SUNCOR ENERGY

Project Millennium Application

2A

Submitted to **Alberta Energy and Utilities Board** and **Alberta Environmental Protection**

Volume 2A
Environmental Impact Assessment
Introduction, Air Quality, Aquatics

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Project Millennium
Taking Suncor into the 21st Century

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LIST OF ABBREVIATIONS

"	Inch
$k	Thousand dollars
%	Percent
<	Less than
>	More than
°C	Temperature in degrees Celsius
°F	Temperature in degrees Fahrenheit
7Q10	Lowest 7-day consecutive flow that occurs, on average, once every 10 years
AAC	Annual Allowable Cut
AEOSRD	Alberta Energy Oil Sands and Research Division
AEP	Alberta Environmental Protection
AEP-LFS	Alberta Environmental Protection - Lands and Forest Service
AEPEA	Alberta Environmental Protection and Enhancement Act
AEUB	Alberta Energy and Utilities Board (also EUB)
Al-Pac	Alberta Pacific Forest Industries Inc.
AMD	Air Monitoring Directive
ANC	Acid Neutralizing Capacity
AOSERP	Alberta Oil Sands Environmental Research Program
API	American Petroleum Institute
ARC	Alberta Research Council
asl or ASL	Above sea level
ATP	AOSTRA Taciuk Process
avg.	Average
AVI	Alberta Vegetation Inventory
bbl	Barrel, petroleum (42 U.S. gallons)
bbl/cd	Barrels per calendar day
BCM	Bank cubic metres
BCY	Bank cubic yards
BOD	Biological oxygen demand
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
C	Carbon
C&R	Conservation and Reclamation
Ca^{2+}	Calcium base cation (particle)
$CaCO_3$	Calcium carbonate
CANMET	Canada Centre for Mineral and Energy Technology
CASA	Clean Air Strategic Alliance
$CaSO_4$	Calcium sulphate
CCME	Canadian Council of Ministers of the Environment
cd	Calendar day
CEA	Cumulative Effects Assessment
CEAA	Canadian Environmental Assessment Association
CEC	Cation exchange capacity
CEPA	Canadian Environmental Protection Act
ch	Calendar hour
CHWE	Clark Hot Water Extraction
CLI	Canadian Land Inventory

cm	Centimetre
cm/s	Centimetres per second
cm^2	Square centimetre
CO	Carbon monoxide
CO_2	Carbon dioxide
COD	Chemical oxygen demand
COH	Co-efficient of haze
CONRAD	Canadian Oil Sands Network for Research and Development
Consortium	Fine Tailings Fundamentals Consortium
CPUE	Cateh per unit of effort
CSEM	Continuous Stack Emissions Monitor
CT	Consolidated Tailings
CWQG	Canadian Water Quality Guidelines
d	Day
DBH	Diameter at breast height
DCU	Delayed Coking Unit
DEA	Diethanolamine
DEM	Digital Elevation Model
DIAND	Department of Indian Affairs and Northern Development
DL	Detection Limit
DO	Dissolved oxygen
DRU	Diluent Recovery Unit
e.g.	For example
EA	Effective Acidity
EC	Effective Concentration
EIA	Environmental Impact Assessment
ELC	Ecological Land Classification
elev	Elevation
EPL	End Pit Lake
ER	Exposure Ratio
ESPs	Electrostatic Precipitators
FEM	Finite Element Modelling
FGD	Flue Gas Desulphurization
FMA	Forest Management Agreement
ft	Feet
ft^3	Cubic feet
FTPH	Final Tailings Pump House
g	Grams
g/cc	Grams per cubic centimetre
g/s	Grams per second
GC/FID	Gas Chromatography/Flare Ionization Detection
GC/MS	Gas Chromatography/Mass Spectrometry
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIS	Geographic Information System
GJ	Giga-joules (10^9 joules)
GLC	Ground Level Concentration
Golder	Golder Associates Ltd.
GTG	Gas Turbine Generator
h	Hour

H_2S	Hydrogen sulphide
ha	Hectares
HNO_3	Nitric Acid (gas)
HQ	Hazard Quotient
HRSG	Heat Recovery Steam Generator
HSI	Habitat Suitability Indicies
HU	Habitat Unit
i.e.	That is
ibid.	In the same place
IC	Inhibiting Concentration
ICP	Inductively Coupled Argon Plasma Atomic Emission Spectrometric Analysis
IR	Infrared Spectrophotometric Analysis
IRIS	Integrated Risk Information System
IRP	Integrated Resource Plan
k	Thousand
K^+	Potassium Base Cation (particle)
kg	Kilogram
kg/d	Kilograms per day
kg/ha	Kilograms per hectare
kg/hr	Kilograms per hour
KIRs	Key Indicator Resources
km	Kilometre
km^2	Square kilometre
kmol.	kilo mole
kV	Kilovolt
kW	Kilowatt
L or l	Litre
lb/hr	Pounds per hour
LC	Lethal Concentration
LC/MS	Liquid Chromatography/Mass Spectrometry
LGHR	Low-Grade Heat Recovery
LHV	Lower Heating Value
LOAEL	Lowest Observed Adverse Effect Level
LOEC	Lowest Observed Effect Concentration
LOEL	Lowest Observed Effect Level
m	Metre
M	Mega (SI prefix)
m/s	Metres per second
m^2	Square metres
m^3	Cubic metres
m^3/cd	Cubic metres per calendar day
m^3/d	Cubic metres per day
m^3/ha	Cubic metres per hectare
m^3/hr	Cubic metres per hour
m^3/s	Cubic metres per second
masl	metres above sea level
MDEA	Methyl-diethanolamine
meq	Milli-equivalents
MFT	Mature Fine Tails

mg	Milligrams
MOU	Memorandum of Understanding
MSL	Mineral Surface Lease
µg	Microgram
µg/g	Micrograms per gram
µg/kg/d	Micrograms per kilogram body weight per day
mg/kg/d	Milligrams per kilograms body weight per day
µg/L	Micrograms per litre
mg/L	Milligrams per litre
$\mu g/m^3$	Micrograms per cubic metre
Mg^{2+}	Magnesium base cation (particle)
MJ	Megajoule (10^6 joules)
MM	Million
mm	Millimetre
MM.BTU	Million British Thermal Units
Mm^3	Mega metres (Million cubic metres)
Mobil	Mobil Oil Canada
mS/cm	milli-siemens per centimetre
MVA	Mega volt-amperes
MW	Megawatt
N	Nitrogen
ND	Not detected
N.D.	No data
N/A and n/a	Not applicable
NAP	Net Acidifying Potential
NAQUADAT	Alberta Environmental Historical Water Database
NH_4	Ammonia (particle)
NO	Nitric Oxide (gas)
No.	Number
NO_2	Nitrogen Dioxide (gas)
NO_3	Nitrate (particle)
NOAEL	No Observed Adverse Effect Level
NOEC	No Observed Effect Concentration
NOEL	No Observed Effect Level
NO_x	Oxides of nitrogen (NO, NO_2) (gas)
NO_y	All nitrogen species, $NO_x + N_2O + N_3O +$ ......(gas)
NPRI	National Pollutant Release Inventory
NRBS	Northern River Basin Study
NRU	Naphtha Recovery Unit
O & G	Oil and Grease
OB	Overburden
OSEC	Oil Sands Environmental Coalition
OSLO	Other Six Lease Owners
OSRPAP	Oil Sands Reclamation Performance Assessment Protocol
OSWRTWG	Oil Sands Water Release Technical Working Group
P	Phosphorus
PAH	Polycyclic aromatic hydrocarbons
PAI	Potential Acid Input
PANH	Polycyclic aromatic nitrogen heterocycles

PASH	Polycyclic aromatic sulphur heterocycles
PM_{10}	Particulate matter with mean aerodynamic diameter $\leq$ 10 microns
$PM_{2.5}$	Particulate matter with mean aerodynamic diameter $\leq$ 2.5 microns
PMF	Probable maximum flood
ppb	Parts per billion
ppm	Parts per million
psi	Pounds per square inch
Q	Quarter (i.e., three months of a year)
QA/QC	Quality Assurance/Quality Control
RA	Reclamation Area
RAMP	Regional Aquatic Monitoring Program
RAQCC	Regional Air Quality Coordinating Committee
RfD	Reference Dose
RIWG	Regional Infrastructure Working Group
RMWB	Regional Municipality of Wood Buffalo
RRTAC	Reclamation Research Technical Advisory Committee
RSA	Regional Study Area
RsD	Risk Specific Dose
s	Second
S	Sulphur
SAR	Sodium absorption ratio
scf/d	Standard cubic feet per day
SCO	Synthetic crude oil
sd	Stream day
sep cell	Separation cell
SFR	Sand to fines ratio
Shell	Shell Canada Limited
SLC	Screening Level Criteria
SO_2	Sulphur dioxide
SO_4^{2-}	Sulphate (particle)
SO_x	Sulphur oxides
spp	Species
Suncor	Suncor Energy Inc., Oil Sands
Syncrude	Syncrude Canada Ltd.
t	Tonne
t/cd	Tonnes per calendar day
t/d	Tonnes per day
t/h	Tonnes per hour
t/hr	Tonnes per hour
t/sd	tonnes per stream day
TDS	Total dissolved solids
TEH	Total extractable hydrocarbons
THC	Total hydrocarbons
TID	Tar Island Dyke
TIE	Toxicity Identification Evaluation
TKN	Total Kjeldahl Nitrogen
TOC	Total organic carbon
Ton	2 000 pounds
Tonne	2 205 pounds (1000 kg)
TRV	Toxicity Reference Value

TSS	Total suspended solids
TV/BIP	Ratio of total volume removed to total volume of bitumen in place
TV/NRB	Ratio of total volume removed to net recovered bitumen (in barrels)
Twp.	Township
U.S. EPA	United States Environmental Protection Agency
USgpm	U.S. gallons per minutes
VOC	Volatile organic compound
Vol.	Volume
VRU	Vapour Recovery Unit
vs.	Versus
WA	Waste Area

A1 MANAGEMENT FRAMEWORK

A1.1 OVERVIEW

The report on the Environmental Impact Assessment (EIA) of environmental, historical and socio-economic considerations for the Suncor Energy Inc., Oil Sands (Suncor) Project Millennium (the Project) is presented herein as Volume 2 of the Project Millennium application.

As stated in the Terms of Reference for Project Millennium (AEP 1998), the EIA report will identify development activities, describe environmental effects, mitigation options and residual effects that are relevant to the assessment of the Project ncluding, as appropriate, those related to Steepbank Mine and Lease 86/17 necessitated by the Project.

This section of the EIA reviews the integral connections among Suncor's proposed Project Millennium, Suncor's environmental management system, its stakeholder consultation program, project design and engineering, and the environmental assessment process.

The critical nature of the EIA in terms of supporting the application for project development is reviewed together with the linkage between the EIA terms of reference and other government policies.

The methodology employed for the EIA is described in detail in Section A2 (Approach). A key componenet of the EIA methodology revolves around the iterative nature of the assessment process. This is also described in some detail in this section.

Data sources for this EIA included literature, data previously gathered during studies in the oil sands development area, and EIAs completed for Suncor oil sands project developments as well as for other oil sands developments. Additional information specific to Project Millennium was also gathered as required.

A1.2 SUNCOR'S ENVIRONMENTAL MANAGEMENT SYSTEM

Suncor is committed to excellence in implementation of standards of care for the environment. This means that Suncor will not only comply with legislated requirements, but it will also respond to the expectations of regional communities, its customers, the government and the public, within the limits of technology and the company's capability to fund. This "We Care" environmental policy is incorporated into all aspects of its activities.

Suncor's environmental management involves continuous improvement through planning and disciplined implementation at all levels to eliminate, minimize or mitigate the impacts associated with its operations. Environmental conservation is an integral part of the operation.

Additional details on Suncor's environmental protection program is provided in Section A1.4 of Volume 1 of this Application.

Environmental Assessments

Suncor completes a variety of programs annually to assess the potential impacts of its operation on the environment. These annual programs include routine monitoring activities associated with the regulatory approvals Suncor has for operation of its oil sands development. Other programs include research and scientific studies to assess specific aspects of the operation and to evaluate potential environmental impacts associated with components of the development. Results of these programs are part of the feedback in the continuous improvement process and verification of previous impact predictions

Completion of environmental impact assessments associated with a proposed major expansion or modification of the Suncor development focuses on predicting impacts of the changes related to the development. The EIA draws information from the above research and monitoring programs.

Suncor's involvement in several regional environmental monitoring programs (e.g., the Regional Air Quality Coordinating Committee [RAQCC] and the Regional Aquatics Monitoring Program [RAMP]) provide regular information on environmental impacts associated with air emissions and water releases. These programs provide information to Suncor to allow ongoing assessment of environmental impacts. They also provide critical information for the EIA.

Public Involvement

Integral to the Project development is consultation with Suncor's stakeholders. The EIA process which is described later integrates stakeholder input and project design/planning at various stages. The various components of the EIA in this Volume will describe the consultation interaction. Section A3 of Volume 1 of this application describes the stakeholder consultation program in its entirety.

Database Evolution

In the Athabasca oil sands region there is a history of project development and associated EIA's as well as government and industry environmental research programs. Databases are regional and site-specific which provide a growing foundation for project EIA and cumulative effects assessments.

The specific sources of information used for the Project Millennium EIA are reviewed within each of the EIA component areas (including: air quality, aquatics, terrestrial resources, human health, historical resources, traditional and non-traditional land use and socio-economics). Provided below is a list of the major sources of information available for the oil sands development area.

- Suncor Oil Sands Debottlenecking Project (1988) - provided a detailed environmental review of Suncor's operations on Lease 86/17.
- Suncor Fixed Plant Expansion and Steepbank Mine Project (1996) - a comprehensive environmental impact and cumulative effects assessment for a production increase and development of a new mining area on the east bank of the Athabasca River.
- Syncrude Mildred Lake Project (1973, 1978) - baseline environmental impact and cumulative effects assessment for the Mildred Lake operation.
- Additions to the Syncrude Mildred Lake Project (1984, 1985, 1987 and 1992) - biophysical or environmental impact assessments filed in support of new facilities, new mining areas and for project production expansions.
- Syncrude Aurora Mine Project (1996) - comprehensive environmental impact and cumulative effects assessment for the development of new mining areas on the east bank of the Athabasca River, north of the Syncrude Mildred Lake operation.
- SOLV-EX Co-production Experimental Project (1995) - a environmental impact assessment for development of a seven-year experimental project.
- Shell Muskeg River Mine Project (1997) - a comprehensive environmental impact and cumulative effects assessment of a proposed new development, south of the Aurora North Mine, on the east bank of the Athabasca River.
- OSLO Project (1985) - an environmental impact assessment prepared on the basis of limited project details. The EIA was never officially submitted, but documentation of assessments is available.
- Alsands Project (1979) - an environmental impact assessment completed on a proposed oil sands mining operation in the area of the Muskeg River Mine Project and Syncrude Aurora North Mine. The project did not proceed.
- Alberta Oil Sands Environmental Research Program (1975 - 1980) - a comprehensive baseline information program focused on air, land, water and human systems.

- Fine Tailings Fundamentals Consortium (1989 - 1995) - research program involving industry, regulators, academia and consultants focused on specific oil sands extraction and extraction by-product issues.
- Northern River Basins Study (1992 - 1996) - extensive study to obtain scientific information on northern rivers, one of which was the Athabasca River.
- Canadian Oil Sands Network for Research and Development (1993 to present) - collaborative and coordinated research network focused on resolution of technical and environmental issues associated with oil sands and heavy oil development.
- Suncor and Syncrude in-house research - ongoing, oil sands development-specific programs to evaluate environmental impacts associated with operations.
- Regional Air Quality Coordinating Committee (RAQCC) (1989 to present) - multi-party group representing communities, industry and government who share a common interest in addressing concerns raised about air quality in the Fort McMurray / Fort McKay region.
- Regional Aquatics Monitoring Program (RAMP) (1997 to present) - a program initiated by Suncor and Syncrude. RAMP, which includes stakeholder participation, is designed to address some of the aquatic monitoring requirements for oil sands developments.

A1.3 GOVERNMENT REGULATION AND POLICY

The proposed development of Suncor's Project Millennium is linked with the current Suncor operations, including both the Lease 86/17 base operation, as well as the recently approved Steepbank Mine and Fixed Plant Expansion. Development of Project Millennium has therefore incorporated the understanding from the existing operation, the conditions included in the project approvals for the expanded operations, and the operating conditions detailed in the various regulatory approvals under which Suncor operates.

The proposed development of Project Millennium has also included consideration of various government policies, including the:

- Fort McMurray- Athabasca Oil Sands Subregional Integrated Resource Plan (AEP 1996a);
- Canadian Biodiversity Strategy (Environment Canada 1995);
- Alberta Native Plant Council Guidelines for Approaches to Rare Plant Surveys (Alberta Native Plant Council 1997); and
- Canadian Organization of the Status of Endangered Wildlife in Canada (COSEWIC 1997).

Terms of Reference

A Project Millennium Public Disclosure Document was issued on August 1, 1997. At the same time the proposed Terms of Reference for the Environmental Impact Assessment for Project Millennium was submitted to Alberta Environmental Protection (AEP). Copies of the proposed Terms of Reference were also provided directly to the Alberta Energy and Utilities Board (EUB) as well as to the Canadian Environmental Assessment Agency (CEAA).

The advertisement of the proposed Terms of Reference is geared toward involving stakeholders in the planning for the EIA. Input to the proposed Terms of Reference is solicited by AEP to allow issuance of the Final Terms of Reference. Both federal and provincial government agencies, as well as regional residents, development Stakeholders and interested parties had input to the final Terms of Reference. The Final Terms of Reference for the project Millennium EIA were issued by AEP on March 4, 1998 (AEP 1998). A copy of the Final Terms of Reference is provided in Appendix 1 of the EIA. A cross-reference between each term and the various sections of this application is provided in Section A5 of Volume 1 of this Application.

Part of the extensive consultation process that Suncor embarked on with the proposed Terms of Reference for Project Millennium included making them widely accessible through the Internet by placing them on Suncor's website. This happened on August 14, 1997 shortly after public disclosure of Project Millennium. Once the Terms of Reference were finalized by AEP on March 4, 1998, the final Terms of Reference were put onto the Suncor website within ten days.

The number of "hits" on both the proposed and final Terms of Reference were monitored. In total, from August 14 to March 31, there were 382 visitors who read Suncor's Terms of Reference. The highest activity was in the month of March with 85 "hits", followed closed by 84 during the last half of August. The "slowest" month was September, with only 17 "hits".

Interest around Suncor's Project Millennium spanned provincial, national and international boundaries. Readers plugged in to Suncor's Terms of Reference from as far away as Australia, New Zealand, Taiwan, the United Kingdom, Turkey, Germany and the Netherlands.

A1.4 EIA PROCESS IN PROJECT DEVELOPMENT

The EIA process in project development is iterative in nature. This means it includes a number of steps which typically occur as part of the assessment. These steps are summarized below:

1. The project, or a component of the project, is described in a preliminary design fashion.

2. The potential environmental impacts of this design (including any inherent mitigative aspects) are assessed at a feasibility level to identify potential major issues/impacts related to the known baseline environmental conditions.

3. Where major issues are identified at the feasibility level, options for modification of design or enhancement of mitigation are identified and reviewed with the project/component design team.

4. Revised project/component feasibility designs are reviewed to assess potential environmental impacts and identify continuing or new issues.

5. Once the preliminary reviews indicate project/component designs have manageable impacts, that design becomes integral to the full impact assessment.

6. Where the detailed EIA identifies new or re-defined environmental impacts, alternate or additional mitigative options are considered and presented to the design team for review.

This interative process is continued until the level of impact defined for the project or project component is deemed acceptable.

The impact analysis for the project also involves definition of additional mitigative options which may be available for predicted impacts. Additionally, recommendation are made for both monitoring programs to verify predicted impacts, as well as for specific studies to reduce uncertainties.

A2 APPROACH

A2.1 OVERVIEW

The report on the Environmental Impact Assessment (EIA) for Project Millennium is presented herein as Volume 2 of the Project Millennium application. The EIA is organized by components, within which the baseline or environmental conditions, project impact and cumulative effects assessments are discussed. The relationship of the component discussions to requirements listed in the Project Millennium EIA Terms of Reference (AEP 1998) are reviewed under each subsection and summarized in a Terms of Reference cross-reference table presented in Volume 1 (Section A5) of the Application. The Project Millennium EIA is divided into the following subsections:

- Air Quality (B);
- Surface Hydrology and Hydrogeology (C2);
- Surface Water Quality (C3);
- Fisheries and Fish Habitat (C4);
- Soils and Terrain (D2);
- Vegetation and Wetlands (D3);
- Ecological Land Classification (D4);
- Wildlife (D5);
- Reclamation and Closure (E);
- Human Health (F1);
- Socio-Economics (F2);
- Traditional Land Use and Resource Use (F3); and
- Historical Resources (F4).

The cumulative effects assessments completed for Project Millennium are presented in the following subsections:

- Air Cumulative Effects (B4);
- Water Cumulative Effects (C5);
- Terrestrial Cumulative Effects (D6);
- Human Health Cumulative Effects (F1.4); and
- Traditional Land Use and Resource Use Cumulative Effects (F3.6).

Although the baseline conditions for each of the EIA components are described in a stand-alone fashion, it is recognized that there are significant interdependencies among them. This interdependency is shown schematically in Figure A2-1, which shows the confluence of the outputs from the mine development and plant operations in terms of physical parameters (e.g., groundwater, surface water, air quality), which can have an impact on components that constitute the viability or productivity of the natural ecosystem (as measured in terms of socio-economics, human health, fish and wildlife habitat and health, and plant communities).

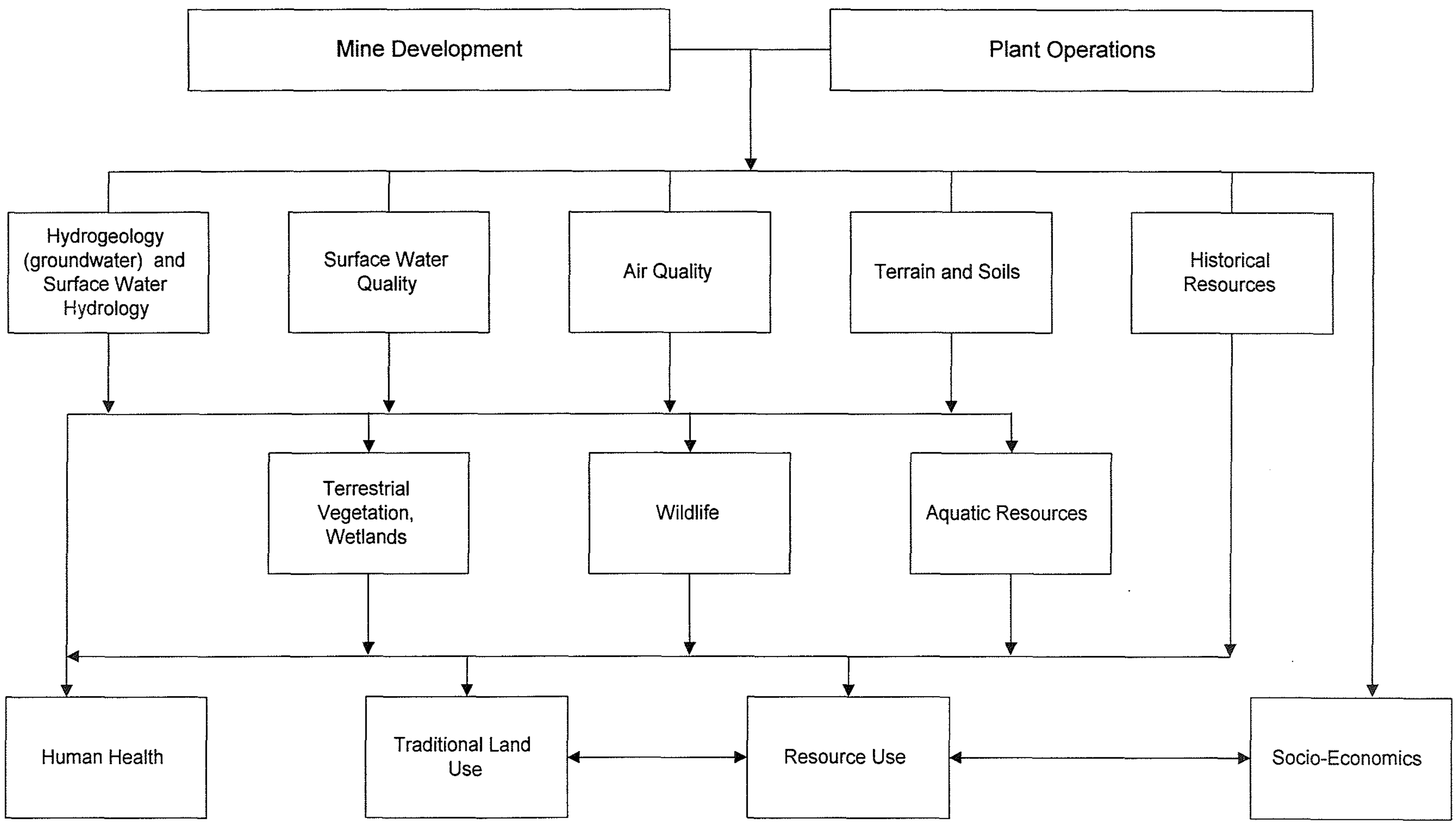
A2.1.1 Introduction

The Project Millennium EIA provides information as required by the Project Terms of Reference issued on March 4, 1998 (AEP 1998). The Terms of Reference provide the summary of key issues associated with the development of the proposed oil sands project. The document is prepared by the project proponent based on their understanding of the issues associated with the development. As described in Section A1, the proposed Terms of Reference are submitted to regulatory agencies and other stakeholders for review. Both federal and provincial government agencies, as well as regional residents, development stakeholders and other interested parties had input to the final Terms of Reference.

The Project EIA has been prepared to address the following requirements, which were detailed in the Terms of Reference:

- provide information on the environmental resources and resource uses that could be affected by the project;
- provide a sufficient base to predict positive and negative impacts;
- detail the extent to which negative impacts can be mitigated by planning, project design, construction techniques, operational practices and reclamation techniques;
- quantify impacts and assess in terms of spatial, temporal and cumulative aspects;
- review the sources of information used in the EIA, discuss the sources of information as well as limitations to the information;
- include the following information sources:
  - literature,
  - previous EIA reports and environmental studies,
  - operating experience from current oil sands operations,
  - industry study groups,
  - traditional knowledge, and
  - government sources;

Figure A2-1 Linkages Between EIA Components



Note: Some linkages between components have not been depicted.

- undertake studies and investigations, where required, to obtain additional information; and
- describe and rationalize the selection of key components and indicators examined based on a broad-based examination of ecosystem components, including previous environmental assessment work.

For each environmental parameter:

- describe existing development locations and comment whether available data are sufficient to assess impacts and mitigative measures;
- identify environmental disturbance from previous activities that have become part of baseline conditions;
- describe the nature and significance of environmental effects and impacts associated with development activities;
- present plans to minimize, mitigate or eliminate negative effects and impacts, together with a discussion of the key elements of such plans;
- identify residual impacts and comment on significance;
- present a plan to identify possible effects and impacts, monitor environmental impacts and manage environmental changes to demonstrate the project is operating in a environmentally sound manner;
- present a plan that addresses adverse impacts associated with the project; and
- describe how the plan will be implemented and how it will incorporate the participation of government, industry and the community.

A2.1.2 Framework

This environmental impact assessment (EIA) is structured to provide focused, understandable and relevant information and analysis about the type and extent of environmental impacts related to Project Millennium.

One of the goals of this EIA is to integrate the scientific analysis with societal values raised by the aboriginal and non-aboriginal communities, industry stakeholders, regulators and technical experts. To some extent, these issues and concerns may be shared, but each group may also have independent perspectives. The greatest impacts, both positive and negative, of a project are on the neighbouring communities. It is essential to incorporate the views of regional communities into the design of Project Millennium. Suncor's policies and programs ensure ongoing consultation and input into the project design. Regulators, who are charged with a responsibility to ensure public interests, are considered, through the application of public policy and legislation. The EIA must provide sufficient information about the project and potential impacts to allow regulators to fulfill their responsibilities.

The EIA must be explicit in identifying the issues which are addressed, and how the relationships between Project Millennium and the environmental impacts have been examined. This allows reviewers to understand the rationale and assumptions being used to make conclusions.

The purpose of an EIA is to examine the relationships between a proposed project and its potential impacts on the human and natural environments. These relationships, which provide the focus of the EIA, are revealed in the impact analyses, particularly in terms of definable assessment and measurement end points. The impact analyses are based on an examination of the ways the proposed project may result in changes to the environment, and then assessing if those environmental changes impact an issue of importance to the potentially affected communities.

Finally, the impact analysis cannot assess the effects of Project Millennium in isolation, but must examine the incremental impacts of the project on those of existing and approved developments (i.e., the baseline). The baseline includes both oil sands and other regional resource development activities. In addition, the impact of the cumulative effects of Project Millennium together with the existing, approved and planned developments is assessed.

The EIA process utilized in the development and assessment of this Project is shown schematically in Figure A2-2.

A2.1.3 Issues

A key component of the impact assessment process is to identify and focus on the issues that are of greatest concern to the community and regulators. This process was initiated through evaluation of the issues and responses in recent oil sands EIAs and other relevant documents as well as through community consultation. Some of the primary information sources previously reviewed in Section A1 (Environmental Management) are shown in Table A2-1.

Volume 1, Section A4 describes Suncor's public consultation approach and activities specific to Project Millennium. A sample of questions raised at various consultation events are listed below:

Figure A2-2 The EIA Process

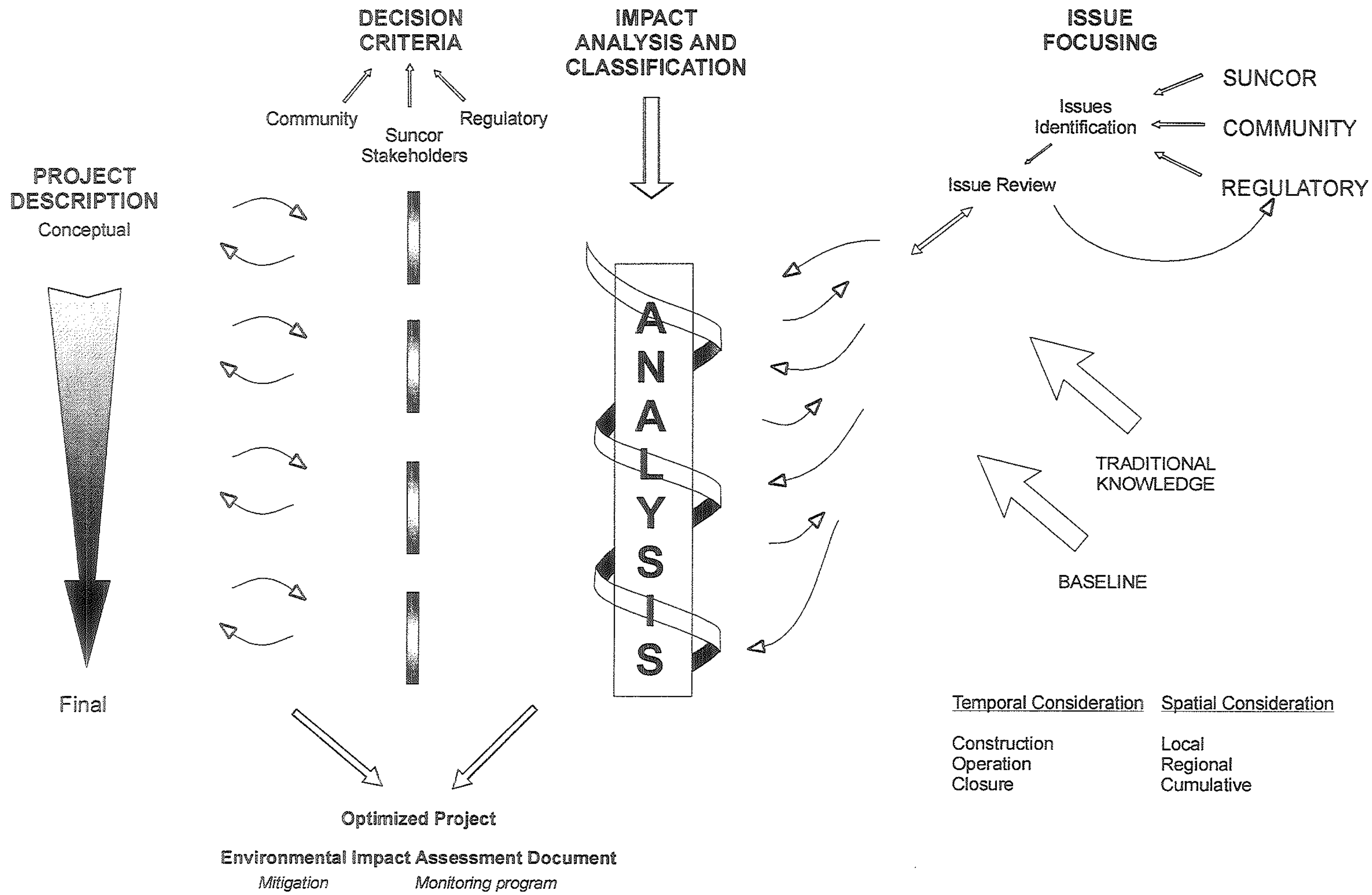


Table A2-1 Information Sources for Issue Focusing

EIA	Documents
Steepbank Mine EIA	Comments on EIA from Department of Fisheries and Oceans, Environment Canada, Pembina Institute for Appropriate Development.
	Axys Environmental Consulting Ltd.'s review of Steepbank EIA for the Athabasca Chipewyan First Nation Band.
	Steepbank Mine and Fixed Plant Expansion Application Approvals.
	EUB Project Approval.
	Alberta Environmental Protection (AEP) Environmental Operating Approval for Steepbank Mine.
Suncor Environmental Operating Approval	Requests for supplemental information to the environmental operating approval application (Lease 86/17 base operation).
	10-year Environmental Operating Approval conditions.
Aurora Mine EIA	Supplemental information questions and responses.
	Hearing notification submissions.
	Alberta Energy and Utilities Board (EUB) Approval for Project.
Muskeg River Mine Project EIA	AEP comments on draft EIA terms of reference.
	Canadian Environmental Assessment Agency (CEAA) comments on draft EIA terms of reference.
	Fort McKay (SMART) comments on draft EIA terms of reference.

- Regional Municipality of Wood Buffalo
  - How will wetlands be preserved?
  - What is the level of dangerous goods transported through Fort McMurray?
  - How will Suncor accommodate the construction workforce?
- Oil Sands Environmental Coalition
  - What are the emissions from the truck fleet?
  - Is the external tailings pond off property and how much mineable ore is beneath it?
  - How were facility siting decisions made?
- General Public
  - What is being done about supply of affordable housing?
  - What is being done about the traffic problem?
  - Will there be enough workforce for construction of all projects?
- Athabasca Chipewyan First Nations
  - Will fish tainting be addressed in the EIA?
  - Why doesn't the air quality study area include Fort Chipewyan?
  - How can aboriginal people become involved in river monitoring?

A2.1.4 Key Questions

Key questions have been identified for each EIA component to address the specific issues identified by the communities, stakeholders, regulators or technical experts. The Key Questions also reflect many of the information requests presented in the Project Terms of Reference, because these also are designed to focus on the key issues associated with the proposed questions; issues over and above those captured in the key questions are also addressed. The summary of key questions for Project Millennium is provided in Table A2-2.

Table A2-2 Summary of Key Questions for Project Millennium

Number	Key Question
Air Quality	
AQ-1	What impacts will air emissions from Project Millennium have on ambient air quality?
AQ-2	What impacts will air emissions from Project Millennium have on the deposition of acid forming compounds?
AQ-3	What impacts will air emissions from Project Millennium have on concentrations of ground level ozone (O_3)?
Surface Hydrology and Hydrogeology	
SHH-1	What impacts will development and closure of Project Millennium have on groundwater levels (volumes), flow patterns and quality?
SHH-2	What changes to groundwaters will development and closure of Project Millennium have that may impact flow and water levels in receiving streams, lakes, ponds and wetlands?
SHH-3	What impacts will development and closure of Project Millennium have on the water balance or open water areas of lakes, ponds, wetlands and streams?
SHH-4	What impacts will development and closure of Project Millennium have on sediment yields from project area river and stream basins, sediment concentrations in receiving streams and the channel regime of receiving streams?
SHH-5	What level of sustainability is expected for Project Millennium closure landscape drainage systems?
Surface Water Quality	
WQ-1	What impacts will operational and reclamation water releases from Project Millennium have on water quality and toxicity guideline attainment in the Athabasca and Steepbank rivers, small streams and Shipyard Lake?
WQ-2	What impacts will operational and reclamation water releases from Project Millennium have on the thermal regime of small streams and Shipyard Lake?
WQ-3	What impacts will muskeg dewatering activities associated with Project Millennium have on dissolved oxygen concentrations in small streams?
WQ-4	What impacts will operational and reclamation waters released from Project Millennium have on levels of polycyclic aromatic hydrocarbons (PAHs) in sediments in the Athabasca River?
WQ-5	What impacts will operational and reclamation water releases from Project Millennium have on toxicity guideline attainment in the end pit lake?
WQ-6	What impacts will acidifying emissions from Project Millennium have on regional waterbodies?
Fisheries and Fish Habitat	
F-1	What impacts will development and closure of Project Millennium have on fish habitat?
F-2	What impacts will development and closure of Project Millennium have on levels of acute or chronic toxicity to fish?
F-3	What impacts will development and closure of Project Millennium have on fish abundance?
F-4	What changes to fish tissue quality will result from development and closure of Project

Number	Key Question
	Millennium?
F-5	What type of aquatic ecosystem is expected in Project Millennium reclamation streams, wetlands and the end pit lake?
Soils and Terrain	
ST-1	What impacts will development and closure of Project Millennium have on the quantity and quality of soils and terrain units?
ST-2	What impacts will acidifying emissions from Project Millennium have on regional soils?
Vegetation and Wetlands	
VW-1	What impacts will development and closure of Project Millennium have on ecological land classification (ELC) units, vegetation communities and wetlands?
VW-2	What impacts will air emissions and water releases from Project Millennium have on vegetation health?
VW-3	What impacts will development and closure of Project Millennium have on vegetation and wetlands diversity?
Wildlife	
W-1	What impacts will development and closure of Project Millennium have on wildlife habitat, movement, abundance and diversity?
W-2	What impacts will chemicals in operational air and water releases from Project Millennium have on wildlife health?
W-3	What impacts will chemicals in soils, plants and waters from the Project Millennium reclaimed landscapes have on wildlife health?
Human Health	
HH-1	What impacts will chemicals in operational water releases from Project Millennium have on human health?
HH-2	What impacts will chemicals in operational air emissions from Project Millennium have on human health?
HH-3	What impacts will consumption of local plants and game animals exposed to operational water releases and air emissions from Project Millennium have on human health?
HH-4	What impacts will the combined exposure to water, air, plants and game animals have on human health during the operational phase of Project Millennium?
HH-5	What impacts will the chemicals in soils, plants and waters from the Project Millennium reclaimed landscapes have on human health?
Historical Resources	
HR-1	What impacts to historical resource sites, that warrant avoidance or further information recovery, will result from Project Millennium development activities?
Traditional Land Use and Resource Use	
TLU- 1	What impacts will development and closure of Project Millennium have on traditional land use practices?
RU-1	What impacts will development and closure of Project Millennium have on potential development of surface and mineral material extraction activities, agricultural developments and forestry operations?
RU-2	What impacts will development and closure of Project Millennium have on environmentally significant areas?
RU-3	What impacts will development and closure of Project Millennium have on consumptive resource use, including berry-picking, hunting, fishing and trapping?
RU-4	What impacts will development and closure of Project Millennium have on non-consumptive recreational use?

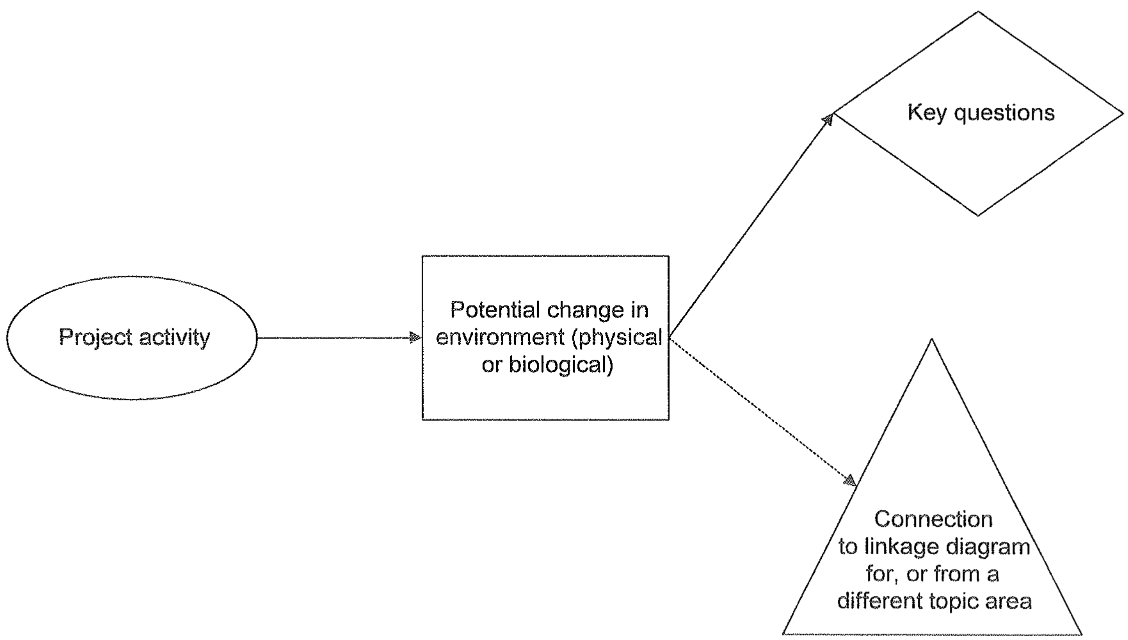
A2.1.5 Linkage Diagrams

Linkage diagrams are used to clearly describe how project activities could potentially lead to environmental changes, which in turn can affect specific components of the environment. Figure A2-3 illustrates the general format of the linkage diagrams. Symbols on the linkage diagrams include:

- ovals (project activities);
- rectangles (potential changes in the environment);
- diamonds (key questions); and
- triangles (connection to or from a different component area).

These diagrams are used as tools to guide the impact analysis, which addresses each link on the linkage diagram. They also show how the different environmental and social components are inter-related.

Figure A2-3 Key to Using Linkage Diagrams



The potential linkages between activities and impacts are evaluated to determine whether they apply to the Project. When this evaluation indicates a potential impact, the linkage is ruled valid for assessment. When the evaluation does not indicate a potential impact, the linkage is ruled invalid for the Project and is not assessed for the EIA.

A2.1.6 Spatial and Temporal Considerations

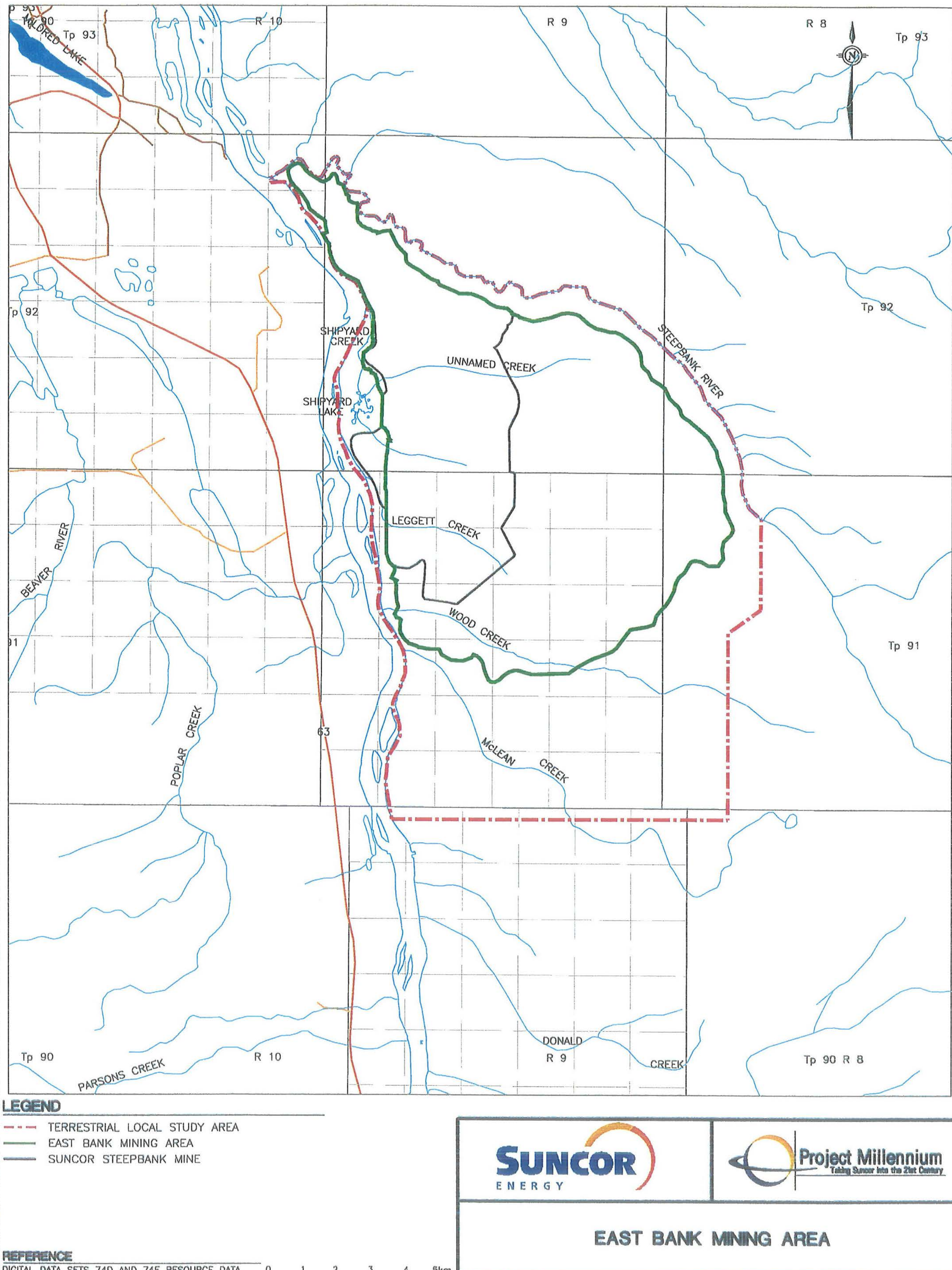
Spatial Considerations

Project Millennium includes an open pit oil sands mine as well as some extraction and utilities operations on the east side of the Athabasca River. This operation is associated with Suncor's recently approved Steepbank Mine. Additionally, Project Millennium includes an expansion of upgrading facilities on the west side of the river in the area of the current Suncor fixed plant, including the recently approved Fixed Plant Expansion. Details on Project Millennium are provided in Volume 1 of this Application.

Development of the mining area on the east bank of the Athabasca River under Project Millennium will include activities within the recently approved Steepbank Mine area as well as in areas being applied for under this application. The development on the east side of the Athabasca River will be referred to in this EIA as the east bank mining area, as shown in Figure A2-4.

Figure A2-4 shows various spatial areas included in the assessment and impact analysis. The largest area, outlined in red, is the local study area for the terrestrial components of the EIA. The next boundary, outlined in green, is the east bank mining area. The smallest boundary, outlined in black, represents the Steepbank Mine area previously approved for development in 1997. The boundary of the east bank mining area includes all areas expected to be developed as part of Steepbank and Project Millennium plus a 50m buffer around the outside.

Two major study area levels have been defined for the assessment of the potential impacts from Project Millennium. The study areas include a regional study area and local study areas. As described below, the spatial distribution of the study areas may vary for different EIA components. For some, such as air quality and human health, the local study area and the regional study area are the same.



SUNCOR ENERGY

Project Millennium
Taking Suncor into the 21st Century

EAST BANK MINING AREA

05 Apr. 1998 | Figure A2-4 | DRAWN BY: CG

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

Regional Study Area (RSA)

The Regional Study Area (RSA) for the Project Millennium EIA has been expanded from that used for the Suncor Steepbank Mine EIA (Suncor 1996b). This expansion accommodates requests from regulatory representatives for inclusion of additional areas that may be affected by air emissions from oil sands developments. The RSA, as shown in Figure A2-5, is used primarily during assessments of cumulative effects resulting from Project Millennium in combination with other developments. However, as noted above, the RSA is used for impact analyses for the Project as well as cumulative effects assessment for the air quality and human health components.

Some minor variations to the Project Millennium RSA were made depending on the specific EIA component being addressed. Some of these changes are reviewed below. Additional details on these variations are made, as required, within the EIA component discussions.

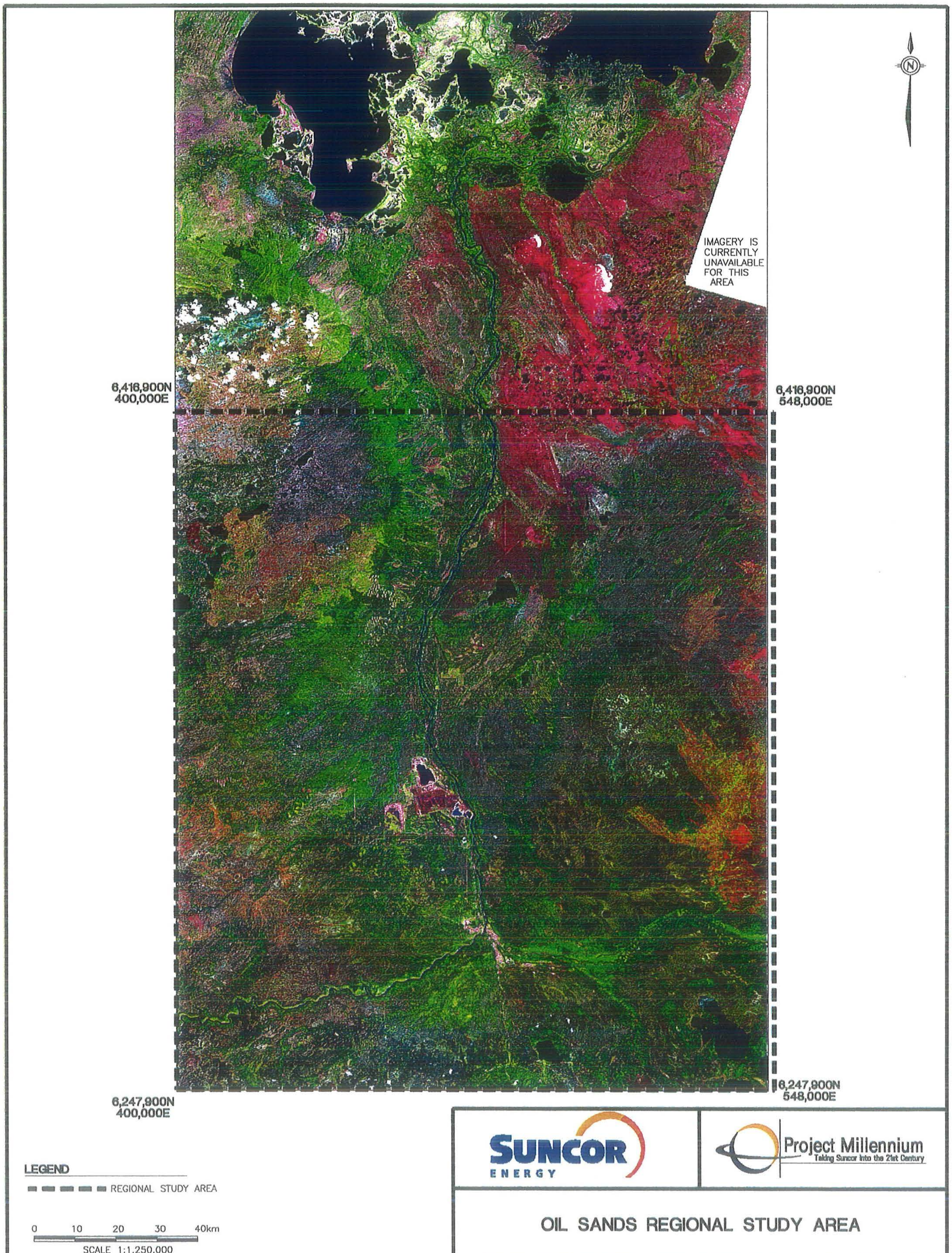
Air Quality

The Air Quality LSA (or local airshed) is defined by a 148 by 169 km area centred on the Suncor Upgrader. This area represents the north/south and east/west limits of predicted impacts related to air emissions from oil sands developments. It is within this area that air quality changes due to Project Millennium are expected to be greatest. This study area includes the communities of Fort McMurray and Fort McKay.

Air quality changes related to the Project activities are considered for Fort Chipewyan and the Chipewyan First Nations reserves even though these areas are located outside the RSA.

Water Quality Component of Aquatics

A difference between the Project Millennium water quality RSA and that used in the Steepbank and Syncrude Aurora Mine EIAs is the inclusion of a longer, downstream portion of the Athabasca River, ending at the confluence with the Embarras River. This extension was added to allow consideration of the communities along this stretch of the river and to evaluate potential regional development impacts on surface water quality.



SUNCOR ENERGY

Project Millennium
Taking Suncor Into the 21st Century

OIL SANDS REGIONAL STUDY AREA

05 Apr. 1998	Figure A2–5	DRAWN BY: TM

Human Health

The study area for the human health component was selected based on the areas identified for evaluation of changes in air quality and aquatics, and the location of the nearest residential communities. The human health study area includes the air and aquatic RSAs.

Socio-Economics

The socio-economic RSA includes the communities and peoples of the Regional Municipality of Wood Buffalo.

Historical Resources

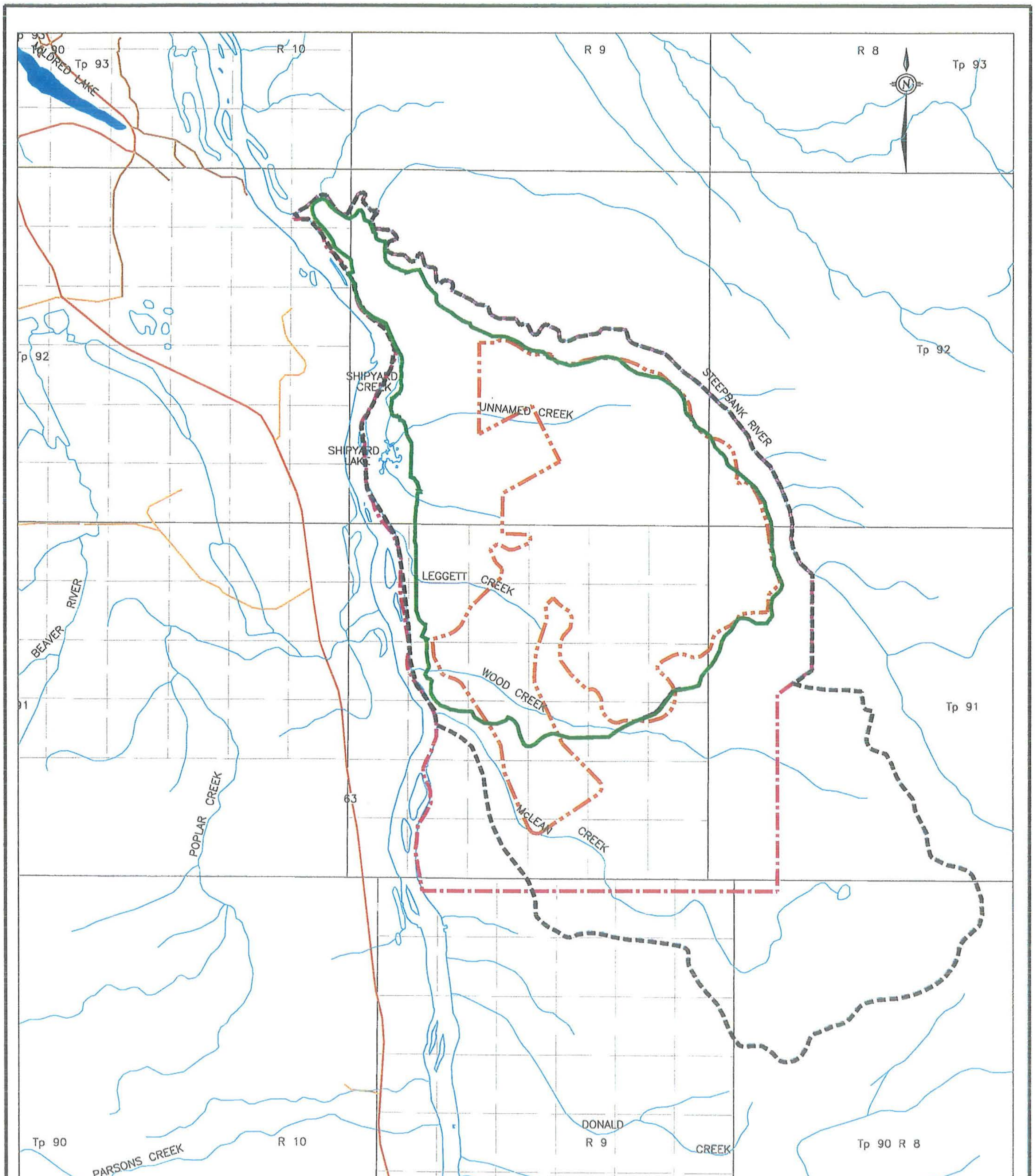
The historical resources RSA was centred around the primary oil sands development or planned development areas. This RSA, which included all or portions of 132 Townships totalled 1,100,000 ha in area.

Local Study Areas (LSA)

The Local Study Areas (LSAs) have been defined to include the spatial extent of resources directly or indirectly affected by Project Millennium. Therefore, the LSAs encompass the Project Millennium development area or a larger area depending on the environmental component (Figure A2-6).

There are four different LSAs for the Project:

- Aquatics (Surface Hydrology and Hydrogeology, Water Quality, and Fisheries and Fish Habitat);
- Terrestrial (Terrain and Soils, Vegetation and Wetlands, and Wildlife);
- Historical Resources; and
- Traditional Land Use and Resource Use (combination of Terrestrial and Aquatics LSAs).



LEGEND

- EAST BANK MINING AREA
- LOCAL STUDY AREA FOR TERRESTRIAL AND HISTORICAL RESOURCES
- LOCAL STUDY AREA FOR AQUATICS
- HISTORICAL RESOURCES IMPACT ASSESSMENT STUDY BOUNDARY

NOTE:

TRADITIONAL LAND USE AND RESOURCE USE ARE A COMBINATION OF TERRESTRIAL AND AQUATICS LSAs

REFERENCE

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

0 1 2 3 4 5km

SCALE 1:150,000

SUNCOR ENERGY

Project Millennium
Taking Suncor into the 21st Century

PROJECT MILLENNIUM
LOCAL STUDY AREAS

06 Apr. 1998	Figure A2-6	DRAWN BY: CG/TM

Aquatics

The Aquatics LSA includes the Hydrogeology (groundwater), Surface Water Hydrology, Surface Water Quality, and Fisheries and Fish Habitat components of the EIA. The LSA established for the Aquatics impact assessment is based on project areas between the Athabasca and Steepbank rivers. It includes the areas south from where the Steepbank River discharges into the Athabasca River, southeast along the north and east banks of the Steepbank River. The southeastern and southern boundaries of the aquatics LSA are defined by the drainage basin areas of Wood Creek and McLean Creek. The east shoreline of the Athabasca River then forms the western boundary of the LSA.

The Athabasca and Steepbank rivers represent the base of subsurface drainage for regional and local groundwater flow systems and therefore form natural hydrogeologic boundaries. Consequently, overburden dewatering effects and tailings or consolidated tailings seepage will not extend across these hydrogeologic boundaries.

The LSA also focuses on watercourses and waterbodies in the Project Millennium development area. The study area includes the drainage basins of Shipyard, Leggett, Wood, and McLean creeks, as well as smaller basins between the McLean Creek basin and the Steepbank River. Also included in the Aquatics LSA is the Steepbank River, from its confluence with the Athabasca River upstream for approximately 18 km.

The Athabasca River is not directly included in the Aquatics LSA. Rather, the Athabasca River is considered in the RSA where impacts related to the upstream operations, current and proposed Suncor operations, as well as developments downstream are evaluated to the point where the Embarras River connects with the Athabasca River.

Terrestrial

The Terrestrial LSA has been designed to encompass potential direct effects to terrain and soils, vegetation and wetlands, and wildlife components. The Terrestrial LSA is defined by the north or eastern shore of the Steepbank River at the north and eastern sides, south along the eastern shoreline of the

Athabasca River, east along a line positioned a minimum of 500 m south of the nearest east bank mining area development, and north along a line running to meet the Steepbank River.

Historical Resources

The Historical Resources LSA includes areas in the proposed development footprint for the Project Millennium portion of the east bank mining area. It includes only areas directly affected by the mine footprint and associated infrastructure on the east side of the Athabasca River.

Traditional Land Use and Resource Use

The Traditional Land Use and Resource Use LSA is generally the same as the Terrestrial LSA, as most aspects of these components are related to the terrestrial resources (e.g., forestry, environmentally significant areas, non-consumptive resource use, hunting and trapping). For aspects of traditional land use and resource use related to the aquatic environment (e.g., fishing, hunting and trapping), the LSA includes consideration of the waterbodies and watercourses within the Aquatics LSA.

Temporal Considerations

The temporal considerations for the EIA are based on the Project description and include unique conditions that may affect environmental components differently. Table A2-3 summarizes the main project and reclamation activities of Project Millennium from construction to closure.

The main project phases include construction, operations and closure. For most components, impact analyses considered construction and operations together. Construction is considered alone where it adds a large short-term change to the component under consideration (e.g., socio-economics - the influence of the construction workforce).

Time snapshots were used for some components to allow detailing of the evolution of changes in potential impacts during the life of the project. As an example, surface water hydrology and water quality incorporate water-related changes for the years 2005, 2015, closure (assumes a 10-year post mining closure activity period - 2042) and far future. The waters associated with each project phase generally overlap (e.g., reclamation proceeding concurrent with operations means that water quality changes associated with the release of reclamation waters can occur during both phases). However, each project phase will have a distinct combination of water types (e.g., muskeg and overburden dewatering, seepage, reclamation releases), flows and water qualities. The time snapshots allow modelling of variations in water releases and, by extension, all possible water quality conditions.

Other EIA components, particularly the terrestrial components, examine the project under three phases, including: the pre-development conditions; full development; and closure (or full reclamation). Although there will be sequential removal and reclamation of terrestrial systems, this sequential development and reclamation process is not included in the assessment. Restriction of the examination of impacts to the three phases builds conservatism into the impact assessment.

Table A2-3 Suncor Project - Activity Phases

Phase / Year	Activity
Baseline Conditions	
• 1997	• Approval for Steepbank Mine in January • Construction of Steepbank Mine Bridge completed • Initial clearing of forests and muskeg soils
• 1998	• Overburden stripping for Pit 1 • Construction of Steepbank Mine facilities - shops, ore preparation and hydrotransport facilities • commencement of mining activities in Pit 1 (4th quarter of year)
Construction Phase	
• 1999	• mining in Pit 1 continues • construction of Millennium extraction, energy services and upgrading components begins
• 2000	• mining in Pit 1 continues • Dyke 11a and 11b construction begins • Pond 8a (external tailings pond) construction begins • NE overburden dump under construction • tailings disposal to Pond 8a commences
• 2001	• mining in Pit 1 continues • commencement of mining activities in Pit 2 (3rd quarter) • commissioning of Millennium extraction, upgrading and energy services components
• 2002	• production at 210,000 bbl/day rate begins • mining in Pits 1 and 2 continues • Dyke 11 construction begins • North overburden dump is completed
Operation Phase	
• 2003	• mining in Pit 1 continues
• 2004	• mining in Pit 1 continues
• 2005	• Pit 1 mining completed in 1st quarter • ore excavation moves east into Lease 25 • Pond 9 use begins • Dyke 12 construction begins
• 2005 - 2011	• CT tailings deposition to Pond 8 begins around 2007; CT to Pond 8 during the years 2007-2012 • Dyke 14 construction begins in 2009 • Pond 10 use begins in 2011 • Overburden to Ponds 8 and 9 (2007-2011)
• 2012 - 2033	• mining advances in a southeast clockwise direction through Pit 2 • truck dumps and crushers located to the centre of Pit 2 (likely around 2012) • base (Lease 86/17) extraction Plant 3 shut down in 2012, with primary extraction operations moved to east bank mining area • centre plant construction and commencement of operations • by 2012, infilling of Pond 7 (Pit 1) with CT completed • about 2014, all overflow from extraction plants diverted from external tailings pond (8A) to Pond 7 (placement on top of

Phase / Year	Activity
	deposited CT • Pond 7 used as the water recycle pond between 2014 and about 2030 • East muskeg stockpile area under construction • Dyke 15 construction begins in 2015 • Pond 11 use begins in 2017 • Dyke 16 construction begins in 2022 • Pond 12 use begins in 2026 • Primary extraction plant commences operation in east bank • Overburden to Pond 10 - 2012-2017 • Overburden to Pond 11 - 2018-2026 • Overburden to Pond 12 - 2027-2033 • Pond 9 -receives CT from 2012-2017 • Pond 10 receives CT from 2017-2022 • Pond 11 receives CT from 2022-2033 • infilling of external tailings pond commences in 2027; all remaining tailings in Pond 8A transferred to small pond in Pond 12 • Pond 7 topped up with CT after 2030
Closure Phase	
• 2033 - 2043	• mining completed in 2032 • residual tailings located in small pond in Pit 12 (i.e., the south end of the end pit lake) • final surfacing of reclamation areas completed • drainage system to Shipyard Lake fully re-established • final drainage systems developed and commissioned • final reclamation activities completed
• Far Future	• full closure scenario • end pit lake functioning as a viable aquatic ecosystem • hummock surface on reclaimed CT deposits are well established, with approximately 20% of total surface areas remaining as open water/wetlands systems • forest systems well-established on overburden areas

Key Indicator Resources

Selection of KIRs is based on a process defined in detail by BOVAR Environmental (1996a) for the Aurora Mine project. In summary, the KIRs were selected based on ecological importance and vulnerability, resource use value, monitoring value and/or social importance. Selection criteria details for KIRs are provided for aquatic resources in Table A2-4, terrestrial vegetation and wetlands in Table A2-5, and wildlife in Table A2-6.

The final list of KIRs for the Project Millennium EIA and the rational for selection are summarized in Table A2-7.

Discussions on the KIRs selected for Project Millennium are provided in the Fisheries and Fish Habitat (Section C4), Vegetation and Wetlands (Section D3) and Wildlife (Section D5) sections of the EIA.

Table A2-4 Criteria Used to Select Fish Key Indicator Resources

Criteria	Description
Abundance	Ranked based on residence and relative abundance: • Common • Moderately abundant • Uncommon
Status Classification	Rank based on provincial importance (or status, measure of the relative abundance and degree of management concern or aesthetic value): • Species abundant, no concern (green-listed) • Species rare, but not threatened or special status (yellow-listed) • Threatened or vulnerable species (blue-listed) • Endangered species (red-listed)
Commercial Economic Importance	Rank based on importance of fish to guides, outfitters and fisheries: • No importance • Low importance • Moderate importance • High importance
Subsistence Economic Importance	Rank based on fish species importance for subsistence: • Not fished for food • Low • Moderate • High
Recreational Importance	Rank based on fish species importance for recreational fishing: • Non-game species • Low • Moderate • High
Habitat Niche/Sediment Exposure	Rank based on habitat niche/sediment exposure: • Yes • No
Spawning in Study Area	Rank based on spawning in study area: • Yes • No
Benthic Food Preference	Rank based on benthic food preference: • Yes • No
Importance of Prey	Rank based on importance as prey: • Yes • No
Fecundity	Rank based on fecundity: • Low fecundity • Moderate fecundity • High fecundity
Growth Rate	Rank based on growth rate: • Low growth rate • High growth rate
Age to Maturity	Rank based on age to maturity: • Long age to maturity • Moderate age to maturity • Short age to maturity
Feasibility of Studying	Rank based on feasibility of studying: • None • Limited • Moderate • Abundant
Availability of Information	Rank based on the amount of information available for each species or species: • None • Limited • Moderate • Abundant

From BOVAR (1996a)

Table A2-5 Criteria Used to Select Terrestrial Vegetation and Wetlands

Criteria	Description
Abundance	Ranked based on relative abundance in the LSA: • Common • Moderately abundant • Uncommon
Status Classification	Rank based on national, provincial or regional classification of rare or uncommon species: • Designated rare species, group or community • Species, group or community at extreme end of range • Species, group or community uncommon, but not threatened • Species abundant and no concern
Diversity	Rank based on number or extent of species in a community and their distribution within the community: • Diverse • Moderately diverse • Simple
Sensitivity to Physical Disturbance	Rank based on species' or communities' ability to recover following disturbance: • Unable to survive minor changes in habitat • Able to recover rapidly after minor changes in habitat • Very hardy species or communities, able to recover from a high level of disturbance
Economic Importance (Consumptive Use)	Rank based on forestry and food gathering: • High productivity • Moderate productivity • Low productivity
Recreational Importance	Rank based on aesthetic value and recreational importance: • High • Moderate • Low

From BOVAR (1996a)

Table A2-6 Criteria Used to Select Wildlife Key Indicator Resources

Criteria	Description
COSEWIC Status	Rank based on wildlife species of concern at the federal level (Committee on Status of Endangered Wildlife in Canada 1996)[a]: • Not listed • Vulnerable species • Threatened species • Endangered species
Provincial Status	Rank based on wildlife species of concern at the provincial level [b]: • Green - listed, or not listed • Yellow - listed species • Blue - listed species • Red - listed species
Commercial Economic Importance	Rank based on importance of species to trappers, guides and outfitters: • No importance • Low importance • Moderate importance • High importance
Subsistence Economic Importance	Rank based on importance of species as food for people: • No importance • Low importance • Moderate importance • High importance
Consumptive Recreational Importance	Rank based on importance to recreational hunters: • No importance • Low importance • Moderate importance • High importance
Non-Consumptive Recreational Importance	Rank based on species attractiveness to viewers: • Low interest • Moderate interest • High interest
Ecological Importance	Rank based on importance of a species as a predator or as a prey item in the ecosystem, or as an ecosystem modifier such as beaver: • No importance • Low importance • Moderate importance • High importance
Habitat Specificity	Rank based on the ability of a species to use a variety of habitats and altered habitats: • Habitat generalist • Habitat moderate • Habitat specialist • Nil
Inherent Land Capability	Rank based on the capability of the land to support a species: • Low • Moderate • High

From BOVAR (1996a)

[a] COSEWIC (1997) classifications: **Vulnerable** - a species of special concern because of characteristics that make it particularly sensitive to human activities or natural events; **Threatened** - a species likely to become endangered if limiting factors are not reversed; and **Endangered** - a species facing imminent extirpation or extinction.

[b] Alberta status evaluation system (AEP 1996c):

Red: These species are in serious trouble. Their populations are nonviable or at immediate risk of declining to nonviable levels in Alberta. They have been or will be considered for designation as endangered species in Alberta;

Blue: These species are also at risk, but the threats they face are less immediate. They are particularly vulnerable to noncyclical declines in population or habitat, or to reductions in provincial distribution. Species that are generally suspected of being vulnerable, but for which information is too limited to clearly define their status, have also been placed in this category;

Yellow: These are sensitive species that are not at risk. They may require special management to address concerns related to low natural populations, limited provincial distribution, or particular biological features (e.g., colonial nesting, narrow habitat requirements);

Green: These species are not at risk. Their populations are healthy and often widespread, and their key habitats are generally secure. This category also includes non-resident migrants and species whose occurrence in Alberta is accidental or at the periphery of their normal distribution.

Table A2-7 Summary of Project Millennium Key Indicator Resources and Rationale for Selection

Resource	KIR	Rationale
Aquatic	walleye (Athabasca River)	economical and recreational importance, abundance, top predator
	goldeye (Athabasca River)	economic importance, abundance
	lake whitefish (Athabasca River)[(a)]	economic importance, stage and migrate through LSA
	longnose sucker (Athabasca and Steepbank rivers)	importance in food chain, abundance, spawns in Steepbank River
	Arctic grayling (Steepbank River)	recreational importance, spawns in Steepbank River
	northern pike (Shipyard Lake)	recreational importance, spawns in LSA, top predator
	forage fish guild (Steepbank River, small streams, Shipyard Lake) [(a)]	spawns in LSA, importance in food chain
Terrestrial	aspen - white spruce communities	economic importance, multiple use
	riparian shrub complexes	diversity, multiple use, disturbance sensitivity, wildlife corridor
	patterned fens	diversity, disturbance sensitivity, wetlands type
	old growth forests	rare plant community, wildlife habitat
	rare plant species	biodiversity
	traditional use plants	subsistence and medicinal/spiritual importance
Wildlife	moose	economic importance, early successional species
	red-backed vole	importance in food chain
	snowshoe hare	importance in food chain
	black bear	economic importance, carnivore
	beaver	economic importance, semi-aquatic
	fisher	use of mature forests, economic importance, carnivore
	dabbling ducks	importance in food chain, economic and recreational importance
	ruffed grouse	economic and recreational importance
	Cape May warbler	use of white spruce forests, neotropical migrant
	western tanager[(a)]	use of open mixedwood forest, neotropical migrant
	pileated woodpecker[(a)]	use of mature forests, large-diameter trees and snags
	great gray owl	raptor, use of wetlands

[(a)] KIRs added to those originally used for the Steepbank Mine EIA.

A2.1.7 Impact Analyses

Impact analyses were performed for the key questions for each EIA component. The analyses address each link on the component linkage diagram. The impact analysis consists of four main steps:

- identification of activities that could contribute to environmental change;
- analysis of potential linkages;
- analysis and classification of impacts; and
- identification and description of mitigation measures and monitoring for potential residual impacts.

The impact analysis includes validation of causal linkages between particular Project Millennium activities and potential environmental impacts. These potential linkages between project activities and environmental change were evaluated for each EIA component. Where the changes in an environmental component are impacted by changes in another environmental component, the linkages are represented as triangles. Sub-headings are provided for each link on the linkage diagram. Within each of the sub-headings the potential for Project Millennium to result in an environmental change is determined and the link is classified as valid or invalid.

Validation of the link includes consideration of the mitigation measures. Mitigation, within the context of this EIA, is defined as follows: "the application of design, construction or scheduling principles to minimize or eliminate potential adverse impacts and, where possible, enhance environmental quality" (Sadar 1994). For certain activities, ongoing mitigation (e.g., operating practices changes) can minimize or eliminate physical or chemical stresses, thereby rendering invalid the link between Project Millennium activity and environmental changes.

If a link between a Project Millennium activity and an environmental change is considered valid, the key question under consideration is examined. For components with KIRs, impacts on each KIR are evaluated separately.

Quantitative methods of assessment are used where possible. Predictive modelling is used as a tool in the air, surface hydrology and hydrogeology, surface water quality, fisheries and fish habitat, and wildlife assessments. Risk assessment techniques are used to assess impacts on human and wildlife health. Ecological land classification and geographic information systems were used to assess impacts on terrestrial resources. The assessment techniques are described in the individual component sub-sections.

A2.1.8 Impact Description

Impact Description Criteria

Residual impacts for air, aquatics, terrestrial and human health components are classified using quantification criteria to determine environmental consequence. Each impact is first described in terms of the following criteria: direction, magnitude, geographic extent, duration, reversibility and frequency (including seasonal effects).

Direction of an impact may be positive, neutral, or negative with respect to the key question (e.g., a habitat gain for a KIR would be classed as positive, whereas a loss in habitat would be considered negative).

Magnitude is a measure of the degree of change in a measurement or analysis endpoint (e.g., the area of merchantable forest, or a water quality guideline value for a metal), and is classified as negligible, low, moderate or high, (e.g., no change from background, near existing background, above background but less than guideline, exceeds guidelines). The categorization of the impact magnitude (i.e., high, moderate, low, or negligible) was based on a set of criteria, ecological concepts and professional judgment pertinent to each of the discipline areas and key questions analyzed. The criteria are defined in detail in the specific sections describing the methods of assessment and the impact.

Geographic extent refers to the area affected by the impact and is classified as local, regional or beyond regional. It is recognized that a method of defining impacts within the regional area, in terms of the percentage of a certain vegetative, ELC or wildlife habitat unit is influenced by the size of the regional study area. As such, quantitative values of impacts must be tempered with an overall qualitative approach that considers the impacts of disturbance on overall viability and diversity of ecological units.

Duration refers to the length of time over which an environmental impact occurs. It considers the actual length of the period during which the impact occurs and whether it is reversible once its source is removed.

Reversibility is an indicator of the potential for recovery of the ecological endpoint from the impact. In some cases, reversibility is closely tied to duration (e.g., in the case of a temporary loss of habitat). In other cases, the effect may extend well beyond the end of the period of the original impact (e.g., a spill of chemicals might result in longer-term effects on fish health).

Frequency describes how often the effect occurs within a given time period and is classified as low, medium or high in occurrence. Discussions on seasonal considerations are made when they are important in the evaluation of the impact.

Table A2-8 details the Impact Description Criteria for each of the Project Millennium EIA components. Criteria for direction, reversibility and frequency are the same for all environmental components. Magnitude, geographic extent and duration vary depending on the component.

Scientific Uncertainty

Although not explicitly included in the criteria of Table A2-8, there will always be some uncertainty associated with the information and methods used in an EIA because of its predictive nature. The certainty with which an impact analysis can be completed depends on a number of factors including:

Table A2-8 Impact Description Criteria for Project Millennium

RESOURCE	DIRECTION[a]	MAGNITUDE[b]	GEOGRAPHIC EXTENT[c]	DURATION[d]	REVERSIBILITY[e]	FREQUENCY[f] [g]
Air Quality	Positive: a decrease in emissions and/or ambient concentrations Negative: an increase in emissions and/or ambient concentrations	Negligible: non-detectable Low: near existing ambient conditions Moderate: > existing ambient conditions, but < ambient guidelines High: above ambient guidelines	Local: effect restricted to LSA Regional: effect restricted to within 60 km of development site Beyond Regional: effect beyond 60 km of development site	Short-term: acute (1 hour to 1 day) Mid-term: chronic (annual) Plant-life: during operation/reclamation period of Project (30 years) Long-term: >30 years	Reversible or Irreversible	Low: occurs once Medium: occurs intermittently High: occurs continuously Seasonal Influence: as applicable
Hydrogeology - Groundwater	Positive, Negative or Neutral for the measurement endpoints	Negligible: no change from pre-development condition Low: <1% change Moderate: 1 to 10% change High: >10% change	Local: effect restricted to LSA Regional: effect extends beyond the LSA into the RSA Beyond Regional: effect extends beyond the RSA	Short-term: <2 years Medium-term: 2 to 30 years Long-term: >30 years	Reversible or Irreversible	Low: occurs once Medium: occurs intermittently High: occurs continuously Seasonal Influence: as applicable
Surface Water Hydrology	Positive, Negative or Neutral for the measurement endpoints	Negligible: <1% change Low: 1 to 5% change Moderate: 5 to 15% change High: >15% change	Local: effect restricted to LSA Regional: effect extends beyond the LSA into the RSA Beyond Regional: effect extends beyond the RSA	Short-term: <1 years Medium-term: 1 to 30 years Long-term: >30 years	Reversible or Irreversible	Low: occurs once Medium: occurs intermittently (1 to 10 times per year) High: occurs frequently (> 10 times per year)
Surface Water Quality	Positive, Negative or Neutral for the measurement endpoints	Negligible: releases do not cause exceedance of guidelines Low: releases contribute to existing background exceedances Moderate: releases cause marginal exceedance of guidelines High: releases cause substantial exceedance of guidelines	Local: effect restricted to LSA Regional: effect extends beyond the LSA into the RSA Beyond Regional: effect extends beyond the RSA	Short-term: <2 years Medium-term: 2 to 30 years Long-term: >30 years	Reversible or Irreversible	Low: occurs once Medium: occurs intermittently High: occurs continuously Seasonal Influence: as applicable

(a) Direction: positive or negative effect for measurement endpoints, as defined for the specific component.
(b) Magnitude: degree of change to analysis endpoint.
(c) Geographic Extent: area affected by the impact.
(d) Duration: length of time over which the environmental effect occurs.
(e) Reversibility: effect on the resource (or resource capability) can or cannot be reversed.
(f) Frequency: how often the environmental effect occurs.
(g) Seasonal effects are assessed when relevant for a specific component as Spring, Summer, Fall or Year-Round.
(h) Criteria can include acute and chronic aquatic life as well as no observed effects concentration (NOEC).
(i) ER: exposure ratio, the predicted exposure divided by the exposure limit.

RESOURCE	DIRECTION[(a)]	MAGNITUDE[(b)]	GEOGRAPHIC EXTENT[(c)]	DURATION[(d)]	REVERSIBILITY[(e)]	FREQUENCY[(f) (g)]
Fisheries and Fish Habitat	Positive, Negative or Neutral for the measurement endpoints	Negligible: no measurable change Low: <10% change in measurement endpoint Moderate: 10 to 20% change in measurement endpoint High: >20% change in measurement endpoint Where guidelines or criteria [(h)] exist: Negligible: releases do not cause exceedance of guidelines Low: releases contribute to existing background exceedances Moderate: releases cause marginal exceedance of guidelines High: releases cause substantial exceedance of guidelines	Local: effect restricted to LSA Regional: effect extends beyond the LSA into the RSA Beyond Regional: effect extends beyond the RSA	Short-term: <2 years Medium-term: 2 to 30 years Long-term: >30 years	Reversible or Irreversible	Low: occurs once Medium: occurs intermittently High: occurs continuously Seasonal Influence: as applicable
Soil and Terrain	Positive, Negative or Neutral for the pre-development soil or terrain resource	Negligible: No measurable effect (<1%) on the pre-development soil or terrain resource Low: <10% change on the pre-development soil or terrain resource Moderate: 10 to 20% change on the pre-development soil or terrain resource High: >20% change on the pre-development soil or terrain resource	Local: effect restricted to LSA	Project Life	Reversible or Irreversible	Not Applicable

(a) Direction: positive or negative effect for measurement endpoints, as defined for the specific component.
(b) Magnitude: degree of change to analysis endpoint.
(c) Geographic Extent: area affected by the impact.
(d) Duration: length of time over which the environmental effect occurs.
(e) Reversibility: effect on the resource (or resource capability) can or cannot be reversed.
(f) Frequency: how often the environmental effect occurs.
(g) Seasonal effects are assessed when relevant for a specific component as Spring, Summer, Fall or Year-Round.
(h) Criteria can include acute and chronic aquatic life as well as no observed effects concentration (NOEC).
(i) ER: exposure ratio, the predicted exposure divided by the exposure limit.

RESOURCE	DIRECTION[a]	MAGNITUDE[b]	GEOGRAPHIC EXTENT[c]	DURATION[d]	REVERSIBILITY[e]	FREQUENCY[f] [g]
Terrestrial Vegetation and Wetlands Ecological Land Classification (macroterrain and component ELC units)	Positive, Negative or Neutral for the terrestrial resources under review	Negligible: No measurable effect Low: < 10% change in terrestrial resource Moderate: 10 to 20% change in terrestrial resource High: >20% change in measurement endpoint	Local: effect restricted to LSA Regional: effect extends beyond the LSA into the RSA Beyond Regional: effect extends beyond the RSA	Short-term: <2 years Medium-term: 2 to 30 years Long-term: >30 years	Reversible or Irreversible	Not Applicable
Wildlife	Positive, Negative or Neutral for the wildlife species under consideration	Negligible: No measurable effect Low: < 10% change in terrestrial resource Moderate: 10 to 20% change in terrestrial resource High: >20% change in terrestrial resource	Local: effect restricted to LSA Regional: effect extends beyond the LSA into the RSA Beyond Regional: effect extends beyond the RSA	Short-term: <2 years Medium-term: 2 to 30 years Long-term: >30 years	Reversible or Irreversible	Low: occurs once Medium: occurs intermittently High: occurs continuously Seasonal Influence: as applicable
Wildlife Health	Positive, Negative or Neutral for the measurement endpoints	Negligible: Exposure Risk (ER[i])<1 or, ER marginally greater than 1 (i.e., 1<ER <10)due to naturally elevated background exposures and/or conservative exposures Low: no ER due to lack of data, but anecdotal data suggests low hazard; additional information necessary to characterize potential impact Moderate: 10<ER<20 and no immediately apparent mitigation options available; individual risks may result in population impacts High: ER >20 and no immediately apparent mitigation options available; individual risks likely to result in population impacts	Local: effect restricted to LSA Regional: effect extends beyond the LSA into the RSA Beyond Regional: effect extends beyond the RSA	Short-term: <1 years Medium-term: 1 to 30 years Long-term: >30 years	Reversible or Irreversible	Low: occurs once Medium: occurs intermittently High: occurs continuously Seasonal Influence: as applicable

(a) Direction: positive or negative effect for measurement endpoints, as defined for the specific component.
(b) Magnitude: degree of change to analysis endpoint.
(c) Geographic Extent: area affected by the impact.
(d) Duration: length of time over which the environmental effect occurs.
(e) Reversibility: effect on the resource (or resource capability) can or cannot be reversed.
(f) Frequency: how often the environmental effect occurs.
(g) Seasonal effects are assessed when relevant for a specific component as Spring, Summer, Fall or Year-Round.
(h) Criteria can include acute and chronic aquatic life as well as no observed effects concentration (NOEC).
(i) ER: exposure ratio, the predicted exposure divided by the exposure limit.

RESOURCE	DIRECTION[a]	MAGNITUDE[b]	GEOGRAPHIC EXTENT[c]	DURATION[d]	REVERSIBILITY[e]	FREQUENCY[f] [g]
Human Health	Positive, Negative or Neutral for the measurement endpoints	Negligible: ER [i] <1 and no data gaps or 1<ER<10 due to naturally elevated background exposures and/or conservative exposure assumptions Low: No ER Moderate: 10<ER<20 and no immediately apparent mitigation options are available High: ER>20, and no immediately apparent mitigation options are available; hence exposure has potential to adversely affect people's health	Local: effect restricted to LSA Regional: effect extends beyond the LSA into the RSA Beyond Regional: effect extends beyond the RSA	Short-term: <1 years Medium-term: 1 to 30 years Long-term: >30 years	Reversible or Irreversible	Low: occurs once Medium: occurs intermittently High: occurs continuously Seasonal Influence: as applicable

(a) Direction: positive or negative effect for measurement endpoints, as defined for the specific component.
(b) Magnitude: degree of change to analysis endpoint.
(c) Geographic Extent: area affected by the impact.
(d) Duration: length of time over which the environmental effect occurs.
(e) Reversibility: effect on the resource (or resource capability) can or cannot be reversed.
(f) Frequency: how often the environmental effect occurs.
(g) Seasonal effects are assessed when relevant for a specific component as Spring, Summer, Fall or Year-Round.
(h) Criteria can include acute and chronic aquatic life as well as no observed effects concentration (NOEC).
(i) ER: exposure ratio, the predicted exposure divided by the exposure limit.

- understanding of natural/ecological processes at work now and in the future; and
- understanding of present and future properties of the KIR affected.

The level of uncertainty for an impact analysis will be discussed when there are questions about the factors reviewed above. Where the level of uncertainty makes a prediction of the impact problematic, a subjective assessment is made based on the available information, the applicability of information on surrogates and on professional opinion.

Environmental Consequence

Environmental consequence is an overall property associated with an impact and is a function of direction, magnitude, duration, frequency, geographic extent and reversibility. Table A2-9 shows the screening system used to determine an environmental consequence for residual impacts. The screening system uses a numerical score for each of the parameters considered in evaluating an impact. The total is then used as a guide to assign environmental consequence of residual impacts as follows:

- negligible 0 to 5
- low 6 to 10
- moderate 11 to 15
- high greater than 15

It must be emphasized that the scoring system is used as a guide to facilitate the final assessment step; it is not used to provide a definitive value.

Table A2-9 Screening System for Environmental Consequences

Magnitude (Severity)	Duration	Frequency	Geographic Extent	Reversibility
Negligible 0	Short-term +0	Low +0	Local +0	Yes -3
Low 5	Medium-term +1	Moderate +1	Regional +1	No +3
Moderate 10	Long-term +2	High +2	Beyond Regional +2	
High 15				

In some cases, such as acidification of soils and end pit lake predictions, the level of scientific uncertainty is sufficiently high that an estimate of environmental consequence cannot be made with a sufficient degree of confidence. In these cases, the environmental consequence is rated as "undetermined". Undetermined ratings are accompanied by recommendations for research or monitoring to provide more data in the future.

Significance

The Canadian Environmental Assessment Act (CEAA) requires an assessment to consider the environmental effects of the proposed project and the significance of those effects. CEAA also requires consideration of cumulative environmental effects arising from the project and the likelihood of those effects occurring.

For the purposes of this EIA, Suncor has defined residual impacts classified as either of negligible or low consequence to be of no "significance". For residual impacts initially rated as being of moderate or high environmental consequence, the significance of those effects is further evaluated by re-examining the different rating criteria to a greater level of detail and providing a broader assessment of a particular issue. For example, the impact from a geographic perspective can be further examined in a regional context. If, after this further consideration and evaluation, the predicted impacts of moderate or high environmental consequence are found to be acceptable, then Suncor deems them not to be of "significance".

Suncor uses the environmental consequence and significance ratings as direct feedback into its environmental management system. This impact information provides input to a process where a number of options are considered, including for example:

- re-engineering of systems;
- redesign of mine or operational plans;
- enhancement of mitigation plans or processes;
- improvements in monitoring systems to enhance information on effects; and
- collection of information to reduce levels of uncertainty.

Suncor views the definition of environmental consequence and significance of project impacts as an important part of its business. This system of evaluating potential impacts associated with a project or components of the project allows Suncor to work towards operations that are environmentally sustainable. It provides input to Suncor's annual process of defining environmental objectives based on the principles laid out in Suncor's We Care environmental policy.

A2.2 CUMULATIVE EFFECTS ASSESSMENT METHODOLOGY

A2.2.1 Introduction

The Project Millennium EIA also includes the assessment of cumulative effects related to the development. The assessment includes consideration of the following points, as required by the Project Terms of Reference issued on March 4, 1998 (AEP 1998). Specifically, the following is addressed:

- temporal and spatial considerations, with a rationale of the assumptions used to define these for each environmental component;
- the cumulative environmental effects that are likely to result from Project Millennium in combination with other existing and planned projects (i.e., those that have advanced to the public disclosure stage) or reasonably foreseeable activities in the region;
- how information or data from previous oil sands and other development projects is appropriate, supplemented where required, and with all relevant environmental components considered; and
- the approach and methods used to identify and assess cumulative impacts, with documentation of assumptions, confidence in data and analysis to support conclusions.

CEA Premises

The cumulative effects of Project Millennium are assessed only when:

- There is an environmental impact related to Project Millennium; and
- The environmental impact is demonstrated to operate cumulatively with the environmental impact from other developments or activities.

CEA Framework

The EIA impact assessment methodology is based on the incremental impact of Project Millennium on the environment over and above the existing conditions and those expected from the approved developments. Although this analysis is technically "cumulative" since it considers other existing developments and interactive agents, it is referred to in this document as the impact assessment of Project Millennium.

Cumulative effects assessments are defined for the purposes of this EIA as providing similar analyses to the impact assessment but extending the scope to consideration of the impacts of additional developments that are planned for the oil sands region. For this part of the assessment, the oil sands region is considered to be the regional study area (RSA) It is important to consider these developments to fully understand the potential incremental impacts of Project Millennium and all other oil sands developments. The analyses follow the same approach as the impact assessment analyses with reference to key questions and linkages.

Cumulative effects are considered to be those that result from the Project in combination with other existing or planned developments/activities in the region that could reasonably be considered to have a combined effect. These impacts may be the result of a number of developments within a geographic area, or may be the result of a number of developments occurring over time. Although impacts of an individual activity may be acceptable, the combined impacts of several developments may indicate that additional mitigative measures are necessary.

An EIA provides an estimate of the incremental impact of a proposed project and an estimate of the total impact after addition of the increment. The CEA undertakes the same estimation for a number of additional projects, each of which has an incremental impact, to allow an assessment of the synergistic results of many incremental impacts on an affected entity (Hegmann and Yarranton 1995).

Suncor, in cooperation with a number of oil sands regional developers, municipal representatives, stakeholders and regulators are developing a common framework for conducting CEAs. The Athabasca Oil Sands CEA Initiative has resulted in a current regional development definition, with consideration of likely developments over a specific period of time. This process has provided a reasonable maximum development scenario against which to assess questions of environmental capacity.

Key Questions

Component specific CEA key questions have been developed, similar to the approach applied for the environmental impact assessment. These questions derive from issues identified by government agencies, local communities and other stakeholders.

These key questions focus the effects assessment on the primary cumulative effects issues associated with Project Millennium. Table A2-10 lists the CEA key questions.

New linkage diagrams were not developed for the cumulative effects assessments because the linkages defined for the Project Millennium impact assessment remain valid, unless specifically discussed in the component section. The impact description criteria and environmental consequences definitions, as defined above and detailed in Tables A2-8 and A2-9, also apply for the CEA.

Table A2-10 Summary of Cumulative Effects Assessment Key Questions for Project Millennium

Question Number	Key Question
Air Quality	
CAQ-1	What impacts to ambient air quality and acidification of water, soils and vegetation will result from air emissions associated with Project Millennium and the combined developments?
Aquatics	
CA-1	What impacts to the Athabasca River will result from changes in hydrogeology, surface water hydrology, surface water quality, and fisheries and fish habitat associated with Project Millennium and the combined developments?
Terrestrial Resources	
CTER-1	What impacts will result from changes to ecological land units (soils, terrain, vegetation and wetlands) associated with Project Millennium and the combined developments?
CTER-2	What impacts will result from changes to wildlife habitat, abundance or diversity associated with Project Millennium and the combined developments?
Human Health, Land Use and Resource Utilization	
CHH-1	What impacts to human health will result from chemical exposure related to Project Millennium and the combined developments?
CRU-1	What impacts will result from changes to traditional land use and non-traditional resource use associated with Project Millennium and the combined developments?

A2.3 ASSESSMENT SCENARIOS

The assessment scenarios for Project Millennium include consideration of baseline conditions, an impact assessment and cumulative effects assessment. Table A2-11 overviews the scenarios and the developments included in the three scenarios.

Figure A2-7 shows the locations of developments included in the baseline, as well as the location of Project Millennium.

Figure A2-8 shows the locations of all developments included in the CEA.

A2.3.1 Baseline Conditions

The impact analyses consider the potential effects of Project Millennium on both a local and a regional baseline. Baseline conditions for the Project are defined as the existing (1997) environmental conditions, including the developments in both the LSA and RSA, and conditions predicted for currently approved developments.

The baseline conditions are characterized in terms of the data specifically collected as part of this EIA, data collected as part of other regional environmental programs, and knowledge of the processes and environmental impacts of other developments that may impact the LSA and RSA.

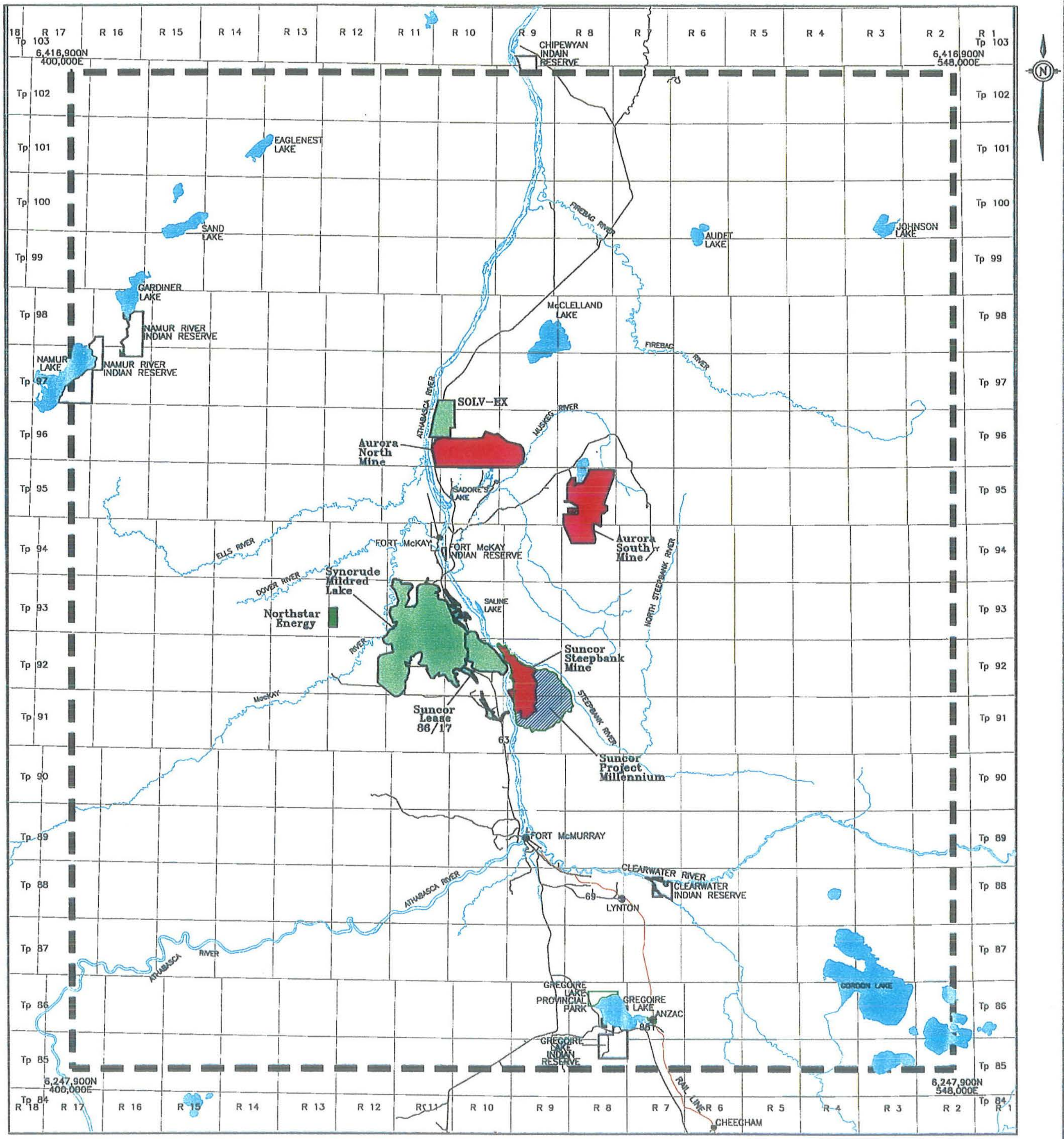
The recently approved developments in the oil sands region have been included in the baseline as "fully-developed". Because predictions are made on the environmental conditions associated with this fully-developed stage, it allows a more accurate reflection of conditions against which planned projects should be measured.

Description of Activities in the Baseline

Baseline activities in the RSA include both existing and approved surface mine and in-situ oil sands operations as well as non-oil and gas operations such as roadways and transmission lines, municipalities and forestry developments. Basic assumptions associated with the developments included within the baseline are provided below by development or development type.

Table A2-11 Impact Assessment Scenarios

DEVELOPMENT	Baseline	Impact Assessment	Cumulative Effects Assessment
	EXISTING + APPROVED DEVELOPMENTS	EXISTING + APPROVED DEVELOPMENTS + SUNCOR PROJECT MILLENNIUM	EXISTING + APPROVED DEVELOPMENTS + SUNCOR PROJECT MILLENNIUM + PLANNED DEVELOPMENTS
EXISTING	**Suncor Lease 86/17**	Suncor Lease 86/17	Suncor Lease 86/17
	Syncrude Mildred Lake	Syncrude Mildred Lake	Syncrude Mildred Lake
	Suncor Steepbank Mine	Suncor Steepbank Mine	Suncor Steepbank Mine
	Northstar Energy	Northstar Energy	Northstar Energy
	SOLV-EX	SOLV-EX	SOLV-EX
	Municipalities	Municipalities	Municipalities
	Pulp mills for water quality	Pulp mills for water quality	Pulp mills for water quality
	Forestry	Forestry	Forestry
	Pipelines/roadways/others	Pipelines/roadways/others	Pipelines/roadways/others
APPROVED	**Suncor Steepbank Mine and Fixed Plant Expansion**	Suncor Steepbank Mine and Fixed Plant Expansion	Suncor Steepbank Mine and Fixed Plant Expansion
	Syncrude Mildred Lake Debottlenecking Phase 1/2	Syncrude Mildred Lake Debottlenecking Phase 1/2	Syncrude Mildred Lake Debottlenecking Phase 1/2
	Syncrude Aurora Mine	Syncrude Aurora Mine	Syncrude Aurora Mine
	Forestry	Forestry	Forestry
THE PROJECT		**Suncor Project Millennium - Upgrader and Mine**	Suncor Project Millennium - Upgrader and Mine
PLANNED			**Muskeg River Mine Project**
			Syncrude Project 21 Mildred Lake Upgrader Expansion
			Mobil Kearl Oil Sands Mine and Upgrader
			Shell Lease 13 East Mine
			Gulf Surmont - In-situ
			Petro-Canada MacKay River - In-situ
			JACOS Hangingstone - In-situ
			Fee Lot 2 Development
			Major pipelines, utility corridors and roadways
			Municipal Growth



LEGEND

- EXISTING DEVELOPMENTS
- APPROVED DEVELOPMENTS
- PROJECT MILLENNIUM
- REGIONAL STUDY AREA
- ROADWAYS

0 10 20 30 40 50km

SCALE 1:1,000,000

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA DIVISION
ALBERTA ENVIRONMENTAL PROTECTION, 1997.
DATUM IS IN NAD83 UTM PROJECTION

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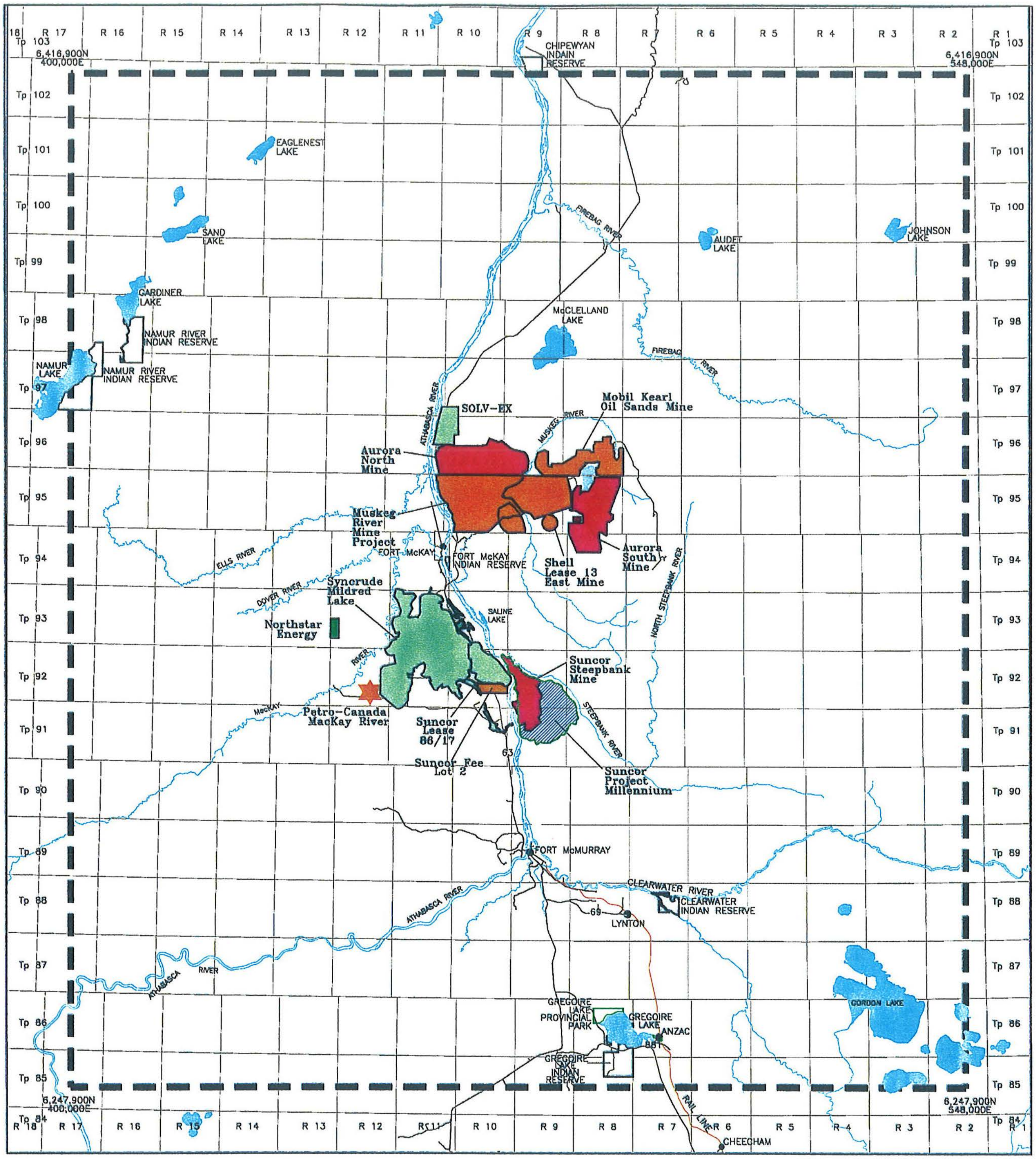
EXISTING, APPROVED AND PROJECT MILLENNIUM DEVELOPMENTS IN REGIONAL STUDY AREA

05 Apr. 1998	Figure A2–7	DRAWN BY: RFM/CG



LEGEND

- EXISTING DEVELOPMENTS
- APPROVED DEVELOPMENTS
- PLANNED DEVELOPMENTS
- PROJECT MILLENNIUM
- REGIONAL STUDY AREA
- ROADWAYS

0 10 20 30 40 50km

SCALE 1:1,000,000

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA DIVISION
ALBERTA ENVIRONMENTAL PROTECTION, 1997.
DATUM IS IN NAD83 UTM PROJECTION

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REGIONAL STUDY AREA DEVELOPMENTS FOR CUMULATIVE EFFECTS ASSESSMENT

05 Apr. 1998	Figure A2-8	DRAWN BY: RFM/CG

Suncor Energy Inc., Oil Sands (Suncor) - Lease 86/17

The Suncor Lease 86/17 development includes an open-pit oil sands mine, extraction and upgrading operation. Suncor also operates a utilities plant on Lease 86/17. Current production from the Lease 86/17 operation is 85,000 barrels per calendar day (bpcd) of upgraded product.

The fundamental assumptions associated with the Lease 86/17 development include:

- mining and reclamation activities for approved lease areas, with mining completed around 2002;
- production of air emissions from the operation of the mine, extraction plant, upgrader and utilities plant;
- implementation of consolidated tailings (CT) technology for mature fine tailings (MFT) management;
- use of water from the Athabasca River; and
- discharge of effluents to the Athabasca River via an industrial wastewater treatment system.

Although mining activities on Lease 86/17 will cease around 2002, the area will continue to be an integral component of Suncor's oil sands development activities. The current upgrading facility, much of the extraction operation, as well as various ponds and other infrastructure will remain operational for Steepbank Mine and Project Millennium.

Reclamation activities on Lease 86/17 were initiated at the start of operations on this lease. These activities will continue as mining is completed on this lease and mine pits are backfilled with CT.

Syncrude Canada Ltd. (Syncrude) Mildred Lake

The Syncrude Mildred Lake development includes an open-pit oil sands mine, extraction and upgrading operation. Syncrude also operates a utilities plant at Mildred Lake. Current production from the Mildred Lake operation is 210,000 bpcd of upgraded product.

Syncrude received approval in 1994 for a capacity increase to 300,000 bpd of synthetic crude from the Mildred Lake upgrader.

The fundamental assumptions associated with the Mildred Lake development include:

- mining and extraction activities based on mining of oil sands areas of Leases 17 and 22 with completion of mining of the currently approved area expected about 2025;
- production of air emissions from the operation of the mine, extraction plant, upgrader and utilities plant;
- employment of a water-capped fine tails lake as well as composite tailings (CT) technology for MFT management; and
- use of water from the Athabasca River.

Syncrude expects to operate the Mildred Lake site beyond completion of mining on Leases 17 and 22, with continued operation of upgrading and utilities facilities, some froth treatment capacity, and various supporting ponds, storage areas and infrastructure.

Reclamation activities on the Mildred Lake site were initiated at the start of operations on this area. These activities will continue at an accelerated rate as mining is completed on the Mildred Lake mining areas.

Syncrude Mildred Lake Debottlenecking Phases 1 and 2

Syncrude Mildred Lake debottlenecking phases one and two, which will bring production of upgraded product to above 260,000 bpcd are proceeding under Approval No. 7550 issued in 1994, as confirmed by the EUB July 19, 1996. Current approved facility capacity is 300,000 bpcd.

The fundamental assumptions associated with the Mildred Lake development, as listed above, still apply.

Suncor Steepbank Mine/Fixed Plant Expansion

The Suncor Steepbank Mine / Fixed Plant Expansion development was approved in 1997 as a new mine to replace diminishing reserves on Lease 86/17 as well as an expansion to the current fixed plant (upgrading) operation. The Steepbank Mine will feed Suncor's extraction and upgrading facility on Lease 86/17, while the Fixed Plant Expansion will expand Suncor's approved bitumen upgrading capacity from 79,500 to 105,000 bpcd of upgraded product. The Steepbank Mine approval also included authorization for the construction of a bridge across the Athabasca River from the current Lease 86/17 operation to the new mine on the east side of the Athabasca River.

The fundamental assumptions associated with the Steepbank Mine and Fixed Plant Expansion developments include:

- mining and reclamation activities for approved lease areas;

- production of air emissions from the operation of the mine, slurry preparation/hydrotransport operation and a higher capacity upgrader;
- use of water from the Lease 86/17 operation; and
- use of CT technology for mature fine tailings (MFT) management.

Syncrude Aurora Mine

The Syncrude Aurora Mine development include mining and bitumen extraction operations on the east side of the Athabasca River. The details used in the assessment of these developments are based on an application for regulatory approval (Syncrude 1996, BOVAR 1996a).

The Aurora North Mine will be located north of the proposed Muskeg River Mine Project, while the Aurora South Mine will be south of Kearl Lake (Figure A2-5). The fundamental assumptions associated with the Aurora Mines development include:

- mining and reclamation activities for approved lease areas;
- on-site bitumen extraction to produce a froth that will be transported by pipelines to the Mildred Lake facility;
- other pipelines to support the development, including natural gas, diesel and hot water (pipelines located in the same corridor as the froth lines);
- production of air emissions from the operation of the mines and extraction plant;
- use of CT technology for MFT management; and
- use of water from the Mildred Lake facility.

The production from the Aurora North and Aurora South mines will either replace or supplement current Syncrude production at the Mildred Lake facility. The Syncrude Aurora North Mine, as detailed in the Aurora Mine Application (Syncrude 1996), received an EUB board decision late in 1997. This mining and extraction operation will eventually result in production of 200,000 bpd of bitumen from the Aurora North Mine.

The Syncrude Aurora South Mine, also as detailed in the Aurora Mine Application (Syncrude 1996), will be located east of the Shell Lease 13. This project received a decision by the EUB board, but an AEP approval was not applied for since the proposed commencement date is not until 2008. Eventual production from the Aurora South Mine is also 200,000 bpd.

Northstar Energy Dovar SAGD Project

The Northstar Energy Dovar SAGD development includes the operation of a steam assisted gravity drainage (SAGD) operation formerly known as the

AOSTRA Underground Test Facility. Production from the facility is approximately 2,000 bpcd of bitumen.

This development is considered from the point of view of air quality and terrestrial disturbance. All water is obtained from, and disposed to groundwater systems.

SOLV-EX Development

The SOLV-EX development has included initiation of a mining and processing operation. The development was approved, but actual production of bitumen has been limited. Despite the fact that the development has recently changed owners and activities are suspended, for the purposes of this EIA, the assumptions for this development include:

- mining and reclamation activities for approved lease area;
- withdrawal of water from the Athabasca River; and
- production of air emissions from the operation of the mine and processing of bitumen (as per approved limits).

Municipalities

The municipalities included in the baseline include the main areas within the RSA, including Fort McMurray and Fort McKay. The municipalities, which were assessed through remote sensing, are considered from the point of view of:

- residents (human health);
- surface disturbance (terrestrial); and
- resource use.

Pulp Mills

Water quality impacts assessed include consideration of the potential influence of pulp mills located upstream on the Athabasca River. These potential influences are included through establishment of water quality background conditions for the Athabasca River on entry to the oil sands development area.

Forestry

Forestry activities for the RSA are based on the forest management plans for Al-Pac and Northland Forest Products. These plans include the 1998 Annual Operating Plan and the twenty year operating plan produced in 1995. Forestry considerations centre around the harvesting of timber resources. Therefore, these considerations involve no reclassification of existing soils or terrain. Forest cutblocks for the existing (baseline) conditions are allocated into three groups:

- existing old revegetated cutblocks;
- recent cutblocks; and
- future cutblocks.

Pipelines, Roadways and Other Linear Developments

Pipelines, roadways and other linear developments primarily involve impacts to vegetative cover, although roadways may impact terrain units. Other environmental impacts considered involve the influence of these developments on wildlife (e.g., barriers to movement, areas of increased wildlife/vehicle collisions).

For the Project Millennium assessment, it has been assumed that no reclassification of the existing soils or terrain is required. It is also assumed that during the operational life of pipeline corridors, herbaceous vegetation is established although establishment of woody species is discouraged. Following abandonment of the linear corridors, invasion of woody species from the adjacent vegetation communities ensures compatible vegetative cover.

Linear corridors in the baseline activities for the RSA are the:

- Major pipelines servicing the oil sands development area, including: the Albersun gas pipeline to Suncor; the Simmons gas pipeline to Syncrude; a spur line to the Northstar Dovar facility; the Suncor oil pipeline from Lease 86/17; the Alberta Energy oil pipeline from Syncrude Mildred Lake; and a natural gas pipeline that services the Fort McMurray area.
- Major roadways, including: Highway 63, from the point where it enters the RSA south of Fort McMurray to its northern point at the Lougheed Bridge near Fort McKay; Highway 963, which runs north from the Lougheed Bridge; the winter road to Fort Chipewyan (area within the RSA); and the gravel road from Highway 63 to the Northstar Energy development.
- Major power line right of ways to service the oil sands development areas and Fort McMurray.

Existing development areas not included in the assessment are linear disturbances below a width of 10 m (e.g., seismic lines).

Oil Production Summary

The production of bitumen and synthetic crude from existing and approved developments is listed in Table A2-12

Table A2-12 Athabasca Oil Sands Production for Existing and Approved Developments plus Project Millennium

Oil Sands Development	Capacity (bpcd) [a]	Production	
		Bitumen (bpcd)	Synthetic Crude (bpcd)
Suncor			
- Lease 86/17 + Steepbank Mine	125,000 B	125,000	---
- Lease 86/17 Upgrader	105,000 S	---	105,000
Syncrude			
- Mildred Lake Mine	270,000 B	160,000 [b]	---
- Aurora Mine (four trains)	400,000 B	400,000	---
- Mildred Lake Upgrader	300,000 S	---	300,000
Northstar Energy	---	2,000	---
Suncor Project Millennium			
- Mine	125,000 B	125,000	---
- Upgrader Expansion		---	105,000
Total		**612,000**	**510,000**

(a) B = Bitumen; S = Synthetic Crude Products.
(b) Potential bitumen sales not included.

Environmental Parameter Summary

Table A2-13 summarizes some of the major environmental parameters considered for existing and approved oil sands developments. Additional details on these parameters, as well as additional parameters are discussed in the relevant EIA component subsections.

Table A2-13 Environmental Parameters for the Existing and Approved Developments plus Project Millennium

Development	Development Area (ha)	Water Withdrawal (1,000 m^3/a)	Air Emissions (t/cd)	
			SO_2	NO_x
Suncor Lease 86/17	3,369	59,801	68	68
Syncrude Mildred Lake	23,244	63,500	200[(a)]	37
Steepbank Mine/Fixed Plant Expansion	3,234	[(b)]	[(c)]	[(f)]
Aurora Mine (four trains)	15,171	[(d)]	[(e)]	23
SOLV-EX	2,088	5,000	4	2
Northstar Energy	22	0	0.06	0.23
Suncor Project Millennium	5,437	[(b)]	[(c)]	[(f)]

(a) Based on data provided by Syncrude in December 1997 for actual operation. SO_2 emissions could increase to 220 t/d based on approved Syncrude capacity.
(b) Withdrawal requirements included in Suncor's existing approval.
(c) Values for Steepbank and Millennium Mines included in Lease 86/17 values.
(d) Withdrawal requirements included in Syncrude's existing approval.
(e) Value for Aurora Mines included in Mildred Lake number.
(f) Values for Steepbank Mine / Fixed Plant Expansion and Project Millennium included in the Suncor Lease 86/17 value.

A2.3.2 Planned Developments

For the purposes of the Project Millennium cumulative effects assessment, planned developments are considered in addition to the existing and approved developments. It is recognized that other planned oil sands developments have been publicly disclosed as of the end of January 1998. Although these developments have not yet been the subject of formal approval applications, if they were to proceed, they would result in additional environmental impacts in the RSA. The planned developments included in the CEA, as well as existing and approved developments, are shown in Figure A2-8 and detailed in Table A2-11.

The planned developments included in the CEA are reviewed below. The development details provided are based on publicly available information. Because these planned developments are in varying stages of planning, the following conditions apply:

- there is uncertainty about whether they will proceed;
- a variable amount of information (typically limited) is available for the developments; and
- all must submit applications and undergo assessment to receive approval to proceed.

Shell Canada Limited (Shell) Muskeg River Mine Project

The Shell Muskeg River Mine Project is located on the western portion of Lease 13. An application and EIA were submitted for approval of this project in December 1997 (Shell 1997). The project plan includes an open pit mining operation, extraction and utilities operations. Bitumen product will be shipped off-site to an upgrading facility (Scotford) near Fort Saskatchewan, Alberta.

The ultimate bitumen production from the Muskeg River Mine Project will be 150,000 bpcd day starting in 2002.

The fundamental assumptions associated with the Muskeg River Mine Project include:

- mining and reclamation activities for approved lease areas;
- production of air emissions from the operation of the mine and extraction plant;
- shipment of the produced bitumen to an out-of-region upgrading facility;
- implementation of CT technology for MFT management; and
- use of water from the Athabasca River.

Syncrude Project 21 Mildred Lake Upgrader Expansion

The expansion of the Syncrude upgrader was publicly disclosed in November 1997. This expansion increases the Syncrude upgrading capacity to 480,000 bpd from the currently approved level of 300,000 bpd. The fundamental assumptions associated with the Syncrude upgrader expansion include production of air emissions from the integrated operation of the existing upgrader and utilities plant together with the new modifications and additions to upgrading. Air emission estimates, as provided by Syncrude, are detailed in Section B2 of the EIA.

Mobil Oil Canada Properties Kearl Oil Sands Mine and Upgrader

The Mobil Kearl Oil Sands Mine will be located on Mobil's Lease 36 north of Kearl Lake. Preliminary information supplied by Mobil (Mobil 1997) indicates that this development will involve a truck and shovel mining operation, with bitumen upgrading using a warm water, non-caustic process. The development's bitumen production will commence in 2003, with full production of up to 130,000 bpcd planned to occur by 2005.

Final plans for a Mobil Kearl Oil Sands Mine upgrader within the RSA had not been announced at the time of preparation of this EIA. Mobil have discussed various possible locations for the upgrader in their discussions with project stakeholders. Although the upgrader location is still uncertain at the time of this submission, estimates were considered for emissions from a 130,000 bpcd facility located in the RSA.

The fundamental assumptions associated with the Kearl Oil Sands Mine and Upgrader development include:

- mining and reclamation activities for approved lease areas, with methodologies similar to those described in recent oil sands applications;
- production of air emissions (SO_2 and NO_x) from the operation of the mine, extraction plant and upgrader, with emission estimates provided by Mobil;
- implementation of CT technology for MFT management, as described in recent oil sands applications; and
- use of water from the Athabasca River.

Shell Lease 13 East Mine

The Shell Lease 13 East development will be located immediately east of the Muskeg River Mine Project. The current plan is for this development to be similar to the Muskeg River Mine Project, with an ultimate bitumen production of 200,000 bpcd day starting sometime between 2010 and 2015. It is assumed that a bitumen extraction facility similar to that proposed for the Muskeg River Mine Project will be associated with the Lease 13 East development.

The fundamental assumptions associated with the Lease 13 East development include pro-rating the emissions from the Muskeg River Mine Project, based on a production increase from 150,000 to 200,000 bpd for Lease 13 East. Other assumptions are identical to those for the Muskeg River Mine Project.

In-Situ Developments

The disclosed developments involved with in-situ extraction of bitumen include:

- Gulf Surmont;
- Petro-Canada MacKay River Project; and
- JACOS Hangingstone.

The impact of the in-situ developments will be related primarily to the groundwater, terrestrial and air environmental components. For the CEA, the considerations included air emissions and some minor terrestrial impacts. Aquatic impacts related to in-situ developments were not considered in the Project Millennium EIA because it is assumed that water supply and disposal for all in-situ developments will utilize groundwater resources that will not have an impact on the Project.

Gulf Surmont

The Gulf Canada Resources Limited Surmont Commercial Oil Sands Project was publicly disclosed in October 1997 (Gulf 1997). The target production for the Surmont development is 100,000 bpd of bitumen. Since this development is located south of the RSA, the only consideration included in the Project Millennium CEA is related to air quality because emissions from the Surmont development may enter the RSA from the south.

Petro-Canada MacKay River

The Petro-Canada MacKay River development was detailed in a public disclosure document (Petro-Canada 1997). The preliminary information for the project indicates a production of approximately 20,000 bpd of bitumen.

Information for the MacKay River development was incorporated into the air and terrestrial components of the CEA. Preliminary air quality design information has been provided by Petro-Canada related to the MacKay River development.

JACOS Hangingstone

The proposed JACOS Hangingstone in-situ development is located south of the Project Millennium RSA. However, it is included in this assessment because of the potential for air emissions from the development to move north into the Fort McMurray area. The developer has stated initial targets are for a pilot development that will produce from 2,000 bpd in Phase I to 10,000 bpd in Phases I, II and III combined, of bitumen. Project is scheduled to come on-line according to a scheduled start-up in 1998, with ramping to full production in 2001.

The estimated emissions for the JACOS development have been based on information in the development approval application.

Note: Phase I of the JACOS Hangingstone was approved just prior to submission of this EIA. The project, as listed in the Planned Projects, was not moved to the approved section of Table A2-11.

Other Developments - Fee Lot 2 Development

Suncor Energy Inc. is planning a number of developments on Fee Lot 2, which is located immediately south of Lease 86/17. Possible developments on Fee Lot 2 include:

- Novagas Natural Gas Liquids Plant;
- administration building;
- warehouse;
- camp;
- pumpstation for the IPL pipeline;
- truck stop; and
- other infrastructure.

The potential Fee Lot 2 developments are only considered in this CEA from a terrestrial land base point of view. Details on other potential environmental impacts associated with this proposed development will be the subject of a separate application.

Major Pipelines, Roadways and Other Linear Developments

The planned developments which involve construction of pipelines include:

- Suncor IPL Wildrose Pipeline;
- Shell product and diluent pipelines;
- Novagas NGL pipeline; and
- Additional regional natural gas supply pipeline.

The locations of the proposed pipelines, except the Wildrose pipeline, are uncertain at this time. The total impact of existing and planned pipelines in the RSA is small (approximately 600 ha). Therefore, this total value for pipeline developments was included within the baseline.

Electrical power right of ways and roadways, while assumed to be in the planning stage under planned developments, have not been documented. Because of this lack of information, no values were added for these developments under the CEA.

Linear disturbances primarily involve impacts to vegetative cover, although roadways may impact terrain units. As such, it has been assumed that no reclassification of the existing soils or terrain is required. It is also assumed that during the operational life of these corridors, herbaceous vegetation is established although establishment of woody species is discouraged. Following abandonment of the linear corridor, invasion of woody species from the adjacent vegetation communities ensures compatible vegetative cover.

Municipalities

Municipal development planned in association with the planned developments in the RSA is available for Fort McMurray. A projected development for Fort McMurray was made based on this municipal development plan.

Oil Production for the Cumulative Effects Assessment

Table A2-14 summarizes the production of bitumen and synthetic crude from planned developments in the RSA.

The values presented in this table are estimates. It is recognized that the amount of bitumen or synthetic crude oil produced from the region will be limited by market demand. The current view is that the long-term market demand is less than the potential production as outlined in the table. Therefore, the proposed CEA scenario is conservative from an environmental point of view. In the event that other projects are announced after the filing of the Project Millennium application, it is likely that they would replace projects currently in the planned development scenario. Therefore, environmental impacts from these possible developments would not be over and above those assessed for the current CEA scenario.

Environmental Parameter Summary

Table A2-15 summarizes selected environmental parameters considered for the major planned oil sands developments.

Emission data used for modelling was provided to Suncor by the various companies in April 1998. It is recognized that these projects are still in the development stage and that the numbers may change as project definition improves.

Table A2-14 Athabasca Oil Sands Production for Existing, Approved and Planned Developments Plus Project Millennium

Oil Sands Development	Capacity (bpcd)	Expected Production (2010)	
		Bitumen (bpcd)	Synthetic Crude (bpcd)
Suncor			
- Lease 86/17 + Fixed Plant Expansion + Steepbank Mine	125,000	125,000	105,000
- Project Millennium	125,000	125,000	105,000
Syncrude			
- Mildred Lake Mine	270,000	160,000 [a]	- - -
- Aurora Mine	400,000	400,000	- - -
- Project 21 Upgrader	480,000	- - -	480,000
Shell			
- Muskeg River Mine Project	150,000	150,000	- - -
- Lease 13 East	200,000	200,000	- - -
Mobil Kearl Mine	130,000	130,000	- - -
Mobil Upgrader	130,000	- - -	130,000
Gulf Surmont	100,000	100,000	- - -
Petro-Canada MacKay River	20,000	20,000	- - -
JACOS Hangingstone	10,000	10,000	- - -
Northstar Energy	2,000	2,000	- - -
Total		**1,432,000**	**820,000**

(a) Potential bitumen sales not included.

Table A2-15 Environmental Parameters for Planned Developments

Development	Development Area (ha)	Water Withdrawal (1,000 m^3/a)	Air Emissions (t/cd) SO_2	Air Emissions (t/cd) NO_x
Shell Muskeg River Mine Project	4,343	55,100	0	12
Shell Lease 13 East	7,215	[a]	0	16
Syncrude Project 21 Upgrader	0	[b]	200[c]	83[c]
Mobil Kearl Oil Sands Mine and Upgrader	5,350	49,500[d]	17[e]	18[e]
Gulf Surmont[f]	n/a[f]	n/a[h]	0.34[i]	4.5[i]
Petro-Canada MacKay River	33[g]	n/a[h]	0.7[j]	0.9[j]
JACOS Hangingstone[f]	n/a[f]	n/a[h]	<0.01[k]	0.5[k]

(a) Withdrawal requirements considered included in Muskeg River Mine Project allotment.
(b) Withdrawal requirements included in development's existing approval.
(c) Total for combined Syncrude developments (Mildred Lake, Aurora Mine, and Project 21 Upgrader).
(d) Pro-rated from Muskeg River Mine Project value for 150,000 bpcd production.
(e) Information provided by Mobil.
(f) n/a = not applicable as these developments are physically outside the RSA; only air emissions included as these may enter the RSA.
(g) Development area listed represents only a small plantsite area, not the full area that may be impacted by development of in-situ wells.
(h) n/a = not applicable because these developments will not withdraw water from the Athabasca River.
(i) Information from Gulf Surmont.
(j) Information pro-rated from Gulf Surmont.
(k) Information from project application.

A3 QUALITY ASSURANCE AND CONTROL

A3.0 OVERVIEW

Data used in support of Environmental Impact Assessments (EIAs) must be of sufficient quality such that the conclusions are not compromised. Quality Assurance (QA) and Quality Control (QC) procedures were designed for the Project Millennium (the Project) EIA to ensure that representative data was collected that is of known, acceptable and defensible quality. QC was used in all components of the EIA process, including study design, sample collection, analysis and data evaluation. It included such procedures as calibration and standardization of sampling procedures, use of replicate samples and clear and concise record keeping. QA activities such as audits, reviews and compilation of complete and thorough documentation were used to verify QC procedures. Together, these QA and QC protocols formed the QA/QC Plan for the EIA.

A3.1 KEY COMPONENTS OF THE QA/QC PLAN

The QA/QC Plan provided the overall umbrella of QA/QC procedures that were used for the EIA. Key components of the Plan included:

- Data Quality Objectives for all components of the EIA;
- standard Technical Procedures that describe sampling methods in detail;
- standard Specific Work Instructions (SWIs) that specify the Technical Procedures and time and budget allocation for each task;
- training of staff in all relevant Technical Procedures and SWIs;
- document control procedures, including procedures for the receipt, coding, copying and storage of all documents related to the Project;
- use of certified laboratories for chemical analyses;
- use of laboratory quality control criteria; and
- audit and review procedures, including field audits and standardized review of data, reports, and health and safety activities.

A3.2 DEFINITIONS

Data quality parameters used to assess the acceptability of the data are precision, accuracy, comparability and completeness.

Accuracy

Accuracy is the closeness of a measured or computed value to its true value. Accuracy measurements were applied to the chemical analysis portion of the EIA. Accuracy measurements were not possible for toxicity testing or benthic invertebrate sorting because true values do not exist. Accuracy may be expressed most often as the difference between two measured values (expressed as a percent difference) or as a percentage of the true or reference value.

Precision

Precision is the measure of the reproducibility among individual measurements of the same property, usually under similar conditions, such as replicate measurements of the same sample. Precision is typically assessed by duplicate analyses and is expressed as a relative percent difference.

Comparability

Comparability expresses the confidence with which one data set can be evaluated in relationship to another data set. For the EIA, comparability of data was established through the use of: 1) explicit methods and reporting formats; 2) common calibration and reference materials; and 3) participation in an interlaboratory comparison program (for chemical analyses only).

Completeness

Completeness is a measure of the proportion of data specified in the sampling plan which is determined to be valid. The Data Quality Objective for completeness for all components of this project was 95%.

A3.3 PRE-FIELD ACTIVITIES

Pre-field activities included the appointment of a Project QA/QC Manager who was responsible for all aspects of the Plan.

Data Quality Objectives were established for each field task (i.e., explicit statements of the expected accuracy and precision of field measurements as well as the rationale for sample sizes and sample sites).

Technical Procedures were developed for each field task that described the methods to be used in detail. Technical Procedures included sections on the purpose, applicability, methods, equipment and materials, and references for each task. Golder maintains a set of oil sands-specific Technical Procedures and has a standardized procedure for revising them.

A task specific data sheet was also prepared for each field program to ensure that data was collected consistently and completely.

Finally, a Health and Safety Plan was prepared for each field program. Each team involved in field work had documented procedures for insuring the safety of their workers.

A3.4 FIELD PROCEDURES

Field crews were audited against the Technical Procedures and Specific Work Instructions for their component. The audits were conducted by members of the QA team. The purpose of the audits was to help ensure that: proper field procedures were followed; data collection was consistent; and, if deviations from procedures were found, corrective action was taken.

Procedures and documentation were provided to field crews for sample handling and shipment. Documentation ensured that all sample handling requirements were carried out properly and in a legally defensible manner. Proper chain-of-custody (COC) procedures were used to trace the possession and handling of samples from field collection through analysis to final disposal.

Generation of quality data begins with sample collection, and therefore the integrity of the sample collection process is of concern to the laboratory performing the analyses (either biological, chemical, or physical). Samples were collected in appropriate containers in such a way that no foreign material was introduced into the sample and no material of interest was lost due to adsorption, chemical or biological degradation or volatilization. Samples were clearly labelled with permanent ink.

All pertinent information on field activities and sampling efforts were recorded in waterproof, bound logbooks. The logbooks were filled out sufficiently to enable someone unfamiliar with the project to completely reconstruct field activity without relying on the memory of the field crew.

A number of techniques were used to ensure that the samples collected were of high quality, including the use of sample replicates and field blanks. Field replicates provided information that was useful in assessing sample heterogeneity and variability. Field blanks (e.g., samples with no contaminants, such as distilled water) were used to assess whether or not samples were contaminated during sample collection.

Sample preservation requirements were followed for each type of analysis. For example, sediment samples were placed in coolers with a sufficient number of ice packs (or crushed ice) to keep them cold through the completion of that day's sampling, and through transport to the laboratories.

Sample handling and custody procedures were undertaken such that samples were traceable from the time of sample collection, through laboratory and data analysis, to reporting. The principal documents used to identify samples and to document possession were COC records and field notebooks.

Appropriate shipping procedures were used to ensure that COC was maintained, sample containers were properly packaged to prevent damage, and that samples were received within the appropriate time frame so that holding times for analyses could be met.

A3.5 LABORATORY PROCEDURES

Only laboratories that had passed stringent performance evaluations were used for the EIA. Laboratories were required to provide written protocols for the analytical methods used for each analysis, including the target detection limit for each chemical tested.

Laboratory documentation included clear instructions for the lab in the form of an Analytical Request Form. All samples were tracked by means of Work Orders. Samples were identified and tracked by means of sample location (station) and replicate identifiers. Transfer of samples both between and within labs were tracked through COC procedures.

Laboratory quality control criteria included calibration of all equipment, analysis of certified reference materials (e.g., samples with known concentrations of contaminants) and analysis of blanks. All excess sample materials were archived by the labs for future reference.

Sample results were provided by the labs using government approved methods.

A3.6 DATA EVALUATION AND DATABASE MANAGEMENT

Data sheets were reviewed upon completion of the field programs for completeness and errors. Similarly, results of the laboratory analyses were reviewed to ensure that the data complied with the QA/QC Plan.

An organized and consistent system of data control and filing was implemented for the project. The system was designed to ensure that team members could obtain up-to-date, protected information in one place. Each storage file was named using a unique identifier and protected by means of a password.

B1 AIR QUALITY SCOPE OF ASSESSMENT

B1.1 COMPONENT DESCRIPTION

The Suncor Project Millennium (the Project) Environmental Impact Assessment (EIA) has been prepared as part of an Application to obtain approval for the Project. This air emissions impact analysis section, together with an associated air quality key reference report, constitute the air component of the EIA.

The objective of the air emissions impact analysis is to identify and analyze the potential effects associated with Project Millennium. Current and expected air quality changes associated with Suncor's current, approved (Fixed Plant Expansion Project and the Steepbank Mine) and proposed Project operations are provided in this assessment. As the Suncor facility is located in an airshed that contains other sources, the regional air quality assessment has included the combined operation of these other sources, the major one being the Syncrude Canada Ltd. (Syncrude) operations.

The air quality impact analysis focuses on determining changes to the chemical composition of the air and not on the effect these changes may have on receptors. Effects of air quality changes to aquatic and forest ecosystems and human health are discussed in the Aquatics Impact Analysis, Terrestrial Resources Impact Analysis and the Human Health Impact Analysis sections, respectively.

B1.2 ASSESSMENT APPROACH AND ORGANIZATION

This section outlines the approach taken to meet the requirements of the air assessment component of Project Millennium EIA. It includes presentation of the air assessment requirements of Alberta Environmental Protection (AEP) and the other regulatory agencies that had input to development of the Final Terms of Reference for Project Millennium (AEP 1998). The air assessment study areas are identified. Also included is an overview of the air quality guidelines and criteria that will apply to the Project.

B1.2.1 Air Quality Management

Suncor has approval under Alberta Environmental Protection and Enhancement Act (AEPEA) to operate its existing facilities. This approval also includes the Fixed Plant Expansion Project and the Steepbank Mine Project, both of which are presently under construction. The current approval:

- identifies the operations at the site including emission sources;

- describes the air emission limits for the overall plant and for major sources, stacks and flares, including pertinent operational parameters;
- identifies the monitoring programs required to ensure the air pollution management systems are operating as designed; and
- identifies the reporting requirements to document and communicate the results of the monitoring program to AEP.

Suncor's air quality management systems address the AEP requirements specified in the approval and is comprised of the following activities:

- **Source Control Activities.** Suncor's facilities employ design features and management practices to control emissions to the atmosphere. New emission control programs are in progress to further reduce current emissions.
- **Airshed Management Activities.** The development of the Clean Air Strategic Alliance (CASA) for Alberta has led the members of the Regional Air Quality Coordinating Committee (RAQCC) to form the Wood Buffalo Airshed Monitoring Zone (WBAMZ) as an airshed for this region of Alberta. Suncor will participate fully in WBAMZ and supports the zone as an effective and efficient regional approach that provides scientifically credible information on air quality and its environmental effects. Suncor's involvement in future air quality studies relating to the regional airshed will be through WBAMZ.
- **Monitoring Activities.** Source monitoring to identify and quantify emission sources is routinely carried out by Suncor. Suncor has participated in additional ambient air quality monitoring programs to further document spatial and temporal concentration patterns.
- **Global Climate Change.** Global warming is recognized as a national and international issue. Suncor is continuing to work on global warming and greenhouse gas within the framework of its existing facilities and the proposed Project Millennium. In March 1998 Suncor entered into a deal with Niagara Mohawk Power, subject to approval by the governments in Canada and the United States, to purchase greenhouse gas emission credits. More information on the corporate policies of Suncor is presented in Section B1.2.5.
- **Assessment Activities.** Suncor's environmental management systems include periodic review, analysis and summary of air emissions and associated data collection. These assessment activities occur at regular (e.g., annual reports) or intermittent (e.g., environmental assessments) intervals.

The air quality impact assessment prepared for the Project forms part of the ongoing regional airshed management activities conducted by Suncor.

B1.2.2 Background Key Reference Report

A background air quality key reference report, Technical Reference for the Meteorology, Emissions and Ambient Air Quality in the Athabasca Oil Sands Region (Golder and Conor Pacific 1998), has been prepared for the Project. This report, which summarizes the air quality baseline data information to the end of 1997, describes the status of current air quality parameters and can be used for the preparation and review of future development applications. Furthermore, this report can also be used by WBAMZ or RAQCC in support of their regional air quality related initiatives. In summary, this report includes:

- The sources of anthropogenic atmospheric emissions in the Athabasca Oil Sands region. The air emissions in the Fort McMurray - Fort McKay corridor, including industrial point, fugitive, traffic and residential sources, are identified. Emissions of interest are sulphur dioxide (SO_2), oxides of nitrogen (NO_x), carbon monoxide (CO), total hydrocarbons (THC) that include volatile organic compounds (VOC), total reduced sulphur (TRS), particulates (PM) and carbon dioxide (CO_2).
- The ambient air quality observations in the Athabasca Oil Sands region. Ambient air quality monitoring undertaken in the Fort McMurray - Fort McKay airshed are summarized. The sources include data from the Suncor, Syncrude and AEP networks, and data associated with other monitoring programs; and,
- The meteorological observations in the Athabasca Oil Sands region. Meteorological data which describe the transport, dispersion and deposition of emissions in the area are summarized. The focus is on the meteorological data collected by Suncor from the Lower Camp and Mannix towers. A review of the terrain in the region and its effect on meteorology is also provided.

B1.2.3 Air Quality Issues

AEP issued the Terms of Reference for the Project Millennium EIA on March 4, 1998 (AEP 1998). The following issues were identified from an air quality perspective and are directly extracted from the Final Terms of Reference:

- Develop an emissions profile (e.g. type, rate and source) for each component of the Project, including construction and vehicle emissions. Consider both normal operating and upset conditions.
- Discuss the emission control technologies proposed for the Project in the context of available technologies.

- Estimate the incremental loading of greenhouse gases to the atmosphere as a result of the Project. Place emission estimates in context with total emissions, provincially and nationally. Discuss the proponent's overall greenhouse gas management plans and comment on the effect of this Project on its greenhouse gas management plans.
- Discuss baseline climatic and air quality conditions. Review current emission sources and discuss changes as a result of anticipated future development scenarios within the EIA Study Area. Consider emission point sources, as well as, fugitive emissions and emissions from mine mobile sources (vehicles).
- Identify components of the Project that will affect air quality from a local and regional perspective. Discuss appropriate air quality parameters such as sulphur dioxide (SO_2), hydrogen sulphide (H_2S), total hydrocarbons (THC), oxides of nitrogen (NO_x), volatile organic compounds (VOC), ground level ozone and particulates.
- Estimate ground level concentration of appropriate air quality parameters. Discuss any expected changes to particulate deposition or acidic deposition patterns. Justify the selection of the models used and identify any model short comings or constraints on findings.
- Identify the potential for decreased air quality (including odours) resulting from the Project and discuss any implications of the expected air quality for the environmental protection and public health. Discuss consideration of interactive effects that may occur as a result of co-exposure of a receptor to various emissions and discuss limitations in the present understanding of this project.
- Describe how air quality impacts resulting from the Project will be mitigated .
- Identify ambient air quality monitoring that will be conducted during construction and operation of the Project.
- Identify components of the Project that have the potential for creating increased noise levels and discuss the implications and measures to mitigate.
- Assess the cumulative effects on the air quality of the Study Area.

