–	–	–	–	–	–	–	–
52	(0.00–0.10 m)	17-Oct-06	17	49	34	Loam	1,030	7	2.9	<0.1	2.9	0.24	5.0	27	511	8
	(0.30–0.50 m)	17-Oct-06	21	46	33	Loam	1,080	–	–	<0.09	–	–	–	–	–	–
	(0.80–1.00 m)	17-Oct-06	17	69	14	Sandy loam	–	–	–	<0.09	–	–	–	–	–	–

Note:
– in detail data row(s) denotes parameter not analyzed.

ALS Laboratory Group

ANALYTICAL CHEMISTRY & TESTING SERVICES

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Environmental Division

ANALYTICAL REPORT

WORLEYPARSONS CANADA LTD

ATTN: LENZ HADERLEIN

705, 10240 124 ST

EDMONTON AB T5N 3W6

Reported On: 16-FEB-07 01:15 PM

Revision: 12

Lab Work Order #: **L445303** **Date Received:** **18-OCT-06**

Project P.O. #:

Job Reference: C62720104 BRUDERHEIM FACILITY

Legal Site Desc: BRUDERHEIM FACILITY

CofC Numbers: 208405, 208407, 208408, 208432, 208437

Other Information:

Comments:

Revised Report 31-OCT-06

SAR result for sample L445303-29 changed from 20300 to "Incalculable". SAR:M qualifier added to L445303-24.

ADDITIONAL 22-DEC-06 16:23

ADDITIONAL 31-JAN-07 14:14

ROY JONES

General Manager, Edmonton

For any questions about this report please contact your Account Manager:

ERIN ANDERSON

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ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-1 44-(0.0-0.1M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	0.2		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	1.8		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	2.2		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	2.0		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	1.6		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	0.6		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	24.3		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	7.6		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	21.9		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926
Organic Matter	6		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								
% Sand	29		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	53		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	18		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Silt loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		04-JAN-07	LL	R481352
Total Kjeldahl Nitrogen	0.17		0.02	%	24-OCT-06	24-OCT-06	JRB	R457734
Sulfur (S)-Total	200		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
Available N, P, K and S								
Available Nitrate-N	5.6		0.4	mg/kg	24-OCT-06	24-OCT-06	BFE	R457626
Available Phosphate & Potassium								
Available Phosphate-P	35		1	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Potassium	196		2	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Sulfate-S	10		2	mg/kg	24-OCT-06	24-OCT-06	BEM	R457319
Detailed Salinity								
Chloride (Cl)	29		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	24		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	5		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	10		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	172		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	7.4		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	36.9		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	50		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	7.9		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	0.8		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
L445303-2 44-(0.8-1.0M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	3.3		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	0.4		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	24.3		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	12.0		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	17.2		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-2 44-(0.8-1.0M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								
CEC and Extractable Cations								
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	0.78		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	6.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Particle Size - Hydrometer								
% Sand	37		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	35		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	27		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam / Clay loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		04-JAN-07	LL	R481352
Detailed Salinity								
Chloride (Cl)	34		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	12		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	4		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	17		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	326		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	14.2		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	465		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	67		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	8.3		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	1.6		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
L445303-3 33-(0.4-0.6M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Particle Size - Hydrometer								
% Sand	45		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	36		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	19		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		04-JAN-07	LL	R481352
Detailed Salinity								
Chloride (Cl)	18		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	68		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	3		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	16		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	28		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	0.8		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	54.2		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	37		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	7.2		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	0.5		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
L445303-4 33-(0.31-0.35M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Inorganic Carbon / Calcium Carbonate								

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-4 33-(0.31-0.35M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	<0.09		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Particle Size - Hydrometer								
% Sand	48		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	34		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	17		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	17		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	62		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	3		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	13		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	28		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	0.9		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	45.5		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	39		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	7.0		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	0.5		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
L445303-5 33-(1.0-1.2M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Boron (B), Hot Water Ext.	0.2		0.1	mg/kg	24-OCT-06	24-OCT-06	BEM	R457295
Bulk Density	1200		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	<0.09		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
PITS Metals (ICP)								
Arsenic (As)	4.4		0.1	mg/kg		24-OCT-06	JGP	R457427
Barium (Ba)	87		5	mg/kg		24-OCT-06	JGP	R457427
Beryllium (Be)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Cadmium (Cd)	<0.5		0.5	mg/kg		24-OCT-06	JGP	R457427
Cobalt (Co)	7		1	mg/kg		24-OCT-06	JGP	R457427
Chromium (Cr)	10.8		0.5	mg/kg		24-OCT-06	JGP	R457427
Copper (Cu)	9		2	mg/kg		24-OCT-06	JGP	R457427
Mercury (Hg)	<0.05		0.05	mg/kg		24-OCT-06	JGP	R457427
Manganese (Mn)	230		20	mg/kg		24-OCT-06	JGP	R457427
Molybdenum (Mo)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Nickel (Ni)	17		2	mg/kg		24-OCT-06	JGP	R457427
Lead (Pb)	5		5	mg/kg		24-OCT-06	JGP	R457427
Selenium (Se)	<0.1		0.1	mg/kg		24-OCT-06	JGP	R457427
Strontium (Sr)	21		1	mg/kg		24-OCT-06	JGP	R457427
Thallium (Tl)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Vanadium (V)	19		1	mg/kg		24-OCT-06	JGP	R457427
Zinc (Zn)	29		5	mg/kg		24-OCT-06	JGP	R457427
Particle Size - Hydrometer								
% Sand	68		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	18		1	%	24-OCT-06	25-OCT-06	HSL	R457956

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-5 33-(1.0-1.2M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Particle Size - Hydrometer								
% Clay	14		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Sandy loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	20		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	33		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	3		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	11		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	36		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	1.4		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	69.3		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	34		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	6.5		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	0.4		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
L445303-6 33-(0-0.2M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	<0.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	5.0		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	5.0		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	0.4		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	0.9		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	21.4		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	2.9		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	16.4		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926
Bulk Density	930		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Organic Matter	13		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								
% Sand	50		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	38		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	12		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		04-JAN-07	LL	R481352
Total Kjeldahl Nitrogen	0.42		0.02	%	24-OCT-06	24-OCT-06	JRB	R457734
Sulfur (S)-Total	500		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
Available N, P, K and S								
Available Nitrate-N	23.0		0.4	mg/kg	24-OCT-06	24-OCT-06	BFE	R457626
Available Phosphate & Potassium								
Available Phosphate-P	35		1	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Potassium	280		2	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Sulfate-S	12		2	mg/kg	24-OCT-06	24-OCT-06	BEM	R457319
Detailed Salinity								

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-6 33-(0-0.2M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Detailed Salinity								
Chloride (Cl)	47		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	57		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	16		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	9		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	60		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	2.0		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	63.9		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	57		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	5.6		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	0.6		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
L445303-7 1-(0.8-1.0M)								
Sampled By: NOT PROVIDED on 12-OCT-06								
Matrix: SOIL								
Boron (B), Hot Water Ext.	0.3		0.1	mg/kg	24-OCT-06	24-OCT-06	BEM	R457295
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	1.01		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	8.6		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
PITS Metals (ICP)								
Arsenic (As)	6.8		0.1	mg/kg		24-OCT-06	JGP	R457427
Barium (Ba)	167		5	mg/kg		24-OCT-06	JGP	R457427
Beryllium (Be)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Cadmium (Cd)	<0.5		0.5	mg/kg		24-OCT-06	JGP	R457427
Cobalt (Co)	10		1	mg/kg		24-OCT-06	JGP	R457427
Chromium (Cr)	21.5		0.5	mg/kg		24-OCT-06	JGP	R457427
Copper (Cu)	15		2	mg/kg		24-OCT-06	JGP	R457427
Mercury (Hg)	<0.05		0.05	mg/kg		24-OCT-06	JGP	R457427
Manganese (Mn)	360		20	mg/kg		24-OCT-06	JGP	R457427
Molybdenum (Mo)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Nickel (Ni)	30		2	mg/kg		24-OCT-06	JGP	R457427
Lead (Pb)	10		5	mg/kg		24-OCT-06	JGP	R457427
Selenium (Se)	0.1		0.1	mg/kg		24-OCT-06	JGP	R457427
Strontium (Sr)	49		1	mg/kg		24-OCT-06	JGP	R457427
Thallium (Tl)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Vanadium (V)	36		1	mg/kg		24-OCT-06	JGP	R457427
Zinc (Zn)	53		5	mg/kg		24-OCT-06	JGP	R457427
Particle Size - Hydrometer								
% Sand	49		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	26		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	25		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Sandy clay loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	17		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	96		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	3		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	21		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	19		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	0.5		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-7 1-(0.8-1.0M)								
Sampled By: NOT PROVIDED on 12-OCT-06								
Matrix: SOIL								
Detailed Salinity								
SAR, Cations and SO4 in saturated soil								
Sulphate (SO4)	26.0		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	45		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	7.5		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	0.6		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
L445303-8 1-(0.35-0.5M)								
Sampled By: NOT PROVIDED on 12-OCT-06								
Matrix: SOIL								
Boron (B), Hot Water Ext.	0.4		0.1	mg/kg	24-OCT-06	24-OCT-06	BEM	R457295
Bulk Density	1100		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	<0.09		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
PITS Metals (ICP)								
Arsenic (As)	8.2		0.1	mg/kg		24-OCT-06	JGP	R457427
Barium (Ba)	169		5	mg/kg		24-OCT-06	JGP	R457427
Beryllium (Be)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Cadmium (Cd)	<0.5		0.5	mg/kg		24-OCT-06	JGP	R457427
Cobalt (Co)	12		1	mg/kg		24-OCT-06	JGP	R457427
Chromium (Cr)	21.6		0.5	mg/kg		24-OCT-06	JGP	R457427
Copper (Cu)	13		2	mg/kg		24-OCT-06	JGP	R457427
Mercury (Hg)	<0.05		0.05	mg/kg		24-OCT-06	JGP	R457427
Manganese (Mn)	390		20	mg/kg		24-OCT-06	JGP	R457427
Molybdenum (Mo)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Nickel (Ni)	29		2	mg/kg		24-OCT-06	JGP	R457427
Lead (Pb)	11		5	mg/kg		24-OCT-06	JGP	R457427
Selenium (Se)	0.3		0.1	mg/kg		24-OCT-06	JGP	R457427
Strontium (Sr)	26		1	mg/kg		24-OCT-06	JGP	R457427
Thallium (Tl)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Vanadium (V)	34		1	mg/kg		24-OCT-06	JGP	R457427
Zinc (Zn)	66		5	mg/kg		24-OCT-06	JGP	R457427
Particle Size - Hydrometer								
% Sand	34		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	43		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	23		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	23		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	75		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	3		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	15		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	25		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	0.7		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	60.0		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	43		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	7.4		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	0.6		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-8 1-(0.35-0.5M)								
Sampled By: NOT PROVIDED on 12-OCT-06								
Matrix: SOIL								
Detailed Salinity								
L445303-9 1-(0.25-0.3M)								
Sampled By: NOT PROVIDED on 12-OCT-06								
Matrix: SOIL								
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	<0.2		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	0.3		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	15.2		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	3.2		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	17.6		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926
Particle Size - Hydrometer								
% Sand	40		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	39		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	21		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	28		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	108		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	3		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	20		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	26		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	0.6		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	129		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	41		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	7.0		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	0.7		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
L445303-10 1-(0.0-0.2M)								
Sampled By: NOT PROVIDED on 12-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	<0.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	3.8		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	3.8		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	0.2		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	0.3		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	22.7		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	3.6		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	26.9		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926
Bulk Density	1020		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Organic Matter	9		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								
% Sand	35		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	53		1	%	24-OCT-06	25-OCT-06	HSL	R457956

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-10 1-(0.0-0.2M) Sampled By: NOT PROVIDED on 12-OCT-06 Matrix: SOIL								
Particle Size - Hydrometer								
% Clay	12		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Silt loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		08-FEB-07	LL	R481352
Total Kjeldahl Nitrogen	0.31		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Sulfur (S)-Total	300		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
Available N, P, K and S								
Available Nitrate-N	6.4		0.4	mg/kg	24-OCT-06	24-OCT-06	BFE	R457626
Available Phosphate & Potassium								
Available Phosphate-P	4		1	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Potassium	102		2	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Sulfate-S	15		2	mg/kg	24-OCT-06	24-OCT-06	BEM	R457319
Detailed Salinity								
Chloride (Cl)	40		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	74		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	3		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	12		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	40		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	1.1		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	96.0		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	51		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	6.3		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	0.6		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
L445303-11 11A (0.70-1.2M) Sampled By: NOT PROVIDED on 13-OCT-06 Matrix: SOIL								
Boron (B), Hot Water Ext.	0.3		0.1	mg/kg	24-OCT-06	24-OCT-06	BEM	R457295
Bulk Density	1100		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	0.15		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	1.5		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
PITS Metals (ICP)								
Arsenic (As)	8.6		0.1	mg/kg		24-OCT-06	JGP	R457427
Barium (Ba)	259		5	mg/kg		24-OCT-06	JGP	R457427
Beryllium (Be)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Cadmium (Cd)	<0.5		0.5	mg/kg		24-OCT-06	JGP	R457427
Cobalt (Co)	10		1	mg/kg		24-OCT-06	JGP	R457427
Chromium (Cr)	25.0		0.5	mg/kg		24-OCT-06	JGP	R457427
Copper (Cu)	20		2	mg/kg		24-OCT-06	JGP	R457427
Mercury (Hg)	0.06		0.05	mg/kg		24-OCT-06	JGP	R457427
Manganese (Mn)	320		20	mg/kg		24-OCT-06	JGP	R457427
Molybdenum (Mo)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Nickel (Ni)	34		2	mg/kg		24-OCT-06	JGP	R457427
Lead (Pb)	12		5	mg/kg		24-OCT-06	JGP	R457427
Selenium (Se)	<0.1		0.1	mg/kg		24-OCT-06	JGP	R457427
Strontium (Sr)	54		1	mg/kg		24-OCT-06	JGP	R457427
Thallium (Tl)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Vanadium (V)	40		1	mg/kg		24-OCT-06	JGP	R457427

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-11 11A (0.70-1.2M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
PITS Metals (ICP)								
Zinc (Zn)	74		5	mg/kg		24-OCT-06	JGP	R457427
Particle Size - Hydrometer								
% Sand	9		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	58		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	33		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Silty clay loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	26		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	11		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	<1		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	5		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	236		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	14.8		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	202		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	73		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	8.0		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	1.0		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
L445303-12 11A (0.32-0.38M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	<0.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	0.3		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	0.3		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
Bulk Density	1220		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Organic Matter	2		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								
% Sand	37		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	56		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	7		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Silt loam				24-OCT-06	25-OCT-06	HSL	R457956
Total Kjeldahl Nitrogen	0.05		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Detailed Salinity								
Chloride (Cl)	67		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	20		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	1		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	7		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	134		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	6.6		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	140		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	30		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	7.0		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	0.7		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-12 11A (0.32-0.38M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Detailed Salinity								
L445303-13 11A (0.38-0.70M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	3.0		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	0.3		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	11.4		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	6.1		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	20.1		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	<0.09		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Particle Size - Hydrometer								
% Sand	40		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	33		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	27		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	31		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	9		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	<1		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	3		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	151		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	10.7		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	96.9		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	48		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	7.5		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	0.7		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
L445303-14 11A (0.0-0.32M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	<0.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	3.6		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	3.6		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	0.6		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	0.3		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	10.2		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	2.4		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	22.7		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926
Organic Matter	8		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								

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Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-14 11A (0.0-0.32M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Particle Size - Hydrometer								
% Sand	31		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	52		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	17		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Silt loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		08-FEB-07	LL	R481352
Total Kjeldahl Nitrogen	0.33		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Sulfur (S)-Total	300		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
Available N, P, K and S								
Available Nitrate-N	8.0		0.4	mg/kg	24-OCT-06	24-OCT-06	BFE	R457626
Available Phosphate & Potassium								
Available Phosphate-P	13		1	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Potassium	114		2	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Sulfate-S	22		2	mg/kg	24-OCT-06	24-OCT-06	BEM	R457319
Detailed Salinity								
Chloride (Cl)	53		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	35		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	2		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	9		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	77		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	3.0		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	160		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	46		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	5.0		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	0.6		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
L445303-15 12A (0.0-0.25M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	<0.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	2.2		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	2.2		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	<0.2		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	0.3		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	9.4		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	1.2		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	13.1		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926
Bulk Density	1130		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Organic Matter	5		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								
% Sand	56		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	32		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	12		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Sandy loam				24-OCT-06	25-OCT-06	HSL	R457956

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Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-15 12A (0.0-0.25M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Sulphur, Elemental	<0.01		0.01	%		15-FEB-07	LL	R494124
Total Kjeldahl Nitrogen	0.15		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Sulfur (S)-Total	200		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
Available N, P, K and S								
Available Nitrate-N	13.0		0.4	mg/kg	24-OCT-06	24-OCT-06	BFE	R457626
Available Phosphate & Potassium								
Available Phosphate-P	8		1	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Potassium	132		2	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Sulfate-S	6		2	mg/kg	24-OCT-06	24-OCT-06	BEM	R457319
Detailed Salinity								
Chloride (Cl)	29		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	53		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	8		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	8		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	21		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	0.7		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	34.2		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	34		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	5.7		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	0.4		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
L445303-16 12A (0.25-0.35M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	<0.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	0.3		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	0.3		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
Bulk Density	1190		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Organic Matter	2		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								
% Sand	62		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	27		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	11		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Sandy loam				24-OCT-06	25-OCT-06	HSL	R457956
Total Kjeldahl Nitrogen	0.06		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Detailed Salinity								
Chloride (Cl)	22		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	92		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	6		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	15		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	26		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	0.7		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	25.8		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								

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Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-16 12A (0.25-0.35M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Detailed Salinity								
Saturated Paste pH and EC								
% Saturation	26		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	6.5		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	0.7		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
L445303-17 12A (1.3-1.5M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Boron (B), Hot Water Ext.	0.2		0.1	mg/kg	24-OCT-06	24-OCT-06	BEM	R457295
Bulk Density	1330		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	<0.09		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
PITS Metals (ICP)								
Arsenic (As)	4.3		0.1	mg/kg		24-OCT-06	JGP	R457427
Barium (Ba)	46		5	mg/kg		24-OCT-06	JGP	R457427
Beryllium (Be)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Cadmium (Cd)	<0.5		0.5	mg/kg		24-OCT-06	JGP	R457427
Cobalt (Co)	4		1	mg/kg		24-OCT-06	JGP	R457427
Chromium (Cr)	6.4		0.5	mg/kg		24-OCT-06	JGP	R457427
Copper (Cu)	7		2	mg/kg		24-OCT-06	JGP	R457427
Mercury (Hg)	<0.05		0.05	mg/kg		24-OCT-06	JGP	R457427
Manganese (Mn)	200		20	mg/kg		24-OCT-06	JGP	R457427
Molybdenum (Mo)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Nickel (Ni)	12		2	mg/kg		24-OCT-06	JGP	R457427
Lead (Pb)	<5		5	mg/kg		24-OCT-06	JGP	R457427
Selenium (Se)	0.1		0.1	mg/kg		24-OCT-06	JGP	R457427
Strontium (Sr)	11		1	mg/kg		24-OCT-06	JGP	R457427
Thallium (Tl)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Vanadium (V)	12		1	mg/kg		24-OCT-06	JGP	R457427
Zinc (Zn)	20		5	mg/kg		24-OCT-06	JGP	R457427
Particle Size - Hydrometer								
% Sand	82		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	10		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	9		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loamy sand				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	10		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	28		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	6		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	6		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	17		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	0.8		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	8.97		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	27		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	7.5		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	0.3		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714

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Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-18 12A (0.35-0.53M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Bulk Density	1200		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Particle Size - Hydrometer								
% Sand	64		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	22		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	14		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Sandy loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	16		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	40		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	7		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	8		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	15		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	0.6		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	15.7		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	34		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	6.7		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	0.3		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
L445303-19 17 (0.3-0.4M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	0.4		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	19.5		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	3.2		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	19.9		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	2.4		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	1.6		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	77.3		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	13.3		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	76.6		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926
Bulk Density	440		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Organic Matter	41		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Saturated Paste pH and EC								
% Saturation	103		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	7.2		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	2.8		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
Total Kjeldahl Nitrogen	2.04		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Available N, P, K and S								
Available Nitrate-N	13.0		0.4	mg/kg	24-OCT-06	24-OCT-06	BFE	R457626
Available Phosphate & Potassium								
Available Phosphate-P	4		1	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Potassium	444		2	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Sulfate-S	1350		2	mg/kg	24-OCT-06	24-OCT-06	BEM	R457319

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-20 17 (0.7-0.9M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Boron (B), Hot Water Ext.	1.1		0.1	mg/kg	24-OCT-06	24-OCT-06	BEM	R457295
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	0.96		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	8.2		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
PITS Metals (ICP)								
Arsenic (As)	5.2		0.1	mg/kg		24-OCT-06	JGP	R457427
Barium (Ba)	426		5	mg/kg		24-OCT-06	JGP	R457427
Beryllium (Be)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Cadmium (Cd)	<0.5		0.5	mg/kg		24-OCT-06	JGP	R457427
Cobalt (Co)	11		1	mg/kg		24-OCT-06	JGP	R457427
Chromium (Cr)	26.8		0.5	mg/kg		24-OCT-06	JGP	R457427
Copper (Cu)	22		2	mg/kg		24-OCT-06	JGP	R457427
Mercury (Hg)	<0.05		0.05	mg/kg		24-OCT-06	JGP	R457427
Manganese (Mn)	230		20	mg/kg		24-OCT-06	JGP	R457427
Molybdenum (Mo)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Nickel (Ni)	31		2	mg/kg		24-OCT-06	JGP	R457427
Lead (Pb)	13		5	mg/kg		24-OCT-06	JGP	R457427
Selenium (Se)	0.4		0.1	mg/kg		24-OCT-06	JGP	R457427
Strontium (Sr)	100		1	mg/kg		24-OCT-06	JGP	R457427
Thallium (Tl)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Vanadium (V)	38		1	mg/kg		24-OCT-06	JGP	R457427
Zinc (Zn)	86		5	mg/kg		24-OCT-06	JGP	R457427
Particle Size - Hydrometer								
% Sand	6		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	45		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	49		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Silty clay				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	6		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	106		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	24		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	38		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	132		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	2.8		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	532		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	125		1	%	24-OCT-06	24-OCT-06	CMF	R457714
pH in Saturated Paste	7.7		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457714
Conductivity Sat. Paste	1.3		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457714
L445303-21 31 (0.3-0.5M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Particle Size - Hydrometer								
% Sand	41		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	34		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	26		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	15		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-21 31 (0.3-0.5M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Detailed Salinity								
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	60		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	3		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	21		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	99		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	2.8		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	113		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	51		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	7.3		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	0.7		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
L445303-22 31 (0-0.2M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	<0.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	3.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	3.1		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	0.3		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	0.3		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	17.7		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	4.5		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	24.0		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926
Bulk Density	1050		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Organic Matter	8		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								
% Sand	32		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	46		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	22		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		08-FEB-07	LL	R481352
Total Kjeldahl Nitrogen	0.28		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Sulfur (S)-Total	300		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
Available N, P, K and S								
Available Nitrate-N	11.0		0.4	mg/kg	24-OCT-06	24-OCT-06	BFE	R457626
Available Phosphate & Potassium								
Available Phosphate-P	14		1	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Potassium	120		2	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Sulfate-S	15		2	mg/kg	24-OCT-06	24-OCT-06	BEM	R457319
Detailed Salinity								
Chloride (Cl)	30		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	51		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	3		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	13		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	59		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-22 31 (0-0.2M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Detailed Salinity								
SAR, Cations and SO4 in saturated soil								
SAR	1.9		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	74.5		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	52		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	6.2		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	0.5		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
L445303-23 31 (0.8-1.0M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Boron (B), Hot Water Ext.	0.6		0.1	mg/kg	24-OCT-06	24-OCT-06	BEM	R457295
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	0.26		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	2.4		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
PITS Metals (ICP)								
Arsenic (As)	7.2		0.1	mg/kg		24-OCT-06	JGP	R457427
Barium (Ba)	287		5	mg/kg		24-OCT-06	JGP	R457427
Beryllium (Be)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Cadmium (Cd)	<0.5		0.5	mg/kg		24-OCT-06	JGP	R457427
Cobalt (Co)	12		1	mg/kg		24-OCT-06	JGP	R457427
Chromium (Cr)	21.8		0.5	mg/kg		24-OCT-06	JGP	R457427
Copper (Cu)	23		2	mg/kg		24-OCT-06	JGP	R457427
Mercury (Hg)	<0.05		0.05	mg/kg		24-OCT-06	JGP	R457427
Manganese (Mn)	290		20	mg/kg		24-OCT-06	JGP	R457427
Molybdenum (Mo)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Nickel (Ni)	29		2	mg/kg		24-OCT-06	JGP	R457427
Lead (Pb)	10		5	mg/kg		24-OCT-06	JGP	R457427
Selenium (Se)	<0.1		0.1	mg/kg		24-OCT-06	JGP	R457427
Strontium (Sr)	84		1	mg/kg		24-OCT-06	JGP	R457427
Thallium (Tl)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Vanadium (V)	32		1	mg/kg		24-OCT-06	JGP	R457427
Zinc (Zn)	84		5	mg/kg		24-OCT-06	JGP	R457427
Particle Size - Hydrometer								
% Sand	37		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	38		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	25		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	29		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	33	DLIS	10	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	5	DLIS	5	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	12	DLIS	5	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	391	DLIS	5	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	14.8		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	341	DLIS	30	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	61		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	7.9		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	1.4		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-23 31 (0.8-1.0M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Detailed Salinity								
L445303-24 16 (1.0-1.2M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Boron (B), Hot Water Ext.	2.0		0.1	mg/kg	24-OCT-06	24-OCT-06	BEM	R457295
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	0.94		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	8.0		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
PITS Metals (ICP)								
Arsenic (As)	9.1		0.1	mg/kg		24-OCT-06	JGP	R457427
Barium (Ba)	291		5	mg/kg		24-OCT-06	JGP	R457427
Beryllium (Be)	1		1	mg/kg		24-OCT-06	JGP	R457427
Cadmium (Cd)	<0.5		0.5	mg/kg		24-OCT-06	JGP	R457427
Cobalt (Co)	13		1	mg/kg		24-OCT-06	JGP	R457427
Chromium (Cr)	30.7		0.5	mg/kg		24-OCT-06	JGP	R457427
Copper (Cu)	26		2	mg/kg		24-OCT-06	JGP	R457427
Mercury (Hg)	<0.05		0.05	mg/kg		24-OCT-06	JGP	R457427
Manganese (Mn)	390		20	mg/kg		24-OCT-06	JGP	R457427
Molybdenum (Mo)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Nickel (Ni)	34		2	mg/kg		24-OCT-06	JGP	R457427
Lead (Pb)	14		5	mg/kg		24-OCT-06	JGP	R457427
Selenium (Se)	0.3		0.1	mg/kg		24-OCT-06	JGP	R457427
Strontium (Sr)	139		1	mg/kg		24-OCT-06	JGP	R457427
Thallium (Tl)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Vanadium (V)	50		1	mg/kg		24-OCT-06	JGP	R457427
Zinc (Zn)	89		5	mg/kg		24-OCT-06	JGP	R457427
Particle Size - Hydrometer								
% Sand	10		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	39		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	50		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Silty clay / Clay				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	25		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	<2		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	4		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	3		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	938		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	117	SAR:M	0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	1410		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	252		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	9.4		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	3.2		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
L445303-25 16 (0.0-0.23M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	<0.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	4.2		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-25 16 (0.0-0.23M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	4.2		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	0.3		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	3.1		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	18.8		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	4.3		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	24.0		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926
Bulk Density	1010		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Organic Matter	10		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								
% Sand	48		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	37		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	15		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		08-FEB-07	LL	R481352
Total Kjeldahl Nitrogen	0.41		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Sulfur (S)-Total	500		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
Available N, P, K and S								
Available Nitrate-N	6.0		0.4	mg/kg	24-OCT-06	24-OCT-06	BFE	R457626
Available Phosphate & Potassium								
Available Phosphate-P	132		1	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Potassium	1130		2	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Sulfate-S	15		2	mg/kg	24-OCT-06	24-OCT-06	BEM	R457319
Detailed Salinity								
Chloride (Cl)	43		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	87		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	188		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	25		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	35		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	0.9		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	59.8		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	57		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	6.8		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	1.1		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
L445303-26 16 (0.8-1.0M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Boron (B), Hot Water Ext.	1.0		0.1	mg/kg	24-OCT-06	24-OCT-06	BEM	R457295
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	0.89		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	7.6		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
PITS Metals (ICP)								
Arsenic (As)	3.8		0.1	mg/kg		24-OCT-06	JGP	R457427

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-26 16 (0.8-1.0M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
PITS Metals (ICP)								
Barium (Ba)	93		5	mg/kg		24-OCT-06	JGP	R457427
Beryllium (Be)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Cadmium (Cd)	<0.5		0.5	mg/kg		24-OCT-06	JGP	R457427
Cobalt (Co)	4		1	mg/kg		24-OCT-06	JGP	R457427
Chromium (Cr)	9.8		0.5	mg/kg		24-OCT-06	JGP	R457427
Copper (Cu)	7		2	mg/kg		24-OCT-06	JGP	R457427
Mercury (Hg)	<0.05		0.05	mg/kg		24-OCT-06	JGP	R457427
Manganese (Mn)	160		20	mg/kg		24-OCT-06	JGP	R457427
Molybdenum (Mo)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Nickel (Ni)	13		2	mg/kg		24-OCT-06	JGP	R457427
Lead (Pb)	<5		5	mg/kg		24-OCT-06	JGP	R457427
Selenium (Se)	0.3		0.1	mg/kg		24-OCT-06	JGP	R457427
Strontium (Sr)	121		1	mg/kg		24-OCT-06	JGP	R457427
Thallium (Tl)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Vanadium (V)	19		1	mg/kg		24-OCT-06	JGP	R457427
Zinc (Zn)	24		5	mg/kg		24-OCT-06	JGP	R457427
Particle Size - Hydrometer								
% Sand	65		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	16		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	19		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Sandy loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	71		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	7		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	26		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	11		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	1090		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	58.3		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	1360		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	89		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	9.5		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	3.4		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
L445303-27 16 (0.23-0.48M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Bulk Density	1050		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Particle Size - Hydrometer								
% Sand	46		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	28		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	26		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	155		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	48		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	110		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	52		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863

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Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-27 16 (0.23-0.48M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Detailed Salinity								
SAR, Cations and SO4 in saturated soil								
Sodium (Na)	816		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	19.4		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	748		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	49		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	8.4		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	3.1		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
L445303-28 29 (0.2-0.5M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	<0.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	2.0		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	2.0		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
Organic Matter	6		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								
% Sand	54		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	29		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	17		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Sandy loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		04-JAN-07	LL	R481352
Total Kjeldahl Nitrogen	0.19		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Sulfur (S)-Total	300		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
Detailed Salinity								
Chloride (Cl)	22		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	274		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	4		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	48		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	89		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	1.3		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	330		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	43		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	6.8		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	1.5		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
L445303-29 29 (0.8-1.0M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Boron (B), Hot Water Ext.	1.2		0.1	mg/kg	24-OCT-06	24-OCT-06	BEM	R457295
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	0.93		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	8.0		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
PITS Metals (ICP)								
Arsenic (As)	7.1		0.1	mg/kg		24-OCT-06	JGP	R457427

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Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-29 29 (0.8-1.0M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
PITS Metals (ICP)								
Barium (Ba)	232		5	mg/kg		24-OCT-06	JGP	R457427
Beryllium (Be)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Cadmium (Cd)	<0.5		0.5	mg/kg		24-OCT-06	JGP	R457427
Cobalt (Co)	10		1	mg/kg		24-OCT-06	JGP	R457427
Chromium (Cr)	23.8		0.5	mg/kg		24-OCT-06	JGP	R457427
Copper (Cu)	20		2	mg/kg		24-OCT-06	JGP	R457427
Mercury (Hg)	<0.05		0.05	mg/kg		24-OCT-06	JGP	R457427
Manganese (Mn)	510		20	mg/kg		24-OCT-06	JGP	R457427
Molybdenum (Mo)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Nickel (Ni)	28		2	mg/kg		24-OCT-06	JGP	R457427
Lead (Pb)	11		5	mg/kg		24-OCT-06	JGP	R457427
Selenium (Se)	0.2		0.1	mg/kg		24-OCT-06	JGP	R457427
Strontium (Sr)	105		1	mg/kg		24-OCT-06	JGP	R457427
Thallium (Tl)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Vanadium (V)	41		1	mg/kg		24-OCT-06	JGP	R457427
Zinc (Zn)	66		5	mg/kg		24-OCT-06	JGP	R457427
Particle Size - Hydrometer								
% Sand	46		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	26		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	27		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Sandy clay loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		04-JAN-07	LL	R481352
Sulfur (S)-Total	600		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
Detailed Salinity								
Chloride (Cl)	20		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	<2		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	3		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	<1		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	847		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	Incalculable	SAR:INC	0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	1150		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	204		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	9.0		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	2.8		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
L445303-30 29 (0.0-0.2M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	<0.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	2.0		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	0.8		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	2.0		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	0.7		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	0.2		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	18.8		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869

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Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-30 29 (0.0-0.2M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Magnesium (Mg)	4.1		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	17.9		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926
Bulk Density	1190		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Organic Matter	6		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								
% Sand	57		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	29		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	14		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Sandy loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		04-JAN-07	LL	R481352
Total Kjeldahl Nitrogen	0.17		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Sulfur (S)-Total	300		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
Available N, P, K and S								
Available Nitrate-N	2.8		0.4	mg/kg	24-OCT-06	24-OCT-06	BFE	R457626
Available Phosphate & Potassium								
Available Phosphate-P	5		1	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Potassium	77		2	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Sulfate-S	20		2	mg/kg	24-OCT-06	24-OCT-06	BEM	R457319
Detailed Salinity								
Chloride (Cl)	26		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	120		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	3		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	29		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	172		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	3.7		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	132		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	37		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	7.6		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	1.1		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
L445303-31 13 (0.0-0.15M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	<0.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	4.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	4.1		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	0.3		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	1.5		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	22.7		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	6.3		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	34.4		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926

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Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-31 13 (0.0-0.15M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Bulk Density	970		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Organic Matter	11		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								
% Sand	34		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	42		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	25		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		08-FEB-07	LL	R481352
Total Kjeldahl Nitrogen	0.37		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Sulfur (S)-Total	600		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
Available N, P, K and S								
Available Nitrate-N	4.2		0.4	mg/kg	24-OCT-06	24-OCT-06	BFE	R457626
Available Phosphate & Potassium								
Available Phosphate-P	8		1	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Potassium	523		2	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Sulfate-S	14		2	mg/kg	24-OCT-06	24-OCT-06	BEM	R457319
Detailed Salinity								
Chloride (Cl)	22		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	65		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	34		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	17		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	46		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	1.3		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	55.0		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	63		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	6.2		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	0.6		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
L445303-32 13 (0.15-0.3M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Particle Size - Hydrometer								
% Sand	34		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	41		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	25		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	33		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	36		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	16		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	10		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	54		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	2.0		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	55.3		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	44		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	6.1		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	0.4		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719

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Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-32 13 (0.15-0.3M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Detailed Salinity								
L445303-33 13 (0.8-1.0M)								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	<0.09		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Particle Size - Hydrometer								
% Sand	38		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	40		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	23		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	20		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	24		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	4		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	9		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	45		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	2.0		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	54.4		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	54		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	6.7		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	0.3		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
L445303-34 13-CF								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	0.4		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	28.0		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	3.3		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	28.4		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	0.5		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	3.0		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	81.3		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	15.2		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	114		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926
Bulk Density	380		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Organic Matter	65		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Saturated Paste pH and EC								
% Saturation	303		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	6.8		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	1.0		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
Total Kjeldahl Nitrogen	1.91		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Available N, P, K and S								
Available Nitrate-N	65.0		0.4	mg/kg	24-OCT-06	24-OCT-06	BFE	R457626

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-34 13-CF								
Sampled By: NOT PROVIDED on 13-OCT-06								
Matrix: SOIL								
Available N, P, K and S								
Available Phosphate & Potassium								
Available Phosphate-P	31		1	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Potassium	913		2	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Sulfate-S	53		2	mg/kg	24-OCT-06	24-OCT-06	BEM	R457319
L445303-35 3 (0.2-0.4M)								
Sampled By: NOT PROVIDED on 12-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	<0.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	2.6		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	2.6		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
Bulk Density	1000		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457522
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	<0.09		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Organic Matter	6		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								
% Sand	51		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	36		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	14		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Total Kjeldahl Nitrogen	0.22		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Detailed Salinity								
Chloride (Cl)	124		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	25		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	2		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	7		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	332		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	15.0		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	194		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	102		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	6.5		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	1.2		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
L445303-36 3 (0.0-0.15M)								
Sampled By: NOT PROVIDED on 12-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	<0.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	4.3		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	4.3		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	1.7		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-36 3 (0.0-0.15M)								
Sampled By: NOT PROVIDED on 12-OCT-06								
Matrix: SOIL								
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Potassium (K)	0.4		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	12.6		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	4.4		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	24.5		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926
Bulk Density	890		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457524
Organic Matter	10		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								
% Sand	48		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	39		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	13		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		08-FEB-07	LL	R481352
Total Kjeldahl Nitrogen	0.39		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Sulfur (S)-Total	500		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
Available N, P, K and S								
Available Nitrate-N	3.4		0.4	mg/kg	24-OCT-06	24-OCT-06	BFE	R457626
Available Phosphate & Potassium								
Available Phosphate-P	13		1	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Potassium	144		2	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Sulfate-S	20		2	mg/kg	24-OCT-06	24-OCT-06	BEM	R457319
Detailed Salinity								
Chloride (Cl)	80		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	36		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	4		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	13		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	198		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	7.2		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	98.7		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	64		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	5.8		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	0.9		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
L445303-37 3 (0.6-0.8M)								
Sampled By: NOT PROVIDED on 12-OCT-06								
Matrix: SOIL								
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	<0.09		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Particle Size - Hydrometer								
% Sand	50		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	32		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	17		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	103		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	25		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-37 3 (0.6-0.8M)								
Sampled By: NOT PROVIDED on 12-OCT-06								
Matrix: SOIL								
Detailed Salinity								
SAR, Cations and SO4 in saturated soil								
Potassium (K)	1		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	5		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	605		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	28.8		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	708		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	86		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	7.7		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	2.3		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
L445303-38 3 (1.0-1.2M)								
Sampled By: NOT PROVIDED on 12-OCT-06								
Matrix: SOIL								
Boron (B), Hot Water Ext.	0.2		0.1	mg/kg	24-OCT-06	24-OCT-06	BEM	R457295
Bulk Density	1040		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457524
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	0.40		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	3.5		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
PITS Metals (ICP)								
Arsenic (As)	5.2		0.1	mg/kg		24-OCT-06	JGP	R457427
Barium (Ba)	135		5	mg/kg		24-OCT-06	JGP	R457427
Beryllium (Be)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Cadmium (Cd)	<0.5		0.5	mg/kg		24-OCT-06	JGP	R457427
Cobalt (Co)	8		1	mg/kg		24-OCT-06	JGP	R457427
Chromium (Cr)	17.3		0.5	mg/kg		24-OCT-06	JGP	R457427
Copper (Cu)	13		2	mg/kg		24-OCT-06	JGP	R457427
Mercury (Hg)	<0.05		0.05	mg/kg		24-OCT-06	JGP	R457427
Manganese (Mn)	250		20	mg/kg		24-OCT-06	JGP	R457427
Molybdenum (Mo)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Nickel (Ni)	22		2	mg/kg		24-OCT-06	JGP	R457427
Lead (Pb)	7		5	mg/kg		24-OCT-06	JGP	R457427
Selenium (Se)	<0.1		0.1	mg/kg		24-OCT-06	JGP	R457427
Strontium (Sr)	44		1	mg/kg		24-OCT-06	JGP	R457427
Thallium (Tl)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Vanadium (V)	29		1	mg/kg		24-OCT-06	JGP	R457427
Zinc (Zn)	45		5	mg/kg		24-OCT-06	JGP	R457427
Particle Size - Hydrometer								
% Sand	64		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	18		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	17		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Sandy loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	14		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	53		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	<1		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	14		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	1360		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	43.0		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	2560		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-38 3 (1.0-1.2M)								
Sampled By: NOT PROVIDED on 12-OCT-06								
Matrix: SOIL								
Detailed Salinity								
Saturated Paste pH and EC								
% Saturation	84		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	8.3		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	4.6		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
L445303-39 3 (1.2-1.4M)								
Sampled By: NOT PROVIDED on 12-OCT-06								
Matrix: SOIL								
Boron (B), Hot Water Ext.	0.3		0.1	mg/kg	24-OCT-06	24-OCT-06	BEM	R457295
Bulk Density	1100		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457524
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	0.71		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	6.1		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
PITS Metals (ICP)								
Arsenic (As)	6.9		0.1	mg/kg		24-OCT-06	JGP	R457427
Barium (Ba)	188		5	mg/kg		24-OCT-06	JGP	R457427
Beryllium (Be)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Cadmium (Cd)	<0.5		0.5	mg/kg		24-OCT-06	JGP	R457427
Cobalt (Co)	11		1	mg/kg		24-OCT-06	JGP	R457427
Chromium (Cr)	22.5		0.5	mg/kg		24-OCT-06	JGP	R457427
Copper (Cu)	18		2	mg/kg		24-OCT-06	JGP	R457427
Mercury (Hg)	<0.05		0.05	mg/kg		24-OCT-06	JGP	R457427
Manganese (Mn)	370		20	mg/kg		24-OCT-06	JGP	R457427
Molybdenum (Mo)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Nickel (Ni)	30		2	mg/kg		24-OCT-06	JGP	R457427
Lead (Pb)	10		5	mg/kg		24-OCT-06	JGP	R457427
Selenium (Se)	<0.1		0.1	mg/kg		24-OCT-06	JGP	R457427
Strontium (Sr)	69		1	mg/kg		24-OCT-06	JGP	R457427
Thallium (Tl)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Vanadium (V)	36		1	mg/kg		24-OCT-06	JGP	R457427
Zinc (Zn)	62		5	mg/kg		24-OCT-06	JGP	R457427
Particle Size - Hydrometer								
% Sand	47		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	26		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	27		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Sandy clay loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	45		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	234		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	<1		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	55		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	1850		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	28.3		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	3940		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	107		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	7.9		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	5.9		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-40 35 (0-.16M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	2.2		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	1.6		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	13.6		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	5.3		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	19.6		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926
Bulk Density	940		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457524
Particle Size - Hydrometer								
% Sand	76		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	16		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	9		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Sandy loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		04-JAN-07	LL	R481352
Sulfur (S)-Total	200		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
Available N, P, K and S								
Available Nitrate-N	3.0		0.4	mg/kg	24-OCT-06	24-OCT-06	BFE	R457626
Available Phosphate & Potassium								
Available Phosphate-P	2		1	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Potassium	182		2	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Sulfate-S	20		2	mg/kg	24-OCT-06	24-OCT-06	BEM	R457319
Detailed Salinity								
Chloride (Cl)	11		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457970
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	21		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Potassium (K)	5		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Magnesium (Mg)	6		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Sodium (Na)	112		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
SAR	5.5		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457863
Sulphate (SO4)	86.1		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457863
Saturated Paste pH and EC								
% Saturation	50		1	%	24-OCT-06	24-OCT-06	CMF	R457719
pH in Saturated Paste	7.6		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457719
Conductivity Sat. Paste	0.6		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457719
L445303-41 35 (1.3-1.5M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Bulk Density	1090		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457524
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	0.16		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	1.5		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Particle Size - Hydrometer								
% Sand	51		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	29		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	20		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		04-JAN-07	LL	R481352
Detailed Salinity								
Chloride (Cl)	46		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								

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Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-41 35 (1.3-1.5M)								
Sampled By: NOT PROVIDED on 16-OCT-06								
Matrix: SOIL								
Detailed Salinity								
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	101		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	11		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	27		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	194		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	4.4		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	72.1		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	49		1	%	24-OCT-06	24-OCT-06	CMF	R457729
pH in Saturated Paste	7.5		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457729
Conductivity Sat. Paste	1.2		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457729
L445303-42 47 (0-0.1M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	1.1		0.2	meq/100g	29-DEC-06	29-DEC-06	MKP	R479792
Potassium (K)	0.4		0.2	meq/100g	29-DEC-06	29-DEC-06	MKP	R479792
Calcium (Ca)	23.0		0.2	meq/100g	29-DEC-06	29-DEC-06	MKP	R479792
Magnesium (Mg)	5.3		0.4	meq/100g	29-DEC-06	29-DEC-06	MKP	R479792
Cation Exchange Capacity	20.1		0.2	meq/100g	29-DEC-06	29-DEC-06	BFE	R479871
Bulk Density	1140		50	kg/m3	28-DEC-06	28-DEC-06	JMD	R479603
Particle Size - Hydrometer								
% Sand	40		1	%	28-DEC-06	02-JAN-07	ANT	R480425
% Silt	40		1	%	28-DEC-06	02-JAN-07	ANT	R480425
% Clay	20		1	%	28-DEC-06	02-JAN-07	ANT	R480425
Texture	Loam				28-DEC-06	02-JAN-07	ANT	R480425
Sulphur, Elemental	<0.01		0.01	%		04-JAN-07	LL	R481352
Sulfur (S)-Total	300		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
pH (1:2 soil:water)	8.4		0.1	pH	02-FEB-07	02-FEB-07	MKP	R489823
Available N, P, K and S								
Available Nitrate-N	12.2		0.4	mg/kg	28-DEC-06	28-DEC-06	BFE	R479592
Available Phosphate & Potassium								
Available Phosphate-P	27		1	mg/kg	28-DEC-06	28-DEC-06	BFE	R479617
Available Potassium	158		2	mg/kg	28-DEC-06	28-DEC-06	BFE	R479617
Available Sulfate-S	18		2	mg/kg	28-DEC-06	28-DEC-06	MKP	R479526
Detailed Salinity								
Chloride (Cl)	64		3	mg/L	29-DEC-06	29-DEC-06	BFE	R479921
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	90		2	mg/L	29-DEC-06	29-DEC-06	MKP	R479895
Potassium (K)	5		1	mg/L	29-DEC-06	29-DEC-06	MKP	R479895
Magnesium (Mg)	24		1	mg/L	29-DEC-06	29-DEC-06	MKP	R479895
Sodium (Na)	169		1	mg/L	29-DEC-06	29-DEC-06	MKP	R479895
SAR	4.1		0.1	SAR	29-DEC-06	29-DEC-06	MKP	R479895
Sulphate (SO4)	156		6	mg/L	29-DEC-06	29-DEC-06	MKP	R479895
Saturated Paste pH and EC								
% Saturation	43		1	%	28-DEC-06	28-DEC-06	JMD	R479802
pH in Saturated Paste	7.7		0.1	pH	28-DEC-06	28-DEC-06	JMD	R479802
Conductivity Sat. Paste	1.1		0.1	dS m-1	28-DEC-06	28-DEC-06	JMD	R479802

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Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-43 47 (0.3-0.4M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								
Particle Size - Hydrometer								
% Sand	45		1	%	28-DEC-06	02-JAN-07	ANT	R480425
% Silt	33		1	%	28-DEC-06	02-JAN-07	ANT	R480425
% Clay	22		1	%	28-DEC-06	02-JAN-07	ANT	R480425
Texture	Loam				28-DEC-06	02-JAN-07	ANT	R480425
Sulphur, Elemental	<0.01		0.01	%		04-JAN-07	LL	R481352
Sulfur (S)-Total	<100		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
pH (1:2 soil:water)	8.7		0.1	pH	02-FEB-07	02-FEB-07	MKP	R489823
Detailed Salinity								
Chloride (Cl)	34		3	mg/L	29-DEC-06	29-DEC-06	BFE	R479921
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	14		2	mg/L	29-DEC-06	29-DEC-06	MKP	R479895
Potassium (K)	3		1	mg/L	29-DEC-06	29-DEC-06	MKP	R479895
Magnesium (Mg)	4		1	mg/L	29-DEC-06	29-DEC-06	MKP	R479895
Sodium (Na)	226		1	mg/L	29-DEC-06	29-DEC-06	MKP	R479895
SAR	13.7		0.1	SAR	29-DEC-06	29-DEC-06	MKP	R479895
Sulphate (SO4)	177		6	mg/L	29-DEC-06	29-DEC-06	MKP	R479895
Saturated Paste pH and EC								
% Saturation	55		1	%	28-DEC-06	28-DEC-06	JMD	R479802
pH in Saturated Paste	7.9		0.1	pH	28-DEC-06	28-DEC-06	JMD	R479802
Conductivity Sat. Paste	1.0		0.1	dS m-1	28-DEC-06	28-DEC-06	JMD	R479802
L445303-44 47 (0.8-1.0M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								
Bulk Density	1150		50	kg/m3	28-DEC-06	28-DEC-06	JMD	R479603
Particle Size - Hydrometer								
% Sand	41		1	%	28-DEC-06	02-JAN-07	ANT	R480425
% Silt	34		1	%	28-DEC-06	02-JAN-07	ANT	R480425
% Clay	25		1	%	28-DEC-06	02-JAN-07	ANT	R480425
Texture	Loam				28-DEC-06	02-JAN-07	ANT	R480425
Sulphur, Elemental	<0.01		0.01	%		04-JAN-07	LL	R481352
Sulfur (S)-Total	300		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
pH (1:2 soil:water)	8.9		0.1	pH	02-FEB-07	02-FEB-07	MKP	R489823
Detailed Salinity								
Chloride (Cl)	25		3	mg/L	29-DEC-06	29-DEC-06	BFE	R479921
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	24		2	mg/L	29-DEC-06	29-DEC-06	MKP	R479895
Potassium (K)	4		1	mg/L	29-DEC-06	29-DEC-06	MKP	R479895
Magnesium (Mg)	10		1	mg/L	29-DEC-06	29-DEC-06	MKP	R479895
Sodium (Na)	607		1	mg/L	29-DEC-06	29-DEC-06	MKP	R479895
SAR	26.2		0.1	SAR	29-DEC-06	29-DEC-06	MKP	R479895
Sulphate (SO4)	995		6	mg/L	29-DEC-06	29-DEC-06	MKP	R479895
Saturated Paste pH and EC								
% Saturation	84		1	%	28-DEC-06	28-DEC-06	JMD	R479802
pH in Saturated Paste	8.2		0.1	pH	28-DEC-06	28-DEC-06	JMD	R479802
Conductivity Sat. Paste	2.4		0.1	dS m-1	28-DEC-06	28-DEC-06	JMD	R479802
L445303-45 52 (0-0.1M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								

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Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-45 52 (0-0.1M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	<0.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	2.9		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	2.9		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	<0.2		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	1.6		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	19.3		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	3.1		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	21.6		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926
Bulk Density	1030		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457524
Organic Matter	7		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								
% Sand	49		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	34		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	17		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		08-FEB-07	LL	R481352
Total Kjeldahl Nitrogen	0.24		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Sulfur (S)-Total	200		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
Available N, P, K and S								
Available Nitrate-N	5.0		0.4	mg/kg	24-OCT-06	24-OCT-06	BFE	R457626
Available Phosphate & Potassium								
Available Phosphate-P	27		1	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Potassium	511		2	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Sulfate-S	8		2	mg/kg	24-OCT-06	24-OCT-06	BEM	R457319
Detailed Salinity								
Chloride (Cl)	27		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	79		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	44		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	13		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	29		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	0.8		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	37.2		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	46		1	%	24-OCT-06	24-OCT-06	CMF	R457729
pH in Saturated Paste	7.2		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457729
Conductivity Sat. Paste	0.6		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457729
L445303-46 52 (0.3-0.5M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								
Bulk Density	1080		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457524
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	<0.09		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Particle Size - Hydrometer								

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Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-46 52 (0.3-0.5M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								
Particle Size - Hydrometer								
% Sand	46		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	33		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	21		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	64		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	42	DLA	10	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	36	DLA	5	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	7	DLA	5	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	172	DLA	5	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	6.4		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	104	DLA	30	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	37		1	%	24-OCT-06	24-OCT-06	CMF	R457729
pH in Saturated Paste	7.9		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457729
Conductivity Sat. Paste	0.9		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457729
L445303-47 52 (0.8-1.0M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	<0.09		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Particle Size - Hydrometer								
% Sand	69		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	14		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	17		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Sandy loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	12		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	87	DLA	10	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	>5	DLA	5	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	16	DLA	5	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	376	DLA	5	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	9.7		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	394	DLA	30	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	38		1	%	24-OCT-06	24-OCT-06	CMF	R457729
pH in Saturated Paste	7.6		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457729
Conductivity Sat. Paste	1.6		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457729
L445303-48 4 (0.0-0.2M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	<0.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	3.2		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426

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Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-48 4 (0.0-0.2M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Total Carbon by Combustion	3.2		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
CEC and Extractable Cations								
Ammonium Acetate Extractable Cations								
Sodium (Na)	<0.2		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Potassium (K)	2.6		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Calcium (Ca)	13.7		0.2	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Magnesium (Mg)	2.1		0.4	meq/100g	25-OCT-06	25-OCT-06	MKP	R457869
Cation Exchange Capacity	20.9		0.2	meq/100g	25-OCT-06	25-OCT-06	IGH	R457926
Bulk Density	960		50	kg/m3	24-OCT-06	24-OCT-06	VMC	R457524
Organic Matter	7		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								
% Sand	36		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	50		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	14		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Silt loam / Loam				24-OCT-06	25-OCT-06	HSL	R457956
Sulphur, Elemental	<0.01		0.01	%		08-FEB-07	LL	R481352
Total Kjeldahl Nitrogen	0.35		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Sulfur (S)-Total	300		100	mg/kg	06-FEB-07	06-FEB-07	MKP	R490630
Available N, P, K and S								
Available Nitrate-N	10.0		0.4	mg/kg	24-OCT-06	24-OCT-06	BFE	R457626
Available Phosphate & Potassium								
Available Phosphate-P	99		1	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Potassium	872		2	mg/kg	24-OCT-06	24-OCT-06	BFE	R457632
Available Sulfate-S	27		2	mg/kg	24-OCT-06	24-OCT-06	BEM	R457319
Detailed Salinity								
Chloride (Cl)	68		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	73		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	115		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	12		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	30		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	0.8		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	188		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	54		1	%	24-OCT-06	24-OCT-06	CMF	R457729
pH in Saturated Paste	6.0		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457729
Conductivity Sat. Paste	0.8		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457729
L445303-49 4 (0.3-0.35M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								
Total Organic Carbon -Inorg & Total C								
Inorg/Org Carbon calc needs C-TOT-LECO								
Inorganic Carbon	<0.1		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Organic Carbon	1.5		0.1	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Total Carbon by Combustion	1.5		0.1	%	24-OCT-06	24-OCT-06	HSL	R457354
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	<0.09		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426

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Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-49 4 (0.3-0.35M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								
Inorganic Carbon / Calcium Carbonate								
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Organic Matter	4		1	%	24-OCT-06	24-OCT-06	MMC	R457850
Particle Size - Hydrometer								
% Sand	39		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	48		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	14		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Loam				24-OCT-06	25-OCT-06	HSL	R457956
Total Kjeldahl Nitrogen	0.15		0.02	%	25-OCT-06	25-OCT-06	JRB	R457977
Detailed Salinity								
Chloride (Cl)	33		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	77		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	17		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	12		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	36		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	1.0		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	177		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	44		1	%	24-OCT-06	24-OCT-06	CMF	R457729
pH in Saturated Paste	6.4		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457729
Conductivity Sat. Paste	0.6		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457729
L445303-50 4 (0.5-0.7M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	<0.09		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
Particle Size - Hydrometer								
% Sand	21		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	53		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	26		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Silt loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	25		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	48		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	6		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	7		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	50		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	1.8		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	122		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	47		1	%	24-OCT-06	24-OCT-06	CMF	R457729
pH in Saturated Paste	6.5		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457729
Conductivity Sat. Paste	0.5		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457729
L445303-51 4 (0.8-1.0M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								

ALS LABORATORY GROUP ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	By	Batch
L445303-51 4 (0.8-1.0M)								
Sampled By: NOT PROVIDED on 17-OCT-06								
Matrix: SOIL								
Boron (B), Hot Water Ext.	0.4		0.1	mg/kg	24-OCT-06	24-OCT-06	BEM	R457295
Inorganic Carbon / Calcium Carbonate								
Inorganic Carbon	<0.09		0.09	%	24-OCT-06	24-OCT-06	ANT	R457426
CaCO3 Equivalent	<0.7		0.7	%	24-OCT-06	24-OCT-06	ANT	R457426
PITS Metals (ICP)								
Arsenic (As)	9.6		0.1	mg/kg		24-OCT-06	JGP	R457427
Barium (Ba)	161		5	mg/kg		24-OCT-06	JGP	R457427
Beryllium (Be)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Cadmium (Cd)	<0.5		0.5	mg/kg		24-OCT-06	JGP	R457427
Cobalt (Co)	12		1	mg/kg		24-OCT-06	JGP	R457427
Chromium (Cr)	26.1		0.5	mg/kg		24-OCT-06	JGP	R457427
Copper (Cu)	24		2	mg/kg		24-OCT-06	JGP	R457427
Mercury (Hg)	0.07		0.05	mg/kg		24-OCT-06	JGP	R457427
Manganese (Mn)	380		20	mg/kg		24-OCT-06	JGP	R457427
Molybdenum (Mo)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Nickel (Ni)	32		2	mg/kg		24-OCT-06	JGP	R457427
Lead (Pb)	12		5	mg/kg		24-OCT-06	JGP	R457427
Selenium (Se)	0.6		0.1	mg/kg		24-OCT-06	JGP	R457427
Strontium (Sr)	30		1	mg/kg		24-OCT-06	JGP	R457427
Thallium (Tl)	<1		1	mg/kg		24-OCT-06	JGP	R457427
Vanadium (V)	41		1	mg/kg		24-OCT-06	JGP	R457427
Zinc (Zn)	73		5	mg/kg		24-OCT-06	JGP	R457427
Particle Size - Hydrometer								
% Sand	14		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Silt	53		1	%	24-OCT-06	25-OCT-06	HSL	R457956
% Clay	33		1	%	24-OCT-06	25-OCT-06	HSL	R457956
Texture	Silty clay loam				24-OCT-06	25-OCT-06	HSL	R457956
Detailed Salinity								
Chloride (Cl)	258		3	mg/L	25-OCT-06	25-OCT-06	RAA	R457856
SAR, Cations and SO4 in saturated soil								
Calcium (Ca)	87		2	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Potassium (K)	7		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Magnesium (Mg)	14		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Sodium (Na)	119		1	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
SAR	3.1		0.1	SAR	25-OCT-06	25-OCT-06	MKP	R457798
Sulphate (SO4)	289		6	mg/L	25-OCT-06	25-OCT-06	MKP	R457798
Saturated Paste pH and EC								
% Saturation	58		1	%	24-OCT-06	24-OCT-06	CMF	R457729
pH in Saturated Paste	6.4		0.1	pH	24-OCT-06	24-OCT-06	CMF	R457729
Conductivity Sat. Paste	1.0		0.1	dS m-1	24-OCT-06	24-OCT-06	CMF	R457729

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Sample Parameter Qualifier key listed:

Qualifier	Description
DLA	Detection Limit Adjusted For Dilution
DLIS	Detection Limit Adjusted: Insufficient Sample
SAR:INC	SAR is incalculable due to Ca and Mg below detection limit.
SAR:M	Reported SAR represents a maximum value. Actual SAR would be lower if all cations were detectable.

Methods Listed (if applicable):

ALS Test Code	Matrix	Test Description	Preparation Method Reference(Based On)	Analytical Method Reference(Based On)
B-HOTW-SK	Soil	Available Boron, Hot Water		Methods of Soil Analysis (1996) SSSA
B-HOTW-SK	Soil	Available Boron, Hot Water		Methods of Soil Analysis (1996) SSSA
C-INORG-ORG-SK	Soil	Inorg/Org Carbon calc needs C-TOT-LECO		SSSA (1996) P455-456
C-INORG-SK	Soil	Inorganic Carbon / Calcium Carbonate		SSSA (1996) P455-456

H. Tiessen, T.L. Roberts, J.W.B. Stewart. 1983. Carbonate Analysis in Soils and Minerals by Acid Digestion and Two-Endpoint Titration. Communications in Soil Science and Plant Analysis 14(2) p. 161-166.

The distillation / titration method consists of the digestion of a sample in 6N HCl followed by the determination of the evolved carbon dioxide in a sodiun hydroxide trap. The carbon dioxide is titrated directly as carbonic acid in a titration between pH 8.3 and 3.7

HCO3- + H+ --------> H2CO3 --------> H2O + CO2

1 mole (2 equivalents) of CO2 are produced per mole (equivalent) of acid used.

ALS Test Code	Matrix	Test Description	Preparation Method Reference(Based On)	Analytical Method Reference(Based On)
C-INORG-SK	Soil	Inorganic Carbon / Calcium Carbonate		SSSA (1996) P455-456

H. Tiessen, T.L. Roberts, J.W.B. Stewart. 1983. Carbonate Analysis in Soils and Minerals by Acid Digestion and Two-Endpoint Titration. Communications in Soil Science and Plant Analysis 14(2) p. 161-166.

The distillation / titration method consists of the digestion of a sample in 6N HCl followed by the determination of the evolved carbon dioxide in a sodiun hydroxide trap. The carbon dioxide is titrated directly as carbonic acid in a titration between pH 8.3 and 3.7

HCO3- + H+ --------> H2CO3 --------> H2O + CO2

1 mole (2 equivalents) of CO2 are produced per mole (equivalent) of acid used.

ALS Test Code	Matrix	Test Description	Preparation Method Reference(Based On)	Analytical Method Reference(Based On)
C-TOT-LECO-SK	Soil	Total Carbon by combustion method		SSSA (1996) - Combustion Instrument

Nelson, D.W. and Sommers, L.E. 1996. Total carbon and organic matter. p 961-1010. In: J.M. Bartels et al. (ed.). Methods of Soil Analysis: Part 3 Chemical Methods. (3rd ed.) ASA and SSSA, Madison, WI. Book series no. 5.

The sample is introduced into a quartz tube where it undergoes combustion at 900° C in the presence of oxygen.
Combustion gases are first carried through a catalyst bed in the bottom of the combustion tube, where oxidation is completed and then carried through a reducing agent (copper), where the nitrogen oxides are reduced to elemental nitrogen.
This mixture of N2, CO2, and H2O is then passed through an absorber column containing magnesium perchlorate to remove water. N2 and CO2 gases are then separated in a gas chromatographic column and detected by thermal conductivity.

ALS Test Code	Matrix	Test Description	Preparation Method Reference(Based On)	Analytical Method Reference(Based On)
C-TOT-LECO-SK	Soil	Total Carbon by combustion method		SSSA (1996) - Combustion Instrument

Nelson, D.W. and Sommers, L.E. 1996. Total carbon and organic matter. p 961-1010. In: J.M. Bartels et al. (ed.). Methods of Soil Analysis: Part 3 Chemical Methods. (3rd ed.) ASA and SSSA, Madison, WI. Book series no. 5.

The sample is introduced into a quartz tube where it undergoes combustion at 900° C in the presence of oxygen.
Combustion gases are first carried through a catalyst bed in the bottom of the combustion tube, where oxidation is completed and then carried through a reducing agent (copper), where the nitrogen oxides are reduced to elemental nitrogen.
This mixture of N2, CO2, and H2O is then passed through an absorber column containing magnesium perchlorate to remove water. N2 and CO2 gases are then separated in a gas chromatographic column and detected by thermal conductivity.