In addition, under the heading of Public Health and Safety Issues, in the Final Terms of Reference, the following additional air quality issue was identified:

- Discuss the potential for changes to water quality, air quality and the bioaccumulation of contaminants in natural food sources in the Study Area to increase human exposure to contaminants.

Current and expected air quality changes associated with Suncor's current, approved (Fixed Plant Expansion and Steepbank Mine Projects) and proposed (Project Millennium) operations are provided in this assessment.

B1.2.4 Consultation and Assessment Focus

Consultation with stakeholders and regulatory agencies involved with oil sands development is ongoing through RAQCC. RAQCC has been providing regular and ongoing input and direction to air issues in the Fort McMurray/Fort McKay region. During recent meetings between regulatory agencies and Suncor, a number of air resources items specific to Project Millennium were identified and discussed. The need to address acidification and ground level ozone were identified for Project Millennium. The agencies indicated the need to document the air dispersion models used to calculate ground level concentrations.

During discussions held with aboriginal communities as part of Project Millennium public consultation process, it was decided that modelled ambient air quality results would also be considered for Fort Chipewyan and the Athabasca Cree First Nations reserves. This was done notwithstanding their distance from Suncor and their location outside the Regional Study Area (RSA). Part of the assessment process includes predicting ambient air quality at these locations.

B1.2.5 Greenhouse Gases

Suncor has developed a corporate policy to manage greenhouse gas (GHG) emissions. Suncor is committed to leadership and action in seven areas that address the risk of climate change:

1. **Managing the Company's own GHG emissions and their impact:** Suncor has produced a progressive GHG management plan as part of its participation in Canada's Voluntary Challenge and Registry Program.
2. **Developing alternative and renewable sources of energy:** Suncor has formed an alternate energy team to pursue alternative sources of energy as part of its portfolio of business opportunities.
3. **Supporting environmental and economic research:** Suncor is working with research institutions to develop more advanced production and processing technology for conventional, synthetic and heavy crude oil production that will reduce GHG emissions. Suncor is also working with industry associations and governments on selected research projects to address the environmental and economic policy aspects of climate change.
4. **Pursuing domestic and international offsets:** Offsets are GHG emission reductions that are achieved through actions that either reduce, prevent or absorb the emission of GHGs to offset a company's own

emissions. This can include investment in forest conservation projects, technology transfer to developing countries, energy efficiency investments, cogeneration, alternate energy and improving energy infrastructure.

5. **Providing constructive public policy input in support of sustainable solutions:** Suncor is engaged with its communities and various stakeholder organizations to address climate change policy at provincial, national and international levels.
6. **Educating and engaging Company's employees, customers and communities on the issue of global climate change:** Suncor supports education on climate change on a community level with a number of organizations and plans to further fund global climate change education initiatives.
7. **Measuring and reporting on the Company's progress:** Suncor takes a thorough and open approach to measuring its Environment, Health and Safety performance. This includes measurement of its progress in reducing GHG emissions.

Suncor Energy published its third annual progress report to Canada's Climate Change Voluntary Challenge and Registry program in August 1997. That report provides a total Company performance review; it outlines significant improvements in actual and forecast GHG emissions performance for the 1990 to 2000 period. While production volumes are projected to increase by 64% in the period 1990 to 2000, GHG emissions are projected to increase significantly less, by 12%. GHG emissions per unit of production will be reduced by 32%. Suncor's plan was rated fifth among nearly 600 plans by the Pembina Institute for Appropriate Development, and Suncor has been recognized by the federal government for leadership in this area.

Suncor Energy integrates GHG issues into its every day management processes for each of its operating business units by:

- commitment and leadership of senior management;
- employee education and involvement;
- stakeholder and public involvement; and
- life cycle value analysis.

B1.2.6 Impact Assessment Approach

The air emission impact analysis uses the key reference report to define current conditions and provides an evaluation of changes in air quality that could be associated with the proposed Project Millennium. The information and format presented in this assessment are based on the expectations for the air quality portion of an EIA as defined by AEP (1994).

Section B2 of this report summarizes the baseline conditions and environmental setting and includes the following:

- identification of existing emissions, including greenhouse gases, associated with the current, as approved, facilities;
- summary of the current ambient air quality in the region based on the last five years of available monitoring data;
- summary of meteorological observations collected in the area;
- description of the topography in the vicinity of the oil sands operations;
- dispersion model predictions of ambient concentrations associated with the current, as approved, operation;
- summary of existing ozone levels and assessment approach; and,
- comments on existing noise levels and fugitive dust levels from the current, as approved, facilities.

Section B3 of this report defines air quality changes associated with Project Millennium and includes the following:

- identification of changes in emissions from the current, as approved, sources, and any new emission sources;
- dispersion model predictions of ambient concentrations associated with the proposed operation; and,
- discussion of greenhouse gas emissions, ozone levels, noise and fugitive dust.

Section B4 describes the cumulative effects on the air quality in the region of, the existing regional operations, the approved but not yet constructed new projects, the planned developments and Project Millennium.

Section B5 of this report provides the conclusions of the air quality impacts associated with Project Millennium.

B1.3 STUDY AREA CONSIDERATIONS

The study area for Project Millennium EIA is defined by both a Local Study Area (LSA) and a Regional Study Area (RSA). The former is delineated by the Lease and Lot boundaries which comprise Project Millennium, the Steepbank Mine development as well as the existing development on Lease

86/17. The RSA is based on airshed, watershed and ecological criteria. For the air quality impact assessment of Project Millennium, the Local Study Area and the Regional Study Area (LSA/RSA) are one and the same. The LSA/RSA is defined by a 148 by 169 km area (Figure B1-1). This area exceeds the north/south and east/west limits, respectively, of the predicted cumulative impacts related to air emissions from oil sands developments in the vicinity of Suncor. It is within this area that air quality changes due to Project Millennium are expected to be quantifiable. This study area includes the communities of Fort McMurray and Fort McKay.

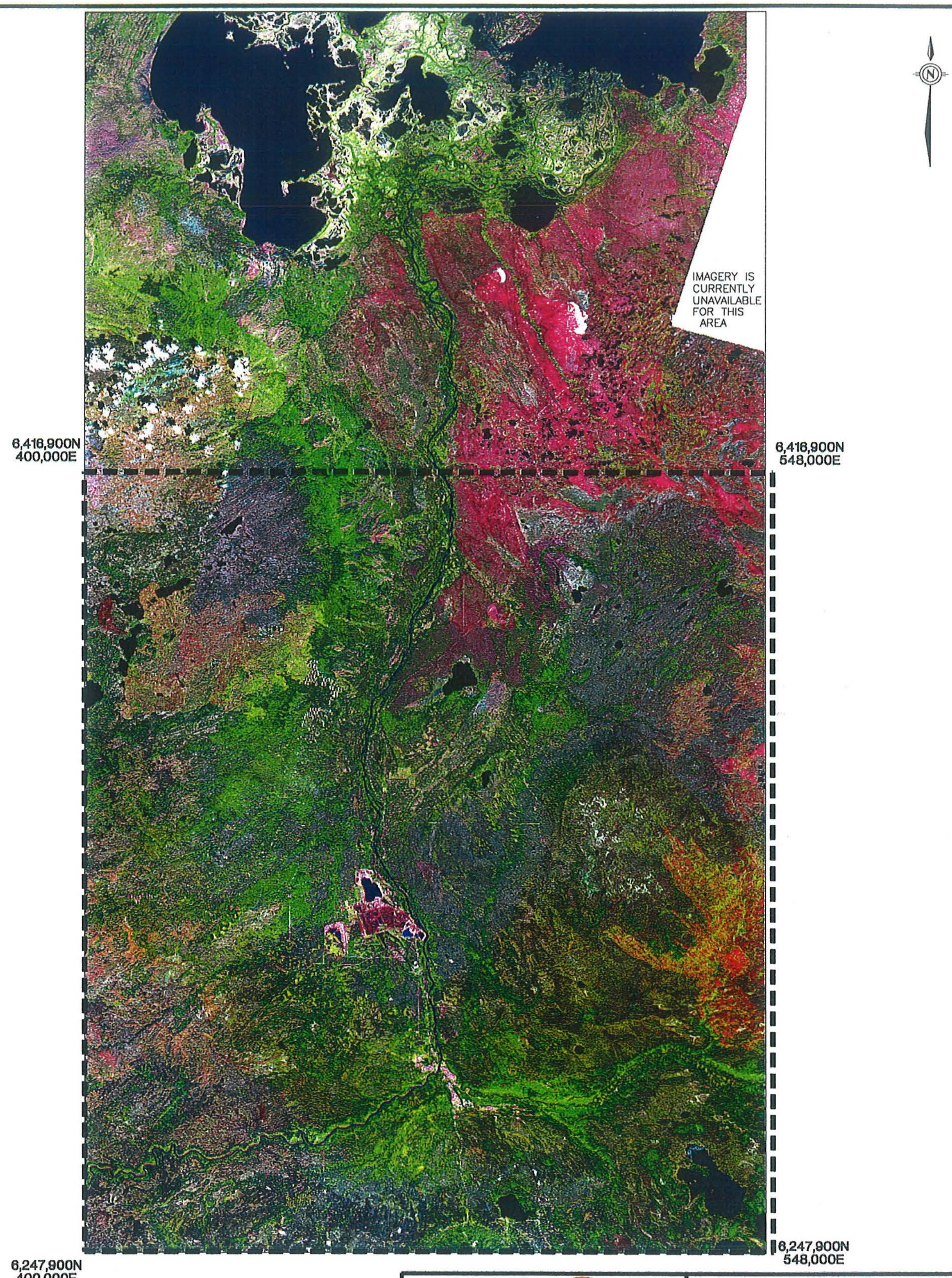
During discussions held with aboriginal communities as part of the Project Millennium public consultation process, it was decided that modelled ambient air quality results would also be considered for Fort Chipewyan and the Athabasca Cree First Nations reserves. This was done notwithstanding their distance from Suncor and their location outside the RSA. It is possible for the model to predict results at these locations; however, such predictions may not be as accurate as those results within the RSA. The major unknown is the air emission contributions from other activities (industrial, commercial or urban) that might impact these locations and are located outside the Suncor Project Millennium RSA. Sources outside the RSA, Fort Chipewyan and the Athabasca Cree First Nations reserves, were not explicitly included in the predictions but have been included by way of background air concentrations and deposition rates. The calculated concentrations will provide an indication of the ambient concentration for the modelled pollutants, from the existing facilities, the proposed Project Millennium, and planned projects, at Fort Chipewyan and on the Athabasca Cree First Nations reserves.

B1.4 AIR QUALITY GUIDELINES AND OBJECTIVES

The impact of air emissions introduced into the atmosphere by industrial activities can be broad. The emissions can have direct and indirect effects on humans, animals, vegetation, soil, water and visibility. For these reasons, environmental regulatory agencies have established maximum ambient air concentration limits.

B1.4.1 Ambient Concentration Criteria

Table B1-1 presents the Alberta provincial guidelines and the Canadian federal government air quality objectives for regulated compounds. The compounds include: sulphur dioxide (SO_2), hydrogen sulphide (H_2S), nitrogen dioxide (NO_2), carbon monoxide (CO), oxidants expressed as ozone (O_3) and suspended particulates. These guidelines and objectives refer to averaging periods ranging from one hour to one year. In addition, the federal government has established three levels of objectives (Environment Canada 1981). The levels are described below:



LEGEND

▬ ▬ ▬ ▬ REGIONAL STUDY AREA

0 10 20 30 40km

SCALE 1:1,250,000

SUNCOR ENERGY

Project Millennium — Taking Suncor Into the 21st Century

AIR QUALITY STUDY AREA

20 Apr. 1998	Figure B1-1	DRAWN BY: TM

Table B1-1 Federal, Alberta and Other Government Ambient Air Quality Guidelines and Objectives

	Alberta Guidelines		Federal Objectives[a] Desirable	Acceptable	Tolerable
SO_2 (µg/m^3)					
Annual	30	(0.01 ppm)	30	60	--[b]
24-Hour	150	(0.06 ppm)	150	300	800
1-Hour	450	(0.17 ppm)	450	900	--
H_2S (µg/m^3)					
24-Hour	4	(0.003 ppm)	--	5[c]	--
1-Hour	14	(0.01 ppm)	1[c]	15[c]	--
NO_2 (µg/m^3)					
Annual	60	(0.03 ppm)	60	100	--
24-Hour	200	(0.11 ppm)	--	200	300
1-Hour	400	(0.21 ppm)	--	400	1000
CO (mg/m^3)					
8-Hour	6	(5 ppm)	6	15	20
1-Hour	15	(13 ppm)	15	35	--
Oxidants (µg/m^3)[d]					
Annual	--	--	--	30	--
24-Hour	50	(0.025 ppm)	30	50	--
1-Hour	160	(0.082 ppm)	100	160	300
Suspended Particulates (µg/m^3)					
Annual[e]	60	--	60	70	--
24-Hour	100	--	--	120	400
PM_{10}[f]					
24-Hour[g] [h]	--	--	--	--	--
Annual[h]	--	--	--	120	400
$PM_{2.5}$[i]					
24-Hour[h]	(i)	--	--	--	--
Annual[h]	(i)	--	--	--	--

(a) At a temperature of 25°C and pressure of 101.3 kPa.
(b) '--' = not applicable.
(c) Proposed.
(d) As ozone (O_3).
(e) As a geometric mean.
(f) PM_{10} - particulate matter emissions with particle diameter less than 10 µm.
(g) Based on BC and Ontario 24 hour PM_{10} - 50 µg/m^3.
(h) Based on U.S. EPA 24 hour PM_{10} - 150 µg/m^3.
(i) $PM_{2.5}$ - particulate matter emissions with particle diameter less than 2.5 µm. Based on U.S. EPA 24 hour $PM_{2.5}$ - 65 µg/m^3 Annual $PM_{2.5}$ - 15 µg/m^3.

- The maximum **desirable** level defines the long-term goal for air quality and provides a basis for an anti-degradation policy for the unpolluted parts of the country and for the continuing development of control technology.
- The maximum **acceptable** level is intended to provide adequate protection against adverse effects on soil, water, vegetation, materials, animals, visibility, personal comfort and well-being.
- The maximum **tolerable** level denotes a concentration of an air contaminant that requires abatement (mitigation) without delay to avoid further deterioration to an air quality that endangers the prevailing Canadian lifestyle or ultimately, to an air quality that poses a substantial risk to public health.

In Alberta, the maximum concentrations in ambient air are currently specified as guidelines for SO_2, H_2S, NO_2, CO, oxidants expressed as O_3 (ozone) and total suspended particulate matter (Government of Alberta 1993).

With the exception of oxidants and the proposed federal one-hour average objective for H_2S, the Alberta Environment guidelines are equal to the most stringent of the federal objectives. The Alberta guidelines for oxidants are less strict when compared with the Federal Air Quality objectives since rural ozone concentrations in Alberta have been observed to exceed the Federal Desirable Level (Angle and Sandhu 1986, 1989).

The primary focus on Particulate Matter (PM) emissions, from a human health perspective, is not Total Suspended Particulate (TSP) matter. Rather it is the inhalable fraction, with diameters less than 10 μm (referred to as PM_{10}) and the respirable fraction, with diameters less than 2.5 μm (referred to as $PM_{2.5}$). Neither the Alberta or federal governments have adopted PM_{10} or $PM_{2.5}$ guidelines; the values provided in Table B1-1 reflect those adopted by B.C., Ontario and the U.S. EPA.

B1.4.2 Deposition Criteria

Deposition includes both wet and dry processes and can result in long-term accumulation of emissions in aquatic and terrestrial ecosystems. Wet processes involve the removal of emissions vented into the atmosphere by precipitation. Dry processes involve the removal by direct contact with surface features (e.g., vegetation). Both wet and dry deposition are expressed as a flux in units of "kg/ha/y." Because several chemical species of nitrogen, sulphur and base cations are considered in the estimate of deposition, the flux is expressed in "keq/ha/y" where "keq" refers to hydrogen ion equivalents (1 keq = 1 kmol H^+). Deposition of sulphur and nitrogen compounds is associated with acidification of water and soil.

Table B1-2 presents target loading values that have been considered for application to the deposition of acidic compounds in Alberta. The preferred AEP method is based on the Potential Acid Input (PAI) that is similar to the acid neutralizing capacity (ANC) except the negligible contribution of oceanic salt contribution has not been included (i.e., [Na^+] and [Cl^-]). The calculation of the PAI is based on sulphur compounds (e.g., SO_2 gas, SO_4^{2-} particle), nitrogen compounds (e.g., NO gas, NO_2 gas, HNO_3 gas, NO_3^- particle), and base cations (e.g., Ca^{2+} particle, Mg^+ particle and K^+ particle).

The critical target loading recommended by the Target Loading Subgroup of CASA (1996) is for sensitive systems and is based on the European Approach outlined in the World Health Organization document (WHO 1994). This approach specifies target loads of 0.25, 0.5, 1.0 and 1.5 keq/ha/y that range from the most sensitive to least sensitive ecosystems. The terrestrial sensitivities depend on the geology of the parent material. The surface water sensitivities depend on the base cation concentration in the receiving waterbody and the runoff amounts. In Alberta, an interim critical load of 0.25 keq/ha/y is being proposed for sensitive soils; aquatic ecosystems loadings have not yet been defined.

Table B1-2 Deposition Target Loadings for Acid Forming Emissions

Form	Loading[a]	Comments	Reference
Wet Sulphate Deposition	20 kg/ha/y (Target)	SO_4^{2-} not strongly correlated with H^+ in western Canada. Does not include dry deposition or NO_x precursors.	US-Canada Memorandum of Intent (1983)
Acidifying Potential (AP)	0.12 to 0.31 keq/ha/y (Critical)	Does not include dry deposition or NO_x precursors. $AP = [SO_4^{2-}]-([Ca^{2+}]+[Mg^{2+}])$	Interim Acid Deposition Target Loadings Task Group (1990)
Effective Acidity (EA)	0.1 to 0.7 keq/ha/y depending on soil sensitivity (Critical)	Various forms account for wet and dry deposition and NO_x precursors. Accounts for soil response to deposition. $EA = [H^+] + 1.15 [NH_4^+] - 0.7 [NO_3^-] + [SO_2] + [SO_4^{2-}]$	Alberta Environment (1990) and Peake and Fong (1992)
Acid Neutralizing Capacity (ANC)	0.25 to 1.5 keq/ha/y depending on ecosystem (Critical)	Includes wet and dry deposition of all components. e.g., $ANC = ([Ca^{2+}] + [Mg^{2+}] + [K^+] + [Na^+]) - ([SO_4^{2-}] + [NO_3^-] + [NH_4^+] + [Cl^-])$	World Health Organization (1994)
Potential Acid Input (PAI)	0.25 keq/ha/y (Critical)	For sensitive soils. Includes SO_x and NO_x, wet and dry deposition and baseline precipitation. $PAI = ([SO_4^{2-}] + [NO_3^-] + [NH_4^+]) - ([Ca^{2+}] + [Mg^+] + [K^+])$	Target Loading Subgroup (1996)

(a) Target Load: Maximum level of atmospheric deposition, which provides long-term protection from adverse ecological consequences, and is practically and politically achievable.
Critical Load: Highest load that will not cause chemical changes leading to long-term harmful effects on the most sensitive ecological systems.

B2 AIR QUALITY BASELINE/ENVIRONMENTAL SETTING

B2.1 CURRENT EMISSIONS AND BASELINE DATA

B2.1.1 Current Emissions

The operation of oil sands mining, extraction and upgrading facilities in the Athabasca oil sands region results in gaseous and particulate emissions from controlled and fugitive sources. Additional emissions to the airshed result from other sources, including other industrial operations, transportation and community sources. This section summarizes the Baseline projects as defined in Table A2-11.

Additional information on current emissions is provided in the EIA key reference report "Technical Reference for Meteorology, Emissions and Ambient Air Quality in the Oil Sands Region" (Golder and Conor Pacific 1998).

B2.1.1.1 Baseline Suncor Emissions

Emission sources from Suncor's operations are listed below. Included are sources from operating and approved facilities at the Suncor site. Sources are in all of Suncor's operating units: mining, extraction, upgrading and energy services.

- Continuous combustion sources include: the Flue Gas Desulphurization (FGD) stack that services three coke-fired boilers; the powerhouse stack that services five gas fired boilers and, if necessary, three coke-fired boilers; incinerator stack that services the sulphur recovery plant; upgrading secondary stacks that are either natural gas or refinery gas-fired; continuous flaring; and exhaust gases from the mine fleet that use diesel fuel;
- Intermittent combustion sources include two hydrocarbon flares, one acid gas flare and a hydrogen plant flare that are used for plant start-up, shut-down and upset conditions. The flare stacks are serviced by continuous pilots and are used for both planned and unplanned combustion of gas streams;
- Plant vents that service various storage tanks, process vessels and buildings. The vent gases typically contain hydrocarbon product which may also include reduced sulphur compounds;
- Fugitive particulate emissions result from surface disturbances that include mining activities, traffic, storage piles (e.g., coke) and tailings pond dykes; and

- Fugitive hydrocarbon emissions result from leaks in the upgrading area (i.e., valves, flanges, piping, rotating seals, drains) and from area sources (mine surfaces and tailings ponds).

The current operations employ a number of emission reduction technologies or practices. The major ones are summarized below:

- the Flue Gas Desulphurization (FGD) plant designed to remove 95% of SO_2 from the five gas coke fired boilers;
- a SuperClaus sulphur recovery plant designed to remove more than 98% of the sulphur in the acid gas prior to venting through the incinerator stack;
- a Naphtha Recovery Unit (NRU) recovers light hydrocarbons from Extraction Plant 4 tailings prior to discharge to Tailings Pond 1;
- electrostatic precipitators designed to remove 98% of particulate matter from flue gases generated during coke combustion in the power house;
- a Vapour Recovery Unit (VRU) recovers about 95% of the hydrocarbon and Total Reduced Sulphur (TRS) emission from Plant 4 vents, the NRU and the south tank farm vents;
- a sour water stripping system is used to strip H_2S from process water. The stripped H_2S is routed to the sulphur plant;
- improved operating procedures and equipment reliability has reduced the frequency of intermittent flaring;
- during times when the FGD unit is down, the Supplementary Emission Control (SEC) system can be used to control powerhouse SO_2 emissions;
- mine haul roads are sprayed with water in non-freezing conditions to reduce fugitive dust on dry, windy days; and
- tailings pond dykes are revegetated on the exterior slopes to reduce wind blown sand.

Table B2-1 provides a summary of the predicted emissions from Suncor's current and approved operations. The values are the sum of current and predicted emissions for the existing facility and the approved Fixed Plant Expansion and Steepbank Mine Projects. The emission sources have been grouped for ease of presentation. In developing the ambient air quality predictions (Section B2.2) the individual source emission rates and locations were modelled. The Volatile Organic Compounds (VOC) emissions are based on a VRU uptime of 90%. No estimates for surface generated particulate matter (PM_s) have been provided.

Table B2-1 Summary of Baseline (Current + Approved) Suncor Emissions

Source	Emission Rates (t/cd)					
	SO_2	NO_x	CO	PM[(a)]	VOC	TRS
Suncor						
Powerhouse Stack	13.1	3.9	3.3	0.2	0.008	n/a
FGD Stack	18.0	29.8	25.7	1.1	0.15	n/a
Sulphur Incinerator	18.8	0.1	2.9	0.03	0.051	n/a
Upgrading Furnaces	2.8	2.5	0.8	0.3	7.7	--
Flaring (Continuous and Acid Gas)	12.6	0.1	0.2	0.005	0.033	--
Mine Fleet	0.04	11.3	0.6	0.1	0.27	--
Extraction	-	-	-	-	6.1	0.1
Tank Farms	-	-	-	-	3.5	0.1
Tailings Ponds	-	-	-	-	102.0	1.3
Mine Surface[(b)]	-	-	-	-	10.4	0.023
Total	**65.3**	**47.7**	**33.5**	**1.7**	**130.2**	**1.5**

n/a Data not available.
\- Not a source of this emission.
(a) Assumed as PM10.
(b) Estimated based on Syncrude data.

SO_2 Sources

The major approved sources of SO_2 emissions to the atmosphere are the powerhouse, FGD and incinerator stacks and three flares stacks. When the FGD process is on line, effluent gas from the three coke-fired boilers (powerhouse) is processed via the FGD plant and vented up the FGD stack. The FGD plant has been designed to be operational 95% of the time. When FGD is down, effluent gas from the three coke fired boilers is routed up the power house stack. In this configuration, SO_2 emission rates from the powerhouse stack approach 259 t/d. The "current" part of the baseline emissions are based on 1997, a year in which the FGD was still being commissioned and one of the coke fired boilers was down for an extended overhaul.

Suncor has spent considerable effort in understanding and reducing SO_2 emissions. Over the last few years Suncor has substantially reduced total SO_2 emissions with the installation of the FGD unit, improvements in the Upgrader sulphur plant and in overall operational reliability. This approach has initially been directed toward the major sources of SO_2. At the same time, Suncor has been identifying and quantifying smaller SO_2 sources. These include the flares and the upgrading furnace stacks. With success in reducing emissions from the largest sources, Suncor is now looking more closely at emissions from smaller sources. As a result, more accurate estimates of total SO_2 emissions from the facility have been acquired.

Table B2-2 provides a review of sulphur emissions from Suncor from 1994 to 1997. This time frame was selected to match available meteorological data for modelling purposes (see Section B2.2). Historically, Suncor's SO_2 emissions have been assessed based on the powerhouse and incinerator stacks. As Table B2-2 indicates, these two sources represented about 95% of the overall Suncor SO_2 emissions. These two sources plus the main stack at Syncrude (emissions of 208 t/d) represented the major area sources and formed the basis for historical SO_2 modelling efforts. In 1997, the FGD unit was commissioned and SO_2 emissions are expected to be reduced from approximately 250 t/d in 1994 to 65 t/d for the baseline case from all sources and from approximately 240 t/d to 50 t/d from the historical main sources.

The focus in the air quality assessments for Suncor has historically been the large SO_2 emissions. In the last three years Suncor has implemented new SO_2 emission controls on its principal sources and has quantified all of its smaller SO_2 emission sources (i.e., smaller in terms of SO_2 mass emission rates). When these smaller sources are included in model predictions for the past four years of operation at Suncor, the effect of these smaller sources are masked by the larger principal sources. However, with the full implementation of FGD in 1997 and the subsequent reduction of SO_2 GLCs, the contribution of the smaller sources to GLCs becomes apparent. Their contribution to the overall SO_2 GLC is significant within 20 km of the fixed plant and represents more than a third of the 450 $\mu g/m^3$ hourly AAAQG exceedances. Whereas the Baseline AAAQG exceedances appear to result from increased emissions, they are in fact from existing historical sources, now made significant due to the large SO_2 emission reductions.

There are many industrial SO_2 emission sources in the oil sands region which contribute to GLCs over a large area around the Suncor facility within a radius of approximately 40 km. Within this area the contribution of the individual sources, large or small, result in an integrated GLC very near the SO_2 AAAQG. Therefore, a better understanding of the sources, subtle changes in emission rates, source exit characteristics (e.g., temperature and velocity), or modelling assumptions (e.g., plume rise, dispersion coefficients, or terrain influences) can result in dramatic changes in the number of predicted exceedences of the AAAQG. For example, a predicted 25 $\mu g/m^3$ increase for a maximum one hour average ambient level could result in a significant increase in exceedances. Hence, a regional perspective is required when addressing development, significant increases in SO_2 emission in the area and the distributed nature of the existing emissions in the area.

Table B2-2 Summary of Historical SO_2 Suncor Emissions

Source	Suncor Emission Rates (t/sd)				
	1994	1995	1996	1997	Baseline
Powerhouse stack	211	215	153	171	259 [(a)]
FGD stack	-	-	-	10.8	18.9
Sulphur Incinerator	31	16	18	19.4	19.1
Upgrading furnaces	2.6	2.9	3.0	3.1	3.1
Continuous flaring	7.8	8.7	9.1	9.3	7.3
Mine fleet	-	-	-	-	0.04
Total	**252.4**	**242.6**	**183.1**	**213.6**	**48.4**

\- Not a source of this emission.
[(a)] Emissioin rate when FGD is not in operation.

NO_x Sources

The calculation of NO_x emissions was based on a combination of measured stack survey data, emissions supplied by equipment designers and suppliers, and U.S. EPA emission factors.

CO Sources

The CO emissions are based on emission factors. CO emissions are relatively small compared to NO_x or SO_2 emissions.

Particulate Matter (PM) Sources

Particulate matter (PM) emissions from the Powerhouse and FGD stacks, are based on stack survey measurements and are the major sources of PM emissions. All flue gas from the coke fired boilers passes through electrostatic precipitators designed to remove 98% of the PM. When FGD is on line, gases from the coke fired boilers are passed through the Jet Bubbling Reactor which acts as a wet scrubber and removes approximately 85% of the remaining particulate. Other sources of PM were estimated using appropriate emission factors.

VOC Sources

Total hydrocarbon emissions include methane and non-methane components. The latter are referred to as VOC (volatile organic compounds). The methane emission rates for the combustion sources, extraction plant, tank farms, and other vents were based on U.S. EPA emission factors. The VOC emission rates for the combustion sources, extraction plant, tank farms, upgrading facilities and other vents were also based on U.S. EPA emission factors. The emission rates from the tailings ponds were based on field characterization studies commissioned by Suncor in 1997.

TRS Sources

Reduced sulphur emissions include emissions of hydrogen sulphide (H_2S), carbonyl sulphide (COS), carbon disulphide (CS_2), mercaptans and thiophenes. The largest sources of TRS are the secondary extraction tailings ponds due to biogenic activity within the pond. A minor source of TRS is the Suncor fixed plant with the operation of the vapour recovery unit which is in operation 90% of the time. TRS is also a small component, exposed at oil sands. For the purposes of this assessment, TRS has been speciated with VOCs, implying that since VOCs have been assumed to scale with production rates, then TRS will also. This likely over estimates TRS because the dominant source of TRS is the Suncor tailings pond emissions which is believed to be biogenic in origin.

Greenhouse Gases

Greenhouse gases (GHG) include emissions of carbon dioxide (CO_2), methane (as equivalent CO_2) and NO_X (as equivalent CO_2). Overall GHG emissions for the Baseleine case are estimated at 13,350 CO_2 eq t/cd. Existing emissions for 1997 were 9,952 CO_2 eq t/cd.

B2.1.1.2 Baseline Syncrude Emissions

The other existing source of primary emissions in the region is Syncrude's Mildred Lake mining, extraction and upgrading operations. Table B2-3 provides an overview of their average emissions. The primary source of SO_2 emissions is the main stack, which services the CO boiler, the sulphur recovery plant and the sour water stripper. The THC/VOC and TRS emissions are based on updated estimates for the tailings settling pond (1992) and older estimates (1987) for the plant area. Given recent improvements in the plant operation, THC/VOC and TRS emissions from the plant area may be lower than those given in the table.

Table B2-3 Summary of Syncrude Baseline Emissions

Source	Emission Rates [a] (t/cd)					
	SO_2	NO_x	CO	PM[b]	VOC	TRS
Main Stack	208	10.9	45.0	3.6	0.002	0.00
Secondary Sources	0	14.0	3.4	1.2	0.14	0.00
Fugitive	0	0	0.0	0.0	5.4	1.9
Mine Fleet	1.0	19.5	5.2	0.6	0.9	0.00
Settling Basin (Fugitive)	-	-	-	-	26.5	0.36
Mine Surface (Fugitive)	-	-	-	-	10.9	0.03
Total	**209.0**	**44.4**	**53.6**	**5.4**	**43.84**	**2.3**

n/a Data not available.
- Not a source of this emission.
(a) Data provide by Syncrude or Syncrude's consultants.
(b) Assumed as PM_{10}.

B2.1.1.3 Other Existing or Approved Development Emission Sources

Other existing or approved industrial sources in the Athabasca Oil Sands Region include the following:

- **Northstar Energy Dover SAGD.** The emission sources at the Northstar Energy Dover SAGD facility include a central utilities flare stack, a glycol heater, a mine heater and five steam generators;
- **Northland Forest Products.** The main source of air emissions from Northland Forest Products' lumber mill is the conical waste wood burner;
- **Fort McMurray Hospital.** The hospital incinerator operates on an intermittent basis;
- **Syncrude Aurora Mine.** The approved Aurora North and South mines will include four operating trains with an ultimate production rate of 431,000 b/d of bitumen. The emission sources include eight stacks when the project is fully developed. A number of emissions (CO, VOC, PM_{10}) were not identified in the Aurora application and these

values are based on scaling emissions from the existing Mildred Lake sources; and

- **SOLV-EX.** SOLV-EX has approval for a combined bitumen and metal extraction plant located near Bitumount. The emission sources from the facility include a sulphur recovery plant and tail gas incinerator, the sulphuric acid plant, and various secondary sources (i.e., heaters, boilers, dryers and turbines).

Table B2-4 summarizes and compares the emissions from these industrial sources. The emission estimates are provided from a combination of existing approvals, existing operations, preliminary engineering design estimates and extrapolation of existing data. Emissions from these sources, however, are much smaller than those associated with the Suncor and Syncrude operations. The emissions for these sources, unlike the others, are expressed on a "stream day (s/d)" basis instead of a "calendar day (c/d)" basis.

Table B2-4 Summary of Baseline Emissions from Other Existing or Approved Industrial Projects

Source	Emission Rates [a] - (t/cd)					
	SO_2	NO_x	CO	PM[b]	VOC	TRS
Other estimates						
Northstar - Dover SAGD	-	0.2	0.10	0.0	0.004	n/a
Northlands Forest Products	0.02	0.2	25.0	0.2	2.1	n/a
Fort McMurray Hospital	0.0005	0.001	0.006	0.003	-	-
Syncrude - Aurora[c]	0.3	7.6	1.8	0.3	3.40	0.011
SOLV-EX - Bitumount	3.6	0.7	0.2	0.40	0.02	n/a
Total	**3.9**	**8.7**	**27.1**	**0.9**	**5.5**	**0.01**

n/a Data not available.
\- Not a source of this emission.
(a) Assumed as PM_{10}.
(b) For one train only.

B2.1.1.4 Transportation and Residential Source Emissions

There are a number of non-industrial sources of NO_x, CO and CO_2 emissions in the Athabasca oil sands region that result from combustion sources. Specifically, these sources include the following:

- Highway 63 traffic (gasoline and diesel fueled vehicles);
- local community traffic (gasoline and diesel fueled vehicles);
- natural gas combustion for residential and commercial space heating, cooking and water heating;
- residential wood combustion (fireplace or wood stove); and
- natural sources.

The two primary communities are Fort McMurray and Fort McKay, with respective populations of 38,700 and 330. The number of occupied residences are 12,955 and 110, respectively. For the most part, natural gas is used as the primary heating source in both communities. Table B2-5 summarizes the emissions from these other sources.

Table B2-5 Summary of Baseline Emissions From Transportation and Residential Sources

Source	Emission Rates (t/cd)				
	SO_2	NO_x	CO	PM[a]	VOC[b]
Highway	0.05	0.35	1.19	0.32	0.21
Fort McMurray					
Traffic	0.136	0.900	3.408	0.919	1.415
Residential Natural Gas	0.002	0.099	0.137	0.017	0.038
Residential Wood	0.003	0.018	1.713	0.233	1.279
Fort McKay					
Traffic	<0.001	<0.001	0.005	<0.001	<0.001
Residential Natural Gas	<0.001	0.007	0.003	<0.001	0.001
Residential Wood	<0.001	<0.001	0.014	0.002	0.01
Total	**0.191**	**1.374**	**6.47**	**1.49**	**2.95**

(a) Assumed as PM_{10}.
(b) Assume THC equals VOC.

B2.1.1.5 Summary of Baseline Emissions

Table B2-6 summarizes the emissions from Suncor, Syncrude, other industries, transportation and residential sources in the oil sands region. While the results in the table indicate the two oil sands operations are the major sources of emissions to the atmosphere, there are other smaller sources that can also influence air quality. This is especially true for those smaller sources which originate from the communities.

Table B2-6 Summary of Baseline Emissions in the Athabasca Oil Sands Region

	Emission Rates (t/cd)					
	SO_2	NO_x	CO	PM[a]	VOC	TRS
Suncor	65.3	47.7	33.5	1.7	130.2	1.5
Syncrude	209.0	44.4	53.6	5.4	43.8	2.3
Other Industries	3.9	8.7	27.1	0.9	5.5	0.01
Transportation and Residential	0.2	1.37	6.5	1.5	2.95	-
Total	**278.4**	**102.17**	**120.7**	**9.5**	**182.49**	**3.8**

\- Not a source of this emission.
(a) Assumed as PM_{10}.

B2.1.2 Air Quality Baseline Observations

The ambient air quality monitoring program in the Athabasca oil sands region is comprised of continuous monitoring, passive monitoring, precipitation monitoring and specialized studies. Up until very recently, Suncor, Syncrude and Alberta Environmental Protection (AEP) collectively maintained 12 continuous ambient air quality stations and 76 passive monitoring stations. AEP and Environment Canada collectively maintain 8 precipitation monitoring stations in northern Alberta and Saskatchewan. These monitoring programs are further supplemented by short-term specialized studies that have focused on characterizing ambient hydrocarbon and reduced sulphur species concentrations, odours and deposition.

Additional information on air quality in the oil sands region is provided in the EIA key reference report "Technical Reference for Meteorology, Emissions and Ambient Air Quality in the Oil Sands Region" (Golder and Conor Pacific 1998).

B2.1.2.1 Continuous Monitoring Summary

Five years of continuous ambient air quality data (1993 to 1997) from the Suncor, Syncrude and Alberta Environmental Protection monitoring stations were summarized and compared to air quality guidelines (Figure B2-1 and Table B2-7).

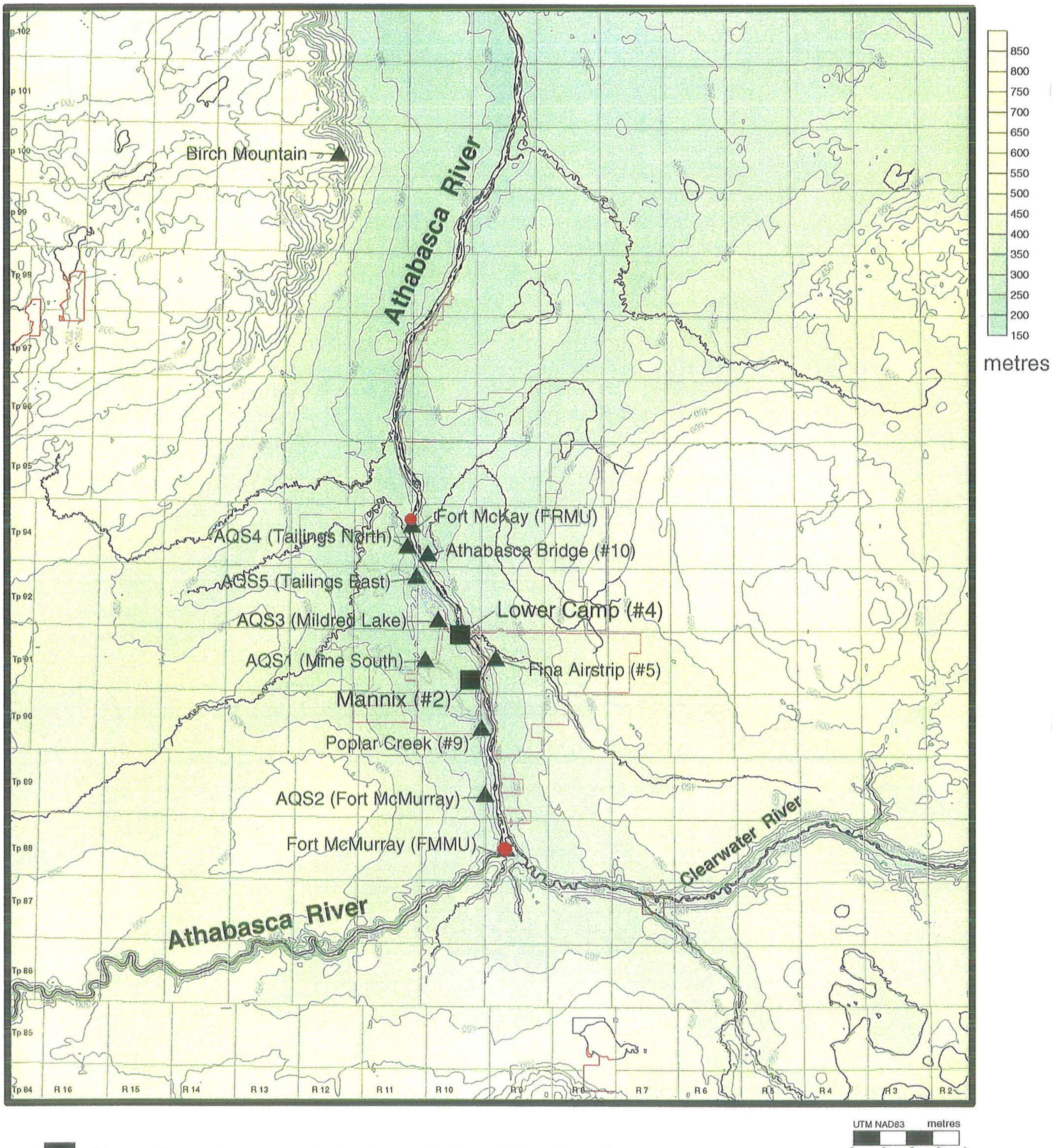
Table B2-7 Summary of Parameters Currently Monitored on a Continuous Basis

Operation	Station	U	θ	SO_2	H_2S	NO_x	THC	O_3	CO
Suncor	Mannix (#2)	✓	✓	✓	✓	×	×	×	×
	Lower Camp (#4)	✓	✓	✓	✓	×	×	×	×
	Fina Airstrip (#5)	✓	✓	✓	×	×	×	×	×
	Poplar Creek (#9)	✓	✓	✓	✓	×	✓	×	×
	Athabasca (#10)	✓	✓	✓	✓	×	✓	×	×
Syncrude	AQS1 (Mine South)	✓	✓	✓	✓	×	×	×	×
	AQS2 (Fort McMurray)	✓	✓	✓	✓	×	✓	×	×
	AQS3 (Mildred Lake)	✓	✓	✓	✓	×	×	×	×
	AQS4 (Tailings North)	✓	✓	✓	✓	✓	✓	×	×
	AQS5 (Tailings East)	✓	✓	✓	✓	×	×	×	×
AEP	FMMU (Fort McMurray)	✓	✓	✓	✓	✓	✓	✓	✓
	FRMU (Fort McKay)	✓	✓	✓	✓	×	✓	×	×

NOTE:
✓ = currently being monitored
× = not being monitored
U = wind speed
θ = wind direction
AEP = Alberta Environmental Protection
CO = carbon monoxide
H_2S = hydrogen sulphide
NO_x = oxides of nitrogen
THC= total hydrocarbons
O_3 = ozone
SO_2 = sulphur dioxide

Sulphur Dioxide (SO_2) Concentrations

Concentrations of SO_2 in excess of the federal acceptable objectives level of 0.34 ppm (900 $\mu g/m^3$) have been observed at four of the five Suncor stations in the five year review period. Since the beginning of 1996,



■ Air quality and meteorological monitoring station location

▲ Air quality monitoring station location

● Major city

Figure B2-1 Locations of Continuous Air Quality Monitoring Stations

readings greater than 0.34 ppm have occurred only at the Fina and Poplar Creek sites (Table B2-8).

While exceedances of the Alberta Guideline of 0.17 ppm (450 μg/m³) have been observed at least once at all of the monitoring sites, these exceedances are most frequently observed at the Fina and Mannix stations and least frequently at the AQS5 (Syncrude Tailings East) and FMMU (Fort McMurray) stations (Table B2-9). The total number of exceedances has been decreasing since 1994 and in 1997 the overall network recorded the fewest exceedances in the five year study period.

Table B2-8 Number of Hourly SO_2 Concentrations Greater Than 0.34 ppm (900 μg/m³)

Station	1993	1994	1995	1996	1997	Total	Average
Mannix (#2)	0	3	13	0	0	16	3
Lower Camp (#4)	0	0	5	0	0	5	1.4
Fina (#5)	3	0	3	3	0	9	1.2
Poplar Creek (#9)	0	1	0	0	2	3	0.6
Athabasca (#10)	0	0	0	0	0	0	0
AQS1 (Mine South)	0	2	0	0	0	2	0.4
AQS2 (Fort McMurray)	0	0	0	0	0	0	0
AQS3 (Mildred Lake)	0	1	0	0	0	1	0.2
AQS4 (Tailing North)	0	0	0	0	0	0	0
AQS5 (Tailing East)	0	0	0	0	0	0	0
Fort McMurray (FMMU)	0	0	0	0	0	0	0
Fort McKay (FRMU)	0	0	0	0	0	0	0
Total	**3**	**7**	**21**	**3**	**2**	**36**	**7**

Table B2-9 Number of Hourly SO_2 Concentrations Greater Than 0.17 ppm (450 μg/m³)

Station	1993	1994	1995	1996	1997	Total	Average
Mannix (#2)	9	21	20	10	1	61	12.2
Lower Camp (#4)	3	6	5	3	0	17	3.4
Fina (#5)	14	16	21	11	3	65	13.0
Poplar Creek (#9)	0	4	4	3	0	11	2.2
Athabasca (#10)	2	6	2	0	0	10	2.0
AQS1 (Mine South)	3	7	3	1	0	14	2.8
AQS2 (Fort McMurray)	0	5	6	0	0	11	2.2
AQS3 (Mildred Lake)	4	8	5	2	0	19	3.8
AQS4 (Tailing North)	0	3	3	2	0	8	1.6
AQS5 (Tailing East)	0	1	0	2	0	3	0.6
Fort McMurray (FMMU)	0	0	1	0	0	1	0.2
Fort McKay (FRMU)	1	2	2	0	0	5	1.0
Total	**36**	**79**	**72**	**34**	**4**	**225**	**45**

The ambient SO_2 concentrations observed at Suncor's monitoring stations have exceeded the daily Alberta guideline of 150 $\mu g/m^3$ (0.06 ppm) either once or twice per year except in 1997 when there were no exceedances. The average number of combined daily exceedances over the 1993 to 1997 period is 1.4 days per year.

Background annual values of SO_2 are expected to be in the 1 to 4 $\mu g/m^3$ range (summer and winter, respectively). This value is based on extrapolating measurements from Cree Lake, Saskatchewan and Vegreville, Alberta to the region. The compliance monitoring program conducted by Suncor, Syncrude and AEP does not allow meaningful annual or background values to be calculated.

Hydrogen Sulphide (H_2S) Concentrations

Concentrations of H_2S in excess of the Alberta guideline of 0.10 ppm (14 $\mu g/m^3$) have been observed at all locations. The most frequent exceedances have been observed at the Mannix station (Table B2-10). Exceedances have been decreasing with 1997 measuring the lowest number in the five year period.

The H_2S concentrations above the Alberta Guideline were mainly observed during the summer months and the month of January.

Table B2-10 Number of Hourly H_2S Concentrations Greater Than 0.01 ppm (14 $\mu g/m^3$)

Station	1993	1994	1995	1996	1997	Total	Average
Mannix (#2)	24	42	10	16	6	98	19.6
Lower Camp (#4)	2	2	4	12	4	24	4.8
Poplar Creek (#9)	0	0	4	0	0	4	0.8
Athabasca (#10)	1	2	2	2	0	7	1.4
AQS1 (Mine South)	4	10	0	1	0	15	3.0
AQS2 (Fort McMurray)	3	13	0	0	0	16	3.2
AQS3 (Mildred Lake)	3	1	0	3	0	7	1.4
AQS4 (Tailing North)	5	6	2	0	0	13	2.6
AQS5 (Tailing East)	0	0	2	0	0	2	0.4
Fort McMurray (FMMU)	0	5	0	0	0	5	1.0
Fort McKay (FRMU)	0	0	2	1	0	3	0.6
Total	**42**	**81**	**26**	**35**	**10**	**194**	**39**

Oxides of Nitrogen (NO_x) Concentrations

The continuous monitoring for NO_x occurs at two stations within the region, AQS4 (Tailings North) and FMMU (Fort McMurray). The AQS4 station reports NO_x while the FMMU Station reports NO_x, NO and NO_2. The Alberta Guideline for NO_2 is 400 µg/m^3 (0.21 ppm).

A review of the NO_2/NO_x ratio indicated a dependence on the NO_x concentrations. For small NO_x concentrations (that is, less than 0.05 ppm), the NO_2 concentration is typically 55 to 75% of the NO_x value. For larger NO_x concentrations (that is, greater than 400 µg/m^3), the NO_2 concentration is typically 20% of the NO_x value.

Two hourly NO_x values at AQS4 were observed to exceed 400 µg/m^3 (0.21 ppm). Both of these readings occurred in 1993 and there have been no values or exceedance of the NO_2 guideline since 1993 at this location.

During the five year assessment period for the Fort McMurray station there has been, on a yearly average, four NO_x readings that have exceeded 400 µg/m^3 (0.21 ppm).

Ozone (O_3) Concentrations

Ozone concentrations are only measured at FMMU station in Fort McMurray. Exceedances of the hourly Alberta guideline of 160 µg/m^3 (0.08 ppm) are relatively infrequent during the five year review period and occurred only in 1993. There have been no exceedances since 1993. Exceedances of the daily Alberta guideline of 50 µg/m^3 (0.025 ppm) occur on average about 118 days per year (Table B2-11).

High ozone concentrations have been observed in rural areas of Alberta (Angle and Sandhu 1986, Peake and Fong 1990). Exceedances of the guideline occur more frequently in rural than in urban areas such as Calgary and Edmonton. Exceedances of the daily guidelines have been observed 50 to 90% of the time in rural Alberta areas compared with only 10 to 40% of the time in urban areas (Angle and Sandhu 1989).

Table B2-11 Summary of Hourly and Daily O_3 Concentrations Observed at Fort McMurray

Station	1993	1994	1995	1996	1997
Hourly Statistics					
Mean (ppb)	22	24	25	18	18
Median (ppb)	21	22	22	17	n/a
Maximum (ppb)	91	77	71	58	61
N ≥ 80 ppb (h/y)	4	0	0	0	0
Daily Statistics					
Mean (ppb)	22	24	23	18	18
Median (ppb)	21	23	22	17	n/a
Maximum (ppb)	54	58	68	44	n/a
N ≥ 25 (ppb) (d/y)	127	153	135	93	81

h/y = Hours per year.
d/y = Days per year.
n/a = not available

Carbon Monoxide (CO) Concentrations

Carbon monoxide concentrations are only measured at FMMU station in Fort McMurray. All observed CO one-hour average values have been within the Alberta guideline of 15,000 μg/m^3 (13 ppm).

Total Hydrocarbons (THC) Concentrations

Total hydrocarbons are measured at six locations. While median THC concentrations are typically in the 1.6 to 1.9 ppm range, maximum values in excess of 30 ppm have been reported in Athabasca River valley locations (that is, Poplar Creek and Athabasca) (Table B2-12). These values suggest channeling by the valley of emissions from low level fugitive hydrocarbon sources. Further along the valley, the maximum observed values were less, with a maximum observed value at Fort McMurray of 2,492 μg/m^3 (3.8 ppm) and at Fort McKay of 5,442 μg/m^3 (8.3 ppm).

Table B2-12 Median and Maximum THC Concentrations (ppm)

		Poplar Creek (#9)	Athabasca (#10)	AQS2 (Fort McMurray)	AQS4 (Tailings North)	Fort McMurray (FMMU)	Fort McKay (FRMU)
Median	1993	1.7	1.9	1.6	1.8	2.0	1.8
	1994	1.5	1.6	1.4	1.5	2.2	1.7
	1995	1.7	n/a[(a)]	1.6	1.7	2.0	1.6
	1996	1.7	n/a[(a)]	2.0	1.7	2.2	1.8
	1997	1.7	n/a[(a)]	n/a[(a)]	1.9	2.1	1.6
Maximum	1993	51.4	35.0	3.3	5.7	3.2	3.6
	1994	11.1	13.7	4.6	4.3	3.7	3.3
	1995	35.0	n/a[(a)]	6.1	14.6	3.2	8.3
	1996	35.0	n/a[(a)]	3.4	16.2	3.8	3.9
	1997	35.0	n/a[(a)]	n/a[(a)]	7.5	3.2	4.7

(a) No data.
n/a Data not available.`

Suncor conducts fugitive emission surveys each calendar year for compounds such as THC. A condition of the latest approval requires Suncor, commencing in 1997, to monitor fugitive volatile organic compounds (VOC) according with the Canadian Council of Ministers of Environment (CCME) fugitive VOC emission code. THC results during the five year assessment period are only available for 1993 and 1994 and maximum one minute values were 40,700 μg/m^3 (62 ppm) and 55,700 μg/m^3 (85 ppm) respectively. No VOC readings were available for review.

Non-methane hydrocarbons (NMHC) were measured at the SOLV-EX background site. On a monthly basis, the maximum values ranged from 3,500 μg/m^3 (5.3 ppm) to 8,700 μg/m^3 (13.3 ppm). However, in February and March 1997, the peak values were 47,750 (73 ppm) and 14,400 μg/m^3 (22 ppm), respectively.

Particulates

Total suspended particulate matter (TSP or PM) is measured at AQS2 (Fort McMurray) and AQS4 (Tailings North). Only 1993 and 1994 data were available for review during the five year period. The annual geometric mean at both sites of between 9.4 and 16.6 $\mu g/m^3$ is less than the 60 $\mu g/m^3$ Alberta guideline. There has been one exceedance, at AQS4, of the daily guideline of 100 $\mu g/m^3$.

AEP commenced measurement of $PM_{2.5}$ in 1997 at the Fort McMurray site (FMMU). The maximum hourly observed value was 105.5 $\mu g/m^3$ and this reading exceeds the U.S. EPA 24-hour guideline of 65 $\mu g/m^3$. The annual average of 6.50 $\mu g/m^3$ is less than the U.S. EPA annual guideline of 15 $\mu g/m^3$.

B2.1.2.2 Passive Monitoring Summary

The locations of the passive samplers are biased on a north/south axis parallel to the Athabasca River valley. Maximum total sulphation and hydrogen sulphide values occur in the vicinity of each plant and in the river valley near Lower Camp.

A review of selected Suncor, Syncrude and AEP passive samplers for total sulphation and hydrogen sulphide that are closely located indicated biases that may be due to either the sampling approach and/or the analytical approach. Adjustment factors were applied to normalize the data prior to analysis.

B2.1.2.3 Summary of Acid Forming Compounds

Precipitation Chemistry and Wet Potential Acid Input (PAI_{wet})

The average acidity (pH) of the precipitation observed in Fort McMurray in the 1993 to 1996 period (1997 data not available) is 4.8. This is more acidic than other locations measured in northern Alberta or Saskatchewan (pH = 4.9 to 5.3).

The level of acidification (PAI_{wet}) caused by rain depends on a balance between the amount of acid forming compounds (e.g., SO_4^{-2}, NO_3^- and NH_4^+) and the available cations (e.g., Mg^{+2}, Ca^{+2} and K^+) in the precipitation. The measure of this acidification preferred by AEP is the PAI approach, which is calculated in the following manner:

$$PAI_{wet}=([SO_4^{-2}]+[NO_3^-]+[NH_4^+])-([Ca^{+2}]+[Mg^{+2}]+[K^+])$$

The PAI takes into account sulphur and nitrogen species and all values are in units of "keq/ha/y" (1 keq = 1 kmol H^+).

The annual average wet potential acidic input (PAI_{wet}) observed in Fort McMurray is 0.08 keq/ha/y. Regional data (Table B2-13) indicates a range of 0.00 to +0.09 keq/ha/y and an average background level of PAI_{wet} of 0.040 keq/ha/y.

Table B2-13 Annual Average Wet Potential Acidic Input Observed at Selected Precipitation Stations, keq/ha/y

Site	1993	1994	1995	1996	Average
Beaverlodge	0.05	0.09	0.07	0.06	0.07
Cold Lake	-	0.07	0.05	0.09	0.07
Fort Chipewyan	0.00	-	0.01	-	0.01
Fort Vermilion	0.02	0.03	0.00	-	0.02
High Prairie	0.03	-	-	-	0.03
Vegreville	-	0.11	0.05	0.10	0.09
Cree Lake	0.00	0.00	0.00	0.00	0.00
Snare Rapids	0.03	0.03	0.03	0.05	0.04
Average	**0.03**	**0.05**	**0.04**	**0.06**	**0.04**
Fort McMurray	0.08	0.06	0.10	0.09	0.08

Dry Deposition and Potential Acid Input (PAI_{dry})

The contribution of dry deposition mechanisms of acidification is calculated in a similar manner to that of wet deposition. The average concentration of acid forming compounds (e.g., SO_2, SO_4^{-2}, HNO_3, NO_3^- and NH_4^+) and the available cations (e.g., Mg^{+2}, Ca^{+2} and K^+) are converted into dry deposition rates by multiplying by an appropriate deposition velocity. The dry component of the PAI (in hydrogen equivalents) can be given by:

$$PAI_{dry}=([SO_2]+[SO_4^{-2}]+[HNO_3]+[NO_3^-]+[NH_4^+])-([Ca^{+2}]+[Mg^{+2}]+[K^+])$$

The calculation of the annual dry PAI required the estimation of dry deposition velocities (see the EIA key reference report "Technical Reference for Meteorology, Emissions and Ambient Air Quality in the Oil Sands Region" (Golder and Conor Pacific 1998). The estimated dry PAI contribution is 0.06 keq/ha/y.

Total Potential Acid Input (PAI)

The total PAI can be calculated for both the current measured conditions at Fort McMurray and the background air quality in the region. This is done by using the appropriate wet PAI and the dry PAI of 0.06 keq/ha/y.

The total current baseline PAI using the measured Fort McMurray data is 0.14 keq/ha/y. The total background PAI for the background air quality in the region is estimated at 0.10 keq/ha/y.

Alberta has selected an interim critical load of 0.25 keq/ha/y for highly sensitive soils following recent European experience. In order to evaluate this selection and compare it with other options, Alberta Environmental Protection and Environment Canada have developed a regional model based on 1990 provincial emission rates (Fox, McDonald and Cheng, Air and Waste Management 1998, in press). Their model results, based on 1990 emissions (i.e., significantly increased SO_2 emissions but reduced NO_x emissions from present emission rates in the oil sands region) have found "on the regional scale, effects of urbanization, power generation and transportation increases may overwhelm effects due to expansion in the oil sands region". Their sensitivity assessment indicates that doubling NO_x emissions and halving the SO_2 emissions would not increase PAI above 0.25 keq/ha/y in the oil sands region. Based on the modelling results, Fox et al. have concluded that the southern part of the province be more closely monitored than the northeast oil sands region

B2.1.2.4 Odour Assessment Studies

A review of the odour complaint information, collected in response to the initiation of a regional odour response protocol, indicates a reduction of both the frequency and magnitude of odour incidents over the 1993 to 1997 period (Table B2-14).

Table B2-14 Oil Sands Odour Complaints Received by Alberta Environmental Protection 1993 - 1997

Year	Fort McMurray Complaints/Incidents	Fort McKay Complaints/Incidents
1993	263/116	22/18
1994	102/59	11/11
1995	62/40	19/9
1996	43/28	15/12
1997	13/10	4/4

B2.1.2.5 Conclusions

The operation of the Suncor and Syncrude oil sands facilities has resulted in changes to the quality of the air downwind of the facilities. The major changes are associated with the emissions of SO_2 from the main stacks and from fugitive total hydrocarbon and total reduced sulphur emissions from lower level sources.

The historical SO_2 emissions from the main stacks have resulted in ambient SO_2 ground level concentrations that are in excess of ambient guidelines. These exceedances occurred most frequently in the vicinity of the Suncor site. The wet sulphate deposition is higher than in other regions in northern Alberta or Saskatchewan.

Fugitive hydrocarbon and reduced sulphur compound emissions from the oil sands plant area and associated ponds have historically contributed to off-site odours. There has been a significant reduction in odour complaints suggesting that the recently instituted mitigation measures are reducing odour emission sources.

B2.1.3 Meteorology

Suncor currently maintains a network of five ambient air quality monitoring stations in the vicinity of their operation. In the summer of 1993, the meteorological instrumentation at the Lower Camp and Mannix stations was upgraded to meet the needs associated with the Supplemental Emission Control (SEC) program as well as those of a regional-based meteorological monitoring program. The objective of the enhanced meteorological monitoring program is to gain a better understanding of plume-level air flow and dispersion characteristics in the vicinity of the Fort McMurray oil sands operations.

Meteorological data collected at the Mannix site is summarized and is used to assess the local and regional air quality changes. The Mannix station is comprised of a communications tower that is instrumented at the 20, 45 and 75 m levels; this analysis uses the data from the 75 m level. Validated data are available for the period November 1993 to October 1997.

Meteorology plays a significant role in the transport and dispersion of gaseous emissions vented to the atmosphere. Specific meteorological parameters of concern for air quality modelling of ground level concentrations and deposition include: wind direction, wind speed, mixing height and atmospheric turbulence.

Additional information on meteorological data collected by the Suncor enhanced monitoring program is provided in the EIA key reference report "Technical Reference for Meteorology, Emissions and Ambient Air Quality in the Oil Sands Region" (Golder and Conor Pacific 1998).

B2.1.3.1 Wind Related Observations

Wind direction and speed data can be displayed by plotting the frequency distribution as a "windrose". The windrose is comprised of bars whose length indicates the frequency the wind blows from a given direction. Wind direction information is displayed for the 16 points of a compass. The windrose also indicates the frequency of wind speed for each of the 16 compass points. Five different wind speed summaries are displayed.

- **Wind Direction.** Wind directions tend to be either from the south (S) to south-southeast (SSE) sector or from the north (N) to north-northeast

(NNE) sector (Figure B2-2). These two sectors represent the orientation of the Athabasca River Valley; and

- **Wind Speed.** The mean wind speed is 16.3 km/h. Wind speeds less than 11 km/h occur approximately 35% of the time. Mean wind speed is consistent throughout each season with summer having the lowest mean speed (15.6 km/h) and autumn having the highest mean speed (17.2 km/h).

B2.1.3.2 Atmospheric Stability Class Related Observations

Atmospheric stability can be viewed as a synonymous measure of the atmosphere's ability to disperse emissions. Atmospheric turbulence plays an important role in the dilution of a plume as it is transported by the wind. Turbulence can be generated by either thermal or mechanical mechanisms. Surface heating or cooling by radiation contributes to the generation or suppression of thermal turbulence, while high wind speeds contribute to the generation of mechanical turbulence.

The Pasquill-Gifford (PG) stability classification scheme is one classification of the atmosphere. The classification ranges from Unstable (Stability Classes A, B and C), Neutral (Stability Class D) to Stable (Stability Classes E and F). Unstable conditions are primarily associated with daytime heating conditions, which result in enhanced turbulence levels (enhanced dispersion). Stable conditions are associated primarily with nighttime cooling conditions, which result in suppressed turbulence levels (poorer dispersion). Neutral conditions are primarily associated with higher wind speeds or overcast conditions.

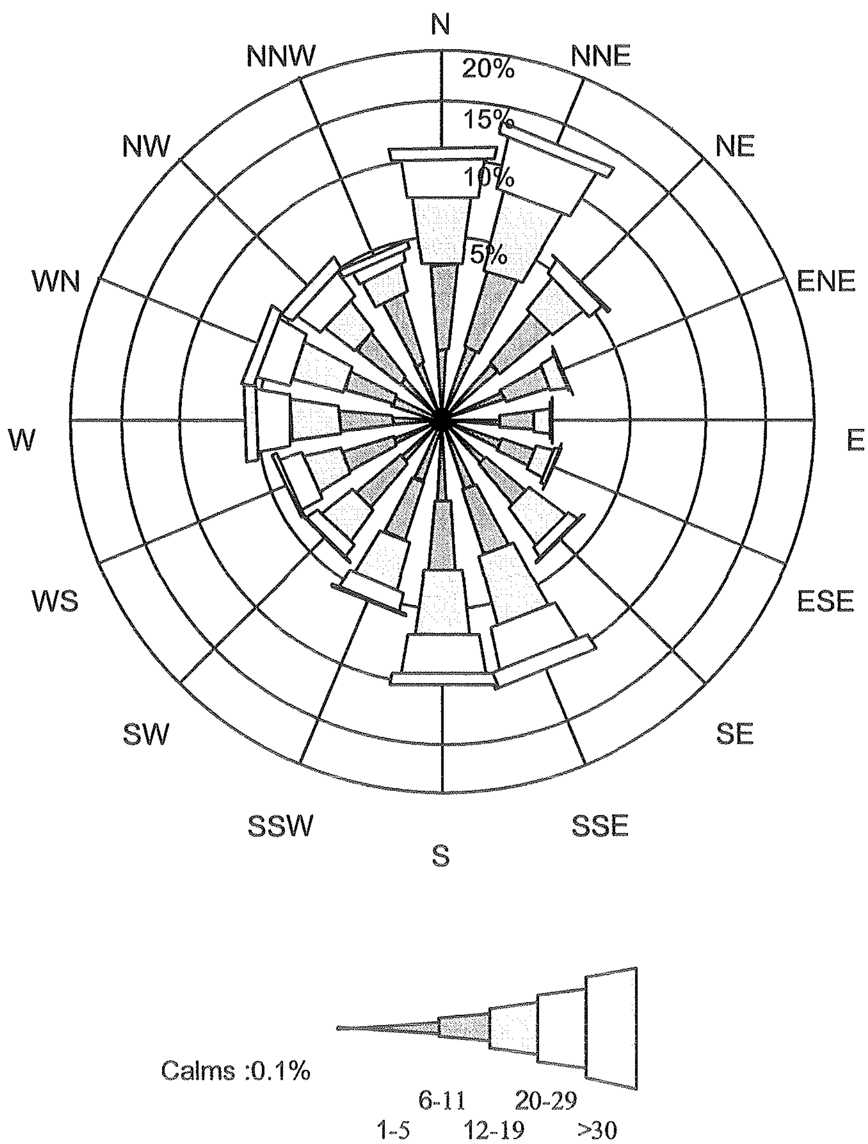
At the Mannix station the PG stability classes for the time period assessed indicates Neutral conditions 54.4 percent of the time, Stable conditions 23.6 percent of the time and Unstable conditions 21.8 percent of the time (Figure B2-3).

B2.1.3.3 Mixing Height Estimation

Mixing height is the depth of the atmospheric surface layer in which mixing of emissions occurs. In a well-mixed atmosphere, the temperature tends to decrease 1°C for every 100 m increase in height above the ground, which defines the norm. During the night, when the ground cools due to radiation heat loss, the temperature may increase above this norm with increasing height. This is referred to as a temperature inversion. The base of an inversion can be ground level or elevated.

The mean mixing height value at the Mannix station for the time period assessed is 650 m. There is a seasonally and monthly variation to the mixing height levels with the winter season having a lowest mixing height

Figure B2-2 Observed Wind Speeds and Directions at the Mannix Station (75 m Level)



mean of 418 m and the summer having the highest mixing height mean of 884 m. Monthly mixing height means, maximums and minimums are presented in Figure B2-4.

B2.1.3.4 Temperature Related Observations

Mean monthly surface temperatures at the Mannix station ranged from approximately -20°C in January to 18°C in July. Extreme temperatures (i.e., above 30°C and below -30°C) were observed in the months from May to September and November to March, respectively. The annual average temperature was approximately 0°C. Figure B2.1-5 summarizes the monthly temperatures during the assessment time period.

Figure B2-6 shows a map of the terrain on a regional scale. The dominant terrain features on a regional scale include:

- The Athabasca River Valley, which has a general north-south orientation in the vicinity of the oil sands plants;
- The Clearwater River Valley, which has a general east-west orientation;
- The highest elevations are associated with the Birch Mountains, which are approximately 50 km to 75 km to the northwest of the Suncor plant area. These mountains reach an elevation of 820 masl;
- Muskeg Mountain is about 40 km to the east of the plant area. At a distance of 55 km, this mountain reaches an elevation of 665 masl;
- The Thickwood Hills are about 20 km to the southwest of the plant area. At a distance of 25 km, these hills rise to an elevation of 515 masl; and
- Stoney Mountain is about 60 km to the south of the plant area. At a distance of 65 km, this mountain rises to an elevation of 760 masl.

For the purposes of comparison, the base elevation of the Suncor plant stacks is about 259 masl and the base elevation of the Syncrude plant stack is about 304 masl.

The roughness and smoothness of a vegetation canopy affect the wind speed and turbulence profiles. The oil sands area is located in the Boreal Forest Region which supports a variety of upland and lowland vegetation. The area is characterized by forest associations of white spruce, black spruce, jack pine, balsam fir, tamarack, aspen, balsam poplar and white birch.

Figure B2-3 Observed Pasquill-Gifford Stability Classifications

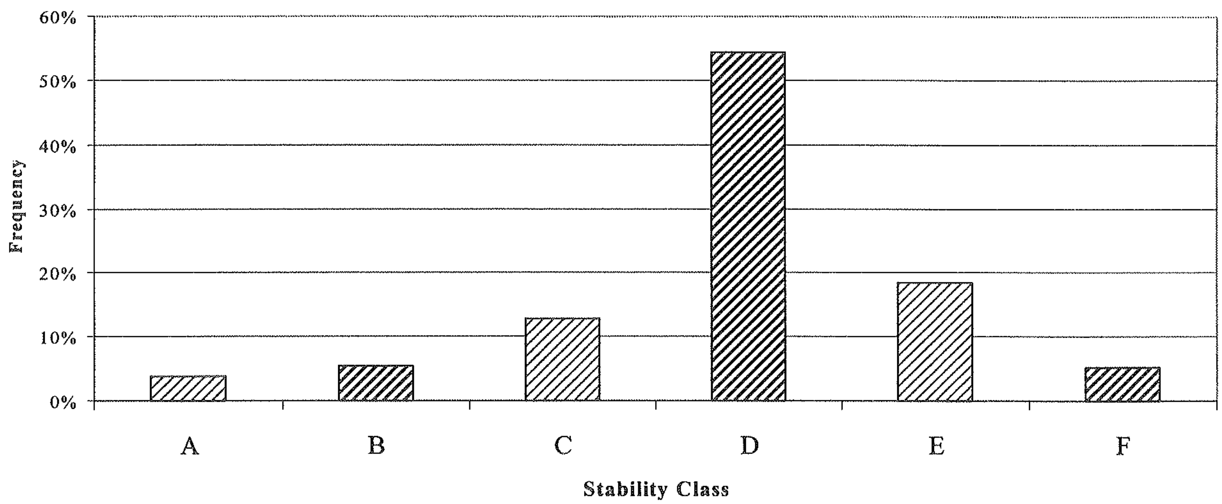


Figure B2-4 Summary of Monthly Mixing Heights Estimations

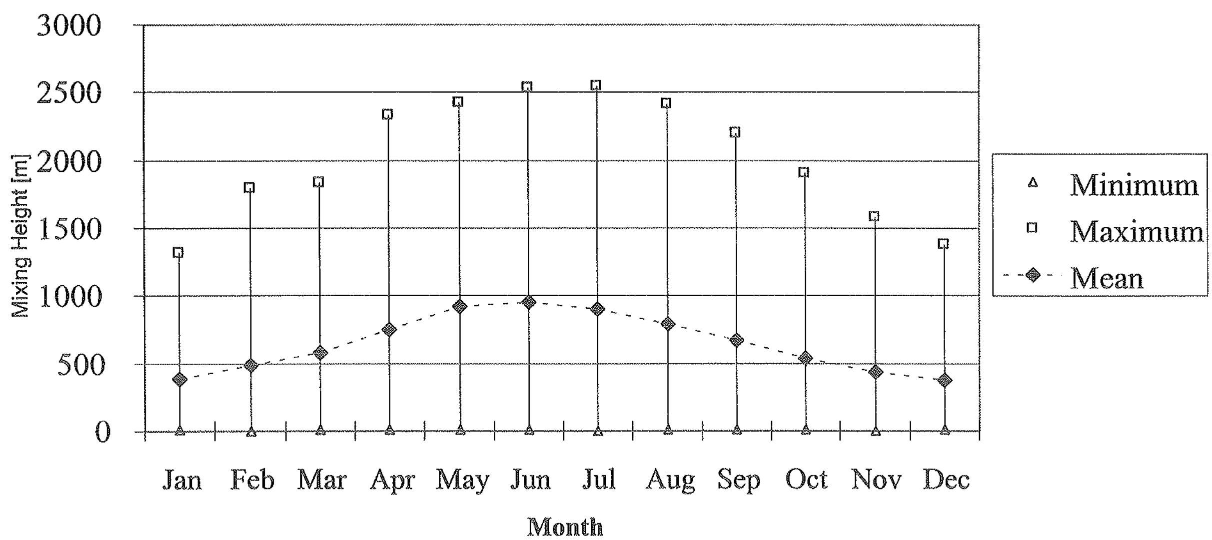
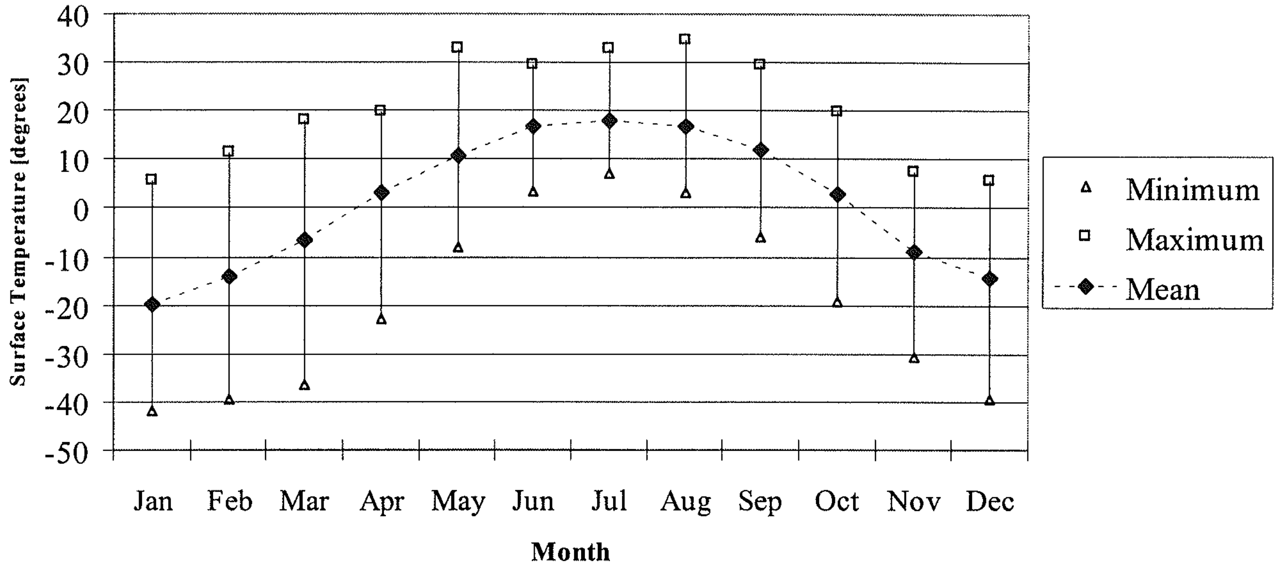


Figure B2-5 Summary of Observed Monthly Temperatures



B2.1.3.5 Precipitation

A review of the precipitation at the Mannix station for the assessment period indicates that approximately 60% of the precipitation falls in the summer months (June to August). In total, the mean precipitation was 455 mm/y.

B2.1.4 Topography

The path followed by a plume and the turbulence levels that result in the dilution of the plume can be affected by terrain features such as valleys and hills. The magnitude of the terrain effect is dependent on factors such as terrain elevation, the slope of the terrain feature, the relative height of the plume with respect to the terrain and the meteorological conditions.

Step-like terrain features can cause complex recirculating flow patterns in their immediate vicinity. A valley can generate its own air flow path independent of the regional winds above the valley. In some cases, the plume will flow either around or over hills or other dominant terrain features. In extreme cases, the plume may impinge directly on a hill in its path.

Mature tree heights range from 10 m for black spruce in low-lying areas to 30 m for jack pine located on sandy soils. Mature white spruce and aspen

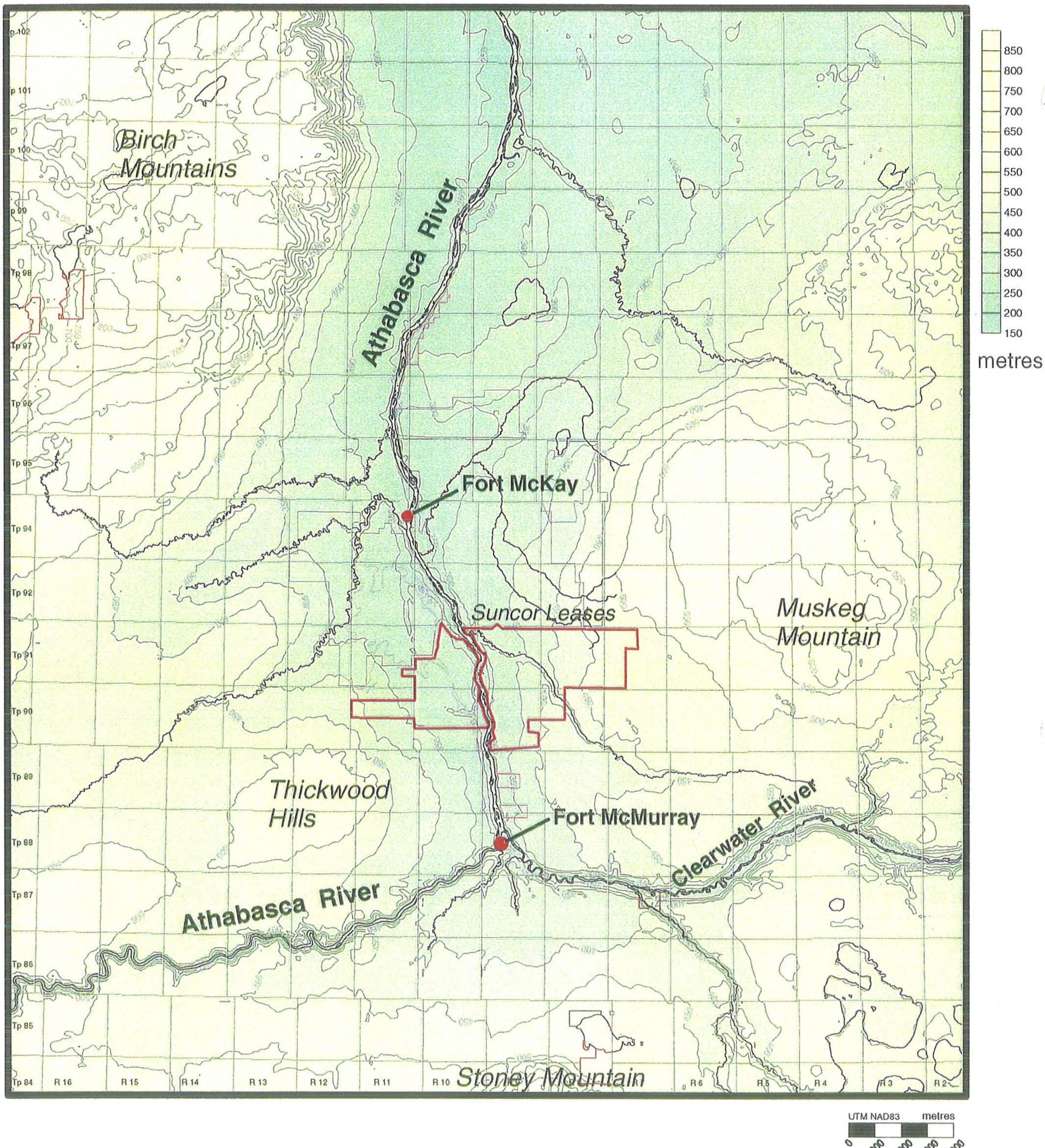


Figure B2-6 Terrain Over the RSA Used in the Air Quality Analysis

forest stands tend to be 25 and 15 m in height, respectively. Due to differing soil types and drainage patterns, the vegetation cover is non-uniform within the region.

B2.2 AMBIENT AIR QUALITY PREDICTIONS

B2.2.1 Model Approach and Limitations

The selection of an air quality model for use in evaluating the atmospheric emissions in the Athabasca oil sands region should be able to satisfy the following key conditions:

- evaluate the various source types present in the region;
- predict the necessary pollutant concentrations or deposition rates;
- have a technical basis which is scientifically sound, and is in keeping with the current understanding of the dispersion of contaminants in the atmosphere;
- have assumptions and formulations which are clearly set out, and have undergone rigorous independent scrutiny; and
- predictions made by the model should be consistent with local observations.

A series of dispersion models were considered for use in the assessment, ranging from the simpler SCREEN3 model (which requires minimal inputs to run), to the more elaborate CALPUFF and CALGRID models. Details of the model review are presented in Appendix III, Air Quality Modelling Documentation.

The SCREEN3 model is an easy-to-use Gaussian plume model that has built in meteorological conditions to aid in determining the worst case concentrations from individual sources. Due to the screening nature of the model, it is possible for SCREEN3 to significantly over predict the worst case concentrations under specific scenarios.

The Industrial Source Complex Short Term Model, Version 3 (ISCST3) is a steady-state Gaussian plume model, recommended by the USEPA for evaluating pollutant releases from a wide variety of sources associated with industrial source complexes. This model can account for: building downwash; area, line and volume sources; plume rise as a function of downwind distance; separation of point sources; and limited terrain adjustment. Local hourly meteorological data are required by the ISCST3 model.

The ISC3BE dispersion model is a modified version of the original ISCST3 model developed by BOVAR Environmental. The modifications made to the original model code were undertaken to enable the model to yield maximum predictions during the daylight hours and to predict similar numbers of exceedances as observed at the local monitoring stations (Conor Pacific, 1998). Although the tuning done to the ISC3BE model has not been subjected to the same rigorous independent review as the original code, the changes are designed to yield model predictions which correspond to the observations made at sampling locations along the Athabasca River valley. This model has been extensively used in previous air assessments in the oil sands region.

CALPUFF is a multi-layer, multi-species non-steady-state puff dispersion model which can simulate the effects of time- and space-varying meteorological conditions on pollutant transport, transformation, and removal. CALPUFF can use the three dimensional meteorological fields developed by CALMET or similar models, or simple, single station winds in a format consistent with the meteorological files used to drive the ISCST3 model. The use of single station wind files do not allow CALPUFF to take advantage of its capabilities to treat spatially-variable meteorological fields.

CALGRID is an Eulerian photochemical transport and dispersion model which includes modules for horizontal and vertical advection/diffusion, dry deposition, and a detailed photochemical mechanism. The full implementation of the CALPUFF modelling system, including a 3-dimensional wind field, a digital terrain model and more rigorous, hourly source and ambient air quality characterizations are required in order to run the CALGRID model. It is being considered for use in calculating ozone levels in the study area.

Dispersion models employ simplifying assumptions to describe the random processes associated with atmospheric motions and turbulence. These simplifying processes limit the capability of a model to replicate individual events. A model's predictive capability and strength lies in the capability to predict an average for a given set of meteorological conditions. Other factors that limit the capability of a model to predict values that match observations are limitations in the input data and information used by the model. The modelling does not account, for example, the hour-by-hour emission rates in the source strength and exit characteristics (such as temperature and velocity). The models do not replicate the special flow patterns and reduced dispersion within the Athabasca River valley, although the ISC3BE model has been tuned in an attempt to account for some of these effects.

Notwithstanding these limitations, the data used by the models and for the model evaluation did undergo a review in the key reference report (Appendix III) and were found to be sufficient for the modelling application. Specifically, the model predictions show good agreement with observations, both in terms of magnitude and diurnal trends.

Emission rates used in the tables in this report are presented as daily tonnes per calendar day (t/cd). All distances to readings are measured from the Suncor Incinerator Stack and are referred to as distances from Suncor.

B2.2.2 SO_2 Predicted Concentrations

There are numerous SO_2 emission sources associated with the baseline operations as summarized in Section B2.1 (e.g., Tables B2-1 to B2-6). The estimated total SO_2 emission rate in the oil sands region is 278.4 t/cd. Suncor emits an estimated 25% (65.3 t/cd) of the total SO_2 emissions to the atmosphere (Table B2-6). The major sources of SO_2 at Suncor are the Sulphur Incinerator stack (18.8 t/cd), the FGD stack (18.0 t/cd), the Powerhouse stack (13.1 t/cd) and continuous flaring (12.6 t/cd).

The predicted maximum hourly, daily and annual ground level ambient SO_2 concentrations resulting from emissions of all approved industrial sources and residential emissions in the oil sands region were estimated using the ISC3BE model. The CALPUFF model was used to address acidic deposition, hence annual SO_2 GLC are presented for comparison to the ISC3BE model. Emission rates used were the calendar day (total annual emissions divided by 365 days) for annual values and stream day (typical operating conditions which represent emissions for 95% of time) for hourly and daily values. Four years of observed meteorological measurements from the Suncor Mannix station (75 m level) were used in the modelling. These models provide an efficient means of estimating the predicted ambient SO_2 concentrations from all sources and provides an indication where maximum concentrations could occur.

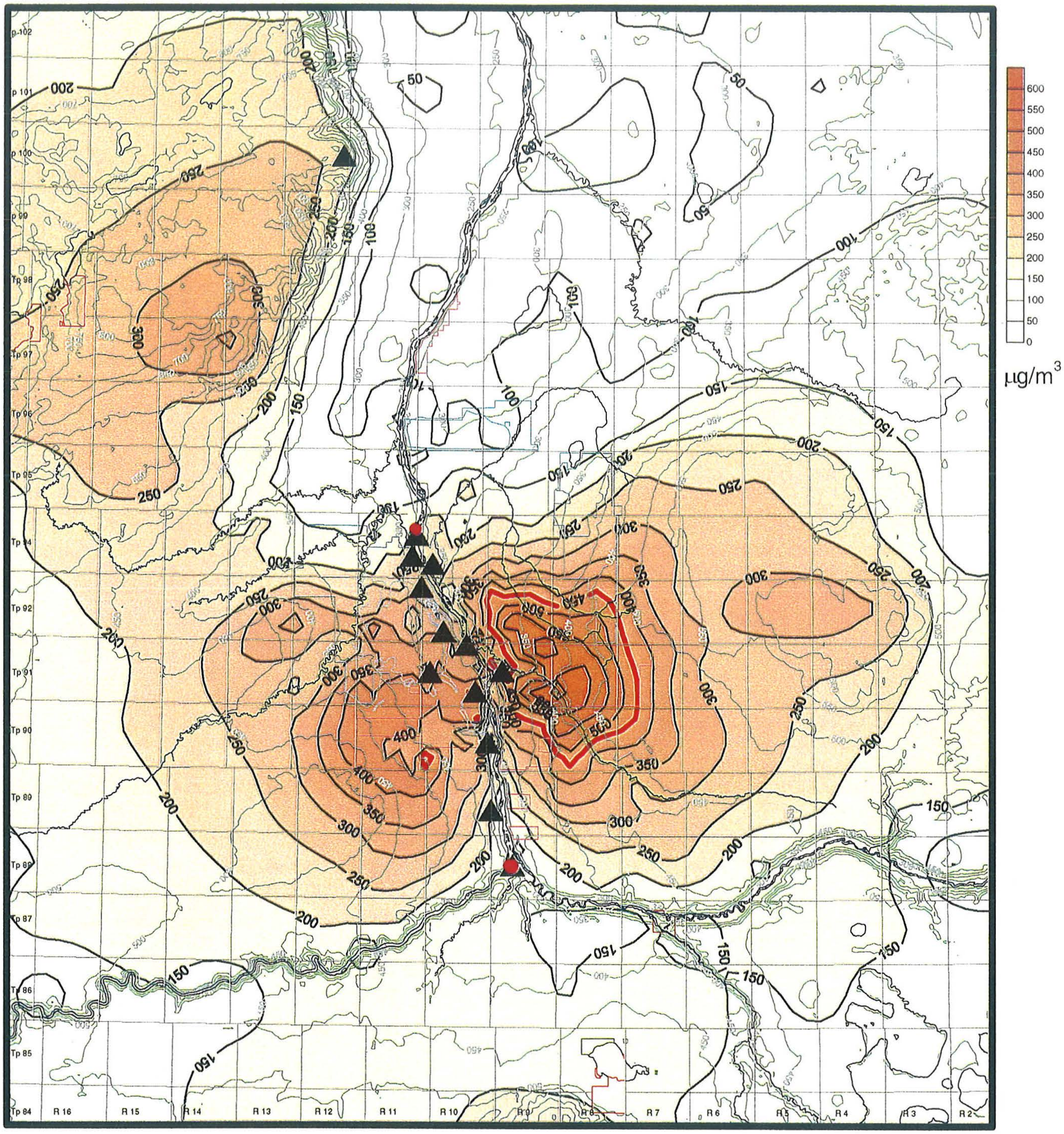
The modelling predictions for daily SO_2 emission rate cases are summarized in Table B2-15 for each model. The predicted ground level concentrations are mapped in Figures B2-7 to B2-12 and described below:

- Figures B2-7 show the maximum hourly average SO_2 ground level concentrations (GLC) associated with the Baseline operations for the ISC3BE model. An overall maximum hourly average SO_2 concentration, as determined by ISC3BE, of 648 $\mu g/m^3$ is predicted to occur at a location 13 km ESE of Suncor and is within the lease boundary (Figure B2-7). This maximum hourly average value exceeds the Alberta Ambient Air Quality Guideline (AAAQG) of 450 $\mu g/m^3$. The ISC3BE predictions indicate two areas that result in maximum hourly averages in excess of the AAAQG. A very small area, located SSW of Suncor and a large area located east of Suncor. The area ESE of Suncor encompasses approximately 33,310 ha of land of which about 90% are within the Suncor lease boundaries. The ISC3BE model predicts a maximum of 3 yearly exceedances of the Alberta hourly guideline. The location of the maximum number of exceedances is predicted to occur 12 km ESE of Suncor within the Suncor development area.

- Figure B2-8 shows the maximum daily average ground level SO_2 concentrations associated with Baseline operations for the ISC3BE model. An overall maximum daily average SO_2 concentration of 199 $\mu g/m^3$ is predicted to occur WNW of Suncor. This maximum average value exceeds the Alberta Guideline of 150 $\mu g/m^3$. In total, 358 ha are predicted to have the maximum average in excess of the Alberta daily guideline. The ISC3BE model predicts a maximum of 6 yearly exceedances of the Alberta daily guideline at a location 16 km WNW of Suncor.
- Figure B2-9 and Figure B2-10 show the annual average ground level concentration map for SO_2 for the ISC3BE and CALPUFF models, respectively. The maximum annual average concentration is 74 $\mu g/m^3$ and this predicted value is in excess of the AAAQG of 30 $\mu g/m^3$. The single area of high annual averages is WNW of the Suncor site and is approximately 356 ha in size. The corresponding values for the CALPUFF model indicate an overall maximum annual average SO_2 concentration of 79 $\mu g/m^3$, at the same location as predicted by the ISC3BE model (Figure B2-10). This maximum average value also exceeds the Alberta Guideline of 30 $\mu g/m^3$. The areal extent of the high annual average is 365 ha. There is good agreement between the two models particularly in relation to the areal extent of the predicted longer time averaged concentrations. The CALPUFF model suggests a slightly higher maximum value.

From the ISCBE model results, the location and areal extent of the maximum hourly GLC SO_2 concentration can be assessed. Figures B2-7 to B2-10 indicate that the predicted areas that exceed the daily and annual guidelines will occur WNW of Suncor; the area where the hourly guideline exceeds will occur mostly (90%) within the Suncor lease area. Repeating this analysis using the Federal Acceptable hourly and daily standards (900 $\mu g/m^3$ and 300 $\mu g/m^3$ respectively) indicates no predicted exceedances. However, there would remain an exceedance of the Federal annual value of 60 $\mu g/m^3$. The exceedence of the daily and annual guidelines is a result of the generalized characterization of the mine fleet (common to all developments) coupled with receptor points which happen to be located within the mine pit. These circumstances lead to unrealistically high long-term averages near the source, which have not been verified through monitoring data.

There are twelve air quality monitoring stations in the region which can be used to support the model predictions through direct observation of SO_2 air concentrations.



Sources	SO_2 [t/sd]
Suncor	
Powerhouse	0.3
FGD	18.9
Incinerator	19.1
Flaring	7.3
Other Sources, Suncor	3
Syncrude (total)	209
Other Emissions (total)	3.9
TOTAL	261.5

Model Description	
Development	Baseline
Model	ISC3BE (7BG)
SO_2 Guideline [$\mu g/m^3$]	450
Maximum [$\mu g/m^3$]	648
Exceedences / Year [#]	3

UTM NAD83 metres
0 5000 10000 15000 20000

Figure B2-7 Predicted Baseline SO_2 Maximum Hourly Average Ground Level Concentrations in the RSA using the ISCBE Model

Table B2-15 Maximum Predicted Ground Level Concentrations of SO_2 for Baseline Sources

Source	Hourly	Daily	Annual
Baseline Condition - ISC3BE[(b)]			
Maximum SO_2 Concentration ($\mu g/m^3$)	648	199	74
Location of Maximum Concentration (km)	13 ESE	18 WNW	15 WNW
Maximum Number of Exceedances[(a)]	3	6	1
Location of Maximum Exceedances (km)	12 ESE	16 WNW	n/a
Baseline Condition - CALPUFF[(c)]			
Maximum SO_2 Concentration ($\mu g/m^3$)	n/m	n/m	79
Location of Maximum Concentration (km)	n/m	n/m	15 WNW
Maximum Number of Exceedances[(a)]	n/m	n/m	1
Location of Maximum Exceedances (km)	n/m	n/m	15-WNW
SO_2, Alberta Guideline ($\mu g/m^3$)	450	150	30
SO_2, Federal Acceptable ($\mu g/m^3$)	900	300	60

n/m Not modelled.
(a) Exceeds SO_2 Alberta Guideline. Normalized for a 12-month period.
(b) Based on Stream day emission rates for hourly and daily; Calendar day for annual.
(c) Based on Calendar day emission rates.

Table B2-16 summarizes the observed and predicted maximum hourly GLC and the number of times the AAAQG have been exceeded in the past 4 years. For comparison, the Baseline assessment scenario results have also been appended to the table.

The modelling for the actual 1994 to 1997 SO_2 historical review was based on SO_2 emission rates listed in Table B2-2. The SO_2 emission sources at Suncor include the Powerhouse, Incinerator, continuous flaring and upgrading furnace stacks (containing mercaptans). Emission rates for the principal sources were based on stack tests reported in Suncor annual reports and other rates were prorated based on 1997 production levels and emissions. The Syncrude main stack emission rates were assumed constant over the 4 year assessment based on 1997 rates. Two scenarios were presented for 1997 based on whether the FGD was operational during its commissioning phase. Table B2-16 reflects a "Powerhouse Case" (worst case) that assumes the Powerhouse was 100% operational over the year, and a "FGD Case" (best case) that assumes the FGD was 100% operational throughout the year. The actual 1997 performance is expected to fall between these two extreme cases.

A review of the data presented in Table B2-16 indicates that, in general, the observed maximum hourly concentrations at the monitoring stations is under-predicted by the ISC3BE model. However, the maximum concentration in the RSA predicted by the ISC3BE model exceeds the observed maxima except at the Lower Camp and Fina stations in 1996. In these cases the observed concentrations are approximately 30% greater than the overall predicted concentrations. On average the ISC3BE model maximum GLC predictions are 80% of the observed concentrations at the

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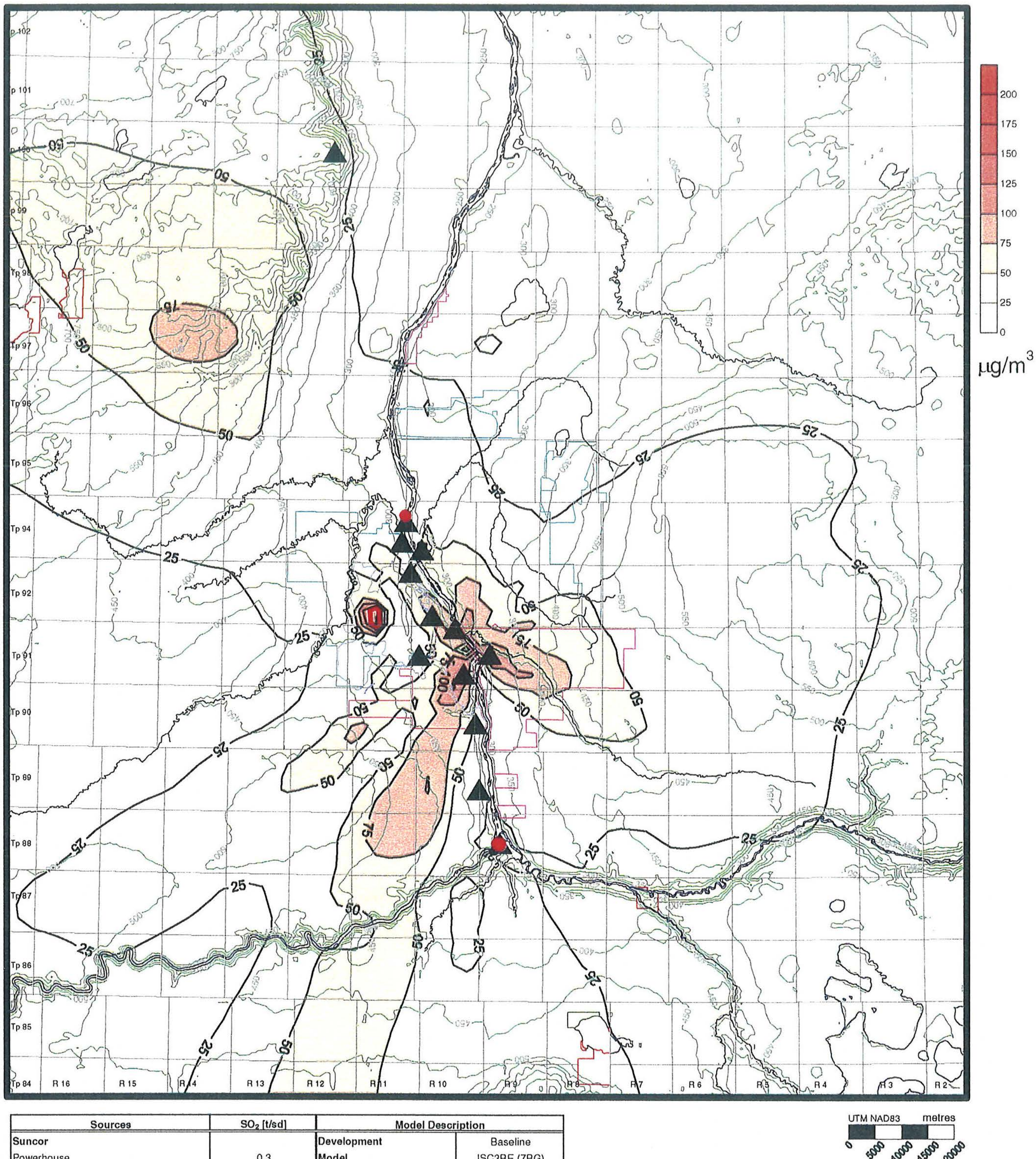
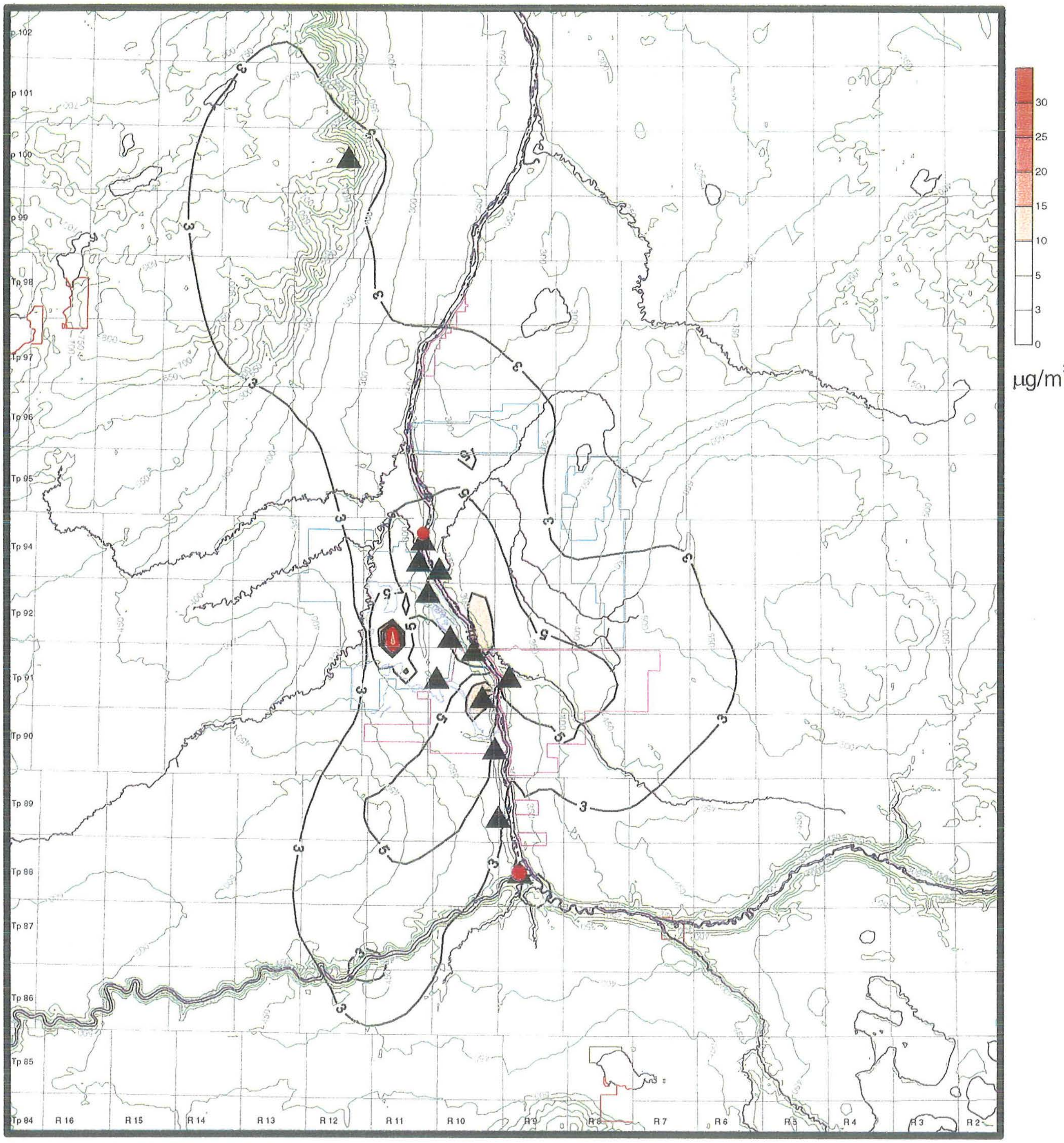
r:/1997/2200/972-2205/8600/8660/8662/ISCBE/figs/SO2SD_6D.srf



Sources	SO_2 [t/sd]
Suncor	
Powerhouse	0.3
FGD	18.9
Incinerator	19.1
Flaring	7.3
Other Sources, Suncor	3
Syncrude (total)	209
Other Emissions (total)	3.9
TOTAL	261.5

Model Description	
Development	Baseline
Model	ISC3BE (7BG)
SO_2 Guideline [µg/m^3]	150
Maximum [µg/m^3]	199
Exceedences / Year [#]	6

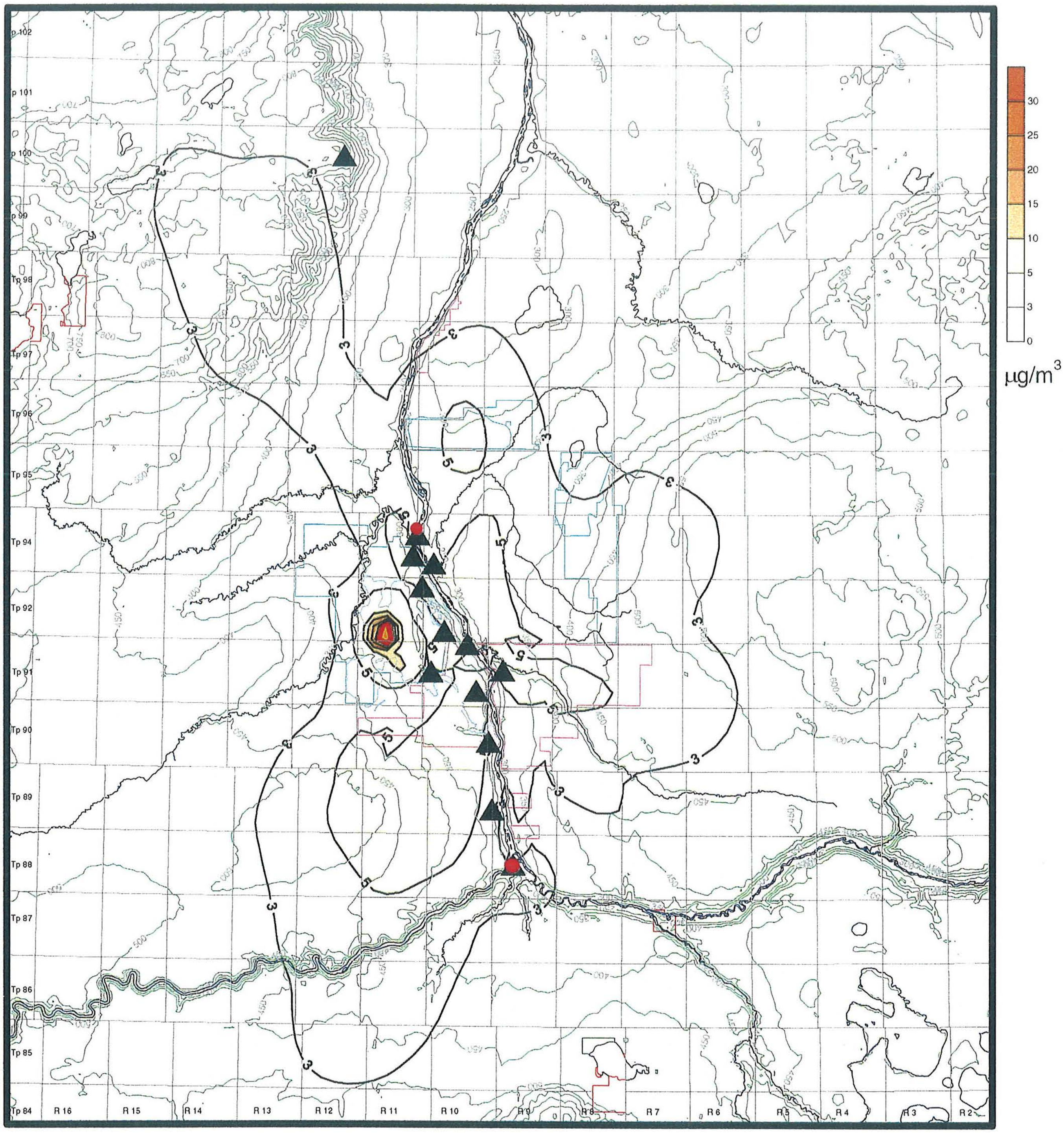
Figure B2-8 Predicted Baseline SO_2 Maximum Daily Average Ground Level Concentrations in the RSA using the ISCBE Model



Sources	SO_2 [t/cd]
Suncor	
Powerhouse	13.1
FGD	18
Incinerator	18.8
Flaring	12.6
Other Sources, Suncor	2.8
Syncrude (total)	209
Other Emissions (total)	3.9
TOTAL	278.2

Model Description	
Development	Baseline
Model	ISC3BE (7BG)
SO_2 Guideline [µg/m³]	30
Maximum [µg/m³]	74
Exceedences / Year [#]	1

Figure B2-9 Predicted Baseline SO_2 Maximum Annual Average Ground Level Concentrations in the RSA using the ISC3BE Model



Sources	SO₂ [t/cd]
Suncor	
Powerhouse	13.1
FGD	18
Incinerator	18.8
Flaring	12.6
Other Sources, Suncor	2.8
Syncrude (total)	209
Other Emissions (total)	3.9
TOTAL	278.2

Model Description	
Development	Baseline
Model	CALPUFF
SO_2 Guideline [µg/m³]	30
Maximum [µg/m³]	79
Exceedences / Year [#]	1

UTM NAD83 metres
0 5000 10000 15000 20000

Figure B2-10 Predicted Baseline SO_2 Maximum Annual Average Ground Level Concentrations in the RSA using the CALPUFF Model

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Table B2-16 Summary of Predicted and Observed Maximum Hourly Ground Level Concentrations of SO_2 From 1994 to 1997 Plus Baseline Sources Using ISC3BE Model

Source[a]		1994	1995	1996	1997[c]	Baseline
Maximum Predicted Concentration in RSA	Concentration (μg/m^3) [b]	1441	1272	959	1057/343	582
	Concentration (μg/m^3)	1642	1446	1246	1250/648	648
	Exceedances	80	43	32	49/2	3
Mannix Location	Predicted (μg/m^3)	707	695	569	588/447	524
	Observed (μg/m^3)	1101	1272	725	535	n/a
	Exceedances, Predicted	39	20	10	12/0	2
	Exceedances, Observed	21	20	10	1	n/a
Lower Camp Location	Predicted (μg/m^3)	544	438	346	390/394	370
	Observed (μg/m^3)	839	1363	1506	381	n/a
	Exceedances, Predicted	5	0	0	0	0
	Exceedances, Observed	6	5	3	0	n/a
Fina Location	Predicted (μg/m^3)	558	482	450	487/309	405
	Observed (μg/m^3)	736	1175	1583	630	n/a
	Exceedances, Predicted	22	4	1	4/0	0
	Exceedances, Observed	16	21	11	3	n/a
Poplar Creek Location	Predicted (μg/m^3)	400	418	324	278/169	252
	Observed (μg/m^3)	958	622	392	n/a	n/a
	Exceedances, Predicted	0	0	0	0	0
	Exceedances, Observed	4	4	3	0	n/a
Athabasca Bridge Location	Predicted (μg/m^3)	489	431	249	333/226	248
	Observed (μg/m^3)	802	630	450	392	n/a
	Exceedances, Predicted	1	0	0	0	0
	Exceedances, Observed	6	2	0	0	n/a
AQS1 Location	Predicted (μg/m^3)	563	489	517	469/325	361
	Observed (μg/m^3)	1,046	752	482	220	n/a
	Exceedances, Predicted	6	3	2	1/0	0
	Exceedances, Observed	7	3	1	0	n/a
AQS2 Location	Predicted (μg/m^3)	526	488	424	352/169	243
	Observed (μg/m^3)	545	625	418	289	n/a
	Exceedances, Predicted	3	2	0	0	0
	Exceedances, Observed	5	6	0	0	n/a
AQS3 Location	Predicted (μg/m^3)	769	658	486	622/410	412
	Observed (μg/m^3)	,072	675	559	442	n/a
	Exceedances, Predicted	12	16	3	5/0	0
	Exceedances, Observed	8	5	2	0	n/a
AQS4 Location	Predicted (μg/m^3)	433	338	294	354/190	222
		686	651	728	315	n/a
	Exceedances, Predicted	0	0	0	0	0
	Exceedances, Observed	3	3	2	0	n/a
AQS5 Location	Predicted (μg/m^3)	398	341	312	262/262	292
	Observed (μg/m^3)	469	386	588	357	n/a
	Exceedances, Predicted	0	0	0	0	0
	Exceedances, Observed	1	0	2	0	n/a
Fort McMurray (FMMU) Location	Predicted (μg/m^3)	396	368	253	227/138	199
	Observed (μg/m^3)	400	455	257	177	n/a
	Exceedances, Predicted	0	0	0	0	0
	Exceedances, Observed	0	1	0	0	n/a
Fort McKay (FRMU) Location	Predicted (μg/m^3)	416	357	193	313/191	201
	Observed (μg/m^3)	649	611	394	296	n/a
	Exceedances, Predicted	0	0	0	0	0
	Exceedances, Observed	2	2	0	0	n/a
Alberta Ambient Air Quality Guideline (μg/m^3)		**450**				
Federal Acceptable (μg/m^3)		**900**				

n/a Data not available.
[a] Using all potential sources indicated in Table B2-2 unless noted differently.
[b] Based on Powerhouse, Incinerator and Syncrude Main Stack.
[c] Concentrations provided are for the Powerhouse case / FGD case.

monitoring locations. The emission rates for the model predictions in Table B2-16 are based on stream day rates. Stream day rates reflect typical operation rates for each piece of equipment. This does not necessarily reflect hourly fluctuations in production levels or unpredictable upset conditions. These emission variabilities may however be captured in the ambient monitoring data, hence the maximum observed concentrations at the monitoring stations could exceed the maximum hourly predicted concentrations.

The predicted maximum SO_2 ground level concentrations, assuming all emission sources for 1994 through 1997 are presented in Figures B2-13 to B2-17. Figure B2-11, representing the 1994 concentrations, indicates a significant amount of the RSA would have had maximum values in excess of the Alberta guideline of 450 $\mu g/m^3$. In 1995 (Figure B2-12) and 1996 (Figure B2-13) the areal extent of the readings in excess of the guideline are reduced substantially. These plots tend to show the effect of the SO_2 reduction activities implemented by Suncor. The two figures for 1997 (Figures B2-14 and B2-15) indicate the extremes for the operation depending on whether the boiler emissions are going through the FGD unit or directly through the Powerhouse stack.

B2.2.3 NO_2 Predicted Concentrations

There are numerous NO_x emission sources associated with the baseline operations as summarized in Section B2.1 (e.g., Tables B2-1 to B2-6). The estimated total NO_x emission rate in the oil sands region is 102.2 t/cd. Suncor emits an estimated total of 47.7 t/cd which is approximately 45% of the total (Table B2-5). The major sources of NO_x at Suncor are the FGD stack (29.8 t/cd) and the mine fleet (11.3 t/cd).

The predicted maximum hourly, daily and annual ground level ambient NO_x and NO_2 concentrations resulting from emissions of all approved industrial sources and residential emissions in the oil sands region were estimated using the ISC3BE and CALPUFF models. Four years of observed meteorological measurements from the Suncor Mannix station (75 m level) were used in the modelling. These models provide an efficient means of estimating the predicted ambient NO_x/NO_2 concentrations from all sources and provides an indication where maximum concentrations could occur.

The conversion of NO_x to NO_2 has been estimated using onsite NO_2/NO_x observations from fleet emissions adjacent to one of Syncrude's operational mine pits. Conor Pacific (1998) has analyzed these data sets and have conservatively estimated the ratio as

$$\frac{NO_2}{NO_x} = 0.1\, NO_x^{-0.608}$$

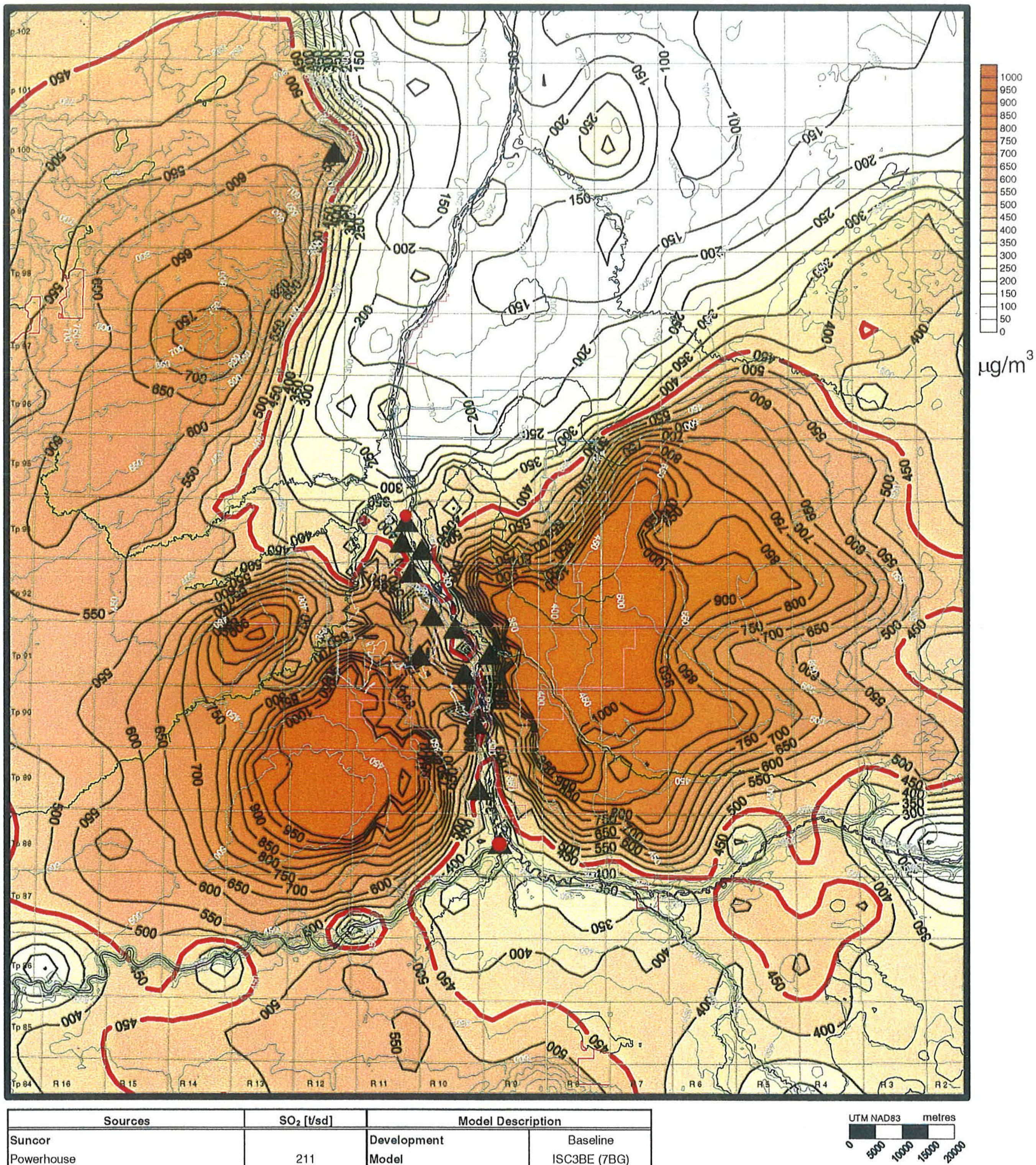
This equation is based on a power-law fit to the upper 99% of the NO_2/NO_x data (units are ppm). It has been applied to the averaged results as well as to the hourly predictions of NO_x made using the ISC3BE model. The application of this equation and the methodology had previously been discussed with AEP and Environment Canada during consultation meetings in the preparation of this EIA (10 March 1998 in AEP's office in Edmonton).

The CALPUFF dispersion model is able to account for chemical transformations, and therefore directly outputs estimated NO_2 concentrations. The formulations used in the model focus on the effect of photochemical reactions on the formulation of nitrates and other deposition chemicals. The estimates of ambient NO_2 assumes that the remaining nitrogen species are oxidized at a steady state. Near the mine pits, however, the formulation approach may not be able to deal with the excess quantity of NO_x, and will therefore tend to over predict the amount of NO_2 present.

The modelling predictions are summarized in Table B2-17 and predicted ground level concentrations are mapped in Figures B2-16 to B2-21.

Figures B2-16 and B2-17 show the maximum hourly average ground level NO_2 concentrations associated with Baseline operations for the ISC3BE and CALPUFF models. The overall maximum hourly average NO_2 concentration, as determined by ISC3BE, of 316 μg/m^3 is predicted to occur at a location 14 km WNW of Suncor. This maximum value is less than the Alberta Guideline of 400 μg/m^3 for ambient hourly average NO_2 concentrations. Comparison values for the CALPUFF model indicate an overall maximum hourly average NO_2 concentration of 1,305 μg/m^3, at a location 15 km WNW from the Suncor also in the Syncrude development area (Figure B2-17). This maximum average value is much greater than the hourly Alberta NO_2 Guideline of 400 μg/m^3. In total, approximately 64,000 ha are predicted to have the maximum average in excess of the guideline. The model predicts a maximum of 572 yearly exceedances of the hourly guideline. There is poor agreement between the two models at estimating maximum NO_2 concentrations. The CALPUFF model predicts much higher maximum average values and a large number of exceedances. The predictions of the two models become more comparable at greater distances from the sources.

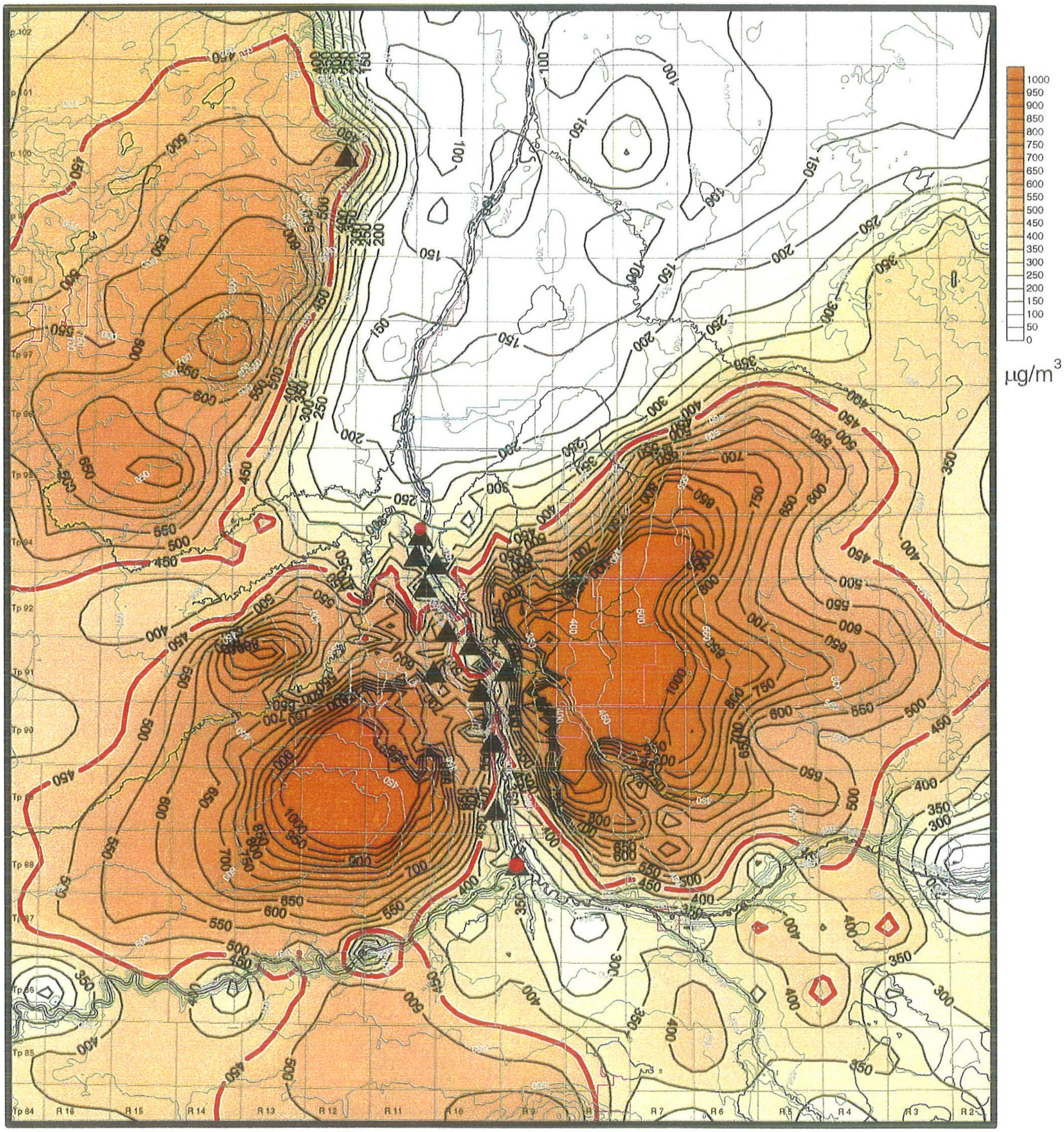
- Figures B2-18 and B2-19 shows the maximum daily average ground level NO_2 concentrations associated with Baseline operations for the ISC3BE and CALPUFF models. An overall maximum daily average NO_2 concentration, as determined by ISC3BE, of 259 μg/m^3 is predicted to occur 12 km WNW of Suncor. This maximum average value exceeds the daily AAAQG of 200 μg/m^3. The ISC3BE model predicts that there will be a maximum of 101 exceedances of the daily



Sources	SO_2 [t/sd]
Suncor	
Powerhouse	211
FGD	-
Incinerator	31
Flaring	8.3
Other Sources, Suncor	2.8
Syncrude (total)	208
Other Emissions (total)	-
TOTAL	461.1

Model Description	
Development	Baseline
Model	ISC3BE (7BG)
SO_2 Guideline [µg/m³]	450
Maximum [µg/m³]	1642
Exceedences / Year [#]	80

Figure B2-11 Predicted Historical SO_2 Maximum Hourly Average Ground Level Concentrations in the RSA for 1994

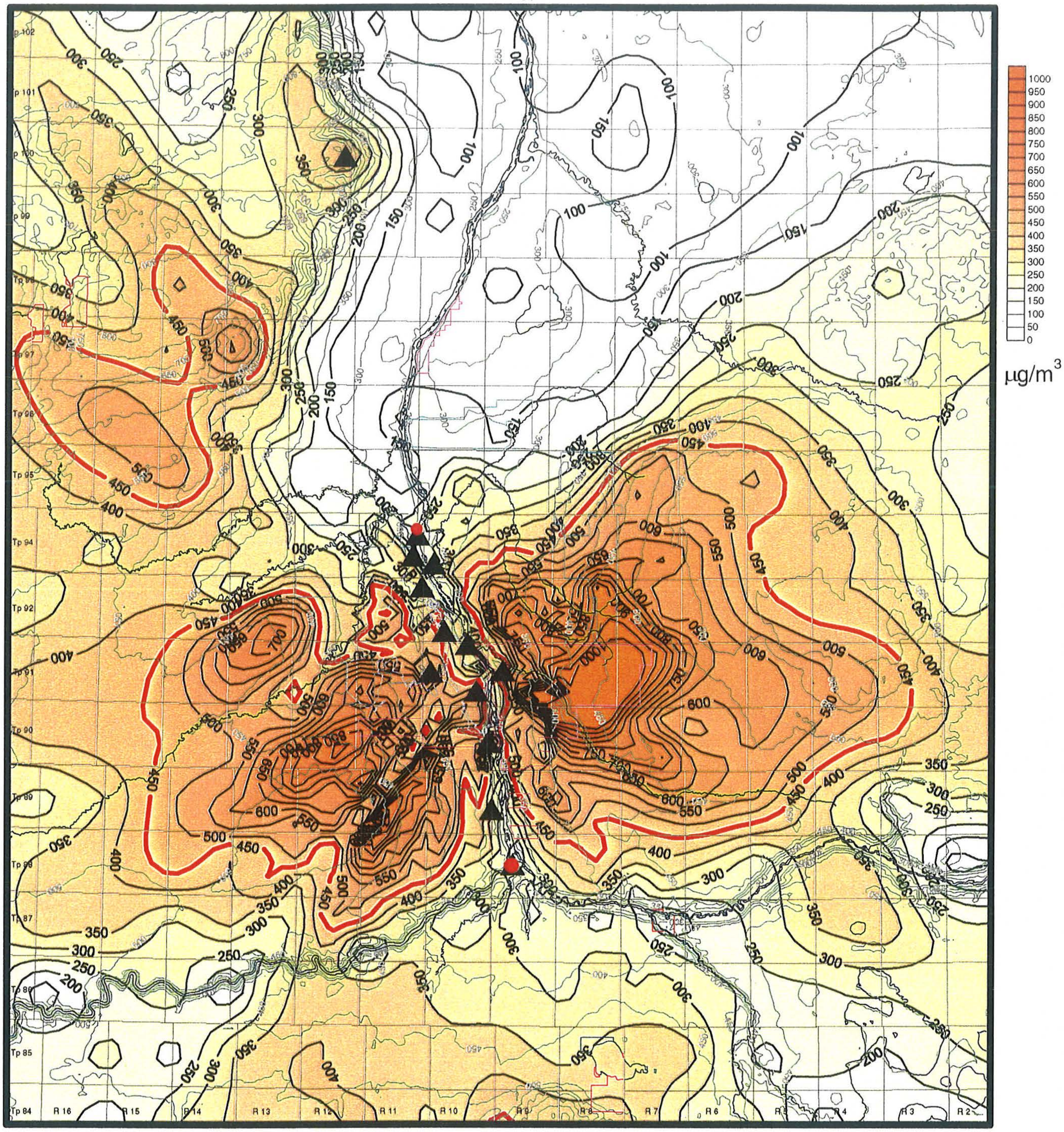


Sources	SO_2 [t/sd]
Suncor	
Powerhouse	215
FGD	-
Incinerator	16
Flaring	8.9
Other Sources, Suncor	3.0
Syncrude (total)	209
Other Emissions (total)	-
TOTAL	451.9

Model Description	
Development	Baseline
Model	ISC3BE (7BG)
SO_2 Guideline [$\mu g/m^3$]	450
Maximum [$\mu g/m^3$]	1446
Exceedences / Year [#]	43

UTM NAD83 metres
0 5000 10000 15000 20000

Figure B2-12 Predicted Historical SO_2 Maximum Hourly Average Ground Level Concentrations in the RSA for 1995



Sources	SO_2 [t/sd]
Suncor	
Powerhouse	153
FGD	-
Incinerator	18
Flaring	9.1
Other Sources, Suncor	3.0
Syncrude (total)	209
Other Emissions (total)	-
TOTAL	392.1

Model Description	
Development	Baseline
Model	ISC3BE (7BG)
SO_2 Guideline [µg/m³]	450
Maximum [µg/m³]	1246
Exceedences / Year [#]	32

UTM NAD83 metres
0 5000 10000 15000 20000

Figure B2-13 Predicted Historical SO_2 Maximum Hourly Average Ground Level Concentrations in the RSA for 1996

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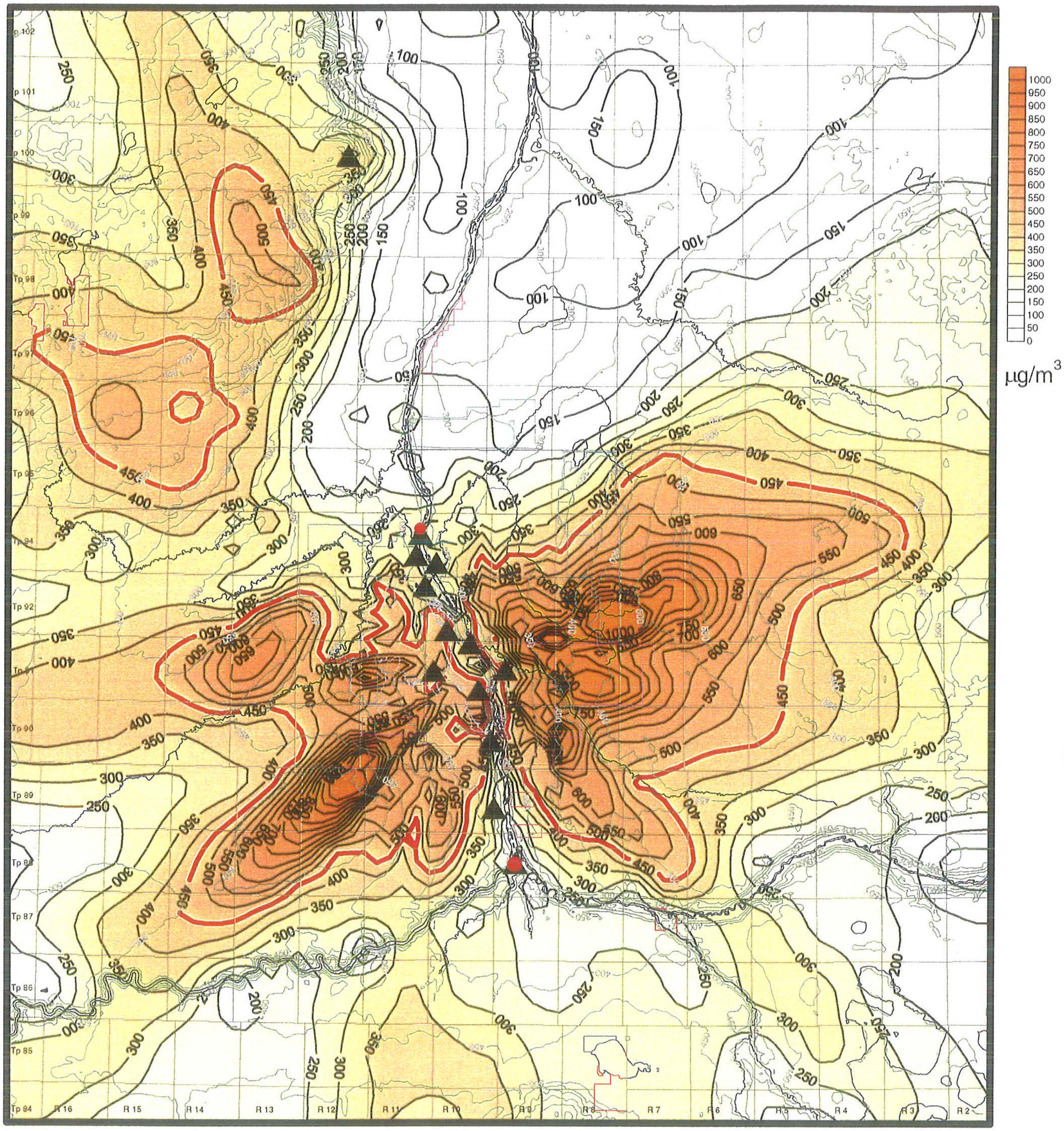

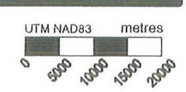

Sources	SO_2 [t/sd]
Suncor	
Powerhouse	171
FGD	-
Incinerator	19.1
Flaring	9.3
Other Sources, Suncor	3.1
Syncrude (total)	209
Other Emissions (total)	-
TOTAL	411.5

Model Description	
Development	1997 "Powerhouse"
Model	ISC3BE (7BG)
SO_2 Guideline [µg/m³]	450
Maximum [µg/m³]	1250
Exceedences / Year [#]	49

Figure B2-14 Predicted Historical SO_2 Maximum Hourly Average Ground Level Concentrations in the RSA for 1997 (assuming PH operational 100% of time with two boilers)

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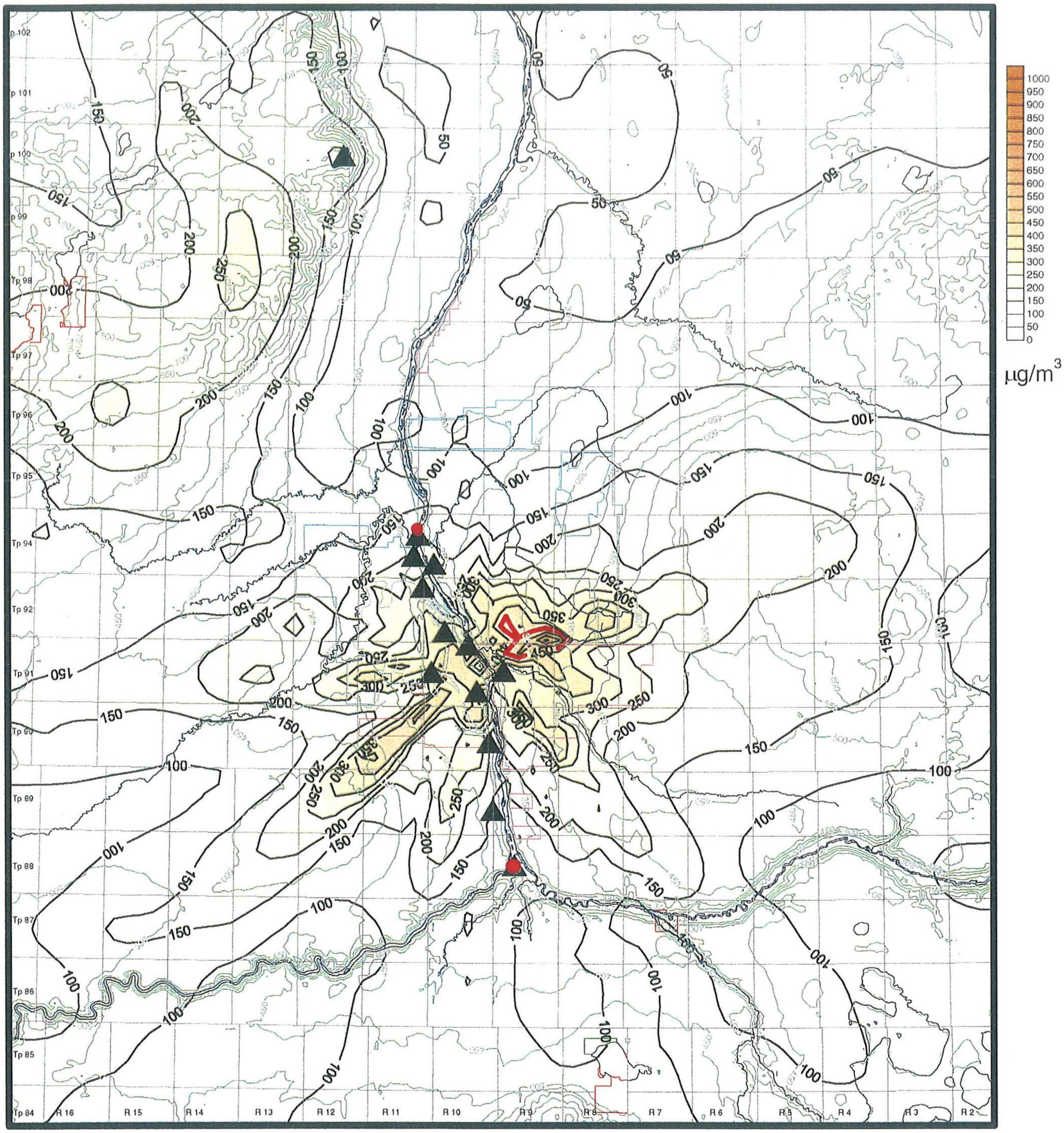


Sources	SO_2 [t/sd]
Suncor	
Powerhouse	-
FGD	10.8
Incinerator	19.1
Flaring	7.3
Other Sources, Suncor	3.1
Syncrude (total)	209
Other Emissions (total)	-
TOTAL	249.3

Model Description	
Development	1997 "FGD"
Model	ISC3BE (7BG)
SO_2 Guideline [µg/m³]	450
Maximum [µg/m³]	648
Exceedences / Year [#]	2

Figure B2-15 Predicted Historical SO_2 Maximum Hourly Average Ground Level Concentrations in the RSA for 1997 (assuming FGD operational 100% of time with two boilers)

Table B2-17 Maximum Observed Ground Level Concentrations of NO_x and NO_2 for Baseline Sources

Source	Hourly	Daily	Annual
Baseline Condition - ISC3BE[b]			
Maximum NO_x Concentration ($\mu g/m^3$)	7,093	4,259	1,279
Maximum NO_2 Concentration ($\mu g/m^3$)	316	259	162
Location of Maximum Concentration (km)	14 WNW	12 WNW	13 WNW
Maximum Number of Exceedances[a]	0	101	1
Location of Maximum Exceedances (km)	0	n/a	n/a
Baseline Case CALPUFF[c]			
Maximum NO_2 Concentration ($\mu g/m^3$)	1,305	598	239
Location from Suncor incinerator stack (km)	15 WNW	15 WNW	15 WNW
Maximum Number of Exceedances[a]	572	83	1
Location of Maximum Exceedances (km)	15 WNW	15 WNW	n/a
NO_2, Alberta Guideline ($\mu g/m^3$)	400	200	60
NO_2, Federal Acceptable ($\mu g/m^3$)	400	200	100

(a) Exceeds NO_2 Alberta Guideline. Normalized for a 12-month period.
(b) Based on Stream day emission rates for hourly and daily; Calendar day for annual.
(c) Based on Calendar day emission rates.

guideline, all within the Syncrude Mine Pit. In total, about 825 ha are predicted to have a maximum average in excess of the guideline. Corresponding values for the CALPUFF model indicate an overall maximum daily average NO_2 concentration of 598 $\mu g/m^3$, at a location similar to the ISC3BE prediction. This maximum average value also exceeds the daily Alberta NO_2 Guideline of 200 $\mu g/m^3$. The predictions shown in Figure B2-19 indicate the three areas that result in maximum daily averages in excess of the guideline. The areas are all in or adjacent to the Syncrude and Suncor existing operations. In total, about 23,500 ha are predicted to have maximum average in excess of the guideline. The CALPUFF model predicts that there will be a maximum of 83 exceedances of the daily guideline on an annual basis for the Baseline case. There is poor agreement between the two models for predicting the maximum concentrations or the number of exceedances due to their respective chemistry assumptions to estimate NO_2.

- Figure B2-20 and B2-21 shows the maximum annual average ground level NO_2 concentrations associated with Project Millennium for the ISC3BE and CALPUFF models, respectively. The overall maximum annual average NO_2 concentration, as determined by ISC3BE, of 162 mg/m3 is predicted to occur in the same vicinity as the maximum hourly concentration. This annual average value exceeds the AAAQG of 60 mg/m3. The predicted concentrations indicate three areas totaling 5,818 ha, all within the Suncor or Syncrude development areas, with maximum annual concentrations that are in excess of the annual guideline. Corresponding values for the CALPUFF model indicate an overall annual average NO_2 concentration of 239 $\mu g/m^3$, at the same location (Figure B.2-21). This maximum average value also exceeds the annual Alberta NO_2 Guideline of 60 µg/m^3. The predictions shown in Figure B.2-21 indicate three areas that result in annual averages in excess of the guideline. The areas are in or adjacent to the Suncor or Syncrude development areas. In total, approximately 4,000 ha are predicted to have a maximum average in excess of the guideline. There is better correlation between the two models for the annual results but the CALPUFF model continues to predict higher maximum values.