ALS Test Code	Matrix	Test Description	Preparation Method Reference(Based On)	Analytical Method Reference(Based On)
CAT-XTR-SK	Soil	Ammonium Acetate Extractable Cations		CSSS 19.4 - 1M NH4OAc Extraction @ pH 7
CEC-SK	Soil	Cation Exchange Capacity (NH4OAC Extn)		CSSS 19.4 - 1M NH4OAc Extraction @ pH 7
CL-SAR-SK	Soil	Chloride (Cl) (Saturated Paste)	CSSS (1993) 18.2.2	APHA 4500 Cl E-Colorimetry
DENSITY-BULK-SK	Soil	Bulk Density - disturbed soil		CSSS 50.2-Wt./Vol Density

Reference Information

METAL-PITS-ED	Soil	PITS Metals (ICP)	EPA 3050	EPA 6020
N-TOTKJ-SK	Soil	Total Kjeldahl Nitrogen (Organic N)		FORESTRY CANADA (1991) P. 57-59
NO3-AVAIL-SK	Soil	Available Nitrate-N		CSSS (1993) 4.3
OM-LOI-SK	Soil	Organic Matter by LOI at 375 deg C.		CSSS (1978) p. 160

McKeague, J.A., Manual on Soil Sampling and Methods of Analysis, Canadian Society of Soil Science, 2nd Edition, 1978, P. 160.

PH-SK	Soil	pH 1:2 soil to water extraction		CSSS 16.3 - pH of 1:2 water extract
PO4/K-AVAIL-SK	Soil	Available Phosphate & Potassium		Comm. Soil Sci. Plant Anal, 25 (5&6)
PSA-1-SK	Soil	Particle Size - Hydrometer		Forestry Canada (1991) p.42-45.

Kalra, Y.P., Maynard, D.G. 1991. Methods manual for forest soil and plant analysis. Forestry Canada. p. 42-45.

S-ELEMENT-LL	Soil	Sulphur, Elemental		Done by Loring Labs
S-TOT-SK	Soil	Total Sulphur - HNO3/HClO4 Digestion		SSSA (1996) P. 931

Tabatabai, M.A. 1996. Total Sulfur: Wet Chemical Methods. p. 931. In: J.M. Bartels et al. (ed.) Methods of Soil Analysis: Part 3. Chemical Methods. (3r ed.) ASA and SSSA, Madison, WI. Book series no. 5.

SAR-CALC-SO4-SK	Soil	SAR, Cations and SO4 in saturated soil	CSSS (1993) 18.2.2	APHA 3120B
SAT/PH/EC-SK	Soil	Saturated Paste pH and EC	CSSS (1993) 18.2.2	CSSS(1978)3.14, 3.21
SO4-AVAIL-SK	Soil	Available Sulfate-S		NCR-13 (1998) p. 35-39

** Laboratory Methods employed follow in-house procedures, which are generally based on nationally or internationally accepted methodologies.

Chain of Custody numbers:

208405	208407	208408	208432	208437

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location	Laboratory Definition Code	Laboratory Location
ED	ALS LABORATORY GROUP - EDMONTON, ALBERTA, CANADA	LL	Loring Laboratories Ltd. - Calgary, Alberta, Canada
SK	ALS LABORATORY GROUP - SASKATOON, SASKATCHEWAN, CANADA		

Reference Information

GLOSSARY OF REPORT TERMS
Surr - A surrogate is an organic compound that is similar to the target analyte(s) in chemical composition and behavior but not normally detected in environmental samples. Prior to sample processing, samples are fortified with one or more surrogate compounds.
The reported surrogate recovery value provides a measure of method efficiency. The Laboratory control limits are determined under column heading D.L.
mg/kg (units) - unit of concentration based on mass, parts per million.
mg/L (units) - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

ALS LABORATORY GROUP SOIL SALINITY CONVERSION

L445303

Lab ID L445303-1 — Sample ID 44-(0.0-0.1M)
Sample Date: 17-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	29	50	0.81	14.4
Calcium (Ca)	24	50	1.22	12.2
Potassium (K)	5	50	0.12	2.3
Magnesium (Mg	10	50	0.83	5.1
Sodium (Na)	172	50	7.48	85.9
Sulphate (SO4)	36.9	50	0.77	18.5

Lab ID L445303-2 — Sample ID 44-(0.8-1.0M)
Sample Date: 17-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	34	67	0.95	22.5
Calcium (Ca)	12	67	0.59	7.9
Potassium (K)	4	67	0.11	2.9
Magnesium (Mg	17	67	1.40	11.4
Sodium (Na)	326	67	14.17	218.2
Sulphate (SO4)	465	67	9.68	311.5

L445303-3 — 33-(0.4-0.6M)
Sample Date: 16-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	18	37	0.51	6.7
Calcium (Ca)	68	37	3.41	25.3
Potassium (K)	3	37	0.08	1.2
Magnesium (Mg	16	37	1.32	5.9
Sodium (Na)	28	37	1.20	10.2
Sulphate (SO4)	54.2	37	1.13	20.1

L445303-4 — 33-(0.31-0.35M)
Sample Date: 16-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	17	39	0.47	6.4
Calcium (Ca)	62	39	3.08	24.1
Potassium (K)	3	39	0.07	1.0
Magnesium (Mg	13	39	1.05	5.0
Sodium (Na)	28	39	1.23	11.0
Sulphate (SO4)	45.5	39	0.95	17.7

L445303-5 — 33-(1.0-1.2M)
Sample Date: 16-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	20	34	0.57	6.9
Calcium (Ca)	33	34	1.66	11.3
Potassium (K)	3	34	0.09	1.2
Magnesium (Mg	11	34	0.88	3.6
Sodium (Na)	36	34	1.58	12.4
Sulphate (SO4)	69.3	34	1.44	23.6

L445303-6 — 33-(0-0.2M)
Sample Date: 16-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	47	57	1.32	26.7
Calcium (Ca)	57	57	2.85	32.5
Potassium (K)	16	57	0.41	9.2
Magnesium (Mg	9	57	0.71	4.9
Sodium (Na)	60	57	2.61	34.3
Sulphate (SO4)	63.9	57	1.33	36.4

"Calculations are as per:
Methods of Analysis for Soils, Plants and Waters
Homer D. Chapman and Parker F. Pratt
University of California, Riverside, Cl.
August, 1961."

ALS LABORATORY GROUP SOIL SALINITY CONVERSION

L445303

Lab ID Sample ID

L445303-7 1-(0.8-1.0M)
Sample Date: 12-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	17	45	0.47	7.5
Calcium (Ca)	96	45	4.78	43.1
Potassium (K)	3	45	0.08	1.4
Magnesium (Mg	21	45	1.71	9.3
Sodium (Na)	19	45	0.84	8.7
Sulphate (SO4)	26.0	45	0.54	11.7

L445303-9 1-(0.25-0.3M)
Sample Date: 12-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	28	41	0.80	11.6
Calcium (Ca)	108	41	5.40	44.4
Potassium (K)	3	41	0.07	1.1
Magnesium (Mg	20	41	1.68	8.3
Sodium (Na)	26	41	1.13	10.7
Sulphate (SO4)	129	41	2.68	52.8

L445303-11 11A (0.70-1.2M)
Sample Date: 13-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	26	73	0.72	18.6
Calcium (Ca)	11	73	0.54	7.9
Potassium (K)	<1	73	<0.03	<0.7
Magnesium (Mg	5	73	0.41	3.7
Sodium (Na)	236	73	10.25	172.1
Sulphate (SO4)	202	73	4.21	147.6

Lab ID Sample ID

L445303-8 1-(0.35-0.5M)
Sample Date: 12-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	23	43	0.65	9.8
Calcium (Ca)	75	43	3.76	32.4
Potassium (K)	3	43	0.08	1.4
Magnesium (Mg	15	43	1.23	6.4
Sodium (Na)	25	43	1.08	10.6
Sulphate (SO4)	60.0	43	1.25	25.8

L445303-10 1-(0.0-0.2M)
Sample Date: 12-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	40	51	1.13	20.3
Calcium (Ca)	74	51	3.70	37.8
Potassium (K)	3	51	0.07	1.4
Magnesium (Mg	12	51	1.00	6.2
Sodium (Na)	40	51	1.75	20.6
Sulphate (SO4)	96.0	51	2.00	48.9

L445303-12 11A (0.32-0.38M)
Sample Date: 13-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	67	30	1.88	20.0
Calcium (Ca)	20	30	0.99	5.9
Potassium (K)	1	30	0.03	0.3
Magnesium (Mg	7	30	0.59	2.2
Sodium (Na)	134	30	5.83	40.2
Sulphate (SO4)	140	30	2.92	42.1

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August, 1961."

ALS LABORATORY GROUP SOIL SALINITY CONVERSION

L445303

Lab ID Sample ID

L445303-13 11A (0.38-0.70M)
Sample Date: 13-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	31	48	0.88	14.9
Calcium (Ca)	9	48	0.47	4.5
Potassium (K)	<1	48	<0.03	<0.5
Magnesium (Mg	3	48	0.28	1.6
Sodium (Na)	151	48	6.57	72.5
Sulphate (SO4)	96.9	48	2.02	46.5

L445303-15 12A (0.0-0.25M)
Sample Date: 13-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	29	34	0.82	9.8
Calcium (Ca)	53	34	2.65	18.1
Potassium (K)	8	34	0.20	2.7
Magnesium (Mg	8	34	0.63	2.6
Sodium (Na)	21	34	0.89	7.0
Sulphate (SO4)	34.2	34	0.71	11.6

L445303-17 12A (1.3-1.5M)
Sample Date: 13-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	10	27	0.27	2.6
Calcium (Ca)	28	27	1.42	7.7
Potassium (K)	6	27	0.15	1.6
Magnesium (Mg	6	27	0.49	1.6
Sodium (Na)	17	27	0.75	4.7
Sulphate (SO4)	8.97	27	0.19	2.4

Lab ID Sample ID

L445303-14 11A (0.0-0.32M)
Sample Date: 13-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	53	46	1.49	24.3
Calcium (Ca)	35	46	1.77	16.3
Potassium (K)	2	46	0.05	1.0
Magnesium (Mg	9	46	0.73	4.1
Sodium (Na)	77	46	3.33	35.2
Sulphate (SO4)	160	46	3.34	73.8

L445303-16 12A (0.25-0.35M)
Sample Date: 13-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	22	26	0.63	5.8
Calcium (Ca)	92	26	4.58	23.9
Potassium (K)	6	26	0.15	1.6
Magnesium (Mg	15	26	1.20	3.8
Sodium (Na)	26	26	1.15	6.9
Sulphate (SO4)	25.8	26	0.54	6.7

L445303-18 12A (0.35-0.53M)
Sample Date: 13-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	16	34	0.45	5.4
Calcium (Ca)	40	34	2.00	13.6
Potassium (K)	7	34	0.18	2.4
Magnesium (Mg	8	34	0.63	2.6
Sodium (Na)	15	34	0.64	5.0
Sulphate (SO4)	15.7	34	0.33	5.4

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ALS LABORATORY GROUP SOIL SALINITY CONVERSION

L445303

Lab ID: L445303-20 Sample ID: 17 (0.7-0.9M)
Sample Date: 13-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	6	125	0.18	8.0
Calcium (Ca)	106	125	5.31	132.9
Potassium (K)	24	125	0.62	30.5
Magnesium (Mg	38	125	3.09	47.0
Sodium (Na)	132	125	5.75	165.1
Sulphate (SO4)	532	125	11.08	665.0

Lab ID: L445303-21 Sample ID: 31 (0.3-0.5M)
Sample Date: 16-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	15	51	0.42	7.7
Calcium (Ca)	60	51	3.01	30.8
Potassium (K)	3	51	0.07	1.4
Magnesium (Mg	21	51	1.72	10.6
Sodium (Na)	99	51	4.32	50.6
Sulphate (SO4)	113	51	2.36	57.9

L445303-22 31 (0-0.2M)
Sample Date: 16-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	30	52	0.85	15.7
Calcium (Ca)	51	52	2.53	26.3
Potassium (K)	3	52	0.08	1.6
Magnesium (Mg	13	52	1.04	6.6
Sodium (Na)	59	52	2.56	30.7
Sulphate (SO4)	74.5	52	1.55	38.8

L445303-23 31 (0.8-1.0M)
Sample Date: 16-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	29	61	0.80	17.4
Calcium (Ca)	33	61	1.62	19.9
Potassium (K)	5	61	0.13	3.1
Magnesium (Mg	12	61	1.00	7.4
Sodium (Na)	391	61	17.02	238.6
Sulphate (SO4)	341	61	7.09	207.8

L445303-24 16 (1.0-1.2M)
Sample Date: 13-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	25	252	0.69	61.7
Calcium (Ca)	<2	252	<0.10	<5.0
Potassium (K)	4	252	0.10	10.1
Magnesium (Mg	3	252	0.24	7.4
Sodium (Na)	938	252	40.78	2362.7
Sulphate (SO4)	1410	252	29.41	3559.1

L445303-25 16 (0.0-0.23M)
Sample Date: 13-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	43	57	1.22	24.7
Calcium (Ca)	87	57	4.33	49.4
Potassium (K)	188	57	4.80	107.1
Magnesium (Mg	25	57	2.03	14.0
Sodium (Na)	35	57	1.53	20.1
Sulphate (SO4)	59.8	57	1.24	34.1

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L445303-26   16 (0.8-1.0M)
Sample Date: 13-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	71	89	2.00	63.2
Calcium (Ca)	7	89	0.37	6.7
Potassium (K)	26	89	0.67	23.3
Magnesium (Mg	11	89	0.94	10.2
Sodium (Na)	1090	89	47.30	967.8
Sulphate (SO4)	1360	89	28.26	1207.8

L445303-28   29 (0.2-0.5M)
Sample Date: 16-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	22	43	0.63	9.6
Calcium (Ca)	274	43	13.66	117.7
Potassium (K)	4	43	0.11	1.8
Magnesium (Mg	48	43	3.94	20.6
Sodium (Na)	89	43	3.89	38.4
Sulphate (SO4)	330	43	6.86	141.7

L445303-30   29 (0.0-0.2M)
Sample Date: 16-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	26	37	0.73	9.5
Calcium (Ca)	120	37	5.98	44.4
Potassium (K)	3	37	0.08	1.1
Magnesium (Mg	29	37	2.41	10.8
Sodium (Na)	172	37	7.49	63.7
Sulphate (SO4)	132	37	2.75	48.9

L445303-27   16 (0.23-0.48M)
Sample Date: 13-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	155	49	4.37	76.0
Calcium (Ca)	48	49	2.41	23.7
Potassium (K)	110	49	2.81	53.8
Magnesium (Mg	52	49	4.29	25.5
Sodium (Na)	816	49	35.47	399.6
Sulphate (SO4)	748	49	15.57	366.5

L445303-29   29 (0.8-1.0M)
Sample Date: 16-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	20	204	0.56	40.8
Calcium (Ca)	<2	204	<0.10	<4.1
Potassium (K)	3	204	0.08	6.5
Magnesium (Mg	<1	204	<0.08	<2.0
Sodium (Na)	847	204	36.84	1728.0
Sulphate (SO4)	1150	204	23.96	2347.9

L445303-31   13 (0.0-0.15M)
Sample Date: 13-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	22	63	0.61	13.7
Calcium (Ca)	65	63	3.25	41.0
Potassium (K)	34	63	0.87	21.5
Magnesium (Mg	17	63	1.40	10.7
Sodium (Na)	46	63	1.99	28.8
Sulphate (SO4)	55.0	63	1.15	34.7

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L445303-32   13 (0.15-0.3M)
Sample Date: 13-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	33	44	0.93	14.4
Calcium (Ca)	36	44	1.78	15.7
Potassium (K)	16	44	0.41	7.0
Magnesium (Mg	10	44	0.85	4.5
Sodium (Na)	54	44	2.35	23.8
Sulphate (SO4)	55.3	44	1.15	24.3

L445303-35   3 (0.2-0.4M)
Sample Date: 12-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	124	102	3.50	126.6
Calcium (Ca)	25	102	1.24	25.4
Potassium (K)	2	102	0.04	1.6
Magnesium (Mg	7	102	0.62	7.6
Sodium (Na)	332	102	14.44	338.5
Sulphate (SO4)	194	102	4.04	198.1

L445303-37   3 (0.6-0.8M)
Sample Date: 12-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	103	86	2.91	88.6
Calcium (Ca)	25	86	1.25	21.6
Potassium (K)	1	86	0.03	1.1
Magnesium (Mg	5	86	0.42	4.4
Sodium (Na)	605	86	26.30	519.9
Sulphate (SO4)	708	86	14.74	608.8

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L445303-33   13 (0.8-1.0M)
Sample Date: 13-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	20	54	0.56	10.7
Calcium (Ca)	24	54	1.19	12.8
Potassium (K)	4	54	0.09	1.9
Magnesium (Mg	9	54	0.72	4.7
Sodium (Na)	45	54	1.96	24.3
Sulphate (SO4)	54.4	54	1.13	29.4

L445303-36   3 (0.0-0.15M)
Sample Date: 12-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	80	64	2.26	51.3
Calcium (Ca)	36	64	1.78	22.8
Potassium (K)	4	64	0.10	2.6
Magnesium (Mg	13	64	1.09	8.5
Sodium (Na)	198	64	8.62	126.8
Sulphate (SO4)	98.7	64	2.05	63.2

L445303-38   3 (1.0-1.2M)
Sample Date: 12-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	14	84	0.39	11.8
Calcium (Ca)	53	84	2.64	44.4
Potassium (K)	<1	84	<0.03	<0.8
Magnesium (Mg	14	84	1.13	11.5
Sodium (Na)	1360	84	59.04	1140.1
Sulphate (SO4)	2560	84	53.39	2154.0

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L445303-39 — Sample ID: 3 (1.2-1.4M)
Sample Date: 12-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	45	107	1.27	48.2
Calcium (Ca)	234	107	11.66	250.1
Potassium (K)	<1	107	<0.03	<1.1
Magnesium (Mg	55	107	4.54	59.0
Sodium (Na)	1850	107	80.58	1982.2
Sulphate (SO4)	3940	107	82.02	4215.0

L445303-40 — Sample ID: 35 (0-.16M)
Sample Date: 16-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	11	50	0.32	5.7
Calcium (Ca)	21	50	1.07	10.7
Potassium (K)	5	50	0.13	2.6
Magnesium (Mg	6	50	0.52	3.1
Sodium (Na)	112	50	4.88	56.0
Sulphate (SO4)	86.1	50	1.79	43.0

L445303-41 — Sample ID: 35 (1.3-1.5M)
Sample Date: 16-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	46	49	1.28	22.3
Calcium (Ca)	101	49	5.05	49.6
Potassium (K)	11	49	0.27	5.3
Magnesium (Mg	27	49	2.22	13.2
Sodium (Na)	194	49	8.43	95.0
Sulphate (SO4)	72.1	49	1.50	35.3

L445303-42 — Sample ID: 47 (0-0.1M)
Sample Date: 17-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	64	43	1.80	27.4
Calcium (Ca)	90	43	4.50	38.8
Potassium (K)	5	43	0.12	2.1
Magnesium (Mg	24	43	1.97	10.3
Sodium (Na)	169	43	7.36	72.7
Sulphate (SO4)	156	43	3.25	67.1

L445303-43 — Sample ID: 47 (0.3-0.4M)
Sample Date: 17-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	34	55	0.96	18.7
Calcium (Ca)	14	55	0.67	7.4
Potassium (K)	3	55	0.07	1.4
Magnesium (Mg	4	55	0.35	2.3
Sodium (Na)	226	55	9.82	124.2
Sulphate (SO4)	177	55	3.69	97.3

L445303-44 — Sample ID: 47 (0.8-1.0M)
Sample Date: 17-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	25	84	0.69	20.7
Calcium (Ca)	24	84	1.19	20.1
Potassium (K)	4	84	0.10	3.4
Magnesium (Mg	10	84	0.84	8.6
Sodium (Na)	607	84	26.41	510.0
Sulphate (SO4)	995	84	20.72	836.0

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Lab ID L445303-45 — Sample ID 52 (0-0.1M)
Sample Date: 17-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	27	46	0.76	12.4
Calcium (Ca)	79	46	3.95	36.4
Potassium (K)	44	46	1.13	20.3
Magnesium (Mg	13	46	1.09	6.1
Sodium (Na)	29	46	1.26	13.3
Sulphate (SO4)	37.2	46	0.77	17.1

Lab ID L445303-46 — Sample ID 52 (0.3-0.5M)
Sample Date: 17-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	64	37	1.81	23.7
Calcium (Ca)	42	37	2.11	15.6
Potassium (K)	36	37	0.92	13.4
Magnesium (Mg	7	37	0.61	2.7
Sodium (Na)	172	37	7.46	63.5
Sulphate (SO4)	104	37	2.16	38.4

L445303-47 52 (0.8-1.0M)
Sample Date: 17-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	12	38	0.34	4.6
Calcium (Ca)	87	38	4.35	33.1
Potassium (K)	>5	38	0.08	1.2
Magnesium (Mg	16	38	1.32	6.1
Sodium (Na)	376	38	16.36	143.0
Sulphate (SO4)	394	38	8.20	149.6

L445303-48 4 (0.0-0.2M)
Sample Date: 17-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	68	54	1.92	36.8
Calcium (Ca)	73	54	3.65	39.5
Potassium (K)	115	54	2.94	62.1
Magnesium (Mg	12	54	1.00	6.6
Sodium (Na)	30	54	1.29	16.1
Sulphate (SO4)	188	54	3.91	101.4

L445303-49 4 (0.3-0.35M)
Sample Date: 17-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	33	44	0.92	14.4
Calcium (Ca)	77	44	3.83	33.8
Potassium (K)	17	44	0.44	7.6
Magnesium (Mg	12	44	0.97	5.2
Sodium (Na)	36	44	1.56	15.8
Sulphate (SO4)	177	44	3.68	77.8

L445303-50 4 (0.5-0.7M)
Sample Date: 17-OCT-06
Matrix: SOIL

	Result mg/L	% Sat	Meq/L	Dry Soil mg/kg
Chloride (Cl)	25	47	0.70	11.6
Calcium (Ca)	48	47	2.41	22.7
Potassium (K)	6	47	0.15	2.8
Magnesium (Mg	7	47	0.60	3.4
Sodium (Na)	50	47	2.18	23.5
Sulphate (SO4)	122	47	2.54	57.4

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Lab ID	Sample ID				Lab ID	Sample ID
L445303-51	4 (0.8-1.0M)					
Sample Date: 17-OCT-06						
Matrix: SOIL						
	Result mg/L	**% Sat**	**Meq/L**	**Dry Soil mg/kg**		
Chloride (Cl)	258	58	7.28	149.6		
Calcium (Ca)	87	58	4.32	50.2		
Potassium (K)	7	58	0.17	3.8		
Magnesium (Mg	14	58	1.16	8.2		
Sodium (Na)	119	58	5.18	69.1		
Sulphate (SO4)	289	58	6.03	167.9		

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ALS Laboratory Group Quality Control Report

Workorder: L445303 Report Date: 16-FEB-07

Client: WORLEYPARSONS CANADA LTD
705, 10240 124 ST
EDMONTON AB T5N 3W6

Contact: LENZ HADERLEIN

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
B-HOTW-SK	**Soil**							
Batch R457295								
WG514539-1 DUP		**L445303-20**						
Boron (B), Hot Water Ext.		1.1	1.0	J	mg/kg	0.1	0.29	24-OCT-06
WG514539-3 IRM		**FARM2005**						
Boron (B), Hot Water Ext.			80		%		27-116	24-OCT-06
WG514539-2 MB								
Boron (B), Hot Water Ext.			0.1		mg/kg		0.2	24-OCT-06
C-INORG-ORG-SK	**Soil**							
Batch R457426								
WG514363-5 DUP		**L445303-49**						
CaCO3 Equivalent		<0.7	<0.7	RPD-NA	%	N/A	26	24-OCT-06
Inorganic Carbon		<0.1	<0.1	RPD-NA	%	N/A	12	24-OCT-06
WG514363-6 IRM		**0.4%IC**						
Inorganic Carbon			0.4		%		0.3-0.5	24-OCT-06
C-INORG-SK	**Soil**							
Batch R457426								
WG514363-1 DUP		**L445303-5**						
CaCO3 Equivalent		<0.7	<0.7	RPD-NA	%	N/A	26	24-OCT-06
Inorganic Carbon		<0.09	<0.09	RPD-NA	%	N/A	12	24-OCT-06
WG514363-2 DUP		**L445303-20**						
CaCO3 Equivalent		8.2	8.6		%	5.5	26	24-OCT-06
Inorganic Carbon		0.96	1.01	J	%	0.05	1.1	24-OCT-06
WG514363-3 DUP		**L445303-29**						
CaCO3 Equivalent		8.0	7.6		%	3.9	26	24-OCT-06
Inorganic Carbon		0.93	0.90	J	%	0.03	1.1	24-OCT-06
WG514363-4 DUP		**L445303-39**						
CaCO3 Equivalent		6.1	6.0	J	%	0.1	2.8	24-OCT-06
Inorganic Carbon		0.71	0.70	J	%	0.02	1.1	24-OCT-06
WG514363-5 DUP		**L445303-49**						
CaCO3 Equivalent		<0.7	<0.7	RPD-NA	%	N/A	26	24-OCT-06
Inorganic Carbon		<0.09	<0.09	RPD-NA	%	N/A	12	24-OCT-06
WG514363-6 IRM		**0.4%IC**						
Inorganic Carbon			0.36		%		0.34-0.48	24-OCT-06
C-TOT-LECO-SK	**Soil**							

ALS Laboratory Group Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
C-TOT-LECO-SK	**Soil**							
Batch R457354								
WG514333-1	**DUP**	**L445303-14**						
Total Carbon by Combustion		3.6	3.7	J	%	0.1	0.2	24-OCT-06
WG514333-2	**DUP**	**L445303-30**						
Total Carbon by Combustion		2.0	2.0	J	%	0.0	0.2	24-OCT-06
WG514333-3	**DUP**	**L445548-1**						
Total Carbon by Combustion		32.0	32.1		%	0.22	6.4	24-OCT-06
WG514333-4	**IRM**	**1.6%C**						
Total Carbon by Combustion			1.7		%		1.4-1.7	24-OCT-06
CAT-XTR-SK	**Soil**							
Batch R457869								
WG514548-1	**DUP**	**L445303-22**						
Calcium (Ca)		17.7	17.6		meq/100g	0.57	13	25-OCT-06
Magnesium (Mg)		4.5	4.5		meq/100g	0.0	13	25-OCT-06
Potassium (K)		0.3	0.3	J	meq/100g	0.0	2	25-OCT-06
Sodium (Na)		0.3	0.3	J	meq/100g	0.0	2	25-OCT-06
WG514548-2	**IRM**	**FARM2005**						
Calcium (Ca)			95		%		62-118	25-OCT-06
Magnesium (Mg)			100		%		73-110	25-OCT-06
Potassium (K)			80		%		46-118	25-OCT-06
Batch R479792								
WG542175-2	**IRM**	**FARM2005**						
Calcium (Ca)			90		%		62-118	29-DEC-06
Magnesium (Mg)			94		%		73-110	29-DEC-06
Potassium (K)			80		%		46-118	29-DEC-06
CEC-SK	**Soil**							
Batch R457926								
WG514550-1	**DUP**	**L445303-22**						
Cation Exchange Capacity		24.0	24.1		meq/100g	0.12	11	25-OCT-06
WG514550-2	**IRM**	**FARM2005**						
Cation Exchange Capacity			89		%		79-110	25-OCT-06
Batch R479871								
WG542177-2	**IRM**	**FARM2005**						
Cation Exchange Capacity			90		%		79-110	29-DEC-06
CL-SAR-SK	**Soil**							

ALS Laboratory Group Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
CL-SAR-SK	**Soil**							
Batch R457856								
WG514510-1 DUP		**L445303-7**						
Chloride (Cl)		17	17	J	mg/L	1	25	25-OCT-06
WG514510-2 DUP		**L445303-15**						
Chloride (Cl)		29	31	J	mg/L	2	25	25-OCT-06
WG514513-1 DUP		**L445303-46**						
Chloride (Cl)		64	59		mg/L	9.1	27	25-OCT-06
WG514510-3 IRM		**SAL2005**						
Chloride (Cl)			128		%		38-158	25-OCT-06
WG514513-3 IRM		**SAL2005**						
Chloride (Cl)			129		%		38-158	25-OCT-06
Batch R457970								
WG514511-1 DUP		**L445303-30**						
Chloride (Cl)		26	27	J	mg/L	1	25	25-OCT-06
WG514511-2 DUP		**L445303-32**						
Chloride (Cl)		33	35	J	mg/L	2	25	25-OCT-06
WG514511-3 IRM		**SAL2005**						
Chloride (Cl)			97		%		38-158	25-OCT-06
Batch R479921								
WG542197-1 DUP		**L465524-4**						
Chloride (Cl)		31	32	J	mg/L	1	25	29-DEC-06
WG542197-3 IRM		**SAL2005**						
Chloride (Cl)			121		%		38-158	29-DEC-06
DENSITY-BULK-SK	**Soil**							
Batch R457522								
WG514552-1 DUP		**L445303-25**						
Bulk Density		1010	1020	J	kg/m3	10	34	24-OCT-06
WG514552-2 DUP		**L445303-35**						
Bulk Density		1000	1010	J	kg/m3	10	34	24-OCT-06
Batch R457524								
WG514579-1 DUP		**L445303-40**						
Bulk Density		940	950	J	kg/m3	10	34	24-OCT-06
Batch R479603								
WG542178-1 DUP		**L445303-44**						
Bulk Density		1150	1150	J	kg/m3	0	34	28-DEC-06
METAL-PITS-ED	**Soil**							

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Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
METAL-PITS-ED	**Soil**							
Batch R457427								
WG514566-2 CRM		**2702 SOIL**						
Arsenic (As)			102		%		79-121	25-OCT-06
Barium (Ba)			111		%		84-131	25-OCT-06
Beryllium (Be)			110		%		71-133	25-OCT-06
Cadmium (Cd)			106		%		79-121	25-OCT-06
Chromium (Cr)			106		%		84-120	25-OCT-06
Cobalt (Co)			110		%		87-124	25-OCT-06
Copper (Cu)			106		%		88-123	25-OCT-06
Lead (Pb)			107		%		80-124	25-OCT-06
Manganese (Mn)			104		%		85-127	25-OCT-06
Mercury (Hg)			136		%		73-167	25-OCT-06
Molybdenum (Mo)			101		%		79-116	25-OCT-06
Nickel (Ni)			112		%		88-125	25-OCT-06
Selenium (Se)			95		%		68-134	25-OCT-06
Strontium (Sr)			101		%		83-120	25-OCT-06
Thallium (Tl)			103		%		63-122	25-OCT-06
Vanadium (V)			100		%		80-120	25-OCT-06
Zinc (Zn)			98		%		82-122	25-OCT-06
WG514650-2 CRM		**2702 SOIL**						
Arsenic (As)			103		%		79-121	25-OCT-06
Barium (Ba)			112		%		84-131	25-OCT-06
Beryllium (Be)			111		%		71-133	25-OCT-06
Cadmium (Cd)			107		%		79-121	25-OCT-06
Chromium (Cr)			107		%		84-120	25-OCT-06
Cobalt (Co)			111		%		87-124	25-OCT-06
Copper (Cu)			107		%		88-123	25-OCT-06
Lead (Pb)			109		%		80-124	25-OCT-06
Manganese (Mn)			105		%		85-127	25-OCT-06
Mercury (Hg)			137		%		73-167	25-OCT-06
Molybdenum (Mo)			102		%		79-116	25-OCT-06
Nickel (Ni)			113		%		88-125	25-OCT-06
Selenium (Se)			95		%		68-134	25-OCT-06
Strontium (Sr)			102		%		83-120	25-OCT-06
Thallium (Tl)			104		%		63-122	25-OCT-06

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Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
METAL-PITS-ED	**Soil**							
Batch R457427								
WG514650-2 CRM		**2702 SOIL**						
Vanadium (V)			101		%		80-120	25-OCT-06
Zinc (Zn)			99		%		82-122	25-OCT-06
WG514566-3 DUP		**L446061-7**						
Arsenic (As)		6.0	6.1		mg/kg	0.95	13	24-OCT-06
Barium (Ba)		499	492		mg/kg	1.5	13	24-OCT-06
Beryllium (Be)		<1	<1	RPD-NA	mg/kg	N/A	31	24-OCT-06
Cadmium (Cd)		<0.5	<0.5	RPD-NA	mg/kg	N/A	23	24-OCT-06
Chromium (Cr)		25.2	24.9		mg/kg	1.3	15	24-OCT-06
Cobalt (Co)		9	9	J	mg/kg	0	4	24-OCT-06
Copper (Cu)		16	16	J	mg/kg	0	8	24-OCT-06
Lead (Pb)		10	10	J	mg/kg	0	20	24-OCT-06
Manganese (Mn)		490	470		mg/kg	3.2	14	24-OCT-06
Mercury (Hg)		<0.05	<0.05	RPD-NA	mg/kg	N/A	46	24-OCT-06
Molybdenum (Mo)		<1	<1	RPD-NA	mg/kg	N/A	23	24-OCT-06
Nickel (Ni)		31	30		mg/kg	2.4	11	24-OCT-06
Selenium (Se)		<0.1	0.2	RPD-NA	mg/kg	N/A	23	24-OCT-06
Strontium (Sr)		102	99		mg/kg	2.8	15	24-OCT-06
Thallium (Tl)		<1	<1	RPD-NA	mg/kg	N/A	27	24-OCT-06
Vanadium (V)		30	31		mg/kg	1.5	11	24-OCT-06
Zinc (Zn)		67	66		mg/kg	2.3	17	24-OCT-06
WG514566-1 MB								
Arsenic (As)			<0.1		mg/kg		0.5	24-OCT-06
Barium (Ba)			<5		mg/kg		25	24-OCT-06
Beryllium (Be)			<1		mg/kg		5	24-OCT-06
Cadmium (Cd)			<0.5		mg/kg		2.5	24-OCT-06
Chromium (Cr)			<0.5		mg/kg		2.5	24-OCT-06
Cobalt (Co)			<1		mg/kg		5	24-OCT-06
Copper (Cu)			<2		mg/kg		10	24-OCT-06
Lead (Pb)			<5		mg/kg		25	24-OCT-06
Manganese (Mn)			<20		mg/kg		100	24-OCT-06
Mercury (Hg)			<0.05		mg/kg		0.25	24-OCT-06
Molybdenum (Mo)			<1		mg/kg		5	24-OCT-06
Nickel (Ni)			<2		mg/kg		10	24-OCT-06

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Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
METAL-PITS-ED	**Soil**							
Batch R457427								
WG514566-1 MB								
Selenium (Se)			<0.1		mg/kg		0.5	24-OCT-06
Strontium (Sr)			<1		mg/kg		5	24-OCT-06
Thallium (Tl)			<1		mg/kg		5	24-OCT-06
Vanadium (V)			<1		mg/kg		5	24-OCT-06
Zinc (Zn)			<5		mg/kg		25	24-OCT-06
WG514650-1 MB								
Arsenic (As)			<0.1		mg/kg		0.5	24-OCT-06
Barium (Ba)			<5		mg/kg		25	24-OCT-06
Beryllium (Be)			<1		mg/kg		5	24-OCT-06
Cadmium (Cd)			<0.5		mg/kg		2.5	24-OCT-06
Chromium (Cr)			<0.5		mg/kg		2.5	24-OCT-06
Cobalt (Co)			<1		mg/kg		5	24-OCT-06
Copper (Cu)			<2		mg/kg		10	24-OCT-06
Lead (Pb)			<5		mg/kg		25	24-OCT-06
Manganese (Mn)			<20		mg/kg		100	24-OCT-06
Mercury (Hg)			<0.05		mg/kg		0.25	24-OCT-06
Molybdenum (Mo)			<1		mg/kg		5	24-OCT-06
Nickel (Ni)			<2		mg/kg		10	24-OCT-06
Selenium (Se)			<0.1		mg/kg		0.5	24-OCT-06
Strontium (Sr)			<1		mg/kg		5	24-OCT-06
Thallium (Tl)			<1		mg/kg		5	24-OCT-06
Vanadium (V)			<1		mg/kg		5	24-OCT-06
Zinc (Zn)			<5		mg/kg		25	24-OCT-06
WG514566-4 MS		**L446061-7**						
Arsenic (As)			102		%		88-120	24-OCT-06
Beryllium (Be)			105		%		82-127	24-OCT-06
Cadmium (Cd)			108		%		89-120	24-OCT-06
Chromium (Cr)			91		%		77-109	24-OCT-06
Cobalt (Co)			90		%		82-118	24-OCT-06
Copper (Cu)			91		%		80-118	24-OCT-06
Lead (Pb)			99		%		85-122	24-OCT-06
Mercury (Hg)			99		%		74-130	24-OCT-06
Molybdenum (Mo)			107		%		86-120	24-OCT-06

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Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
METAL-PITS-ED	**Soil**							
Batch R457427								
WG514566-4 MS		**L446061-7**						
Nickel (Ni)			100		%		80-118	24-OCT-06
Selenium (Se)			110		%		91-127	24-OCT-06
Thallium (Tl)			110		%		89-125	24-OCT-06
Vanadium (V)			92		%		80-119	24-OCT-06
Zinc (Zn)			84		%		78-129	24-OCT-06
Strontium (Sr)			67	G	%		75-123	24-OCT-06
N-TOTKJ-SK	**Soil**							
Batch R457734								
WG514593-2 CRM		**01-119 SOIL**						
Total Kjeldahl Nitrogen			0.05		%		0.04-0.08	24-OCT-06
WG514593-1 DUP		**L445303-1**						
Total Kjeldahl Nitrogen		0.17	0.18	J	%	0.02	0.076	24-OCT-06
Batch R457977								
WG514371-2 CRM		**01-119 SOIL**						
Total Kjeldahl Nitrogen			0.07		%		0.04-0.08	25-OCT-06
WG514371-1 DUP		**L445303-28**						
Total Kjeldahl Nitrogen		0.19	0.19	J	%	0.00	0.076	25-OCT-06
NO3-AVAIL-SK	**Soil**							
Batch R457626								
WG514528-2 DUP		**L445303-30**						
Available Nitrate-N		2.8	2.8		mg/kg	0.0	27	24-OCT-06
WG514528-4 IRM		**FARM2005**						
Available Nitrate-N			105		%		76-124	24-OCT-06
WG514528-3 MB								
Available Nitrate-N			0.8		mg/kg		2	24-OCT-06
Batch R479592								
WG542002-1 DUP		**L445303-42**						
Available Nitrate-N		12.2	13.4		mg/kg	9.4	27	28-DEC-06
WG542002-3 IRM		**FARM2005**						
Available Nitrate-N			108		%		76-124	28-DEC-06
WG542002-2 MB								
Available Nitrate-N			1.6		mg/kg		2	28-DEC-06
OM-LOI-SK	**Soil**							

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
OM-LOI-SK	**Soil**							
Batch R457850								
WG514388-1 DUP		**L445303-14**						
Organic Matter		8	8		%	1.2	13	24-OCT-06
WG514388-2 DUP		**L445303-35**						
Organic Matter		6	6		%	3.2	13	24-OCT-06
WG514388-3 IRM		**FARM2004**						
Organic Matter			4		%		2-4	24-OCT-06
PH-SK	**Soil**							
Batch R489823								
WG554469-1 DUP		**L445303-44**						
pH (1:2 soil:water)		8.9	9.0	J	pH	0.1	0.3	02-FEB-07
WG554469-2 IRM		**FARM2005**						
pH (1:2 soil:water)			7.9		pH		7.7-8.2	02-FEB-07
PO4/K-AVAIL-SK	**Soil**							
Batch R457632								
WG514535-1 DUP		**L445303-10**						
Available Phosphate-P		4	4		mg/kg	0.0	25	24-OCT-06
Available Potassium		102	100		mg/kg	2.0	16	24-OCT-06
WG514535-2 DUP		**L445303-36**						
Available Phosphate-P		13	12		mg/kg	8.0	25	24-OCT-06
Available Potassium		144	142		mg/kg	1.4	16	24-OCT-06
WG514535-4 IRM		**FARM2005**						
Available Phosphate-P			77		%		73-127	24-OCT-06
Available Potassium			85		%		62-117	24-OCT-06
WG514535-3 MB								
Available Phosphate-P			1		mg/kg		2	24-OCT-06
Available Potassium			6		mg/kg		10	24-OCT-06
Batch R479617								
WG542007-1 DUP		**L445303-42**						
Available Phosphate-P		27	28		mg/kg	3.6	25	28-DEC-06
Available Potassium		158	153		mg/kg	3.2	16	28-DEC-06
WG542007-3 IRM		**FARM2005**						
Available Phosphate-P			110		%		73-127	28-DEC-06
Available Potassium			86		%		62-117	28-DEC-06
WG542007-2 MB								
Available Phosphate-P			<1		mg/kg		2	28-DEC-06
Available Potassium			3		mg/kg		10	28-DEC-06

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Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PSA-1-SK	**Soil**							
Batch R457956								
WG513996-1 DUP		**L445303-5**						
% Clay		14	15	J	%	1	2.1	25-OCT-06
% Sand		68	68	J	%	0	3.1	25-OCT-06
% Silt		18	17	J	%	1	3.1	25-OCT-06
WG513996-2 DUP		**L445303-15**						
% Clay		12	11	J	%	1	2.1	25-OCT-06
% Sand		56	58	J	%	2	3.1	25-OCT-06
% Silt		32	31	J	%	1	3.1	25-OCT-06
WG513996-3 DUP		**L445303-25**						
% Clay		15	13	J	%	2	2.1	25-OCT-06
% Sand		48	48	J	%	0	3.1	25-OCT-06
% Silt		37	38	J	%	1	3.1	25-OCT-06
WG513996-4 DUP		**L445303-35**						
% Clay		14	12	J	%	2	2.1	25-OCT-06
% Sand		51	50	J	%	1	3.1	25-OCT-06
% Silt		36	38	J	%	2	3.1	25-OCT-06
WG513996-5 DUP		**L445303-45**						
% Clay		17	16	J	%	1	2.1	25-OCT-06
% Sand		49	48	J	%	1	3.1	25-OCT-06
% Silt		34	37	J	%	3	3.1	25-OCT-06
WG513996-6 DUP		**L446028-2**						
% Clay		17	17	J	%	0	2.1	25-OCT-06
% Sand		53	54	J	%	1	3.1	25-OCT-06
% Silt		30	30	J	%	0	3.1	25-OCT-06
WG513996-7 IRM		**FARM98**						
% Clay			23		%		20-29	25-OCT-06
% Sand			47		%		42-54	25-OCT-06
% Silt			30		%		22-33	25-OCT-06
Batch R480425								
WG541905-1 DUP		**L464944-2**						
% Clay		17	17	J	%	0	2.1	02-JAN-07
% Sand		55	56	J	%	1	3.1	02-JAN-07
% Silt		28	27	J	%	1	3.1	02-JAN-07
WG541905-2 IRM		**FARM98**						
% Clay			23		%		20-29	02-JAN-07
% Sand			45				42-54	

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Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PSA-1-SK	**Soil**							
Batch R480425								
WG541905-2 IRM		**FARM98**						
% Sand			45		%		42-54	02-JAN-07
% Silt			32		%		22-33	02-JAN-07
S-TOT-SK	**Soil**							
Batch R490630								
WG554480-2 CRM		**SS-1 SOIL**						
Sulfur (S)-Total			100		%		77-119	06-FEB-07
WG554480-3 DUP		**L445303-29**						
Sulfur (S)-Total		600	600	J	mg/kg	0	400	06-FEB-07
WG554480-4 DUP		**L445303-48**						
Sulfur (S)-Total		300	300	J	mg/kg	0	400	06-FEB-07
WG554480-1 MB								
Sulfur (S)-Total			<100		mg/kg		100	06-FEB-07
SAR-CALC-SO4-SK	**Soil**							
Batch R457798								
WG514510-1 DUP		**L445303-7**						
Calcium (Ca)		96	96		mg/L	0.35	28	25-OCT-06
Magnesium (Mg)		21	21	J	mg/L	0	50	25-OCT-06
Potassium (K)		3	3	J	mg/L	0	50	25-OCT-06
Sodium (Na)		19	19	J	mg/L	0	50	25-OCT-06
Sulphate (SO4)		26.0	25.8	J	mg/L	0.120	25	25-OCT-06
WG514510-2 DUP		**L445303-15**						
Calcium (Ca)		53	58		mg/L	8.5	28	25-OCT-06
Magnesium (Mg)		8	9	J	mg/L	1	50	25-OCT-06
Potassium (K)		8	9	J	mg/L	1	50	25-OCT-06
Sodium (Na)		21	23	J	mg/L	2	50	25-OCT-06
Sulphate (SO4)		34.2	38.3	J	mg/L	4.14	25	25-OCT-06
WG514510-3 IRM		**SAL2005**						
Calcium (Ca)			110		%		54-144	25-OCT-06
Magnesium (Mg)			116		%		41-149	25-OCT-06
Potassium (K)			109		%		64-136	25-OCT-06
Sodium (Na)			96		%		30-138	25-OCT-06
Sulphate (SO4)			127		%		48-156	25-OCT-06
WG514513-3 IRM		**SAL2005**						
Calcium (Ca)			102		%		54-144	25-OCT-06

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Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
SAR-CALC-SO4-SK	**Soil**							
Batch R457798								
WG514513-3 IRM		**SAL2005**						
Magnesium (Mg)			108		%		41-149	25-OCT-06
Potassium (K)			103		%		64-136	25-OCT-06
Sodium (Na)			101		%		30-138	25-OCT-06
Sulphate (SO4)			121		%		48-156	25-OCT-06
Batch R457863								
WG514511-1 DUP		**L445303-30**						
Calcium (Ca)		120	124		mg/L	3.7	28	25-OCT-06
Magnesium (Mg)		29	31	J	mg/L	2	50	25-OCT-06
Potassium (K)		3	3	J	mg/L	0	50	25-OCT-06
Sodium (Na)		172	172		mg/L	0.062	23	25-OCT-06
Sulphate (SO4)		132	131		mg/L	0.71	28	25-OCT-06
WG514511-2 DUP		**L445303-32**						
Calcium (Ca)		36	39	J	mg/L	3	50	25-OCT-06
Magnesium (Mg)		10	12	J	mg/L	1	50	25-OCT-06
Potassium (K)		16	16	J	mg/L	1	50	25-OCT-06
Sodium (Na)		54	52		mg/L	4.6	23	25-OCT-06
Sulphate (SO4)		55.3	54.8		mg/L	0.95	28	25-OCT-06
WG514511-3 IRM		**SAL2005**						
Calcium (Ca)			112		%		54-144	25-OCT-06
Magnesium (Mg)			119		%		41-149	25-OCT-06
Potassium (K)			110		%		64-136	25-OCT-06
Sodium (Na)			87		%		30-138	25-OCT-06
Sulphate (SO4)			121		%		48-156	25-OCT-06
Batch R479895								
WG542197-1 DUP		**L465524-4**						
Calcium (Ca)		321	316		mg/L	1.5	28	29-DEC-06
Magnesium (Mg)		134	133		mg/L	1.4	27	29-DEC-06
Potassium (K)		22	23	J	mg/L	1	50	29-DEC-06
Sodium (Na)		72	73		mg/L	1.6	23	29-DEC-06
Sulphate (SO4)		1100	1110		mg/L	0.95	28	29-DEC-06
WG542197-3 IRM		**SAL2005**						
Calcium (Ca)			105		%		54-144	29-DEC-06
Magnesium (Mg)			114		%		41-149	29-DEC-06
Potassium (K)			106		%		64-136	29-DEC-06

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Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
SAR-CALC-SO4-SK	**Soil**							
Batch R479895								
WG542197-3 IRM		**SAL2005**						
Sodium (Na)			81		%		30-138	29-DEC-06
Sulphate (SO4)			122		%		48-156	29-DEC-06
SAT/PH/EC-SK	**Soil**							
Batch R457714								
WG514510-1 DUP		**L445303-7**						
% Saturation		45	45	J	%	0	5	24-OCT-06
Conductivity Sat. Paste		0.6	0.6	J	dS m-1	0.0	6	24-OCT-06
pH in Saturated Paste		7.5	7.5	J	pH	0.0	0.2	24-OCT-06
WG514510-2 DUP		**L445303-15**						
% Saturation		34	34	J	%	0	5	24-OCT-06
Conductivity Sat. Paste		0.4	0.5	J	dS m-1	0.1	6	24-OCT-06
pH in Saturated Paste		5.7	5.8	J	pH	0.1	0.2	24-OCT-06
WG514510-3 IRM		**SAL2005**						
% Saturation			56		%		50-62	24-OCT-06
Conductivity Sat. Paste			110		%		64-136	24-OCT-06
pH in Saturated Paste			7.3		pH		6.6-7.8	24-OCT-06
Batch R457719								
WG514511-1 DUP		**L445303-30**						
% Saturation		37	37	J	%	0	5	24-OCT-06
Conductivity Sat. Paste		1.1	1.2		dS m-1	4.3	18	24-OCT-06
pH in Saturated Paste		7.6	7.6	J	pH	0.0	0.2	24-OCT-06
WG514511-2 DUP		**L445303-32**						
% Saturation		44	44	J	%	0	5	24-OCT-06
Conductivity Sat. Paste		0.4	0.4	J	dS m-1	0.0	6	24-OCT-06
pH in Saturated Paste		6.1	6.1	J	pH	0.0	0.2	24-OCT-06
WG514511-3 IRM		**SAL2005**						
% Saturation			56		%		50-62	24-OCT-06
Conductivity Sat. Paste			107		%		64-136	24-OCT-06
pH in Saturated Paste			7.2		pH		6.6-7.8	24-OCT-06
Batch R457729								
WG514513-1 DUP		**L445303-46**						
% Saturation		37	37	J	%	0	5	24-OCT-06
Conductivity Sat. Paste		0.9	0.9	J	dS m-1	0.1	6	24-OCT-06
pH in Saturated Paste		7.9	8.0	J	pH	0.1	0.2	24-OCT-06
		SAL2005						

ALS Laboratory Group Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
SAT/PH/EC-SK	**Soil**							
Batch R457729								
WG514513-3 IRM		**SAL2005**						
% Saturation			56		%		50-62	24-OCT-06
Conductivity Sat. Paste			106		%		64-136	24-OCT-06
pH in Saturated Paste			7.3		pH		6.6-7.8	24-OCT-06
Batch R479802								
WG542197-1 DUP		**L465524-4**						
% Saturation		41	41	J	%	0	5	28-DEC-06
Conductivity Sat. Paste		2.1	2.1		dS m-1	0.97	18	28-DEC-06
pH in Saturated Paste		7.5	7.5	J	pH	0.0	0.2	28-DEC-06
WG542197-3 IRM		**SAL2005**						
% Saturation			54		%		50-62	28-DEC-06
Conductivity Sat. Paste			111		%		64-136	28-DEC-06
pH in Saturated Paste			7.2		pH		6.6-7.8	28-DEC-06
SO4-AVAIL-SK	**Soil**							
Batch R457319								
WG514532-2 DUP		**L445303-30**						
Available Sulfate-S		20	19		mg/kg	4.6	24	24-OCT-06
WG514532-4 IRM		**FARM2005**						
Available Sulfate-S			75		%		47-100	24-OCT-06
WG514532-3 MB								
Available Sulfate-S			<2		mg/kg		4	24-OCT-06
Batch R479526								
WG542005-1 DUP		**L445303-42**						
Available Sulfate-S		18	23		mg/kg	22	24	28-DEC-06
WG542005-3 IRM		**FARM2005**						
Available Sulfate-S			66		%		47-100	28-DEC-06
WG542005-2 MB								
Available Sulfate-S			<2		mg/kg		4	28-DEC-06

ALS Laboratory Group Quality Control Report

Legend:

Limit	99% Confidence Interval (Laboratory Control Limits)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Qualifier:

RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.
A	Method blank exceeds acceptance limit. Blank correction not applied, unless the qualifier "RAMB" (result adjusted for method blank) appears in the Analytical Report.
B	Method blank result exceeds acceptance limit, however, it is less than 5% of sample concentration. Blank correction not applied.
E	Matrix spike recovery may fall outside the acceptance limits due to high sample background.
F	Silver recovery low, likely due to elevated chloride levels in sample.
G	Outlier - No assignable cause for nonconformity has been determined.
J	Duplicate results and limit(s) are expressed in terms of absolute difference.
K	The sample referenced above is of a non-standard matrix type; standard QC acceptance criteria may not be achievable.
L	Low matrix spike recovery due to instability of spiked analyte in the sample matrix.

Loring Laboratories Ltd.

629 Beaverdam Road N.E.,
Calgary Alberta T2K 4W7
Tel: 274-2777 Fax: 275-0541

To: ALS LABORATORY GROUP
9936 - 67th Avenue
Edmonton, Alberta

Attn: ALSED Reporting

File No : 49319
Date : January 4, 2007
Samples : Soil
P.O.No. :L445303

Certificate of Assay

ETL Sample No.	Client ID	Elemental Sulphur %
L445303 - 1	44-(0.0-0.1M)	<0.01
L445303 - 2	44-(0.8-1.0M)	<0.01
L445303 - 3	33-(0.4-0.6M)	<0.01
L445303 - 6	33-(0-0.2M)	<0.01
L445303 - 28	29 (0.2-0.5M)	<0.01
L445303 - 29	29 (0.8-1.0M)	<0.01
L445303 - 30	29 (0.0-0.2M)	<0.01
L445303 - 40	35 (0-0.1M)	<0.01
L445303 - 41	35 (1.3-1.5M)	<0.01
L445303 - 42	47 (0-0.1M)	<0.01
L445303 - 43	47 (0.3-0.4M)	<0.01
L445303 - 44	47 (0.8-1.0M)	<0.01

I HEREBY CERTIFY that the above results are those assays made by me upon the herein described samples:

Assayer

Rejects and pulps are retained for one month unless specific arrangements are made in advance.

Loring Laboratories Ltd.
629 Beaverdam Road N.E.,
Calgary Alberta T2K 4W7
Tel: 274-2777 Fax: 275-0541

To: **ALS LABORATORY GROUP**
9936 - 67th Avenue
Edmonton, Alberta

Attn: ALSED Reporting

File No : 49400
Date : February 8, 2007
Samples : Soil
P.O.No. :L445303

Certificate of Assay

ETL Sample No.	Client ID	Elemental Sulphur %
L445303 - 10	1 - (0.0-0.2M)	<0.01
L445303 - 14	11A (0.0-0.32M)	<0.01
L445303 - 22	31 (0-0.2M)	<0.01
L445303 - 25	16 (0.0-0.23M)	<0.01
L445303 - 31	13 (0.0-0.15M)	<0.01
L445303 - 36	3 0.0-0.15M)	<0.01
L445303 - 45	62 (0-0.1M)	<0.01
L445303 - 48	4 (0.0-0.2M)	<0.01

I HEREBY CERTIFY that the above results are those assays made by me upon the herein described samples:

Assayer

Rejects and pulps are retained for one month unless specific arrangements are made in advance.

Loring Laboratories Ltd.

629 Beaverdam Road N.E.,
Calgary Alberta T2K 4W7
Tel: 274-2777 Fax: 275-0541

To:ALS LABORATORY GROUP
9936 - 67th Avenue
Edmonton, Alberta

Attn: ALSED Reporting

File No : 49424
Date : February 15, 2007
Samples : Soil
P.O.No. :L445303

Certificate of Assay

ETL Sample No.	Client ID	Elemental Sulphur %
L445303 - 15	12A (0-0.25M)	<0.01

I HEREBY CERTIFY that the above results are those assays made by me upon the herein described samples:

Assayer

Rejects and pulps are retained for one month unless specific arrangements are made in advance.