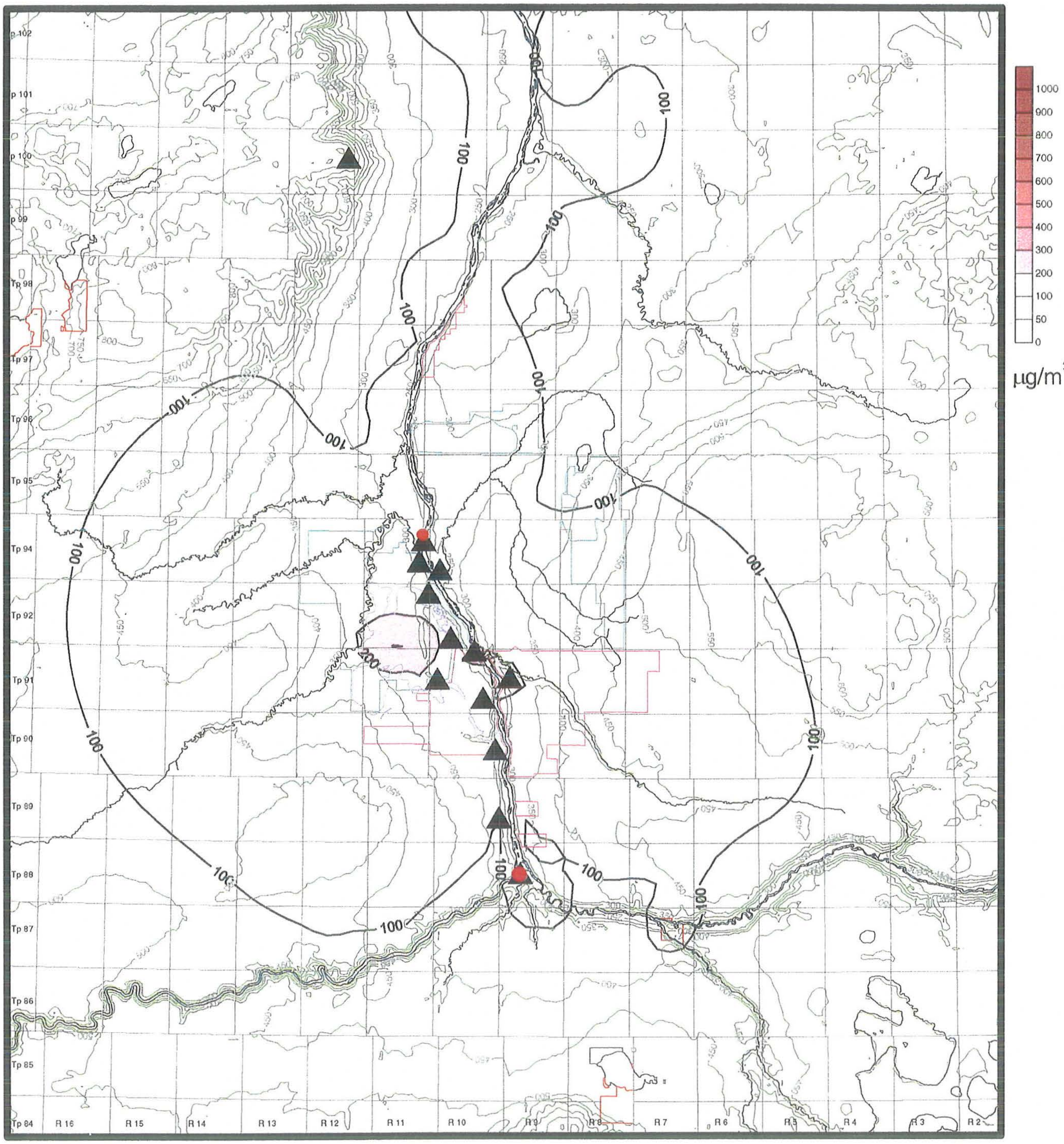
The modelling predictions indicate that the maximum NO_2 concentrations will tend to occur in or near the development areas. The principal contributors to these maximum values would be the mine fleet. The mine fleet emissions have been modelled as ground level sources with an areal extent matching the mine pit area. Because the fleet emissions are relatively large and are at ground level, there is a decreased opportunity for dispersion and dilution of their plumes as compared to a tall stack with a similar emission rate. It is this ground level characterization which produces the increase in the ground level low concentrations throughout a large portion of the RSA. This characterization is expected to be a conservative modelling assumption. Therefore, the largest concentrations and exceedances of the daily and annual average Guidelines are expected to be within the lease area boundaries. The ability to compare the model predictions to existing monitoring data are limited because only a few locations within the region measure NO_2.

B2.2.4 Potential Acid Input (PAI) Predictions

Acidic deposition in the RSA results from the cumulative emissions of SO_2 and NO_x. The total estimated emissions of SO_2 and NO_x within the RSA (278.4 t/cd and 102.2 t/cd, respectively) are presented in Table B2.6. Suncor contributes about 30% of the combined SO_2 and NO_x emissions.

Potential Acid Input (PAI) is the preferred method for evaluating the overall effects of acid forming chemicals on the environment since it accounts for the acidifying effect of the sulphur and nitrogen species, as well as the neutralizing effect of available base cations. A discussion on the calculation methods for PAI is provided in Section B2.1.2.3.

PAI in the oil sands region was predicted using the CALPUFF model and four years of meteorological observations from the 75 m level at the Suncor Mannix station. The CALPUFF model is a good tool for estimating the PAI in the oil sands region as it takes into account the chemical transformations of the emitted SO_2 and NO_x and predicts wet (rain and snow scavenged) and dry (via an effective dry deposition velocity) deposition of SO_2, SO_4, NO, NO_2, NO_3^-, and HNO_3. These deposition rates are combined following the methodology in Section B2.1.2.3 to predict the PAI for the region.



Sources	NO_2 [t/sd]
Suncor	
Powerhouse	2.8
FGD	30.9
Incinerator	0.1
Flaring	0.1
Other Sources, Suncor	13.9
Syncrude (total)	44.4
Other Emissions (total)	10.1
TOTAL	102.3

Model Description	
Development	Baseline
Model	ISC3BE (7BG)
NO_2 Guideline [µg/m³]	400
Maximum [µg/m³]	316
Exceedences / Year [#]	0

Figure B2-16 Predicted Baseline NO_2 Maximum Hourly Average Ground Level Concentrations in the RSA using the ISC3BE Model

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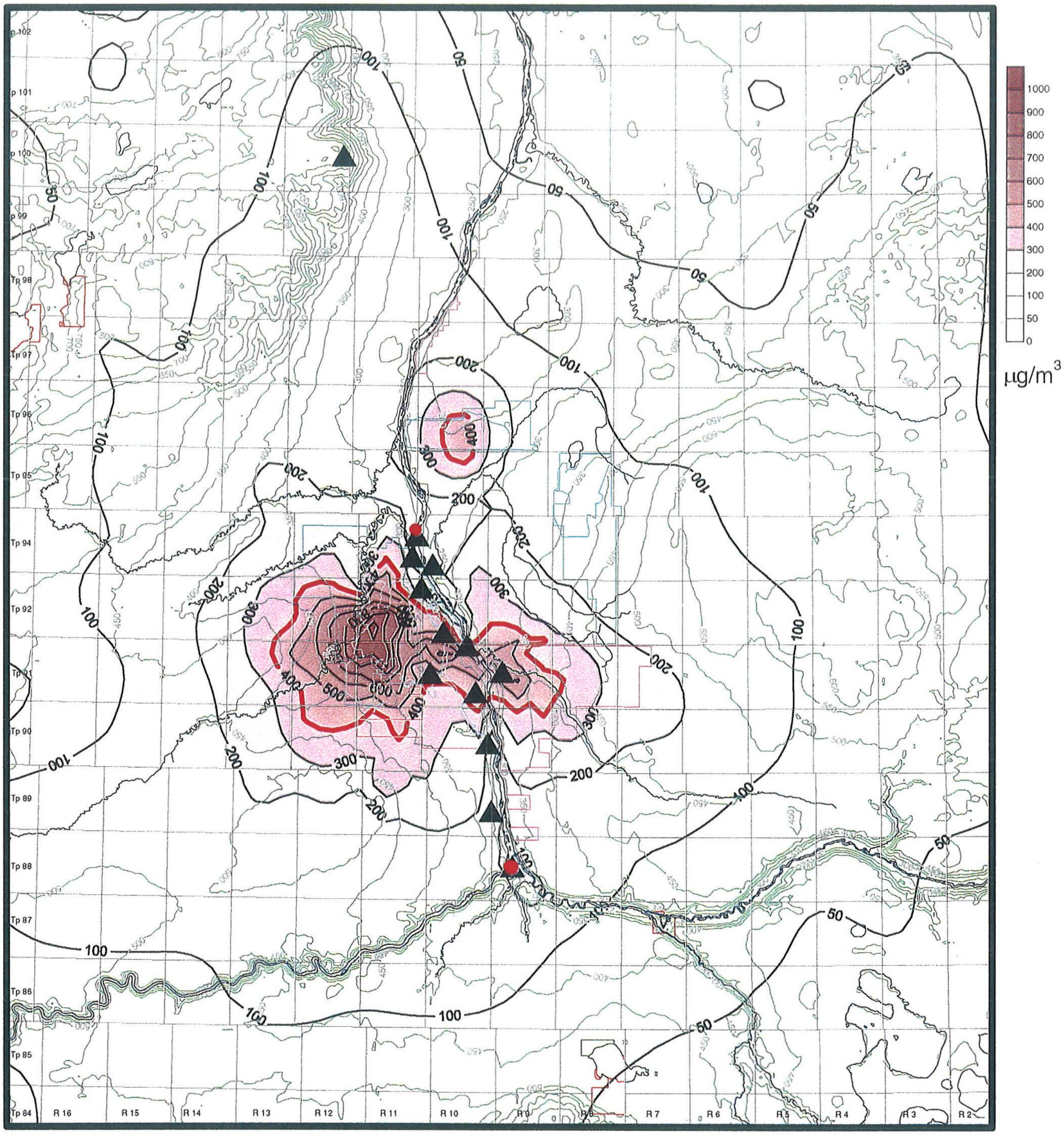

Sources	NO_x [t/cd]
Suncor	
Powerhouse	2.8
FGD	30.9
Incinerator	0.1
Flaring	0.1
Other Sources, Suncor	13.9
Syncrude (total)	44.4
Other Emissions (total)	10.1
TOTAL	102.3

Model Description	
Development	Baseline
Model	CALPUFF
NO_2 Guideline [µg/m³]	400
Maximum [µg/m³]	1305
Exceedences / Year [#]	572

Figure B2-17 Predicted Baseline NO_2 Maximum Hourly Average Ground Level Concentrations in the RSA using the CALPUFF Model

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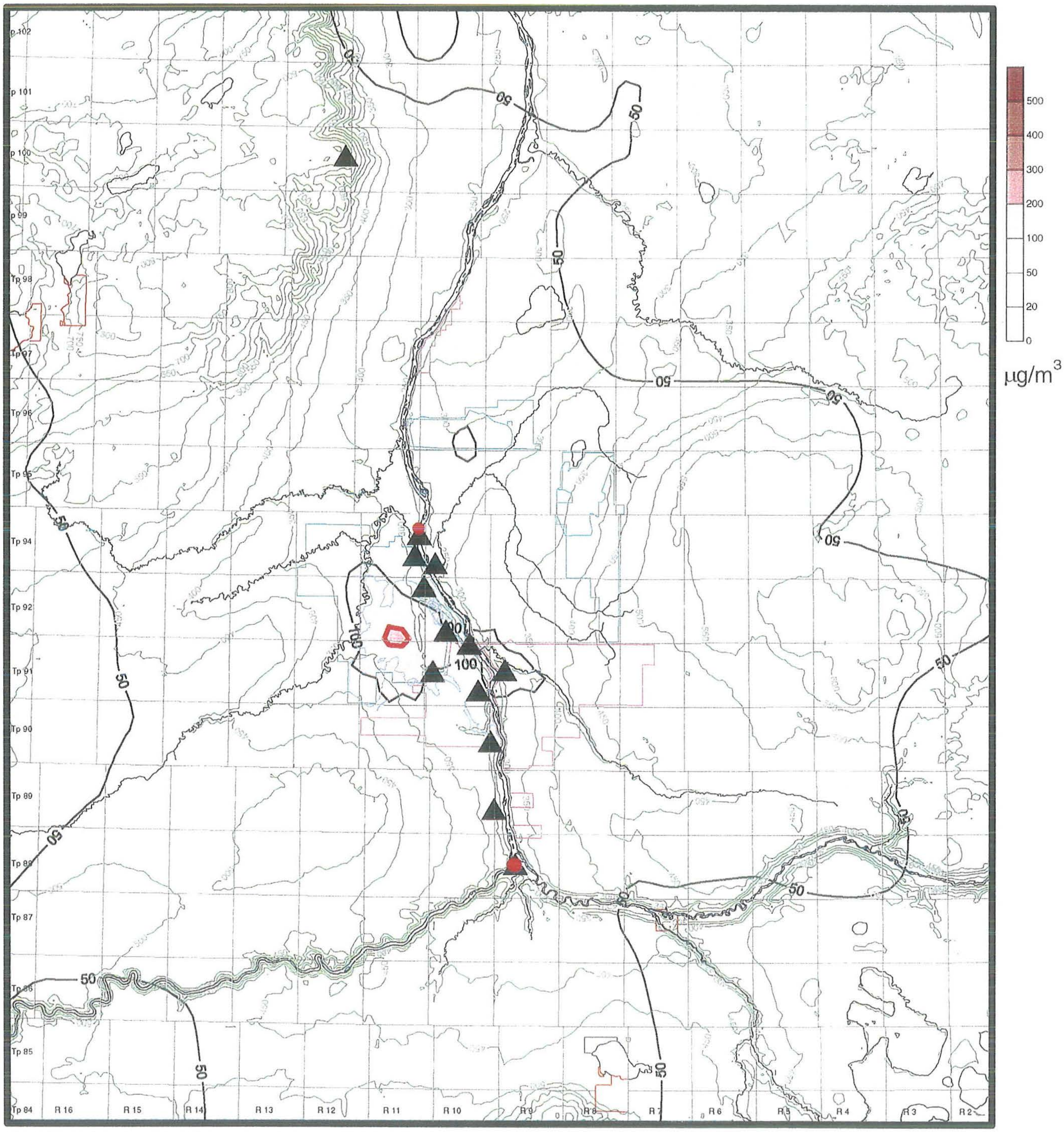

Sources	NO_2 [t/sd]
Suncor	
Powerhouse	2.8
FGD	30.9
Incinerator	0.1
Flaring	0.1
Other Sources, Suncor	13.9
Syncrude (total)	44.4
Other Emissions (total)	10.1
TOTAL	102.3

Model Description	
Development	Baseline
Model	ISC3BE (7BG)
NO_2 Guideline [µg/m³]	200
Maximum [µg/m³]	259
Exceedences / Year [#]	101

UTM NAD83 metres
0 5000 10000 15000 20000

Figure B2-18 Predicted Baseline NO_2 Maximum Daily Average Ground Level Concentrations in the RSA using the ISC3BE Model

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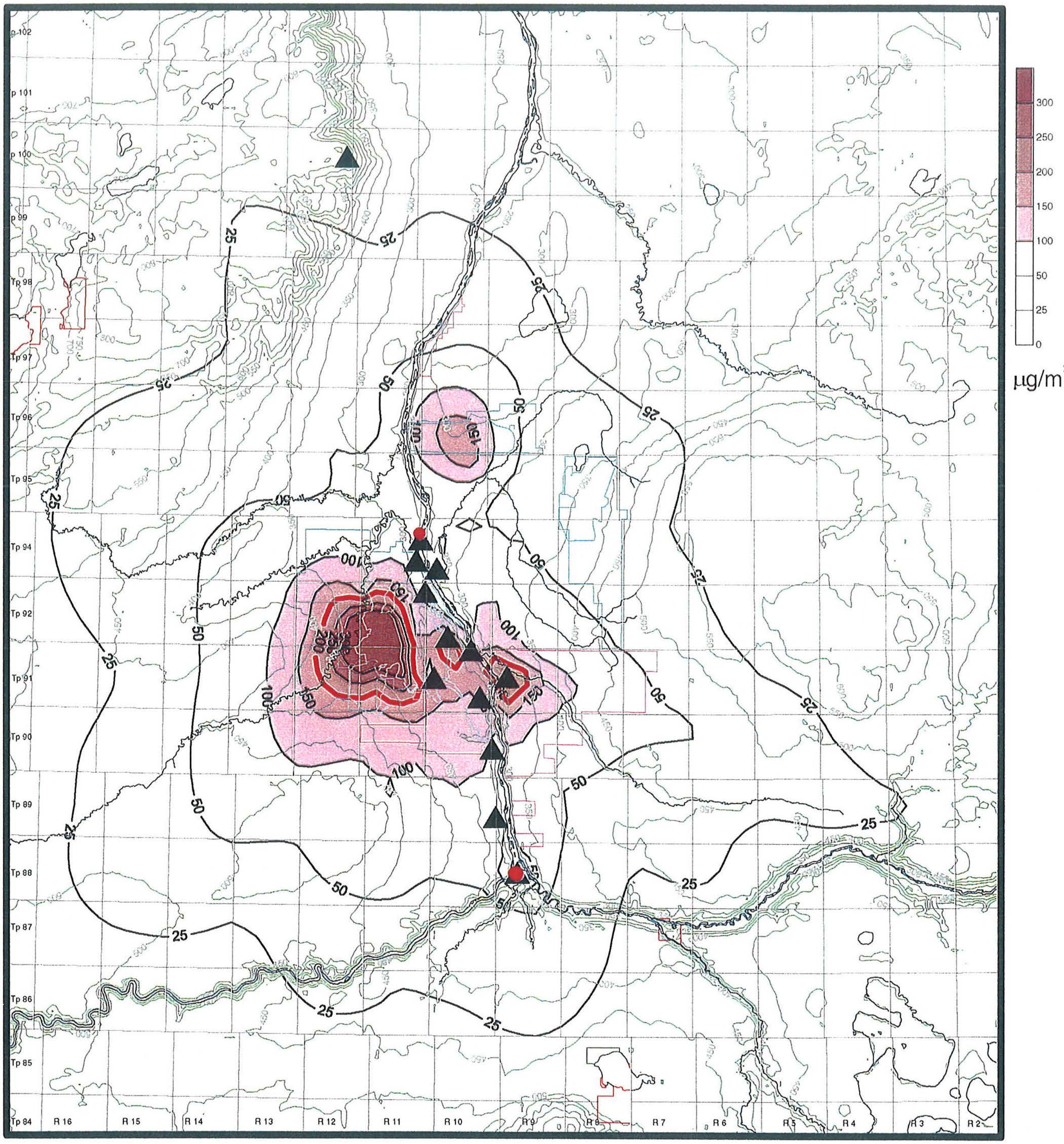

Sources	NO_x [t/cd]
Suncor	
Powerhouse	2.8
FGD	30.9
Incinerator	0.1
Flaring	0.1
Other Sources, Suncor	13.9
Syncrude (total)	44.4
Other Emissions (total)	10.1
TOTAL	102.3

Model Description	
Development	Baseline
Model	CALPUFF
NO_2 Guideline [µg/m³]	200
Maximum [µg/m³]	598
Exceedences / Year [#]	83

Figure B2-19 Predicted Baseline NO_2 Maximum Daily Average Ground-Level Concentrations in the RSA using the CALPUFF Model

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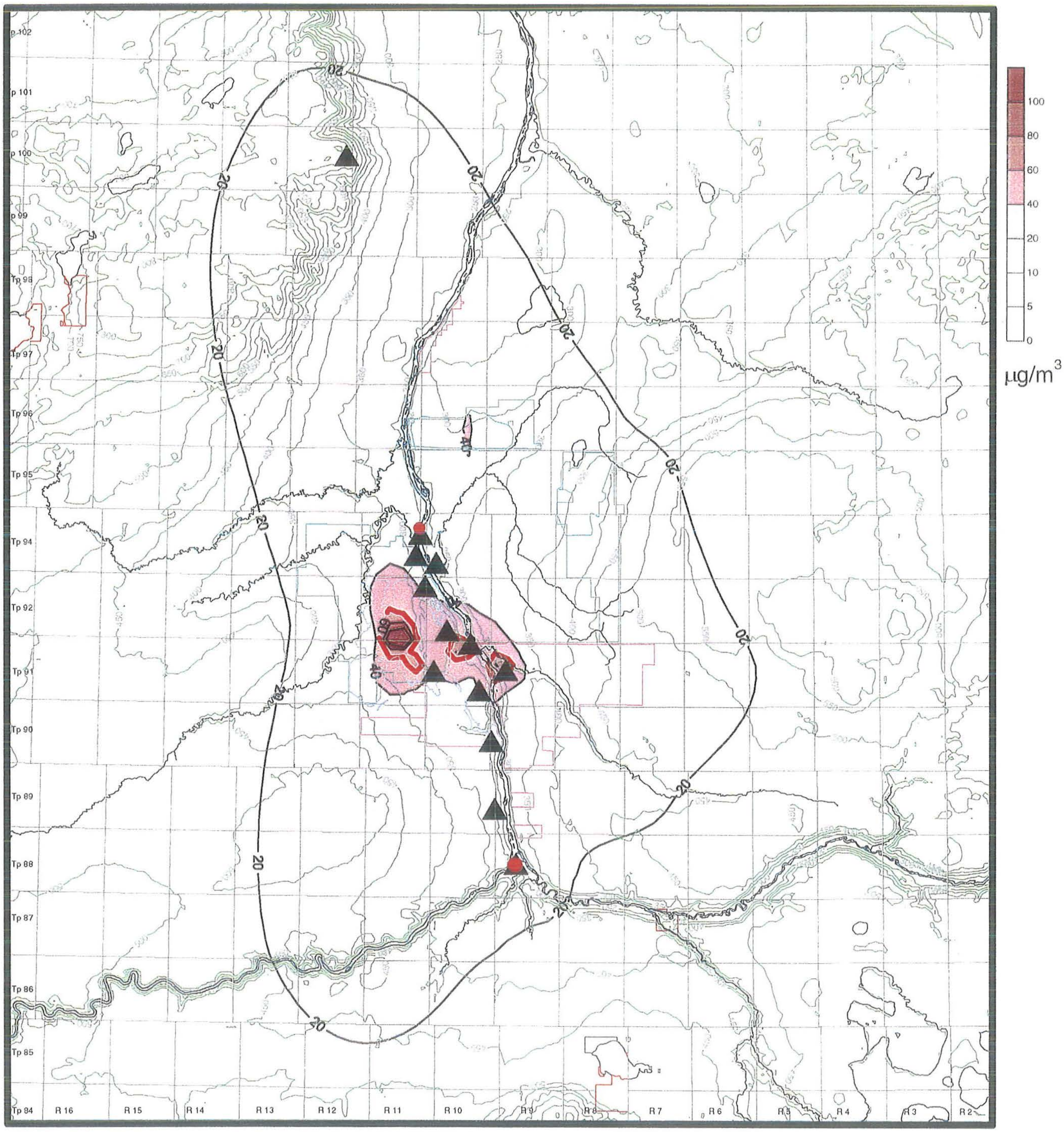

Sources	NO_2 [t/cd]
Suncor	
Powerhouse	3.9
FGD	29.8
Incinerator	0.1
Flaring	0.1
Other Sources, Suncor	13.8
Syncrude (total)	44.4
Other Emissions (total)	10.1
TOTAL	102.2

Model Description	
Development	Baseline
Model	ISC3BE (7BG)
NO_2 Guideline [µg/m³]	60
Maximum [µg/m³]	162
Exceedences / Year [#]	1

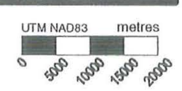

Figure B2-20 Predicted Baseline NO_2 Maxiimum Annual Average Ground Level Concentrations in the RSA using the ISC3BE Model

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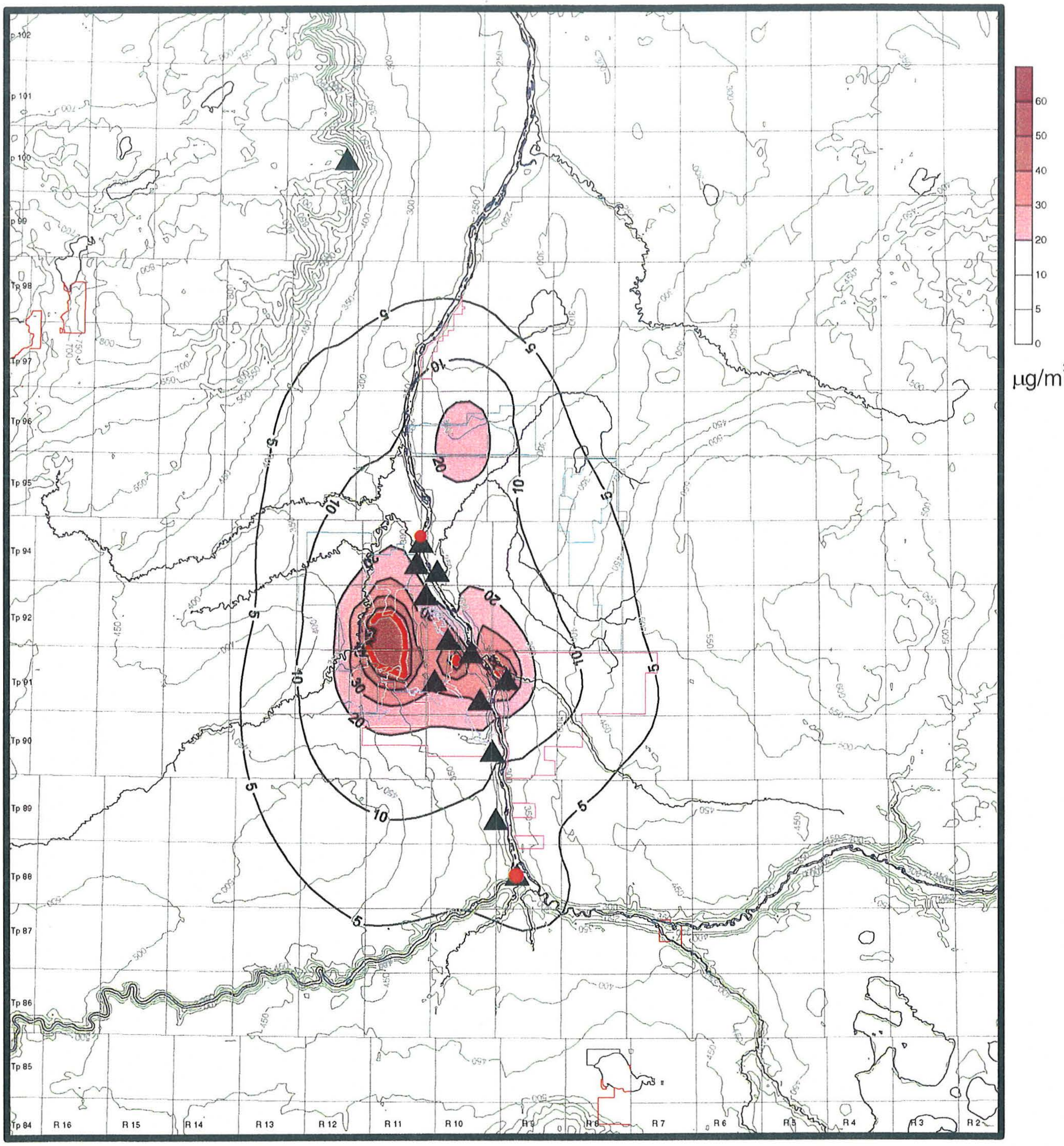


Sources	NO_x [t/cd]
Suncor	
Powerhouse	3.9
FGD	29.8
Incinerator	0.1
Flaring	0.1
Other Sources, Suncor	13.8
Syncrude (total)	44.4
Other Emissions (total)	10.1
TOTAL	102.2

Model Description	
Development	Baseline
Model	CALPUFF
NO_2 Guideline [µg/m^3]	60
Maximum [µg/m^3]	239
Exceedences / Year [#]	1

Figure B2-21 Predicted Baseline NO_2 Maximum Annual Average Ground Level Concentrations in the RSA using the CALPUFF Model

A background PAI of 0.1 keq/ha/y has been assumed for the region based on estimates of sulphur, nitrogen and base cation concentrations and depositions in the region surrounding the RSA. This background PAI may be conservatively high since it was derived from monitoring data at stations adjacent to the RSA. These data were used, as opposed to remote pristine arctic monitoring station data, to better reflect the local Alberta airshed. While these data may represent air flows entering the RSA, they may also reflect air leaving the RSA. Therefore a nominal amount of "double counting" may be assumed for the select background PAI.

The PAI predictions are summarized in Table B2-18 and shown graphically in Figure B2-24. The predicted PAI exceeds the 0.25 keq/ha/y Alberta interim critical load for sensitive soils over an area of 670,483 ha (27.6% of the RSA). The areal extent over which the PAI exceeds the critical loadings for less sensitive soils is significantly lower, namely: 11,543 ha (0.5% of the RSA) greater than 0.50 keq/ha/y; 3,206 ha (0.1% of the RSA) greater than 1.0 keq/ha/y; and 250 ha (0.01% of the RSA) greater than 1.5 keq/ha/y.

Table B2-18 Areal Extent For Predicted PAI Values

PAI Threshold (keq/ha/y)	AREA	
	(ha)	(%)[a]
0.25	670,483	27.6
0.50	11,543	0.5
1.0	3,206	0.1
1.5	250	0.01

(a) as % of the total RSA

The maximum deposition rates of the sulphur and nitrogen species were calculated as interim variables by the CALPUFF model. These are summarized in Table B2-19 and presented graphically in Figures B2-21 and B2-22. The maximum deposition rates of both nitrates and sulphates occur in the immediate vicinity of the active mine pits. This is the same area where the maximum overall PAI is predicted to occur, suggesting that the highest deposition and PAI values occur in the areas where there are sizable ground level releases of SO_2 and NO_x.

Table B2-19 Maximum Predicted Acid Forming Deposition

Parameter	Maximum [keq/ha/y]	Distance [km from Suncor]	Direction
PAI	2.10	14	WNW
Nitrate Deposition	0.97	14	WNW
Sulphate Deposition	1.07	16	WNW

The methodology for predicting PAI on a regional scale using CALPUFF has only been applied in a limited number of cases and the experience at applying and interpreting the model predictions is undergoing development. Further, there is considerable uncertainty in the background PAI for the region ranging from approximately -0.5 to 0.25 keq/ha/y. For this reason, the PAI map presented in the Figure B2-20 should be regarded as providing an indication of relative spatial distributions and relative changes associated with differing emissions scenarios. This map should also be used in conjunction with the sulphate and nitrate deposition maps (Figures B2-24 and B2-22, respectively) as input in the evaluation of impacts to sensitive soil or vegetation, and in the design of any long-term monitoring programs deemed necessary in such evaluations.

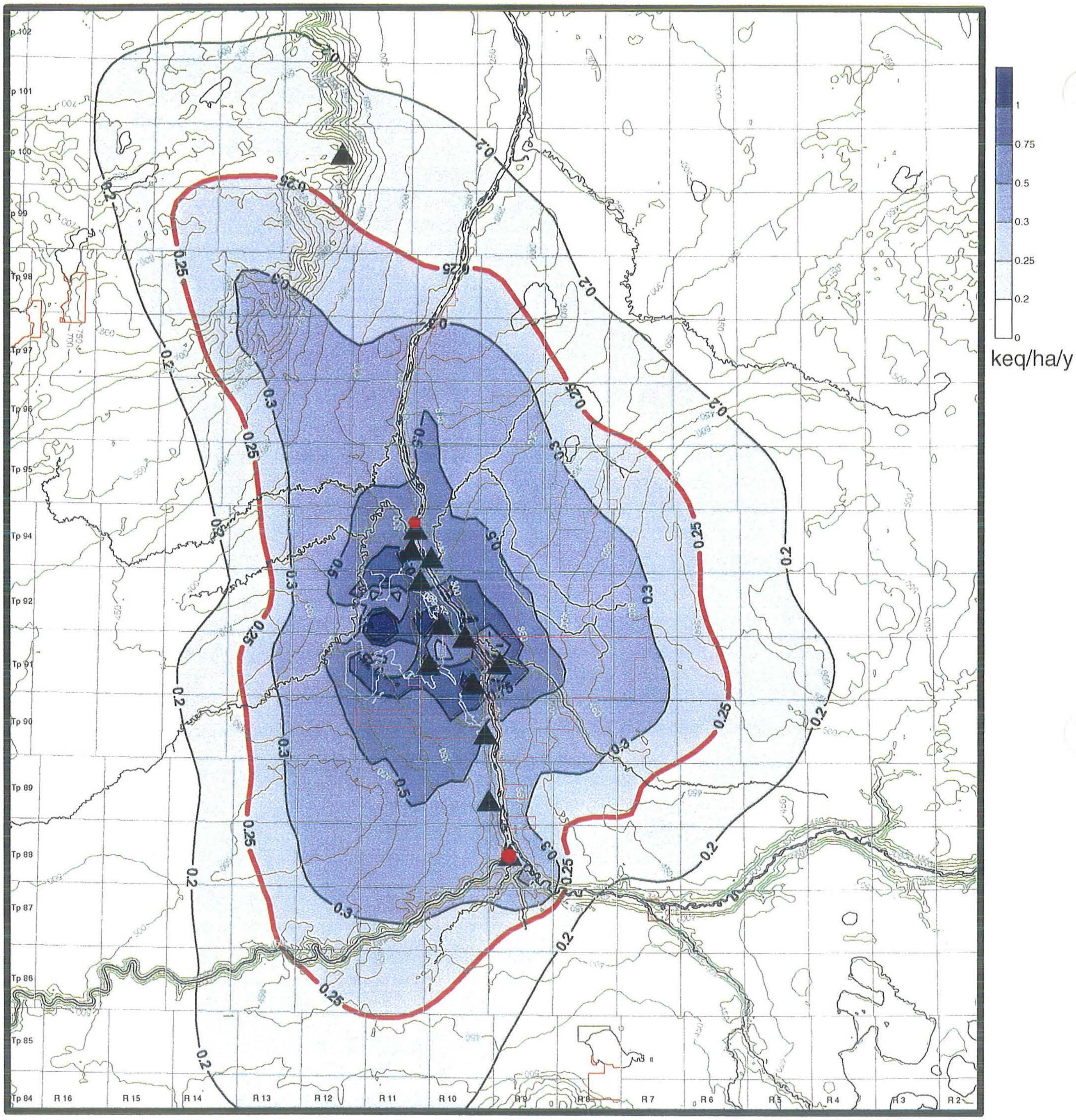
B2.2.5 CO Predicted Concentrations

The CO emission sources associated with the baseline operations are summarized in Section B2.1 (e.g., Tables B2-1 to B2-6). Total estimated CO emission rate for the baseline case is 120.7 t/cd. The major continuous source of CO emissions at Suncor is the FGD Stack (25.7 t/d) which represents about 21% of the total.

The predicted maximum hourly, daily and annual ground level ambient CO concentrations resulting from emissions of all approved industrial sources and residential emissions in the oil sands region were estimated using ISC3BE and meteorology measurements from the Mannix station. This model provides an efficient means of calculating the overall ambient CO concentration from all sources and provides an indication of where maximum concentrations could occur. The modelling predictions are summarized in Table B2-20 and predicted ground level concentrations are mapped in the figures described below:

- Figure B2-25 shows the maximum hourly average ground level CO concentrations associated with the Baseline operations. An overall maximum hourly average CO concentration of 5,561 $\mu g/m^3$ is predicted to occur at a location SSE of the Suncor. This maximum value is less than the hourly Alberta CO guideline of 15,000 $\mu g/m^3$
- Figure B2-26 shows the maximum 8-hour average ground level CO concentrations associated with the Baseline operations. The overall maximum 8-hour average CO concentration of 2,226 $\mu g/m^3$ is predicted to occur at a location SSE of Suncor. This 8-hour maximum value is less than the Alberta 8-hour guideline of 6,000 $\mu g/m^3$.

The modelling predicts that the maximum hourly and 8-hour CO concentrations will occur SSE of Suncor in or near Fort McMurray. The principal contributor to high values in the area of the existing developments



UTM NAD83 metres
0 5000 10000 15000 20000

Sources	SO_2 [t/cd]	NO_x [t/cd]
Suncor		
Powerhouse	13.1	3.9
FGD	18	29.8
Incinerator	18.8	0.1
Flaring	12.6	0.1
Other Sources, Suncor	2.8	13.8
Syncrude (total)	209	44.4
Other Emissions (total)	4.1	10.1
TOTAL	278.4	102.2

Model Description	
Development	Baseline
Model	CALPUFF
Critical Loading [keq/ha/y]	0.25
Maximum [keq/ha/y]	2.1

Figure B2-22 Predicted Baseline Potential Acid Input (PAI) in the RSA using the CALPUFF Model

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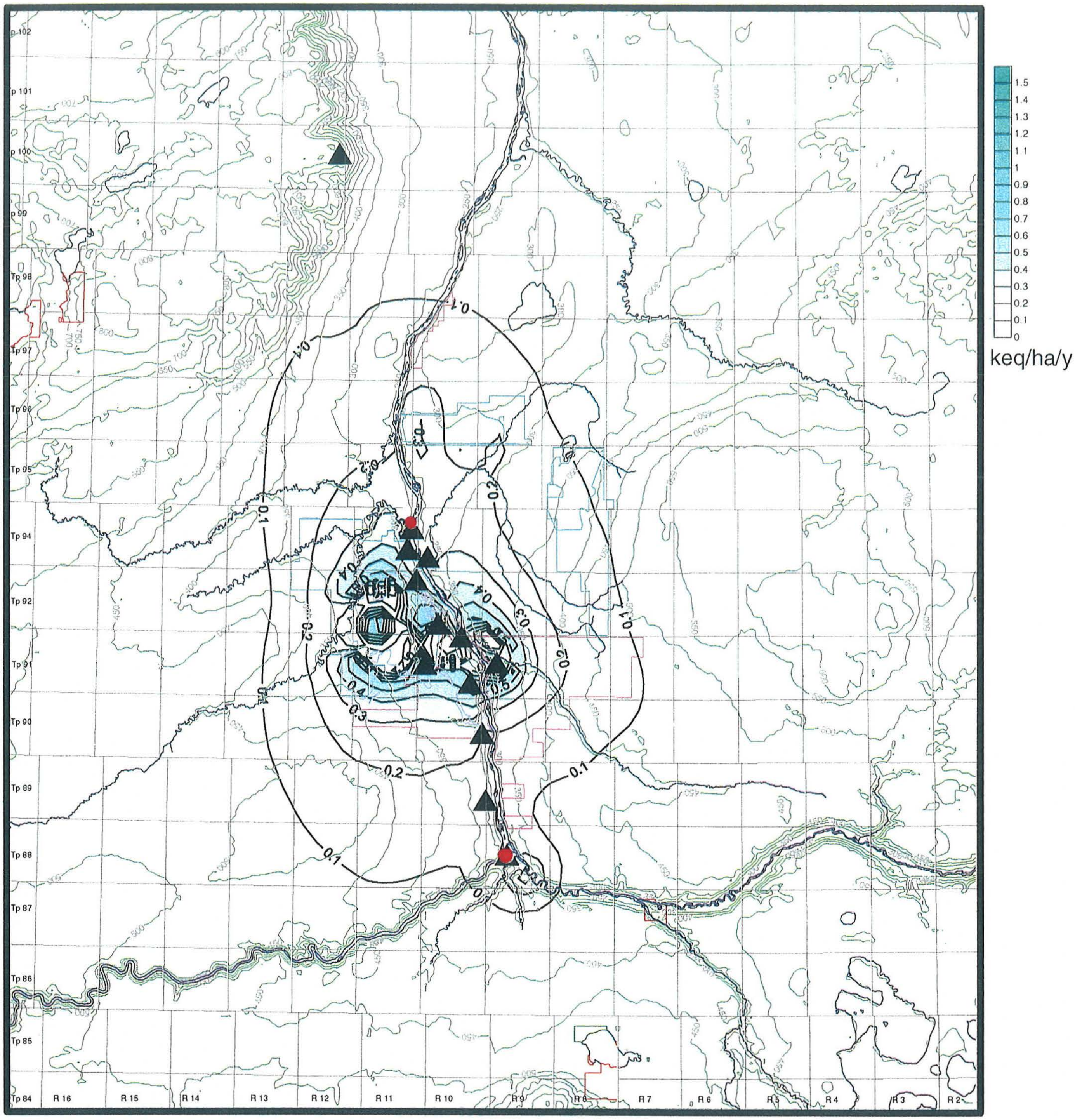

Sources	SO_2 [t/cd]	NO_x [t/cd]
Suncor		
Powerhouse	13.1	3.9
FGD	18	29.8
Incinerator	18.8	0.1
Flaring	12.6	0.1
Other Sources, Suncor	2.8	13.8
Syncrude (total)	209	44.4
Other Emissions (total)	4.1	10.1
TOTAL	278.4	102.2

Model Description	
Development	Baseline
Model	CALPUFF
Critical Loading [keq/ha/y]	0.25
Maximum [keq/ha/y]	1.0

Figure B2-23 Predicted Baseline Nitrate Equivalent Deposition in the RSA using the CALPUFF Model

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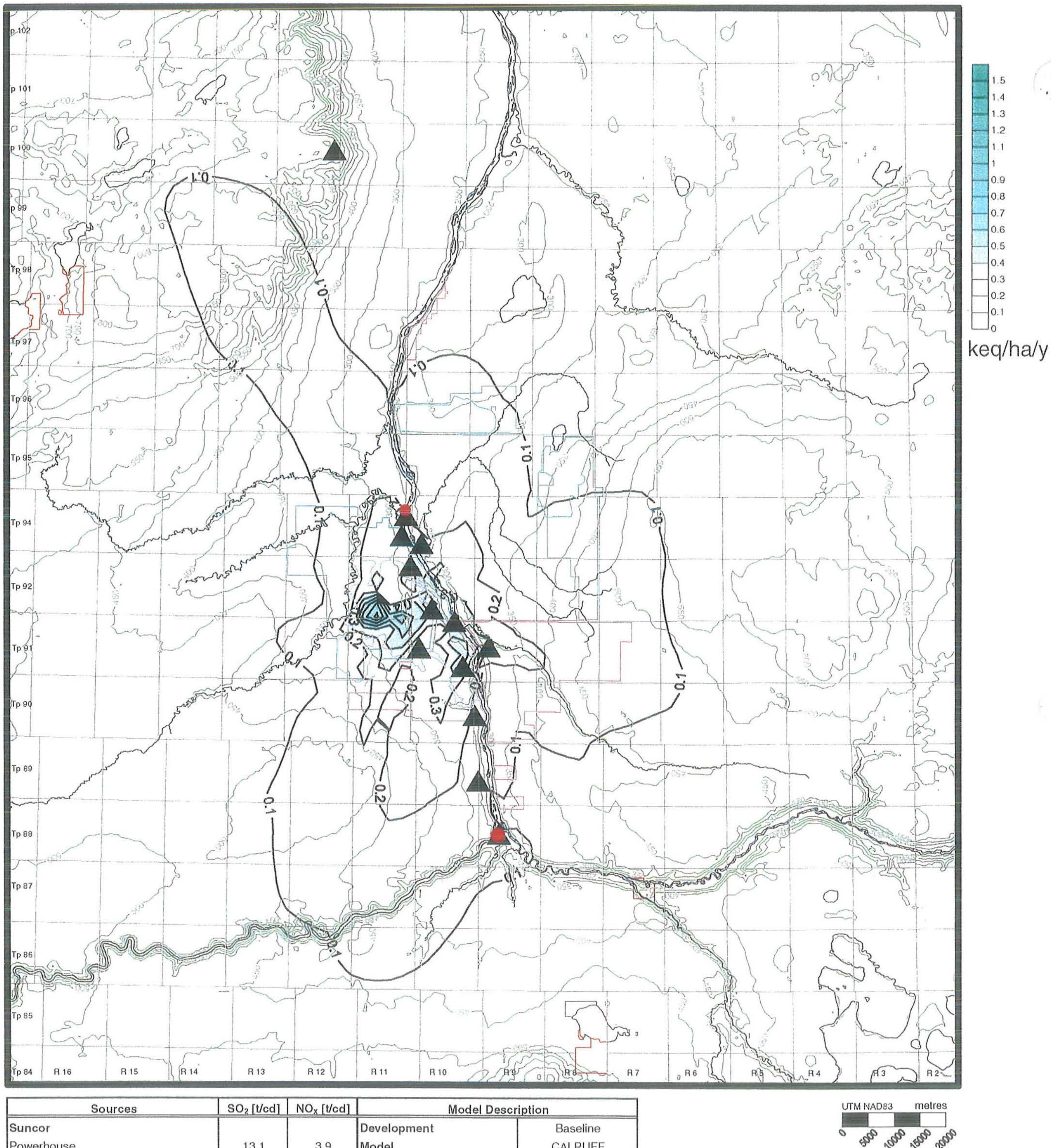

Sources	SO_2 [t/cd]	NO_x [t/cd]
Suncor		
Powerhouse	13.1	3.9
FGD	18	29.8
Incinerator	18.8	0.1
Flaring	12.6	0.1
Other Sources, Suncor	2.8	13.8
Syncrude (total)	209	44.4
Other Emissions (total)	4.1	10.1
TOTAL	278.4	102.2

Model Description	
Development	Baseline
Model	CALPUFF
Critical Loading [keq/ha/y]	0.25
Maximum [keq/ha/y]	1.1

Figure B2-24 Predicted Baseline Sulphate Equivalent Deposition in the RSA using the CALPUFF Model

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Table B2-20 Maximum Observed Ground Level Concentrations of CO for Baseline Sources

Source	Hourly	8-Hour
Baseline Condition - Model ISC3BE		
Maximum CO Concentration (μg/m^3)	5,561	2,226
Location of Maximum Concentration (km)	30 SSE	30 SSE
Maximum Number of Exceedances [(a)]	0	0
Location of Maximum Exceedances	n/a	n/a
CO, Alberta Guideline (μg/m^3)	15,000	6,000

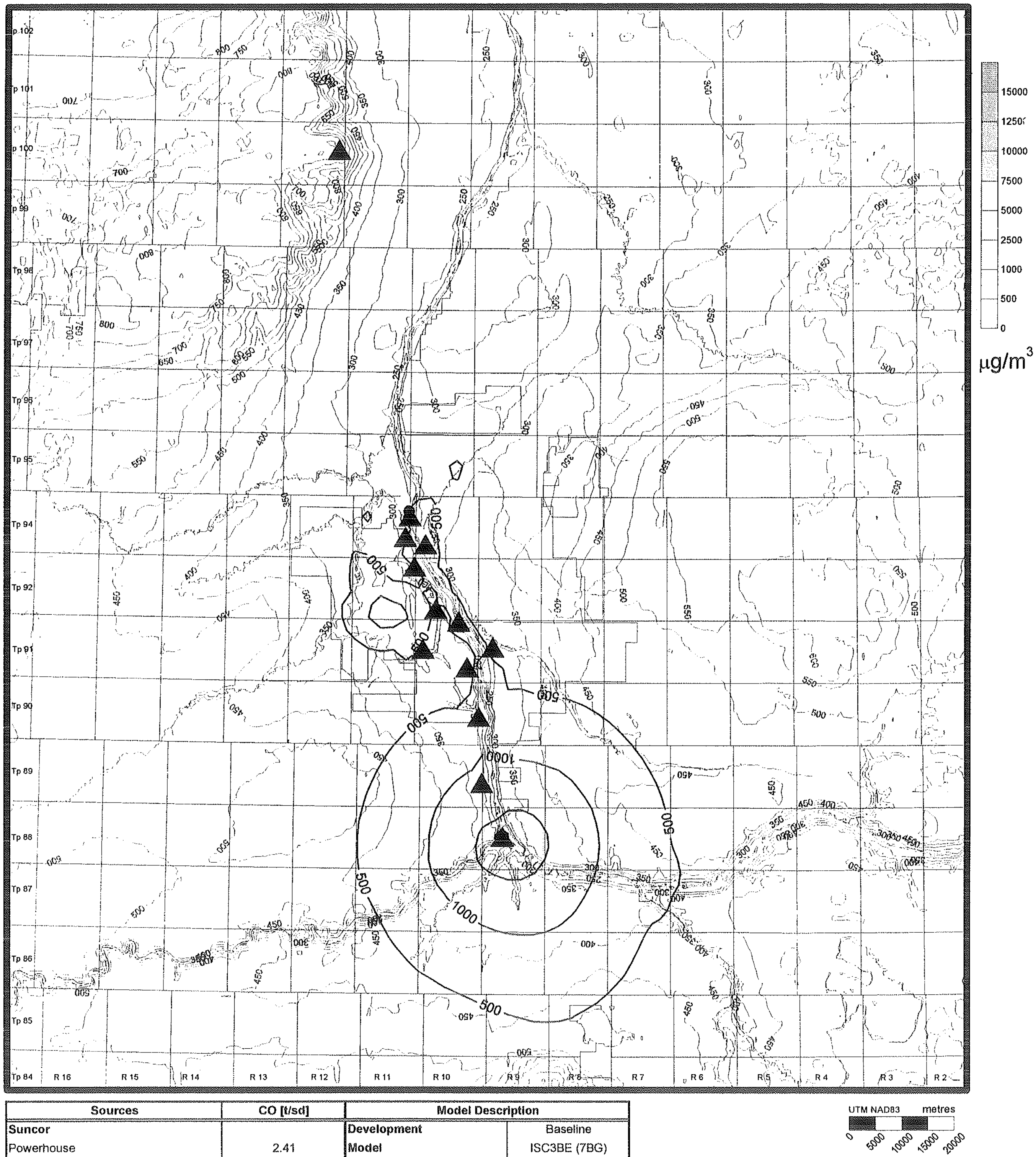
(a) Exceeds CO Alberta Guideline. Normalized for a 12-month period.

appears to be the mine fleet. The mine fleet emissions have been modelled as ground level sources with an areal extent matching the mine pit area. Because the fleet emissions are relatively large and at ground level, there is a decreased opportunity for dispersion and dilution of their plumes as compared to a tall stack with a similar emission rate. It is this ground level characterization which produces the increase in the ground level concentrations and this characterization is expected to be a conservative modelling assumption. The ability to compare the model predictions to monitoring data are limited because only one station within the region measures CO.

B2.2.6 Particulates

The ambient PM emission sources associated with the baseline operations are summarized in Section B2.1 (e.g., Tables B2-1 to B2-5). Total estimated PM emission rate for the baseline case is 9.5 t/cd. The major continuous source of particulate emissions from Suncor is the FGD Stack and it emits approximately 1.1 t/cd. In total Suncor emits approximately 20% of the PM. For the purpose of modelling, all PM was assumed to be PM_{10}. In addition to the PM emissions, metals and PAHs have been determined from stack sampling surveys collected by Syncrude. Based on the speciation completed for the stack sampling surveys, concentrations of metals and PAHs were estimated. These results are discussed in subsections following this section.

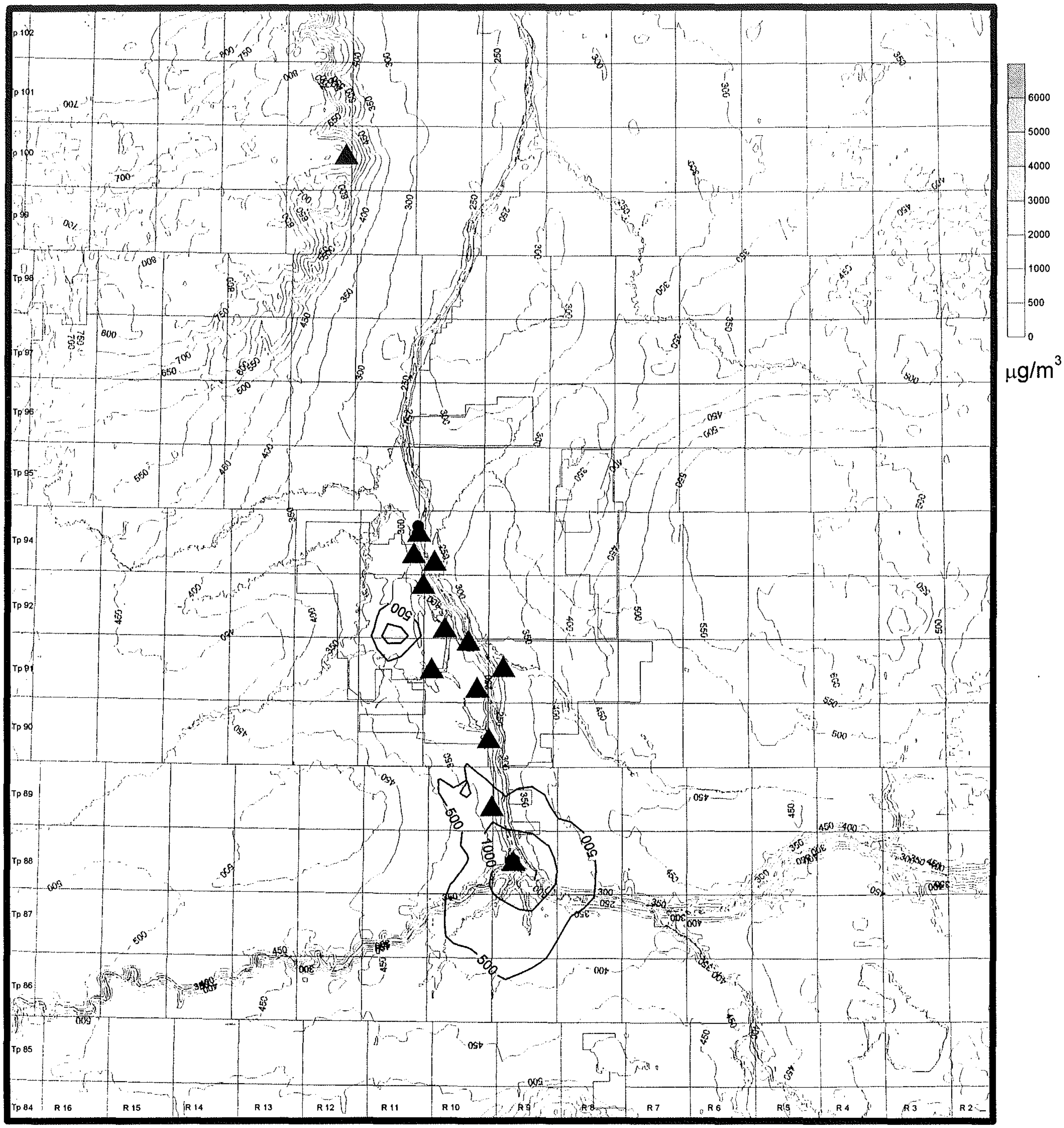
The predicted maximum daily and annual ground level ambient PM_{10} concentrations resulting from emissions of all approved industrial sources and residential emissions in the oil sands region were estimated using ISC3BE and meteorology measurements from the Mannix station. The modelling results are summarized in Table B2-21 which includes the PM_{10} predictions based on the source sampling results. Predicted PM_{10} ground level concentrations are mapped in the figures described below:



Sources	CO [t/sd]
Suncor	
Powerhouse	2.41
FGD	26.57
Incinerator	2.9
Flaring	0.2
Other Sources, Suncor	1.4
Syncrude (total)	53.6
Other Emissions (total)	33.57
TOTAL	120.65

Model Description	
Development	Baseline
Model	ISC3BE (7BG)
CO Guideline [µg/m³]	15000
Maximum [µg/m³]	5561
Exceedences / Year [#]	0

Figure B2-25 Predicted Baseline CO Maximum Hourly Average Ground Level Concentrations in the RSA



UTM NAD83 metres

0 5000 10000 15000 20000

Sources	CO [t/sd]
Suncor	
Powerhouse	2.41
FGD	26.57
Incinerator	2.9
Flaring	0.2
Other Sources, Suncor	1.4
Syncrude (total)	53.6
Other Emissions (total)	33.57
TOTAL	120.65

Model Description	
Development	Baseline
Model	ISC3BE (7BG)
CO Guideline [µg/m³]	6000
Maximum [µg/m³]	2226
Exceedences / Year [#]	0

Figure B2-26 Predicted Baseline CO Maximum 8-Hour Average Ground Level Concentrations in the RSA using the ISC3BE Model

- Figure B2-27 shows the maximum daily average ground level PM_{10} concentrations associated with the Baseline operations. The overall maximum daily average PM_{10} concentration of 113 $\mu g/m^3$ is predicted to occur at a location WNW of Suncor. This daily maximum average value exceeds the Alberta Guideline of 100 $\mu g/m^3$. The high readings and all the exceedances occur in a very small area within the existing development areas.
- Figure B2-28 shows the annual average ground level concentration contours for PM_{10}. The results show that the overall maximum annual concentration of 45.8 $\mu g/m^3$ is predicted to occur at the same location as the daily results.

Table B2-21 Maximum Observed Ground Level Concentrations of PM_{10} for Baseline Sources

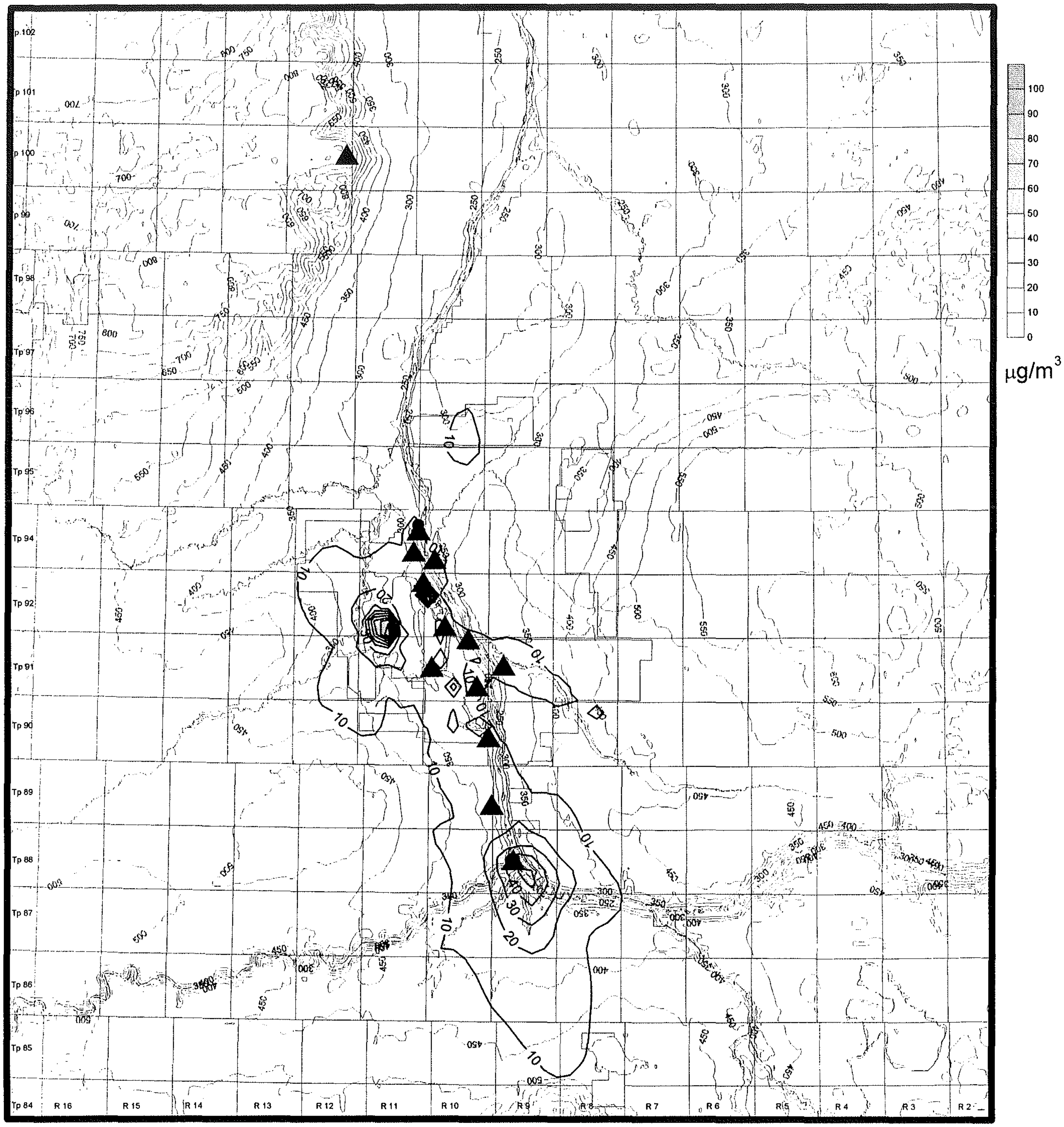
Source	Daily	Annual
Baseline Condition - Model ISC3BE		
Maximum PM_{10} Concentration ($\mu g/m^3$)	113	45.8
Location of Maximum Concentration (km)	WNW	WNW
Maximum Number of Exceedances	33	0
Location of Maximum Exceedances	n/a	n/a
PM_{10}, Alberta Guideline ($\mu g/m^3$)	100	60

n/a data not available.

The modelling predicts high levels of PM_{10} in the development area and low levels in the rest of the RSA based on the existing emission sources.

The particulate emissions from the Suncor FGD and Syncrude Main stacks contain metals and PAH compounds. The ISC3BE was configured to predict particulates from these two stacks to determine ground level concentrations and deposition rates. Particulate size fraction, metal composition and PAH composition for the Suncor FGD stack emissions were based on a recent stack survey (March 1998). The survey results indicate that the size fraction of FGD emissions is predominantly in the $PM_{2.5}$ size range with a total emission rate of about 2.6 t/d. Information on the Syncrude Main stack emissions indicate a range of particulate sizes. These ranges are 40% $PM_{2.5}$, 10% PM_{10} and 50% PM_{50} (based on emissions information provided from Syncrude) with a total emission rate of about 7.1 t/d.

The predicted average annual ground level concentrations of total particulates from these two sources are shown in Figure B2-29. A summary of the predicted metals and PAHs concentrations derived from the total particulate air concentrations are listed in Tables B2-22 and B2-23, respectively for selected locations.



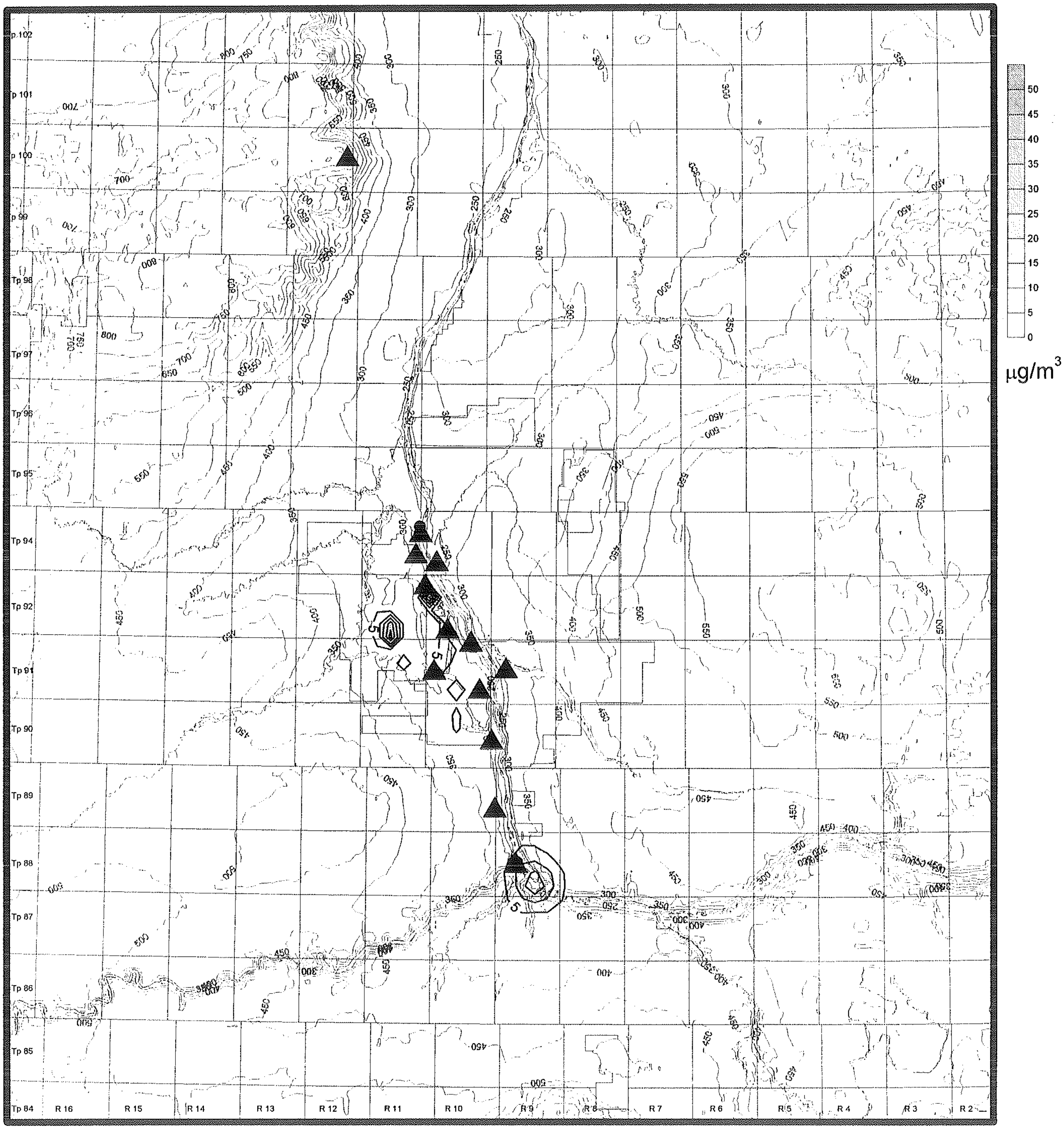
UTM NAD83 metres

0 5000 10000 15000 20000

Sources	PM [t/cd]
Suncor	
FGD	1.10
Powerhouse	0.24
Incinerator	0.03
Lease 86/17 Mine Fleet	0.05
Steepbank Mine Fleet	0.05
Other Sources, Suncor	0.23
Syncrude (total)	5.6
Other Emissions (total)	2.2
TOTAL	9.5

Model Description	
Development	Baseline
Model	ISC3BE
PM_{10} Guideline [µg/m³]	50
Maximum [µg/m³]	113
Exceedences / Year [#]	33

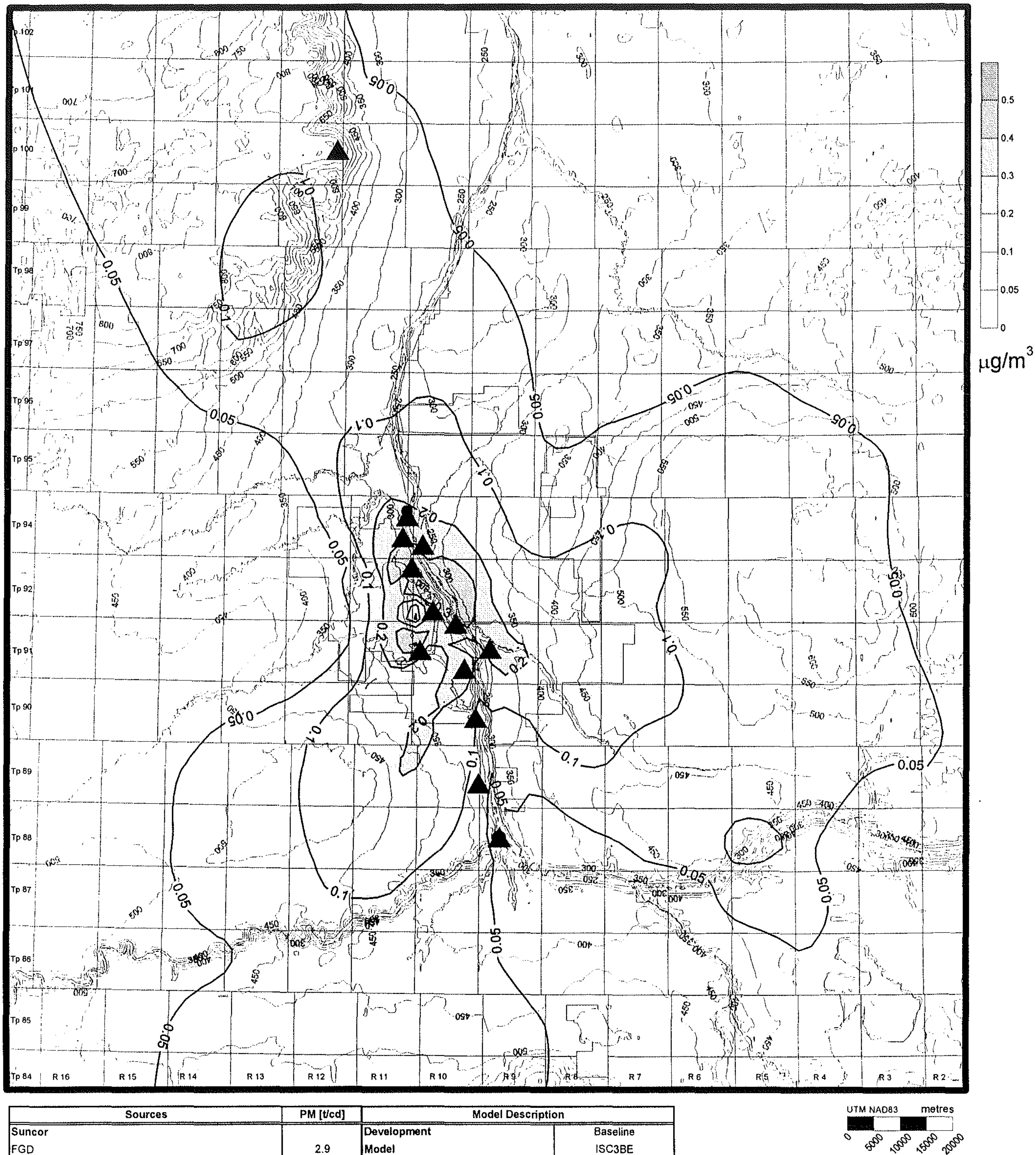
Figure B2-27 Predicted Baseline PM_{10} Maximum Daily Average Ground Level Concentrations in the RSA



Sources	PM [t/cd]
Suncor	
FGD	1.10
Powerhouse	0.24
Incinerator	0.03
Lease 86/17 Mine Fleet	0.05
Steepbank Mine Fleet	0.05
Other Sources, Suncor	0.23
Syncrude (total)	5.6
Other Emissions (total)	2.2
TOTAL	9.5

Model Description	
Development	Baseline
Model	ISC3BE
PM_{10} Guideline [µg/m³]	50
Maximum [µg/m³]	45.8
Exceedences / Year [#]	0

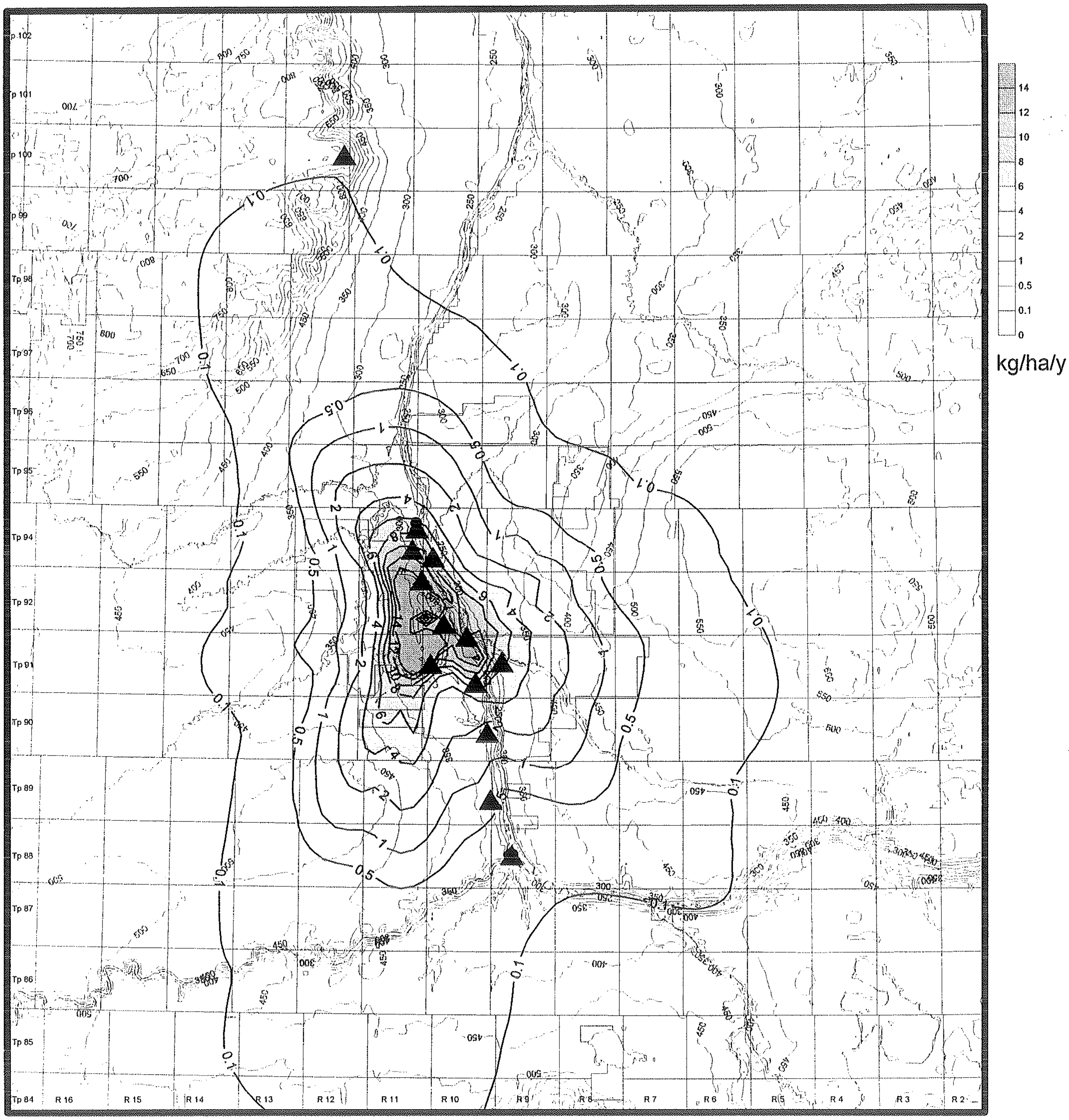
Figure B2-28 Predicted Baseline PM_{10} Annual Average Ground Level Concentrations in the RSA



Sources	PM [t/cd]
Suncor	
FGD	2.9
Powerhouse	-
Incinerator	-
Lease 86/17 Mine Fleet	-
Steepbank Mine Fleet	-
Other Sources, Suncor	-
Syncrude Main Stack	7.1
Other Emissions (total)	-
TOTAL	10.0

Model Description	
Development	Baseline
Model	ISC3BE

Figure B2-29 Predicted Baseline Particulate Annual Average Ground Level Concentrations in the RSA from the operation of the Suncor FGD and Syncrude Main stacks



Sources	PM [t/cd]
Suncor	
FGD	2.9
Powerhouse	-
Incinerator	-
Lease 86/17 Mine Fleet	-
Steepbank Mine Fleet	-
Other Sources, Suncor	-
Syncrude Main Stack	7.1
Other Emissions (total)	-
TOTAL	10.0

Model Description	
Development	Baseline
Model	ISC3BE

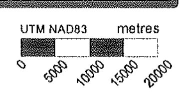


Figure B2-30 Predicted Baseline Particulate Annual Average Deposition in the RSA from the operation of the Suncor FGD and Syncrude Main stacks

Table B2-22 Average Ground Level Concentrations of Heavy Metals at Selected Sites as a Result of Emissions From Suncor FGD and Syncrude Main Stack

Location	Average Daily Ground Level Concentration					Average Annual Ground Level Concentration			
	Ontario AAQC, Daily [ng/m³]	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan
Heavy Metals [ng/m³]									
Antimony	—	5.6E-02	8.4E-03	2.8E-02	2.8E-03	2.9E-03	3.6E-04	2.2E-03	1.2E-04
Arsenic	3.00E+03	8.9E-02	1.3E-02	4.4E-02	4.4E-03	4.6E-03	5.7E-04	3.5E-03	1.9E-04
Aluminum	—	9.2E+00	1.3E+00	5.4E+00	4.5E-01	4.8E-01	5.1E-02	4.3E-01	1.9E-02
Barium	1.00E+05	8.9E-01	1.3E-01	4.3E-01	4.4E-02	4.6E-02	5.8E-03	3.4E-02	1.9E-03
Beryllium	0.00E+00	1.0E-02	1.5E-03	5.3E-03	5.1E-04	5.4E-04	6.5E-05	4.2E-04	2.2E-05
Cadmium	2.00E+04	2.0E-02	2.7E-03	1.2E-02	9.7E-04	1.0E-03	1.0E-04	9.8E-04	3.9E-05
Calcium	—	1.0E+01	1.4E+00	6.5E+00	4.9E-01	5.2E-01	5.1E-02	5.1E-01	1.9E-02
Chromium	1.50E+04	4.5E+00	6.6E-01	2.5E+00	2.2E-01	2.4E-01	2.7E-02	1.9E-01	9.5E-03
Cobalt	1.00E+03	2.4E-01	3.5E-02	1.4E-01	1.2E-02	1.3E-02	1.4E-03	1.1E-02	5.0E-04
Copper	5.00E+05	4.1E-01	5.8E-02	2.3E-01	2.0E-02	2.1E-02	2.4E-03	1.8E-02	8.4E-04
Iron	—	4.2E+01	5.8E+00	2.6E+01	2.1E+00	2.2E+00	2.3E-01	2.0E+00	8.3E-02
Lead	0.00E+00	6.0E-01	9.1E-02	2.8E-01	2.9E-02	3.1E-02	4.0E-03	2.3E-02	1.3E-03
Magnesium	—	2.8E+00	4.2E-01	1.5E+00	1.4E-01	1.5E-01	1.8E-02	1.1E-01	6.0E-03
Manganese	—	1.8E+00	2.6E-01	8.9E-01	8.7E-02	9.2E-02	1.1E-02	7.1E-02	3.8E-03
Mercury	2.00E+04	1.2E-02	1.7E-03	6.2E-03	5.8E-04	6.1E-04	7.2E-05	4.9E-04	2.5E-05
Molybdenum	1.20E+06	8.7E-01	1.3E-01	4.6E-01	4.3E-02	4.5E-02	5.4E-03	3.6E-02	1.8E-03
Nickel	2.00E+04	7.2E+00	1.0E+00	4.1E+00	3.5E-01	3.8E-01	4.2E-02	3.2E-01	1.5E-02
Phosphorus	—	4.6E+00	7.5E-01	1.8E+00	2.3E-01	2.4E-01	3.5E-02	1.4E-01	1.1E-02
Selenium	1.00E+05	2.5E+00	4.2E-01	9.0E-01	1.3E-01	1.3E-01	2.0E-02	7.2E-02	6.0E-03
Silicon	—	8.1E+01	1.0E+01	5.8E+01	4.0E+00	4.2E+00	3.5E-01	4.6E+00	1.5E-01
Silver	1.00E+04	8.5E-02	1.1E-02	5.5E-02	4.2E-03	4.4E-03	4.3E-04	4.3E-03	1.6E-04
Sodium	—	7.3E+01	1.1E+01	3.7E+01	3.6E+00	3.8E+00	4.6E-01	2.9E+00	1.6E-01
Tin	1.00E+05	6.1E-01	9.3E-02	3.0E-01	3.0E-02	3.2E-02	4.0E-03	2.4E-02	1.3E-03
Titanium	—	1.0E+00	1.5E-01	5.6E-01	5.0E-02	5.3E-02	6.1E-03	4.4E-02	2.1E-03
Vanadium	2.00E+04	3.4E+00	5.0E-01	1.8E+00	1.7E-01	1.8E-01	2.1E-02	1.4E-01	7.1E-03
Zirconium	—	6.1E-01	9.3E-02	3.0E-01	3.0E-02	3.2E-02	4.0E-03	2.4E-02	1.3E-03
Zinc	1.20E+06	1.7E+01	1.9E+00	1.4E+01	8.1E-01	8.6E-01	5.6E-02	1.1E+00	2.7E-02

OAAQC: Ontario Ambient Air Quality Criteria
Ontario Ministry of the Environment 1994
Summary of Point of Impingement Standards, Ambient Air Quality Criteria (AAQC), and Approvals Screening Levels

Table B2-23 Average Ground Level Concentrations of PAHs at Selected Sites as a Result of Emissions From Suncor FGD and Syncrude Main Stack

Location	Average Daily Ground Level Concentration				Average Annual Ground Level Concentration			
	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan
PAHs [ng/m^3]								
Acenaphthene	9.3E-04	1.5E-04	4.0E-04	4.6E-05	4.9E-05	6.6E-06	3.2E-05	2.1E-06
Acenaphylene	2.7E-02	3.1E-03	2.3E-02	1.3E-03	1.4E-03	8.8E-05	1.8E-03	4.4E-05
Anthracene	2.5E-03	4.1E-04	1.0E-03	1.3E-04	1.3E-04	1.9E-05	8.0E-05	5.9E-06
1,2-Benzathracene	1.1E-03	1.7E-04	5.7E-04	5.6E-05	6.0E-05	7.3E-06	4.5E-05	2.5E-06
Benzo(b & j)fiuoranthene	6.9E-03	1.1E-03	2.9E-03	3.4E-04	3.6E-04	5.0E-05	2.3E-04	1.6E-05
Benzo(k)fluoranthene	1.1E-03	1.7E-04	6.3E-04	5.6E-05	5.9E-05	6.8E-06	4.9E-05	2.4E-06
Benzo(a)fluorene	1.0E-03	1.6E-04	4.4E-04	5.1E-05	5.4E-05	7.4E-06	3.5E-05	2.3E-06
Benzo(b)fluorene	6.2E-04	9.4E-05	2.9E-04	3.0E-05	3.2E-05	4.1E-06	2.3E-05	1.3E-06
Benzo(g, h, i)perylene	1.3E-03	2.0E-04	7.2E-04	6.6E-05	7.0E-05	8.1E-06	5.7E-05	2.8E-06
Benzo(a)pyrene	9.5E-04	1.4E-04	4.7E-04	4.7E-05	5.0E-05	6.2E-06	3.7E-05	2.1E-06
Benzo(e)pyrene	6.2E-04	9.4E-05	2.9E-04	3.0E-05	3.2E-05	4.1E-06	2.3E-05	1.3E-06
Camphene	1.7E-03	2.7E-04	6.7E-04	8.3E-05	8.8E-05	1.3E-05	5.3E-05	3.9E-06
Carbazole	9.5E-04	1.5E-04	4.1E-04	4.7E-05	5.0E-05	6.8E-06	3.3E-05	2.2E-06
1 -Chloronaphthalene	8.7E-04	1.3E-04	4.0E-04	4.3E-05	4.5E-05	5.9E-06	3.1E-05	1.9E-06
2-Chloronaphthalene	1.3E-03	1.8E-04	7.7E-04	6.4E-05	6.8E-05	7.3E-06	6.0E-05	2.6E-06
Chrysene	2.2E-03	3.1E-04	1.3E-03	1.1E-04	1.1E-04	1.2E-05	1.0E-04	4.4E-06
Dibenz(a, j)acridine	1.0E-03	1.5E-04	5.3E-04	5.1E-05	5.4E-05	6.5E-06	4.2E-05	2.2E-06
Dibenz(a, h)acridine	8.4E-04	1.3E-04	3.7E-04	4.2E-05	4.4E-05	5.9E-06	3.0E-05	1.9E-06
Dibenz(a, h anthracene	8.7E-04	1.3E-04	4.0E-04	4.3E-05	4.5E-05	5.9E-06	3.1E-05	1.9E-06
Dibenzothiophene	1.1E-01	1.2E-02	9.1E-02	5.3E-03	5.6E-03	3.5E-04	7.1E-03	1.8E-04
7,12-dimethylbenz(a)anthracene	8.4E-04	1.3E-04	3.7E-04	4.2E-05	4.4E-05	5.9E-06	3.0E-05	1.9E-06
1, 6-Dinitropyrene	8.4E-04	1.3E-04	3.7E-04	4.2E-05	4.4E-05	5.9E-06	3.0E-05	1.9E-06
1, 8-Dinitropyrene	8.4E-04	1.3E-04	3.7E-04	4.2E-05	4.4E-05	5.9E-06	3.0E-05	1.9E-06
Fluoranthene	7.6E-03	1.2E-03	3.5E-03	3.8E-04	4.0E-04	5.2E-05	2.8E-04	1.7E-05
Fluorene	4.3E-03	7.1E-04	1.6E-03	2.1E-04	2.3E-04	3.3E-05	1.3E-04	1.0E-05
Ideno(l, 2, 3-cd)pyrene	1.2E-03	1.7E-04	7.0E-04	6.0E-05	6.4E-05	7.1E-06	5.5E-05	2.5E-06
Indole	1.7E-03	2.8E-04	6.9E-04	8.6E-05	9.1E-05	1.3E-05	5.5E-05	4.0E-06
1 -Methylnaphthalene	3.4E-02	4.2E-03	2.5E-02	1.6E-03	1.7E-03	1.4E-04	1.9E-03	6.0E-05
2-Methylnaphthalene	3.2E-02	4.2E-03	2.2E-02	1.6E-03	1.7E-03	1.5E-04	1.8E-03	6.0E-05
Naphthalene	4.4E-01	5.2E-02	3.4E-01	2.1E-02	2.3E-02	1.6E-03	2.7E-02	7.4E-04
Nitro-pyrene	1.2E-03	1.9E-04	4.9E-04	5.8E-05	6.2E-05	8.5E-06	3.9E-05	2.7E-06
Perylene	6.2E-04	9.4E-05	2.9E-04	3.0E-05	3.2E-05	4.1E-06	2.3E-05	1.3E-06
Phenanthrene	6.1E-02	8.2E-03	3.9E-02	3.0E-03	3.2E-03	3.1E-04	3.1E-03	1.2E-04
Pyrene	7.4E-03	1.0E-03	4.5E-03	3.6E-04	3.9E-04	4.1E-05	3.5E-04	1.5E-05
Retene	1.0E-02	1.6E-03	4.5E-03	4.9E-04	5.2E-04	6.9E-05	3.6E-04	2.2E-05

The PM assessment from the Suncor FGD stack reflects the most recent stack survey data which included analysis of heavy metals, PAHs and particulate size fractions. This data has been included in the air quality section, but was not available in time for the writing of the health assessment in Section F.

B2.2.7 Fugitive Dust Discussion

The maximum predicted PM does not include contributions due to non-combustion sources nor natural background levels. Potential fugitive sources associated with the Suncor operation includes the coke piles, road dust, beaches, and sand dykes. It is Suncor's experience that the mining area, given the coarse nature of oil sands (bitumen and sand combination), is expected to produce minimal PM fugitive emissions. The existing reclamation activities will control fugitive particulate emissions from the sand dykes and beaches. Suncor's ongoing operations include particulate control programs for the coke piles and the haul roads. Overall, fugitive emissions are possible on an episodic basis but are managable with existing management systems.

B2.2.8 Volatile Organic Compounds Predicted Concentrations

The VOC emission sources associated with the baseline operations are summarized in Section B2.1 (e.g., Tables B2-1 to B2-6). Total estimated emission rates for the baseline case are 180 t/cd for VOC (Table B2-6). Suncor represents about 70% of the VOC total emissions. The major emission sources from Suncor are the Tailings Pond 1 and the mine surface areas (Table B2-1). Overall, tailings ponds and exposed mine surfaces emissions represent about 85% of the VOC emissions. Using the VOC runs and the unique fingerprint of each emission source, specific VOCs were further speciated from the modelling results.

The predicted annual average ground level ambient total VOC concentrations resulting from emissions of all approved industrial sources and residential emissions in the oil sands region were estimated using ISC3BE and meteorology measurements from the Mannix station. This model provides an efficient means of predicting the overall ambient VOC concentration and the speciated compounds from all sources.

The predicted total VOC annual average ground level concentrations are mapped in Figure B2-31. The results show that the overall maximum annual concentrations are expected to occur over the Suncor's Tailings Pond 1 (a secondary extraction tailings pond). Because source characterization simplifications are used to model large sources such as tailings ponds, which include annualized emission rates and homogeneous emissions over the ponds surfaces, maximum concentrations under worst case meteorology are likely over-estimated very close to the pond. The annual concentrations for selected receptors are listed in Table B2-24 and are put into perspective in the health discussion in Section F1.

Table B2-24 Maximum Observed Annual Average Ground Level Concentrations of VOCs for Baseline Conditions at Selected Locations

	VOC Concentration [µg/m³]				
Species	Location of Maximum	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan
Total VOCs					
Maximum concentration [µg/m³]	17,400	428	50	107	7
Speciated VOCs					
C2 to C4 alkanes and alkenes	252	6.2	0.7	1.6	0.10
C5 to C8 Alkanes and alkenes	6,565	162	18.9	40.4	2.7
C9 to C12 alkanes and alkenes [(a)]	6,508	160	18.8	40.0	2.6
Cyclohexane	1,467	36	4.2	9.0	0.6
Benzene	59	1.4	0.17	0.36	0.024
C6 to C8 non-benzene aromatics	898	22	2.6	5.5	0.4
Total aldehydes	24	0.6	0.069	0.147	0.010
Total ketones	7	0.2	0.019	0.040	0.003
Total Reduced Sulphur Compounds	378	9.3	1.1	2.3	0.2

[(a)] Unknown speciation are included in Group C9 to C12.

The large sources have been represented in the ISC3BE model using an area source characterization. Because sources such as tailings ponds are large and because their emissions originate at ground level, there is decreased opportunity for dispersion of their plume compared to an elevated source, such as a stack. Persistent low concentrations (i.e., not varying greatly with changes in meteorology compared to stack emissions) can be expected in the modelling results from these large area sources and is reflected in Figure B2-31 throughout a large portion of the RSA.

B2.2.9 TRS Predicted Concentration

The ambient TRS emission sources associated with the baseline operations are summarized in Section B2.1 (e.g., Tables B2-1 to B2-6). Total estimated TRS emission rate for the Baseline case is 3.8 t/cd. The major sources of TRS emissions from Suncor are the tailing ponds representing approximately 1.3 t/cd. In total, Suncor emits approximately 40% of the TRS.

The predicted maximum hourly, daily and annual ground level ambient TRS concentrations resulting from emissions of all approved industrial sources and residential emissions in the oil sands region were estimated using ISC3BE and meteorology measurements from the Mannix station. Selected results of the speciated reduced sulphide compounds are shown in Figure B2-32 and Figure B2-33 for the hourly and daily H_2S and in Figure B2-34 for hourly mercaptans. These TRS species were selected

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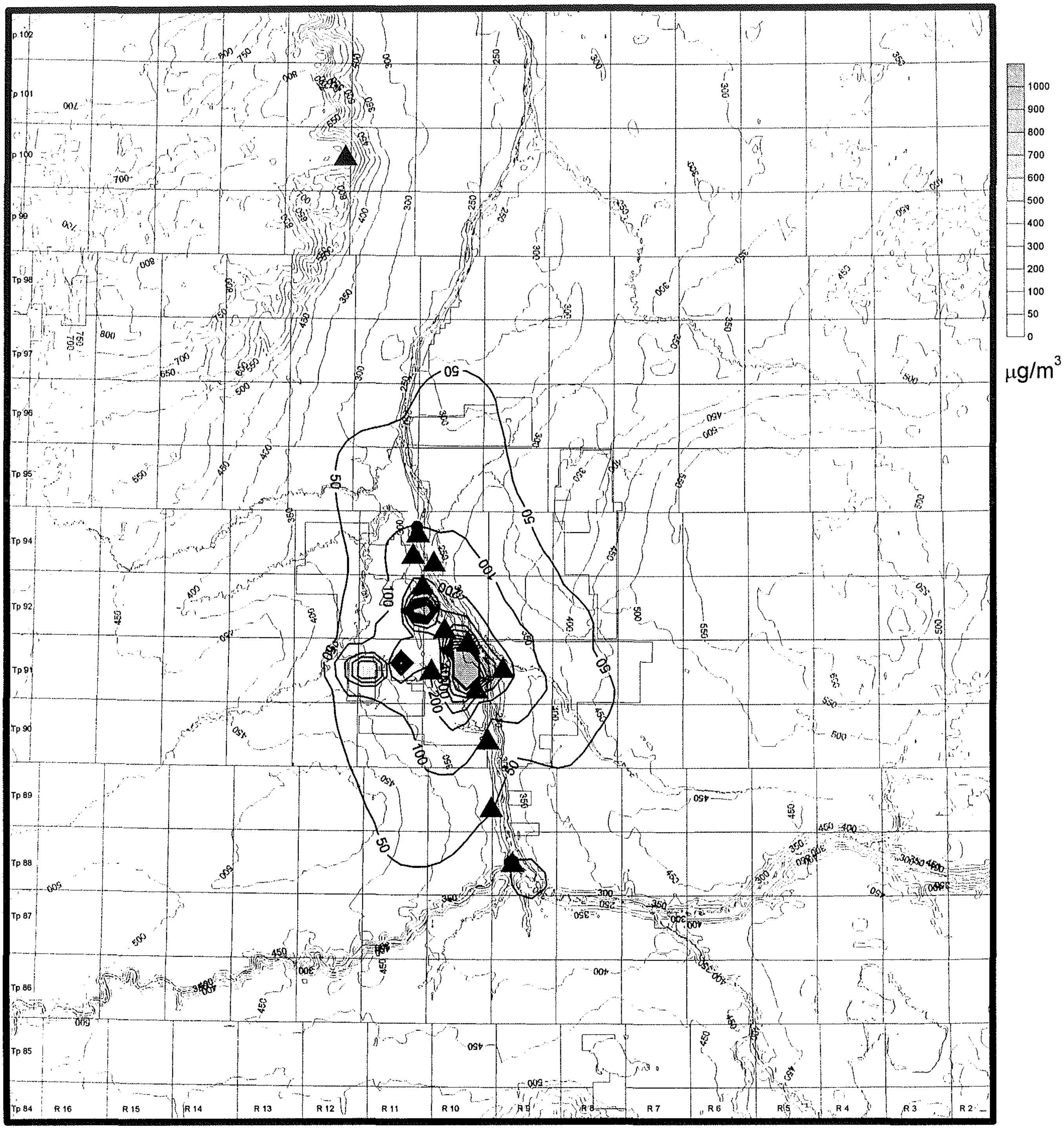

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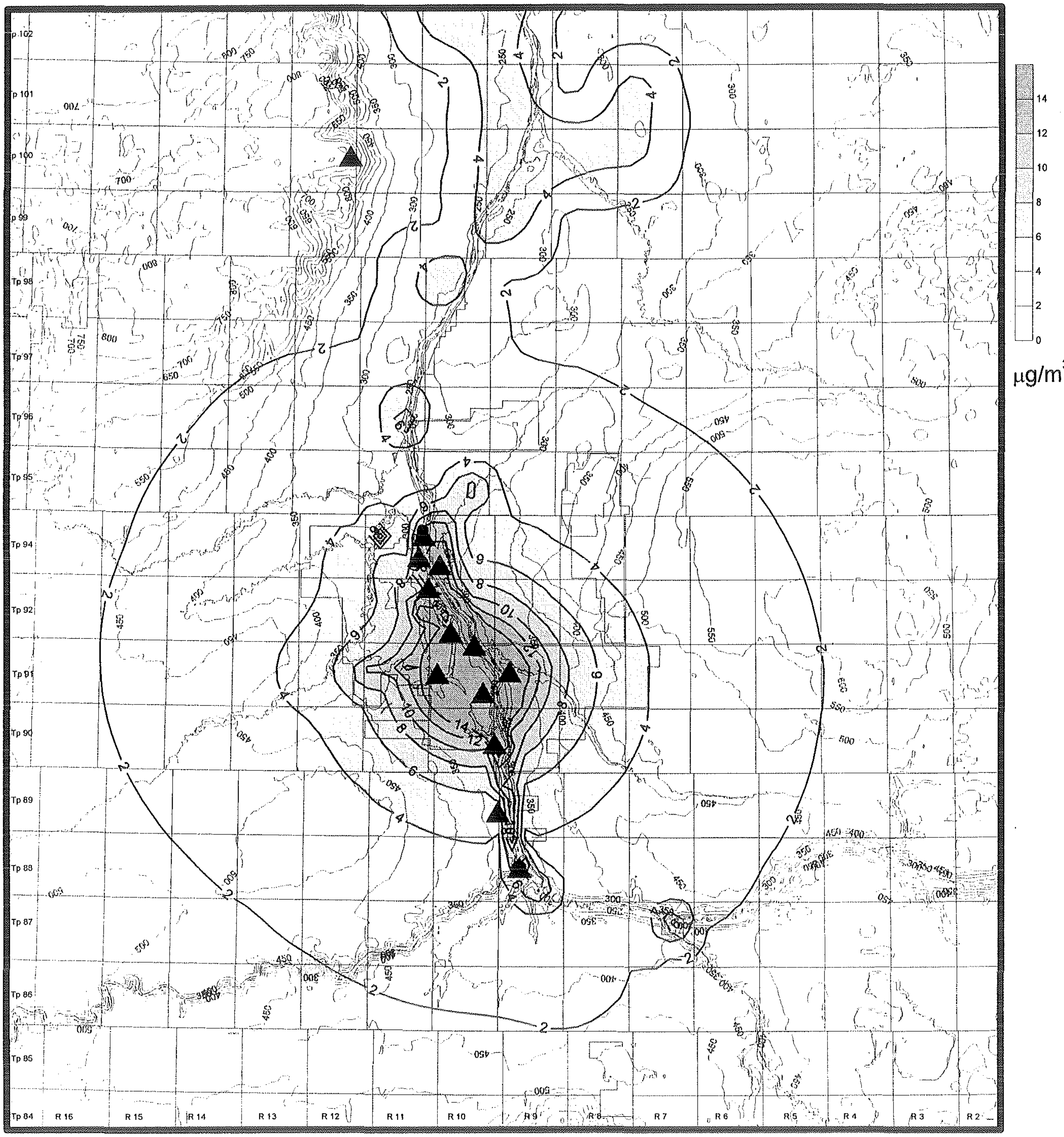
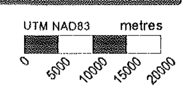
Sources	VOC [t/cd]
Suncor Plant	17.6
Syncrude Plant	5.4
Mine Fleets	1.7
Mine Faces	17.2
Tailings Ponds	128.6
TOTAL	170.5

Model Description	
Development	Baseline
Model	ISC3BE

Figure B2-31 Predicted Baseline VOC Maximum Annual Average Ground Level Concentrations in the RSA





Sources	H_2S [t/cd]
Suncor Plant	0.027
Syncrude Plant	0.008
Mine Fleets	0.003
Mine Faces	0.026
Tailings Ponds	0.195
TOTAL	0.259

Model Description	
Development	Baseline
Model	ISC3BE

Figure B2-32 Predicted Baseline H_2S Maximum Hourly Average Ground Level Concentrations in the RSA

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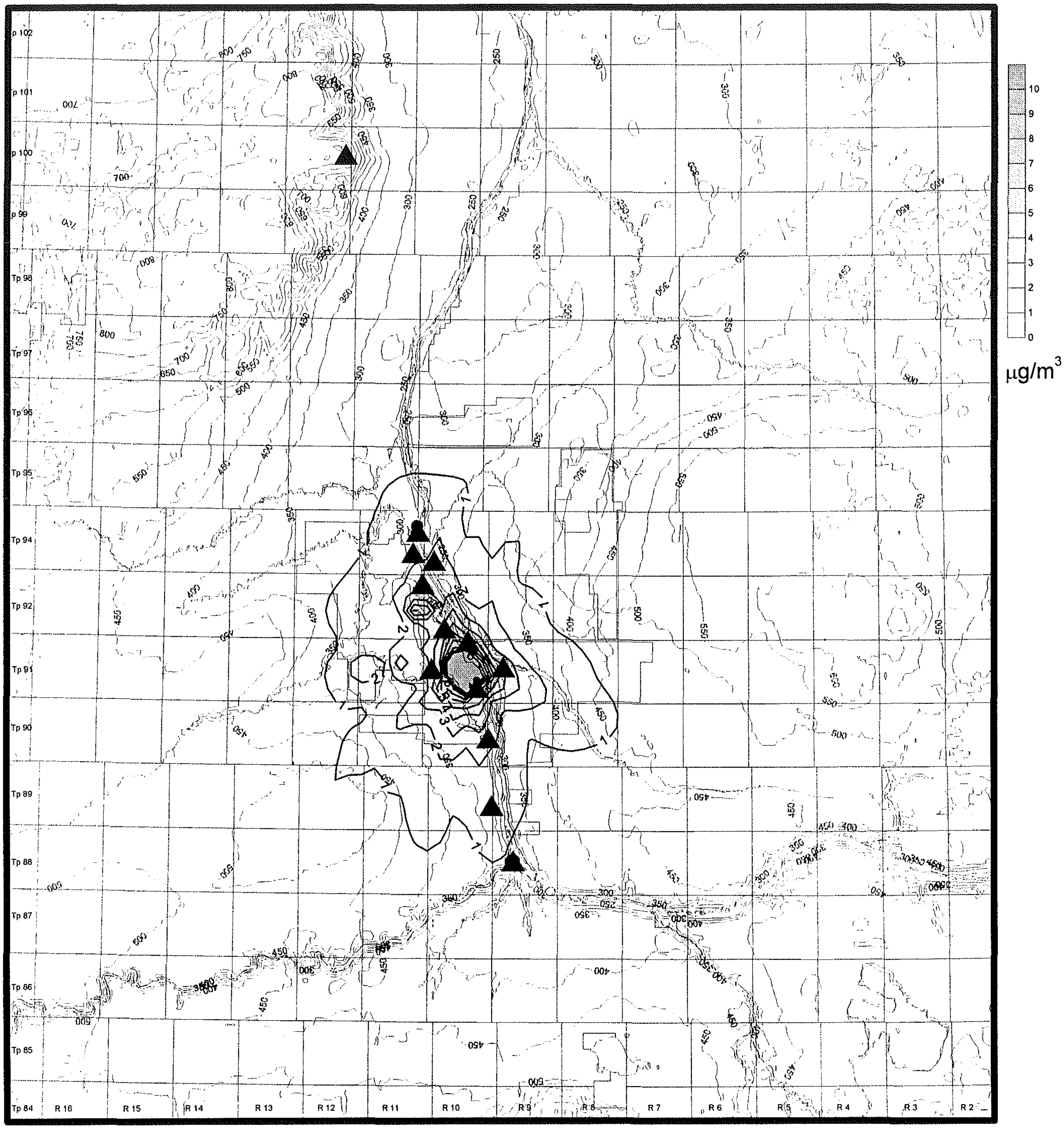


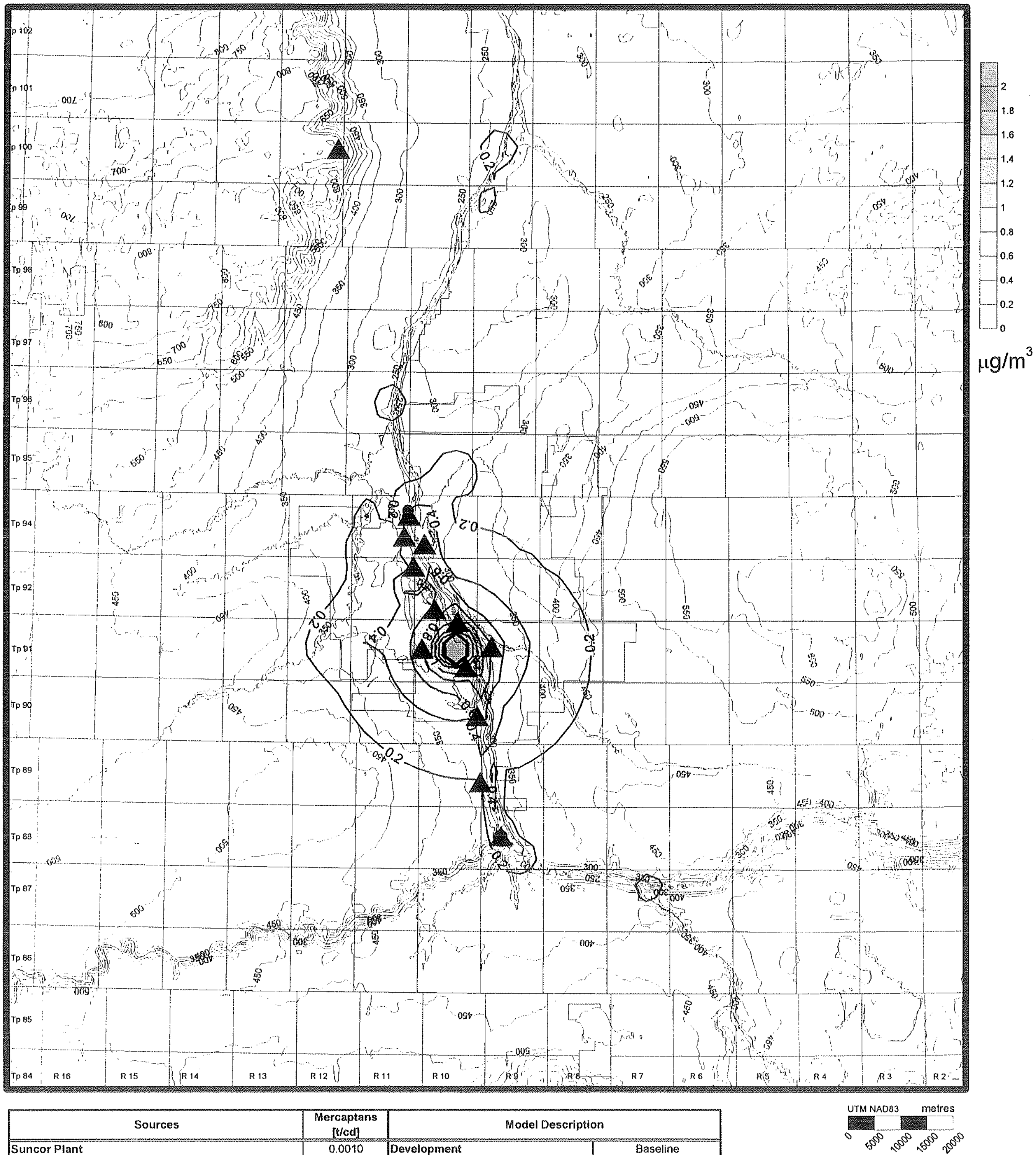
UTM NAD83 metres

0 5000 10000 15000 20000

Sources	H_2S [t/cd]
Suncor Plant	0.027
Syncrude Plant	0.008
Mine Fleets	0.003
Mine Faces	0.026
Tailings Ponds	0.195
TOTAL	0.259

Model Description	
Development	Baseline
Model	ISC3BE

Figure B2-33 Predicted Baseline H_2S Maximum Daily Average Ground Level Concentrations in the RSA



Sources	Mercaptans [t/cd]
Suncor Plant	0.0010
Syncrude Plant	0.0003
Mine Fleets	0.0001
Mine Faces	0.0010
Tailings Ponds	0.0075
TOTAL	0.0100

Model Description	
Development	Baseline
Model	ISC3BE

Figure B2-34 Predicted Baseline Mercaptans Maximum Hourly Average Ground Level Concentrations in the RSA

because they have particularly low odour thresholds. Maximum hourly and daily concentrations at selected locations are listed in Table B2-24 and Table B2-25. Similar to the discussion in the VOC section above, the predicted maximum concentration occurs directly over a Suncor tailings pond and the predicted maximum concentration at that location is a result of the modelling simplifications.

Whereas the ISC3BE model was not configured to explicitly assess odours, the concentrations at the selected locations can be used to qualitatively assess the potential for odour detection at these locations. The results presented in the figures do not address the complexities of thorough odour assessment which would take into account concentration magnitude, duration above a threshold, frequency of exceeding various thresholds and receptor sensitivity. As a part of the ISC3BE development, the dispersion coefficients were adjusted for receptors within the Athabasca River valley such that limited mixing could occur under certain meteorological conditions. The result of this fine tuning can be seen in Figure B2-32 in the elevated H_2S concentrations within the Athabasca River valley.

The results in Table B2-25 and Table B2-26 indicate that the predicted concentrations could potentially lead to the detection of odours originating from the developments in the oil sands area for sensitive individuals.

Table B2-25 Maximum Predicted Hourly Concentrations of TRS at Selected Sites for Baseline Sources

	TRS Concentration [μg/m³]				
Species	Location of Maximum	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan
Total Reduced Sulphur Compounds					
Maximum VOC concentration [μg/m³]	71,800	21,036	6,063	7,722	2,081
Maximum TRS concentration [μg/m³]	1,561	457	132	168	45
Speciated Compounds					
H_2S	109	31.9	9.2	11.7	3.2
COS	0	0	0	0	0
CS_2	0	0	0	0	0
Mercaptans	4.20	1.23	0.36	0.45	0.12
Thiophenes	563	165	48	61	16

Alberta H_2S hourly guideline - 15 μg/m³
Odour threshold for mercaptans is 0.04 to 2.0 μg/m³
Odour threshold for H_2S is 0.7 to 14 μg/m³

Table B2-26 Maximum Predicted Daily Concentrations of TRS at Selected Sites for Baseline Sources

	TRS Concentration [μg/m³]				
Species	Location of Maximum	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan
Total Reduced Sulphur Compounds					
Maximum VOC concentration [μg/m³]	46,900	5,448	597	1,093	127
Maximum TRS concentration [μg/m³]	1,019	118	13	24	3
Speciated Compounds					
H_2S	71	8.3	0.9	1.7	0.2
COS	0	0	0	0	0
CS_2	0	0	0	0	0
Mercaptans	2.75	0.32	0.03	0.06	0.00
Thiophenes	367	43	5	9	0

Alberta H_2S hourly guideline - 15 μg/m³
Odour threshold for mercaptans is 0.04 to 2.0 μg/m³
Odour threshold for H_2S is 0.7 to 14 μg/m³

B3 AIR QUALITY

B3.1 PROPOSED EMISSIONS

Suncor's oil sands operations result in a number of air emissions from a variety of sources. This section describes and quantifies the changes in the air emissions as a result of Project Millennium. A detailed project description is provided in Section C, Volume I, of the application.

Air quality changes due to the emissions from Project Millennium will combine with emissions from existing sources in the RSA and with ambient conditions associated with air flow into the region. Air quality related issues associated with these emissions can be summarized as a series of key questions whose linkages are identified in Figure B3-1. The key questions are as follows:

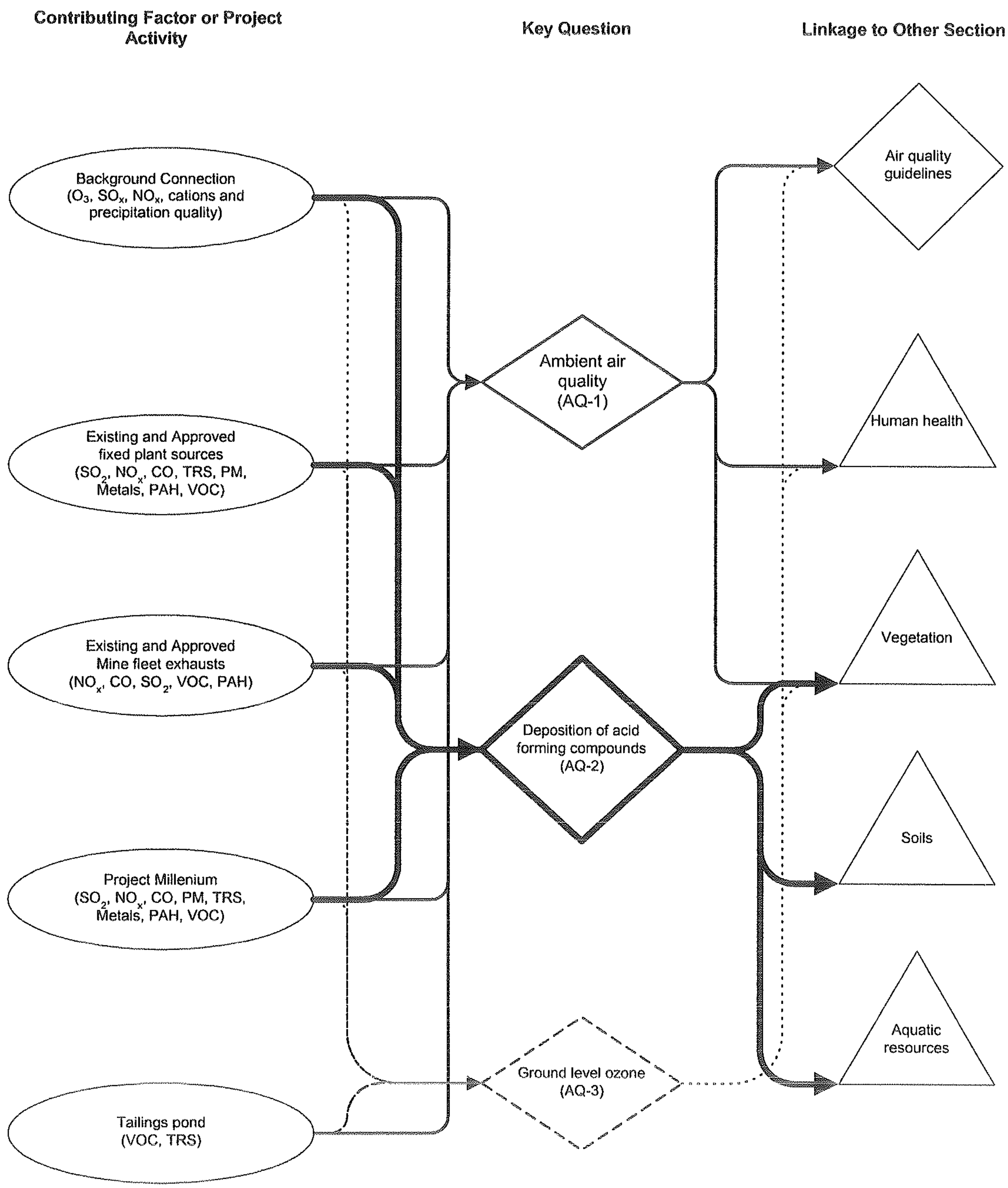
AQ-1 What impacts will air emissions from Project Millennium have on ambient air quality?

The potential for air emissions to have an impact on ambient air quality has been raised as a concern. To address this issue, predicted air quality concentrations were modelled using the ISC3BE air dispersion model. The selected parameters for air quality are SO_2, NO_2, CO, PM, VOC and TRS. The modelling results were compared to Alberta Ambient Air Quality Guidelines, Canadian Federal Air Quality Objectives or other guidelines to assist in the prediction of impacts. The linkage pathway for this key question is depicted by the narrow line in Figure B3-1.

AQ-2 What impacts will air emissions from Project Millennium have on the deposition of acid-forming compounds?

In the Project Millennium case, NO_x and SO_2 air emissions are considered the primary sources that result in the deposition of acid-forming compounds. The preferred method for evaluating the overall effects of these compounds is by determining the Potential Acid Input (PAI). This method takes into account the acidification effect of sulphur and nitrogen species as well as the neutralizing effect of available cations. Modelling of PAI was undertaken for the Project Millennium case using the CALPUFF model and the results presented in a manner that allowed for use in other components of the EIA. In particular the results were incorporated into determining impacts to Water Quality (C3), Soils (D2) and Vegetation and Wetlands (D3). The linkage pathway for this key question is depicted by the bolded line in Figure B3-1.

Figure B3-1 Air Quality Linkage Diagram for Project Millennium



AQ-3 What impacts will air emissions from Project Millennium have on concentrations of ground level ozone?

The evaluation of ground level ozone concentrations is complicated since ozone is not directly emitted from Project Millennium, but rather results from a series of chemical reactions in the atmosphere. Research is ongoing to determine the most appropriate tools to predict ozone concentrations. Until the research is completed in October 1998, predicted impacts this project will have on ozone levels is undetermined. The linkage pathway for this key question is depicted by the dotted line in Figure B3-1.

B3.1.1 Proposed Emissions

B3.1.1.1 Project Millennium

The Project Millennium expansion will increase Suncor's overall production rate and change overall air emissions. Important air emissions and their potential changes to ambient air quality as a result of this project are summarized below.

- **Sulphur Dioxide** (SO_2) emissions result from the combustion of petroleum coke and upgrading operations. These can acidify surrounding soils and water bodies and cause changes to ambient air quality.
- **Oxides of Nitrogen** (NO_x) emissions result from the mine fleet and combustion sources in Energy Services and Upgrading. These emissions can cause ambient air quality changes and deposition of acidifying emissions. They also can act as precursors for the photochemical production of ozone which may impact human health and vegetation.
- **Volatile Organic Compounds** (VOC) and other hydrocarbon emissions result from the tailings ponds mine fleet exhaust, the mine pit area, and upgrading and extraction operations. These emissions can cause ambient air quality changes, the photochemical production of ground level ozone and potential impact on human health.
- Fugitive emissions including **Total Reduced Sulphur** (TRS) and H_2S can result from the extraction and upgrading operations and tailings ponds. These have the potential to cause off-site odours.
- **Particulate Matter** (PM) emissions can result from site clearing, mining activities, combustion sources, and coke handling and storage. PM and associated polycyclic aromatic hydrocarbons (PAHs) can have adverse impacts on human health and aquatic life.

Proposed Emissions

An overall summary of the emissions from the baseline conditions and Project Millennium is provided in Table B3-1. This table summarizes the overall air emissions expected from the facility and includes data on SO_2, NO_x, CO, PM, VOC and TRS. Comments specific to each emission parameter accompany the table and include design mitigation inputs. The existing baseline emission data were provided in Table B2-1.

Table B3-1 Summary of Suncor Project Millennium Emissions

Source	Emission [t/cd]					
	SO_2	NO_x	CO	PM[(a)]	VOC	TRS
Project Millennium						
Powerhouse stack	14.0	2.9	2.5	0.2	0.008	n/a
FGD stack	18.7	29.7	25.6	1.0	0.2	n/a
Millennium mine boilers / GTGs [(c)]	1.1	4.1	0.3	0.1	0.01	-
Sulphur incinerator	12.3	0.064	3.4	0.038	0.06	n/a
Tail gas treatment unit	8.7	0.029	3.8	0.04	0.2	n/a
Upgrading furnace stacks	4.7	3.8	1.4	0.5	14.2	-
Flaring - continuous and acid gas	10.6	0.191	0.2	0.01	0.041	0.011
Mine fleet	0.08	26.9	1.4	0.3	0.8	-
Extraction	-	-	-	-	5.4	0.1
Tank farms	-	-	-	-	4.0	0.1
Tailings ponds	-	-	-	-	200.2	2.5
Mine surface[(b)]	-	-	-	-	15.3	0.03
Total	**70.2**	**67.7**	**38.6**	**2.2**	**240.4**	**2.73**

n/a data not available
- not a source of this emission
(a) Assumed as PM_{10}.
(b) Estimated based on Syncrude data.
(c) Gas turbine generators.

SO_2 Sources

Project Millennium will result in very little change to overall SO_2 emissions when compared to the baseline conditions. As indicated in Table B3-1, the new total SO_2 emission rate is projected to be 70.2 t/cd. The major sources of SO_2 emissions to the atmosphere are the Powerhouse stack, the FDG stack, the incinerator and the continuous flare stacks.

Improved equipment, technology and operating procedures have resulted in this essentially no increase strategy. The existing sulphur plant achieves 98% recovery and the Project Millennium Upgrader sulphur plant is designed to achieve 99.7% recovery. There will be no new continuous flaring sources in the Project Millennium Upgrader. Continuous flare gas from the base plant will be recompressed for treatment and used in upgrading as part of Suncor's flare gas recovery project and will be completed in 1999 prior to Project Millennium start up.

NO_x Sources

The proposed project will result in approximately a 40 percent increase in total NO_x emissions from the baseline conditions of 47.7 t/cd to Project Millennium levels of 67.7 t/cd. The majority of the increase comes from the expansion of the mine fleet (75% of the increase) and, to a lesser degree, from the new Millennium Mine Boilers and Gas Turbine Generators. The calculation of NO_x emissions was based on a combination of emissions supplied by equipment designers and U.S. EPA emission factors.

Project Millennium will utilize the best technologies available considering capital costs, operating costs, fuel efficiency and emission performance. Suncor will initiate discussions with mining equipment suppliers to make low NO_x a priority in their design. With Millennium, Suncor expects to produce diesel with a higher cetane number than currently produced diesel. This is expected to have favourable impacts on mine vehicle fleet emissions.

CO Sources

The proposed project will result in approximately a 15% increase of the CO emissions from the baseline conditions of 33.5 t/cd to Project Millennium emissions of 38.6 t/cd. CO emissions are smaller when compared to the NO_x or SO_2 emissions. The major source of CO emissions to the atmosphere is the FGD stack.

Particulate Matter (PM_{10}) Sources

Project Millennium will result in about a 25% increase in PM emissions to the atmosphere. The major source of PM emissions will continue to be the FGD stack. PM controls on this unit include an electrostatic precipitator, that removes 98% of the particulate matter, and an additional 85% of the remainder is removed by the FGD wet scrubbing process.

VOC Sources

Project Millennium will result in approximately a 85% increase in total VOC emissions from the baseline conditions of 130.2 t/cd to emissions of 240.4 t/cd. The major source of VOC emissions to the atmosphere are the fugitive emissions generated from the tailings ponds. This source represents about 80% of the VOC emissions for Project Millennium. These emission rates are based on recent field data collection surveys completed by Suncor and a reinterpretation of historical results. The emission estimate provide for Project Millennium is based on this new data and is considered to be an upper limit or worst case estimate. Thus, the EIA has taken a conservative approach.

TRS Sources

Project Millennium will result in an approximately 80% increase in emission rates of TRS. The total emissions will increase from the baseline case of 1.523 t/cd to 2.73 t/cd. Similar to VOC emissions, the tailings ponds are the largest source of TRS from Project Millennium and represent about 90% of the emissions. TRS emissions from pond 2/3 have been assumed to scale with production levels from Baseline production levels. This likely over-estimates TRS emissions since TRS is believed to be a biogenic emission.

Greenhouse Gases

Greenhouse gases (GHG) include emissions of carbon dioxide (CO_2), methane (as equivalent CO_2) and NO_x (as equivalent CO_2). Overall GHG emissions for Project Millennium are estimated at 20,643 CO_2 eq t/cd. The majority, over 95%, is generated by direct emissions of CO_2.

B3.1.1.2 Syncrude Sources

The baseline section of this report (Section B2.1.1.2) summarizes the emissions from Syncrude. No additional sources of air emissions from Syncrude were considered in the Project Millennium impact assessment.

B3.1.1.3 Other Approved Development Industrial Sources

Air emissions from other approved developments were considered in the baseline section of this report (Section 2.1.13). No additional sources have been added to the Project Millennium case.

B3.1.1.4 Transportation and Residential Sources

No changes were made to the emission estimates from these sources as outlined in Section 2.1.1.4.

B3.1.1.5 Summary

The summary of the air emissions from Project Millennium, Syncrude, other industries, transportation and residential sources are included in Table B3-2.

Table B3-2 Summary of Project Millennium Emissions in the Athabasca Oil Sands Region

	Emission Rates (t/cd)					
	SO_2	NO_x	CO	PM_c	VOC	TRS
Suncor	70.2	67.7	38.6	2.2	240.3	2.7
Syncrude	209.0	44.4	53.61	5.4	43.84	2.3
Other Industries	3.9	8.7	27.1	0.9	5.5	0.00
Transportation and Residential	0.2	1.37	6.5	1.5	2.95	n/a
Total	**283.3**	**122.2**	**125.8**	**10.0**	**292.59**	**5.1**

n/d no data

B3.2 DISPERSION MODEL PREDICTIONS

B3.2.1 Model Approach and Limitations

Descriptions of the models used to determine the predicted ground level concentrations were discussed in Section B2.2.1. In assessing the results of Project Millennium the same models were used, in particular the ISC3BE and CALPUFF.

B3.2.2 SO_2 Predicted Concentrations

There are numerous SO_2 emission sources associated with the Project as summarized in Section B3.1.1 (Tables B3-1 and B3-2). The estimated total SO_2 emission rate in the oil sands region including the Project is 283.3 t/cd. Suncor will emit an estimated 25% (70.2 t/cd) of the total SO_2 emissions to the atmosphere (Table B3-2). The major sources of SO_2 at Suncor will be the FGD stack (18.7 t/cd), the Powerhouse stack (14.0 t/cd), the Sulphur Incinerator stack (12.3 t/cd) and continuous flaring (10.6 t/cd).

The predicted maximum hourly, daily and annual ground level ambient SO_2 concentrations resulting from emissions of Project Millennium and all approved industrial sources and residential emissions in the oil sands region were estimated using ISC3BE and CALPUFF models. Emission rates used were the calendar day (cd) for annual GLC predictions and stream day (sd) for hourly and daily GLC predictions. Four years of observed meteorological measurements from the Suncor Mannix station (75 m level) were used in the modelling. These models provide an efficient means of estimating the predicted ambient SO_2 concentrations from all sources and provides an indication where maximum concentrations could occur.

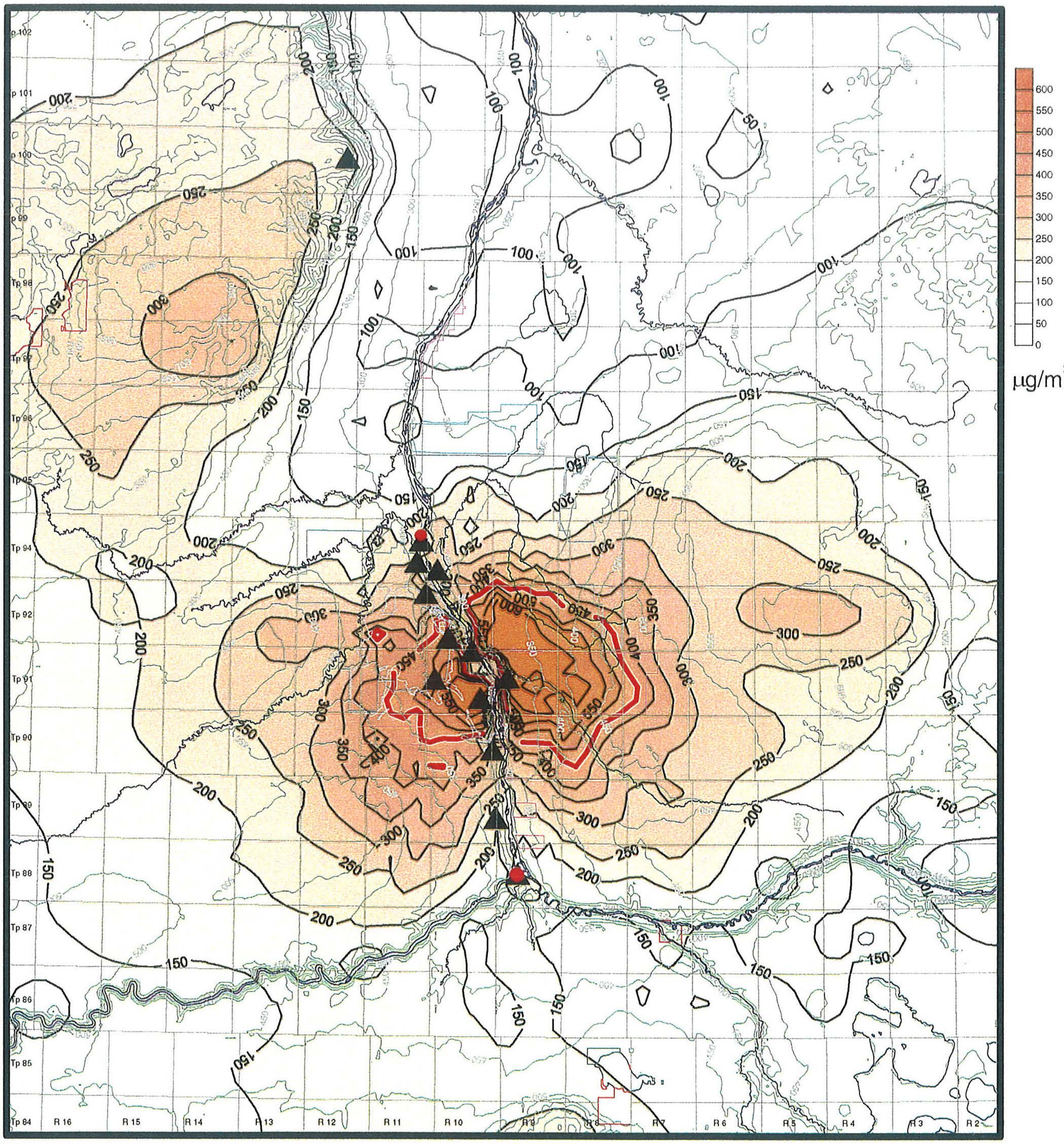
Table B3-3 Maximum Observed Ground Level Concentrations of SO_2 for Project Millennium Sources

Source	Hourly[(d)]	Daily[(d)]	Annual
Project Millennium - ISC3BE[(b)]			
Maximum SO_2 Concentration (μg/m^3)	870	200	82
Location of Maximum Concentration (km)	4 S	2 SSW	15 WNW
Maximum Number of Exceedances[(a)]	49	9	1
Location of Maximum Exceedances (km)	2 S	16 WNW	n/a
Project Millennium - CALPUFF[(c)]			
Maximum SO_2 Concentration (μg/m^3)	n/a	n/a	80
Location of Maximum Concentration (km)	n/a	n/a	15 WNW
Maximum Number of Exceedances[(a)]	n/a	n/a	1
Location of Maximum Exceedances (km)	n/a	n/a	n/a
SO_2, Alberta Guideline (μg/m^3)	450	150	30
SO_2, Federal Acceptable (μg/m^3)	900	300	60

n/a = data not available
(a) Exceeds SO_2 Alberta Guideline. Normalized for a 12-month period.
(b) Based on Stream day emission rates for hourly and daily; Calendar day for annual.
(c) Based on Calendar day emission rates.
(d) Based on a single year of meteorological variation.

The modelling predictions for daily SO_2 emission rate cases are summarized in Table B3-3 for each model. The predicted ground level concentrations are mapped in Figures B3-2 to B3-5 and described below:

- Figure B3-2 shows the maximum hourly average ground level SO_2 concentrations associated with Project Millennium for the ISC3BE model. An overall maximum hourly average SO_2 concentration, as determined by ISC3BE, of 870 μg/m^3 is predicted to occur at a location 4 km south of Suncor within the facility boundary (Figure B3-2). This maximum average value exceeds the Alberta guideline of 450 μg/m^3. This model predicts two areas that result in maximum hourly averages in excess of the guideline. The areas are south and east of Suncor and include a total of 58,860 ha of land. Approximately 70% of this area is within Suncor's lease areas. The ISC3BE model predicts a maximum of 49 yearly exceedances of the hourly guideline.
- Figure B3-3 shows the maximum daily average ground level SO_2 concentrations associated with the Project Millennium for the ISC3BE model. The overall maximum daily average SO_2 concentration, as determined by ISC3BE, of 200 μg/m^3 is predicted to occur within the existing Suncor lease boundary. This maximum average value exceeds the daily Alberta guideline of 150 μg/m^3. The predictions shown in Figure B3-3 indicate a small area of 289 ha that will have a maximum



Sources	SO_2 [t/sd]
Suncor	
Powerhouse	1.2
FGD	19.7
Incinerator	10.2
Flaring	1.3
Tail Gas Treatment Unit	5.2
Other Sources, Suncor	6.2
Syncrude (total)	209
Other Emissions (total)	4.1
TOTAL	256.9

Model Description	
Development	Project Millennium
Model	ISC3BE (7BG)
SO_2 Guideline [µg/m³]	450
Maximum [µg/m³]	870
Exceedences / Year [#]	49

Note: Results are based on a 1 year simulation

UTM NAD83 metres 0 5000 10000 15000 20000

Figure B3-2 Predicted Millennium SO_2 Maximum Hourly Average Ground Level Concentrations in the RSA using the ISCBE Model

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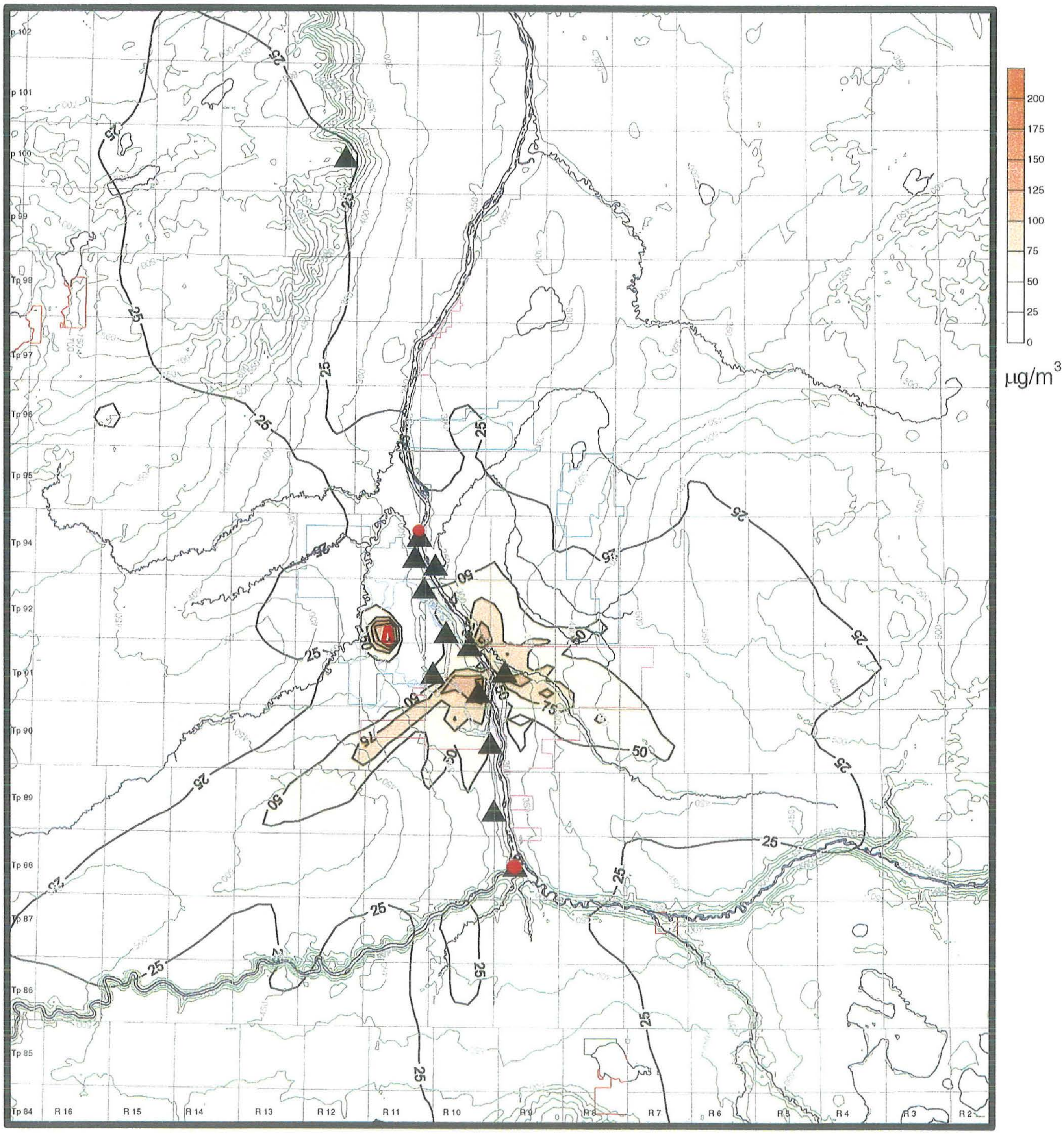

Note: Results are based on a 1 year simultaion

UTM NAD83 metres
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Sources	SO_2 [t/sd]
Suncor	
Powerhouse	1.2
FGD	19.7
Incinerator	10.2
Flaring	1.3
Tail Gas Treatment Unit	5.2
Other Sources, Suncor	6.2
Syncrude (total)	209
Other Emissions (total)	4.1
TOTAL	256.9

Model Description	
Development	Project Millennium
Model	ISC3BE (7BG)
SO_2 Guideline [µg/m³]	150
Maximum [µg/m³]	200
Exceedences / Year [#]	9

Figure B3-3 Predicted Millennium SO_2 Maximum Daily Average Ground Level Concentrations in the RSA using the ISCBE Model

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r:/1997/2200/972-2205/8600/8660/8663/ISCBE/figs/SO2SD23D.srf average in excess of the Guideline. The model predicts a maximum of 9 yearly exceedances of the guideline.

- Figures B3-4 and B3-5 show the annual average ground level concentration map for SO_2 for the ISC3BE model and CALPUFF model, respectively. The maximum annual average concentration, as determined by ISC3BE, is 82 $\mu g/m^3$ located in the current development area and covers an area of approximately 409 ha. The predicted concentrations are in excess of the annual Alberta guideline of 30 $\mu g/m^3$, with a predicted frequency of once per year.

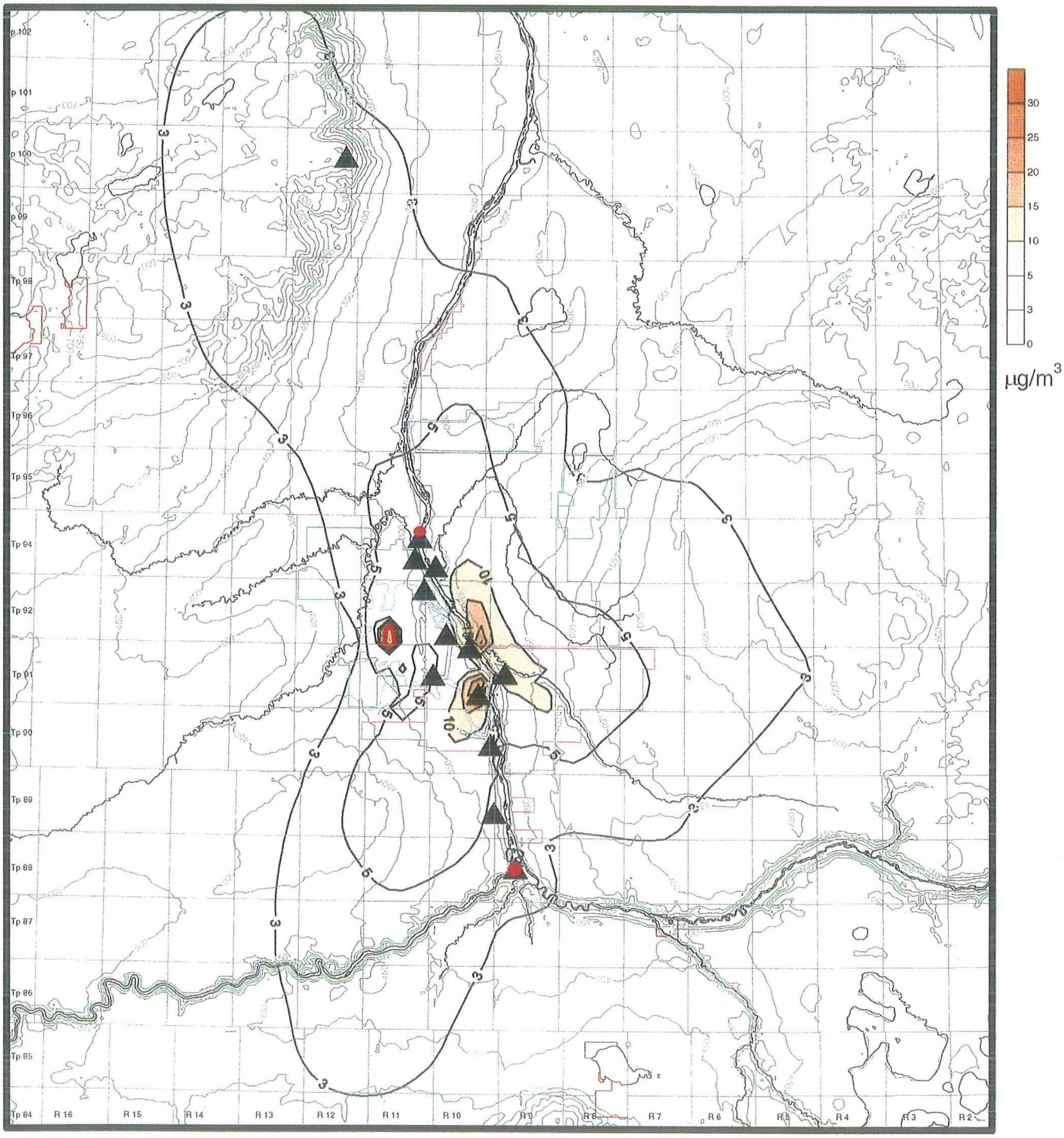
The ISC3BE modelling predictions indicate that the location and areal extent of the maximum hourly and daily SO_2 concentrations will tend to occur close to the existing operations and be are expected to be within the lease boundaries. The maximum annual averages will occur WNW of Suncor. Comparing this analysis to the Federal acceptable hourly and daily standards indicates no predicted exceedances. However, there would remain an exceedance of the Federal annual standard.