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LABORATORIES

CHAIN OF CUSTODY / ANALYTICAL REQUEST FORM
CANADA TOLL FREE 1-800-668-9878

COC # 208405

Page 1 of 5

Report to: Lee Hedenlein
Company: WorleyParsons Komex
Address: 4705 10240-124st
Edmonton, AB
Phone: 496-9055 Fax: 496-9575

Date: Oct 18/06

Report distribution: all final results will be mailed

Email: lindsay.youck@worleyparsons.com

Select: pdf ___ digital ___ both ✓

Lab work order #: L445303

Regular service (default)
Rush service (50% surcharge)
Emergency service (100% surcharge)

PO: CE720104

Site: Bruderheim Facility
Project #: Q13602

Data Management Sheet

Due: Oct 25/06

ANALYSIS REQUEST

Hold 90 days

Sample	Date	Method	Type	PSA-1	SAL-DETAIL	DENSITY-BULK	NPKS-AVAIL	CEC+CAT	C-TOT-ORG + NTOTK	OMLOI	METAL-PITS + B-HOTW	C-INORG-	S - Elemental	Sulphur-Total	S-Tot-SK
44 -(0.0-0.1m)	Oct17/06.	Grab.	Soil	X	X		X	X	X	X			⊗	(✱)	
44 -(0.8-1.0m)	Oct17/06	Grab	Soil	X	X			X				X	⊗		
39 -(0.4-0.6m)	Oct16/06.	Grab	Soil	X	X								⊗		
39 -(0.31-0.35m)	↓	↓	↓	X	X							X			
33 -(1.0-1.2m)				X	X	X					X	X			
33 -(0-0.2m)				X	X	X	X	X	X	X			⊗	(✱)	
-(0.8-1.0m)	Oct 12/06			X	X						X	X			
-(0.35-0.5m)	↓			X	X	X					X	X			
-(.25-0.3m)				X	X			X							
-(0.0-0.2m)				X	X	X	X	X	X	X			(✱)	(✱)	
11A (0.70-1.2m)	Oct13/06.	↓	↓	X	X	X					X	X			
11A (0.32-0.38m)	Oct13/06	↓	↓	X	X	X			X	X					

GUIDELINES / REGULATIONS / SPECIAL INSTRUCTIONS / NATURE OF HAZARDOUS MATERIALS / SAMPLE CONDITION

Oct.24/06
Jan 5/07

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CHAIN OF CUSTODY / ANALYTICAL REQUEST FORM
CANADA TOLL FREE 1 800 668-9878

COC # 208407

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Pg 2 of 5

REPORT TO: Louz Mackenzie
COMPANY: WorleyParsons Komex
ADDRESS: #705 10240-124 ST
Edmonton, AB
TEL: 496-9055 FAX: 496-9575

DATE: Oct 18/06

REPORT DISTRIBUTION: ALL FINAL RESULTS WILL BE MAILED

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☑ REGULAR SERVICE (DEFAULT)
PRIORITY SERVICE (50% SURCHARGE)
EMERGENCY SERVICE (100% SURCHARGE)

C6370104

Bruderheim Facility
Q13602

ANALYSIS REQUEST

Sample	Date	Method	Type	HOLD BACKUP	PSA-1	SAL-DETAIL	NPKS-AVAIL	CEC+KAT	C-TOT-ORG + NTOTK	OM-LOI	METAL-PITS + BHOTW	C-INORG	DENSITY-BULK	PH-SAR + EC-SAR	S-ELEMENTAL	SULPHUR-TOTAL
11A (0.38-0.70m)	Oct 13/06	Grab	Soil	(	X	X		X				X				
11A (0.0-0.32m)					X	X	X	X	X	X					*	*
12A (0.0-0.25m)					X	X	X	X	X	X			X		*	*
12A (0.25-0.35m)					X	X			X	X			X			
12A (1.3-1.5m)					X	X					X	X	X			
12A (0.35-0.53m)					X	X							X			
17 (0.3-0.4m)							X	X	X	X			X	X		
17 (0.7-0.9m)					X	X					X	X				
31 (0.3-0.5m)	Oct 16/06				X	X										
31 (0-0.2m)					X	X	X	X	X	X			X		*	*
31 (0.8-1.0m)					X	X					X	X				
16 (1.0-1.2m)	Oct 13/06				X	X					X	X				

GUIDELINES / REGULATIONS — SPECIAL INSTRUCTIONS / NATURE OF HAZARDOUS MATERIAL — SAMPLE CONDITION

Bob Caley Oct 18/06 1:30pm

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CHAIN OF CUSTODY / ANALYTICAL REQUEST FORM

CANADA TOLL FREE 1-800-668-9878

COC # 208408

Pg 3 of 5

Report to: Leroy Haderlein

Company: WorleyParsons Komex

Address: #705 10040-124st Edmonton, AB

Phone: 496-7055 Fax: 496-9575

Date: Oct 18/06

REPORT DISTRIBUTION: ALL FINAL RESULTS WILL BE MAILED

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Quote #: C62720104

Job #/Site: Brudeheim Facility Q13602

Lab work order #:

☐ Regular service (default)

Priority service (50% surcharge)

Emergency service (100% surcharge)

ANALYSIS REQUEST (Hold 90 days)

Sample ID	Date/Time collected	Sample type	Matrix	PSA-1	SAL-DETAIL	DENSITY-BULK	NPKS-AVAIL	CEC+CAT	C-TOT-ORG+NTOTKJ	OM-LOI	METAL-PITS+B-HOTW	C-INORG	PH-SAR+EC-SAR	S-Elemental	SULPUR-TOTAL
16 (0.0-0.23m)	Oct 13/06	Grab	Soil	X	X	X	X	X	X	X				⊗	⊗
16 (0.8-1.0m)				X	X						X	X			
16 (0.23-0.48m)				X	X	X									
29 (0.2-0.5m)	Oct 16/06			X	X				X	X				⊗	⊗
29 (0.8-1.0m)				X	X						X	X		⊗	⊗
29 (0.0-0.2m)				X	X	X	X	X	X	X				⊗	⊗
13 (0-0.05m)	Oct 13/06			X	X	X	X	X	X	X				⊗	⊗
13 (0.15-0.3m)				X	X										
13 (0.8-1.0m)				X	X							X			
13-LF						X	X	X	X	X			X		
3 (0.2-0.4m)	Oct 12/06			X	X	X			X	X		X			
3 (0.0-0.15m)				X	X	X	X	X	X	X				⊗	⊗

GUIDELINES / REGULATIONS | SPECIAL INSTRUCTIONS / NATURE OF HAZARDOUS MATERIAL | SAMPLE CONDITION

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EnviroTest Laboratories

CHAIN OF CUSTODY / ANALYTICAL REQUEST FORM

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COC # 208437

Pg 4-5

REPORT TO: Lenz Haderlein
COMPANY: WORLEYPARSONS Komex
ADDRESS: #705 10240-124st
Edmonton, AB
PHONE: 496 9055 FAX: 496 7575
INVOICE TO: SAME (Y) N

DATE: Oct 18/06
EMAIL: lindsay.yorick@worleyparsons.com
SELECT: pdf digital both ✓
(C 637 20704
LSD: Bruderheim Facility
QUOTE #: Q13602

✓ REGULAR SERVICE

ANALYSIS REQUEST

SAMPLE ID	DATE	SAMPLING METHOD	SAMPLE TYPE	HOLD 90days	PSA-1	SAL-DETAIL	DENSITY-BULK	NPKS-AVAIL	CEC+CAT	C-TOT-ORG+NTOTKJ	OM-LOI	METAL-PITS+B-HOTW	C-INORG	PH-SAR+EC-SAR	S-Elemental	Total-Sulphur	PH
3 (0.6-0.8m)	Oct 12/06	Grab	Soil	✓	X	X							X				
3 (1.0-1.2m)	↓	↓	↓		X	X	X					X	X				
3 (1.2-1.4m)					X	X	X					X	X				
35 (0-0.6m)	Oct 16/06				X	X	X	X	X								
35 (1.3-1.5m)	Oct 16/06				X	X	X						X				
47 (0-0.1m)	Oct 17/06																
47 (0.3-0.4m)																	
47 (0.8-1.0m)																	
52 (0-0.1m)					X	X	X	X	X	X	X						
52 (0.3-0.5m)					X	X	X						X				
52 (0.8-1.0m)					X	X							X				
4 (0.0-0.2m)	↓	↓	↓		X	X	X	X	X	X	X						

GUIDELINES / REGULATIONS — SPECIAL INSTRUCTIONS / NATURE OF HAZARDOUS MATERIAL — SAMPLE CONDITION

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Oct 18 06 1.30 PM

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CHAIN OF CUSTODY / ANALYTICAL REQUEST FORM

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COC # 208432

Pg 5 of 5

REPORT TO: Greg Hockaleir
COMPANY: WorleyParsons Komex
ADDRESS: #705 10240-124 st
Edmonton, AB
PHONE: 496-9055 FAX: 496-9575

DATE: Oct 18/06

REPORT DISTRIBUTION

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PO#: 60730104

LOCATION: Budenheim Facility
QUOTE #: Q13602

LAB WORK ORDER #

✓ REGULAR SERVICE (DEFAULT)
PRIORITY SERVICE (50% SURCHARGE)
EMERGENCY SERVICE (100% SURCHARGE)

ANALYSIS REQUEST

Sample ID	Date/Time Collected	Sample Type	Matrix	DSA-1	SAL-DETAIL	C-TOT-ORG + NTOT (?)	OM-LOI	C-INORG	METALS-PITS+B-HOTW	HAZARDOUS?	NUMBER OF CONTAINERS	HIGHLY CONTAMINATED?
4 (0.3-0.35m)	Oct17/06	Grab	Soil	X	X	X	X	X				
4 (0.5-0.7m)	↓	↓	↓	X	X			X				
4 (0.8-1.0m)	↓	↓	↓	X	X			X	X			

GUIDELINES / REGULATIONS — SPECIAL INSTRUCTIONS / NATURE OF HAZARDOUS MATERIAL — SAMPLE CONDITION

[signature] Oct 18/06

ETL Enviro·Test LABORATORIES

CHAIN OF CUSTODY / ANALYTICAL REQUEST FORM

CANADA TOLL FREE 1-800-668-9878

REPORT TO: Len Haderlein
COMPANY: WorleyParsons Komex
CONTACT:
ADDRESS: #705 10240-124 st Edmonton, AB
PHONE: 496-9055 FAX: 496-9575
CELLPHONE:

INVOICE TO: SAME (Y) N
COMPANY:
CONTACT:
ADDRESS:
PHONE: FAX:

DATE: Oct 18/06
REPORT DISTRIBUTION ALL FINAL RESULTS WILL BE MAILED
EMAIL___ FAX___
EMAIL 1:
EMAIL 2:
DIGITAL EMAIL: lindsay.youck@worleyparsons.com
SELECT: pdf___ digital___ both ✓

INDICATE BOTTLES: FILTERED/PRESERVED (F/P) ▶

JOB # C62720104
PO/AFE:
LSD: Bruderheim Facility
QUOTE #

LAB WORK ORDER # L445303

SERVICE REQUESTED
- ✓ REGULAR SERVICE (DEFAULT)
- PRIORITY SERVICE (50% SURCHARGE)
- EMERGENCY SERVICE (100% SURCHARGE)

ANALYSIS REQUEST: Hold 90 days

SAMPLE ID	SAMPLING LOCATION	SAMPLED BY / DATE / TIME	SAMPLING METHOD	SAMPLE TYPE	Hold 90 days	HAZARDOUS ?	NUMBER OF CONTAINERS	HIGHLY CONTAMINATED ?	LAB SAMPLE #
44-(0.0-0.1m)		Oct 17/06	Grab.	Soil					
44-(0.8-1.0m)		Oct 17/06	Grab	Soil					
39-(0.4-0.6m)		Oct 16/06.	Grab	Soil					
39-(0.31-0.35m)		↓	↓	↓					
33-(1.0-1.2m)		↓	↓	↓					
33-(0-0.2m)		↓	↓	↓					
1-(0.8-1.0m)		Oct 12/06	↓	↓					
1-(0.35-0.5m)		↓	↓	↓					
1-(.25-0.3m)		↓	↓	↓					
1-(0.0-0.2m)		↓	↓	↓					
11A (0.70-1.2m)		Oct 13/06.	↓	↓					
11A (0.32-0.38m)		Oct 13/06	↓	↓					

GUIDELINES / REGULATIONS

SPECIAL INSTRUCTIONS / NATURE OF HAZARDOUS MATERIAL

SAMPLE CONDITION
FROZEN
COLD
AMBIENT ✓
MEAN TEMPERATURE 15.5°C

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RELINQUISHED BY:	DATE & TIME:	RECEIVED BY:	DATE & TIME:	SAMPLE CONDITION ACCEPTABLE UPON RECEIPT ? (Y/N)
[signature]	Oct 18/06 1:30 PM	[signature]	18-Oct-06	
RELINQUISHED BY:	DATE & TIME:	RECEIVED BY:	DATE & TIME: 1526	

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CHAIN OF CUSTODY / ANALYTICAL REQUEST FORM

CANADA TOLL FREE 1-800-668-9878

COC # 208407

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Pg. 2 of 5

REPORT TO: Lou Maderlein
COMPANY: WorleyParsons Komex
CONTACT: ~~[illegible]~~
ADDRESS: #705 10240-124 St
Edmonton, AB
PHONE: 496-9055 FAX: 496-9575
CELLPHONE:

INVOICE TO: SAME (Y) / N
COMPANY:
CONTACT:
ADDRESS:
PHONE: FAX:

DATE: Oct 18/06
REPORT DISTRIBUTION ALL FINAL RESULTS WILL BE MAILED
EMAIL___ FAX___
EMAIL 1:
EMAIL 2:
DIGITAL EMAIL:
SELECT: pdf___ digital___ both ✓
INDICATE BOTTLES: FILTERED/PRESERVED (F/P) ▶
JOB # C63720104
PO/AFE:
LSD: Bruderheim facility
QUOTE #

LAB WORK ORDER #

SERVICE REQUESTED
- ✓ REGULAR SERVICE (DEFAULT)
- PRIORITY SERVICE (50% SURCHARGE)
- EMERGENCY SERVICE (100% SURCHARGE)

ANALYSIS REQUEST: HOLD 90 days

SAMPLE ID	SAMPLING LOCATION	SAMPLED BY / DATE / TIME	SAMPLING METHOD	SAMPLE TYPE	ANALYSIS REQUEST	HAZARDOUS ?	NUMBER OF CONTAINERS	HIGHLY CONTAMINATED ?	LAB SAMPLE #
11A (0.38-0.70m)		Oct 13/06	Grab	Soil	HOLD 90 days				
11A (0.0-0.32m)		↓	↓	↓	↓				
12A (0.0-0.25m)		↓	↓	↓	↓				
12A (0.25-0.35m)		↓	↓	↓	↓				
12A (1.3-1.5m)		↓	↓	↓	↓				
12A (0.35-0.53m)		↓	↓	↓	↓				
17 (0.3-0.4m)		↓	↓	↓	↓				
17 (0.7-0.9m)		↓	↓	↓	↓				
31 (0.3-0.5m)		Oct 16/06	↓	↓	↓				
31 (0-0.2m)		↓	↓	↓	↓				
31 (0.8-1.0m)		↓	↓	↓	↓				
16 (1.0-1.2m)		Oct 13/06	↓	↓	↓				

GUIDELINES / REGULATIONS

SPECIAL INSTRUCTIONS / NATURE OF HAZARDOUS MATERIAL

SAMPLE CONDITION: FROZEN / COLD / AMBIENT — MEAN TEMPERATURE

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RELINQUISHED BY:	DATE & TIME:	RECEIVED BY:	DATE & TIME:	SAMPLE CONDITION ACCEPTABLE UPON RECEIPT ? (Y/N)
[signature]	Oct 18/06 1:30PM			
RELINQUISHED BY:	DATE & TIME:	RECEIVED BY:	DATE & TIME:	

REFER TO BACK PAGE FOR SAMPLING INFORMATION & REGIONAL LOCATIONS WHITE - REPORT COPY, PINK - FILE COPY, YELLOW - CLIENT COPY

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EnviroTest LABORATORIES

CHAIN OF CUSTODY / ANALYTICAL REQUEST FORM

CANADA TOLL FREE 1-800-668-9878

COC # 208408

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REPORT TO: Leroy Haderlein	DATE: Oct 18/06
COMPANY:	LAB WORK ORDER #
CONTACT: WorleyParsons Komex	REPORT DISTRIBUTION: ALL FINAL RESULTS WILL BE MAILED
ADDRESS: #705 10240-124st Edmonton, AB	EMAIL___ FAX___
PHONE: 496-9055 FAX: 496-9575	EMAIL 1:
CELLPHONE:	EMAIL 2:
	DIGITAL EMAIL:
	SELECT: pdf___ digital___ both ✓
	INDICATE BOTTLES: FILTERED/PRESERVED (F/P) ▶
INVOICE TO: SAME Y / N	JOB # C62720104
COMPANY:	PO/AFE:
CONTACT:	LSD: Bruderheim Facility
ADDRESS:	QUOTE #
PHONE: FAX:	

SERVICE REQUESTED

- ✓ REGULAR SERVICE (DEFAULT)
- ☐ PRIORITY SERVICE (50% SURCHARGE)
- ☐ EMERGENCY SERVICE (100% SURCHARGE)

ANALYSIS REQUEST

SAMPLE ID	SAMPLING LOCATION	SAMPLED BY / DATE / TIME	SAMPLING METHOD	SAMPLE TYPE	Hold 90 days	HAZARDOUS ?	NUMBER OF CONTAINERS	HIGHLY CONTAMINATED ?	LAB SAMPLE #
16 (0.0-0.23m)		Oct 13/06	Grab	Soil	✓				
16 (0.8-1.0m)									
16 (0.23-0.48m)									
29 (0.2-0.5m)		Oct 16/06							
29 (0.8-1.0m)									
29 (0.0-0.2m)									
13 (0-0.05m)		Oct 13/06							
13 (0.15-0.3m)									
13 (0.8-1.0m)									
13-LF									
3 (0.2-0.4m)		Oct 12/06							
3 (0.0-0.15m)									

GUIDELINES / REGULATIONS	SPECIAL INSTRUCTIONS / NATURE OF HAZARDOUS MATERIAL	SAMPLE CONDITION
		FROZEN / COLD / AMBIENT; MEAN TEMPERATURE

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COMPANY: WORLEYPARSONS Komex
CONTACT:
ADDRESS: #705 10240-124st Edmonton, AB
PHONE: 496-9055 FAX: 496-1575
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3 (0.6-0.8m)		Oct 12/06	Grab	Soil	✓				
3 (1.0-1.2m)		↓	↓	↓	↓				
3 (1.2-1.4 m)		↓	↓	↓	↓				
35 (0-0.16m)		Oct 16/06	↓	↓	↓				
35 (1.3-1.5m)		Oct 16/06	↓	↓	↓				
47 (0-0.1m)		Oct 17/06	↓	↓	↓				
47 (0.3-0.4m)		↓	↓	↓	↓				
47 (0.8-1.0m)		↓	↓	↓	↓				
52 (0-0.1m)		↓	↓	↓	↓				
52 (0.3-0.5m)		↓	↓	↓	↓				
52 (0.8-1.0m)		↓	↓	↓	↓				
4 (0.0-0.2m)		↓	↓	↓	↓				

GUIDELINES / REGULATIONS

SPECIAL INSTRUCTIONS / NATURE OF HAZARDOUS MATERIAL

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DATE: Oct 19/06

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ADDRESS: # 705 10240-124 St Edmonton, AB

PHONE: 496-9055 FAX: 496-9575

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PO/AFE:

LSD: Bruderheim Facility

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4 (0.5-0.7m)		↓	↓	↓														
4 (0.8-1.0m)																		

GUIDELINES / REGULATIONS

SPECIAL INSTRUCTIONS / NATURE OF HAZARDOUS MATERIAL

SAMPLE CONDITION

FROZEN	MEAN TEMPERATURE
COLD	
AMBIENT	

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[signature]	Oct 19/06			
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resources & energy

Alberta Sulphur Terminals Ltd.
Bruderheim Sulphur Forming and Shipping Facility

Volume IIC – Terrestrial

3. Vegetation

Project Number 62720000
June 2007

Environment & Water Resources
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APPENDICES

Executive Summary

Alberta Sulphur Terminals Ltd. (AST), a division of HAZCO Environmental Services (HAZCO) which, in turn, is a division of CCS Income Trust (CCS), retained WorleyParsons Komex to complete a vegetation assessment for the proposed site of the Bruderheim Sulphur Forming and Shipping Facility (the Project) located on a portion of Section 35, Township 55, Range 20, West of the 4th Meridian (35-55-20 W4M - the Site). The objectives of the vegetation assessment were as follows:

- satisfy the relevant sections of the Final Terms of Reference (TOR) of the Environmental Impact Assessment (EIA)
- conduct baseline vegetation and rare plant surveys of the Site for the proposed Project
- determine the rare plant potential of the Site
- determine if plant communities of conservation concern are present on the Site
- evaluate the impacts of potential acid input to vegetation communities on the Site

The aspects of the TOR that are relevant to the vegetation assessment and the respective conclusions of the assessment are summarized as follows.

4.9.1 General Terrestrial Considerations:

Review current biophysical conditions and identify the nature, location and duration of changes anticipated as a result of the Project.

Provide and discuss the following:

a) *maps indicating the pre-disturbance landscape, elevation and drainage patterns of the Study Areas;*

   Land unit classification using the Central Parkland Native Vegetation Inventory (CPNVI) indicated that 97% of the Local Study Area (LSA) is human modified. The human modified polygon was further delineated using the Alberta Vegetation Inventory indicating that agricultural land classes cover 84.86% of the LSA and anthropogenic non-vegetated land classes cover 11.55% of the LSA.

b) *an assessment of the anticipated changes to the pre-disturbed topography, elevation and drainage patterns of the Study Areas;*

   The construction of the Project is anticipated to reduce the agricultural land classes by 6.10% and increase the following anthropogenic non-vegetated land classes: rights-of-way (4.05%), industrial facilities (1.53%), water reservoir (0.18%) and pipeline (0.34%).

c) *baseline biophysical conditions, including topography, soil and vegetation characteristics and wildlife capability within the Study Area. Conduct the necessary surveys to characterize the biophysical resources in the Study Area and to assist in reclamation planning;*

   Baseline vegetation surveys were conducted in June and August, 2006, as part of the rare plant surveys. The vascular and non-vascular species lists are reported in Appendix II and Appendix III, respectively. A range health assessment was conducted on the rough pasture in the northwest quarter of the Site.

d) *components of the Project that will potentially affect these biophysical resources including soils, vegetation, wildlife and biodiversity;*

The Principal Development Area (PDA) will impact underlying agricultural lands during the construction and operation of the facility. Potential impacts that were assessed included surface disturbance, dust deposition, contaminant spills, introduction of non-native and invasive species, and air emissions. All impacts will affect the underlying agricultural lands negatively, however; the impacts are predicted to be local in extent, negligible to low-to-moderate in magnitude, short-term to mid-term in duration and reversible.

e) *mitigation plans to minimize these effects; and*

These measures include:

- use of best management practices and dust suppressants
- application of best available technology for sulphur forming
- regular monitoring of soil quantity
- containment and control of potentially impacted runoff

f) *an assessment of the relative contribution of the Project (after mitigation) to regional cumulative pressures on biophysical resources (e.g., Project contributions to cumulative potential acid input [PAI]);*

All potential impacts were determined to be local in geographic extent, therefore, the Project's contribution to regional cumulative pressures on biophysical resources is not expected to be significant.

4.9.3 Vegetation

Provide the following:

g) *Conduct an inventory, map and describe the existing terrestrial, wetland and aquatic vegetation. Include any rare vascular and non-vascular plant species and rare plant communities in the Study Areas, including data from historical records as well as any surveys for the purpose of this EIA;*

One rare non-vascular plant, the lichen *Xanthoria fulva*, was identified in the shelterbelt running east to west along Township Road 560 in the northeast corner of the LSA. *X. fulva* is ranked as S1 in Alberta and is on the provincial tracking list. Data associated with this assessment is presented in this report.

h) *describe and assess potential impacts of the project construction and operation on vegetation (abundance, diversity, health, rare species and rare plant communities in the Study Areas) including cumulative impacts of acidifying and other air emissions;*

The PDA will reduce the agricultural land classes by 6.10% during the construction and operation phases of the Project. The rare lichen is not located within the PDA and is not expected to be impacted by the Project.

Five noxious weeds, eleven nuisance weeds and eleven non-native or agronomic invasive species were identified in the LSA. There is potential for weed encroachment to increase during the construction and operation of the Project. Weed management plans developed in conjunction with the rail line right-of-way holders are recommended. The nature of the potential acidifying emissions and their cumulative affects are described in Volume I: Project Description.

i) *describe and discuss measures to be implemented to mitigate and monitor potential impacts of the Project on vegetation in the Study Areas; and*

Vegetation in the potentially impacted area surrounding the PDA will be protected as a result of the proposed soil monitoring and mitigation program described in Volume IIC, Section 2: Soil. This will include regular monitoring of soil quality and treatment as required to buffer any pH impacts.

j) discuss how vegetation monitoring programs will be used to adaptively manage the mitigation measures and monitoring programs.

The results of the monitoring programs will be evaluated to determine if modifications to the mitigation plans are required to reduce impacts. The monitoring programs will be adjusted to address any issues that arise during the operation of the Project.

3. Vegetation

3.1 Introduction

This section presents the results of baseline studies and the impact assessment for vegetation and wetland resources as part of the Environmental Impact Assessment (EIA) for the proposed Bruderheim Sulphur Forming and Shipping Facility (the Project). Existing information was reviewed and field studies were completed to classify, map and describe baseline vegetation and wetland conditions within the Vegetation Local Study Area (LSA) and Regional Study Area (RSA). Section 3.5 presents the application case assessment with potential Project-specific impacts on vegetation and wetland resources. Cumulative impacts to vegetation and wetland resources are considered in Section 3.6. Monitoring and adaptive management measures and the impact summary are considered in the subsequent sections.

3.2 Indicators and Issues

Vegetation and wetland resource indicators, as well as impact issues selected for detailed assessment, follow the Final Terms of Reference (TOR) of Alberta Environment (AENV 2007). Potential impacts on agriculture are addressed in Volume IID, Section 2: Land Use and Reclamation. Indicators and issues were also identified through public consultation and stakeholder interviews (see Volume I: Project Description and Volume IID, Section 5: Public Consultation) and reviews of recent relevant EIAs conducted in the Alberta Industrial Heartland.

The vegetation and wetland indicators selected for detailed assessment are:

- rare plants
- rare plant potential
- plant communities of conservation concern
- vegetation communities sensitive to potential acid input

Vegetation and wetland resources may be directly and indirectly affected by the following potential issues associated with the Project:

- surface disturbance
- dust deposition
- contaminant spills
- introduction of non-native and invasive species
- air emissions

3.2.1 Terms of Reference

In addition to these issues, the assessment also addressed the issues identified in the TOR:

4.9.1 General Terrestrial Considerations:

Review current biophysical conditions and identify the nature, location and duration of changes anticipated as a result of the Project.

Provide and discuss the following:

a) maps indicating the pre-disturbance landscape, elevation and drainage patterns of the Study Areas;

b) an assessment of the anticipated changes to the pre-disturbed topography, elevation and drainage patterns of the Study Areas;

c) baseline biophysical conditions, including topography, soil and vegetation characteristics and wildlife capability within the Study Area. Conduct the necessary surveys to characterize the biophysical resources in the Study Area and to assist in reclamation planning;

d) components of the Project that will potentially affect these biophysical resources including soils, vegetation, wildlife and biodiversity;

e) mitigation plans to minimize these effects; and

f) an assessment of the relative contribution of the Project (after mitigation) to regional cumulative pressures on biophysical resources (e.g., Project contributions to cumulative potential acid input [PAI]);

4.9.3 Vegetation

Provide the following:

a) Conduct an inventory, map and describe the existing terrestrial, wetland and aquatic vegetation. Include any rare vascular and non-vascular plant species and rare plant communities in the Study Areas, including data from historical records as well as any surveys for the purpose of this EIA;

b) describe and assess potential impacts of the project construction and operation on vegetation (abundance, diversity, health, rare species and rare plant communities in the Study Areas) including cumulative impacts of acidifying and other air emissions;

c) describe and discuss measures to be implemented to mitigate and monitor potential impacts of the Project on vegetation in the Study Areas; and

d) discuss how vegetation monitoring programs will be used to adaptively manage the mitigation measures and monitoring programs.

3.3 Methods

3.3.1 Spatial and Temporal Boundaries

3.3.1.1 <u>Principal Development Area</u>

The proposed Project will be developed in the Principle Development Area (PDA), on a portion of Section 35-55-20 W4M (the Site), which comprises the area of disturbance and development. The PDA is equivalent to the Project footprint, which includes the direct footprint of the proposed facility and associated infrastructure and is 24.8 ha in size. All infrastructure and activities will be confined to the Site. The PDA, shown in Figure 3.3-1, consists of:

- rail and road access for receiving and shipping sulphur
- liquid sulphur unloading and transfer facilities
- sulphur forming facilities to produce sulphur pastilles

- loading and shipping facilities for formed sulphur
- a sulphur pastilles temporary storage area

3.3.1.2 Local Study Area

The Vegetation LSA covers 407.4 ha and is defined as the Site surrounded by a 200 m buffer zone (see Figure 3.3-1). The 200 m buffer was included to contain the predicted emissions from the Project within the LSA (Leahey and Whitford 2005). Two rail line rights-of-way (ROW) traverse the LSA. A utility substation is adjacent to a wetland located in the northwest corner and an intermittent stream flows south to north along the eastern portion of the LSA.

The LSA is located 2.2 km east of Bruderheim within the Central Parkland Natural Subregion of Alberta (NRC 2006). This subregion is a transition zone between the Boreal Forest Natural Region to the north and the Grasslands Natural Region to the south. The native vegetation in the Central Parkland is characterized by aspen stands interspersed with grasslands and low-lying wetlands. More detailed ecological descriptions of the LSA are provided in Appendix I. Anthropogenic modifications to the native vegetation for urbanization, transportation, industry and agriculture have reduced the remaining native vegetation in the Central Parkland to about 5% of the subregion (NRC 2006). The LSA is located in the Lamont Country Industrial Heartland, which forms the eastern portion of the Alberta Industrial Heartland. Because of common ecological relationships, the LSA is the same for the vegetation, wildlife and soils sections of this EIA.

3.3.1.3 Regional Study Area

The Vegetation RSA is defined as the Site surrounded by a 1,000 m buffer zone (see Figure 3.3-1). The RSA was delineated based on the preliminary air modelling conducted in 2005 (Leahey and Whitford 2005) for the Project. The RSA was used to evaluate Project effects of potential acid deposition and includes the lands that fall within the predicted sulphur dioxide emissions isopleths estimated in the 2005 air modelling (Leahey and Whitford 2005). Due to common ecological relationships, the RSA is the same for the vegetation, biodiversity and soil sections of this EIA.

3.3.1.4 Temporal Boundaries

Three temporal boundaries are used in this assessment: baseline, application and closure. Baseline refers to conditions in the LSA and RSA as of August 2006. Application is assessed at maximum disturbance or 6,000 t/d production capacity. This approach determines the impact of the Project as if all facilities were fully developed and operational at the same time. Impact predictions during the application case are considered worst case and conservative. Closure is considered when all project facilities have been decommissioned and reclamation has taken place. It is assumed that closure occurs five years after decommissioning and reclamation, therefore, vegetation has been planted or seeded and has had time to establish on each site.

3.3.1.5 Project Inclusion List

The project inclusion list includes the various anthropogenic disturbances on the landscape that must be included in each assessment case in order to effectively determine Project and cumulative effects. Table 3.3-1 provides the list of projects included in each case.

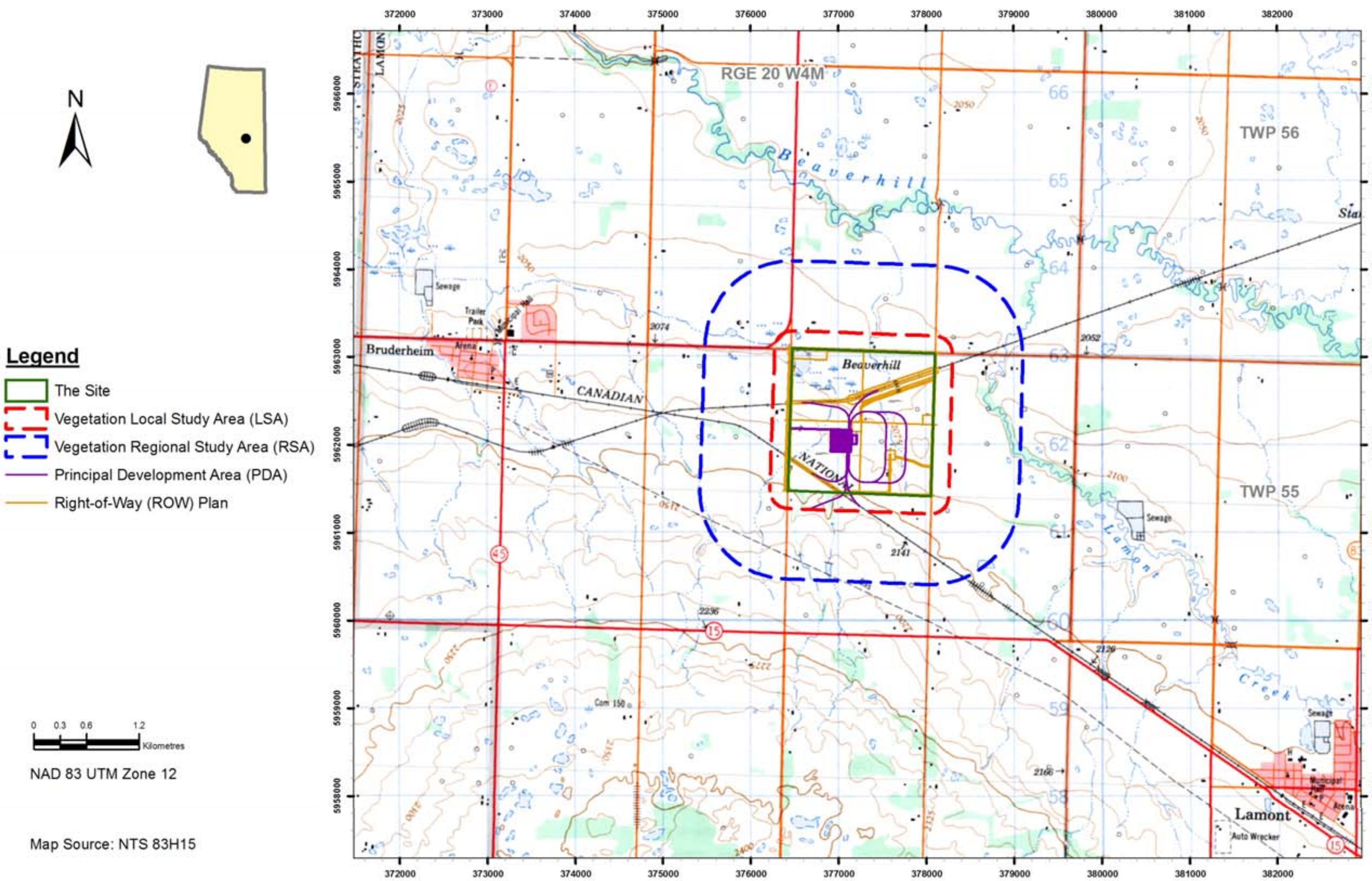

Figure 3.3-1: Vegetation LSA and RSA

Table 3.3-1: Project Inclusion List

Status	Baseline Case	Application Case	Cumulative Effects Case
Existing and Approved	Canexus Chemicals	Canexus Chemicals	Canexus Chemicals
	ERCO Worldwide	n/a	n/a
	Triton	Triton	Triton
Project	n/a	Bruderheim Sulphur Forming and Shipping Facility	Bruderheim Sulphur Forming and Shipping Facility
Planned Projects and Activities	n/a	n/a	n/a

Note:
n/a – not applicable

3.3.2 Baseline Data Acquisition Methods

3.3.2.1 Land Unit Classification and Mapping

Land units were delineated using two vegetation inventories. The Central Parkland Native Vegetation Inventory Version 1.2 (CPNVI; ASRD 2003) was used to preliminarily map the native grassland, native deciduous and human modified cover classes in the LSA. According to the CPNVI, 97.0% of the LSA is human modified, therefore, the human modified polygon of the CPNVI, was further delineated on aerial photographs (October 1998, 1:30,000) into Alberta Vegetation Inventory (AVI) agriculture and anthropogenic non-vegetated land classes. The CPNVI cover classes and AVI land classes delineated within the LSA are defined in Table 3.3-2. More detailed descriptions of the CPNVI and AVI are provided in Appendix I.

Table 3.3-2: CPNVI Cover Classes and AVI Land Classes in the LSA

Inventory	Class	Definition
CPNVI	Human modified	Land not attributed to vegetation or water classes, includes agricultural lands
	Deciduous	Non-native deciduous trees
	Native deciduous	Native deciduous trees
	Native grassland	Native grassland communities
	Wetland	Recurring lake or potential basin from Base Features Hydrography updates
	Water	Water obtained from either Base Features Hydrography or open water classed from IRS imagery
AVI	**Agriculture land classes**	
	CA	Annual crops
	CP	Perennial forage crops
	CPR	Rough pasture
	Anthropogenic non-vegetated land classes	
	AIF	Farmsteads (related to agriculture)
	AIH	Permanent ROW, roads, highways, railroads, dam sites, reservoirs
	AII	Industrial (plant sites), sewage lagoons

Source: ASRD 2003, AEP 1997.

3.3.2.1.1 Field Methods

Field surveys were conducted on June 19 and 20, 2006 and August 17 and 18, 2006, as part of the rare plant surveys. Surveys were conducted along the shelterbelts, seasonal drainage channels, ROW, wetland and rough pasture land units within the LSA. Two locations along Lamont Creek, in the northeast corner of the RSA, were surveyed during the August field visit to include the CPNVI native vegetation cover classes along the creek.

Trees, shrubs, forbs, graminoids, mosses and lichens encountered at each survey point were recorded. A list of all vascular species identified within the LSA is provided in Appendix II and non-vascular species in Appendix III. Notes were also taken on non-native and invasive species encountered.

The health of the rough pasture in the LSA was assessed by evaluating the data collected during the August 2006 field visit according to the recommendations of Rangeland Health Assessment for Grassland, Forest and Tame Pasture by Adams et al. (2005).

3.3.2.1.2 Alberta Wetland Inventory Classification

The Alberta Wetland Inventory (AWI) classification system (Halsey and Vitt 1997) was used to classify the wetland in the northwest corner of the LSA for this impact assessment. The wetland was classified using a combination of aerial photograph interpretation, field data and soils data.

3.3.2.1.3 Non-native and Invasive Species Classification

The *Alberta Weed Control Act* classifies weeds found in Alberta as restricted, noxious and nuisance (Alberta Agriculture 2001, Internet site). A listing of agronomic forage species that could be invasive or persistent in natural landscapes was obtained from the Native Plant Revegetation Guidelines for Alberta (Native Plant Working Group 2001). Appendix IV lists non-native and invasive species and their designations.

3.3.2.2 Rare Plants

The presence of rare plants in the LSA was assessed during field surveys conducted on June 19 and 20, 2006 and August 17 and 18, 2006. All species identified on-site were cross-referenced to the provincial and federal rare plant watch lists described in detail in the following sub-sections. Rare plant potential and plant communities of conservation concern were determined for the cover classes located within the LSA.

3.3.2.2.1 Provincial Classification of Rare Plants

Rare plants are an important component of biodiversity. In Alberta they are defined as those vascular and non-vascular plant species listed in the ANHIC plant tracking list as being globally rare (G1, G2, G3), provincially rare (S1, S2, S2S3), or on the provincial watch list (S3) (Gould 2006) (see Table 3.3-3). A total of 101 rare vascular plants and 144 rare non-vascular plants potentially occur in the Central Parkland (Moss 1983, Kershaw et al. 2001, Gould 2006).

Table 3.3-3: ANHIC Rare Plant Rankings

S – Rank	G – Rank	Description
S1	G1	Five or fewer occurrences or only a few remaining individuals
S2	G2	6–20 occurrences or with many individuals in fewer locations
S3	G3	21–100 occurrences, might be rare and local throughout its range, or in a restricted range (might be abundant in some locations or vulnerable to extirpation because of some factor of its biology)
S4	G4	Apparently secure under present conditions, typically greater than 100 occurrences but might be fewer with many large populations; might be rare in parts of its range, especially peripherally
S5	G5	Demonstrably secure under present conditions, greater than 100 occurrences, might be rare in parts of its range, especially peripherally
SU	GU	Status uncertain often because of low search effort or cryptic nature of the element; possibly in peril, unrankable, more information needed
S?	G?	Not yet ranked
Q	Q	Taxonomic questions or problems
Source: Gould 2006.		

3.3.2.2.2 Federal Classification of Rare Plants

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is formally recognized by the *Species at Risk Act* (SARA) as the authority for assessing the conservation status of plant species that could be at risk of extinction in Canada (COSEWIC 2006, Internet site). Although it was legally established by SARA in 2003, COSEWIC has been operating since 1977 and made its first designations in 1978. Once a species has been designated at risk by COSEWIC, it may qualify for legal protection and recovery under SARA (COSEWIC 2006, Internet site). Table 3.3-4 lists the various levels of designations under both SARA and COSEWIC. Two COSEWIC candidate species may occur in the Central Parkland in Alberta.

Table 3.3-4: SARA and COSEWIC Designations

Category	Description
COSEWIC Candidate Species[1]	
Priority 1	Highest priority for assessment; includes species suspected to be at risk of extirpation from Canada
Priority 2	Intermediate priority for assessment
Priority 3	Lower priority for assessment
COSEWIC Assessed Species	
X	Extinct: a species that no longer exists
XT[2]	Extirpated: a species no longer existing in the wild in Canada, but existing elsewhere
E[2]	Endangered: a species facing imminent extirpation or extinction
T[2]	Threatened: a species likely to become endangered if limiting factors are not reversed
SC[2]	Special Concern: a species that could become a threatened or an endangered species because of a combination of biological characteristics and identified threats
NAR	Not at Risk: a species that has been evaluated and found to be not at risk of extinction given the current circumstances
DD	Data Deficient: a species for which there is inadequate information to make a direct, or indirect, assessment of its risk of extinction
Notes: [1] Non-assessed species that COSEWIC has determined should be assessed based on declining population numbers. [2] Category is also used in the SARA lists.	

Table 3.3-4: SARA and COSEWIC Designations (Cont'd)

Category	Description
SARA List	
Schedule 1	List of species at risk. Species on the list have already been reassessed under the most current criteria by COSEWIC
Schedule 2	Additional species in the three highest risk categories that have to be re-assessed by COSEWIC
Schedule 3	Species of special concern that have not been reassessed by COSEWIC

Notes:
[1] Non-assessed species that COSEWIC has determined should be assessed based on declining population numbers.
[2] Category is also used in the SARA lists.

3.3.2.2.3 Field Methods

Prior to commencing rare plant field surveys, an ANHIC search was conducted for rare plant occurrences within and around the LSA (Twp 55, Rge 20, W4M). No previous rare plant occurrences were identified in the area (Rintoul 2006, pers. comm.). A list of potential rare plants for the entire Central Parkland was also obtained.

Two rare plant surveys were conducted in the LSA by WorleyParsons Komex on June 19 and 20, 2006 and August 17 and 18, 2006. Rare plant surveys followed recognized sampling protocols recommended by the Alberta Native Plant Council (ANPC) (Lancaster 2000). Surveys focused on the shelterbelt, wetland and rough pasture habitats and north rail line ROW in the LSA. Before the field surveys, background information in combination with aerial photograph interpretation was used to concentrate search efforts in areas of the LSA that had a higher potential to support rare plants. Field botanists used a random meander technique to assess the selected sites for rare plants. For each new vegetation community encountered on the meander, a list of all plant species was recorded until no new plant species were found. During the meander, any additional microsites, unusual plant assemblages or ephemeral drainages encountered were examined closely, as these features have a higher potential to support rare plants (Lancaster 2000, Kershaw et al. 2001). Species that were unidentifiable in the field because of time or resource constraints were collected based on the 1 in 50 rule that states: *no more than 1 plant (or clump) should be collected for every 50 that are present in a population,* (ANPC 2006, Internet site). Collected species were compared against known botanical specimens. Non-vascular species were sent to bryologists and lichenologists for identification.

Botanical nomenclature for the plant species listed in this report follows The Flora of Alberta (Moss 1983). Common names follow Alberta Plants and Fungi – Master Species Checklist and Species Group Checklist (AEP 1993).

3.3.2.2.4 Rare Plant Potential

Rare plant potential was assessed for the entire RSA in order to include native vegetation located along Lamont Creek in the eastern portion of the RSA. For each potential rare plant species in the RSA, the cover classes in which they could potentially occur were identified based on:

- information on the plant habitat requirements
- results of the field surveys
- professional experience and judgment

Rare plant potential was then calculated based on the number of rare species likely to occur in each cover class. For the purposes of this EIA, cover classes supporting 30 or more rare plant species were ranked as high potential, those supporting 20–29 species were ranked as moderate potential, those supporting 10–19 were low potential and those supporting 0–9 species were very low potential.

3.3.2.2.5 Plant Communities of Conservation Concern

Plant communities of conservation concern are “unusual” or “uncommon” assemblages of plant species that are rare across a landscape and thus contribute greatly to local biodiversity (Allen 2006). These plant communities of conservation concern consist of both upland and wetland communities. To determine if any of the plant communities surveyed within the LSA are unusual or uncommon, the species composition of the shelterbelts, rough pasture and wetland communities were compared to the rare plant communities of the Central Parkland tracked by ANHIC. Vegetation communities and soils data were cross-referenced to the Preliminary Classification of Plant Communities in the Central Parkland Natural Sub-Region of Alberta (Wheatley and Bentz 2002). Where species compositions did not fit into communities described by Wheatley and Bentz (2002), plant community descriptions were defined following the recommendations of the Alberta Natural Heritage Information Centre (ANHIC) (Allen 2007, pers. comm.). The provincial conservation ranks and definitions were based on the criteria described in Wheatley and Bentz (2002) and are provided in Table 3.3-5.

Table 3.3-5: Provincial Conservation Ranks and Definitions for Plant Communities

Preliminary Rank	Description
S1	Five or fewer occurrences; very few remaining hectares; especially vulnerable to extirpation
S2	6–20 occurrences; few remaining hectares; vulnerable to extirpation throughout its range
S3	21–100 occurrences; may be rare and local throughout its range or found locally, even abundantly, in a restricted range; or vulnerable to extirpation throughout its range because of some specific factor
S4	Uncommon, but not rare; although it may be quite rare in parts of its range, especially at the periphery; apparently not vulnerable in most of its range
S5	Common, widespread and abundant provincially; although it may be quite rare in parts of its range, especially at the periphery; not vulnerable in most of its range
SU	Not able to rank; status is uncertain
Source: Wheatley and Bentz 2002.	

3.3.2.3 <u>Vegetation Communities Sensitive to Potential Acid Input</u>

Predicted impacts on vegetation communities resulting from acid deposition were determined based on the critical loads adopted by AENV. A critical load is the highest load of acid deposition that will not cause chemical changes leading to long-term harmful effects on the most sensitive ecological systems (CASA 1999). The critical loads are listed in Table 3.3-6 for various soil sensitivities (CASA 1996). A more detailed explanation of soil sensitivities is provided in the soil section of the EIA (see Volume IIC, Section 2: Soil). Cover classes sensitive to acid input were determined primarily on soil/vegetation associations.

Table 3.3-6: Potential Acid Input Guidelines in Alberta

Air Emission	Alberta Environment Guidelines	
	Sensitivity	Critical Load keq H^+/(ha•y)
PAI deposition (annual)	Highly sensitive soils	0.25
	Moderately sensitive soils	0.50
	Low sensitivity soils	1.00

3.3.3 Impact Assessment Methods

The impact assessment evaluated Project impacts for the application case and closure case. Residual impacts were measured for the application case at maximum disturbance when all aspects of the Project are constructed and operated concurrently and for the closure case at post-reclamation when all mitigation techniques have been implemented.

Potential impacts of the Project on vegetation indicators were assessed for the application and closure cases using the criteria of direction, geographic extent, magnitude, duration, reversibility and confidence as described in Volume I: Project Description. A final impact rating of Class 1, 2, 3, or 4 was applied to residual impacts for each indicator as defined in Table 3.3-7.

Table 3.3-7: Final Impact Rating

Rating	Level of Action
Class 1	The predicted trend in an indicator under projected land use development could threaten the long-term sustainability of the quantity or quality of the indicator in the LSA and RSA. An action plan, developed jointly by regional stakeholders, is required to monitor the affected indicator, identify and implement further mitigation measures to reduce any impact and promote recovery of the indicator, where appropriate. This class of impact might also be applicable to an exceedance of a regulatory guideline, or where the impact will have long-term effects.
Class 2	The predicted trend in an indicator under projected land use development will likely result in decline in the quantity or quality of the indicator. The decline could be to lower-than-baseline but stable levels in the LSA and RSA after closure and into the foreseeable future. In addition to responsible industrial operational practices, monitoring and recovery initiatives could be required if additional land use activities occur in the study area before closure of the projected land use development. This class of impact might also be applicable to an exceedance of a regulatory guideline, or where the impact is expected to have mid-term effects, but where recovery will take place shortly after closure of the projected land use development.
Class 3	The predicted trend in an indicator under projected land use development could result in a slight decline in the quantity or quality of the indicator in the LSA and RSA during the life of the projected land use development, but resource levels should recover to baseline after closure. In some cases, a short-term, low to moderate magnitude impact could occur, but recovery will take place within five years. No new resource management initiatives are necessary. Responsible industrial operational practices should continue. This class of impact could also be applicable where regulatory guidelines are not exceeded, but where a relative change in magnitude of an indicator occurs.
Class 4	The projected land use development results in no change and no contribution toward affecting the quantity or quality of the indicator in the LSA and RSA during the life of the projected land use development. Responsible industrial operational practices should continue. Therefore, no cumulative effects result from the Project.

The impact assessment focused on the key vegetation issues identified in Section 3.2 and listed below:

- surface disturbance
- dust deposition
- contaminant spills
- introduction of non-native and invasive species
- air emissions

3.3.3.1 *Surface Disturbance*

The direct effects of the construction of the PDA were determined and quantified for the cover classes in the LSA.

The following indirect effects of surface disturbance on vegetation and wetland resources were qualitatively assessed:

- edge effects
- invasion of plant pathogens, pests and non-native and invasive species
- habitat fragmentation and changes to topography
- soil capability and hydrology

Mitigation and monitoring for direct and indirect effects of surface disturbance is suggested.

3.3.3.2 *Dust Deposition*

Dust may be generated from the sulphur pastilles during their transfer from the production facility to the storage area and finally to the rail loading area. The results of Volume IIA, Section 2: Climate and Air Quality were used to determine the potential impacts of this dust source on vegetation in the LSA. Dust can directly affect vegetation by:

- physically damaging cells
- blocking stomata
- reducing the amount of light reaching photosynthetic cells
- affecting plant respiration and transpiration
- soil acidification

Mitigation and monitoring is suggested for the direct and indirect effects of dust deposition.

3.3.3.3 *Contaminant Spills*

The direct effects of contaminant spills from the Project, vehicles transporting liquid sulphur to the Site and rail cars transporting sulphur pastilles from the Site were qualitatively assessed.

Mitigation and monitoring is suggested to reduce the potential impacts of contaminant spills with the LSA.

3.3.3.4 *Introduction of Non-native and Invasive Species*

Vegetation clearing and physical disturbance of the landscape reduce biodiversity and may create opportunities for colonization by non-native and invasive species (Odum 1975; Krebs 1978). Many non-native and invasive species exhibit diverse reproductive strategies and are successful competitors that are able to out-compete native species in natural and anthropogenically altered habitats. Vegetation communities differ in their susceptibilities to invasion by non-native species. Natural areas under stress from disturbances, such as air and water pollution and habitat fragmentation as a result of agricultural and industrial activities, are easily affected by non-native and invasive species (Haber 2002, Internet site; White and Haber 2002, Internet site).

Activities that result in soil disturbances, such as constructing roads and clearing linear corridors, further favour the establishment of non-native and invasive plant species by creating disturbed sites for colonization (Belcher and Wilson 1989; Sakai et al. 2001). Rights-of-way (ROW), such as roads, pipelines and rail line corridors, may facilitate the movement of non-native and invasive plant species into natural areas, as corridors can be connected to areas where non-native and invasive plant species have already become established (Zink et al. 1995; Tikka et al. 2001). Once non-native and invasive species are established within a disturbed area, they are often able to successfully colonize natural habitats (Howald 1992; Vitousek et al. 1996; Haber 2002, Internet site).

The potential for non-native and invasive plant species introductions resulting from the Project was qualitatively assessed. Mitigation and monitoring for non-native and invasive plant species introductions and control is presented as part of the Project's Conservation and Reclamation Plan (see Volume IID, Section 2: Land Use and Reclamation).

3.3.3.5 *Air Emissions*

Effects of acidifying compounds such as SO_2 and NO_2 on vegetation and wetland resources were considered in the LSA. Acid air emissions can negatively affect vegetation if sufficient amounts are absorbed directly from the air. Direct effects on vegetation may include:

- discoloration
- defoliation
- die back
- reduced plant vigour
- altered growth
- less successful reproduction

These effects, however, may be subtle and difficult to detect. Bryophytes and lichens typically accumulate toxins at a greater rate than vascular plants due to different modes of nutrient and chemical uptake. Surface diffusion in bryophytes and lichens enables toxins to accumulate more effectively in these organisms compared to uptake through root systems in vascular plants (Conti and Cecchetti 2001; Onianwa 2001). Changes to soil and water characteristics that indirectly impact vegetation can generally be detected earlier, are more readily measured and are more definitive than direct impacts on vegetation (CASA 1999, WHO 2000).

The buffering capacity of soils can influence the sensitivity of vegetation communities to impacts from acidifying emissions. Community types most sensitive to acidic inputs occur on sandy soils that have little organic material, low clay content and low soil buffering capacity.

Vegetation communities in the LSA are associated with low, low to moderate, or moderate soil sensitivity therefore, no cover classes were assessed under the 0.25 keq H^+/(ha•y) PAI isopleth, which is the critical load for sensitive soils.

Monitoring of acid deposition is suggested for the LSA.

3.3.4 Cumulative Effects Assessment Methods

Cumulative effects were evaluated on a regional scale and were only assessed when the application case final impact rating was designated as Class 1, 2 or 3 and the applicable data was available.

Impacts of PAI on sensitive vegetation are discussed in the cumulative effects case as the magnitude of this impact is influenced by other developments in the Alberta Industrial Heartland.

3.3.5 Mitigation and Monitoring Methods

The impacts on the key vegetation indicators were evaluated to determine if mitigation, as defined under the *Canadian Environmental Assessment Act* (1992), would be required to implement environmental protection measures. The evaluation considers mitigation measures that would be required to meet regulatory, company or public acceptance during the planning, design, construction, operation or abandonment phases of the Project. To ensure mitigative measures are successful and practice adaptive management, monitoring of mitigative measures is suggested. The mitigation measures are included in the application case for each issue. Monitoring measures are presented in Section 3.7.

3.4 Baseline Case

3.4.1 Land Unit Classification and Mapping

3.4.1.1 CPNVI Cover Classes

The CPNVI shows that 97.0% of the LSA is human modified. A wetland covers 2.2%, deciduous trees cover 0.4% and water covers 0.2% of the LSA. The locations of the CPNVI cover classes within the LSA are shown in Figure 3.4-1.

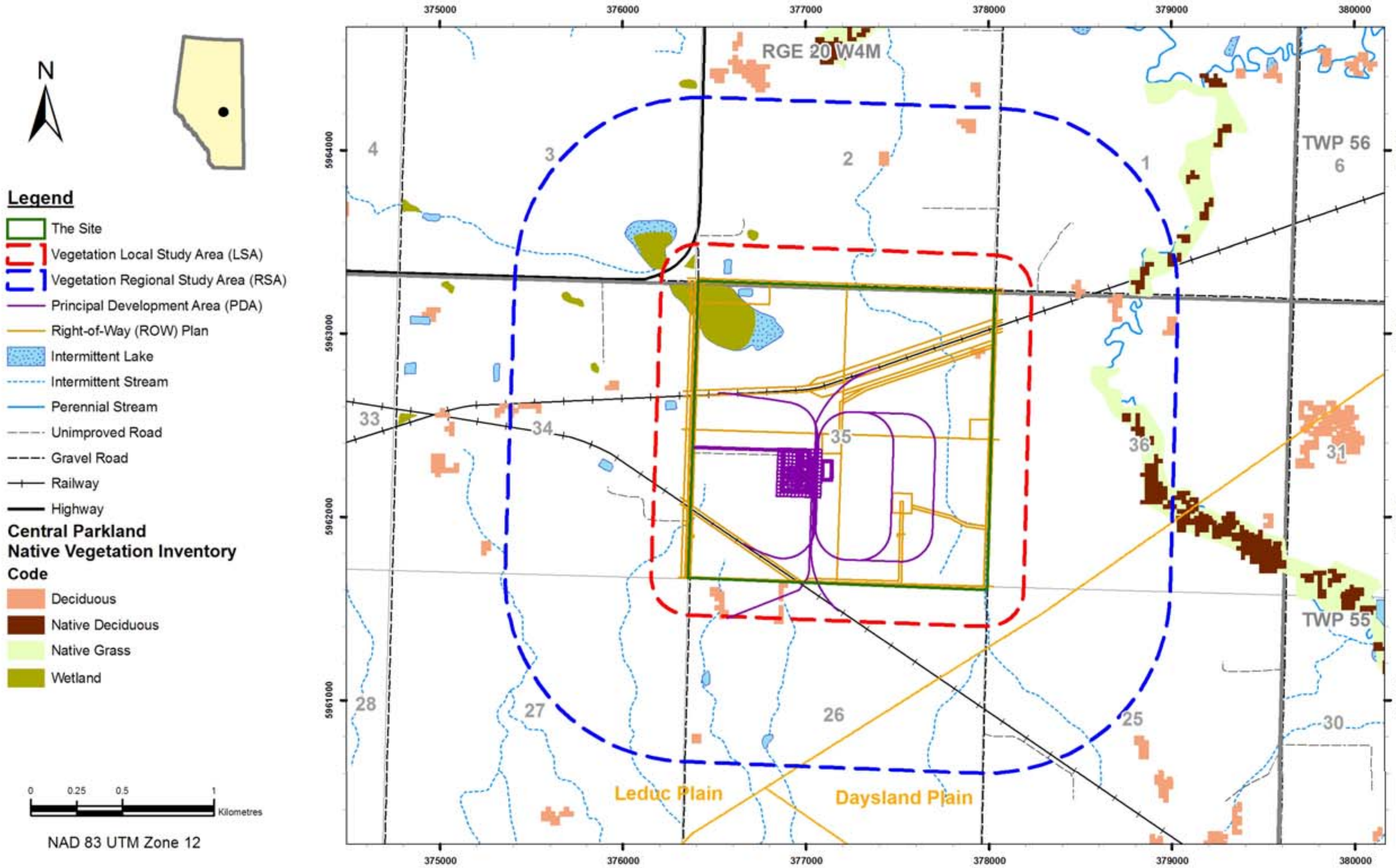

Figure 3.4-1: Distribution of Central Parkland Native Vegetation Inventory Cover Classes at Baseline in the Vegetation LSA and the RSA and Surrounding Area

3.4.1.2 *AVI Land Use Classes*

The human modified area of the LSA consists of three AVI agriculture land use classes and three anthropogenic non-vegetated land use classes. The areas and percentages of the LSA for each AVI land class are presented in Table 3.4-1. The location of the AVI land classes in the LSA are shown in Figure 3.4-2.

Table 3.4-1: Area of AVI Land Classes in the LSA

Land Class		**Area (ha)**	**Area (% of LSA)**
Agriculture land classes			
CA	Annual crops	111.3	27.3
CP	Perennial forage crops	216.8	53.2
CPR	Rough pasture	17.7	4.3
Subtotal		345.8	84.8
Anthropogenic non-vegetated land classes			
AIF	Farmsteads (related to agriculture)	7.8	1.9
AIH	Permanent ROW; roads, highways, railroads, dam sites, reservoirs	24.5	6.0
AII	Industrial (plant sites), sewage lagoons	14.8	3.6
Subtotal		47.1	11.5
Total		**392.9**	**96.3**

The delineation of the AVI land classes covers 96.3% of the LSA. The 0.6% difference from the CPNVI disturbance area reflects minor differences in the delineation of the wetland and waterbodies between the CPNVI and AVI. The CPNVI delineated intermittent lakes on the northeast border of the south end of the wetland and across the northern border of the wetland. The AVI delineation included the intermittent lakes as part of the wetland polygon. In addition, the AVI included the entire triangular parcel of land located on the northwest side of the intersection of Township Road 560 and R.R. 202 and on the southeast side of the bend of Highway 45 in the wetland delineation. The CPNVI delineated only a portion of this parcel as wetland and the remaining area as human modified. These two minor differences in the polygons account for the 0.6% difference in the AVI agricultural and anthropogenic non-vegetated land classes and the CPNVI human modified cover class.

3.4.1.3 *AWI Classification*

According to the AWI classification, the wetland in the northwest corner is a FONG, shown in Figure 3.4-2. A FONG wetland is an open, non-patterned graminoid dominated fen characterized by a continuous sedge cover, a shrub cover of less than 25% and a tree cover of less than 6%. The peat layer in the underlying Manatokan soil series is greater than 40 cm indicative of a peat-based wetland. This fen type can grade into wet meadows associated with uplands and non-peat forming wetlands and occurs as collapsed scars in association with peat plateau as small isolated basins and as flat, featureless fens that slope gently in the direction of drainage. Ground cover generally includes various species of *Sphagnum*, although none were recorded during the field surveys.

The north rail line ROW is bordered by a small wetland community in the centre of the section. This community was not classified according to the AWI classification due to the small size of the wetland and its proximity to the ROW. More information regarding this community is provided in Volume IIB, Section 3: Surface Water Quantity and Section 4: Surface Water Quality.

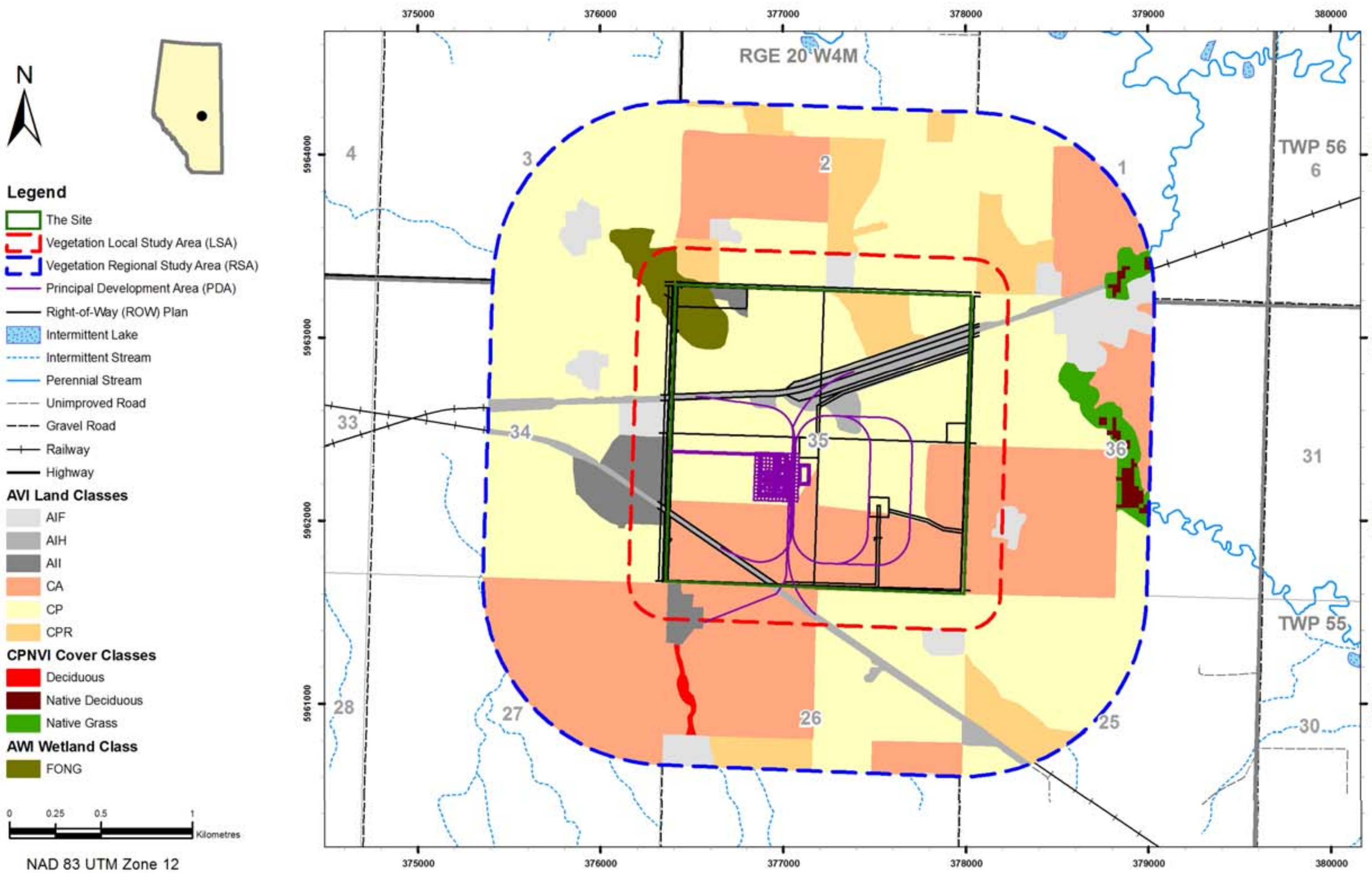

Figure 3.4-2: Location of AVI, CPNVI and AWI Land Units in the LSA and RSA

3.4.2 Baseline Field Surveys

Figure 3.4-3 shows the location of spring and summer survey points.

3.4.2.1.1 Non-native and Invasive Species Inventory

Twenty-seven non-native and invasive species were recorded during the field visits. Five noxious weeds, eleven nuisance weeds and eleven non-native or agronomic invasive species were identified. Weeds were present along the ROW, in all the plant communities described in Section 3.4.2.3 and in croplands. Three noxious weeds, five nuisance weeds and five non-native or agronomic invasive species were identified along the north rail line ROW. Two noxious weeds, two nuisance weeds and two non-native or agronomic invasive species were identified in the power substation access ROW. Two noxious weeds, two nuisance weeds and four non-native or agronomic invasive species were identified in the annual and perennial croplands. Figure 3.4-4 shows the survey points at which non-native and invasive species were recorded. It is important to note, that these survey points do not represent the only locations of the identified weeds. In all shelterbelts and along the ROW, weeds were persistent throughout, not localized to the survey points. The location and habitat of individual species is provided in Appendix V.

3.4.3 Rare Plants

One rare non-vascular species was found in the LSA during the rare plant surveys. The lichen, *Xanthoria fulva*, is ranked as an S1 species in Alberta and is on the provincial tracking list (Gould 2000). This species was found growing in the shelterbelt located along Township Road 560 on the northeast border of the Site (see Figure 3.4-5). In total, seven non-vascular species and 162 vascular species were observed during the rare plant surveys conducted in the LSA. Vascular species lists are provided in Appendix II and non-vascular species are listed in Appendix III.

3.4.3.1 <u>Rare Plant Potential</u>

Rare plant potential was determined for the entire RSA to include the native vegetation delineated along Lamont Creek in the eastern portion of the RSA. Appendix VI lists the rare plant species and their potential cover class associations.

3.4.3.1.1 Cover Class

The rare plant potential for each of the cover classes ranked from very low for the non-native deciduous shelterbelts in the RSA to high for the native grassland and native deciduous riparian area along Lamont Creek in the eastern portion of the RSA. The rough pasture and wetland located within the LSA ranked as moderate (see Table 3.4-2). No cover classes were ranked as having low potential to support rare plants.