When a historical assessment approach is taken by considering only the major stack sources (i.e., Suncor FGD, Incinerator, Continuous flaring, new tail gas treatment unit and Syncrude main stack), the maximum hourly average GLC is predicted to be 503 μ/m^3. The predicted frequency of exceeding the AAAQG based on one year of meteorological variation is 6 times per year. These are the only sources of SO_2 that were included in previous assessments.

B3.2.3 NO_2 Predicted Concentrations

There are numerous NO_x emission sources associated with the Project as summarized in Section B3.1 (Table B3-1). The estimated total NO_x emission rate in the oil sands region including Project Millennium will be 122.2 t/cd (Table B3-2). Suncor will emit an estimated total of 67.7 t/cd which is approximately 55% of the total (Table B3-2). The major sources of NO_x at Suncor are the FGD stack (29.7 t/cd) and the mine fleet (26.9 t/cd).

The predicted maximum hourly, daily and annual ground level ambient NO_x concentrations resulting from emissions of Project Millennium and all approved industrial sources and residential emissions in the oil sands region were estimated using the ISC3BE and CALPUFF models. Four years of observed meteorological measurements from the Suncor Mannix station (75 m level) were used in the modelling. These models provide an efficient means of estimating the predicted ambient NO_x or NO_2 concentrations from all sources and provide an indication of where maximum concentrations could occur. The conversion of predicted NO_x to NO_2 has been estimated for ISC3BE results using the methodology described in Section B2.2.3.



Sources	SO_2 [t/cd]
Suncor	
Powerhouse	14
FGD	18.7
Incinerator	12.3
Flaring	10.6
Tail Gas Treatment Unit	6.4
Other Sources, Suncor	5.9
Syncrude (total)	209
Other Emissions (total)	4.1
TOTAL	281

Model Description	
Development	Project Millennium
Model	ISC3BE (7BG)
SO_2 Guideline [µg/m³]	30
Maximum [µg/m³]	82
Exceedences / Year [#]	1

Figure B3-4 Predicted Millennium SO_2 Annual Average Ground Level Concentrations in the RSA using the ISCBE Model

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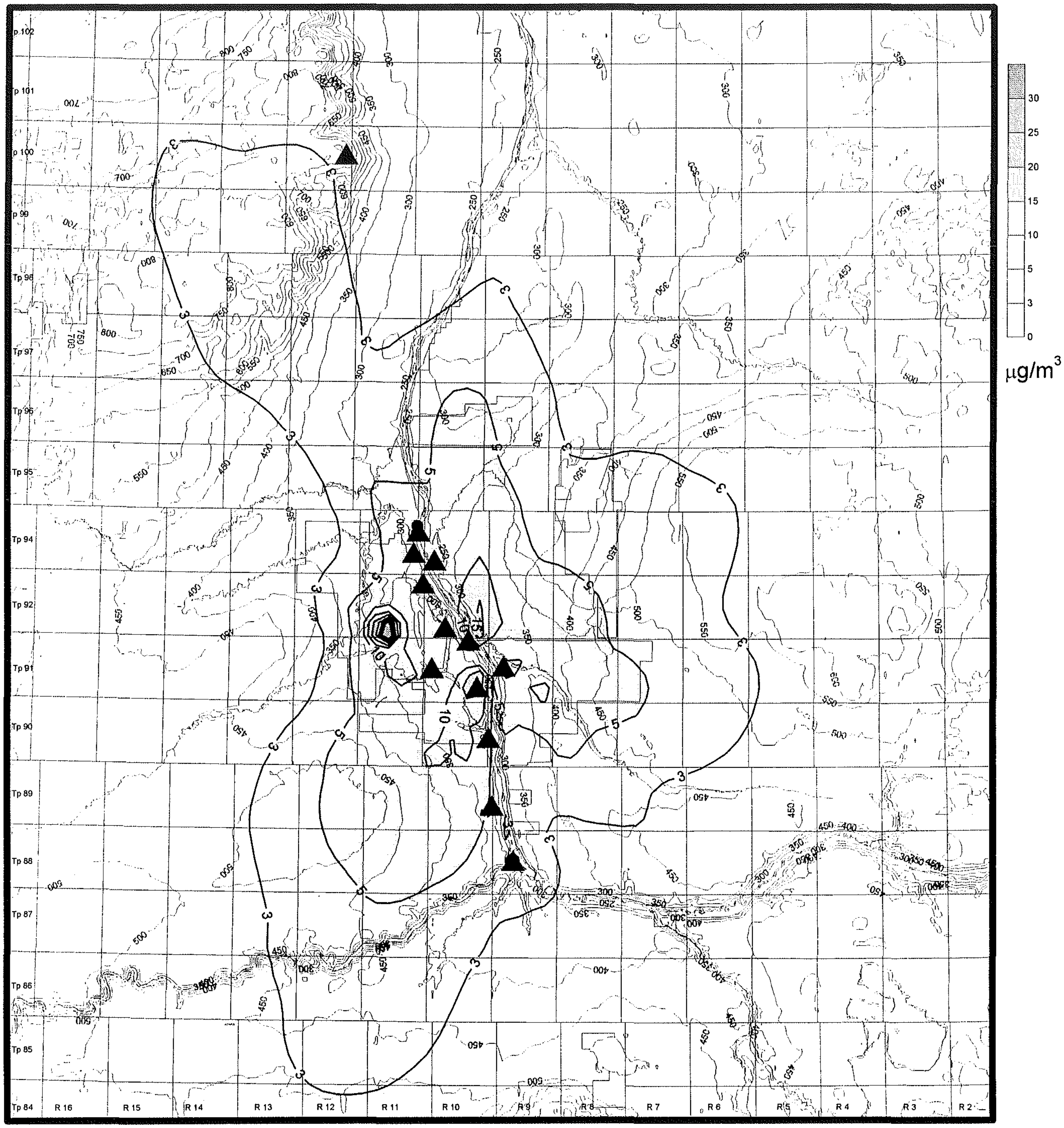

Sources	SO_2 [t/cd]
Suncor	
Powerhouse	14
FGD	18.7
Incinerator	12.3
Flaring	10.6
Tail Gas Treatment Unit	6.4
Other Sources, Suncor	5.9
Syncrude (total)	209
Other Emissions (total)	4.1
TOTAL	281

Model Description	
Development	Project Millennium
Model	CALPUFF
SO_2 Guideline [µg/m³]	30
Maximum [µg/m³]	80
Exceedences / Year [#]	1

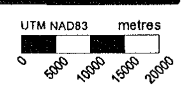

Figure B3-5 Predicted Millennium SO_2 Maximum Annual Average Ground Level Concentrations in the RSA using the CALPUFF Model

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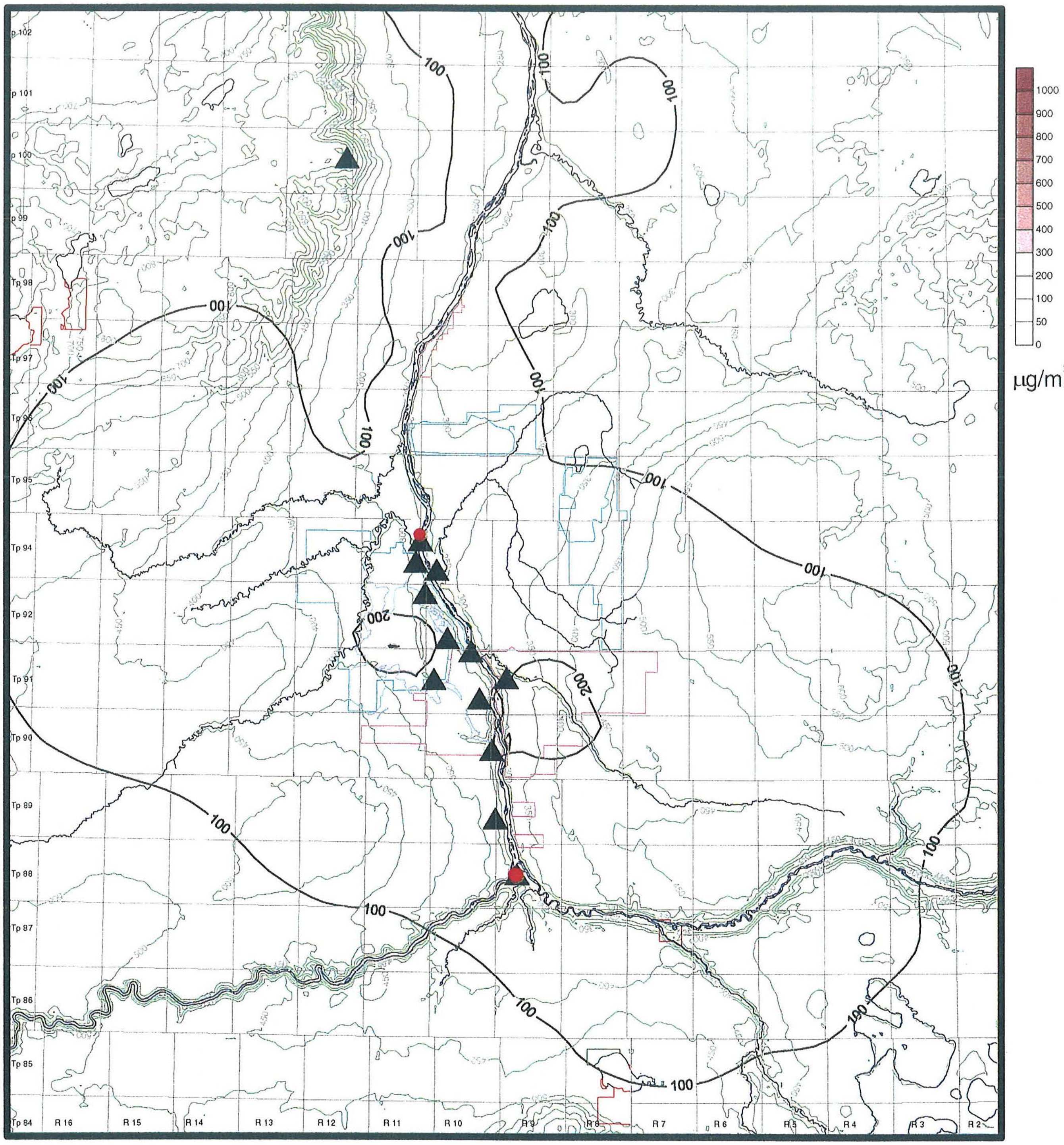
Table B3-4 Maximum Observed Ground Level Concentrations of NO_x and NO_2 for Project Millennium Sources

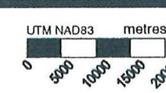
Source	Hourly	Daily	Annual
Project Millennium - ISC3BE[(b)]			
Maximum NO_x concentration ($\mu g/m^3$)	7288	4287	1282
Maximum NO_2 concentration ($\mu g/m^3$)	320	260	162
Location of maximum concentration (km)	14 WNW	14 WNW	11 ESE
Maximum number of exceedances[(a)]	0	101	1
Location of maximum exceedances (km)	0	n/a	n/a
Project Millennium CALPUFF[(c)]			
Maximum NO_2 concentration ($\mu g/m^3$)	1812	708	316
Location from Suncor incinerator stack (km)	11 ESE	11 ESE	11 ESE
Maximum number of exceedances[(a)]	936	103	1
Location of maximum exceedances (km)	11 ESE	11 ESE	n/a
NO_2, Alberta Guideline ($\mu g/m^3$)	400	200	60
NO_2, Federal Acceptable ($\mu g/m^3$)	400	200	100

(a) Exceeds NO_2 Alberta Guideline. Normalized for a 12-month period.
(b) Based on Stream day emission rates for hourly and daily; Calendar day for annual.
(c) Based on Calendar day emission rates.

The modelling predictions are summarized in Table B3-4 and predicted ground level concentrations are mapped in the figures described below:

- Figures B3-6 and B3-7 show the maximum hourly average ground level NO_2 concentrations associated with Project Millennium for the ISC3BE and CALPUFF models respectively. An overall maximum hourly average NO_2 concentration, as determined by ISC3BE, of 320 $\mu g/m^3$ is predicted to occur at a location 14 km WNW of Suncor (Figure B3-6). This maximum concentration is less than the Alberta Guideline of 400 µg/m3 for ambient hourly average NO_2 concentrations. Corresponding values for the CALPUFF model indicate an overall maximum hourly average NO_2 concentration of 1812 $\mu g/m^3$, at a location 11 km ESE of Suncor in the Suncor East Bank mining area (Figure B3-7). This maximum average value is much higher than the hourly NO_2 guideline of 400 $\mu g/m^3$. This model predicts a total of 114,543 ha may have maximum concentration in excess of the guideline and that a maximum of 936 exceedances may occur.
- Figures B3-8 and B3-9 show the maximum daily average ground level NO_2 concentrations associated with Project Millennium for the ISC3BE and CALPUFF models. An overall maximum daily average NO_2 concentration, as determined by ISC3BE, of 260 $\mu g/m^3$ is predicted to occur in the same vicinity as the maximum hourly concentration. This maximum average value exceeds the daily Alberta Guideline of 200 $\mu g/m^3$.

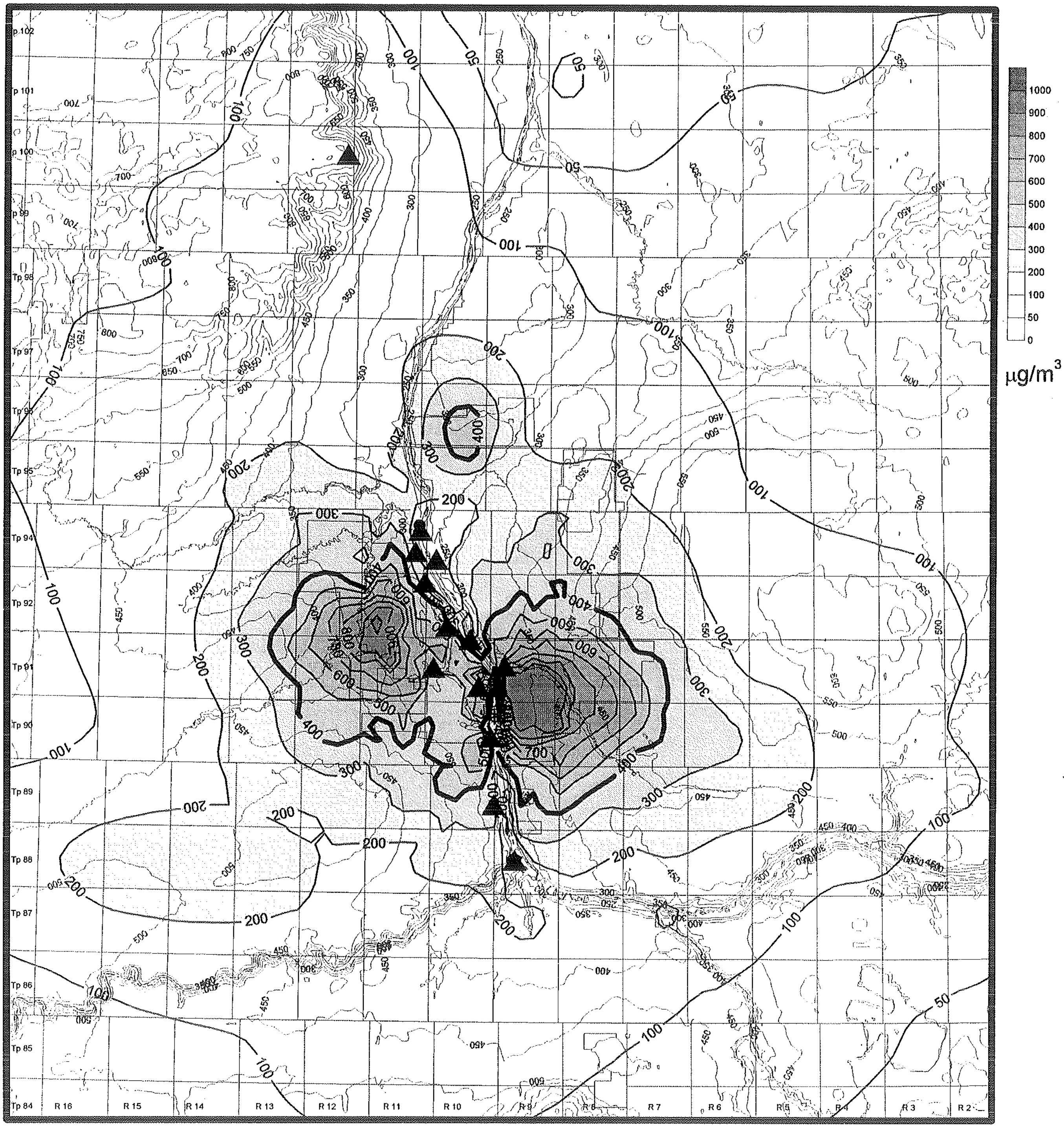




Sources	NO_2 [t/sd]
Suncor	
Powerhouse	3.5
FGD	32
Incinerator	0.07
Flaring	0.03
Tail Gas Treatment Unit	0.03
Other Sources, Suncor	34.8
Syncrude (total)	44.4
Other Emissions (total)	10.1
TOTAL	124.93

Model Description	
Development	Project Millennium
Model	ISC3BE (7BG)
NO_2 Guideline [µg/m³]	400
Maximum [µg/m³]	320
Exceedences / Year [#]	0

Figure B3-6 Predicted Millennium NO_2 Maximum Hourly Average Ground-Level Concentrations in the RSA using the ISC3BE Model



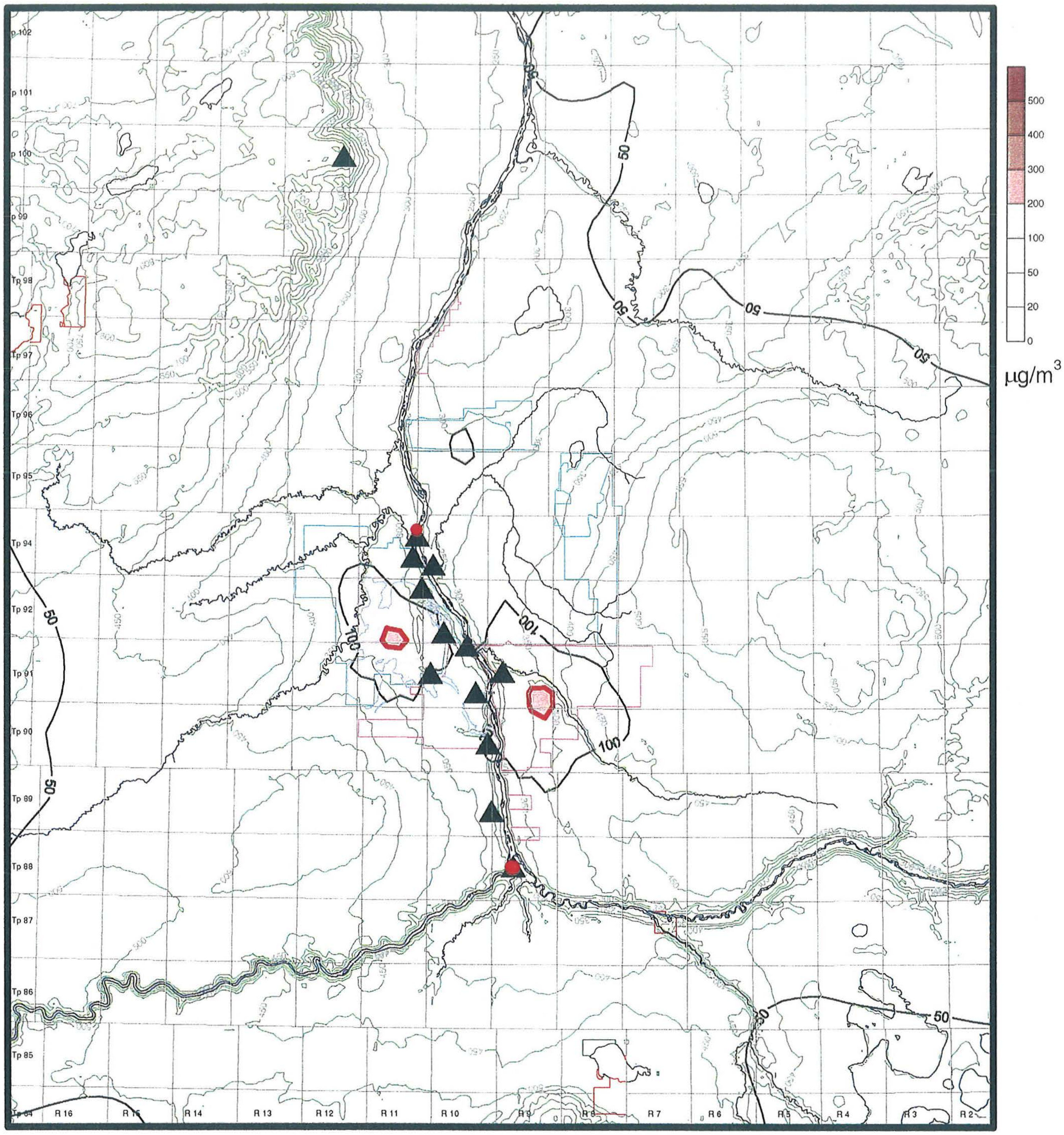
Sources	NOx [t/cd]
Suncor	
Powerhouse	3.5
FGD	32
Incinerator	0.07
Flaring	0.03
Tail Gas Treatment Unit	0.03
Other Sources, Suncor	35
Syncrude (total)	44.4
Other Emissions (total)	10.1
TOTAL	125.13

Model Description	
Development	Project Millennium
Model	CALPUFF
NO_2 Guideline [µg/m³]	400
Maximum [µg/m³]	1812
Exceedences / Year [#]	936

UTM NAD83 metres
0 5000 10000 15000 20000

Figure B3-7 Predicted Millennium NO_2 Maximum Hourly Average Ground Level Concentrations in the RSA using the CALPUFF Model

r:/1997/2200/972-2205/8600/8660/8663/ISCBE/M1_NO2_1H.srf



Sources	NO_2 [t/sd]
Suncor	
Powerhouse	3.5
FGD	32
Incinerator	0.07
Flaring	0.03
Tail Gas Treatment Unit	0.03
Other Sources, Suncor	34.8
Syncrude (total)	44.4
Other Emissions (total)	10.1
TOTAL	124.93

Model Description	
Development	Project Millennium
Model	ISC3BE (7BG)
NO_2 Guideline [µg/m³]	200
Maximum [µg/m³]	260
Exceedences / Year [#]	101

UTM NAD83 metres
0 5000 10000 15000 20000

Figure B3-8 Predicted Millennium NO_2 Maximum Daily Average Ground Level Concentrations in the RSA using the ISC3BE Model

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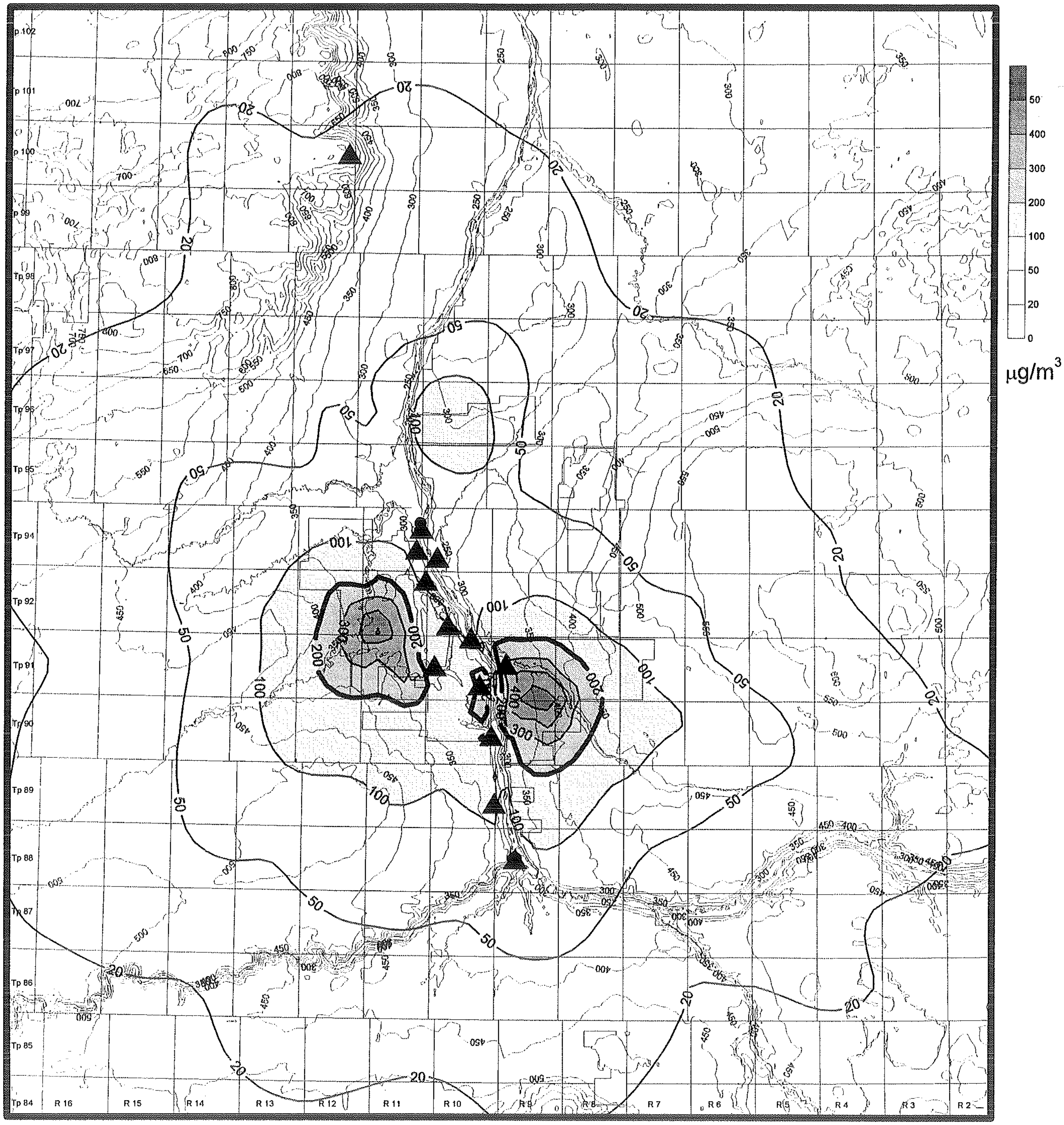
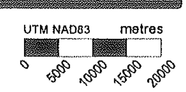




Sources	NO_x [t/cd]
Suncor	
Powerhouse	3.5
FGD	32
Incinerator	0.07
Flaring	0.03
Tail Gas Treatment Unit	0.03
Other Sources, Suncor	35
Syncrude (total)	44.4
Other Emissions (total)	10.1
TOTAL	125.13

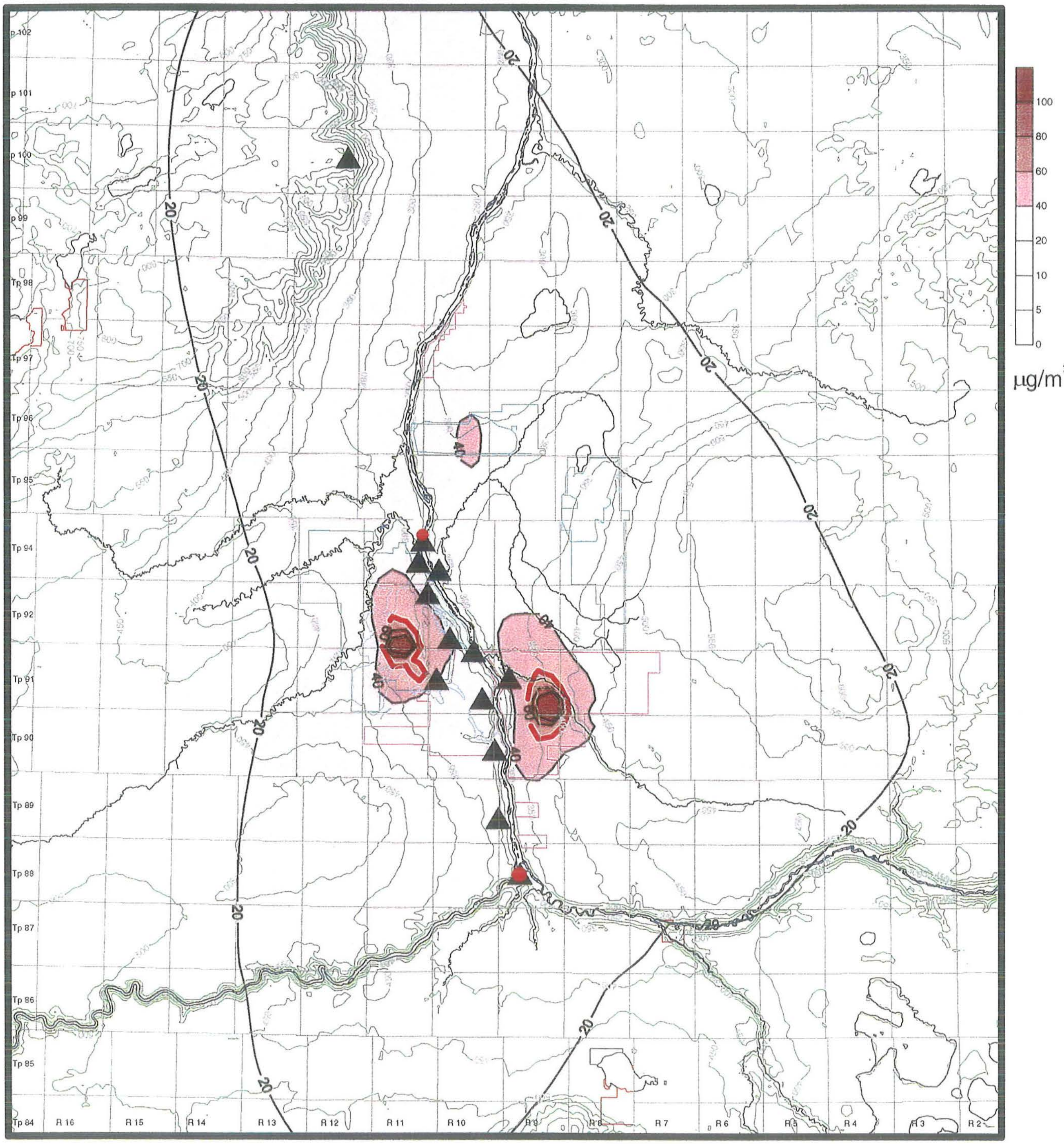
Model Description	
Development	Project Millennium
Model	ISC3BE (7BG)
NO_2 Guideline [µg/m³]	200
Maximum [µg/m³]	708
Exceedences / Year [#]	103

Figure B3-9 Predicted Millennium NO_2 Maximum Daily Average Ground Level Concentrations in the RSA using the CALPUFF Model

- The predictions shown in Figure B3-8 indicate that two areas will result in maximum daily averages in excess of the guideline. The areas are within the Suncor and Syncrude development areas. In total, 2,185 ha are predicted to have maximum average concentrations in excess of the guideline. The ISC3BE model predicts 101 exceedances. Corresponding values for the CALPUFF model indicate an overall maximum hourly average NO_2 concentration of 708 $\mu g/m^3$, at a location 11 km ESE of Suncor in the East Bank mining area (Figure B3-9). The predictions shown in Figure B3-9 indicate two areas that result in maximum daily averages in excess of the Alberta Guideline. The areas are in or adjacent to the Suncor and Syncrude development areas. In total, 51,028 ha are predicted to have maximum average concentrations in excess of the guideline. The CALPUFF model predicts there may be 103 exceedances of the daily guideline on an annual bases for the Project Millennium case.

  Figures B3-10 and B3-11 show the annual average ground level NO_2 concentrations associated with Project Millennium for the ISC3BE and CALPUFF models. An overall maximum annual average NO_2 concentration, as determined by ISC3BE, of 162 $\mu g/m^3$ is predicted to occur at a location 11 km ESE of Suncor in the East Bank mining area (Figure B3-10). This annual average value exceeds the annual Alberta Guideline of 60 $\mu g/m^3$. The predictions shown in Figure B3-10 indicate two areas that result in annual averages in excess of the guideline. The areas are again within the Suncor and Syncrude development areas. In total, 8,343 ha are predicted to have maximum average concentrations in excess of the guideline. Corresponding values for the CALPUFF model indicate an overall maximum annual average NO_2 concentration of 316 $\mu g/m^3$, at a location 11 km ESE from Suncor in the East Bank mining area (Figure B3-11). The predictions shown in Figure B3-11 indicate the two areas that result in maximum annual averages in excess of the Alberta Guideline. The areas are also in or adjacent to Suncor and Syncrude development areas. In total, 14,623 ha are predicted to have maximum average concentrations in excess of the guideline.

- Overall, there is poor correlation between the two models. They both, however, predict the highest concentrations will occur within the Suncor and Syncrude development areas indicating that the ground level emissions from the mine fleets are a major source of NO_2. The ISC3BE model has been selected over the CALPUFF model results because the ISC3BE predictions have been validated based on a comparison to observed NO_x data adjacent to an active mine pit. Further the ISC3BE predicted NO_x concentrations have been converted to NO_2 based on an empirical relationship based on observed data at the same active mine pit. The same level of validation of CALPUFF's chemical transformation algorithms have not been performed for the Suncor site.



UTM NAD83 metres
0 5000 10000 15000 20000

Sources	NO_2 [t/cd]
Suncor	
Powerhouse	2.9
FGD	29.7
Incinerator	0.064
Flaring	0.191
Tail Gas Treatment Unit	0.03
Other Sources, Suncor	34.8
Syncrude (total)	44.4
Other Emissions (total)	10.1
TOTAL	122.185

Model Description	
Development	Project Millennium
Model	ISC3BE (7BG)
NO_2 Guideline [µg/m³]	60
Maximum [µg/m³]	161
Exceedences / Year [#]	1

Figure B3-10 Predicted Millennium NO_2 Maximum Annual Average Ground Level Concentrations in the RSA using the ISC3BE Model

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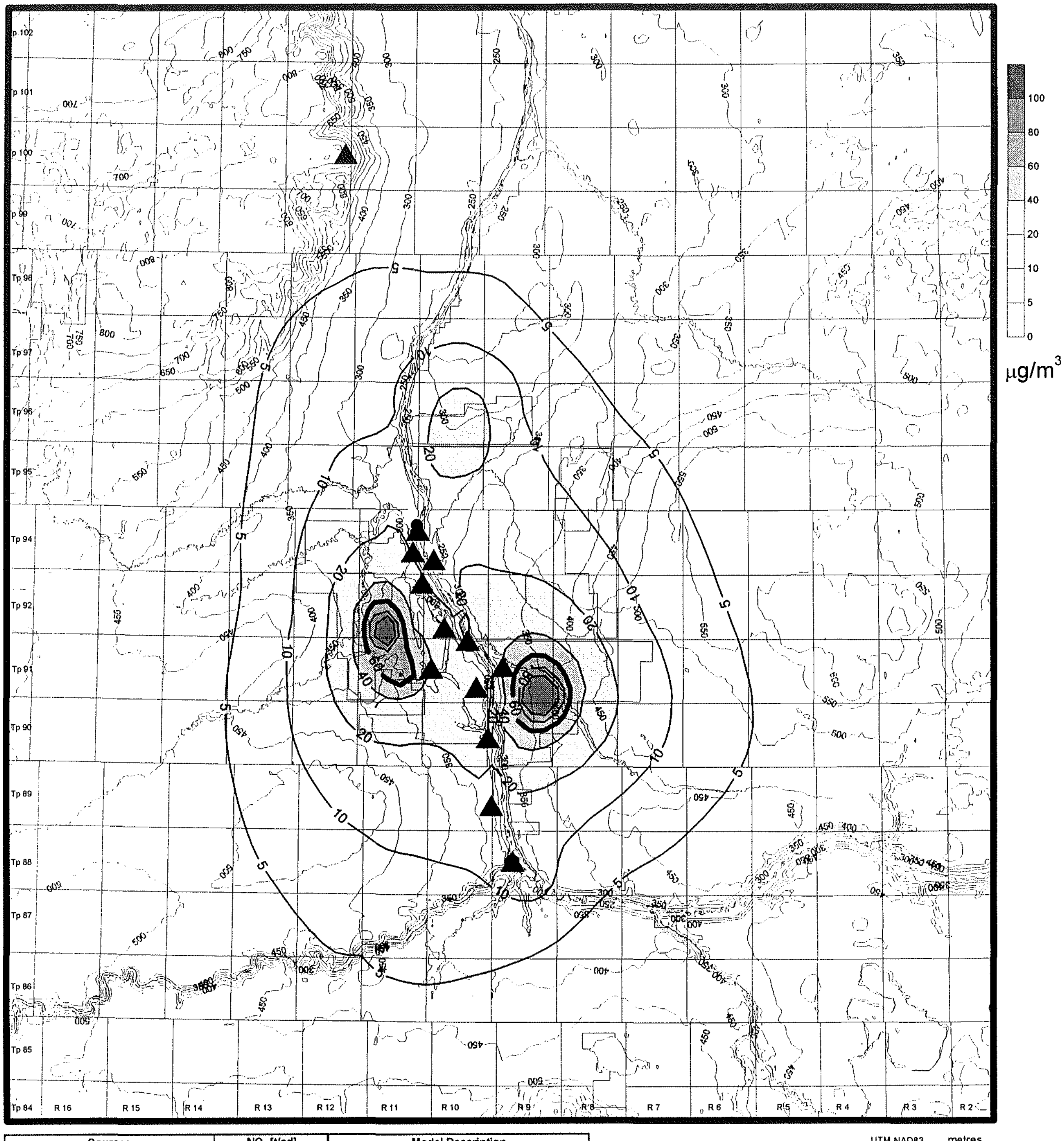


Sources	NO_x [t/cd]
Suncor	
Powerhouse	2.9
FGD	29.7
Incinerator	0.064
Flaring	0.191
Tail Gas Treatment Unit	0.03
Other Sources, Suncor	34.8
Syncrude (total)	44.4
Other Emissions (total)	10.1
TOTAL	122.185

Model Description	
Development	Project Millennium
Model	CALPUFF
NO_2 Guideline [μg/m³]	60
Maximum [μg/m³]	316
Exceedences / Year [#]	1

Figure B3-11 Predicted Millennium NO_2 Maximum Annual Average Ground Level Concentrations in the RSA using the CALPUFF Model

The large number of exceedances of the daily and annual guidelines have not been verified through on-site monitoring. While Syncrude has monitoring stations for NO_x data adjacent to one of its active mine pits, long-term average NO_2 concentrations are not yet available.

B3.2.4 Potential Acid Input (PAI) Predictions

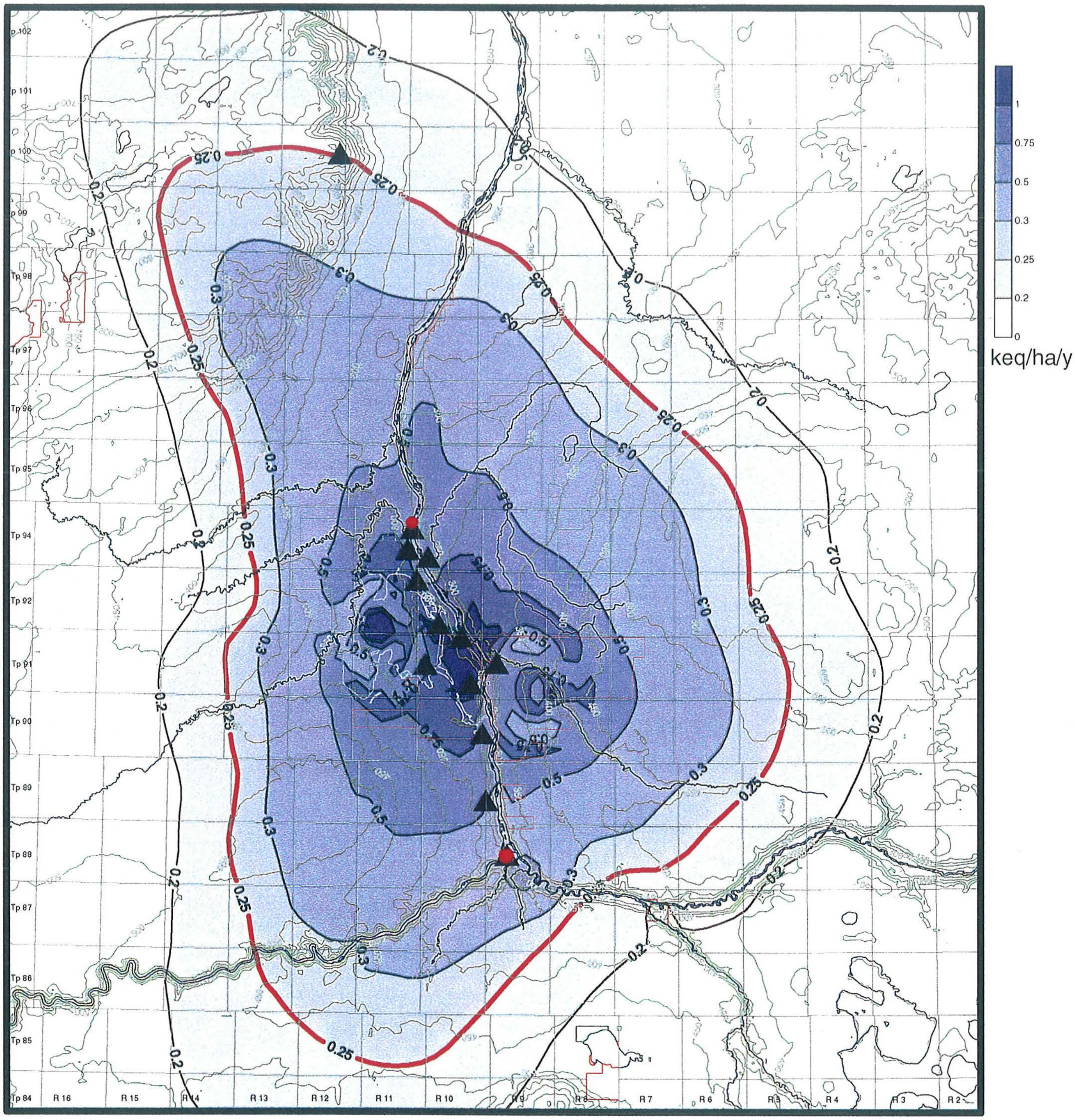
Acidic deposition in the RSA results from the cumulative emissions of SO_2 and NO_x. The total estimated emissions of SO_2 and NO_x (281 t/cd and 122.2 t/cd, respectively) from Project Millennium and all existing and approved developments within the RSA are presented in Table B3-2. Suncor contributes about 34% of the combined SO_2 and NO_x emissions.

PAI is the preferred method for evaluating the overall effects of acid forming chemicals on the environment since it accounts for the acidifying effect of the sulphur and nitrogen species, as well as the neutralizing effect of available base cations. A discussion on the calculation methods for PAI is provided in Section B1.4.2.

PAI in the oil sands region was predicted using the CALPUFF model and four years of meteorological observations from the 75 m level at the Suncor Mannix station. The CALPUFF model is a good tool for estimating the PAI in the oil sands region as it takes into account the chemical transformations of the emitted SO_2 and NO_x and predicts wet (rain and snow scavenged) and dry (via an effective dry deposition velocity) deposition of SO_2, SO_4^{2-}, NO, NO_2, NO_3^-, and HNO_3. These deposition rates are combined following the methodology in Section B1.4.2 to predict the PAI for the region.

A background PAI of 0.1 keq/ha/y has been assumed for the region based on estimates of sulphur and nitrogen and base cation concentrations and depositions in the region surrounding the RSA. This background PAI may be conservatively high, since it was derived from monitoring data at stations adjacent to the RSA. These data were used, as opposed to remote pristine arctic monitoring station data, to better reflect the local Alberta airshed. While these data may represent air flows entering the RSA, they may also reflect air leaving the RSA. Therefore, a nominal amount of "double-counting" may be assumed for the selected background PAI.

The PAI predictions are summarized in Table B3-5 and shown graphically in Figure B3-12. The predicted PAI exceeds the 0.25 keq/ha/y Alberta interim critical load for sensitive soils over an area of 861,263 ha (35.5% of the RSA). The areal extent over which the PAI exceeds the critical loading for less sensitive soils is lower, namely: 195,695 ha (8.1% of the RSA) greater than 0.50 keq/ha/y; 9,598 ha (0.4% of the RSA) greater than 1.0 keq/ha/y; and 317 ha (0.01% of the RSA) greater than 1.5 keq/ha/y.



Sources	SO_2 [t/cd]	NO_x [t/cd]
Suncor		
Powerhouse	14	2.9
FGD	18.7	29.7
Incinerator	12.3	0.064
Flaring	10.6	0.191
Tail Gas Treatment Unit	6.4	0.03
Other Sources, Suncor	5.9	34.8
Syncrude (total)	209	44.4
Other Emissions (total)	4.2	10.1
TOTAL	281.1	122.185

Model Description	
Development	Project Millennium
Model	CALPUFF
Critical Loading [keq/ha/y]	0.25
Maximum [keq/ha/y]	2.1

Figure B3-12 Predicted Millennium Potential Acid Input (PAI) in the RSA

Table B3-5 Areal Extent For Predicted PAI Values for Project Millennium

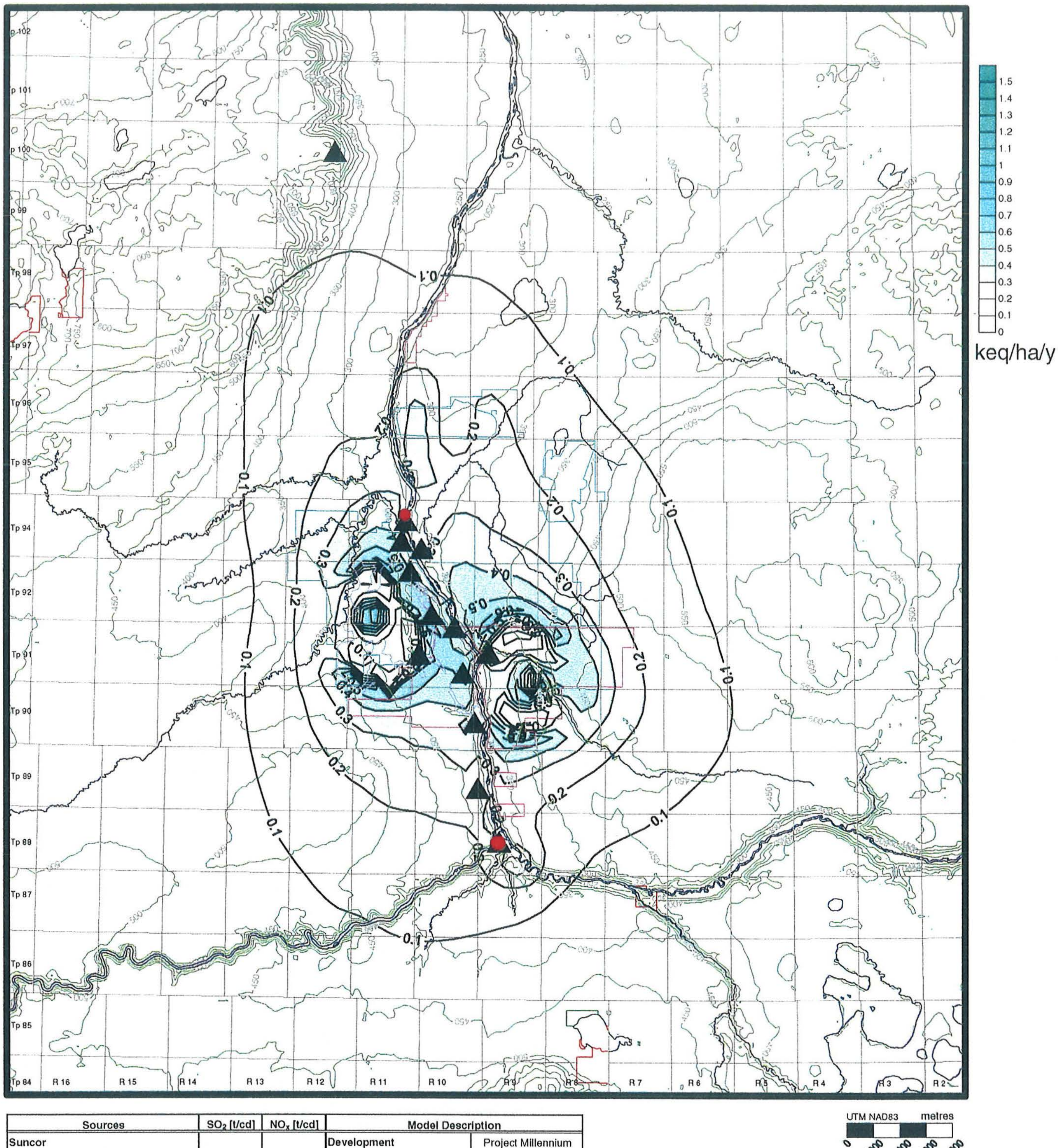
PAI Threshold	AREA	
(keq/ha/y)	(ha)	% of RSA
0.25	861,263	35.5
0.50	195,695	8.1
1.0	9,598	0.4
1.5	317	0.01

The maximum deposition rates of the sulphur and nitrogen species were calculated as interim variables by the CALPUFF model. These are summarized in Table B3-6 and presented graphically in Figures B3-12, B3-13 and B3-14. The maximum deposition rates of nitrates occur in the Suncor east bank mining area, the maximum sulphate deposition rates occur in the immediate vicinity of the Suncor operations, and the maximum overall PAI is predicted to occur in the Syncrude development area. These predicted results suggest the highest deposition and PAI values occur in areas where there are sizable ground level releases of SO_2 and NO_x.

Table B3-6 Maximum Predicted Acid Forming Deposition

Parameter	Maximum [keq/ha/y]	Distance [km from Suncor]	Direction
PAI	2.13	14	WNW
Nitrate Deposition	1.01	12	SE
Sulphate Deposition	1.15	1	SSW

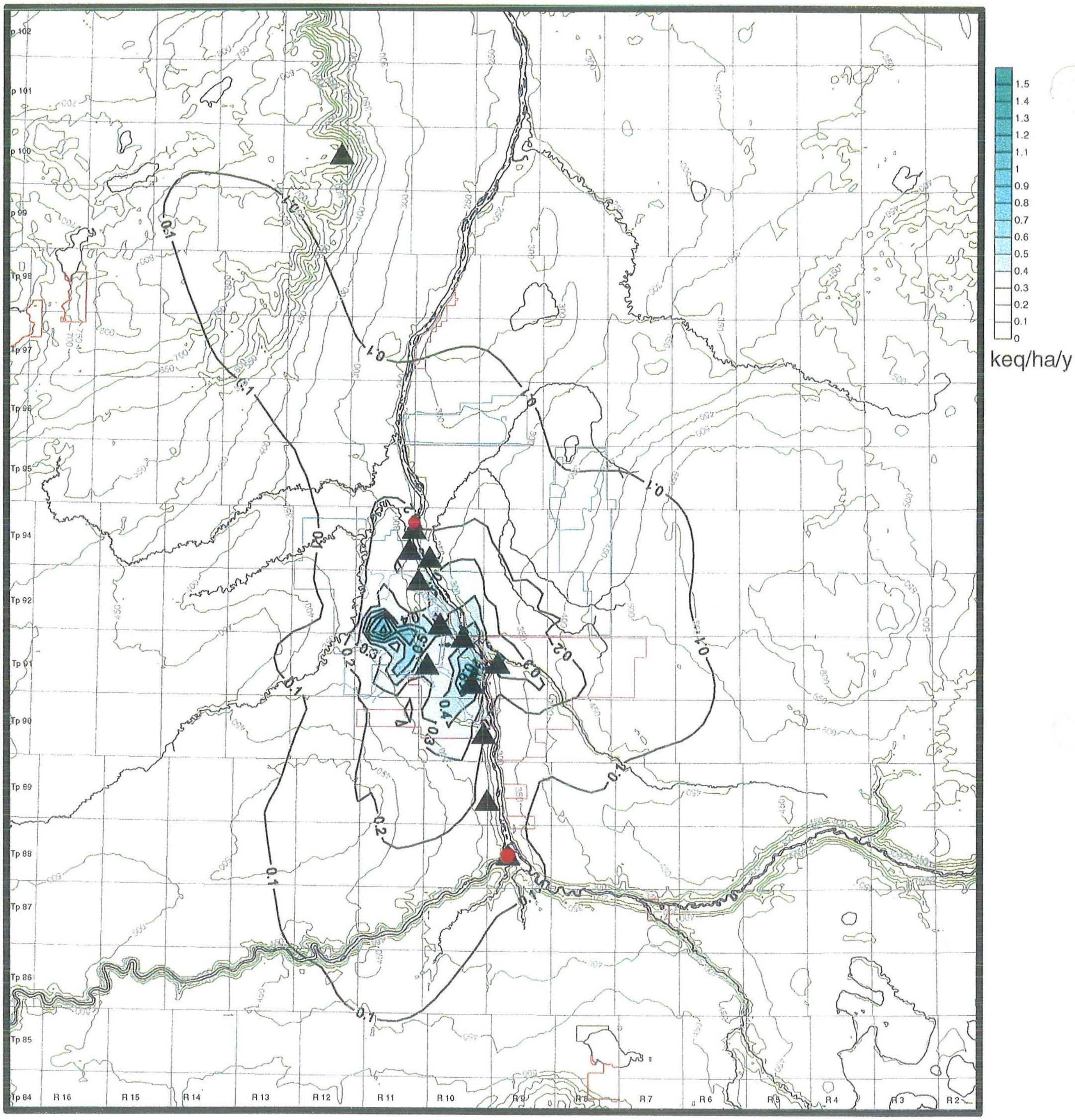
The methodology for predicting PAI on a regional scale using CALPUFF has only been applied in a limited number of cases and experience at applying and interpreting the model predictions is undergoing development. Further, there is considerable uncertainty in the background PAI for the region with estimates ranging from approximately -0.5 to 0.25 keq/ha/y. For this reason, the PAI map presented in Figure B3-12 should be regarded as providing an indication of relative spatial distributions and relative changes associated with differing emission scenarios. This map should also be used in conjunction with the sulphate and nitrate deposition maps (Figures B3-13 and B3-14, respectively) as input in the evaluation of impacts to sensitive soil or vegetation, and in the design of any long-term monitoring programs deemed necessary in such evaluations. This information is further assessed in the soils and terrain impact assessment (Section D2.2).



Sources	SO_2 [t/cd]	NO_x [t/cd]
Suncor		
Powerhouse	14	2.9
FGD	18.7	29.7
Incinerator	12.3	0.064
Flaring	10.6	0.191
Tail Gas Treatment Unit	6.4	0.03
Other Sources, Suncor	5.9	34.8
Syncrude (total)	209	44.4
Other Emissions (total)	4.2	10.1
TOTAL	281.1	122.185

Model Description	
Development	Project Millennium
Model	CALPUFF
Critical Loading [keq/ha/y]	0.25
Maximum [keq/ha/y]	1.0

Figure B3-13 Predicted Millennium Nitrate Equivalent Deposition in the RSA using the CALPUFF Model



Sources	SO_2 [t/cd]	NO_x [t/cd]
Suncor		
Powerhouse	14	2.9
FGD	18.7	29.7
Incinerator	12.3	0.064
Flaring	10.6	0.191
Tail Gas Treatment Unit	6.4	0.03
Other Sources, Suncor	5.9	34.8
Syncrude (total)	209	44.4
Other Emissions (total)	4.2	10.1
TOTAL	281.1	122.185

Model Description	
Development	Project Millennium
Model	CALPUFF
Critical Loading [keq/ha/y]	0.25
Maximum [keq/ha/y]	1.2

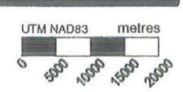


Figure B3-14 Predicted Millennium Sulphate Equivalent Deposition in the RSA using the CALPUFF Model

B3.2.5 CO Predicted Concentrations

The CO emission sources associated with Project Millennium and other approved developments are summarized in Section B3.1 (e.g., Tables B3-1 and B3-2). Total estimated CO emission rate for this case is 125.8 t/cd. The total Suncor CO emissions are approximately 38.6 t/cd with the FDG stack (25.6 t/cd) being the major single continuous source.

The predicted maximum hourly and 8-hour ground level ambient CO concentrations resulting from emissions of Project Millennium and all approved industrial sources and residential emissions in the oil sands region were estimated using ISC3BE and meteorology measurements from the Mannix station. This model provides an efficient means of calculating the overall ambient CO concentration from all sources and provides an indication of where maximum concentrations could occur. The modelling predictions are summarized in Table B3-7 and predicted ground level concentrations are mapped in the figures described below:

- Figure B3-15 shows the maximum hourly average ground level CO concentrations associated with Project Millennium. An overall maximum hourly average CO concentration of 5,560 $\mu g/m^3$ is predicted to occur at a location SSE of the Suncor. This maximum value is less than the Alberta hourly CO guideline of 15,000 $\mu g/m^3$.
- Figure B3-16 shows the maximum daily average ground level CO concentrations associated with Project Millennium. The overall maximum 8-hour average CO concentration of 2,226 $\mu g/m^3$ is predicted to occur in Fort McMurray. This maximum 8-hour value is less than the Alberta 8-hour guideline of 6,000 $\mu g/m^3$.

Table B3-7 Maximum Observed Ground Level Concentrations of CO for Project Millennium Sources

Source	Hourly	8-Hour
Project Millennium - Model ISC3BE		
Maximum CO Concentration ($\mu g/m^3$)	5,560	2,226
Location of Maximum Concentration (km)	30 SSE	30 SSE
Maximum Number of Exceedances [a]	0	0
Location of Maximum Exceedances	n/a	n/a
CO, Alberta Guideline ($\mu g/m^3$)	15,000	6,000

[a] Exceeds CO Alberta Guideline. Normalized for a 12-month period.

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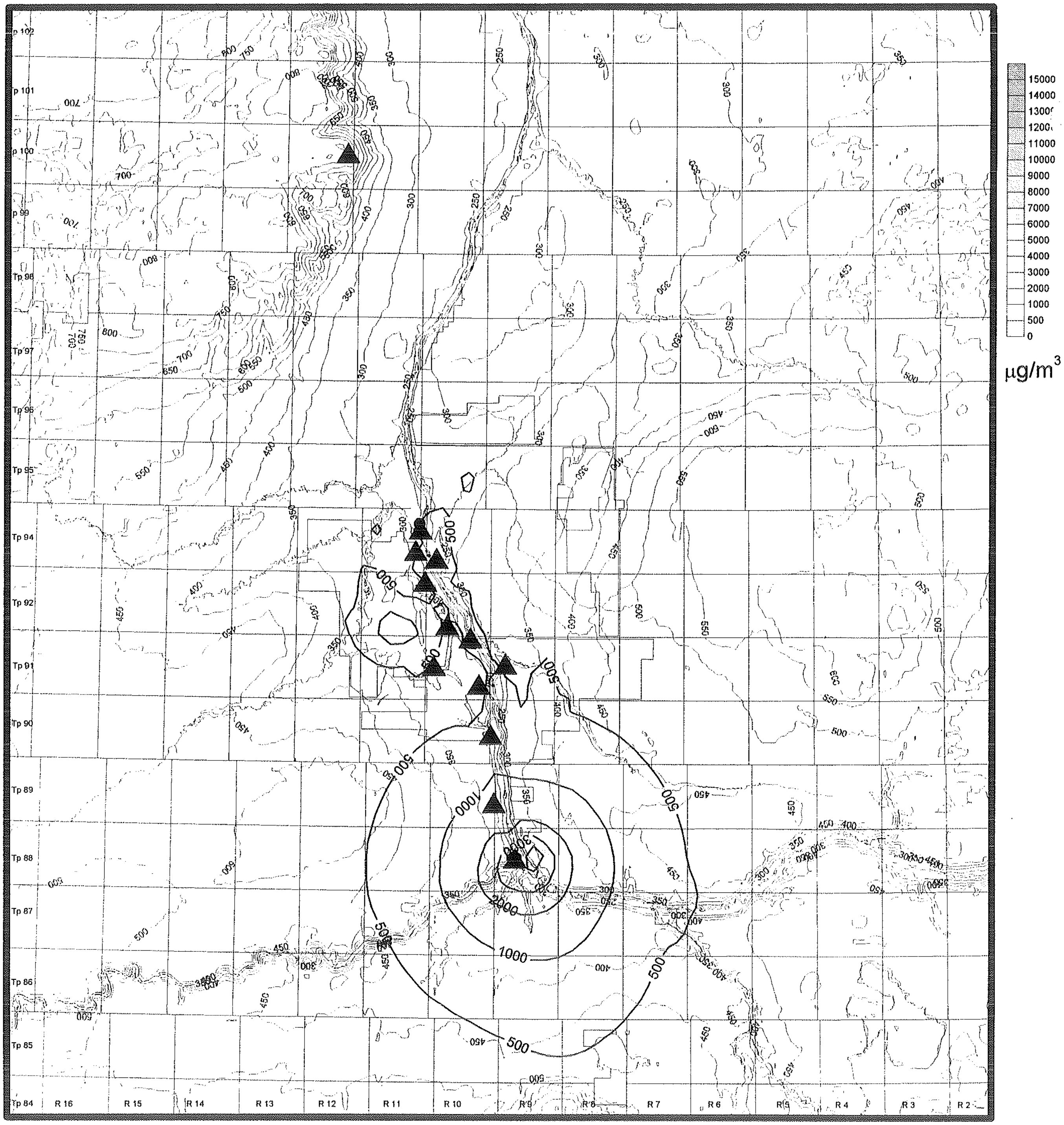

UTM NAD83 metres
0 5000 10000 15000 20000

Sources	CO [t/sd]
Suncor	
Powerhouse	3.01
FGD	27.51
Incinerator	3.4
Flaring	0.01
Tail Gas Treatment Unit	3.8
Other Sources, Suncor	3.6
Syncrude (total)	53.61
Other Emissions (total)	33.6
TOTAL	128.54

Model Description	
Development	Project Millennium
Model	ISC3BE (7BG)
CO Guideline [µg/m³]	15000
Maximum [µg/m³]	5560
Exceedences / Year [#]	0

Figure B3-15 Predicted Millennium CO Maximum Hourly Average Ground Level Concentrations in the RSA using the ISC3BE Model

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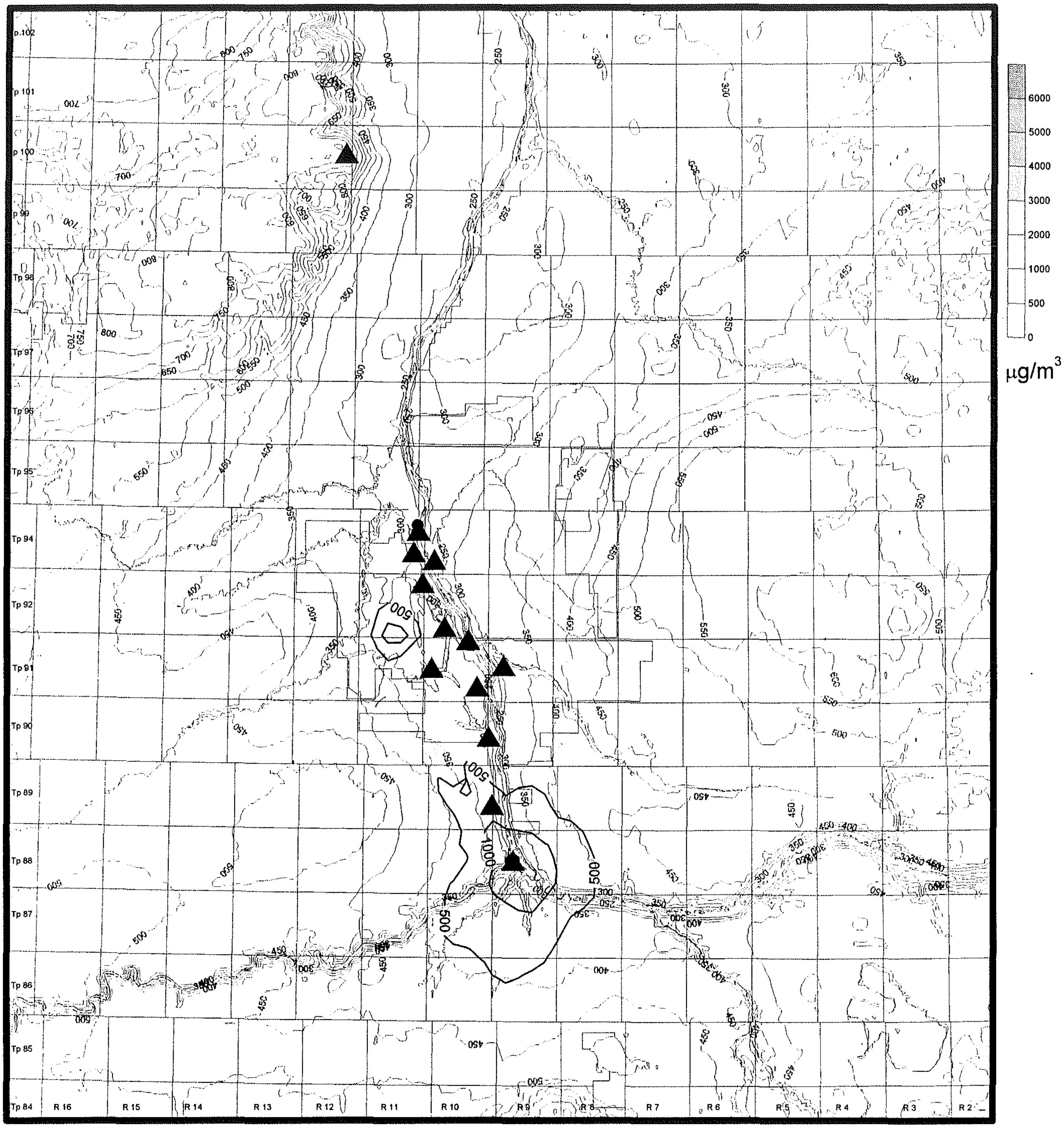


UTM NAD83 metres

0 5000 10000 15000 20000

Sources	CO [t/sd]
Suncor	
Powerhouse	3.01
FGD	27.51
Incinerator	3.4
Flaring	0.01
Tail Gas Treatment Unit	3.8
Other Sources, Suncor	3.6
Syncrude (total)	53.61
Other Emissions (total)	33.6
TOTAL	128.54

Model Description	
Development	Project Millennium
Model	ISC3BE (7BG)
CO Guideline [µg/m³]	6000
Maximum [µg/m³]	2226
Exceedences / Year [#]	0

Figure B3-16 Predicted Millennium CO Maximum 8-Hour Average Ground Level Concentrations in the RSA using the ISC3BE Model

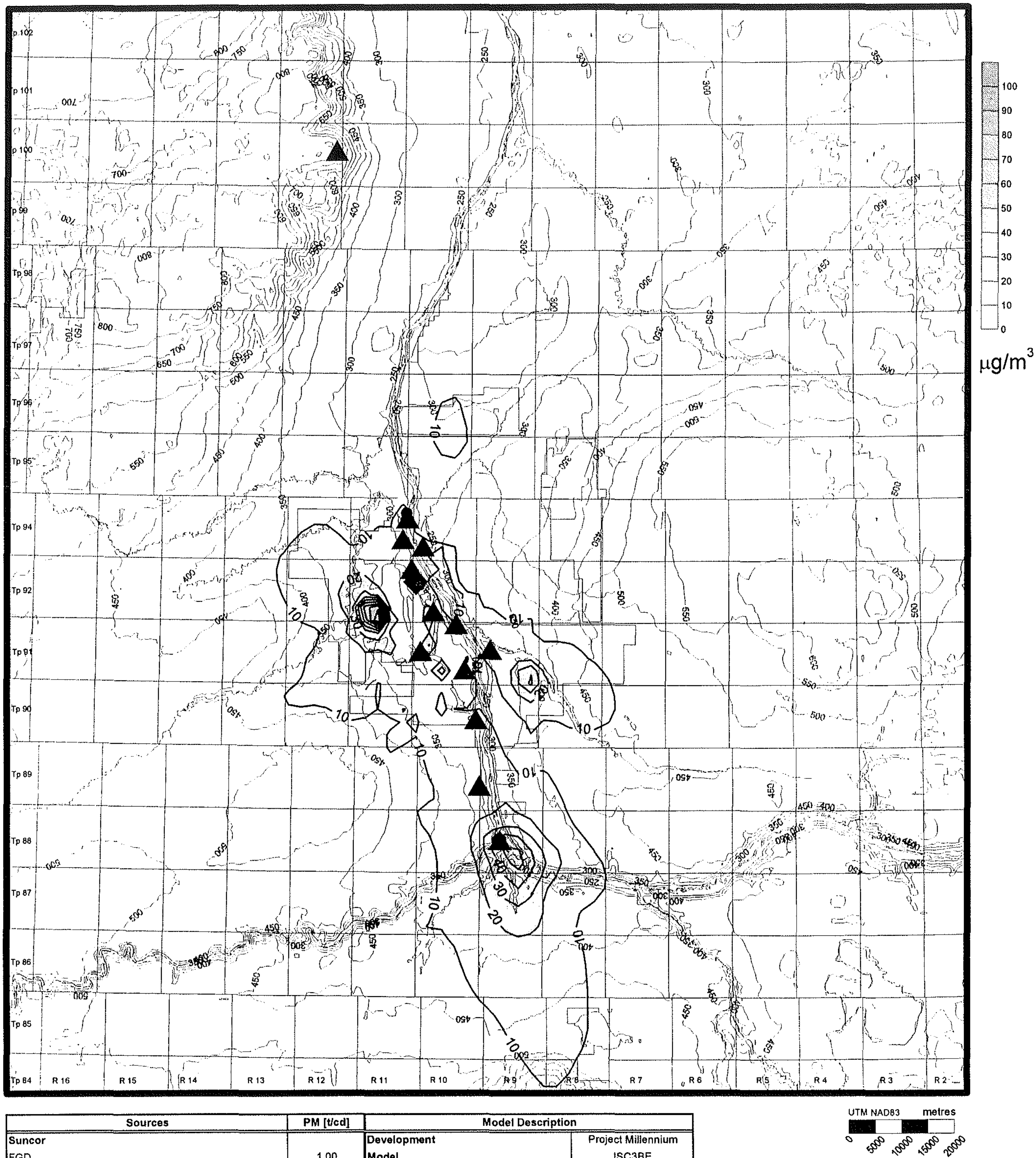
The modelling predicts that the maximum hourly and 8-hour CO concentrations will occur SSE of Suncor near Fort McMurray. The principal contribution to these elevated CO values are the releases from the conical burner operated by Northland Forest Products. The principal contributors to high values outside of Fort McMurray would be the mine fleet. The mine fleet and vehicle emissions have been modelled as a ground level area source. Because these emissions are relatively large and are at ground level, there is a decreased opportunity for dispersion and dilution of their plumes as compared to a tall stack with a similar emission rate. It is this source characterization which produces the increase in the ground level concentrations and this characterization is expected to be a conservative modelling assumption. The ability to compare the model predictions to monitoring data are limited because only one location within the region measures CO.

B3.2.6 Particulate Predicted Concentrations

The ambient PM emission sources associated with Project Millennium and other approved developments are summarized in Section B3.1 (e.g., Tables B3-1 and B3-2). Total estimated PM emission rate for all sources is 10.0 t/cd. The major continuous source of particulate emissions from Suncor is the FGD Stack and it emits approximately 1.0 t/cd. Suncor PM emissions account for approximately 22% of the PM in the RSA. For the purpose of modelling, all PM was assumed to be PM_{10}. In addition to the PM emissions, metals and PAHs have been determined from stack sampling surveys collected by Suncor and Syncrude. Based on the speciation completed for the stack sampling surveys, metals and PAHs were estimated. These results are discussed in subsections following this section.

The predicted maximum daily and annual ground level ambient PM_{10} concentrations resulting from emissions of Project Millennium and all approved industrial sources and residential emissions in the oil sands region were estimated using ISC3BE and meteorology measurements from the Mannix station. The modelling results are summarized in Table B3-8 which includes the PM_{10} results based on source sampling. Predicted PM ground level concentrations are mapped in the figures described below:

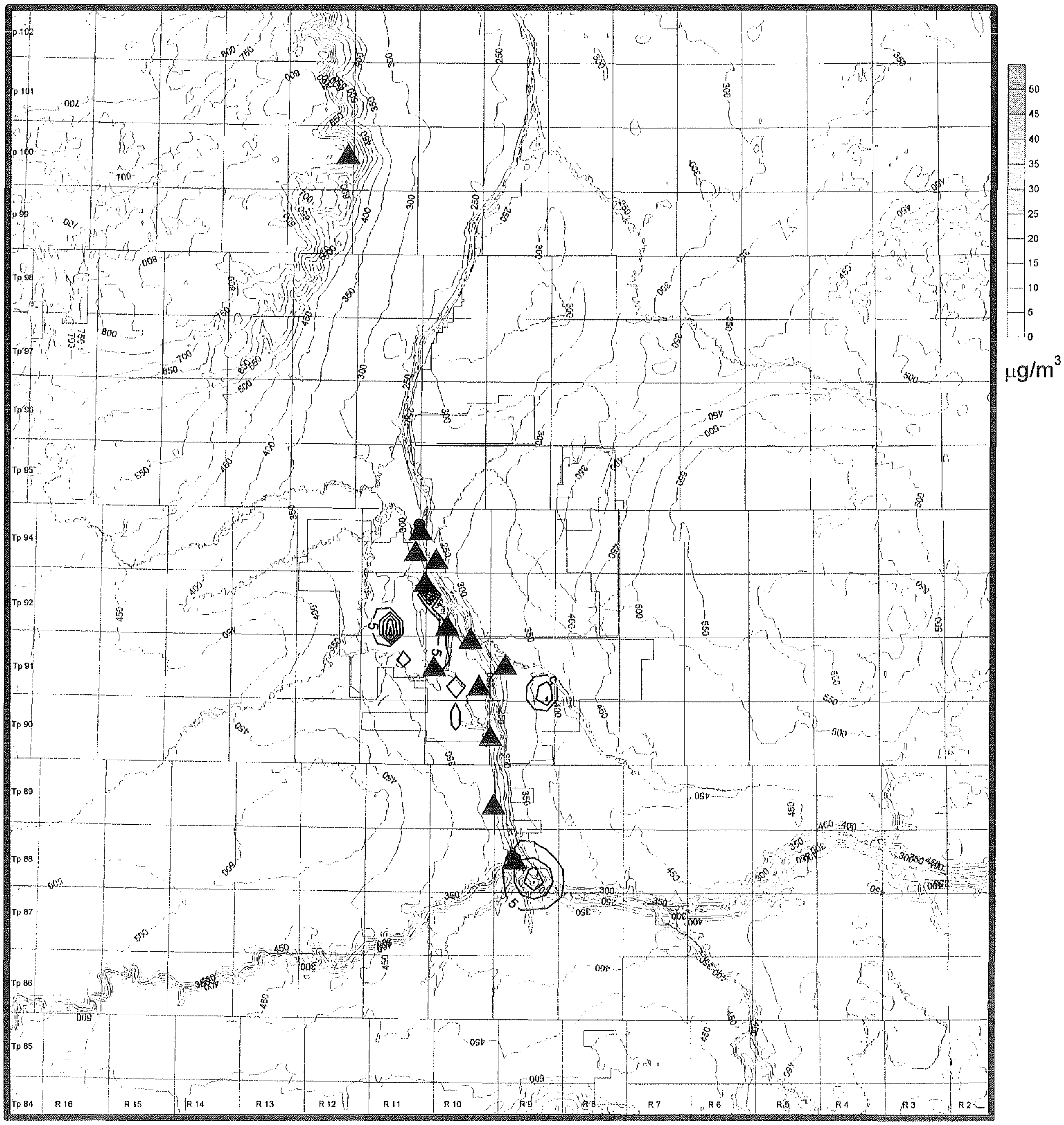
- Figure B3-17 shows the maximum daily average ground level PM concentrations associated with Project Millennium. The overall maximum daily average PM concentration is 113 $\mu g/m^3$ and is predicted to occur WNW of Suncor. All of the exceedances are predicted to occur in the existing development areas.
- Figure B3-18 shows the annual average ground level concentration contours for PM. The results show that the overall maximum annual concentration of 45.9 $\mu g/m^3$ is predicted to occur at the same location as the daily results.

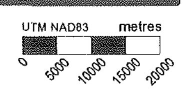


Sources	PM [t/cd]
Suncor	
FGD	1.00
Powerhouse	0.24
Incinerator	0.038
Tail Gas Treatment Unit	0.042
Millennium Mine Fleet	0.3
Other Sources, Suncor	0.653
Syncrude (total)	5.6
Other Emissions (total)	2.2
TOTAL	10.073

Model Description	
Development	Project Millennium
Model	ISC3BE
PM_{10} Guideline [µg/m³]	50
Maximum [µg/m³]	113
Exceedences / Year [#]	33

Figure B3-17 Predicted Millennium PM_{10} Maximum Daily Average Ground Level Concentrations in the RSA





Sources	PM [t/cd]
Suncor	
FGD	1.00
Powerhouse	0.24
Incinerator	0.038
Tail Gas Treatment Unit	0.042
Millennium Mine Fleet	0.3
Other Sources, Suncor	0.653
Syncrude (total)	5.6
Other Emissions (total)	2.2
TOTAL	10.073

Model Description	
Development	Project Millennium
Model	ISC3BE
PM_{10} Guideline [µg/m³]	50
Maximum [µg/m³]	45.9
Exceedences / Year [#]	0

Figure B3-18 Predicted Millennium PM_{10} Maximum Annual Average Ground Level Concentrations in the RSA

Table B3-8 Maximum Observed Ground Level Concentrations of PM_{10} for Millennium Sources

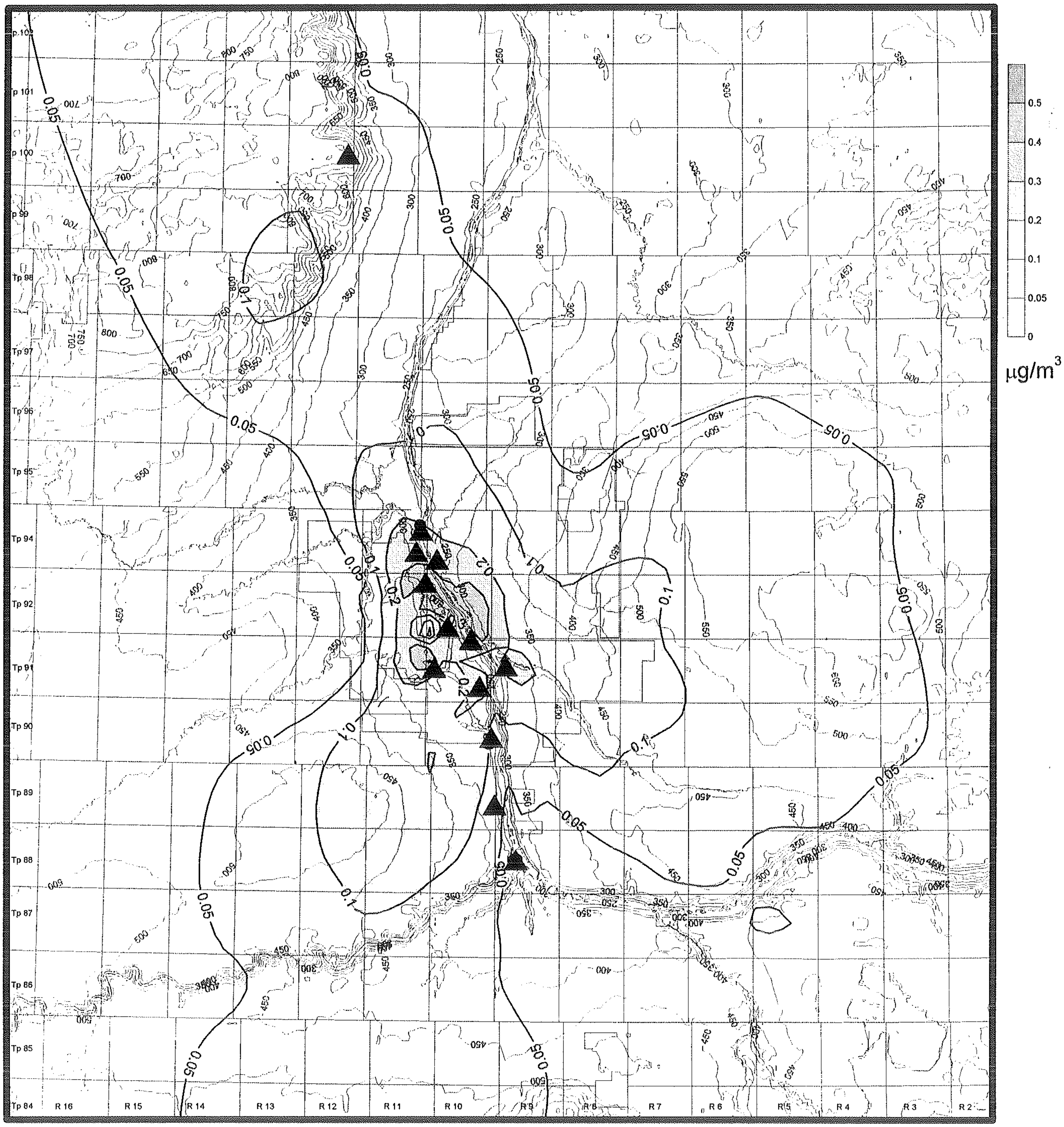
Source	Daily	Annual
Baseline Condition - Model ISC3BE		
Maximum PM_{10} Concentration ($\mu g/m^3$)	113	45.9
Location of Maximum Concentration	WNW	WNW
Maximum Number of Exceedances	33	0
Location of Maximum Exceedances	WNW	n/a
PM_{10}, Alberta Guideline ($\mu g/m^3$)	100	60

The particulate emissions from the Suncor FGD and Syncrude Main stacks contain metals and PAH compounds. The ISC3BE was configured to predict particulates from these two stacks to determine ground level concentrations and deposition rates. The FGD particulate emission rate was estimated for Project Millennium based on the expected operation of the coke fired boilers. The particulate size fraction, metal composition and PAH composition for the Suncor FGD stack emissions was assumed to remain the same as the Baseline case. The FGD emissions for Project Millennium were assumed predominantly to be in the $PM_{2.5}$ size range with a total emission rate of about 1.0 t/d. The Syncrude Main stack emissions were not changed from the Baseline case.

The predicted average daily and annual ground level concentrations of total particulates from these two sources are shown in Figure B3-19 and Figure B3-20. A summary of the predicted metal and PAH concentrations derived from the total particulate air concentrations are listed in Tables B3-9 and B3-10 for selected locations. This PM assessment from the Suncor FGD stack reflects the most recent stack survey data which has included analysis of heavy metals, PAHs and particulate size fractions. This data has been included in the air quality section but was not available in time for the writing of the health assessment in Section F1.

B3.2.7 Fugitive Dust Discussion

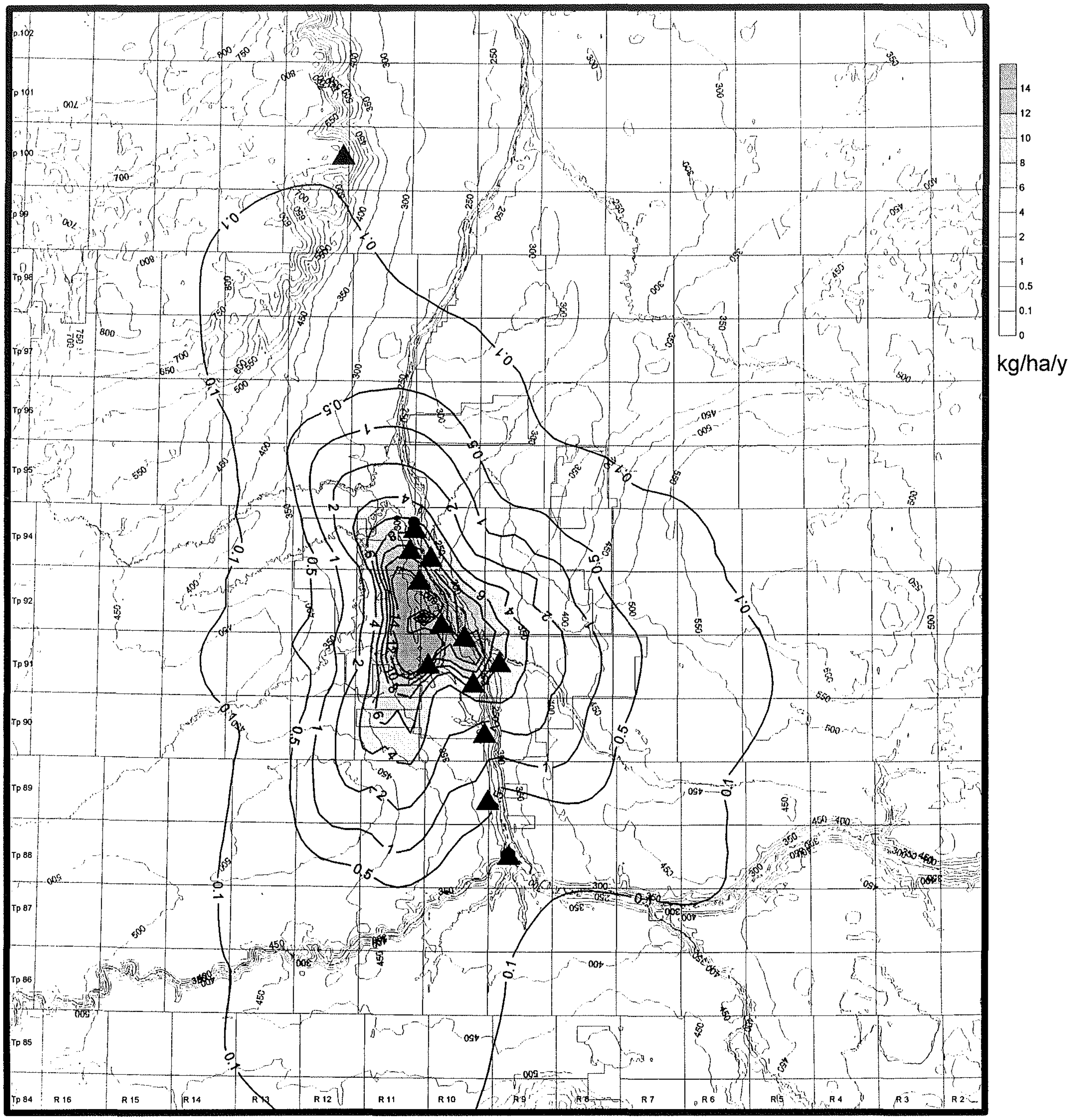
The maximum predicted PM does not include contributions due to non-combustion sources nor natural background levels. Potential fugitive sources associated with Project Millennium include an expanded mine area, new tailings pond areas and additional roads and truck traffic. These new or expanded activities could result in additional sources of fugitive dust emissions. It is Suncor's experience that the mining area, given the coarse nature of oil sands (bitumen and sand combination), is expected to produce minimal PM fugitive emissions. The existing reclamation activities control fugitive particulate emissions and the same management practice will be undertaken for Project Millennium. Overall, fugitive emissions are not expected to change from the existing situation with the development of Project Millennium.



Sources	PM [t/cd]
Suncor	
FGD	2.6
Powerhouse	-
Incinerator	-
Tail Gas Treatment Unit	-
Millennium Mine Fleet	-
Other Sources, Suncor	-
Syncrude Main Stack	7.1
Other Emissions (total)	-
TOTAL	9.7

Model Description	
Development	Project Millennium
Model	ISC3BE

Figure B3-19 Predicted Millennium Particulate Annual Average Ground Level Concentrations in the RSA from the operation of the Suncor and Syncrude main stacks



Sources	PM [t/cd]
Suncor	
FGD	2.6
Powerhouse	-
Incinerator	-
Tail Gas Treatment Unit	-
Millennium Mine Fleet	-
Other Sources, Suncor	-
Syncrude Main Stack	7.1
Other Emissions (total)	-
TOTAL	9.7

Model Description	
Development	Project Millennium
Model	ISC3BE

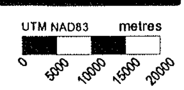


Figure B3-20 Predicted Millennium Particulate Annual Average Deposition in the RSA from the operation of the Suncor and Syncrude Main stacks

Table B3-9 Average Ground Level Concentrations of Heavy Metals at Selected Sites as a Result of Emissions from Suncor FGD and Syncrude Main Stack

Location	Average Daily Ground Level Concentration					Average Annual Ground Level Concentration			
	Ontario AAQC, Daily [ng/m³]	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan
Heavy Metals [ng/m³]									
Antimony	—	5.1E-02	7.7E-03	2.7E-02	2.6E-03	2.6E-03	3.2E-04	2.1E-03	1.1E-04
Arsenic	3.00E+03	8.1E-02	1.2E-02	4.2E-02	4.1E-03	4.2E-03	5.2E-04	3.3E-03	1.8E-04
Aluminum	—	8.6E+00	1.2E+00	5.3E+00	4.3E-01	4.4E-01	4.7E-02	4.1E-01	1.7E-02
Barium	1.00E+05	8.0E-01	1.2E-01	4.1E-01	4.1E-02	4.2E-02	5.3E-03	3.2E-02	1.8E-03
Beryllium	0.00E+00	9.4E-03	1.4E-03	5.1E-03	4.8E-04	4.9E-04	5.8E-05	4.0E-04	2.0E-05
Cadmium	2.00E+04	1.9E-02	2.5E-03	1.2E-02	9.3E-04	9.7E-04	9.5E-05	9.5E-04	3.7E-05
Calcium	—	9.5E+00	1.3E+00	6.4E+00	4.8E-01	4.9E-01	4.7E-02	5.0E-01	1.8E-02
Chromium	1.50E+04	4.2E+00	6.1E-01	2.4E+00	2.1E-01	2.2E-01	2.5E-02	1.9E-01	8.8E-03
Cobalt	1.00E+03	2.2E-01	3.2E-02	1.3E-01	1.1E-02	1.2E-02	1.3E-03	1.0E-02	4.7E-04
Copper	5.00E+05	3.8E-01	5.4E-02	2.2E-01	1.9E-02	2.0E-02	2.2E-03	1.7E-02	7.8E-04
Iron	—	3.9E+01	5.5E+00	2.5E+01	2.0E+00	2.0E+00	2.1E-01	2.0E+00	7.9E-02
Lead	0.00E+00	5.4E-01	8.4E-02	2.7E-01	2.7E-02	2.8E-02	3.6E-03	2.1E-02	1.2E-03
Magnesium	—	2.6E+00	3.9E-01	1.4E+00	1.3E-01	1.3E-01	1.6E-02	1.1E-01	5.6E-03
Manganese	—	1.6E+00	2.4E-01	8.5E-01	8.1E-02	8.3E-02	1.0E-02	6.7E-02	3.5E-03
Mercury	2.00E+04	1.1E-02	1.6E-03	6.0E-03	5.4E-04	5.6E-04	6.5E-05	4.7E-04	2.3E-05
Molybdenum	1.20E+06	8.0E-01	1.2E-01	4.4E-01	4.0E-02	4.2E-02	4.9E-03	3.5E-02	1.7E-03
Nickel	2.00E+04	6.7E+00	9.6E-01	3.9E+00	3.4E-01	3.5E-01	3.8E-02	3.1E-01	1.4E-02
Phosphorus	—	4.0E+00	6.8E-01	1.6E+00	2.1E-01	2.1E-01	3.1E-02	1.3E-01	9.8E-03
Selenium	1.00E+05	2.2E+00	3.8E-01	8.2E-01	1.1E-01	1.1E-01	1.7E-02	6.5E-02	5.4E-03
Silicon	—	7.8E+01	9.9E+00	5.8E+01	3.9E+00	4.1E+00	3.3E-01	4.5E+00	1.4E-01
Silver	1.00E+04	8.0E-02	1.1E-02	5.4E-02	4.0E-03	4.2E-03	4.0E-04	4.2E-03	1.6E-04
Sodium	—	6.6E+01	1.0E+01	3.5E+01	3.4E+00	3.4E+00	4.2E-01	2.8E+00	1.4E-01
Tin	1.00E+05	5.6E-01	8.5E-02	2.8E-01	2.8E-02	2.9E-02	3.6E-03	2.2E-02	1.2E-03
Titanium	—	9.5E-01	1.4E-01	5.4E-01	4.8E-02	4.9E-02	5.6E-03	4.3E-02	2.0E-03
Vanadium	2.00E+04	3.1E+00	4.6E-01	1.7E+00	1.6E-01	1.6E-01	1.9E-02	1.3E-01	6.6E-03
Zirconium	—	5.6E-01	8.5E-02	2.8E-01	2.8E-02	2.9E-02	3.6E-03	2.2E-02	1.2E-03
Zinc	1.20E+06	1.7E+01	1.9E+00	1.4E+01	8.0E-01	8.5E-01	5.5E-02	1.1E+00	2.7E-02

OAAQC: Ontario Ambient Air Quality Criteria
Ontario Ministry of the Environment 1994
Summary of Point of Impingement Standards, Ambient Air Quality Criteria (AAQC), and Approvals Screening Levels

Table B3-10 Average Ground Level Concentrations of PAHs at Selected Sites as a Result of Emissions from Suncor FGD and Syncrude Main Stack

	Average Daily Ground Level Concentration				Average Annual Ground Level Concentration			
Location	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan
PAHs [ng/m^3]								
Acenaphthene	8.3E-04	1.3E-04	3.8E-04	4.3E-05	4.3E-05	5.9E-06	3.0E-05	1.9E-06
Acenaphylene	2.7E-02	3.1E-03	2.3E-02	1.3E-03	1.4E-03	8.7E-05	1.8E-03	4.4E-05
Anthracene	2.2E-03	3.7E-04	9.2E-04	1.2E-04	1.2E-04	1.7E-05	7.3E-05	5.4E-06
1,2-Benzathracene	1.0E-03	1.6E-04	5.5E-04	5.3E-05	5.4E-05	6.6E-06	4.3E-05	2.3E-06
Benzo(b & j)fluoranthene	6.1E-03	1.0E-03	2.7E-03	3.1E-04	3.2E-04	4.4E-05	2.1E-04	1.4E-05
Benzo(k)fluoranthene	1.1E-03	1.5E-04	6.0E-04	5.3E-05	5.5E-05	6.2E-06	4.8E-05	2.2E-06
Benzo(a)fluorene	9.2E-04	1.5E-04	4.1E-04	4.7E-05	4.8E-05	6.6E-06	3.2E-05	2.1E-06
Benzo(b)fluorene	5.5E-04	8.6E-05	2.8E-04	2.8E-05	2.9E-05	3.7E-06	2.2E-05	1.2E-06
Benzo(g, h, i)perylene	1.2E-03	1.8E-04	7.0E-04	6.2E-05	6.4E-05	7.4E-06	5.5E-05	2.6E-06
Benzo(a)pyrene	8.6E-04	1.3E-04	4.4E-04	4.4E-05	4.5E-05	5.6E-06	3.5E-05	1.9E-06
Benzo(e)pyrene	5.5E-04	8.6E-05	2.8E-04	2.8E-05	2.9E-05	3.7E-06	2.2E-05	1.2E-06
Camphene	1.5E-03	2.5E-04	6.1E-04	7.7E-05	7.8E-05	1.1E-05	4.9E-05	3.6E-06
Carbazole	8.5E-04	1.4E-04	3.9E-04	4.4E-05	4.4E-05	6.0E-06	3.0E-05	2.0E-06
1 -Chloronaphthalene	7.8E-04	1.2E-04	3.7E-04	4.0E-05	4.1E-05	5.3E-06	2.9E-05	1.8E-06
2-Chloronaphthalene	1.2E-03	1.7E-04	7.4E-04	6.1E-05	6.3E-05	6.7E-06	5.8E-05	2.5E-06
Chrysene	2.1E-03	2.9E-04	1.3E-03	1.0E-04	1.1E-04	1.1E-05	1.0E-04	4.2E-06
Dibenz(a, j)acridine	9.4E-04	1.4E-04	5.1E-04	4.8E-05	4.9E-05	5.8E-06	4.0E-05	2.0E-06
Dibenz(a, h)acridine	7.5E-04	1.2E-04	3.5E-04	3.8E-05	3.9E-05	5.2E-06	2.8E-05	1.7E-06
Dibenz(a, h)anthracene	7.8E-04	1.2E-04	3.7E-04	4.0E-05	4.1E-05	5.3E-06	2.9E-05	1.8E-06
Dibenzothiophene	1.1E-01	1.2E-02	9.1E-02	5.3E-03	5.6E-03	3.5E-04	7.1E-03	1.8E-04
7,12-dimethylbenz(a) anthracene	7.5E-04	1.2E-04	3.5E-04	3.8E-05	3.9E-05	5.2E-06	2.8E-05	1.7E-06
1, 6-Dinitropyrene	7.5E-04	1.2E-04	3.5E-04	3.8E-05	3.9E-05	5.2E-06	2.8E-05	1.7E-06
1, 8-Dinitropyrene	7.5E-04	1.2E-04	3.5E-04	3.8E-05	3.9E-05	5.2E-06	2.8E-05	1.7E-06
Fluoranthene	6.8E-03	1.1E-03	3.3E-03	3.5E-04	3.6E-04	4.7E-05	2.6E-04	1.6E-05
Fluorene	3.8E-03	6.4E-04	1.4E-03	2.0E-04	2.0E-04	3.0E-05	1.1E-04	9.3E-06
Ideno(l, 2, 3-cd)pyrene	1.1E-03	1.6E-04	6.7E-04	5.7E-05	5.9E-05	6.4E-06	5.3E-05	2.3E-06
Indole	1.5E-03	2.6E-04	6.3E-04	7.9E-05	8.0E-05	1.2E-05	5.0E-05	3.7E-06
1 -Methylnaphthalene	3.3E-02	4.0E-03	2.5E-02	1.6E-03	1.7E-03	1.3E-04	1.9E-03	5.8E-05
2-Methylnaphthalene	3.1E-02	4.0E-03	2.2E-02	1.5E-03	1.6E-03	1.4E-04	1.7E-03	5.8E-05
Naphthalene	4.3E-01	5.1E-02	3.4E-01	2.1E-02	2.2E-02	1.6E-03	2.7E-02	7.3E-04
Nitro-pyrene	1.0E-03	1.7E-04	4.6E-04	5.4E-05	5.5E-05	7.6E-06	3.6E-05	2.5E-06
Perylene	5.5E-04	8.6E-05	2.8E-04	2.8E-05	2.9E-05	3.7E-06	2.2E-05	1.2E-06
Phenanthrene	5.8E-02	7.8E-03	3.8E-02	2.9E-03	3.0E-03	2.9E-04	3.0E-03	1.1E-04
Pyrene	6.9E-03	9.7E-04	4.3E-03	3.5E-04	3.6E-04	3.7E-05	3.4E-04	1.4E-05
Retene	8.9E-03	1.4E-03	4.2E-03	4.6E-04	4.7E-04	6.2E-05	3.3E-04	2.0E-05

B3.2.8 Volatile Organic Compounds Predicted Concentrations

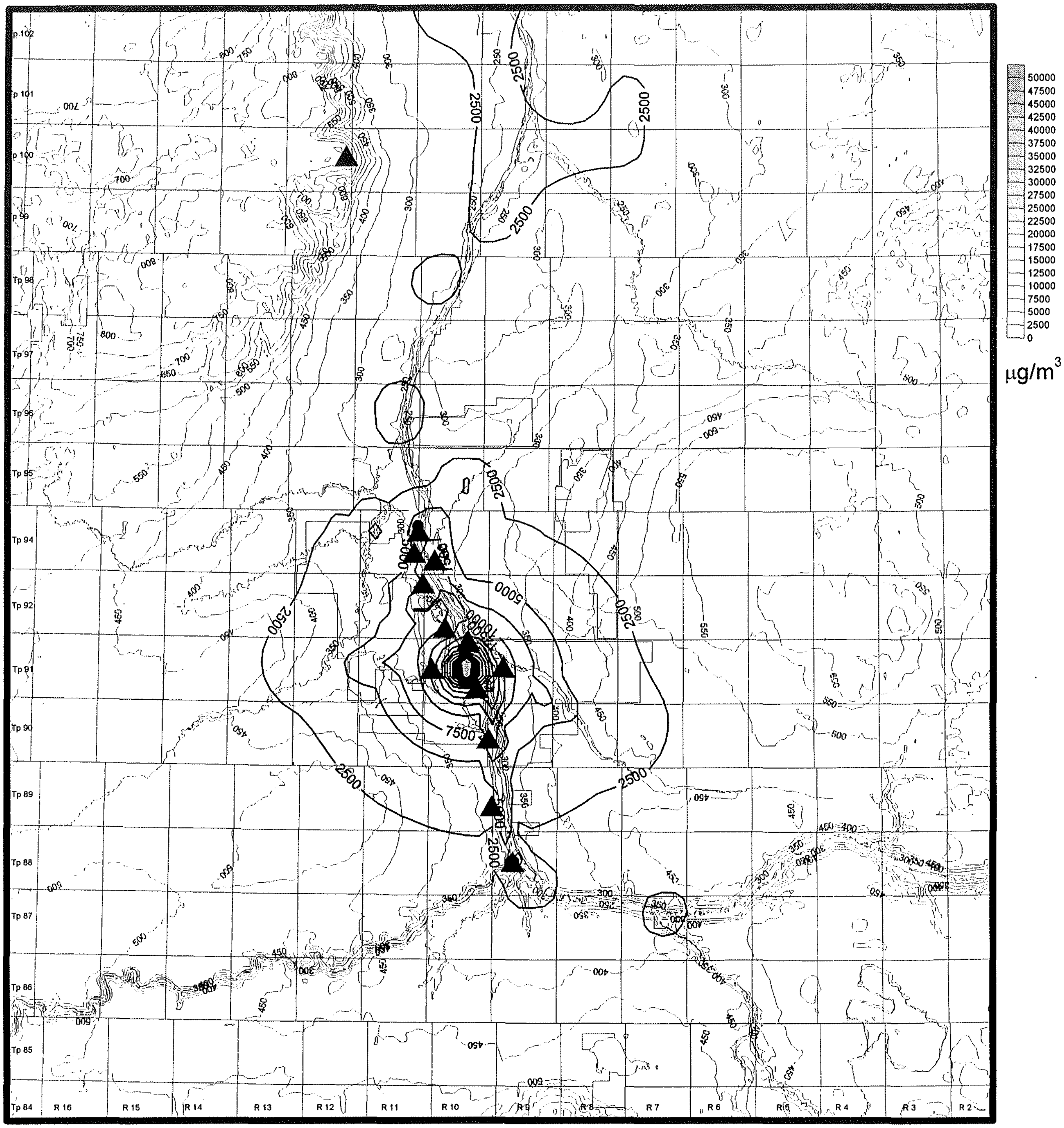
The VOC emission sources associated with Project Millennium and other approved developments are summarized in Section B3-1 (e.g., Tables B3-1 and B3-2). Total estimated emission rates for the Project Millennium case are 293 t/cd (Table B3-2). Suncor emissions account for approximately 80% of the VOC emissions in the RSA. The major VOC emissions sources from Suncor are the tailings pond (Pond 2/3) and the active mine surface areas (Table B3-1). Using the unique fingerprint of each emission source, specific VOCs were speciated from the modelling results based on an overall VOC speciation.

The predicted annual average ground level ambient total VOC concentrations resulting from emissions of Project Millennium and all approved industrial sources and residential emissions in the oil sands region were estimated using ISC3BE and meteorology measurements from Mannix station. This model provides an efficient means of predicting the overall ambient VOC concentration and the extrapolated compounds from all sources and provides an indication of where maximum concentrations could occur. The model also predicted values at specific locations (Fort McMurray, Fort McKay and Fort Chipewyan for use in the Health section (Section F1). The modelling predictions are summarized in Table B3-11.

Table B3-11 Maximum Observed Ground Level Concentrations of VOCs for Project Millennium Sources

Species	VOC Concentration [μg/m³]				
	Maximum	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan
Total VOCs					
Maximum concentration [μg/m³]	34000	796	76	163	12
Speciated VOCs					
C2 to C4 alkanes and alkenes	391	9.2	0.9	1.9	0.14
C5 to C8 Alkanes and alkenes	14831	347	33.2	71.1	5.1
C9 to C12 alkanes and alkenes [(a)]	10638	249	23.8	51.0	3.7
Cyclohexane	3441	81	7.7	16.5	1.2
Benzene	103	2.4	0.23	0.49	0.036
C6 to C8 non-benzene aromatics	1904	45	4.3	9.1	0.7
Total aldehydes	40	0.9	0.090	0.193	0.014
Total ketones	11	0.3	0.025	0.053	0.004
Total Reduced Sulphur Compounds	599	14.0	1.3	2.9	0.2

The predicted total VOC hourly, daily and annual average ground level concentrations are mapped in Figures B3-21, B3-22 and B3-23, respectively. The hourly and daily results show that the overall maximum annual concentrations are expected to occur over the Suncor Pond 2/3 (a secondary extraction tailings pond). Figure B3-23 shows that

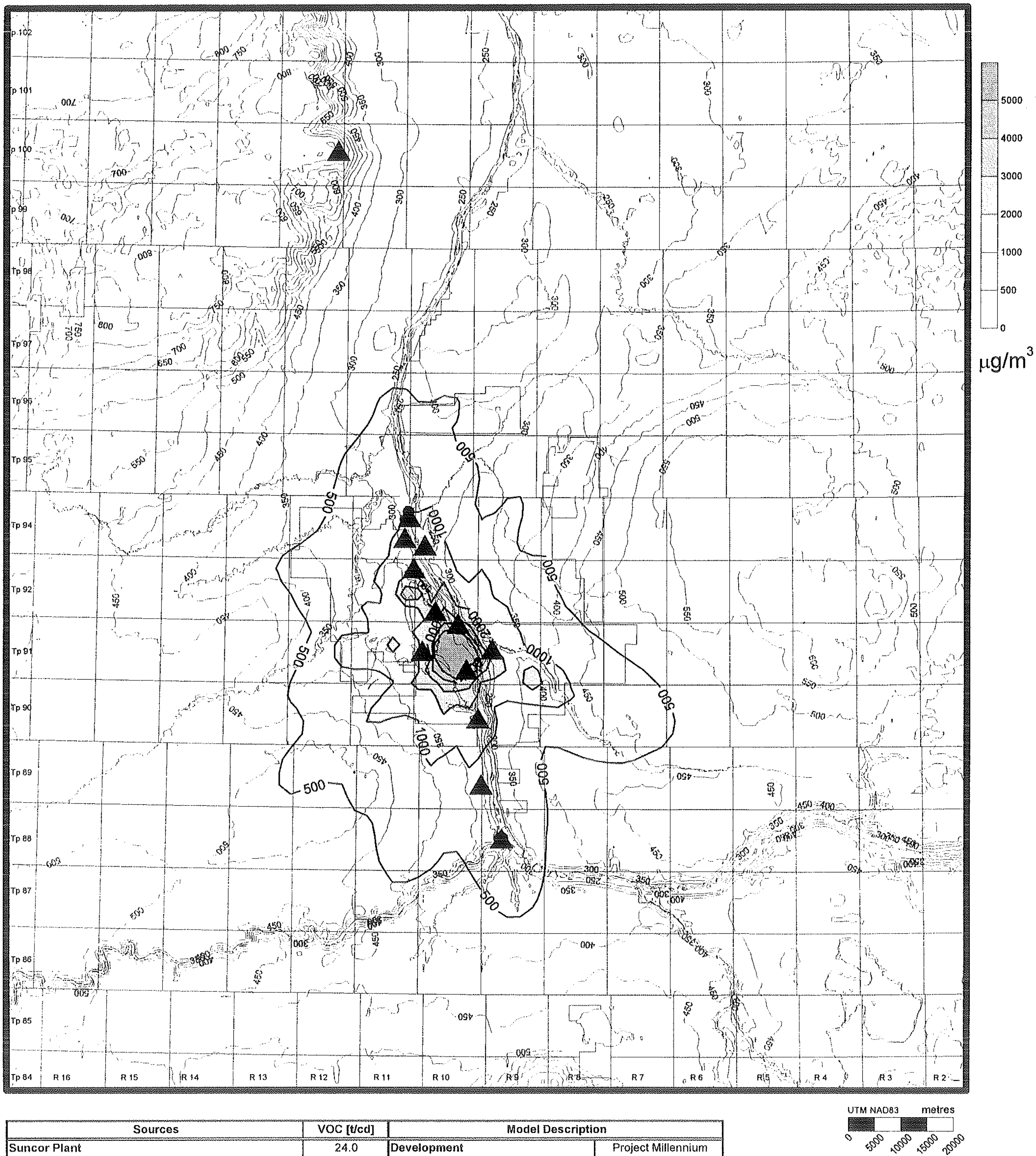


Sources	VOC [t/cd]
Suncor Plant	24.0
Syncrude Plant	5.4
Mine Fleets	2.4
Mine Faces	19.8
Tailings Ponds	226.8
TOTAL	278.4

Model Description	
Development	Project Millennium
Model	ISC3BE

UTM NAD83 metres
0 5000 10000 15000 20000

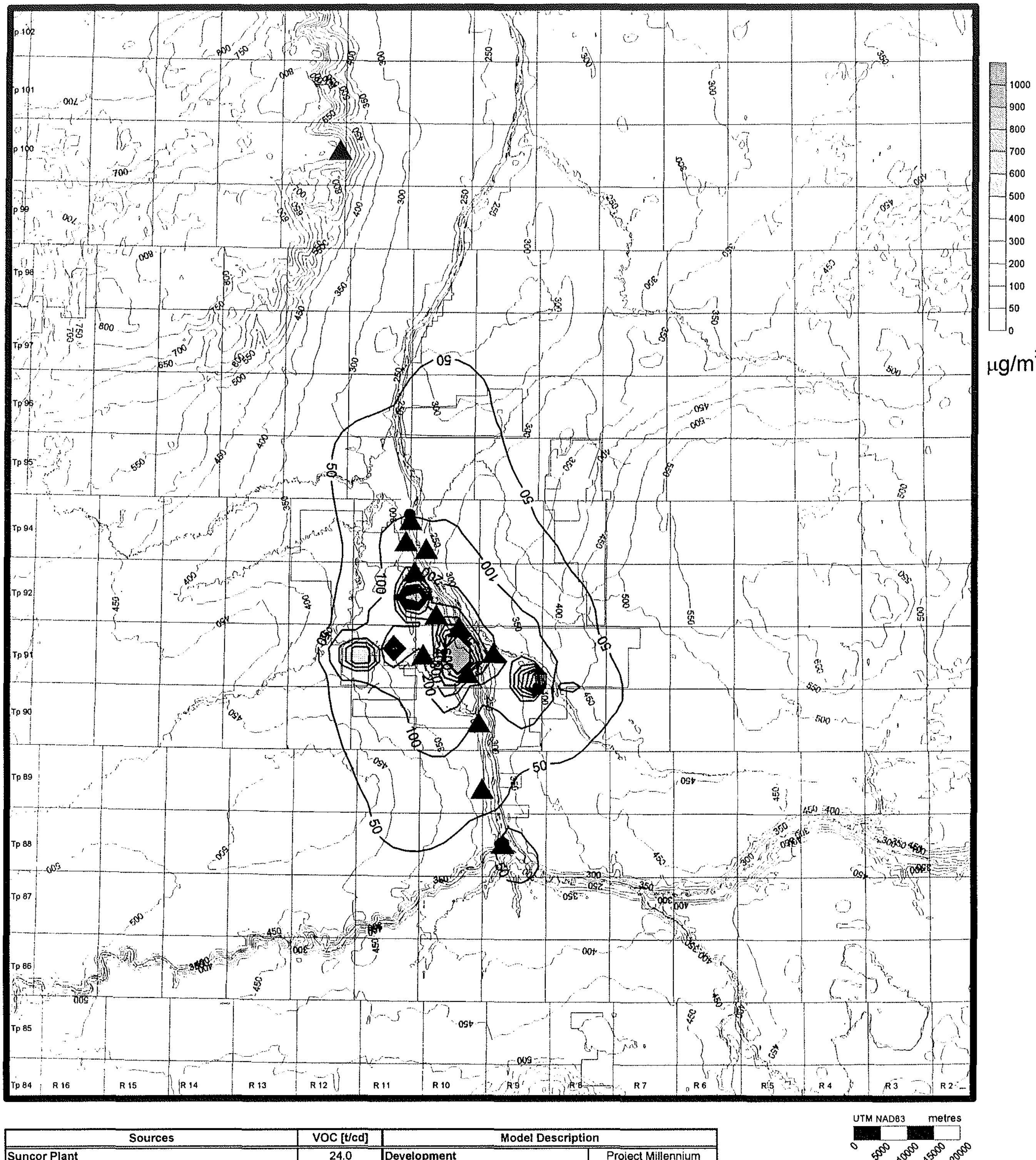
Figure B3-21 Predicted Millennium VOC Maximum Hourly Average Ground Level Concentrations in the RSA



Sources	VOC [t/cd]
Suncor Plant	24.0
Syncrude Plant	5.4
Mine Fleets	2.4
Mine Faces	19.8
Tailings Ponds	226.8
TOTAL	278.4

Model Description	
Development	Project Millennium
Model	ISC3BE

Figure B3-22 Predicted Millennium VOC Maximum Daily Average Ground Level Concentrations in the RSA



Sources	VOC [t/cd]
Suncor Plant	24.0
Syncrude Plant	5.4
Mine Fleets	2.4
Mine Faces	19.8
Tailings Ponds	226.8
TOTAL	278.4

Model Description	
Development	Project Millennium
Model	ISC3BE

Figure B3-23 Predicted Millennium VOC Annual Average Ground Level Concentrations in the RSA

the annual high concentrations occur over the existing and proposed pond areas. Because source characterization simplifications are used to model large sources such as tailings ponds, which include annualized emission rates and homogeneous emissions over the pond's surfaces, maximum concentrations under worst-case meteorology are likely over-estimated very close to the pond. The annual concentrations for selected receptor locations are listed in Table B3-11 and are put into perspective in the health discussion in Section F1.

B3.2.9 TRS Predicted Concentration

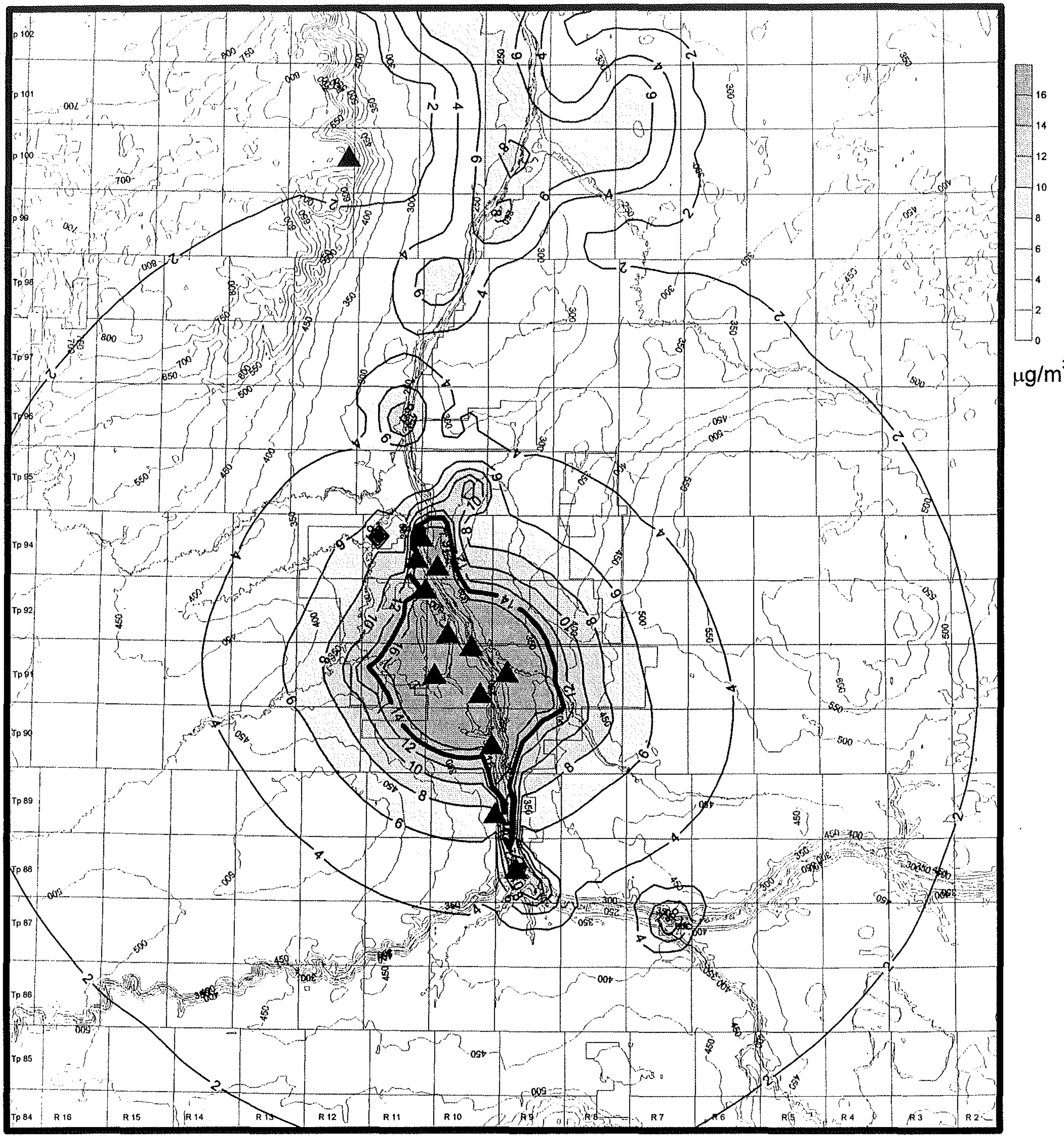
The ambient TRS emission sources associated with Project Millennium and other approved developments are summarized in Section B3.1 (e.g., Tables B3-1 and B3-2). Total estimated TRS emission rate for this case is 5.1 t/cd. The major sources of TRS emissions from Suncor are the tailing ponds and they emit approximately 2.5 t/cd or about 90% of Suncor's total. In total Suncor emits approximately 53% of the TRS. For the purposes of this assessment, TRS has been speciated with VOC emissions, implying that TRS emissions will increase in proportion to VOC emissions. This simplifying assumption over estimates TRS because the TRS emissions from the pond are believed to biogenic in origin.

Selected results of the speciated reduced sulphide compounds are shown in Figure B3-24 and Figure B3-25 for the hourly and daily H_2S and in Figure B3-26 for hourly mercaptans. These TRS species were selected because they have particularly low odour thresholds. Maximum hourly and daily concentrations at selected locations are listed in Table B3-12 and Table B3-13. Similar to the discussion in the VOC section above, the predicted maximum concentration occurs directly over a Suncor tailings pond and the predicted maximum concentration at that location is a result of the modelling simplifications.

Table B3-12 Maximum Predicted Hourly Concentrations of TRS at Selected Sites for Project Millennium Sources

	TRS Concentration [μg/m³]				
Species	Location of Maximum	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan
Total Reduced Sulphur Compounds					
Maximum VOC concentration [μg/m³]	141000	39670	11056	13988	3684
Maximum TRS concentration [μg/m³]	2484	699	195	246	65
Speciated Compounds					
H_2S	180	50.5	14.1	17.8	4.69
COS	0	0	0	0	0
CS_2	0	0	0	0	0
Mercaptans	6.68	1.88	0.52	0.66	0.17
Thiophenes	892	251	70	89	23

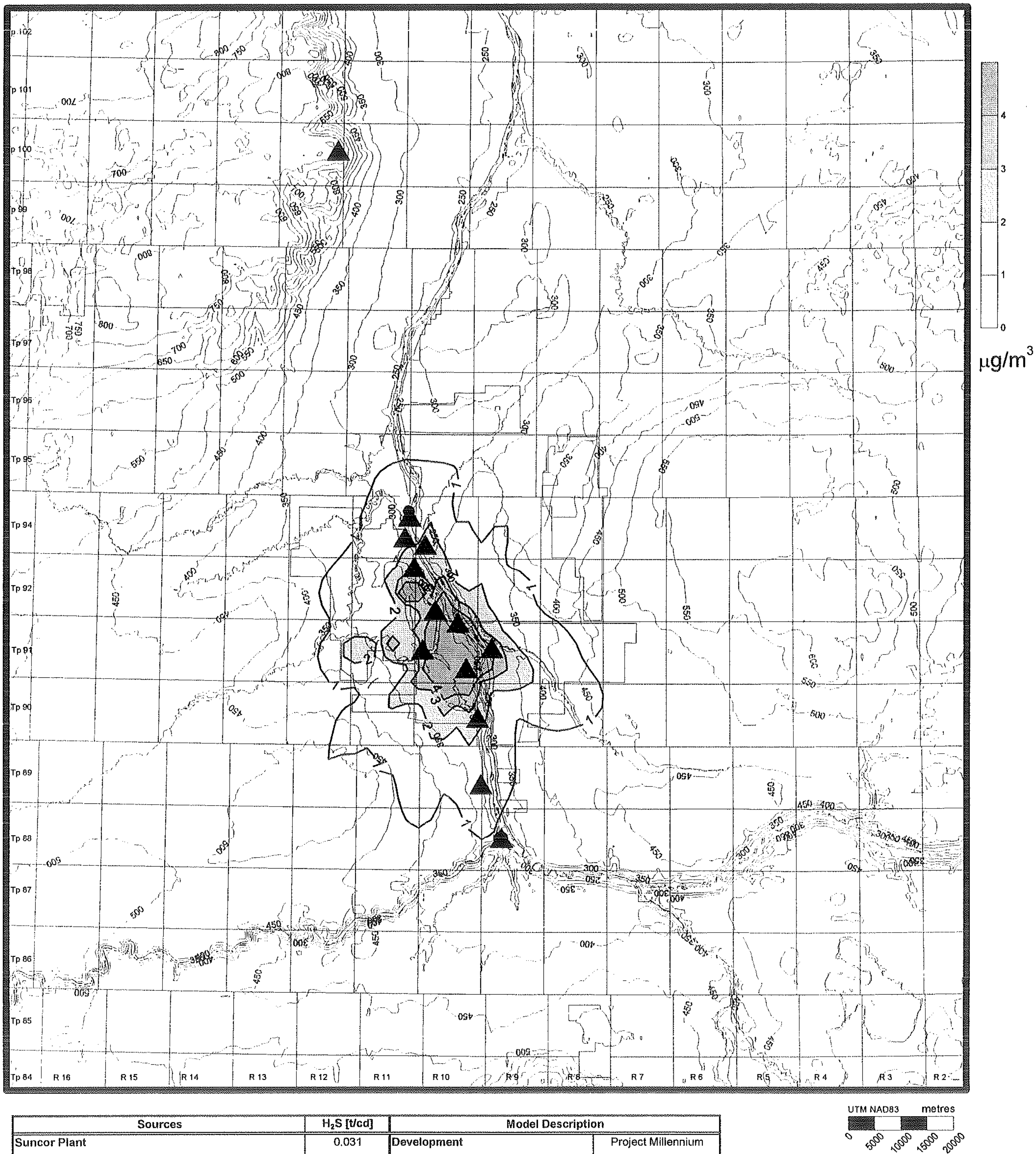
Alberta H_2S daily guideline - 4 μg/m³
Odour threshold for H_2S is 0.7 to 14 μg/m³



Sources	H_2S [t/cd]
Suncor Plant	0.031
Syncrude Plant	0.007
Mine Fleets	0.003
Mine Faces	0.025
Tailings Ponds	0.289
TOTAL	0.355

Model Description	
Development	Project Millennium
Model	ISC3BE

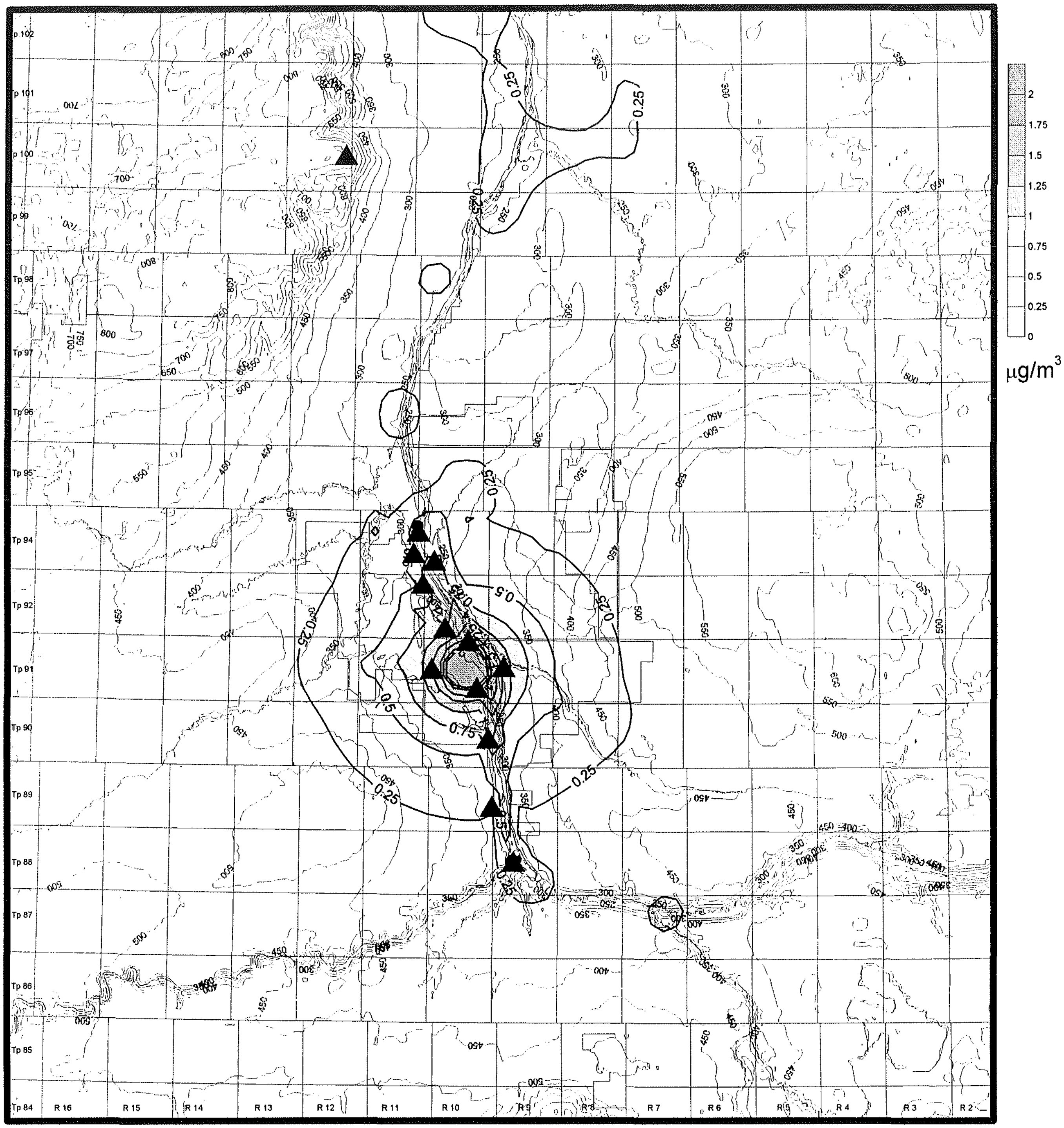
Figure B3-24 Predicted Millennium H_2S Maximum Hourly Average Ground Level Concentrations in the RSA



Sources	H_2S [t/cd]
Suncor Plant	0.031
Syncrude Plant	0.007
Mine Fleets	0.003
Mine Faces	0.025
Tailings Ponds	0.289
TOTAL	0.355

Model Description	
Development	Project Millennium
Model	ISC3BE

Figure B3-25 Predicted Millennium H_2S Maximum Daily Average Ground Level Concentrations in the RSA



Sources	Mercaptans [t/cd]
Suncor Plant	0.0011
Syncrude Plant	0.0003
Mine Fleets	0.0001
Mine Faces	0.0009
Tailings Ponds	0.0107
TOTAL	0.0132

Model Description	
Development	Project Millennium
Model	ISC3BE

Figure B3-26 Predicted Millennium Mercaptans Maximum Hourly Average Ground Level Concentrations in the RSA

Table B3-13 Maximum Predicted Daily Concentrations of TRS at Selected Sites for Project Millennium Sources

Species	TRS Concentration [$\mu g/m^3$]				
	Location of Maximum	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan
Total Reduced Sulphur Compounds					
Maximum VOC concentration [$\mu g/m^3$]	92000	10237	1013	1864	221
Maximum TRS concentration [$\mu g/m^3$]	1621	180	18	33	4
Speciated Compounds					
H_2S	117	13.0	1.3	2.4	0.28
COS	0	0	0	0	0
CS_2	0	0	0	0	0
Mercaptans	4.36	0.49	0.05	0.09	0.01
Thiophenes	582	65	6	12	1

Alberta H_2S daily guideline - 4 $\mu g/m^3$

Whereas the ISC3BE model was not configured to explicitly assess odours, the concentrations at the selected locations can be used to qualitatively assess the potential for odour detection at these locations. The results presented in the figures do not address the complexities of thorough odour assessment which would take into account concentration magnitude, duration above a threshold, frequency of exceeding various thresholds and receptor sensitivity. As a part of the ISC3BE development, the dispersion coefficients were adjusted for receptors within the Athabasca River valley such that limited mixing could occur under certain meteorological conditions. The result of this fine tuning can be seen in Figure B3-24 in the elevated H_2S concentrations within the Athabasca River valley.

The results in Table B3-12 and Table B3-13 indicate that the predicted concentrations could potentially lead to the detection of odours originating from the developments in the oil sands area for sensitive individuals.

B3.2.10 Noise

Heavy machinery and other on-site activities are likely to increase the background and peak noise levels during construction and throughout the operational phase of Project Millennium. Hence it is of interest to understand the scope and magnitude of the potential impacts arising from project related noise. Industrial noise level assessment are general conducted in reference to the nearest residence or community. If a residence is not close by, then a 1.5 km radius may be prescribed. The closest community that may be affected by the noise from Project Millennium are residents of Fort McKay. The local population for Fort McKay is approximately 360.

Noise may be generated from a variety of on-site activities, including engine noise from truck and shovel operations, extraction, on-site power generation, upgrading operations and increased traffic within the local communities. Currently, noise sources exist at the fixed plant and other mining operations at Suncor's Lease 86/17. Additionally, similar activities at the Syncrude Mildred Lake and Aurora Mine operations will also contribute to the ambient levels experienced in Fort McKay.

A detailed noise assessment was conducted by Syncrude (BOVAR 1996e) for the Aurora Mine that provides good insight to the present case. The Aurora Mine is located approximately 15 km northeast of Fort McKay. Project Millennium is located approximately 25 km southeast of Fort McKay. The Syncrude assessment was conducted on noise levels from hydraulic and electric shovels at the Mildred Lake North Mine, which had been established as the loudest noise source on-site. Assuming similar noise sources for Aurora, noise levels were estimated in Fort McKay assuming a theoretical noise attenuation due to distance, but ignored other attenuation effects such as meteorology, vegetation and barrier effects such as equipment operating below grade level. The noise levels estimated at Fort McKay suggested that the predicted noise due to the mine and background noise would meet the recommended day or night sound levels.

In the case of Project Millennium, the incremental contribution is expected to be less than that described above for other locations because of the increased distance from the Project noise sources to Fort McKay and therefore the greater opportunity for noise levels to attenuate. Also, as Suncor operations located west of the Athabasca River (i.e., closer to Fort McKay) are scaled back in the future, with gradual increased activity on the Millennium site (i.e., further from Fort McKay), one can expect the overall Suncor-derived noise levels to become less at Fort McKay.

B3.2.11 Impact Analyses

The air emissions from the project Millennium case have been described and quantified as a result of Project Millennium. The resulting air quality concentrations have been determined using appropriate models. This approach provides the foundation to determine the Project Millennium air impacts using the approach described in Section A2.1.8. The key questions identified at the beginning of this section can now be addressed.

AQ-1 What impacts will air emissions from Project Millennium have on ambient air quality?

The potential for air emissions to have an impact on ambient air quality has been raised as a concern from Project Millennium. To address this issue, predicted air quality concentrations were modelled using the ISC3BE air dispersion model. The select parameters for air quality are SO_2, NO_2, CO, PM, VOC and TRS. The modelling results were compared to Alberta Ambient Air Quality Guidelines, Canadian Federal Air Quality Objectives or other guidelines to assist in the prediction of impacts. The linkage pathway for this key question is depicted by the narrow line in Figure B3-1. Comparison of emissions and concentrations are presented in Table B3-14. A discussion of each parameter follows:

Table B3-14 Summary of Air Emissions for Project Millennium

Description	Baseline Case[a]	Project Millennium Case[a]	Comments
Suncor Process Information			
Capacity [kbbl/d]	105,000	210,000	
Emission Rate of SO_2 [t/cd]	65.3	70.2	
Emission Rate of NO_x [t/cd]	47.7	67.7	
Emission Rate of CO [t/cd]	33.5	38.5	
Emission Rate of PM_{10} [t/cd]	1.7	2.2	
Emission Rate of VOC [t/cd]	130	240.4	
Emission Rate of TRS [t/cd]	1.5	2.73	
Predicted SO_2 Concentrations			
Hourly			
• Maximum average [$\mu g/m^3$]	648	870	Below Federal Acceptable
• Exceedance [number]	3	49	
• Areal extent [ha]	33,313	58,860	Approximately 70% in Lease Area
Daily			
• Maximum average [$\mu g/m^3$]	199	200	Below Federal Acceptable
• Exceedance [number]	6	9	
• Areal extent of exceedance [ha]	358	289	In Development Area
Annual			
• Maximum average [$\mu g/m^3$	74	82	Above Federal Acceptable
• Exceedance [number]	1	1	
• Areal extent of exceedance [ha]	356	409	In Development Area
Predicted NO_2 Concentrations			
Hourly			
• Maximum average ($\mu g/m^3$)	316	320	Below Alberta Guideline
• Exceedance (number)	0	0	
• Areal extent of exceedance [ha]	0	0	
Daily			
• Maximum average ($\mu g/m^3$)	259	260	Above Federal Acceptable
• Exceedance (number)	n/a	101	
• Areal extent of exceedance [ha]	825	2,185	In Development Area
Annual			
• Maximum average ($\mu g/m^3$)	162	162	Above Federal Acceptable
• Exceedance (number)	1	1	
• Areal extent of exceedance [ha]	5,818	8,343	
Predicted CO Concentrations			
Hourly			
• Maximum average ($\mu g/m^3$)	5561	5560	Below Alberta Guideline
• Exceedance (number)	0	0	
• Areal extent of exceedance [ha]	0	0	
8-Hour			
• Maximum average ($\mu g/m^3$)	2226	2226	Below Alberta Guideline
• Exceedance (number)	n/a	n/a	
• Areal extent of exceedance [ha]	n/a	n/a	
Predicted PM Concentrations			

Description	Baseline Case[a]	Project Millennium Case[a]	Comments
Daily			
• Maximum average (μg/m³)	113	113	
• Exceedance (number)	33	33	
• Areal extent of exceedance [ha]	n/a	n/a	
Annual			
• Maximum average (μg/m³)	45.8	45.9	
• Exceedance (number)	0	0	
• Areal extent of exceedance [ha]	n/a	n/a	
Predicted VOC Concentrations			
Annual			
• Maximum average (μg/m³)	50	76	Fort McKay
• Maximum average (μg/m³)	107	163	Fort McMurray
• Exceedance (number)	n/a	n/a	
• Areal extent of exceedance [ha]	n/a	n/a	
Predicted TRS Concentrations			
Hourly			
• Maximum average H_2S (μg/m³)	9.2	14.1	Fort McKay
• Maximum average H_2S (μg/m³)	11.7	17.8	Fort McMurray
• Exceedance (number)	n/a	n/a	
• Areal extent of exceedance [ha]	n/a	n/a	
Daily			
• Maximum average H_2S (μg/m³)	1.7	1.3	Fort McKay
• Maximum average H_2S (μg/m³)	0.9	2.4	Fort McMurray
• Exceedance (number)	n/a	n/a	
• Areal extent of exceedance [ha]	n/a	n/a	

(a) All calculated values based on ISC3BE model unless otherwise noted.
(b) Calculations based on CALPUFF model

Sulphur Dioxide (SO_2)

The ISC3BE model was used to predict SO_2 concentrations resulting from the Project Millennium case. The model provides predicted maximum concentrations, areal extent of land above the Alberta guideline, number of exceedances and the location of the high readings. In comparing the results to historical levels, there has been a substantial decrease in concentrations as shown in Figures B2-11 to B2-15 and emissions (Table B2-2). Using the approach discussed in Section A2 and the analyses summarized in Table B3-15, the following impact predictions and environmental consequences have been derived for SO_2:

- The predicted impacts of hourly SO_2 emissions and concentrations on the air quality are classified as moderate in magnitude, short-term in duration, moderate in frequency, regional in geographic extent and reversible. The environmental consequence of these impacts is low.
- The predicted impacts of daily SO_2 emissions and concentrations on the air quality are classified as moderate in magnitude, short-term in

duration, moderate in frequency, local in geographic extent and reversible. The environmental consequence of these impacts is low.

- The predicted impacts of annual SO_2 emissions and concentrations on the air quality are classified as high in magnitude, mid-term in duration, high in frequency, local in geographic extent and reversible. The environmental consequence of these impacts is moderate.

Table B3-15 Residual Impact Classification for SO_2 Emissions on Ambient Air Quality

SO_2	Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Environmental Consequence
Hourly	Moderate	Short-Term	Moderate	Regional	Reversible	Low
Daily	Moderate	Short-Term	Moderate	Local	Reversible	Low
Annually	High	Mid-Term	High	Local	Reversible	Moderate

Impacts to the annual SO_2 concentrations were assigned a moderate environmental consequence. However, the maximum annual concentration plus the areal extent are all within existing operations. Outside of the Suncor and Syncrude lease boundaries the maximum annual concentrations are predicted to be approximately 20 $\mu g/m^3$ and, therefore, below the annual Alberta guideline of 30 $\mu g/m^3$. The concentrations from Project Millennium at Fort McKay are predicted to be between 5 and 10 $\mu g/m^3$ and at Fort McMurray, less than 5 $\mu g/m^3$. Viewed in this context, it is predicted that there would be no exceedances outside of the lease areas and that the concentrations in the rest of the RSA will be low. Hence the environmental risk is considered to be low and, therefore, this impact is not significant.

Nitrogen Dioxide (NO_2)

The ISC3BE model was used to predict NO_2 concentrations resulting from the Project Millennium case. The model provides predicted maximum concentrations, areal extent of land above the Alberta Guideline, number of exceedances and the location of the high readings. Using the approach discussed in Section A2 and the analyses summarized in Table B3-16, the following impact predictions and environmental consequences have been derived for NO_2:

- The predicted impacts of hourly NO_2 concentrations on the air quality are classified as low in magnitude, short-term in duration, low in frequency, local in geographic extent and reversible. The environmental consequence of these impacts is low.
- The predicted impacts of daily NO_2 concentrations on the air quality are classified as high in magnitude, short-term in duration, moderate in

frequency, local in geographic extent and reversible. The environmental consequence of these impacts is moderate.

- The predicted impacts of annual NO_2 concentrations on the air quality are classified as high in magnitude, mid-term in duration, high in frequency, local in geographic extent and reversible. The environmental consequence of these impacts is moderate.

Table B3-13 Residual Impact Classification for NO_2 Emissions on Ambient Air Quality

NO_2	Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Environmental Consequence
Hourly	Low	Short-Term	Low	Local	Reversible	Low
Daily	High	Short-Term	Moderate	Local	Reversible	Moderate
Annually	High	Mid-Term	High	Local	Reversible	Moderate

Impacts to the daily and annual NO_2 concentrations were assigned a moderate environmental consequence. The maximum daily concentration and the areal extent are all within a small area within the existing operations. There are no exceedances projected outside of the development areas. Daily concentrations are predicted to be well below 100 $\mu g/m^3$ at Fort McKay and Fort McMurray. The maximum annual concentration plus the areal extent are also centered in the existing operational area but occupy a larger area. There are no exceedances predicted outside the development areas. Annual concentrations at both Fort McKay and Fort McMurray are predicted to be between 20 and 40 $\mu g/m^3$. Viewed in this context of low concentrations outside the mine pits, the environmental consequence of the NO_2 emissions is rated as low and, therefore, this impact is not significant.

Carbon Monoxide (CO)

The ISC3BE model was used to predict CO concentrations resulting from the Project Millennium case. The model provides predicted maximum concentrations, areal extent of land above the Alberta guideline, number of exceedances and the location of the high readings. Using the approach discussed in Section A2 and summarized in Table B3-17, the following impact predictions and environmental consequences have been derived for CO:

- The predicted impacts of hourly CO emissions and concentrations on the air quality are classified as low in magnitude, short-term in duration, low in frequency, local in geographic extent and reversible. The environmental consequence of these impacts is low.
- The predicted impacts of 8-hour CO emissions and concentrations on the air quality are classified as low in magnitude, short-term in

duration, low in frequency, local in geographic extent and reversible. The environmental consequence of these impacts is low.

Table B3-17 Residual Impact Classification for CO Emissions on Ambient Air Quality

CO	Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Environmental Consequence
Hourly	Low	Short-Term	Low	Local	Reversible	Low
8-Hour	Low	Short-Term	Low	Local	Reversible	Low

Particulate Matter (PM)

The ISC3BE model was used to predict PM concentrations resulting from the Project Millennium. The model provides predicted maximum concentrations, concentration contours and the location of the high readings. The results were compared to the Alberta suspended particulate guideline and the U.S. EPA PM_{10} guidelines. Using the approach discussed in Section A2 and summarized in Table B3-18, the following impact predictions and environmental consequences have been derived for PM:

- The predicted impacts of daily PM emissions and concentrations on the air quality are classified as moderate in magnitude, short-term in duration, moderate in frequency, local in geographic extent and reversible. The environmental consequence of these impacts is low.
- The predicted impacts of annual PM emissions and concentrations on the air quality are classified as low in magnitude, mid-term in duration, low in frequency, local in geographic extent and reversible. The environmental consequence of these impacts is low.

Table B3-18 Residual Impact Classification for PM Emissions on Ambient Air Quality

PM	Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Environmental Consequence
Daily	Moderate	Short-Term	Moderate	Local	Reversible	Low
Annually	Low	Mid-Term	Low	Local	Reversible	Low

Volatile Organic Components (VOC)

The ISC3BE model was used to predict VOC concentrations resulting from the Project Millennium case. The model provides predicted maximum concentrations, concentration contours and the location of the high readings. Using the unique fingerprint of each emission source, specific VOCs were speciated from the modelling results.

No impact predictions and environmental consequences have been established for VOCs (and the speciated VOCs) in the air section as VOCs are an input into the health section (F1).

Total Reduced Sulphur (TRS)

The ISC3BE model was used to predict TRS concentrations resulting from the Project Millennium case. The major source of TRS is the Suncor ponds. TRS emissions were conservatively assumed to increase in relation to the increase in VOCs for this assessment. It is more likely that the generation of TRSs result from biogenic activity in the pond thus and are expected to remain similar to the existing Baseline case. The ISC3BE model was used to predict maximum VOC concentrations, concentration contour maps, and the location of high readings. From these data, H_2S concentrations were speciated for the TRS assessment end point. There are Alberta guidelines for H_2S based on odour detection limits. Using the approach discussed in Section A2 and summarized in Table B3-19, the following impact predictions and environmental consequences have been derived for TRS:

- The predicted impacts of hourly TRS concentrations on the air quality are classified as high in magnitude, short-term in duration, moderate in frequency, regional in geographic extent and reversible. The environmental consequence of these impacts is moderate.
- The predicted impacts of daily TRS concentrations on the air quality are classified as high in magnitude, short-term in duration, moderate in frequency, local in geographic extent and reversible. The environmental consequence of these impacts is moderate.

Table B3-19 Residual Impact Classification for TRS Emissions on Ambient Air Quality

TRS	Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Environmental Consequence
Hourly	High	Short-Term	Moderate	Regional	Reversible	Moderate
Daily	High	Short-Term	Moderate	Local	Reversible	Moderate

Impacts to the hourly and daily TRS concentrations were assigned a moderate environmental consequence. However, the conservative modelling assumptions are likely to over-estimate TRS because the TRS emissions from the pond are believed to be biogenic in nature and not a function of total VOC emission. It is more likely that there will not be an increase in TRS emissions from the existing Baseline rates. Although TRS may continue to be an occasional odour issue, odour abatement programs have been ongoing at both Suncor and Syncrude and there has been a decrease in complaints from over 275 to less than 20 per year. Hourly concentrations are predicted to be below the H_2S guideline for this component at both Fort McKay and Fort McMurray. The maximum daily concentrations of H_2S are centered in the existing operational area. There are no exceedances predicted outside the development areas. Daily concentrations of H_2S at both Fort McKay and Fort McMurray are predicted to be well below the Alberta guideline. Viewed in this context of low concentrations outside the existing operational areas and the potential of no net increase in emission rates, the environmental consequence of the TRS emissions is rated as low and, therefore, this impact is not significant.

AQ-2 What impacts will air emissions from Project Millennium have on the deposition of acid forming compounds?

The CALPUFF model was used for predicting the PAI resulting from the Project Millennium case. The CALPUFF model is a good tool for estimating the PAI in the oil sands region as it takes into account the chemical transformations of the emitted SO_2 and NO_x and predicts wet (rain and snow scavenged) and dry (via an effective dry deposition velocity) deposition of SO_2, SO_4, NO, NO_2, NO_3^-, and HNO_3. A background PAI of 0.1 keq/ha/y has been incorporated into the PAI presented numbers. This value was based on estimates of sulphur and nitrogen and base cation concentrations and depositions in the region surrounding the RSA. The linkage pathway for this key question is depicted by the bolded line in Figure B3-1. Comparisons of emissions and concentrations are presented in Table B3-20 and discussed below:

- The predicted PAI exceeds the Alberta interim critical loading for sensitive soils (0.25 keq/ha/y) over an area of 861,263 ha (35.5% of the RSA). The areal extents where the PAI exceeds the critical loadings being considered for less sensitive soils are: 195,695 ha (8.1% of the RSA) above 0.50 keq/ha/y; and 9,598 ha (0.4% of the RSA) above 1.0 keq/ha/y.
- The maximum predicted PAI of 2.13 keq/ha/y occurs in the development area, in the immediate vicinity of the open pit mines.
- The maximum predicted sulphate deposition rate of 1.15 keq/ha/y is predicted to occur in the active plant area.
- The highest predicted deposition rate of nitrates (1.01 keq/ha/y) occurs in the development area, adjacent to the open pit mines.
- The maximum wet and dry deposition rates (including both the sulphate and nitrate species) are 0.78 and 1.81 keq/ha/y, respectively. These maximums occur in the vicinity of the active open pit mines.

Table B3-20 Summary of Deposition of Acid Forming Compounds for Project Millennium

	Baseline Case[(a)]	Project Millennium Case[(a)]	Comments
Suncor Process Information			
Capacity	105,000	210,000	
Emission Rate of SO_2 t/cd	65.3	67.9	
Emission Rate of NO_x t/cd	47.7	67.7	
Predicted PAI			
Areal extent > 0.25 keq/ha/y [ha]	670,483	861,263	
Areal extent > 0.50 keq/ha/y [ha]	11,543	195,695	
Areal extent > 1.0 keq/ha/y [ha]	3,206	9,598	In Development Area
Maximum average [keq/ha/y]	2.10	2.13	In Development Area
Predicted Acidic Deposition Rates			
Sulphate (wet + dry) Maximum average [keq/ha/y]	1.07	1.15	In Development Area
Nitrate (wet + dry) Maximum average [keq/ha/y]	0.97	1.01	In Development Area
Wet Deposition (sulphate + nitrate) Maximum average [keq/ha/y]	0.78	0.78	In Development Area
Dry Deposition (sulphate + nitrate) Maximum average [keq/ha/y]	1.79	1.81	In Development Area

(a) All calculated values based CALPUFF model

No impact predictions and environmental consequences have been established for PAI in the air section as PAI is an input into the water quality, soil and terrain, terrestrial vegetation and wetlands evaluations presented in Sections C3.2, D2.2 and D3.2, respectively.

AQ-3 What impacts will air emissions from Project Millennium have on concentrations of ground level ozone (O_3)?

The prediction of ground level ozone (O_3) concentrations is complex because ozone results from a series of chemical reactions in the atmosphere rather than being a direct emission. To simulate the formation of ozone, it is essential that the model developed considers all of the releases from natural or industrial activities combined with an accurate simulation of the meteorological conditions over the region. Compounding these difficulties is the fact that many of the emissions in the region can bring about a decline in the ozone as a result of chemical transformations. Therefore, only minor discrepancies in the emission values used can result in completely different predictions.

In order to address the regional issue of ground level ozone effectively, a separate Working Group has been established with industrial, technical and regulatory representatives to identify suitable methodologies to undertake the assessment and initiate a comprehensive evaluation. The Working Group has identified the CALGRID model as the most appropriate tool for achieving the said goals of simulating the ground level ozone in the oil sands region, and have retained EARTH TECH to conduct the analysis. The results of the CALGRID modelling are expected to provide improved estimates of the expected future ozone trends for the region. The current schedule for initial completion of the EARTH TECH study is in October 1998.

B4 AIR QUALITY CUMULATIVE EFFECTS ASSESSMENT

B4.1 EMISSION SOURCES AND BASELINE DATA

B4.1.1 Introduction

The Cumulative Effects Assessment (CEA) requires a review of all the existing and approved developments, Project Millennium and planned future developments. This section describes the air emission sources that are considered in developing the CEA. The data for the existing and approved operations are based on approved and operating conditions and are summarized in Section B2.1.1. The air emission data for Project Millennium are based on design and are summarized in Section B3.1. The air emission data for the planned developments are based on best estimates as provided by the proponents or have been estimated based on the existing Suncor and Syncrude operations. These emissions and resultant concentrations are summarized in this section of the report.

The objective of the cumulative air emissions impact analysis is to identify and analyze the potential combined effects associated with Project Millennium and other disclosed developments in the region. The air quality impact analysis focuses on determining changes to the chemical composition of the air and not on the effect these changes may have on receptors. Effects of air quality changes to aquatics, terrestrial ecosystems and human health are discussed in the Aquatics Section C, Terrestrial Resources Section D and the Human Health Section F1.

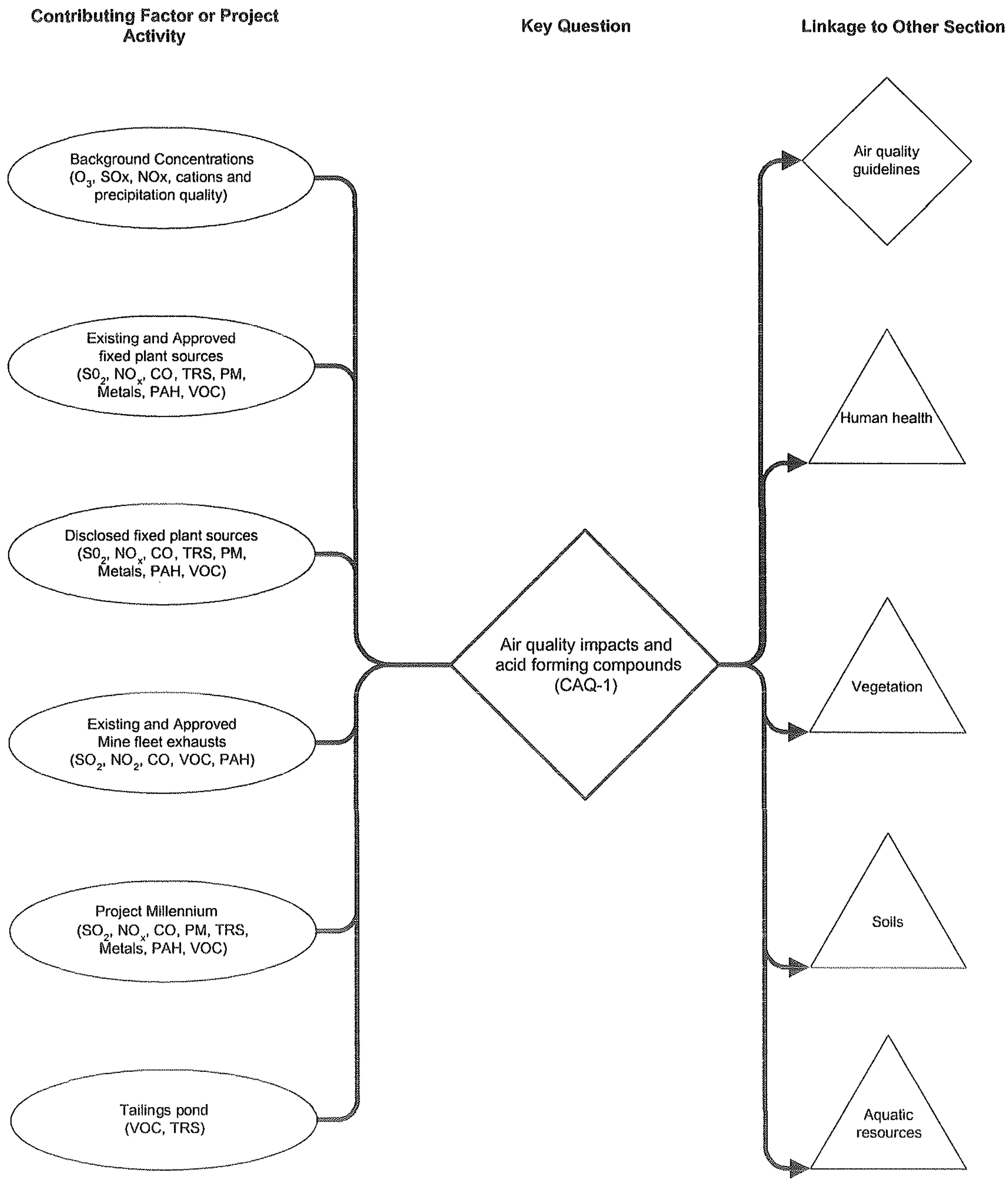
The following overall key question is addressed in this CEA:

CAQ-1: What impacts to ambient air quality and acidification of water, soils and vegetation will result from air emissions associated with Project Millennium and the combined developments?

The potential for air emissions from Project Millennium and combined developments to impact on ambient air quality and the acidification of water, soils and vegetation has been raised as a cumulative concern in the region. This issue was addressed in two stages. The first stage looked at the potential impacts on air quality by predicting air concentrations of SO_2, NO_2, CO, PM, VOC and TRS using the ISC3BE dispersion model. The model results were then compared to Alberta Ambient Air Quality Guidelines, Canadian Federal Air Quality Objectives or other guidelines to assist in the prediction of impacts. The potential for acidification of water, soils and vegetation was then addressed by using the CALPUFF dispersion model to determine the Potential Acid Input (PAI) resulting from the SO_2 and NO_x emitted by Project Millennium and the combined developments. The resulting PAI values were presented in a manner suitable for comparison to appropriate evaluation parameters. In particular the PAI results were incorporated into the Cumulative Aquatics (C6) and

Cumulative Terrestrial (D5) sections of this EIA. The linkage pathway for this key question is depicted in Figure B4-1.

Figure B4-1 Air Quality Linkage Diagram for the CEA



B4.1.2 Emission Projections

B4.1.2.1 Suncor

The Project Millennium section describes the total planned air emissions by Suncor at this time. No additional sources of air emissions were considered in the CEA.

B4.1.2.2 Syncrude

The baseline section of this report (Section B2.1) summarizes the existing and approved emissions from the Syncrude site. Project 21, the Mildred Lake Upgrader Expansion, is a new development project planned by Syncrude. The plan is to expand the existing upgrader to an overall capacity of 480,000 b/d. Predicted air emissions for the proposed upgrader were provided by Syncrude's. In completing the CEA for this project, the new air emissions from the Upgrader were combined with the existing and approved emissions. The resultant Syncrude air emissions are summarized in Table B4-2.

B4.1.2.3 Other Existing or Approved Developments

All air emissions from other approved developments were considered in the baseline section of this report (Section B2.1). No additional sources of air emissions from other existing or approved developments were considered in the CEA.

B4.1.2.4 Transportation and Residential Sources

Future changes were estimated for the air emissions from transportation and residential sources. Table B4-1 presents the estimated air emissions data for transportation and residential sources based on a Fort McMurray population of 49,500 in 2006. These data were used in the prediction of air quality for the CEA.

Table B4-1 Summary of Estimated CEA Emissions From Transportation and Residential Sources

	Emission (t/cd)			
Source	**SO_2**	**NO_x**	**PM**	**VOC[a]**
Highway	0.07	0.54	0.50	0.33
Fort McMurray				
Traffic	0.222	1.473	1.504	2.314
Residential Natural Gas	0.003	0.162	0.022	0.049
Residential Wood	0.004	0.024	0.298	1.279
Fort McKay				
Traffic	<0.001	<0.001	<0.001	<0.001
Residential Natural Gas	<0.001	0.007	<0.001	<0.001
Residential Wood	<0.001	0.000	0.002	0.01
Total	**0.299**	**2.206**	**2.33**	**4.34**

(a) assume THCs equals VOCs.

B4.1.2.5 Planned Developments

A number of additional developments are in the planning stage that could result in air emissions in the region. The planned projects are presented in Table A4-1 and the air emissions from these planned projects are summarized in Table B4-2 and discussed below.

- **Syncrude Project 21 Mildred Lake Upgrader Expansion.** Syncrude is developing plans to expand the existing upgrader to an overall capacity of 480,000 b/d. This is an expansion of 180,000 b/d and will result in increased air emissions. Predicted air emissions for the proposed upgrader were provided by Syncrude. The air emissions are combined with the existing and approved developments and summarized in Table B4-2.

- **Mobil Kearl Oil Sands Mine and Upgrader.** Mobil Oil proposes to develop the Kearl Oil Sands Mine project comprising of a 130,000 b/d mine and associated upgrader. The mine will be a truck and shovel operation. Air emissions from the proposed extraction plant and upgrader were provided by Mobil. Specifically, extraction emissions were scaled from the proposed Aurora North Mine plant on the basis of production and upgrader emissions were scaled from the proposed Syncrude 8-3 coker.

- **Shell Muskeg River Mine Project.** Shell Canada has submitted an Application and Environmental Impact Assessment for the development of the Muskeg River Mine Project located on the western portion of Lease 13 (Shell 1997). Shell also disclosed an interest in further development of Lease 13 East. The nominal bitumen production capacity of the proposed Muskeg River and Lease 13 East developments are 150,000 b/d and 200,000 b/d, respectively.

  The Muskeg River Mine plant will be serviced by six fired heaters and two boilers. No upgrader is planned for the site. The Lease 13 East plant emissions were scaled (for the fired heaters and boilers) from the Muskeg River Mine values on the basis of bitumen production.

- **Gulf Surmont.** Gulf Canada Resources Limited has disclosed an intent to operate a SAGD in-situ project with a bitumen production capacity of 100,000 b/d (Gulf 1997). The operation will consist of five sites, each with a production capacity of 20,000 b/d. Preliminary engineering indicate that each site will be serviced by four natural gas fired boilers. Each boiler was assumed to be serviced by a separate stack.

- **Petro-Canada MacKay River.** Petro-Canada proposes to develop the MacKay River SAGD in-situ project with an initial design production capacity of 20,000 b/d of bitumen. The preliminary design is for five boilers, each served by a separate stack.

- **JACOS Hangingstone.** The JACOS Hangingstone in-situ SAGD development has recently received approval for Phase I at 2,000 b/d and is scheduled to ramp up to 10,000 b/d by 2001. The estimated emissions from this development are based on information in the approved development application and scaled up where necessary to the ultimate production rate of 10,000 b/d.

- **Fee Lot 2 Development.** Suncor Energy Inc. is planning a number of developments on Fee Lot 2. At this time, it appears that such development will not significantly increase air emissions.

Table B4-2 Summary of Estimated CEA Air Emissions from Planned Developments

Source	Emission (t/cd)					
	SO_2	NO_x	CO	PM[a]	VOC[c]	TRS
Planned Developments						
Syncrude - Existing, Approved, Planned						
Main Stack	188.0	14.8	55.2	4.3	0.003	0.000
8-3	10.0	3.5	13.5	2.9	0.002	0.000
Secondary Sources	0.0	26.4	7.8	2.6	0.3	0.000
Fugitive Plant	0.0	0.0	0.0	0.0	9.6	3.100
Mine Fleet	1.0	19.2	5.0	0.6	0.9	0.000
Ponds (Fugitive)	-	-	-	-	22.2	0.399
Mine Surface (Fugitive)		-	-	-	13.3	0.032
Total Syncrude	**199.0**	**63.9**	**81.5**	**10.4**	**66.7**	**3.5**
Mobil Kearl	17.4	13.9	2.9	0.6	11.7	0.025
Shell Muskeg River	0.6	15.7	4.2	0.6	16.7	0.030
Shell Lease 13	0.8	21.0	5.6	0.8	9.9	0.025
Gulf Surmont	-	6.9	3.3	0.42	0.1	n/a
Petro-Canada MacKay River	-	1.4	0.7	0.1	0.02	n/a
JACOS Hangingstone	0.02	2.0	0.2	0.03	0.08	n/a
Fee Lot 2 Development	n/a	n/a	n/a	n/a	n/a	n/a
Total (other)	**18.8**	**60.9**	**16.9**	**2.55**	**53.1**	**0.08**

n/a data not available.
\- not a source of this emission.
(a) Assumed as PM_{10}.
(b) Estimate based on CAPP emission factor.
(c) Assume THCs equals VOCs.

B4.1.2.6 Summary of CEA Emissions

Table B4-3 summarizes the air emission estimates used in the CEA from Suncor, Syncrude, other industries, and transportation and residential sources in the oil sands region. The level of confidence in the data are high for the existing, approved and Project Millennium developments. Assumptions have been made in the air emission data for the planned developments and therefore the level of confidence for this data is lower.

Table B4-3 Summary of Estimated CEA Emissions in the Athabasca Oil Sands Region

Source	Emission Rates (t/cd)					
	SO_2	NO_x	CO	PM_{10}	VOC	TRS
Suncor	70.2	67.7	38.6	2.2	240.4	2.73
Syncrude	199	63.9	81.5	10.4	66.7	3.5
Other Industries	3.9	8.7	27.1	0.9	9.2	0.00
Transportation and Residential	0.3	2.2	9.8	2.3	4.3	n/d
Planned Projects	18.8	60.9	16.9	2.55	57.5	0.08
Total	**292.2**	**203.4**	**173.9**	**18.3**	**540.8**	**6.3**

B4.2 PREDICTIONS

B4.2.1 Model Approach and Limitations

Descriptions of the models used to determine the predicted ground level concentrations were discussed in Section B2.2.1. In this CEA the same models were used, in particular the ISC3BE and CALPUFF, for determining predicted concentrations of air emissions.

B4.2.2 SO_2 Predicted Concentrations

The SO_2 emission sources associated with this CEA are summarized in Section B4.1 (Table B4-3). The estimated total SO_2 emission rate in the oil sands region for the CEA is 292.2 t/cd. Suncor will emit an estimated 24% (70.2 t/cd) of the total SO_2 emissions to the atmosphere.

The predicted maximum hourly, daily and annual ground level ambient SO_2 concentrations resulting from all emissions sources presented in Section 4.1 were estimated using the ISCBE model. Average annual ground level SO_2 concentrations were also estimated using the CALPUFF model. These models provide an efficient means of estimating the predicted ambient SO_2 concentrations from all sources and provides an indication where maximum concentrations could occur.

The modelling predictions for daily SO_2 emission rate cases are summarized in Table B4-4 for each model. The predicted ground level concentrations are mapped in Figures B4-2 to B4-5 and described below:

- Figure B4-2 shows the maximum hourly average SO_2 ground level concentrations (GLC) associated the CEA for the ISC3BE model. An overall maximum hourly average SO_2 concentration of 872 $\mu g/m^3$ is predicted to occur at a location 2 km south of Suncor within the existing facilities (Figure B4-2). This maximum average value exceeds the Alberta Ambient Air Quality Guideline (AAAQG) of 450 $\mu g/m^3$. This model predicts three areas that result in maximum hourly averages in excess of the AAAQG. The areas (54,269 ha) are located south and east of the Suncor (mainly within Suncor and Syncrude leases) and an area northwest of Suncor (near Mobil). The ISC3BE model predicts 50 yearly exceedances per year of the hourly AAAQG.

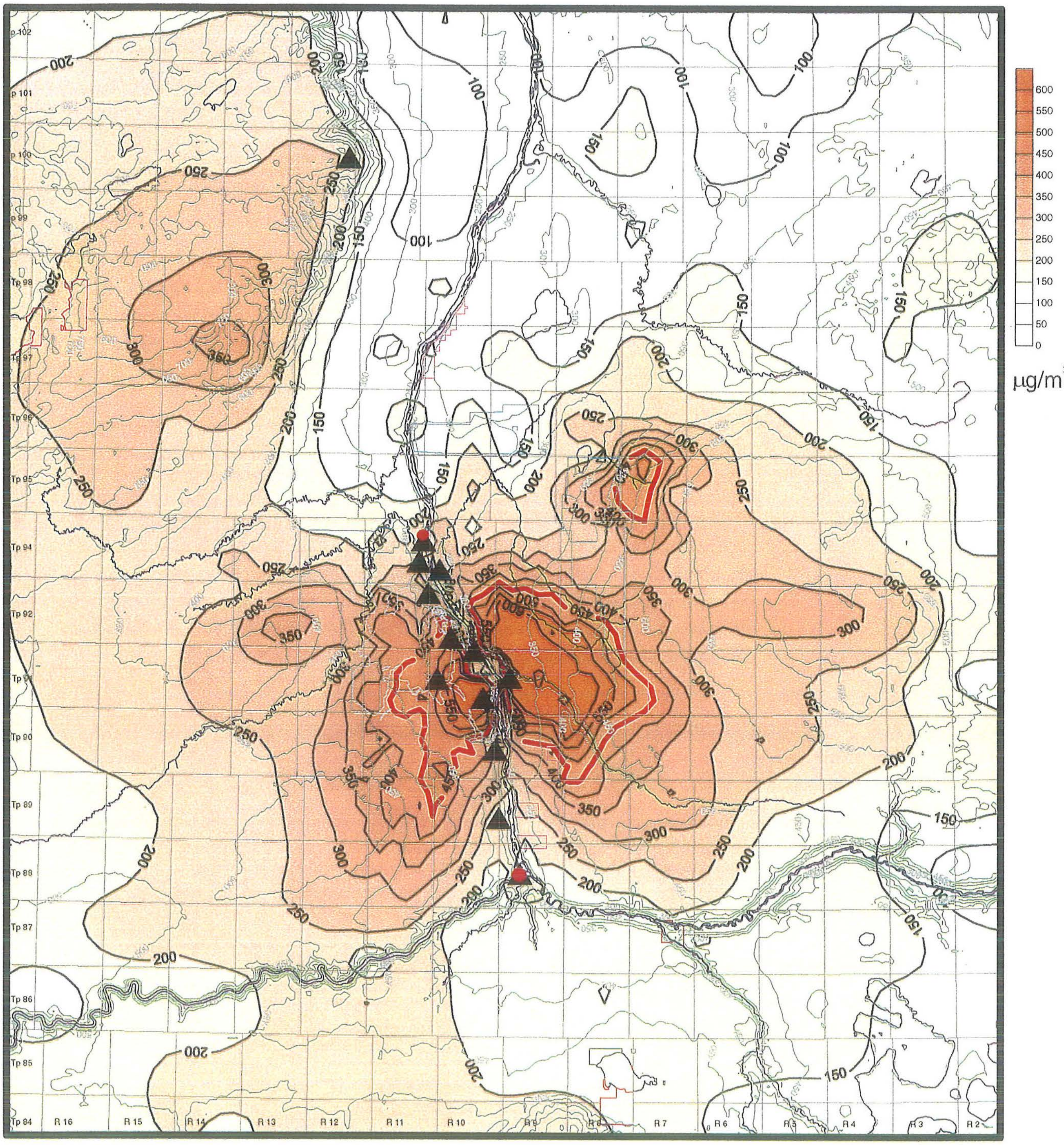
Figure B4-3 shows the maximum daily average SO_2 GLC associated with this CEA for the ISC3BE model. The overall maximum daily average SO_2 concentration of 188 $\mu g/m^3$ is predicted to occur very close to the Suncor plant and within the lease boundaries. This maximum average value exceeds the daily AAAQG of 150 $\mu g/m^3$. The predictions shown in Figure B4-3 indicate a small area of 270 ha that will have maximum average in excess of the Guideline. The model predicts one exceedance per year of the daily AAAQG guideline.

- Figures B4-4 and B4-5 show the annual average ground level concentration map for SO_2 for the ISC3BE and CALPUFF models, respectively. The maximum annual average concentration, as determined by ISC3BE, is 46.1 $\mu g/m^3$ located in the Syncrude development area and covering an area of approximately 540 ha. The predicted concentrations are in excess of the AAAQG of 30 $\mu g/m^3$.

Table B4-4 Maximum Observed Ground Level Concentrations of SO_2 for CEA Sources

Source	Hourly	Daily	Annual
CEA - ISC3BE[(b)]			
Maximum SO_2 Concentration ($\mu g/m^3$)	872	188	46.1
Location of Maximum Concentration (km)	4 S	2 SSW	15 WNW
Maximum Number of Exceedances[(a)]	50	1	1
Location of Maximum Exceedances (km)	2 SSW	4-SSW	n/a
SO_2, Alberta Guideline ($\mu g/m^3$)	450	150	30
SO_2, Federal Acceptable ($\mu g/m^3$)	900	300	60

n/a data not available
(a) Exceeds SO_2 Alberta Guideline. Normalized for a 12-month period.
(b) Based on Stream day emission rates for hourly and daily; Calendar day for annual.
(c) Assume THCs equals VOCs.



Sources	SO_2 [t/sd]
Suncor	
Powerhouse	1.2
FGD	19.7
Incinerator	10.2
Flaring	1.3
Tail Gas Treatment Unit	5.2
Other Sources, Suncor	6.2
Syncrude (total)	199
Other Emissions (total)	4.2
Other Proposed Emissions (total)	18.8
TOTAL	265.8

Model Description	
Development	CEA
Model	ISC3BE (7BG)
SO_2 Guideline [μg/m³]	450
Maximum [μg/m³]	872
Exceedences / Year [#]	50

Note: Results are based on a 1 year simulation

UTM NAD83 metres
0 5000 10000 15000 20000

Figure B4-2 Predicted CEA SO_2 Maximum Hourly Average Ground Level Concentrations in the RSA using the ISC3BE Model

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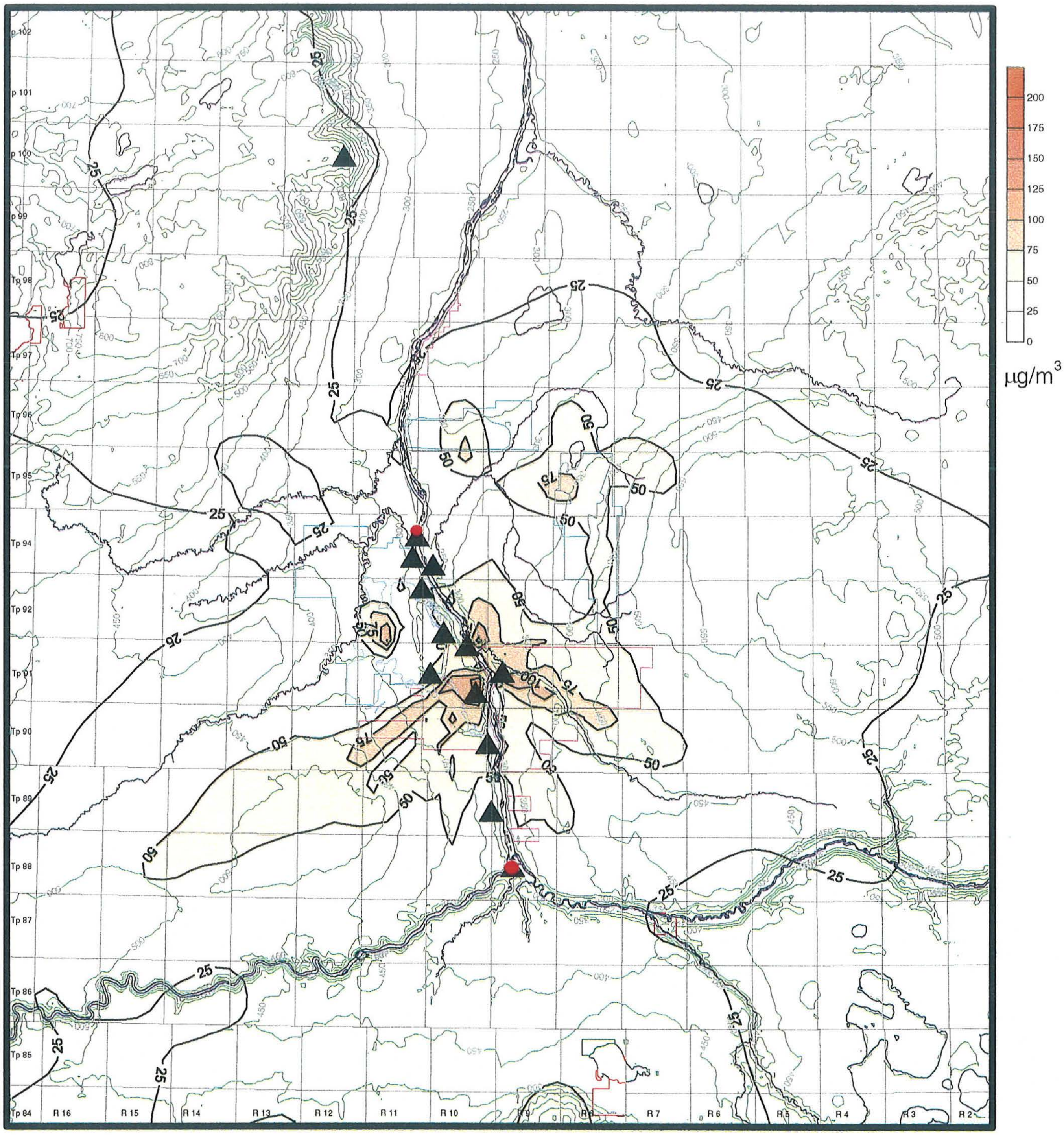

Sources	SO_2 [t/sd]
Suncor	
Powerhouse	1.2
FGD	19.7
Incinerator	10.2
Flaring	1.3
Tail Gas Treatment Unit	5.2
Other Sources, Suncor	6.2
Syncrude (total)	199
Other Emissions (total)	4.2
Other Proposed Emissions (total)	18.8
TOTAL	265.8

Model Description	
Development	CEA
Model	ISC3BE (7BG)
SO_2 Guideline [$\mu g/m^3$]	150
Maximum [$\mu g/m^3$]	188
Exceedences / Year [#]	1

Note: Results are based on a 1 year simulation

Figure B4-3 Predicted CEA SO_2 Maximum Daily Average Ground Level Concentrations in the RSA using the ISC3BE Model

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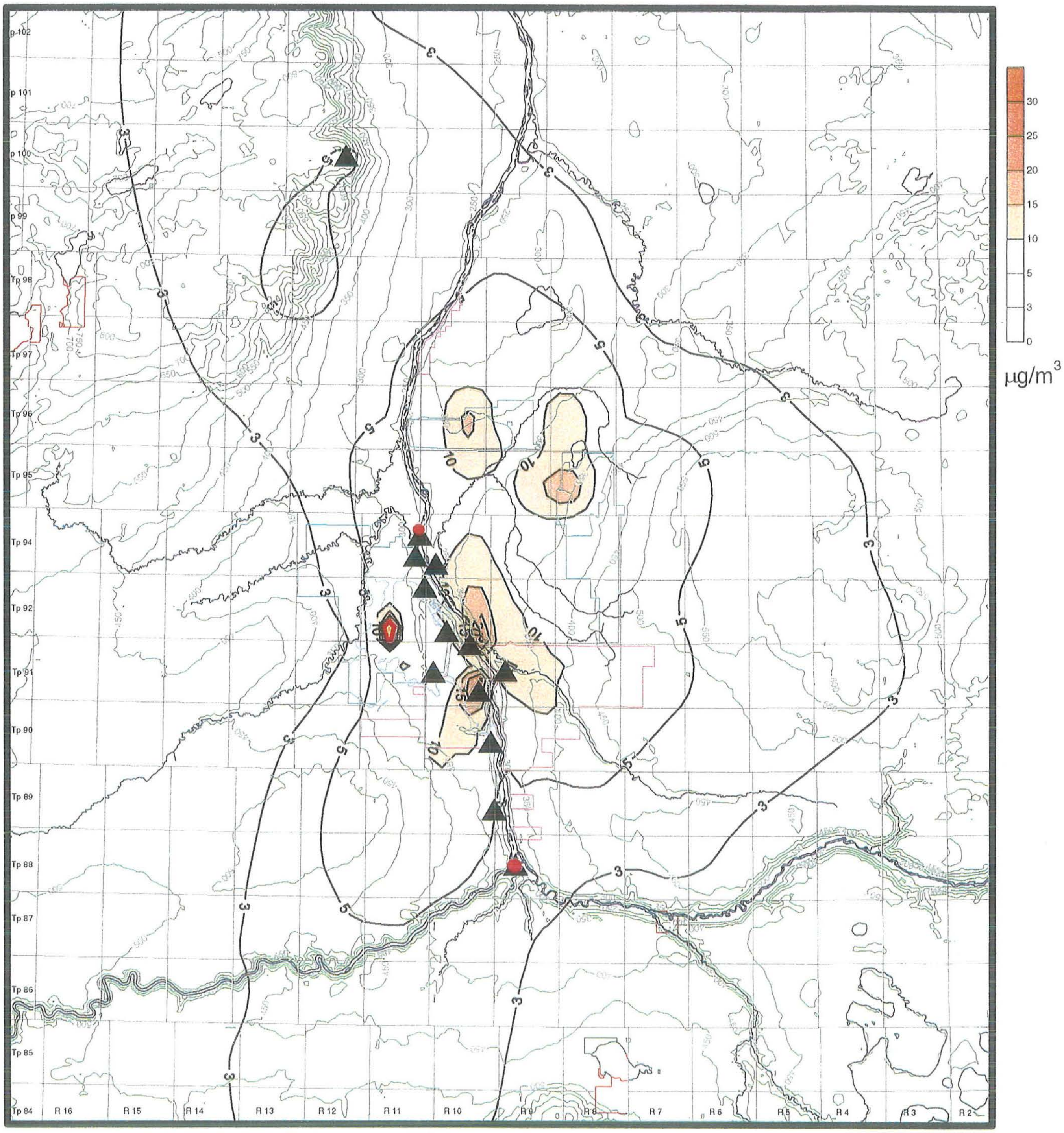

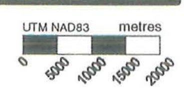

Sources	SO_2 [t/cd]
Suncor	
Powerhouse	14
FGD	18.7
Incinerator	12.3
Flaring	10.6
Tail Gas Treatment Unit	6.4
Other Sources, Suncor	5.9
Syncrude (total)	199
Other Emissions (total)	4.2
Other Proposed Emissions (total)	18.8
TOTAL	289.9

Model Description	
Development	CEA
Model	ISC3BE (7BG)
SO_2 Guideline [µg/m³]	30
Maximum [µg/m³]	46
Exceedences / Year [#]	1

Figure B4-4 Predicted CEA SO_2 Annual Average Ground Level Concentrations in the RSA using the ISC3BE Model

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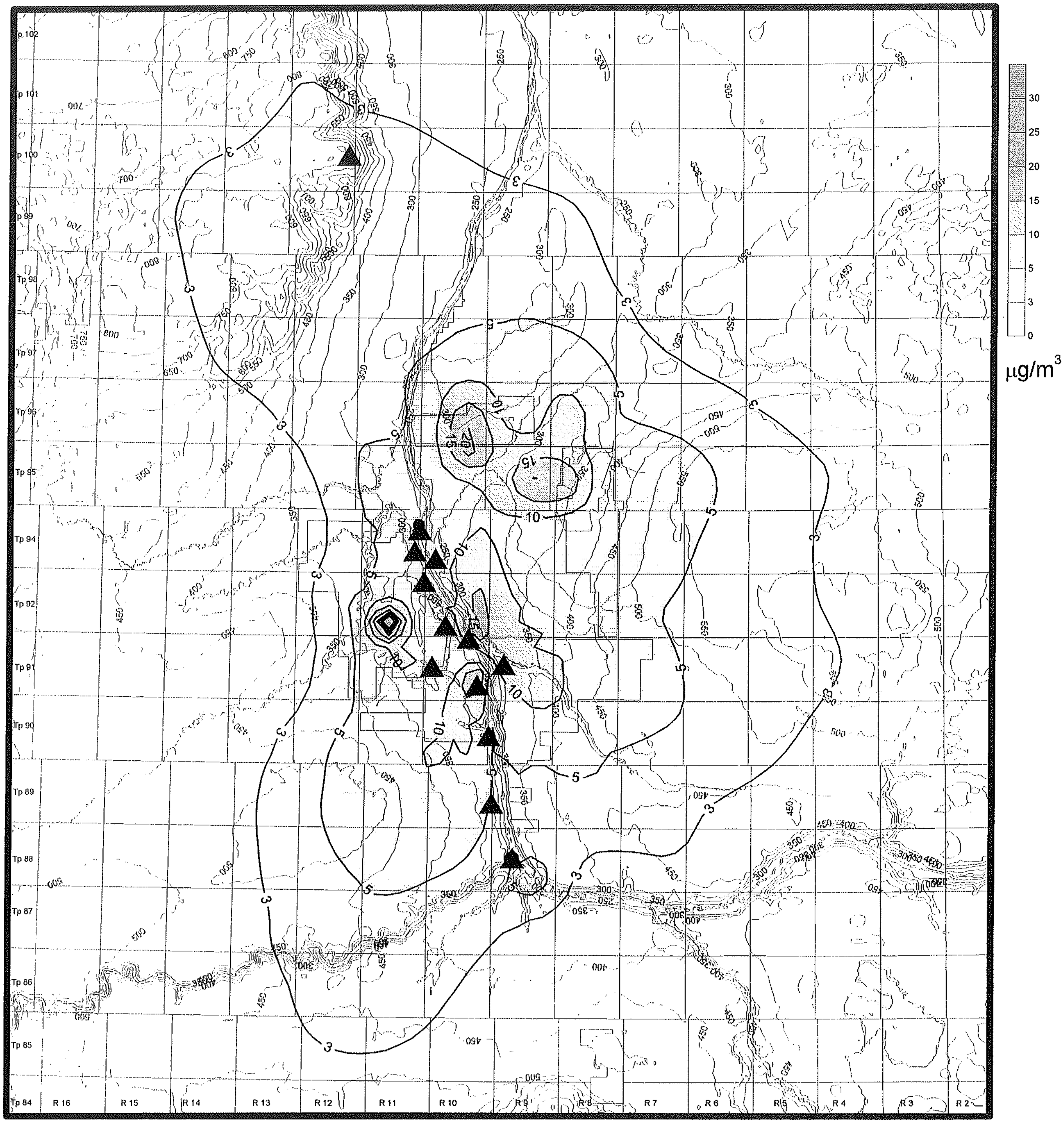

Sources	SO_2 [t/cd]
Suncor	
Powerhouse	14
FGD	18.7
Incinerator	12.3
Flaring	10.6
Tail Gas Treatment Unit	6.4
Other Sources, Suncor	5.9
Syncrude (total)	199
Other Emissions (total)	4.2
Other Proposed Emissions (total)	18.8
TOTAL	289.9

Model Description	
Development	CEA
Model	CALPUFF
SO_2 Guideline [µg/m³]	30
Maximum [µg/m³]	44
Exceedences / Year [#]	1

r/1997/2200/972-2205/8600/8650/8664/CALPUFF/FIGS/C1tSO2_A.srf

Figure B4-5 Predicted CEA SO_2 Annual Average Ground Level Concentrations in the RSA using the CALPUFF Model

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Corresponding values for the CALPUFF model indicate an overall maximum annual average SO_2 concentration of 44.4 $\mu g/m^3$, at a location WNW of Suncor in Syncrude's development area (Figure B4-6). This model predicts a total of 382 ha that result in concentrations in excess of the AAAQG.

From the ISC3BE model results, the location and areal extent of the maximum hourly GLC SO_2 concentration can be assessed. Figures B4-2 to B4-4 indicate that the predicted areas that exceed the daily and annual guidelines will occur within the Suncor or Syncrude development areas; the area where the hourly guideline is exceeded will occur mostly within the Suncor lease area. Repeating this analysis using the Federal acceptable hourly, daily and annual standards (900 $\mu g/m^3$, 300 $\mu g/m^3$ and 60 $\mu g/m^3$ respectively) indicates no predicted exceedances. The exceedance of daily and annual AAAQG is a result of the generalized characteristics of the mine fleet emissions coupled with the receptor points which happen to be located within the mine pit. These circumstances lead to unrealistic, high long-term averages near the source which have not been verified through monitoring data.

B4.2.3 NO_x Predicted Concentrations

The NO_x emission sources associated with this CEA are summarized in Section B4.1. The estimated total NO_x emission rate for this CEA in the oil sands region is 203.4 t/cd. Suncor will emit an estimated total of 67.7 t/cd which is approximately 33% of the total (Table B4-3).

The predicted maximum hourly, daily and annual ground level ambient NO_x concentrations resulting from these emissions were estimated using ISC3BE and CALPUFF models. The conversion of NO_x to NO_2 has been estimated using the methodology described in Section B2.2.3.

The modelling predictions are summarized in Table B4-5 and predicted ground level concentrations are mapped in the figures described below.

Table B4-5 Maximum Observed Ground Level Concentrations of NO_x and NO_2 for CEA Sources

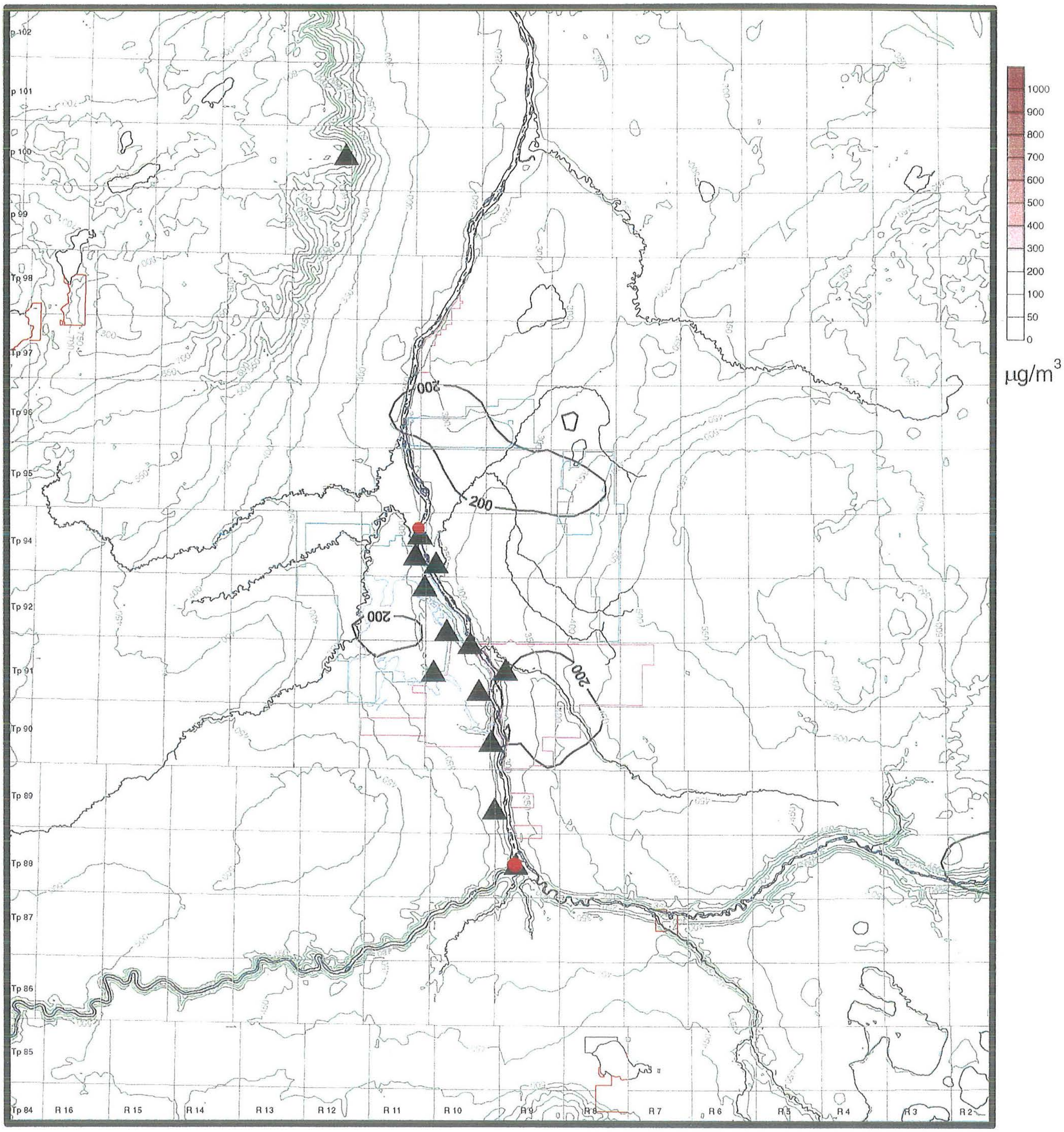
Source	Hourly	Daily	Annual
CEA - ISC3BE[b]			
Maximum NO_x Concentration (μg/m³)	5,953	3,652	1296
Maximum NO_2 Concentration (μg/m³)	295	244	163
Location of Maximum Concentration (km)	12 ESE	11 SE	11 ESE
Maximum Number of Exceedances[a]	0	81	1
Location of Maximum Exceedances (km)	0	n/a	n/a
CEA CALPUFF[c]			
Maximum NO_2 Concentration (μg/m³)	1866	714	314
Location from Suncor incinerator stack (km)	11 ESE	11 ESE	11 ESE
Maximum Number of Exceedances[a]	2,449	274	1
Location of Maximum Exceedances (km)	11 ESE	11 ESE	n/a
NO_2, Alberta Guideline (μg/m³)	400	200	60
NO_2, Federal Acceptable (μg/m³)	400	200	100

(a) Exceeds NO_2 Alberta Guideline. Normalized for a 12-month period.
(b) Based on Stream day emission rates for hourly and daily; Calendar day for annual.
(c) Based on Calendar day emission rates.

- Figures B4-6 and B4-7 show the maximum hourly average ground level NO_2 concentrations associated for the CEA for the ISC3BE and CALPUFF models. An overall maximum hourly average NO_2 concentration, as determined by ISC3BE, of 295 μg/m³ is predicted to occur at a location 12 km ESE of Suncor in the east bank mining area (Figure 4-7). This maximum value is less than the hourly AAAQG NO_2 of 400 μg/m³.

  Corresponding values for the CALPUFF model indicate an overall maximum hourly average NO_2 concentration of 1866 μg/m³, at a location 11 km ESE of Suncor in the east bank mining area (Figure B4-8). This maximum average value is much higher than the hourly Alberta NO_2 Guideline of 400 μg/m³. This model predicts a total of 481,603 ha will have maximum concentrations in excess of the guideline. It also predicts a maximum of 2449 exceedances of the hourly guideline. The predicted NO_2 values by CALPUFF correlate to the observed NO_x concentrations recorded by Syncrude adjacent to their active mine pit. This would suggest that the chemistry conversion rates may require calibration for the oil sands region.

- Figures B4-8 and B4-9 show the maximum daily NO_2 average GLC associated with the CEA emissions for the ISC3BE and CALPUFF models. An overall maximum daily average NO_2 concentration, as determined by ISC3BE, of 244 μg/m³ is predicted to occur in the same vicinity as the maximum hourly concentration (east bank mining area of Suncor). This maximum average value exceeds the daily Alberta Guideline of 200 μg/m³. The predictions shown in Figure B4-9 indicate



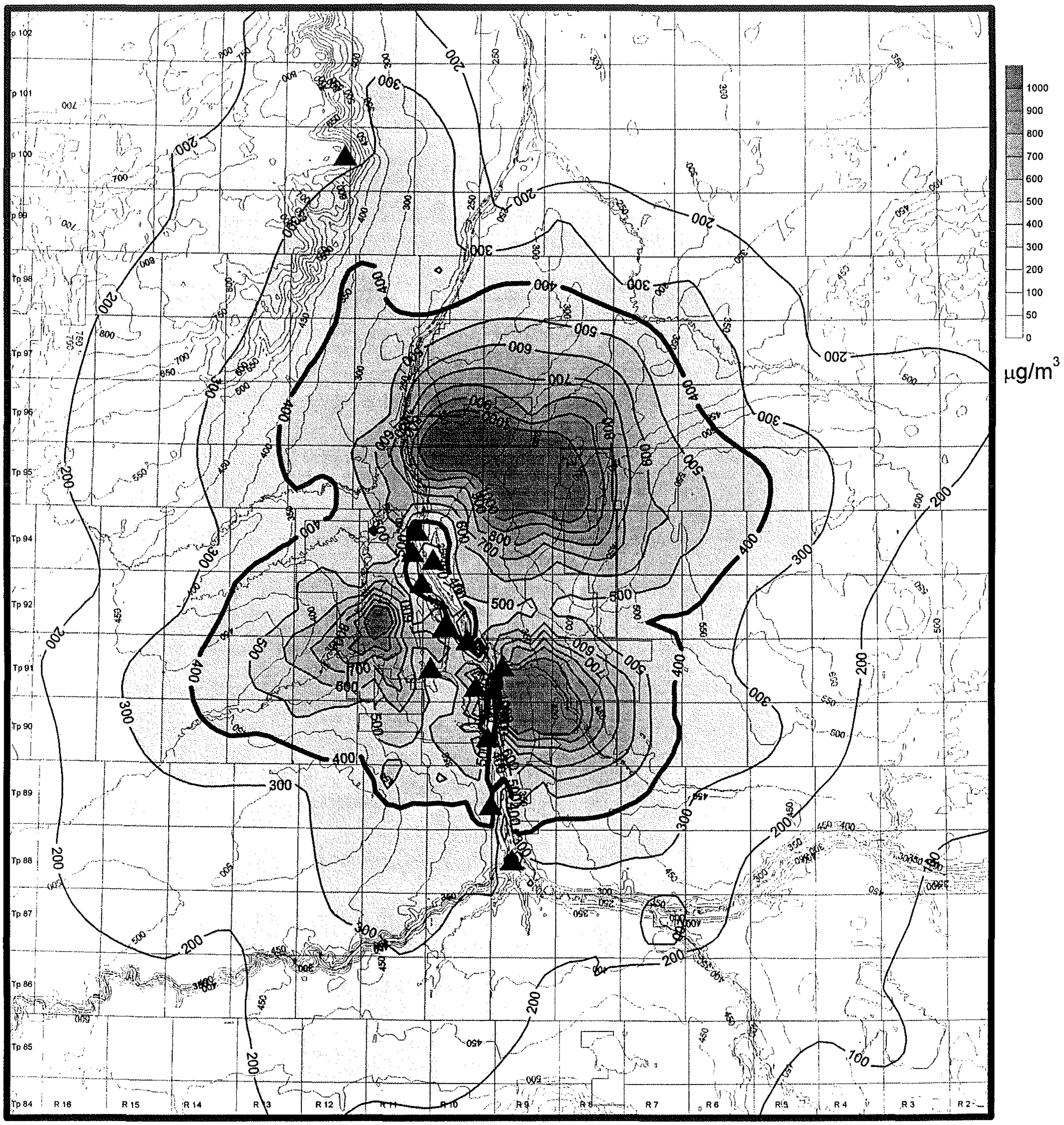
UTM NAD83 metres

0 5000 10000 15000 20000

Sources	NO_2 [t/sd]
Suncor	
Powerhouse	3.5
FGD	32
Incinerator	0.07
Flaring	0.03
Tail Gas Treatment Unit	0.03
Other Sources, Suncor	34.8
Syncrude (total)	63.9
Other Emissions (total)	10.1
Other Proposed Emissions (total)	60.9
TOTAL	205.33

Model Description	
Development	CEA
Model	ISC3BE (7BG)
NO_2 Guideline [µg/m³]	400
Maximum [µg/m³]	295
Exceedences / Year [#]	0

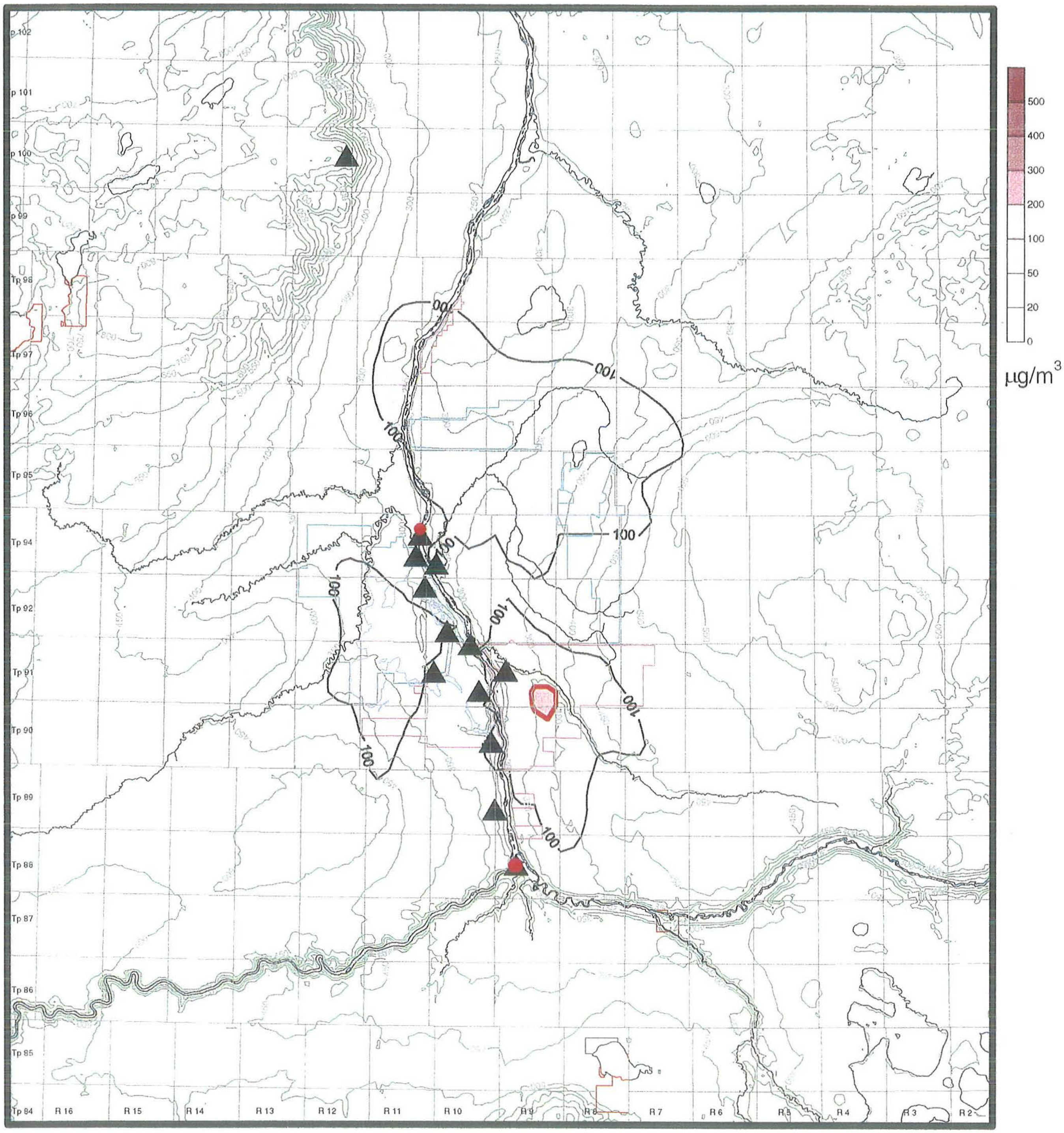
Figure B4-6 Predicted CEA NO_2 Maximum Hourly Average Ground Level Concentrations in the RSA using the ISC3BE Model



Sources	NO_x [t/cd]
Suncor	
Powerhouse	3.5
FGD	32
Incinerator	0.07
Flaring	0.03
Tail Gas Treatment Unit	0.03
Other Sources, Suncor	35
Syncrude (total)	63.9
Other Emissions (total)	10.9
Other Proposed Emissions (total)	60.9
TOTAL	206.33

Model Description	
Development	CEA
Model	CALPUFF
NO_2 Guideline [µg/m³]	400
Maximum [µg/m³]	1866
Exceedences / Year [#]	2449

Figure B4-7 Predicted CEA NO_2 Maximum Hourly Average Ground Level Concentrations in the RSA using the CALPUFF Model



Sources	NO_2 [t/sd]
Suncor	
Powerhouse	3.5
FGD	32
Incinerator	0.07
Flaring	0.03
Tail Gas Treatment Unit	0.03
Other Sources, Suncor	34.8
Syncrude (total)	63.9
Other Emissions (total)	10.1
Other Proposed Emissions (total)	60.9
TOTAL	205.33

Model Description	
Development	CEA
Model	ISC3BE (7BG)
NO_2 Guideline [µg/m³]	200
Maximum [µg/m³]	244
Exceedences / Year [#]	81

Figure B4-8 Predicted CEA NO_2 Maximum Daily Average Ground Level Concentrations in the RSA using the ISC3BE Model

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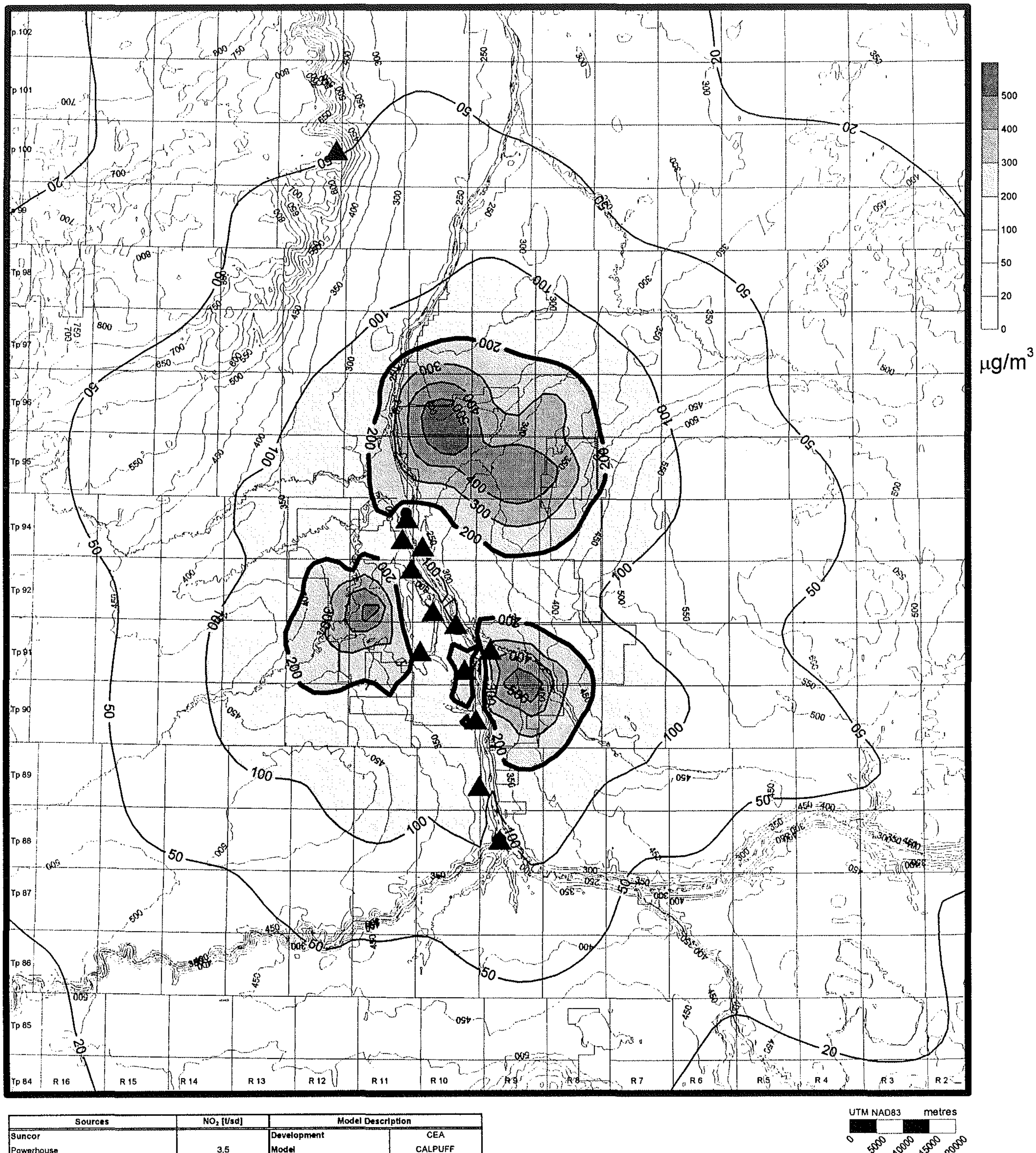


Sources	NO₂ [t/sd]
Suncor	
Powerhouse	3.5
FGD	32
Incinerator	0.07
Flaring	0.03
Tail Gas Treatment Unit	0.03
Other Sources, Suncor	35
Syncrude (total)	63.9
Other Emissions (total)	10.9
Other Proposed Emissions (total)	60.9
TOTAL	206.33

Model Description	
Development	CEA
Model	CALPUFF
NO_2 Guideline [$\mu g/m^3$]	200
Maximum [$\mu g/m^3$]	714
Exceedences / Year [#]	274

Figure B4-9 Predicted CEA NO_2 Maximum Daily Average Ground Level Concentrations in the RSA using the CALPUFF Model

the area, 1,447 ha, of maximum daily average concentrations in excess of the guideline all fall within the east bank mining. In total, the model predicts that there will be a maximum of 81 exceedances of the daily guideline on an annual bases.

Comparison values for the CALPUFF model indicate an overall maximum daily average NO_2 concentration of 714 $\mu g/m^3$, at a location 11 km ESE of Suncor in the east bank mining area (Figure B4-10). The predictions shown in Figure B4-10 indicate three areas that result in maximum daily average concentrations in excess of the Alberta Guideline. The areas are the Suncor and Syncrude existing development areas and an area north of these two developments (in the area of Syncrude Aurora, Shell (Muskeg River and Lease 13), Mobil and Solv-Ex). In total, 158,886 ha are predicted to have maximum average concentrations in excess of the guideline. The CALPUFF model predicts there will be a maximum of 274 exceedances of the daily guideline on an annual bases.

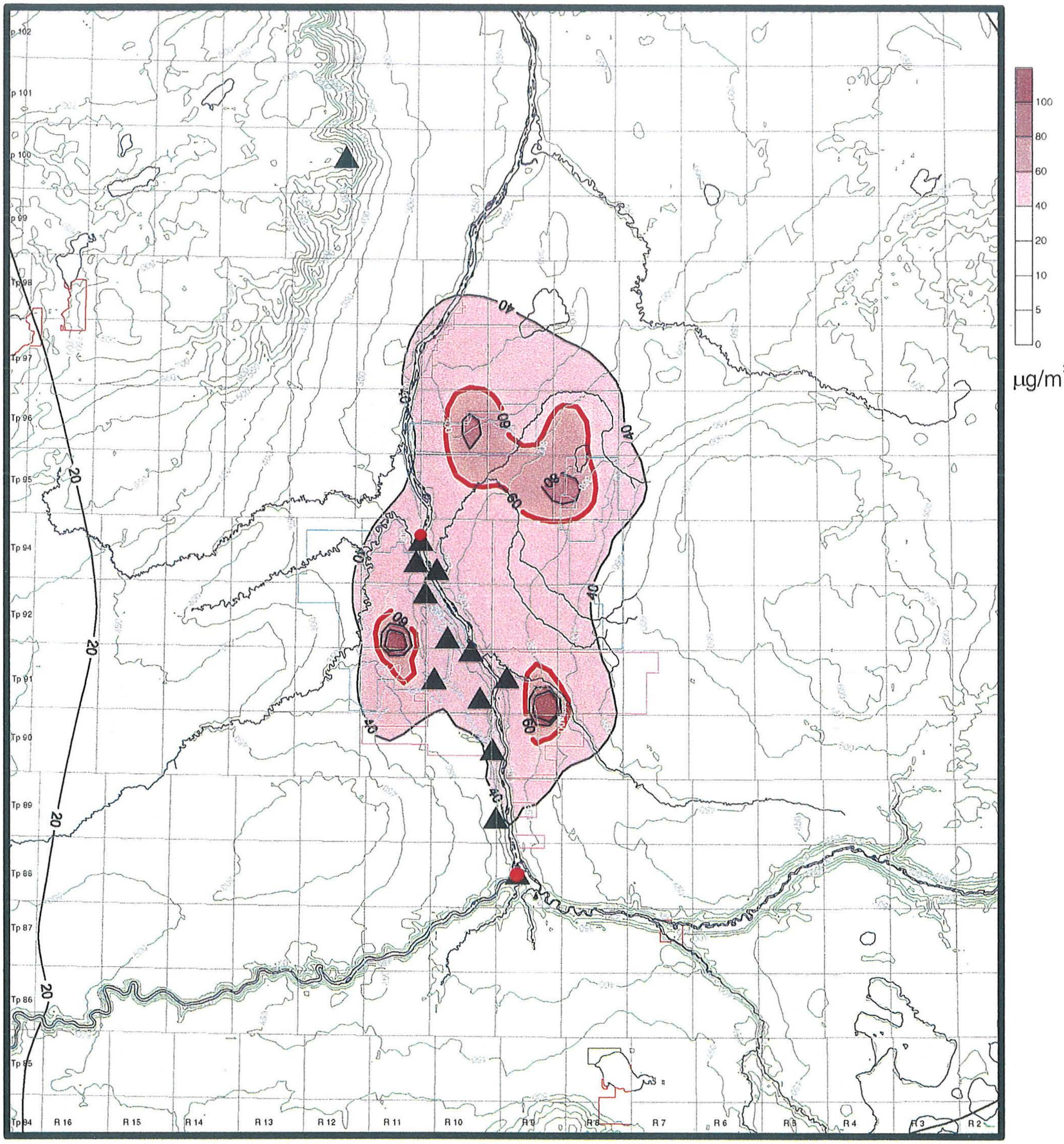
- Figures B4-10 and B4-11 show the annual average ground level NO_2 concentrations associated with the CEA emissions for the ISC3BE and CALPUFF models. The overall maximum annual average NO_2 concentration, as determined by ISC3BE, of 163 $\mu g/m^3$ is predicted to occur at in the east bank mining area of Suncor (Figure B4-12). This annual average value exceeds the Alberta guideline of 60 $\mu g/m^3$. The predictions shown in Figure B4-11 indicate the areas that result in annual averages in excess of the guideline and they are the areas in the Suncor and Syncrude development areas and an area north of the existing operations, near other proposed oil sands projects. In total, 38,624 ha are predicted to have maximum average concentrations in excess of the guideline.

  Comparison values for the CALPUFF model indicate an overall annual average NO_2 concentration of 314 $\mu g/m^3$, at a location 11 km ESE from Suncor in the east bank mining area (Figure B4-12). The predictions shown in Figure B4-12 indicate a similar pattern for the annual maximum concentrations as in the daily results. In total, 58,100 ha are predicted to have maximum average concentrations in excess of the guideline.

The modelling predictions using ISC3BE indicate that the maximum NO_2 concentrations will tend to occur in or near the development areas. The principal contributors to these maximum values would be the mine fleets.

B4.2.4 Potential Acid Input (PAI) Predictions

Acidic deposition in the RSA results from the cumulative emissions of SO_2 and NO_x. The total estimated emissions of SO_2 and NO_x (292.2 t/cd and 203.4 t/cd, respectively) for this CEA are presented in Table B4-3. Suncor contributes about 28% of the combined SO_2 and NO_x emissions.



UTM NAD83 metres
0 5000 10000 15000 20000

Sources	NO_2 [t/sd]
Suncor	
Powerhouse	3.5
FGD	32
Incinerator	0.07
Flaring	0.03
Tail Gas Treatment Unit	0.03
Other Sources, Suncor	34.8
Syncrude (total)	63.9
Other Emissions (total)	10.1
Other Proposed Emissions (total)	60.9
TOTAL	205.33

Model Description	
Development	CEA
Model	ISC3BE (7BG)
NO_2 Guideline [$\mu g/m^3$]	60
Maximum [$\mu g/m^3$]	244
Exceedences / Year [#]	81

Figure B4-10 Predicted CEA NO_2 Annual Average Ground Level Concentrations in the RSA using the ISC3BE Model

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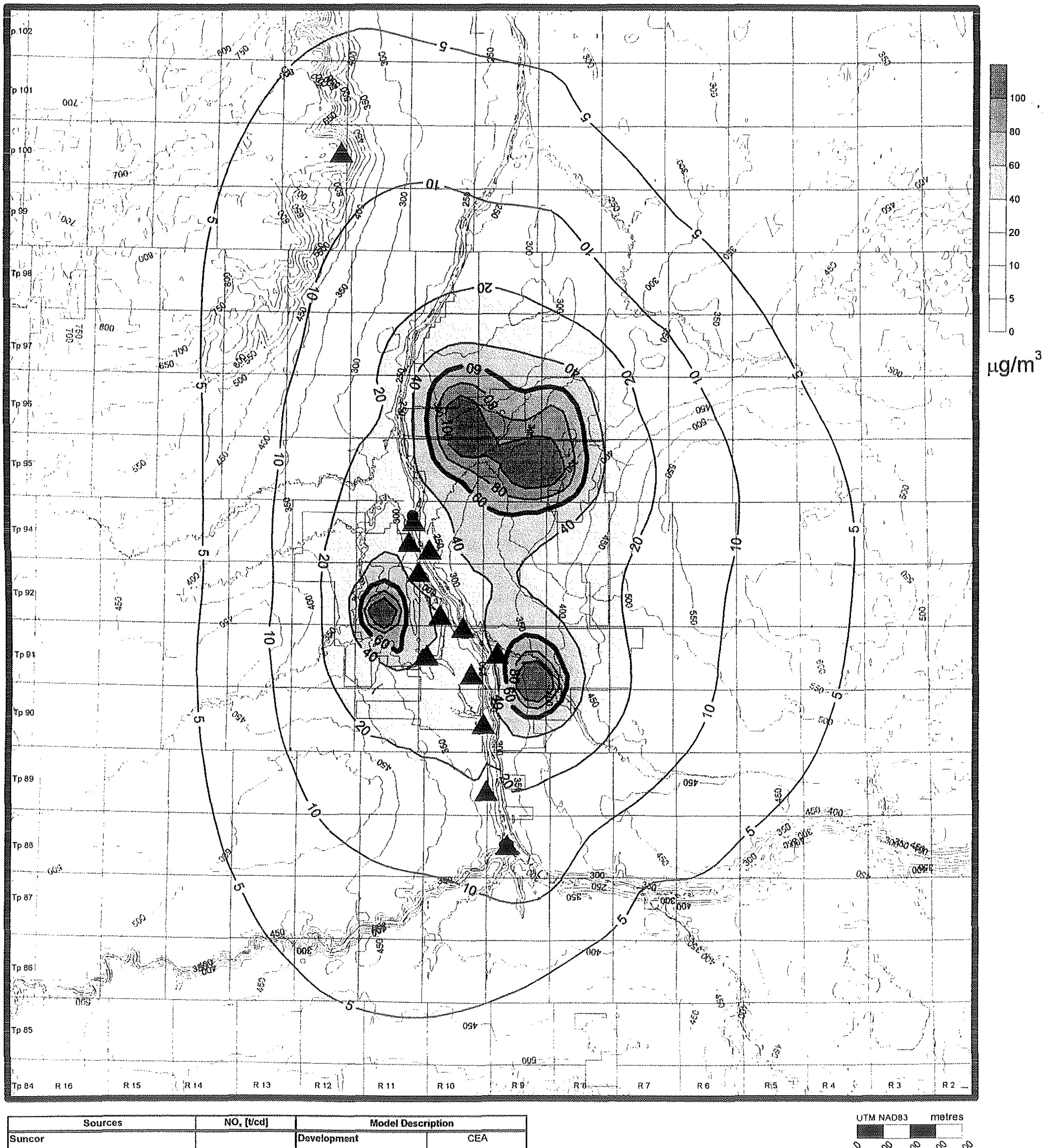

r:1997/2200/972-2205/8600/8660/8664/CALPUFF/FIGS/C1NO2_A.srf

Sources	NO_x [t/cd]
Suncor	
Powerhouse	2.9
FGD	29.7
Incinerator	0.064
Flaring	0.191
Tail Gas Treatment Unit	0.03
Other Sources, Suncor	34.8
Syncrude (total)	63.9
Other Emissions (total)	10.9
Other Proposed Emissions (total)	60.9
TOTAL	203.385

Model Description	
Development	CEA
Model	CALPUFF
NO_2 Guideline [µg/m³]	60
Maximum [µg/m³]	314
Exceedences / Year [#]	1

Figure B4-11 Predicted CEA NO_2 Annual Average Ground Level Concentrations in the RSA using the CALPUFF Model

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PAI is the preferred method for evaluating the overall effects of acid forming chemicals on the environment since it accounts for the acidifying effect of the sulphur and nitrogen species, as well as the neutralizing effect of available base cations. A discussion on the calculation methods for PAI is provided in Section B1.4.2.

PAI in the oil sands region was predicted using the CALPUFF model. A background PAI of 0.1 keq/ha/y has been assumed for the region based on estimates of sulphur and nitrogen and base cation concentrations and depositions in the region surrounding the RSA. This background PAI may be conservatively high since the formulation of the background value uses monitoring data that may both reflect the air shed coming into the RSA as well as possibly being impacted by the air leaving the RSA.

The PAI predictions are summarized in Table B4-6 and shown graphically in Figure B4-12.

Table B4-6 Areal Extent For Predicted PAI Values for the CEA Sources

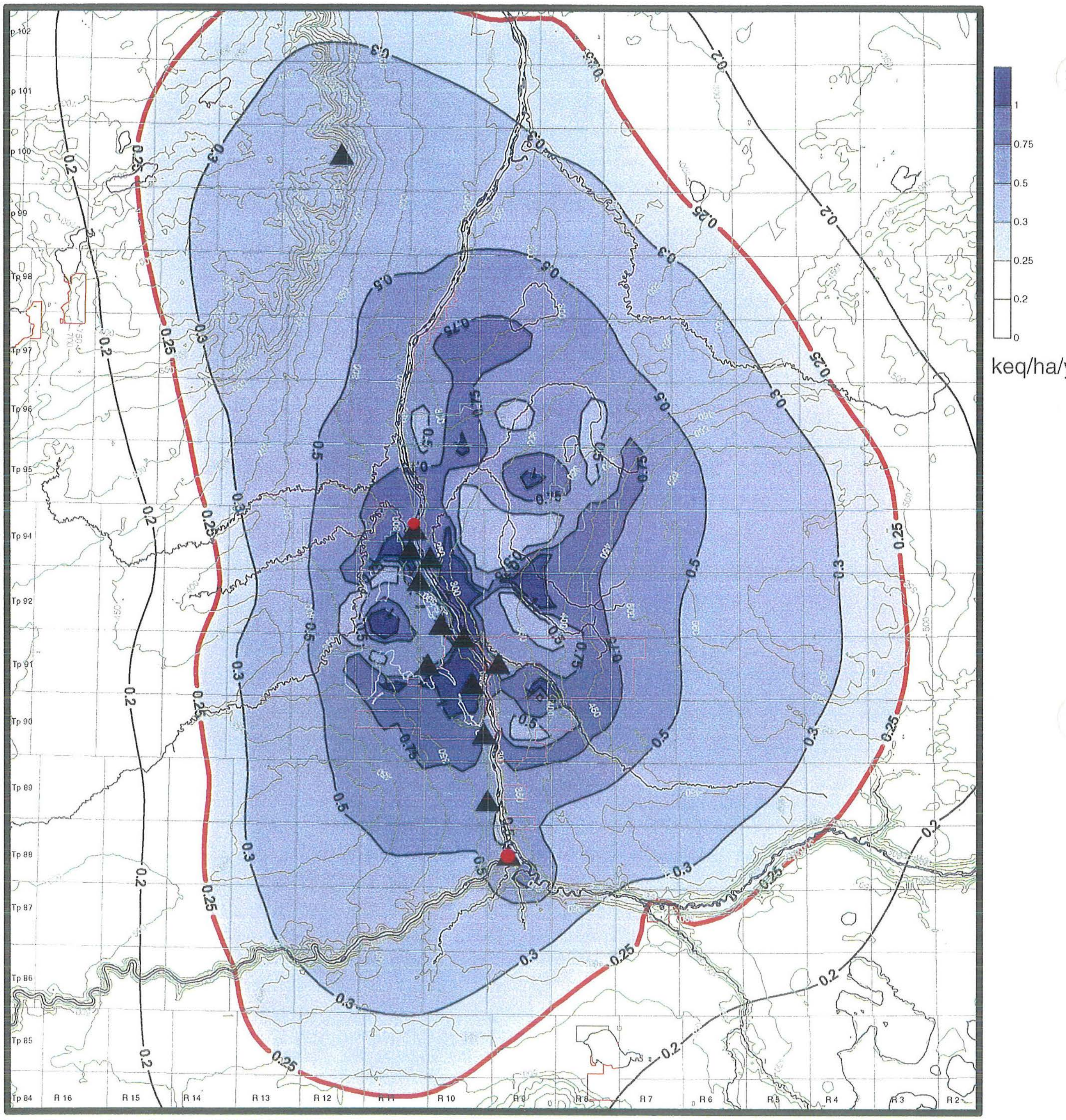
PAI Threshold (keq/ha/y)	Area (ha)	(%)[a]
0.25	1,417,300	58.4
0.50	420,086	17.3
1.0	20,430	0.8
1.5	13	<0.01

(a) as % of the total RSA.

The maximum deposition rates of the nitrogen and sulphur species were calculated as interim variables by the CALPUFF model. These are summarized in Table B4-7 and presented graphically in Figures B4-13 and B4-14. The maximum deposition rate of nitrates occur in the Suncor east bank mining area and the maximum sulphates and overall PAI occur in the immediate vicinity of the existing Suncor operations. These predicted results suggest that the highest deposition and PAI values occur in the areas where there are sizable ground level releases of SO_2 and NO_x.

Table B4-7 Maximum Predicted Acid Forming Deposition

Parameter	Maximum (keq/ha/y)	Distance (km from Suncor)	Direction
PAI	1.66	2	SSW
Nitrate Deposition	1.13	11	ESE
Sulphate Deposition	1.13	1	SSW



Sources	SO_2 [t/cd]	NO_x [t/cd]
Suncor		
Powerhouse	14	2.9
FGD	18.7	29.7
Incinerator	12.3	0.06
Flaring	10.6	0.19
Tail Gas Treatment Unit	6.4	0.03
Other Sources, Suncor	5.9	34.8
Syncrude (total)	199	63.9
Other Emissions (total)	4.2	10.9
Other Proposed Emissions (total)	18.8	60.9
TOTAL	289.9	203.4

Model Description	
Development	CEA
Model	CALPUFF
Critical Loading [keq/ha/y]	0.25
Maximum [keq/ha/y]	1.7

Figure B4-12 Predicted CEA Potential Acid Input (PAI) in the RSA

There is considerable uncertainty in the background PAI for the region, with estimates ranging from approximately -0.5 to 0.25 keq/ha/y. For this reason, the PAI map presented in Figure B4-12 should be regarded as providing an indication of relative spatial distributions and relative changes associated with this emission scenario. This map should also be used in conjunction with the nitrate and sulphate deposition maps (Figures B4-13 and B4-14, respectively) as input in the evaluation of impacts to sensitive soil or vegetation, and in the design of any long-term monitoring programs deemed necessary in such evaluations. This information is further assessed in soils Section D2.2.

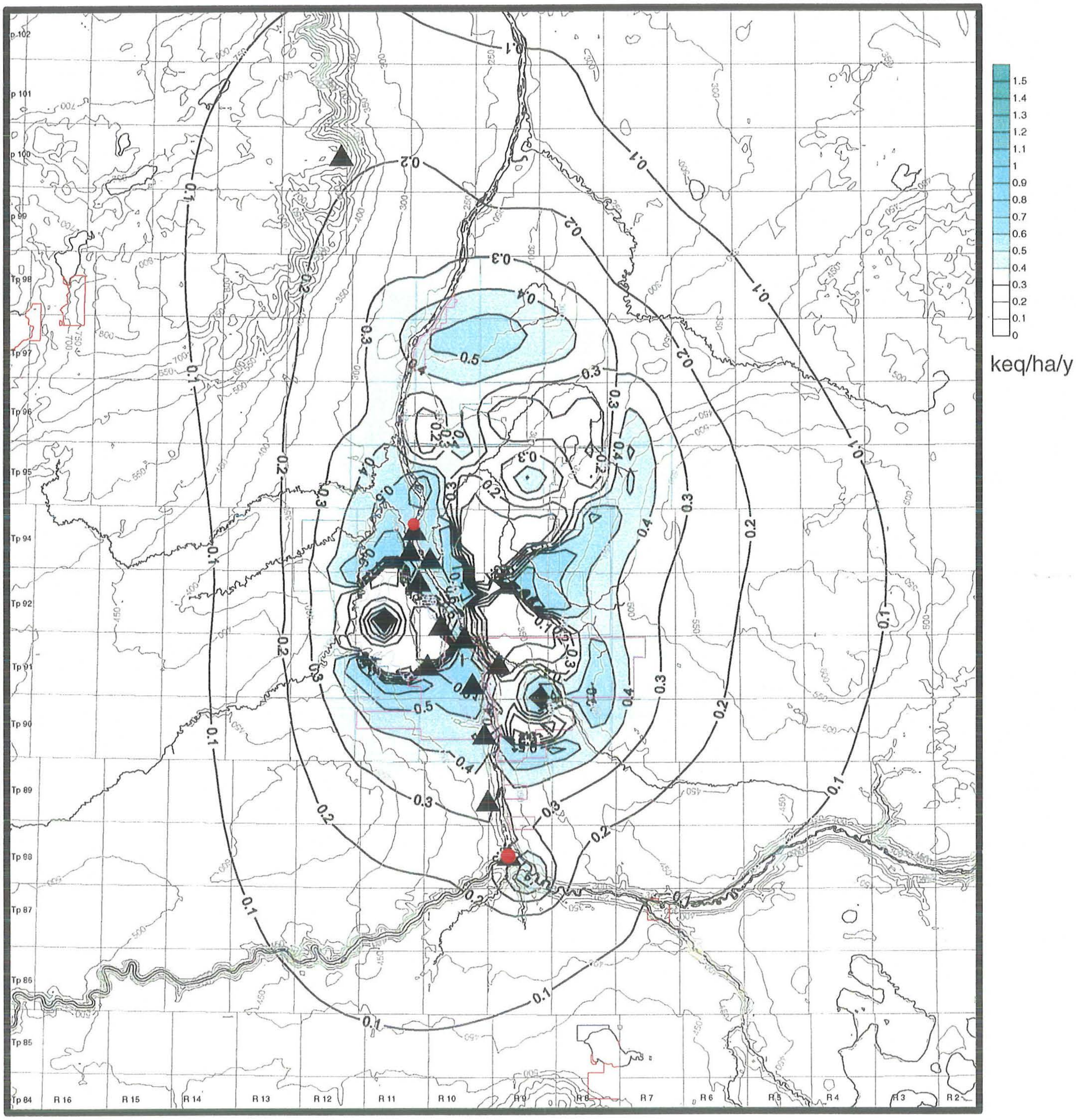
B4.2.5 CO Predicted Concentrations

The CO emission sources associated with this CEA are summarized in Section B4.1. Total estimated CO emission rate for this case is 173.9 t/cd. The total Suncor CO emissions are approximately 38.6 t/cd representing about 22% of the total.

The predicted maximum hourly and 8-hour ground level ambient CO concentrations resulting from these emissions were estimated using ISC3BE and meteorology measurements from the Mannix station. This model provides an efficient means of calculating the overall ambient CO concentration from all sources and provides an indication of where maximum concentrations could occur. The modelling predictions are summarized in Table B4-8 and predicted ground level concentrations are mapped in the figures described below:

- Figure B4-15 shows the maximum hourly average ground level CO concentration associated with the CEA case. An overall maximum hourly average CO concentration of 5,560 $\mu g/m^3$ is predicted to occur at a location SSE of the Suncor. This maximum value is less than the hourly Alberta CO guideline of 15,000 $\mu g/m^3$.
- Figure B4-16 shows the maximum 8-hour average ground level CO concentration associated with the CEA sources. The overall maximum daily average CO concentration of 2,228 $\mu g/m^3$ is predicted to also occur south of Suncor. This 8-hour maximum value is also less than the 8-hour guideline of 6,000 $\mu g/m^3$.

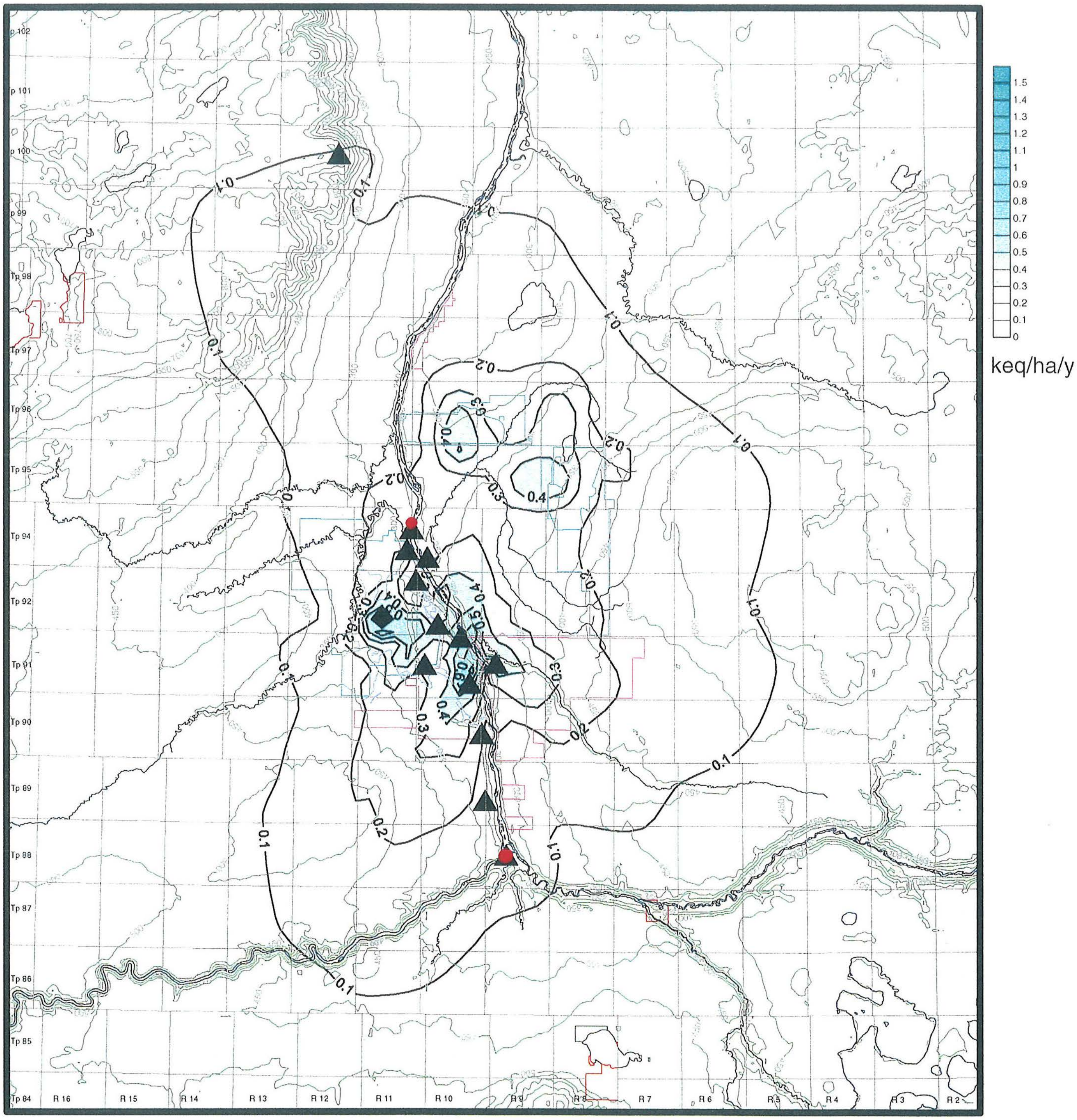
The modelling predicts that the maximum hourly and 8-hour CO concentrations will occur SSE of Suncor in or near Fort McMurray.



Sources	SO₂ [t/cd]	NOₓ [t/cd]
Suncor		
Powerhouse	14	2.9
FGD	18.7	29.7
Incinerator	12.3	0.06
Flaring	10.6	0.19
Tail Gas Treatment Unit	6.4	0.03
Other Sources, Suncor	5.9	34.8
Syncrude (total)	199	63.9
Other Emissions (total)	4.2	10.9
Other Proposed Emissions (total)	18.8	60.9
TOTAL	289.9	203.4

Model Description	
Development	CEA
Model	CALPUFF
Critical Loading [keq/ha/y]	0.25
Maximum [keq/ha/y]	1.1

Figure B4-13 Predicted CEA Nitrate Equivalent Deposition in the RSA



Sources	SO_2 [t/cd]	NO_x [t/cd]
Suncor		
Powerhouse	14	2.9
FGD	18.7	29.7
Incinerator	12.3	0.06
Flaring	10.6	0.19
Tail Gas Treatment Unit	6.4	0.03
Other Sources, Suncor	5.9	34.8
Syncrude (total)	199	63.9
Other Emissions (total)	4.2	10.9
Other Proposed Emissions (total)	18.8	60.9
TOTAL	289.9	203.4

Model Description	
Development	CEA
Model	CALPUFF
Critical Loading [keq/ha/y]	0.25
Maximum [keq/ha/y]	1.1

UTM NAD83 metres
0 5000 10000 15000 20000

Figure B4-14 Predicted CEA Sulphate Equivalent Deposition in the RSA

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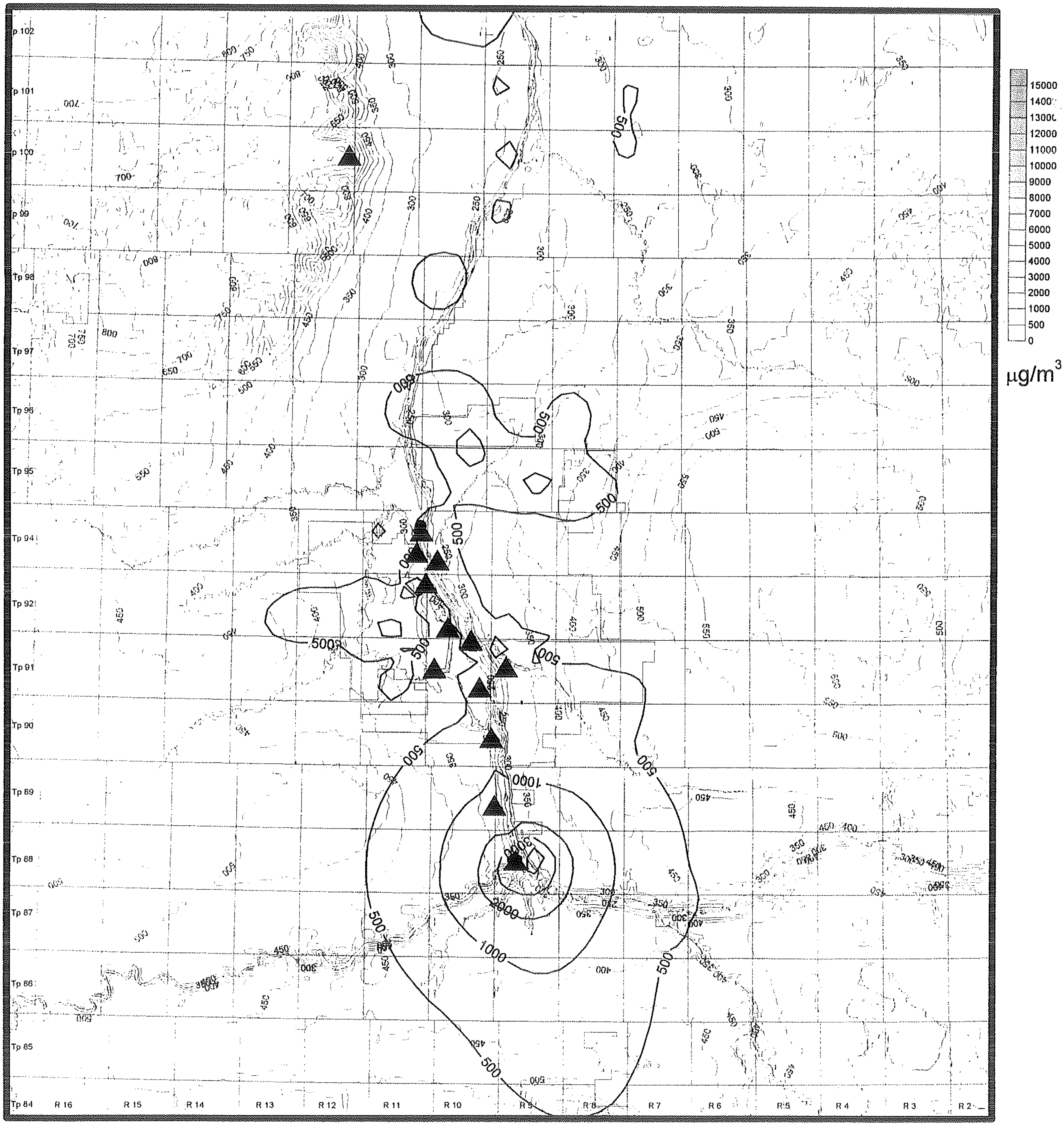

Sources	CO [t/sd]
Suncor	
Powerhouse	3.01
FGD	27.51
Incinerator	3.4
Flaring	0.01
Tail Gas Treatment Unit	3.8
Other Sources, Suncor	3.6
Syncrude (total)	81.5
Other Emissions (total)	36.9
Other Proposed Emissions (total)	16.9
TOTAL	176.6

Model Description	
Development	CEA
Model	ISC3BE (7BG)
CO Guideline [µg/m³]	15000
Maximum [µg/m³]	5560
Exceedences / Year [#]	0

UTM NAD83 metres

0 5000 10000 15000 20000

Figure B4-15 Predicted CEA CO Maximum Hourly Average Ground Level Concentrations in the RSA

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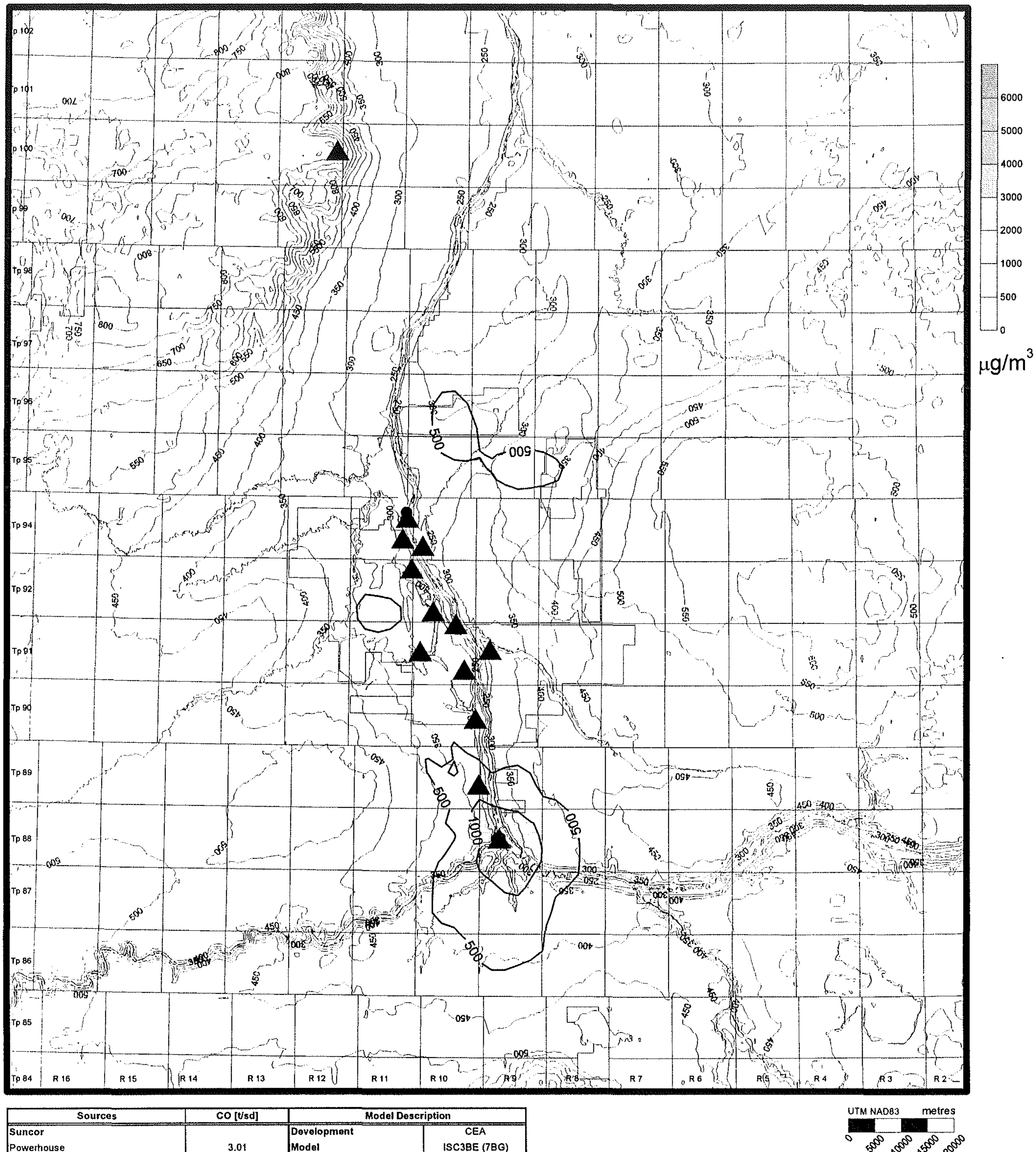


Sources	CO [t/sd]
Suncor	
Powerhouse	3.01
FGD	27.51
Incinerator	3.4
Flaring	0.01
Tail Gas Treatment Unit	3.8
Other Sources, Suncor	3.6
Syncrude (total)	81.5
Other Emissions (total)	36.9
Other Proposed Emissions (total)	16.9
TOTAL	176.63

Model Description	
Development	CEA
Model	ISC3BE (7BG)
CO Guideline [µg/m³]	6000
Maximum [µg/m³]	2228
Exceedences / Year [#]	0

Figure B4-16 Predicted CEA CO Maximum 8-Hour Average Ground Level Concentrations in the RSA using the ISC3BE Model

r:/1997/2200/972-2205/8600/8650/8664/ISCBE/FIGS/COCD_2P.srf

Table B4-8 Maximum Observed Ground Level Concentrations of CO for CEA Sources

Source	Hourly	Daily
CEA - Model ISC3BE		
Maximum CO Concentration (μg/m^3)	5,560	2,228
Location of Maximum Concentration (km)	30 SSE	30-SSE
Maximum Number of Exceedances [(a)]	0	0
Location of Maximum Exceedances	n/a	n/a
CO, Alberta Guideline (μg/m^3)	15,000	6,000

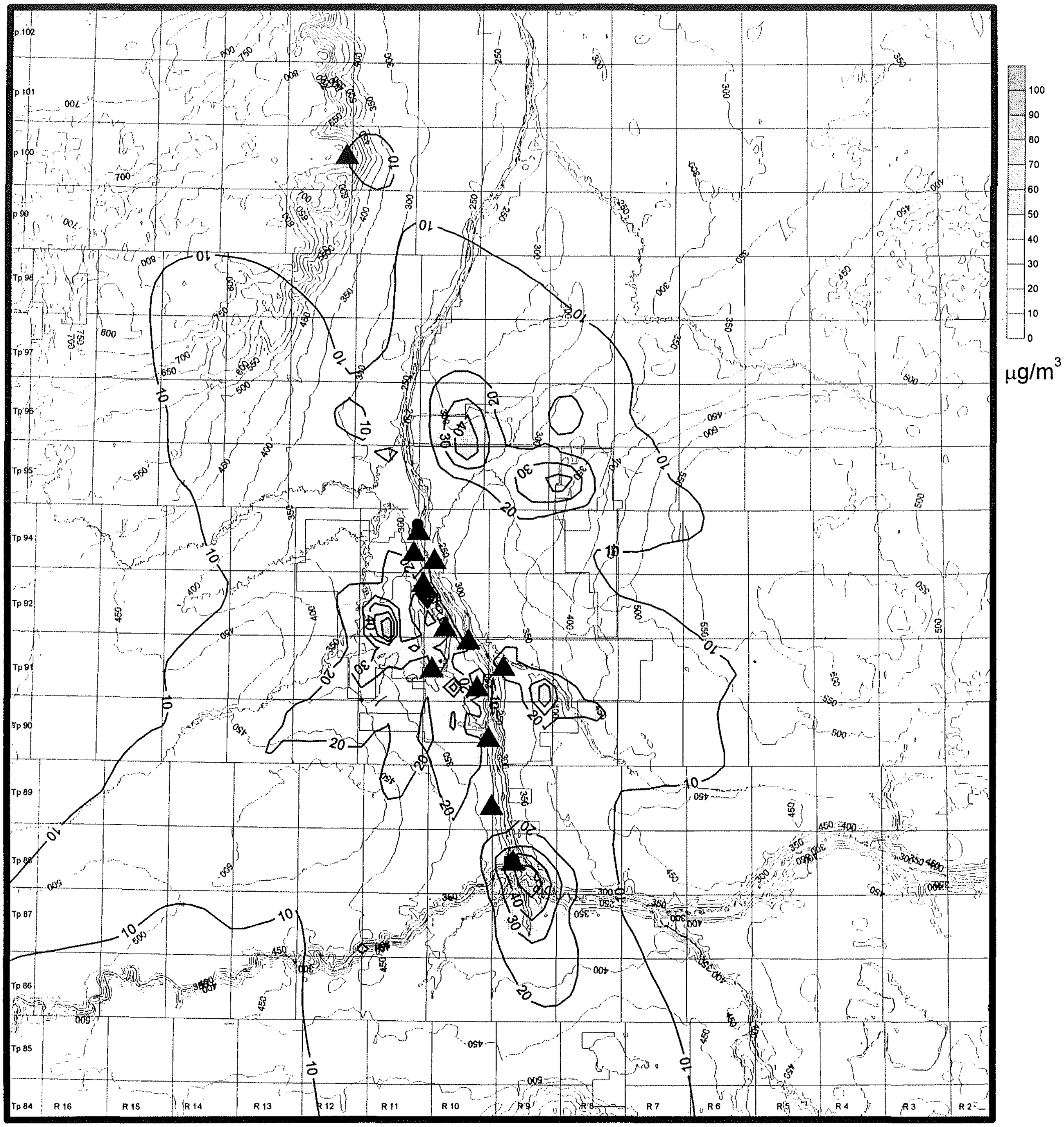
(a) Exceeds CO Alberta Guideline. Normalized for a 12-month period.

B4.2.6 Particulates

The ambient PM emission sources associated with this CEA are summarized in Section B4.1. The total estimated PM emission rate for this case is 18.3 t/cd. In total Suncor emits approximately 12% of the PM. For the purpose of modelling, all PM was assumed to be PM_{10}. In addition to the PM emissions, metals and PAHs have been determined from stack sampling surveys collected by Syncrude. Based on the speciation completed for the stack sampling surveys, concentrations of metals and PAHs have been estimated. These results are discussed in subsections following this section.

The predicted maximum daily and annual ground level ambient PM_{10} concentrations resulting from emissions used in the CEA were estimated using ISC3BE and meteorology measurements from the Mannix station. The modelling results are summarized in Table B4-9 which includes the PM_{10} predictions and selected metals and grouped PAH predictions estimated from the PM_{10} results and based on the source sampling results. Predicted PM_{10} ground level concentrations are mapped in the figures described below:

- Figure B4-17 shows the maximum daily average ground level PM_{10} concentrations associated with CEA emissions. The overall maximum daily average PM_{10} concentration of 116 μg/m^3 is predicted to occur at a location NW of Suncor. This daily maximum average value exceeds the Alberta Guideline of 100 μg/m^3. The high readings occur in a very small area within the existing development areas.
- Figure B4-18 shows the annual average ground level concentration contours for PM_{10}. The results show that the overall maximum annual concentration of 39.2 μg/m^3 is predicted to occur at the same location as the daily results. This high annual average is less than the Alberta guideline of 60 μg/m^3.



UTM NAD83 metres

0 5000 10000 15000 20000

Sources	PM [t/cd]
Suncor	
FGD	1.00
Powerhouse	0.24
Incinerator	0.038
Tail Gas Treatment Unit	0.042
Millennium Mine Fleet	0.3
Other Sources, Suncor	0.653
Syncrude (total)	11.41
Other Emissions (total)	2.125
Other Proposed Emissions (total)	2.59
TOTAL	18.398

Model Description	
Development	CEA
Model	ISC3BE
PM_{10} Guideline [µg/m³]	50
Maximum [µg/m³]	116
Exceedences / Year [#]	25

Figure B4-17 Predicted CEA PM_{10} Maximum Daily Average Ground Level Concentrations in the RSA

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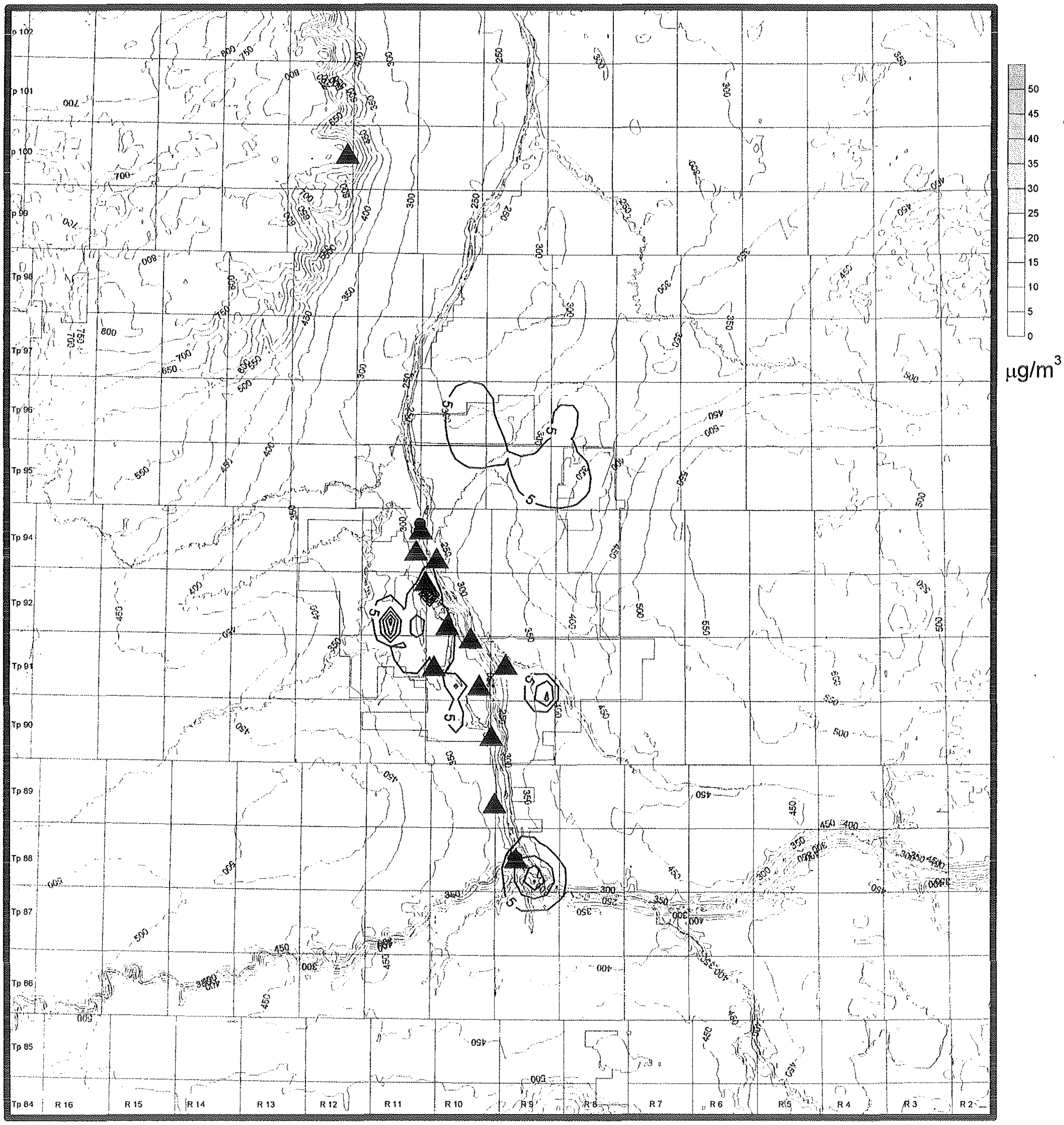


Sources	PM [t/cd]
Suncor	
FGD	1.00
Powerhouse	0.24
Incinerator	0.038
Tail Gas Treatment Unit	0.042
Millennium Mine Fleet	0.3
Other Sources, Suncor	0.653
Syncrude (total)	11.41
Other Emissions (total)	2.125
Other Proposed Emissions (total)	2.59
TOTAL	18.398

Model Description	
Development	CEA
Model	ISC3BE
PM_{10} Guideline [µg/m³]	50
Maximum [µg/m³]	39
Exceedences / Year [#]	0

Figure B4-18 Predicted CEA PM_{10} Maximum Annual Average Ground Level Concentrations in the RSA

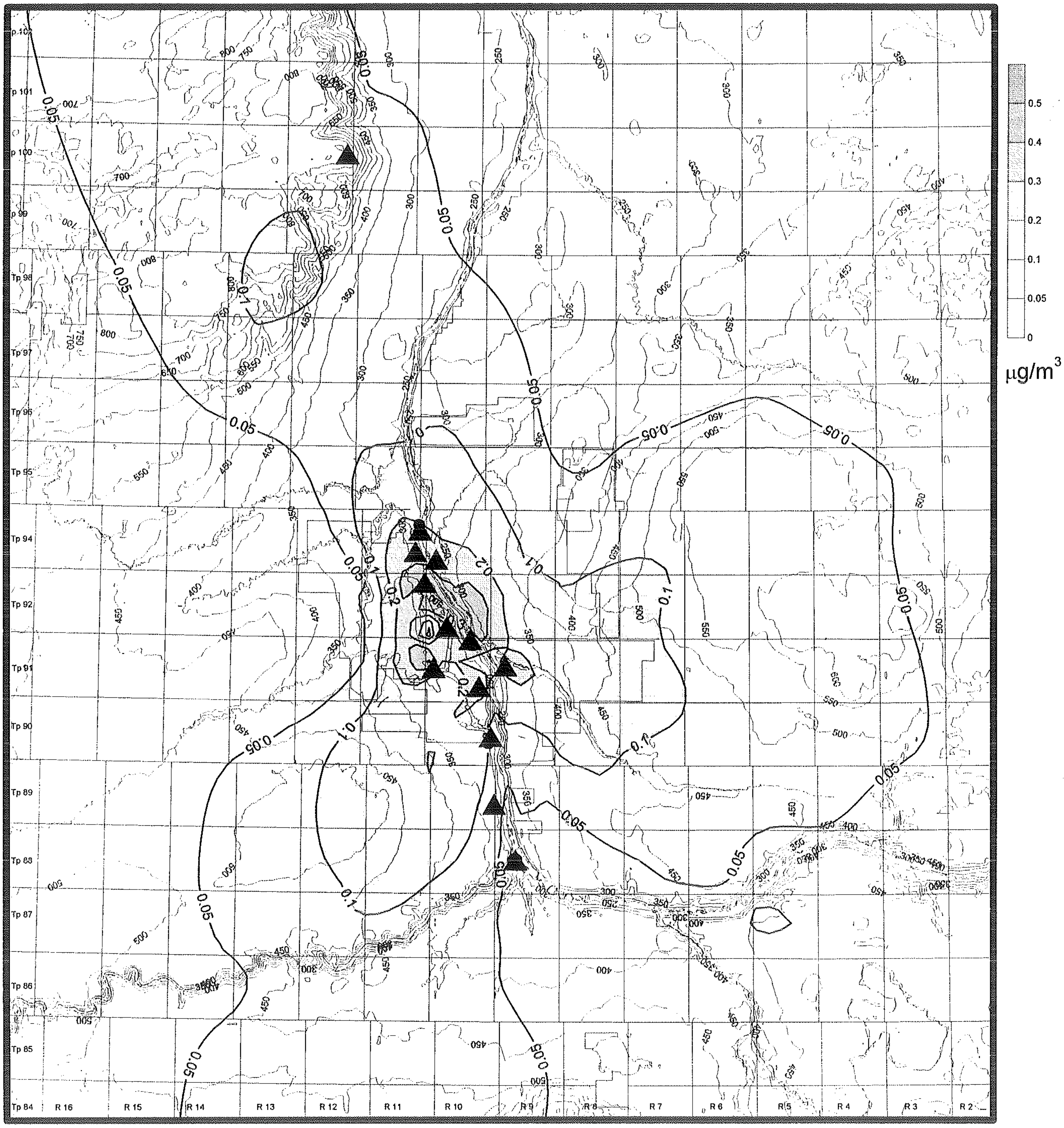
Table B4-9 Maximum Observed Ground Level Concentrations of PM_{10} for Baseline Sources

Source	Daily	Annual
CEA - Model ISC3BE		
Maximum PM_{10} Concentration (μg/m³)	116	39.2
Location of Maximum Concentration (km)	WNW	WNW
Maximum Number of Exceedances	n/a	0
Location of Maximum Exceedances	n/a	n/a
PM10, Alberta Guideline (μg/m3)	100	60

The modelling predicts high levels of PM_{10} in the development area and low levels in the rest of the RSA based on the CEA emission sources.

The particulate emissions from the Suncor FGD and Syncrude stacks contain metals and PAH compounds. The ISC3BE was configured to predict particulates from these two stacks plus the new stack at Syncrude as part of proposed Upgrader expansion to determine ground level concentrations and deposition rates. Particulate characteristics were based on stack surveys completed for the existing stacks.

The predicted average annual ground level concentrations of total particulates from these sources are shown in Figure B4-19. The predicted annual average deposition of total particulates from these sources are shown in Figure B4-20. A summary of the predicted metal and PAH concentrations derived from the total particulate air concentrations are listed in Tables B4-10 and B4-11 for selected locations. The PM assessment from the Suncor FGD stack reflects the most recent stack survey data which included analysis of heavy metals, PAHs, and particulate size fractions. This data has been included in the air quality section but was not available in time for inclusion in the health assessment in Section F1.



Sources	PM [t/cd]
Suncor	
FGD	2.60
Powerhouse	-
Incinerator	-
Tail Gas Treatment Unit	-
Millennium Mine Fleet	-
Other Sources, Suncor	-
Syncrude Main Stack	8.5
Syncrude New Stack	5.8
Other Emissions (total)	-
Other Proposed Emissions (total)	-
TOTAL	16.9

Model Description	
Development	CEA
Model	ISC3BE

UTM NAD83 metres
0 5000 10000 15000 20000

Figure B4-19 Predicted CEA Particulate Annual Average Ground Level Concentrations in the RSA from the operation of the Suncor and Syncrude main stacks

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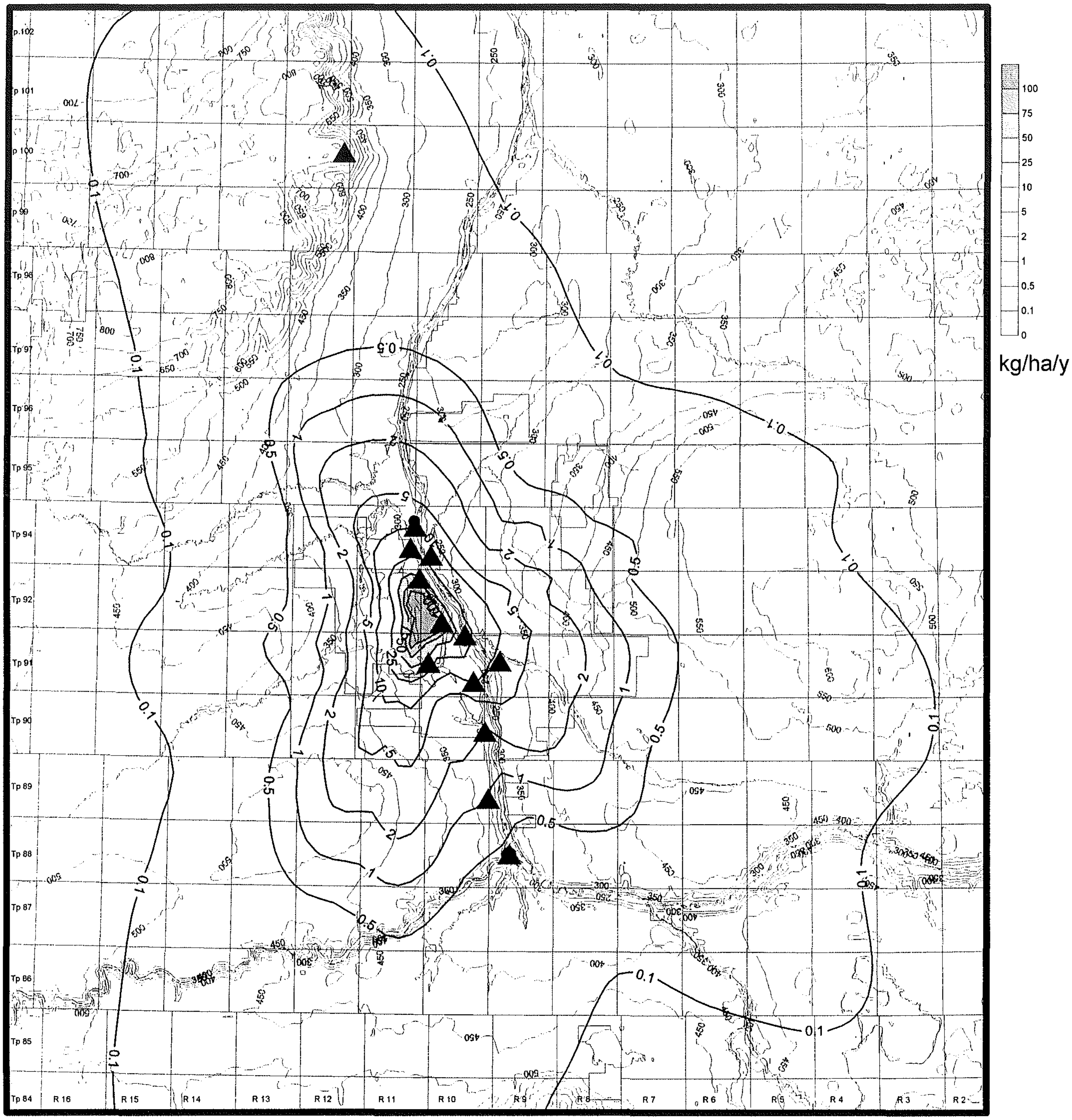

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Sources	PM [t/cd]
Suncor	
FGD	2.60
Powerhouse	-
Incinerator	-
Tail Gas Treatment Unit	-
Millennium Mine Fleet	-
Other Sources, Suncor	-
Syncrude Main Stack	8.5
Syncrude New Stack	5.8
Other Emissions (total)	-
Other Proposed Emissions (total)	-
TOTAL	16.9

Model Description	
Development	CEA
Model	ISC3BE

UTM NAD83 metres
0 5000 10000 15000 20000

Figure B4-20 Predicted CEA Particulate Annual Average Deposition in the RSA from the operation of the Suncor and Syncrude Main stacks

Table B4-10 Average Ground Level Concentrations of Heavy Metals at Selected Sites as a Result of Emissions From Suncor FGD and Syncrude Main Stack

Location	Average Daily Ground Level Concentration					Average Annual Ground Level Concentration			
	Ontario AAQC, Daily [ng/m^3]	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan
Heavy Metals [ng/m^3]									
Antimony	—	7.0E-02	1.5E-02	4.3E-02	5.2E-03	4.4E-03	3.2E-04	2.1E-03	2.5E-04
Arsenic	3.00E+03	1.1E-01	2.3E-02	6.7E-02	8.1E-03	6.8E-03	5.2E-04	3.3E-03	3.9E-04
Aluminum	—	1.3E+01	3.0E+00	9.3E+00	1.1E+00	8.8E-01	4.7E-02	4.1E-01	5.2E-02
Barium	1.00E+05	1.1E+00	2.2E-01	6.3E-01	7.8E-02	6.6E-02	5.3E-03	3.2E-02	3.7E-03
Beryllium	0.00E+00	1.3E-02	2.8E-03	8.4E-03	1.0E-03	8.4E-04	5.8E-05	4.0E-04	4.8E-05
Cadmium	2.00E+04	3.1E-02	7.0E-03	2.2E-02	2.6E-03	2.1E-03	9.5E-05	9.5E-04	1.2E-04
Calcium	—	1.6E+01	3.7E+00	1.2E+01	1.4E+00	1.1E+00	4.7E-02	5.0E-01	6.5E-02
Chromium	1.50E+04	6.1E+00	1.3E+00	4.0E+00	4.8E-01	3.9E-01	2.5E-02	1.9E-01	2.3E-02
Cobalt	1.00E+03	3.3E-01	7.3E-02	2.2E-01	2.7E-02	2.2E-02	1.3E-03	1.0E-02	1.3E-03
Copper	5.00E+05	5.7E-01	1.2E-01	3.8E-01	4.5E-02	3.7E-02	2.2E-03	1.7E-02	2.2E-03
Iron	—	6.3E+01	1.4E+01	4.5E+01	5.3E+00	4.2E+00	2.1E-01	2.0E+00	2.5E-01
Lead	0.00E+00	7.1E-01	1.5E-01	4.1E-01	5.1E-02	4.3E-02	3.6E-03	2.1E-02	2.4E-03
Magnesium	—	3.6E+00	7.6E-01	2.3E+00	2.7E-01	2.3E-01	1.6E-02	1.1E-01	1.3E-02
Manganese	—	2.2E+00	4.7E-01	1.4E+00	1.7E-01	1.4E-01	1.0E-02	6.7E-02	7.9E-03
Mercury	2.00E+04	1.5E-02	3.3E-03	1.0E-02	1.2E-03	9.9E-04	6.5E-05	4.7E-04	5.7E-05
Molybdenum	1.20E+06	1.1E+00	2.4E-01	7.3E-01	8.8E-02	7.3E-02	4.9E-03	3.5E-02	4.2E-03
Nickel	2.00E+04	1.0E+01	2.2E+00	6.8E+00	8.1E-01	6.5E-01	3.8E-02	3.1E-01	3.8E-02
Phosphorus	—	4.4E+00	8.1E-01	1.9E+00	2.6E-01	2.4E-01	3.1E-02	1.3E-01	1.2E-02
Selenium	1.00E+05	2.2E+00	4.0E-01	8.7E-01	1.2E-01	1.2E-01	1.7E-02	6.5E-02	5.9E-03
Silicon	—	1.4E+02	3.4E+01	1.1E+02	1.3E+01	1.0E+01	3.3E-01	4.5E+00	6.2E-01
Silver	1.00E+04	1.4E-01	3.1E-02	1.0E-01	1.2E-02	9.2E-03	4.0E-04	4.2E-03	5.5E-04
Sodium	—	9.1E+01	1.9E+01	5.6E+01	6.9E+00	5.7E+00	4.2E-01	2.8E+00	3.3E-01
Tin	1.00E+05	7.4E-01	1.5E-01	4.4E-01	5.4E-02	4.6E-02	3.6E-03	2.2E-02	2.6E-03
Titanium	—	1.4E+00	3.0E-01	9.3E-01	1.1E-01	9.0E-02	5.6E-03	4.3E-02	5.2E-03
Vanadium	2.00E+04	4.4E+00	9.3E-01	2.8E+00	3.4E-01	2.8E-01	1.9E-02	1.3E-01	1.6E-02
Zirconium	—	7.4E-01	1.5E-01	4.4E-01	5.4E-02	4.6E-02	3.6E-03	2.2E-02	2.6E-03
Zinc	1.20E+06	3.4E+01	8.1E+00	2.8E+01	3.2E+00	2.4E+00	5.5E-02	1.1E+00	1.5E-01

OAAQC: Ontario Ambient Air Quality Criteria
Ontario Ministry of the Environment 1994
Summary of Point of Impingement Standards, Ambient Air Quality Criteria (AAQC), and Approvals Screening Levels

Table B4-11 Average Ground Level Concentrations of PAHs at Selected Sites as a Result of Emissions From Suncor FGD and Syncrude Main Stack

Location	Average Daily Ground Level Concentration				Average Annual Ground Level Concentration			
	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan
PAHs [ng/m³]								
Acenaphthene	1.0E-03	2.0E-04	5.3E-04	6.7E-05	4.3E-05	5.9E-06	3.0E-05	1.9E-06
Acenaphylene	5.6E-02	1.4E-02	4.7E-02	5.4E-03	1.4E-03	8.7E-05	1.8E-03	4.4E-05
Anthracene	2.5E-03	4.7E-04	1.1E-03	1.5E-04	1.2E-04	1.7E-05	7.3E-05	5.4E-06
1,2-Benzathracene	1.4E-03	3.0E-04	8.7E-04	1.1E-04	5.4E-05	6.6E-06	4.3E-05	2.3E-06
Benzo(b & j)fiuoranthene	7.2E-03	1.4E-03	3.6E-03	4.7E-04	3.2E-04	4.4E-05	2.1E-04	1.4E-05
Benzo(k)fluoranthene	1.6E-03	3.4E-04	1.0E-03	1.2E-04	5.5E-05	6.2E-06	4.8E-05	2.2E-06
Benzo(a)fluorene	1.1E-03	2.1E-04	5.6E-04	7.2E-05	4.8E-05	6.6E-06	3.2E-05	2.1E-06
Benzo(b)fluorene	7.3E-04	1.5E-04	4.3E-04	5.3E-05	2.9E-05	3.7E-06	2.2E-05	1.2E-06
Benzo(g, h, i)perylene	1.8E-03	3.9E-04	1.2E-03	1.4E-04	6.4E-05	7.4E-06	5.5E-05	2.6E-06
Benzo(a)pyrene	1.2E-03	2.4E-04	6.9E-04	8.5E-05	4.5E-05	5.6E-06	3.5E-05	1.9E-06
Benzo(e)pyrene	7.3E-04	1.5E-04	4.3E-04	5.3E-05	2.9E-05	3.7E-06	2.2E-05	1.2E-06
Camphene	1.7E-03	3.1E-04	7.7E-04	1.0E-04	7.8E-05	1.1E-05	4.9E-05	3.6E-06
Carbazole	1.0E-03	2.0E-04	5.4E-04	6.8E-05	4.4E-05	6.0E-06	3.0E-05	2.0E-06
1 -Chloronaphthalene	9.8E-04	2.0E-04	5.5E-04	6.9E-05	4.1E-05	5.3E-06	2.9E-05	1.8E-06
2-Chloronaphthalene	1.9E-03	4.2E-04	1.3E-03	1.6E-04	6.3E-05	6.7E-06	5.8E-05	2.5E-06
Chrysene	3.2E-03	7.2E-04	2.3E-03	2.7E-04	1.1E-04	1.1E-05	1.0E-04	4.2E-06
Dibenz(a, j)acridine	1.3E-03	2.8E-04	8.4E-04	1.0E-04	4.9E-05	5.8E-06	4.0E-05	2.0E-06
Dibenz(a, h)acridine	9.3E-04	1.8E-04	5.0E-04	6.3E-05	3.9E-05	5.2E-06	2.8E-05	1.7E-06
Dibenz(a, h anthracene	9.8E-04	2.0E-04	5.5E-04	6.9E-05	4.1E-05	5.3E-06	2.9E-05	1.8E-06
Dibenzothiophene	2.2E-01	5.4E-02	1.9E-01	2.1E-02	5.6E-03	3.5E-04	7.1E-03	1.8E-04
7,12-dimethylbenz(a)anthracene	9.3E-04	1.8E-04	5.0E-04	6.3E-05	3.9E-05	5.2E-06	2.8E-05	1.7E-06
1, 6-Dinitropyrene	9.3E-04	1.8E-04	5.0E-04	6.3E-05	3.9E-05	5.2E-06	2.8E-05	1.7E-06
1, 8-Dinitropyrene	9.3E-04	1.8E-04	5.0E-04	6.3E-05	3.9E-05	5.2E-06	2.8E-05	1.7E-06
Fluoranthene	8.6E-03	1.7E-03	4.8E-03	6.0E-04	3.6E-04	4.7E-05	2.6E-04	1.6E-05
Fluorene	3.9E-03	7.1E-04	1.6E-03	2.2E-04	2.0E-04	3.0E-05	1.1E-04	9.3E-06
Ideno(l, 2, 3-cd)pyrene	1.7E-03	3.8E-04	1.2E-03	1.4E-04	5.9E-05	6.4E-06	5.3E-05	2.3E-06
Indole	1.7E-03	3.2E-04	7.8E-04	1.0E-04	8.0E-05	1.2E-05	5.0E-05	3.7E-06
1 -Methylnaphthalene	6.1E-02	1.4E-02	4.9E-02	5.6E-03	1.7E-03	1.3E-04	1.9E-03	5.8E-05
2-Methylnaphthalene	5.5E-02	1.3E-02	4.2E-02	4.9E-03	1.6E-03	1.4E-04	1.7E-03	5.8E-05
Naphthalene	8.4E-01	2.0E-01	6.9E-01	7.9E-02	2.2E-02	1.6E-03	2.7E-02	7.3E-04
Nitro-pyrene	1.2E-03	2.4E-04	6.1E-04	7.8E-05	5.5E-05	7.6E-06	3.6E-05	2.5E-06
Perylene	7.3E-04	1.5E-04	4.3E-04	5.3E-05	2.9E-05	3.7E-06	2.2E-05	1.2E-06
Phenanthrene	9.6E-02	2.2E-02	7.1E-02	8.3E-03	3.0E-03	2.9E-04	3.0E-03	1.1E-04
Pyrene	1.1E-02	2.5E-03	7.8E-03	9.2E-04	3.6E-04	3.7E-05	3.4E-04	1.4E-05
Retene	1.1E-02	2.2E-03	6.1E-03	7.7E-04	4.7E-04	6.2E-05	3.3E-04	2.0E-05

B4.2.7 Fugitive Dust Discussion

The maximum predicted PM does not include contributions due to non-combustion sources nor natural background levels. Potential fugitive sources associated with all of the existing, planned and proposed projects include the mining operations, coke piles, road dust, beaches, and the physical reclamation activities. It is Suncor's experience that the mining area, given the coarse nature of oil sands (bitumen and sand combination), is expected to produce minimal PM fugitive emissions. The existing reclamation activities will control fugitive particulate emissions from the sand dykes and beaches. Overall, fugitive emissions are most likely an episodic issue and can be managed.

B4.2.8 Volatile Organic Compounds Predicted Concentrations

The VOC emission sources associated with the CEA case are summarized in Section B4.1. Total estimated emission rates for this case are 340 t/cd for VOC (Table B4-2). Suncor represents about 70% of the VOC total emissions. The predicted annual average ground level ambient total VOC concentrations resulting from emissions of all approved industrial sources and residential emissions in the oil sands region were estimated using ISC3BE and meteorology measurements from the Mannix station. Using these VOC runs and the unique fingerprint of each emission source, specific VOCs were further speciated from the modelling results. This model provides an efficient means of predicting the overall ambient VOC concentration and the speciated compounds from all sources.

The predicted total VOC hourly, daily and annual average ground level concentrations are mapped in Figures B4-21, B4-22 and B4-23 respectively. The results show that the overall maximum concentrations are expected to occur within the existing development areas and are associated with the tailings ponds. Because source characterization simplifications are used to model large sources such as tailings ponds, which include annualized emission rates and homogeneous emissions over the pond surfaces, maximum concentrations under worst case meteorology likely overestimates values very close to the pond. The annual concentrations for selected receptors are listed in Table B4-12 and are put into perspective in the health discussion in Section F1.