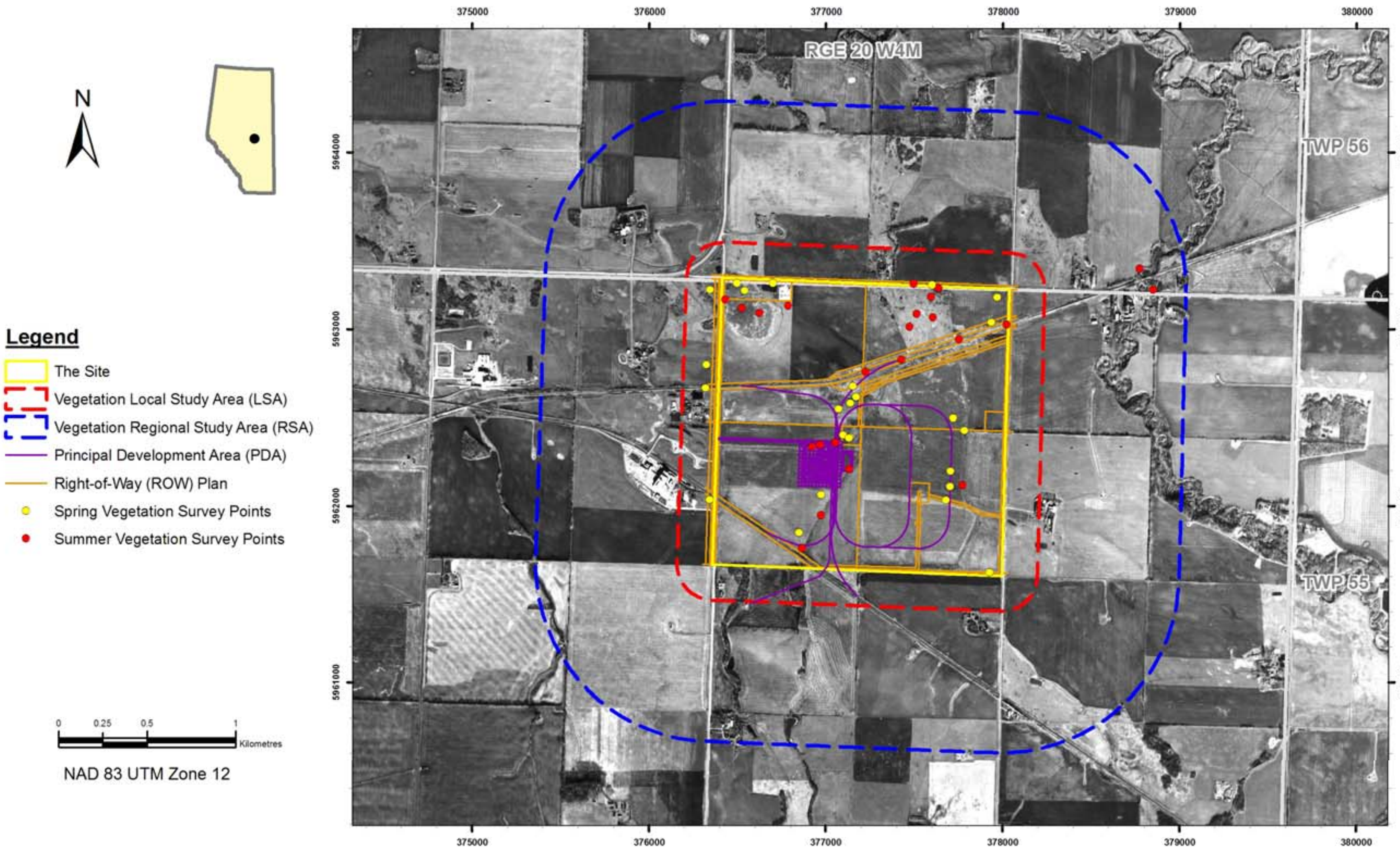

Figure 3.4-3: Vegetation Survey Points

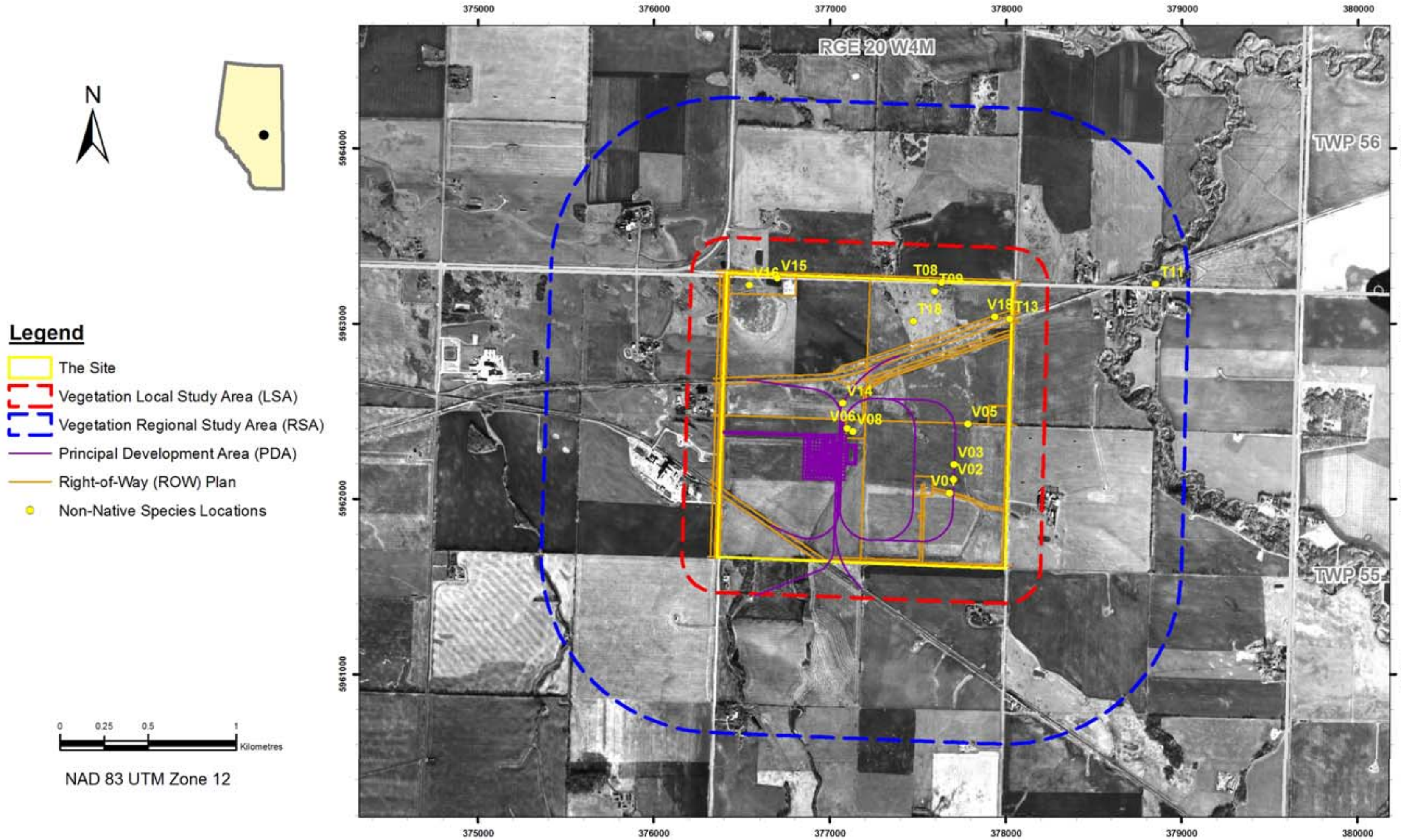

Figure 3.4-4: Location of Non-native and Invasive Species in the Vegetation LSA and RSA

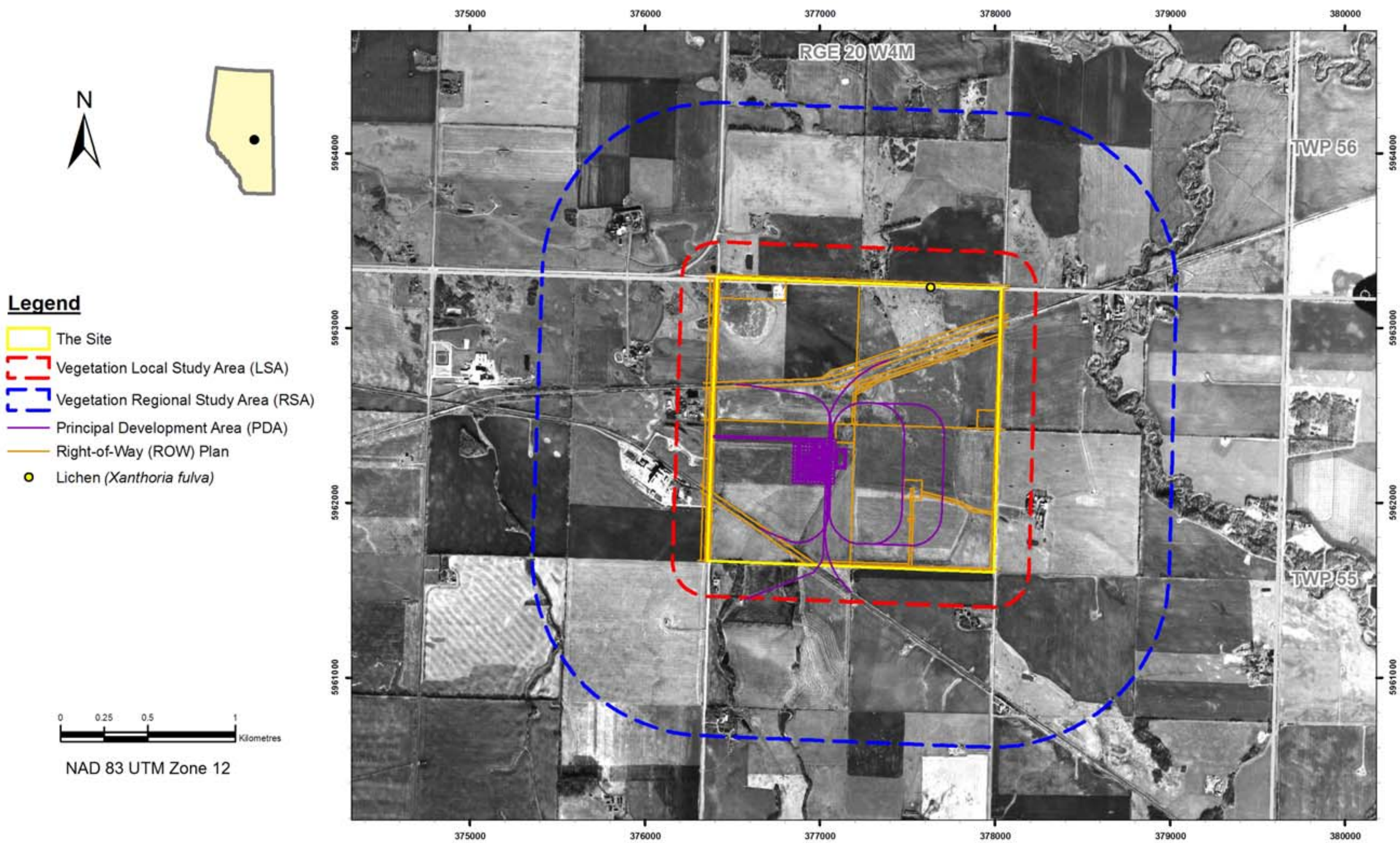

Figure 3.4-5: Location of Rare Plant Found in the Vegetation LSA

Table 3.4-2: Rare Plant Potential Rankings of Cover Classes in the RSA

Land Cover Class	Number of Potential Rare Plants	Ranking
AVI Agricultural		
CPR – rough pasture	20	Moderate
CPNVI Cover Class		
Deciduous – non-native deciduous	8	Very low
N_Decid – native deciduous	30	High
N_Grass – native grassland	39	High
WL– wetland (FONG)	26	Moderate

Although assigning rare plant potential to cover classes has been conducted in a number of current EIAs, there are several limitations to this approach. Some rare plants occur in specific habitats that correspond well to certain cover classes, while others are specific to microsites or substrates that can occur in a variety of cover classes (e.g., rocky calcareous outcrops). Other rare plants can have low habitat fidelity, or occur in a variety of habitats (Kershaw et al. 2001). Because of limited habitat information or lack of habitat fidelity for certain species, this method of ranking cover classes for rare plant potential might overestimate importance. A cover class where several rare plants could potentially occur could be ranked higher than a cover class where one rare plant is extremely likely to, or does, occur.

This ranking exercise is not a substitute for rare plant surveys and cannot definitively predict or rule out the presence of rare plants in a cover class.

Only cover classes with moderate to high potential to support rare plants were considered in this assessment. In the RSA, 90.8 ha are ranked as having moderate potential to support rare plants and 15.0 ha have high potential to support rare plants (see Table 3.4-3). Figure 3.4-6 shows the distribution of cover classes with moderate to high rare plant potential in the RSA.

Table 3.4-3: Cover Classes with Moderate to High Rare Plant Potential in the RSA at Baseline

Land Cover Class	Area (ha)	Area (%)
Moderate Potential		
CPR – rough pasture	71.6	5.8
WL – wetland (FONG)	19.2	1.6
Subtotal	90.8	7.4
High Potential		
N_Decid – native deciduous	4.8	0.4
N_Grass – native grassland	10.1	0.8
Subtotal	15.0	1.2
Total	**105.8**	**8.6**

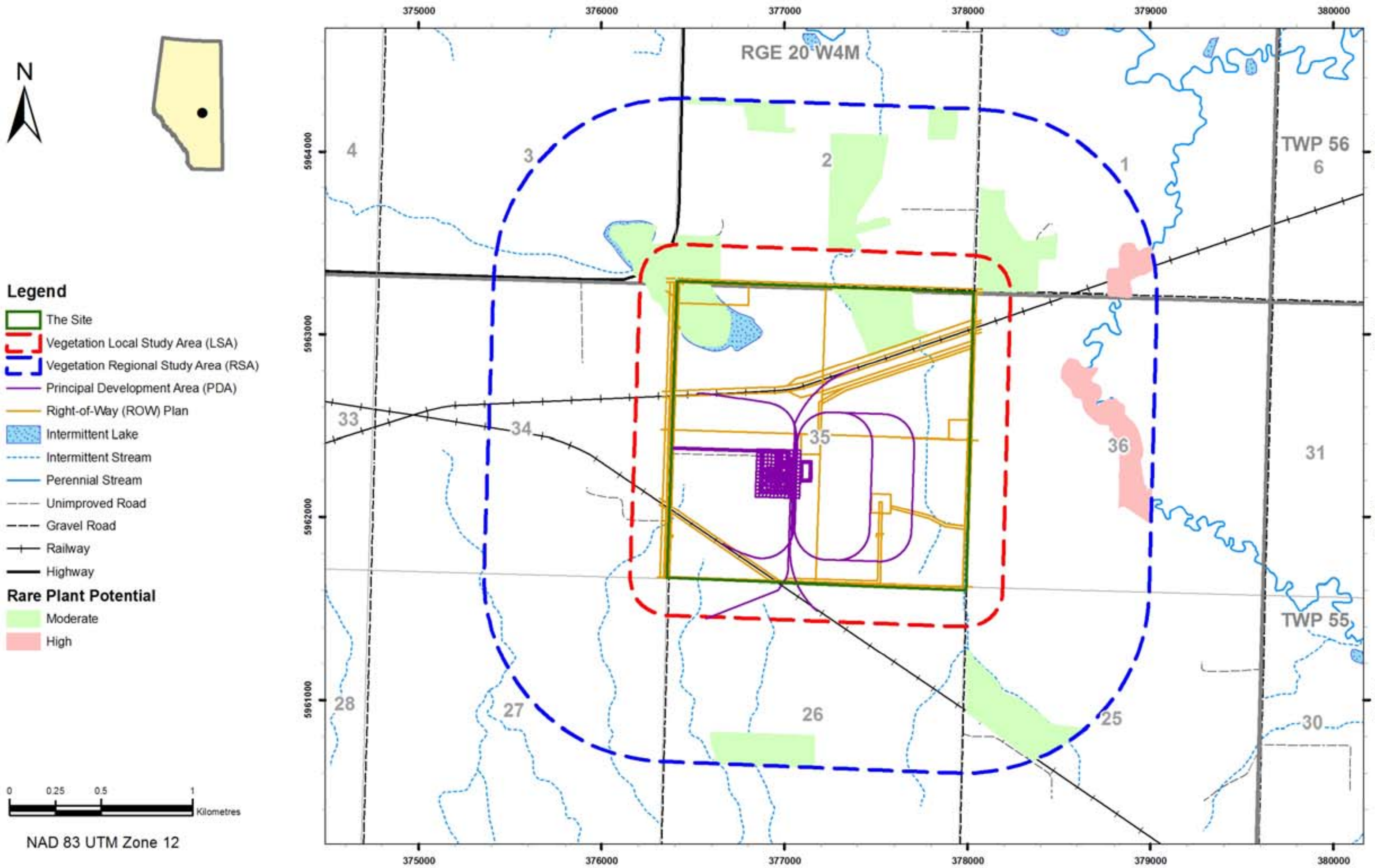

Figure 3.4-6: Cover Classes with Moderate to High Rare Plant Potential in the RSA

3.4.3.2 Plant Communities of Conservation Concern

The wetland, shelterbelts and rough pasture support a variety of different plant communities. Four alliance types and seven community associations were identified in the LSA, based on the field surveys conducted in 2006.

3.4.3.2.1 POPULUS BALSAMIFERA Forest/Woodland Alliance

***Populus balsamifera/Salix bebbiana – Salix maccalliana/Aster* spp.: Rank SU**

The shelterbelt located along the intermittent stream on the south end of the northeast side of the LSA is dominated by *Populus balsamifera*, *Salix bebbiana* and *S. maccalliana*. Various members of the Compositae form the herbaceous layer including *Solidago canadensis*, *Achillea millefolium* and members of the *Aster* genus. Several graminoid species are also present. Two noxious weeds, four nuisance weeds and eight non-native or agronomic invasive species are present within the shelterbelt. This community is not described by Wheatley and Bentz (2002) and is ranked as SU.

***Populus balsamifera/Cornus stolonifera – Rosa acicularis – Salix* spp./(Diverse herb understory): Rank SU**

The plant species composition in this shelterbelt located on the east side of the LSA north of the north rail line is similar to the *Populus tremuloides – Populus balsamifera/Cornus stolonifera – Rosa acicularis – Viburnum edule/Aralia nudicaulis* alliance in Wheatley and Bentz (2002). No *Populus tremuloides, Viburnum edule* or *Aralia nudicaulis* were observed during the surveys. Three noxious weeds, four nuisance weeds and three non-native or agronomic invasive species are present in this shelterbelt. This community type is ranked as SU.

3.4.3.2.2 POPULUS TREMULOIDES Forest/Woodland Alliance

***Populus tremuloides*/(sparse understory): Rank S5**

The north extension of the shelterbelt along the northeast portion of the LSA is dominated by *Populus tremuloides* with a sparse shrubby understory dominated by *Rosa acicularis*. One noxious weed and one nuisance weed are present.

In the middle of the LSA another shelterbelt runs parallel to the access road from R.R. 202. Young *Populus tremuloides* dominate the canopy. The understory is very sparse with a few herbs forming the ground cover. Two noxious weeds, two nuisance weeds and six non-native or agronomic invasive species are present in this shelterbelt.

This community type is described by Wheatley and Bentz (2002) and is ranked as S5.

***Populus tremuloides/Rosa acicularis – Rubus idaeus*: Rank S5**

The shelterbelt running parallel to Township Road 560 on the north border of the Site is dominated by *Populus tremuloides*. Diverse shrub and herb layers are present. Two noxious weeds, two nuisance weeds and three non-native or agronomic invasive species are also present. This community type is described by Wheatley and Bentz (2002) and is ranked as S5.

3.4.3.2.3 POPULUS TREMULOIDES – POPULUS BALSAMIFERA Forest/Woodland Alliance

***Populus tremuloides – Populus balsamifera/Salix* spp./(Diverse herb understory): Rank SU**

The shelterbelt located in the centre of the southern portion of the Site is dominated by *Populus balsamifera*. Several shrub species are present including *Salix bebbiana* and *S. exigua*, both indicative of wetter soils. Several herb species, including *Mentha arvense*, *Equisetum arvense*, *Ranunculus macounii* and *Rumex occidentalis* indicate wetter conditions as well. Three noxious weeds, six nuisance weeds and seven non-native or agronomic invasive species are present in this shelterbelt. This community is not described by Wheatley and Bentz (2002) and is ranked as SU.

3.4.3.2.4 CAREX AQUATILIS Semi-permanently Flooded Herbaceous Alliance

***Carex aquatilis – Carex utriculata*: Rank S4**

The graminoid dominated fen in the northwest corner of the LSA is a common fen type that occurs along the transition zones of wet meadows to open water. Two noxious weeds, three nuisance weeds and two non-native or agronomic invasive species are present in the wetland. This community is described by Wheatley and Bentz (2002) and is ranked S4 because it is not well documented in the provincial literature.

3.4.3.2.5 POA PRATENSIS Herbaceous Alliance

***Poa pratensis – Artemisia frigida*: Rank SU**

The rough pasture located towards the northeast corner of the LSA is dominated by *Poa pratensis*. Several invasive agronomic species and one noxious weed species are present. A range health assessment using the field worksheet for grasslands (Adams et al. 2005) was conducted to determine the range health of the rough pasture. A score of 42% was assessed indicating the rough pasture is unhealthy. The presence of four non-native or agronomic invasive species, one noxious weed and one nuisance weed, as well as evidence of soil erosion reduce the health of the pasture. No palatable grazing species were recorded in the pasture during the field surveys. This community is not described by Wheatley and Bentz (2002) and is ranked as SU.

Although 40 plant communities of conservation concern occur in the Parkland Natural Region (see Appendix VII), none were identified in the LSA during the 2006 rare plant surveys. As no plant communities of conservation concern have been identified, they are not discussed further in this section.

3.4.4 Vegetation Communities Sensitive to Potential Acid Input

Figure 3.4-7 shows the acid sensitivity rating of vegetation communities within the LSA. The majority of the LSA (67.9%) is rated as low to moderate acid sensitivity. This includes all of the annual and perennial croplands within the Site, portions of the west and north border and the entire east border located within the 200 m buffer zone surrounding the Site. The remaining area of the LSA is rated as low (13.6%) or moderate (7.0%). The vegetation communities rated as low sensitivity are the rough pasture north of the rail line and the wetland in the northwest corner of the LSA. A small amount of perennial cropland in the northeast corner of the LSA is also associated with low sensitivity soils. The annual and perennial cropland located along the west and south border of the LSA within the 200 m buffer zone are rated as moderately sensitivity. The disturbed area (11.5% of the LSA) was not rated and refers to industrial facilities, farmsteads and ROW located within the LSA.

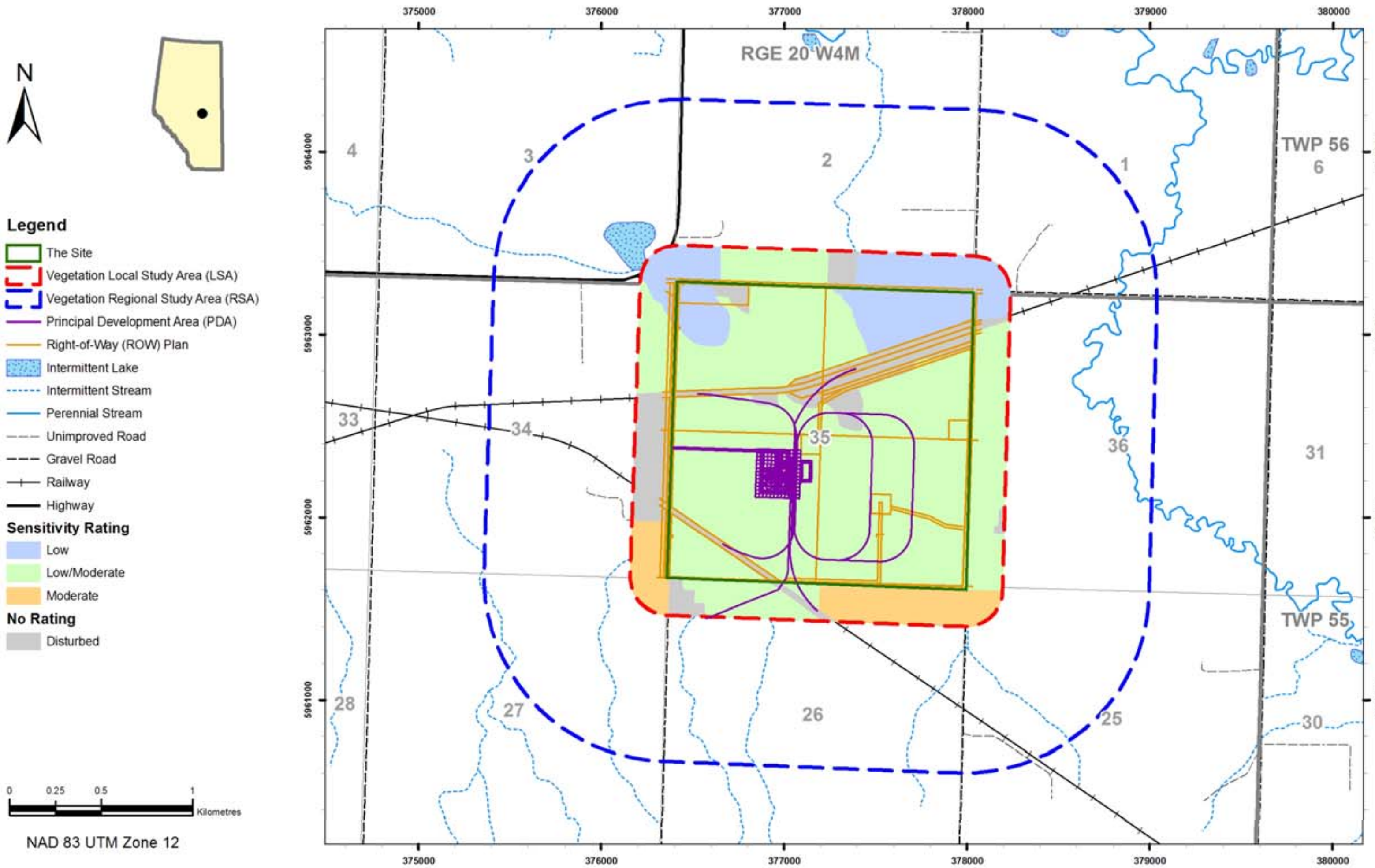

Figure 3.4-7: Vegetation Communities Sensitive to PAI in the LSA

3.5 Application Case

The application case assumed maximum disturbance, in which the sulphur forming and shipping facility is constructed and operated at a maximum production capacity of 6,000 t/d.

Residual impacts were measured at maximum disturbance in the application case and post-reclamation in the closure case, when all mitigation techniques have been implemented. Potential impacts of the Project on vegetation indicators were assessed for the application case and for closure, using the criteria of direction, geographic extent, magnitude, duration, reversibility and confidence were rated as Class 1, 2, 3 or 4 as described in Section 3.3.3. Resources that have residual impacts with a final impact rating of Class 1, 2 or 3 in the LSA were assessed for potential cumulative effects in the RSA if and where cumulative effects were expected.

3.5.1 Surface Disturbance

The surface disturbance, due to the construction and operation of the Project, is summarized in Table 3.5-1. The PDA covers 24.8 ha and will affect annual/perennial cropland within the LSA. All native vegetation classes in the LSA are common in the Central Parkland and the graminoid fen and rough pasture regions will not be affected by surface disturbance. No plant communities supporting moderate-to-high rare plant potential will be affected by surface disturbance (see Table 3.5-2).

The 24.8 ha of the Project will increase the area of ROW by 16.50 ha and industrial land cover by 6.24 ha. The runoff and fire water supply reservoir of the Project will cover 0.72 ha and the potential pipeline from the Scotsford Upgrader will cover 1.37 ha.

Table 3.5-1: Residual Impacts to AWI Wetland Classes and AVI Land Cover Classes at Application and Closure in the LSA

Land Cover Class	Baseline		Application			Closure		
	Area (ha)	% of LSA	Area (ha)	Change from Baseline		Area (ha)	Change from Baseline	
				(ha)	(%)		(ha)	(%)
AWI Wetland								
FONG – graminoid fen	14.66	3.60	14.66	0.0	0.0	14.66	0.0	0.0
AVI Agricultural								
CA/CP – annual/perennial crop	328.04	80.52	303.21	-24.83	-4.93	328.04	0.0	0.0
CRP – rough pasture	17.65	4.33	17.65	0.0	0.0	17.65	0.0	0.0
AVI Anthropogenic non-vegetated								
AIF – farmstead	7.80	1.91	7.80	0.0	0.0	7.80	0.0	0.0
AIH – ROW	24.46	6.00	40.96	16.50	2.90	24.46	0.0	0.0
AII – industrial	14.77	3.63	21.01	6.24	1.53	14.77	0.0	0.0
AIW – water reservoir, dugout	0.0	0.0	0.72	0.72	0.18	0.0	0.0	0.0
CIP – pipeline	0.0	0.0	1.37	1.37	0.34	0.0	0.0	0.0
Total	**407.38**	**100.00**	**407.38**	**0.0**	**0.0**	**407.38**	**0.0**	**0.0**

Table 3.5-2: Residual Impacts to Cover Classes with Moderate to High Rare Plant Potential at Application and Closure in the RSA

Land Cover Class	Baseline		Application			Closure		
	Area (ha)	% of RSA	Area (ha)	Change from Baseline		Area (ha)	Change from Baseline	
				(ha)	(%)		(ha)	(%)
Moderate Potential								
CRP – rough pasture	71.60	5.82	71.60	0.0	0.0	71.60	0.0	0.0
FONG – graminoid fen	19.20	1.56	19.20	0.0	0.0	19.20	0.0	0.0
High Potential								
N_Decid – native deciduous	4.80	0.39	4.80	0.0	0.0	4.80	0.0	0.0
N_Grass – native grassland	10.14	0.82	10.14	0.0	0.0	10.14	0.0	0.0
Total	**105.76**	**8.6**	**105.76**	**0.0**	**0.0**	**105.76**	**0.0**	**0.0**

3.5.1.1 ***Mitigation***

Mitigation implemented by AST is in keeping with the principle of adaptive management. The location of the Project within the Site was selected based on the economic, environmental and Project criteria given in Volume I: Project Description – Section 3.1.2. The Site is located within the Alberta Industrial Heartland and both CPR and CN rail lines run through the Site minimizing disturbance that would otherwise be required to establish rail access to the Site. The Site is zoned for Heavy Industrial Use within Lamont County and the Alberta Industrial Heartland. It possesses natural containment and alkaline buffering capacity which will effectively reduce the potential for environmental impacts associated with sulphur forming and shipping activities.

The use of a previously disturbed area for the Project reduces the amount of new clearing and avoids disturbing sensitive vegetation and wetlands.

3.5.1.2 ***Residual Impacts at Application and Closure***

At application, the direction of the surface disturbance impacts to annual/perennial cropland is negative, is confined to the PDA and considered to be low to moderate in magnitude. The duration of the impact is considered mid-term as this impact will occur during the lifespan of the sulphur forming facility estimated to be 25 years. The impact of the surface disturbance is considered reversible as it is assumed that through reclamation, the cropland will return to baseline conditions. The confidence in this impact prediction is high as the relationship between surface disturbance and vegetation loss is self-evident. This is a Class 3 impact.

At closure, all facilities and infrastructure will be removed and the surface disturbance will be reclaimed. The impact at closure will be neutral in direction and confidence in this prediction is high. This is a Class 4 impact.

3.5.2 Dust Deposition

The maximum elemental sulphur dust emissions expected to be released are predicted to be 1.11 kg/ha/y (see Volume IIA, Section 2: Climate and Air Quality).

3.5.2.1 *Mitigation*

A dust suppression management plan is outlined in Volume 1: Project Description – Section 3.6. A proprietary dust suppression agent and release aid will be used to suppress dust on the sulphur pastille storage pad, transfer points and rail load-out area. Dust suppression agents will be applied at the load-out hopper and at the rail load-out. The agents will be stored in make-up tanks and delivered via pump.

The usage rates of the dust suppression agents are estimated to be less than 100 kg/d during initial operations, increasing to less than 200 kg/d for full-scale operations. The actual amounts used will depend on the size of the trains being loaded and the conveyor size. Dustbind S5 will be applied at the transfer points and IPAC SRB Plus will be applied at each individual Rotoformer.

3.5.2.2 *Residual Impacts at Application and Closure*

At application, the impact of the dust deposition on vegetation and wetland resources is negative, is confined to the LSA and considered to be low to moderate in magnitude. Dust deposition on leaf surfaces may interfere with photosynthesis by clogging stomata and preventing gas exchange (Treshow 1978). Fugitive sulphur dust deposition due to elemental sulphur granulation and processing which was started in 1979 was measured at a sour gas facility in west central Alberta over five years from 1981–1985 (Mayo et al 1992). The amount of dust deposition varied with distance from the facility according to prevailing winds ranging from 4,297 kg/ha/y at 0.5 km to 5.2 kg/ha/y at 5.0 km. Studies on the plant communities within the sulphur deposition zones indicated that mosses were the plant type most susceptible to elemental sulphur (Kennedy et al 1985) and that reduced growth observed in pine close to the facility may be caused by chronic exposure to sulphur dust particles. The cell wall properties in *Pinus contorta x Pinus banksiana* were chemically altered which may represent an osmotic adjustment to general environmental stress caused by chronic exposure to S-gas emissions and S-dust deposition. The annual sulphur deposition estimated for the Project of 1.11 kg/ha/y is much lower than the deposition rates in the zones which impacted plant communities at the sour gas facility in west central Alberta.

The duration of the impact is considered mid-term as this impact will occur during the operational lifespan of the sulphur forming and shipping facility. The impact of the dust deposition is considered reversible as mitigation techniques will be implemented to reduce or prevent dust deposition. The confidence in this impact prediction is moderate because there is a lack of directly applicable data that indicates how much dust deposition will occur and what effects the dust will have on the vegetation and wetland resources. This is a Class 3 impact.

At closure, all facilities and infrastructure will be removed and dust deposition on vegetation and wetland resources will no longer occur. The direction of this impact is neutral and the confidence in this prediction is moderate. This will be a Class 4 impact.

3.5.3 Contaminant Spills

Spills of degassed liquid sulphur from the aboveground storage tanks, shipping containers or pipelines could directly affect vegetation through physical damage. Spills of liquid sulphur will be readily apparent as the sulphur will solidify immediately. Spills of sulphur pastilles may occur during loading the product for storage or shipping. Cleanup would involve removal of the solid sulphur and implementation of a monitoring program to determine the effects on the vegetation.

3.5.3.1 Mitigation

The management plan for chemical storage in the PDA is outlined in Volume I: Project Description – Section 3.7.1.

All storage facilities will comply with the requirements of EUB Guide 55 and AENV guidelines for the containment of potentially hazardous materials. All liquid products will be stored in steel tanks that include double-containment and leak detection monitoring. Liquid products will be managed and applied in enclosed systems with minimum opportunity for accidental release to the environment. None of these products are expected to contain substances that are *Canadian Environmental Protection Act* (CEPA) toxics, Accelerated Reduction/Elimination of Toxics (ARET), Track 1, or on the National Pollutant Release Inventory (NPRI).

The asphalt storage pad for sulphur pastilles will include primary asphalt containment, a secondary clay soil liner, runoff and run-on controls and a leak detection layer.

The leak detection monitoring plan is outlined in Volume I: Project Description – Section 5.5. Leak detection monitoring will be implemented for the surface water runoff collection pond and asphalt stockpile pad to assess potential leakage relative to an action leakage rate (ALR), which is defined in Volume I: Project Description – Section 5.5. Leak detection monitoring will be implemented monthly until the integrity of the primary liners is confirmed, after which the monitoring frequency will be reduced to twice yearly.

3.5.3.2 Residual Impacts at Application and Closure

At application, the impact of degassed liquid sulphur and sulphur pastille spills on vegetation and wetland resources is negative, is confined to the PDA and considered to be low to moderate in magnitude. The duration of the impact is considered mid-term as this impact will occur during the operational lifespan of the sulphur forming and shipping facility. The impact of the spills is considered reversible as mitigation techniques will be implemented to reduce or prevent spills. The confidence in this impact prediction is moderate because there is a lack of directly applicable data that indicates how much degassed liquid sulphur or sulphur pastilles will be spilled and what effects the spills will have on the vegetation and wetland resources. This is a Class 3 impact.

At closure, all facilities and infrastructure will be removed and spills will no longer occur. The direction of this impact is neutral and the confidence in this prediction is moderate. This will be a Class 4 impact.

3.5.4 Introduction of Non-native and Invasive Species

Five noxious weeds, eleven nuisance weeds and eleven non-native or agronomic invasive species were identified near the PDA and on existing disturbances (e.g., ROW, croplands, pasture) during the baseline field surveys. Construction, operation and decommissioning of the Bruderheim Sulphur Forming and Shipping Facility will create disturbances where these species could take hold and proliferate. Using the mitigation measures outlined in Section 3.5.4.1 will help reduce the potential for any new non-native and invasive species to become established within the LSA.

3.5.4.1 *Mitigation*

The following mitigation practices for control of non-native and invasive species should be implemented by AST, where practical or as otherwise required:

- coordination of weed management with CN Rail, CPR and the utility substation operator to control non-native and invasive species currently present on the Site
- construction equipment for rail, pipeline and facility construction should be cleaned before entering the Site
- control of non-native and invasive species infestations should use a combination approach of mechanical and chemical (i.e., herbicide) methods
- control of non-native and invasive species should continue following reclamation and revegetation

3.5.4.2 *Residual Impacts at Application and Closure*

At application, the impact of the introduction of additional non-native and invasive species on vegetation and wetland resources is negative in direction, local in extent and considered to be negligible in magnitude. The duration of the impact is considered short-term and reversible as the suggested mitigation measures can effectively control weed infestations. The confidence in this impact prediction is high. This is a Class 3 impact.

At closure, all facilities and infrastructure will be removed and reclamation and revegetation will occur with respect to the Project. No new potential for the introduction of non-native and invasive species will occur. The application of mitigation measures will continue to control the establishment and spread of non-native and invasive species after the closure of the sulphur forming and shipping facility. The direction of this impact is neutral and the confidence in this prediction is high. This will be a Class 4 impact.

3.5.5 Air Emissions

The emissions of H_2S, SO_2 and NO_2 from the sulphur forming and shipping facility are predicted to be well below ambient air quality objectives in Volume IIA, Section 2: Climate and Air Quality. The impacts of the individual emissions were not assessed based on this data. The PAI from the sulphur forming and shipping facility due to fugitive elemental sulphur emissions are not expected to alter the acid sensitivity of the vegetation communities in the LSA based on the soil sensitivity ratings determined at baseline.

3.5.5.1 *Mitigation*

AST has committed to several management practices to minimize the impacts of air emissions from the sulphur forming and shipping facility outline in Volume I: Project Description – Section 3.6 which were summarized under Dust Deposition above (see Section 3.5.2).

3.5.5.2 *Residual Impacts at Application and Closure*

At application, PAI impacts on vegetation and wetland resources are predicted to be negative in direction, local in extent and low to moderate in magnitude. The duration of the impact is considered mid-term and reversible as the suggested mitigation measures can effectively neutralize acidification. The confidence in this impact prediction is moderate. This is a Class 3 impact.

At closure, the facilities and infrastructure will not generate any further PAI. The impact is neutral and confidence is moderate. This is a Class 4 impact.

3.6 Cumulative Effects Case

Cumulative effects are evaluated on a regional scale and are only assessed when the application case impact is classified as Class 1, 2 or 3. Impacts of such classes were identified for surface disturbance, dust deposition, contaminant spills, non-native and invasive species and air emissions, however; a cumulative effects assessment was not conducted because the impacts were determined to be local in geographic extent and reversible.

The impacts of PAI in the EIA study area are discussed in the cumulative effects case in Volume IIA, Section 2: Climate and Air Quality section of this EIA.

3.7 Monitoring and Adaptive Management

Vegetation monitoring will focus on shelterbelt, rough pasture and wetland habitats to quantify the potential effects of dust deposition on vegetation. The rare lichen, *Xanthoria fulva*, found in the northeast shelterbelt should be monitored to identify any potential impacts to the lichen community due to dust deposition. The potential introduction of non-native and invasive species into the LSA should be monitored annually. The PDA, including stockpiled soil, should be monitored by AST over the operational lifespan of the sulphur forming and shipping facility for non-native and invasive species.

AST will endeavour to incorporate new, innovative reclamation technology into its reclamation plans as the technology becomes available. In addition, AST is an Associate Member of the Northeast Capital Industrial Association (NCIA), which automatically involves partnership and participation in the Fort Air Partnership. The NCIA is a not-for-profit cooperative in northeast Alberta that seeks to understand and reduce the environmental impacts of member industries through collaborative efforts with the community and all levels of government while supporting sustainable industrial growth.

3.8 Summary

In the LSA, the Project will affect vegetation and wetland resources primarily through surface disturbance. The Project-specific impacts in the application case of surface disturbance to vegetation and wetland resources will be local in extent, mid-term in duration and low to moderate in magnitude. The direction of impacts is negative and the confidence in these predictions is high. The overall impact rating class from the Project-specific surface disturbance is Class 3. Impacts of dust deposition, contaminant spills and introduction of non-native and invasive species are also considered at a local scale. They are negative in direction, low to moderate or negligible in magnitude, short- to mid-term in duration, reversible and considered to be Class 3 impacts. Table 3.8-1 summarizes the Project-specific impacts in the application case to vegetation and wetland resources in the LSA.

Table 3.8-1: Final Impact Rating Summary Table for the Application Case

Impact	Geographic Extent	Magnitude	Direction	Duration	Reversibility	Confidence	Rating
Surface disturbance	Local	Low to moderate	Negative	Mid-term	Reversible	High	3
Dust deposition	Local	Low to moderate	Negative	Mid-term	Reversible	Moderate	3
Contaminant spills	Local	Low to moderate	Negative	Mid-term	Reversible	Moderate	3
Introduction of non-native and invasive species	Local	Negligible	Negative	Short-term	Reversible	High	3
Air emissions	Local	Low to moderate	Negative	Mid-term	Reversible	Moderate	3

At closure, residual impacts of surface disturbance, dust deposition, contaminant spills, the introduction of non-native and invasive species and air emissions are considered to be neutral in direction. The confidence in these predictions is moderate to high. The overall impact ratings are considered to be Class 4.

A cumulative effects assessment was not conducted for surface disturbance, dust deposition, contaminant spills or the introduction of non-native and invasive species. The results of the air emissions cumulative effects assessment are reported in Volume IIA, Section 2: Climate and Air Quality section of this EIA.

3.9 References

3.9.1 Literature Cited

Adams, B.W., G. Ehlert, C. Stone, D. Lawrence, M. Alexander, M. Willoughby, C. Hincz, D. Moisey, A. Burkenshaw and J. Carlson. 2005. *Rangeland Health Assessment for Grassland, Forest and Tame Pasture.* Alberta Sustainable Resource Development, Public Lands and Forests Division, Rangeland Management Branch. Edmonton, AB.

Alberta Agriculture Food and Rural Development (AAF). 1999. *Weed Control for Alberta Shelterbelts*. Edmonton, AB.

Alberta Environment (AENV). 2007. *Final Terms of Reference, Environmental Impact Assessment (EIA) Report for the Proposed Bruderheim Sulphur Forming and Shipping Facility.* March 13, 2007, Alberta Environment, Edmonton, AB.

Alberta Environmental Protection (AEP). 1993. *Alberta Plants and Fungi – Master species list and species group checklists*. Alberta Environmental Protection Publication No. Ref. 74. Edmonton, AB.

Alberta Environmental Protection (AEP). 1997. *Alberta Vegetation Inventory Standards Manual – Version 2.2.* Resource Data Division.

Alberta Sustainable Resource Development (ASRD). 2003. *Central Parkland Native Vegetation Inventory – Version 1.2*. Resource Information Management Branch.

Allen, L. 2006. *Alberta Natural Heritage Information Centre Preliminary Plant Community Tracking List*. Alberta Community Development. Edmonton, AB.

Belcher, J.W. and S.D. Wilson. 1989. Leafy spurge and the composition of a mixed-grass prairie. *Range Manage* 42:172-175.

Canadian Environmental Assessment Act, [S.C. 1992, c. 37]

Clean Air Strategic Alliance (CASA). 1996. *Final Report of the Target Loading Subgroup on Critical and Target Loading in Alberta*. Prepared by Target Loading Subgroup, Edmonton, AB.

Clean Air Strategic Alliance (CASA). 1999. *Application of critical, target and monitoring loads for the evaluation and management of acid deposition*. Prepared by Target Loading Subgroup, Edmonton, AB.

Conti, M.E. and Cecchetti, G. 2001. Biological monitoring: lichens as bioindicators of air pollution assessment — a review. *Environmental Pollution* 114: 471-492.

DM Leahey & Associates Limited and Jacques Whitford Limited (Leahey and Whitford). 2005. *An Assessment of Air Quality Impacts Associated with Operations at the Proposed HAZCO Bruderheim Sulphur Forming Facility.* Report prepared for HAZCO Environmental Services Ltd.

Gould, J. 2006. *Alberta Natural Heritage Information Centre Tracking and Watch lists – Vascular Plants, Mosses, Liverworts and Hornworts*. Alberta Community Development, Parks and Protected Areas Division. Edmonton, AB.

Halsey, L. and D.H. Vitt. 1997. Alberta Wetland Inventory Standards – Version 1.0. In: *Alberta Vegetation Inventory Standards Manual*. R. Nesby. 1997. Alberta Environmental Protection. Resource Data Division. Edmonton, AB.

Howald, A.M. 1992. *Wildland Weeds: An overview of the weed problem in wildlands management and restoration*. In: Proceedings of the 44th Annual California Weed Conference. Freemont, CA.

Kennedy, K.A., P.A. Addison and D.G. Maynard. 1985. Effect of Particulate Elemental Sulphur on Moss. Environmental Pollution (Series A) 39: 71-77.

Kershaw, L., J. Gould, D. Johnson and J. Lancaster. 2001. *Rare Vascular Plants of Alberta*. Edmonton, AB: University of Alberta Press.

Krebs. C.J. 1978. *Ecology: The experimental analysis of distribution and abundance* (2nd edition). New York, NY: Harper and Row Publishers.

Lancaster, J. 2000. *Guidelines for Rare Plant Surveys*. Alberta Native Plant Council, Edmonton, AB.

Mayo, J.M., A.H. Legge, E.C. Yeung, S.V. Krupa and J.C. Bogner. 1992. The Effects of Sulphur Gas and Elemental Sulphur Dust Deposition on *Pinus contorta x Pinus banksiana*: cell walls and water relations. Environmental Pollution 76: 43-50.

Moss, E.H. 1983. *Flora of Alberta*. 2nd Edition (Revised by J.G. Packer). Toronto, ON. University of Toronto Press.

Native Plant Working Group. 2001. *Native Plant Revegetation Guidelines for Alberta*. H. Sinton-Gerling (Ed.), Alberta Agriculture, Food and Rural Development and Alberta Environment. Edmonton, AB.

Natural Regions Committee (NRC). 2006. *Natural Regions and Subregions of Alberta*. Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. I/005.

Odum. E.P. 1975. *Ecology*. New York: Holt, Rinehart and Wilson.

Onianwa, P.C. 2001. Monitoring Atmospheric Metal Pollution: A Review of the Use of Mosses as Indicators. *Environmental Monitoring and Assessment* 71: 13-50.

Sakai, A.K., F.W. Allendorf, J.S. Holt, D.M. Lodge, J. Molofsky, K.A. With, S. Baughman, R.J Cabin, J.E. Cohen, N.C. Ellstrand, D.E. McCauley. P. O'Neil, I.M. Parker, J.N. Thompson and S.G. Weller. 2001. The population biology of invasive species. *Annual Rev. Ecol. Syst.* 32:305-332.

Tikka, P.M., H. Hogmander and P. Koski. 2001. Road and railway verges serve as dispersal corridors for grassland plants. *Landscape Ecol.* 16:659-666.

Treshow, M. 1978. Terrestrial Plants and Plant Communities. In: G.C. Butler (Ed.), Principles of Ecotoxicology. Chichester, New York: John Wiley & Sons.

Vitousek, P.M., C.M. D'Antonio, L.M. Loope and R. Westbrooks. 1996. Biological invasions as global environmental change. *American Scientist* 84:468-478.

Wheatley, M. and J. Bentz. 2002. *A preliminary classification of plant communities in the Central Parkland natural sub-region of Alberta*. Prepared for Alberta Sustainable Resource Development, Public Lands Division. Geowest Environmental Consultants Ltd. Edmonton, AB.

World Health Organization (WHO). 2000. *Air Quality Guidelines for Europe* (2nd Edition). World Health Organization Regional Office for Europe, Copenhagen. Copenhagen, Denmark. WHO Regional Publications, European Series, No. 91.

Zink, T.A., M.F. Allen, B. Heindl-Tenhunen and E.B. Allen. 1995. The effect of a disturbance corridor on an ecological reserve. *Restor. Ecol.* 3:304-310.

3.9.2 Personal Communication

Allen, Linda. Senior Community Ecologist. Alberta Natural Heritage Information Centre. Edmonton, AB. E-mail correspondence. June 2007.

Rintoul, John. Coordinator. Alberta Natural Heritage Information Centre. Edmonton, AB. E-mail correspondence. June 2006.

3.9.3 Internet Sites

Alberta Agriculture. 2001. Weed Designation Regulation – Weed Control Act. Available at: http://www.agric.gov.ab.ca/ministry/acts/weeds.html. Accessed November 2006.

Alberta Agriculture and Food (AAF). 2001. Field Shelterbelts for Soil Conservation. Available at: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex2073. Accessed February 2007.

Alberta Native Plant Council (ANPC). 2006. Plant Collection Guidelines for Researchers, Students and Consultants. Available at: http://www.anpc.ab.ca/. Accessed June 2006.

COSEWIC. 2006. About COSEWIC: COSEWIC and the Species at Risk Act. Available at: http://www.cosewic.gc.ca/eng/sct6/sct6_6_e.cfm. Accessed May 2006.

Haber, E. 2002. Impact of invasive plants on species and habitats at risk in Canada. Available at: http://infoweb.magi.com/~ehaber/imapct.html. Accessed: September 2006.

Prairie Farm Rehabilitation Administration (PFRA). 2006. PFRA Shelterbelt Centre. Available at: http://www.agr.gc.ca/pfra/shelterbelt_e.htm. Accessed February 2007.

White, D.J. and E. Haber. 2002. Invasive plants and their biology, impact and control options. Environment Canada. Available at: http://www.cws-scf.ec.gc.ca/publications/inv.html. Accessed September 2006.

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Appendix I: Cover Class Descriptions

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1. Ecodistricts in the Regional Study Area

Alberta is divided into 17 Ecoregions based on distinctive ecological responses to climate as expressed by the development of vegetation, soil, water and fauna, among other variables (Wiken 1986). These Ecoregions are further divided into 136 Ecodistricts characterised by distinctive assemblages of relief, geology, landforms, soils, vegetation, water and fauna (Ecological Stratification Working Group 1995).

The first consideration for delineation of Ecodistricts is regional climate as expressed by vegetation, while the more stable and identifiable local material, landforms and soils are used to define map delineations. To make the Ecodistrict map as useful as possible Ecodistricts also reflect land use patterns and they are given an Agroclimate rating that represents their limitations for spring-seeded small grain production (Nyirfa and Harron 2001).

The Regional Study Area (RSA) is comprised of two Ecodistricts, the Leduc Plain Ecodistrict and the Daysland Plain Ecodistrict. Information characterizing these Ecodistricts was obtained from the Canada – Alberta Environmentally Sustainable Agriculture: Soil Inventory Project Procedures Manual (CAESA Soil Inventory Working Group 1998)

1.1 The Leduc Plain Ecodistrict

The Leduc Plain Ecodistrict is characterized by predominantly undulating terrain with level and hummocky areas. Soils are Black with Solodized Solonetz soils appearing less frequently. Soil texture is equally Loamy and Clayey with smaller amounts of sandy texture present. The Agroclimate of this Ecodistrict predicts a slight temperature or heat units limitation for production of spring-seeded small grain crops.

1.2 The Daysland Plain Ecodistrict

The Daysland Plain Ecodistrict is characterized by undulating terrain and roughly equal areas of Black and Solodized Solonetz soils. Soil texture is Loamy to Clay-loamy and the Agroclimate is classified as having slight limitations, due to temperature or heat units and moisture or aridity, for production of spring-seeded small grain crops.

2. Cover Class Codes used in the RSA

2.1 Central Parkland Native Vegetation Inventory Codes

Alberta Sustainable Resource Development (ASRD) created the Central Parkland Native Vegetation Inventory for the purpose of developing a comprehensive current vegetation/landuse database for the Central Parkland natural subregion of Alberta indicating native verses agricultural land, public verses private ownership and details of the native landbase (ASRD 2006).

The following Central Parkland Native Vegetation Inventory Code descriptions are from a MetaXpress Report prepared by the Resource Information Management Branch (SRD 2006) and Natural Regions and Subregions of Alberta (NRC 2006):

- Decid – Non-Native Deciduous

  Non-native aspen dominated areas with balsam poplar also present.

- N_Decid – Native Deciduous

  Native aspen dominated areas with balsam poplar also present. The understory can include saskatoon, prickly rose, beaked hazelnut, hay sedge and creeping juniper.

- N_Grass – Native Grassland

  Native grassland communities that may include western porcupine grass, June grass, needle-and-thread, blue grama, dryland sedges and pasture sagewort in dryer areas and may include plains rough fescue and slender wheat grass in wetter areas.

- WL – Wetland

  Recurring lake or potential basin interpreted from hydrography updates. Vegetated wetlands include treed fens with black spruce, white spruce, Labrador tea and feather moss as well as willow shrublands, cattail, sedge and bulrush marshes.

2.2 Alberta Vegetation Inventory Anthropogenic Cover Classes

In response to the need for an integrated, comprehensive approach to vegetation information, Alberta Environmental Protection (AENV) initiated the Alberta Vegetation Inventory (AVI) for high priority areas in the White Area in September 1987. The AVI has since been expanded to include an inventory of the provinces Green Area (AENV 1991).

The following AVI cover classes are from the AVI Standard Manual (AEP 1991):

- CA – Annual Crops

  Cultivated farmland or farmland planted with annual crop species.

- CP – Perennial Crops

  Reclaimed lands, farmland planted with cultivated grasses and/or legumes. These lands are used primarily for grazing livestock and/or may have the cultivated species harvested at least once a year. These lands contain <10% crown closure of woody cover (shrubs). These lands also include pastures that have been irrigated or otherwise treated to improve their productivity.

- CPR – Rough Pasture

  Similar to improved pasture with > 10% woody cover. Normally, this pasture has not been irrigated, fertilized or cultivated to improve productivity.

- AIH – Rights-Of-Way

  Permanent right of way; roads, highways, railroads, dam sites and reservoirs.

- AIF – Farmstead

  Farmsteads related to agriculture.

- AII – Industrial

  Plant sites including sewage lagoons.

3. References

3.1 Literature Cited

Alberta Environmental Protection (AENV). 1991. *Alberta Vegetation Inventory Standards Manual Version 2.1*. Edmonton, AB.

Alberta Sustainable Resource Development (ASRD). 2006. *MetaXpress Report – Central Parkland Native Vegetation Inventory Version 1.2*. Resource Information Management Branch. Red Deer, AB.

Ecological Stratification Working Group. 1995. *A National Ecological Framework for Canada.* Agriculture and Agri-Food Canada Research Branch, Centre for Land and Biological Research; and Environment Canada State of Environment Directorate, Ecozone Analysis Branch. Ottawa, ON.

Natural Regions Committee. 2006. *Natural Regions and Subregions of Alberta.* Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. T/852.

Nyirfa, W.N. and B. Harron. 2001. *Assessment of Climate on the Agricultural Resources of the Canadian Prairies.* Prairie Farm Rehabilitation Administration. Regina, SK.

Wiken, E. 1986. *Terrestrial Ecozones of Canada.* Ecological Land Classification Series No. 19. Land Directorate, Environment Canada. Ottawa, ON.

3.2 Internet Sites

CAESA-SIWG (CAESA Soil Inventory Working Group). 1998. CAESA soil inventory project procedures manual. Edited by W.L. Nikiforuk, SLRI Consultants Limited. Alberta Agriculture, Food and Rural Development, Edmonton, AB. Also available at URL: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag6170?opendocument#preface [Oct 31, 2005].

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Appendix II: Vascular Plant Species List

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Table II–1: Vascular Plant Species List for the LSA

Scientific Name	Common Name
Achillea millefolium L.	Common yarrow
Achillea sibirica Ledeb.	Many-flowered yarrow
Actaea rubra (Ait.) Willd.	Red and white baneberry
Agropyron repens (L.) Beauv.	Quack grass
Agropyron smithii Rydb.	Western wheat grass
Agropyron trachycaulum var. *unilaterale* (Cassidy) Malte	Bearded wheat grass
Agrostis scabra Willd.	Rough hair grass
Amelanchier alnifolia Nutt.	Saskatoon
Anemone canadensis L.	Canada anemone
Anemone multifida Poir	Cut-leaved anemone
Anemone riparia Fern.	Tall anemone
Antennaria neglecta Greene	Broad-leaved everlasting
Antennaria parvifolia Nutt.	Small-leaved everlasting
Artemisa frigida Willd.	Pasture sagewort
Artemisia absinthium L.	Absinthe wormwood
Artemisia campestris L.	Plains wormwood
Artemisia ludoviciana Nutt.	Prairie sagewort
Aster ciliolatus Lindl.	Lindley's aster
Aster conspicuus Lindl.	Showy aster
Aster laevis L.	Smooth aster
Aster species	Aster
Astragalus alpinus L.	Alpine milk vetch
Beckmannia syzigachne (Steud.) Fern.	Slough grass
Betula papyrifera Marsh.	White birch
Bidens cernua L.	Nodding beggarticks
Bromus inermis Leyss.	Awnless brome
Bromus tectorum L.	Downy chess
Calamagrostis canadensis (Michx.) Beauv.	Bluejoint
Calamagrostis stricta (Timm) Koeler	Narrow reed grass
Carex aquatilis Wahlenb.	Water sedge
Carex atherodes Spreng.	Awned sedge
Carex bebbii Olney ex Fern.	Bebb's sedge
Carex lanuginosa Michx.	Woolly sedge

Table II–1: Vascular Plant Species List for the LSA (Cont'd)

Scientific Name	Common Name
Carex sartwellii Dewey	Sartwell's sedge
Carex species	Sedge
Cerastium arvense L.	Field mouse-ear chickweed
Chenopodium album L.	Lamb's-quarters
Cicuta maculata L.	Water-hemlock
Cirsium arvense (L.) Scop.	Canada thistle
Collomia linearis Nutt.	Narrow-leaved collomia
Cornus canadensis L.	Bunchberry
Cornus stolonifera Michx.	Red-osier dogwood
Corydalis sempercirens (L.) Pers.	Pink corydalis
Crepis tectorum L.	Annual hawk's-beard
Distichlis stricta (Torr.) Rydb.	Salt grass
Eleocharis palustris (L.) R. & S.	Creeping spike rush
Eleocharis species	Spike-rush
Epilobium angustifolium L.	Common fireweed
Epilobium species	Willowherb
Equisetum arvense L.	Common horsetail
Equisetum pratense Ehrh.	Meadow horsetail
Erigeron glabellus Nutt.	Smooth fleabane
Erigeron lonchophyllus Hook.	Hirsute fleabane
Erigeron philadelphicus L.	Philadelphis fleabane
Erysium species	Mustard
Euphorbia glyptosperma Engelm.	Ridge-seeded spurge
Fragaria virginiana Duchesne	Wild strawberry
Galeopsis tetrahit L.	Hemp-nettle
Galium boreale L.	Northern bedstraw
Geum aleppicum Jacq.	Yellow avens
Geum rivale L.	Purple avens
Glyceria grandis S. Wats. ex A. Gray	Common tall manna grass
Glyceria species	Manna grass
Glyceria striata (Lam.) A. S. Hitchc.	Fowl manna grass
Grindelia squarrosa (Pursh) Dunal	Gumweed
Helianthus maximilianii Schrad.	Narrow-leaved sunflower

Table II–1: Vascular Plant Species List for the LSA (Cont'd)

Scientific Name	Common Name
Heuchera richardsonii R.Br.	Richardson's alumroot
Hierochloe odorata (L.) Beauv.	Sweet grass
Hordeum jubatum L.	Foxtail barley
Juncus balticus Willd.	Wire rush
Koelerica macrantha (Ledeb.) J.A. Schultes	June grass
Lappula squarrosa (Retz.) Dumort.	Bluebur
Lathyrus ochroleucus Hook.	Cream-colored vetchling
Lemna minor L.	Common duckweed
Lepidium densiflorum Schrad.	Common pepper-grass
Linaria vulgaris Hill	Butter-and-eggs
Lycopus uniflorus Michx.	Northern water-horehound
Lysimachia ciliata L.	Fringed loosestrif
Maianthemum canadense Desf.	Wild lily-of-the-valley
Matricaria matricarioides (Less.) Porter	Pineappleweed
Matricaria perforata Merat	Scentless chamomile
Medicago falcata L.	Yellow lucerne
Medicago sativa L.	Alfalfa
Melilotus alba Desr.	White sweet-clover
Melilotus officinalis (L.) Lam.	Yellow sweet-clover
Melilotus species	Sweet-clover
Mentha arvensis L.	Wild mint
Mertensia paniculata (Ait.) G. Don.	Tall lungwort
Muhlenbergia richardsonis (Trin.) Rydb.	Mat muhly
Oenothera breviflora T. & G.	Taraxia
Penstemon procerus Dougl. ex Grah.	Slender blue beardtongue
Penstemon species	Beardtongue
Petasites sagittatus (Pursh) A. Gray	Arrow-leaved coltsfoot
Phalaris arundinacea L.	Reed canary grass
Phleum pratense L.	Timothy
Phragmites australis (Cav.) Trin. Ex Steud.	Reed
Plantago major L.	Common plantain
Poa palustris L.	Fowl bluegrass
Poa pratensis L.	Kentucky bluegrass
Polygonum convolvulus L.	Wild buckwheat

Table II–1: Vascular Plant Species List for the LSA (Cont'd)

Scientific Name	Common Name
Polygonum lapathifolium L.	Pale persicaria
Polygonum ramosissimum Michx.	Bushy knotweed
Polygonum species	Knotweed/Smartweed
Populus balsamifera L.	Balsam poplar
Populus tremuloides Michx.	Aspen
Potamogeton species	Pondweed
Potentilla anserina L.	Silverweed
Potentilla gracilis Dougl. ex Hook.	Graceful cinquefoil
Potentilla norvegica L.	Rough cinquefoil
Potentilla pensylvanica L.	Praire cinquefoil
Potentilla species	Cinquefoil
Prunus virginiana L.	Choke cherry
Ranunculus macounii Britt.	Gray's buttercup
Ranunculus sceleratus L.	Celery-leaved buttercup
Ribes americanum Mill.	Wild black currant
Ribes oxyacanthoides L.	Northern gooseberry
Rorippa palustris (L.) Besser	Marsh yellow cress
Rosa acicularis Lindl.	Prickly rose
Rubus idaeus L.	Wild red raspberry
Rubus pubescens Raf.	Dewberry
Rumex crispus L.	Curled dock
Rumex occidentalis S. Wats	Western dock
Rumex triangulivalvis (Dans.) Rech.f.	Narrow-leaved dock
Salix bebbiana Sarg.	Beaked willow
Salix exigua Nutt.	Sandbar willow
Salix lutea Nutt.	Yellow willow
Salix maccalliana Rowlee	Velvet-fruited willow
Salix species	Willow
Scirpus microcarpus Presl.	Small-fruited bulrush
Scirpus validus Vahl	Common great bulrush
Scutellaria galericulata L.	Marsh skullcap
Senecio congestus (R.Br.) DC.	Marsh ragwort
Senecio fremontii T. & G.	Mountain butterweed
Setaria viridis (L.) Beauv.	Green foxtail

Table II–1: Vascular Plant Species List for the LSA (Cont'd)

Scientific Name	Common Name
Silene pratensis (Rafn) Godron & Gren.	White cockle
Silene species	Catchfly/Campion
Sisyrinchium montanum Greene	Common blue-eyed grass
Sium suave Walt.	Water parsnip
Smilacina stellata (L.) Desf.	Star-flowered Solomon's-seal
Solidago canadensis L.	Canada goldenrod
Sonchus arvensis L.	Perennial sow-thistle
Sonchus uliginosus Bieb.	Smooth perennial sow-thistle
Spirea alba Du Roi	Narrow-leaved meadowsweet
Stachys palustris L.	Marsh hedge-nettle
Stellaria crassifolia Ehrh.	Fleshy stitchwort
Stellaria longipes Goldie	Long-stalked chickweed
Symphoricarpos albus (L.) Blake	Snowberry
Symphoricarpos occidentalis Hook.	Buckbrush
Tanacetum vulgare L.	Common tansy
Taraxacum officinale Weber	Common dandelion
Thalictrum venulosum Trel.	Veiny meadow rue
Thlaspi arvense L.	Stinkweed
Tragopogon dubius Scop.	Goat's-beard
Trifolium hybridum L.	Alsike clover
Trifolium pratense L.	Red clover
Trifolium repens L.	White clover
Typha latifolia L.	Common cattail
Urtica dioica L.	Common nettle
Viburnum edule (Michx.) Raf.	Low-bush cranberry
Vicia americana Muhl.	Wild vetch
Viola canadensis L.	Western Canada violet

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Appendix III: Non-vascular Plant Species List

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Table III-I: Non-vascular Plant Species List for the LSA

Scientific Name	Common Name
Amblystegium serpens	Moss
Brachythecium salebrosum	Moss
Drepanocladus aduncus	Brown Moss
Funaria hygrometrica	Cord Moss
Leptodictyum riparium	Moss
Physcia adscendens	Lichen
Xanthoria fulva	Lichen

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Appendix IV: Non-native and Invasive Species in Alberta

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Table IV–1: Restricted, Noxious, and Nuisance Weed Species in Alberta

Species		Designation	
Scientific Name	**Common Name**	**Alberta Weed Control Act**	**Canada Seeds Act**
Agropyron repens	Quack grass	Nuisance	
Amaranthus retroflexus	Redroot pigweed	Nuisance	
Apocynum androsaemifolium	Spreading dogbane	Noxious	
Avena fatua	Wild oats	Nuisance	2^{o}Noxious
Bromus tectorum	Downy brome	Nuisance	
Campanula rapunculoides	Creeping bellflower	Nuisance	
Capsella bursa-pastoris	Shepherd's purse	Nuisance	
Cardaria spp.	Hoary cress	Noxious	Prohibited noxious
Carduus nutans	Nodding thistle	Restricted	
Centaurea solstitialis	Yellow star-thistle	Restricted	Prohibited noxious
Centaurea diffusa	Diffuse knapweed	Restricted	Prohibited noxious
Centaurea maculosa	Spotted knapweed	Restricted	Prohibited noxious
Centaurea repens	Russian knapweed	Noxious	Prohibited noxious
Cerastium arvense	Field chickweed	Nuisance	
Chrysanthemem leucanthemum	Oxeye daisy	Noxious	1^{o}noxious
Cirsium arvense	Canada thistle	Noxious	1^{o}noxious
Concolculus arvensis	Field bindweed	Noxious	Prohibited noxious
Convolvulus sepium	Hedge bindweed	Nuisance	
Crepis tectorum	Narrow-leaved hawk's beard	Nuisance	
Cuscuta spp.	Dodder	Restricted	Prohibited noxious
Cynoglossum officinale	Hound's tongue	Noxious	
Descurainia pinnata	Green tansy mustard	Nuisance	
Descurainia sophia	Flixweed	Nuisance	
Echium vulgare	Blueweed	Noxious	
Erodium cicutarium	Stork's bill	Noxious	
Erucastrum gallicum	Dog mustard	Nuisance	2^{o}noxious
Erysimum cheiranthoides	Wild mustard	Nuisance	1^{o}noxious
Euphorbia cyparissias	Cypress spurge	Noxious	
Euphorbia esula	Leafy spurge	Noxious	
Fagopyrum tataricum	Tartary buckwheat	Nuisance	
Galeopsis tetrahit	Hemp nettle	Nuisance	
Galium aparine	Cleavers	Noxious	
Galium spurium	Cleavers	Noxious	
Knautia arvensis	Field scabious	Noxious	
Lamium amplexicaule	Henbit	Nuisance	
Lappula echinata	Bluebur	Nuisance	
Linaria dalmatica	Dalmation toadflax	Nuisance	
Linaria vulgaris	Toadflax	Noxious	1^{o}noxious
Lolium persicum	Persian darnel	Noxious	
Source: Alberta Agriculture 2001, Internet site.			

Table IV–1: Restricted, Noxious, and Nuisance Weed Species in Alberta (Cont'd)

Species		Designation	
Scientific Name	**Common Name**	**Alberta Weed Control Act**	**Canada Seeds Act**
Lychnis alba	White cockle	Noxious	1°noxious
Lythrum salicaria	Purple loosestrife	Noxious	
Malva rotundifolia	Round-leaved mallow	Nuisance	
Matricaria maritime	Scentless chamomile	Noxious	2°noxious
Myriophyllum spicatum	Eurasian water milfoil	Restricted	
Neslia paniculata	Ball mustard	Nuisance	
Odontites serotina	Red bartsia	Restricted	Prohibited noxious
Polygonum convolvulus	Wild buckwheat	Nuisance	
Polygonum persicaria	Lady's thumb	Nuisance	
Potentilla norvegica	Rough cinquefoil	Nuisance	
Ranunculus acris	Tall buttercup	Noxious	
Raphanus raphanistrum	Wild radish	Nuisance	1°noxious
Salsola pestifer	Russian thistle	Nuisance	
Saponaria vaccaria	Cow cockle	Nuisance	2°noxious
Scleranthus annuus	Knawel	Noxious	
Setaria viridis	Green foxtail	Nuisance	
Silene cserei	Biennial campion	Nuisance	
Silene cucubalus	Bladder campion	Noxious	1°noxious
Silene noctiflora	Night-flowering catchfly	Nuisance	2°noxious
Sonchus oleraceus	Annual sow thistle	Nuisance	
Sonchus arvensis	Perennial sow thistle	Noxious	1°noxious
Spergula arvensis	Corn spurry	Nuisance	
Stellaria media	Common chickweed	Nuisance	
Taraxacum offincinale	Dandelion	Nuisance	
Thlaspi arvense	Stinkweed	Nuisance	2°noxious
Source: Alberta Agriculture 2001, Internet site.			

Table IV–2: Non-native and Invasive Species in Alberta

Scientific Name	Common Name	Potential Problem Areas
Agropyron pectiniforme	Crested wheat grass	Invasive on prairies where it's not currently found in significant quantity. Persistent in other areas.
Astragalus cicer	Cicer milkvetch	Persistent in foothills grassland and boreal forest.
Bromus inermis	Smooth brome	Invasive on moist prairies (particularly northern fescue) and foothills.
Festuca rubra	Creeping red fescue	Slightly invasive in foothills, parkland, and dark brown soils; persistent in other areas.
Melilotus spp	Sweet clover	Invasive on dry prairies. Persistent in other areas.
Onobrychis viciifolia	Sainfoin	Persistent in foothills grassland and boreal forest.
Phalaris arundinacea	Reed canary grass	The Eurasian version of this species is invasive in wetland areas.
Phleum pratense	Timothy	Invasive in foothills where it is not currently found in any significant quantity. Persistent in other areas.
Poa pratensis	Kentucky blue grass	Invasive in prairies and foothills where it's not currently found in significant quantity.
Source: Native Plant Working Group 2001.		

1. References

1.1 Literature Cited

Native Plant Working Group. 2001. *Native Plant Revegetation Guidelines for Alberta.* H. Sinton-Gerling (ed.), Alberta Agriculture, Food and Rural Development and Alberta Environment. Edmonton, AB.

1.2 Internet Sites

Alberta Agriculture. 2001. Weed Designation Regulation – Weed Control Act. Available at http://www.agric.gov.ab.ca/ministry/acts/weeds.html. Accessed November 2005.

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Appendix V: Non-native and Invasive Species in the RSA

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Table V–1: Non-native and Invasive Species in the RSA

Species Name	Habitat / Plant Community	Plant Community	Survey Point
Noxious Weeds[1]			
Cirsium arvense (L.) Scop. Canada thistle	Pasture/Seasonal Drainage	*Poa pratensis – Artemesia frigida*	T09
	Native Deciduous/Native Grassland	*Populus tremuloides – Populus balsamifera – Betula papyrifera* / shrubs and herbs	T11
	Right-Of-Way	AIH	T13
	Crop	CA / CP	V01
	Seasonal Drainage	*Populus balsamifera – Salix bebbiana – Salix maccalliana* / Compositae	V02
	Seasonal Drainage	*Populus tremuloides* / (sparse understory)	V05
	Abandoned Wellsite	*Populus tremuloides* / (sparse understory)	V06
	Shelterbelt	*Populus balsamifera – Populus tremuloides* / *Salix* spp. / (diverse understory)	V08
	Power Substation	AII	V15
	Wetland	*Carex aquatilis – Carex utriculata*	V16
Linaria vulgaris Hill Butter-and-eggs	Right-Of-Way	AIH	T13
	Power Substation	AII	V15
	Right-Of-Way	AIH	V18
Matricaria perforata Merat Scentless chamomile	Shelterbelt	*Populus tremuloides* / *Rosa acicularis – Rubus idaeus*	T08
	Shelterbelt	*Populus balsamifera – Populus tremuloides* / *Salix* spp. / (diverse understory)	V08
	Right-Of-Way	AIH	V18
Sonchus arvensis L. Perennial sow-thistle	Seasonal Drainage	*Populus balsamifera – Salix bebbiana – Salix maccalliana* / Compositae	V02
	Abandoned Wellsite	*Populus tremuloides* / (sparse understory)	V06
	Shelterbelt	*Populus balsamifera – Populus tremuloides* / *Salix* spp. / (diverse understory)	V08
	Crop	CA / CP	V14
	Wetland	*Carex aquatilis – Carex utriculata*	V16
Tanacetum vulgare L. Common Tansy	Shelterbelt	*Populus tremuloides* / *Rosa acicularis – Rubus idaeus*	T08
	Right-Of-Way	AIH	T13
	Right-Of-Way	AIH	V18

Sources:

[1] Alberta Agriculture 2001, Internet site.

[2] Native Plant Working Group 2000.

Table V–1: Non-native and Invasive Species in the RSA (Cont'd)

Species Name	Habitat / Plant Community	Plant Community	Survey Point
Nuisance Weeds[1]			
Agropyron repens (L.) Beauv. Quack grass	Pasture/Seasonal Drainage	*Poa pratensis – Artemesia frigida*	T09
	Seasonal Drainage	*Populus balsamifera – Salix bebbiana – Salix maccalliana* / Compositae	V02
	Abandoned Wellsite	*Populus tremuloides* / (sparse understory)	V06
	Wetland	*Carex aquatilis – Carex utriculata*	V16
	Right-Of-Way	AIH	V18
Bromus tectorum L. Downy chess	Seasonal Drainage	*Populus tremuloides* / (sparse understory)	V05
Cerastium arvense L. Field mouse-ear chickweed	Seasonal Drainage	*Populus balsamifera – Salix bebbiana – Salix maccalliana* / Compositae	V02
	Shelterbelt	*Populus balsamifera – Populus tremuloides* / *Salix* spp. / (diverse understory)	V08
Crepis tectorum L. Annual hawk's-beard	Right-Of-Way	AIH	T13
	Seasonal Drainage	*Populus balsamifera – Salix bebbiana – Salix maccalliana* / Compositae	V02
	Shelterbelt	*Populus balsamifera – Populus tremuloides* / *Salix* spp. / (diverse understory)	V08
	Crop	CA / CP	V14
Galeopsis tetrahit L. Hemp-nettle	Shelterbelt	*Populus tremuloides* / *Rosa acicularis – Rubus idaeus*	T08
	Right-Of-Way	AIH	T13
	Shelterbelt	*Populus balsamifera – Populus tremuloides* / *Salix* spp. / (diverse understory)	V08
	Power Substation	AII	V15
	Right-Of-Way	AIH	V18
Lappula squarrosa (Retz.) Dumort. Bluebur	Right-Of-Way	AIH	T13
Polygonum convolvulus L. Wild buckwheat	Shelterbelt	*Populus balsamifera – Populus tremuloides* / *Salix* spp. / (diverse understory)	V08
Potentilla norvegica L. Rough cinquefoil	Right-Of-Way	AIH	V18
Setaria viridis (L.) Beauv. Green foxtail	Right-Of-Way	AIH	T13

Sources:
[1] Alberta Agriculture 2001, Internet site.
[2] Native Plant Working Group 2000.

Table V–1: Non-native and Invasive Species in the RSA (Cont'd)

Species Name	Habitat / Plant Community	Plant Community	Survey Point
Taraxacum officinale Weber Common dandelion	Shelterbelt	*Populus tremuloides* / *Rosa acicularis – Rubus idaeus*	T08
	Native Deciduous/Native Grassland	*Populus tremuloides – Populus balsamifera – Betula papyrifera* / shrubs and herbs	T11
	Right-Of-Way	AIH	T13
	Crop	CA / CP	V01
	Seasonal Drainage	*Populus balsamifera – Salix bebbiana – Salix maccalliana* / Compositae	V02
	Abandoned Wellsite	*Populus tremuloides* / (sparse understory)	V06
	Shelterbelt	*Populus balsamifera – Populus tremuloides* / *Salix* spp. / (diverse understory)	V08
	Crop	CA / CP	V14
	Power Substation	AII	V15
	Wetland	*Carex aquatilis – Carex utriculata*	V16
	Right-Of-Way	AIH	V18
Thlaspi arvense L. Stinkweed	Shelterbelt	*Populus balsamifera – Populus tremuloides* / *Salix* spp. / (diverse understory)	V08
	Wetland	*Carex aquatilis – Carex utriculata*	V16
Invasive Agronomic Species[2]			
Bromus inermis Leyss. Awnless brome	Shelterbelt	*Populus tremuloides* / *Rosa acicularis – Rubus idaeus*	T08
	Pasture/Seasonal Drainage	*Poa pratensis – Artemesia frigida*	T09
	Native Deciduous/Native Grassland	*Populus tremuloides – Populus balsamifera – Betula papyrifera* / shrubs and herbs	T11
	Right-Of-Way	AIH	T13
	Seasonal Drainage	*Populus balsamifera – Salix bebbiana – Salix maccalliana* / Compositae	V02
	Abandoned Wellsite	*Populus tremuloides* / (sparse understory)	V06
	Shelterbelt	*Populus balsamifera – Populus tremuloides* / *Salix* spp. / (diverse understory)	V08
	Power Substation	AII	V15
	Wetland	*Carex aquatilis – Carex utriculata*	V16
	Right-Of-Way	AIH	V18
Medicago falcata L. Yellow lucerne	Crop	CA / CP	V14

Sources:

[1] Alberta Agriculture 2001, Internet site.

[2] Native Plant Working Group 2000.

Table V–1: Non-native and Invasive Species in the RSA (Cont'd)

Species Name	Habitat / Plant Community	Plant Community	Survey Point
Medicago sativa L. Alfalfa	Seasonal Drainage	*Populus balsamifera – Salix bebbiana – Salix maccalliana* / Compositae	V02
	Abandoned Wellsite	*Populus tremuloides* / (sparse understory)	V06
	Shelterbelt	*Populus balsamifera – Populus tremuloides* / *Salix* spp. / (diverse understory)	V08
	Crop	CA / CP	V14
Melilotus alba Desr. White sweet-clover	Right-Of-Way	AIH	T13
Melilotus officinalis (L.) Lam. Yellow sweet-clover	Native Deciduous/Native Grassland	*Populus tremuloides – Populus balsamifera – Betula papyrifera* / shrubs and herbs	T11
	Right-Of-Way	AIH	T13
	Seasonal Drainage	*Populus balsamifera – Salix bebbiana – Salix maccalliana* / Compositae	V02
	Shelterbelt	*Populus balsamifera – Populus tremuloides* / *Salix* spp. / (diverse understory)	V08
	Crop	CA / CP	V14
	Right-Of-Way	AIH	V18
Melilotus species Sweet-clover	Abandoned Wellsite	*Populus tremuloides* / (sparse understory)	V06
Phalaris arundinacea L. Reed canary grass	Native Deciduous/Native Grassland	*Populus tremuloides – Populus balsamifera – Betula papyrifera* / shrubs and herbs	T11
	Seasonal Drainage	*Populus balsamifera – Salix bebbiana – Salix maccalliana* / Compositae	V02
	Wetland	*Carex aquatilis – Carex utriculata*	V16
Phleum pratense L. Timothy	Pasture/Seasonal Drainage	*Poa pratensis – Artemesia frigida*	T09
	Right-Of-Way	AIH	T13
	Seasonal Drainage	*Populus balsamifera – Salix bebbiana – Salix maccalliana* / Compositae	V02
	Abandoned Wellsite	*Populus tremuloides* / (sparse understory)	V06
	Shelterbelt	*Populus balsamifera – Populus tremuloides* / *Salix* spp. / (diverse understory)	V08
	Crop	CA / CP	V14

Sources:
[1] Alberta Agriculture 2001, Internet site.
[2] Native Plant Working Group 2000.

Table V–1: Non-native and Invasive Species in the RSA (Cont'd)

Species Name	Habitat / Plant Community	Plant Community	Survey Point
Poa pratensis L. Kentucky bluegrass	Shelterbelt	*Populus tremuloides* / *Rosa acicularis – Rubus idaeus*	T08
	Pasture/Seasonal Drainage	*Poa pratensis – Artemesia frigida*	T09
	Native Deciduous/Native Grassland	*Populus tremuloides – Populus balsamifera – Betula papyrifera* / shrubs and herbs	T11
	Right-Of-Way	AIH	T13
	Seasonal Drainage	*Populus balsamifera – Salix bebbiana – Salix maccalliana* / Compositae	V02
	Abandoned Wellsite	*Populus tremuloides* / (sparse understory)	V06
	Shelterbelt	*Populus balsamifera – Populus tremuloides* / *Salix* spp. / (diverse understory)	V08
	Power Substation	AII	V15
	Right-Of-Way	AIH	V18
Trifolium hybridum L. Alsike clover	Seasonal Drainage	*Populus balsamifera – Salix bebbiana – Salix maccalliana* / Compositae	V02
	Shelterbelt	*Populus balsamifera – Populus tremuloides* / *Salix* spp. / (diverse understory)	V08
Trifolium pratense L. Red clover	Native Deciduous/Native Grassland	*Populus tremuloides – Populus balsamifera – Betula papyrifera* / shrubs and herbs	T11
	Shelterbelt	*Populus balsamifera – Populus tremuloides* / *Salix* spp. / (diverse understory)	V08
	Crop	CA / CP	V14
Trifolium repens L. White clover	Shelterbelt	*Populus tremuloides* / *Rosa acicularis – Rubus idaeus*	T08
	Pasture/Seasonal Drainage	*Poa pratensis – Artemesia frigida*	T09
	Seasonal Drainage	*Populus balsamifera – Salix bebbiana – Salix maccalliana* / Compositae	V02
	Abandoned Wellsite	*Populus tremuloides* / (sparse understory)	V06

Sources:
[1] Alberta Agriculture 2001, Internet site.
[2] Native Plant Working Group 2000.

1. References

1.1 Literature Cited

Native Plant Working Group. 2001. *Native Plant Revegetation Guidelines for Alberta.* H. Sinton-Gerling (ed.), Alberta Agriculture, Food and Rural Development and Alberta Environment. Edmonton, AB.

1.2 Internet Sites

Alberta Agriculture. 2001. Weed Designation Regulation – Weed Control Act. Available at http://www.agric.gov.ab.ca/ministry/acts/weeds.html. Accessed November 2005.

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Appendix VI: Cover Class Rare Plant Potential

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Scientific Name	Common Name	Habitat Description	Phenology	ANHIC Rank	COSEWIC Status	Potential Cover Classes
Alopecurus alpinus	Alpine foxtail	Shores and open woodland.	June-August	S2 G5	-	Wetland, N_Decid,
Artemisia tilesii ssp. elatior	Herriot's sagewort, Mountain sagewort	Open woods and river flats; elsewhere, on open, rocky or gravelly alpine slopes or in heathlands.	July-October	S2 G5	-	Deciduous, N_Decid, N_Grass, CPR
Aster pauciflorus	Few-flowered aster	Alkaline flats.	July-August	S2 G4	-	CPR
Aster umbellatus	Flat-topped white aster	Moist woodlands and swampy sites; elsewhere, in moist thickets and meadows.	July-September	S2 G5	-	Wetland, N_Decid, N_Grass
Bolboschoenus fluviatilis	River bulrush	Margins of ponds, lakes and rivers.	June-July	S1 G5	-	Wetland
Botrychium campestre	Field grape fern, Prairie moonwort	Grassy fields and ditches.	early spring to late spring {late summer}	S1 G3G4	-	CPR, N_Grass
Botrychium multifidum var. intermedium	Leather grape fern	Moist, sandy areas. Disturbed areas.	spring	S2 G5T4?	-	CPR, Deciduous
Botrychium pinnatum	Northwestern grape fern	Sandy meadows.	June-August	S1 G4?	-	N_Grass
Bromus latiglumis	Canada brome	Moist streambanks.	{late June-August}	S1 G5	-	N_Grass, N_Decid
Calyophus serrulatus	Shrubby evening primrose	Sandy prairies and dunes.	{May} June-July	S2 G5	-	CPR, N_Grass
Camassia quamash var. quamash	Blue camas	Moist to wet meadows.	May-July	S2 G5T3T5	-	Wetland, N_Grass
Carex aperta	Open sedge	Open, wet ground.	{April-June} July-August	S1 G4	-	Wetland, CPR, N_Grass
Carex backii	Back's sedge	Dry (to moist), shady woods.	{May-July}	S2 G4	-	N_Decid
Carex crawei	Crawe's sedge	Calcareous meadows.	{May} June-July	S2 G5	-	CPR, N_Grass

Note:
Brackets denote phenology observed outside of Alberta { }.

Table VI–1: Rare Plants Occurring in the Central Parkland and their Potential Cover Classes (Cont'd)

Scientific Name	Common Name	Habitat Description	Phenology	ANHIC Rank	COSEWIC Status	Potential Cover Classes
Carex heleonastes	Hudson Bay sedge	Wet, calcareous sites such as fens and marshes.	{July} August	S2 G4	-	Wetland
Carex hookerana	Sand sedge	Prairies and dry banks, and in open woods at lower elevations.	June {July}	S2 G4?	-	CPR, N_Decid, N_Grass
Carex incurviformis var. incurviformis	Seaside sedge	Moist river shore.	June {July}	S2 G4G5T4T5	-	N_Grass, N_Decid
Carex lacustris	Lakeshore sedge	Moist ditches.	{May-June} July-August	S2 G5	-	CPR, Deciduous,
Carex umbellata	Umbellate sedge	Dry woods.	{May-June}	S1 G5	-	N_Decid
Carex vesicaria var. vesicaria	Blister sedge	Swamps, marshes and shorelines.	{June} July	S1 G5	-	Wetland
Carex vulpinoidea	Fox sedge	Slough edges.	{May-July}	S2 G5	-	Wetland
Crepis intermedia	Intermediate hawk's-beard	Dry, open areas.	{May-July} August	S2 G5	-	CPR, N_Grass
Cryptantha kelseyana	Kelsey's cat's eye	Open, sandy soils, near springs.		S1 G4	-	CPR, N_Grass
Cynoglossum virginianum var. boreale	Hound's tongue, Wild comfrey	Dry woods.	{June-July}	S1 G5T4T5	-	N_Decid
Cyperus schweinitzii	Sand nut-grass	Dry sandy soil, including active sand dunes.	July-August	S2 G5	-	N_Grass
Danthonia spicata	Poverty oat grass	Sandy and rocky sites, mostly in dry woods but sometimes in moist meadows.	{June} July	S1S2 G5	-	N_Decid, N_Grass
Ellisia nyctelea	Waterpod	Moist shady woods and streambanks.	May-June {July}	S2 G5	-	N_Decid, N_Grass

Note:
Brackets denote phenology observed outside of Alberta { }.

Table VI–1: Rare Plants Occurring in the Central Parkland and their Potential Cover Classes (Cont'd)

Scientific Name	Common Name	Habitat Description	Phenology	ANHIC Rank	COSEWIC Status	Potential Cover Classes
Erigeron flagellaris	Creeping fleabane	Dry, open woods, lakeshores and disturbed or poorly vegetated areas.	June-August	S1S2 G5	-	CPR, Deciduous, N_Decid
Gentiana fremontii	Marsh gentian, Lowly gentian	Moist grassy meadows.	June {July-August}	S2 G4	-	N_Grass
Geranium carolinianum	Carolina wild geranium	Clearings and disturbed sites; elsewhere, on granite outcrops and in dry, rocky woods, often on sandy soil.	{April-July}	S1 G5		CPR, Deciduous, N_Grass
Gnaphalium viscosum	Clammy cudweed	Open woods.	July-September	SH G5	-	N_Decid
Gratiola neglecta	Clammy hedge-hyssop	Wet, muddy sites, often in shallow water.	{June-August}	S2S3 G5	-	Wetland
Hedyotis longifolia	Long-leaved bluets	Sandy soil in open woods and on dunes; elsewhere, in grasslands.	June-July {May-September}	S2 G4G5	-	N_Decid, N_Grass
Iris missouriensis	Western blue flag	Open, moist to wet (at least in spring) meadows and streambanks.	{May} June-July	S1 G5	Threatened	Wetland, N_Grass, N_Decid
Lactuca biennis	Tall blue lettuce	Moist woods and clearings; elsewhere, in swampy sites and by hot springs.	July-August	S2 G5	-	Wetland, N_Decid
Lomatogonium rotatum	Marsh felwort	Wet meadows and flats, often on saline soils.	{late July} August-early September	S2S3 G5	-	Wetland, CPR, N_Grass
Lycopus americanus	American water-horehound	Marshy sites and moist, low ground along streams.	July {June-August}	S3 G5	-	Wetland, N_Grass, N_Decid
Lysimachia hybrida	Lance-leaved loosestrife	Moist meadows and shores.	July {June-August}	S2 G5	-	Wetland, N_Grass,
Malaxis monophylla	White adder's-mouth	Damp woods and thickets. Drier parts of bogs and fens.	Mid June to August	S2 G5	-	Wetland, N_Decid

Note:
Brackets denote phenology observed outside of Alberta { }.

Table VI–1: Rare Plants Occurring in the Central Parkland and their Potential Cover Classes (Cont'd)

Scientific Name	Common Name	Habitat Description	Phenology	ANHIC Rank	COSEWIC Status	Potential Cover Classes
Melica spectabilis	Onion grass	Wet to moderately dry, fairly open sites.	{May-July} August	S2 G5	-	Wetland, CPR, N_Grass
Mertensia lanceolata	Lance-leaved lungwort	Open woods, moist slopes and meadows.	May {June-July}	S2 G5	-	N_Decid, N_Grass
Mertensia longiflora	Large-flowered lungwort	Open woods, moist slopes and meadows.	{April} May-June	S2 G4G5	-	N_Decid, N_Grass
Mimulus glabratus	Smooth monkeyflower	Wet places, often in water and around springs.	{May-August}	S1 G5	-	Wetland
Mimulus guttatus	Yellow monkeyflower	Wet meadows, springs and streambanks.	{April-June} July-August	SU G5	-	Wetland, N_Grass, N_Decid
Montia linearis	Linear-leaved montia	Moist to dry, open sites on sandy plains and hills at lower elevations. Also disturbed habitats and open woodlands.	May-July	S1 G5	-	CPR, Deciduous, N_Decid, N_Grass
Muhlenbergia racemosa	Marsh muhly	Dry sand hills, slopes and eroded banks; elsewhere, in a wide variety of habitats including prairies, meadows, streambanks, edges of woodland, dry rocky slopes and waste ground.	{late July-August}	S1 G5	-	CPR, Deciduous, N_Decid, N_Grass
Najas flexilis	Slender water-nymph	Ponds and streams, in clear, shallow to deep, fresh or brackish water.	July to August	S1S2 G5	-	Wetland
Oenothera flava	Low yellow evening-primrose	Clay flats and slough edges.	July-August	S2 G5	-	Wetland
Onosmodium molle var. occidentale	Western false gromwell	Gravelly banks and dry, open woods.	June-July	S2 G4G5	-	N_Decid
Osmorhiza longistylis	Smooth sweet cicely	At lower eleveations, in moist woods in the parkland and prairies.	June	S2 G5	-	N_Decid

Note:
Brackets denote phenology observed outside of Alberta { }.

Table VI–1: Rare Plants Occurring in the Central Parkland and their Potential Cover Classes (Cont'd)

Scientific Name	Common Name	Habitat Description	Phenology	ANHIC Rank	COSEWIC Status	Potential Cover Classes
Panicum leibergii	Leiberg's millet	Dry, sandy soil in grasslands and open woods.	{June-July}	S1 G5	-	N_Decid, N_Grass
Panicum wilcoxianum	Sand millet	Dry, open areas.	June-July	S1 G5	-	CPR, N_Grass
Physostegia ledinghamii	False dragonhead	Moist woods and streambanks; elsewhere, on lake shores and in marshes.	{July-September}	S2 G3?	-	Wetland, N_Decid, N_Grass
Polanisia dodecandra	Clammyweed	Disturbed sites.		S2 G5	-	CPR, Deciduous
Potamogeton strictifolius	Linear-leaved pondweed	Shallow lakes and ponds.	July-September	S2 G5	-	Wetland
Potentilla finitima	Sandhills cinquefoil	Moist flats and sandy lake shores and riverbanks.	{June-July}	S1 G2G4Q	-	N_Grass
Potentilla plattensis	Low cinquefoil	Coulees and dry flats in prairie grassland.	June-July {August}	S1S2 G4	-	N_Grass
Ranunculus uncinatus	Hairy buttercup	Moist, shady woodlands at lower elevations.	April-July	S2 G5	-	N_Decid
Rhynchospora capillacea	Slender beak-rush	Calcareous fens; elsewhere, in calcareous sites in meadows and swamps and on shores.	{July}	S1 G4	-	Wetland, N_Grass
Ruppia cirrhosa	Widgeon-grass	Saline and alkaline lakes, ponds and ditches; elsewhere, in brackish or salt water along the coast, rarely in fresh water.	July {August}	S1S2 G5	-	Wetland, CPR,
Shinneroseris rostrata	Annual skeletonweed	Sandy banks and dunes, where there is considerable loose sand.	August {July-September}	S2 G5?	-	N_Grass
Sisyrinchium septentrionale	Pale blue-eyed grass	Moist meadows and grassy streambanks.	{April} May-July	S2S3 G3G4	-	N_Grass

Note:
Brackets denote phenology observed outside of Alberta { }.

Table VI–1: Rare Plants Occurring in the Central Parkland and their Potential Cover Classes (Cont'd)

Scientific Name	Common Name	Habitat Description	Phenology	ANHIC Rank	COSEWIC Status	Potential Cover Classes
Spergularia salina var. salina	Salt-marsh sand spurry	Brackish or saline mud and sands.	May-August	S2 G5	-	Wetland
Sphenopholis obtusata	Prairie wedge grass	Moist sites in meadows and open woods and on shores.	{June-July}	S2 G5	-	N_Grass, N_Decid
Torreyochloa pallida var. pauciflora	Few-flowered salt-meadow grass	Wet places.	{June-August}	S1 G5T5	-	Wetland
Trisetum cernuum var. cernuum	Nodding trisetum	Moist woods.	{May-July}	S2 G5	-	N_Decid
Viola pedatifida	Crowfoot violet	Dry gravelly hills and exposed banks in prairie grassland.	{April} May-June	S2 G5	-	N_Grass
Wolffia columbiana	Watermeal	Beaver ponds in hummocky moraines, in nutrient-rich ponds.	June-October	S2 G5	-	Wetland

Note:
Brackets denote phenology observed outside of Alberta { }.

Volume IIC, Section 3: Vegetation

Appendix VII: Plant Communities of Conservation Concern in the Parkland Natural Region

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Table VII–1: Plant Communities of Conservation Concern in the Parkland Natural Region

Scientific Name	Common Name	Rank	Group
Acer negundo / Prunus virginiana	Manitoba maple / choke cherry	S1S2	Forest / Woodland
Betula papyrifera / Shepherdia canadensis	Paper birch / buffalo berry	S1S2	Forest / Woodland
Larix laricina – Picea mariana / Cornus stolonifera / Rubus idaeus	Tamarack – black spruce / red osier dogwood – wild red raspberry	S1S2	Forest / Woodland
Picea mariana / Cornus stolonifera / feathermoss	Black spruce/ red –osier dogwood / feathermoss	S1S2	Forest / Woodland
Populus tremuloides / Juniperus horzontalis/ Carex siccata	Aspen / creeping juniper / hay sedge	S2S3	Forest / Woodland
Populus tremuloides / Rubus parviflorus	Aspen / thimbleberry	S2	Forest / Woodland
Betula occidentalis / Juniperus horizontalis	Water birch / creeping juniper	S2S3	Shrubland
Betula occidentalis grassland riparian shrubland	Water birch / grassland riparian shrubland	S2S3	Shrubland
Betula occidentalis montane shrubland	Water birch montane shrubland	S1S2 G3G4	Shrubland
Elaeagnus commutata– Prunus virginiana / Carex siccata	Silverberry – chockcherry / hay sedge	S2S3	Shrubland
Elaeagnus commutate riparian shrubland	Silverberry riparian shrubland	SU G2Q	Shrubland
Salix bebbiana / Cornus stolonifera	Beaked Willow / red osier dogwood	S3?	Shrubland
Salix bebbiana / Rubus idaeus / Geranium richardsonii	Beaked Willow / wild red raspberry / wild white geranium	S2	Shrubland
Juniperus horizontalis / Calamovilfa longifolia – Carex pensylvanica spp. heliophila	Creeping juniper / sand grass – sun loving sedge	S2S3	Dwarf Shrubland
Calamovilfa longifolia – Sporobolus cryptandrus	Sand grass – sand dropseed	S2S3	Herbaceous
Carex pseudocyperus – Calla palustris	Cypress- like sedge – water arum	S1S2	Herbaceous
Carex stenophylla – Pascopyrum smithii	Low sedge – western wheat grass	S1	Herbaceous
Distichlis stricta – Pascopyrum smithii	Salt grass – western wheat grass	S2	Herbaceous
Elymus trachycaulus – Carex atherodes	Slender wheat grass – awned sedge	S1	Herbaceous
Elymus trachycaulus – Stipa spp	Slender wheat grass – needle grass species	S1	Herbaceous
Festuca campestris – Pseudoroegneria spicata grassland	Mountain rough fescue – bluebunch wheat grass grassland	S1S2 G4	Herbaceous
Festuca hallii	Plain's rough fescue	S1	Herbaceous
Festuca hallii – Calamovilfa longifolia	Plain's rough fescue – sand grass	S1	Herbaceous
Festuca hallii - Carex spp. / *Arctostaphylos uva-ursi*	Plain's rough fescue – sedges / common bearberry	S1	Herbaceous
Festuca hallii – Koeleria macrantha / Juniperus horizontalis / forbs	Plain's rough fescue – June grass / creeping juniper / forbs	S2	Herbaceous

Source: Allen 2006.

Table VII–1: Plant Communities of Conservation Concern in the Parkland Natural Region (Cont'd)

Scientific Name	Common Name	Rank	Group
Festuca hallii – Stipa curtiseta	Plain's rough fescue – June grass / creeping juniper / forbs	S2	Herbaceous
Festuca hallii – Stipa viridula	Plain's rough fescue – western porcupine grass	S2	Herbaceous
Koeleria macrantha – Pascopyrum smithii	June grass – western wheat grass	S1S2	Herbaceous
Muhlenbergia asperifolia – Scirpus nevadensis – Distichlis stricta	Scratch grass – Nevada bulrush – salt grass	S1S2	Herbaceous
Pascopyrum smithii – Artemisia tilesii – Artemisia frigida	Western wheat grass – Herriot's sagewort – pasture sagewort	S1	Herbaceous
Pascopyrum smithii – Hordeum jubatum	Western wheat grass –foxtail barley	S1	Herbaceous
Puccinellia nuttalliana	Nuttall's salt-meadow grass	S3? G3?	Herbaceous
Stipa curtiseta – S. viridula – Carex spp.	Western porcupine grass – green needle grass – sedges	S2S3	Herbaceous
Juniperus horizontalis / (Koeleria macrantha) / Cladina mitis	Creeping juniper – (June Grass) / green reindeer lichen	S1S2	Sparsely vegetated
Salicornia rubra emergent marsh	Samphire emergent marsh	S2 G2G3	Sparsely vegetated
Scirpus nevadensis – (Triglochin maritima)	Nevada bulrush – (seaside arrow grass)	S2S3	Sparsely vegetated
Spartina gracilis – (Pascopyrum smithii)	Alkali cord grass – (western wheat grass)	S2S3	Sparsely vegetated
Sporobolus cryptandrus semi-active dune	Sand dropseed semi-active dune	S2	Sparsely vegetated
Triglochin maritima emergent marsh	Seaside arrow-grass emergent marsh	S2?	Sparsely vegetated
Ruppia cirrhosa	Widgeon-grass	S2	Aquatic

Source: Allen 2006.

1. References

Allen, L. 2006. *Alberta Natural Heritage Information Centre Preliminary Plant Community Tracking List*. Alberta Community Development. Edmonton, AB.

WorleyParsons Komex

resources & energy

Alberta Sulphur Terminals Ltd.
Bruderheim Sulphur Forming and Shipping Facility

Volume IIC – Terrestrial Ecosystems

4. Wildlife

Project Number 62720000
June 2007

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Executive Summary

Alberta Sulphur Terminals Ltd. (AST), a division of HAZCO Environmental Services (HAZCO) which, in turn, is a division of CCS Income Trust (CCS), retained WorleyParsons Komex to complete a wildlife assessment for the proposed site of the Bruderheim Sulphur Forming and Shipping Facility (the Project) located a portion of Section 35, Township 55, Range 20, West of the 4th Meridian (35-55-20 W4M - the Site). The objectives of the wildlife assessment were as follows:

- satisfy the relevant Final Terms of Reference (TOR) of the Environmental Impact Assessment (EIA)
- assess potential impacts on the following wildlife indicators
  - waterbirds: waterfowl, wading birds and shore birds
  - ungulates: deer (mule and white-tailed)
  - amphibians (Canadian toad, wood frog, chorus frog and tiger salamander)
- determine how wildlife resources may be directly and indirectly affected by the following issues associated with the Project:
  - potential acid input (SO_2, NO_2 and sulphur dust)
  - direct mortality
  - habitat availability
  - noise
  - fragmentation and wildlife movement

The wildlife Terms of Reference are as follows:

Describe existing wildlife resources (amphibians, reptiles, birds and terrestrial and aquatic mammals), their use and potential use of habitats in the Study Areas. Document the anticipated changes to wildlife in the Study Areas. Specifically:

a) *document and describe species of conservation concern found within the Study Area, using recognized survey protocols;*

   A site visit was conducted on July 21, 2006 which focused on wetlands and critical habitat for Species at Risk (SAR) and indicator species that are wetland dependent. Habitats within the Wildlife Local Study Area (LSA) and Regional Study Area (RSA) were searched on foot or by vehicle. A search of the Fish and Wildlife Historical Information System (FWHIS) was conducted to determine if other wildlife species, in particular SAR, have been detected on or near the site.

   A number of bird species were observed on two natural wetlands present in the northwest corner of the LSA, along with two of the dugouts in the same vicinity. Four SAR were detected during the site survey, including seven green-winged teals, one northern pintail, four sora and two black terns. The only other wildlife observed included a beaver on one of the wetlands. No other wildlife species were detected during the site visit. Sharp-tailed grouse were present in the area prior to 1950. In the past five years, grouse have been detected near Whitford Lake, approximately 50 km east of the Site. More recently, sharp-tailed grouse were detected within a few miles of the Site and the possibility of a lek in the area was noted by Halisky (2007, pers. comm.). A sharp-tailed grouse lek survey was conducted in April 2007 and no individuals were detected. A western toad was detected in the LSA in 1997 (see Figure 4.6-2). In general, potential SAR habitat in the LSA and RSA is very limited resulting in few SAR present in either the LSA or RSA.

b) *describe and assess potential impacts of the Project on wildlife species found in the Study Areas, including impacts on critical habitat, habitat availability and quality, and habitat fragmentation and* *loss. These impacts should be described for the various phases of the Project both locally and cumulatively with other activities in the Study Areas;*

Air emissions at application are predicted to be much less than Alberta's ambient air quality objectives (see Volume IIA, Section 2: Climate and Air quality – Table 2.3-3). The acute effects of NO_2 and SO_2 at application are well below the toxicological reference values (TRV) that result in lethality during the one-hour, 24-hour and annual averaging periods. This is a Class 3 impact. Similarly, the chronic inhalation effects are below TRVs that result in either developmental or respiratory effects. This is a Class 3 impact.

At application, all waterbodies are predicted to have a pH greater than 7.0 (see Volume IIB, Section 3: Surface Water Quantity). With a pH greater than 7, it is likely there will be no detrimental effects on waterbirds and amphibians. This is a Class 3 impact, though long-term monitoring is required to determine if these waterbodies will acidify. Soils within the LSA and RSA are rated as Low to Moderate with respect to acid sensitivity (see Volume IIC, Section 2: Soil). The Air Quality Section of the application (see Volume IIA, Section 2: Climate and Air Quality) indicates that emissions of acidifying substances including NO_2 and SO_2, could potentially contribute to wet acid deposition and fine particles (assumed to be mainly elemental sulphur) with diameters less than 2.5 μm ($PM_{2.5}$). Based on the Project's design and mitigation measures to limit aerial dispersal of elemental sulphur, it is assumed that the majority of impacts to soil from dry deposition of elemental sulphur will occur within the Principal Development Area (PDA) where soils are rated as having a low sensitivity to acid deposition.

It is predicted that there will be an increase by as much as 8.2% in wildlife mortalities, consisting primarily of deer. This is considered a Class 2 impact. Increased traffic volume as a result of the Project is expected to add 350 vehicles per day to Range Road 202 (see Volume I: Project Description – Appendix III, Traffic Impact Assessment). By 2022, it is predicted that total traffic will be 6,042 vehicles per day on Highway 15. The effects of the increased traffic volume on the local avian population are predicted to be a Class 3 impact, based on findings by Reijnen et al. (1996) and Forman et al. (2002).

The Project will be developed on agricultural land and, therefore, there are no impacts to habitats with high wildlife value. This is a Class 4 impact. With regard to SAR (threatened or at risk) that may occur in the LSA and RSA, the loggerhead shrike is likely to be found in deciduous habitats but this habitat will not be affected. The Sprague's pipit is found on two non-native habitat types, perennial forage and annual crop and these habitats will decline by 4.9% at application (see Volume IIC, Section 3: Vegetation). Sharp-tailed grouse are known to be in this area and they may occur in perennial forage and annual crop habitats.

Habitats with high value to wildlife will not be impacted in the cumulative effects case. This is a Class 4 impact. It is expected that the impacts on Elk Island National Park will be minimal. No direct habitat loss will occur to Elk Island National Park. The impacts of PAI in the RSA are discussed in the cumulative effects case in Volume IIA, Section 2: Climate and Air Quality.

c) *proposed strategies to minimize and/or mitigate impacts on the species and their habitats that are found in the Study Areas. These strategies should be tailored to the various phases of the Project and meet the expectations of relevant wildlife legislation;*

AST has committed to several management practices to minimize the impacts of air emissions from the sulphur forming and shipping facility including a dust suppression management plan. This is outlined in Volume 1: Project Description – Section 3.6. A proprietary dust suppression agent and release aid will be used to suppress dust on the sulphur pastille storage pad, transfer points and rail load-out area. Dust suppression agents will be applied at the load-out hopper and at the rail load-out. The agents will be stored in make-up tanks and delivered via pump.

The usage rates of the dust suppression agents are estimated to be less than 100 kg/d during initial operations, increasing to less than 200 kg/d for full-scale operations. The actual amounts used will depend on the size of the trains being loaded and the conveyor size. Dustbind S5 will be applied at the transfer points and IPAC SRB Plus will be applied at each individual Rotoformer.

A mitigation plan is outlined in Volume IIB, Section 3: Surface Water Quantity and Section 4: Surface Water Quality. An environmental management system (EMS) will be implemented to ensure that SO_2 emissions from onsite activities are minimized at all times.

These measures will include, but will not necessarily be limited to:

- the establishment of an air quality monitoring program measuring SO_2 and particulate sulphur (see Volume IIA, Section 2: Climate and Air Quality)
- the establishment of a periodic water quality monitoring program
- the implementation of safe operational procedures to reduce the potential for accidental or uncontrolled releases on site during the operational phase
- the development of an Emergency Response Plan detailing response procedures for potential unplanned events

According to Volume IIC, Section 2: Soil, changes in soil pH may be reversed by appropriate soil treatments such as lime application to reduce impacts to wetlands that support amphibians and waterbirds.

Spills of degassed liquid sulphur from the above-ground storage tanks, shipping containers or pipelines could directly affect some wildlife species through physical damage. Spills of liquid sulphur will be readily apparent as the sulphur will solidify immediately. Spills of sulphur pastilles may occur during the loading of the product for storage or shipping. Cleanup would involve removal of the solid sulphur and implementation of a monitoring program to determine the effects on wildlife species such as amphibians and waterbirds.

The management plan for chemical storage in the PDA is outlined in Volume I: Project Description – Section 3.7.1. All liquid products will be stored in steel tanks that include double-containment and leak detection monitoring. Liquid products will be managed and applied in enclosed systems with minimum opportunity for accidental release to the environment.

The asphalt storage pad for sulphur pastilles will include primary asphalt containment, a secondary clay soil liner, runoff and run-on controls and a leak detection layer.

Leak detection monitoring will be implemented for the surface water runoff collection pond and asphalt storage pad to assess potential leakage relative to an action leakage rate (ALR) (see Volume I: Project Description – Section 5.5). Leak detection monitoring will be implemented monthly until the integrity of the primary liners is confirmed, after which the monitoring frequency will be reduced to twice yearly.

Since native habitats will not be impacted through surface disturbance, no action is required. A possible sharp-tailed grouse lek was identified by a local stakeholder. A sharp-tailed grouse lek survey was conducted in April 2007 and no evidence of individuals using the area was detected.

To reduce potential vehicle-caused mortality and to help facilitate deer movement, the following mitigation measure can be applied:

- plant additional shrubs in adjacent linear features such as side roads and right(s)-of-way (ROW) that the deer may use as travel routes. This will increase security cover, as well as reducing the mortality risk of deer travelling close to roads by creating a buffer between the road and deer travel routes (Merrill et al 1994). Consultation with local stakeholders and SRD will be required.

- track wildlife mortality and if incidents increase, erect fencing 2.0–2.4 m in height in areas of high deer crossing and mortality locations (Foreman et al. 2003). This will deter deer from crossing at certain sections and filter them to areas that are less hazardous to cross. This should be done in collaboration with ASRD and using local knowledge.

d) identify and discuss proposed monitoring programs that will be implemented during various phases of the Project to evaluate the effectiveness of mitigative strategies to reduce impacts to the species and their habitats that are found in the Study Areas. Describe how the results from the monitoring programs will also be used to evaluate the effectiveness of the programs themselves; and

Wetlands, waterbodies and soils will be monitored for changes in acidity levels as part of the Surface Water and Soil monitoring program. Data from these studies will be essential in evaluating the potential affects of increased acidity on amphibians and waterbirds. If pH levels in wetlands and waterbodies become acidic (less than 7.0), actions to reverse this trend will be implemented to protect species that are water-dependent.

e) discuss any existing wildlife studies that may be occurring in the Study Areas and how AST plans to integrate its operational and mitigation activities with those studies.

The Fish and Wildlife Division of Sustainable Resource Development (SRD) will be conducting regional sharp-tailed grouse lek surveys. Site specific lek survey information collected in the LSA will also be shared with SRD.

4. Wildlife Resources

4.1 Introduction

This section presents the results of baseline studies and the impact assessment for wildlife resources as part of the EIA for the proposed Bruderheim Sulphur Forming and Shipping Facility Project (the Project). Reviews of existing information were conducted for the Project and field studies were completed in 2006 to assist in quantifying and describing baseline wildlife conditions within the Wildlife Local Study Area (LSA) and Regional Study Area (RSA). Section 4.7 presents the application case assessment with potential Project-specific impacts on wildlife resources. Cumulative impacts on wildlife resources are considered in Section 4.8. Monitoring and adaptive management measures and the impact summary are considered in the subsequent sections. The Project has the potential to impact wildlife through potential acid input, direct mortality, loss of habitat, noise and habitat fragmentation as it affects wildlife movements.

4.2 Indicators and Issues

The wildlife resource indicators and the impact issues selected for detailed assessment follow the TOR of Alberta Environment (AENV 2007). Indicators and issues were also identified through public consultation and stakeholder interviews (see Volume 1, Project Description) and reviews of recent relevant EIAs conducted in the Alberta Industrial Heartland.

The wildlife indicators selected for detailed assessment are:

- waterbirds: waterfowl, wading birds and shore birds
- ungulates: deer (mule and white-tailed)
- amphibians (Canadian toad, wood frog, chorus frog and tiger salamander)

Wildlife resources may be directly and indirectly affected by the following issues associated with the Project:

- potential acid input (sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and sulphur dust)
- direct mortality
- habitat availability
- noise
- fragmentation and wildlife movements

4.2.1 Potential Acid Input

Effects of acidifying compounds such as SO_2 and NO_2 on vegetation and wetland resources and ultimately wildlife were examined in the LSA and RSA. Acid air emissions can negatively affect vegetation and wildlife health if sufficient amounts are absorbed directly from the air. Direct effects on vegetation may include discolouration, defoliation, die back, reduced plant vigour, altered growth and less successful reproduction (Crittenden and Read 1979, Case and Krouse 1980, Krouse and Case 1981, Addison and Jensen 1987).

Changes to forests and vegetation also directly affect key wildlife habitats. Effects on wildlife may include simplification of forest ecosystems, through reduction in the number of niches that wildlife species can occupy (Schreiber and Newman 1988).

The effects of acidification on wildlife are not clear for many species (Schreiber and Newman 1988). Much of the research has been focused on species that occupy aquatic habitats, such as water birds (e.g., McNicol et al. 1987), passerines (e.g., Eriksson 1987) and amphibians (e.g., Freda 1986). There has been limited work on the effects of acidification on terrestrial wildlife such as ungulates (Schreiber and Newman 1988).

Acid precipitation is not likely to directly affect terrestrial wildlife since the acidification process, includes soils and causes changes to the physiochemistry of water (Schreiber and Newman 1988). Therefore, only species that are limited by such habitats (e.g., fish and soil fauna), will be affected directly. Terrestrial birds and mammals that are not limited by these habitats will not be directly affected (Schreiber and Newman 1988). It is also difficult to separate the impacts of acid precipitation from the numerous other factors that affect wildlife populations and individuals.

Predicted impacts on vegetation communities resulting from acidic deposition are based on critical loads adopted by AENV. A critical load is the highest load of acid deposition that will not cause chemical changes leading to long-term harmful effects on the most sensitive ecological systems (CASA 1999). The critical loads are listed in Volume IIC, Section 2: Soil – Table 2.4–6 for various soil sensitivities (CASA 1996). The potential acid input (PAI) deposition isopleths were derived using the CALPUFF model, which is explained in detail in Volume IIA, Section 2: Climate and Air Quality.

4.2.2 Direct Mortality

Direct Project-related mortality can result from a number of factors, but may primarily result from habitat clearing and collisions with Project equipment and vehicles. Habitat clearing poses a direct risk to wildlife as a result of possible destruction of nests, dens or hibernating species.

The issue of wildlife health is also considered a direct mortality risk. Possible effects on wildlife as a result of changes to air and water include both acute and chronic effects on animal health. This is addressed in the potential acid input section. Contaminant spills are also of concern, as they may directly affect surface water and have impacts on waterbirds and amphibians.

4.2.3 Noise

Noise can negatively affect many wildlife species. In particular, birds are particularly sensitive to noise generated by high traffic volumes (Foppen and Reijnen 1994, Reijnen and Foppen 1994, Brotons and Herrando 2001, Forman et al. 2002, Peris and Pescador 2004, Habib et al. 2007). High traffic volumes and associated noise can reduce avian populations through displacement that are less than 500 m from a road (Reijnen et al. 1995, 1996; Forman et al. 2002).

4.2.4 Habitat Availability

Infrastructure construction can result in direct loss of habitat, as well as reduced habitat effectiveness adjacent to the facilities. Other projects and activities in the area will add cumulatively to habitat loss and effectiveness. However, facilities for the Project will be on disturbed land and will not impinge upon any natural habitats either locally or regionally.

4.2.5 Habitat Fragmentation and Wildlife Movements

Habitat fragmentation is the transformation of a relatively connected landscape into smaller areas or habitat patches that are interspersed with disturbed areas (McGarigal and Marks 1994). Disturbances that cause habitat fragmentation can be either natural (e.g., fire) or human-caused (e.g., agriculture, logging, infrastructure). Agriculture, urbanization, forestry and oil and gas disturb the greatest amount of natural area in Alberta and this can negatively affect the persistence of some species, as well as reduce biodiversity in some areas (Fahrig 2001).

4.3 Terms of Reference

In addition to the issues described above, the assessment also addresses the issues identified in the Final Terms of Reference (TOR) for the Project as follows:

Describe existing wildlife resources (amphibians, reptiles, birds and terrestrial and aquatic mammals), their use and potential use of habitats in the Study Areas. Document the anticipated changes to wildlife in the Study Areas. Specifically:

a) document and describe species of conservation concern found within the Study Area, using recognized survey protocols;

b) describe and assess potential impacts of the Project on wildlife species found in the Study Areas, including impacts on critical habitat, habitat availability and quality, and habitat fragmentation and loss. These impacts should be described for the various phases of the Project both locally and cumulatively with other activities in the Study Areas;

c) proposed strategies to minimize and/or mitigate impacts on the species and their habitats that are found in the Study Areas. These strategies should be tailored to the various phases of the Project and meet the expectations of relevant wildlife legislation;

d) identify and discuss proposed monitoring programs that will be implemented during various phases of the Project to evaluate the effectiveness of mitigative strategies to reduce impacts to the species and their habitats that are found in the Study Areas. Describe how the results from the monitoring programs will also be used to evaluate the effectiveness of the programs themselves; and

e) discuss any existing wildlife studies that may be occurring in the Study Areas and how AST plans to integrate its operational and mitigation activities with those studies.

As well, a relevant issue from the Biodiversity TOR addressed in this Section includes:

f) identify and evaluate the extent of potential effects from fragmentation (e.g., disruption of movement corridors) that may result from the Project;

4.4 Methods

4.4.1 Spatial and Temporal Boundaries

4.4.1.1 ***Principal Development Area***

The proposed Project will be developed in the Principle Development Area (PDA), a portion of Section 35-55-20 W4M (the Site) that comprises the area of disturbance and development. The PDA is equal to the Project Footprint, which includes the direct footprint of the proposed facility and associated infrastructure and is 24.8 ha in size. All infrastructure and activities will be confined to Section 35-55-20 W4M. The PDA, shown in Figure 4.4-1, consists of:

- rail and road access for receiving and shipping sulphur
- liquid sulphur unloading and transfer facilities
- sulphur forming facilities to produce sulphur pastilles
- loading and shipping facilities for formed sulphur
- a sulphur pastille temporary storage area

4.4.1.2 Local Study Area

The Wildlife LSA covers 407.4 ha and is defined as Section 35-55-20 W4M surrounded by a 200 m buffer zone (see Figure 4.4-1). The 200 m buffer was included to contain the predicted emissions from the Project within the LSA (DM Leahey & Jacques Whitford 2005). Two railways ROW traverse the LSA. A utility substation is adjacent to a wetland located in the northwest corner and an intermittent stream flows south to north along the eastern portion of the LSA. The LSA is located in the Lamont Country Industrial Heartland, which forms the eastern portion of the Alberta Industrial Heartland. Due to common ecological relationships, the LSA is the same for the vegetation, wildlife, biodiversity and soils sections of this EIA.

4.4.1.3 Regional Study Area

The Wildlife RSA is defined as Section 35-55-20 W4M surrounded by a 1,000 m buffer zone (see Figure 4.4-1). The RSA was delineated based on the preliminary air modeling conducted in 2005 for the sulphur processing facility. The RSA was used to evaluate the Project effects of potential acid deposition and includes lands that fall within the predicted SO_2 emissions isopleths estimated in the 2005 air modeling (DM Leahey & Jacques Whitford 2005). Due to common ecological relationships, the RSA is the same for the vegetation, wildlife, biodiversity and soils sections of this EIA.

4.4.1.4 Temporal Boundaries

Three temporal boundaries are used in this assessment: baseline, application and closure. Baseline refers to the present conditions in the LSA and RSA as of August 2006. Application is assessed at maximum disturbance. This approach determines the impact of the Project as if all facilities were fully developed and operating concurrently. Therefore, impact predictions during the application case are considered worst case and conservative. Closure is considered when all project facilities have been decommissioned and reclamation has taken place. It is assumed that closure occurs five years after decommissioning and reclamation, therefore, vegetation has been planted or seeded and has had time to establish on the site.

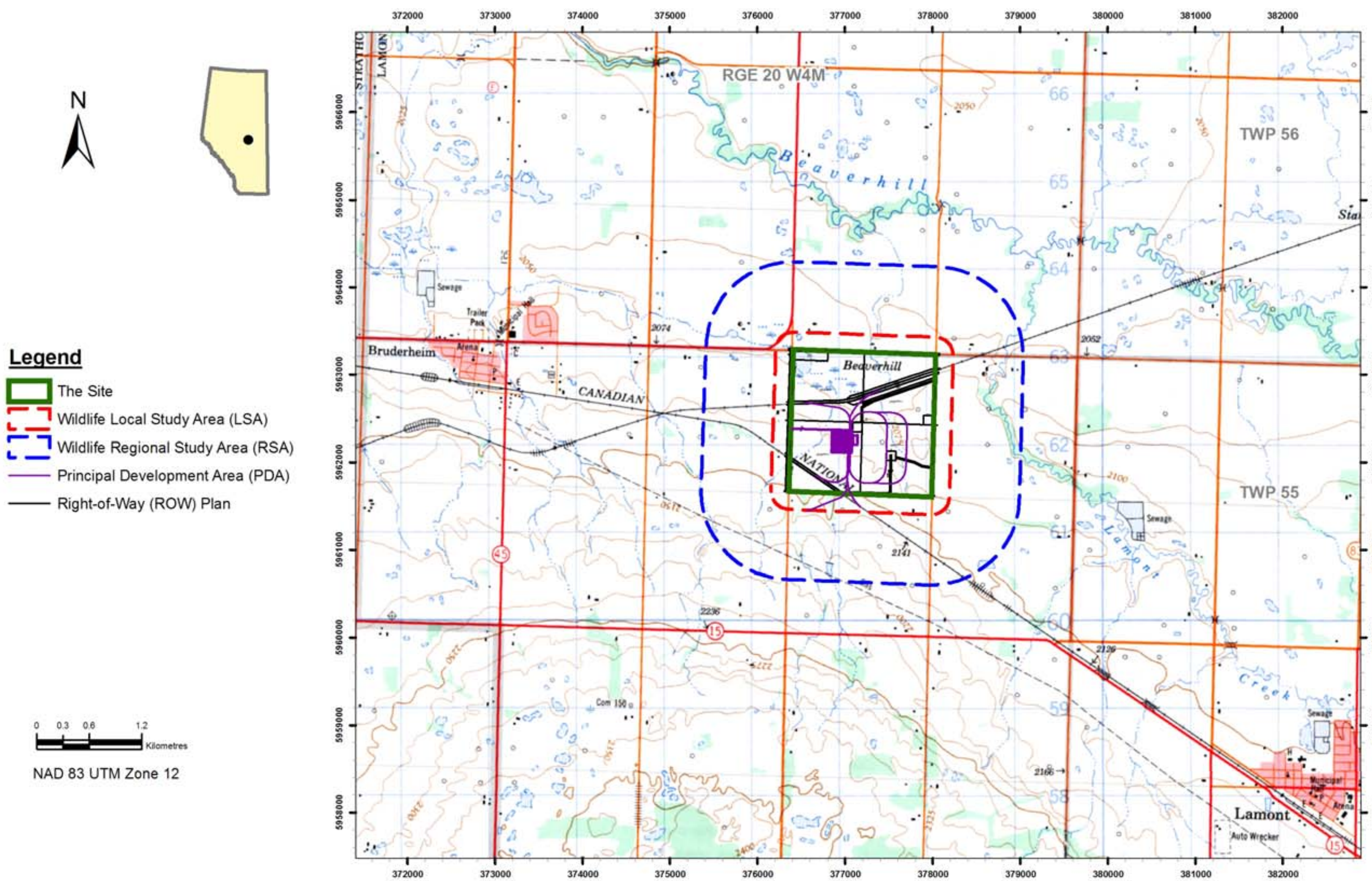

Figure 4.4-1: Wildlife LSA and RSA

4.4.2 Project Inclusion List

The project inclusion list consists of the various anthropogenic disturbances in the RSA. Inclusion of the disturbances in the analysis is required to effectively determine Project and cumulative effects. Table 4.4-1 provides the list of projects included in each case.

Table 4.4-1: Project Inclusion List

Status	Baseline Case	Application Case	Cumulative Effects Case
Existing and Approved	Canexus Chemicals	Canexus Chemicals	Canexus Chemicals
	ERCO Worldwide	n/a	n/a
	Triton	Triton	Triton
Project	n/a	Bruderheim Sulphur Forming and Shipping Facility	Bruderheim Sulphur Forming and Shipping Facility
Planned Projects and Activities	n/a	n/a	n/a

Note:
n/a – not applicable

4.5 Baseline Data Acquisition Methods

4.5.1.1 Field Surveys

The purpose of the baseline surveys was to provide site-specific information on species presence, relative abundance, distribution and habitat use at key locations within the LSA. These surveys helped to identify important wildlife habitat and seasonal use for some wildlife species. The primary concern with regard to this project is species associated with wetland habitat and sharp-tailed grouse which were previously detected in the area. Wetlands provide key habitat for waterbirds and amphibians and are important for the overall biodiversity of the area.

4.5.1.2 Field Methods

A site visit was conducted on July 21, 2006 which focused on wetlands and critical habitat for SAR and indicator species that are wetland dependent (see Figure 4.5-1). Habitats within the LSA and RSA were searched on foot or from a truck. Considerable time was spent surveying wetlands in the area to search for evidence of amphibians and waterbirds.

A sharp-tailed grouse lek survey was conducted on April 8, 2007. The site was surveyed by driving along roads surrounding the site and stopping every 800 m to listen for and look for evidence of grouse for three minutes (Ministry of Environment, Lands and Parks 1997). The survey was conducted from half an hour before sunrise until three hours after sunrise.

A search of the Fish and Wildlife Historical Information System (FWHIS) was conducted to determine if other wildlife species, in particular SAR, have been detected on or near the site.

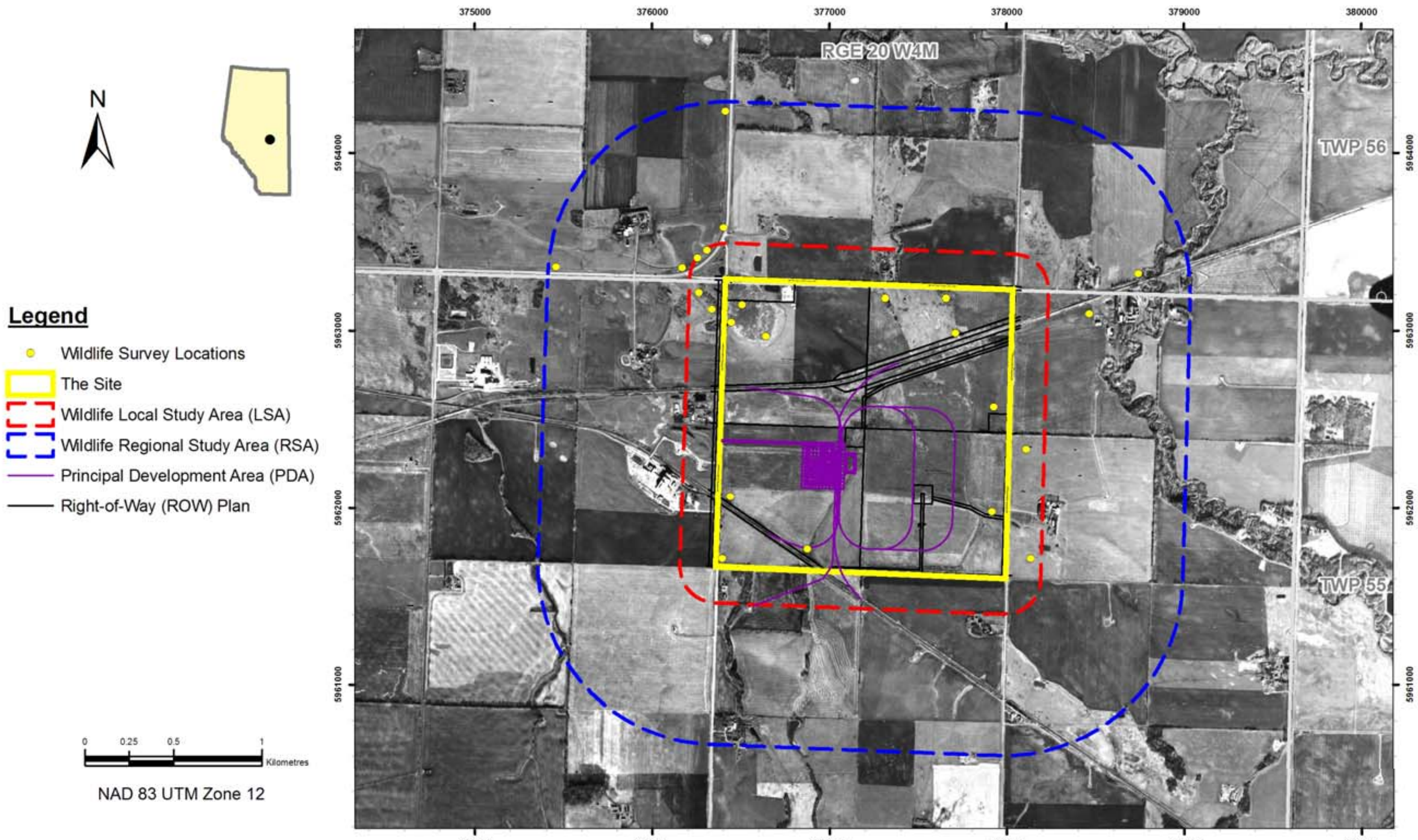

Figure 4.5-1: Wildlife Survey

4.5.2 Species at Risk

There are three designations of SAR: species listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2006, Internet site) as endangered, threatened, or of special concern, those listed on Schedules 1, 2 and 3 of the *Species at Risk Act* (SARA 2006, Internet site) and those listed by Alberta Sustainable Resource Development (ASRD 2006) as at risk, may be at risk or sensitive.