Table B4-12 Maximum Observed Annual Average Ground Level Concentrations of VOCs for CEA at Selected Locations

	VOC Concentration [μg/m³]				
Species	Location of Maximum	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan
Total VOCs					
Maximum concentration [μg/m³]	34100	811	85	190	16
Speciated VOCs					
C2 to C4 alkanes and alkenes	616	14.7	1.5	3.4	0.29
C5 to C8 Alkanes and alkenes	13029	310	32.5	72.5	6.0
C9 to C12 alkanes and alkenes [(a)]	13862	330	34.6	77.1	6.4
Cyclohexane	2894	69	7.2	16.1	1.3
Benzene	102	2.4	0.25	0.56	0.047
C6 to C8 non-benzene aromatics	1705	41	4.3	9.5	0.8
Total aldehydes	66	1.6	0.165	0.368	0.031
Total ketones	18	0.4	0.045	0.101	0.008
Total Reduced Sulphur Compounds	664	15.8	1.7	3.7	0.3

(a) Unknown speciation are included in group C9 to C12

B4.2.9 TRS Predicted Concentration

The ambient TRS emission sources associated with this case are summarized in Section B4.1. Total estimated TRS emission rate for the

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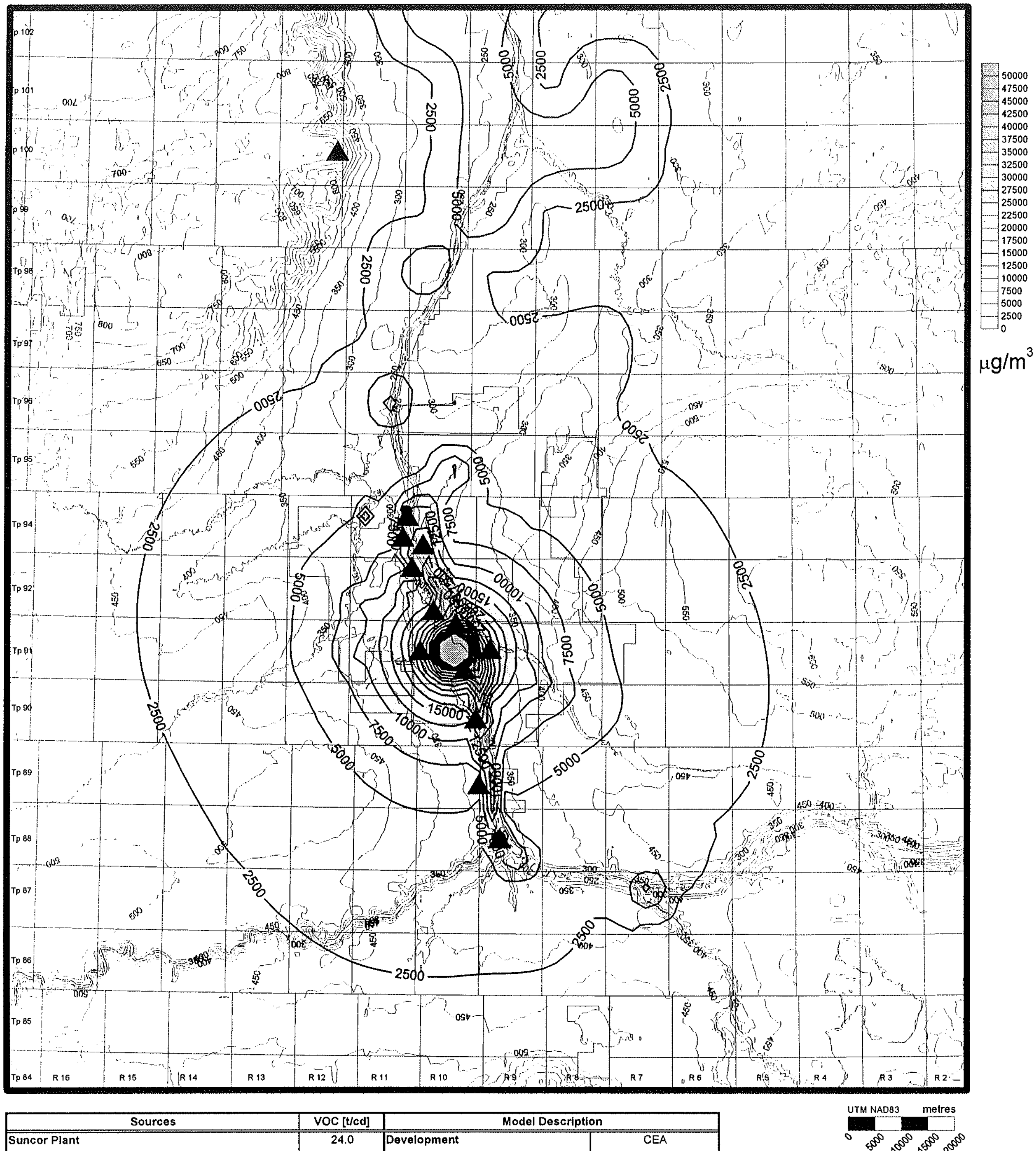

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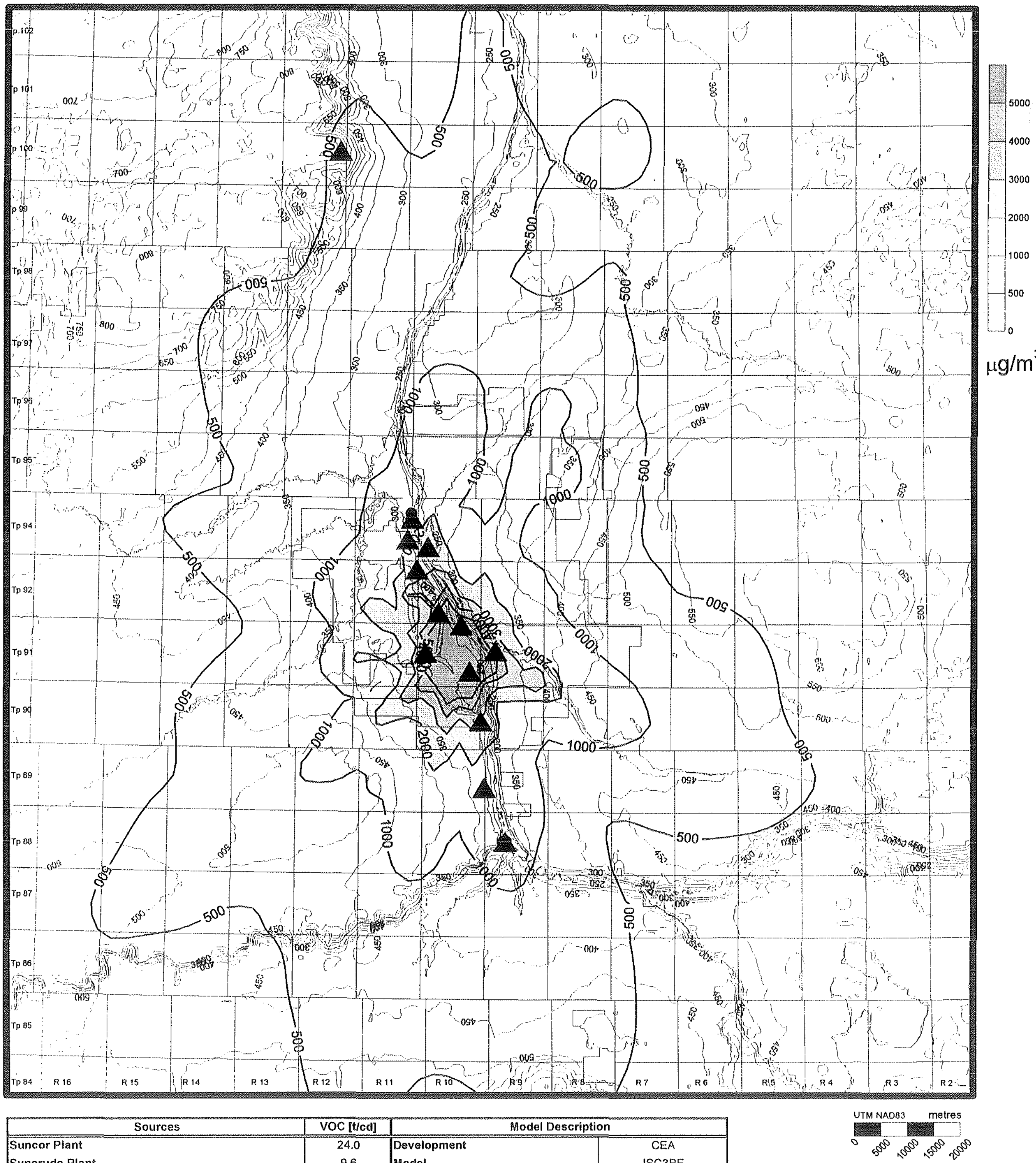
Sources	VOC [t/cd]
Suncor Plant	24.0
Syncrude Plant	9.6
Mine Fleets	4.8
Mine Faces	50.8
Tailings Ponds	243.4
TOTAL	332.5

Model Description	
Development	CEA
Model	ISC3BE

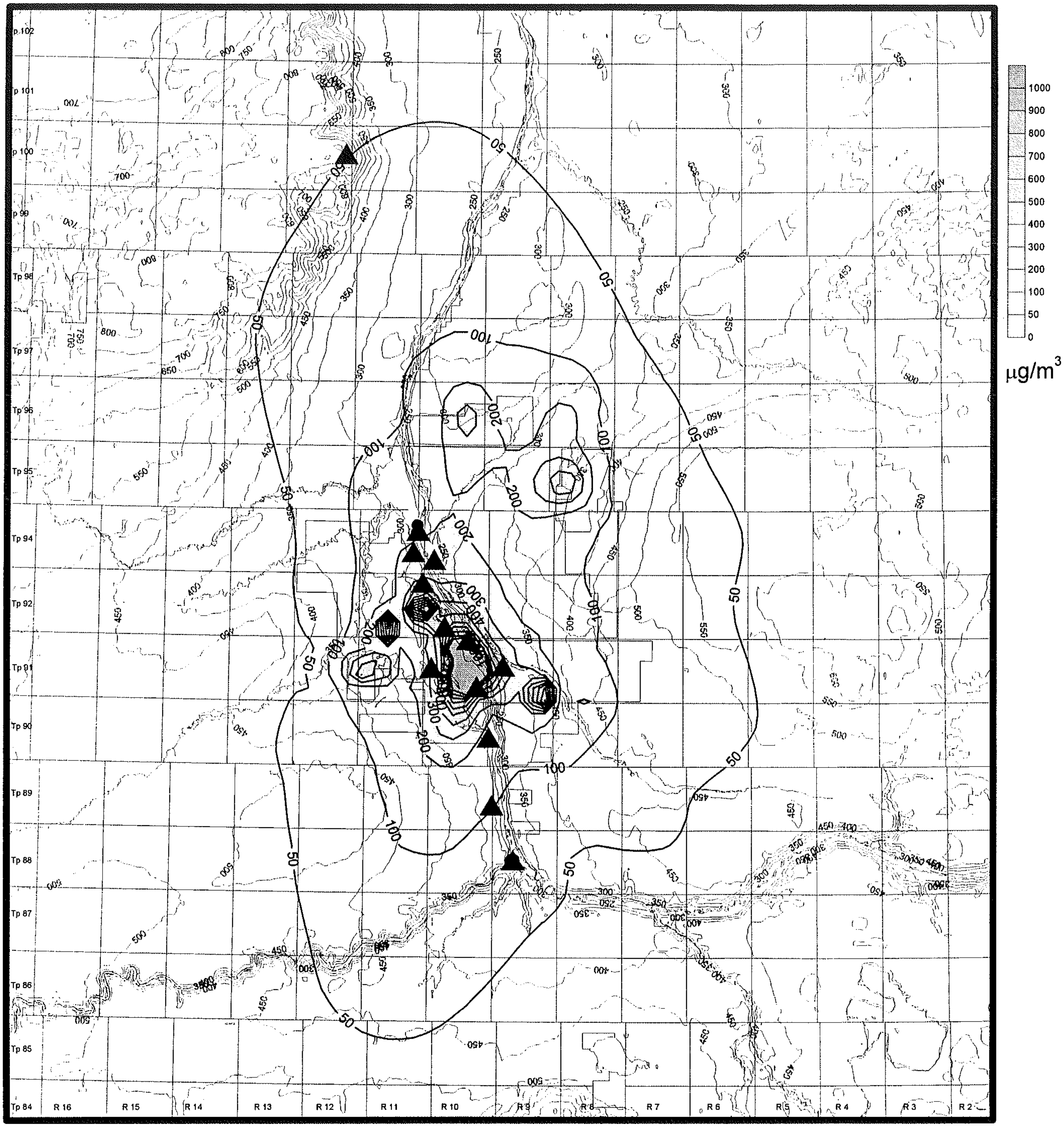
Figure B4-21 Predicted CEA VOC Maximum Hourly Average Ground Level Concentrations in the RSA

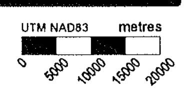


Sources	VOC [t/cd]
Suncor Plant	24.0
Syncrude Plant	9.6
Mine Fleets	4.8
Mine Faces	50.8
Tailings Ponds	243.4
TOTAL	332.5

Model Description	
Development	CEA
Model	ISC3BE

Figure B4-22 Predicted CEA VOC Maximum Daily Average Ground Level Concentrations in the RSA





Sources	VOC [t/cd]
Suncor Plant	24.0
Syncrude Plant	9.6
Mine Fleets	4.8
Mine Faces	50.8
Tailings Ponds	243.4
TOTAL	332.5

Model Description	
Development	CEA
Model	ISC3BE

Figure B4-23 Predicted CEA VOC Annual Average Ground Level Concentrations in the RSA

CEA case is 6.3 t/cd. Suncor emits about 2.7 t/cd of TRS mainly from the tailing ponds. In total Suncor emits approximately 43% of the TRS.

The predicted maximum, daily and annual ground level ambient TRS concentrations resulting from the CEA emissions were estimated using ISC3BE and meteorology measurements from the Mannix station. Selected results of the speciated reduced sulphur compounds are shown in Figure B4-24 and Figure B4-25 for the hourly and daily H_2S and in Figure B4-26 for hourly mercaptans. These TRS species were selected because they have particularly low odour thresholds. Maximum hourly and daily concentrations at selected locations are listed in Table B4-13 and Table B4-14.

Whereas the ISC3BE model was not configured to explicitly assess odours, the concentrations at the selected locations can be used to qualitatively assess the potential for odour detection at these locations. The results presented in the figures do not address the complexities of thorough odour assessment which would take into account concentration, duration above a threshold, frequency of exceeding various thresholds and receptor sensitivity. As a part of the ISC3BE development, the dispersion coefficients were adjusted for receptors within the Athabasca River valley such that limited mixing could occur under certain meteorological conditions. The results of this fine tuning can be seen in Figure B4-24 in the elevated H_2S concentrations within the Athabasca River valley.

The results in Table B4-13 and Table B4-14 indicate that the predicted concentrations could potentially lead to the detection of odours originating from the developments in the oil sands area for sensitive individuals.

Table B4-13 Maximum Predicted Hourly Concentrations of TRS at Selected Sites for CEA Sources

	TRS Concentration [µg/m³]				
Species	Location of Maximum	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan
Total Reduced Sulphur Compounds					
Maximum VOC concentration [µg/m³]	141000	39492	11057	13987	3989
Maximum TRS concentration [µg/m³]	2747	769	215	273	78
Speciated Compounds					
H_2S	221	62	17	22	6
COS	0	0	0	0	0
CS_2	0	0	0	0	0
Mercaptans	7.35	2.06	0.58	0.73	0.21
Thiophenes	977	274	77	97	28

Alberta H_2S hourly guideline - 4 µg/m³
Odour threshold for mercaptans is 0.04 to 2.0 µg/m³
Odour threshold for H_2S is 0.7 to 14 µg/m³

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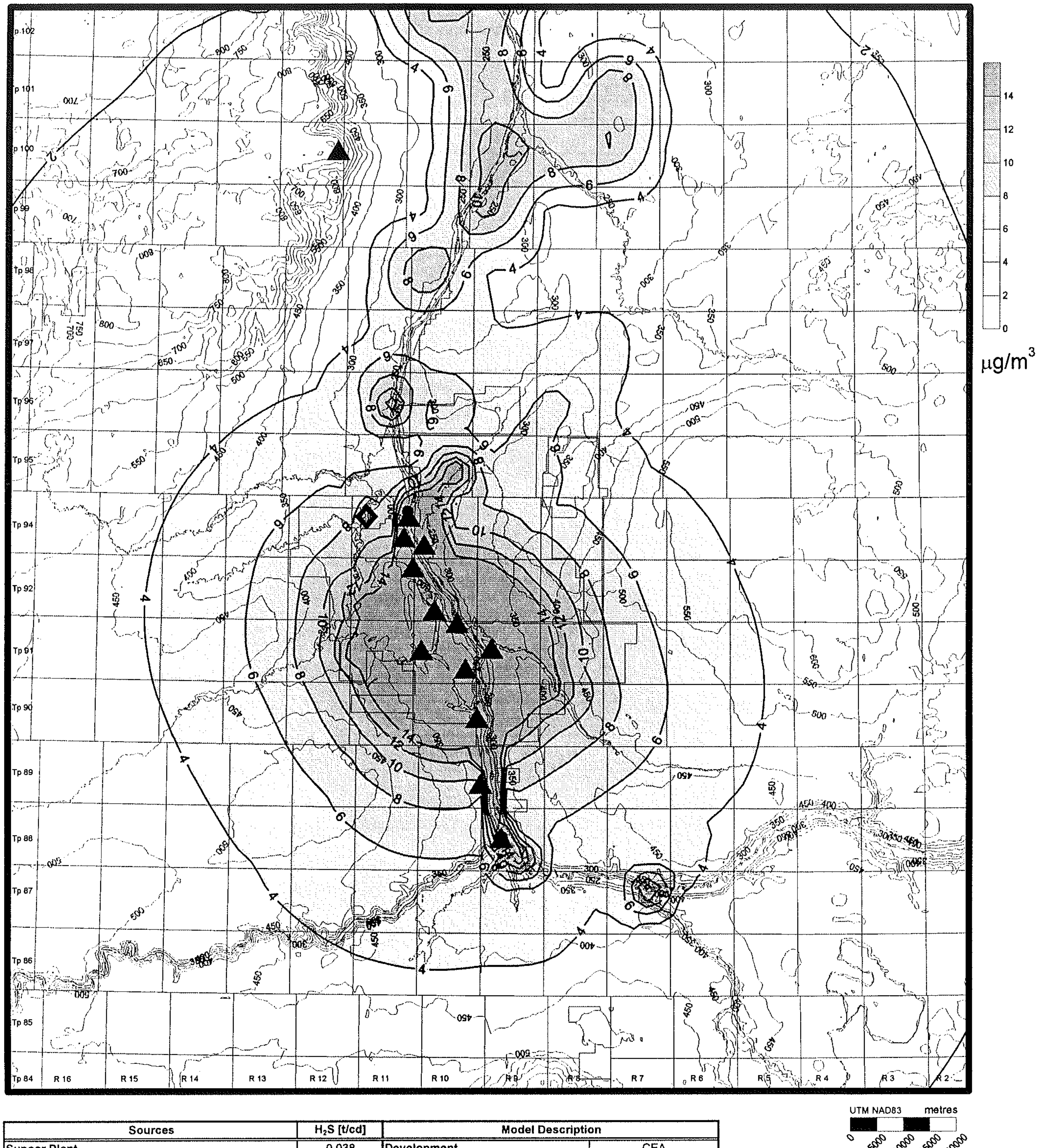
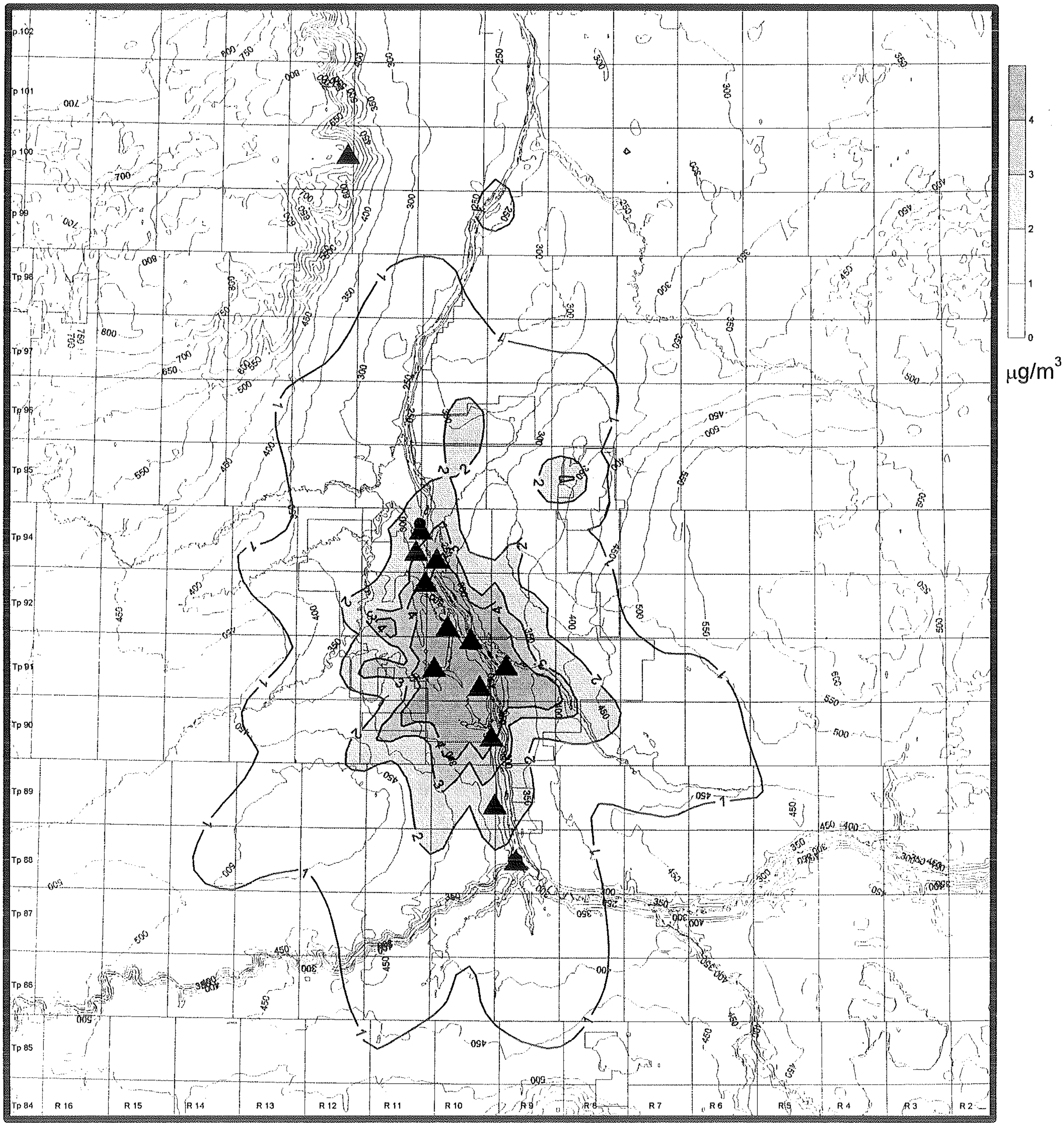


Sources	H_2S [t/cd]
Suncor Plant	0.038
Syncrude Plant	0.015
Mine Fleets	0.007
Mine Faces	0.080
Tailings Ponds	0.382
TOTAL	0.521

Model Description	
Development	CEA
Model	ISC3BE

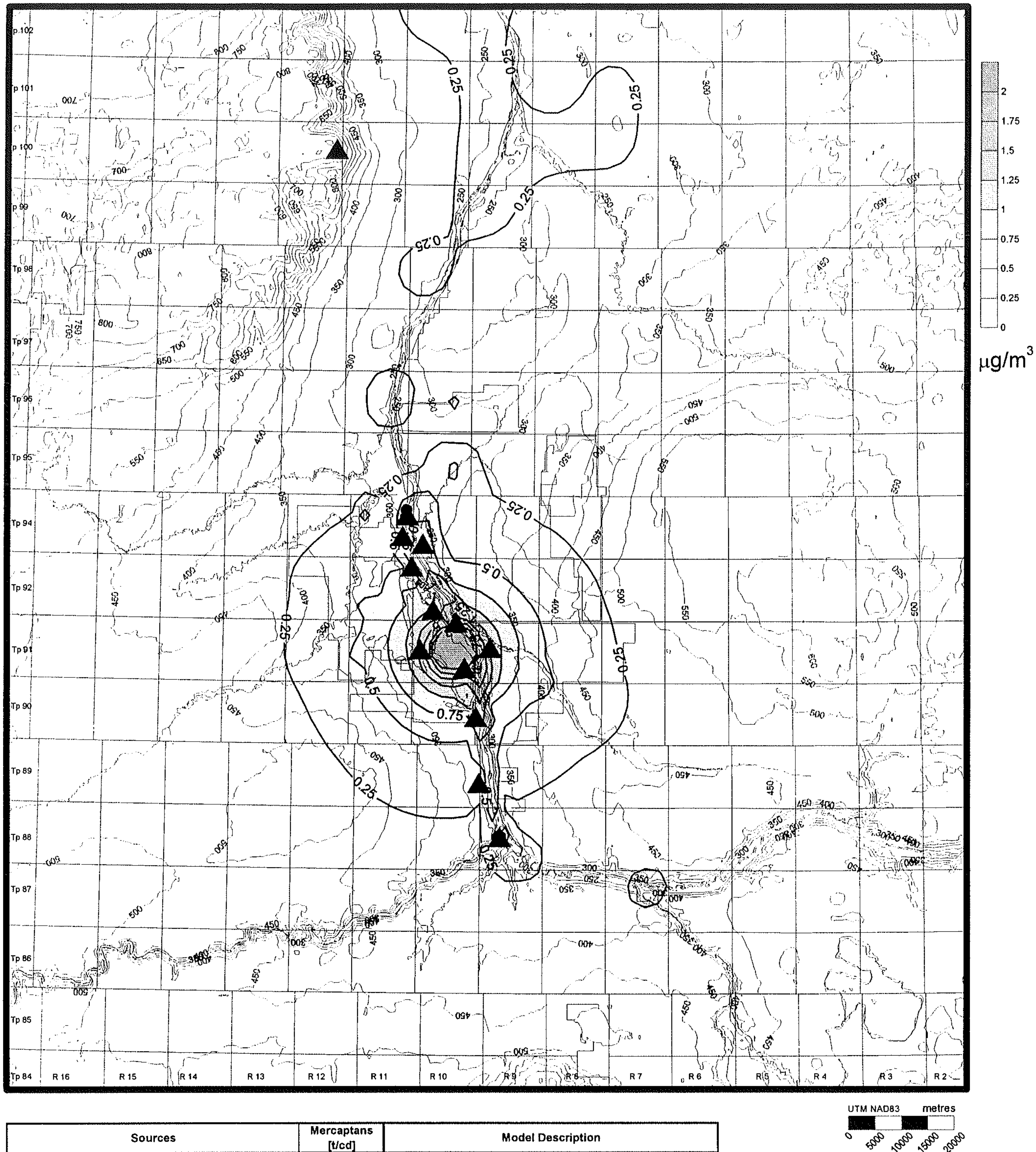
Figure B4-24 Predicted CEA H_2S Maximum Hourly Average Ground Level Concentrations in the RSA



Sources	H_2S [t/cd]
Suncor Plant	0.038
Syncrude Plant	0.015
Mine Fleets	0.007
Mine Faces	0.080
Tailings Ponds	0.382
TOTAL	0.521

Model Description	
Development	CEA
Model	ISC3BE

Figure B4-25 Predicted CEA H_2S Maximum Daily Average Ground Level Concentrations in the RSA



Sources	Mercaptans [t/cd]
Suncor Plant	0.0013
Syncrude Plant	0.0005
Mine Fleets	0.0002
Mine Faces	0.0026
Tailings Ponds	0.0127
TOTAL	0.0173

Model Description	
Development	CEA
Model	ISC3BE

Figure B4-26 Predicted CEA Mercaptans Maximum Hourly Average Ground Level Concentrations in the RSA

Table B4-14 Maximum Predicted Daily Concentrations of TRS at Selected Sites for CEA Sources

Species	TRS Concentration [μg/m³]				
	Location of Maximum	Mannix	Fort McKay	Fort McMurray	Fort Chipewyan
Total Reduced Sulphur Compounds					
Maximum VOC concentration [μg/m³]	141000	39492	11057	13987	3989
Maximum TRS concentration [μg/m³]	2747	769	215	273	78
Speciated Compounds					
H_2S	221	62	17	22	6
COS	0	0	0	0	0
CS_2	0	0	0	0	0
Mercaptans	7.35	2.06	0.58	0.73	0.21
Thiophenes	977	274	77	97	28

Alberta H_2S hourly guideline - 14 μg/m³
Odour threshold for mercaptans is 0.04 to 2.0 μg/m³
Odour threshold for H_2S is 0.7 to 14 μg/m³

B4.2.10 Noise

The closest community that may be affected by the noise from the existing and approved projects, Project Millennium and the proposed projects is Fort McKay. Noise may be generated from a variety of on-site activities, including engine noise from truck and shovel operations, extraction, on-site power generation, upgrading operations and increased traffic within the local communities. Currently, noise sources exist at the fixed plant and other mining operations at Suncor's Lease 86/17. Additionally, similar activities at the Syncrude Mildred Lake operation, as well as from the Aurora Mine and the planned Shell Muskeg River Mine and Lease 13 will also contribute to the ambient levels experienced in Fort McKay.

Comprehensive assessment of the anticipated noise levels in Fort McKay would need to consider the collective contribution of all mine operations, in addition to background. As the level of detailed information required to complete an assessment is not available, only general comments can be made. The modelling of all regional sources will be complex given the variability in noise emission of the equipment, the mobile nature of many of the noise sources, the effects of the mine pits and general terrain features in addition to the meteorological inputs. Mitigation, such as using natural or man made sound barriers and noise mufflers, is available should final operating plans predict high noise levels.

B4.2.11 Cumulative Impact Analyses

The air emissions from all of the CEA emission sources have been described and quantified as a result of Project Millennium. The resulting air quality concentrations have been determined using appropriate models. This approach provides the foundation to determine the potential cumulative air impacts using the approach described in Section A2.1.8. The key question identified at the beginning of this section can now be addressed.

CAQ-1: What impacts to ambient air quality and acidification of water, soils and vegetation will result from air emissions associated with Project Millennium and the combined developments?

The potential for air emissions from Project Millennium and combined developments to impact ambient air quality and the acidification of water, soils and vegetation has been raised as cumulative concern in the region. This issue was addressed in two stages. The first stage looked at the potential impacts on air quality by predicting air concentrations of SO_2, NO_2, CO, PM, VOC and TRS using the ISC3BE dispersion model. The model results were then compared to Alberta Ambient Air Quality Guidelines, Canadian Federal Air Quality Objectives or other guidelines to assist in the prediction of impacts. The potential for acidification of water, soils and vegetation was then addressed by using the CALPUFF dispersion model to determine the Potential Acid Input (PAI) resulting from the SO_2 and NO_x emitted by Project Millennium and the combined developments. The linkage pathway for this key question is depicted in Figure B4-1. Comparison of emissions and concentrations are presented in Table B4-14 and a discuss follows.

Table B4-14 Summary of Air Emissions for Project Millennium and the Combined Developments

	Baseline Case[a]	Project Millennium Case[a]	Cumulative Environmental Assessment[a]	Comments
Suncor Process Information				
Capacity	105,000	210,000	210,000	
Emission Rate of SO_2 t/cd	65.3	70.2	70.2	
Emission Rate of NO_x t/cd	47.7	67.7	67.7	
Emission Rate of CO t/cd	33.5	38.5	38.5	
Emission Rate of PM t/cd	1.7	2.2	2.2	
Emission Rate of VOC t/cd	130	240.4	240.4	
Emission Rate of TRS t/cd	1.5	2.73	2.73	
Predicted SO_2 Concentrations				
Hourly				
• Maximum average (µg/m^3)	648	870	872	Below Federal Acceptable
• Exceedance (number)	3	49	50	
• Areal extent (ha)	33,313	58,860	68,950	
Daily				
• Maximum average (µg/m^3)	199	200	188	Below Federal Acceptable
• Exceedance (number)	6	9	1	
• Areal extent (ha)	358	289	neg	In Development Area
Annual				
• Maximum average (µg/m^3)	74	82	47.5	Above Federal Acceptable
• Exceedance (number)	1	1	1	
• Areal extent (ha)	356	409	540	In Development Area

	Baseline Case[a]	Project Millennium Case[a]	Cumulative Environmental Assessment[a]	Comments
Predicted NO_2 Concentrations				
Hourly				
• Maximum average ($\mu g/m^3$)	316	320	295	Below Alberta Guideline
• Exceedance (number)	0	0	0	
• Areal extent (ha)	0	0	0	
Daily				
• Maximum average ($\mu g/m^3$)	259	260	244	Above Federal Acceptable
• Exceedance (number)	n/a	n/a	n/a	
• Areal extent (ha)	825	2,185	1,447	In Development Area
Annual				
• Maximum average ($\mu g/m^3$)	162	162	163	Above Federal Acceptable
• Exceedance (number)	1	1		
• Areal extent (ha)	5,818	8,343	38,624	
Predicted PAI Concentrations				
• Areal extent if 0.25 keq/ha/y (ha)[b]	670,483	861,263	1,417,300	
• Areal extent if 0.50 keq/ha/y (ha)[b]	11,543	195,695	420,086	
• Areal extent if 1.0 keq/ha/y (ha)[b]	3,206	9,598	20,430	
• Areal extent if 1.5 keq/ha/y (ha)[b]	250	317	13	
Predicted CO Concentrations				
Hourly				
• Maximum average ($\mu g/m^3$)	5,561	5,560	5,560	Below Alberta Guideline
• Exceedance (number)	0	0	0	
• Areal extent (ha)	0	0	0	
8-Hour				Below Alberta Guideline
• Maximum average ($\mu g/m^3$)	1,160	1,169	928	
• Exceedance (number)	n/a	n/a	n/a	
• Areal extent (ha)	n/a	n/a	n/a	
Predicted PM Concentrations				
Daily				
• Maximum average ($\mu g/m^3$)	115	113	116	
• Exceedance (number)	n/a	n/a	n/a	
• Areal extent (ha)	n/a	n/a	n/a	
Annual	45	45.9	39.2	
• Maximum average ($\mu g/m^3$)				
• Exceedance (number)	n/a	n/a	n/a	
• Areal extent (ha)	n/a	n/a	n/a	
Predicted VOC Concentrations				
Annual				
• Maximum average ($\mu g/m^3$)	50	76	85	Fort McKay
• Maximum average ($\mu g/m^3$)	107	163	190	Fort McMurray
• Exceedance (number)	n/a	n/a	n/a	
• Areal extent (ha)	n/a	n/a	n/a	
Predicted TRS Concentrations				
Hourly				
• Maximum average H_2S ($\mu g/m^3$)	11.7	17.8	17	Fort McKay
• Maximum average H_2S ($\mu g/m^3$)	9.2	14.1	22	Fort McMurray
• Exceedance (number)	n/a	n/a	n/a	
• Areal extent (ha)	n/a	n/a	n/a	
Daily				
• Maximum average H_2S ($\mu g/m^3$)	1.7	2.4		Fort McKay
• Maximum average H_2S ($\mu g/m^3$)	0.9	1.3		Fort McMurray
• Exceedance (number)	n/a	n/a	n/a	
• Areal extent (ha)	n/a	n/a	n/a	

(a) All predicted values based on ISC3BE model unless otherwise noted.
(b) Predictions based on CALPUFF model

A review of the potential impacts on air quality of air concentrations of SO_2, NO_2, CO, PM, VOC and TRS was completed using the ISC3BE dispersion model. The model results were then compared to Alberta Ambient Air

Quality Guidelines, Canadian Federal Air Quality Objectives or other guidelines to assist in the assessment of impacts following the approach outlined in Section A2. The assessment is summarized as follows:

- The predicted cumulative impacts of hourly, daily and annual SO_2 emissions and concentrations are very similar to Project Millennium and the conclusion is the same. For hourly and daily SO_2, the environmental consequence of the impacts are low. The annual SO_2 environmental consequence is predicted to be moderate. However, because most of the maximum annual concentrations that exceed guidelines are inside the development area, the impact is not deemed to be significant.
- The predicted cumulative impacts for NO_2 are the same as developed for Project Millennium. The hourly environmental consequences are low while the environmental consequences for the maximum annual daily and annual concentrations are moderate. As in the case of SO_2, this moderate environmental consequence is tempered by the limited areal extent of the concentrations exceeding the Alberta guidelines. While more area is involved in the annual maximum average, the high values continue to be within the existing or proposed development areas. Therefore, this impact is rated as not significant.
- Particulate emissions and concentrations for the cumulative assessment are very similar to Project Millennium and the conclusions are the same. That is, the predicted environmental consequence of these impacts is low.
- Cumulative impacts for VOC emissions and concentrations are discussed in the Human Health Section (F1).
- The cumulative impacts of the TRS emissions were rated as moderate environmental consequence for Project Millennium and the same prediction holds for the cumulative case. As indicated in Section B3, TRSs may continue to be an occasional odour issue. Viewed in the context that most of the concentrations exceeding guidelines lie inside the development areas, and the conservatism built into the Suncor component of the emission estimate, the impact is not deemed to be significant.

The acidification of water, soils and vegetation was addressed using the CALPUFF dispersion model to determine the Potential Acid Input (PAI) resulting from the SO_2 and NO_x emitted by Project Millennium and the combined developments. A background PAI of 0.1 keq/ha/y has been incorporated into the PAI generated numbers. The areal extent of the 0.25 keq/ha/y PAI contour represents approximately 60% of the RSA. The PAI results were incorporated into the Cumulative Aquatics (C6) and Cumulative Terrestrial (D5) sections of this EIA.

B5 AIR QUALITY CONCLUSION

B5.1 INTRODUCTION

Project Millennium has been designed to mitigate air quality impacts through:

- continuing use of the Flue Gas Desulphurization (FGD) plant to reduce SO_2 and particulate emissions associated with coke combustion;
- installation of a flare gas recovery project whereby gases currently being flared will be recompressed for treatment and use (scheduled for completion in 1999);
- meeting additional energy requirements for the Project by waste heat recovery from the Millennium Upgrader and by natural gas fired turbine generators with attached heat recovery steam generators;
- installation of two Claus sulphur recovery trains with a downstream tail gas treatment unit for the Millennium Upgrader;
- use of low-NO_x burners for new plant equipment;
- use of mine fleet vehicles with state of the art emission control technology;
- improvement in the quality of diesel fuels used for mine fleet vehicles;
- implementation of a site-wide NO_x management plan;
- tie-in of any new diluted bitumen and diluent tanks to the Vapour Recovery System;
- installation of a new larger vacuum column and upgrading of the overhead circuit in the Naphtha Recovery Unit (NRU) to handle the new rates with a minimum diluent recovery of 99.3%;
- modification of the diluent (e.g., narrower boiling range, and less benzene and light ends) for use in secondary extraction to improve recovery in the NRU and reduce volatile organic compound (VOC) emissions from diluent;
- watering of roads and active areas of the coke pile during warm weather periods to suppress dust;
- participating in a regional ground-level ozone modelling program;
- managing greenhouse gas emissions on a corporate basis through implementation of a seven-point plan; and
- maintaining its active role in the Regional Air Quality Coordinating Committee (RAQCC) to:
  - further understanding of the relationship between acid loading and environmental sensitivity, and

- use data collected by the enhanced air quality monitoring network to: protect human health, vegetation and wildlife; examine soil and water acidification; and minimize odours in the region over the long term.

The air quality impact assessment predicted the incremental effects of the Project on top of existing and approved oil sands operations. The assessment considered the issues, as addressed through the key question approach in Section B3 of the EIA. The issues and environmental consequences are summarized in Table B5-1.

Table B5.1-1 Air Quality Issues and Environmental Consequences

Issue	Environmental Consequence
Impacts of Project emissions on ambient air quality. Includes prediction of air quality concentrations for SO_2, NO_2, CO, PM, VOC and TRS.	Low to Moderate (depending on parameter)
Impacts of Project emissions on deposition of acid-forming compounds. Includes modelling of NO_x and SO_2 emissions.	Evaluated in Water Quality, Soils and Terrain, and Terrestrial Vegetation and Wetlands sections
Impacts of Project emissions on concentrations of ground level ozone	Undetermined
Noise from the Project	Negligible

B5.2 IMPACT ASSESSMENT

B5.2.1 Ambient Air Quality Concentrations

The Project, in combination with existing and approved developments in the study area, will result in changes to ambient air quality concentrations as reviewed below for the compounds of interest.

B5.2.1.1 Sulphur Dioxide (SO_2)

The ISC3BE model was used to predict SO_2 concentrations resulting from the Project. The model provides predicted maximum concentrations, areal extent of land above the Alberta Guideline, number of exceedances and the location of the high readings. In comparing the results to historical levels, there has been a substantial decrease in concentrations and emissions. The model results indicate:

- The predicted impacts of hourly SO_2 emissions and concentrations on the air quality are classified as moderate in magnitude, short-term in duration, moderate in frequency, regional in geographic extent and reversible. The environmental consequence of these impacts was rated as low.

- The predicted impacts of daily SO_2 emissions and concentrations on the air quality are classified as moderate in magnitude, short-term in duration, moderate in frequency, local in geographic extent and reversible. The environmental consequence of these impacts was rated as low.
- The predicted impacts of annual SO_2 emissions and concentrations on the air quality are classified as high in magnitude, mid-term in duration, high in frequency, local in geographic extent and reversible. The environmental consequence of these impacts was rated as moderate.

Impacts to the annual SO_2 concentrations were assigned a moderate environmental consequence. The maximum annual concentration plus the areal extent are predicted to be limited to the footprints of the existing or proposed operations. There are no exceedances projected outside of the development areas. Outside of the Suncor and Syncrude lease boundaries, the maximum annual concentrations are predicted to be approximately 20 $\mu g/m^3$ and therefore below the annual Alberta Guideline of 30 $\mu g/m^3$. The concentrations from the Project at Fort McKay are predicted to be between 5 and 10 $\mu g/m^3$, while those at Fort McMurray are predicted to be less than 5 $\mu g/m^3$. Viewed in this context, it is predicted that there would be no exceedances outside of the lease areas and that the concentrations in the rest of the RSA will be low. Hence the environmental risk is considered to be low and, therefore this impact is not significant.

B5.2.1.2 Nitrogen Dioxide (NO_2)

The ISC3BE model was used to predict NO_2 concentrations resulting from the Project Millennium case. The model results indicate:

- The predicted impacts of hourly NO_2 concentrations on the air quality are classified as low in magnitude, short-term in duration, low in frequency, local in geographic extent and reversible. The environmental consequence of these impacts was rated as low.
- The predicted impacts of daily NO_2 concentrations on the air quality are classified as high in magnitude, short-term in duration, moderate in frequency, local in geographic extent and reversible. The environmental consequence of these impacts was rated as moderate.
- The predicted impacts of annual NO_2 concentrations on the air quality are classified as high in magnitude, mid-term in duration, high in frequency, local in geographic extent and reversible. The environmental consequence of these impacts was rated as moderate.

Impacts to the daily and annual NO_2 concentrations were assigned a moderate environmental consequence. The maximum daily concentration plus the areal extent are all within a small area within the existing operations. There are no exceedances projected outside of the development areas. Daily concentrations are predicted to be well below 100 $\mu g/m^3$ at Fort McKay and Fort McMurray. The maximum annual concentration plus the areal extent are also centered in the existing operational area but occupy a larger area. There are no exceedances predicted outside the development areas. Annual concentrations at both Fort McKay and Fort McMurray are predicted to be between 20 and 40 $\mu g/m^3$. Viewed in this context of low concentrations outside the mine pits, the environmental consequence of the NO_2 emissions is rated as being of no significance.

B5.2.1.3 Carbon Monoxide (CO)

The ISC3BE model was used to predict CO concentrations resulting from the Project. The model results indicate:

- The predicted impacts of hourly CO emissions and concentrations on the air quality are classified as low in magnitude, short-term in duration, low in frequency, local in geographic extent and reversible. The environmental consequence of these impacts was rated as low.
- The predicted impacts of 8-hour CO emissions and concentrations on the air quality are classified as low in magnitude, short-term in duration, low in frequency, local in geographic extent and reversible. The environmental consequence of these impacts was rated as low.

B5.2.1.4 Particulate Matter (PM)

The ISC3BE model was used to predict PM concentrations resulting from the Project Millennium case. The model results indicate:

- The predicted impacts of daily PM concentrations on the air quality are classified as moderate in magnitude, short-term in duration, moderate in frequency, local in geographic extent and reversible. The environmental consequence of these impacts was rated as low.
- The predicted impacts of annual PM concentrations on the air quality are classified as low in magnitude, short-term in duration, low in frequency, local in geographic extent and reversible. The environmental consequence of these impacts is negligible.

B5.2.1.5 Volatile Organic Compounds (VOC)

The impacts related to VOC emissions are evaluated under the Human Health section of the EIA (Section F1).

B5.2.1.6 Total Reduced Sulphur (TRS)

The ISC3BE model was used to predict TRS concentrations resulting from the Project. The model results indicate:

- The predicted impacts of hourly TRS concentrations on the air quality are classified as high in magnitude, short-term in duration, moderate in frequency, local in geographic extent and reversible. The environmental consequence of these impacts was rated as moderate.
- The predicted impacts of daily TRS concentrations on the air quality are classified as high in magnitude, short-term in duration, moderate in frequency, regional in geographic extent and reversible. The environmental consequence of these impacts was rated as moderate.

Impacts to the hourly and daily TRS concentrations were assigned a moderate environmental consequence based on the assumption that the TRS emissions will be increasing in proportion to the increasing VOC emissions from the ponds. This modelling assumption overestimates TRS because the TRS emission from the ponds are believed to be biogenic in nature. Therefore, it is more probable that there will be no significant increase in the TRS releases from the existing Baseline rates. Both Suncor and Syncrude have ongoing abatement programs in place. Over the past few years, there has been a decrease in the number of odour complaints from over 275 to less than 20 per year. The annual concentrations of H_2S at Fort McKay and Fort McMurray are predicted to be below the Alberta guideline. In fact, the model using the high emission rates predicts the daily concentration will not exceed the Alberta guideline outside the development areas. Viewed in the context of low concentrations outside the existing operational areas, the potential of no net increase in emission rates, and the decrease of off-site odour complaints, the impact of TRS emissions is not considered to be significant.

B5.2.2 Acid-Forming Compounds (NO_x and SO_2)

The CALPUFF model was used for predicting the PAI resulting from the Project. The CALPUFF model is a good tool for estimating the PAI in the oil sands region as it takes into account the chemical transformations of the emitted SO_2 and NO_x and predicts wet (rain and snow scavenged) and dry (via an effective dry deposition velocity) deposition of SO_2, SO_4^{2-}, NO, NO_2, NO_3^- and HNO_3. A background PAI of 0.1 keq/ha/y has been incorporated into the presented PAI numbers. This value was based on estimates of sulphur and nitrogen and base cation concentrations and depositions in the region surrounding the RSA. Comparisons of emissions and concentrations are discussed below:

- The predicted PAI exceeds the Alberta interim critical loading for sensitive soils (0.25 keq/ha/y) over an area of 861,263 ha (35.5% of the

RSA). The areal extents where the PAI exceeds the critical loadings being considered for less sensitive soils are: 195,695 ha (8.1% of the RSA) above 0.50 keq/ha/y; and 9,598 ha (0.4% of the RSA) above 1.0 keq/ha/y.

- The maximum predicted PAI of 2.13 keq/ha/y occurs in the development area, in the immediate vicinity of the open pit mines.
- The maximum predicted sulphate deposition rate of 1.15 keq/ha/y is predicted to occur in the active plant area.
- The highest predicted nitrate deposition rate of 1.01 keq/ha/y is predicted to occur in the development area, adjacent to the open pit mines.
- The maximum wet and dry deposition rates (including both the sulphate and nitrate species) are 0.78 and 1.81 keq/ha/y, respectively. These maximums occur in the vicinity of the active open pit mines.

No impact predictions and environmental consequences have been established for PAI in the air section as PAI is used as an input into the water quality, soils and terrain, and terrestrial vegetation and wetlands evaluations. These are presented in Sections C3.2, D2.2 and D3.2, respectively.

B5.2.3 Ground Level Ozone

The impact of Project emissions on concentrations of ground level ozone was not evaluated as part of the EIA because of the known inaccuracy of the model (SMOG) previously used for oil sands developments. Suncor is participating in a joint industry and government working group to research and assess ground level ozone issues in the oil sands region. This project includes development of a new modelling framework for ground level ozone in the region. The initial results of this new model are expected by October 1998.

The magnitude of impacts associated with the Project contribution to ground level ozone cannot be determined prior to completion of the new modelling program. Therefore, the environmental consequence is rated as undetermined at this time.

B5.2.4 Noise

Operation of an open pit oil sands mine and associated extraction and upgrading equipment produces noise. The impact of this noise on residents in surrounding communities was assessed with consideration of the location of Fort McKay, the nearest community, and the locations of other operations relative to the Project and to Fort McKay.

The relative distance of the Project from Fort McKay means that contributions to noise levels in Fort McKay from the Project are predicted to be negligible. Current contributions from Suncor operations will be modified once the mining operation on Lease 86/17 is closed down and replaced by Project Millennium operations (which are located further from Fort McKay).

The predicted impact of noise from Project Millennium is classified as negligible in magnitude, high in frequency and of regional geographic extent. The impact ceases upon closure. The relatively large distance from the Project to Fort McKay means the impacts of noise related to the Project are negligible. The environmental consequence was rated as negligible.

B5.3 CUMULATIVE EFFECTS ASSESSMENT

The air emissions from Project Millennium, combined with those from all of the approved and disclosed projects in the CEA region will result in changes in the ambient air quality and in the deposition of acid forming compounds. Compounds of interest are reviewed individually below.

Sulphur Dioxide (SO_2)

The ISC3BE model was used to predict the SO_2 concentrations resulting from the Project and CEA facilities. The predicted cumulative impacts of hourly, daily and annual SO_2 emissions and concentrations are very similar to Project Millennium. The hourly and daily SO_2 concentrations are considered to be reversible, of moderate magnitude, short term in duration, moderate in frequency and regional in geographic extent. The environmental consequence of these impacts is low.

The annual SO_2 concentrations were classified as having a high magnitude, moderate term duration, high frequency, reversible effect and is local in geographic extent. The resulting environmental consequence of these impacts is moderate.

The moderate environmental consequence assigned to the annual SO_2 concentrations was determined on areal extents and maximum concentrations which occur within the development areas of existing operations. There are no exceedances projected outside of the development areas. Outside of the Suncor and Syncrude lease boundaries the maximum annual concentrations are predicted to be below the annual Alberta Guideline of 30 $\mu g/m^3$. Viewed in this context, the environmental risk is considered to be low and, therefore, this impact is not significant.

Nitrogen Dioxide (NO_2)

The ISC3BE model was used to predict NO_2 concentrations resulting from the combined Project and CEA emission sources. The predicted hourly NO_2 concentrations are classified as having impacts on the air quality which are low in magnitude, short term in duration, low in frequency, local in geographic extent and reversible. The environmental consequence of these impacts is low.

The predicted daily NO_2 concentrations were classified as having air quality impacts which are described as high in magnitude, short term in duration, moderate in frequency, local in geographic extent and reversible. The environmental consequence of these impacts is moderate.

Impacts based on the predicted annual NO_2 concentrations are classified as high in magnitude, mid term in duration, high in frequency, local in geographic extent and reversible. The environmental consequence of these impacts is moderate.

Impacts to the daily and annual NO_2 concentrations were assigned a moderate environmental consequence. The maximum daily concentration plus the areal extent are confined to a small area within the existing operations. There are no exceedances projected outside of the development areas. The maximum annual concentration plus the areal extent are also centered in the existing operational area but occupy a larger area. There are no exceedances predicted outside the development areas. Viewed in this context, the environmental consequence of the NO_2 emissions is rated as low and, therefore, this impact is not significant.

Carbon Monoxide (CO)

The hourly and 8-hour CO concentrations resulting from the CEA emission sources were predicted using the ISC3BE dispersion model. The impacts of both the hourly and 8-hour CO concentrations are classified as having impacts that are low in magnitude, short term in duration, low in frequency, local in geographic extent and reversible. The resulting environmental consequence of these impacts is low.

Particulate Matter (PM)

The ISC3BE model was used to predict daily and annual PM concentrations resulting from the CEA emission sources. The predicted impacts of the daily concentrations are classified as moderate in magnitude, short term in duration, moderate in frequency, local in geographic extent and reversible. The predicted impacts of annual PM emissions and concentrations on the air quality are classified as low in magnitude, short term in duration, low in frequency, local in geographic extent and reversible. The environmental consequence of both these sets of impacts is low.

Volatile Organic Components (VOC)

The ISC3BE model was used to predict VOC concentrations resulting from the CEA case. No impact predictions and environmental consequences have been established for VOCs (and the speciated VOCs) in the air section as VOCs are an input into the health section (F1).

Total Reduced Sulphur (TRS)

The ISC3BE model was used to predict TRS concentrations resulting from the CEA case. The major source of TRS was assumed to be the Suncor ponds, with the TRS emissions increasing in proportion to the increase in VOCs. This may result in an overestimate of TRS emissions.

The predicted impacts of hourly TRS concentrations on the air quality are classified as high in magnitude, short term in duration, moderate in frequency, regional in geographic extent and reversible. The environmental consequence of these impacts is moderate.

The predicted impacts of daily TRS concentrations on the air quality are classified as high in magnitude, mid term in duration, high in frequency, local in geographic extent and reversible. The environmental consequence of these impacts is moderate.

Impacts to the hourly and daily TRS concentrations were assigned a moderate environmental consequence based on the assumption that the TRS emissions will be increasing in proportion to the increasing VOC emissions from the ponds. The assumption may have been conservative, as it may be just as likely that there will be no significant increase in the TRS releases from the existing Baseline rates. TRS emissions are principally a concern for causing odours, and both Suncor and Syncrude have ongoing abatement programs in place. Over the past few years, there has been a decrease in the number of odour complaints from over 275 to less than 20 per year. Viewed in the context of low concentrations outside the existing operational areas, the potential of no net increase in emission rates, and the nuisance nature of off-site odours, the environmental consequence of the TRS emissions is rated as low and, therefore, this impact is not significant.

Acid-Forming Compounds

The CALPUFF model was used for predicting the deposition of acid forming compounds (measured as PAI) resulting from the CEA emission sources. The CALPUFF model takes into account the chemical transformations of the emitted SO_2 and NO_x and predicts both wet and dry deposition of SO_2, SO_4^{2-}, NO, NO_2, NO_3^- and HNO_3. Comparisons of emissions and concentrations are discussed below:

- The predicted PAI exceeds the Alberta interim critical loading for sensitive soils (0.25 keq/ha/y) over an area of 1,417,300 ha (58.4% of the RSA). The areal extents where the PAI exceeds the critical loadings being considered for less sensitive soils are: 420,086 ha (17.3% of the RSA) above 0.50 keq/ha/y; and 20,430 ha (0.8% of the RSA) above 1.0 keq/ha/y.
- The maximum predicted PAI of 2.1 keq/ha/y occurs in the development area, in the immediate vicinity of the open pit mines.
- The maximum predicted sulphate deposition rate of 1.13 keq/ha/y is predicted to occur in the active plant area.
- The highest predicted nitrate deposition rate of 1.1 keq/ha/y is predicted to occur in the development area, adjacent to the open pit mines.

No impact predictions and environmental consequences have been established for PAI in the air section as PAI is used as an input into the water quality, soils and terrain, and terrestrial vegetation and wetlands evaluations. These are presented in Sections C3.2, D2.2 and D3.2, respectively.

B5.4 MONITORING

Air quality monitoring programs will include:

- continued routine source monitoring of approved major air emission sources on a continuous basis as well as smaller sources on a more limited basis;
- continued participation in the Air Monitoring System operated by the Wood Buffalo Environmental Association;
- continued participation in the Terrestrial Environmental Effects Monitoring Committee to evaluate changes in vegetation and soils resulting from air emissions; and
- continued participation in the Alberta Oil Sands Community Exposure and Health Effects Assessment Program.

C1 AQUATICS SCOPE OF ASSESSMENT

C1.1 COMPONENT DESCRIPTION

Aquatics has been subdivided into three components including:

- surface hydrology and hydrogeology;
- water quality; and
- fisheries and fish habitat.

There is considerable interdependency among these sub-components, particularly on the local scale. Field work specific to Project Millennium was conducted for surface hydrology, hydrogeology, and fisheries and fish habitat. Additional information related to water quality and fisheries and fish habitat has been collected as part of the ongoing Regional Aquatic Monitoring Program (RAMP). The aquatic models and descriptions used in this EIA build upon established models and previous studies conducted in the area, including EIAs for previous oil sands developments and environmental studies (as listed in Section A1 of the EIA).

C1.2 TERMS OF REFERENCE

The aquatics section of the Project Millennium (the Project) EIA provides information on surface hydrology and hydrogeology, surface water quality and fisheries and fish habitat, as required by the Project Terms of Reference issued on March 4, 1998 (AEP 1998). The final Terms of Reference were defined based on recommended modifications made to a draft submitted by Suncor. Provincial and federal government agencies, regional stakeholders and other interested parties provided Alberta Environmental Protection with suggested modifications to the Project EIA Terms of Reference. This section of the EIA addresses the following:

C1.2.1 Surface Hydrology and Hydrogeology

- Describe the surface hydrology in the Study Area before and after the Project.
- Describe the pre- and post-disturbance watercourse configuration for draws, ephemeral streams and permanent streams which collect and disperse surface water flow.
- Discuss the effects on surface water quantity, including changes in timing, volume and deviation of peak and minimum flows due to physical changes in topography, landscape and drainage patterns caused by the Project.

- Identify temporary and permanent alterations, diversions, withdrawals or disturbances and the resultant impacts under a variety of operating conditions and scenarios, including emergency operating conditions. Discuss the effect of these changes on hydrology (timing, volume, and peak flow rates), including the significance for downstream basins and implications for reclaimed and down-stream vegetation, soil erosion, water quality and habitat quality.
- Discuss how permanent alterations, diversions, disturbances can be used to enhance existing or rebuilt streams to increase the productivity of fish habitat and recreational potential.
- Using the 1:100 year floodplain, discuss the potential for flooding during heavy precipitation events and spring runoff. Discuss the effects of probable maximum flood or probable maximum precipitation events, especially on tailings ponds and containment structures. Discuss the potential effects of ice jams on the Athabasca River flood levels.
- Identify project activities that will result in land disturbance, water diversions or other effects to stream beds and shores in the Study Area. Outline the mitigative measures to be used to reduce impacts to the streams and associated features.
- Discuss implementation of a monitoring program for surface water runoff in order to assess performance of water management systems.
- Describe the groundwater regime in the Study Area, particularly, where groundwater may be impacted by the proposed development.
- Describe the effect the Project might have on the groundwater. Discuss options to manage and protect groundwater systems.
- Discuss the interrelationship of the groundwater to the surface water in the Study Area and the potential for impacts on water quality, quantity, and discharge to streams, Shipyard Lake and the Athabasca River.
- Discuss the potential effects that alterations to the groundwater regime might have on terrestrial and riparian vegetation and surface water.
- Discuss the implications of development activities on the surface and groundwater flows to associated wetlands.
- Discuss the potential impacts on other water users, including wildlife and fisheries, of withdrawing water from the Athabasca River or any other potential surface water source to meet the requirements for the Project. Describe the impact on downstream watercourses. Consider seasonal fluctuations in both the water demand and the river flows.

C1.2.2 Water Quality

- Describe aquatic quality monitoring programs in the Study Area with respect to variables such as polycyclic aromatic hydrocarbons (PAHs), related aromatics, metals and other relevant contaminants. Consider

Describe the water quality in the Study Area before and after project development and operation.

- Discuss the seasonal variations in water quality which may be expected due to natural conditions and with respect to the construction, operation, or reclamation of the Project. Assess any changes between summer and winter conditions and high/low flow conditions.
- Identify components within each stage of the Project that may influence or impact both surface and groundwater quality. Describe the potential impacts of the Project on surface water quality within the Study Area with respect to location, magnitude, duration and extent and significance.
- Predict water quality in the Athabasca River and any other affected watercourses downstream from Suncor. Compare the predicted water quality and existing water quality using, as appropriate, the Alberta Ambient Surface Water Quality Interim Guidelines, relevant United States Environmental Protection Agency Guidelines, and the Canadian Water Quality Guidelines. Consider the recommended procedure for using existing guidelines which is described in the document entitled: "Protocol to Develop Alberta Water Quality Guidelines for Protection of Freshwater Aquatic Life." Discuss the implications of any predicted non-compliance with the surface water quality guidelines. Consider impacts on sediments and compare these with the Canadian Interim Sediment Quality Guidelines.
- Discuss how the assessment addresses the oil sands and other relevant issues identified by the NRBS program.
- Identify and discuss the existence of any watercourses in the Regional Study Area that may be sensitive to acidic deposition, and discuss the potential impacts of the Project on the waterbodies.
- Discuss and describe water quality after reclamation of the site under the proposed reclamation scenario. Discuss the impact that consolidated tailings (CT) water discharges will have to the land, soils and vegetation and receiving watercourses.
- Discuss the impact CT waters will have on Shipyard Lake. Discuss how water quality, both in Shipyard Lake and in the streams feeding into Shipyard Lake will be monitored and managed.
- Describe aquatic quality monitoring programs in the Study Area with respect to variables such as polycyclic aromatic hydrocarbons (PAHs), related aromatics, metals and other relevant contaminants. Consider seasonality and sampling medium (water, sediment).

C1.2.3 Fisheries and Fish Habitat

- Describe the existing fish resource in the waters likely to be impacted by the Project. Identify species composition, distribution, relative abundance, movements and general life history parameters. Discuss the use of the fish resources by existing or potential domestic, sport or commercial fisheries.

- Describe and map, as appropriate, the fish habitat of the Athabasca River, Steepbank River, Shipyard Lake and other tributaries likely to be affected by the Project. Identify critical or sensitive areas such as spawning, rearing, and overwintering habitats. Discuss seasonal habitat use. Describe the existing information base, any deficiencies in information and any studies proposed to evaluate the status of the fish and aquatic resources in the Study Area. Identify key indicator species and provide the rationale and selection criteria used.
- Identify pre-construction, construction, operation and reclamation activities that may potentially affect fish and fish habitat. Describe how stream alterations and changes to substrate conditions, water quality and quantity may affect fish and fish habitat in the Study Area. Consider fish tainting, survival of eggs and fry, chronic or acute health effects and increased stress on fish populations from release of contaminants, sedimentation and habitat changes.
- Discuss the design, construction and operational factors to be incorporated into the Project for the protection of fish resources.
- Identify residual impacts on fish and fish habitat and discuss their significance in the context of local and regional fisheries. Identify plans proposed to offset any loss in the productivity of fish habitats. Indicate how environmental protection plans address applicable provincial and federal policies on fish habitat, including the development of a "No Net Loss" fish habitat objective. Discuss any cooperative mitigation strategies which might be planned with other oil sands and industrial operators.
- Discuss the potential for increased fishing pressures in the Study Area that could arise from increased access, including any implications for the fish resource.

Identify any monitoring programs that will be initiated by Suncor or conducted in cooperation with other oil sands operators to assess regional fisheries impacts and the effectiveness of mitigation strategies to ensure protection of the fisheries resource in the area.

C1.3 KEY ISSUES/KEY QUESTIONS

The key aquatic issues relate to the sub-components that are described above. Key issues have been identified based on a screening process that incorporated previous EIA experience, specific issues related to Project Millennium and public consultation. These key issues have been synthesized in terms of key questions to provide project focus. The complete list of key questions is presented in Table A2-3 of Section A2 of this EIA. The list of key questions related to the aquatics components is duplicated in Table C1-1.

Table C1-1 Summary of Key Questions for Project Millennium Aquatic Components

Question Number	Key Question
Surface Hydrology and Hydrogeology	
SHH-1	What impacts will development and closure of Project Millennium have on groundwater levels (volumes), flow patterns and quality?
SHH-2	What changes to groundwater will development and closure of Project Millennium have that may impact flow and water levels in receiving streams, lakes, ponds and wetlands?
SHH-3	What impacts will development and closure of Project Millennium have on the water balance or open water areas of lakes, ponds, wetlands and streams?
SHH-4	What impacts will development and closure of Project Millennium have on sediment yields from project area river and stream basins, sediment concentrations in receiving streams and the channel regime of receiving streams?
SHH-5	What level of sustainability is expected for Project Millennium closure landscape drainage systems?
Surface Water Quality	
WQ-1	What impacts will operational and reclamation water releases from Project Millennium have on water quality and toxicity guideline attainment in the Athabasca and Steepbank rivers, small streams and Shipyard Lake?
WQ-2	What impacts will operational and reclamation water releases from Project Millennium have on the thermal regime of small streams and Shipyard Lake?
WQ-3	What impacts will muskeg dewatering activities associated with Project Millennium have on dissolved oxygen concentrations in small streams?
WQ-4	What impacts will operational and reclamation waters released from Project Millennium have on levels of polycyclic aromatic hydrocarbons (PAHs) in sediments in the Athabasca River?
WQ-5	What impacts will operational and reclamation water releases from Project Millennium have on toxicity guideline attainment in the end pit lake?
WQ-6	What impacts will acidifying emissions from Project Millennium have on regional waterbodies?
Fisheries and Fish Habitat	
F-1	What impacts will development and closure of Project Millennium have on fish habitat?
F-2	What impacts will development and closure of Project Millennium have on levels of acute or chronic toxicity to fish?
F-3	What impacts will development and closure of Project Millennium have on fish abundance?
F-4	What changes to fish tissue quality will result from development and closure of Project Millennium?
F-5	What type of aquatic ecosystem is expected in Project Millennium reclamation streams, wetlands and the end pit lake?
Cumulative Effects	
CA-1	What impacts to the Athabasca River will result from changes in hydrogeology, surface hydrology, surface water quality, and fisheries and fish habitat associated with Project Millennium and the combined developments?

The key issues related to surface water and hydrogeology include:

- groundwater levels, flow directions and volumes, and quality;
- impact of changing groundwater regimes on receiving streams, lakes, ponds and wetlands;
- maintenance of flow to ensure the viability of Shipyard Lake;
- water conveyance down the Athabasca embankment;

- establishment of flow quantities in Shipyard, Unnamed and McLean creeks during operations and closure;
- hydrologic and hydrogeologic viability of the end pit lake;
- variation of sediment yields during operations and closure with emphasis on receiving streams and the long term viability of constructed wetlands; and
- sustainability of the drainage systems on the closure landscape.

The key issues related to surface water quality include:

- operational and reclamation water quality for the following water bodies:
  - Athabasca River
  - Steepbank River
  - Unnamed Creek
  - McLean Creek
  - Shipyard Lake
- thermal regimes of Shipyard Lake and McLean Creek;
- discharge of muskeg dewatering water, with emphasis on the dissolved oxygen in McLean Creek;
- polycyclic aromatic hydrocarbons (PAHs) in sediments in the Athabasca River;
- water quality and toxicity potential in the end pit lake; and
- impact of potential acid input from air emissions on waterbodies.

The key issues related to fisheries and fish habitat include:

- the risk of acute or chronic toxicity to fish from waters impacted by Project Millennium;
- changes in fish habitat and abundance due to Project Millennium;
- changes in fish tissue quality (e.g., tainting, bioaccumulation) due to waters impacted by Project Millennium; and
- aquatic ecosystems in Project Millennium reclamation streams, wetlands and the end pit lake.

From a cumulative effects viewpoint, the key issues include:

- water quality in the Athabasca River;
- tainting of fish in the Athabasca River;

- PAHs in Athabasca River sediments; and
- changes in regional fish habitat.

In addition to the key issues described above, other aquatic issues are addressed in this EIA. An example is aquifer drawdown which can effect the terrestrial components. Additional issues that relate to aquatics are also addressed in other components such as human health (Section F1), and traditional land use and resource use (Section F3).

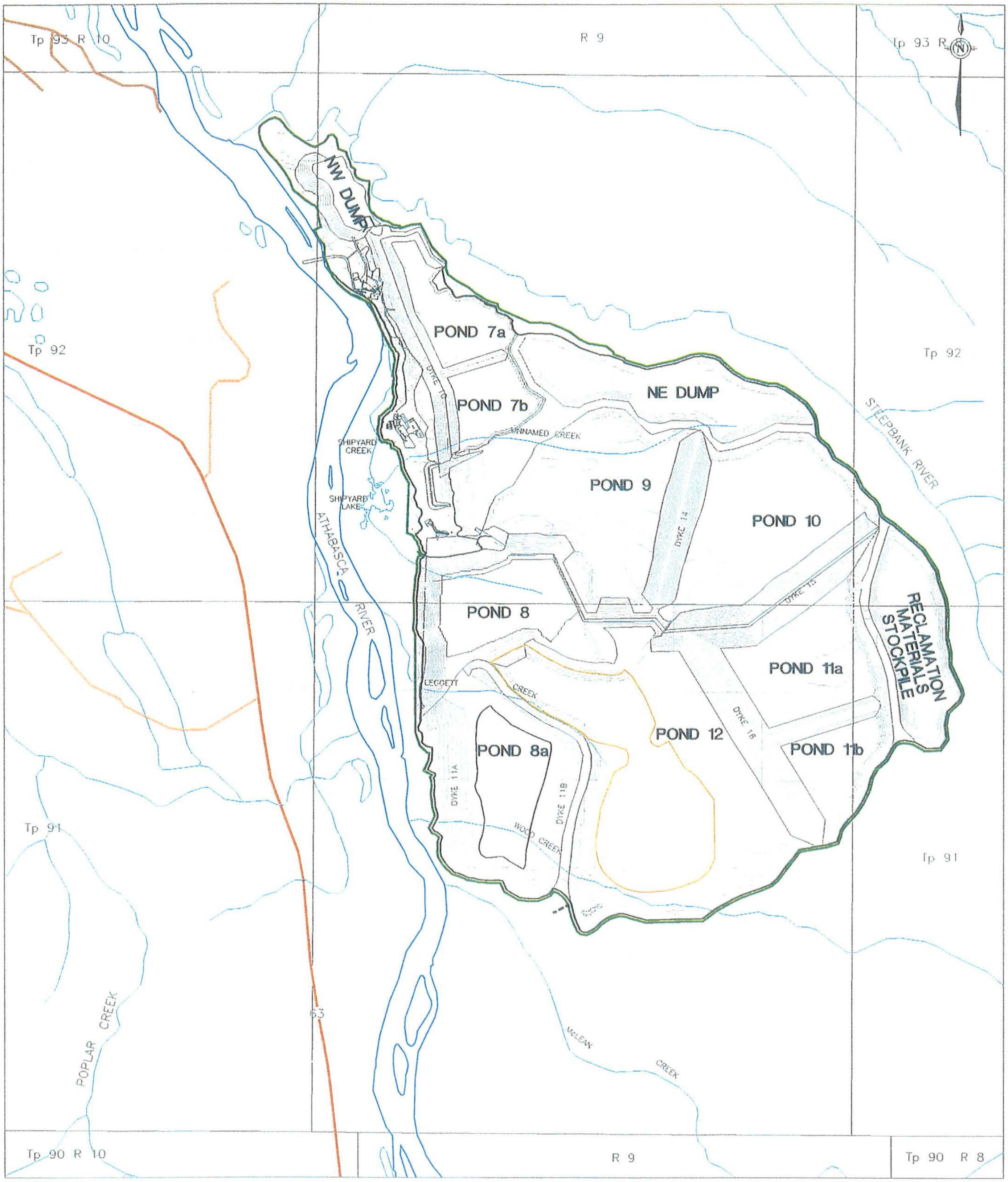
C1.4 RELATIONSHIP WITH THE APPROVED STEEPBANK MINE

Project Millennium represents an extension of the approved Steepbank Mine on the east side of the Athabasca River. Pit 1 of Steepbank will be developed as per the application submitted in April 1996 and approved by the Alberta Energy and Utilities Board (AEUB) on January 22, 1997. Under Project Millennium, development of Pit 2 of Steepbank will be accelerated in time and extended to the east and south. The locations of these pits along with the waste dumps, tailings pond, and infrastructure and mining/extraction facilities are shown on Figure C1-1.

The combined Steepbank/Millennium area on the east bank of the Athabasca River is referred to as the east bank mining area. The assessment of aquatics related to Project Millennium is made by considering the entire east bank mining area with the recognition that a portion of this area has already been approved for development. This approach allows direct comparison of pre-development resources with those for the integrated closure plan for the Steepbank Mine and Project Millennium.

The relationship of the approved Steepbank footprint and the east bank mining area is shown on Figure C1-2.

The area of the east bank mining area is 9,281 hectares. The area of the approved Steepbank Mine is 3,776 hectares. The approved Steepbank Mine footprint is as per drawing number A1E-Y219-103-0-557 in the



LEGEND

EAST BANK MINING AREA

REFERENCE

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

0 1 2 3km

SCALE 1:100,000

SUNCOR ENERGY

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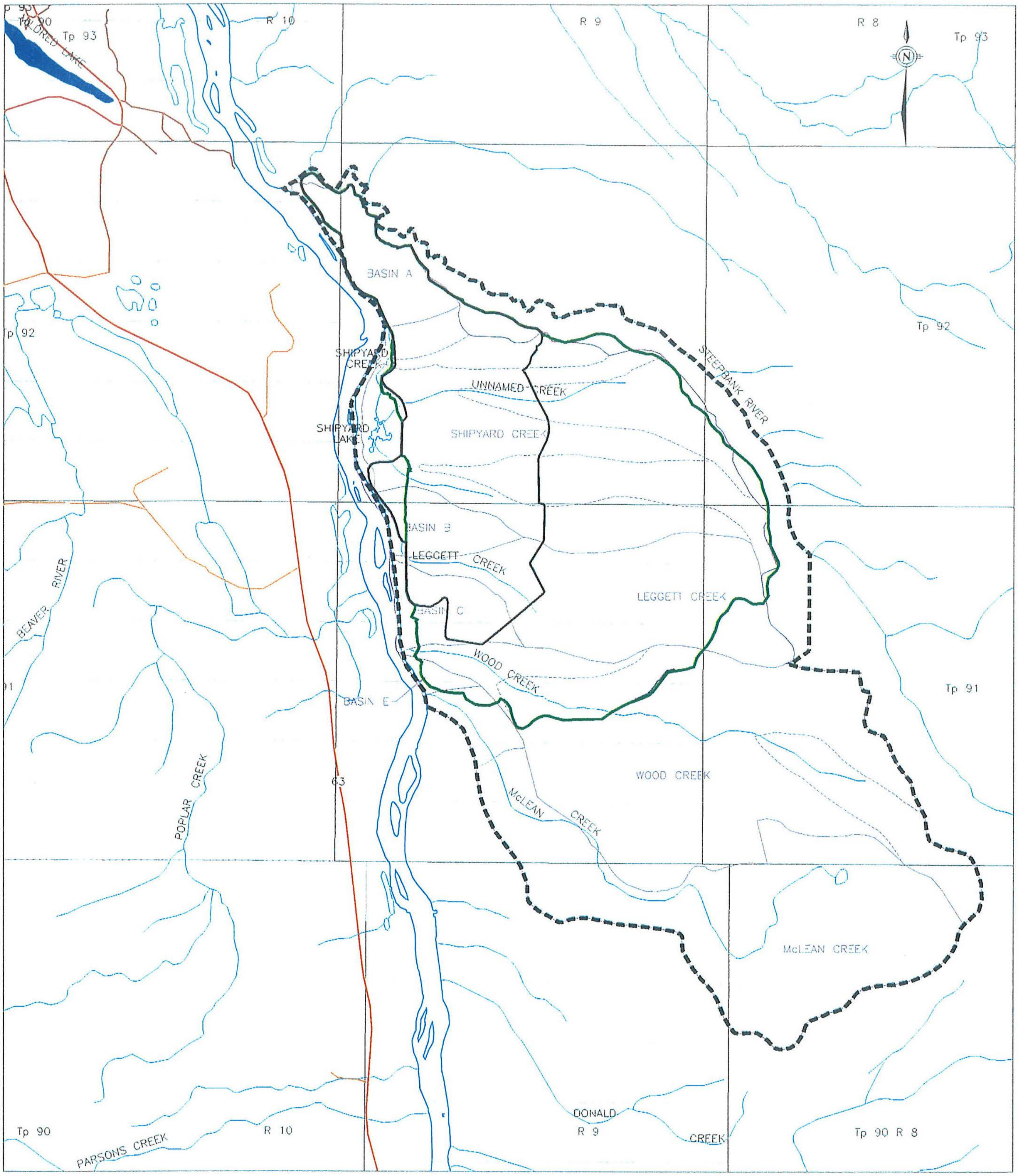
EAST BANK MINING AREA

14 Apr. 1998	Figure C1-1	DRAWN BY: RFM



LEGEND

- EAST BANK MINING AREA
- SUNCOR STEEPBANK MINE
- LOCAL STUDY AREA FOR AQUATICS
- LOCAL DRAINAGE BASIN
- LOCAL DRAINAGE SUB BASIN

REFERENCE

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

0 1 2 3 4 5km
SCALE 1:150,000

SUNCOR ENERGY

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LOCAL STUDY AREA FOR AQUATICS

14 Apr. 1998	Figure C1-2	DRAWN BY: CG

Supplemental Information Response report, which was submitted to AEUB by Suncor on July 29, 1996 (Suncor 1996c).

The majority of the approved Steepbank Mine is within the development zone for the east bank mining area. There is, however, a 137 ha portion of a waste dump for the approved Steepbank Mine to the south of Shipyard Lake which has been eliminated in the Project Millennium design. This change results in less impact on the Athabasca River valley and reduced potential impacts to Shipyard Lake.

Since the mining and closure plans for Pit 2 are being revised as part of the Project Millennium application, the aquatic analyses have been similarly revised. The water quantity and quality associated with the incremental effect of the new Project Millennium area cannot be calculated incrementally from those determined during the Steepbank application due to changes in the flows in the various watercourses and the timing of these changes. As a result, revised groundwater and surface water analyses have been conducted, consistent with the new mine and closure plans.

C1.5 SPATIAL CONSIDERATIONS

As with the other EIA components, the assessment of the impact of Project Millennium on terrestrial resources is made for a local study area (LSA) and for a regional study area (RSA). The local study area consists of watersheds which will be directly impacted by mining and upgrading operations and has been the focus for obtaining the majority of the baseline data. The regional study area recognizes potential water impacts beyond the LSA due to potential acid input from air emissions and downstream effects on the Athabasca River.

C1.5.1 Local Study Area

The aquatics LSA is defined to include the spatial extent of aquatics that may be directly or indirectly affected by Project Millennium. The aquatics LSA is shown on Figure C1-2. The area is defined by the northeastern bank of the Steepbank River to the northeast, the eastern bank of the Athabasca River to the west, and south and east to include the catchment basins of McLean and Wood creeks. Based on the plan for the east bank mine development area, it is unlikely that Donald Creek and the associated sub-basins will be effected by Project Millennium. However, some baseline water quality and fisheries data for this area is documented in the fall fisheries baseline report.

The governing factor in the determination of the southern extent of the LSA is whether there is a likelihood that either the water quality or quantity in a particular water course has the potential of being impacted by Project

Millennium. Diversion of flows in the Wood Creek basin will increase the McLean Creek flows both during operation and after closure. It is unlikely that there will be significant restrictions to McLean Creek that would cause water to spill over into the Donald Creek basin.

The area of the aquatic LSA is 20,495 hectares. The east bank mining area comprises 45% of the LSA.

C1.5.2 Regional Study Area

The regional study area (RSA) is used to study potential regional aquatic impacts due to Project Millennium and for the assessment of cumulative effects due to regional development. The RSA for aquatics has been expanded from that used for the Suncor Steepbank Mine (Suncor 1996b). This expansion accommodates requests from regulatory representatives and stakeholders for inclusion of additional areas that may be affected by air emissions from oil sands developments. These air emissions could have potential acid input (PAI) to lakes within the RSA. The regional study area also includes the Athabasca River as far north as the confluence with the Embarras River. This extension of the RSA has been made to allow assessment of water quality down the Athabasca River until it enters the complex delta system at Lake Athabasca, an area which is difficult to model accurately.

The RSA is used to evaluate the impact of the change in aquatic resources in a regional context. As such, the focus of the regional impacts will be the Athabasca River for both regional and cumulative effects. Effects on tributary streams by other developments are not considered to be within the scope of this EIA.

The location of the RSA is shown on Figure C1-3. The area of the aquatics LSA is 2,433,920 ha, of which 70,803 ha (3%) are open water.

C1.6 TEMPORAL CONSIDERATIONS

Integration of the approved Steepbank Mine area within the assessment for Project Millennium results in pre-development conditions for the aquatic assessment being the pre-clearing state, which dates back to mid-1996. Baseline conditions for the regional study area analysis are based on the appropriate time snapshot. Impact assessments for the Athabasca River also reference upstream water quality as another "background" parameter. Maximum development of the site is anticipated to occur by the year 2033.

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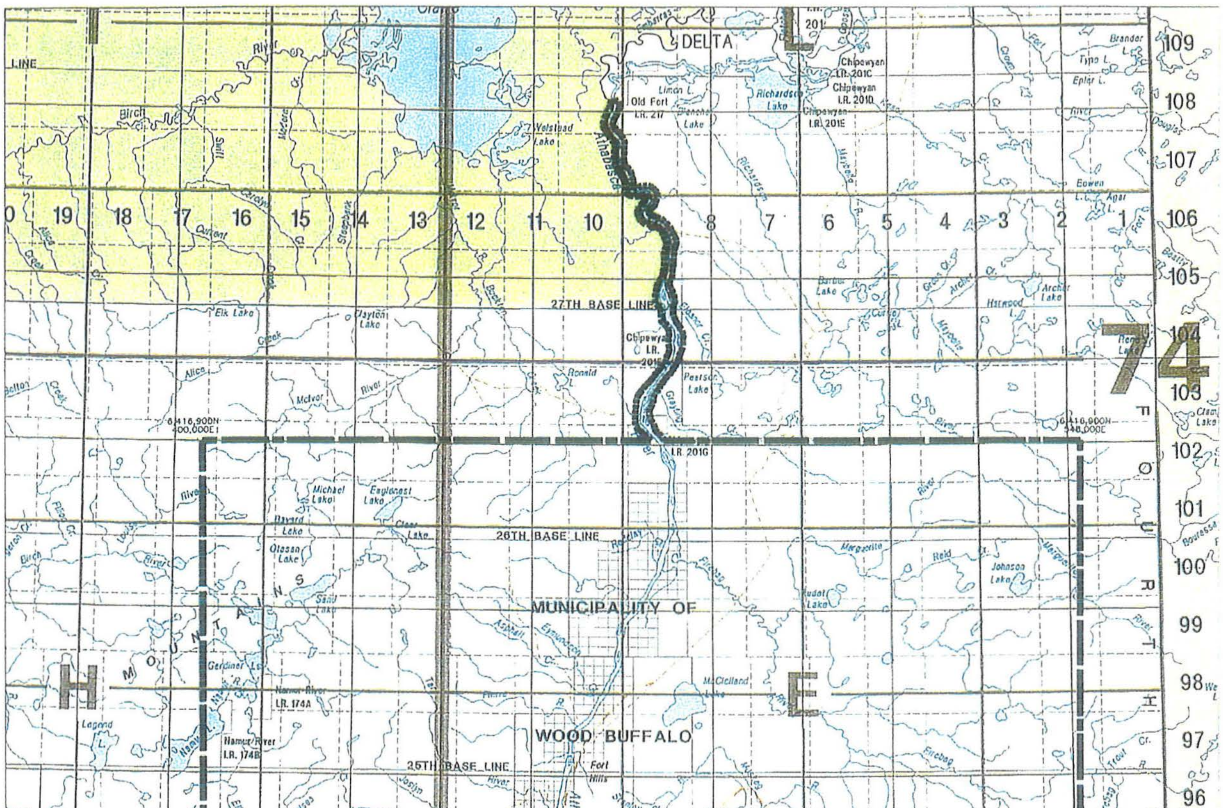

LEGEND

— — — REGIONAL STUDY AREA

0 10 20 30 40 50km

SCALE 1:1,250,000

REFERENCE

SCANNED IMAGE OF ALBERTA ENVIRONMENTAL PROTECTION PROVINCIAL BASE MAP 1997, ORIGINAL SCALE 1:1,000,000

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REGIONAL STUDY AREA FOR AQUATICS

14 Apr. 1998	Figure C1-3	DRAWN BY: RFM

For the purposes of impact analysis, the aquatic conditions are assessed at different time increments (or snapshots) during mine development. These snapshot times are 1997 (pre-development), 2005, 2010/2012, 2015/2018, 2020, 2025, 2030, 2033/2040 and "far future". Analyses of each snapshot enable an assessment of aquatics issues during different phases of project activity to determine when each issue is critical. For example, maintenance of flows to Shipyard Lake may be most critical during the late stages of operation, whereas end pit lake issues may be a final reclamation and closure consideration.

The closure assessment is based on a far-future time frame when ecosystems have become fully established. However, there needs to be a balance between the duration over which wetlands are needed as bioreactors for water quality improvement and the expected lifespan of the wetlands due to geomorphological changes.

C1.7 CONSULTATION AND ASSESSMENT FOCUS

Consultation with stakeholders and regulatory agencies involved with oil sands developments led to identification of specific aquatic key indicator resources (KIRs) that are used to focus the assessment. KIRs are used because environmental systems include a very large number of complex interconnected elements with each element contributing to the functioning as a whole. KIRs are used a surrogates for the entire system and are chosen to represent the range of ecological activity that is being studied.

Selection of KIRs is based on a process defined in Section A2.2 of this EIA. KIRs for the aquatics component of the Project Millennium EIA include a variety of fish species ranging from sport fish to forage fish that inhabit the smaller streams. These KIRs were chosen based on aquatic life appropriate for the area, with emphasis on those that are considered most valuable to the nearby communities, or those which have been identified in previous documents such as the integrated resource plan for the area (AEP 1996a). Part of the selection process includes consideration of ecological importance and vulnerability, resource use value and monitoring value.

Traditional knowledge of the historic use of aquatic resources and the change in this usage over time is integrated into the impact assessment. Primary issues relate to the impact of oil sands development on fish abundance and quality in the Athabasca River. The integration of traditional knowledge into the ongoing aquatic monitoring and in scientific research on fish health and tainting is described in the impact assessment.

C1.8 ASSESSMENT METHODOLOGY

A schematic depiction of the data analysis and assessment processes for the aquatics components is shown in Figure C1-4. Much of the assessment process is concentrated in the LSA, with items such as impacts on the Athabasca River and potential acid input on lakes and other waterbodies being assessed on a regional and cumulative basis. The outputs from the LSA analyses (stream flows, water quality) are used as inputs (with others such as plant site wastewater treatment system effluent) for the RSA analysis of the Athabasca River.

C1.8.1 Local Study Area Methodology

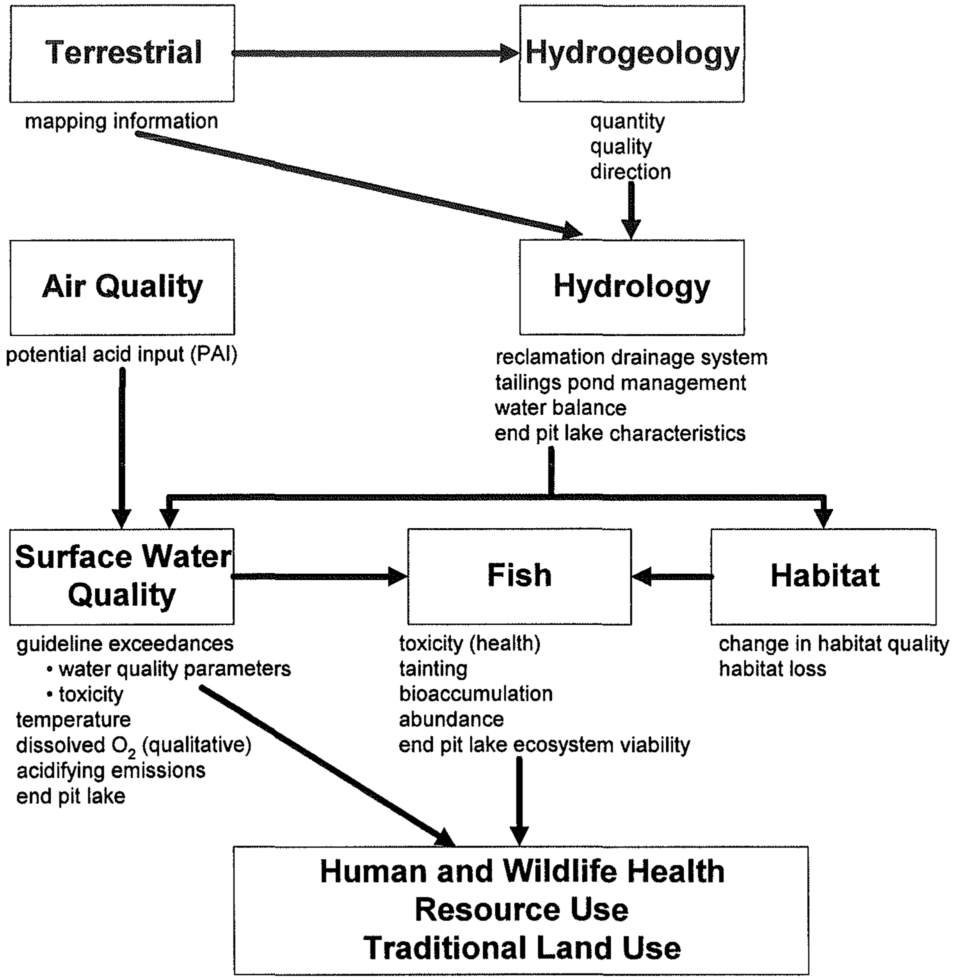
The data used for the assessment of the aquatics components is based on information obtained during field work conducted as part of the Steepbank and Project Millennium EIAs as well as data and analysis from the terrestrial components. The physical building blocks for the analysis of the aquatic impacts due to Project Millennium are the hydrogeology and surface hydrology. Additional information from the terrestrial components (soil and vegetation mapping) and the air quality component (potential acid input modelling) is also used. In addition, baseline data on water quality, fish habitat, fish abundance and fish health has been obtained as part of the Steepbank and Project Millennium EIAs, as well as the ongoing regional aquatic monitoring program (RAMP).

Actual and predicted surface water and groundwater flows are combined with other baseline information to provide input into the predictive modelling for water quality, aquatic ecosystem viability and potential changes in fish habitat. Water quality is evaluated in terms of comparison to guidelines and evaluating the toxicity of a waterbody. Changes in water quality, fisheries and fish habitat can potentially impact other components such as human health (Section F1), and traditional land use and resource use (Section F3).

C1.8.1.1 Field Observations and Data

Data for the aquatic LSA is primarily based on the results of field work and laboratory analysis completed during the Steepbank and Project Millennium

Figure C1-4 Aquatics Assessment Methodology



EIAs and the RAMP program. The recent Project Millennium and RAMP field observations, sampling and analysis included:

- stream gauges and monitoring on Unnamed, Leggett, Wood and McLean creeks;
- hydrologic monitoring of Shipyard Lake;
- logging of boreholes, installation of groundwater monitoring wells and hydrogeologic testing at these well locations;
- fish inventory and habitat mapping of Unnamed, Creek Two, Leggett, Wood, McLean and Donald creeks, Shipyard Lake, and the Steepbank and Athabasca rivers;
- water quality sampling and analysis from locations on Leggett, Wood, McLean and Shipyard creeks, Shipyard Lake, and the Steepbank and Athabasca rivers;
- sampling for PAHs in sediments in the Athabasca River; and
- mapping of wetlands vegetation in Shipyard Lake.

Terrestrial field information on vegetation and terrain types (e.g., wetlands, sloping ground) is also used to develop infiltration and runoff characteristics as a basic input into the hydrologic and hydrogeologic analyses.

This data is described in detail in the key reference reports which accompany this EIA. Specifically, the key reference reports for the aquatics component include:

- Suncor Project Millennium - 1997 Fall Fisheries Investigations (Golder 1998j);
- 1997 Synthesis of Environmental Information on Consolidated/ Composite Tails (CT) (Golder 1998a);
- Project Millennium Conceptual Plan for "No Net Loss" of Fish Habitat (Golder 1998i);
- Winter Aquatics Surveys - Steepbank River, Shipyard Lake, and Leases 19, 25 and 29 (Golder 1997m);
- Oil Sands Regional Aquatics Monitoring Program: 1997 Report (Golder 1998h);
- Hydrogeology Baseline for Project Millennium (Klohn-Crippen 1998a); and
- Hydrology Baseline for Project Millennium (Klohn-Crippen 1998b).

C1.8.1.2 Impact Analyses

The analyses for the surface hydrology and hydrogeology components is based on predictive modelling of the water flows in terms of sources (e.g., rainfall runoff, muskeg dewatering, overburden dewatering, reclamation water flows) at a number of discrete time "snapshots". The flows in the different outlets from the Project Millennium area change as the mine operation advances. The implications of these flow changes on the hydraulic performance of the outlets (typically creeks such as Unnamed and McLean creeks), sedimentation and on specific aquatic habitats such as Shipyard Lake are evaluated. Hydrologic impacts on the Athabasca and Steepbank rivers are also evaluated.

Water quality analysis is based on the flow quantities, the flow sources and the estimated quality of each of the flow sources. The estimated quality of each source is based on laboratory analysis of field samples, data obtained from monitoring of recent mining activities (e.g., muskeg mine water quality) and ongoing research information gained for specific water such as CT reclamation drainage. Water quality analysis within the LSA is concentrated on:

- the small streams within the LSA;
- Shipyard Lake;
- the Steepbank River within the LSA; and
- closure drainage, including that from the end-pit lake.

Different water quality models are used for each of these different types of waterbodies. These models are described in detail in Section C3.2.

The assessment of fish health (in terms of acute and chronic effects) is made in terms of the predicted water quality and links to published fish health studies. In addition to the existing data base, an extensive study is currently underway to further the understanding of the effects of CT reclamation waters on fish health. This study will also provide greater information on fish tissue quality including research on fish tainting.

Habitat impacts are assessed based on quantity and quality. Geographic Information System (GIS) methods are used to evaluate habitat area changes. Habitat quality assessment includes an evaluation of the changes of factors such as water temperature, water quality, and flow quantities on the KIRs. A "No Net Loss" Plan (Golder 1998i) has been developed in parallel to this EIA to develop mitigative measures to prevent and compensate for habitat impacts.

C1.8.2 Regional Study Area Methodology

The assessment of impacts within the regional study area is focused on two primary key issues within the aquatics RSA:

- water quality and habitat in the Athabasca River; and
- acidification of lakes and streams due to potential acid inputs from the air emissions.

Project Millennium does not include an application to increase the current allotment of water to be taken from, or process water to be returned to the Athabasca River. Although changes in the hydrologic characteristics of the development and closure areas may result in a variation in the quantity of runoff from the RSA, the impact of Project Millennium on the Athabasca River flow quantity will be relatively small and thus the most significant potential impact to the Athabasca River within the RSA is due to a change in the water quality inputs to the river from the full Suncor operation. On a cumulative basis, water quality inputs from existing, approved and planned projects (See Table A2-11 and Figure A2-6 in Section A2 of this EIA) are evaluated for the Athabasca River. Since Project Millennium potentially impacts the Athabasca River and not other systems such as the Muskeg River, only Athabasca River issues are assessed in this CEA.

The issue of acidification is addressed through consideration of deposition of PAI from the air pathway. The acid deposition quantity is assessed in terms of the natural capability of the waterbody to buffer this input in using methods currently outlined in the scientific literature. It is recognized that there are seasonal effects which should be considered.

C2 SURFACE HYDROLOGY AND HYDROGEOLOGY

C2.1 BASELINE/ENVIRONMENTAL SETTING

Suncor's Project Millennium comprises an extension of the Steepbank Mine presently being developed on the east bank of the Athabasca River. This section presents a summary of the surface hydrology and hydrogeology pre-development information for the Project. The data has been summarized from the detailed hydrologic and hydrogeologic baseline studies (Hydrogeology Baseline for Project Millennium, Klohn-Crippen 1998a, Hydrology Baseline for Project Millennium, Klohn-Crippen 1998b).

C2.1.1 Regional Setting

The Regional Study Area (RSA) encompasses approximately 2,433,940 ha and is shown in Figure C1-3. This region encompasses the hydrologic and hydrogeologic basins in the oil sands region near Fort McMurray. The regional data provides a basis for establishing conditions and trends against which the impacts of the proposed project including the proposed east bank mine area will be assessed.

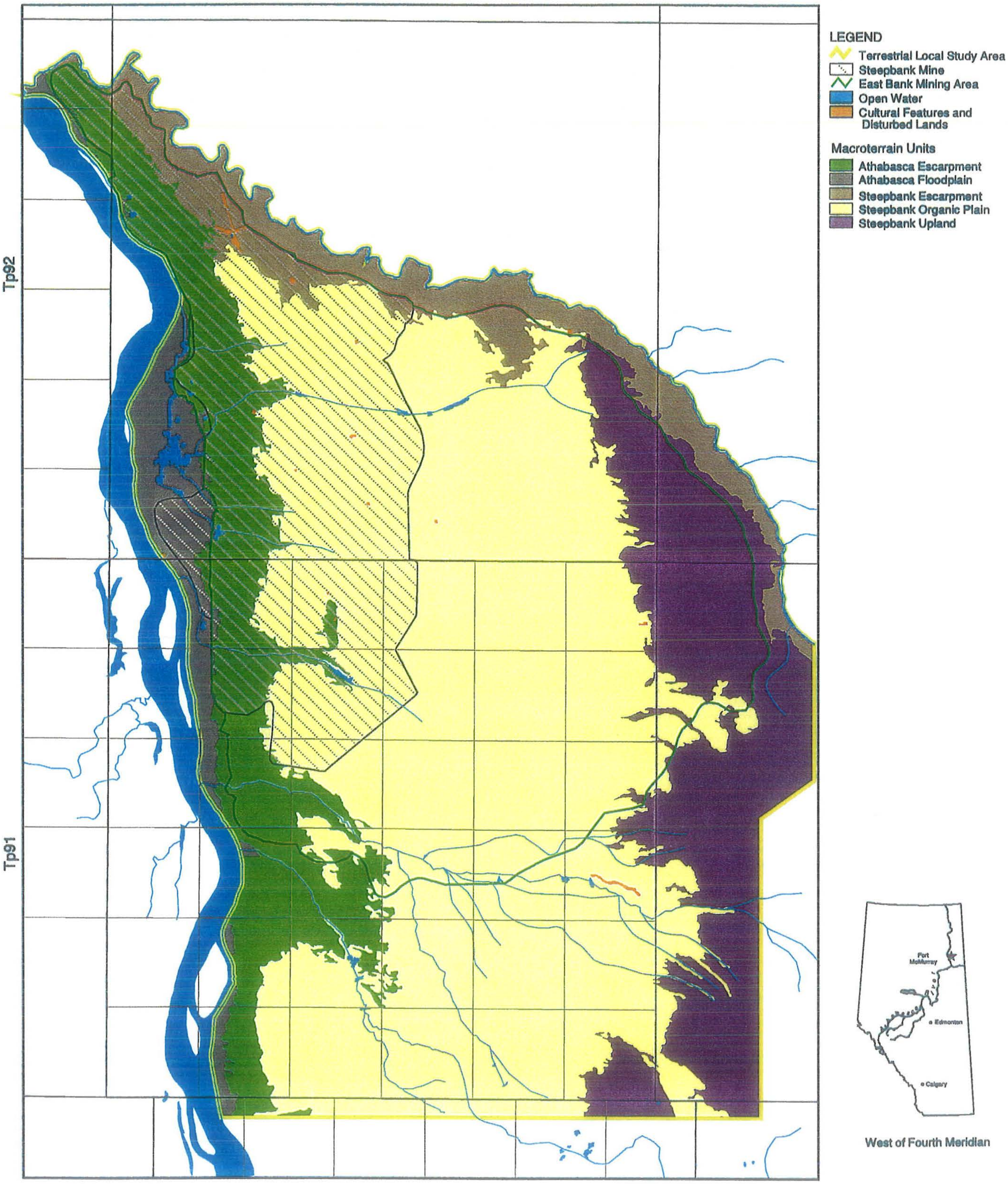
C2.1.2 Local Setting

The LSA is approximately triangular in shape with the apex to the north as shown in Figure C2.1-1. It is bounded by the Athabasca River on the west, Steepbank River on the northeast and the McLean Creek drainage basin on the south. The apex is formed by the confluence of the Steepbank and Athabasca rivers.

Physiographically, the area is divided into Floodplain, Athabasca and Steepbank Escarpment, Organic Plain and Upland as shown in Figure C2.1-1.

The Uplands and Organic Plain slope downward from east to west towards the Athabasca River from an elevation of about 425 masl in the east to the top of the Athabasca Escarpment at about elevation 320 masl (metres above sea level). The slope in the Organic Plain is about 0.7%.

The Athabasca River flows from south to north and has eroded through the surficial soils and bedrock to the current floodplain at an elevation of about 235 to 240 masl. The reach of the Athabasca River bordering the east bank mining area is about 14 km. The banks form the Athabasca Escarpment with a total height of about 80 m. The average slope of the Athabasca Escarpment is about 8% with local slopes at the toe of 20 to 40%.



SOURCES: Suncor
Golder
Klohn-Crippen
CAN-AG
The Forestry Corp

Map Projection: UTM 12
Datum: NAD 83

SUNCOR ENERGY

Project Millennium

LOCAL STUDY AREA
MACROTERRAIN CLASSIFICATION

13 Apr. 1998	Figure C2.1-1	PRODUCED BY: JS REVIEWED BY:

/data14/suncor/local/8700/8740/arcview/lsa_macro.apr

The Steepbank River flows from southeast to northwest through the Upland and Organic Plain in the Project area. The reach of Steepbank River bordering the east bank mining area extends approximately 35 km.

The Steepbank Escarpment is approximately 80 m high throughout this reach. From the confluence of the Athabasca to about 6 km upstream, the escarpment slopes are locally very steep with gradients of 60% or more. Upstream the escarpment slopes flatten to about 18%.

The dominant terrain in the LSA is Organic Plain composed of fen and bog soils. These soils are highly absorbent, poorly drained and characterized by a high water table. The fen soils average 0.8 to 1.5 m in thickness and are underlain by aeolian sands, glacio-fluvial sands and gravels, and glacio-lacustrine sand silts and clays. Details of the surficial soils and terrain are provided in Section D2.

Vegetation in the LSA consists of mixed forest in the escarpment, upland and flood plain areas and muskeg in the Organic Plain. Details on the Project area vegetation are provided in Section D3.

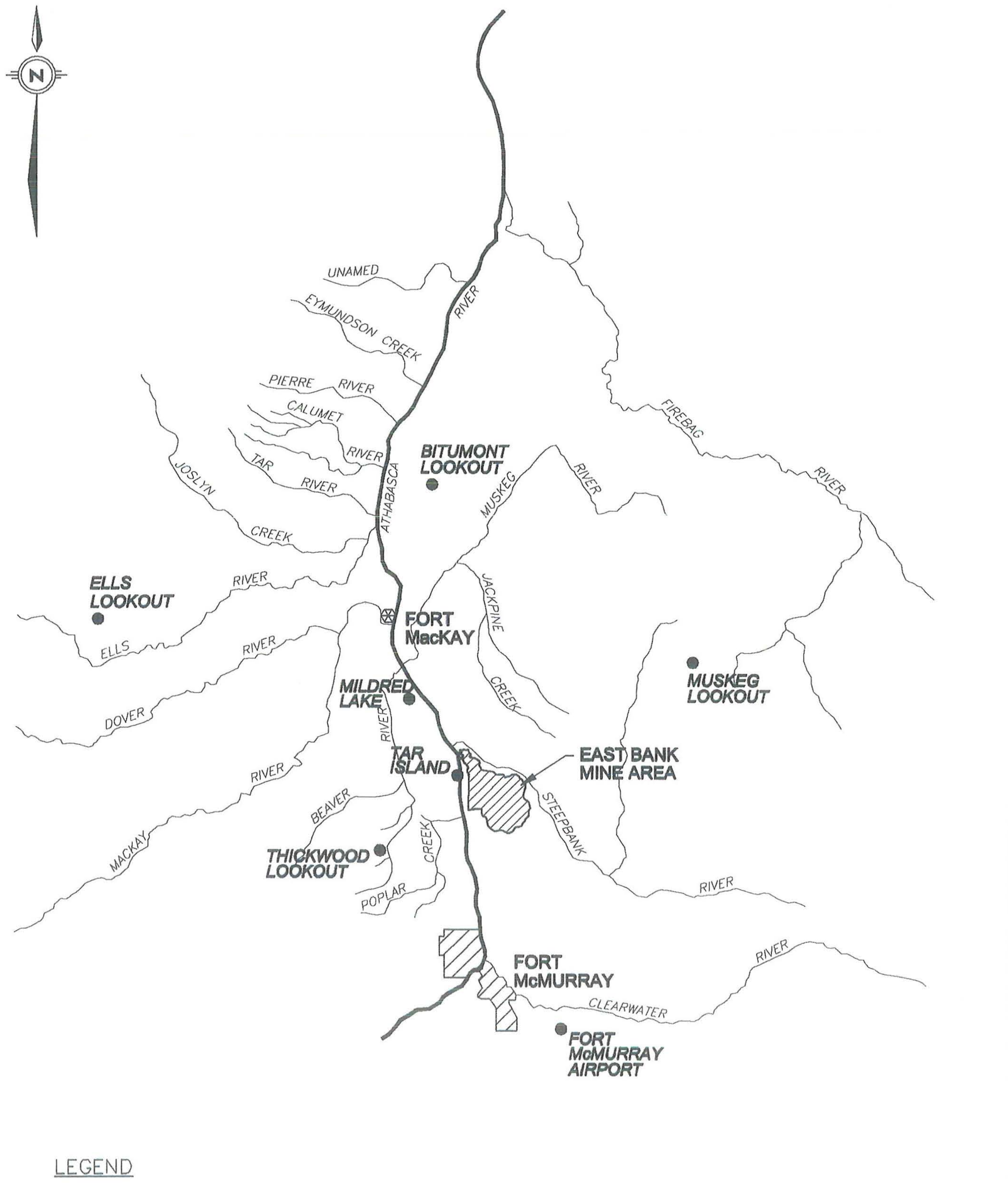
C2.1.3 Climate

The climate in the Athabasca Oil Sands is characterized by long cold winters and short cool summers. Mean daily temperatures at Fort McMurray in January average about -20°C while July temperatures average 17°C. The mean annual temperature at this location is 0.2°C. There are an average of 84 frost-free days per year.

Atmospheric data with a length of record suitable for statistical analysis is available primarily from the Atmospheric Environment Service (AES) of Environment Canada and the Alberta Forest Service monitoring stations listed in Table C2.1-1 and shown in Figure C2.1-2. Additional information was gathered from various shorter term stations.

Table C2.1-1 Long-Term Precipitation Monitoring Stations

Station	Location	Period of Record	Type of Record	Elevation (masl)
Bitumont Lookout	57E22'N 111E32'W	1962-1995	Seasonal	349
Ells Lookout	57E11'N 112E20'W	1961-1995	Seasonal	610
Fort McMurray Airport	56E39'N 111E13'W	1908-1923 1924-1997	Partial Annual	369
Mildred Lake	57E05'N 111E35'W	1973-1982 1996-1997	Annual	310
Muskeg Lookout	57E08'N 110E54'W	1959-1995	Seasonal	652
Tar Island	56E 59'N 111E 28'W	1970-1984	Annual	346
Thickwood Lookout	56E53'N 111E39'W	1957-1995	Seasonal	604



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CLIMATE STATIONS IN VICINITY OF LOCAL STUDY AREA

APRIL 1998	FIGURE C2.1–2	DRAWN BY: C.L.F.

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Precipitation (rainfall and snowfall) estimates were derived for the local study area as described in Klohn-Crippen 1998b.

Annual Precipitation (rainfall and snowfall) estimates were derived for the local study area using regression techniques for data from Mildred Lake, Tar Island and Fort McMurray as described in detail in Klohn-Crippen 1998b. Figure C2.1-3 shows the mean monthly precipitation for the local study area.

Annual Precipitation extremes were determined by a frequency analysis using the Gumbel distribution for the 1 in 100 year dry year through the 1 in 100 year wet year.

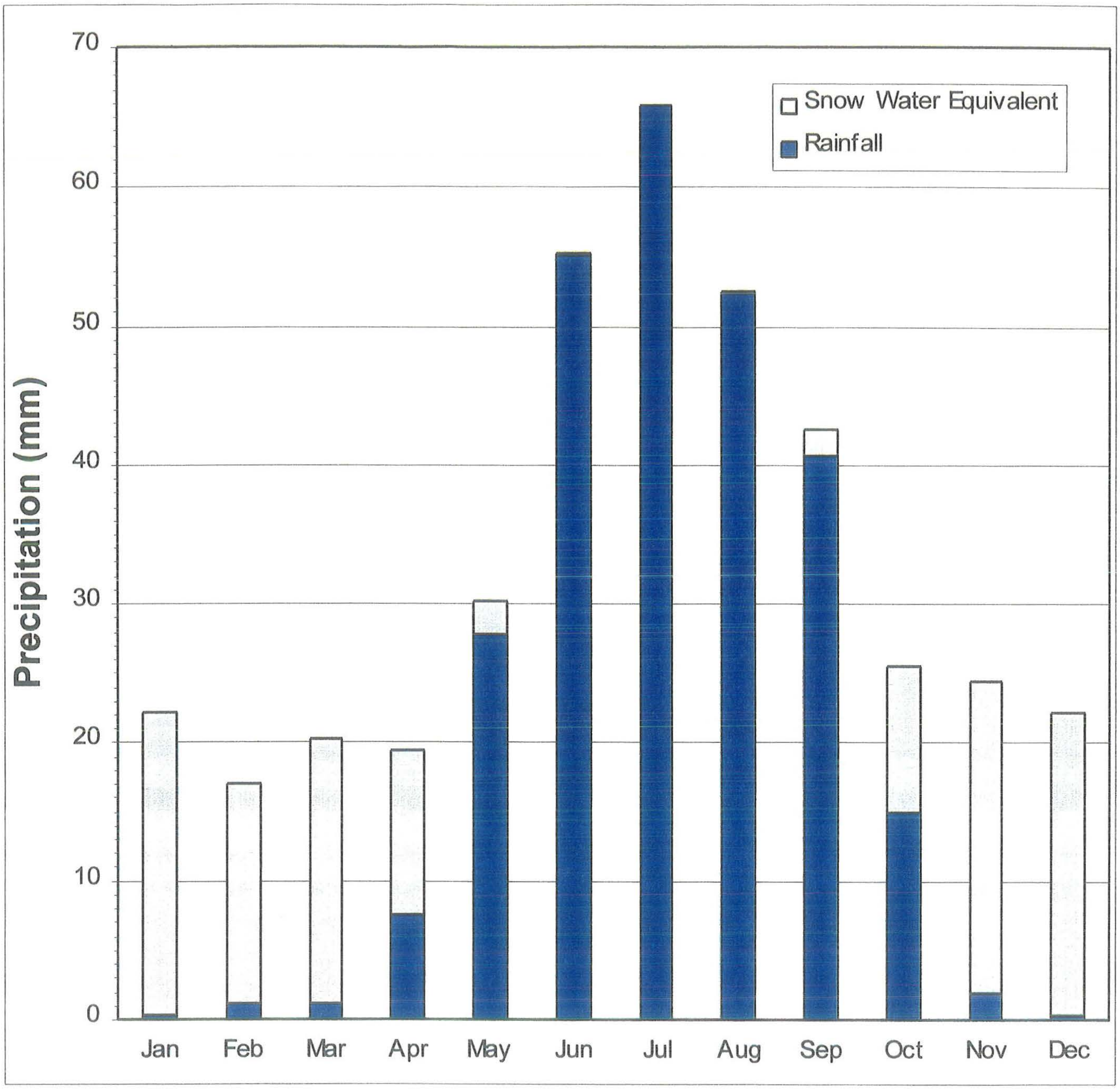
Rainfall-intensity-duration-frequency analysis was performed by AES on data from the airport at Fort McMurray from 1966 through 1990. An estimate for the LSA was derived from this data. Evaporation and Evaportranspiration parameters were derived by Alberta Environmental Protection for the period 1972 to 1994. These data are considered to be representative of the study area.

C2.1.4 Hydrology

Major watercourses in the LSA are the Athabasca and the Steepbank rivers. The Steepbank River is the major tributary to the Athabasca River in the east bank mining area. Smaller watercourses include Unnamed Creek and Creek 2, both of which drain to Shipyard Lake as well as Shipyard Creek (which flows out of Shipyard Lake), Leggett Creek, Wood Creek and McLean Creek. All these creeks drain to Athabasca River. Pre-development drainage patterns are shown in Figure C2.1-4. The drainage areas for these water courses are shown in Table C2.1-2.

Table C2.1-2 Local Basin Drainage Areas (km^2)

Node	Area (km^2)
Athabasca River	133,000
Steepbank River	1,320
Shipyard Lake	42.9
Shipyard Creek	48.4
Unnamed Creek	8.7
Creek Two	9.5
Leggett Creek	23.0
Wood Creek	56.5
McLean Creek	43.4
Athabasca A	6.6
Athabasca B	6.0
Athabasca C	5.7



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ESTIMATED PRECIPITATION FOR LOCAL STUDY AREA

APRIL 98	FIGURE C2.1-3	DRAWN BY: C.L.F.

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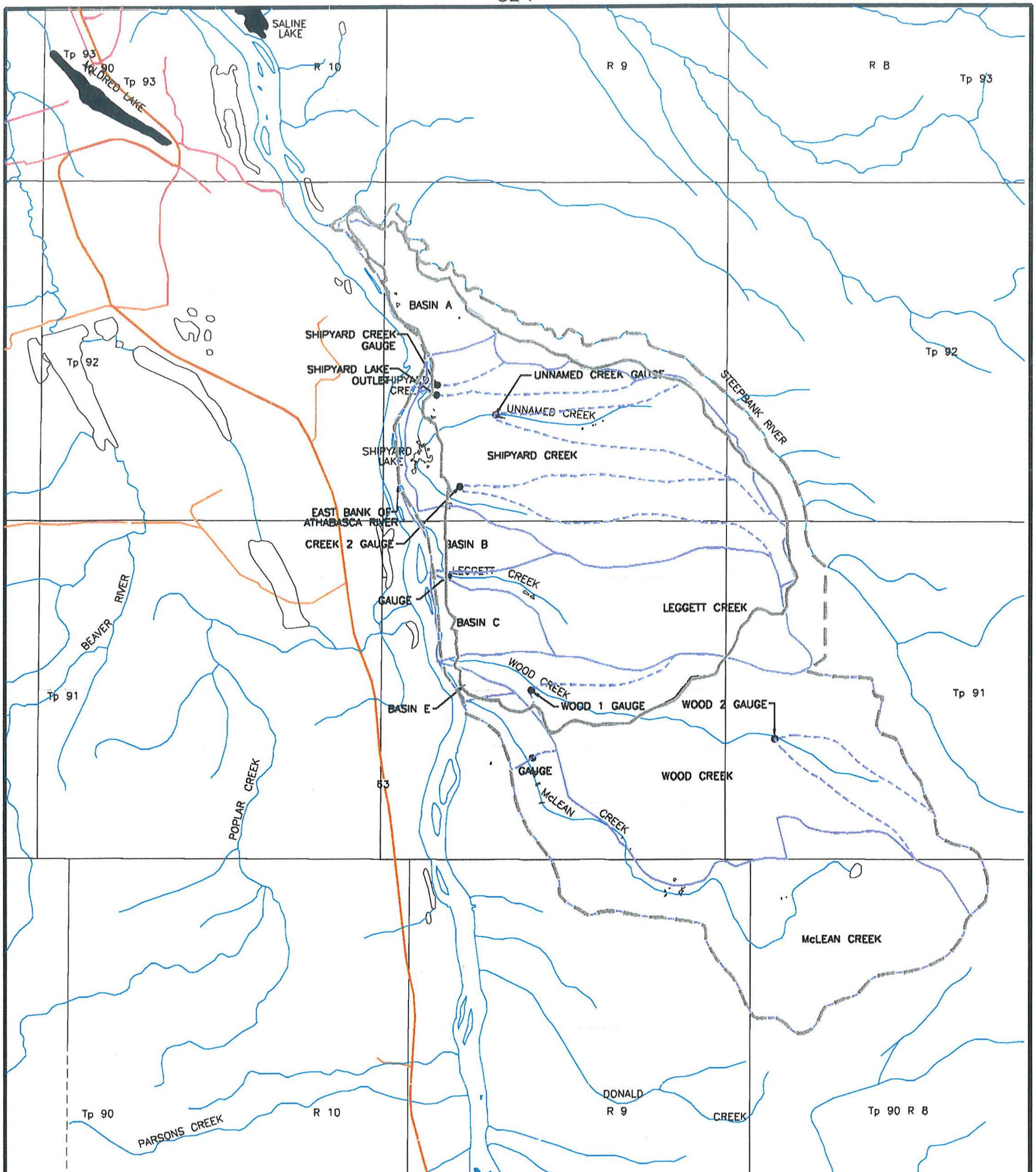

LEGEND

- MINE DEVELOPMENT AREA
- LOCAL DRAINAGE BASIN
- LOCAL DRAINAGE SUB BASIN
- LOCAL BASIN GAUGE
- LOCAL STUDY AREA FOR HYDROLOGY, HYDROGEOLOGY, WATER QUALITY AND AQUATICS

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

1:150,000 0 1.5 3km

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DRAINAGE BASINS IN LOCAL STUDY AREA

APRIL 1998	FIGURE C2.1-4	DRAWN BY: RFM

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About 70% of the catchment area of the smaller watercourses in the east bank mining area is in the Organic Plain. Within this area the water courses are poorly defined with much of the drainage through fens and bogs 50 to over 500 m in width with no discernible channel. The watercourses have eroded steep walled channels through the surface soils and bedrock at the Athabasca Escarpment. Unnamed Creek, Creek 2 and Leggett Creek have their drainage basins entirely within the proposed development area. Wood Creek has about 17% of its drainage in the development area, while McLean Creek has about 1% of the drainage area within the development area.

There is one large, permanent wetland known as Shipyard Lake within the study area. It is located on the Athabasca River floodplain approximately 6 km upstream (south) of the Steepbank River confluence with the Athabasca River. As noted above, tributaries of Shipyard Lake include Unnamed Creek and Creek 2. These two basins account for approximately 40% of the inflow to Shipyard Lake.

The four small basins designated as Athabasca A through C have no defined watercourses and appear to discharge run-off directly to the Athabasca River through overland flow or small ephemeral streams.

C2.1.5 Streamflow Characteristics

Streamflow estimates have been developed based on a regional analysis of records of streams with similar basin characteristics. The following tables provide flows for the study area basins:

- Estimated Annual Runoff - Table C2.1-3;
- Baseline Maximum Mean Daily Flows - Table C2.1-4; and
- Baseline Minimum Mean Daily Flows - Table C2.1-5.

C2.1.5.1 Athabasca River

The Athabasca River is largely unregulated except for the outflows from Lesser Slave Lake and Paddle River Dam. Flows at Lesser Slave Lake and Paddle River Dam represent approximately 6% of the flow in the Athabasca River at the study area.

Flows have been recorded continuously upstream of the study area at Fort McMurray since 1957. There is only about a 0.5% difference in catchment area between the study area and the gauging station at Fort McMurray. Therefore, flow data for Fort McMurray are considered to be representative of flows at the Project location.

The average flow at Fort McMurray is 655 m^3/s, while the maximum and minimum recorded mean daily flows are 4,700 m^3/s and 89 m^3/s, respectively. The maximum recorded instantaneous flow is 4,790 m^3/s. Peak flows are typically experienced at Fort McMurray during the month of July.

Table C2.1-3 Estimated Annual Runoff

Watercourse or Basin	Average Annual Discharge (L/s)		
	1 in 100 dry year	Average Year	1 in 100 wet year
Athabasca River	405,000	655,000	945,000
Steepbank River	1,200	6,000	10,800
Shipyard Creek	3	190	380
Unnamed Creek	0	142	355
Leggett Creek	2	66	163
Wood Creek	7	197	486
McLean Creek	5	130	321
Athabasca A	0	28	72
Athabasca B	0	19	62
Athabasca C	0	22	57

Table C2.1-4 Baseline Maximum Mean Daily Flows (m^3/s)

Water Course	Return Interval			
	5 Years	10 Years	50 Years	100 Years
Athabasca River	3,240	3,780	4,990	5,510
Steepbank River	55	72	112	131
Shipyard Lake	2.6	3.3	4.7	5.2
Shipyard Creek	2.8	3.6	5.1	5.8
Unnamed Creek	0.7	0.9	1.4	1.5
Leggett Creek	1.6	2.0	2.9	3.2
Wood Creek	3.2	4.0	5.8	6.5
McLean Creek	2.6	3.3	4.7	5.3
Athabasca A	0.6	0.8	1.1	1.2
Athabasca B	0.6	0.7	1.0	1.2
Athabasca C	0.5	0.7	1.0	1.1

Table C2.1-5 Baseline Minimum Mean Daily Flows (m^3/s)

Node	Return Interval			
	5 Years	10 Years	50 Years	100 Years
Athabasca River	114,000	102,000	83,500	76,500
Steepbank River	190	135	31	0
Shipyard Lake	0	0	0	0
Shipyard Creek	0	0	0	0
Unnamed Creek	0	0	0	0
Leggett Creek	0	0	0	0
Wood Creek	0	0	0	0
McLean Creek	0	0	0	0
Athabasca A	0	0	0	0
Athabasca B	0	0	0	0
Athabasca C	0	0	0	0

C2.1.5.2 Steepbank River

The average streamflow in the Steepbank River at the WSC gauging station near its confluence with the Athabasca River is approximately 6.0 m^3/s, or about 1% of the average flow in the Athabasca River. The maximum recorded mean daily flow is 81.0 m^3/s while the maximum instantaneous flow was 92.0 m^3/s.

C2.1.5.3 Smaller Watercourses

Stream flow has been monitored in the east bank mine area since 1996 at Unnamed Creek, Creek Two, and Shipyard Creek. Monitoring at Wood Creek (2 locations), Leggett Creek and McLean Creek has been monitored since 1997. This length of record is insufficient for inclusion in a regional analysis.

Flows have been estimated for these watercourses using a regional area discharge relationship as discussed in Klohn-Crippen 1998a.

C2.1.5.4 Shipyard Lake

Shipyard Lake receives its water from two sources; the Athabasca River and the creeks draining the local Shipyard Lake basin. Water level is naturally controlled by a beaver dam complex at the outlet. The lake level for the period of record is about 237.2 masl and is relatively constant.

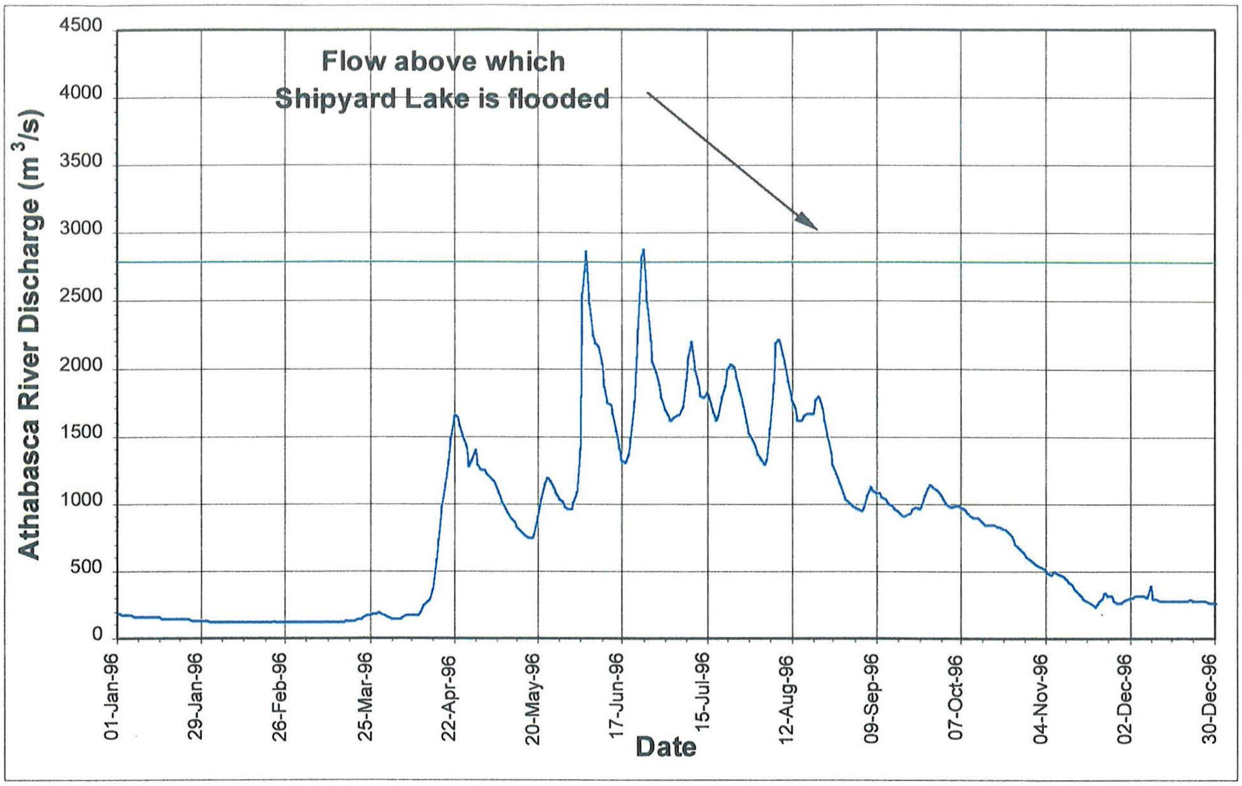
During periods when the Athabasca River is in flood, water can flow into Shipyard Lake from the Athabasca River across a divide to the south near Inglis Island. For the balance of the year, inflow is from creeks draining the organic plain and areas upslope of the Athabasca River valley escarpment. Based on available data for the Athabasca River levels between Fort McMurray and Suncor Energy's water intake downstream, and observations by Klohn-Crippen personnel, water will flow into the lake from the Athabasca River at discharges in excess of approximately 2800 m^3/s. This occurs, on average, once every three years. Overflow from the Athabasca River typically occurs in June or July and lasts, on average, about 4 days. Figure C2.1-5 shows the periods of inundation from the Athabasca River in 1996 and 1997.

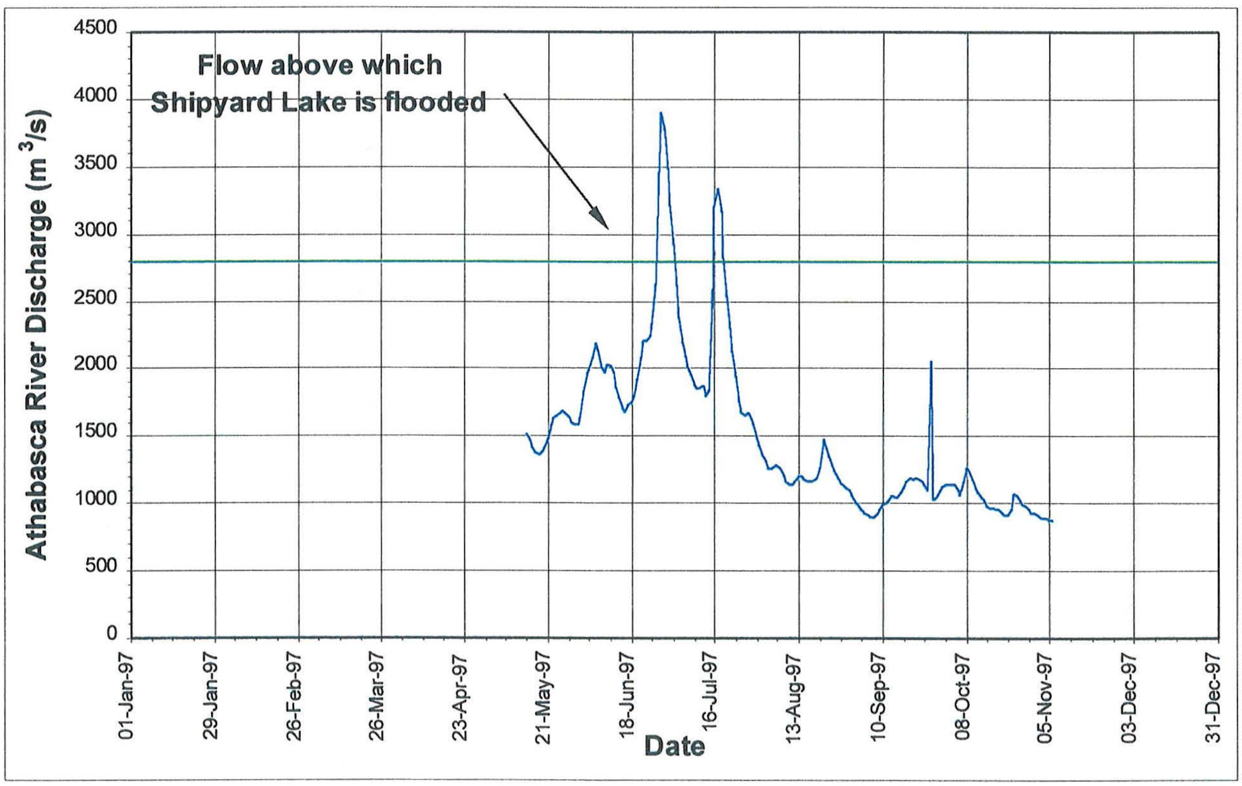
C2.1.6 Hydrogeology

Geology

The stratigraphy of the east bank mining area from top to bottom consists of:

- Drift Deposits (till, silt, sand and gravel);
- Clearwater Formation;
- McMurray Formation Oil Sands;





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INUNDATION OF SHIPYARD LAKE FROM ATHABASCA RIVER

APRIL 1998	FIGURE C2.1-5	DRAWN BY: C.L.F.

2839w160.dwg

- Basal Aquifer; and
- Upper Devonian Limestone.

Major Aquifers

Three major aquifers have been identified, including:

- Surficial aquifers in the drift deposits;
- Basal Aquifer; and
- Devonian Limestone.

Surficial Aquifers

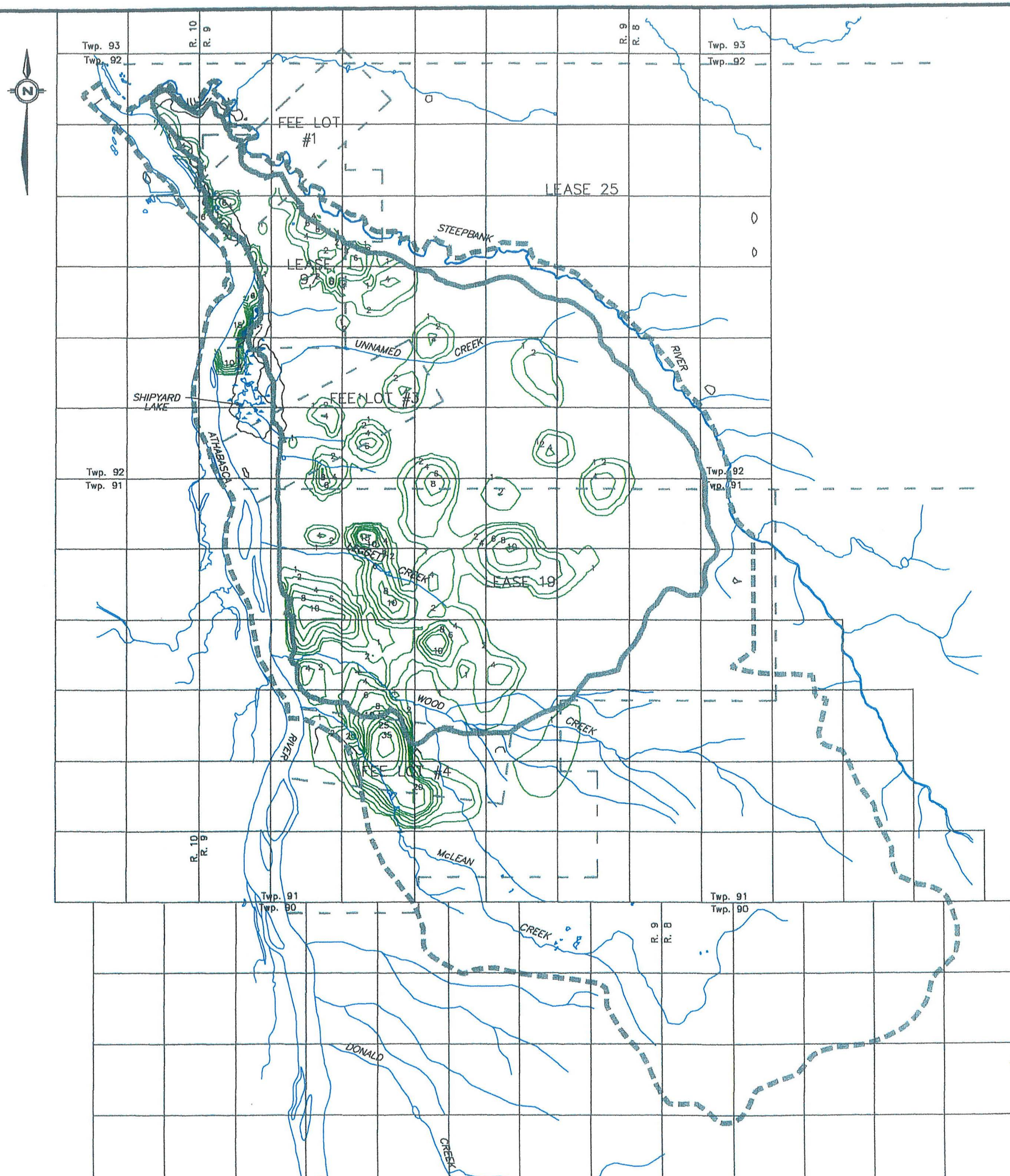
Water bearing sand and gravel deposits within the drift underlying the organic plain have been identified. Theses aquifers are discontinuous over the Local Study Area and range in thickness from 1 to 10 m, with local accumulations of 16 to 32 m. The greatest thickness was noted near the south end of the LSA. The distribution of the surficial aquifers in the area above the escarpments is presented in Figure C2.1-6. Water in these units is generally fresh. The concentration of total dissolved solids ranges from 24 mg/L to 623 mg/L. The freshest water is similar to water found in the muskeg. The water with higher TDS is associated with till and bedrock. The major ions in the surficial groundwater are calcium, magnesium and bicarbonate. The water with higher TDS levels also tends to have higher concentrations of sodium.

In the Athabasca River valley upstream of Tar Island Dyke, there is a variable thickness (up to 40 m) of sand and gravel deposits, that may be hydraulically connected to the Athabasca River. Fluvial sands and silts in excess of 20 m in thickness are also present at the north end of Shipyard Lake adjacent to the Mine Complex for Steepbank mine.

Bedrock Aquifers

In the bedrock, the Basal Aquifer and Upper Devonian limestone have both been identified as aquifers. Based on available data they appear to behave as a single aquifer at some locations. The Basal Aquifer is a discontinuous zone of lean oil sands in the McMurray Formation, that generally rests upon the Upper Devonian surface. It is highly variable in both thickness and extent as shown in Figure C2.1-7.

The Upper Devonian rock is limestone of the Waterways Formation. The structure of the Devonian surface is shown in Figure C2.1-8. As shown the surface is highly irregular with numerous depressions and rises. the elevation of top of limestone ranges from 220 masl to 270 masl.



LEGEND:

- LEASE BOUNDARY
- LOCAL STUDY AREA
- MINE DEVELOPMENT AREA
- 2 ISOPACH OF SAND AND GRAVEL

NOTE:

1. STRATIGRAPHY IS INTERPRETED FROM AVAILABLE INFORMATION, ACTUAL GEOLOGY MAY VARY FROM THAT SHOWN.

1:100,000 0 1 2km

MAP PROJECTION: UTM 12
DATUM: NAD 83

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ISOPACH MAP OF SURFICIAL SAND AND GRAVEL

APRIL 1998	FIGURE C2.1-6	DRAWN BY: K.C.B. / C.S.F.

2839w045.dwg

LEGEND:

- LEASE BOUNDARY
- LOCAL STUDY AREA
- MINE DEVELOPMENT AREA
- 302 — TOP OF THE McMURRAY FORMATION

NOTE:

1. STRATIGRAPHY IS INTERPRETED FROM AVAILABLE INFORMATION, ACTUAL GEOLOGY MAY VARY FROM THAT SHOWN.

1:100,000 0 1 2km

MAP PROJECTION: UTM 12
DATUM: NAD 83

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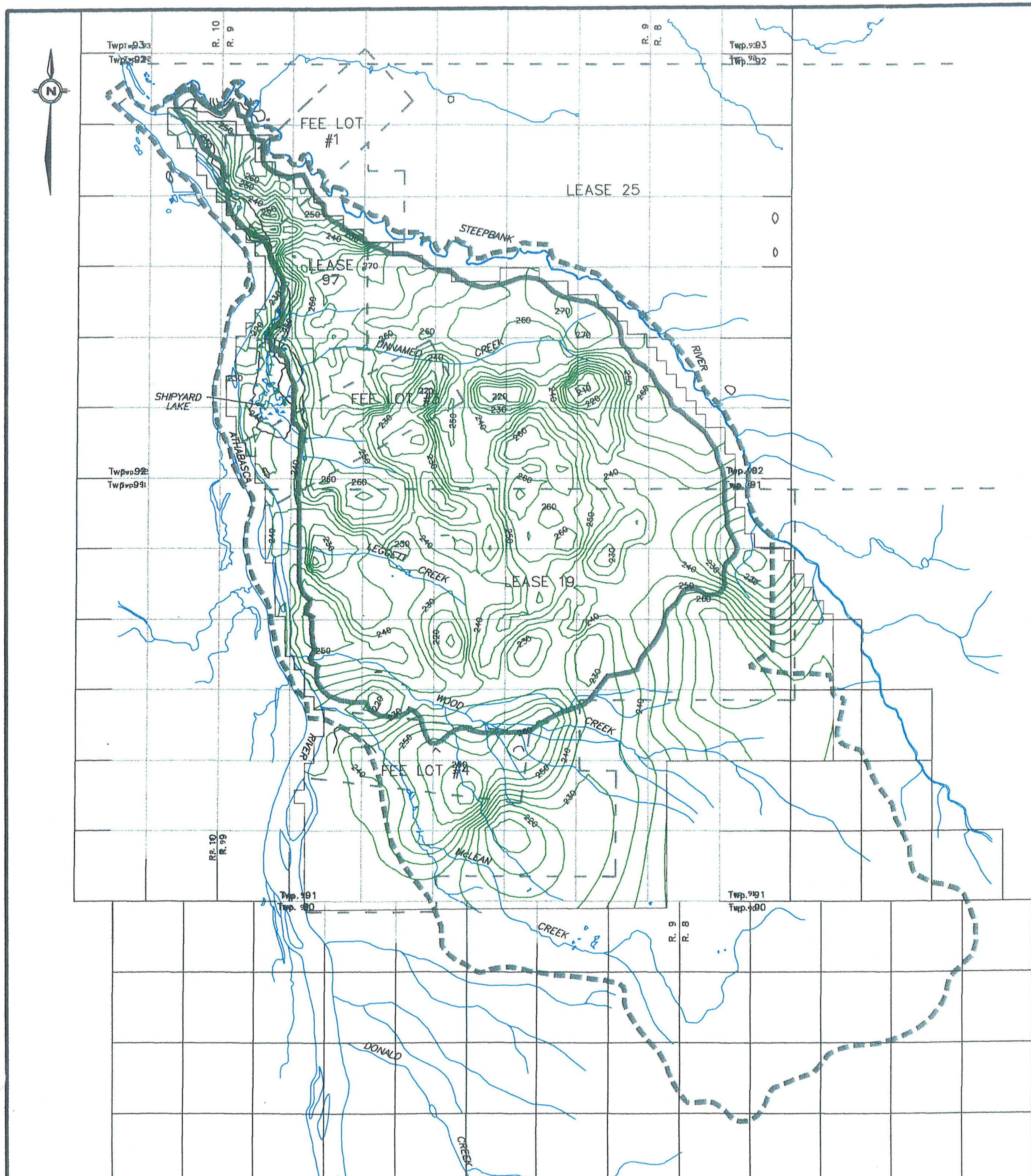
ISOPACH MAP OF THE BASAL AQUIFER

APRIL 1998	FIGURE C2.1-7	DRAWN BY: K.C.B. / C.S.F.

2839w049.dwg



LEGEND:

- LEASE BOUNDARY
- LOCAL STUDY AREA
- MINE DEVELOPMENT AREA
- 302 TOP OF THE DEVONIAN (MASL)

NOTE:

1. STRATIGRAPHY IS INTERPRETED FROM AVAILABLE INFORMATION, ACTUAL GEOLOGY MAY VARY FROM THAT SHOWN.

1:100,000 0 1 2km

MAP PROJECTION: UTM 12
DATUM: NAD 83

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STRUCTURE CONTOUR MAP OF THE TOP OF THE DEVONIAN

APRIL 1998	FIGURE C2.1-8	DRAWN BY: K.C.B. / C.S.F.

2839w051.dwg

The bedrock groundwater is brackish, and contains organic compounds, including PAHs and naphthenic acids.

Direction of Groundwater Flow

The direction of groundwater flow in all aquifers is principally horizontal, toward the Athabasca River. Figure C2.1-9 shows the direction of flow in the surficial materials and Figure C2.1-10 shows the direction of flow in the bedrock aquifers.

As Shipyard Lake is located in the Athabasca River floodplain, a portion of groundwater flowing towards the river discharges into the wetlands. There is also a small component of groundwater flow toward the Steepbank River.

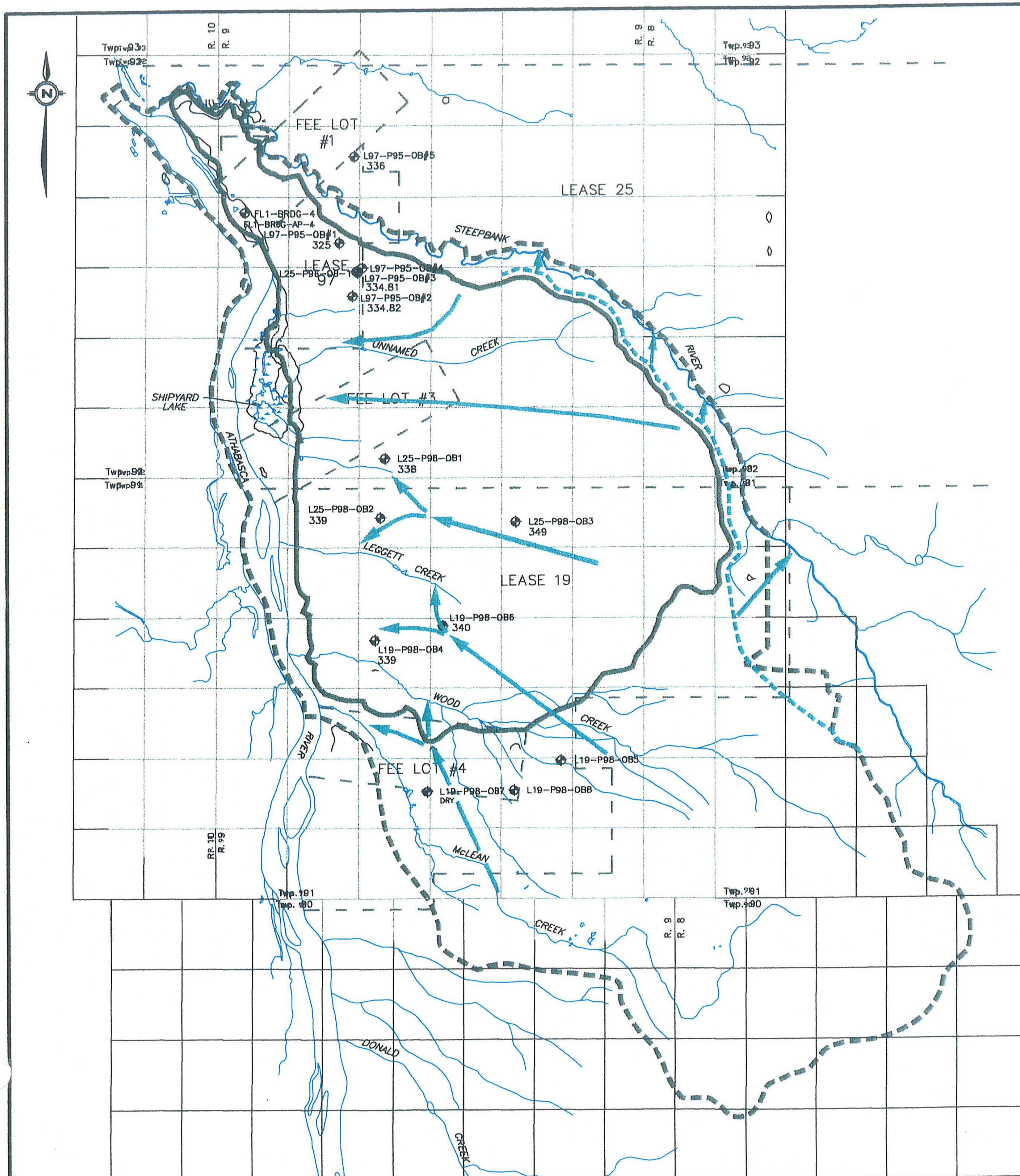
Groundwater as a Resource

There are no groundwater users in the LSA other than Suncor. The sand and gravel deposits in the Athabasca River valley have the potential to be used for water supply purposes. Due to the close proximity to the river, wells completed in sand and gravel are expected to induce recharge from the Athabasca River.

The thicker sand and gravel deposits in the drift may also be a water supply. The bedrock aquifers are likely not useable for potable water supply purposes. Although they meet and exceed the minimum required yield for a domestic supply, the water quality in the bedrock is poor.

Groundwater Discharge to Surface Waters

Groundwater discharges to the surface from each of the geologic units where they outcrop along the Athabasca and Steepbank River Escarpments. Where the local creeks have eroded through the Athabasca Escarpment, groundwater will discharge to these creeks and add to the baseflow in these streams. The estimated rate of groundwater discharge to surface from all aquifers is summarized in Table C2.2-1.



LEGEND:

- LEASE BOUNDARY
- LOCAL STUDY AREA
- MINE DEVELOPMENT AREA
- STANDPIPE PIEZOMETERS AND WATER LEVELS
- APPROXIMATE GROUNDWATER FLOW DIRECTION

NOTE:

1. STRATIGRAPHY IS INTERPRETED FROM AVAILABLE INFORMATION, ACTUAL GEOLOGY MAY VARY FROM THAT SHOWN.
2. WATER LEVELS FOR THE P98 SERIES OF WELLS WERE MEASURED DURING FEBRUARY 1998.
3. WATER LEVELS FOR THE P95 SERIES OF WELLS WERE MEASURED DURING MARCH 1995.