Information on SAR was gathered during the wildlife survey conducted on July 21, 2006 and was also gathered incidentally during the vegetation field surveys. A total of 65 species that could potentially occur in the RSA were identified as SAR including two species of amphibian, two species of reptile, 54 species of birds and seven species of mammals (see Table 4.5-1).

Table 4.5-1: Species at Risk Potentially Occurring in the RSA and their Provincial and Federal Status

Common Name	Provincial[1]	Federal[1]	SARA[1]
Amphibians and Reptiles			
Canadian toad	May be at risk	Not at risk	
Western toad	Sensitive	Special concern	Schedule 1
Red-sided garter snake	Sensitive		
Plains garter snake	Sensitive		
Birds			
Pied-billed grebe	Sensitive		
Horned grebe	Sensitive		
Western grebe	Sensitive		
American white pelican	Sensitive	Not at risk	
American bittern	Sensitive		
Great blue heron	Sensitive	Special concern	
Black-crowned night-heron	Sensitive		
Trumpeter swan	At risk	Not at risk	
Green-winged teal	Sensitive		
Northern pintail	Sensitive		
Lesser scaup	Sensitive		
White-winged scoter	Sensitive		
Turkey vulture	Sensitive		
Osprey	Sensitive		
Bald eagle	Sensitive	Not at risk	
Northern harrier	Sensitive		
Northern goshawk	Sensitive	Not at risk	
Broad-winged hawk	Sensitive		
Swainson's hawk	Sensitive		

Notes:
[1] Status definitions are provided in Appendix I.
Sources: ASRD (2006), COSEWIC (2006 Internet site), SARA (2006 Internet site).

Table 4.5-1: Species at Risk Potentially Occurring in the RSA Including their Provincial and Federal Status (Cont'd)

Common Name	Provincial[1]	Federal[1]	SARA[1]
Golden eagle	Sensitive	Not at risk	
Peregrine falcon	At risk	Threatened	Schedule 1
Sharp-tailed grouse	Sensitive		
Yellow rail	Undetermined	Special concern	Schedule 1
Sora	Sensitive		
Sandhill crane	Sensitive	Not at risk	
Piping plover	At risk	Endangered	Schedule 1
Upland sandpiper	Sensitive		
Forster's tern	Sensitive	Data deficient	
Black tern	Sensitive	Not at risk	
Barred owl	Sensitive		
Great gray owl	Sensitive	Not at risk	
Short-eared owl	May be at risk	Special concern	
Common nighthawk	Sensitive		
Pileated woodpecker	Sensitive		
Least flycatcher	Sensitive		
Eastern phoebe	Sensitive		
Great crested flycatcher	Sensitive		
Purple martin	Sensitive		
Barn swallow	Sensitive		
Brown creeper	Sensitive		
Sedge wren	Sensitive	Not at risk	
Sprague's pipit	Sensitive	Threatened	Schedule 1
Loggerhead shrike	Sensitive	Threatened	Schedule 1
Cape May warbler	Sensitive		
Black-throated green warbler	Sensitive		
Blackburnian warbler	Sensitive		
Bay-breasted warbler	Sensitive		
Common yellowthroat	Sensitive		
Canada warbler	Sensitive		
Western tanager	Sensitive		
Baird's sparrow	May be at risk	Not at risk	
Baltimore oriole	Sensitive		
Bobolink	Sensitive		
Rusty blackbird	Secure	Special concern	

Notes:
[1] Status definitions are provided in Appendix I.
Sources: ASRD (2006), COSEWIC (2006 Internet site), SARA (2006 Internet site).

Table 4.5-1: Species at Risk Potentially Occurring in the RSA Including their Provincial and Federal Status (Cont'd)

Common Name	Provincial[1]	Federal[1]	SARA[1]
Mammals			
Northern long-eared bat	May be at risk		
Silver-haired bat	Sensitive		
Red bat	Sensitive		
Hoary bat	Sensitive		
Long-tailed weasel	May be at risk	Not at risk	
American badger	Sensitive	Not at risk	
Canada lynx	Sensitive	Not at risk	

Notes:
[1] Status definitions are provided in Appendix I.
Sources: ASRD (2006), COSEWIC (2006 Internet site), SARA (2006 Internet site).

4.5.3 Impact Assessment Methods

The impact assessment evaluated Project impacts for the application case and closure case. Residual impacts were measured for the application case at maximum disturbance when all aspects of the Project are constructed and operated concurrently and for the closure case at post-reclamation when all mitigation techniques have been implemented.

Potential impacts of the Project on wildlife indicators were assessed for the application and closure cases using the criteria of direction, geographic extent, magnitude, duration, reversibility and confidence as described in Volume I. A final impact rating of Class 1, 2, 3 or 4 was applied to residual impacts for each indicator as defined in Table 4.5-2.

Table 4.5-2: Final Impact Rating

Rating	Level of Action
Class 1	The predicted trend in an indicator under projected land use development could threaten the long-term sustainability of the quantity or quality of the indicator in the local and RSA. An action plan, developed jointly by regional stakeholders, is required to monitor the affected indicator, identify and implement further mitigation measures to reduce any impact and promote recovery of the indicator, where appropriate. This Class of impact might also be applicable to an exceedance of a regulatory guideline, or where the impact will have long-term effects.
Class 2	The predicted trend in an indicator under projected land use development will likely result in decline in the quantity or quality of the indicator. The decline could be to lower-than-baseline but stable levels in the LSA and RSA after closure and into the foreseeable future. In addition to responsible industrial operational practices, monitoring and recovery initiatives could be required if additional land use activities occur in the study area before closure of the projected land use development. This Class of impact might also be applicable to an exceedance of a regulatory guideline, or where the impact is expected to have mid-term effects, but where recovery will take place shortly after closure of the projected land use development.

Table 4.5-2: Final Impact Rating (Cont'd)

Rating	Level of Action
Class 3	The predicted trend in an indicator under projected land use development could result in a slight decline in the quantity or quality of the indicator in the LSA and RSA during the life of the projected land use development, but resource levels should recover to baseline after closure. In some cases, a short-term, low to moderate magnitude impact could occur, but recovery will take place within five years. No new resource management initiatives are necessary. Responsible industrial operational practices should continue. This Class of impact could also be applicable where regulatory guidelines are not exceeded, but where a relative change in magnitude of an indicator occurs.
Class 4	The projected land use development results in no change and no contribution toward affecting the quantity or quality of the indicator in the LSA and RSA during the life of the projected land use development. Responsible industrial operational practices should continue. Therefore, no cumulative effects result from the Project.

4.5.4 Potential Acid Input

Effects of acidifying compounds such as SO_2 and NO_2 on wildlife and wildlife habitats were considered in the LSA and RSA for surface water and soils. The baseline, application and cumulative effects from the results of the air quality (see Volume IIA, Section 2: Climate and Air Quality), groundwater (see Volume IIB, Section 2: Groundwater Quantity and Quality) and soil (see Volume IIC, Section 2: Soil) components were used to evaluate effects of PAI on wildlife.

4.5.4.1 Air Emissions

This section was adapted from Komex (2006) which was prepared to evaluate wildlife health. For the effects of air emissions on wildlife, the maximum predicted ground-level air concentrations for application and cumulative effects assessment (CEA) were compared against the toxicological reference values (TRVs) (see Table 4.5-3). If the maximum predicted ground-level air concentrations attained were equal to, or lower than, the TRVs, it was assumed that the wildlife receptors would be protected (i.e., would not be at risk from inhaling emissions).

Canadian Council of Ministers of the Environment (CCME) or Environment Canada does not provide standard guidance for deriving wildlife TRVs. However, British Columbia Ministry of Environment, Lands and Parks (BC MWLAP) (1998) has recommended an allometric approach for extrapolating toxicity data between certain mammalian species. However, the use of allometric scaling to extrapolate toxicity data from one species to another does not take into account differences in physiology, which may alter a chemical's uptake, distribution and excretion. Moreover, Sample and Arenal (1999) state that the basis for applying a given scaling factor for extrapolating toxicity is weak. Therefore, allometric scaling was not used to estimate wildlife TRVs.

BC MWLAP (1998) recommends that an EC20, or concentration that affects 20% of the exposed (i.e., test) organisms, be selected as the TRV. A 10-fold uncertainty factor was applied to account for interspecies differences.

Methods proposed by BC MWLAP (1998) were used in selecting the TRVs for the acute inhalation assessment, as EC20's are typically associated with a time duration that seldom exceeds 96 hours (e.g., 24 or 48 hours). If an EC20 was not known, then the EC50 (the concentration that affects 50% of the test organisms) was used. An uncertainty factor of 10 was applied to the identified EC20 or EC50 to account for interspecies variability (BC MWLAP 1998). Where an EC20 or EC50 could not be identified, a lowest-observed-adverse-effect-level (LOAEL) based on short-term exposure was used in the acute effects assessment, without applying any uncertainty factors.

The United States Environmental Protection Agency (USEPA) (1998) guide for ecological risk was used to derive chronic screening ecotoxicity values. USEPA (1998) recommends using no-observed-adverse-effect-levels (NOAEL) based on population-level effects for chronic exposures to contaminants. Adverse affects may occur to species development, reproduction and survivorship. Where inhalation NOAELs were unavailable, inhalation LOAELs or oral NOAELs were applied as the TRV (assuming 100% inhalation bioavailability). If a LOAEL was used, an uncertainty factor of 5 was conservatively applied to account for interspecies differences based on CCME (1996) guidance. CCME (1996) recommends applying a safety factor (uncertainty factor) of 1–5 to a LOAEL, for extrapolating to other wildlife species.

Table 4.5-3: Acute Inhalation TRVs Protective of Wildlife Receptors

COPC1	TRV (mg/m^3)	TRV (ppm)	End Point	Comment	Reference
NO_2	16.4	8.6	Lethality	An LC50 of 164 mg/m^3 was identified in rats exposed via inhalation to NO_2 for 4 hours. An uncertainty factor of 10 was applied to account for interspecies variation, based on BC MWLAP guidance	HSDB (2006, Internet site)
SO_2	260.0	98.2	Lethality	An LC50 of 2,600 mg/m^3 was identified in mice exposed via inhalation to SO_2 for 4 hours. An uncertainty factor of 10 was applied to account for interspecies variation, based on BC MWLAP guidance	ACGIH (1991, Internet site)
NO_2	0.1	0.05	Developmental effects	A NOAEL of 0.1 mg/m^3 was identified in Wistar rats exposed via inhalation to NO_2 at concentrations of 0, 0.05, 0.10, 1.0 or 10 mg/m^3 for 6 hours a day, 7 days a week, throughout gestation. The postnatal development of the pups was followed, until the age of two months	Tabacova et al. (1985)
SO_2	2.6	1.0	Respiratory effects	A NOAEL of 2.6 mg/m^3 was identified in guinea pigs exposed via inhalation to an average SO_2 concentration of 0.34, 2.6, or 15 mg/m^3 continuously for 52 weeks	Alarie et al. (1970)

4.5.4.2 *Waterbodies*

The effect of PAI manifests itself most readily in aquatic ecosystems. The primary wildlife taxa that will be most affected by pH depression are amphibians and waterbirds. Low pH values can reduce the reproductive capacity of amphibians in numerous ways. The potential effects of pH depression (pH less than 7.0) can have the following effects (from Schreiber and Newman 1988):

- embryonic deformities and mortalities
- decreased egg mass
- reduced densities
- increased percentage of dead or molded egg masses
- iono-regulatory failure
- delayed development
- abnormalities
- decreased sperm motility

The effects of acidification on waterbirds are indirect. Acidification may result in reduced biomass of primary foods for waterbirds such as fish, aquatic invertebrates and amphibians (Schreiber and Newman 1988).

4.5.4.3 *Soils*

Changes to soil acidity can affect both vegetation and water pH. The buffering capacity of soils has a strong influence on the sensitivity of vegetation and aquatic environments to impacts from acidifying emissions. Community types most sensitive to acidic inputs occur on sandy soils that have little organic material, low clay content and low soil buffering capacity. Acidification of soils can affect the acidity of waterbodies through runoff, which may impact wildlife species dependent upon aquatic ecosystems (Schreiber and Newman 1988).

Table 4.5-4: Potential Acid Input Guidelines in Alberta

Air Emission	Alberta Environment Guidelines	
	Sensitivity	**Critical Load ($keq\ H^+/(ha•y)$)[1]**
PAI deposition (annual)	Highly sensitive soils	0.25
	Moderately sensitive soils	0.50
	Low sensitivity soils	1.00

Note:
[1] $keq\ H^+/(ha•y)$ = kiloequivalents of hydrogen ion deposition per hectare, per year.

4.5.5 Direct Mortality

The largest source of direct mortality from the Project will likely be from wildlife-vehicle collisions (WVC). Large mammals are particularly susceptible to highway mortality because of their large range requirements cause individuals to regularly cross roads. However, a wide diversity of wildlife is killed on a variety of roads under a range of different conditions (Evink et al. 1996, Jalkotzy et al. 1997, Clevenger et al. 2002). Typically, wildlife collisions occur at night, during spring and fall and are most pronounced on sections of roads that intersect movement corridors or important habitat patches. Wildlife may also be attracted to roads by forage conditions along road edges or by salt. Divided highways with large traffic volumes (≥ 10,000 average annual daily traffic) are known to act as partial wildlife barriers and sources of mortality, while lower traffic volume highways have proportionally lower barrier and mortality effects. Smaller roads with relatively low traffic volumes (e.g., 5–100 vehicles per day) may not inhibit wildlife movements and are not often associated with wildlife collisions (Beringer et al. 1990, Forman et al. 2003).

Estimates of mortality from WVC were assessed for moose, white-tail and mule deer and coyote. These species were chosen for risk assessment since estimates of direct mortality could be made for these species based on WVC records and projections from current traffic volumes.

For moose, white-tail and mule deer and coyote, the direct mortality risk was based on the last five years of WVC reports recorded along Highway 38/45, Highway 21/15 and Highway 830, located around the town of Bruderheim. The correlation between traffic volumes and WVCs was used to assess potential road-kills likely to occur with projected traffic volume increases associated with the Project.

Contaminant spills are also a potential source of direct mortality and mitigation dealing with this issue is discussed.

4.5.6 Habitat Availability

Habitat availability reflects an area's capability to support a species. Measures of habitat availability consider both habitat suitability and habitat effectiveness. Habitat suitability refers to an area's potential to support a species given its biophysical characteristics (US Fish and Wildlife Service 1980, 1981). Habitat effectiveness refers to the willingness, or ability, of a species to use habitat that is identified as suitable (Gibeau 1998). Thus, regardless of the suitability of an area, a species may be unwilling to use the habitat due to factors such as its proximity to human disturbance.

Suitable wildlife habitats were ranked according to overall species diversity (see Volume IIC, Section 5: Biodiversity and Fragmentation). The habitats were classified into broad vegetation categories (see Volume IIC, Section 3: Vegetation). Impacts to habitat availability were assessed using the surface disturbance from the Project.

4.5.7 Habitat Fragmentation and Wildlife Movements

Habitat fragmentation may lead to the loss of habitat connectivity, which occurs when large, contiguous tracts of habitat are divided into smaller, isolated patches (Noss and Csuti 1997). Large blocks of habitat in the landscape that are exclusive of major human disturbances and infrastructure are extremely important to the persistence of many species. Wildlife must be able to move freely between these large blocks for various life requirements and to maintain genetic flow between populations (Noss et al. 1996). These movement areas are referred to as linkage zones (Servheen et al. 2001). Linkages between habitats can occur on a coarse landscape level or on a fine-scale, site-specific basis.

Roads present a partial barrier, but they are permeable to many wildlife species (Forman et al. 2003). The largest impediment for wildlife movements will be the Project footprint. Mule and white-tailed deer were chosen as the primary species to assess the effects of the Project on wildlife movements. Local environmental knowledge (LEK) was used to map and assess deer movements at baseline and application. LEK was used to help substitute baseline information on deer movements that was not available from empirical scientific studies (see Gilchrist and Mallory 2007).

4.6 Baseline Case

4.6.1 Site Visit

The LSA is located in the Central Parkland Natural Subregion of Alberta, in a transition area between the Boreal Forest and the Grassland Natural Subregion (Natural Regions Committee 2006) (see Figure 4.6-1).

During the first site visit, a number of bird species were observed on two natural wetlands present in the northwest corner of the LSA, along with two of the dugouts in the same vicinity (see Table 4.6-1). Four SAR were detected during the site survey, including seven green-winged teals, one northern pintail, four sora and two black terns (see Figure 4.6-2). The only other wildlife observed included a beaver on one of the wetlands. No other wildlife species were detected during the first site visit. Discussions with landowners in the area have indicated that several other species have been detected on site. Sharp-tailed grouse were present in the area prior to 1950 (Halisky 2007, pers. comm.). In the past five years, grouse have been detected near Whitford Lake, approximately 50 km east of the Site. More recently, sharp-tailed grouse have been detected within a few miles of the site and the possibility of a lek in the area has been noted by Halisky (2007, pers. comm.). Sharp-tailed grouse leks consist of areas with significant grass cover (70%) and limited forb and shrub cover (Baydack 1988). In order to provide cover habitat, aspen stands are generally found within 500 m of a lek (Baydack 1988, Swenson 1985). Suitable habitat is present on site; however, no individuals were detected during the sharp-tailed grouse survey.

A search of the Fish and Wildlife Historical Information System (FWHIS) was conducted to determine if other wildlife species, in particular SAR, have been detected on or near the LSA. A western toad was detected in the LSA in 1997 (see Figure 4.6-2). In general, habitat is very limited for the many SAR in the LSA and RSA. This results in few SAR present in either the LSA or RSA and the vast majority of these species do not occur in either the LSA or RSA.

Table 4.6-1: Bird Species Detected During Wetland Survey

Species	Number of Adults Observed	Number of Offspring Observed
Waterbirds		
Green-winged teal	1	6
Mallard	6	21
Northern pintail	1	0
Redhead	1	0
Sora	4	0
Killdeer	31	0
Greater yellowlegs	1	0
Solitary sandpiper	5	0
Black tern	2	0

Table 4.6-1: Bird Species Detected During Wetland Survey (Cont'd)

Species	Number of Adults Observed	Number of Offspring Observed
Raptors		
Red-tailed hawk	1	0
Passerines		
Eastern kingbird	1	0
Cedar waxwing	3	0
Swamp sparrow	1	0
Red-winged blackbird	13	0
Yellow-headed blackbird	1	0
Unknown	3	0

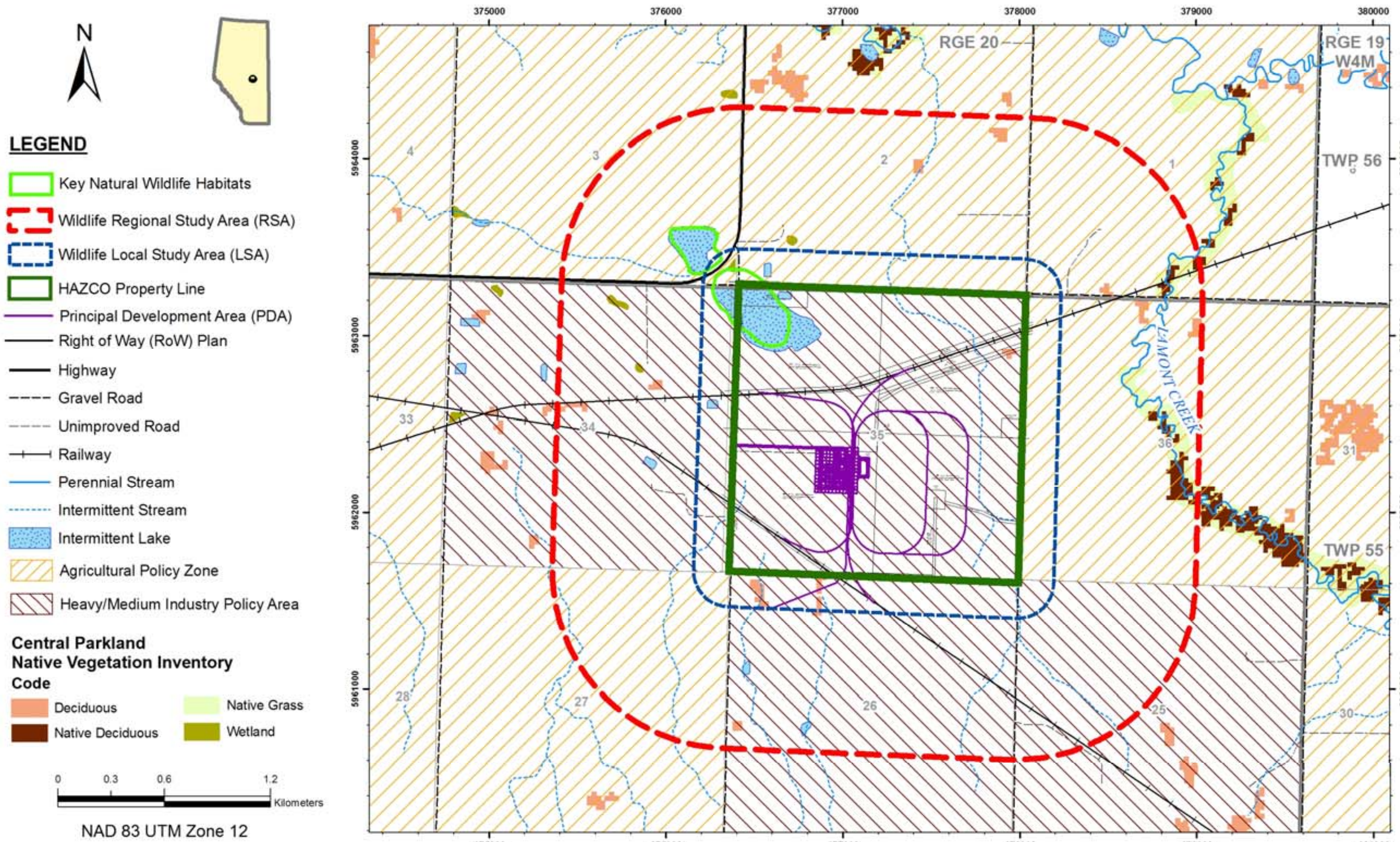

Figure 4.6-1: Vegetation Class

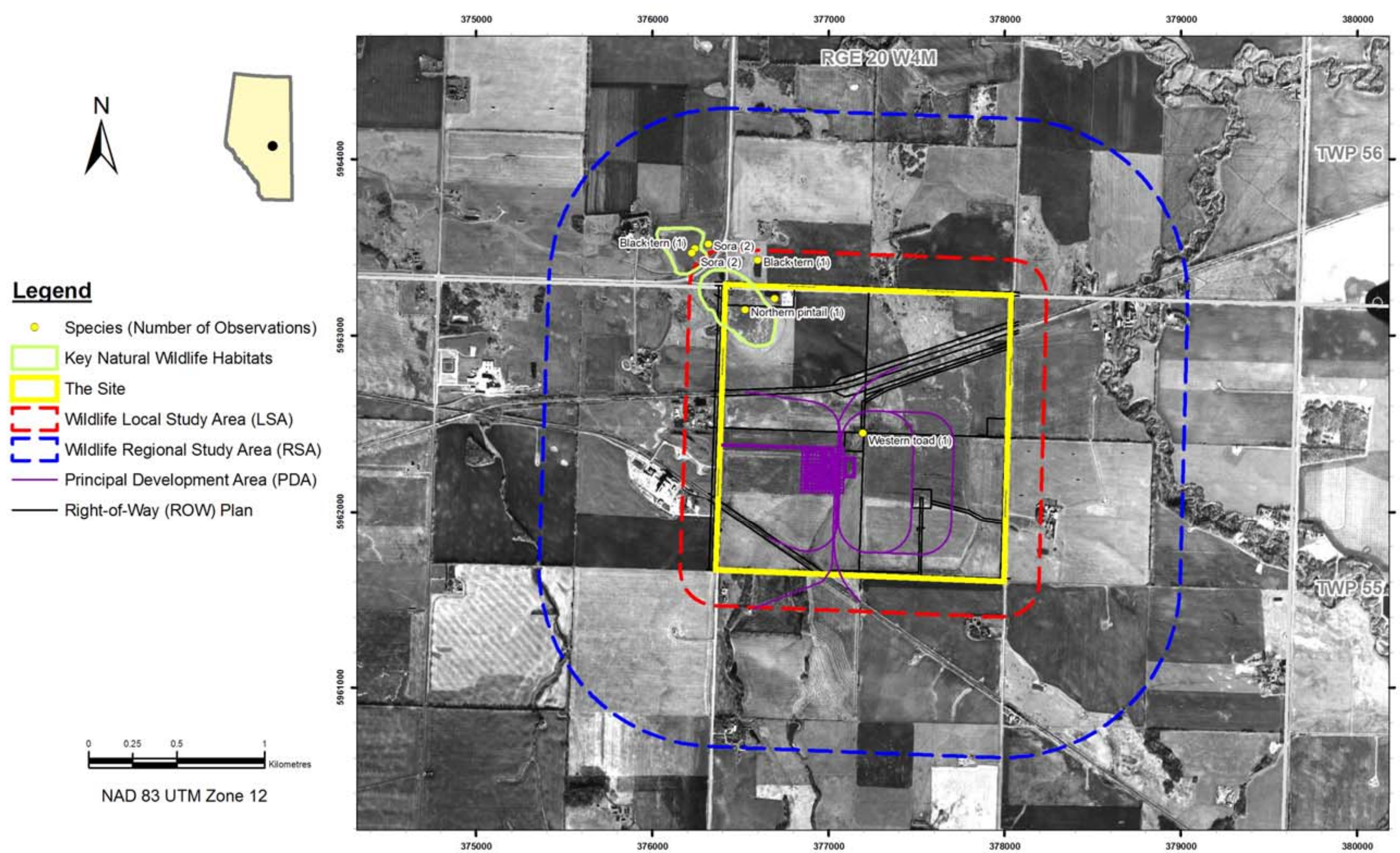

Figure 4.6-2: Wildlife Sensitive Species

4.6.2 Potential Acid Input

4.6.2.1 Waterbodies

At baseline, pH levels measured at seven waterbodies including creeks, wetlands and streams in the LSA and RSA indicate alkaline conditions at all these locations, with pH values between 7.2 and 8.9 (see Volume IIB, Section 4: Surface Water Quality). These pH values are not detrimental to amphibians and waterbirds (Schreiber and Newman 1988) (see Table 4.6-2).

Table 4.6-2: Surface Water pH Levels in Waterbodies Sampled in the LSA and RSA at Baseline

Indicator	Sample Location	pH
pH	SW1	7.2
	SW2	7.8
	SW4	7.6
	SW6	7.2
	SW7	7.2
	SW9	8.9

4.6.2.2 Soils

At baseline, areas in the LSA and RSA currently have levels of acid input (PAI) below the critical load of 0.50 keq H+/(ha•y) for soils which are moderately sensitive to acid input (see Volume IIC, Section 2: Soil). These soils have a good buffering capacity to acid input.

4.6.3 Direct Mortality

Moose, deer and coyote were used to assess baseline traffic-related wildlife mortality rates. These species were the most frequently reported in motor-vehicle collisions (MVC) and account for 99.2% of all reported mortalities (see Table 4.6-3).

Based on the available data from the identified roads, there have been a total of 393 wildlife mortalities during the past five years (see Table 4.6-3). As mentioned, deer are the most commonly reported and account for 88.8% (349 animals) of all wildlife mortalities. Other wildlife species include moose (9.0%, 34 animals), coyote (2.0%, 7 animals) and 3 unidentified mortalities (1.0%).

Existing MVC rates for this area are quite high, with 100 wildlife mortalities for an average of 3,060 vehicles per day. There is a strong, positive, but not significant, correlation between the total number of mortalities and traffic volume, where mortalities have increased with increasing traffic volumes (r^2 = 0.67, P = 0.08, F = 6.1; Figure 4.6-3). The trend towards increased mortality with higher traffic volumes was consistent between highways. This trend is most evident with deer, where deer mortalities had the strongest correlation with increased traffic volume (r^2 = 0.74, F = 8.6, P = 0.22). This is less evident with moose and coyote, though only five years of data are available and sample sizes are small (see Table 4.6-3). Traffic volumes from 1996–2005 indicate a very strong positive increase over this 10 year time span (r^2 = 0.89, F = 66.7, P < 0.001; Table 4.6-4).

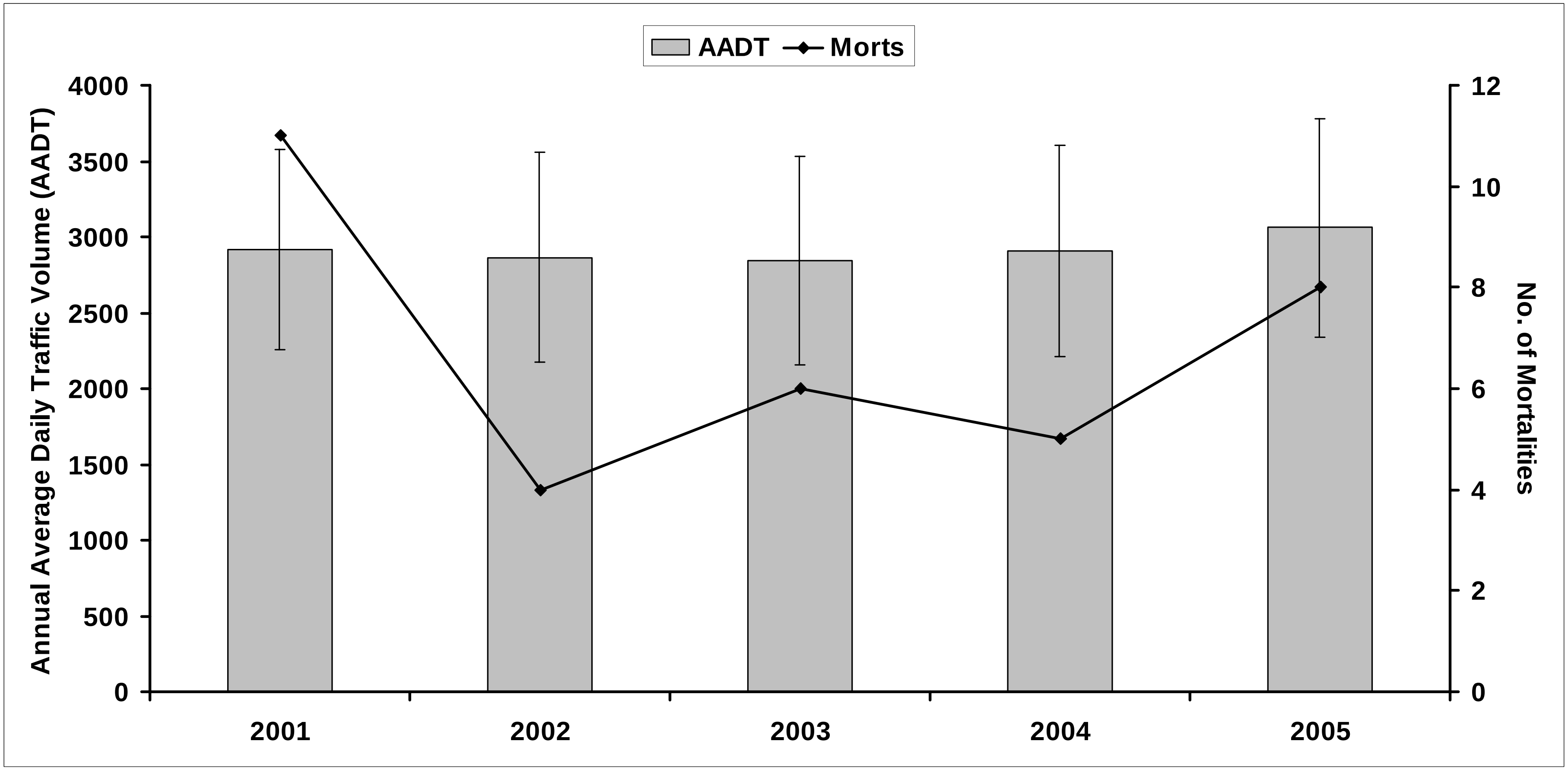

Figure 4.6-3: Annual Average Daily Traffic Volume

Table 4.6-3: Wildlife Mortalities from Vehicle Collisions Listed by Species

Species	2001	2002	2003	2004	2005	Total	Percentage of Total Mortalities
Coyote	1	1	2	3	0	7	1.8
Deer	73	48	60	77	91	349	88.8
Moose	11	4	6	5	8	34	8.7
Unknown	0	0	1	1	1	3	0.8
Total	**85**	**53**	**69**	**86**	**100**	**393**	**100.0**

Note:
2001–2005 wildlife mortality data are from Alberta Government (Infrastructure and Transportation – Driver Safety and Research, Internet site).

Table 4.6-4: Average Annual Daily Traffic Volumes at Locations Surrounding the Project Site at Baseline

Highway #	Highway Section	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
15	Scotford to Lamont	2,800	2,960	2,980	4,760	4,710	4,950	3,260	3,230	3,410	3,790
21	Highway 16 to Ft. Saskatchewan	11,090	11,840	13,790	14,340	14,540	15,500	16,550	16,320	16,380	18,320
28A	Gibbons to Highway 37	5,350	5,550	6,000	6,020	6,090	6,100	6,500	6,390	6,850	7,130
37	Ft. Saskatchewan to Highway 28A	3,080	3,200	3,900	3,930	3,970	4,120	3,850	3,790	3,990	5,380
38	Between Highway 643 and Highway 831	823	827	907	907	1,037	1,140	1,180	1,120	1,060	1,310
45	Between Highway 831 and Highway 830	1,030	1,040	1,100	1,070	1,035	1,210	1,210	1,170	1,210	1,455
830	Highway 16 to Highway 38	593	603	763	787	983	960	1,000	980	990	1,170
831	Between Highway 45 and Elk Island Park	1,243	1,300	1,349	1,388	1,412	1,740	1,700	1,690	1,690	2,120
	Mean	3,251	3,415	1,349	2,675	2,684	2,918	2,866	2,843	2,906	3,060
	± SE	1,254	1,340	1,560	635	628	659	692	689	696	716

Source: Alberta Infrastructure, Government of Alberta, 2005.

4.6.4 Habitat Availability

At baseline, there is approximately 14.6 ha (3.6%) of natural habitat (wetland) in the LSA (see Table 4.6-5, Figure 4.6-1). Approximately 96.4% of the LSA is disturbed, industrial and agricultural and does not provide highly suitable habitat for most wildlife species (see Volume IIC, Section 5: Biodiversity and Fragmentation). In the RSA, there is slightly less (by percent area) natural habitat, which totals approximately 38.9 ha or 3.2% (see Table 4.6-5, Figure 4.6-1). These natural habitats include deciduous forest (native and non-native), native grasslands and wetlands (see Table 4.6-5).

Agricultural lands comprise the largest portion of the landscape of the LSA (85%) and RSA (87%) (see Table 4.6-5, Figure 4.6-1). Agricultural lands are extremely detrimental to native wildlife and typically have low or no suitability for most wildlife species (Haila 1999, Green et al 2005).

Table 4.6-5: Land Unit Areas in the LSA and RSA

Land Unit	LSA		RSA	
	Area (ha)	Area (% total)	Area (ha)	Area (% total)
AVI				
AIF – farmstead	7.8	1.9	47.8	3.9
AIH – ROW, roads, railroads	24.5	6.0	39.2	3.2
AII – industrial, plant sites	14.8	3.6	27.8	2.3
CA – annual crop	111.3	27.3	374.3	30.1
CP – perennial forage crops	216.8	53.2	624.5	51.0
CPR – rough pasture	17.6	4.3	76.8	6.3
Total Disturbed	392.8	96.3	1,190.4	96.8
CPNVI				
Deciduous (native and non native)	–	–	7.1	0.6
Native grass	–	–	12.6	1.0
Wetland	14.6	3.6	19.2	1.6
Total natural	14.6	3.6	38.9	3.2
Total Disturbed and Natural	**407.4**	**100.0**	**1,229.3**	**100.0**

Notes:
– denotes not present.

4.6.5 Habitat Fragmentation and Wildlife Movements

At baseline, both the LSA and RSA are highly fragmented, with ≥ 96% being non-natural habitats. The large majority of the LSA and RSA are agricultural lands. However, key wildlife movements occur through the LSA and RSA. Local environmental knowledge revealed that both mule deer and white-tailed deer pass through the AST property line and adjacent to the PDA and follow five travel routes (Halisky 2007, pers. comm.; Figure 4.6-4). Each of these routes follows a vegetated linear feature and deer travel to and from forested and riparian areas. Deer primarily travel through the AST property at dawn and dusk, likely travelling between feeding and bedding locations, such as Beaverhill Creek (see Figure 4.6-4). However, deer may also bed in areas along these travel routes where adequate cover exists. Both species of deer will travel these routes during all seasons. In deep snow conditions, deer will use areas close to suitable hiding and snow interception cover and are less likely to travel in open areas.

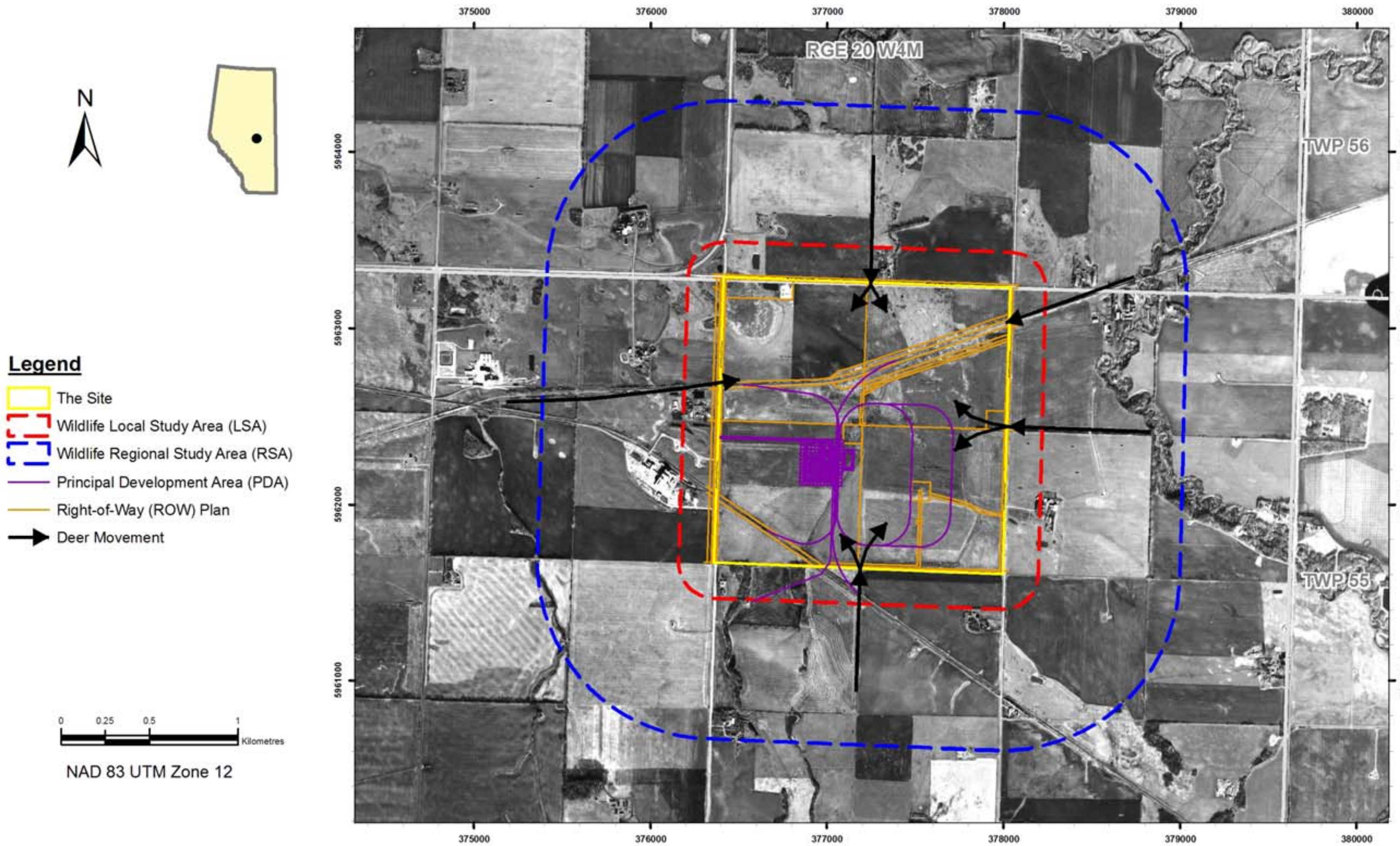

Figure 4.6-4: Deer Movement

4.7 Application Case

4.7.1 Potential Acid Input

4.7.1.1 Air

Air emissions at application are predicted to be much less than Alberta's ambient air quality objectives (see Volume IIA, Section 2: Climate and Air Quality – Table 2.6-1). The acute effects of NO_2 and SO_2 at application are well below the toxicological reference values (TRV) that result in lethality during the one-hour, 24-hour and annual averaging periods (see Table 4.7-1). This is a Class 3 impact. Similarly, the chronic inhalation effects are below TRVs that result in either developmental or respiratory effects (see Table 4.7-2). This is a Class 3 impact.

Table 4.7-1: Acute Inhalation TRVs Protective of Wildlife Receptors at Application

Indicator	TRV (ppm) [1]	End Point	Total Ground-level Concentration, Including Background (ppm) [1]			Impact Class
			One-hour	24-hour	Annual	
NO_2	8.6	Lethality	0.02	0.01	0.004	Class 3
SO_2	98.2	Lethality	0.002	0.002	0.002	Class 3

Note:
[1] parts per million.

Table 4.7-2: Chronic Inhalation TRVs Protective of Wildlife Receptors at Application

Indicator	TRV (ppm) [1]	End Point	Total Ground-level Concentration, Including Background (ppm) [1]			Impact Class
			One-hour	24-hour	Annual	
NO_2	0.05	Developmental effects	0.02	0.01	0.004	Class 3
SO_2	1.0	Respiratory effects	0.002	0.002	0.002	Class 3

Note:
[1] parts per million.

4.7.1.1.1 Mitigation

AST has committed to several management practices to minimize the impacts of air emissions from the sulphur forming and shipping facility including a dust suppression management plan. These are outlined in Volume 1: Project Description. A proprietary dust suppression agent and release aid will be used to suppress dust on the sulphur pastille storage pad, transfer points and rail load-out area. Dust suppression agents will be applied at the load-out hopper and at the rail load-out. The agents will be stored in make-up tanks and delivered via pump.

The usage rates of the dust suppression agents are estimated to be less than 100 kg/d during initial operations, increasing to less than 200 kg/d for full-scale operations. The actual amounts used will depend on the size of the trains being loaded and the conveyor size. Dustbind S5 will be applied at the transfer points and IPAC SRB Plus will be applied at each individual Rotoformer.

4.7.1.2 Waterbodies

At application, all of the waterbodies are predicted to have a pH greater than 7.0 (see Volume IIB, Section 4: Surface Water Quality – Table 4.5-1). With pH greater than 7, it is likely there will be no detrimental effects on waterbirds and amphibians. This is a Class 3 impact, though long-term monitoring is required to determine if these waterbodies acidify.

Table 4.7-3: Predicted Changes in Surface Water pH at Application

Indicator	Sample Location	Baseline	Application	Impact Class
pH	SW1	7.2	>7.0	Class 3
	SW2	7.8	>7.0	Class 3
	SW4	7.6	>7.0	Class 3
	SW6	7.2	>7.0	Class 3
	SW7	7.2	>7.0	Class 3
	SW9	8.9	>7.0	Class 3

4.7.1.2.1 Mitigation

A mitigation plan has been outlined in Volume IIB, Section 3: Surface Water Quantity and Section 4: Surface Water Quality. An environmental management system (EMS) will be implemented to ensure that SO_2 emissions from onsite activities are minimized at all times. These measures will include, but will not necessarily be limited to:

- the establishment of an air quality monitoring program measuring SO_2 and particulate sulphur (see Volume IIA, Section 2: Climate and Air Quality)
- the establishment of a periodic water quality monitoring program
- the implementation of safe operational procedures to reduce the potential for accidental or uncontrolled releases on site during the operation phase
- the development of an Emergency Response Plan detailing response procedures for potential unplanned events

4.7.1.3 Soils

It is assumed that the majority of impacts to soil from dry deposition of elemental sulphur will occur within the PDA, where soils are rated as having a low sensitivity to acid deposition (see Volume IIC, Section 2: Soil). Based on the sulphur deposition modelling data presented in Volume IIA, Section 2: Climate and Air Quality – Figure 2.5-14, the maximum average predicted annual deposition of sulphur at the Air LSA boundary will be 1.11 kg/ha/y. The effect of this rate of deposition on agricultural soils of moderate to low acid sensitivity may be small in comparison to localized soil acidification that generally occurs due to the current agricultural practice of ammonia-based fertilizer application. For agricultural soils, changes to the chemical composition of the soils will occur within timescales (i.e., years) that allow for detection by a periodic soil monitoring program (see Volume IIC, Section 2: Soil).

Soils within the LSA and RSA are rated as low to moderate with respect to acid sensitivity (see Volume IIC, Section 2: Soil). The Air Quality Section of the application (see Volume IIA, Section 2: Climate and Air Quality) indicates that emissions of acidifying substances, including NO_2 and SO_2, could potentially contribute to wet acid deposition and will include fine particles (assumed to be mainly elemental sulphur) with diameters less than 2.5 µm ($PM_{2.5}$). Based on the Project design and mitigation measures to limit aerial dispersal of elemental sulphur it is assumed that the majority of impacts to soil from dry deposition of elemental sulphur will occur within the PDA, where soils are rated as having a low sensitivity to acid deposition.

Increased acidification of soils over time may lead to increasing acidity to wetlands that support amphibians and waterbirds.

4.7.1.3.1 Mitigation

From Volume IIC, Section 2: Soil, changes in soil pH may be reversed by an appropriate soil treatment such as a lime application to reduce impacts to wetlands that support amphibians and waterbirds.

4.7.2 Direct Mortality

Existing WVC rates for this area are quite high, with 100 wildlife mortalities per year for an average of 3,060 vehicles per day. Traffic volume is correlated with the number of roadkills. Project-related growth in traffic along regional highways is projected to be an increase of approximately 350 vehicle trips per day for sulphur truck deliveries and facility staff combined, an 8.2% increase to the existing traffic volume (see Volume I, Appendix III: Traffic Impact Assessment).

It is predicted that there will be an increase by as much as 8.2% in wildlife mortalities, consisting of primarily deer. However, the regression was not based on a long-term robust dataset (n = 5 years) and is confounded by the fact that the majority of roadkills go unreported. Nietvelt (2003) found that approximately 92% of mule deer go unreported when comparing WVC with systematic roadkill surveys in Wyoming. Therefore, the use of a predictive equation is unreliable. This is considered a Class 3 impact.

4.7.2.1 Mitigation

Mitigation to prevent WVC is varied. A practical mitigation would be 2.0–2.4 m high fencing in areas of high deer crossing and mortality locations (Foreman et al. 2003). This will deter deer from crossing at certain sections of the road and filter them to areas that are less hazardous to cross. This will have to be done in collaboration with ASRD and using local knowledge.

Spills of degassed liquid sulphur from the aboveground storage tanks, shipping containers or pipelines could directly affect some wildlife species through physical damage from ingestion. Spills of liquid sulphur will be readily apparent as the sulphur will solidify immediately. Spills of sulphur pastilles may occur during the loading of the product for storage or shipping. Cleanup would involve removal of the solid sulphur and implementation of a monitoring program to determine the effects on wildlife species such as amphibians and waterbirds.

The management plan for chemical storage in the PDA is outlined in Volume I: Project Description – Section 3.7.1. All storage facilities will comply with the requirements of EUB Guide 55 and AENV guidelines for the containment of potentially hazardous materials. Liquid products will be managed and applied in enclosed systems with minimum opportunity for accidental release to the environment. None of these products are expected to contain substances that are CEPA toxics, ARET, Track 1 or on the NPRI.

The asphalt storage pad for sulphur pastilles will include primary asphalt containment, a secondary clay soil liner, runoff and run-on controls and a leak detection layer.

The leak detection monitoring plan is outlined in Volume I: Project Description – Section 5.5. Leak detection monitoring will be implemented for the surface water runoff collection pond and asphalt stockpile pad to assess potential leakage relative to an action leakage rate (ALR), which is defined in Volume I: Project Description – Section 5.5. Leak detection monitoring will be implemented monthly until the integrity of the primary liners is confirmed, after which the monitoring frequency will be reduced to twice yearly.

4.7.3 Noise

Avian populations can be impacted indirectly by a variety of factors related to vehicle traffic. Many studies suggest that indirect effects such as traffic noise and volume are key factors that have the potential to affect avian communities (Foppen and Reijnen 1994, Reijnen and Foppen 1994, Reijnen et al. 1995, Reijnen et al. 1996, Brotons and Herrando 2001, Forman et al. 2002, Peris and Pescador 2004, Habib et al. 2007).

Effects from vehicle traffic are more pronounced closer to the road. Generally, traffic volumes of less than 5,000 vehicles per day have been found to have little effect on avian populations within 500 m of a road (Reijnen et al. 1996, Forman et al. 2002). Forman et al. (2002) noted that at 8,000–15,000 vehicles per day, there was no effect on bird presence, however, regular breeding was reduced for 400 m from a road. Reijnen et al. (1996) found that at approximately 5,000 vehicles per day, 58% (7 out of 12) of the bird species studied experienced a significant population loss through displacement (greater than 10%) within 100 m of a road, while 17% (2 out of 12) of the bird species studied experienced population losses of 22–44%. Very high traffic volumes (15,000–30,000 vehicles per day) decreased both bird presence and breeding within 700 m of a road (Forman et al. 2002).

At baseline, the largest background traffic volumes occur on Highway 15 with 4,240 vehicles per day. Increased traffic volume as a result of the Project is expected to add 350 vehicles per day on R.R. 202 (see Volume I, Appendix III: Traffic Impact Assessment). By 2020 it is predicted that there will be 6,042 vehicles per day of total traffic on Highway 15. The effects of the increased traffic volume on the local avian population are predicted to be a Class 3 impact, based on findings by Reijnen et al. (1996) and Forman et al. (2002). However, the impacts are species specific and some species may be affected more than others (e.g., shorebirds). While the literature has not defined a threshold with regards to traffic volume, predicted traffic volumes as a result of an already increasing traffic volume in this area will not greatly reduce local avian populations and distribution (Reijnen et al. 1996, Forman et al. 2002). Moreover, habitat is limited in the LSA and RSA for many avian species.

There are few studies that have directly related the effect of anthropogenic noise related to industrial developments on avian populations. The effects of anthropogenic noise also vary among species and depend on the species' ability to adapt by altering their song characteristics (Slabbekoorn and den Boer-Visser 2006). Chronic noise was found to have a significant effect on breeding success of ovenbirds in mature forest habitat (Habib et al. 2007).

4.7.3.1 Mitigation

Due to the proximity of some wetlands with key bird habitats to roads, there is little mitigation that can be applied to help reduce the effects on bird populations. There is an increasing trend in traffic volumes likely due to an overall increase in industry and commerce in the region.

4.7.4 Habitat Availability

The Project will be developed on agricultural land and, therefore, there are no impacts to habitats with high wildlife value (see Table 4.7-4 and Table 4.7-5). This is a Class 4 impact.

With regard to SAR (threatened or at risk) that may occur in the LSA and RSA, the loggerhead shrike is likely to be found in deciduous habitats and this habitat will not be affected. Sprague's pipit is found on two non-native habitat types, perennial forage and annual crop and these habitats will decline by 4.9% at application (see Volume IIC, Section 3: Vegetation). Sharp-tailed grouse are known to be in the area and they may occur in perennial forage and annual crop habitats. A sharp-tailed grouse lek survey was conducted and no evidence of individuals using the area was detected.

Table 4.7-4: Impacts to Land Units with High Wildlife Species Habitat Potential at Application and Closure in the LSA

Land Cover Class	Baseline		Application			Closure		
	Area (ha)	% of LSA	Area (ha)	Change from Baseline		Area (ha)	Change from Baseline	
				(ha)	(%)		(ha)	(%)
AWI Wetland								
FONG – graminoid fen	14.66	3.60	14.66	0.0	0.0	14.66	0.0	0.0
AVI Agricultural								
CRP – rough pasture	17.65	4.33	17.65	0.0	0.0	17.65	0.0	0.0
Total	**32.31**	**7.93**	**32.31**	**0.00**	**0.00**	**32.31**	**0.00**	**0.00**

Table 4.7-5: Impacts to Land Units with High Wildlife Species Habitat Potential at Application and Closure in the RSA

Land Cover Class	Baseline		Application			Closure		
	Area (ha)	% of RSA	Area (ha)	Change from Baseline		Area (ha)	Change from Baseline	
				(ha)	(%)		(ha)	(%)
AWI and Native Vegetation								
Deciduous	4.80	0.39	4.80	0.0	0.0	4.80	0.0	0.0
Native grassland	10.14	0.82	10.14	0.0	0.0	10.14	0.0	0.0
Wetland	19.20	1.56	19.20	0.0	0.0	19.20	0.0	0.0
AVI Agricultural								
CRP – rough pasture	71.60	5.82	71.60	0.0	0.0	71.60	0.0	0.0
Total	**105.74**	**8.59**	**105.74**	**0.0**	**0.0**	**105.74**	**0.0**	**0.0**

4.7.4.1 ***Mitigation***

Since native habitats will not be impacted through surface disturbance, no action is required.

4.7.5 Habitat Fragmentation and Wildlife Movements

The Project will deflect deer movements away from the PDA at application. Deer are predicted to follow linear features with adequate cover (hedge ROW) for travel to and from feeding and bedding areas rather than through the PDA. Deer are also predicted to reduce their use of areas adjacent to the PDA for feeding and bedding as compared to baseline. Merrill et al. (1994) found that mule deer migrated in areas away, though adjacent to, a phosphate mine, especially during high snow years in Idaho. Sawyer et al. (2006) also found that mule deer in NW Wyoming used habitats well away from well pads after the construction of an oil and gas development.

4.7.5.1 ***Mitigation***

To reduce potential vehicle-caused mortality and to help facilitate deer movement, the following mitigation measure can be applied:

- monitor wildlife mortality on adjacent roads. If incidents increase, consider planting additional shrubs in linear features adjacent to the Project, such as side roads and ROW for the deer to use as travel routes. This will increase security cover, as well as reduce the mortality risk of deer traveling close to roads by creating a buffer between the road and deer travel routes (Merrill et al 1994). Consultation with local stakeholders and SRD will be required.

4.8 Cumulative Effects Case

Impacts from the Project and from other planned and proposed projects (i.e., cumulative effects) were assessed within the RSA for habitat availability.

4.8.1 Habitat Availability

Habitats with high value to wildlife will not be impacted in the cumulative affects case (see Table 4.8-1). This is a Class 4 impact.

With regard to SAR (threatened or at risk) that may occur in the LSA and RSA, the loggerhead shrike is likely to be found in deciduous habitats and this habitat will not be affected. The Sprague's pipit is found on two non-native habitat types, perennial forage and annual crop and these habitats will decline a further 2.2% in the cumulative effect case (see Volume IIC, Section 3: Vegetation). Sharp-tailed grouse are known to be in this area and they may occur in perennial forage and annual crop habitats. A sharp-tailed grouse lek survey was conducted and no evidence of individuals using the area was detected.

Table 4.8-1: Project and Cumulative Effect Impacts to Land Units with High Wildlife Species Habitat Potential in the RSA

Land Unit	Baseline	Application			Cumulative Effects		
	Area (ha)	Area (ha)	Change from Baseline		Area (ha)	Change from Baseline	
			ha	%		ha	%
AWI and Native Vegetation							
Deciduous	7.1	7.1	0.0	0.0	7.1	0.0	0.0
Native grassland	12.6	12.6	0.0	0.0	12.6	0.0	0.0
Wetland	19.2	19.2	0.0	0.0	19.2	0.0	0.0
AVI Agricultural							
CPR – rough pasture	76.8	76.8	0.0	0.0	76.8	0.0	0.0
Total	**115.7**	**115.7**	**0.0**	**0.0**	**115.7**	**0.0**	**0.0**

4.8.2 Impacts on Elk Island National Park

It is expected that the impacts on Elk Island National Park will be minimal. No direct habitat loss will occur to Elk Island National Park. The impacts of PAI in the RSA are discussed in the cumulative effects case in Volume IIA, Section 2: Climate and Air Quality section of this EIA.

4.9 Summary

Projects impacts to potential acid input and subsequent effects on key wildlife indicators (amphibians, waterbirds and sharp-tailed grouse) are predicted to be moderate. Monitoring of air, soils and water will be implemented to detect possible changes in pH levels that may be detrimental to water dependent species. Increased traffic volumes may result in an increase of as much as 8% in terms of wildlife mortality, especially for deer. The development will likely deflect deer movements away from the PDA, with deer predicted to travel along areas adjacent to the development area. There will be no impacts to highly suitable wildlife habitat since surface disturbance will occur within agricultural, industrial and other disturbed land.

Cumulative effects on habitat availability of highly suitable wildlife habitats will not result in any loss. Impacts to Elk Island National Park are expected to be minimal.

Table 4.9-1: Final Impact Rating Summary Table for the Application Case in the LSA and RSA

	Geographic Extent	Magnitude	Direction	Duration	Confidence	Rating at Application	Rating at Closure
Potential acid input: air emissions	Local and regional	Low to moderate	Negative	Mid-term	Moderate	3	4
Potential acid input: Waterbodies	Local and regional	Low to moderate	Negative	Mid-term	Moderate	3	3
Potential acid input: soils	Local and regional	Low to moderate	Negative	Long-term	Moderate	3	3

Table 4.9-1: Final Impact Rating Summary Table for the Application Case in the LSA and RSA (Cont'd)

	Geographic Extent	Magnitude	Direction	Duration	Confidence	Rating at Application	Rating at Closure
Direct Mortality	Local and regional	Low to Moderate	Negative	Mid-term	Moderate	3	3
Habitat availability	Local	-	Neutral	-	Moderate	4	4
Fragmentation and Wildlife Movements	Local	Moderate	Negative	Mid-term	Moderate	3	3
Noise	Local and regional	Low to moderate	Negative	Mid-term	Moderate	3	3

Table 4.9-2: Final Impact Rating Summary Table for the Cumulative Effects Case

	Geographic Extent	Magnitude	Direction	Duration	Confidence	Rating at Application
Habitat availability	Regional	-	Neutral	-	Moderate	4

4.9.1 Monitoring and Adaptive Management

Wetlands, waterbodies and soils will be monitored for changes in acidity as part of the Surface Water and Soils monitoring program. Data from these studies are essential to evaluate the potential effects of increased acidity on amphibians and waterbirds. If pH levels in wetlands and waterbodies become acidic (less than 7.0), actions to reverse this will be implemented to protect species that are water-dependent.

4.10 References

4.10.1 Literature Cited

Addison, P.A. and K.F. Jensen. 1987. *Long-range air pollution effects on the forest ecosystem.* Proceedings of the 52nd North American Wilderness and Natural Resources Conference, Quebec, Canada.

Alberta Environment (AENV). 2007. *Final Terms of Reference, Environmental Impact Assessment (EIA) Report for the Proposed Bruderheim Sulphur Forming and Shipping Facility.* March 13, 2007, Alberta Environment, Edmonton, AB.

Alarie, Y., C.E. Ulrich, W.M. Busey, H.E. Swann and H.N. MacFarland. 1970. Long-term continuous exposure of guinea pigs to sulphur dioxide. *Arch. Environ. Health* 21:769-777.

Alberta Sustainable Resource Development (ASRD). 2006. *The General Status of Alberta Wild Species 2005*. Edmonton, AB: Natural Resources Service, Wildlife Management Division.

American Conference of Governmental Industrial Hygienists (ACGIH). 1991. Documentation *of the Threshold Limit Values and Biological Exposure Indices*. 6th Ed. Volumes I-III. Cincinnati, OH.

Baydack, R.K. 1988. Characteristics of sharp-tailed grouse, *T. phas*., leks in the parklands of Manitoba. *Canadian Field Naturalist* 102(1):39-44.

Beringer, J.J., S.G. Siebert and M.R. Pelton. 1990. *Incidence of road crossing by black bears in Pisgah National Forest, North Carolina.* International Conference on Bear Research and Management 8:85-92.

British Columbia Ministry of Environment, Lands and Parks (MWLAP). 1998. *Standards for Components of British Columbia's Biodiversity No. 1.* Prepared by Ministry of Environment, Lands and Parks Resources Inventory Branch for the Terrestrial Ecosystems Task Force Resources Inventory Committee, Victoria, BC. Version 2.0, November 1998.

Brotons, L. and S. Herrando. 2001. Reduced bird occurrence in pine forest fragments associated with road proximity in a Mediterranean agricultural area. *Landscape and Urban Planning.* 57: 77-89.

Canadian Council of Ministers of the Environment (CCME). 1996b. *A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines.* The National Contaminated Sites Remediation Program, Canadian Council of Ministers of the Environment. March 1996.Eriksson 1987.

Case, J.W. and H.R. Krouse. 1980. Variations in sulphur content and stable sulphur isotope composition of vegetation near a SO_2 source at Fox Creek, Alberta, Canada. *Oecologia*. 44(2): 248-257.

Clean Air Strategic Alliance (CASA). 1996. *Final Report of the Target Loading Subgroup on Critical and Target Loading in Alberta*. Prepared by Target Loading Subgroup, Edmonton, AB.

Clean Air Strategic Alliance (CASA). 1999. *Application of Critical, Target and Monitoring Loads for the Evaluation and Management of Acid Deposition*. Target Loading Subgroup, CASA and Environmental Service, Environmental Sciences Division, Alberta Environment, Edmonton, AB. Publication No. T/472.

Clevenger, A.P., B. Chruszcz, K. Gunson, and J. Wierzchowski. 2002. *Roads and wildlife in the Canadian Rocky Mountain Parks - Movements, mortality and mitigation*. Final Report (November 2002). Report prepared for Parks Canada, Banff, AB.

Crittenden, P.D. and D.J. Read. 1979. The effects of air pollution on plant growth with special reference to sulphur dioxide. III. Growth studies with Lolium multiflorum lam. and Dactylis glomerata l. *The New Phytologist*. 83: 655-651.

DM Leahey and Associates Limited and Jacques Whitford. 2005. *An Assessment of Air Quality Impacts Associate with Operations at the Proposed HAZCO Bruderheim Sulphur Forming Facility.* Prepared for HAZCO Environmental Services. August, 2005.

Evink, G.L., P. Garrett, D. Zeigler and J. Berry. 1996. *Trends in addressing transportation related wildlife mortality.* Proceedings of the Transportation Related Wildlife Mortality Seminar. State of Florida, Department of Transportation, Environmental Management Office, Tallahassee, FL.

Fahrig, L. 2001. How much habitat is enough? *Biological Conservation*. 100:65-74.

Foppen, R. and R. Reijnen. 1994. The effects of car traffic on breeding bird populations in woodland. II. Breeding dispersal of male willow warblers (Phylloscopus trochilus) in relation to the proximity of a highway. *The Journal of Applied Ecology*. 31(1): 95-101.

Forman, R.T.T., B. Reineking, A.M. Hersperger. 2002. Road traffic and nearby grassland bird patterns in a suburbanizing landscape. *Environmental Management*. 29(6): 782-800.

Forman, R.T.T., J. Bissonette, A. Clevenger, C. Cutshall, V. Dale, L. Fahrig, C. Goldman, K. Heanue, J. Jones, D. Sperling, F. Swanson, T. Turrentine and T. Winter. 2003. *Road ecology: Science and Solutions.* Island Press, Washington DC. 481 pp.

Freda, J. 1986. The influence of acidic pond water on amphibians: a review. *Water, Air and Soil Pollution.* 30: 439-450.

Gibeau, M.L. 1998. Grizzly bear habitat effectiveness model for Banff, Yoho and Kootenay National Parks. *Ursus*. 10:235-241.

Gilchrist, G. and M.L. Mallory. 2007. Comparing expert-based science with local ecological knowledge:what are we afraid of? *Ecology and Society* 12(1): r1. [online] URL: http://www.ecologyandsociety.org/vol12/iss1/resp1/.

Green, R.E., S.J. Cornell, J.P.W. Scharlemann, and A. Balmford. 2005 Farming and the fate of wild nature. *Science*. 307: 550–555.

Habib, L. E.M. Bayne, S. Boutin. 2007. Chronic industrial noise affects pairing success and age structure of ovenbirds Seiurus aurocapilla. *Journal of Applied Ecology*. 44: 716-184.

Haila, Y. 1999*. Islands and fragments.* Pages 234-264 In: Hunter, M.L. Editor. Maintaining Biodiversity in Forest Ecosystems. Cambridge University Press, Cambridge, U.K. 698 p.

Jalkotzy, M.G., P.I. Ross and M.D. Nasserden. 1997. *The effects of linear developments on wildlife: a review of selected scientific literature.* Prepared for Canadian Association of Petroleum Produces, Calgary, AB, p. 115.

Komex International. 2006. *Wildlife Appendix AA: Screening-Level Wildlife Risk Assessment*.

Krouse, H.R. and J.W. Case. 1981. Sulphur isotope ratios in water, air, soil and vegetation near tepee creek gas plant, Alberta. *Water, Air, & Soil Pollution*. 15(1): 11-28.

McNicol, D.K., B.E. Bendell and D.G. McAuley. 1987. *Avian trophic relationships and wetland activity.* Transactions of the North American Wildlife and Natural Resources Conference. 52: 619-627.

Merrill, E.H., T.P. Hemker, K.P. Woodruff and L. Kuck. 1994. Impacts of mining facilities on fall migration of mule deer. *Wildlife Society Bulletin*. 22:68–73.

Ministry of Environment, Lands and Parks, British Columbia. 1997. *Standardized Inventory Methodologies for Components of British Columbia's Biodiversity: Upland Gamebirds: Grouse, Quail and Columbids*. Prepared by Ministry of Environment, Lands and Parks Resources Inventory Branch for the Terrestrial Ecosystems Task Force Resources Inventory Committee, Victoria, BC. Version 1.1, March 1997.

Natural Regions Committee. 2006. *Natural Regions and Subregions of Alberta*. Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. I/005.

Nietvelt, C.G. 2003*. U.S. Highway 26/287 wildlife linkage study: progress report for fall and winter 2002-2003: Year 1.* A report prepared for the Wyoming Department of Transportation, Cheyenne, Wyoming and the U.S. Forest Service, Bridger-Teton National Forest, Jackson, Wyoming, April 2003.

Noss, R.F., H.B. Quigley, M.G. Hornocker, T. Merrill and P.C. Paquet. 1996. Conservation biology and carnivore conservation in the Rocky Mountains. *Conservation Biology* 10:949–963.

Noss, R.F. and B. Csuti. 1997. *Habitat fragmentation*, pp. 269–304. In G.K. Meffe and R.C. Carroll (eds.), Principles of conservation biology. Second edition. Sunderland, MA: Sinauer Associates.

Peris, S.J. and M. Pescador. 2004. Effects of traffic noise on passerine populations in Mediterranean wooded pastures. *Applied Acoustics*. 65:357-366.

Reijnen, R. and R. Foppen. 1994. The effects of car traffic on breeding bird populations in woodland. I. Evidence of reduced habitat quality for willow warblers (Phylloscopus trochilus) breeding close to a highway. *The Journal of Applied Ecology*. 31(1): 85-94.

Reijnen, R., R. Foppen, C. Ter Braak, J. Thissen. 1995. The effects of car traffic on breeding bird populations in woodland. III. Reduction of density in relation to the proximity of main roads. *The Journal of Applied Ecology*. 32(1):187-202.

Reijnen, R., R. Foppen, H. Meeuwsen. 1996. The effects of traffic on the density of breeding birds in Dutch agricultural grasslands. *Biological Conservation*. 75:255-260.

Sample, B.E. and C.A. Arenal. 1999. Allometric models for interspecies extrapolation of wildlife toxicity data. Environ. *Contam. Tox*. 62:653-663.

Sawyer, H., R. Nielson, F. Lindzey and L. McDonald. 2006. Winter habitat selection of mule deer before and during development of a natural gas field. *Journal of Wildlife Management.* 70:396-403.

Schreiber, K.R. and J.R. Newman. 1988. Acid precipitation effects on forest habitats: Implications for wildlife. *Conservation Biology*. 2(3): 249-259.

Servheen, C., J.S. Waller and P. Sandstrom. 2001*. Identification and Management of Linkage Zones for Grizzly Bears Between Large Blocks of Public Land in the Northern Rocky Mountains.* U.S. Fish and Wildlife Service and University of Montana.

Slabbekoorn, H. and A. den Boer-Visser. 2006. Cities change the songs of birds. *Current Biology.* 16: 2326-2331.

Swenson, J.E. 1985. Seasonal habitat use by sharp-tailed grouse, *Tymphanuchus phasianellus*, on mixed-grass prairie in Montana. *Canadian Field Naturalist* 99(1):40-46.

Tabacova, S., B. Nikiforov and L. Balabaeva. 1985. Postnatal effects of maternal exposure to nitrogen dioxide. *Neurobehav Toxicol Teratol* 7(6):785-789.

United States Environmental Protection Agency (USEPA). 1998. *Screening Level Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Volume I Peer Review Draft.* (US) United States Environmental Protection Agency Region VI. Multimedia Planning and Permitting Division. Center for Combustion Science and Engineering. Office of Solid Waste.

US Fish and Wildlife Service. 1980. *Habitat evaluation procedures (HEP).* Div. Ecol. Serv. Man. 102. Washington, DC: US Department of Interior, Fish & Wildlife Service.

US Fish and Wildlife Service. 1981. *Standards for the development of habitat suitability index models for use in the habitat evaluation procedure.* Div. Ecol. Serv. Man. 103. Washington, DC: US Department of Interior, Fish and Wildlife Service, p. 170.

4.10.2 Personal Communications

Halisky, Vince, President Fish and Game Lamont County, AB. Telephone conversation. January 2007 and e-mail June 2007.

4.10.3 Internet Sites

Alberta Infrastructure, Government of Alberta. Available at: http://www.infratrans.gov.ab.ca/Ministry_Contacts/Contact_Us.htm. Accessed 2005.

Alberta Fisheries and Wildlife Management Information System (FWMIS). Available at: http://www.srd.gov.ab.ca/fishwildlife/guidelinesresearch/fwmis.aspx. Accessed: February 2007

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2006. COSEWIC Status Assessments. Available at: www.cosewic.gc.ca/eng/sct5/index_e.cfm. Accessed April 2006.

Hazardous Substances Data Bank (HSDB). 2006. On-line search engine of comprehensive, peer-reviewed toxicology data for about 5,000 chemicals. Hazardous Substances Data Bank (HSDB), Toxicological Data Network (TOXNET), U.S. National Library of Medicine. URL: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.

Species at Risk Act. (SARA) 2006. Species at Risk Act Public Registry: Species List. Available at: http://www.sararegistry.gc.ca/species/default_e.cfm. Accessed October 2006.

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resources & energy

Alberta Sulphur Terminals Ltd.
Bruderheim Sulphur Forming and Shipping Facility

Volume IIC: Terrestrial Ecosystems

5. Biodiversity and Fragmentation

Project Number 62720000
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APPENDICES

Executive Summary

Alberta Sulphur Terminals Ltd. (AST), a division of HAZCO Environmental Services (HAZCO) which, in turn, is a division of CCS Income Trust (CCS), retained WorleyParsons Komex to complete a biodiversity assessment for the proposed site of the Bruderheim Sulphur Forming and Shipping Facility (the Project) located on a portion of Section 35, Township 55, Range 20, West of the 4th Meridian (35-55-20 W4M - the Site). The objectives of the biodiversity assessment were as follows:

- satisfy the relevant section of the Final Terms of Reference (TOR) of the Environmental Impact Assessment (EIA)
- assess the potential impacts on the following indicators:
    - patch area and mean size
    - patch anthropogenic edge to area ratio
    - linear features and disturbances
    - species diversity

The biodiversity TOR are as follows:

a) *Discuss how the impacts defined in the EIA report could affect local and regional biodiversity and habitat fragmentation, both Project specific and cumulatively. Use quantitative data where possible to describe the potential effects on biodiversity and habitat;*

Surface disturbance, fragmentation, anthropogenic edge and linear disturbances can potentially affect the landscape and species indicators of biodiversity. These impacts increase edge and decrease the connectivity of a landscape, creating additional and smaller patches, and populations that ultimately results in decreased habitat area and population viability for many species.

Project application will increase the area of right(s)-of-way (ROW), roads and railroads as well as industrial plant sites in the Biodiversity Local Study Area (LSA). The increases in anthropogenic lands will come from clearing annual and perennial cropland, both of which will decrease in area at application. Land units that will not be impacted include farmsteads, rough pastures and wetlands. At closure, the area of all land units will return to baseline levels. No natural land units will be affected in area at application while croplands, which have some limited value to biodiversity, will decrease in area. Therefore, the application impact is negative in direction as biodiversity is predicted to decrease. Impact extent will be local as it will not extend beyond the LSA, duration will be long-term, magnitude will be low and confidence in this prediction is moderate. This is a Class 3 impact.

Mean patch size in the LSA will decrease by 7 ha (41%) at Project application. As with patch area, the mean patch size of ROW, roads and railroads, industrial plant sites, dugouts and pipelines will all increase at application while mean patch size of annual and perennial cropland will decrease. The mean patch sizes of farmsteads, rough pasture and wetlands do not change at application or closure. All mean patch sizes will return to baseline levels at Project closure. While no natural land units are affected in either case, decreases will occur to croplands that have some limited value for biodiversity. This increased fragmentation in the LSA is predicted to decrease biodiversity slightly as smaller patches cannot support as many species as large patches. Therefore, the impact at application is negative in direction, local in extent, long-term in duration and low in magnitude, with moderate confidence in these predictions. This is a Class 3 impact.

No change to the anthropogenic edge to area ratio of any of the natural land units in the LSA is predicted at Project application or closure. These are, therefore, Class 4 impacts.

At application, the length of railways, gravel/improved roads and pipelines will all increase in the LSA over baseline levels. Highway length in the LSA will not increase. Total linear disturbance will more than double at application, but will return to baseline levels at Project closure. Total linear density in the LSA will double from 2.4 km/km^2 at baseline to 4.8 km/km^2 at application.

The increase in linear disturbance is predicted to have a negative effect on biodiversity by increasing habitat fragmentation in the LSA. The Project impact to linear disturbance is, therefore, negative in direction, local in extent, long-term in duration and moderate in magnitude with moderate confidence. However, all of the increased linear disturbance will occur within currently disturbed land and no natural areas will be impacted. Therefore, this is a Class 3 impact.

In the LSA, the area of land units with high and moderate plant species diversity (rough pasture and wetlands) will not change at Project application. Annual and perennial cropland area will decrease at application but will return to baseline levels at closure. These croplands can provide some habitat for native plant species, especially in drainage ditches and along field margins. Therefore, Project impacts to plant species diversity are negative in direction, local in extent, long-term in duration and low in magnitude with moderate confidence. This is a Class 3 impact. At closure, all patch areas that have high species diversity will return to baseline levels. This is a Class 4 impact.

In the LSA, the land units with high wildlife species diversity (rough pasture and wetlands) will not change at Project application. These land units have greater vegetation structural diversity and species variety which, in turn, support a more varied assemblage of wildlife species. There will be a decrease in annual crop and perennial forage crop patch area, which has lower species diversity. Project impacts to wildlife species are negative in direction, local in extent, long-term in duration and low in magnitude with moderate confidence. This is a Class 3 impact. At closure, the area of each land unit type will return to baseline levels and no further impact to wildlife species diversity is expected. This is a Class 4 impact.

ES-1: Summary of Project Impacts to Landscape Diversity in the LSA

Indicator	**Application**		**Closure**	
	Change From Baseline	Impact Class	Change From Baseline	Impact Class
Patch area	Reduced agricultural land unit area	Class 3	All land units returned to baseline levels	Class 4
Mean patch size (ha)	-7.2 (-40.6%)	Class 3	0 (0.0%)	Class 4
Anthropogenic edge-To-area ratio (km/km^2)	0.0 (0.0%)	Class 4	0 (0.0%)	Class 4
Linear disturbance (km)	9.9 (102.1%)	Class 3	0 (0.0%)	Class 4
Vegetation species diversity	Small change to areas with low diversity	Class 3	All land units returned to baseline levels	Class 4
Wildlife species diversity	Small change to areas with low diversity	Class 3	All land units returned to baseline levels	Class 4

b) discuss the contribution of the Project to any anticipated changes in regional biodiversity, including measures to minimize such changes;

Land units in the Biodiversity Regional Study Area (RSA) that will increase in area at application include ROW, roads and railroads, industrial plant sites, dugouts and pipelines, with the greatest increases to the first two types (see Table 5.6-1). Only ROW, roads and railroads have an additional cumulative increase.

Annual and perennial croplands will experience small decreases at application and cumulatively. Land units that are unaffected in either case include farmsteads, rough pasture, deciduous forests, native grassland and wetlands.

No natural land units are impacted by the Project or other projects in the RSA. However, cropland does have some minor value for biodiversity and is reduced in area both at application and cumulatively. Therefore, the impact to patch area is negative in direction, regional in extent, long term in duration and low in magnitude with moderate confidence for both cases. These are Class 3 impacts.

The following mitigation measures will be used to reduce Project impacts on biodiversity indicators during construction and ongoing operations, where practicable or otherwise required:

- use previously disturbed areas to reduce the amount of new clearing
- minimize the proposed surface disturbance for the Project facilities
- optimize linear corridor widths and accommodate multiple-use areas such as roads, pipelines and power lines within the same ROW to minimize surface disturbance
- monitor and remove invasive and non-native plant species from the Project area when found to prevent their spread into adjacent native areas
- minimize the amount of disturbed areas during construction and operation of Project facilities to prevent the establishment and spread of invasive and non-native plant species

c) *discuss how AST's plans for mitigation and monitoring will meet the expectations of Sustaining Alberta's Biodiversity An Overview of Government of Alberta Initiatives Supporting the Canadian Biodiversity Strategy;*

AST's plans for mitigating impacts to air, water and soil quality will ultimately have the effect of protecting vegetation and thus, wildlife. This is particularly true of the wetlands in the northwest corner of the LSA. Protection of the wetlands is consistent with the expectations of these strategies and initiatives.

d) *determine the current and proposed level of habitat fragmentation for the Study Areas;*

Total patch area in the LSA is 407 ha and 1,229 ha in the RSA. Annual crops and perennial forage crops are the largest land units comprising 111 ha (27%) and 217 ha (53%) of the LSA, respectively, and 374 ha (30%) and 625 ha (51%) of the RSA, respectively. Farmsteads (AIF) comprise the smallest patch area in the LSA with 8 ha (2%). The remaining 71 ha (17%) of the LSA is comprised of rights-of-way, transportation routes, industrial facilities, rough pasture and wetland. Deciduous and native grass land units comprise the smallest patch area of the RSA with 7 ha and 13 ha, respectively. The remaining 210 ha (17%) of the RSA is comprised of rights-of-way, transportation routes, industrial facilities, farmstead, rough pasture and wetland.

Mean patch size for the LSA is 18 ha. The annual crop land unit had the largest mean patch size of 37 ha. The only natural land unit (wetland) in the LSA had a mean patch size of 15 ha. The small patch sizes are a result of the small size of the LSA and the large amount of disturbance found in the area. Mean patch size in the RSA is 21 ha. The largest patch size occurs in the perennial forage crop land unit (78 ha). The deciduous and native grass land units had the smallest mean patch size of approximately 1 ha each. Mean patch size in the LSA will decrease by 7 ha (41%) at Project application.

The anthropogenic edge to area ratio was only assessed for the natural vegetation land units (i.e., deciduous, native grass and wetland). Total anthropogenic edge to area ratio for the LSA is 9.1 km/km^2. This includes only the wetland land unit, as it is the only natural class in the LSA. The total anthropogenic edge to area ratio for the RSA is 17.2 km/km^2. The high edge to area ratios are caused by the large amount of anthropogenic disturbance in both the LSA and RSA. No change to the anthropogenic edge to area ratio of any of the natural land units in the LSA is predicted at application.

Linear features at baseline in the LSA are approximately 10 km in total length and include railways, highways and gravel roads. The total linear disturbance ratio is 2.4 km/km^2. Linear features at baseline for the RSA total 19 km and also include railways, highways and gravel roads. The total linear disturbance ratio in the RSA is 1.5 km/km^2. Total linear disturbance will more than double at application, but will return to baseline levels at Project closure. Total linear density in the LSA will double from 2.4 km/km^2 at baseline to 4.8 km/km^2 at application.

e) *describe the techniques used in the fragmentation analysis;*

To assess impacts to landscape diversity indicators, a fragmentation analysis was completed. The indicators and analysis were based on the program FRAGSTATS (McGarigal and Marks 1994) with ArcGIS 9.1 used for all analysis. Polygons with the same attribute (land unit) were combined and then patches were separated out. Once this was complete, details on patch size and area were obtained.

Vegetation species richness was calculated for the wetland and rough pasture land units using data collected from the 2006 rare plant surveys (see Volume IIC, Section 3: Vegetation). All other land units within the LSA were not sampled during these surveys and, therefore, richness could not be directly calculated. Rare plant species are defined as those plant species listed in the Alberta Natural Heritage Information Centre (ANHIC) plant tracking list as being globally rare, provincially rare, or on the provincial watch list (Gould 2006).

Several indices of species diversity were calculated including species richness, wildlife species at risk (SAR) potential and unique species. These three measurements were combined into a single overall measurement of diversity for each land unit, with a maximum value of three.

f) *identify and evaluate the extent of potential effects from fragmentation (e.g., disruption of movement corridors) that may result from the Project; and*

Deer preferentially follow adequately covered linear features (hedge ROW) between feeding and bedding areas. In the application scenario, deer movements will be deflected away from the Principal Development Area (PDA). Compared to baseline conditions, deer use of areas adjacent to the PDA for feeding and bedding will be reduced (see Volume 2C, Section 4: Wildlife – Section 4.6.5).

g) *discuss measures to mitigate, monitor and reclaim impacts from fragmentation.*

Monitoring will be in conjunction with the vegetation, wildlife, air, surface water and soil monitoring programs. Any changes to air quality, soil acidity and water pH levels may negatively impact some vegetation and wildlife species. Vegetation monitoring will focus on shelterbelt, rough pasture and wetland habitats to quantify the potential effects of dust deposition on vegetation and the potential introduction of non-native and invasive species into the LSA. The PDA, including stockpiled soil, will be monitored by AST over the operational lifespan of the sulphur forming and shipping facility for non-native and invasive species. It is also recommended that the remaining natural areas, in particular wetlands, be protected. This will maintain species diversity in the region and is in accordance with the Canadian Biodiversity Strategy (1995).

5. Biodiversity

5.1 Introduction

Biodiversity is an expression of the variability among living organisms and the ecological systems of which they are a part of (Environment Canada 1995, Lindenmayer and Franklin 2002). It is measurable at several levels of biological organization including genes, species, habitats or communities and landscapes (Noss 1990, Lindenmayer and Franklin 2002). Sustaining the values associated with biodiversity is a high priority for natural resource management in Alberta (AEP 1999, Lindenmayer and Franklin 2002).

This section presents the results of baseline studies and the impact assessment for biodiversity and fragmentation as part of the EIA for the proposed Bruderheim Sulphur Forming and Shipping Facility Project (the Project). Biodiversity indicators were selected to describe the composition and structure of the environment at local and regional scales. The indicators were measured and the risk to biodiversity was determined or inferred from this baseline. This report presents a detailed analysis of baseline biodiversity conditions near the Project and an impact and cumulative effects assessment of biodiversity as defined by the TOR (AENV 2007). In addition, mitigation to reduce potential adverse effects of the Project is described in subsequent sections.

5.2 Indicators and Issues

Biodiversity issues identified for the detailed assessment follow the TOR (AENV 2007). The potential issues concerning biodiversity include:

- direct loss of native species diversity (measured for selected taxonomic groups)
- changes in the composition or distribution of natural terrestrial habitat
- changes in the structure of natural terrestrial habitat (i.e., through habitat fragmentation or increased access for non-native or opportunistic species into natural habitat)
- changes in landscape-level diversity at the regional scale (measured as changes in landscape habitat composition and structure)

Indicators were selected to measure key aspects of biodiversity in this assessment and were chosen based on the issues identified above and to reflect two important components of biodiversity – landscape diversity and species diversity. It is important to examine biodiversity on a number of levels as higher levels (landscape structure) of organization incorporate and affect the behavior of lower levels (Species Diversity, Noss 1990). The selected indicators are:

- patch area and mean size
- patch anthropogenic edge to area ratio
- linear features and disturbances
- species diversity

5.2.1 Terms of Reference

In addition to the issues provided above, the assessment also addressed the issues identified in the TOR for the Project as follows:

a) *Discuss how the impacts defined in the EIA report could affect local and regional biodiversity and habitat fragmentation, both Project specific and cumulatively. Use quantitative data where possible to describe the potential effects on biodiversity and habitat;*

b) *discuss the contribution of the Project to any anticipated changes in regional biodiversity, including measures to minimize such changes;*

c) *discuss how AST's plans for mitigation and monitoring will meet the expectations of Sustaining Alberta's Biodiversity An Overview of Government of Alberta Initiatives Supporting the Canadian Biodiversity Strategy (Alberta Environmental Protection, 1998);*

d) *determine the current and proposed level of habitat fragmentation for the Study Areas;*

e) *describe the techniques used in the fragmentation analysis;*

f) *identify and evaluate the extent of potential effects from fragmentation (e.g., disruption of movement corridors) that may result from the Project; and*

g) *discuss measures to mitigate, monitor and reclaim impacts from fragmentation.*

5.3 Methods

5.3.1 Spatial and Temporal Boundaries

5.3.1.1 Principal Development Area

The proposed Project will be developed in the Principle Development Area (PDA), on a portion of Section 35-55-20 W4M (the Site), which comprises the area of disturbance and development. The PDA is equivalent to the Project footprint, which includes the direct footprint of the proposed facility and associated infrastructure and is 24.8 ha in size. All infrastructure and activities will be confined to the Site. The PDA, shown in Figure 3.3-1, consists of:

- rail and road access for receiving and shipping sulphur
- liquid sulphur unloading and transfer facilities
- sulphur forming facilities to produce sulphur pastilles
- loading and shipping facilities for formed sulphur
- a sulphur pastilles temporary storage area

5.3.1.2 Local Study Area

The Biodiversity Local Study Area (LSA) covers 407.4 ha and is defined as Section 35-55-20 W4M surrounded by a 200 m buffer zone (see Figure 5.3-1). The 200 m buffer was included to contain the predicted emissions from the Project within the LSA (D.M. Leahey et al. 2005). Two railways ROW traverse the LSA. A utility substation is adjacent to a wetland located in the northwest corner and an intermittent stream flows south to north along the eastern portion of the LSA. The LSA is located in the Lamont Country Industrial Heartland, a portion of the Alberta Industrial Heartland. Due to common ecological relationships, the LSA is the same for the vegetation, wildlife, biodiversity and soils sections of this EIA.

5.3.1.3 Regional Study Area

The Biodiversity Regional Study Area (RSA) is defined as Section 35-55-20 W4M surrounded by a 1,000 m buffer zone (see Figure 5.3-1). The RSA was delineated based on the preliminary air modelling conducted in 2005 (D.M. Leahey et al. 2005) for the sulphur processing facility. The RSA was used to evaluate the Project effects on potential acid deposition and includes the lands that fall within the predicted sulphur dioxide emissions isopleths estimated in the 2005 air modelling (D.M. Leahey et al. 2005). Due to common ecological relationships, the RSA is the same for the vegetation, wildlife, biodiversity and soils sections of this EIA.

5.3.1.4 Temporal Boundaries

Three temporal boundaries are used in this assessment: baseline, application and closure. Baseline refers to the present conditions in the LSA and RSA as of August 2006. Application is assessed at maximum disturbance. This approach determines the impact of the Project as if all facilities were fully developed and operating concurrently. Therefore, impact predictions during the application case are considered worst case and conservative. Closure is considered when all project facilities have been decommissioned and reclamation has taken place. It is assumed that closure occurs five years after decommissioning and reclamation, therefore, vegetation has been planted or seeded and has had time to establish on each site.

5.3.1.5 Project Inclusion List

The project inclusion list includes the various anthropogenic disturbances on the landscape that must be included in each assessment case in order to effectively determine Project and cumulative effects. Table 5.3-1 provides the list of projects included in each case.

Table 5.3-1: Project Inclusion List

Status	Baseline Case	Application Case	Cumulative Effects Case
Existing and approved	Canexus Chemicals	Canexus Chemicals	Canexus Chemicals
	ERCO Worldwide	n/a	n/a
	Triton	Triton	Triton
Project	n/a	Bruderheim Sulphur Forming and Shipping Facility	Bruderheim Sulphur Forming and Shipping Facility
Planned projects and activities	n/a	n/a	n/a

Note:
n/a – not applicable

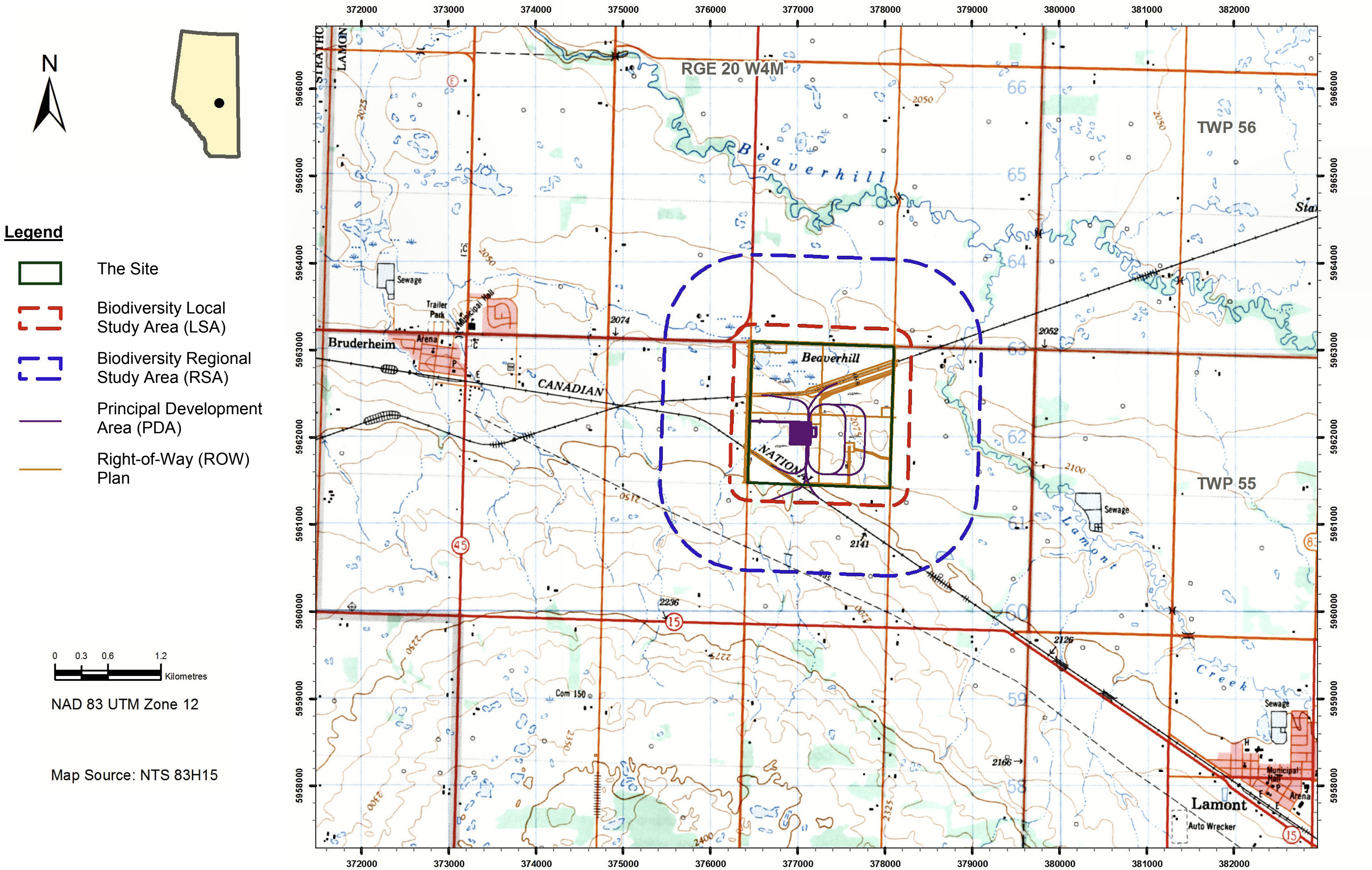

Figure 5.3-1: Biodiversity LSA and RSA

5.3.2 Baseline Data Acquisition Methods

5.3.2.1 Land Unit Classification and Mapping

Landscape diversity indicators are described by land units. Land units were delineated into distinctive disturbance areas, agricultural lands and vegetation classes for the baseline assessment in the LSA using aerial photographs and existing vegetation inventories prior to conducting the field surveys. The Central Parkland Native Vegetation Inventory Version 1.2 (CPNVI) was used to preliminary map the LSA. Lands classified as human modified according to the CPNVI, were further delineated on aerial photographs (October 1998, 1:30,000) into the Alberta Vegetation Inventory (AVI) agriculture and anthropogenic non-vegetated land classes (Nesby 1997). The CPNVI cover classes and AVI land classes delineated within the LSA are defined in Table 5.3-2. More detailed descriptions of the CPNVI and AVI classes are provided in Volume IIC, Section 3: Vegetation – Appendix I.

Table 5.3-2: CPNVI Cover Classes and AVI Land Classes in the LSA

Inventory	Class	Definition
CPNVI	Human Modified	Land not attributed to vegetation or water classes, includes agricultural lands
	Deciduous	Deciduous trees
	Wetland	Recurring lake or potential basin from Base Features Hydrography updates
	Water	Water obtained from either Base Features Hydrography or open water classed from IRS imagery
AVI	**Agriculture land classes**	
	CA	Annual crops
	CP	Perennial forage crops
	CPR	Rough pasture
	Anthropogenic non-vegetated land classes	
	AIF	Farmsteads (related to agriculture)
	AIH	Permanent ROW; roads, highways, railroads, dam sites, reservoirs
	AII	Industrial (plant sites), sewage lagoons

5.3.2.2 Species Diversity

5.3.2.2.1 Vegetation

Vegetation field surveys were conducted in the summer of 2006. However, data from the vegetation surveys were not robust enough to determine plant species richness and diversity values for all of the land units present except the rough pasture and wetland units. Therefore, plant species diversity levels were not estimated for the annual crop and perennial forage crop land units. Anthropogenic land classes (i.e., industrial plant sites, farmsteads, etc.) were excluded from the analysis. Professional opinion was exercised when determining species diversity for the land units. This was especially true for cropland and pasture estimates.

While natural landscapes have much greater plant diversity than disturbed areas, cropland, pasture and transitional areas can still contribute to overall biodiversity (Boutin et al. 2002, is Luoto et al. 2002, Hoffman and Greef 2004, Sanderson et al. 2004). However, cultivated lands are unlikely to contain unique species that are not found in the surrounding natural areas, and, therefore, it will most likely have a lower level of biodiversity (Benton et al. 2003; Green et al. 2005). Land units were classified as natural areas – uncultivated land – cultivated land for overall plant diversity.

5.3.2.2.2 Wildlife

A wildlife field survey was conducted in July 2006 and focused on wetland habitats, rather than all of the habitat types present in the LSA. Due to the focus on wetlands, empirical data collected cannot be used to determine wildlife species richness and diversity values for all the land units present. Professional judgment and literature was used to determine species habitat associations.

Land units in the LSA and RSA were broken down according to vegetation species composition and structural composition. The wetland land unit consisted of small bodies of open water with flood tolerant vegetation such as *Typha latifolia* and a variety *Carex* spp. Generally, vegetation species diversity in wetlands is high, which supports a varied and distinct assemblage of wildlife (Campbell et al. 1999). The deciduous land unit consists of aspen and poplar trees in the RSA and is suitable nesting habitat for several species including the least flycatcher and common yellowthroat (Jobin et al. 2004).

Several types of grassland communities exist in the LSA and RSA. Vegetation structure (i.e., height and growth form of species) in grassland communities has been known to be more important for birds than vegetation species diversity (Rotenberry and Wiens 1980, Johnson and Schwartz 1993, Fritcher et al. 2004). Grassland and agricultural land units were broken down according to these features. Annual crops are assumed to be monocultures with little-to-no structural diversity. Rough pasture and perennial forage crops are assumed to have more species than annual crops and along with that, more structural diversity. Native prairie is assumed to have the most species diversity of the grassland land units corresponding to the greatest structural diversity (Kruess and Tscharntke 2002). According to these vegetation communities, potential wildlife species diversity levels were estimated for the wetland, deciduous, rough pasture, annual crop, native grassland and perennial forage crop.

5.3.2.3 Fragmentation analysis

To assess impacts to landscape diversity indicators, a fragmentation analysis was completed. The indicators and analysis were based on the program FRAGSTATS (McGarigal and Marks 1994) with ArcGIS 9.1 used for all the analysis. Polygons with the same attribute (land unit) were combined and then patches were separated out. Once this was complete, details on patch size and area were obtained.

5.3.3 Indicators

5.3.3.1 Patch Area

Patch area is the total area of each patch type in a given study area. Patch area indicates how much of the landscape is composed of a particular patch type. An increase in the area of non-disturbed patches is expected to increase biodiversity because habitat fragmentation is decreased. Therefore, more core habitat is available for species use. Conversely, a decrease in patch area will negatively affect biodiversity (Lindenmayer and Franklin 2002).

5.3.3.2 *Patch Size*

Mean patch size represents both the amount of patch type present and the spatial distribution of that patch type (McGarigal and Marks 1994). Mean patch size is the patch area (ha) of a certain land unit divided by its patch number. The mean size of land unit patches can be related to biologically significant requirements. For example, a mean patch size of 1 ha for a certain habitat type may be suitable for one species, but unsuitable for another. As well, an increase in mean patch size of non-disturbed patches is expected to increase biodiversity as larger, non-disturbed patches are less fragmented, therefore, providing more core habitat.

5.3.3.3 *Patch Anthropogenic Edge-to-Area Ratio*

The patch anthropogenic edge-to-area ratio is an absolute measure of the total edge length as a result of human disturbance (e.g., pipeline) of a particular patch type or of all patch types (at the landscape level) divided by its area (km/km^2). Total edge is a function of the amount of border between patches and, therefore, varies as a function of the heterogeneity of the landscape. However, this metric does not depend explicitly on patch location in a landscape or individual spatial character (McGarigal and Marks 1994). A decrease in total edge of a non-disturbed patch type with a decrease in patch number and class area of this type could suggest that patches of this habitat type have been lost as a result of disturbance. This is expected to have a negative effect on biodiversity. At a landscape level, a decrease in total edge is generally expected to have a positive effect on biodiversity (reduction of fragmentation). However, if the decrease in edge is due to several undisturbed patches being replaced by a large disturbance patch with less total edge, this could result in a negative effect on biodiversity.

5.3.3.4 *Linear Features and Disturbances*

Linear disturbance density is a primary attribute of landscape fragmentation and relates to the quality of habitat for higher-order species (Bayne 2003). The greater the number of linear features within a landscape, the higher the degree of fragmentation. The type of linear disturbance is also important as certain types can be reclaimed (e.g., seismic) at a faster rate. In addition, the rate of reclamation and regeneration is strongly influenced by whether the linear disturbance occurs in an upland or wetland area.

5.3.3.5 *Species Diversity*

5.3.3.5.1 *Vegetation*

Species Richness

Species richness is the total number of mammal, bird or vascular and non-vascular plant species identified for a given area (Magurran 1988). Vegetation species richness was calculated for the wetland and rough pasture land units using data collected from the 2006 rare plant surveys (see Volume IIC, Section 3: Vegetation – Appendix VI, Table VI-1). All other land units within the LSA were not sampled during these surveys and, therefore, richness could not be directly calculated.

Rare Plant Species

Rare plant species are defined as those plant species listed in the Alberta Natural Heritage Information Centre (ANHIC) plant tracking list as being globally rare, provincially rare or on the provincial watch list (Gould 2006). By reviewing current literature, it was determined that a total of 101 rare vascular plants and 144 rare non-vascular plants potentially occur in the

Central Parkland (Moss 1983, Kershaw et al. 2001, Gould 2006). By researching habitat information for each rare plant and using professional judgment, corresponding natural land units were assigned to each rare plant. More than one species of rare plant could occur in each land unit. Table I–1 in Appendix I lists the potential rare plants for each land unit. Possible impacts to rare plant potential are assessed in Volume IIC, Section 3: Vegetation.

5.3.3.5.2 Wildlife

Several indices of species diversity were calculated including species richness, Wildlife Species at Risk (SAR) potential and unique species. Unique species were defined as those species occurring in three or less land unit types. These three measurements were combined into a single overall measurement of diversity for each land unit, with a maximum value of three. Not all species potentially occurring in the region were observed during field surveys and habitat associations for species richness and SAR were based on literature reviews (see Appendix II – Table II-1 and Appendix III – Table III–1).

There are three designations of wildlife species at risk (SAR): two federal and one provincial. These include species listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2006, Internet site) as Endangered, Threatened or Special Concern, those listed by Alberta Sustainable Resource Development (ASRD 2006) as At Risk, May be at Risk or Sensitive and those listed on Schedules 1, 2 and 3 of the *Species at Risk Act* (SARA 2006, Internet site). The number of SAR potentially occurring in each vegetation community was then compiled from reference materials and professional judgment (Banfield 1974, Semenchuk 1992, Russell and Bauer 1993, Smith 1993, Chapman et al. 2004, Fritcher et al. 2004). A total of 65 SAR species potentially occur in the region, with at least one SAR species potentially occurring in each of the land unit types (see Table IV–1 in Appendix IV). Potential impacts to wildlife SAR are assessed in Volume IIC, Section 4: Wildlife.

The relative index for species richness, SAR potential and unique species was calculated by dividing the value for each habitat unit by the maximum listed value. Therefore, for each index, the maximum score is one. For example, the relative index for species richness and SAR potential in the deciduous land unit was calculated as follows:

- number of species in the deciduous land unit = 150
- maximum number of species listed for all land units = 150
- species richness index for the deciduous land unit = 150/150 = 1.00

The proportion of unique species index in the deciduous land unit was calculated as follows:

- number of unique species in the deciduous land unit = 11
- maximum number of unique species (wetland land unit) = 14
- unique species index for the deciduous land unit = 11/14 = 0.79

The three relative indices for each ecosite phase were then added together to determine an overall diversity index, with the maximum potential overall diversity equal to three.

5.3.4 Impact Assessment Methods

The impact assessment evaluated the Project impacts for the application case and closure case. Residual impacts were measured for the application case at maximum disturbance, when all aspects of the Project are constructed and operated concurrently and for the closure case at post-reclamation, when all mitigation techniques have been implemented.

Potential impacts of the Project on landscape and species diversity indicators were assessed for the application and closure cases using the criteria of direction, geographic extent, magnitude, duration and confidence as described in Volume I: Project Description. A final impact rating of Class 1, 2, 3 or 4 was applied to residual impacts for each indicator as described in Table 5.3-3.

Table 5.3-3: Final Impact Rating

Rating	Level of Action
Class 1	The predicted trend in an indicator under projected land use development could threaten the long-term sustainability of the quantity or quality of the indicator in the LSA and RSA. An action plan, developed jointly by regional stakeholders, could be developed to monitor the affected indicator, identify and implement further mitigation measures to reduce any impact and promote recovery of the indicator, where appropriate. This class of impact might also be applicable to an exceedance of a regulatory guideline, or where the impact will have long-term effects.
Class 2	The predicted trend in an indicator under projected land use development will likely result in decline in the quantity or quality of the indicator. The decline could be to lower-than-baseline but stable levels in the LSA and RSA after closure and into the foreseeable future. In addition to responsible industrial operational practices, monitoring and recovery initiatives could be required if additional land use activities occur in the study area before closure of the projected land use development. This class of impact might also be applicable to an exceedance of a regulatory guideline, or where the impact is expected to have mid-term effects, but where recovery will take place shortly after closure of the projected land use development.
Class 3	The predicted trend in an indicator under projected land use development could result in a slight decline in the quantity or quality of the indicator in the LSA and RSA during the life of the projected land use development, but resource levels should recover to baseline after closure. In some cases, a short-term, low to moderate magnitude impact could occur, but recovery will take place within five years. No new resource management initiatives are necessary. Responsible industrial operational practices should continue. This class of impact could also be applicable where regulatory guidelines are not exceeded, but where a relative change in magnitude of an indicator occurs.
Class 4	The projected land use development results in no change and no contribution toward affecting the quantity or quality of the indicator in the local and regional study areas during the life of the projected land use development. Responsible industrial operational practices should continue. Therefore, no cumulative effects result from the processing facility.

5.4 Baseline Case

The Project LSA is located 2.2 km east of Bruderheim within the Central Parkland Natural Subregion of Alberta (NRC 2006). This subregion is a transition zone between the Boreal Forest Natural Region to the north and the Grasslands Natural Region to the south. The native vegetation in the Central Parkland is characterized by aspen stands interspersed with grasslands and low lying wetlands. More detailed ecological descriptions of the LSA are provided in Volume IIC, Section 3: Vegetation. Anthropogenic modifications to the native vegetation for urbanization, transportation, industry and agriculture have reduced the remaining native vegetation in the Central Parkland to less than 5% of the subregion (NRC 2006).

A total of 7 land units were classified in the LSA. They include one CPNVI classification and six AVI classifications (see Table 5.4-1, Figure 5.4-1 and Figure 5.4-2). A large percentage of the LSA is disturbed, with approximately 96% (393 ha) consisting of non-native habitats (see Table 5.4-1). Perennial forage and annual crops comprise approximately 80% of the LSA.

A total of 10 land units were classified in the RSA. They include four CPNVI and six AVI classifications. Similar to the LSA, the RSA is predominantly disturbed, with approximately 97% (1,193 ha) made up of non-native habitats. Approximately 81% (999 ha) is annual and perennial forage crops. Included in the RSA are two additional CPNVI classifications. Deciduous forest (both native and non native) and native grasslands comprise approximately 2% of the RSA (see Table 5.4-1). Due to the small patch sizes of deciduous forest in the RSA they were not considered in the biodiversity analysis.

Table 5.4-1: Baseline Land Unit Area in the LSA and RSA

Land Unit	LSA		RSA	
	Area (ha)	Area (%)	Area (ha)	Area (%)
AVI				
AIF – farmstead	7.8	1.9	47.8	3.9
AIH – ROW, roads, railroads	24.5	6.0	39.2	3.2
AII – industrial, plant sites	14.8	3.6	27.8	2.3
CA – annual crop	111.3	27.3	374.3	30.1
CP – perennial forage crops	216.8	53.2	624.5	51.0
CPR – rough pasture	17.6	4.3	76.8	6.3
CPNVI				
Non-native deciduous	–	–	2.3	0.2
Native deciduous	–	–	4.8	0.4
Native grassland	–	–	12.6	1.0
Wetland (native)	14.6	3.6	19.2	1.6
Total	**407.4**	**100.0**	**1,229.3**	**100.0**

Note:
– denotes not present.

5.4.1 Patch Area

Total patch area in the LSA is 407 ha and 1,229 ha in the RSA (see Table 5.4-2). Annual crops and perennial forage crops are the largest land units comprising 111 ha (27%) and 217 ha (53%) of the LSA, respectively, and 374 ha (30%) and 625 ha (51%) of the RSA, respectively (see Table 5.4-1). Farmsteads (AIF) comprise the smallest patch area in the LSA with 8 ha (2%). The remaining 71 ha (17%) of the LSA is comprised of rights-of-way, transportation routes, industrial facilities, rough pasture and wetland. Deciduous and native grass land units comprise the smallest patch area of the RSA with 7 ha and 13 ha, respectively. The remaining 210 ha (17%) of the RSA is comprised of rights-of-way, transportation routes, industrial facilities, farmstead, rough pasture and wetland.

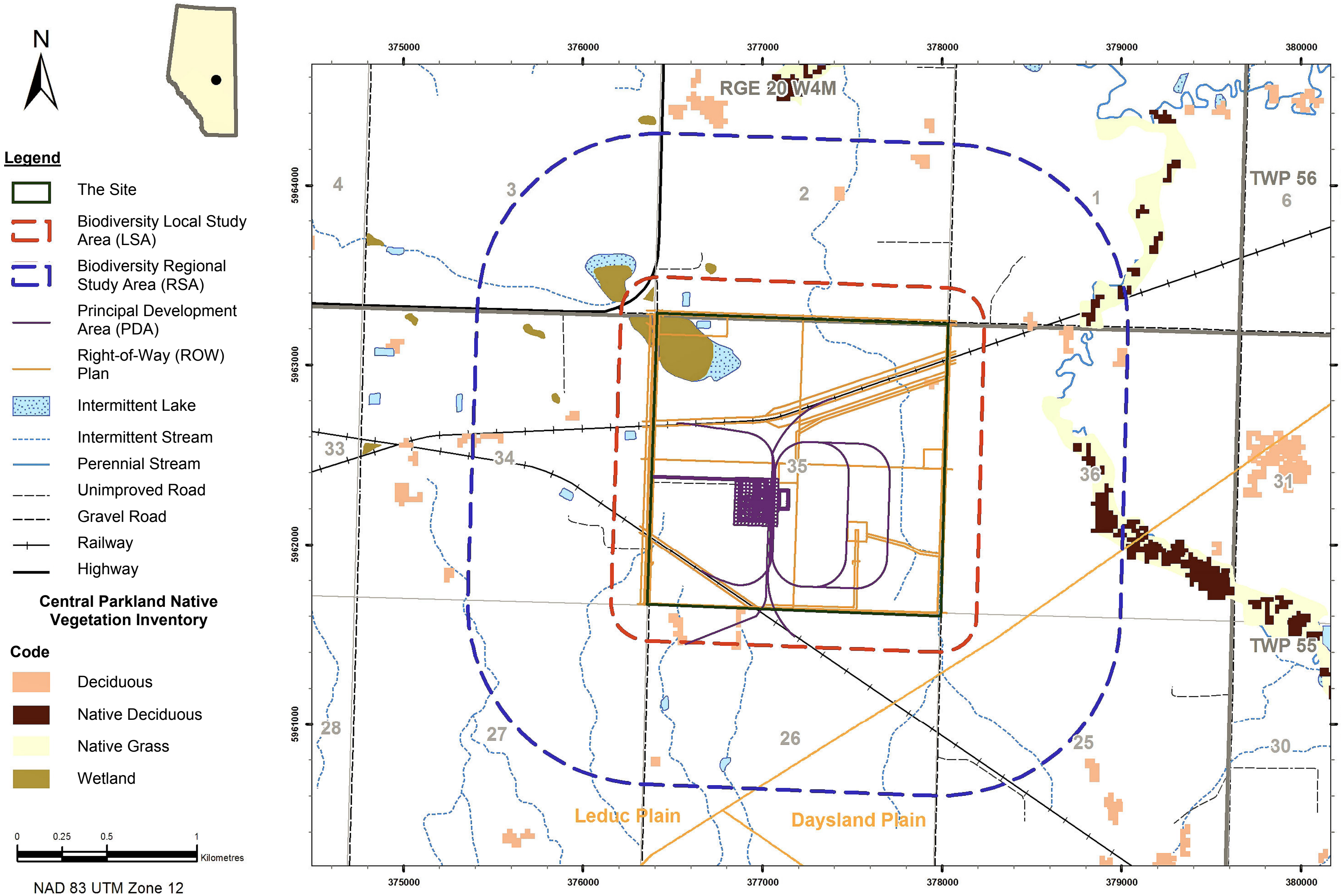

Figure 5.4-1: CPNVI Classification in the LSA and RSA

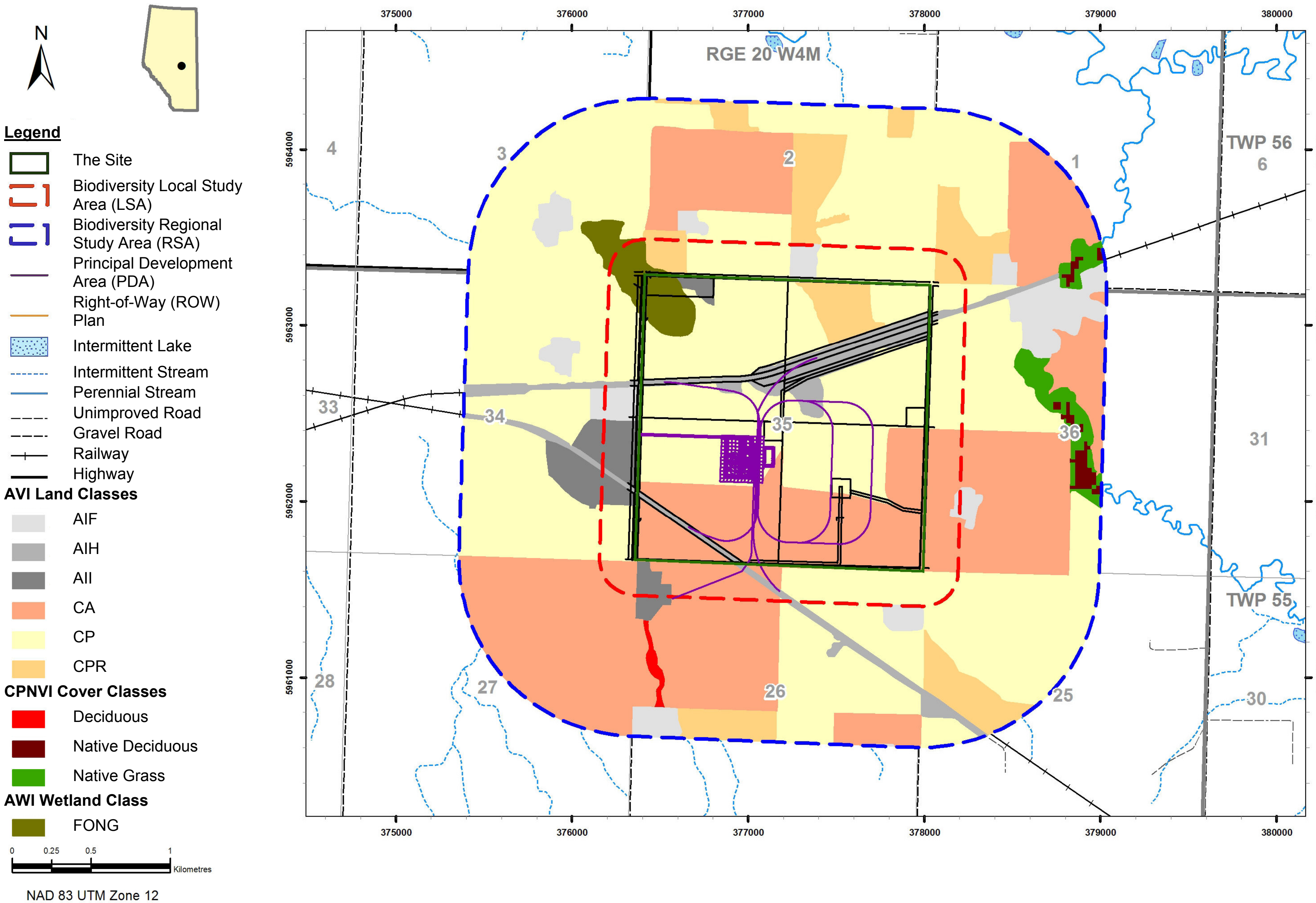

Figure 5.4-2: AVI Classifications in the LSA and RSA

5.4.2 Patch Size

Mean patch size for the LSA is 18 ha (see Table 5.4-2). The annual crop land unit had the largest mean patch size of 37 ha. The only natural land unit (wetland) in the LSA had a mean patch size of 15 ha (see Table 5.4-2). The small patch sizes are a result of the small size of the LSA and the large amount of disturbance found in the area.

Mean patch size in the RSA is 21 ha (see Table 5.4-2). The largest patch size occurs in the perennial forage crop land unit (78 ha). The deciduous and native grass land units had the smallest mean patch size of approximately one hectare each.

Table 5.4-2: Baseline Patch Area and Mean Patch Size for Land Units in the LSA and RSA

Land Unit	LSA		RSA	
	Patch Area (ha)	Mean Patch Size (ha)	Patch Area (ha)	Mean Patch Size (ha)
AIF – farmstead	7.8	2.0	47.8	4.3
AIH – ROW, roads, railroads	24.5	12.2	39.2	13.1
AII – industrial, plant sites	14.8	3.7	27.8	6.9
CA – annual crop	111.3	37.1	374.3	46.8
CP – perennial forage crops	216.8	36.1	624.5	78.1
CPR – rough pasture	17.6	5.9	76.8	9.6
Deciduous	–	–	7.1	1.0
Native grass	–	–	12.6	1.4
Wetland	14.6	14.6	19.2	19.2
Total	**407.4**	**17.7**	**1,229.3**	**20.8**

Note:
– denotes not present.

5.4.3 Anthropogenic Edge-to-Area Ratio

The anthropogenic edge to area ratio was only assessed for the natural vegetation land units (i.e., deciduous, native grass and wetland). Total anthropogenic edge to area ratio for the LSA is 9.1 km/km^2 (see Table 5.4-3). This includes only the wetland land unit, as it is the only natural class in the LSA. The total anthropogenic edge to area ratio for the RSA is 17.2 km/km^2. The high edge to area ratios are caused by the large amount of anthropogenic disturbance in both the LSA and RSA.

Table 5.4-3: Baseline Anthropogenic Edge-to-Area Ratios for Land Units in the LSA and RSA

Land Unit	LSA (km/km^2)	RSA (km/km^2)
Deciduous	–	19.1
Native grass	–	25.0
Wetland	9.1	11.4
Total	**9.1**	**17.2**

Note:
– denotes not present.

5.4.4 Linear Disturbance

Linear features at baseline in the LSA are approximately 10 km in total length and include railways, highways and gravel roads (see Table 5.4-4). The total linear disturbance ratio is 2.4 km/km^2. Linear features at baseline for the RSA total 19 km and also include railways, highways and gravel roads. The total linear disturbance ratio in the RSA is 1.5 km/km^2.

Table 5.4-4: Baseline Density of Linear Features in the LSA and RSA

Linear Disturbance	LSA		RSA	
	Km	km/km^2	km	km/km^2
Railway	3.4	0.8	7.3	0.6
Highway	0.2	0.1	9.3	0.2
Gravel/improved roads	6.1	1.5	1.9	0.8
Total	**9.7**	**2.4**	**18.5**	**1.5**

5.4.5 Species Diversity

5.4.5.1 Vegetation

Within the LSA, plant species diversity is high within the wetland land unit (39 native plant species, 26 potential rare plants; see Appendix I for land unit rare plant potential), moderate in the rough pasture (CPR) land unit (26 native plant species, 20 potential rare plants) and low in the annual and perennial croplands based on professional judgment (no estimates for species richness or potential rare plants possible). Anthropogenic lands were not surveyed for plant species diversity, but are assumed to have little to no value for plant species diversity. Appendix IV lists the plant species identified in the wetland and CPR land units.

5.4.5.2 Wildlife

Within the LSA, the wetland land unit had high values for wildlife species richness (112 species), number of SAR (32 species) and the number of unique species (14 species), leading to the highest overall species diversity ranking (2.75) (see Table 5.4-5). The three remaining land units had low overall species diversity with the rough pasture having a higher overall ranking than the perennial forage crop which had a higher ranking than the annual crop (see Table 5.4-5). Each of these communities had low species richness, few SAR and no unique species (see Table 5.4-5).

Two additional land units exist in the RSA, the deciduous and native prairie land unit. The deciduous land unit had the highest species richness of all the communities in the LSA and RSA (150 species), a high number of SAR (29 species) and unique species (11 species) (see Table 5.4-5). The deciduous land unit had a high overall species diversity ranking (2.69) which was lower than the wetland land unit (see Table 5.4-5). The native prairie land unit had a lower overall species diversity ranking, which was similar to the other grassland communities in the LSA (annual crop, perennial forage crop and rough pasture, see Table 5.4-5). Species richness, number of SAR and unique species values were all low for the native prairie (see Table 5.4-5).

Table 5.4-5: Wildlife Species Richness, SAR, Unique Species and Overall Species Diversity Rankings for Land Units in the LSA and RSA

Land Unit	Species Richness	Species Richness Index	Number of SAR	SAR Index	Number of Unique Species	Unique Species Index	Overall Species Diversity Ranking
Deciduous	150	1.00	29	0.91	11	0.79	2.69
Annual crop	65	0.43	12	0.38	0	0.00	0.81
Perennial forage crop	66	0.44	13	0.41	0	0.00	0.85
Rough pasture	67	0.45	15	0.47	0	0.00	0.92
Native prairie	69	0.46	19	0.59	0	0.00	1.05
Wetland	112	0.75	32	1.00	14	1.00	2.75

5.5 Application Case

5.5.1 Potential Impacts

Surface disturbance, fragmentation, anthropogenic edge and linear disturbances can potentially affect the landscape and species indicators of biodiversity. These impacts increase edge and decrease the connectivity of a landscape, creating additional and smaller patches and populations that ultimately results in decreased habitat area and population viability for many species. These potential impacts on biodiversity indicators are introduced and discussed in Section 5.3.3.

5.5.2 Mitigation

The following mitigation measures will be used to reduce Project impacts on biodiversity indicators during construction and ongoing operations, where practicable or otherwise required:

- use previously disturbed areas to reduce the amount of new clearing
- minimize the proposed surface disturbance for the Project facilities
- optimize linear corridor widths and accommodate multiple-use areas such as roads, pipelines and power lines within the same right-of-way to minimize surface disturbance
- monitor and remove invasive and non-native plant species from the Project area when found to prevent their spread into adjacent native areas
- minimize the amount of disturbed areas during construction and operation of Project facilities to prevent the establishment and spread of invasive and non-native plant species

The facilities will be reclaimed after the life of the Project, which is approximately 25 years. Reclamation activities will involve replacing soil and revegetation activities. A full description of reclamation and revegetation activities is provided in the Volume IID, Section 2: Land Use and Reclamation – Appendix I, Conservation and Reclamation Plan.

5.5.3 Residual Impacts – LSA

5.5.3.1 Patch Area

Project application will increase the area of ROW, roads and railroads as well as industrial plant sites in the LSA (see Table 5.5-1). Small increases in the area of dugouts and pipelines will also occur. The increases in anthropogenic lands will come from the clearing of annual and perennial cropland, both of which will decrease in area at application. Land units that will not be impacted include farmsteads, rough pasture and wetlands. At closure the area of all land units will return to baseline levels.

No natural land units will be affected in area at application, while croplands, which have some limited value to biodiversity, will decrease in area. Therefore, the application impact is negative in direction as biodiversity is predicted to decrease. Impact extent will be local as it will not extend beyond the LSA, duration will be mid-term, magnitude will be low and confidence in this prediction is moderate. This is a Class 3 impact.

There is no impact to patch area after Project closure; therefore, this is a Class 4 impact.

Table 5.5-1: Project Impacts to Patch Area in the LSA

Land Unit	Baseline	Application			Closure		
	Area (ha)	Area (ha)	Change from Baseline		Area (ha)	Change from Baseline	
			ha	%		ha	%
AIF – farmstead	7.8	7.8	0.0	0.0	7.8	0.0	0.0
AIH – ROW, roads, railroads	24.5	34.4	9.9	40.4	24.5	0.0	0.0
AII – industrial, plant site	14.8	21.0	6.2	41.9	14.8	0.0	0.0
AIW – dugouts	–	0.7	0.7	n.d.	–	0.0	n.d
CA – annual crop	111.3	104.8	-6.5	-5.8	111.3	0.0	0.0
CIP – pipelines	–	1.2	1.2	n.d	–	0.0	n.d.
CP – perennial forage crops	216.8	205.2	-11.6	-5.3	216.8	0.0	0.0
CPR – rough pasture	17.6	17.6	0.0	0.0	17.6	0.0	0.0
Wetland	14.6	14.6	0.0	0.0	14.6	0.0	0.0
Total	**407.4**	**407.4**	**0.0**	**0.0**	**407.4**	**0.0**	**0.0**

Notes:
– denotes not present.
n.d. – not defined.
Numbers may not add exactly due to rounding error.

5.5.3.2 Patch Size

Overall mean patch size in the LSA will decrease by 7 ha (41%) at Project application (see Table 5.5-2). As with patch area, the mean patch size of ROW, roads and railroads; industrial plant sites, dugouts and pipelines will all increase at application while mean patch size of annual and perennial cropland will decrease. The mean patch sizes of farmsteads, rough pasture and wetlands do not change at application or closure. All mean patch sizes will return to baseline levels at Project closure.

While no natural land units are affected in either case, decreases will occur to croplands, which have some limited value for biodiversity. This increased fragmentation in the LSA is predicted to decrease biodiversity slightly as smaller patches cannot support as many species as large patches. Therefore, the impact at application is negative in direction, local in extent, mid-term in duration and low in magnitude with moderate confidence in these predictions. This is a Class 3 impact.

There is no impact to mean patch size after Project closure; therefore, this is a Class 4 impact.

Table 5.5-2: Project Impacts to Mean Patch Size in the LSA

Land Unit	Baseline	Application			Closure Effects		
	Mean Size (ha)	Mean Size (ha)	Change from Baseline		Mean Size (ha)	Change from Baseline	
			ha	%		ha	%
AIF – farmstead	2.0	2.0	0.0	0.0	2.0	0.0	0.0
AIH – ROW, roads, railroads	12.2	17.2	5.0	41.0	12.2	0.0	0.0
AII – industrial, plant site	3.7	4.2	0.5	13.5	3.7	0.0	0.0
AIW – dugouts	–	0.7	0.7	n.d.	–	0.0	n.d.
CA – annual crop	37.1	13.1	-24.0	-64.7	37.1	0.0	0.0
CIP – pipelines	–	0.4	0.4	n.d.	–	0.0	n.d.
CP – perennial forage crops	36.1	17.1	-19.0	-52.6	36.1	0.0	0.0
CPR – rough pasture	5.9	5.9	0.0	0.0	5.9	0.0	0.0
Deciduous	–	–	-	-	–	–	–
Native grass	–	–	-	-	–	–	–
Wetland	14.7	14.7	0.0	0.0	14.7	0.0	0.0
Overall patch size	**17.7**	**10.5**	**-7.2**	**-40.6**	**17.7**	**0.0**	**0.0**

Notes:
– denotes not present.
n.d. – not defined.