MAP PROJECTION: UTM 12
DATUM: NAD 83

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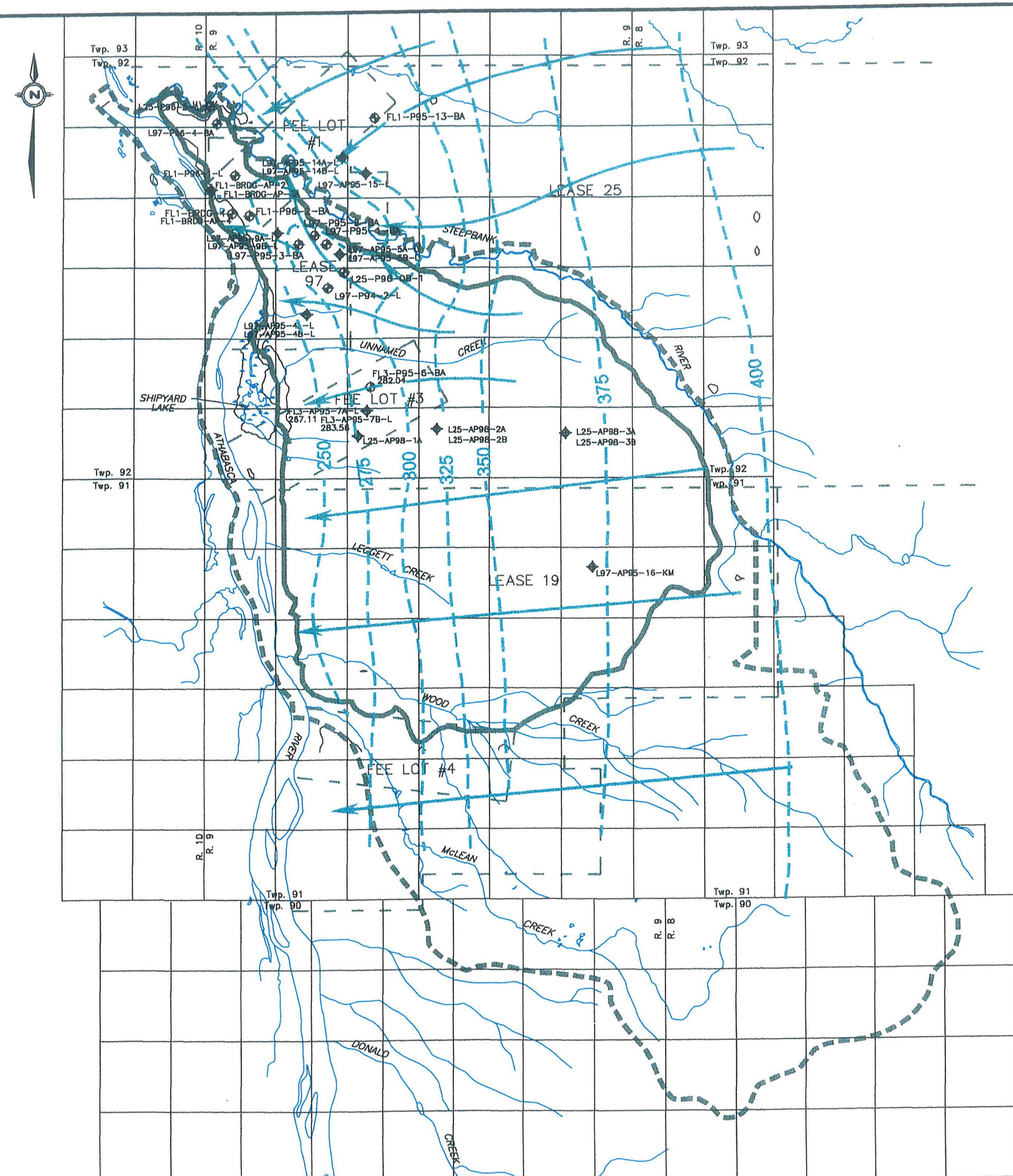
DIRECTION OF GROUNDWATER FLOW IN THE SURFICIAL MATERIALS

APRIL 1998	FIGURE C2.1–9	DRAWN BY: K.C.B. / C.S.F.

2839w116.dwg



LEGEND:

- LEASE BOUNDARY
- LOCAL STUDY AREA
- MINE DEVELOPMENT AREA
- PNEUMATIC PIEZOMETERS
- APPROXIMATE GROUNDWATER FLOW DIRECTION
- PIEZOMETRIC SURFACE CONTOUR (MARCH 1995 DATA)

NOTE:

1. STRATIGRAPHY IS INTERPRETED FROM AVAILABLE INFORMATION, ACTUAL GEOLOGY MAY VARY FROM THAT SHOWN.

MAP PROJECTION: UTM 12
DATUM: NAD 83

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DIRECTION OF GROUNDWATER FLOW IN THE BASAL AQUIFER AND UPPER DEVONIAN

APRIL 1998	FIGURE C2.1-10	DRAWN BY: C.S.F.

C2.2 SURFACE HYDROLOGY AND HYDROGEOLOGY PROJECT IMPACT ASSESSMENT

C2.2.1 Introduction

The Key Questions used to assess the environmental impacts of Project Millennium are listed below:

SHH-1: **What impacts will development and closure of Project Millennium have on groundwater levels (volumes), flow patterns and quality?**

SHH-2: **What changes to groundwaters will development and closure of Project Millennium have that may impact flow and water levels in receiving streams, lakes, ponds and wetlands?**

SHH-3: **What impacts will development and closure of Project Millennium have on the water balance of open water areas of lakes, ponds, wetlands and streams?**

SHH-4: **What impacts will development and closure of Project Millennium have on sediment yields from project area river and stream basins, sediment concentrations in receiving streams and the channel regime of receiving streams?**

SHH-5: **What level of sustainability is expected for Project Millennium closure landscape drainage systems?**

These questions were developed to assess the potential impacts of changes to flow, water levels and water quality from the baseline conditions. These changes vary in time and space throughout each phase of the mine life cycle and may also have effects on other topic areas in the EIA.

The mine life cycle phases used were:

- Construction - activities related to building of infrastructure prior to operations;
- Operations - active mine operations including, pre-stripping, overburden removal, ore production and tailings disposal; and
- Far Future (Closure) - the future time when landscape reclamation is complete.

Questions SHH-1 and SHH-2 address groundwater issues. Potential impacts to groundwater arise from changes to the flow regimes in the natural hydrogeologic units. In addition, the effects of the constructed CT deposits, tailings ponds and the end pit lake, which will become a part of the permanent landscape, are assessed.

For these questions, the assessment was conducted as follows:

1. Each key question was stated and the appropriate periods in the mine life cycle to which the key question is applicable was evaluated.

2. The effects of the mining activities or new landscape feature on the baseline characteristics of the individual hydrogeologic unit in each period of the life cycle was discussed and the relevant changes quantified where possible.

3. Where changes are identified, the environmental significance of the changes were assessed by a qualitative evaluation of the severity, duration and anticipated extent of each impact.

Questions SHH-3, SHH-4 and SHH-5 deal primarily with surface water hydrology. Changes to these systems and mitigation options vary widely depending on the phase in the mine life cycle being discussed.

For these questions, the assessment was conducted as follows:

1. Each key question was stated and the appropriate periods in the mine life cycle to which the key question is applicable were evaluated.

2. The effects of the mining activities on the baseline characteristics of the affected waterbodies were discussed for each phase of the mine life cycle and the relevant changes quantified where possible.

3. Where changes are identified, the environmental significance of the changes are assessed by a qualitative evaluation of the severity, duration, reversibility and anticipated extent of each impact.

The changes relevant to hydrogeology and hydrology also have implications to other topic areas in the EIA. These linkages also vary with the mine life phase. Figures C2.2-1 through C2.2-3 present the potential linkages between general mine activities, potential effects on surface and groundwater and the connection to related topic areas in the EIA.

The severity of each impact was assessed as either low, moderate or high based on the impacts to either flow or quality. The duration of the impact was categorized as being short-term if the impact occurred throughout the life of the project, or long-term if beyond the life of the mine. The reversibility of the effect was also evaluated. The areal extent of the impact was considered local if the effect was in the immediate mine area, or regional if beyond the immediate mine area. A final assessment of the significance was made based on the expected impact on the receiving waterbody (either the Athabasca River, the Steepbank River, or Shipyard Lake).

Figure C2.2-1 Surface and Groundwater Linkage Diagram, Phase: Construction

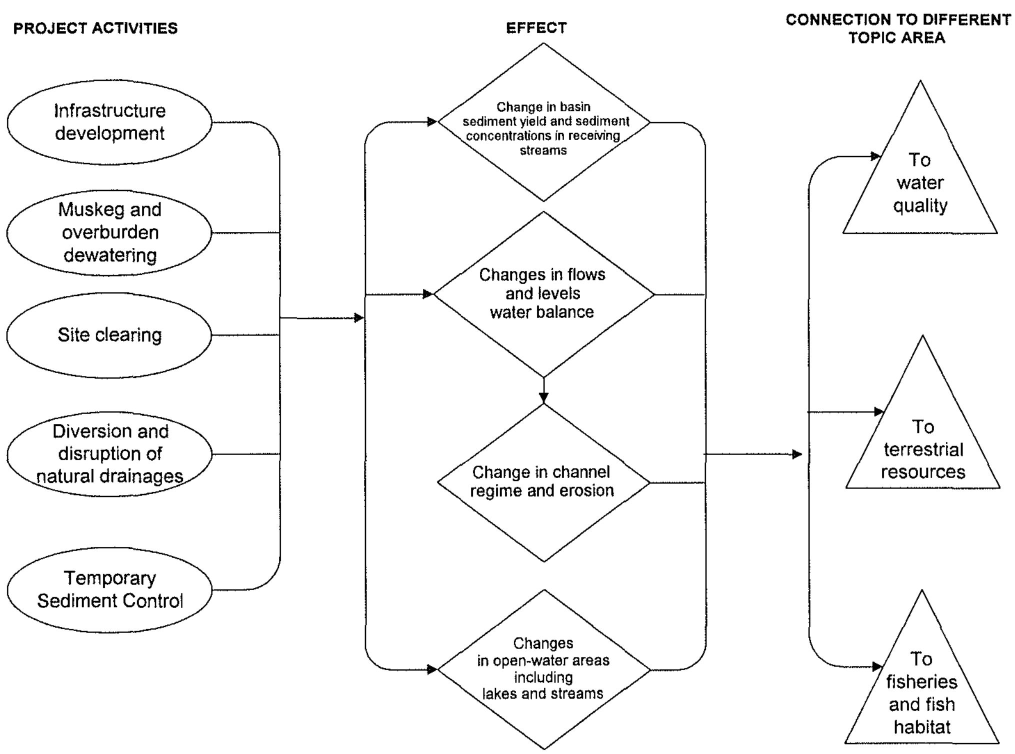


Figure C2.2-2 Surface and Groundwater Linkage Diagram, Phase: Operation

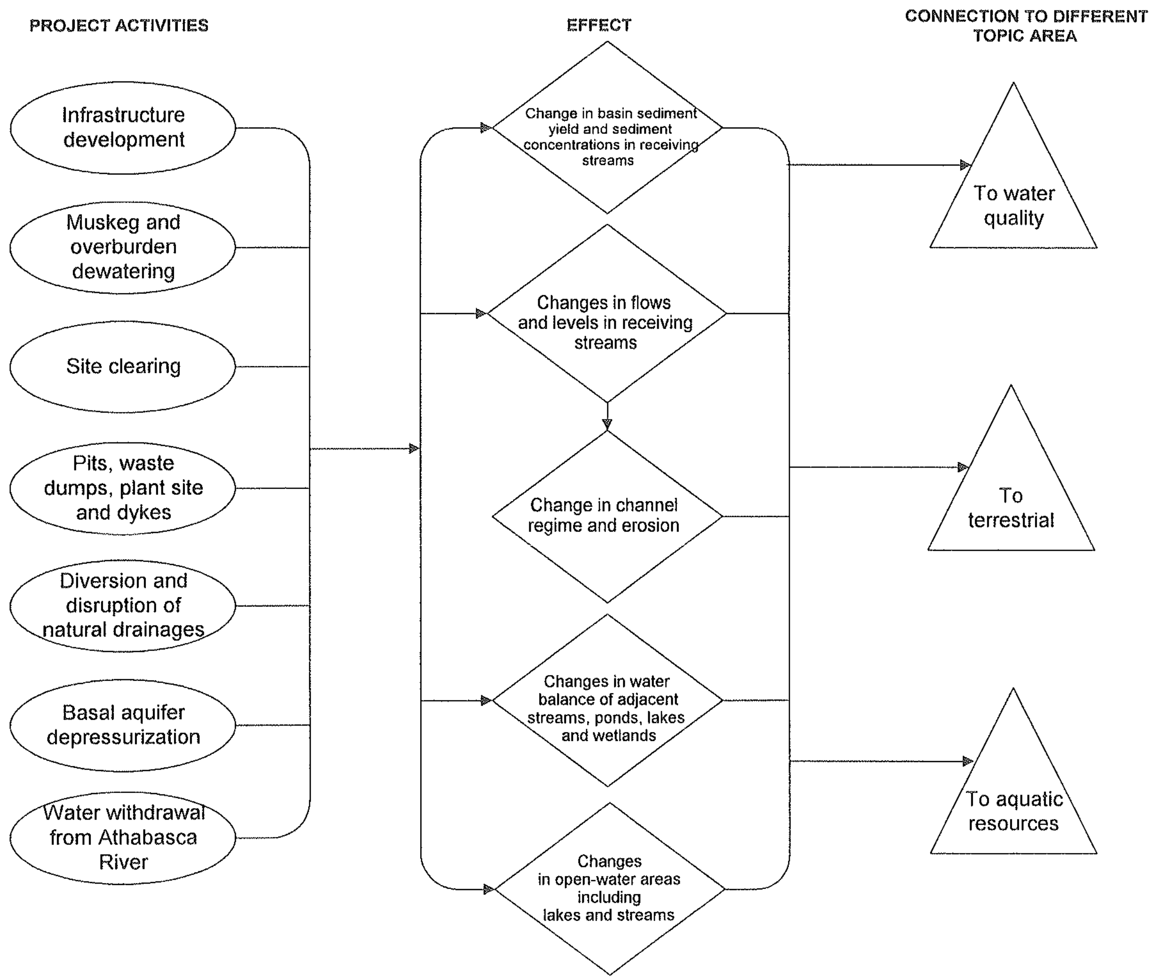
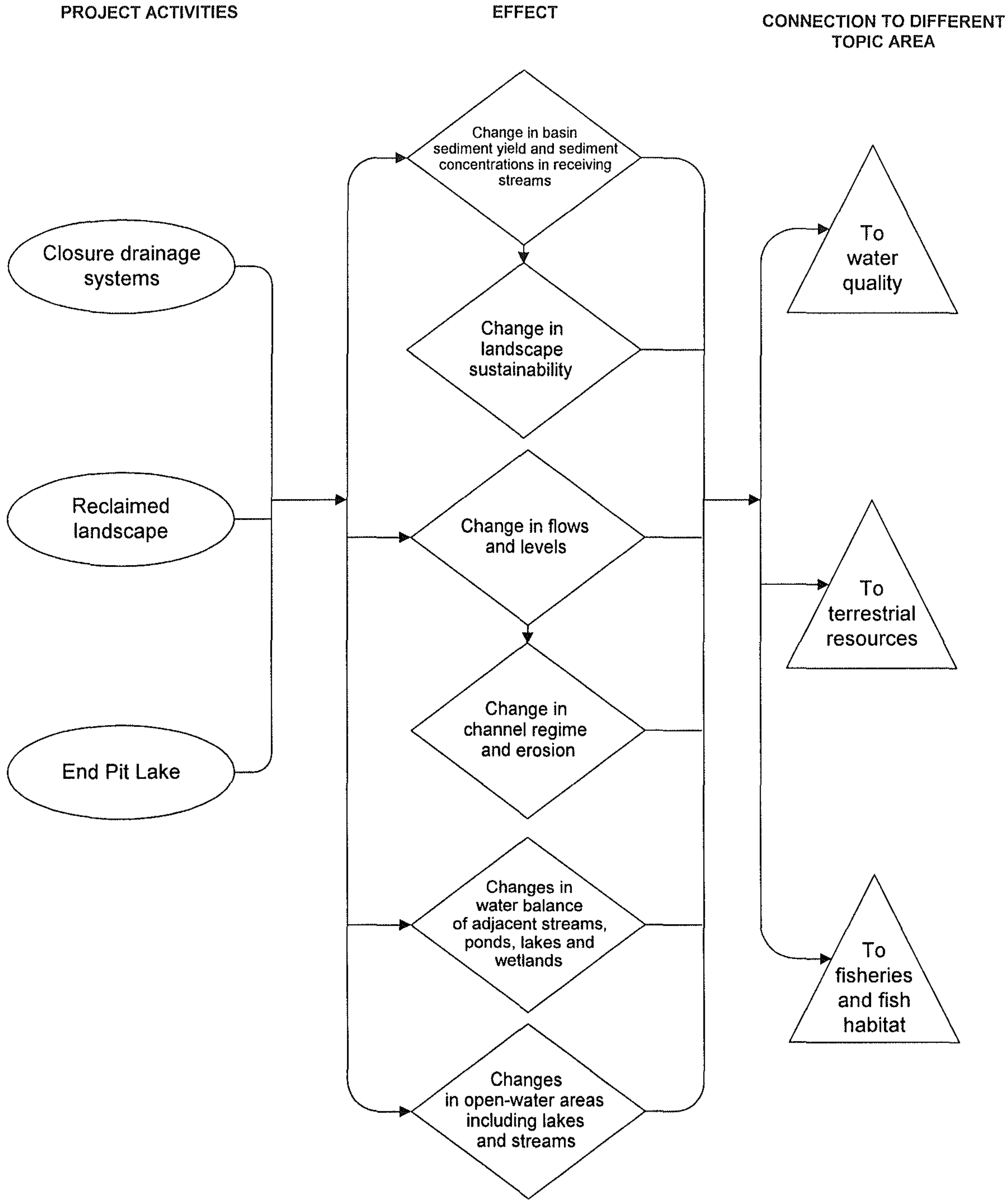


Figure C2.2-3 Surface and Groundwater Linkage Diagram, Phase: Closure



C2.2.2 Groundwater Assessment

C2.2.2.1 Key Question SHH-1: What Impacts Will Development and Closure of Project Millennium Have on Groundwater Levels (Volumes), Flow Patterns and Quality?

C2.2.2.2 Key Question SHH-2: What Changes to Groundwaters Will Development and Closure of Project Millennium Have That may Impact Flow and Water Levels in Receiving Streams, Lakes, Ponds, and Wetlands?

During the construction period, the groundwater flow systems will not be affected by the proposed activities. During operations and after closure the groundwater flow systems in both the surficial and bedrock aquifers will be affected by the proposed activities.

Therefore both questions are valid.

Surficial Aquifers

The surficial aquifers will be dewatered by shallow trenches or wells as the mine active area advances during the Operations Phase. The water will be released to the interception drainage system for discharge to Athabasca River via Unnamed Creek or McLean Creek.

Table C2.2-1 summarizes the expected dewatering flows in various years as well as identifies the receiving surface waterbody. This data shows that the peak discharge is expected in about 2025 to 2030 when the thickest surface deposits are encountered during the excavation of Pond 12 and the greatest amount of water is removed from storage. Over this time the groundwater discharge to McLean Creek rises from the baseline of 18.6 L/s to about 51 L/s. The increase in groundwater flow corresponds to an increase in surface water flows as discussed in Section C2.2.3. The ratio of groundwater flow to surface water flow remains constant at about 11%.

Flow from the surficial aquifers flowing to Steepbank River decreases from 0.8 to 0.6 L/s due to the removal of the surficial sands and gravels. This decrease extends into the Far Future. Similarly the baseline flows from this source in Unnamed Creek and Wood Creek of 0.1 L/s each are lost as a result of the removal of the aquifer. The contribution of groundwater to McLean Creek from this aquifer will return to its pre-development level of 18.6 L/s in the Far Future.

These effects are considered low in magnitude, local in extent and with negligible environmental consequence to the receiving waterbody flow regime.

Table C2.2-1 Estimated Groundwater Discharge

Date	Steepbank River (L/sec)	Unnamed Creek (L/sec)	Leggett Creek (L/sec)	Wood Creek (L/sec)	McLean Creek (L/sec)	Basin A-C Athabasca River (L/sec)	Total (L/sec)
Groundwater discharge from the surficial sand and gravel							
Baseline	0.8	0.1	0.08	0.1	18.6	0.3	20.8
2005	0.6	8.2	-	0.1	18.6	-	27.5
2012	0.6	3.8	-	0.1	18.6	-	23.1
2018	0.6	2.5	-	0.1	20.0	-	23.2
2025	0.6	-	-	0.1	38.4	-	39.1
2030	0.6	-	-	0.0	50.8	-	51.5
Far Future	0.6	-	-	-	18.6	-	19.3
Groundwater discharge from the bedrock							
Baseline	0.8	3.8	0.2	0.2	0.2	8.5	13.8
2005	1.3	-	0.2	0.2	0.2	5.6	7.4
2012	1.9	1.4	0.2	0.2	0.2	11.6	15.5
2018	1.9	4.0	0.2	0.2	0.2	11.6	18.0
2025	1.9	7.7	-	0.2	0.2	8.1	18.0
2030	1.9	7.5	-	-	0.2	9.7	19.2
Far Future	1.9	7.5	0.8	0.8	0.2	12.3	28.4

Bedrock Aquifers

The hydraulic head in the Basal Aquifer and Devonian aquifers ranges from 279 to 315 masl which is higher than the elevation of the base of the McMurray Oil Sands. Depressurization of part of Pit 1 (as part of Steepbank Mine operation) and Pit 2 may be required for pit wall and base stability. The result of the depressurization will be a change in the direction of groundwater flow in the bedrock aquifers and the rate of discharge to surface will be reduced to near zero. Groundwater in the bedrock will flow toward Pit 1 and Pit 2. The areal extent of this impact will be limited to within about 2 km of the pit boundary.

The water pumped from the bedrock will be discharged to the mine drainage system and used in process at the same rate as the natural discharge shown in Table C2.2-1 (about 13.8 L/s maximum).

The bedrock groundwater discharge to surface water is a minor component of the flow in Shipyard Lake, Athabasca River and Steepbank River (3.0%, <0.01%, <0.04% respectively), the severity of these changes is negligible. The areal extent of the impact will be local. The duration of the impact will also be short-term as CT will be deposited in Pit 1 and Pit 2 by 2007. Once the CT is placed in the pit, the head in the bedrock aquifers and the direction of the groundwater flow will return to the baseline conditions. As shown in Table C2.2-1, the groundwater discharge from bedrock will be higher than baseline increased as discussed below.

Consolidated Tailings

CT will be placed in the mine pits, as a component of the mine reclamation. CT technology will provide a stable, dry surface, that will be reclaimed as outlined in Section E, Reclamation and Closure.

When CT is initially placed and the consolidation process begins most of the water will move vertically upward and be pumped from the CT ponds for use in the operations process.

The CT is expected to interact with the groundwater in the bedrock once it is placed in the tailings ponds. Porewater within the CT will seep downward into the bedrock, and eventually discharge with the groundwater to surface water. The impact that the seepage will have on the groundwater will be the result of the combined effects of the rate of flow and the chemical composition of the porewater. These are both discussed in the following paragraphs.

The rate of seepage from the ponds will be a function of the hydraulic conductivity of the CT, the vertical hydraulic gradient between the CT and the underlying bedrock aquifers, and the area of the ponds. The equation used to calculate the seepage rate is:

$$Q = K\,i\,A$$

where;
Q = seepage rate, (m^3/s)
K = the hydraulic conductivity of the aquifer, m/s
i = the hydraulic gradient in the aquifer, m/m
A = area of the pond, m^2.

The hydraulic conductivity of the CT has been estimated to be 1×10^{-9} m/s (AGRA 1996). The vertical hydraulic gradient in the ponds is difficult to predict, because it is not known what the elevation of the phreatic surface within the CT will be. However, as the hydraulic conductivity of the CT is quite low, it is anticipated that the phreatic surface within the CT will be very close to ground level. Therefore, the vertical hydraulic gradient in the CT has been calculated using the estimated elevation of the top surface of the CT in each pond. This is a conservative assumption representing the worst case. It is possible that the phreatic surface may return to the baseline level in which case flows would be less.

The estimates of seepage of CT porewater to surface water through the bedrock are shown in Table C2.2-2. These estimates assume instantaneous release. This is also a conservative assumption.

Chemical analyses have been conducted on porewater samples collected from test batches of consolidated tailings. Tables C2.2-3 and C2.2-4 show the results of inorganic analyses of CT porewater. Table C2.2-5 shows the results of organic analyses, including naphthenic acids, of the CT porewater.

Table C2.2-2 Estimated CT Seepage Through the Bedrock

Date	Pond 7 to Athabasca Basin A (L/sec)	Pond 7 to Steepbank River (L/sec)	Pond 7 to Unnamed Creek (L/sec)	Pond 8 to Athabasca Basin B (L/sec)	Pond 8 to Unnamed Creek (L/sec)	Pond 9 to Unnamed Creek (L/sec)	Pond 10 to Pond 12 (L/sec)	Pond 10 to Unnamed Creek (L/sec)	Pond 11 to Pond 12 (L/sec)	Pond 12 to Athabasca Basin C (L/sec)	Pond 12 to Leggett Creek (L/sec)	Pond 12 to Wood Creek (L/sec)
2005	1.0	0.5	0.2									
2007	1.8	0.9	0.3									
2012	2.1	1.1	0.4	1.1	1.1							
2018	2.1	1.1	0.4	1.1	1.1	2.6						
2025	2.1	1.1	0.4	1.1	1.1	2.3	0.2	0.2				
2030				1.1	1.1	2.3		-	0.3	0.2	0.2	0.2
Far Future	2.1	1.1	0.3	1.1	1.1	2.3		-	1.4	0.6	0.6	0.6

Table C2.2-3 Consolidated Tailings (CT) - Major Ions in Porewater

Parameter	Detection Limits	Units	Min	Max	Median	No. of Samples
Calcium	0.003	mg/L	<0.003	0.0066	<0.003	9
Magnesium	0.01	mg/L	7.2	28	12	18
Sodium	0.01	mg/L	347	1170	445	18
Potassium	0.02	mg/L	11.5	29	16.6	18
Chloride	0.5	mg/L	45.4	510	55	18
Sulphate	0.5	mg/L	555	1290	659	18
Total Alkalinity	0.5	mg/L	277	688	353.5	18
Bicarbonate	0.5	mg/L	331	800	409	18
Silicon	0.02	mg/L	<2.3	5.6	2.9	8
Total Dissolved Solids	1	mg/L	1400	1805	1600	7
Specific Conductance	0.1	μS/cm	1891	4900	2337	9
pH	0.01	Units	7.9	8.5	8.3	18
Phenols	0.001	mg/L	<0.002	0.016	0.004	5
Dissolved Organic Carbon	0.2	mg/L	52	65.3	60.6	8
Nitrite + Nitrate	0.003	mg/L	<0.003	0.05	0.016	18
Total Phosphorus (ICP)	0.1	mg/L	<0.1	0.1	<0.1	6

Data obtained from Chemex Labs (Suncor ID: RW 162, 163, 164).
Samples collected in July, August and September 1995.
Other CT samples from Suncor: ST1219.

Table C2.2-4 Consolidated Tailings (CT) - Metals and Cyanide in Porewater

Parameter	Detection Limits	Units	Min	Max	Median	No. of Samples
Aluminum	0..01	mg/L	<0.01	1.92	0.05	9
Arsenic	0.0002	mg/L	0.0007	0.0058	0.0029	8
Barium	0.01	mg/L	0.05	0.18	0.1	9
Beryllium	0.001	mg/L	<0.001	0.004	<0.001	9
Boron		mg/L	2.26	4.26	3.19	9
Cyanide	0.001	mg/L	<0.001	0.055	<0.001	8
Cadmium	0.003	mg/L	<0.003	0.0066	<0.003	9
Chromium	0.002	mg/L	<0.002	0.003	<0.002	9
Cobalt	0.003	mg/L	<0.003	0.007	<0.003	9
Copper	0.001	mg/L	<0.001	0.004	0.002	9
Iron	0...01	mg/L	<0.01	1.01	0.04	9
Lead	0.02	mg/L	<0.0003	0.02	0.02	9
Lithium	0.001	mg/L	0.16	0.27	0.19	9
Manganese	0.001	mg/L	<0.001	0.058	0.024	9
Mercury	0.05	mg/L	<0.05	0.05	<0.05	7
Molybdenum	0.003	mg/L	0.15	1.42	1.15	9
Nickel	0.005	mg/L	<0.005	0.030	0.018	9
Selenium	0.0002	mg/L	<0.0002	0.04	0.0015	8
Silver	0.002	mg/L	<0.0002	0.002	<0.002	9
Strontium	0.002	mg/L	0.75	2.12	1.02	9
Titanium	0.003	mg/L	<0.003	0.016	<0.003	9
Uranium	0.5	mg/L	0.0068	0.5	0.5	9
Vanadium	0.002	mg/L	<0.002	0.1	0.006	9
Total Ammonia	0.01	mg/L	0.098	3.8	0.7	17
Total Sulphur	0.2	mg/L	186	266	229	7
Total Kjeldhal Nitrogen	0.05	mg/L	0.95	6.8	1.82	16
Total Dissolved Solids	1	mg/L	1400	1805	1600	7
Titanium	0.003	mg/L	<0.003	0.016	<0.003	9
Total Organic Carbon	0.2	mg/L	56.1	68	64.5	6
Total Alkalinity	0.5	mg/L	277	688	354	18
Total Phosphorus	0.003	mg/L	0.006	0.096	0.037	16
Total Suspended Solids	0.4	mg/L	<0.4	187	6	6
Uranium	0.5	mg/L	0.0068	0.5	0.5	9
Vanadium	0.002	mg/L	<0.002	0.17	0.006	9
Zinc	0.001	mg/L	0.003	0.056	0.043	9

Data obtained from Chemex Labs (Suncor ID: RW 162, 163, 164).
Samples collected in July, August and September 1995.
Other CT samples from Suncor: ST1219.

The results of the evaluations of the chemistry of CT porewater are preliminary and ongoing research into the composition of the porewater is being conducted by Suncor. The inorganic chemistry of the CT porewater is relatively benign with respect to the potential impacts to surface water. The porewater does contain dissolved organic compounds, including phenols, PAHs and naphthenic acids. However, as shown in Table C2.2-6, the types and concentrations of organic compounds found in the CT porewater are similar to the naturally-occurring organic composition of the groundwater in the bedrock aquifers. Of the 33 organic compounds detected in the CT porewater, all but three were also found to be naturally present in the groundwater from the limestone. These three compounds were acenaphthylene, phenol and m-cresol. The range of concentrations of naphthenic acids measured in the CT porewater (62 to 94 mg/L) is slightly higher than in the bedrock aquifers (8 to 57 mg/L).

Table C2.2-5 Consolidated Tailings (CT) - Organic Compounds in Porewater (μg/L)

Parameter	Suncor Consolidated Tailings			
	Min	Median	Max	No. of Samples
PAH & Alkylated PAHs				
Naphthalene	<0.02	<0.02	0.05	16
Acenaphthene	0.02	<0.02	0.08	16
Acenaphthylene	<0.02	0.03	0.16	16
Fluorene	<0.02	<0.02	0.03	16
Dibenzothiophene	<0.02	<0.02	0.07	14
Phenanthrene	<0.02	<0.02	0.09	16
Pyrene	<0.02	<0.02	0.04	16
Benzo[(a)] anthracene/Chrysene	<0.02	<0.02	0.27	16
Methyl naphthalene	0.02	<0.04	0.08	14
C2 sub'd naphthalene	<0.04	<0.04	0.25	16
C3 sub'd naphthalene	<0.04	<0.04	0.3	16
C4 sub'd naphthalene	<0.04	<0.04	2	16
Methyl biphenyl	0.04	<0.04	0.08	16
C2 sub'd biphenyl	<0.04	<0.04	0.25	16
Methyl acenaphthene	<0.04	<0.04	0.19	16
Methyl fluorene	<0.04	<0.04	0.3	16
C2 sub'd fluorene	<0.04	<0.04	1.1	16
Methyl phenanthrene/anthracene	<0.04	<0.04	0.79	16
C2 sub'd phenanthrene/anth	<0.04	<0.04	4.5	16
C3 sub'd phenanthrene/anth.	<0.04	<0.04	3.6	16
C4 sub'd phenanthrene/anth.	<0.04	<0.04	1.7	15
Methyl dibenzothiophene	<0.04	<0.04	0.65	16
C2 sub'd dibenzothiophene	<0.04	<0.04	2.2	16
C3 sub'd dibenzothiophene	<0.04	<0.04	4.1	16
C4 sub'd dibenzothiophene	<0.04	<0.04	4.4	16
Methyl fluoranthene/pyrene	<0.04	<0.04	0.65	16
Methyl B(a)/chrysene	<0.04	<0.04	0.5	16
C2 sub'd B(a)A/chrysene	<0.04	<0.04	0.83	16
Phenolic Compounds in Water				
Phenol	<0.1	0.2	0.2	6
m-Cresol	<0.1	0.3	0.5	5
m-Cresol	1	1	1	3
p-Cresol	0.1	<0.1	0.2	5
2,4-Dimethylphenol	<0.2	0.35	1	4
PANH & Alkylated PANHs	nd	nd	nd	
Volatile Organics (MS):H20	nd	nd	nd	
Naphthenic Acids (mg/L)	62	76	94	
Hydrocarbons, Recoverable (mg/L)	<1	<1	22	18

Data obtained from Envirotest Laboratories (Suncor ID: RW 162, 163, 164) & PD5, CT1219.
Samples Collected in July, August, September 1995.
Additional CT900 & CT1400 obtained from Syncrude Research Center.
nd = not detected.

The severity of the impacts associated with the seepage of CT porewater from the ponds is expected to be low. The rate of seepage is less than 1 % of the flows in the Athabasca and Steepbank rivers, and Shipyard Lake. The chemistry of the CT porewater is similar to the chemistry of the groundwater in the bedrock aquifers that currently discharges to surface water in the in the Study Area. Therefore, the chemistry of the receiving waters is not expected to be altered by the seepage of the CT from the ponds. The areal extent of the impact of the seepage will be local and the

Table C2.2-6 Comparison of Organic Compounds Detected in Consolidated Tailings (CT) and Groundwater Samples (μg/L)

Parameter	Suncor Consolidated Tailings				Basal Aquifer				Limestone				Surficial Sand			
	Min	Median	Max	No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max	No. of Samples	Min	Median	Max	No. of Samples
PAH and Alkylated PAHs																
Naphthalene	<0.02	<0.02	0.05	16	<0.02	<0.02	0.05	5	<0.02	0.035	0.05	2	<0.02	<0.02	<0.02	6
Acenaphthene	0.02	<0.02	0.08	16	<0.02	0.03	0.04	5	0.04	0.06	0.08	2	<0.02	<0.02	<0.02	6
Acenaphthylene	<0.02	0.03	0.16	16	<0.02	<0.02	<0.02	5	<0.02	<0.02	<0.02	2	<0.02	<0.02	<0.02	6
Fluorene	<0.02	<0.02	0.03	16	<0.02	0.02	0.06	5	0.07	0.075	0.08	2	<0.02	<0.02	<0.02	6
Dibenzothiophene	<0.02	<0.02	0.07	14	<0.02	<0.02	<0.02	5	<0.02	0.02	0.02	2	<0.02	<0.02	<0.02	6
Phenanthrene	<0.02	<0.02	0.09	16	0.02	0.03	0.07	5	0.11	0.125	0.14	2	<0.02	<0.02	<0.02	6
Pyrene	<0.02	<0.02	0.04	16	<0.02	<0.02	<0.02	5	<0.02	0.025	0.03	2	<0.02	<0.02	0.02	6
Benzo(a)anthracene/Chrysene	<0.02	<0.02	0.27	16	<0.02	<0.02	0.02	5	<0.02	0.03	0.04	2	<0.02	<0.02	<0.02	6
Methyl naphthalene	0.02	<0.04	0.08	14	<0.02	0.04	0.07	5	<0.02	0.03	0.04	2	<0.02	<0.02	<0.02	6
C2 sub'd naphthalene	<0.04	<0.04	0.25	16	<0.04	0.09	0.32	5	<0.04	0.05	0.06	2	<0.04	<0.04	<0.04	6
C3 sub'd naphthalene	<0.04	<0.04	0.3	16	0.04	0.12	0.82	5	0.31	0.42	0.53	2	<0.04	<0.04	0.17	6
C4 sub'd naphthalene	<0.04	<0.04	2	16	<0.04	0.09	0.5	5	0.19	0.27	0.35	2	<0.04	<0.04	0.20	6
Methyl biphenyl	0.04	<0.04	0.08	16	<0.04	<0.04	<0.04	5	<0.04	0.04	0.04	2	<0.04	<0.04	<0.04	6
C2 sub'd biphenyl	<0.04	<0.04	0.25	16	<0.04	<0.04	<0.04	5	<0.04	0.075	0.11	2	<0.04	<0.04	<0.04	6
Methyl acenaphthene	<0.04	<0.04	0.19	16	<0.04	<0.04	0.06	5	<0.04	0.06	0.08	2	<0.04	<0.04	<0.04	6
Methyl fluorene	<0.04	<0.04	0.3	16	<0.04	0.04	0.14	5	0.08	0.125	0.17	2	<0.04	<0.04	0.04	6
C2 sub'd fluorene	<0.04	<0.04	1.1	16	<0.04	0.07	0.13	5	0.09	0.155	0.22	2	<0.04	<0.04	0.06	6
Methyl phenanthrene/anthracene	<0.04	<0.04	0.79	16	0.05	0.1	0.13	5	0.22	0.265	0.31	2	<0.04	<0.04	<0.04	6
C2 sub'd phenanthrene/anth.	<0.04	<0.04	4.5	16	<0.04	0.09	0.23	5	0.15	0.25	0.35	2	<0.04	<0.04	0.05	6
C3 sub'd phenanthrene/anth.	<0.04	<0.04	3.6	16	<0.04	0.05	0.21	5	0.11	0.2	0.29	2	<0.04	<0.04	0.06	6
C4 sub'd phenanthrene/anth.	<0.04	<0.04	1.7	15	<0.04	<0.04	0.16	5	0.04	0.085	0.13	2	<0.04	<0.04	<0.04	6
Methyl dibenzothiophene	<0.04	<0.04	0.65	16	<0.04	0.06	0.16	5	0.12	0.18	0.24	2	<0.04	<0.04	<0.04	6
C2 sub'd dibenzothiophene	<0.04	<0.04	2.2	16	<0.04	0.08	0.13	5	0.15	0.29	0.43	2	<0.04	<0.04	0.04	6
C3 sub'd dibenzothiophene	<0.04	<0.04	4.1	16	<0.04	0.09	0.24	5	0.19	0.32	0.45	2	<0.04	<0.04	0.06	6
C4 sub'd dibenzothiophene	<0.04	<0.04	4.4	16	<0.04	<0.04	0.06	5	<0.04	0.15	0.26	2	<0.04	<0.04	<0.04	6
Methyl fluoranthene/pyrene	<0.04	<0.04	0.65	16	<0.04	<0.04	0.06	5	<0.04	0.045	0.05	2	<0.04	<0.04	<0.04	6
Methyl B(a)A/chrysene	<0.04	<0.04	0.5	16	<0.04	<0.04	0.05	5	<0.04	0.045	0.05	2	<0.04	<0.04	<0.04	6
C2 sub'd B(a)A/chrysene	<0.04	<0.04	0.83	16	<0.04	<0.04	0.05	5	<0.04	0.05	0.06	2	<0.04	<0.04	<0.04	6
Phenolic Compounds in Water																
Phenol	<0.1	0.2	0.2	6	<2	<0.2	<0.1	5	<0.1	<0.1	<0.1	2	<0.2	<0.1	<0.1	6
m-Cresol	<0.1	0.3	0.5	5	<2	<0.2	<0.1	5	<0.1	<0.1	<0.1	2	<0.2	<0.1	<0.1	6
m-Cresol	1	1	1	3												
p-Cresol	0.1	<0.1	0.2	5	<2	<0.2	0.2	5	0.3	0.3	0.3	2	<0.2	<0.1	<0.1	6
2,4-Dimethylphenol	<0.2	0.35	1	4	<2	<0.2	<0.1	5	0.1	0.15	0.2	2	<0.2	<0.1	<0.1	6
PANH & Alkylated PANHs	nd	nd	nd		nd	nd	nd		nd	nd	nd		nd	nd	nd	
Volatile Organics (MS):H_2O	nd	nd	nd		nd	nd	nd		nd	nd	nd		nd	nd	nd	
Naphthenic Acids (mg/L)	62	76	94		8	21	36	11	47	52	57	3	<4	4	7	12
Hydrocarbons, Recoverable (mg/L)	<1	<1	22	18	<1	3	5	3	<1	<1	<1	1	<1	<1	<1	3

Notes: Data obtained from Envirotest Laboratories (Suncor ID: RW 162, 163, 164) & PD5, CT1219.
Samples collected in July, August, September 1995.
Additional CT900 & CT1400 obtained from Syncrude Research Center.
nd = not detected.

duration long-term. Considering the rates and quality of the seepage, the environmental consequences of the impact from the CT porewater will be low.

Pond 8A

The dykes for Pond 8A will be constructed using the upstream construction method. The dyke will be raised in lifts starting with a compacted overburden starter dyke. The remainder of the dyke will consist of beached sands. The pond will contain MFT.

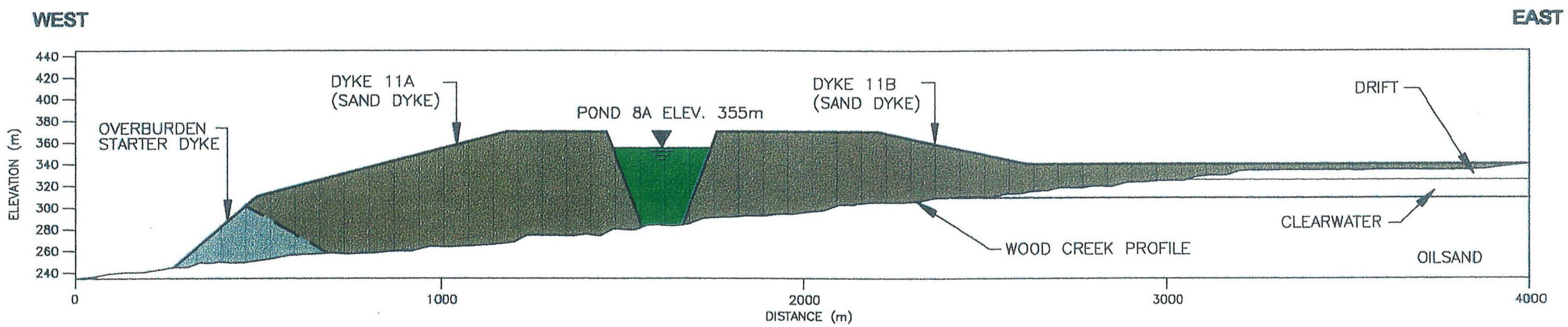
The seepage to groundwater beneath the dykes was estimated using the program SEEP/W by Geo-Slope International. Borehole information in the foundation area of the pond is limited. The available data suggests the foundation consists of muskeg overlying sand which in turn overlays clay till. The numerical simulations indicate that seepage will migrate preferentially through the underlying drift deposits, rather than through the dyke. The rate of seepage is estimated to be 560 to 1,300 L/s, depending upon the extent to which muskeg is present within the Pond 8A area.

The final elevation of the Pond 8A is above ground surface as shown on Figure C2.2-4 and seepage can be expected in all directions. The seepage to the west will discharge to the Athabasca River Escarpment and be collected at the former Wood Creek and Leggett Creek. The seepage to the east and south will flow to toe drains routed to the mine drainage system. Seepage to the north will flow to Pond 8 or to the end pit lake, depending on the phase of the mine life. All of this seepage will be collected in the Mine Drainage System and not released to the environment. During the detailed design of Pond 8A, additional investigations of the geology and hydrogeology will be undertaken for the design of the seepage collection system.

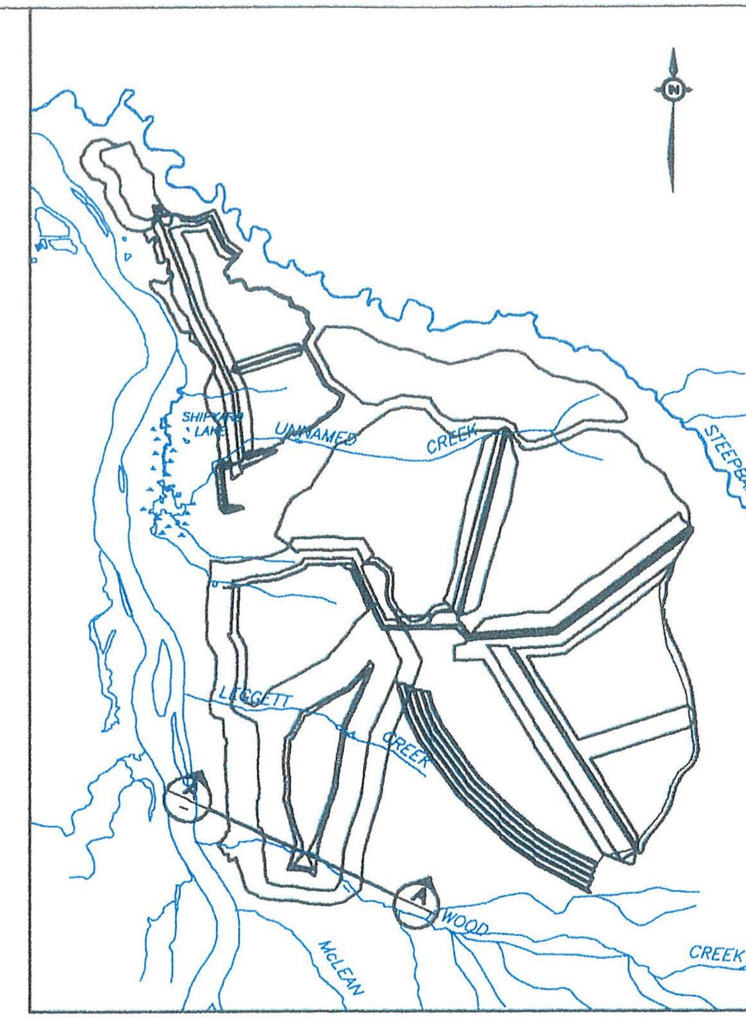
Pond 8A will cease operation in 2027. The liquids and MFT will be removed and the pond backfilled with overburden. This will remove the driving head on the system and the seepage through the dyke will gradually dissipate to the infiltration rate of the reclaimed slopes. Assuming the infiltration rate of 170 mm for a steep vegetated sand dyke, long-term flow is expected to be about 10 L/s towards Athabasca River and 10 L/s toward end pit lake.

End Pit Lake

Surface water, seepage water and groundwater discharge will be directed to the former Pond 12, which will form an end pit lake. The details of the end pit lake are presented in Section E, Reclamation and Closure. Water in the lake will be in direct hydraulic contact with the bedrock. The lake will be filled to the final elevation of 340 masl within ten years of the end of



SECTION A
HOR 1:15,000
VERT 1:5,000



KEY PLAN
N.T.S.

LEGEND:

- OVERBURDEN DYKE
- MANUFACTURED FINE TAILS
- SAND DYKE

NOTE:

1. STRATIGRAPHY IS INTERPRETED FROM AVAILABLE INFORMATION, ACTUAL GEOLOGY MAY VARY FROM THAT SHOWN.

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POND 8A ALONG WOOD CREEK AT 2025

APRIL 1998	FIGURE C2.2-4	DRAWN BY:	C.L.F.

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operations. The hydraulic head of the bedrock in the area of end pit lake is about 282 masl. The bottom of Pond 12 will be about 260 masl.

The flow between the end pit lake and the bedrock will vary with the water level in the lake. Initially, groundwater will discharge from the bedrock into the lake. In the far future, the water level in the end pit lake will be above the baseline hydraulic head in the bedrock and so a downward vertical gradient will result. At this time water from the end pit lake will recharge the bedrock. Discharge from the bedrock from end pit lake is estimated to be about 0.8 L/s.

C2.2.2.3 Hydrogeology Impacts Summary

The following activities have been evaluated with regard to their impacts on the direction of groundwater flow, the rate of groundwater discharge, and the quality of groundwater:

- de-watering of the surficial deposits up-gradient of the mine;
- lowering of the hydraulic head in the bedrock aquifers during mining;
- placement of consolidated tailings (CT) in the pits to reclaim the mine;
- seepage from Tailings Pond 8A; and
- seepage from end pit lake.

The groundwater from the surficial deposits is expected to be diverted to Shipyard Lake and the Athabasca River via Unnamed Creek and Wood Creek. Once again, because the rate of groundwater flow in the aquifer is so low in comparison to the surface water flows, the level of concern over this impact is low. The rate of groundwater discharge is less than 0.01% of the minimum monthly flow in the Athabasca River and 1% of the minimum monthly flow in the Steepbank River, and less than 3% of the average monthly flow in Shipyard Lake.

The pore water from CT is expected to seep through the bedrock aquifers, and discharge to the Athabasca River, Steepbank River and Shipyard Lake. The quality of the CT pore water is very similar to the natural quality of groundwater in the bedrock aquifers. The CT contains essentially the same organic compounds as the groundwater, although at slightly higher concentrations. Therefore, the environmental consequence associated with the long-term seepage of pore water from CT is considered to be low.

Seepage from Pond 8A will be collected during operations and used in process. In the Far Future, this seepage will be about 10 L/s to the Athabasca River and end pit lake.

In all instances, the areal extent of the impacts will be local. Because the groundwater flow rates are small in comparison to the flow rates in the Athabasca River, Steepbank River and Shipyard Lake, the severity of changes in groundwater flow direction and discharge rate are low. The duration of most impacts to the groundwater will be short-term, with the exception of the diversion of groundwater in the surficial deposits and the seepage of pore water from CT.

C2.2.2.4 Monitoring

Extensive groundwater monitoring is routinely conducted at Suncor. The groundwater monitoring plan is presented in detail in the report entitled "Five Year Groundwater Monitoring Plan" Klohn-Crippen (1998c).

C2.2.3 Surface Water

C2.2.3.1 Key Question SHH-3: What Impacts Will Development and Closure of Project Millennium Have on the Water Balance or Open Water Areas of Lakes, Ponds, Wetlands and Streams?

During Project Millennium, all small waterbodies in the LSA (Shipyard Lake, and Leggett, Wood and McLean creeks) will be affected by changes in flow and in, some cases, diversion of flow.

The Athabasca River will also be affected during construction and operations and after closure since it receives flows from the small waterbodies in the LSA.

Part of the NE Dump and the Materials Reclamation Stockpile of Project Millennium will encroach into the Steepbank River drainage basin affecting flows in that watercourse during operations and after closure.

Therefore, the question is valid.

The effects of Project Millennium on annual runoff to waterbodies and the mine drainage system were estimated using the water balance parameters presented in Table C2.2-4. The values presented in the table are similar to those used in the Steepbank Mine Application and were estimated using the methodology described in "Hydrology Baseline for Project Millennium" (Klohn-Crippen 1998b).

Maximum and minimum mean daily flows for the small watercourses in the LSA were also estimated using a regional approach also described in "Hydrology Baseline for Project Millennium" (Klohn-Crippen 1998b).

The changes in soil characteristics and flows for each basin are presented in Tables C2.2-7 through C2.2-11.

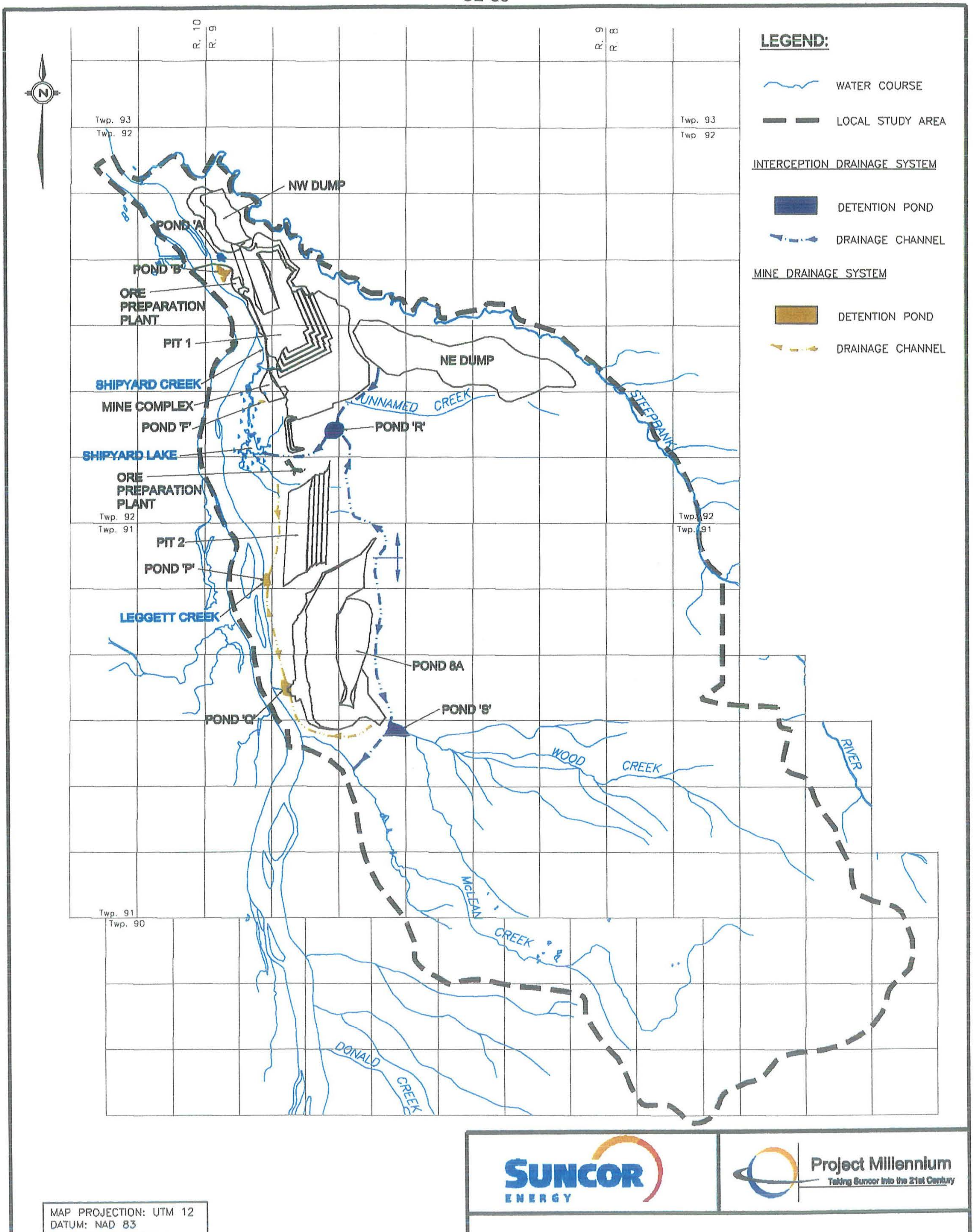
Construction Phase

The drainage systems and mine development at the end of construction (2002) are shown in Figure C2.2-5. The following activities will affect runoff to the receiving waterbodies during the construction phase:

- *Infrastructure Construction* includes plant construction (a second Ore Preparation Plant), dyke for the Gland Water Pond and associated facilities (including roads, conveyors and pipelines), the starter dyke for Dyke 11A and the shell for the NE Dump. None of these will be operating in this phase. Infrastructure development will be above the 1 in 100 year ice jam levels for the Athabasca River.
- An *Interception Drainage System* will be constructed upslope of the active development area. One drainage channel will divert run-on from the Leggett basin upslope of the active development area to the natural Unnamed Creek channel. Another drainage channel will be constructed to divert run-on from Wood Creek basin to McLean Creek. Ponds "R" and "S" will be constructed to attenuate flows and control sediment. By 2002, these diversions will increase the mean annual runoff flow in Shipyard Lake and McLean Creek by 50% and 140% respectively, as shown in Table C2-11 and Figures C2.2-6 and C2.2-7. Erosion control measures, such as armouring and channel reconstruction, will be undertaken to prevent channel degradation.
- *Clearing, and Muskeg and Overburden Dewatering* will be performed in advance of the initial pre-stripping and overburden removal. Flows from overburden dewatering are discussed under Key Questions SHH-1 and SHH-2. Flows from muskeg and overburden dewatering will be directed to the interception drainage system, and will increase the base flows to the Unnamed and McLean Creeks as discussed previously.

Flows from muskeg and overburden dewatering and run-on to the interception drainage system, and runoff from the NE Dump will temporarily increase flows in Unnamed Creek. This increase in flow was also present in the Steepbank Mine but did not occur until 2008. Pond "R" constructed on Unnamed Creek as part of the Steepbank Mine interception drainage system will be sized to attenuate the increase in flood peaks in Unnamed Creek. This pond, together with a diversion (also constructed as part of the approved Steepbank Mine interception drainage system to route excess flows downstream of Shipyard Lake), will ensure that flows into Shipyard Lake do not exceed baseline conditions. There will therefore be no impact on the water balance or levels Shipyard Lake.

Diverting flows from Wood Creek to McLean Creek in the interception drainage system will increase runoff to McLean Creek. Pond "S"



DRAINAGE PLAN - 2002

APRIL 1998	FIGURE C2.2–5	DRAWN BY: C.L.F.

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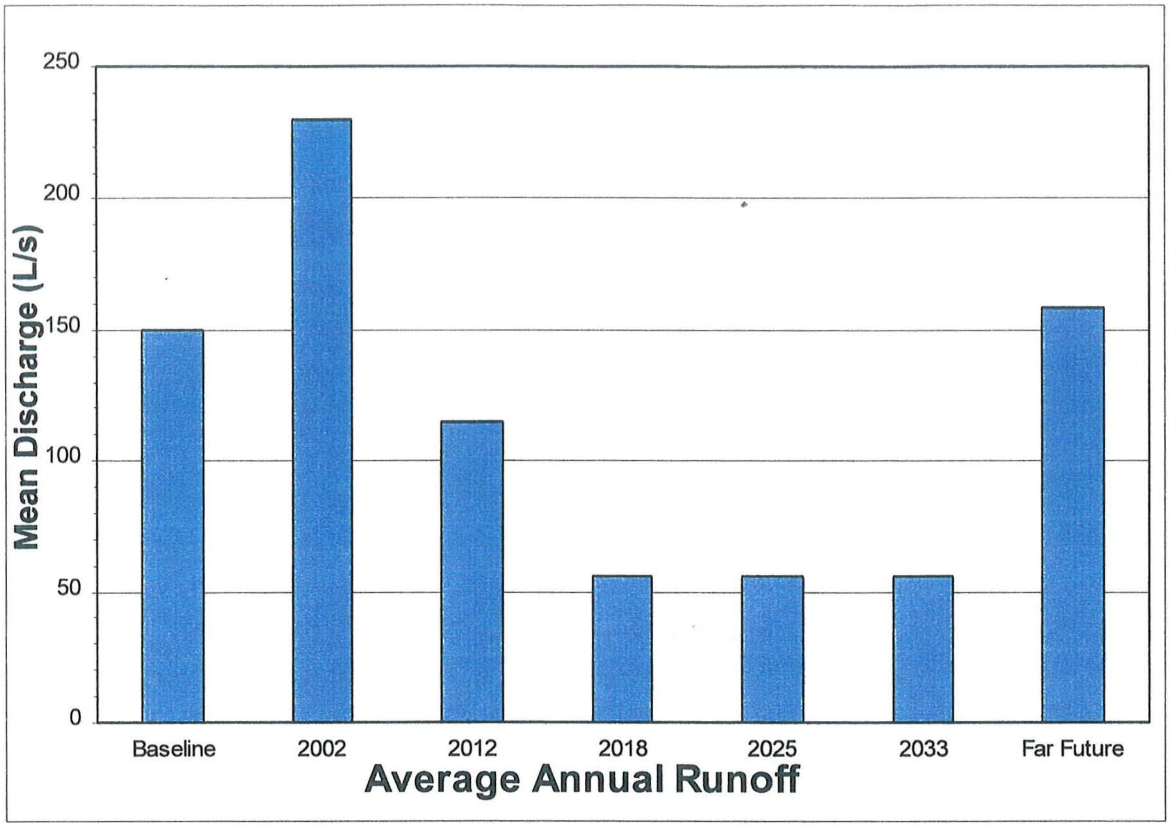

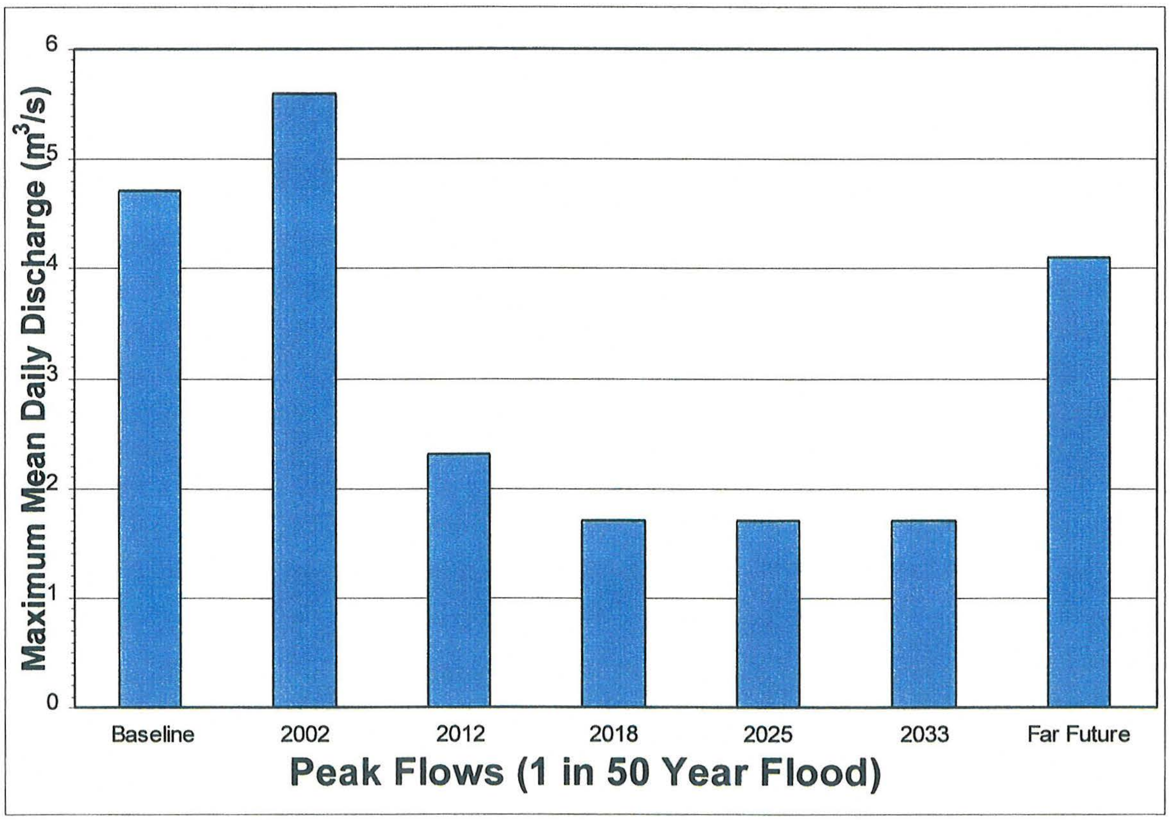

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VARIATION IN FLOWS TO SHIPYARD LAKE

APRIL 1998	FIGURE C2.2-6	DRAWN BY: C.L.F.

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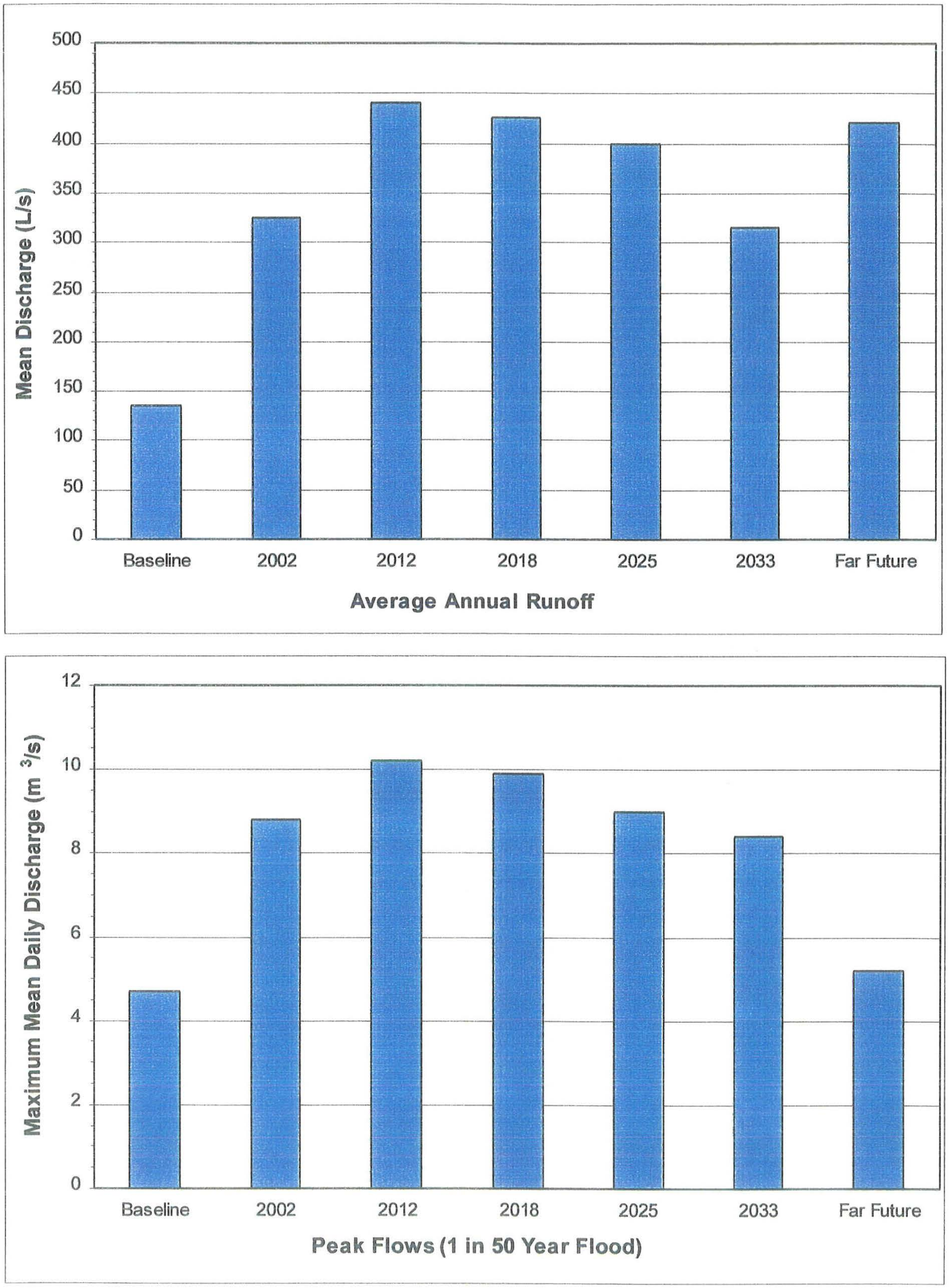

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VARIATION IN FLOWS IN McLEAN CREEK

APRIL 1998	FIGURE C2.2-7	DRAWN BY: C.L.F.

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Table C2.2-7 Water Balance Parameters

		Annual Depth (mm)		
		1:100 Dry Year	**Mean**	**1:100 Wet Year**
All Areas	Precipitation	234	396	696
Uncleared Natural *Inorganic Soil*	Evapotranspiration	234	251	330
	Percolation	0	0	0
	Runoff	0	145	366
Organic Soil	Evapotranspiration	234	324	513
	Percolation	0	0	0
	Runoff	0	73	183
Cleared Natural *Inorganic Soil*	Evapotranspiration	234	222	257
	Percolation	0	0	0
	Runoff	0	174	439
Organic Soil	Evapotranspiration	234	309	476
	Percolation	0	0	0
	Runoff	0	87	220
Disturbed (Pre-stripped) *10% Slope*	Evapotranspiration	47	50	66
	Percolation	10	10	10
	Runoff	177	336	620
1% Slope	Evapotranspiration	70	75	99
	Percolation	20	20	20
	Runoff	144	301	577
Sand Dykes *Flat Vegetated*	Evapotranspiration	176	188	248
	Percolation	59	183	385
	Runoff	0	25	64
Steep vegetated	Evapotranspiration	176	188	248
	Percolation	59	170	353
	Runoff	0	38	95
Flat unvegetated	Evapotranspiration	23	40	70
	Percolation	211	331	563
	Runoff	0	25	64
Steep unvegetated	Evapotranspiration	23	40	70
	Percolation	211	319	531
	Runoff	0	38	95
Lakes (Open Water)	Evapotranspiration	638	580	522
	Percolation	0	0	0
	Runoff	-404	-184	174
Overburden Dykes & Dumps *(Reclaimed)*	Evapotranspiration	211	226	297
	Percolation	0	0	0
	Runoff	23	170	399
Mine and Plant	Evapotranspiration	12	20	35
	Percolation	0	0	0
	Runoff	222	376	399

Table C2.2-8 Changes in Natural Drainage Basins

Drainage Basin	Proportion of Total Basin Area (%)			
	Undisturbed	Disturbed	Dumps/Stockpiles	Mine Footprint
Athabasca River				
Baseline	100	0	0	0
Construction - 2002	100	0	0	0
Operations - 2012	100	0	0	0
Operations - 2018	100	0	0	0
Operations - 2025	100	0	0	0
Operations - 2033 (End of Pit)	100	0	0	0
Closure - Far Future	100	0	0	0
Steepbank River				
Baseline	100	0	0	0
Construction - 2002	99	0	1	0
Operations - 2012	99	0	1	0
Operations - 2018	99	0	1	0
Operations - 2025	99	0	1	0
Operations - 2033 (End of Pit)	99	0	1	0
Closure - Far Future	99	0	1	0
Shipyard Lake			0	
Baseline	100	0	10	0
Construction - 2002	22	58	17	10
Operations - 2012	5	20	17	58
Operations - 2018	5	0	17	78
Operations - 2025	5	0	17	78
Operations - 2033 (End of Pit)	5	0	17	78
Closure - Far Future	5	0	17	78
Unnamed Creek				
Baseline	100	0	0	0
Construction - 2002	5	85	10	0
Operations - 2012	0	45	15	40
Operations - 2018	0	0	15	85
Operations - 2025	0	0	15	85
Operations - 2033 (End of Pit)	0	0	15	85
Closure - Far Future	0	0	15	85
Leggett Creek				
Baseline	100	0	0	0
Construction - 2002	73	0	27	0
Operations - 2012	38	35	27	0
Operations - 2018	10	63	27	0
Operations - 2025	10	9	27	54
Operations - 2033 (End of Pit)	10	0	27	63
Closure - Far Future	10	0	27	63
Wood Creek				
Baseline	100	0	0	0
Construction - 2002	95	0	5	0
Operations - 2012	94	1	5	0
Operations - 2018	82	13	5	0
Operations - 2025	82	11	5	2
Operations - 2033 (End of Pit)	82	0	5	13
Closure - Far Future	82	0	15	13
McLean Creek				
Baseline	100	0	0	0
Construction - 2002	100	0	0	0
Operations - 2012	100	0	0	0
Operations - 2018	100	0	0	0
Operations - 2025	100	0	0	0
Operations - 2033 (End of Pit)	100	0	0	0
Closure - Far Future	100	0	0	0

Table C2.2-9 Estimated Annual Runoff

Drainage Basin	Average Annual Flow (L/s) 1 in 100 Dry Year	Average	1 in 100 Wet Year
Athabasca River *All Years*	405,000	655,000	945,000
Steepbank River *All Years*	1,200	6,000	10,800
Shipyard Lake *Baseline*	0	150	380
Construction - 2002	1	230	500
Operations - 2012	7	115	245
Operations - 2018	4	56	135
Operations - 2025	4	56	135
Operations - 2033 (End of Pit)	4	56	135
Closure - Far Future	0	158	425
Unnamed Creek *Baseline*	0	142	355
Construction - 2002	0	222	475
Operations - 2012	4	107	220
Operations - 2018	1	48	110
Operations - 2025	1	48	110
Operations - 2033 (End of Pit)	1	48	110
Closure - Far Future	0	150	400
Leggett Creek *Baseline*	0	70	175
Construction - 2002	0	0	0
Operations - 2012	0	0	0
Operations - 2018	0	0	0
Operations - 2025	0	0	0
Operations - 2033 (End of Pit)	0	0	0
Closure - Far Future	0	0	0
Wood Creek *Baseline*	0	205	515
Construction - 2002	0	0	0
Operations - 2012	0	0	0
Operations - 2018	0	0	0
Operations - 2025	0	0	0
Operations - 2033 (End of Pit)	0	0	0
Closure - Far Future	0	0	0
McLean Creek *Baseline*	0	135	340
Construction - 2002	0	325	825
Operations - 2012	5	440	1,045
Operations - 2018	3	425	1,015
Operations - 2025	10	400	935
Operations - 2033 (End of Pit)	0	315	800
Closure - Far Future	0	420	1200

Table C2.2-10 Estimated Flood Flows

Drainage Basin	Maximum Mean Daily Flow (m^3/s)		
	1 in 10 Year	1 in 50 Year	1 in 100 Year
Athabasca River *All Years*	3,780	4,990	5,510
Steepbank River *All Years*	72.0	112	113
Shipyard Lake *Baseline*	3.2	4.7	5.2
Construction - 2002	3.9	5.6	6.3
Operations - 2012	1.6	2.3	2.6
Operations - 2018	1.1	1.7	1.8
Operations - 2025	1.1	1.7	1.8
Operations - 2033 (End of Pit)	1.1	1.7	1.8
Closure - Far Future	2.9	4.1	4.6
Unnamed Creek *Baseline*	0.9	1.4	1.5
Construction - 2002	2.8	5.4	6.0
Operations - 2012	1.4	2.1	2.3
Operations - 2018	0.9	1.4	1.5
Operations - 2025	0.9	1.4	1.5
Operations - 2033 (End of Pit)	0.9	1.4	1.5
Closure - Far Future	2.7	3.9	4.4
Leggett Creek *Baseline*	2.0	2.9	3.2
All Years	0	0	0
Wood Creek *Baseline*	4.0	5.8	6.4
All Years	0	0	0
McLean Creek *Baseline*	3.3	4.7	5.3
Construction - 2002	6.1	8.8	9.7
Operations - 2012	7.0	10.2	11.3
Operations - 2018	6.9	9.9	11.0
Operations - 2025	6.2	9.0	10.0
Operations - 2033 (End of Pit)	5.8	8.4	9.4
Closure - Far Future	5.2	5.2	5.8

Table C2.2-11 Estimated Low Flows

Drainage Basin	Minimum Mean Daily Flow (m^3/s)		
	1 in 10 Year Low	1 in 50 Year Low	1 in 100 Year Low
Athabasca River *All Years*	102	83.5	76.5
Steepbank River *All Years*	135	31	0
Shipyard Lake			
All Years	0	0	0
Unnamed Creek			
All Years	0	0	0
Leggett Creek			
All Years	0	0	0
Wood Creek			
All Years	0	0	0
McLean Creek *All Years*	0	0	0

constructed on Wood Creek will attenuate flood peaks. However, there will still be an increase in flood peaks and annual flows in McLean Creek of approximately 87% above baseline conditions as shown in Table C2.2-9 and Figure C2.2-7.

Construction of Dyke 11A and the South Dump will eliminate the Leggett Creek and Wood Creek channels on the Athabasca River Escarpment. Flows at the downstream end of both creeks from surface runoff will be reduced to nil.

Runoff from the plant area and starter dyke for Dyke 11A will be directed to a temporary drainage system during construction. Flows in the temporary drainage system will be passed through temporary sedimentation ponds before being released to the Athabasca River. As part of the construction process, this system will be upgraded to Mine Drainage Standards before the operation begins.

The NE Dump footprint also encroaches into the Steepbank River drainage basin and flows in the Steepbank River will be reduced as a result. However, the area affected is only about 0.04% of the total drainage area of the Steepbank River and the impact will therefore be negligible.

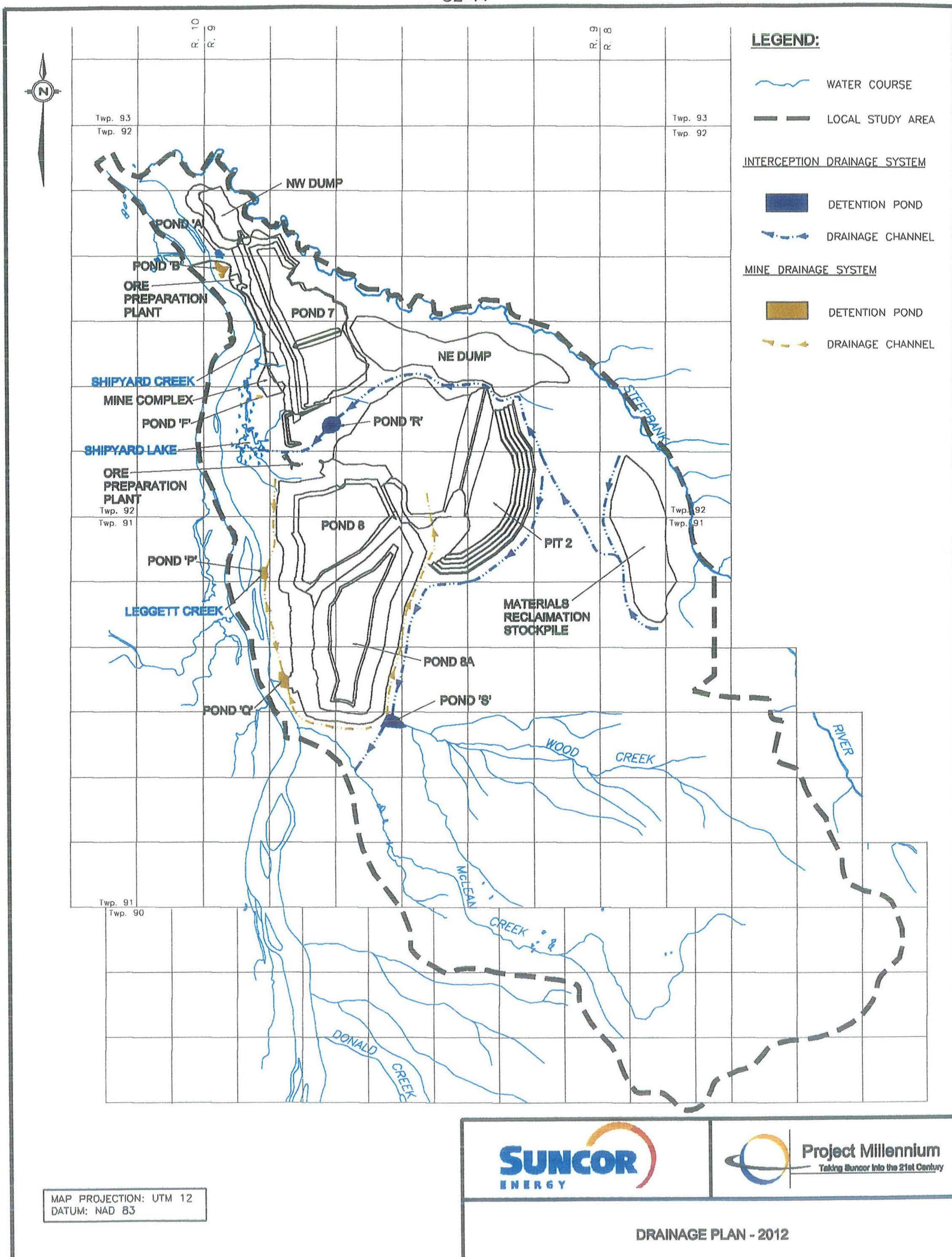
The impact of the above activities on the quantity of flows in the Athabasca River will be negligible.

All development will be above the 1 in 100 year ice jam levels for the Athabasca River. Ice jams on the Athabasca River will not affect the infrastructure and the impact will be negligible.

Operation

The drainage systems and mine development during operation are shown in Figures C2.2-8 through C2.2-11 for 2012, 2018, 2025 and 2033 (end of mine). No additional water withdrawals from the Athabasca River for consumptive use are required. Water diversion requirements are discussed in Volume 1, Section C2.4.4. The following activities will affect runoff to the receiving waterbodies during the operation phase:

- *Infrastructure Development* includes moving the Steepbank Mine Ore Preparation Plant to the Centre Plant site in about 2012 and the construction of roads, conveyors and pipelines. The infrastructure constructed as pat of the construction phase will be commissioned at the beginning of mine operations. The temporary drainage system built during the construction phase to handle runoff from the plant area, and the starter dyke for Dyke 11A will be upgraded to mine drainage system standards and flows diverted to process. Flows to the mine



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DRAINAGE PLAN - 2012

APRIL 1998	FIGURE C2.2-8	DRAWN BY: C.L.F.

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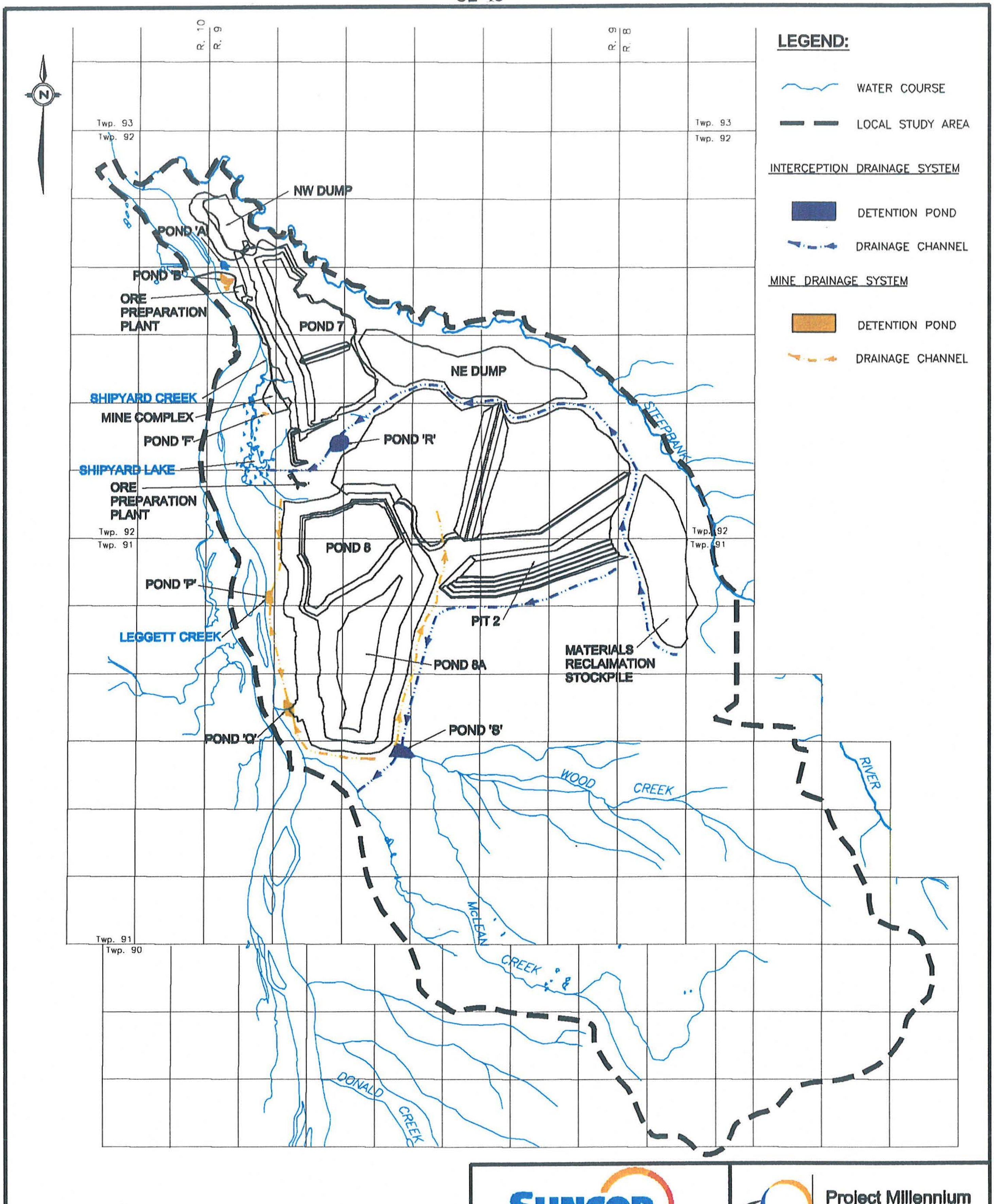

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DRAINAGE PLAN - 2018

APRIL 1998	FIGURE C2.2-9	DRAWN BY: C.L.F.

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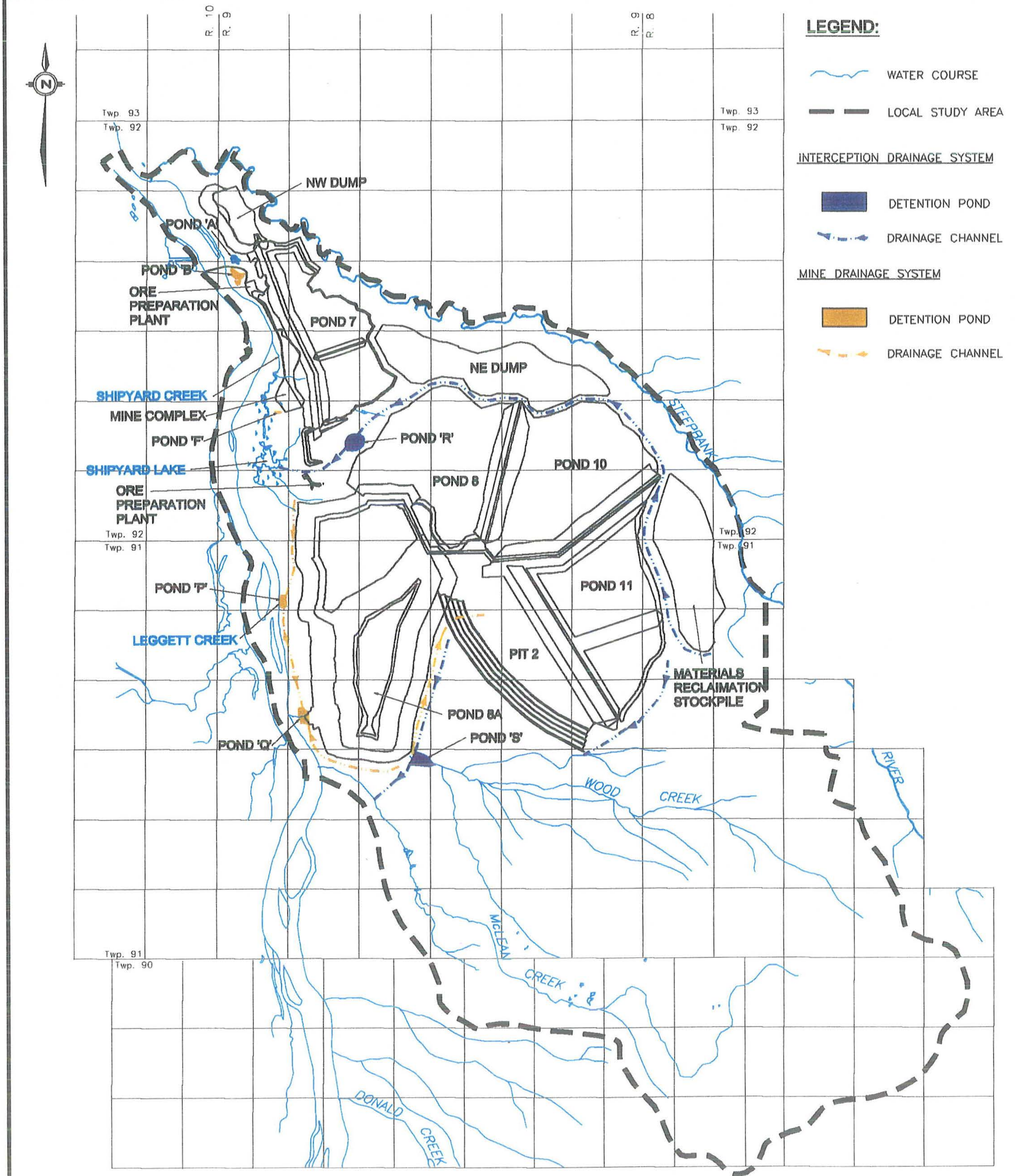

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DRAINAGE PLAN - 2025

APRIL 1998	FIGURE C2.2-10	DRAWN BY: C.L.F.

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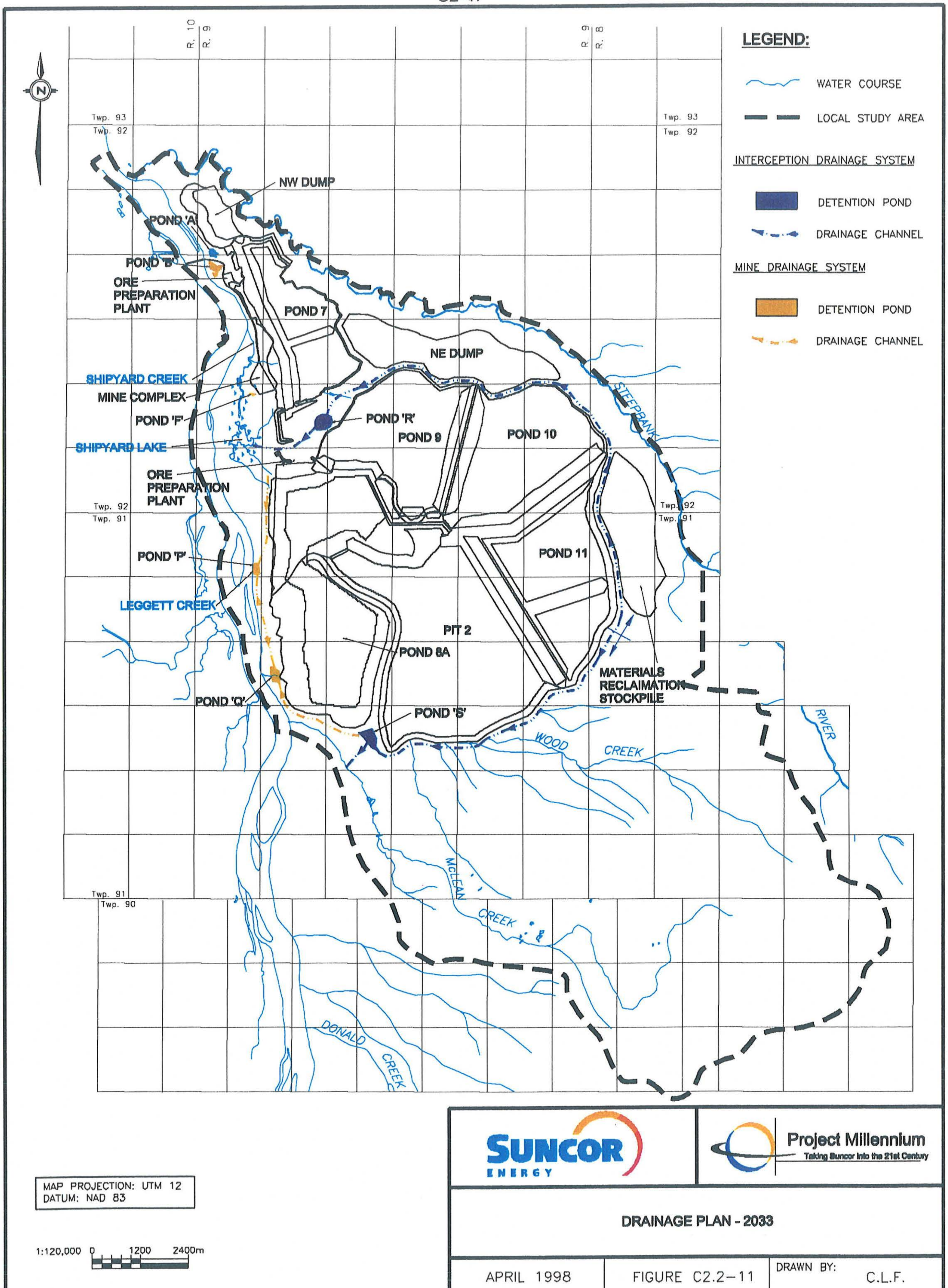

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DRAINAGE PLAN - 2033

APRIL 1998	FIGURE C2.2-11	DRAWN BY: C.L.F.

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water retention ponds will not be released to the environment. Runoff from the Centre Plant site will be directed to the mine drainage system and used in process. The effect and impact of these flows is presented under mine development.

- *Clearing, and Muskeg and Overburden Dewatering* will continue in advance of pre-stripping and overburden removal. Clearing will increase run-on to the interception drainage system compared with existing conditions. Clearing blocks are scheduled for 2005, 2010 and 2020. Flows from muskeg and overburden dewatering will be directed to the interception drainage system and will increase the flows to McLean Creek. The impacts will be the same as discussed under the construction phase.

- *Mine Development* includes the tailings pond (Pond 8A), CT ponds (Ponds 8 through 11) and associated overburden dykes and end pit lake (Pond 12). Runoff from mine development activities will be directed to the in-pit mine drainage system. Flows in the mine drainage system will be directed to the process water system and will not be released to the environment. The development of Pit 1 (part of the approved Steepbank Mine) will eliminate the natural channel of Unnamed Creek in about 2002. To ensure that flows to Shipyard Lake can be maintained, the creek will be replaced by an interception drainage channel and drop structure constructed between Pit 1 and Pit 2 as shown in Figure C2.2-5. The drainage channel will be extended east as Pit 2 encroaches on the Unnamed Creek channel. Pit development will also reduce run-on from the basins upslope of the mine to the interception drainage system. The effect and impact of the reduced run-on is presented under the interception drainage system below.

- Runoff from the NE Dump and Reclamation materials Stockpile will be directed to Shipyard Creek via the interception drainage system. The overall footprint of the NE Dump will not change during the operation phase. Therefore, there will be no change in the effect and impact during this phase beyond that discussed in the construction phase. The natural drainage area and runoff to Unnamed Creek will be reduced by the area of the stockpile. The net effect will be a slight increase in flood and base flows to the interception drainage system. The impact of these effects is presented under the interception drainage system.

- The *Interception Drainage System,* constructed upslope of the active development area, will be modified as the mine advances as shown in the drainage plan drawings. Until about 2015, the drainage system will divert runoff from the NE Dump and Reclamation Materials Stockpile and run-on from upslope of the mine development to Shipyard Lake via the Unnamed Creek channel. After this time, the area of the mine contributing flow to Shipyard Lake is mined out, and runoff will be diverted to the in-pit mine drainage system. The effect of this is to reduce mean annual flows to Shipyard Lake from the baseline of 150 L/s to about 56 L/s as shown in Figure C2.2-6 and Table C2.2-7. If necessary, water from the Athabasca River may be used to maintain the water balance of the Shipyard Lake ecosystem. The impact of this effect is also addressed in Section C4, Fisheries and Fish Habitat.

Flows in McLean Creek downstream of the interception drainage system outlet will increase during mine operations as shown in Table C2.2-8 and Figure C2.2-7. Pond “S” constructed on Wood Creek will attenuate flood peaks. However, there will still be an increase in flood peaks and base flows in McLean Creek compared with baseline conditions as shown in Figure C2.2-7. The impact on the quantity of flows in the Athabasca River will be negligible. There will be no impact to the timing of flood events on the Athabasca River.

Far Future

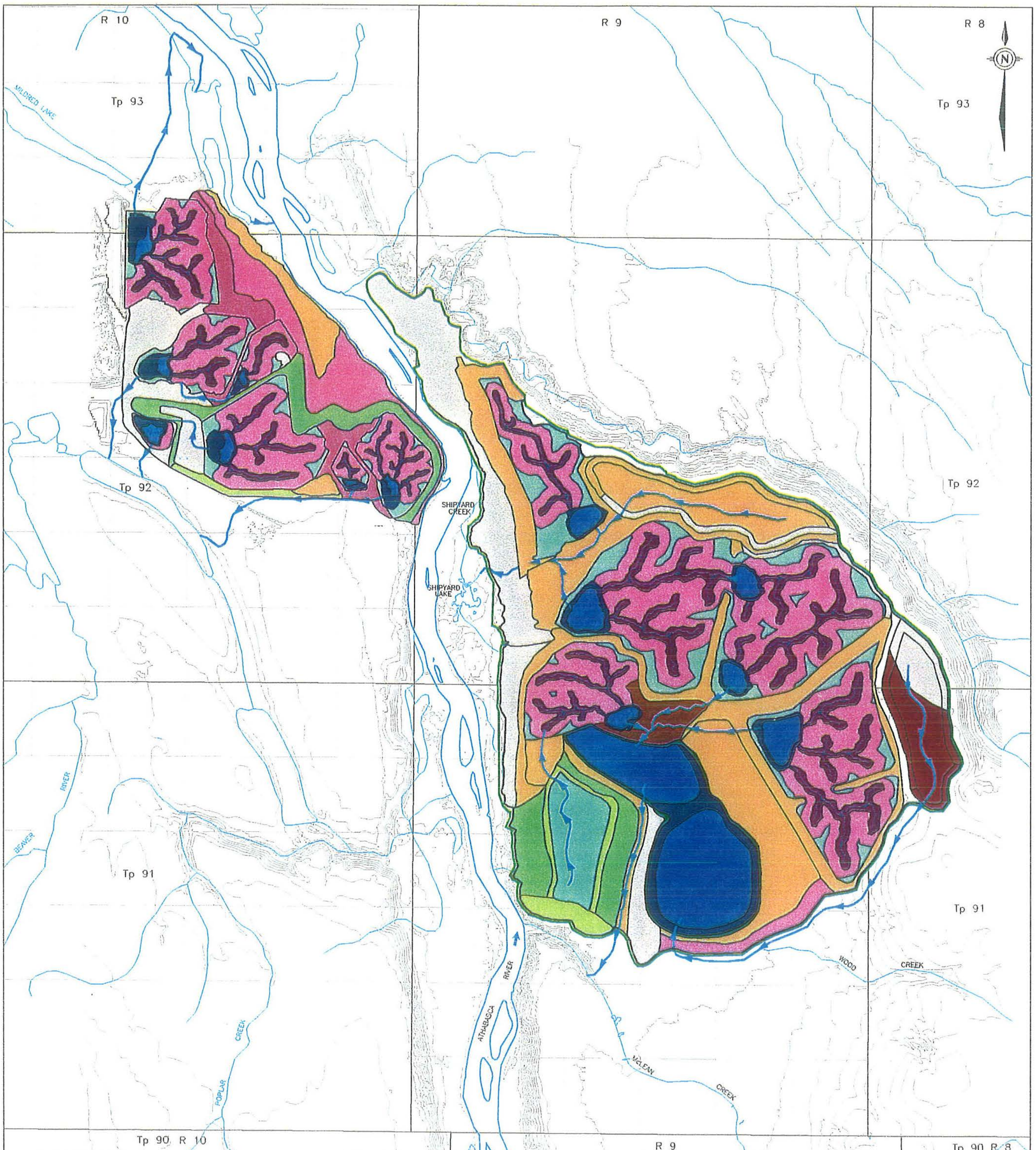
The landscape and drainage patterns for the Far Future are shown in Figure C2.2-12. The detailed description of reclamation work to be conducted is presented in Section E, Reclamation and Closure. The Far Future drainage systems will be different from existing conditions as listed below:

- The runoff from the mine development area will change due to the change in surface characteristics. The drainage pattern will be well-defined channels leading to wetlands. In the CT Pond areas the proportion of dry lands to wetlands will be 80% and 20% respectively, compared with existing values of 40% and 60% in the LSA.
- The end pit lake will be constructed in Pond 12. It will have an open water area of about 6.9 km^2.

The Far Future drainage patterns have been designed to meet various reclamation objectives including restoring the baseline flow conditions to Shipyard Lake. This will be accomplished by using a combination of the measures discussed under the operation phase, such as necessary channel diversion, as well as, routing flows through the wetlands and end pit lake for flood peak attenuation in the Far Future landscape.

The water balance in end pit lake will be maintained by routing runoff from part of Pond 10, Pond 11, the Reclamation Materials Stock Pile Area, and the reclaimed Pond 8A and Pond 8 to the lake. Runoff from the upslope areas of Wood Creek outside the east bank mining area, will also be routed to the end pit lake system, as well as, to maintain the lake level. A water balance for end pit lake in the Far Future is shown in Table C2.2-12.

Flows in McLean Creek will be permanently increased in average and peak conditions as shown in Table C2.2-8 and C2.2-9. Low flows will remain at 0 for events beyond the 1 in 10 year event.



LEGEND

- B1-BLUEBERRY PJ-AW
- B2-BLUEBERRY AW(BW)
- B3-BLUEBERRY AW-SW
- D1-LOW-BUSH CRANBERRY AW
- D2-LOW-BUSH CRANBERRY AW-SW
- D3-LOW-BUSH CRANBERRY SW
- E1-DOGWOOD PB-AW
- E2-DOGWOOD PB-SW
- E3-DOGWOOD SW
- SH(SONS)-DECIDUOUS SWAMPS
- OPEN WATER
- CONSTRUCTED WETLANDS
- SHRUBLAND
- INTERMITTENT DRAINAGE

0 2.5 5km

SCALE 1:125,000

REFERENCE

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

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DRAINAGE PLAN
FAR FUTURE

15 Apr. 1998	Figure C2.2-12	DRAWN BY: RFM

Table C2.2-12 End Pit Lake Far Future Water Balance

Source Basin or Area	Mean Annual Flow (L/s)
Undisturbed Area of Leggett Creek	10
Wood Creek	172
Surficial Aquifer Inflow	1
Bedrock Outflow	-1
Overburden Dykes and Dumps	70
Reclaimed Pond 8A	
Surface Runoff	18
Seepage	10
Reclaimed CT Ponds	44
Evaporation	-29
Net Flow	**295**

C2.2.4 Key Question SHH-3 Impact Summary

C2.2.4.1 Construction Impacts

Annual flows in Unnamed Creek downstream of the interception drainage system will increase. Flood peaks and the timing of flood flows are not expected to change. With the mitigation measures in place, there will be no impact to the water balance or levels of Shipyard Lake.

Leggett Creek and Wood Creek will be eliminated in the development area, and flows reduced to nil. The impact on both creeks is considered to have a high severity, be local in extent and long-term. The impact on the Athabasca River is negligible. Other impacts of these effects are discussed in Section C4, Fisheries and Fish Habitat.

Annual and flood flows in McLean Creek downstream of the interception drainage system will increase. The timing of flood flows is not expected to change. The impact on McLean Creek is considered to have a high severity, be local in extent and long-term. The impact on the Athabasca River is negligible. Other impacts of these effects area discussed in Section C4, Fisheries and Fish Habitat.

Flows in the Steepbank River will change by less than 0.1%. The impact is considered to have a negligible severity, be local in extent and long-term. The overall environmental consequences will be negligible.

Flows in the Athabasca River will change by less than 0.01%. The impact is considered to have a negligible severity, be regional in extent and long-term. Overall environmental consequences will be negligible.

Impacts During Operation

Unnamed Creek will be realigned. The impact on flows to Shipyard Lake will have a negligible severity, be local in extent and long-term with negligible consequences.

Annual and flood flows to Shipyard Lake will be reduced to below baseline conditions in about 2015. Mitigation by providing make-up flows from the Athabasca River, will eliminate the impact on water balance. Other impacts of these effects are discussed in Section C4, Fisheries and Fish Habitat, and Section D4, Vegetation and Wetlands.

Annual and flood flows in McLean Creek downstream of the interception drainage system will be higher than baseline conditions. The timing of flood flows is not expected to change. The impact of these effects on McLean Creek is considered to have a high severity, be local in extent and short-term. Other impacts of these effects are discussed in Section C4, Fisheries and Fish Habitat. The impact on Athabasca River is negligible.

There will be no further impact on the Steepbank River.

Flows in the Athabasca River will be increased by less than 0.01%. The impact is considered to have a negligible severity, be regional in extent and long-term.

Impacts After Closure

Annual and flood flows to Shipyard Lake will be restored to baseline conditions.

Annual and flood flows in McLean Creek downstream of the interception drainage system will increase. The timing of flood flows is not expected to change. The impact is considered to have a high severity, be local in extent and long-term. These effects on McLean Creek is considered to have a high severity, be local in extent and short-term. Other impacts of these effects are discussed in Section C4, Fisheries and Fish Habitat.

There will be no further impact on the Steepbank River.

Flows in the Athabasca River will be increased by less than 0.01%. The impact is considered to have a negligible severity, be regional in extent, and long-term.

Monitoring

The existing monitoring program for flows in watercourses in the Local Study Area, water levels in Shipyard Lake and climate data such as snow pack and precipitation will be continued. The monitoring will be an extension of Suncor's ongoing surface water monitoring programs for its Lease 86/17 and Steepbank Mines. This data is necessary to provide a sound basis for the design of water management facilities during construction and operation, and after closure.

Suncor is currently evaluating joining a regional hydrology monitoring program with Shell, Mobil and Syncrude.

C2.2.4.2 Key Question SHH-4: What Impacts Will Development and Closure of Project Millennium Have on Sediment Yields From Project Area River and Stream Basins, Sediment Concentrations in Receiving Streams and the Channel Regime of Receiving Streams?

Activities associated with mine development such as clearing, muskeg drainage and pre-stripping are expected to increase the sediment concentration in runoff to receiving waterbodies. In addition, increased runoff to the watercourses may result in increased channel erosion. Monitoring of sediment loads will be conducted in the future.

Therefore, the question is valid.

Construction and Operations

- Run-on from cleared and pre-stripped areas and runoff from facilities such as the NE Dump and Materials Reclamation Stockpile will have a higher sediment yield when compared with baseline conditions. During construction the potential increase in yield will be managed using temporary controls including silt fencing and cross-berms. Also, the dump and stockpile will be reclaimed as soon as activities allow. This approach is consistent with Suncor's erosion control philosophy for its Lease 86/17 and Steepbank Mines.
- Increased sediment concentration flows in the interception drainage system caused by channel erosion will be managed using temporary controls including ditch checks and sedimentation basins. Again, this is consistent with Suncor's current erosion control philosophy.
- Two ponds will be constructed on Unnamed Creek and Wood Creek to further control sediment concentration. They will be sized to ensure that the sediment concentration released from the pond during the 1 in 10 year flood are no greater than those in the receiving waterbody (Shipyard Lake and McLean Creek). There may be a reduction in sediment concentration in the receiving waterbodies for flows less than the 1 in 10 year event.
- The NE Dump footprint encroaches into the Steepbank River drainage basin and runoff from the shell could enter the Steepbank River. Temporary ditches and sediment ponds will be utilized, as necessary.

The shell will be revegetated immediately after construction and erosion control measures (for example, coconut matting) will be used to control erosion from these areas until the vegetation becomes established.

- After 2002, when the channel realignment for Unnamed Creek is commissioned, any increase in erosion potential for Unnamed Creek will be minimal.
- In-stream erosion protection including armouring will be employed in the McLean Creek channel downstream of the interception drainage system to eliminate potential degradation from an increase in flows. These measures will be designed based on the maximum increase in flow expected in about year 2012 and will incorporate the provisions in the No Net Loss Plan for McLean Creek.

Far Future

The landscape for the far-future situation is described under Key Question SHH-3. The landforms and any channel protection works will be designed to ensure that sediment concentrations and loads in Shipyard Lake and McLean Creek meet long-term objectives for the aquatic ecosystems in both waterbodies.

Impacts Summary

Sediment load to Shipyard Lake may be reduced to below baseline conditions as a result of the construction of the upstream ponds. The impact is considered to have a low severity, be local in extent and short-term. Other impacts of these effects are discussed in Section C4, Fisheries and Fish Habitat, and Section D4, Terrestrial Vegetation and Wetlands.

Leggett Creek and Wood Creek will be eliminated and sediment discharge to Athabasca River reduced to nil. This effect on the Athabasca River is considered negligible, long-term, local with negligible environmental consequences.

With mitigation measures in place, the impact of increased sediment yield from portions of the NE Dump and Reclamation Materials Stockpile in the basin on sediment load in the Steepbank River is considered be negligible, local in extent, and, reversible in the short-term. Environmental consequence is negligible.

With mitigation measures in place, the impact of increased sediment yield within the LSA on sediment load in the Athabasca River is considered to be negligible, local in extent and short-term.

With the mitigation measures in place sediment concentrations is expected to decrease and the load increase in McLean Creek downstream of the interception drainage system. The impact on Leggett Creek is considered to have a low severity, be local in extent and short-term. Other impacts of these effects are discussed in Section C4, Fisheries and Fish Habitat.

Far Future

The reclamation landscape drainage plans have assumed an average landslope of 1.0%. This is comparable to the existing natural slope of about 0.7%. Detailed landform descriptions are given in Section E, Reclamation and Closure. As noted in Figure C2.2-12, the watercourses will be located in deciduous swamp and will have a relatively shallow gradient. The combination of vegetation cover and shallow gradient will minimize channel erosion and degradation within the landscape.

The reclamation landscape has a surface cover of about 70 to 80% dry landscape and 20 to 30% wetlands. Comparison of terrain types in the RSA using GIS Techniques indicates this is similar to the ratio of natural cover in Steepbank River, Muskeg River and Jackpine Creek drainage basins as shown in Table C2.2-13.

Table C2.2-13 Basin Soil Types as Percentage of Total Area

Watercourse	Location	Dry Landscape (%)	Wedlands Soil (%)	Disturbed Areas (%)	Open Water (%)	Total (%)
Steepbank River	At WSC Gauge	65.6	33.8	0.1	0.5	100.0
Muskeg River	At WSC Gauge	66.5	27.2	5.9	0.5	100.0
Jackpine Creek	At WSC Gauge	78.6	21.4	0.0	0.0	100.0

Sediment yield for Steepbank River, Muskeg River and Jackpine Creek drainage basins has been measured by the Water Survey of Canada. Due to the similarity in basin characteristics, the long-term sediment yield from the reclaimed surface is expected to be similar to these natural basins, and has been estimated from the relationship.

$L = 12.3(A)^{-0.5}\,(Q)^{1.3}$ (Klohn-Crippen 1998a)

Where:

L = daily load (tonnes)
A = Catchment area (km^2)
Q = mean daily flow (m^3/s)

Estimated loading to each wetland in the reclaimed landscape is about 15 to 25 m^3/year. As discussed in Section E4, this is equivalent to about 1 mm per year deposition rate in each pond. Based on an average depth of 1.5 to 2.0 m, sediment deposition is not expected to cause loss of wetland area for many years.

Outflows from the reclaimed landscape will be to Shipyard Lake and McLean Creek. The flows to Shipyard Creek will be routed through the Unnamed Creek structure which will be designed to accommodate the peak flow during operations of about 6.0 m^3/s. After reclamation, the 1 in 100 year peak flood is expected to reduce to about 4.4 m^3/s. Since this is significantly reduced from the design flow, no significant long-term impacts to the Unnamed Creek channel are expected.

McLean Creek receives maximum impact during operations as well. The 1 in 100 year peak flows rise from 5.3 m^3/s under baseline conditions, to about 11.3 m^3/s in 2012 as shown in Table C2.2-9. Following reclamation, the flood events will be attenuated by the end pit lake storage capacity which will result in the 1 in 100 year peak flows again being reduced to about 5.8 m^3/s. Since the in-channel works installed in the construction and operation phases will have been designed to accommodate the higher flows, no significant residual impacts to McLean Creek are anticipated.

Monitoring

A monitoring program will be established to collect sediment data for the east bank mine area. This data is necessary to provide a sound basis for designing sedimentation ponds and erosion control works during construction, operation and after closure.

C2.2.4.3 Key Question SHH-5: What Level of Sustainability is Expected for Project Millennium Closure Landscape Drainage Systems?

Reclamation activities after closure will be directed towards providing a landscape that is sustainable in time. The flow and erosion control measures discussed in the previous section will provide a robust drainage system with opportunity to incorporate habitat enhancement. The mitigation measures are well established which minimizes the degree of uncertainty associated with the long-term performance of the closure drainage systems.

Multiple lines of defense will be incorporated; particularly in areas where the landscape is vulnerable to gully and channel erosion. Drainage channel will be designed to replicate, as far as possible, natural watercourses in the area. Engineered surfaces (at dumps, stockpiles, dykes and ponds) will be re-contoured to provide a more natural undulating topography. Drainage swales on these surfaces will be vegetated to minimize surface erosion. Wetlands provided to enhance landform diversity will also reduce any sediment load to receiving watercourses and attenuate flood peaks.

C2.3 SURFACE HYDROLOGY AND HYDROGEOLOGY CONCLUSION

C2.3.1 Introduction

Project Millennium has been designed to mitigate to the extent possible, the impacts on surface hydrology and hydrogeology expected for an open pit mining operation. The Project includes design considerations to:

- divert natural surface waters from the mining operation area;
- dewater groundwater areas impacted by the mine operation, with diversion to the interception drainage system for discharge or containment in the process water recycle system;
- maintain flows to Shipyard Lake during the mining operations, with incorporation of a self-sustaining drainage stream to provide flows to this wetlands on Project closure; and
- re-establish self-sustaining surface hydrology systems on the closure landscape.

The surface hydrology and hydrogeology impact assessment predicted the incremental effects of the Project on top of existing and approved oil sands operations. The assessment considered the issues, as addressed through the key question approach in Section C2.2 of the EIA. The issues and environmental consequences are summarized in Table C2.3-1.

Table C2.3-1 Surface Hydrology and Hydrogeology Issue and Environmental Consequence

Issue	Environmental Consequence
Groundwater levels (volumes) and flow patterns	High
Groundwater impacts to flow, water levels and quality in receiving streams, lakes, ponds and wetlands	Low
Water balance for open water areas of lakes, ponds, wetlands and streams	Negligible
Sediment yields from project area river and stream basins, sediment concentrations in receiving streams and the channel regime of receiving streams	Negligible
Sustainability of closure landscape drainage systems	Low

C2.3.2 Groundwater Levels (Volume) and Flow Patterns

Within the LSA the groundwater will be disturbed during operations. This disturbance will vary as the mine pit advances. The surficial aquifers in the mine area will be removed and replaced with tailings deposits. The bedrock aquifers will be depressurized during the time of operations which will reduce the natural discharge from these units to zero. This change in flow will be offset by an expected increase in flow resulting from an assumed increased head on the bedrock aquifers due to the changed terrain. There is some uncertainty associated with this increase since the change depends on the performance of the CT process. The assumption that the head in the bedrock aquifers will reach the elevation of the reclaimed surface is conservative. Under this assumption, the overall flow in the groundwater systems is expected to increase from a baseline level of about 35 L/s to about 48 L/s in the far future. Groundwater levels may return to the baseline level. Under this assumption, the groundwater flows would be expected to return to near baseline values.

The planned monitoring programs will establish the actual heads in the subsurface and reduce the uncertainty.

The magnitude of the impact in the LSA is high, the duration is short-term. The frequency is high, the geographic extent is local and the impact is reversible. Therefore, the overall environmental consequence due to changes in the groundwater levels and flow are high in the LSA. However, the change in flow of the receiving waterbodies is 0.01 to 3% as discussed in the next section. Therefore, the overall impact is not significant.

C2.3.3 Groundwater Impacts to Flow, Water Levels and Quality in Receiving Streams, Lakes, Ponds and Wetlands

The following activities have been evaluated with regard to their impacts on the direction of groundwater flow, the rate of groundwater discharge and the quality of groundwater:

- changes to current groundwater regimes, including:
  - dewatering of the surficial deposits up-gradient of the mine,
  - lowering of the hydraulic head in the bedrock aquifers during mining, and
  - placement of consolidated tailings (CT) in the pits to reclaim the mine;
- changes to groundwater quality, including:
  - seepage from infilled mine pit areas,
  - seepage from Tailings Pond 8A, and
  - seepage from the end pit lake.

The groundwater from the surficial deposits will be diverted to Shipyard Lake and the Athabasca River, via Unnamed Creek and McLean Creek. The change in flow in the receiving streams is less than 1%. Therefore the environmental consequence is low.

The porewater from CT is expected to seep through the bedrock aquifers, and discharge to the Athabasca River, Steepbank River and Shipyard Lake. The rate of this groundwater discharge is less than 0.01% of the minimum monthly flow in the Athabasca River, 1% of the minimum monthly flow in the Steepbank River and less than 3% of the average monthly flow to Shipyard Lake. The quality of the CT porewater is very similar to the natural quality of groundwater in the bedrock aquifers. The CT contains essentially the same organic compounds as the groundwater, although at slightly higher concentrations.

Seepage from Pond 8A will be collected during operations and used in process. In the Far Future, following closure of the pond, seepage from this sand and overburden area will be about 10 L/s to the Athabasca River and end pit lake.

In terms of groundwater flow and quality to receiving areas, the magnitude of the changes is low. The frequency is high, while the geographic extent is local and irreversible. Therefore, the environmental consequence is low.

C2.3.4 Water Balance for Open Water Areas of Lakes, Ponds, Wetlands and Streams

Annual flows in Unnamed Creek downstream of the interception drainage system will increase. Flood peaks and the timing of flood flows are not expected to change. With the mitigation measures in place, there will be negligible environmental consequence to the water balance or levels of the Shipyard Lake wetlands.

Leggett Creek and Wood Creek will be eliminated in the development area and flows reduced to nil. The impact on both creeks is considered to be high in magnitude, local in extent and long-term. The impact to flow in the Athabasca River is less than 1% of the mean annual flow. Therefore the magnitude is negligible. Other impacts of these changes to the creeks are discussed in Section C4, Fisheries and Fish Habitat.

Annual and flood flows in McLean Creek downstream of the interception drainage system will increase. The impact on McLean Creek is considered to be high in magnitude, local in extent and short-term. The impact to flow in the Athabasca River is less than 1% of the mean annual flow. Therefore the magnitude is negligible. Other impacts of these effects are discussed in Section C4, Fisheries and Fish Habitat.

The water balance of the end pit lake is sustainable from runoff in the LSA. Therefore impacts from this change are negligible.

In summary, the change in mean annual flow to the Athabasca River for various times in the mine life cycle from both surface water and groundwater sources by basin and year is low. The maximum change in flow is less than 1% of the mean annual flow.

Low flows from surface water in the local study area are estimated to be zero for all periods greater than the 1 in 10 year drought. Groundwater discharges will likely remain at baseline levels.

These flow impacts are negligible to low in magnitude, local in geographic extent, long-term and irreversible. Therefore, the environmental consequence is negligible.

C2.3.5 Sediment Yields

The mitigation measures employed in Project Millennium will control the sediment released from the east bank mine area to levels compatible with the receiving watercourses during construction and operations. In the far future, the reclaimed landscape will have a well established vegetation cover with a similar sediment yield as existing natural basins in the area.

Unnamed Creek, Mclean Creek and the Wood Creek diversion channels which will conduct runoff from the LSA will employ well established erosion control measures to maintain the channel regime.

The magnitude of impacts from sediment is negligible, the duration short term, the frequency low, the geographic extent local and reversible. The scientific uncertainty is low. Therefore, the environmental consequence of this issue is negligible.

C2.3.6 Closure Drainage Systems

There is uncertainty on the ultimate success of the various reclamation and closure activities integral to re-establishment of the groundwaters and surface hydrology. This uncertainty means there is a low rather than negligible environmental consequence associated with the expected level of sustainability for closure landscape drainage systems. The planned monitoring programs on groundwater and surface water systems, as well as studies to verify designs for reclamation drainage systems will reduce the scientific uncertainty.

C2.3.7 Monitoring

Suncor will continue operational monitoring programs to confirm predicted impacts to groundwater and surface water systems. These programs will monitor groundwater levels and quality, as well as flows and quality in surface drainage systems.

The riparian wetlands, Shipyard Lake, will be monitored throughout the operations of the Project to ensure that adequate supplies of water are maintained. The reclamation surface drainage systems will ensure that a self-sustaining system for provision of these waters is established as part of the Project closure plan.

C3 WATER QUALITY

C3.1 WATER QUALITY BASELINE/ENVIRONMENTAL SETTING

C3.1.1 Introduction

Surface water, sediment and porewater quality data were summarized from a variety of information sources, including routine monitoring by AEP (Hamilton et al. 1985, Noton and Shaw 1989, Noton and Saffran 1995), the Northern River Basins Study (Crosley 1996, Brownlee et al. 1997), baseline programs for various oil sands developments (R.L.&L. 1989, Golder 1996c) and the Oil Sands Regional Aquatic Monitoring Program (RAMP) established for the oil sands area (Golder 1998h). Data are not available for the two inflows to Shipyard Lake, Unnamed Creek and Creek Two.

Water quality of rivers and lakes in the study area is described below in terms of chemical characteristics and toxicity. Descriptions of water chemistry are focused on parameters that are considered indicators of certain aspects of water quality. These parameters and toxicity are briefly described below:

- pH is an indication of the acidic or basic (alkaline) nature of water. Neutral waters have a pH near 7. The pH of natural surface waters usually falls between 6 and 9 in Alberta. Acidification causes a decline in pH.
- Dissolved salts can occur in a variety of forms in surface waters (e.g., sodium chloride, calcium sulphate). Total dissolved solids (TDS) is a frequently used indicator of total salt level in water. As a general rule, TDS levels in excess of 2,000 mg/L are usually considered deleterious to aquatic life.
- Suspended solids includes all solid particles suspended in the water column. An increase in suspended solids level usually results in a corresponding increase in stress to aquatic animals. Total suspended solids levels below 25 mg/L are usually not considered harmful to aquatic life. However much higher levels are typically tolerated for short periods.
- Nutrients include a variety of nitrogen and phosphorus compounds that are required for plant growth in very small quantities. Biological productivity of lakes and rivers is usually limited by one nutrient (frequently phosphorus), referred to as the limiting nutrient. Total phosphorus levels typically range between 0.001 mg/L in unproductive waters such as alpine lakes, to >0.1 mg/L in highly productive waters.
- Metals usually occur in small quantities (<1 mg/L) in surface waters, since they are usually associated with suspended sediments and tend to

settle out. Exceptions include metals forming water-soluble salts (e.g., calcium, magnesium, sodium, potassium), which may occur in dissolved form, as positively charged ions (cations), in excess of 100 mg/L. These are frequently referred to as "major ions," along with the negative ions (anions) that balance them in surface waters. Elevated levels of metals are usually harmful to aquatic organisms. The level causing toxicity varies by metal.

- Organic compounds include chemicals consisting of chains or rings of carbon atoms, such as hydrocarbons, phenols, polycyclic aromatic hydrocarbons (PAHs) and naphthenic acids. These may originate from natural sources (e.g., oil sands deposits, forest fires), or may be released from industrial sources. Elevated levels of organic compounds may be harmful to aquatic organisms. The level causing toxicity varies widely by chemical. In the oil sands area, naturally occurring hydrocarbons and PAHs have been reported at elevated (but not toxic) levels in natural surface waters.
- Toxicity refers to harmful effects on organisms caused by chemicals. It is usually evaluated by exposing standard test organisms (e.g., trout, water flea, aquatic worm) to various dilutions of the test waters or sediments.

To provide an indication of the "level" of water quality in the waterbodies discussed, concentrations of individual substances were compared with water and sediment quality guidelines for the protection of aquatic life and human health. Whenever possible, winter water chemistry data were used for these comparisons, because in the winter, concentrations of the majority of chemicals in surface waters are usually at their annual maximum. This is due to the lowest annual dilution capacity in rivers during the winter low-flow period. In the absence of winter data, fall data were used for guideline comparisons. Since sediment chemistry does not vary greatly by season, all available sediment data were compared with guidelines.

Guidelines developed by regulatory agencies based on toxicity data were used for these comparisons (Table C3.1-1), as recommended by AEP (1996b). Compliance with acute guidelines in surface waters protects aquatic organisms from short-term, lethal effects; compliance with chronic guidelines provides protection from longer-term, lethal or sublethal effects (e.g., reduced growth or reproduction). Sediment chemistry was compared with values of the threshold effect level (TEL) and the probable effect level (PEL), using the interim freshwater Canadian sediment quality guidelines (Smith et al. 1996).

C3.1.2 Water Quality Baseline

C3.1.2.1 Athabasca River

Surface Water

Water quality of the lower Athabasca River has not changed measurably over the last two decades. It is characterized by a typical pH range of 7.6 to 8.3 and moderate levels of dissolved salts (TDS), hardness and alkalinity (Table C3.1-2). Spring and summer high flows usually cause a large increase in suspended solids load, which is reflected in elevated concentrations of nutrients (e.g., total phosphorus) and a number of metals (e.g., aluminum, iron, manganese; measured as total metals) during these seasons. Total alkalinity, TDS and total hardness are typically highest in the winter, reflecting seasonal changes in hydrology. Nutrient levels are indicative of moderate enrichment from natural sources and, potentially, from upstream point sources (pulp mills and sewage treatment plants). Levels of dissolved metals, PAHs and naturally occurring hydrocarbons are generally low. Microtox® tests have not provided evidence of toxicity in river water.

Recent toxicity studies conducted under the Panel for Energy Research and Development (PERD) also documented detectable but low levels of trace organic compounds (PAHs and chlorophenolic compounds) in the Athabasca River and found low or no acute or chronic toxicity to a variety of test organisms (Brownlee 1990, Dutka et al. 1990, 1991, McInnis et al. 1992, 1994 Xu et al. 1992, Brownlee et al. 1993, Golder 1996c).

Comparisons of measured water quality constituents with water quality guidelines were made using fall medians near Donald Creek and upstream from the Muskeg River due to lack of winter data for these reaches; winter medians were used for the other two reaches. Guidelines for aquatic life were exceeded for a number of metals and total phosphorus (Table C3.1-3). These exceedances were typically minor and were largely caused by metals that tend to be elevated due to increased suspended solids levels (e.g., aluminum, iron, manganese). Guideline exceedances for human health were noted for total arsenic, iron and manganese. Additional guideline exceedances would result from comparing the maximum measured ranges with guideline levels. Overall, the guideline exceedances found under baseline conditions are likely of no concern regarding potential adverse effects on aquatic organisms.

In general terms, water quality of the Athabasca River is good, though periods of naturally high suspended solids may cause stress to aquatic organisms. The available data do not provide evidence of spatial trends in water quality along the lower Athabasca River.

Table C3.1-1 Water and Sediment Quality Guidelines for the Protection of Aquatic Life and Human Health

Parameter	Units	Aquatic Life		Human Health		Reference
		Acute	Chronic	HHC	HHNC	
Surface Water						
Chloride	mg/L	860	230			USEPA
Nitrate	mg/L	-	10	-	10	CCME
Nitrite	mg/L	-	0.06	-	-	CCME
Total Suspended Solids	mg/L	-	10	-	-	ASWQG
Total Phenolics	mg/L	-	0.005	-	-	ASWQG
Total Ammonia (low winter flow)	mg/L	16	2.1	-	-	USEPA
Total Ammonia (open water flow)	mg/L	10	1.9	-	-	USEPA
Total Phosphorus	mg/L	-	0.05	-	-	ASWQG
Aluminum (Al)	mg/L	-	0.1	-	-	CCME
Antimony (Sb)	mg/L	-	-	-	0.014	USEPA
Arsenic (As)	mg/L	0.36	0.01	0.000018	-	USEPA, ASWQG
Barium (Ba)	mg/L	-	1	-	1	ASWQG
Beryllium (Be)	mg/L	0.13	0.0053	-	-	USEPA
Boron (B)	mg/L	-	0.5	-	-	ASWQG
Cadmium (Cd)	mg/L	0.0074*	0.0018*	-	-	USEPA
Chromium (Cr)	mg/L	0.016	0.011	-	-	USEPA
Cobalt (Co)	mg/L	-	0.05	-	-	CCME
Copper (Cu)	mg/L	0.027*	0.007*	-	-	ASWQG
Iron (Fe)	mg/L	-	1	-	0.3	ASWQG
Lead (Pb)	mg/L	0.17*	0.007*	-	-	USEPA
Lithium (Li)	mg/L	-	2.5	-	-	CCME
Manganese (Mn)	mg/L	-	0.05**	-	0.05	ASWQG
Mercury (Hg)	mg/L	0.0024	0.000012	-	0.00014	USEPA
Molybdenum (Mo)	mg/L	-	1	-	-	BCMOE
Nickel (Ni)	mg/L	2.3*	0.25*	-	0.61	USEPA
Selenium (Se)	mg/L	-	0.01	-	-	ASWQG
Silver (Ag)	mg/L	0.01*	0.05	-	-	USEPA, ASWQG
Uranium (U)	mg/L	-	0.01	-	-	CCME
Vanadium (V)	mg/L	-	10	-	-	BCMOE
Zinc (Zn)	mg/L	0.19*	0.17*	-	-	USEPA
Benzo(a)anthracene group	mg/L	-	-	0.0000028	-	USEPA
Benzo(a)pyrene group	mg/L	-	-	0.0000028	-	USEPA
Ethylbenzene	mg/L	-	-	-	3.1	CCME, USEPA
Fluorene	mg/L	-	-	1.3	-	USEPA
Pyrene	mg/L	-	-	0.96	-	USEPA
Sediment		TEL	PEL			
Arsenic	µg/g	5.9	17	-	-	Smith et al. 1996
Cadmium	µg/g	0.596	3.53	-	-	Smith et al. 1996
Chromium	µg/g	37.3	90	-	-	Smith et al. 1996
Copper	µg/g	35.7	197	-	-	Smith et al. 1996
Lead	µg/g	35	91.3	-	-	Smith et al. 1996
Mercury	µg/g	0.174	0.486	-	-	Smith et al. 1996
Nickel	µg/g	18	35.9	-	-	Smith et al. 1996
Zinc	µg/g	123	315	-	-	Smith et al. 1996
Phenanthrene	µg/g	0.0419	0.515	-	-	Smith et al. 1996
Benzo(a)anthracene	µg/g	0.0317	0.385	-	-	Smith et al. 1996
Benzo(a)pyrene	µg/g	0.0319	0.782	-	-	Smith et al. 1996
Chrysene	µg/g	0.0571	0.862	-	-	Smith et al. 1996
Fluoranthene	µg/g	0.111	2.355	-	-	Smith et al. 1996
Pyrene	µg/g	0.053	0.875	-	-	Smith et al. 1996

NOTES: - = no guideline
* = guideline specified for hardness of 175 mg/L CaCO3
** = aesthetic guideline
n/a = not applicable
HHC = human health carcinogen; HHNC = human health non-carcinogen
ASWQG = Alberta Surface Water Quality Guidelines
BCMOE = British Columbia Ministry of the Environment
CCME = Canadian Council of Ministers of the Environment
USEPA = United States Environmental Protection Agency
TEL = Threshold effect level
PEL = Probable effect level

Table C3.1-2 Water Quality of the Lower Athabasca River (1976-1997)

Parameter	Units	Upstream Fort McMurray				Near Donald Creek[(a)]			Below Existing Oil Sands Operations			Below Fort Creek[(a)]			
		Winter	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Conventional Parameters and Nutrients															
pH	-	7.88	8.01	7.98	7.90	7.81-8.10	7.63*	7.82-8.00	7.94	7.63-8.00	-	7.92	8.20	7.95	8.30
Total Alkalinity	mg/L	169	102	98	110	76-97	88*	92-95	104	90-94	-	144	99	90	104
Total Dissolved Solids	mg/L	243	159	144	158	140-141	120*	146-200	146-240	123-158	-	-	46	182*	140-160
Total Suspended Solids	mg/L	2	82	127	19	19-181	624*	4-57	30-190	624-676	-	3	215	266	36
Total Hardness	mg/L	190	114	105	124	111	114*	100-104	121	101-118	-	158	103	92	105.7
Dissolved Organic Carbon	mg/L	8.0	10.0	8.0	8.0	7.1-11.0	16.7*	9.0-9.2	7.6	13.0-16.1	-	6.8	11.0	12.7	8.8
Total Kjeldahl Nitrogen	mg/L	0.54	0.87	0.81	0.62	1.20	-	<0.2*	-	0.20	-	0.33	1.20*	1.01*	0.5*
Total Ammonia	mg/L	0.03	0.02	0.01	0.01	<0.01-<0.05	0.04*	<0.01-<0.05	<0.01	0.04-<0.05	-	0.06	0.05*	0.03*	<0.05*
Total Phosphorus	mg/L	0.022	0.110	0.128	0.033	0.140-0.144	0.390*	0.084-0.087	0.120	0.298-0.440	0.08*	0.029	0.082	0.290	0.058
Dissolved Phosphorus	mg/L	0.012	0.013	0.013	0.007	0.020	-	0.022*	-	0.019	0.01*	0.020	0.015	0.018	0.013
Metals (Total)															
Aluminum (Al)	mg/L	0.055	0.844	0.908	0.23	0.17-5.18	8.64*	0.11-2.23	0.15-4.05	10.1-14.1	3.89*	0.0155	3.66*	6.13*	2.38*
Arsenic (As)	mg/L	0.0004	0.0012	0.0012	0.001	0.0006-0.002	0.007*	0.0005-0.0013	0.0008-0.0017	0.0057-0.007	0.0015*	0.004	0.0011	0.0045	0.0008
Cadmium (Cd)	mg/L	0.001	0.001	<0.001	<0.001	<0.0002-<0.003	<0.003*	<0.002-<0.003	<0.0002-<0.003	0.0002-<0.003	<0.0002*	0.001	<0.001	0.001	0.001
Chromium (Cr)	mg/L	0.003	0.0045	0.004	0.0025	<0.002-0.0051	0.003*	<0.002-0.0026	<0.002-0.0051	<0.002-0.0197	0.0043*	0.0025	0.005	0.00995	0.003
Copper (Cu)	mg/L	0.001	0.004	0.005	0.0015	<0.001-0.007	-	0.049*	0.004-0.0061	0.0181	0.0041*	0.0015	0.002	0.008	0.002
Iron (Fe)	mg/L	0.17	3.21	3.12	0.35	0.43-5.24	17.90*	0.91-2.19	0.43-3.76	17.60-19.40	2.98*	0.46	5.04*	16.10*	2.41*
Manganese (Mn)	mg/L	-	-	-	-	0.040-0.106	0.509*	0.033-0.071	0.044-0.101	0.408-0.534	0.074*	-	0.120*	-	0.075*
Mercury (Hg)	mg/L	0.0001	0.0001	<0.0001	<0.0001	<0.0002-<0.05	<0.05*	<0.0001-<0.05	<0.0002-<0.05	<0.0001-<0.05	<0.0001*	0.0001	<0.0001	<0.0001	<0.0001
Nickel (Ni)	mg/L	-	-	-	-	0.005	<0.005*	<0.005-0.003	<0.005-0.014	0.009-0.021	0.007*	-	0.005	0	0.003
Vanadium (V)	mg/L	<0.002*	0.002*	0.005	-	<0.002-0.013	0.009*	0.0001*	0.004-0.011	0.015-0.038	0.010*	<0.002*	0.009*	0.023*	0.006*
Zinc (Zn)	mg/L	0.007	0.015	0.013	0.007	0.019-0.812	0.085	0.014*	0.019-0.036	0.064-0.095	0.034*	0.004	0.003	0.029	0.005
Metals (Dissolved)															
Aluminum (Al)	mg/L	0.010	0.068	<0.002-0.020	0.020	0.241*	0.0159**	0.0443*	0.057*	0.050*	0.073*	-	0.415*	0.026*	0.036*
Arsenic (As)	mg/L	0.0005	0.0009	0.0009	0.0006	0.001*	0.0004*	0.0005*	0.0006*	0.0006*	0.0006*	-	0.0012*	0.0005*	0.0005*
Cadmium (Cd)	mg/L	<0.001*	<0.001-0.006	0.001*	-	<0.0001*	0.0028*	0.0001*	<0.0001*	0.0002*	0.0001*	-	0.0001*	0.0002*	0.0001*
Chromium (Cr)	mg/L	0.003	0.003	0.003	0.003	<0.0004*	<0.0004*	0.0004*	<0.0004*	<0.0004*	<0.0004*	-	0.0007*	<0.0004*	<0.0004*
Copper (Cu)	mg/L	<0.001*	<0.001-0.003	0.002*	-	0.0043*	0.0022*	0.0022*	0.0024*	0.006*	0.0042*	-	0.0049*	0.003*	0.002*
Iron (Fe)	mg/L	0.11	0.1	0.07	0.12*	1.14*	0.1*	0.14*	0.32*	0.08*	<0.01*	-	1.93*	0.43*	0.14*
Manganese (Mn)	mg/L	-	-	-	-	0.074*	0.003*	0.011*	0.024*	0.001*	0.01*	-	0.092*	0.025*	0.013*
Mercury (Hg)	mg/L	-	-	-	-	<0.0002*	<0.0002*	0.0002*	<0.0002*	<0.0002*	<0.0002*	-	<0.0002*	<0.0002*	<0.0002*
Vanadium (V)	mg/L	<0.001	<0.001-<0.002	<0.001*	-	0.0012*	<0.0001*	0.0001*	0.0002*	<0.0001*	0.0002*	-	0.002*	0.0001*	<0.0001*
Zinc (Zn)	mg/L	0.002*	0.001*	<0.001*	-	-	0.038*	0.014*	0.006*	0.027*	0.023*	-	0.015*	0.016*	0.019*
Organics															
Naphthenic Acids	mg/L	-	-	-	-	<1-2	<1	<1*	<1	<1	ND*	-	1*	-	<1*
Recoverable Hydrocarbons	mg/L	-	-	-	-	<0.5-<1	1	<1*	<0.5-<1	<0.5-<1	-	-	<0.5*	-	0.6*
PAHs and Alkylated PAHs	µg/L	-	-	-	-	ND	ND	ND*	ND-0.03	ND	-	-	-	-	-
PANHs	µg/L	-	-	-	-	ND	ND	ND*	ND	ND	-	-	-	-	-
Phenolics	µg/L	-	-	-	-	ND	ND	-	ND	ND	-	-	-	-	-
Total Phenolics	mg/L	0.003	0.003	0.002	0.002	0.001	0.001*	<0.001	<0.001-0.002	<0.001	<0.01*	0.004	0.003-0.007	0.004	0.005
Volatile Organics	µg/L	-	-	-	-	ND	-	-	ND	-	-	-	-	-	-
Toxicity															
Microtox IC50	%	-	-	-	-	100	100*	>100*	91-100	100	-	-	-	-	-
Microtox IC25	%	-	-	-	-	100	100*	>100*	91-100	100	-	-	-	-	-

NOTES: - = No data
ND = Not detected
PAH = Polycyclic aromatic hydrocarbon
PANH = Polycyclic aromatic nitrogen heterocycle
* = measured concentration (n=1) is presented; median concentrations (n>2) or ranges (n=2) are presented for all other samples and parameters
(a) Near Donald Creek: upstream oil and area; Below Fort Creek: downstream oil sand area.

Bottom Sediments

Bottom sediments of the Athabasca, Peace, Smoky and Wapiti rivers were collected during the Northern River Basins Study (NRBS) for assessment of PAHs, PCBs and pulp mill-related organic compounds (Crosley 1996, Brownlee et al. 1997). Brownlee et al. (1997) reported low levels of individual PAHs (<22 μg/g) at a number of sites along the Athabasca River, including three sites in the lower reaches (above Horse River, above Firebag River and at the mouth of Rifebay River). None of the reported concentrations exceeded the applicable TEL guidelines. Levels of PAHs were similar at all sites in the Athabasca River and were generally lower than in Peace and Wapiti river sediments.

Crosley (1996) reported an increase in total PAHs in the clay-silt fraction of bottom sediments from approximately 1 μg/g in the upper and mid-reaches of the Athabasca River to >2 μg/g above Fort McMurray. This abrupt increase was followed by a minor decline near Fort McKay. Crosley (1996) suggested that the increase in the lower reaches of the river was most likely due to natural sources, and speculated that the decline in sediment PAH levels between Fort McMurray and Fort McKay suggests that oil sands industries are not contributing significant PAHs to river sediments.

Bottom sediment quality of three closely-spaced sites near Suncor's Tar Island Dyke (TID) was assessed in 1994 and 1995 by Golder Associates (1994b, 1996c). The presence of varying amounts of oil sands was indicated by detectable but low levels of PAHs in both years and relatively high hydrocarbon content at all three sites in 1995 (Table C3.1-4). Levels of certain PAHs exceeded the TEL guidelines at one site, located just upstream from existing oil sands operations (Table C3.1-3). Levels of metals were typical of the bottom sediments of large rivers in Alberta (e.g., Shaw et al. 1994). Cadmium concentration was equal to the TEL in one sample (at TID, east bank) and the TEL guideline for nickel was exceeded at two sites (both banks at TID). Microtox® tests of sediment extracts in 1994 did not detect toxicity to bacteria at any of the sites sampled (Microtox® screen test results between 75 and 100% are generally considered to indicate lack of toxicity).