5.5.3.3 ***Anthropogenic Edge***

No change to the anthropogenic edge to area ratio of any of the natural land units in the LSA is predicted at Project application or closure (see Table 5.5-3). These are, therefore, Class 4 impacts.

Table 5.5-3: Project Impacts to Anthropogenic Edge to Area Ratio on Natural Land Units in the LSA

Land Unit	Baseline	Application			Closure Effects		
	km/km^2	km/km^2	Change from Baseline		km/km^2	Change from Baseline	
			km/km^2	%		km/km^2	%
Wetland	9.1	9.1	0.0	0.0	9.1	0.0	0.0
Total	**9.1**	**9.1**	**0.0**	**0.0**	**9.1**	**0.0**	**0.0**

5.5.3.4 Linear Disturbance

At application, the length of railways, gravel/improved roads and pipelines will all increase in the LSA over baseline levels (see Table 5.5-4). Highway length in the LSA will not increase. Total linear disturbance will more than double at application, but will return to baseline levels at Project closure.

Total linear density in the LSA will double from 2.4 km/km^2 at baseline to 4.8 km/km^2 at application.

The increase in linear disturbance is predicted to have a negative effect on biodiversity by increasing habitat fragmentation in the LSA. The Project impact to linear disturbance is therefore, negative in direction, local in extent, mid-term in duration and moderate in magnitude with moderate confidence. However, all of the increased linear disturbance will occur within currently disturbed land and no natural areas will be impacted. Therefore, this is a Class 3 impact.

At closure all linear disturbances will return to baseline levels, therefore, the impact at closure is Class 4.

Table 5.5-4: Project Impacts to Linear Features in the LSA

Land Unit	Baseline	Application			Closure		
	Length (km)	Length (km)	Change from Baseline		Length (km)	Change from Baseline	
			km	%		km	%
Railways	3.4	11.1	7.7	226.5	3.4	0.0	0.0
Highways	0.2	0.2	0.0	0.0	0.2	0.0	0.0
Gravel/improved roads	6.3	7.3	1.0	15.9	6.3	0.0	0.0
Pipeline	0.0	1.0	1.0	n.d.	0.0	0.0	n.d.
Total	**9.7**	**19.6**	**9.9**	**102.1**	**9.7**	**0.0**	**0.0**

Note:
n.d. – not defined.

5.5.3.5 Species Diversity

5.5.3.5.1 Vegetation

In the LSA, the area of land units with high and moderate plant species diversity (rough pasture and wetlands) will not change at Project application. Annual and perennial cropland area will decrease at application but will return to baseline levels at closure. These croplands can provide some habitat for native plant species, especially in drainage ditches and along field margins. Therefore, Project impacts to plant species diversity are negative in direction, local in extent, mid-term in duration and low in magnitude with moderate confidence. This is a Class 3 impact.

At closure all patch areas that have high species diversity will return to baseline levels. This is a Class 4 impact.

5.5.3.5.2 Wildlife

In the LSA, the land units with high wildlife species diversity (rough pasture and wetlands) will not change at Project application. These land units have greater vegetation structural diversity and species variety, which in turn support a more varied assemblage of wildlife species. There will be a decrease in annual crop and perennial forage crop patch area, which had lower species diversity. Project impacts to wildlife species are negative in direction, local in extent, mid-term in duration and low in magnitude with moderate confidence. This is a Class 3 impact.

At closure, the area of each land unit type will return to baseline levels and impact to wildlife species diversity is not expected. This is a Class 4 impact.

5.5.4 Impact Classification

Project impacts to biodiversity at application were either Class 3 or Class 4 (see Table 5.5-5). At closure all impacts to biodiversity are Class 4.

Table 5.5-5: Summary of Project Impacts to Landscape Diversity in the LSA

Indicator	Application		Closure	
	Change From Baseline	Impact Class	Change From Baseline	Impact Class
Patch area	Reduced agricultural land unit area	Class 3	All land units returned to baseline levels	Class 4
Mean patch size (ha)	-7.2 (-40.6%)	Class 3	0 (0.0%)	Class 4
Anthropogenic edge-to-area ratio (km/km^2)	0.0 (0.0%)	Class 4	0 (0.0%)	Class 4
Linear disturbance (km)	9.9 (102.1%)	Class 3	0 (0.0%)	Class 4
Vegetation species diversity	Small change to areas with low diversity	Class 3	All land units returned to baseline levels	Class 4
Wildlife species diversity	Small change to areas with low diversity	Class 3	All land units returned to baseline levels	Class 4

5.6 Cumulative Effects Case

Impacts from Project application and impacts from other planned and proposed projects (i.e., cumulative effects) were assessed within the RSA.

5.6.1 Mitigation

Mitigation measures to reduce cumulative impacts to landscape diversity in the RSA are identical to those for the application case in the LSA described in Section 5.5.2.

5.6.1.1 <u>Patch Area</u>

Land units in the RSA that will increase in area at application include ROW, roads and railroads; industrial plant sites; dugouts; and pipelines, with the greatest increases to the first two types (see Table 5.6-1). Only ROW, roads and railroads have an additional cumulative increase.

Annual and perennial croplands will experience small decreases at application and cumulatively. Land units that are unaffected in either case include farmsteads, rough pasture, deciduous forests, native grassland and wetlands.

No natural land units are impacted by the Project or other projects in the RSA. However, cropland does have some minor value for biodiversity and is reduced in area both at application and cumulatively. Therefore, the impact to patch area is negative in direction, regional in extent, mid-term in duration and low in magnitude with moderate confidence for both cases. These are Class 3 impacts.

Table 5.6-1: Project and Cumulative Effect Impacts to Patch Area in the RSA

Land Unit	Baseline	Application			Cumulative Effects		
	Area (ha)	Area (ha)	Change from Baseline		Area (ha)	Change from Baseline	
			ha	%		ha	%
AIF – farmstead	47.8	47.8	0.0	0.0	47.8	0.0	0.0
AIH – ROW, roads, railroads	39.2	49.1	9.9	25.3	52.9	13.7	34.9
AII – industrial, plant site	27.8	34.0	6.2	22.3	34.0	6.2	22.3
AIW – dugouts	0.0	0.7	0.7	n.d.	0.7	0.7	n.d.
CA – annual crop	374.3	367.6	-6.5	-1.7	366.2	-8.1	-2.2
CIP – pipelines	0.0	1.3	1.3	n.d.	1.3	1.3	n.d.
CP – perennial forage crops	624.5	612.9	-11.6	-1.9	610.7	-13.8	-2.2
CPR – rough pasture	76.8	76.8	0.0	0.0	76.8	0.0	0.0
Deciduous	7.1	7.1	0.0	0.0	7.1	0.0	0.0
Native grassland	12.6	12.6	0.0	0.0	12.6	0.0	0.0
Wetland	19.2	19.2	0.0	0.0	19.2	0.0	0.0
Total	**1,229.3**	**1,229.3**	**0.0**	**0.0**	**1,229.3**	**0.0**	**0.0**

Note:
n.d. – not defined.

5.6.1.2 Patch Size

Overall mean patch size in the RSA decreases by 4.4 ha (21%) at application and 4.8% (23%) cumulatively (see Table 5.6-2). Decreases in mean patch size occur in annual and perennial cropland as well as industrial plant sites. Land units with increases in mean patch size include ROW, roads and railroads; dugouts; and pipelines.

Cumulatively both annual and perennial croplands show decreases in mean patch size over the application case, while ROW, roads and railroads show patch size increases. All other land units do not change from the application to the cumulative case or are not affected in either case (e.g., farmsteads, rough pasture, deciduous forest, native grasslands and wetlands).

Patch size reduction indicates greater habitat fragmentation within a landscape, which reduces biodiversity as smaller patches cannot support the same number of species as larger patches. While no natural land units are affected in either case, cropland is affected and does play a small role in biodiversity. Therefore, impacts to patch size are negative in direction, regional in extent, mid-term in duration and moderate in magnitude with low confidence. These are Class 3 impacts.

Table 5.6-2: Project and Cumulative Effect Impacts to Patch Size in the RSA

Land Unit	Baseline	Application			Cumulative Effects		
	Mean Size (ha)	Mean Size (ha)	Change from Baseline		Mean Size (ha)	Change from Baseline	
			(ha)	%		(ha)	%
AIF – farmstead	4.3	4.3	0.0	0.0	4.3	0.0	0.0
AIH – ROW, roads, railroads	13.1	16.4	3.3	25.1	17.6	4.5	34.4
AII – industrial, plant site	6.9	6.8	-0.1	-1.4	6.8	0.0	0.0
AIW - dugouts	-	0.7	0.7	n.d.	0.7	0.7	n.d.
CA – annual crop	46.8	28.3	-18.5	-39.5	26.2	-20.6	-44.0
CIP - pipelines	-	0.4	0.4	n.d.	0.4	0.4	n.d.
CP – perennial forage crops	78.1	43.8	-34.3	-43.9	40.7	-37.4	-47.9
CPR – rough pasture	9.6	9.6	0.0	0.0	9.6	0.0	0.0
Deciduous	1.0	1.0	0.0	0.0	1.0	0.0	0.0
Native grassland	1.4	1.4	0.0	0.0	1.4	0.0	0.0
Wetland	19.2	19.2	0.0	0.0	19.2	0.0	0.0
Overall patch size	**20.8**	**16.4**	**-4.4**	**-21.2**	**16.0**	**-4.8**	**-23.1**

Note:
n.d. – not defined.

5.6.1.3 *Anthropogenic Edge*

No impacts to the anthropogenic edges of any of the natural land units in the RSA are predicted to occur in either case (see Table 5.6-3). Therefore, these are all Class 4 impacts.

Table 5.6-3: Project and Cumulative Effect Impacts to Natural Land Unit Anthropogenic Edge-to-Area Ratio in the RSA

Land Unit	Baseline	Application			Cumulative Effects		
	km/km^2	km/km^2	Change from Baseline		km/km^2	Change from Baseline	
			km/km^2	%		km/km^2	%
Deciduous	18.8	18.8	0.0	0.0	18.8	0.0	0.0
Native grassland	25.0	25.0	0.0	0.0	25.0	0.0	0.0
Wetland	11.4	11.4	0.0	0.0	11.4	0.0	0.0
Total	**17.2**	**17.2**	**0.0**	**0.0**	**17.2**	**0.0**	**0.0**

5.6.1.4 *Linear Features*

In the RSA, railways, gravel/improved roads and pipelines will all increase in length at application (see Table 5.6-4). Cumulatively, only railway length will increase over the application case. Total linear density in the RSA will increase from 1.5–2.3 km/km^2 (53.3%) at Project application.

Increased linear features result in fragmented habitats and decreased biodiversity. Impacts for both cases are negative in direction, local in extent, mid-term in duration and moderate in magnitude with moderate confidence. However, as most linear feature increases occur in previously disturbed areas, these are rated as Class 3 impacts.

Table 5.6-4: Project and Cumulative Effect Impacts to Linear Features in the RSA

Land Unit	Baseline	Application			Cumulative Effects		
	Length (km)	Length (km)	Change from Baseline		Length (km)	Change from Baseline	
			(km)	%		(km)	%
Railways	7.3	15.0	7.7	105.5	16.4	9.1	124.7
Highways	1.9	1.9	0.0	0.0	1.9	0.0	0.0
Gravel/improved roads	9.3	10.6	1.3	14.0	10.6	1.3	14.0
Pipeline	0.0	1.1	1.1	n.d.	1.1	1.1	n.d.
Total	**18.5**	**28.5**	**10.1**	**54.6**	**30.0**	**11.5**	**62.2**

Note:
n.d. – not defined.
Numbers may not add exactly due to rounding error.

5.6.1.5 Species Diversity

5.6.1.5.1 Vegetation

Land units with potential high and moderate plant species diversity (native grassland, native deciduous forest, wetlands and rough pasture) will not change at Project application or from cumulative effects (see Table 5.6-1). Annual cropland and perennial forage cropland will decrease in area very slightly at Project application and cumulative effects, but these areas have a potentially low plant diversity. Project impacts and cumulative effects to plant species diversity are therefore, negative in direction, regional in extent, mid-term in duration and low in magnitude with moderate confidence. These are Class 3 impacts.

5.6.1.6 Wildlife

In the RSA, the land units with high wildlife species diversity (deciduous and wetlands) will not change at Project application or as a result of cumulative effects. There will be a decrease in annual crop and perennial forage crop patch area, which had lower species diversity. Project impacts to wildlife species at application and due to cumulative effects are negative in direction, regional in extent, mid-term in duration and low in magnitude with moderate confidence. These are Class 3 impacts.

5.6.2 Impact Classification

Project and cumulative impacts to biodiversity indicators in the RSA were Class 3 and Class 4 (see Table 5.6-5). The majority of impact to biodiversity indicators in the RSA is from the Project.

Table 5.6-5: Summary of Project and Cumulative Impacts to Biodiversity Indicators in the RSA

Indicator	Application		Cumulative Effects	
	Change From Baseline	Impact Class	Change From Baseline	Impact Class
Patch area	Reduced agricultural land unit area	Class 3	Slight reduction in agricultural land unit area	Class 3
Mean patch size (ha)	-4.4 (-21.2%)	Class 3	-4.8 (-23.1%)	Class 3
Anthropogenic edge-to-area ratio (km/km^2)	0.0 (0.0%)	Class 4	0 (0.0%)	Class 4
Linear disturbance (km)	10.1 (54.6%)	Class 3	11.5 (62.2%)	Class 3
Wildlife species diversity	Small change to areas with low diversity	Class 3	Slight decrease in agricultural land unit area	Class 3
Vegetation species diversity	Small decrease to areas with low potential diversity	Class 3	Small decrease to areas with low potential diversity	Class 3

5.7 Summary of Impacts

Project impacts to biodiversity indicators in the LSA will be minimal. Impacts are expected to be Class 3 and Class 4 for all indicators at application and Class 4 at closure (see Table 5.7-1). Patch area and patch size will only be affected for the annual and perennial forage crop land units; no natural areas will be affected. Linear features will increase at Project application but only within previously disturbed areas of the LSA. Species diversity is lowest in the annual and perennial forage crop land units, which are the land units that will be impacted by the Project.

Project impacts to biodiversity indicators in the RSA will also be minimal, with impacts expected to be Class 3 and Class 4 for all indicators at Project application and cumulative effects (see Table 5.7-2). Most of the impact in the RSA to biodiversity indicators will be from the Project and not from other projects occurring in the area.

Table 5.7-1: Impacts to Biodiversity Indicators in the LSA at Project Application and Closure

	Geographic Extent	Magnitude	Direction	Duration	Confidence	Rating at Application	Rating at Closure[1]
Landscape Diversity							
Patch area	Local	Low	Negative	Mid term	Moderate	Class 3	Class 4
Patch size	Local	Low	Negative	Mid term	Moderate	Class 3	Class 4
Anthropogenic edge	Local	-	Neutral	-	High	Class 4	Class 4
Linear features	Local	Moderate	Negative	Mid term	Moderate	Class 3	Class 4
Species Diversity							
Vegetation species diversity	Local	Low	Negative	Mid term	Moderate	Class 3	Class 4
Wildlife species diversity	Local	Low	Negative	Mid term	Moderate	Class 3	Class 4

Note:
[1] Impact descriptors (i.e., magnitude, direction, etc.) pertain solely to application. Closure is a final impact rating only.

Table 5.7-2: Impacts to Biodiversity Indicators in the RSA at Project Application and Cumulatively

	Geographic Extent	Magnitude	Direction	Duration	Confidence	Rating at Application	Rating at Cumulative Effects[1]
Landscape Diversity							
Patch area	Regional	Low	Negative	Mid term	Moderate	Class 3	Class 3
Patch size	Regional	Moderate	Negative	Mid term	Low	Class 3	Class 3
Anthropogenic edge	Regional	-	Neutral	-	High	Class 4	Class 4
Linear features	Regional	Moderate	Negative	Mid term	Moderate	Class 3	Class 4
Species Diversity							
Vegetation species diversity	Regional	Low	Negative	Mid term	Moderate	Class 3	Class 3
Wildlife species diversity	Regional	Low	Negative	Mid term	Moderate	Class 3	Class 3

Note:
[1] Impact descriptors (i.e., magnitude, direction, etc.) pertain solely to application. Cumulative impact is a final impact rating only.

5.8 Monitoring and Adaptive Management

Monitoring will be in conjunction with the vegetation, wildlife, air, surface water and soils monitoring programs. Any changes to air quality, soil acidity and water pH may negatively impact some vegetation and wildlife species. Vegetation monitoring will focus on shelterbelt, rough pasture and wetland habitats to quantify the potential effects of dust deposition on vegetation and the potential introduction of non-native and invasive species into the LSA. The PDA, including stockpiled soil, will be monitored by AST over the operational lifespan of the sulphur forming and shipping facility for non-native and invasive species. It is noted that the remaining natural areas, in particular wetlands, are protected. This will maintain species diversity in the region and is in accordance with the Canadian Biodiversity Strategy (Environment Canada 1995).

5.9 References

5.9.1 Literature Cited

Alberta Environmental Protection (AEP). 1999. *Regional sustainable development strategy for the Athabasca Oil Sands Area*. Edmonton, AB.

Alberta Environment (AENV). 2007. *Final Terms of Reference, Environmental Impact Assessment (EIA) Report for the Proposed Bruderheim Sulphur Forming and Shipping Facility.* March 13, 2007, Alberta Environment, Edmonton, AB.

Alberta Sustainable Resource Development (ASRD). 2006. *The General Status of Alberta Wild Species 2005*. Natural Resources Service, Wildlife Management Division, Edmonton, AB.

Banfield, A.W.F. 1974. *The Mammals of Canada.* Toronto, ON: University of Toronto Press.

Bayne, E. 2003. *Cumulative effects of linear features on boreal forest bird communities. NSERC.* ARC Chair. Integrated Land Management Newsletter. Spring 2003.

Benton, T.G., J.A. Vickery and J.D. Wilson. 2003. Farmland biodiversity: is habitat heterogeneity the key? *Trends Ecology and Evolution.* 18, 182–188.

Boutin, C., B. Jobin, L. Bélanger and L. Choinière. 2002. Plant diversity in three types of hedgerows adjacent to cropfields. *Biodiversity and Conservation* 11(1): 1-25.

Campbell, N.A., J.B. Reece and L.G. Mitchell. 1999. *Biology – Fifth Editions.* Benjamin Cummings, Don Mills, ON.

Chapman, R.N, D.M Engle, R.E. Masters and D.M. Leslie, Jr. 2004. Grassland vegetation and bird communities in the southern Great Plains of North America. *Agriculture, Ecosystems and Environment*. 104: 557-585

D.M. Leahey and Associates Limited and Jacques Whitford. 2005. *An Assessment of Air Quality Impacts Associate with Operations at the Proposed HAZCO Bruderheim Sulphur Forming Facility.* Prepared for HAZCO Environmental Services. August, 2005.

Environment Canada. 1995. *Canadian Biodiversity Strategy.* Canada's Response to the Convention on Biological Diversity. Report of the Biodiversity Working Group. Canadian Museum of Nature.

Fritcher, S.C., M.A. Rumble and L.D. Flake. 2004. Grassland bird densities in seral stages of mixed-grass prairie. *Journal of Range Management*. 57(4):351-357.

Gould, J. 2006. *Alberta Natural Heritage Information Centre Tracking and Watch lists – Vascular Plants, Mosses, Liverworts and Hornworts.* Alberta Community Development, Parks and Protected Areas Division. Edmonton, AB.

Green, R.E., S.J. Cornell, J.P.W. Scharlemann and A. Balmford. 2005 Farming and the fate of wild nature. *Science*. 307: 550–555.

Hoffman, J. and J.M. Greef. 2004. *Mosaic indicators for species diversity in agricultural landscapes.* 4th International Crop Science Congress Proceedings.

Jobin, B., L. Belanger, C. Boutin and C. Maisonneuve. 2004. Conservation value of agricultural riparian strips in the Boyer River watershed, Quebec (Canada). *Agriculture, Ecosystems and Environment.* 103:413-423.

Johnson, D.H. and M.D. Schwartz. 1993. The Conservation Reserve Program and grassland birds. *Conservation Biology*. 7:934-937.

Kershaw, L., J. Gould, D. Johnson and J. Lancaster (Eds). 2001. *Rare Vascular Plants of Alberta.* Prepared by Alberta Native Plant Council. Published by University of Alberta Press and the Canadian Forest Service. Edmonton, AB.

Kruess, A. and T. Tscharntke. 2002. Contrasting responses of plant and insect diversity to variation in grazing intensity. *Biological Conservation* 106:293-302.

Lindenmayer, D.B. and J.F. Franklin. 2002. *Managed unreserved forest land for biodiversity conservation: the importance of the matrix.* In J.L. Craig, N. Mitchell and D.A. Saunders (Eds.) Nature Conservation 5: Nature Conservation in Production Environments: Managing the Matrix (pp. 13-25). Chipping Norton, Australia: Surrey Beatty and Sons.

Luoto, M., T. Toivonen and R.K. Heikkinen. 2002. Prediction of total and rare plant species richness in agricultural landscapes from satellite images and topographic data. *Landscape Ecology* 17(3): 195-217.

Magurran, A.E. 1988. *Ecological Diversity and its Measurements.* Princeton, NJ: Princeton University Press.

McGarigal, K. and B.J. Marks. 1994. *FRAGSTATS: Spatial pattern analysis program for quantifying landscape structure.* Version 2.0. Oregon State University, Corvallis, OR.

Moss, E.H. 1983. *Flora of Alberta* (2nd edition, revised by J.G. Packer). Toronto, ON: University of Toronto Press.

Natural Regions Committee (NRC). 2006. *Natural Regions and Subregions of Alberta.* Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. 1/005.

Nesby, R. 1997. *Alberta Vegetation Inventory Standards Manual*. Version 2.2. Alberta Environmental Protection, Edmonton, AB.

Noss, R. 1990. Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology* 4:355-364.

Rotenberry, J.T. and J.A. Wiens. 1980. Habitat structure, patchiness and bird communities in North American steppe vegetation: a multivariate analysis. *Ecology* 61:1228-1250.

Russell, A.P. and A.M. Bauer. 1993. *The Amphibians and Reptiles of Alberta.* University of Calgary Press, Calgary, AB.

Sanderson, M.A., R.H. Skinner, D.J. Barker, G.R. Edwards, B.F. Tracy and D.A. Wedin. 2004. Plant species diversity and management of temperate forage and grazing land ecosystems. *Crop Science* 44(4): 1132-1144.

Semenchuk, G.P. 1992. *The Atlas of Breeding Birds of Alberta. Federation of Alberta Naturalists.* Edmonton, AB.

Smith, H.C. 1993. *Alberta Mammals: An Atlas and Guide.* Provincial Museum of Alberta. Edmonton, AB.

5.9.2 Internet Sites

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2006. COSEWIC Status Assessments, May 2006. www.cosewic.gc.ca/eng/sct5/index_e.cfm. Accessed June 2006.

Species at Risk Act (SARA). 2006. Species at risk act public registry. http://www.sararegistry.gc.ca/default_e.cfm. Last Accessed March, 2007

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Appendix I: Land Unit Rare Plant Potential

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Scientific Name	Common Name	Habitat Description	Phenology	ANHIC Rank	COSEWIC Status	Potential Cover Classes
Alopecurus alpinus	Alpine foxtail	Shores and open woodland	June-August	S2 G5	-	Wetland, N_Decid,
Artemisia tilesii ssp. elatior	Herriot's sagewort, Mountain sagewort	Open woods and river flats; elsewhere, on open, rocky or gravelly alpine slopes or in heathlands	July–October	S2 G5	-	Deciduous, N_Decid, N_Grass, CPR
Aster pauciflorus	Few-flowered aster	Alkaline flats	July–August	S2 G4	-	CPR
Aster umbellatus	Flat-topped white aster	Moist woodlands and swampy sites; elsewhere, in moist thickets and meadows	July–September	S2 G5	-	Wetland, N_Decid, N_Grass
Bolboschoenus fluviatilis	River bulrush	Margins of ponds, lakes and rivers	June–July	S1 G5	-	Wetland
Botrychium campestre	Field grape fern, Prairie moonwort	Grassy fields and ditches	early spring to late spring {late summer}	S1 G3G4	-	CPR, N_Grass
Botrychium multifidum var. *intermedium*	Leather grape fern	Moist, sandy areas. Disturbed areas	spring	S2 G5T4?	-	CPR, Deciduous
Botrychium pinnatum	Northwestern grape fern	Sandy meadows	June–August	S1 G4?	-	N_Grass
Bromus latiglumis	Canada brome	Moist streambanks	{late June–August}	S1 G5	-	N_Grass, N_Decid
Calyophus serrulatus	Shrubby evening primrose	Sandy prairies and dunes	{May} June–July	S2 G5	-	CPR, N_Grass
Camassia quamash var. *quamash*	Blue camas	Moist to wet meadows	May–July	S2 G5T3T5	-	Wetland, N_Grass
Carex aperta	Open sedge	Open, wet ground	{April–June} July–August	S1 G4	-	Wetland, CPR, N_Grass
Carex backii	Back's sedge	Dry (to moist), shady woods	{May–July}	S2 G4	-	N_Decid
Carex crawei	Crawe's sedge	Calcareous meadows	{May} June–July	S2 G5	-	CPR, N_Grass

Note:
Brackets denote phenology observed outside of Alberta { }.

Table I–1: Rare Plants Occurring in the Central Parkland and their Potential Cover Classes (Cont'd)

Scientific Name	Common Name	Habitat Description	Phenology	ANHIC Rank	COSEWIC Status	Potential Cover Classes
Carex heleonastes	Hudson Bay sedge	Wet, calcareous sites such as fens and marshes	{July} August	S2 G4	-	Wetland
Carex hookerana	Sand sedge	Prairies and dry banks, and in open woods at lower elevations	June {July}	S2 G4?	-	CPR, N_Decid, N_Grass
Carex incurviformis var. *incurviformis*	Seaside sedge	Moist river shore	June {July}	S2 G4G5T4T5	-	N_Grass, N_Decid
Carex lacustris	Lakeshore sedge	Moist ditches	{May–June} July–August	S2 G5	-	CPR, Deciduous,
Carex umbellata	Umbellate sedge	Dry woods	{May–June}	S1 G5	-	N_Decid
Carex vesicaria var. *vesicaria*	Blister sedge	Swamps, marshes and shorelines	{June} July	S1 G5	-	Wetland
Carex vulpinoidea	Fox sedge	Slough edges	{May–July}	S2 G5	-	Wetland
Crepis intermedia	Intermediate hawk's-beard	Dry, open areas	{May–July} August	S2 G5	-	CPR, N_Grass
Cryptantha kelseyana	Kelsey's cat's eye	Open, sandy soils, near springs		S1 G4	-	CPR, N_Grass
Cynoglossum virginianum var. *boreale*	Hound's tongue, Wild comfrey	Dry woods	{June–July}	S1 G5T4T5	-	N_Decid
Cyperus schweinitzii	Sand nut-grass	Dry sandy soil, including active sand dunes	July–August	S2 G5	-	N_Grass
Danthonia spicata	Poverty oat grass	Sandy and rocky sites, mostly in dry woods but sometimes in moist meadows	{June} July	S1S2 G5	-	N_Decid, N_Grass
Ellisia nyctelea	Waterpod	Moist shady woods and streambanks	May–June {July}	S2 G5	-	N_Decid, N_Grass

Note:
Brackets denote phenology observed outside of Alberta { }.

Table I–1: Rare Plants Occurring in the Central Parkland and their Potential Cover Classes (Cont'd)

Scientific Name	Common Name	Habitat Description	Phenology	ANHIC Rank	COSEWIC Status	Potential Cover Classes
Erigeron flagellaris	Creeping fleabane	Dry, open woods, lakeshores and disturbed or poorly vegetated areas	June–August	S1S2 G5	-	CPR, Deciduous, N_Decid
Gentiana fremontii	Marsh gentian, Lowly gentian	Moist grassy meadows	June {July–August}	S2 G4	-	N_Grass
Geranium carolinianum	Carolina wild geranium	Clearings and disturbed sites; elsewhere, on granite outcrops and in dry, rocky woods, often on sandy soil	{April–July}	S1 G5		CPR, Deciduous, N_Grass
Gnaphalium viscosum	Clammy cudweed	Open woods.	July–September	SH G5	-	N_Decid
Gratiola neglecta	Clammy hedge-hyssop	Wet, muddy sites, often in shallow water	{June–August}	S2S3 G5	-	Wetland
Hedyotis longifolia	Long-leaved bluets	Sandy soil in open woods and on dunes; elsewhere, in grasslands	June–July {May–September}	S2 G4G5	-	N_Decid, N_Grass
Iris missouriensis	Western blue flag	Open, moist to wet (at least in spring) meadows and streambanks	{May} June–July	S1 G5	Threatened	Wetland, N_Grass, N_Decid
Lactuca biennis	Tall blue lettuce	Moist woods and clearings; elsewhere, in swampy sites and by hot springs	July–August	S2 G5	-	Wetland, N_Decid
Lomatogonium rotatum	Marsh felwort	Wet meadows and flats, often on saline soils	{late July} August–early September	S2S3 G5	-	Wetland, CPR, N_Grass
Lycopus americanus	American water-horehound	Marshy sites and moist, low ground along streams	July {June–August}	S3 G5	-	Wetland, N_Grass, N_Decid
Lysimachia hybrida	Lance-leaved loosestrife	Moist meadows and shores	July {June–August}	S2 G5	-	Wetland, N_Grass,
Malaxis monophylla	White adder's-mouth	Damp woods and thickets. Drier parts of bogs and fens	Mid June–August	S2 G5	-	Wetland, N_Decid

Note:
Brackets denote phenology observed outside of Alberta { }.

Table I–1: Rare Plants Occurring in the Central Parkland and their Potential Cover Classes (Cont'd)

Scientific Name	Common Name	Habitat Description	Phenology	ANHIC Rank	COSEWIC Status	Potential Cover Classes
Melica spectabilis	Onion grass	Wet to moderately dry, fairly open sites	{May-July} August	S2 G5	-	Wetland, CPR, N_Grass
Mertensia lanceolata	Lance-leaved lungwort	Open woods, moist slopes and meadows	May {June–July}	S2 G5	-	N_Decid, N_Grass
Mertensia longiflora	Large-flowered lungwort	Open woods, moist slopes and meadows	{April} May–June	S2 G4G5	-	N_Decid, N_Grass
Mimulus glabratus	Smooth monkeyflower	Wet places, often in water and around springs	{May–August}	S1 G5	-	Wetland
Mimulus guttatus	Yellow monkeyflower	Wet meadows, springs and streambanks	{April–June} July–August	SU G5	-	Wetland, N_Grass, N_Decid
Montia linearis	Linear-leaved montia	Moist to dry, open sites on sandy plains and hills at lower elevations. Also disturbed habitats and open woodlands	May–July	S1 G5	-	CPR, Deciduous, N_Decid, N_Grass
Muhlenbergia racemosa	Marsh muhly	Dry sand hills, slopes and eroded banks; elsewhere, in a wide variety of habitats including prairies, meadows, streambanks, edges of woodland, dry rocky slopes and waste ground	{late July–August}	S1 G5	-	CPR, Deciduous, N_Decid, N_Grass
Najas flexilis	Slender water-nymph	Ponds and streams, in clear, shallow to deep, fresh or brackish water	July–August	S1S2 G5	-	Wetland
Oenothera flava	Low yellow evening-primrose	Clay flats and slough edges	July–August	S2 G5	-	Wetland
Onosmodium molle var. *occidentale*	Western false gromwell	Gravelly banks and dry, open woods	June–July	S2 G4G5	-	N_Decid
Osmorhiza longistylis	Smooth sweet cicely	At lower elevations, in moist woods in the parkland and prairies	June	S2 G5	-	N_Decid

Note:
Brackets denote phenology observed outside of Alberta { }.

Table I–1: Rare Plants Occurring in the Central Parkland and their Potential Cover Classes (Cont'd)

Scientific Name	Common Name	Habitat Description	Phenology	ANHIC Rank	COSEWIC Status	Potential Cover Classes
Panicum leibergii	Leiberg's millet	Dry, sandy soil in grasslands and open woods	{June–July}	S1 G5	-	N_Decid, N_Grass
Panicum wilcoxianum	Sand millet	Dry, open areas	June–July	S1 G5	-	CPR, N_Grass
Physostegia ledinghamii	False dragonhead	Moist woods and streambanks; elsewhere, on lake shores and in marshes	{July–September}	S2 G3?	-	Wetland, N_Decid, N_Grass
Polanisia dodecandra	Clammyweed	Disturbed sites		S2 G5	-	CPR, Deciduous
Potamogeton strictifolius	Linear-leaved pondweed	Shallow lakes and ponds	July–September	S2 G5	-	Wetland
Potentilla finitima	Sandhills cinquefoil	Moist flats and sandy lake shores and riverbanks	{June–July}	S1 G2G4Q	-	N_Grass
Potentilla plattensis	Low cinquefoil	Coulees and dry flats in prairie grassland	June–July {August}	S1S2 G4	-	N_Grass
Ranunculus uncinatus	Hairy buttercup	Moist, shady woodlands at lower elevations	April–July	S2 G5	-	N_Decid
Rhynchospora capillacea	Slender beak-rush	Calcareous fens; elsewhere, in calcareous sites in meadows and swamps and on shores	{July}	S1 G4	-	Wetland, N_Grass
Ruppia cirrhosa	Widgeon-grass	Saline and alkaline lakes, ponds and ditches; elsewhere, in brackish or salt water along the coast, rarely in fresh water	July {August}	S1S2 G5	-	Wetland, CPR,
Shinneroseris rostrata	Annual skeletonweed	Sandy banks and dunes, where there is considerable loose sand	August {July–September}	S2 G5?	-	N_Grass
Sisyrinchium septentrionale	Pale blue-eyed grass	Moist meadows and grassy streambanks	{April} May–July	S2S3 G3G4	-	N_Grass

Note:
Brackets denote phenology observed outside of Alberta { }.

Table I–1: Rare Plants Occurring in the Central Parkland and their Potential Cover Classes (Cont'd)

Scientific Name	Common Name	Habitat Description	Phenology	ANHIC Rank	COSEWIC Status	Potential Cover Classes
Spergularia salina var. *salina*	Salt-marsh sand spurry	Brackish or saline mud and sands	May–August	S2 G5	-	Wetland
Sphenopholis obtusata	Prairie wedge grass	Moist sites in meadows and open woods and on shores	{June–July}	S2 G5	-	N_Grass, N_Decid
Torreyochloa pallida var. *pauciflora*	Few-flowered salt-meadow grass	Wet places	{June–August}	S1 G5T5	-	Wetland
Trisetum cernuum var. *cernuum*	Nodding trisetum	Moist woods	{May–July}	S2 G5	-	N_Decid
Viola pedatifida	Crowfoot violet	Dry gravelly hills and exposed banks in prairie grassland	{April} May–June	S2 G5	-	N_Grass
Wolffia columbiana	Watermeal	Beaver ponds in hummocky moraines, in nutrient-rich ponds	June–October	S2 G5	-	Wetland

Note:

Brackets denote phenology observed outside of Alberta { }.

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Appendix II: Wildlife Species Diversity Habitat Associations

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1. Introduction

The following table outlines wildlife species potentially occurring in the region and the land units that these species would be expected to use. Although several of these species may be detected incidentally in all of the land units, species were only considered to be using the various land units if these habitats were essential for breeding and producing young.

Due to the types of wetlands on site (small sized with no sandy edges), it is assumed that certain waterbirds (i.e., American white pelican, trumpeter swan, merganser spp., white-winged scoter and piping plover) would not be associated with any of the land units present on site. Along with unsuitable wetland habitats, land units present on site are not believed to support several of the raptor species (osprey, bald eagle, northern harrier, northern goshawk, broad-winged hawk, Swainson's hawk and golden eagle). Suitable nesting habitat for peregrine falcon (cliffs) and barn swallows (human structures) is also not present on site.

Table II-1: Wildlife Habitat Associations Based on Land Units in the LSA and RSA for Species Richness Calculations

Common Name	Scientific Name	Land Unit					
		Deciduous	Annual Crop	Perennial Forage	Rough Pasture	Native Prairie	Wetland
Tiger salamander	*Ambystoma tigrinum*	1		1	1	1	1
Boreal chorus frog	*Pseudacris maculata*	1	1	1	1	1	1
Wood frog	*Rana sylvatica*	1	1	1	1	1	1
Canadian toad	*Bufo hemiophrys*	1					1
Western toad	*Bufo boreas*	1				1	1
Plains garter snake	*Thamnophis radix*	1	1	1	1	1	1
Red-sided garter snake	*Thamnophis sirtalis*	1	1	1	1	1	1
Common loon	*Gavia immer*						1
Pied-billed grebe	*Podilymbus podiceps*						1
Horned grebe	*Podiceps auritus*						1
Red-necked grebe	*Podiceps grisegena*						1
Western grebe	*Aechmophorus occidentalis*						1
Eared grebe	*Podiceps nigricollis*						1
American white pelican	*Pelecanus erythrorhynchos*						
Double-crested cormorant	*Phalacrocorax auritus*						
American bittern	*Botaurus lentiginosus*						1
Great blue heron	*Ardea herodias*						
Black-crowned night-heron	*Nycticorax nycticorax*						1
Trumpeter swan	*Cygnus buccinators*						

Table II-1: Wildlife Habitat Associations Based on Land Units in the LSA and RSA for Species Richness Calculations (Cont'd)

Common Name	Scientific Name	Land Unit					
		Deciduous	Annual Crop	Perennial Forage	Rough Pasture	Native Prairie	Wetland
Canada goose	*Branta canadensis*						1
Green-winged teal	*Anas crecca*						1
Mallard	*Anas platyrhynchos*						1
Northern pintail	*Anas acuta*						1
Blue-winged teal	*Anas discors*						1
Cinnamon teal	*Anas cyanoptera*						1
Northern shoveler	*Anas clypeata*						1
Gadwall	*Anas strepera*						1
American wigeon	*Anas americana*						1
Canvasback	*Aythya valisineria*						1
Redhead	*Aythya americana*						1
Ring-necked duck	*Aythya collaris*						1
Lesser scaup	*Aythya affinis*						1
White-winged scoter	*Melanitta fusca*						
Common goldeneye	*Bucephala clangula*						1
Bufflehead	*Bucephala albeola*						1
Hooded merganser	*Lophodytes cucullatus*						
Common merganser	*Mergus merganser*						
Red-breasted merganser	*Mergus serrator*						
Ruddy duck	*Oxyura jamaicensis*						1
Turkey vulture	*Cathartes aura*	1	1	1	1	1	1
Osprey	*Pandion haliaetus*						
Bald eagle	*Haliaeetus leucocephalus*						
Northern harrier	*Circus cyaneus*						
Sharp-shinned hawk	*Accipiter striatus*						
Cooper's hawk	*Accipiter cooperii*						
Northern goshawk	*Accipiter gentilis*						
Broad-winged hawk	*Buteo platypterus*						
Swainson's hawk	*Buteo swainsoni*						
Red-tailed hawk	*Buteo jamaicensis*						
Golden eagle	*Aquila chrysaetos*						
American kestrel	*Falco sparverius*						
Merlin	*Falco columbarius*						
Peregrine falcon	*Falco peregrinus*						
Gray partridge	*Perdix perdix*	1	1	1	1	1	

Table II-1: Wildlife Habitat Associations Based on Land Units in the LSA and RSA for Species Richness Calculations (Cont'd)

Common Name	Scientific Name	Land Unit					
		Deciduous	Annual Crop	Perennial Forage	Rough Pasture	Native Prairie	Wetland
Ring-necked pheasant	*Phasianus colchicus*	1	1	1	1	1	1
Spruce grouse	*Falcipennis canadensis*						
Ruffed grouse	*Bonasa umbellus*	1					
Sharp-tailed grouse	*Tympanuchus phasianellus*	1	1	1	1	1	
Sora	*Porzana carolina*						1
Yellow rail	*Coturnicops noveboracensis*						1
Virginia rail	*Rallus limicola*						1
American coot	*Fulica americana*						1
Sandhill crane	*Grus canadensis*						
Semipalmated plover	*Charadrius semipalmatus*						
Piping plover	*Charadrius melodus*						
Killdeer	*Charadrius vociferus*		1	1	1	1	1
American avocet	*Recurvirostra Americana*						1
Greater yellowlegs	*Tringa melanoleuca*						1
Lesser yellowlegs	*Tringa flavipes*						1
Solitary sandpiper	*Tringa solitaria*	1	1	1	1	1	1
Willet	*Catoptrophorus semipalmatus*						1
Spotted sandpiper	*Actitis macularia*						1
Upland sandpiper	*Bartramia longicausa*	1	1	1	1	1	1
Marbled godwit	*Limosa fedoa*		1	1	1	1	1
Least sandpiper	*Calidris minutilla*						1
Short-billed dowitcher	*Limnodromus griseus*						1
Common snipe	*Gallinago gallinago*	1	1	1	1	1	1
Wilson's phalarope	*Phalaropus tricolor*						1
Red-necked phalarope	*Phallaropus lobatus*						1
Franklin's gull	*Larus pipixcan*						1
Bonaparte's gull	*Larus philadelphia*						1
Ring-billed gull	*Larus delawarensis*						
Herring gull	*Larus argentatus*						
California gull	*Larus californicus*						
Common tern	*Sterna hirundo*						1
Forster's tern	*Sterna forsteri*						1

Table II-1: Wildlife Habitat Associations Based on Land Units in the LSA and RSA for Species Richness Calculations (Cont'd)

Common Name	Scientific Name	Land Unit					
		Deciduous	Annual Crop	Perennial Forage	Rough Pasture	Native Prairie	Wetland
Black tern	*Chlidonias niger*						1
Rock dove	*Columba livia*						
Mourning dove	*Zenaida macroura*	1	1	1	1	1	
Black-billed cuckoo	*Coccyzus erythropthalmus*	1					
Great horned owl	*Bubo virginianus*	1	1	1	1	1	
Barred owl	*Strix varia*	1					
Hermit thrush	*Catharus guttatus*	1					
Great gray owl	*Strix nebulosa*	1					
Long-eared owl	*Asio otus*	1					
Short-eared owl	*Asio flammeus*		1	1	1	1	
Boreal owl	*Aegolius funereus*	1					
Northern saw-whet owl	*Aegolius acadicus*	1					
Common nighthawk	*Chordeiles minor*	1	1	1	1	1	
Marsh wren	*Cistothorus palustris*						1
Golden-crowned kinglet	*Regulus satrapa*	1					
Ruby-crowned kinglet	*Regulus calendula*	1					
Mountain bluebird	*Sialia currucoides*	1	1	1	1	1	
Veery	*Catharus fuscescens*	1					
Swainson's thrush	*Catharus ustulatus*	1					
Ruby-throated hummingbird	*Archilochus colubris*	1					
Belted kingfisher	*Ceryle alcyon*						
Yellow-bellied sapsucker	*Sphyrapicus varius*	1					
Downy woodpecker	*Picoides pubescens*	1					
Hairy woodpecker	*Picoides villosus*	1					
Three-toed woodpecker	*Picoides tridactylus*	1					
Northern flicker	*Colaptes auratus*	1					
Pileated woodpecker	*Dryocopus pileatus*	1					
Olive-sided flycatcher	*Contopus cooperi*	1					1
Western wood-pewee	*Contopus sordidulus*	1					1
Yellow-bellied flycatcher	*Empidonax flaviventris*	1					1
Alder flycatcher	*Empidonax alnorum*	1					1
Least flycatcher	*Empidonax minimus*	1					1
Eastern pheobe	*Sayornis phoebe*	1					
Say's phoebe	*Sayornis saya*		1	1	1	1	

Table II-1: Wildlife Habitat Associations Based on Land Units in the LSA and RSA for Species Richness Calculations (Cont'd)

Common Name	Scientific Name	Land Unit					
		Deciduous	Annual Crop	Perennial Forage	Rough Pasture	Native Prairie	Wetland
Great crested flycatcher	*Myiarchus crinitus*	1					
Eastern kingbird	*Tyrannus tyrannus*	1	1	1	1	1	
Horned lark	*Eremophila alpestris*		1	1	1	1	
Purple martin	*Progne subis*	1					
Tree swallow	*Tachycineta bicolor*	1					1
Bank swallow	*Riparia riparia*						
Cliff swallow	*Petrochelidon pyrrhonota*						
Barn swallow	*Hirundo rustica*						
Gray jay	*Perisoreus canadensis*	1					
Blue jay	*Cyanocitta cristata*	1					
Black-billed magpie	*Pica hudsonia*	1	1	1	1	1	
American crow	*Corvus brachyrhynchos*	1	1	1	1	1	
Common raven	*Corvus corax*	1					
Black-capped chickadee	*Poecile atricapilla*	1					
Boreal chickadee	*Poecile hudsonica*	1					
Red-breasted nuthatch	*Sitta canadensis*	1					
White-breasted nuthatch	*Sitta carolinensis*	1					
Brown creeper	*Certhia americana*	1					
House wren	*Troglodytes aedon*	1	1	1	1	1	
Winter wren	*Troglodytes troglodytes*	1					
Sedge wren	*Cistothorus platensis*						1
American robin	*Turdus migratorius*	1	1	1	1	1	
Gray catbird	*Dumetella carolinensis*	1					
Brown thrasher	*Toxostoma rufum*	1					
Sprague's pipit	*Anthus spragueii*		1	1	1	1	
Bohemian waxwing	*Bombycilla garrulus*	1					
Cedar waxwing	*Bombycilla cedrorum*	1					
Northern shrike	*Lanius excubitor*	1					
Loggerhead shrike	*Lanius ludovicianus*	1					
European starling	*Sturnus vulgaris*	1	1	1	1	1	
Blue-headed vireo	*Vireo solitarius*	1					
Warbling vireo	*Vireo gilvus*	1					
Philadelphia vireo	*Vireo philadelphicus*	1					
Red-eyed vireo	*Vireo olivaceus*	1					

Table II-1: Wildlife Habitat Associations Based on Land Units in the LSA and RSA for Species Richness Calculations (Cont'd)

Common Name	Scientific Name	Land Unit					
		Deciduous	Annual Crop	Perennial Forage	Rough Pasture	Native Prairie	Wetland
Tennessee warbler	*Vermivora peregrina*	1					
Orange-crowned warbler	*Vermivora celata*	1					
Yellow warbler	*Dendroica petechia*	1					
Chestnut-sided warbler	*Dendroica pensylvanica*	1					
Magnolia warbler	*Dendroica magnolia*	1					1
Cape May warbler	*Dendroica tigrina*	1					
Yellow-rumped warbler	*Dendroica coronata*	1					
Black-throated green warbler	*Dendroica virens*	1					
Blackburnian warbler	*Dendroica fusca*	1					
Palm warbler	*Dendroica palmarum*						1
Bay-breasted warbler	*Dendroica castanea*	1					
Blackpoll warbler	*Dendroica striata*	1					
Black-and-white warbler	*Mniotilta varia*	1					1
American redstart	*Setophaga ruticilla*	1					1
Ovenbird	*Seiurus aurocapillus*	1					
Northern waterthrush	*Seiurus noveboracensis*	1					1
Connecticut warbler	*Oporornis agilis*	1					
Mourning warbler	*Oporornis philadelphia*	1					
Common yellowthroat	*Geothlypis trichas*						1
Wilson's warbler	*Wilsonia pusilla*						1
Canada warbler	*Wilsonia canadensis*	1					1
Western tanager	*Piranga ludoviciana*	1					
Rose-breasted grosbeak	*Pheucticus ludovicianus*	1					
Chipping sparrow	*Spizella passerina*	1					1
Clay-colored sparrow	*Spizella pallida*		1	1	1	1	1
Vesper sparrow	*Pooecetes gramineus*		1	1	1	1	
Baird's sparrow	*Ammodramus bairdii*				1	1	
Savannah sparrow	*Passerculus sandwichensis*		1	1	1	1	1
Le Conte's sparrow	*Ammodramus leconteii*			1	1	1	1
Sharp-tailed sparrow	*Ammodramus nelsoni*		1	1	1	1	1

Table II-1: Wildlife Habitat Associations Based on Land Units in the LSA and RSA for Species Richness Calculations (Cont'd)

Common Name	Scientific Name	Land Unit					
		Deciduous	Annual Crop	Perennial Forage	Rough Pasture	Native Prairie	Wetland
Fox sparrow	*Paserella iliaca*	1	1	1	1	1	1
Song sparrow	*Melospiza melodia*	1	1	1	1	1	1
Lincoln's sparrow	*Melospiza lincolnii*						1
Swamp sparrow	*Melospiza georgiana*						1
White-throated sparrow	*Zonotrichia albicollis*	1					1
White-crowned sparrow	*Zonotrichia leucophrys*	1	1	1	1	1	1
Dark-eyed junco	*Junco hyemalis*	1					
Bobolink	*Dolichonyx oryzivorus*		1	1	1		1
Snow bunting	*Plectrophenax nivalis*	1	1	1	1	1	1
Red-winged blackbird	*Agelaius phoeniceus*						1
Western meadowlark	*Sturnella neglecta*		1	1	1	1	1
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*						1
Rusty blackbird	*Euphagus carolinus*						1
Brewer's blackbird	*Euphagus cyanocephalus*	1	1	1	1	1	1
Common grackle	*Quiscalus quiscula*	1	1	1	1	1	1
Brown-headed cowbird	*Molothrus ater*	1	1	1	1	1	1
Baltimore oriole	*Icterus galbula*	1					
Pine grosbeak	*Pinicola enucleator*	1					
Purple finch	*Carpodacus purpureus*	1					
Red crossbill	*Loxia curvirostra*	1					
White-winged crossbill	*Loxia leucoptera*	1					
Common redpoll	*Carduelis flammea*	1	1	1	1	1	
Hoary redpoll	*Carduelis hornemanni*	1					
Pine siskin	*Carduelis pinus*	1					
American goldfinch	*Carduelis tristis*	1	1	1	1	1	
Evening grosbeak	*Coccothraustes vespertinus*	1					
House sparrow	*Passer domesticus*	1	1	1	1	1	
Masked shrew	*Sorex cinereus*	1	1	1	1	1	
Prairie shrew	*Sorex haydeni*	1	1	1	1	1	
Dusky shrew	*Sorex monticolus*	1					
Water shrew	*Sorex palustris*	1					1
Arctic shrew	*Sorex arcticus*	1					1
Pygmy shrew	*Sorex hoyi*	1					
Little brown bat	*Myotis lucifugus*	1					1

Table II-1: Wildlife Habitat Associations Based on Land Units in the LSA and RSA for Species Richness Calculations (Cont'd)

Common Name	Scientific Name	Land Unit					
		Deciduous	Annual Crop	Perennial Forage	Rough Pasture	Native Prairie	Wetland
Northern long-eared bat	*Myotis septentrionalis*	1					1
Big brown bat	*Eptesicus fuscus*	1					1
Red bat	*Lasiurus borealis*	1					1
Hoary bat	*Lasiurus cinereus*	1					1
Silver-haired bat	*Lasionycteris noctivagans*	1					1
Snowshoe hare	*Lepus americanus*	1					
White-tailed jack rabbit	*Lepus townsendii*		1	1	1	1	
Least chipmunk	*Tamias minimus*	1					
Woodchuck	*Marmota monax*	1	1	1	1	1	1
Richardson's ground squirrel	*Spermophilus richardsonii*		1	1	1	1	
Thirteen-lined ground squirrel	*Spermophilus tridecemlineatus*		1	1	1	1	
Franklin's ground squirrel	*Spermophilus franklinii*	1	1			1	
Red squirrel	*Tamiasciurus hudsonicus*	1					
Northern flying squirrel	*Glaucomys sabrinus*	1					
Northern pocket gopher	*Thomomys talpoides*		1	1	1	1	
American beaver	*Castor canadensis*						1
Deer mouse	*Peromyscus maniculatus*	1	1	1	1	1	1
Southern red-backed vole	*Clethrionomys gapperi*	1				1	1
Heather vole	*Phenacomys intermedius*						
Meadow vole	*Microtus pennsylvanicus*		1	1	1	1	1
Prairie vole	*Microtus ochrogaster*	1	1	1	1	1	
Muskrat	*Ondatra zibethicus*						1
Northern bog lemming	*Synaptomys borealis*						1
House mouse	*Mus musculus*	1	1	1	1	1	1
Meadow jumping mouse	*Zapus hudsonius*						1
Western jumping mouse	*Zapus princes*						1
Porcupine	*Erethizon dorsatum*	1					
Coyote	*Canis latrans*	1	1	1	1	1	
Gray wolf	*Canis lupus*	1	1	1	1	1	
Red fox	*Vulpes vulpes*	1	1	1	1	1	

Table II-1: Wildlife Habitat Associations Based on Land Units in the LSA and RSA for Species Richness Calculations (Cont'd)

Common Name	Scientific Name	Land Unit					
		Deciduous	Annual Crop	Perennial Forage	Rough Pasture	Native Prairie	Wetland
Black bear	*Ursus americanus*	1					
Raccoon	*Procyon lotor*	1					
Short-tailed weasel	*Mustela erminea*	1					
Least weasel	*Mustela nivalis*	1	1	1	1	1	
Long-tailed weasel	*Mustela frenata*	1	1	1	1	1	
Mink	*Mustela vison*						1
American Badger	*Taxidea taxus*	1	1	1	1	1	
Northern river otter	*Lutra canadensis*						1
Striped skunk	*Mephitis mephitis*	1	1	1	1	1	
Canada lynx	*Lynx canadensis*	1					
Elk	*Cervus elaphus*	1					
Mule deer	*Odocoileus hemionus*	1	1	1	1	1	
White-tailed deer	*Odocoileus viginianus*	1	1	1	1	1	
Moose	*Alces alces*	1	1	1	1	1	
Total		**150**	**65**	**66**	**67**	**69**	**112**

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Appendix III: Wildlife Species at Risk Habitat Associations

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1. Introduction

The following table outlines the Species at Risk (SAR) potentially occurring in the region and the land units that these species would be expected to use. Although several of these species may be detected incidentally in all of the land units, species were only considered to be using the various land units if these habitats were essential for breeding and producing young.

Due to the types of wetlands on site (small sized with no sandy edges), it is assumed that certain waterbirds (i.e., American white pelican, trumpeter swan, white-winged scoter and piping plover) would not be associated with any of the land units present on site. Along with unsuitable wetland habitats, land units present on site are not believed to support several of the raptor species (osprey, bald eagle, northern harrier, northern goshawk, broad-winged hawk, Swainson's hawk and golden eagle). Suitable nesting habitat for peregrine falcon (cliffs) and barn swallows (human structures) is also not present on site.

Table III-1 Wildlife Species at Risk Habitat Associations Based on Land Units in the LSA and RSA

Common Name	Scientific Name	Land Unit					
		Deciduous	Annual Crop	Perennial Forage	Rough Pasture	Native Prairie	Wetland
Amphibians and Reptiles							
Canadian toad	*Bufo hemiophrys*	1					1
Western toad	*Bufo boreas*	1				1	1
Red-sided garter snake	*Thamnophis sirtalis*					1	1
Birds							
American bittern	*Botaurus lentiginosus*						1
American white pelican	*Pelecanus erythrorhynchos*						
Baird's sparrow	*Ammodramus bairdii*			1	1	1	
Bald eagle	*Haliaeetuus leucocephalus*						
Baltimore oriole	*Icterus galbula*	1					
Barn swallow	*Hirundo rustica*						
Barred owl	*Strix varia*	1					
Bay-breasted warbler	*Dendroica castanea*	1					
Black tern	*Chlidonias niger*						1
Blackburnian warbler	*Dendroica fusca*	1					
Black-crowned night-heron	Nycticorax nycticorax						1
Black-throated green warbler	*Dendroica virens*	1					
Bobolink	*Dolichonyx oryzivorus*		1	1	1		
Broad-winged hawk	*Buteo platypterus*						

Table III-1: Wildlife Species at Risk Habitat Associations Based on Land Units in the LSA and RSA (Cont'd)

Common Name	Scientific Name	Land Unit					
		Deciduous	Annual Crop	Perennial Forage	Rough Pasture	Native Prairie	Wetland
Birds (Cont'd)							
Brown creeper	*Certhia americana*	1					
Canada warbler	*Wilsonia canadensis*	1					1
Cape May warbler	*Dendroica tigrina*	1					
Common nighthawk	*Chordeiles minor*		1	1	1	1	
Common yellowthroat	*Geothlypis trichas*						1
Eastern phoebe	*Sayornis phoebe*	1	1	1	1	1	1
Forster's tern	*Sterna forsteri*						1
Golden eagle	*Aquila chrysaetos*						
Great blue heron	*Ardea herodias*						
Great crested flycatcher	*Myiarchus crinitus*	1			1	1	
Great gray owl	*Strix nebulosa*	1					1
Green-winged teal	*Anas crecca*						1
Horned grebe	*Podiceps auritus*						1
Least flycatcher	*Empidonax minimus*	1	1	1	1	1	1
Lesser scaup	*Aythya affinis*						1
Loggerhead shrike	*Lanius ludovicianus*	1					
Northern goshawk	*Accipiter gentilis*						
Northern harrier	*Circus cyaneus*						
Nothern pintail	*Anas acuta*						1
Osprey	*Pandion haliaetus*						
Peregrine falcon	*Falco peregrinus*						
Pied-billed grebe	*Podilymbus podiceps*						1
Pileated woodpecker	*Dryocopus pileatus*	1					
Piping plover	*Charadrius melodus*						
Purple martin	*Progne subis*	1					1
Rusty blackbird	*Euphagus carolinus*						1
Sandhill crane	*Grus canadensis*						
Sedge wren	*Cistothorus platensis*		1	1	1	1	1
Sharp-tailed grouse	*Tympanuchus phasianellus*	1	1	1	1	1	
Short-eared owl	*Asio flammeus*		1	1	1	1	1
Sora	*Porzana Carolina*						1
Sprague's pipit	*Anthus spragueii*		1	1	1	1	
Swainson's hawk	*Buteo swainsoni*						
Trumpeter swan	*Cygnus buccinator*						
Turkey vulture	*Cathartes aura*	1	1	1	1	1	1
Upland sandpiper	*Bartramia longicauda*	1			1	1	1
Western grebe	*Aechmophorus occidentalis*						1

Table III-1: Wildlife Species at Risk Habitat Associations Based on Land Units in the LSA and RSA (Cont'd)

Common Name	Scientific Name	Land Unit					
		Deciduous	Annual Crop	Perennial Forage	Rough Pasture	Native Prairie	Wetland
Birds (Cont'd)							
Western tanager	*Piranga ludoviciana*	1					
White-winged scoter	*Melannita fusca*						
Yellow rail	*Coturnicops noveboracensis*						1
Mammals							
American badger	*Taxidea taxus*	1	1	1	1	1	
Canada lynx	*Lynx canadensis*	1					
Hoary bat	*Lasiurus cinereus*	1				1	1
Long-tailed weasel	*Mustela frenata*	1	1	1	1	1	1
Northern long-eared bat	*Myotis septentrionalis*	1					1
Red bat	*Lasiurus borealis*	1				1	1
Silver-haired bat	*Lasionycteris notivagans*	1				1	1
Total SAR in Each Land Unit		**29**	**12**	**13**	**15**	**19**	**32**

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Appendix IV: Land Unit Plant Species Lists

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1. Plant Species Lists

Plant species surveys were conducted within the LSA in the summer of 2006 (see Volume IIC, Vegetation: Section 3). Of the land units present in the LSA, only the perennial forage cropland and wetland units were surveyed. The table below lists the vascular plant species found in these two land units during the surveys. Non-vascular species were not collected or identified during the surveys.

Table IV–1: Plant Species Identified in the Perennial Forage (CPR) and Wetland Land Units

Common Name	Scientific Name	Land Unit	
		Perennial Forage (CPR)	Wetland
Trees			
Balsam poplar	*Populus balsamifera*	X	X
Shrubs			
Red-osier dogwood	*Cornus stolonifera*		X
Sandbar willow	*Salix exigua*		X
Yellow willow	*Salix lutea*		X
Snowberry	*Symphoricarpos albus*	X	
Forbs			
Common yarrow	*Achillea millefolium*	X	X
Small-leaved everlasting	*Antennaria parvifolia*	X	
Pasture sagewort	*Artemisia frigida*	X	
Prairie sagewort	*Artemisia ludoviciana*	X	
Common horsetail	*Equisetum arvense*		X
Hirsute fleabane	*Erigeron lonchophyllus*	X	X
Gumweed	*Grindelia squarrosa*	X	
Common duckweed	*Lemna minor*		X
Northern water-horehound	*Lycopus uniflorus*		X
Wild mint	*Mentha arvensis*		X
Beardtongue species	*Penstemon spp.*	X	
Common plantain	*Plantago major*	X	
Pale persicaria	*Polygonum lapathifolium*		X
Bushy knotweed	*Polygonum ramosissimum*	X	
Knotweed/Smartweed species	*Polygonum spp.*		X
Pondweed species	*Potamogeton spp.*		X
Silverweed	*Potentilla anserina*		X

Table IV–1: Plant Species Identified in the Perennial Forage (CPR) and Wetland Land Units (Cont'd)

Common Name	Scientific Name	Land Unit	
		Perennial Forage (CPR)	Wetland
Forbs			
Graceful cinquefoil	*Potentilla gracilis*	X	
Prairie cinquefoil	*Potentilla pensylvanica*		X
Cinquefoil species	*Potentilla spp.*	X	
Celery-leaved buttercup	*Ranunculus sceleratus*		X
Marsh yellow cress	*Rorippa palustris*		X
Curled dock	*Rumex crispus*	X	X
Willow dock	*Rumex salicifolius*		X
Marsh skullcap	*Scutellaria galericulata*		X
Marsh ragwort	*Senecio congestus*		X
Water parsnip	*Sium suave*		X
Fleshy stitchwort	*Stellaria crassifolia*		X
Blue-eyed grass	*Sisyrinchium montanum*		X
Common nettle	*Urtica dioica*		X
Graminoids			
Western wheat grass	*Agropyron smithii*	X	
Rough hair grass	*Agrostis scabra*	X	
Hair grass species	*Agrostis spp.*		X
Bearded wheat grass	*Agrostis trachycaulum var. unilaterale*	X	
Slough grass	*Beckmannia syzigachne*	X	X
Narrow reed grass	*Calamagrostis stricta*		X
Water sedge	*Carex aquatilis*		X
Bebb's sedge	*Carex bebbii*	X	
Small bottle sedge	*Carex utriculata*		X
Creeping spike rush	*Eleocharis palustris*		X
Fowl manna grass	*Glyceria striata*		X
Foxtail barley	*Hordeum jubatum*	X	X
Sweet grass species	*Hierochloe spp.*	X	
Wire rush	*Juncus balticus*	X	X
Rush species	*Juncus spp.*	X	
June grass	*Koeleria macrantha*	X	

Table IV–1: Plant Species Identified in the Perennial Forage (CPR) and Wetland Land Units (Cont'd)

Common Name	Scientific Name	Land Unit	
		Perennial Forage (CPR)	Wetland
Graminoids			
Mat muhly	*Muhlenbergia richardsonis*	X	
Reed	*Phragmites australis*		X
Fowl bluegrass	*Poa palustris*	X	X
Great bulrush	*Scirpus acutus*		X
Common great bulrush	*Scirpus validus*		X
Common cattail	*Typha latifolia*		X
Total Species in each Land Unit		**26**	**39**