Bottom sediments of the Athabasca River were most recently sampled in 1997, during the fall field program of the RAMP (Golder 1998h). The sample collected below the oil sands area contained higher levels of hydrocarbons and PAHs than the sample from upstream of the oil sands area (Table C3.1-4), which conflicts with findings of Crosley (1996). Levels of most metals were higher than those reported in previous samples from this river. Nickel levels exceeded the TEL below Fort Creek (Table C3.1-3). Sediment toxicity tests using three different test organisms found no evidence of deleterious effects above or below the oil sands area (Golder 1998h).

Table C3.1-3 Summary of Water and Sediment Quality Guideline Exceedances

Parameter	Athabasca R. upstream Fort McMurray (Winter)	Athabasca R. near Donald Creek (Fall)	Athabasca River above TID, West Bank (Fall)	Athabasca River at TID, West Bank (Fall)	Athabasca River at TID, East Bank (Fall)	Athabasca R. upstream Muskeg River (Fall)	Athabasca R. below Fort Creek (Water in Winter, Sediment in Fall)	Mouth of Steepbank River (Water in Winter, Sediment in Fall)	Lower Steepbank River (Water in Winter, Sediment in Fall)	Upper Steepbank River (Fall)	McLean Creek (Fall)	Wood Creek (Fall)	Leggett Creek (Fall)	Shipyard Lake (Summer)	Shipyard Creek (Fall)	Muskeg Drainage Water
Water Quality Guideline Exceedances for Aquatic Life																
Total Phosphorus	-	C	ND	ND	ND	C	-	-	C	C	-	-	-	-	C	-
Total Aluminum	-	C	ND	ND	ND	C	-	C	-	-	-	-	C	-	C	C
Total Chromium	-	-	ND	ND	ND	-	-	-	-	-	-	-	-	-	-	A,C
Total Copper	-	A,C	ND	ND	ND	-	-	-	ND	ND	ND	ND	ND	-	ND	C
Total Iron	-	C	ND	ND	ND	C	C	C	ND	C	-	C	C	C	C	C
Total Manganese	ND	C	ND	ND	ND	C	ND	-	ND	-	-	-	-	-	ND	-
Total Mercury	C	-	ND	ND	ND	-	C	-	-	-	-	-	-	-	-	-
Total Phenolics	-	-	ND	ND	ND	-	-	-	C	-	-	-	-	ND	ND	-
Water Quality Exceedances for Human Health																
Total Arsenic	HHC	HHC	ND	ND	ND	HHC	HHC	HHC	HHC	HHC	HHC	HHC	HHC	HHC	HHC	-
Total Iron	-	HHNC	ND	ND	ND	HHNC	HHNC	HHNC	ND	HHNC	HHNC	HHNC	HHNC	HHNC	HHNC	HHNC
Total Manganese	ND	HHNC	ND	ND	ND	HHNC	HHNC	-	-	-	-	-	HHNC	HHNC	ND	HHNC
Sediment Quality Guideline Exceedances for Aquatic Life																
Cadmium	ND	-	-	-	TEL	ND	-	-	-	ND	ND	ND	ND	ND	ND	ND
Nickel	ND	-	-	TEL	TEL	ND	TEL	-	-	ND	ND	ND	ND	ND	ND	ND
Benzo(a)anthracene	ND	-	TEL*	-	-	ND	-	PEL*	ND	ND	ND	ND	ND	ND	ND	ND
Benzo(a)pyrene	ND	-	-	-	-	ND	-	TEL	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	ND	-	TEL*	-	-	ND	-	PEL*	ND	ND	ND	ND	ND	ND	ND	ND
Fluoranthene	ND	-	TEL	-	-	ND	-	TEL	ND	ND	ND	ND	ND	ND	ND	ND
Pyrene	ND	-	TEL	-	-	ND	-	TEL	ND	ND	ND	ND	ND	ND	ND	ND

NOTES: *Sum of benzo(a)anthracene and chrysene concentrations were reported, which exceeded the sum of TELs or PELs for these compounds.

- = guidelines not exceeded
C = aquatic life chronic guideline exceeded
A = aquatic life acute guideline exceeded
HHC = human heath carcinogen guideline exceeded
HHNC = human health non-carcinogen guideline exceeded

ND = no data
TEL = threshold effect level exceeded
PEL = probable effect level exceeded
TID = Tar Island Dyke

Table C3.1-4 Sediment Quality of the Athabasca River (1994, 1995 and 1997)

Parameter	Units	1994 [a]			1995 [b]			1997 [c]	
		1 km Above TID West Bank	At TID East Bank	At TID West Bank	1 km Above TID West Bank	At TID East Bank	At TID West Bank	At Donald Creek[d]	At Fort Creek[d]
Total Organic Carbon	Weight %	1.07	1.31	0.49-1.61	1.39	0.49	1.02	0.67	2.32
Recoverable Hydrocarbons	µg/g	-	-	-	2,160	450	703	423	1,190
Metals									
Aluminum	µg/g	6,420	7,670	4,250-7,740	3,910	3,730	4,890	10,700	7,790
Arsenic	µg/g	1.7	2.1	1.3-2.0	0.6	0.9	1.0	5.6	5.1
Cadmium	µg/g	<0.3	<0.3	<0.3	<0.3	0.6	0.5	<0.5	<0.5
Chromium	µg/g	15.3	17.3	13.4-17.2	13.9	11.1	12.4	19.0	20.2
Copper	µg/g	5.1	7.9	3.6-8.6	4.6	3.6	6.5	15	15
Iron	µg/g	13,600	16,400	10,200-14,800	11,000	9,820	13,100	15,000	15,500
Lead	µg/g	3	6	6-8	4	5	5	9	8
Mercury	µg/g	0.023	0.03	<0.02-0.03	0.03	0.04	0.03	0.05	0.06
Nickel	µg/g	15.0	18.0	14.0-19.0	13.8	11.8	15.6	16.0	19.0
Molybdenum	µg/g	1.0	1.2	0.9-1.4	<0.3	0.4	0.5	<1	<1
Vanadium	µg/g	18.8	19.4	14-19.8	14.7	12.8	14.5	28.0	18.5
Zinc	µg/g	35.6	43.6	26.3-46.1	29.9	27.6	39.6	53.0	57.4
PAHs									
Phenanthrene	µg/g	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01	0.01
Benzo(a)anthracene/Chrysene	µg/g	2.1	<0.01	<0.01-0.02	0.03	<0.01	0.01	0.02	0.025
Benzo(a)pyrene	µg/g	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.006
Fluoranthene	µg/g	0.4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.006
Pyrene	µg/g	1.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Total PAHs	µg/g	4.30	-	0.50	0.66	0.07	0.13	0.48	1.203
Toxicity									
Microtox Screen	% Control	73-99	118	91-120	-	-	-	-	-
C. tentans 10-day Survival Test	%	-	-	-	-	-	-	NT	NT
C. tentans 10-day Growth Test	%	-	-	-	-	-	-	NT	NT
L. variegatus 10-day Survival Test	%	-	-	-	-	-	-	NT	NT
L. variegatus 10-day Growth Test	%	-	-	-	-	-	-	NT	NT
H. azteca 10-day Survival Test	%	-	-	-	-	-	-	NT	NT
H. azteca 10-day Growth Test	%	-	-	-	-	-	-	NT	NT

NOTES: - =No data; NT = Not toxic; PAH = Polycyclic aromatic hydrocarbon; TID = Tar Island Dyke.
(a) Golder (1994b).
(b) Golder (1996c).
(c) Samples collected in fall 1997 for RAMP (Golder 1998h).
(d) Donald Creek: upstream oil sands area; Fort Creek: downstream oil sands area.

The limited data available do not reveal consistent spatial trends indicating input of PAHs from oil sands operations, but suggest there is an increase in natural input of PAHs in the oil sands area relative to the upper reaches of the river.

Porewater

Limited data suggest that porewater quality is indicative of the amount of oil sands in the river bottom. The concentrations of dissolved salts varied widely in porewater samples collected in 1995 from the Athabasca River (Table C3.1-5; Golder 1996c). Naphthenic acids concentrations were also variable. Naturally occurring PAHs were detectable at one site in the Athabasca River, and none of the samples were toxic to bacteria in the Microtox® test.

C3.1.2.2 Steepbank River

Surface Water

The Steepbank River is characterized by relatively clear water, except during the spring when total suspended sediments are elevated (Table C3.1-6). Dissolved salt concentrations are low to moderate and pH ranges between 7.4 and 8. Nutrient levels are moderate. Dissolved organic carbon levels are elevated, reflecting inputs of muskeg drainage water. Concentrations of most total metals are near the detection limits. Naturally occurring hydrocarbons and naphthenic acids are occasionally detectable, but at very low levels. Trace organic compounds have not been detected. River water was not toxic to bacteria in samples collected in 1997 (Microtox® test).

Comparisons with water quality guidelines were made using fall medians in the upper Steepbank River due to lack of winter data; winter medians were used for the other two reaches. Concentrations of total phosphorus, total phenolics, aluminum and iron occasionally exceeded chronic water quality guidelines for aquatic life and total arsenic and total iron exceeded water quality guidelines for human health (Table C3.1-3). Overall, water quality of the Steepbank River can be classified as good and occasional guideline exceedances do not appear to be of concern to aquatic life.

Table C3.1-5 Porewater Chemistry and Toxicity in the Athabasca and Steepbank Rivers (1995)

Site	Sodium (mg/L)	Total Dissolved Solids (mg/L)	Naphthenic Acids (mg/L)	Total Ammonia (mg/L)	Recoverable Hydrocarbons (mg/L)	Total PAHs (mg/L)	Microtox IC50 (%)
Athabasca River,1 km above TID, West Bank	1,210	3,220	17	0.78	<1	0.04	>100
Athabasca River at TID, West Bank	12.8	259	<1	0.58	<1	ND	>100
Athabasca River at TID, East Bank	423	1,730	<1	0.59	<1	ND	>100
Steepbank River at the mouth	12.6-26.5	240-374	2-4	0.47-0.62	<1-16	ND-0.84	>100
Steepbank River, 17 km from the mouth	380-5,120	1,370-14,500	3-16	0.50-3.01	3-138	1.21-33.75	>100
Steepbank River, 25 km from the mouth	11.5-26.1	125-228	<1-5	0.03-0.06	<1-1	ND-0.03	>100

NOTES: TID = Tar Island Dyke.
ND = Not detected.
PAH = Polycyclic aromatic hydrocarbon.
Data from Golder (1996c).

Table C3.1-6 Water Quality of the Steepbank River (1972-1997)

Parameter	Units	At Mouth				Lower Steepbank River				Upper Steepbank River		
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Spring	Summer	Fall
Conventional Parameters and Nutrients												
pH	-	7.9	7.8	8.0	7.8	7.8	7.5	7.8	7.5	7.4*	7.7*	7.7*
Total Alkalinity	mg/L	306	87	90	109	314	68	85	89	98*	80*	106*
Total Dissolved Solids	mg/L	350	125	100	126	353	88	114	105	111*	87*	115*
Total Suspended Solids	mg/L	3	39	3	16	5	50	10	9	<0.4*	4*	<0.4*
Total Hardness	mg/L	236	77	95	100	246	76	91	97	83*	83*	75*
Dissolved Organic Carbon	mg/L	10.1	14.1	22.9	19.7	14.8	17.0	21.5	22.0	15.7*	23.3*	22.6*
Total Kjeldahl Nitrogen	mg/L	0.75	1.10	0.62-1.00	0.20	0.77	0.95	0.96	1.10	-	-	-
Total Ammonia	mg/L	0.05	0.03	0.07	<0.035	-	-	-	-	0.02*	0.07*	0.03*
Total Phosphorus	mg/L	0.050	0.098	0.093	0.117	0.060	0.048	0.042	0.046	0.171*	0.123*	0.114*
Dissolved Phosphorus	mg/L	<0.02	0.030	0.020	0.019	-	-	-	-	-	-	-
Metals (Total)												
Aluminum (Al)	mg/L	0.12	0.67	0.04	0.44	0.03	0.53	0.10	0.13	<0.01*	0.05*	0.02*
Arsenic (As)	mg/L	0.0004	0.0005	0.0004	0.0007	-	-	<0.005*	0.004	0.0004*	0.0004*	<0.0002*
Cadmium (Cd)	mg/L	0.0002	<0.0016	0.002	0.003	-	-	-	-	<0.003*	0.005*	<0.003*
Chromium (Cr)	mg/L	<0.0027	0.0018	0.004	0.003	-	-	-	-	<0.002*	0.005*	0.003*
Copper (Cu)	mg/L	0.0017	0.00215	0.007	0.00135	-	-	-	-	<0.001*	-	-
Iron (Fe)	mg/L	1.07	1.30	0.67	0.74	-	-	-	-	0.81*	0.74*	0.57*
Manganese (Mn)	mg/L	0.021	0.051	0.032	0.033	-	-	-	-	0.028*	0.046*	0.014*
Mercury (Hg)	mg/L	<0.0002	<0.0251	<0.0012	<0.001	0.0001	<0.0001	0.0001	0.0001	<0.00005*	<0.00005*	<0.00005*
Nickel (Ni)	mg/L	0.0015	0.0029	<0.005	0.0035	-	-	-	-	<0.005*	<0.005*	<0.005*
Vanadium (V)	mg/L	0.0006	0.003	0.005	0.002	-	-	-	-	0.004*	0.004*	<0.002*
Zinc (Zn)	mg/L	0.067	0.0195	0.025	0.016	-	-	-	-	0.162*	0.029*	0.012*
Metals (Dissolved)												
Aluminum (Al)	mg/L	0.006	0.160	0.019	0.059	-	-	-	-	-	-	-
Arsenic (As)	mg/L	<0.0004	0.0005	0.0005	0.0004	0.0006	0.0005	0.0004	0.0005	-	-	-
Cadmium (Cd)	mg/L	<0.0001	<0.0001	0.0007	0.0001	-	<0.001	<0.001*	-	-	-	-
Chromium (Cr)	mg/L	<0.0004	<0.0004	<0.0004	<0.0004	0.003	0.003	0.003	0.003	-	-	-
Copper (Cu)	mg/L	0.0008	0.002	0.0012	0.0009	-	0.003*	0.001*	-	-	-	-
Iron (Fe)	mg/L	<0.01	1.08	0.39	0.29	-	0.33*	0.34*	-	-	-	-
Manganese (Mn)	mg/L	0.0003	0.053	0.024	0.018	-	-	-	-	-	-	-
Mercury (Hg)	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	-	-	-	-	-	-	-
Vanadium (V)	mg/L	<0.0001	0.0007	0.0001	<0.0001	-	<0.001*	<0.001*	-	-	-	-
Zinc (Zn)	mg/L	0.006	0.009	0.028	0.013	-	<0.001*	<0.001*	-	-	-	-
Organics												
Naphthenic Acids	mg/L	2	1.5	<1	<1	-	-	-	-	<1*	<1*	<1*
Recoverable Hydrocarbons	mg/L	<1	<0.75	<1	<0.85	-	-	-	-	1*	2*	<1*
PAHs and Alkylated PAHs	µg/L	ND	ND	ND	ND	-	-	-	-	-	-	-
PANHs	µg/L	ND	ND	ND	ND	-	-	-	-	-	-	-
Phenolics	µg/L	ND	ND	ND	ND	-	-	-	-	-	-	-
Total Phenolics	mg/L	0.004	0.003-0.004	0.001	0.001	0.01	<0.005	0.001	-	-	0.003	<0.001
Volatile Organics	µg/L	-	ND	-		-	-	-	-	-	-	-
Toxicity												
Microtox IC50	%	>91	>100	99.5	>100	-	-	-	-	>100*	>100*	>100*
Microtox IC25	%	>91	>100	>100	>100	-	-	-	-	>100*	>100*	>100*

NOTES: No data; ND = Not detected; PAH = Polycyclic aromatic hydrocarbon; PANH = Polycyclic aromatic nitrogen heterocycle
- = measured concentration (n=1) is presented; median concentrations (n>2) or ranges (n=2) are presented for all other samples and parameters.

C3.1.2.3 Bottom Sediments

Bottom sediment samples were collected in fall 1997 from a number of rivers and streams as part of the RAMP for the oil sands area. Bottom sediment samples were also collected in 1995 from the Steepbank River as part of the baseline studies for the Aurora and Steepbank Mines.

Levels of metals in Steepbank River sediments were typically lower than in the Athabasca River (Table C3.1-7) or the North Saskatchewan River (Shaw et al. 1994). Concentrations of PAHs and total recoverable hydrocarbons were higher in the Steepbank River than in the Athabasca River, especially at the mouth where a relatively large proportion of bottom sediments is composed of oil sands.

Table C3.1-7 Sediment Quality of the Steepbank River (1995, 1997)

Parameter	Units	Steepbank River at Mouth [(a)]	Steepbank River 17 km above Mouth [(b)]
Total Organic Carbon	%	0.86-3.51	1.36-2.17
Recoverable Hydrocarbons	mg/kg	5,720-17,833	154-247
Metals			
Aluminum (Al)	µg/g	2,070-3,333	3,950-49,90
Arsenic (As)	µg/g	1-2.1	1.1-1.7
Cadmium (Cd)	µg/g	<0.5-0.3	<0.3
Chromium (Cr)	µg/g	5.5-7.9	13.4-17.7
Copper (Cu)	µg/g	2.3-7	3..4-5.7
Iron (Fe)	µg/g	6,800-10,237	10,400-12,600
Lead (Pb)	µg/g	<5-4	2.0-4
Mercury (Hg)	µg/g	<20-0.03	<20-28
Molybdenum (Mo)	µg/g	<0.3-0.9	<0.3-1
Nickel (Ni)	µg/g	7-8.9	10.5-14.6
Silver (Ag)	µg/g	<1	<0.2-0.2
Vanadium (V)	µg/g	7.0-13	13-15.4
Zinc (Zn)	µg/g	15.7-24.2	22.8-30.5
PAHs			
Phenanthrene	µg/g	<0.01-0.31	-
Fluoranthene	µg/g	0.023-0.12	-
Pyrene	µg/g	0.072-0.2	-
Benzo(a)anthracene/Chrysene	µg/g	0.17-1.9	-
Benzo(a)pyrene	µg/g	0.097-0.21	-
Total PAHs	µg/g	14.352-57.420	-

(a) RAMP 1997 (Golder 1998h) pooled with Golder (1996c).
(b) Golder (1996c).
- = No data.

Porewater

The limited porewater data from the oil sands area suggest that the chemical composition of porewaters can vary greatly, depending on the amount of oil sands in the substratum. Porewater quality from the Steepbank River differs from the Athabasca River, reflecting the greater amount of oil sands at the Steepbank River sampling sites. Dissolved salt concentrations were high and varied widely in porewater samples collected in 1995 from the Steepbank River (Table C3.1-5; Golder 1996c). Ammonia level varied moderately among sites, with the highest value at 15 km from the mouth. Naphthenic acids concentrations were variable but generally low at all sites. Naturally occurring PAHs were detectable at all three sites in the Steepbank River. One sample taken 15 km from the mouth contained higher levels of PAHs than previously found in process-affected porewaters adjacent to TID (Golder 1994b, 1995). None of the samples were toxic to bacteria in the Microtox® test.

C3.1.3 Leggett, Wood and McLean Creeks

Water quality of these streams is characterized by seasonally varying levels of suspended solids (Table C3.1-8). Dissolved salt concentrations are moderate and pH ranges between 7.4 and 8.2. Nutrient levels are moderate and dissolved organic carbon is elevated, reflecting inputs of muskeg drainage water. Naturally occurring hydrocarbons are occasionally detectable at very low levels and naphthenic acids have not been detected. Trace organic compounds and toxicity have not been evaluated in these streams.

Comparisons with water quality guidelines were made using fall values in all Athabasca River tributaries due to lack of winter data. Concentrations of total iron exceeded chronic water quality guidelines for aquatic life in Wood and Leggett creeks, and aluminum exceeded the chronic water quality guideline in Leggett Creek (Table C3.1-3). There were no water quality guideline exceedances for aquatic life in McLean Creek. Concentrations of total arsenic and total iron exceeded the water quality guidelines for human health in all tributaries, and total manganese exceeded the guideline in Leggett Creek. Overall, water quality of these streams can be classified as good and occasional guideline exceedances do not appear to be of concern to aquatic life.

C3.1.4 Shipyard Lake and Shipyard Creek

Shipyard Lake is characterized by high suspended solids in seasons with available data (Table C3.1-9). Dissolved salt concentrations and nutrient levels are moderate and pH ranges between 6.8 and 7.8. Naturally occurring hydrocarbons and naphthenic acids were not detectable and lake water was not toxic to bacteria in samples collected in summer 1996 (Microtox® test).

Table C3.1-8 Water Quality of Athabasca River Tributaries (1995)

Parameter	Units	McLean Creek at Mouth			Wood Creek at Mouth			Leggett Creek at Mouth	
		Spring	Summer	Fall	Spring	Summer	Fall	Summer	Fall
Conventional Parameters and Nutrients									
pH	-	7.7	8.2	8.0	7.9	8.1	8.1	7.6	7.4
Total Alkalinity	mg/L	162	132	133	238	157	178	148	168
Total Dissolved Solids	mg/L	339	156	167	328	191	207	167	188
Total Suspended Solids	mg/L	46	17	1	9	87	5	10	211
Total Hardness	mg/L	190	138	142	226	185	175	172	175
Dissolved Organic Carbon	mg/L	12.0	21.9	21.4	12.3	27.5	23.0	25.7	26.2
Total Ammonia	mg/L	0.03	0.05	<0.01	0.01	<0.01	<0.01	0.03	0.03
Total Phosphorus	mg/L	0.048	0.033	0.014	0.037	0.049	0.021	0.019	0.196
Metals (Total)									
Aluminum (Al)	mg/L	0.29	0.28	0.06	0.06	1.12	0.09	0.14	1.89
Arsenic (As)	mg/L	0.0002	0.0003	0.0008	0.0003	0.0015	0.0003	0.0005	0.0012
Cadmium (Cd)	mg/L	<0.003	0.003	0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Chromium (Cr)	mg/L	<0.002	0.008	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Copper (Cu)	mg/L	0.002	-	-	0.002	-	-	-	-
Iron (Fe)	mg/L	0.89	0.77	0.41	0.64	2.22	0.38	0.76	4.81
Manganese (Mn)	mg/L	0.061	0.045	0.02	0.053	0.053	0.017	0.088	0.21
Mercury (Hg)	mg/L	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Nickel (Ni)	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.012
Vanadium (V)	mg/L	<0.002	0.007	<0.002	<0.002	<0.002	<0.002	0.006	0.008
Zinc (Zn)	mg/L	0.023	0.066	0.024	0.032	0.043	0.023	0.038	0.035
Organics									
Naphthenic Acids	mg/L	<1	<1	<1	<1	<1	<1	<1	<1
Recoverable Hydrocarbons	mg/L	1	<1	<1	<1	9	<1	<1	<1
Total Phenolics	mg/L	0.003	<0.001	0.002	0.001	<0.001	<0.001	0.004	<0.001

Notes: - = No data.
Measured concentrations (n=1) are presented.
Data from Golder (1996c).

Table C3.1-9 Water Quality of Shipyard Creek (1995) and Shipyard Lake (1996)

Parameter	Units	Shipyard Creek [a]			Shipyard Lake [b]	
		Spring	Summer	Fall	Spring	Summer
Conventional Parameters and Nutrients						
pH	-	7.6	7.8	7.6	6.8	7.4
Total Alkalinity	mg/L	-	-	-	108	135
Total Dissolved Solids	mg/L	268	190	196	-	147
Total Suspended Solids	mg/L	30	2	79	157	182
Total Hardness	mg/L	-	-	-	111	134
Total Organic Carbon	mg/L	-	-	-	18.3	23.9
Total Ammonia	mg/L	-	-	-	0.01	0.091
Total Phosphorus	mg/L	0.075	0.030	0.102	0.029	0.034
Dissolved Phosphorus	mg/L	-	-	-	0.019	0.015
Metals (Total)						
Aluminum (Al)	mg/L	0.30	0.03	1.09	0.02	0.053
Arsenic (As)	mg/L	0.00018	0.0008	0.0001	0.0002	<0.001
Cadmium (Cd)	mg/L	0.003	<0.003	<0.003	-	<0.003
Chromium (Cr)	mg/L	-	-	-	0.0075	0.01
Copper (Cu)	mg/L	-	-	-	0.001	-
Iron (Fe)	mg/L	3.28	1.16	3.29	1.39	2.54
Manganese (Mn)	mg/L	-	-	-	0.05	0.19
Mercury (Hg)	mg/L	<0.00005	<0.00005	<0.00005	-	<0.00005
Nickel (Ni)	mg/L	-	-	-	0.011	0.011
Vanadium (V)	mg/L	0.002	0.002	<0.002	-	<0.002
Zinc (Zn)	mg/L	0.047	0.051	0.039	0.016	0.013
Organics						
Naphthenic Acids	mg/L	-	-	-	-	<1
Recoverable Hydrocarbons	mg/L	-	-	-	-	<1
Toxicity						
Microtox (IC50 and IC20)	%	-	-	-	-	>100

NOTES: - = No data.
Measured concentrations (n=1) are presented.
[a] Golder (1996c).
[b] Golder (1996p).

Comparisons with water quality guidelines were made using summer values in Shipyard Lake, due to the lack of winter data. Only iron exceeded chronic water quality guidelines for aquatic life and concentrations of total arsenic, total iron and total manganese exceeded guidelines for human health (Table C3.1-3). Overall, water quality of Shipyard Lake can be classified as good and occasional guideline exceedances do not appear to be of any concern to aquatic life.

Shipyard Creek is the outlet of Shipyard Lake. In terms of water quality, this stream is similar to Shipyard Lake (Table C3.1-9). Comparisons with water quality guidelines were made using fall values in Shipyard Creek due to the lack of winter data. Concentrations of total phosphorus, aluminum and iron exceeded chronic water quality guidelines for aquatic life (Table C3.1-3). Concentrations of total arsenic and total iron exceeded the water quality guidelines for human health. Overall, water quality of Shipyard Creek can be classified as good and guideline exceedances do not appear to be of any concern to aquatic life.

C3.1.5 Dissolved Versus Total Metal Concentrations in Surface Waters

The available data were examined to see if there are general relationships between total and dissolved metal concentrations on a seasonal basis. In rivers with seasonally varying levels of suspended solids, total metal levels also tend to fluctuate by season. However, because typically only a small fraction of the total metals is in the dissolved form, total metal measurements reveal little about the potential for biological effects during periods of high suspended solids levels. Therefore, seasonal estimates of the proportions of dissolved and particulate forms of metals may advance our understanding of the potential effects of elevated levels of metals on aquatic biota.

Limited data are presently available on dissolved metal concentrations in the study area. However, some patterns are beginning to emerge (Table C3.1-10). In the rivers sampled, dissolved aluminum, cobalt, titanium and vanadium tended to form a small percentage of total metals. In contrast, antimony, calcium, sodium and strontium were mostly in the dissolved form. Other metals were either in the intermediate range (e.g., molybdenum), or the percentage of the dissolved form varied widely by season (e.g., iron).

Overall, percentages of dissolved metals were typically lower in the Athabasca River than in the Steepbank River, which reflects the generally higher suspended sediment levels in the Athabasca River. As well, seasonal variation in the percentage of dissolved metals was greater in the Athabasca River, as may be expected, since this river carries a seasonally varying sediment load, whereas suspended solids level is relatively constant in the Steepbank River.

C3.1.6 Muskeg Drainage Water

Muskeg drainage water refers to water released from muskeg, which covers large areas in northern river basins. It accounts for a large proportion of stream flow during the open-water season. Large volumes of muskeg drainage water are expected to enter surface waters during muskeg dewatering, which occurs during the site preparation phase of oil sands mine development. The available information on muskeg water was summarized to provide background information on the characteristics of these waters.

Table C3.1-10 Dissolved Metals Expressed as the Percentage of Total Metals in Surface Waters

Metal	Athabasca River			Steepbank River		
	Spring (n=3)	Summer (n=1)	Fall (n=1)	Spring (n=3)	Fall (n=3)	Winter (n=3)
Aluminum (Al)	6	<1	2	7	7	7
Antimony (Sb)	-	83	100	100	86	100
Arsenic (As)	52	11	40	66	52	93
Barium (Ba)	59	22	52	62	67	91
Beryllium (Be)	-	-	-	50	50	50
Boron (B)	70	55	79	83	96	92
Cadmium (Cd)	-	100	-	50	67	50
Calcium (Ca)	89	54	92	-	-	-
Chromium (Cr)	19	-	-	31	89	69
Cobalt (Co)	42	3	25	50	40	20
Copper (Cu)	57	33	100	95	100	60
Iron (Fe)	23	<1	-	35	21	1
Lead (Pb)	40	9	92	53	100	6
Lithium (Li)	66	28	64	67	83	85
Manganese (Mn)	57	2	14	59	33	2
Mercury (Hg)	-	-	-	100	100	100
Molybdenum (Mo)	49	50	83	80	100	90
Nickel (Ni)	70	22	32	100	63	39
Potassium (K)	59	80	53	-	-	-
Selenium (Se)	-	-	-	100	65	100
Silicon (Si)	24	8	-	30	-	82
Silver (Ag)	-	-	-	20	100	20
Sodium (Na)	100	100	93	-	-	-
Strontium (Sr)	84	68	91	85	92	82
Titanium (Ti)	4	1	1	7	5	8
Uranium (U)	58	34	73	67	50	115
Vanadium (V)	11	-	2	14	5	19
Zinc (Zn)	28	42	68	53	85	8

NOTES: - = No data.
Data from 1997 RAMP field program (Golder 1998h).

In rivers and streams flowing through muskeg areas, the proportions of total flow contributed by muskeg drainage water, groundwater and precipitation vary considerably by season (Schwartz 1980). Baseflow in winter is contributed almost exclusively by groundwater. The makeup of spring flows is highly variable, and includes precipitation (snowmelt), groundwater and muskeg drainage water in rapidly changing proportions. From late spring to freeze up, muskeg drainage contributes an average of 80% of stream flow in Jackpine Creek and about 60% of the flow in the Muskeg River (Schwartz 1980). Similar proportions of muskeg drainage water may be expected in Leggett, Wood and McLean creeks during these seasons.

The quality of muskeg drainage waters has not been characterized in detail, with the exception of major ion concentrations (Schwartz 1980). In addition, four samples of muskeg drainage water were recently collected by Syncrude in the Aurora Mine area and were analyzed for a wider variety of parameters (Table C3.1-11).

In the available data set for muskeg drainage waters, most pH measurements are in the natural range for surface waters (6 to 8). Dissolved salt concentrations are moderate and calcium is typically the dominant cation; bicarbonate dominates the anions. Concentrations of most ions varied seasonally in 1978, but within a relatively narrow range (Schwartz 1980). The limited nutrient data suggest that levels of nitrogen compounds are within natural ranges in surface waters. Levels of metals were variable in Syncrude's samples, with the widest ranges exhibited by cobalt, copper and zinc (Table C3.1-11). Concentrations of suspended solids, aluminum, chromium, copper, iron and manganese exceeded water quality guidelines (Table C3.1-3). A number of these exceedances were likely caused by the elevated suspended sediment level in Syncrude's muskeg water samples.

Comparison of the available muskeg drainage water data with seasonal ranges for small streams in the Project area suggests that muskeg drainage waters are generally similar to surface waters (Table C3.1-11). This is not unexpected, since a large proportion of stream flow in the Project area is made up of muskeg drainage waters during the open-water season (Schwartz 1980). Major ion concentrations were similar in muskeg waters and stream waters, although concentration ranges were generally wider in muskeg waters. Ranges in levels of metals in muskeg water overlapped with those in stream water, but in some cases, higher maximum levels were measured in muskeg water (e.g., barium, chromium, cobalt copper, manganese, silicon, zinc). As noted above, this is partly the reflection of the higher suspended solids levels in some of the muskeg water samples collected by Syncrude.

In summary, the limited data available on the quality of muskeg drainage waters suggest that these waters are not substantially different from stream water in the Project Millennium area.

Table C3.1-11 Water Quality of Muskeg Drainage Waters Compared with Stream Water in the Oil Sands Area

Parameter	Units	Muskeg Drainage Water [(a)] (n=4)	Muskeg Drainage Water [(b)] (n=144)	McClean, Wood and Leggett Creeks Spring (n=2)	Summer (n=3)	Fall (n=3)
Conventional Parameters and Major Ions						
pH	-	7.0-7.2	5.51-8.27	7.7-7.9	7.6-8.18	7.4-8.08
Conductance	µS/cm	458-614	50-811	544-572	291-319	307-368
Total Dissolved Solids	mg/L	247-334	-	328-339	156-191	167-207
Total Suspended Solids	mg/L	9-162	-	9.0-46	10.0-87	1-211
Total Alkalinity	mg/L	243-345	-	162-238	132-157	133-178
Total Organic Carbon	mg/L	9.1-12.2	-	-	-	-
Dissolved Inorganic Carbon	mg/L	66.9-80.7	-	-	-	-
Dissolved Organic Carbon	mg/L	8.5-10.9	-	12-12.3	21.9-27.5	21.4-26.2
Biochemical Oxygen Demand	mg/L	<0.05-8	-	-	-	-
Chemical Oxygen Demand	mg/L	24-31	-	-	-	-
Total Phenolics	mg/L	<0.001	-	0.002	0.001-0.004	<0.001
Hardness	mg/L	245-319	-	190-226	138-185	142-175
Calcium	mg/L	78.5-106	0.7-33.6	53.3-60	38.5-51.7	38.8-49.5
Magnesium	mg/L	11.5-13	0.5-9.9	13.8-18.4	10.1-13.6	11-13.6
Potassium	mg/L	0.41-1.31	0.1-2.4	2.1-2.2	0.6-0.92	1.3-1.4
Sodium	mg/L	3.8-5.75	1.3-212	47.7-61.3	8.6-16.3	10.5-18.9
Bicarbonate	mg/L	296-421	19.5-566	197-290	161-191	162-217
Chloride	mg/L	<0.05	1.3-9.1	29.2-56.9	1.2-8	3.7-10.5
Sulphate	mg/L	<0.1-3.1	3.2-15.6	25.4-53.2	5.3-7.3	7.8-11
Sulphide	mg/L	<0.005	-	-	-	-
Naphthenic Acids	mg/L	-	-	<1	<1	<1
Recoverable Hydrocarbons	mg/L	-	-	<1	<1-9	<1
Oil and Grease	mg/L	<2	-	-	-	-
Nutrients						
Nitrate + Nitrite	mg/L	<0.03-0.016	-	0.012-0.019	<0.03-0.1	<0.003-0.005
Total Ammonia	mg/L	0.13-0.91	-	0.01-0.03	<0.01-0.05	<0.01-0.03
Total Kjeldahl Nitrogen	mg/L	0.13-1.4	-	-	-	-
Total Phosphorus	mg/L	<0.1	-	0.037-0.048	0.019-0.049	0.014-0.196
Metals (Total)						
Aluminum (Al)	mg/L	0.06-0.53	-	0.06-0.29	0.14-1.12	0.06-1.89
Antimony (Sb)	mg/L	-	-	<0.0002	<0.0002-0.0003	<0.0002
Arsenic (As)	mg/L	-	-	0.0002-0.0003	0.0003-0.0015	0.0003-0.0012
Barium (Ba)	mg/L	0.08-0.2	-	0.04-0.05	0.03-0.04	0.02-0.07
Beryllium (Be)	mg/L	<0.001-0.001	-	<0.001	0.001-0.004	<0.001
Boron (B)	mg/L	0.02-0.04	-	0.09-0.13	0.05-0.12	0.08-0.1
Cadmium (Cd)	mg/L	<0.0002	-	<0.003	<0.003-0.003	<0.003-0.003
Chromium (Cr)	mg/L	0.009-0.023	-	<0.002	<0.002-0.008	<0.002
Cobalt (Co)	mg/L	<0.0003-0.0311	-	0.004-0.005	<0.003	<0.003-0.004
Copper (Cu)	mg/L	<0.001-0.01	-	0.002	-	-
Iron (Fe)	mg/L	2.58-6.12	0.06-0.6	0.64-0.89	0.76-2.22	0.38-4.81
Lead (Pb)	mg/L	<0.0003-0.0019	-	<0.02	<0.02	<0.02
Lithium (Li)	mg/L	0.003-0.008	-	0.016-0.02	0.006-0.011	0.007-0.016
Manganese (Mn)	mg/L	0.24-0.80	-	0.053-0.061	0.045-0.088	0.017-0.21
Mercury (Hg)	mg/L	-	-	<0.00005	<0.00005	<0.00005
Molybdenum (Mo)	mg/L	<0.003-0.003	-	<0.003	<0.003	<0.003-0.004
Nickel (Ni)	mg/L	<0.0005-0.004	-	<0.005	<0.005	<0.005-0.012
Selenium (Se)	mg/L	-	-	<0.0002	<0.0002-0.0003	<0.0002
Silicon (Si)	mg/L	8.95-6.28	-	2.93-3.76	-	-
Silver (Ag)	mg/L	<0.0001	-	<0.002	<0.002	<0.002
Strontium (Sr)	mg/L	0.103-0.168	-	0.18-0.21	0.103-0.15	0.096-0.163
Titanium (Ti)	mg/L	<0.003-0.019	-	<0.003-0.006	<0.003	0.007-0.046
Uranium (U)	mg/L	<0.0004	-	<0.5	-	-
Vanadium (V)	mg/L	<0.002-0.005	-	<0.002	<0.002-0.007	<0.002-0.008
Zinc (Zn)	mg/L	0.007-0.204	-	0.023-0.032	0.038-0.066	0.023-0.035

NOTES: - = No data.

(a) Data from Syncrude, Aurora Mine, February and March, 1997.

(b) Data from Schwartz (1980); range in mean values at 16 sites.

C3.2 WATER QUALITY IMPACT ASSESSMENT

C3.2.1 Introduction

This section of the Project Millennium (the Project) EIA provides information required by the Project Terms of Reference (TofR) issued on March 4, 1998 (AEP 1998). It describes the anticipated impacts of Project-related water releases, in combination with releases from existing developments, on water quality in the Local Study Area (LSA). The Cumulative Effects Assessment (CEA) in Section C5 assesses the effects of approved (but not yet operating) and planned projects on water quality in the Regional Study Area (RSA).

Water quality predictions were based on baseline water quality data summarized in Section C3.1. Chemistry of oil sands-related waters is discussed in Golder (1996d). Hydrogeological and hydrological input data were derived from Section C2.2. Predictions of the effects of acidic deposition on water quality were based on air quality modelling discussed in Section B3.

The water quality predictions in this section are used to assess impacts on fish and fish habitat (Section C4.2), wildlife (Section D5.2) and human health (Section F1.3).

C3.2.2 Approach

The overall approach for assessing potential impacts of the Project on water quality consisted of the following steps:

1. Identify issues of concern to stakeholders and regulators.
2. Formulate key questions that address these issues.
3. Identify Project activities and associated water releases that may affect water quality.
4. Review the scale and timing of these activities and water releases.
5. Conservatively predict changes in water quality.
6. Evaluate those changes relative to regulatory water quality guidelines.
7. Use the information generated in steps 3 to 6 to address key questions.

C3.2.2.1 Overview of Activities and Water Releases That May Affect Water Quality

Several aspects of the Project, associated with construction, operation and closure phases could potentially affect water quality, including:

- construction activities;

- muskeg and overburden dewatering;
- tailings sand seepage;
- consolidated tailings (CT) flux;
- acid deposition from air emissions; and
- end pit lake (EPL) outflow.

Table C3.2-1 provides a short description of each of these activities and release waters.

Table C3.2-1 Activities and Water Releases That May Affect Water Quality

Activity/Release	Description
Muskeg and overburden dewatering	• operational[a] water released to the environment • the quality of these waters is presented in Table V-1 (Appendix V) • may affect the thermal regime and dissolved oxygen levels of the receiving waters
Tailings sand seepage	• reclamation[a] water released from tailings sand dykes or sand deposited on reclamation landscape • the quality of these waters is presented in Table V-1 (Appendix V) • seepage waters are collected in perimeter interceptor ditches during operation and recycled to the tailings pond • at closure, seepage is directed to wetlands systems, into the EPL and eventually to the Athabasca River • travel time to receiving waters is likely to require several decades
CT flux	• reclamation[a] water released from CT deposits placed within mined-out pits • the quality of these waters is presented in Table V-1 (Appendix V) • CT flux generated during operations will be recycled to the tailings ponds • at closure, any remaining CT flux will be directed to the EPL
Release of acid-forming substances	• NO_x and other acid-forming emissions from plant utilities, vehicle fleet and other developments • SO_2 from stack emissions
End pit lake	• contains CT flux, tailings pond water, process water and surface runoff from the reclaimed landscape, as well as surface runoff from undisturbed areas draining into the Project footprint • EPL will also contain mature fine tails (MFT) and CT • release of EPL water may influence the thermal regime of receiving waters

(a) operational and reclamation waters are defined in Appendix V.

C3.2.2.2 Overview of Water Management for the Project

During construction of mine facilities and in preparation for mining, muskeg and overburden must be dewatered before being removed to expose the oil sands deposits. These waters are the only operational waters released from the east bank mining area during the life of the Project. These waters will be directed to sedimentation ponds before release to McLean Creek and Shipyard Lake. Questions have been raised about how this water might affect water chemistry, oxygen levels and the thermal regime of the receiving waters.

Reclamation water releases, such as seepage from sand dykes around the tailings pond, will be collected in a perimeter interceptor ditch and pumped back into the tailings pond during operation. At mine closure, these releases will be directed through a series of wetlands and ultimately discharged to the Athabasca River. As described in Section C2.2, no reclamation seepages are expected to reach McLean Creek and only very limited volumes may reach Shipyard Lake.

CT flux, which is water expelled from the surface of CT deposits as they consolidate, will be pumped to the recycle water system during operations. At closure, CT flux will be directed via surface wetlands and drainage channels to the EPL. Once in the EPL, this water will be further diluted and bioremediated prior to release.

End pit lake water will be directed to the Athabasca River either through a temporary pipeline or an engineered channel and directed to McLean Creek once flows have stabilized The intended future channel from the EPL to McLean Creek will be developed initially and serve as an overflow structure while the EPL is discharging to the Athabasca River.

C3.2.2.3 Control and Mitigation Measures

In making predictions about water quality in the receiving waters, a number of mitigation controls were assumed to be in place. Mitigation features relevant to water quality protection are reviewed in Table C3.2-2.

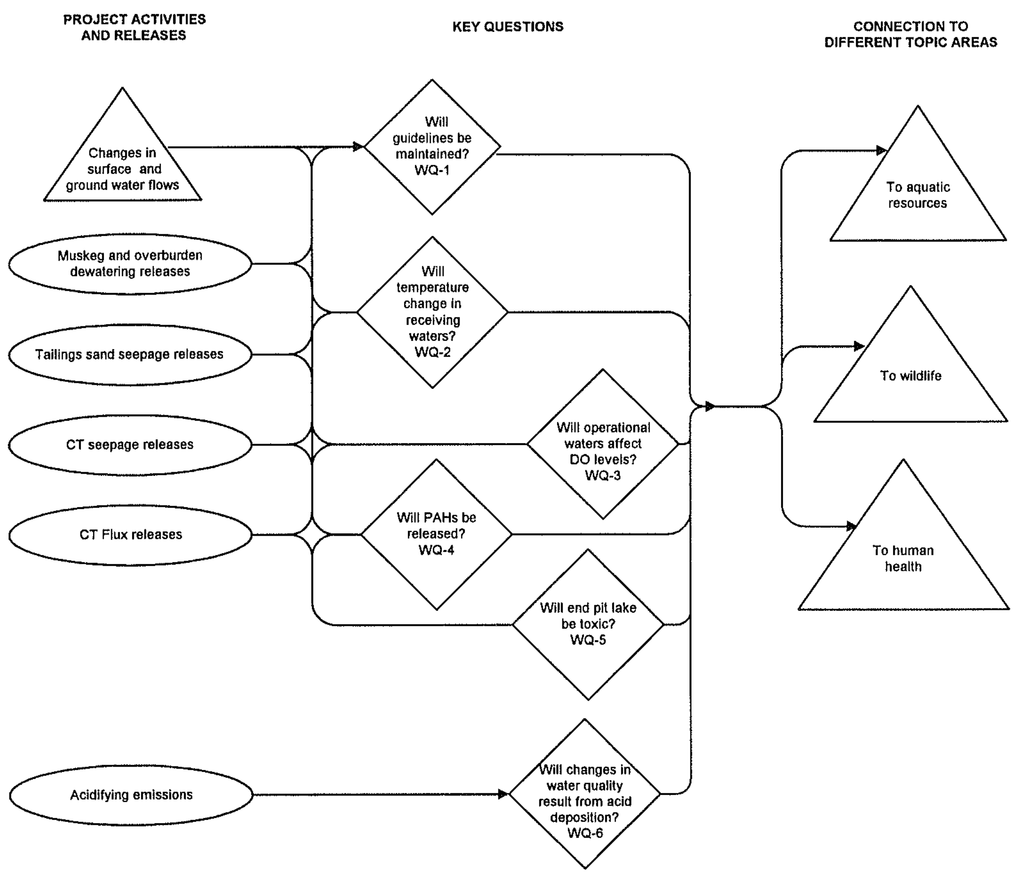
Table C3.2-2 Key Mitigation Features

Key Mitigation Feature	Description
Construction activity mitigation	• follow comprehensive guidelines • implement best management practices
Perimeter interceptor ditch around tailings ponds	• seepages will be collected in perimeter interceptor ditch around tailings ponds and pumped back into the ponds during operation
CT flux water recycled into closed-circuit system during operation	• water released from solidifying CT deposits will be recycled into the closed-circuit system during operation • at closure, CT flux will be directed to the EPL
Tailings sand seepage from reclaimed tailings ponds directed through wetlands into the Athabasca River at closure	• at closure, the perimeter interceptor ditch surrounding the tailings pond will be connected to a series of wetlands, which drain to the Athabasca River
Wetlands associated with CT deposits and reclaimed tailings pond	• wetlands will be part of the reclaimed landscape, and will help collect and treat upward fluxes of CT and sand porewater • these waters are directed to the EPL
End pit lake	• contains CT, MFT, CT flux, tailings pond water, process water and surface runoff from the reclaimed landscape, as well as surface runoff from undisturbed areas draining to the Project area footprint • EPL will help promote natural degradation of organic chemicals released through mine activities • filling of the EPL will be controlled so that it will be non-toxic when it begins to discharge to the environment

C3.2.3 Potential Linkages and Key Questions

Figure C3.2-1 shows the linkages between Project activities and potential changes in water quality.

Figure C3.2-1 Linkage Diagram for Water Quality for Construction, Operation and Closure Phases of Project Millennium



Each key question shown on the linkage diagram is examined in detail in the sections that follow. Key questions were as follows:

WQ-1: What impacts will operational and reclamation water releases from Project Millennium have on water quality and toxicity guideline attainment in the Athabasca and Steepbank rivers, small streams and Shipyard Lake?

The potential for effects on water quality has been raised as a concern. To address this issue, predicted water chemistry and toxicity at various phases of the Project were compared with water quality guidelines for the protection of aquatic life and human health.

WQ-2: **What impacts will operational and reclamation water releases from Project Millennium have on the thermal regime of small streams and Shipyard Lake?**

Since changes are predicted in the discharge and source waters of McLean Creek and Shipyard Lake during the life of the Project, water temperature may be altered in these waterbodies. Predicted temperature changes were compared with the applicable guideline, and the potential for these changes to impair sensitive life stages of fish was assessed in Section C4.2.

WQ-3: **What impacts will muskeg dewatering activities associated with Project Millennium have on dissolved oxygen concentrations in small streams?**

Muskeg drainage waters contain levels of organic carbon that may result in oxygen depletion. Declines in dissolved oxygen levels may have adverse effects on aquatic biota.

WQ-4: **What impacts will operational and reclamation waters released from Project Millennium have on levels of polycyclic aromatic hydrocarbons (PAHs) in sediments in the Athabasca River?**

PAHs are a group of organic compounds that are toxic to aquatic biota at elevated levels and may also affect human health. PAHs have been measured in oil sands reclamation waters and natural sediments in the oil sands area. PAHs released from oil sands operations may contribute to levels in sediments of receiving waterbodies.

WQ-5: **What impacts will operational and reclamation water releases from Project Millennium have on toxicity guideline attainment in the end pit lake?**

The EPL will be constructed at closure. It will treat reclamation waters derived from the reclaimed landscape. The lake will receive drainage from all mine-disturbed areas and surrounding lands that drain into surface waters in mine-disturbed areas. It is critical that EPL water be non-toxic to allow development of a productive, self-sustaining aquatic ecosystem.

WQ-6: What impacts will acidifying emissions from Project Millennium have on regional waterbodies?

NO_x and SO_2 emissions result in the deposition of acid-forming compounds on land and water in the area surrounding sources of such emissions. This question addresses whether the combined effects of NO_x and SO_2 emissions from the Project and existing developments in the region could result in acidification of waterbodies.

C3.2.4 Methods

This section describes the methods used to address the key questions. First, the general approaches followed to predict changes in different aspects of water quality are described; then, the physical, chemical and temporal aspects of the models are outlined, and the computer models used to predict changes in water quality are described. Last, model assumptions and screening criteria used to evaluate potential changes in water quality are presented.

C3.2.4.1 Predicting Changes in Water Quality

A number of different modelling approaches were employed, each specific to the issue or question addressed. General descriptions of each model and boundary conditions are provided below.

Water Quality Modelling - Athabasca River and McLean Creek

The approach used to predict water quality changes in the Athabasca River and McLean Creek consisted of the following steps:

1. Mean open-water flow and annual 7Q10 flow (1 in 10 year, 7-day low flow) statistics were generated for the Athabasca River, and mean annual flow values were calculated for McLean Creek (Section C2.1).

2. Background water quality data representing each flow condition were compiled for each watercourse modelled (Section C3.1). These data reflect input from upstream municipalities, pulp mills and other natural or anthropogenic inputs to the Athabasca River.

3. Water chemistry data were compiled for existing oil sands release waters (Appendix V, Table V-1).

4. Regulatory water quality guidelines developed for the protection of aquatic life (Appendix V, Table V-2) were assembled according to the recommended sequence contained in AEP's Protocol to Develop Alberta Water Quality Guidelines for Protection of Freshwater Aquatic Life (AEP 1996b). Guidelines for protection of human health were also

compiled as recommended in AEP's Water Quality Based Effluent Limits Procedures Manual (AEP 1995d).

5. Time snapshots representing each stage of the Project were identified, to account for different operational conditions and associated combinations of release waters.

6. Nodes were identified for modelling based on locations of water release points to surface waters. Nodes represent specific locations where water quality is predicted.

7. Computer models were used to predict substance concentrations for the time snapshots and conditions specified for modelling, consistent with AEP's Water Quality Based Effluent Limits Procedures Manual (AEP 1995d).

8. Predicted substance concentrations were compared with regulatory guidelines for the protection of aquatic life and human health.

9. If exceedances of guidelines were projected, the possible reasons for the exceedances were explored and the significance of exceedances were evaluated.

Water Quality Modelling - Shipyard Lake and End Pit Lake

Water quality modelling for Shipyard Lake and the EPL was similar to the Athabasca River and McLean Creek modelling. However, rather than modelling at unique time snapshots, Shipyard Lake and the EPL were modelled continuously over the life of the Project and beyond. Mean annual flow rates were used for all inflows, and lake concentrations were calculated on a yearly basis. Continuous modelling was used to account for the retention time of these waterbodies. Unlike McLean Creek and the Athabasca River, where substances introduced into the receiving water instantly move downstream, substances introduced in Shipyard Lake and the EPL would remain until flushed out, which may take years.

Toxicity Modelling - Athabasca River, McLean Creek, Shipyard Lake and End Pit Lake

The procedures used to model water quality were also used to predict acute and chronic toxicity in receiving waters for comparison with water quality guidelines based on whole effluent toxicity (AEP 1995d).

Since reclamation waters will not be produced by the Project until well into the operational phase, it was necessary to assume that the toxicity of reclamation waters produced by the Project will be similar to those of existing oil sands reclamation waters. Toxicity of tailings sand seepage water was assumed to be the same as that measured for Tar Island Dyke (TID) water during testing in 1995 for Suncor (HydroQual 1996a). Toxicity of CT water was assumed to be the same as that of CT water produced by addition of gypsum to Suncor's fine tailings during recent CT trials.

Concentrations representing the LC50 (median lethal concentration) and the IC25 (concentration causing 25% inhibition of reproduction or growth) to the most sensitive test organisms in laboratory tests were used to assign acute and chronic Toxic Units (TUa and TUc, respectively) to CT water. LC50 and IC25 values representative of TID seepage water toxicity were assigned to tailings sand seepage water. These were obtained from the Steepbank Mine EIA (Golder 1996b). Toxic Units were calculated as 100 divided by the LC50 (to arrive at TUa) or IC25 (to arrive at TUc). The resulting TU values were as follows:

Reclamation Water	TUa	TUc
Tailings sand seepage water	2.8	6.3
CT water	2.7	7.2

During water quality modelling, the TUa and TUc values were treated as concentrations (e.g., TUa/L). Predicted toxicity levels were compared with toxicity guidelines to evaluate the potential for acute or chronic effects on aquatic organisms. More detail on the use of toxicity data is provided in Appendix V.

Thermal Regime Modelling - McLean Creek

The approach to predict river temperature consisted of the following steps:

1. Characterize baseline thermal regime on a monthly basis, using available data.

2. Estimate the monthly average temperature of muskeg drainage water, overburden drainage water and EPL water. These waters represent the majority of mine-related water discharges.

3. Select time snapshots corresponding to periods of highest water discharges during mine development and through to mine reclamation.

4. Obtain predicted monthly discharge estimates for McLean Creek, muskeg drainage water, overburden drainage water and EPL discharge water (far future only) for each time snapshot.

5. Predict river water temperature on a monthly basis for each time snapshot year, using thermal balance equations.

6. Compare predicted temperatures with the applicable temperature guideline.

C3.2.4.2 Water Releases and Flows Modelled

Section C2.2 describes the methods used to calculate groundwater and surface water flows. A chemical profile was assigned to each operational and reclamation water (Appendix V, Table V-1), based on water chemistry of operational and reclamation waters produced by existing oil sands operations. Then, flows of each water type, obtained from Section C2.2, were assigned to each node. Node locations are illustrated in Figure C3.2-2). Figures V-2 to V-10 in Appendix V illustrate the specific waters associated with each node. Models were used to simulate water quality at these nodes for the various time snapshots identified for the Project.

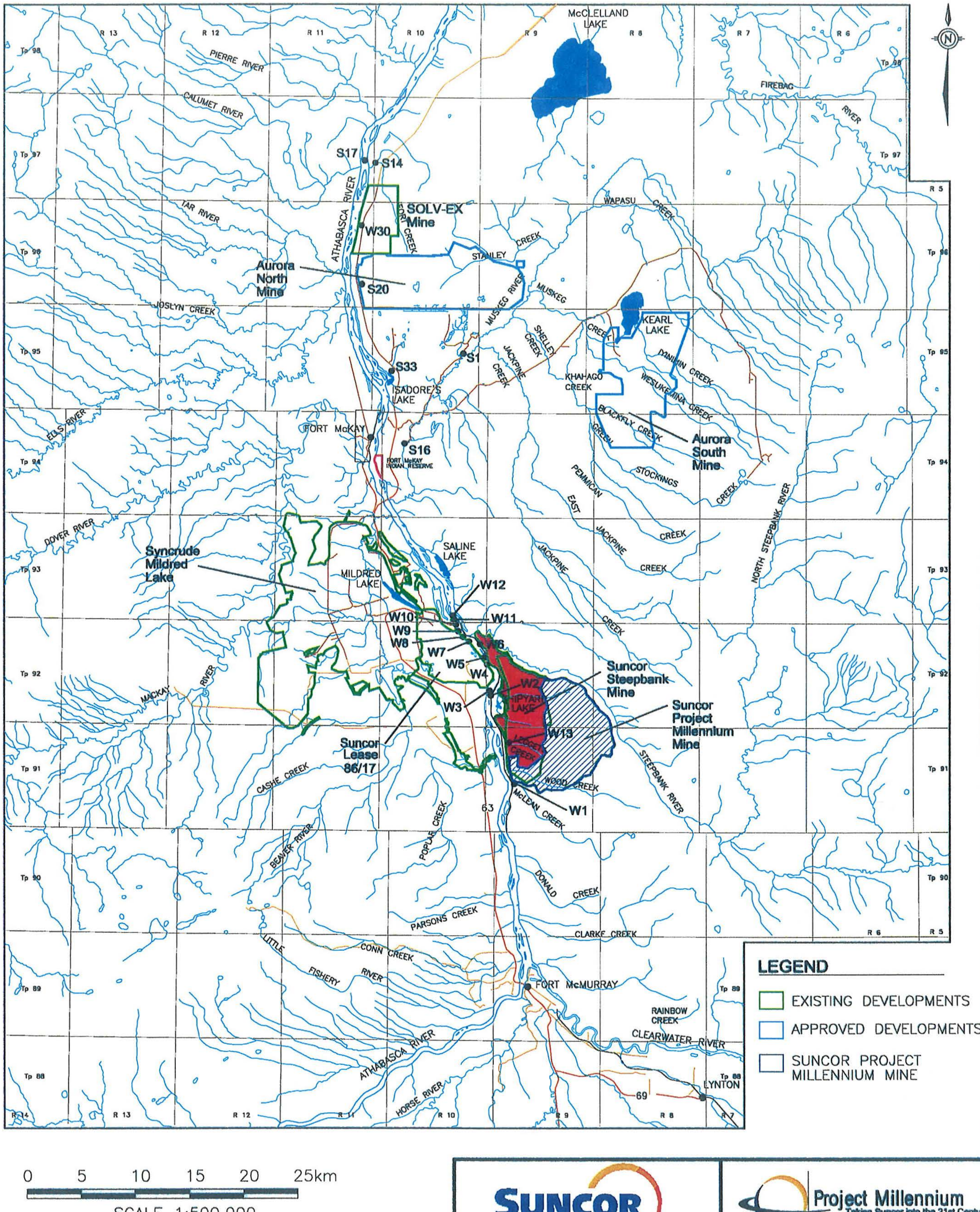
Simulations were run for the Athabasca River at annual 7Q10 and mean open-water flows to examine seasonal impacts. Annual 7Q10 flow was used to predict worst-case water quality, due to the lowest dilution capacity under this flow condition. Screening at mean open-water flows was done for two reasons: (1) to assess the potential water quality differences associated with the higher natural sediment loading during that period; and (2) to arrive at predictions regarding potential exceedances of human health water quality guidelines, which were assessed during that flow condition (AEP 1995d).

Similar steps were taken with McLean Creek, although a lack of historical flow records prohibited the use of the same flow conditions. Annual average flows were used in place of mean open-water flows. Water quality was assessed at low flow by assuming that no natural surface flow occurred during that period and that, with the exception of small volumes of natural groundwater, mine-related waters dominated the creek. The resulting concentrations were then compared to guideline levels.

C3.2.4.3 Time Snapshots Modelled

Water Quality Modelling

Impacts on water quality were examined for each major phase of the Project: construction, operation, closure and far future. The waters associated with each phase generally overlap. For example, because reclamation will proceed concurrently with operation, water quality changes associated with releases of reclamation waters can occur during all phases. However, each Project phase will have a distinct combination of flows and associated water quality. The sequence of mine activities and descriptions of how different Project phases and activities are expected to affect water flows are described in Table A2-3.



SUNCOR ENERGY

Project Millennium — Taking Suncor into the 21st Century

WATER QUALITY MODELLING NODES FOR IMACT ASSESSMENT

31 Mar. 1998	Figure C3.2-2	DRAWN BY: RFM

REFERENCE

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

To capture all combinations of water releases and, by extension, all possible water quality conditions, the following time snapshots were selected for water quality modelling:

- Year 2005
- Year 2010
- Year 2015
- Year 2020
- Year 2025
- Year 2030
- Year 2045
- Far Future

Thermal Regime Modelling

Temperature predictions were made for the following time snapshots:

- year 2025, corresponding to the highest releases of muskeg and overburden drainage waters; and
- far future.

C3.2.4.4 Models Employed

Five different computer models were used to predict water quality changes:

- Small Streams Model
- Athabasca River Model
- End Pit Lake Model
- Shipyard Lake Model
- Thermal Regime Model

Small Streams Model

A steady-state, dilution model was used to predict water quality in McLean Creek. Operational and reclamation waters discharged from the Project Site were assigned chemistry based on existing information (Appendix V, Table V-1), and assumed to completely mix within the receiving waterbody. Chemical concentrations within the receiving waterbodies were calculated as a function of total incoming mass divided by total water volume. Given the short residence time of water in McLean Creek, no decay of organic substances was modelled before discharge to the Athabasca River.

The following is an example of the equation used to predict water chemistry in streams:

$$(C_1Q_1 + C_2Q_2 + C_3Q_3 + \ldots\ldots C_nQ_n) / (Q_1 + Q_2 + Q_3 + \ldots\ldots + Q_n)$$

where:

n = number of water flows mixing together

C_1 = concentration of a substance in water flow 1

Q_1 = flow rate of water flow 1

C_2 = concentration of a substance in water flow 2

Q_2 = flow rate of water flow 2

C_3 = concentration of a substance in water flow 3

Q_3 = flow rate of water flow 3

C_n = concentration of a substance in water flow n

Q_n = flow rate of water flow n

Athabasca River Model

A two-dimensional (cross-river and downstream), steady-state, dilution model was used to predict water quality and mixing in the Athabasca River. The model is based on analytical solutions to river dispersion equations. It has the capability of handling both point-source discharges (e.g., surface runoff or mine effluents) and non-point source discharges (e.g., groundwater seepage). A detailed description of the model is provided by Golder (1996d).

Reclamation waters from the Project will be released to the Athabasca River at several points. These include discharges traveling via McLean Creek, Shipyard Lake and the EPL. In addition, there are numerous mine water sources that discharge into the Athabasca River, both upstream and downstream of the Project (e.g., Suncor Lease 86/17 and Syncrude Mildred Lake Mine; other approved and planned projects are included in the cumulative effects modelling).

To accommodate these multiple sources, the model was set up to simulate each discharge separately, and the total downstream concentration was obtained by an additive approach. This was accomplished by applying a grid to the study reach (Poplar Creek to Athabasca delta) with more than 2,800 nodes. For each discharge, downstream concentrations were calculated at each node. Total concentrations at each node were then determined by summing all individual, discharge-specific concentrations attributed to that node. Using this summation procedure, all discharges to the Athabasca River were accounted for and their combined effects were assessed.

End Pit Lake Model

A dynamic model was used to predict water quality in the EPL. The lake was considered to be a completely mixed waterbody, with a maximum volume of 430 Mm^3. Inflows included surface runoff, precipitation, CT flux water collected in the reclamation areas, tailings pond water and MFT. Water loss through evaporation was also accounted for and lake outflow volumes were equal to total inflows minus within-lake water losses. Influent and evaporation volumes were taken from Section C2.2. Each water flow was assigned chemistry based on available data from existing oil sands operations (Appendix V, Table V-1).

Given the projected retention time of the EPL, the model incorporated the decay of organic compounds and their associated acute and chronic toxicity. The model was also configured to account for the consolidation of CT and MFT placed into the bottom of the EPL. Chemical concentrations within the lake were calculated as a mass-balance of incoming flows mixing with existing lake volumes minus lake outflows.

Shipyard Lake Model

A modified version of the EPL model was used to predict water quality in Shipyard Lake. Inflow streams, precipitation and evaporation rates, pond size and influent chemistry were modified to suit Shipyard Lake's characteristics. Water quality predictions proceeded in the same manner as the EPL model; lake outflow volumes were equal to total inflows minus within-lake water losses, and chemical concentrations within the lake were calculated as a mass-balance of incoming flows mixing with existing lake volumes minus lake outflows.

Thermal Regime Model

A mass-balance equation was used to calculate predicted mean monthly water temperatures in McLean Creek for each time snapshot. The equation incorporated the discharge rate and temperature of each water source contributing to stream flow:

$$T_P = (T_{SW} \times Q_{SW} + T_{M/O} \times Q_{M/O} + T_{EPL} \times Q_{EPL}) / (Q_{SW} + Q_{M/O} + Q_{EPL})$$

Where:

T_P = Predicted monthly mean water temperature (°C) in McLean Creek

T_{SW}, Q_{SW} = Assumed monthly mean temperature (°C) and predicted combined discharges (m^3/s) of natural surface waters contributing to flow in McLean Creek (i.e., existing flow and flow diverted from other creeks), respectively;

$T_{M/O}$, $Q_{M/O}$ = Assumed monthly mean temperature (°C) and predicted combined discharges (m^3/s) of muskeg and overburden drainage waters contributing to flow in McLean Creek, respectively

T_{EPL}, Q_{EPL} = Assumed monthly mean temperature (°C) and predicted discharge (m^3/s) of EPL drainage water, respectively.

C3.2.4.5 Screening Criteria

Oil sands parameters used to screen against water quality guidelines were discussed in Golder (1996d) and were used in two recent environmental impact assessments (EIAs) for oil sands developments (BOVAR 1996a, Golder 1996d). Parameters used in the water quality modelling included those that were both detectable in one or more release waters and for which an established guideline exists (Appendix V, Table V-2).

The following water quality screening criteria (Table C3.2-3) were used for comparing predicted substance concentrations against regulatory water quality guidelines (Appendix V, Table V-2). This approach is consistent with AEP (1995d, 1996b) recommendations and previous EIAs.

Table C3.2-3 Water Quality Screening Conditions

Receiving Waterbody	Water Quality Guideline	Stream Flow Modelled	Mixing Zone Boundary Condition
Athabasca River	Protection of aquatic life	annual 7Q10	at 10% river width, on both sides of the river
	Protection of aquatic life	mean open-water	at 10% river width, on both sides of the river
	Human health non-carcinogen	mean open-water	at 10% river width, on both sides of the river
	Human health carcinogen	mean open-water	at 10% river width, on both sides of the river
Shipyard Lake	Protection of aquatic life	mean annual	full mixing
	Human health non-carcinogen	mean annual	full mixing
	Human health carcinogen	mean annual	full mixing
McLean Creek	Protection of aquatic life	low flow	full mixing
	Protection of aquatic life	mean annual	full mixing
	Human health non-carcinogen	mean annual	full mixing
	Human health carcinogen	mean annual	full mixing
	Protection of aquatic life (temperature)	monthly means	full mixing

The guidelines for toxicity in the receiving environment were <0.3 for TUa (calculated using the LC50) and <1 for TUc (calculated using the IC25) as specified by AEP (AEP 1995d). These guidelines were developed by the U.S. EPA, based on a large set of effluent toxicity data. The guideline values correspond to the approximate value of the No Observed Effects Concentration (NOEC). The NOEC is the highest concentration of a substance or an effluent at which no adverse effects are found during a toxicity test. Hence, TU values below the guidelines indicate the absence of toxicity.

Water quality screening assumptions for operational and reclamation waters associated with the Project are described in Appendix V.

C3.2.5 Key Question WQ-1: What Impacts will Operational and Reclamation Water Releases From Project Millennium Have on Water Quality and Toxicity Guideline Attainment in the Athabasca and Steepbank Rivers, Small Streams and Shipyard Lake?

C3.2.5.1 Analysis of Potential Linkages

Background Information

Operational water releases consist of muskeg and overburden drainage waters. These waters are essentially shallow groundwater, which constantly seep into waterbodies under natural conditions and can account for a large proportion of stream flow in the study area. For example, Schwartz (1980) estimated that 60% of the flow of the Muskeg River during the open-water season is made up of muskeg drainage water. Therefore, it was assumed that muskeg and overburden drainage waters are not toxic to aquatic organisms.

Reclamation waters include CT water and tailings sand seepage. Seepage from the tailings pond will be captured in a perimeter ditch and pumped back to the tailings pond during operation. Toxicity tests of Suncor's reclamation waters have shown that they have the potential to cause acute (short-term, usually lethal) and chronic (long-term, sublethal or lethal) effects on aquatic organisms.

Linkage Between Changes in Flows and Attainment of Water Quality Guidelines

Changes in flows in surface waters may result from diversion of streams, discharges of muskeg, overburden and EPL waters as well as changes in groundwater seepage rates. Because these waters have different chemical characteristics, changes in flows may affect water quality. Therefore, this linkage is valid.

Linkage Between Water Releases and Attainment of Water Quality Guidelines in the Athabasca River

Operational and reclamation water releases will reach the Athabasca River from the EPL and through wetlands associated with the tailings pond perimeter interceptor ditch. Since these waters may have substance levels in excess of water quality guidelines, it is concluded that these waters have the potential to cause or contribute to exceedances of water quality guidelines in the Athabasca River. Therefore, this linkage is valid.

Linkage Between Water Releases and Attainment of Water Quality Guidelines in the Steepbank River

Reclamation water releases will reach the Steepbank River through seepage associated with mining activities. However, seepage rates to the Steepbank River would be exceedingly small (0.0011 m^3/s).

The maximum level of chronic toxicity in the Steepbank River is estimated as only 0.014 TUc (based on *Ceriodaphnia dubia* IC25 of 16% for CT water from Table V-4, which corresponds to a TUc of 6.25; CT seepage to the river of 0.0011 m^3/s; mean winter river flow of 0.48 m^3/s; and a background TUc of 0 in the river. Hence, a simple dilution calculation yields [6.25 TUc x 0.0011 m^3/s + 0 TUc x 0.48 m^3/s] / [0.0011 m^3/s + 0.48 m^3/s] = 0.014 TUc). Thus, no toxicity is expected in the Steepbank River as a result of the inflow of CT water, even under low-flow, winter conditions.

Using chronic toxicity as a surrogate for other reclamation water substance concentrations and recognizing that a greater than 200:1 dilution would be available for CT seepage even at low winter flows, it is concluded that these waters will not cause exceedances of water quality guidelines. Therefore, this linkage is invalid.

Linkage Between Water Releases and Attainment of Water Quality Guidelines in Small Streams

Operational and reclamation water releases will reach Leggett, Wood and McLean creeks. Leggett and Wood creeks will be physically impacted by mining activities (Figure C1-1). Flow from the remaining upper portions of these streams will be routed to Unnamed Creek and McLean Creek either directly during mining, or through the EPL (to McLean Creek) in the far future. Although McLean Creek will not be directly affected by mine related seepages, it will initially receive muskeg and overburden dewatering flows and the outflow from the EPL in the far future. Therefore, this linkage is valid.

Linkage Between Water Releases and Attainment of Water Quality Guidelines in Shipyard Lake

Operational and reclamation water releases will reach Shipyard Lake from mining and reclamation activities. Since these waters may have substance levels in excess of water quality guidelines, it is concluded that these waters have the potential to cause exceedances of water quality guidelines in Shipyard Lake. Therefore, this linkage is valid.

C3.2.5.2 Analysis of Key Question

Results are presented in Appendix V for each substance modelled during each snapshot and flow condition in the Athabasca River. The summary tables below provide results for exceedances of water quality guidelines, the majority of which are due to background levels of the substances in question. The values shown in the summary tables represent the highest concentrations predicted in all snapshot years simulated. Results are subsequently discussed under "Significance of Water Quality Guideline Exceedances."

Summary tables for the Athabasca River provide the following information for acute and chronic toxicity and for substances that would exceed water quality guidelines:

- existing concentrations upstream of Fort McMurray, as measured during baseline studies or monitoring;
- predicted concentrations at 10% river width on both sides of the river, resulting from existing and approved oil sands developments;
- the effects of Project Millennium at 10% river width on both sides of the river, in combination with existing and approved oil sands developments; and
- the water quality guidelines associated with each substance.

Summary tables for McLean Creek provide the following information for acute and chronic toxicity and for substances that would exceed water quality guidelines:

- in the case of average annual flows, existing concentrations in McLean Creek, as measured during baseline studies;
- in the case of winter low flows, predicted concentrations in surficial and Basal aquifer flows in McLean Creek;
- the effects of Project Millennium, in the form of existing concentrations from above plus the increase caused by Project Millennium; and
- the water quality guidelines associated with each substance.

Summary tables for Shipyard Lake provide the following information for acute and chronic toxicity and for substances that would exceed water quality guidelines:

- predicted baseline (1997) concentrations in Shipyard Lake based on field studies and surface and groundwater flows described in Section C2.2;
- the effects of Project Millennium; and
- the water quality guidelines associated with each substance.

Mean Open-Water Flow in Athabasca River

Model results indicate that during mean open-water flow, compliance with most water quality guidelines is achieved during all time snapshots (Appendix V, Tables V-8 and V-10). Table C3.2-4 provides the concentrations of substances that would exceed water quality guidelines. The acute and chronic toxicity values represent the highest concentrations predicted for all simulated snapshot years; no exceedances of toxicity guidelines would occur. Dispersion model contour plots of all substances discussed in Table C3.2-4 are presented in Appendix V, Figures V-11 to V-21.

Annual 7Q10 Flow in Athabasca River

Model results indicate that during 7Q10 flow, compliance with most water quality guidelines is achieved during all time snapshots (Appendix V, Tables V-7 and V-9). Table C3.2-5 provides the concentrations of substances that would exceed water quality guidelines. The acute and chronic toxicity values represent the highest concentrations predicted for all snapshot years simulated; no exceedances of toxicity guidelines would occur. Dispersion model contour plots of all substances discussed in Table C3.2-5 are presented in Appendix V, Figures V-11 to V-21.

Mean Annual Flow in McLean Creek

Table C3.2-6 provides the concentrations of substances that would exceed water quality guidelines under annual average flow in McLean Creek. The acute and chronic toxicity values represent the highest concentrations predicted for all simulated snapshot years; toxicity guidelines are not exceeded. Complete modelling results are presented in Table V-11.

Low Flow in McLean Creek

McLean Creek is an intermittent stream. Occasionally, water flows cease, either due to freezing or insufficient head waters. However, waters released from the Project may flow throughout the year. As a result, mine waters from the Project may represent a large proportion of the flow in McLean Creek during these extreme low flow conditions.

Table C3.2-7 describes instream concentrations projected for McLean Creek if its flow originates solely from natural surficial and Basal Aquifer seepage, plus muskeg and overburden dewatering flows. Concentrations reflect various proportions of muskeg and overburden flows according to dewatering phases, for substances that would exceed water quality guidelines. Complete modelling results are in Table V-12.

Table C3.2-4 Predicted Substance Concentrations Compared with Water Quality Guidelines at Mean Open-Water Flow in the Athabasca River

Substance	Upstream Fort McMurray[a]	Existing plus Approved[b]	Project[c] Millennium	Guideline[d]	Comment (on Project concentrations)
aluminum (mg/L)	0.68 (<0.005 - 11.4)	0.68	0.68	0.1 C	exceedance of C guideline is a result of existing river conditions; concentrations are consistent throughout all Project phases
arsenic (mg/L)	0.001 (0.0003 - 0.0125)	0.002	0.002	0.01 C 0.000018 HC	exceedance of HC guideline is a result of existing river conditions; Project contribution of arsenic minimal relative to background levels
benzo(a) anthracene (mg/L)	n.d.	0.0000048	0.0000057	0.0000028 HC	guideline exceedance projected for 2044 and far future due to approved operations in Muskeg River basin and incremental effect of the Project
iron (mg/L)	3.0 (0.25 - 10.7)	3.0	3.0	1.0 C 0.3 HNC	exceedance of C and HNC guidelines are a result of existing river conditions; Project contribution of iron minimal relative to background levels
manganese (mg/L)	0.4	0.4	0.4	0.05 HNC	exceedance of HNC guideline is a result of existing river conditions; Project contribution of manganese minimal relative to background levels
mercury (mg/L)	0.0001 (<0.00004 - 0.0001)	0.0001	0.0001	0.000012 C 0.00014 HNC	exceedance of C and HNC guidelines are a result of existing river conditions; Project contribution of mercury minimal relative to background levels
acute toxicity (TUa)	0	0.008	0.004	0.3 A	acute toxicity guideline maintained; projected drop in acute toxicity levels results from CT water previously released from Steepbank Mine now being used in Project operations
chronic toxicity (TUc)	0	0.05	0.03	1.0 C	chronic toxicity guideline maintained; projected drop in chronic toxicity levels results from CT water previously released from Steepbank Mine now being used in Project operations and reduced upgrader wastewater flows from Suncor Lease 86/17 Mine Site

(a) Upstream concentrations taken from Golder (1997d); n.d. = non-detectable.
(b) Concentrations at 10% river width resulting from Suncor Lease 86/17, Steepbank, Syncrude Mildred Lake and Aurora North and South.
(c) Concentrations at 10% river width resulting from Suncor Lease 86/17, Steepbank, Syncrude Mildred Lake, Aurora North and South plus Project Millennium.
(d) A = Aquatic Life Acute; C = Aquatic Life Chronic; HC = Human Health Carcinogen; HNC = Human Health Non-Carcinogen.

Table C3.2-5 Predicted Substance Concentrations Compared with Water Quality Guidelines at Annual 7Q10 Flow in the Athabasca River

Substance	Upstream Fort McMurray[a]	Existing plus Approved[b]	Project[c] Millennium	Guideline[d]	Comment (on Project concentrations)
mercury (mg/L)	0.0001 (<0.00004 - 0.0001)	0.0001	0.0001	0.000012 C	exceedance of C guideline is a result of existing river conditions; Project contribution of mercury minimal relative to background levels
acute toxicity (TUa)	0	0.02	0.01	0.3 A	acute toxicity guideline maintained; projected drop in acute toxicity levels results from CT water previously released from Steepbank Mine now being used in Project operations
chronic toxicity (TUc)	0	0.14	0.07	1.0 C	chronic toxicity guideline maintained; projected drop in chronic toxicity levels results from CT water previously released from Steepbank Mine now being used in Project operations and reduced upgrader wastewater flows from Suncor Lease 86/17 Mine Site

(a) Upstream concentrations taken from Golder (1997d).
(b) Concentrations at 10% river width resulting from Suncor Lease 86/17, Steepbank, Syncrude Mildred Lake and Aurora North and South.
(c) Concentrations at 10% river width resulting from Suncor Lease 86/17, Steepbank, Syncrude Mildred Lake, Aurora North and South plus Project Millennium.
(d) A = Aquatic Life Acute; C = Aquatic Life Chronic.

Table C3.2-6 Predicted Substance Concentrations Compared with Water Quality Guidelines at Mean Annual Flow in McLean Creek

Substance	Baseline[a]	Project[b] Millennium	Guideline[c]	Comment (on Project concentrations)
aluminum (mg/L)	0.28 (0.06 - 1.89)	0.37	0.1 C	background aluminum concentration naturally exceeds C guideline; highest concentrations projected for far future when EPL outflow routed to McLean Creek; concentration falls within natural range of variability
arsenic (mg/L)	0.0003 (0.0002 - 0.0015)	0.003	0.000018 HC	background arsenic concentration naturally exceeds HC guideline; highest concentrations projected for 2025, due to dewatering activities; concentration falls within natural range of variability; result is further evaluated in human health Section F1.3
cadmium (mg/L)	0.003 (<0.003 - 0.003)	0.003	0.0018 C	background cadmium concentration naturally exceeds C guideline; Project releases are minimal compared with background levels
iron (mg/L)	0.8 (0.38 - 4.81)	1.3	0.3 HNC 1.0 C	background naturally exceeds HNC guideline; highest concentrations projected for 2025, due to dewatering activities; concentration falls within natural range of variability; result is further screened in human health Section F1.3
manganese (mg/L)	0.045 (0.045 - 0.21)	0.17	0.05 HNC	exceedance of HNC guideline projected for several time snapshots; predicted instream concentrations are highest in 2025, due to dewatering activities; concentration falls within natural range of variability; result is further screened in human health Section F1.3
acute toxicity (TUa)	0	0.004	0.3 A	acute toxicity guideline maintained
chronic toxicity (TUc)	0	0.006	1.0 C	chronic toxicity guideline maintained

(a) Baseline water quality from Golder (1996c); (concentration) = measured open-water concentrations from Table C3.1-11)
(b) Concentrations including effects of Project Millennium.
(c) A = Aquatic Life Acute; C = Aquatic Life Chronic; HC = Human Health Carcinogen; HNC = Human Health Non-Carcinogen

Table C3.2-7 Predicted Substance Concentrations in McLean Creek Assuming No Natural Surface Flow

Substance	Baseline[a]	Project[b] Millennium	Guideline[c]	Comment (on Project concentrations)
aluminum (mg/L)	0.5 (0.06-1.89)	0.5	0.1 C	potential exceedance of chronic guideline results from natural Basal and surficial aquifer flows; Project releases have little affect on projected instream concentration; concentration falls within natural range of variability
arsenic (mg/L)	0.004 (0.0003 - 0.0012)	0.014	0.01 C	potential exceedance of chronic guideline projected for several snapshots; predicted concentrations highest in 2015, due to dewatering activities
boron (mg/L)	0.8 (0.08-0.1)	0.8	0.5 C	potential exceedance of chronic guideline results from natural Basal and surficial aquifer flows; Project releases have little affect on projected instream concentrations
cadmium (mg/L)	0.004 (<0.003 - 0.003)	0.004	0.0018 C	potential exceedance of chronic guideline results from natural Basal and surficial aquifer flows; Project releases have little affect on projected instream concentrations
chromium (mg/L)	0.013 (<0.002)	0.02	0.011 C 0.016 A	potential exceedance of chronic guideline results from natural Basal and surficial aquifer flows; potential exceedance of acute guideline in 2015, 2020 and 2025, as a result of dewatering activities
copper (mg/L)	0.01 (no fall data)	0.01	0.027 A 0.007 C	potential exceedance of chronic guideline results from natural Basal and surficial aquifer flows; Project releases have little affect on projected instream concentrations
iron (mg/L)	0.5 (0.38 - 4.81)	4.3	1.0 C	potential exceedance of chronic guideline projected for several snapshots; predicted concentrations highest in 2015, due to dewatering activities; concentration falls within natural range of variability
selenium (mg/L)	0.0004 (<0.0002)	0.008	0.005 C	potential exceedance of chronic guideline projected for several snapshots; predicted concentrations highest in 2015, due to dewatering activities

[a] Modelled baseline conditions, assuming that groundwater currently seeping into McLean Creek continues to do so when there is no surface flow into the creek; (concentration) = measured fall concentrations from Table C3.1-11)
[b] Baseline conditions plus Project releases.
[c] A = Aquatic Life Acute; C = Aquatic Life Chronic.

Mean Annual Conditions in Shipyard Lake

Table V-13 describes mean annual substance concentrations predicted in Shipyard Lake. Table C3.2-8 lists those substances whose concentrations would exceed water quality guidelines in addition to acute and chronic toxicity concentrations. Unlike Athabasca River and McLean Creek, Shipyard Lake was examined using a dynamic model. As such, the concentrations described in Table C3.2-8 are the maximum substance concentrations projected throughout the life of the Project, rather than the highest concentration observed during the different model snapshots.

Table C3.2-8 Predicted Substance Concentrations in Shipyard Lake Compared with Water Quality Guidelines

Substance	Baseline[(a)]	Project[(b)] Millennium	Guideline[(c)]	Comment (on Project concentrations)
aluminum (mg/L)	0.58 (0.2 - 0.053)	0.65	0.1 C	background naturally exceeds C guideline when Shipyard Lake is periodically flooded with Athabasca River water; highest concentrations projected to occur from 2020 to 2033, when surface flows to Shipyard Lake are restricted and Athabasca River water is added to supplement these losses
arsenic (mg/L)	0.001 (0.0002 - 0.001)	0.001	0.000018 HC	background naturally exceeds HC guideline when Shipyard Lake is periodically flooded with Athabasca River water; highest concentrations projected to occur from 2020 to 2033, when surface flows to Shipyard Lake are restricted and Athabasca River water is added to supplement these losses
iron (mg/L)	2.5 (1.39 - 2.54)	2.8	0.3 HNC 1.0 C	background naturally exceeds HNC and C guidelines when Shipyard Lake is periodically flooded with Athabasca River water; highest concentrations projected to occur from 2020 to 2033, when surface flows to Shipyard Lake are restricted and Athabasca River water is added to supplement these losses
manganese (mg/L)	0.32 (0.05 - 0.19)	0.37	0.05 HNC	background naturally exceeds HNC guideline when Shipyard Lake is periodically flooded with Athabasca River water; highest concentrations projected to occur from 2020 to 2033, when surface flows to Shipyard Lake are restricted and Athabasca River water is added to supplement these losses
mercury (mg/L)	0.00008 (<0.00005)	0.00009	0.000012 C	background naturally exceeds C guideline when Shipyard Lake is periodically flooded with Athabasca River water; highest concentrations projected to occur from 2020 to 2033, when surface flows to Shipyard Lake are restricted and Athabasca River water is added to supplement these losses

(a) Maximum modelled baseline concentrations observed between 1997 and 2004; (concentration) = measured open-water concentrations from Table C3.1-9.
(b) Maximum concentration including effects of Project Millennium.
(c) C = Aquatic Life Chronic; HC = Human Health Carcinogen; HNC = Human Health Non-Carcinogen.

Significance of Water Quality Guideline Exceedances

Concentrations of the substances in Table C3.2-9 that would exceed water quality guidelines (x = exceedance) in the Athabasca River, McLean Creek, and Shipyard Lake.

There are several lines of evidence that suggest these exceedances are of limited environmental consequence. These are briefly discussed below.

Of the substances identified above, aluminum, arsenic, iron, manganese and mercury frequently exceed water quality guidelines under natural, background conditions in the RSA; cadmium occasionally equals the chronic guideline in McLean Creek and copper occasionally exceeds the chronic and acute guidelines in the Athabasca River (Section C3.1). Moreover, predicted concentrations of these metals from combined developments generally fall into the natural ranges in watercourses in the RSA, as summarized in Section C3.1. Naturally elevated levels of metals are usually not considered to be of concern in surface waters. Iron and manganese human health non-carcinogen guideline values are based on aesthetic considerations. The screening analysis in Section F1.3 rejected the above metals as being of risk to human health

Table C3.2-9 Summary of Water Quality Guideline Exceedances

Substance	Athabasca River	McLean Creek	Shipyard Lake	Comments
aluminum	X	X	X	due to background concentrations (all waterbodies) and EPL outflow (McLean Creek far future)
arsenic	X	X	X	due to background concentrations (Athabasca River and Shipyard Lake) and dewatering flows (McLean Creek)
benzo(a)anthracene	X			due to reclamation waters
boron		X		mainly due to Basal Aquifer seepage
cadmium		X		background concentrations exceed guideline
chromium		X		due to muskeg and overburden water
copper		X		due to Basal Aquifer seepage
iron	X	X	X	background concentrations exceed guideline (Athabasca River and Shipyard Lake) and dewatering flows (McLean Creek)
manganese	X	X	X	background concentrations exceed guideline (Athabasca River and Shipyard Lake) and dewatering flows (McLean Creek)
mercury	X		X	background concentrations exceed guideline
selenium		X		due to muskeg and overburden water

Exceedance of the chromium guideline would occur due to elevated total chromium levels in muskeg and overburden waters. This guideline exceedance is unlikely to be of significance, because the guideline is for the hexavalent form of this metal and total chromium concentration was modelled. Typically, the concentration of hexavalent chromium is a small fraction of total chromium.

Frequently, a large fraction of total metals is associated with suspended sediments and is thus not in a bioavailable form. The dissolved fraction may be considered an approximation of the bioavailable portion of total metals. Although limited data are presently available on dissolved metal levels in surface waters in the study area, some patterns are beginning to emerge (Section C3.1.5). In the Steepbank and Athabasca rivers, dissolved aluminum tends to form a small percentage of total metals. This same finding was evident for the Muskeg River (Shell 1998). All mercury and the majority of boron was in the dissolved form. Variable (moderate) percentages of cadmium and chromium were measured. Dissolved metal fractions were typically lower in the Athabasca River, which usually carries a greater suspended sediment load.

Overall, the available metals data suggest that, for the majority of metals predicted to exceed water quality guidelines, the bioavailable fraction would likely be considerably lower than the predicted total metal concentrations.

The predicted concentrations of substances that tend to be bound to particulates are conservative, since no reductions in these concentrations were assumed during modelling, even though most of the particulates would settle in sedimentation ponds, the EPL and wetlands, or would be trapped as seepage waters travel through the ground. As well, modelling was carried out using conservative, worst-case assumptions regarding concentrations of substances in release waters and flows of release waters. Therefore, actual concentrations will likely be lower than those predicted.

The benzo(a)anthracene group would exceed the human health water quality guideline in the Athabasca River due to incremental additions from the Project in combination with downstream developments. The predicted guideline exceedance by benzo(a)anthracene group was brought forward for further screening under the human health section (F1.3). The analysis in Section F1.3 indicates that the risks posed by these compounds to human health are very low.

There is a remote possibility that Shipyard Lake would be affected by small quantities of CT seepage, but only after several hundred years of travel time through extremely impermeable material. This has not been considered in the water quality modelling. The main contributors to projected exceedances in Shipyard Lake would be the natural Basal Aquifer water and water from the Athabasca River that have naturally elevated levels of substances such as aluminum, manganese, arsenic and mercury.

Based on the above information, operational and reclamation water releases from Project Millennium have limited potential to affect the environmental quality of the Athabasca River, McLean Creek and Shipyard Lake, despite the water quality guideline exceedances predicted by modelling.

C3.2.5.3 Uncertainty

The objective of the water quality modelling is to predict substance concentrations and compare them to regulatory water quality guidelines. Ultimately, it is the frequency of compliance with instream guidelines that is the underlying objective being addressed in this activity. Golder Associates have employed the steady-state approach to modelling for small streams and the Athabasca River as an acceptable surrogate (AEP 1995d) to directly resolving this frequency of compliance. More sophisticated, data intensive, dynamic modelling would be required to gain more accuracy in the results.

Although the steady-state approach is subject to more uncertainty, this uncertainty is offset by the use of conservative assumptions to arrive at a worst-case result. The uncertainty of the steady-state water quality model predictions is a function of:

- the prediction of mine related flows; and
- the steady-state model assumptions recommended by AEP:
  - use of extreme low flows (7Q10);
  - use of maximum values for substance concentrations;
  - use of 10% river width as the mixing zone boundary (on both sides of the river); and
  - degradation rates of substances modelled (or lack thereof).

It is more likely that the conservative assumptions employed will result in predictions that overestimate, rather than underestimate the concentrations of substances that are compared with water quality guidelines. Continued monitoring of water quality during baseline conditions, mine operation and reclamation to verify the results presented herein will be conducted by Suncor through their on-site monitoring program and through Regional Aquatic Monitoring Program (RAMP).

C3.2.5.4 Residual Impact Classification

The predicted impacts of operational and reclamation water releases to the Athabasca River are classified as negligible in magnitude, long-term in duration, moderate in frequency, regional in geographic extent and irreversible, with a low degree of uncertainty during both mean open-water flow and annual 7Q10 flow. The environmental consequence of these impacts is low.

The predicted impacts to McLean Creek and Shipyard Lake are classified as negligible to low in magnitude, long-term in duration, moderate in frequency, local in geographic extent and irreversible, with a low degree of uncertainty (Table C3.2-10). The environmental consequence of these impacts is low to moderate.

Table C3.2-10 Residual Impact Classification for Water Quality Guideline Exceedances

Impact	Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Scientific Uncertainty	Environmental Consequence
Mean open-water flow in the Athabasca River	Negligible	Long-term	Moderate	Regional	Irreversible	Low	Low
Annual 7Q10 flow in the Athabasca River	Negligible	Long-term	Moderate	Regional	Irreversible	Low	Low
Annual average flow in McLean Creek	Negligible	Long-term	Moderate	Local	Irreversible	Low	Low
Low flow in McLean Creek	Low	Long-term	Moderate	Local	Irreversible	Low	Moderate
Shipyard Lake	Negligible	Long-term	Moderate	Local	Irreversible	Low	Low

Impacts to McLean Creek were assigned a moderate environmental consequence. This stream will not be impacted by reclamation seepages. The exceedances projected are due solely to natural Basal and surficial aquifer waters and muskeg drainage waters. No acute or chronic toxicity will occur. The EPL outflow would only be directed to McLean Creek once its discharge rate was stabilized. Finally, McLean Creek is an intermittent stream that has no flow in the winter and will occasionally dry up in the summer. Viewed in this context, it is arguable whether the Project could decrease the environmental quality of McLean Creek. Hence the environmental risk to McLean Creek posed by the Project is considered to be low and, therefore, this impact is not significant.

C3.2.5.5 Monitoring

The proposed monitoring plan for the Athabasca River, McLean Creek and Shipyard Lake will be finalized upon review by regulatory agencies and acceptance of the joint industry RAMP.

The monitoring program will initially focus on collecting more baseline data from Shipyard Lake and McLean Creek and further monitoring the quality of muskeg and overburden drainage waters. The full suite of oil sands parameters will be monitored with emphasis on the substances predicted to be elevated. The effectiveness of sedimentation ponds to control these substances will be assessed.

C3.2.5.6 Mitigation

In the event that changes in water quality caused by water releases from the Project are detected, mitigation will be applied in the form of increasing the retention time of sedimentation ponds and wetlands. This is particularly important for muskeg and overburden drainage that may reach McLean Creek during extreme low flow periods. This will enhance degradation of chemicals and settling of particulates, thereby reducing potential impacts in receiving waters.

As discussed in Section E4.4.5, reclamation landscapes that will contribute drainage to Shipyard Lake will be monitored to ensure that any surface flows will be of acceptable quality to the receiving wetlands. The water quality modelling has assumed that drainage from reclamation landscapes will be of acceptable quality before it is allowed to drain to Shipyard Lake. Should these flows not be of acceptable quality for the first few years, they will be directed to the EPL.

C3.2.6 Key Question WQ-2: What Impacts Will Operational and Reclamation Water Releases From Project Millennium Have on the Thermal Regime of Small Streams and Shipyard Lake?

C3.2.6.1 Analysis of Potential Linkages

Linkage Between Changes in Flows and Water Releases, and Thermal Regime of Small Streams and Shipyard Lake

Since changes are predicted in the flows and origins of source waters of McLean Creek and Shipyard Lake during the life of the Project, this linkage is valid.

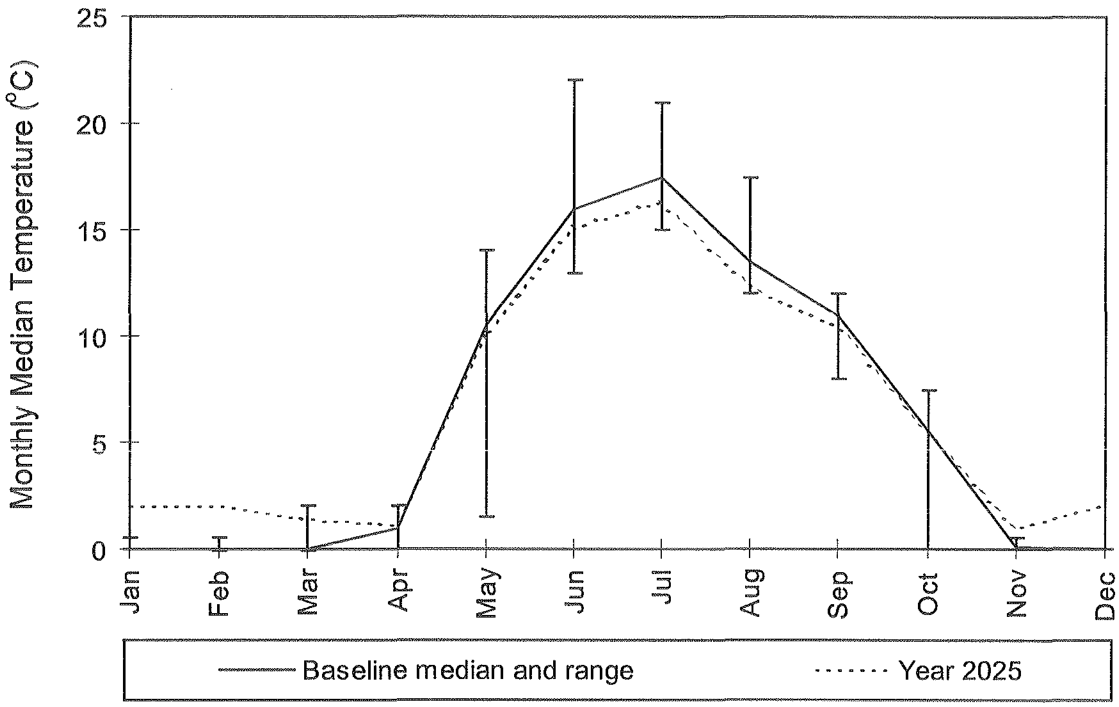
C3.2.6.2 Analysis of Key Question

Muskeg and Overburden Drainage to McLean Creek - Year 2025

Results of conservative temperature modelling suggest that the highest rates of muskeg and overburden drainage water releases during the life of the Project (year 2025) would have little potential to alter water temperature in McLean Creek. A slight reduction in water temperature was predicted during the open-water season in 2025, with a maximum change of 1.2°C in July and August (Figure C3.2-3). In addition, slight warming of stream water may occur during the winter. This warming is the result of assuming that muskeg and overburden drainage waters will flow year-round, thus contributing all of the winter flow in McLean Creek which normally does not flow, or flows at a very low rate in the winter.

The assumption of year-round flow of muskeg and overburden waters may be unrealistic, because small streams usually do not flow in the winter in the oil sands region. This is a worst-case assumption made for water quality modelling purposes. In the event that muskeg and overburden drainage waters do not reach McLean Creek in the winter, summer temperature declines would be slightly higher. Additional analysis has shown that under this scenario, the maximum temperature reduction in the summer would be 2.0°C.

Figure C3.2-3 Predicted Monthly Mean Water Temperatures in McLean Creek in the Year 2025 and the Assumed Baseline Thermal Regime



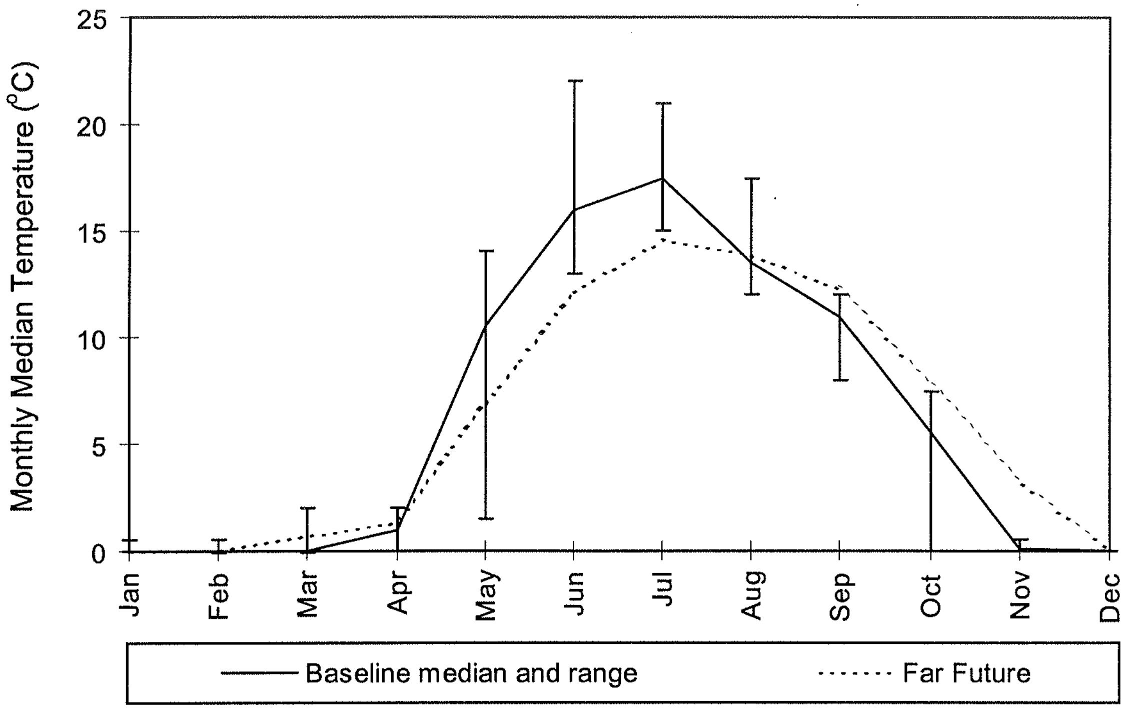
All predicted temperature changes caused by discharges of muskeg and overburden waters are below the interim temperature guideline of <3°C change in receiving waters.

End Pit Lake Drainage to McLean Creek - Far Future

EPL water inputs may also alter the temperature regime of McLean Creek. In the far future, the EPL will discharge into McLean Creek, provided that discharge water quality is acceptable (Section C3.2.2.2). Since large lakes possess greater thermal inertia (i.e., warm up or cool down slower) than streams and tend to be cooler, EPL discharges may have a cooling effect in McLean Creek during the open-water season and may also moderate daily temperature fluctuation.

The temperature model predicted a maximum temperature decline of 4.0°C in McLean Creek in June (Figure C3.2-4) and a general shift of stream temperatures towards the assumed thermal regime of the EPL (Appendix V). These changes originate from the prediction that a large proportion of the flow in McLean Creek will originate from the EPL (estimated as 60 to 70%). Predicted temperatures in McLean Creek equal or exceed the guideline in May, June and July.

Figure C3.2-4 Predicted Monthly Mean Water Temperatures in McLean Creek in the Far Future and the Assumed Baseline Thermal Regime



It is not possible to quantify changes in diurnal temperature variation in McLean Creek below the EPL discharge channel. As noted above, a general moderation of daily temperature fluctuation may be expected in this reach. Based on the anticipated characteristics of the EPL discharge channel, some diurnal fluctuation would develop, which may offset potential effects on daily temperature variation in McLean Creek.

Shipyard Lake

During the life of the Project, Shipyard Lake will receive muskeg and overburden drainage waters at the maximum annual average rate of 0.030 m^3/s in the year 2010. The remainder of inflows to the lake will consist of surface waters, such as natural streams and runoff, which are of no concern regarding lake thermal regime.

It is unlikely that the thermal regime of Shipyard Lake would be affected by muskeg and overburden drainage water inputs. The lake is shallow and surrounded by wetlands, which facilitate warming of incoming waters. The average daily contribution of muskeg and overburden waters to Shipyard Lake (2,600 m^3) corresponds to about 0.8% of the total lake volume (310,000 m^3). These waters will enter the lake near its shallow, vegetated margins, where warming to ambient temperature can be expected to occur relatively quickly. In addition, muskeg and overburden drainage waters will flow through sedimentation ponds and drainage channels of varying lengths before discharge to Shipyard Lake, which will also facilitate development of a more natural thermal regime in these waters.

Based on the above information, releases of muskeg and overburden drainage waters are not anticipated to cause measurable changes in the thermal regime of Shipyard Lake.

C3.2.6.3 Uncertainty

Results of temperature modelling for McLean Creek are subject to a high degree of uncertainty. The predicted changes in water temperature of McLean Creek represent conservative, worst-case estimates, which could not be refined due to lack of data. The following factors account for the uncertainty inherent in this analysis:

- It was assumed that the temperature of mine-related waters will not change during travel from the source (i.e., the area being dewatered or EPL) to the river. Muskeg and overburden drainage waters will flow through sedimentation ponds and drainage channels of varying lengths. The EPL discharge channel will be several km long and will include reaches designed to form wetlands. Therefore, a more natural thermal regime would be achieved in these waters before discharge to the receiving stream.

- The analysis was based on limited data. Available temperature data for a larger stream (Muskeg River) was used as the assumed thermal regime of McLean Creek; muskeg and overburden water temperatures were estimated based on professional judgment (Appendix V).

Since the temperature guideline was designed to protect fish, it is useful to consider the location in McLean Creek used by fish. Studies to date have only documented fish in the lower reach of this stream, below the escarpment. This reach is located at least 1 km downstream from the anticipated point of discharge of mine-related waters, which further increases the length of the reach within which water temperature may increase to near-ambient. Hence, there is further uncertainty regarding the potential for effects of discharges from the Project on fish that use McLean Creek

Overall, because of the relatively high uncertainty regarding temperature predictions for McLean Creek, results of temperature modelling should be interpreted as an indication that some temperature changes may be caused by water releases from the Project. However, because of the conservative approach used and the lack of data to refine the model, the predicted changes may be viewed as the maximum potential effects in McLean Creek.

Although the analysis of potential temperature changes in Shipyard Lake was only qualitative, its result is subject to considerably less uncertainty. Size and morphology of this lake and the large difference between its volume and the volume of incoming waters are sufficient to rule out changes in thermal regime that would be of concern to aquatic life.

C3.2.6.4 Residual Impact Classification

The predicted impact of mine activities on the thermal regime of McLean Creek is classified as low in magnitude, long-term in duration, moderate in frequency, local in geographic extent and reversible (Table C3.2-11). The environmental consequence of this impact is low.

The predicted impact on the thermal regime of McLean Creek is classified as negligible in magnitude, medium-term in duration, moderate in frequency, local in geographic extent and reversible (Table C3.2-11). The environmental consequence of this impact is negligible.

Table C3.2-11 Residual Impact Classification for Change in Thermal Regime of McLean Creek and Shipyard Lake

Impact	Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Environmental Consequence
McLean Creek	Low	Long-term	Moderate	Local	Reversible	Low
Shipyard Lake	Negligible	Medium-term	Moderate	Local	Reversible	Negligible

C3.2.6.5 Monitoring

Because of the considerable uncertainty regarding the analysis for McLean Creek, temperature will be monitored in this stream under baseline conditions and during the life of the Project. Baseline monitoring will characterize the natural thermal regime of McLean Creek and provide data for comparisons with results of subsequent monitoring. Monitoring should proceed during mine development to verify impact predictions.

Smaller-scale temperature monitoring will also be carried out in Shipyard Lake to verify impact predictions.

C3.2.6.6 Mitigation

In the event that temperature monitoring detects unacceptable changes that could affect aquatic life in waters receiving discharges from the Project, mitigation will be applied in the form of increasing the retention time of sedimentation ponds for discharge waters. This will allow discharge waters to attain temperatures closer to those of the receiving waters.

C3.2.7 Key Question WQ-3: What Impacts Will Muskeg Dewatering Activities Associated With Project Millennium Have on Dissolved Oxygen Concentrations in Small Streams?

C3.2.7.1 Analysis of Potential Linkages

Linkage Between Muskeg Dewatering and Dissolved Oxygen Concentrations

Recent muskeg drainage water data collected by Syncrude (Appendix V, Table V-1) were used for the small streams model predictions. As determined in Key Question WQ-1, these waters have limited potential to cause exceedances of water quality guidelines in receiving waters. However, they have elevated organic matter concentrations (as reflected by BOD) and hence, the potential for lowered dissolved oxygen levels in small streams theoretically exists. Therefore, this linkage is classified as valid.

Other Linkages to Dissolved Oxygen Concentrations

Predicted flow changes are negligible to small in streams and rivers in the LSA with the exception of McLean Creek. An approximately three-fold increase in flow is predicted in this stream, beginning during mine construction (Section C2.2.3, Table C2.2-8). However an increase in flow is unlikely to negatively affect dissolved oxygen levels in streams. Therefore, the linkage between changes in flows and dissolved oxygen levels is invalid.

Available chemistry data for seepage waters and CT water indicate that these waters do not contain nutrients or organic material at sufficient concentrations to affect dissolved oxygen levels in receiving waters. Therefore, linkages between tailings sand seepage, CT seepage and CT flux and dissolved oxygen levels are invalid.

C3.2.7.2 Analysis of Key Question

The quality of muskeg drainage waters has not been fully characterized. The most recent data consist of four samples collected by Syncrude from the Aurora Mine area in September of 1997 (data received from G. Kampala of Syncrude on 20 November 1997). Biochemical oxygen demand (BOD_5) levels were <0.05, 6.7, 6.1 and 8.0 mg/L in these samples.

Discharge of muskeg drainage waters will be very low, or will cease in the winter, due to freezing of both the channel walls and the water in drainage channels in dewatering areas (note that water quality modelling assumed year-round flow of these waters for worst-case analysis). Very low flows of this water may occur in areas where the thickness of the muskeg and overburden are sufficient to be below the depth of winter freezing.

Levels of organic material could be controlled in muskeg drainage waters during low-flow periods, if monitoring of dissolved oxygen levels showed a potential problem. Sedimentation ponds will intercept all engineered muskeg drainage water flows.

Based on the above analysis, it is concluded that the discharge of muskeg drainage waters will likely not unacceptably lower dissolved oxygen concentrations in small streams. However, monitoring will be conducted to confirm this prediction and enable effective mitigation to be employed if necessary.

C3.2.7.3 Uncertainty

Although recent muskeg drainage data were used in this analysis, questions remain regarding the representativeness of the data, especially in light of the large variability in BOD measurements in the samples collected by Syncrude.

C3.2.7.4 Residual Impact Classification

The predicted impact of dewatering activities on dissolved oxygen levels in small streams is classified as negligible in magnitude, medium-term in duration, moderate in frequency, local in geographic extent and reversible, (Table C3.2-12). The environmental consequence of this impact is negligible.

It is not expected that dewatering activities would result in an unacceptable lowering of dissolved oxygen levels. In any case, mitigation measures are available to address potential problems.

Table C3.2-12 Residual Impact Classification for Change in Dissolved Oxygen Concentrations

Impact	Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Environmental Consequence
Effect on dissolved oxygen levels	Negligible	Medium-term	Moderate	Local	Reversible	Negligible

C3.2.7.5 Monitoring

The surface water monitoring program will include dissolved oxygen monitoring to verify impact predictions. Suncor will follow anticipated regulatory requirements to develop the monitoring program.

C3.2.7.6 Mitigation

If monitoring of dissolved oxygen levels indicates a potential problem, oxygen levels could be controlled in muskeg drainage waters.

C3.2.8 Key Question WQ-4: What Impacts Will Operational and Reclamation Water Releases From Project Millennium Have on Levels of Polycyclic Aromatic Hydrocarbons (PAHs) in Sediments in the Athabasca River?

Oil sands mining and processing does not result in the production of PAHs; rather, PAHs that occur naturally in oil sand deposits are mobilized by the extraction process and may be released into the environment. The PAHs of greatest concern include the larger molecules with four rings or more, which are largely insoluble in water and thus tend to adsorb to sediments and organic material. These compounds are bioaccumulative and toxic to aquatic organisms at elevated concentrations.

Reclamation waters produced by oil sands operations contain PAHs at low concentrations (Appendix V, Table V-1) and hence may contribute PAHs to receiving waters. Sediment-bound PAHs may be transported for long distances in rivers and affect aquatic organisms at locations distant from the point of discharge.

C3.2.8.1 Analysis of Potential Linkages

Linkage Between PAHs in Operational and Reclamation Waters and PAH Accumulation and Transport in Sediments

Operational and reclamation waters contain PAHs at low concentrations. Although pathways for the release of PAHs into surface waters appear limited (see below), they cannot be discounted based on available data. Therefore, this linkage is valid.

C3.2.8.2 Analysis of Key Question

The effects of oil sands developments on sediment quality and toxicity have not been evaluated in detail. Most surveys of PAHs in bottom sediments sampled only two to three sites in the lower Athabasca River (Brownlee 1990, Brownlee et al. 1993, 1997, Crosley 1996, Golder 1996b, Golder 1998h). Sediment PAH data are also available for two sites in each of the Steepbank and Muskeg rivers and at single sites in the MacKay River, Poplar Creek and Jackpine Creek (Golder 1998h). The following are the major findings of the above studies:

- Although there may be an increase in sediment PAH levels in the Athabasca River within the oil sands area relative to upstream reaches (Crosley 1996), the available data are inconsistent regarding spatial variation within the oil sands reach. Crosley (1996) found a slight decline below oil sands operations (at Fort McKay) from levels measured upstream of Fort McMurray. Brownlee et al. (1997) found no spatial trend in PAH levels in bottom sediments in the lower Athabasca River. Golder (1998h) reported a two to three-fold increase in total PAHs below the oil sands area relative to levels at a site between Fort McMurray and Suncor's current operations. Brownlee (1990) found slight increases in levels of individual PAHs in suspended sediments in the Athabasca River below the oil sands area.

- Typical levels of total PAHs in bottom sediments are higher in the Peace and Wapiti rivers than in the lower Athabasca River (Crosley 1996). Natural sources were suggested as the origin of PAHs in all of these rivers.

- Few or no exceedances of sediment quality guidelines were documented in the Athabasca River during NRBS surveys from 1988 to 1995 (Crosley 1996, Brownlee et al. 1997). PAH levels were also below guidelines in samples collected by Golder (1996b, 1998h) from the Athabasca River in 1995 and 1997. Levels of benzo(a)anthracene/ chrysene, flouranthene and pyrene exceeded TELs in one sample collected in the Athabasca River in 1994 (upstream of Suncor's TID).

- Bottom sediment samples collected by Golder (1996b, 1998h) from the mouth of the Steepbank River had considerably higher levels of PAHs than samples from any other sites in the oil sands area. In one sample from this river (fall 1995), levels of most PAHs with available guidelines were higher than threshold effect levels (TELs), and benzo(a)anthracene/chrysene exceeded probable effect levels (PELs; sum of PELs used for benzo(a)anthracene/chrysene). A large proportion of these samples likely consisted of oil sands and represent worst-case natural sediment PAH concentrations.

- Samples from other rivers and streams sampled by Golder (1996b, 1998h; MacKay River, Muskeg River, Jackpine Creek, Poplar Creek) contained PAHs at levels below TELs, with the exception of the MacKay River. Phenanthrene and benzo(a)anthracene/chrysene exceeded the TELs for these compounds in the single sample collected at the mouth of this river in 1997 (sum of TELs used for benzo(a)anthracene/chrysene).

Although the available information is scarce, some general conclusions can be made regarding the release of PAHs by oil sands operations and resulting deleterious effects on aquatic organisms. These are described below:

- Since the PAHs of greatest concern readily partition to sediments in surface waters, there are no obvious pathways for them to leave the

Project area. The water management plan for the Project was designed to incorporate considerable attenuation of discharge waters before release to the environment. This will be achieved by holding reclamation waters in wetlands or lakes for at least one year before release to streams. This holding period is expected to result in biological degradation of a large fraction of organic constituents and the removal of suspended sediments, which are the most likely reservoir of PAHs.

- Biological effects of PAHs mobilized by oil sands operations have not been demonstrated in the Athabasca River. Because this river experiences a considerable natural loading of hydrocarbons, it has not been possible to separate indicators of oil sands industry-related exposure, from those of natural exposure (e.g., mixed function oxidase (MFO) induction in fish). As well, ecological characteristics of the Athabasca River do not reflect any deleterious effects that could be attributed to oil sands operations.

- Baseline studies conducted for Suncor's Steepbank Mine reported PAHs in fish and invertebrate tissues at levels near the analytical detection limits (0.02 to 0.04 μg/g) in the Athabasca River, and no PAH metabolites were detected in fish bile (Golder 1996b). Spatial trends in tissue concentrations of PAHs in benthic invertebrates were not consistent with PAH inputs from oil sands operations. PAHs were largely non-detectable in the Athabasca River (which receives wastewater from Suncor and seepage from TID), but individual PAHs were slightly elevated in samples from the Steepbank and Muskeg rivers, where there are no oil sands developments at this time. Therefore, some bioaccumulation of naturally occurring PAHs is occurring in the oil sands area, but contributions of PAHs by oil sands operations have not been demonstrated to cause bioaccumulation in aquatic organisms.

- The available data provide little evidence that levels of PAHs have changed in sediments of the Athabasca River as the result of oil sands operations. In fact, other northern rivers, (Peace and Wapiti rivers) which are not influenced by such developments, contain sediments with higher PAH levels than the oil sands reach of the Athabasca River (Crosley 1996).

Based on the weight of evidence described above, it is unlikely that PAHs released from the Project would result in substantial accumulation in sediments.

C3.2.8.3 Uncertainty

Because the available information regarding this issue is limited, this analysis is subject to a high degree of uncertainty.

C3.2.8.4 Residual Impact Classification

The predicted impact of PAH releases resulting from the Project on sediment levels is classified as negligible in magnitude, long-term in duration, high in frequency, regional in geographic extent and irreversible (Table C3.2-13). The environmental consequence of this impact is low.

Table C3.2-13 Residual Impact Classification for PAH Accumulation in Sediments

Impact	Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Environmental Consequence
PAH accumulation in sediments	Negligible	Long-term	High	Regional	Irreversible	Low

C3.2.8.5 Monitoring

The Project is participating in regional aquatic monitoring efforts (RAMP) aimed at determining the chemical and biological effects of oil sands operations and is committed to develop specific monitoring programs to address issues of concern to regulators and stakeholders.

C3.2.9 Key Question WQ-5: What Impacts Will Operational and Reclamation Water Releases From Project Millennium Have on Toxicity Guideline Attainment in the End Pit Lake?

C3.2.9.1 Analysis of Potential Linkages

Linkage Between End Pit Lake Water Quality and Toxicity to Aquatic Life

The EPL will become a receiving waterbody for drainage from mine-disturbed areas. The intended end-use for the lake is a self-sustaining, biologically productive waterbody. Because EPL water may be toxic to sensitive aquatic organisms as the lake is filling, this linkage is valid.

C3.2.9.2 Analysis of Key Question

EPL water quality will be a function of several variables, including:

- relative amounts of each type of water used to fill the lake;
- rate of filling;
- retention time;
- depth and physical layout of the lake, as this affects mixing; and

- watershed design criteria, such as number and placement of wetlands, as this will affect water quality of the influent streams.

Some of these variables can be optimized to ensure that water quality in the lake will be suitable for the intended end-uses. The concept of a water-capped, fine tails bottom lake has been studied by both Suncor and Syncrude and was approved as a reclamation feature for Syncrude's Mildred Lake facility (Base Mine Lake). The EPL for the Project is similar to Base Mine Lake, with the following important differences:

- The water layer in the Project EPL is considerably deeper (65 to 100 m) than proposed for Base Mine Lake (5 m). This should prevent MFT at the bottom of the lake from mixing with surface waters, but creates the potential for chemicals to accumulate below a thermocline if the lake stratifies.
- MFT at the bottom of the lake will be aged, consisting of 30% solids by volume. Consolidation of the MFT deposit will proceed very slowly, producing a limited amount of tailings water which will mix with the overlying waters.
- In addition to MFT, CT will be deposited at the bottom of the EPL. Unlike the MFT deposit, the CT deposit will consolidate relatively quickly, and stop expressing water within about 10 years of placement.
- This EPL will consist of two lakes linked by a wetland system. Water will flow from the lake containing the MFT and CT deposits through the wetland to the second lake. Outflow from the EPL system will be directed through a series of wetlands, initially to the Athabasca River and later to McLean Creek. This design permits passive water treatment in both lake and wetland environments prior to discharge.

These are positive design differences that should result in an EPL that is sustainable and safe for users. Even so, there are a number of potential issues that need resolution and further evaluation:

- **Stratification potential:** The development and nature of a thermocline is an issue requiring further study. It is expected that the EPL would, periodically, be thermally stratified during the summer. Stratification is a feature common to all deep lakes in Alberta. The fully mixed assumption for modelling purposes may under-estimate the quality of EPL water during periods of stratification and, conversely, may over-estimate its quality during overturn.
- **Nutrient status:** Nutrient levels and algal biomass are not expected to be different than those predicted for the Aurora EPL. The EPL is expected to be oligotrophic to meso-eutrophic.

  Expected dissolved organic carbon (DOC) levels might reduce algal biomass as a result of reduced light penetration. There is some indication that this is the case in Kearl Lake (a natural lake in the region), since the median chlorophyll *a* level of 3 μg/L is lower than expected for a lake with a median total phosphorus level of 23 μg/L (based on Prepas and Trew's (1983) study, a chlorophyll *a* level of 8 μg/L would be expected for a lake in Alberta with similar nutrient levels). Hence, chlorophyll *a* level in the EPL might be suppressed relative to other lakes in Alberta. A combination of modelling and laboratory studies will provide more detailed predictions as to the conditions expected in the EPL.

- **Dissolved oxygen:** The EPL is expected to be oligotrophic to meso-eutrophic. Oxygen demand from MFT and sediments would be low relative to natural lakes. It is, therefore, unlikely that the hypolimnion would become fully anoxic. The epilimnion would remain well oxygenated throughout the year.
- **Solids resuspension:** Resuspension of solids is a topic requiring further research. The following factors are relevant:
  - handling of the MFT would emphasize minimizing resuspension (e.g., the MFT would be pumped from bottom to bottom); and
  - monitoring and strategies for reducing solids resuspension can be gained from Syncrude's current Base Mine Lake program.

  If improvement in the quality of tailings pond top water is desired before discharge into the EPL, it could be directed through the reclamation landscape wetlands. Similarly, remediation of elevated solids concentrations could be achieved through channel outlet design features, such as enhancement with wetlands, or a final sedimentation pond. If necessary, flocculation of solids could be achieved with settling aids.
- **Hydrogen sulphide (H_2S) generation:** Since H_2S is oxidized rapidly under aerobic conditions in aquatic systems, its concentration is expected to be very low in most of the lake, even if there was H_2S production in bottom sediments. Sulphide is, therefore, not expected to lead to any impacts on aquatic biota in the lakes. Ammonia levels would similarly be remediated through oxidation.
- **Time-frame for improvement of water quality to acceptable level:** Suncor will direct EPL outflow to the Athabasca River to ensure the protection of McLean Creek. This will enable guidelines to be achieved within regulatory mixing zones within the Athabasca River. Acute and chronic toxicity guidelines have to be met before the EPL discharges to the receiving stream.

  In the very unlikely event that toxicity guidelines cannot be achieved, or other substance concentrations at the edge of regulatory mixing zones cannot be attained by the time the EPL is ready to discharge into the Athabasca River, additional remediation of the EPL outflow would be undertaken. Options include chemical precipitation, aeration, or additional wetlands remediation.

Modelled substances in the Project EPL (Table C3.3-14) are the same as those modelled in Syncrude's Aurora Mine EPL (BOVAR 1996e) and Shell's Muskeg River Mine EPL (Shell 1998). Discharges from the Project EPL will not begin until the Year 2044.

Table C3.3-14 Predicted Substance Concentrations in the End Pit Lake

Substance	Guideline	Highest Concentration Before Discharge	Year 2045	Far Future
benzo(a)pyrene group (μg/L)	0.0028[(a)]	0.13	0.04	<0.0001
benzo(a)anthracene group (μg/L)	0.0028[(a)]	0.35	0.2	<0.0001
naphthenic acids (mg/L)	NG[(b)]	55	2.6	0.07
acute toxicity (TUa)	0.3	2.82	0.13	0.006
chronic toxicity (TUc)	1.0	6.25	0.2	0.009
total dissolved solids (mg/L)	NG	1180	1170	355

[(a)] human health water quality guideline

[(b)] NG = no guideline

The results of the acute and chronic toxicity modelling were used to address the EPL key question. The concentrations of other substances were addressed through modelling benzo(a)anthracene and benzo(a)pyrene PAH groups, naphthenic acids and TDS. The results from this modelling serve as a surrogate for other substance concentrations in the EPL. Because the EPL receives several mine related waters (tailings sand seepage, CT flux, MFT and MFT porewater) and because maximum substance concentrations for each of the release waters that fill the EPL were in general assumed, it is likely that these constituents and other oil sands related substance concentrations would be unrealistically overestimated.

Modelling results indicate that toxicity guidelines would be met before discharge. Elevated concentrations of organic substances (e.g., naphthenic acids) would decay quickly once reclamation waters were introduced into the EPL.

The values for the benzo(a)pyrene and benzo(a)anthracene groups were compared with U.S. EPA water quality guidelines for human health, which are based on a 70-year exposure period and a one-in-one million risk factor. However, benzo(a)pyrene and benzo(a)anthracene group concentrations would fall below guideline values in a much shorter period (13 and 18 years, respectively). In addition, most organic molecules would be tied up in particulate matter that would likely settle out of the water column in the EPL. As a result, the EPL and water discharged from it should pose little risk to human health. The potential health risks associated with benzo(a) pyrene and benzo(a) anthracene are discussed further in Section F1.3

There is no regulatory guideline for naphthenic acids. However, data collected by AEP and Golder (1996b) indicate that naturally occurring levels of naphthenic acids reach 2 mg/L in streams within the RSA. When the EPL begins discharging to the Athabasca River (2044), naphthenic acid levels are projected to be below 5 mg/L, and would drop below 0.1 mg/L within 12 years (2055).

The concentration of total dissolved solids (TDS) in the EPL is expected to vary from 355 mg/L to over 1,180 mg/L. Although TDS levels at the upper end of this range are higher than those observed in natural lakes within this region, they are still well below levels that tend to suppress algal growth (Bierhuizen and Prepas 1985). Therefore, relatively high TDS concentration in the EPL should not affect lake productivity. Predicted TDS levels are also well below the concentration (2,000 mg/L) that would reduce the diversity of aquatic macrophytes (Pip 1979, Hammer et al. 1975). Therefore, salt concentrations are not expected to limit the productivity of the EPL once it begins discharging to the Athabasca River.

C3.2.9.3 Uncertainty

Suncor understands that there are many uncertainties associated with the EPL, but believes that it can be designed and operated to achieve the desired end-use of a viable, productive, self-sustaining lake with a non-toxic outflow at all times. The key to achieving this goal is proactive planning, research and monitoring. Suncor is committed to participating with other regional operators and regulators to achieve this goal.

C3.2.9.4 Residual Impact Classification

The predicted impacts of EPL water quality are classified as low in magnitude, long-term in duration, high in frequency, local in geographic extent and reversible (Table C3.2-15). The environmental consequence of these impacts is low.

Table C3.2-15 Residual Impact Classification for End Pit Lake Water Quality

Impact	Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Environmental Consequence
Toxicity in EPL	Low	Long-term	High	Local	Reversible	Low

C3.2.9.5 Monitoring

Monitoring will be a function of research and monitoring needs identified in the EIA, recommendations of end land-use and other stakeholder committees and requirements anticipated from regulatory agencies.

Suncor is committed to participate in research to ensure that the EPL meets regulatory and stakeholder end-use goals. Suncor believes it will be necessary to form a dedicated, multi-stakeholder committee to ensure that the knowledge gained on EPLs over the ensuing decades is consistent with that required to ensure that they are viable reclamation features at closure.

Suncor is a member of CONRAD, CEATAG and RAMP and will become regionally involved with research associated with EPLs.

This regional approach will be used not only to continually fine tune design and operational parameters, but to assess the overall feasibility of the EPL concept.

C3.2.9.6 Mitigation

A number of options are available for achieving compliance with water quality and toxicity guidelines in the EPL and the fundamental goal of a non-toxic discharge to surface waters. These include:

- biologically, physically, or chemically treat the CT flux water collected from reclaimed areas prior to discharge to the EPL;
- increase the size of the EPL by removing some of the overburden currently scheduled for disposal in Pond 12, thereby increasing the EPL's retention time;
- alter the design of the EPL to reduce the depth of the overlying surface water, which would promote lake mixing to a sufficient depth to prevent any sudden release of chemicals when the thermocline breaks down;
- introduce Athabasca River water into the EPL at a rate necessary to achieve acceptable water quality;
- add nutrients to the EPL to elevate its level of production, and hence its biological treatment capability. The EPL is not expected to discharge in the winter when the highest potential for oxygen depletion in McLean Creek could occur. If nutrients were added during the reclamation management period to enhance productivity of the EPL and the organic content in the outflow became a concern for McLean Creek, a final polishing pond could be constructed in the outflow channel to settle vegetative matter, or be used as an aeration pond; and
- actively treat EPL outflow, if necessary. For example, if suspended solids concentrations are higher than desired, a sedimentation pond could be designed into the EPL discharge channel to the Athabasca River or McLean Creek and flocculants could be added to enhance settling. This settling pond could also be aerated if necessary. Additional passive treatment could involve enhancing the discharge channel with wetlands. A settling or shallow retention pond would also reduce the potential for temperature changes in receiving waters.

C3.2.10 Key Question WQ-6: What Impacts Will Acidifying Emissions From Project Millennium Have on Regional Waterbodies?

C3.2.10.1 Analysis of Potential Linkages

Linkage Between Acidifying Emissions and Changes in Water Quality

Acid deposition resulting from emissions of acid-forming substances can affect surface water quality and the functioning of aquatic ecosystems. Sources of acidifying emissions associated with the Project include NO_x from the Upgrader and Energy Services and vehicles, and SO_2 emissions from Upgrader and Energy Services stacks. Based on the potential for these compounds to cause acidification in sensitive waterbodies, this linkage is valid.

C3.2.10.2 Analysis of Key Question

The Fort McMurray oil sands area is subject to a higher than background rate of sulphate deposition, which has not been attributed to specific sources (Schindler 1996). Despite the higher sulphate deposition rate, there is no evidence of anthropogenic acidification of lakes in this area, or in the province of Alberta (Schindler 1996).

The sensitivity of Alberta lakes to acidic deposition has been described in numerous AEP reports. The most recent report was updated to include data collected in 1995 (Saffran and Trew 1996). Lakes sensitive to acidic deposition are typically identified as those with low buffering capacity, measured as total alkalinity. About 5% of the 1131 lakes with available data in the province were designated highly sensitive (total alkalinity <10 mg/L as $CaCO_3$); an additional 5% are moderately sensitive (10 to 20 mg/L); 14% have low sensitivity (20 to 40 mg/L); and 76% are not considered susceptible to acidification (>40 mg/L; Saffran and Trew 1996).

Acid-sensitive lakes are concentrated in the Rocky Mountains and north-eastern Alberta, north of the oil sands area. To date, less than 10 lakes have been designated acid-sensitive (alkalinity <20 mg/L) within the Aquatics RSA (Saffran and Trew 1996). These lakes are located just east of the oil sands area and to the north-west, in the Birch Mountain uplands. In contrast, the majority of lakes in the oil sands area are not sensitive to acidification.

Running waters may be sensitive to acidification during the spring, when runoff from rapid snow-melt may quickly reach streams by travelling over frozen ground. This may dilute base cations in streams and deliver acidifying substances deposited during the winter. Based on its water chemistry and large dilution capacity, the Athabasca River is not sensitive to spring acid pulses, but there are a number of known acid-sensitive rivers in the RSA. Schindler (1996) designated the Firebag, Steepbank and Muskeg rivers as acid-sensitive and reported moderate pH depressions in the Firebag and Steepbank rivers during the spring snowmelt period in 1989 and 1990. The magnitude of the pH depressions documented in these rivers (from between 7 and 8.5 to <6) was sufficient to be of concern to aquatic life. These episodes lasted for a "few days" and were followed by a recovery period of up to a month, depending on river. During the same period, the pH of the Muskeg River did not change, despite a greater increase in flow than in the other two rivers. Overall, since some relatively large tributaries of the Athabasca River are susceptible to spring acid pulses, small streams in the region are also potentially acid-sensitive.

Predicted Potential Acid Input (PAI) associated with Project Millennium and existing and approved oil sands operations exceeds the interim critical load of 0.25 keq/ha/y in an approximately 90 x 150 km area (Section B3). This area includes the acid-sensitive lakes in the RSA identified above. Since most lakes in the region are not sensitive to acidification, it is unlikely that oil sands operations would cause large-scale acidification in surface waters. However, modelling suggests that the potential exists for acidification of a small number of lakes in the RSA. Additionally, even in the absence of a large number of acid-sensitive lakes in the RSA, long-term effects of acid deposition remain a concern in the oil sands area.

Critical loads have not been developed for rivers; therefore, model results cannot be used directly to evaluate the potential for spring pH depression in rivers. Comparison of baseline PAI inputs with those predicted for the impact assessment suggests that acid deposition rates would increase slightly in the RSA relative to baseline conditions. Therefore, since spring pH depression has been reported in the oil sands area in the past, its continued occurrence and a potential increase in its severity cannot be ruled out.

In summary, acid deposition from oil sands operations is not expected to cause large-scale acidification of lakes in the RSA, but sensitive lakes may be at risk. Changes in the occurrence and severity of spring pH depression in rivers cannot be evaluated using the available information, but also cannot be ruled out.

C3.2.10.3 Uncertainty

The above analysis is subject to a high degree of uncertainty. Part of this stems from uncertainty inherent in modelling. Additional uncertainty results from the lack of detailed data on lake sensitivity to acidification in the RSA. As well, there are no established techniques at this time to relate modelled acid deposition rates to changes in pH in surface waters. Therefore, results of the above analysis highlight the need for further analysis and monitoring.

Since this is an issue of regional scope, a more refined approach to assess potential impacts of acid deposition from oil sands operations will be considered, on an industry-wide basis. The suggested approach consists of calculating the critical loadings for selected lakes in the region potentially affected by acid deposition from oil sands operations. The steady-state mass-balance equations developed in Europe will be applied to selected lakes for which baseline data are available. These lakes will include a number of the sensitive lakes in the Birch Mountain uplands and lakes in the oil sands region. Application of the model will result in a table of lake-specific critical loadings, rather than a single value applied over the entire region (i.e., 0.25 keq/ha/yr). These individual lake specific critical loads will then be compared with the modelled isopleths of acid deposition to determine whether buffering capacity in these lakes is sufficient to withstand acidification.

A similar approach will be developed to assess the potential for spring pH depression in rivers in the area affected by acid deposition from oil sands operations. The assessment for rivers will incorporate dilution of base cations by snow-melt, which may be responsible for a large proportion of the declines in river pH occurring at the present (Schindler 1996).

C3.2.10.4 Residual Impact Classification

The impact of acidification of lakes is classified as low in magnitude, long-term in duration, high in frequency, regional in geographic extent and reversible (Table C3.2-16). The environmental consequence of this impact is low.

The impact of spring pH depression in surface waters is classified as low in magnitude, long-term in duration, moderate in frequency, regional in geographic extent and reversible, with a high degree of uncertainty (Table C3.2-16). The environmental consequence of this impact is low.

Table C3.2-16 Residual Impact Classification for Changes in Water Quality Caused by Acidifying Emissions

Impact	Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Environmental Consequence
Year-round acidification	Low	Long-term	High	Regional	Reversible	Low
Spring pH depression	Low	Long-term	Moderate	Regional	Reversible	Low

C3.2.10.5 Monitoring

Monitoring will be undertaken under the RAMP to strengthen the available baseline database and to assess long-term trends in water quality. As well, intensive, short term monitoring during the critical snowmelt period will evaluate the sensitivity of selected rivers and streams to spring acid pulses. These studies will also evaluate the existing level of metals and organic compounds released during snowmelt, for which baseline data are not available at present. Details of the monitoring program will be finalized upon review by regulatory agencies

C3.3 WATER QUALITY CONCLUSION

C3.3.1 Introduction

Project Millennium has been designed to mitigate water quality impacts by:

- using an interceptor ditch around the tailings pond to capture seepages;
- operating sedimentation ponds to polish muskeg dewatering flows (and equilibrate temperatures);
- directing CT surface flows exclusively into the end pit lake (EPL);
- developing wetlands systems to provide retention and bioremediation of process-affected waters; and
- initially directing the release of EPL water to the Athabasca River, rather than to McLean Creek.

In addition to the above features, existing discharges from the plant upgrader will be reduced by at least 50% to the Athabasca River by the year 2000.

The water quality impact assessment predicted the incremental effects of the Project on top of existing and approved oil sands operations. The assessment considered the issues, as addressed through the key question approach in Section C3.2 of the EIA. The issues and environmental consequences are summarized in Table C3.3-1.

Table C3.3-1 Water Quality Issues and Environmental Consequences

Issue	Environmental Consequence
Toxicity and water quality in the Athabasca River, McLean Creek and the Shipyard Lake wetlands	Low to Moderate
Thermal regime of McLean Creek and the Shipyard Lake wetlands	Negligible to Low
Dissolved oxygen levels in McLean Creek and the Shipyard Lake wetlands	Negligible
Accumulation of polycyclic aromatic hydrocarbons (PAH) in sediments in the Athabasca River	Low
Toxicity in the EPL water prior to discharge	Low
Water quality resulting from acidifying emissions	Low

C3.3.2 Impact Assessment

Maintenance of Water Quality Guidelines

The Project, in combination with existing and approved developments in the study area, will not cause exceedances of acute or chronic toxicity guidelines for aquatic life. A number of metals exceed water quality guidelines in the Athabasca River naturally and the Project would not contribute an appreciable, additional load of these substances. These metals are not considered to be of concern, because they are largely associated with suspended particulate matter and thus are not in a bioavailable form.

Exceedance of the human health water quality guideline for the benzo(a)anthracene PAH group may occur in the Athabasca River downstream of the Muskeg River due to the incremental contribution of the Project and approved, but not yet developed, oil sands operations in the Muskeg River basin. It is expected that continued examination of this issue will demonstrate that this group of compounds will precipitate out or be bioremediated in EPLs and wetlands before reaching receiving streams. Follow-up human health risk analysis rejected this compound as being of concern to wildlife and human health.

The predicted impact of the Project on Athabasca River water quality is classified as negligible in magnitude. The environmental consequence of this impact is considered to be low.

A similar pattern of natural background exceedances for metals would occur in McLean Creek. However, the number and magnitude of these exceedances may increase during the winter period when no natural surface flows would be available for dilution of mine related waters. The projected exceedances would be due solely to natural Basal and surficial aquifer waters and muskeg drainage waters.

McLean Creek is an intermittent stream that has no flow in the winter and will occasionally dry up in the summer. Viewed in this context and with the Project predicted to increase natural flows, it is arguable whether the Project could decrease the current environmental quality of McLean Creek. The environmental consequence of this impact is considered to be moderate during extreme low flow periods because of water quality guideline exceedances from natural groundwater inputs (basal and surficial aquifer seepage and accelerated muskeg and overburden drainage flows). This environmental consequence rating was based on low magnitude, long-term duration, moderate frequency, local geographic extent and irreversibility. However, because there is no acute or chronic toxicity associated with these streams and because McLean Creek is an intermittent stream, the risk posed by the Project is low and therefore, this impact is not significant.

Although limited baseline water quality data are available for the Shipyard Lake wetlands, worst-case projections can be made. These wetlands will be protected from the influence of Project-related flows by directing reclamation landscape flows to the EPL during periods of CT flux. Other than natural flows, the only mine-related flows that would reach this waterbody would be from muskeg dewatering. Therefore, the residual impact has been classified to be of low environmental consequence.

Thermal Regime

Temperature changes in McLean Creek and Shipyard Lake, as a result of changing flow regimes, would remain within acceptable ranges. Uncertainty regarding the conservative analysis for McLean Creek indicates that temperature monitoring should be conducted in this stream under baseline conditions and during the life of the Project. A lower frequency of temperature monitoring will also be carried out in Shipyard Lake to verify impact predictions. If monitoring indicates a potential problem, the temperature of muskeg drainage waters entering small streams would be equilibrated with the receiving stream temperature by increasing the retention times of sedimentation ponds.

The residual impact of thermal regime changes has been classified as being negligible to low environmental consequence mainly because of the negligible and low magnitude of the potential impacts to Shipyard Lake and McLean Creek, respectively.

Dissolved Oxygen

Dissolved oxygen impacts from muskeg drainage waters are not expected to occur. Suncor will follow expected regulatory requirements to develop a monitoring program. If monitoring of dissolved oxygen levels indicates a potential problem, oxygen levels would be controlled in muskeg drainage waters. The magnitude of impacts associated with dissolved oxygen is negligible. Therefore, the environmental consequence is negligible.

Polycyclic Aromatic Hydrocarbons (PAHs)

Concentrations of the benzo(a)anthracene PAH group were conservatively predicted to exceed the human health water quality guideline in the Athabasca River, downstream of the confluence of the Muskeg River. This is due to the incremental contribution of the Project and approved, but not yet developed oil sands operations in the Muskeg River basin. The accumulation of PAHs in sediments and their subsequent transport in the Athabasca River is not expected to increase because of limited available pathways for PAHs to be released from the Project area. It is anticipated that continuing examination of this issue will demonstrate that this exceedance would not occur because hydrophobic compounds will precipitate out, or be bioremediated in EPLs and wetlands before reaching receiving streams. In any case, conservative health risk analyses rejected this compound as being of concern to wildlife and human health.

The predicted impact of PAH releases is classified as negligible in magnitude, high in frequency and of regional geographic extent. Therefore, the environmental consequence is low.

End Pit Lake

Strategic design and management of the EPL will enable acute and chronic toxicity guidelines to be achieved before the outflow reaches the receiving stream. If continued wetlands monitoring and research demonstrates that remediation is as effective as currently indicated, Suncor will apply to AEP to redirect the outflow from the Athabasca River to McLean Creek. Notwithstanding the capability to strategically design and manage the EPL, it is recognized there are a number of potential issues that require resolution and further evaluation. Suncor is committed to participate in research to ensure that the EPL meets regulatory and stakeholder end-use goals. Since these are issues facing all oil sands operators, they are best addressed in a coordinated effort.

Predicted impacts of the EPL water quality are classified as low in magnitude and local in geographic extent. The environmental consequence of these impacts is low.

Acidification

Acidification of waterbodies as a result of air emissions is unlikely, though questions remain about possible spring pH depression in rivers and acidification of a small number of sensitive lakes in the RSA. The Fort McMurray oil sands area is subject to a higher than background rate of sulphate deposition, which has not been attributed to specific sources. However, despite the higher deposition rate, there is no evidence of anthropogenic acidification of lakes in this area, or in the province of Alberta.

There are no acid-sensitive lakes in the Aquatics LSA, and to date, fewer than ten lakes have been designated acid-sensitive within the RSA. These lakes are located just east of the oil sands area and to the northwest, in the Birch Mountains uplands.

Based on its water chemistry and large dilution capacity, the Athabasca River is not sensitive to spring acid pulses, but there are a number of known acid-sensitive rivers in the RSA. The Firebag, Steepbank and Muskeg rivers may be acid-sensitive. Since some relatively large tributaries of the Athabasca River are susceptible to spring acid pulses, small streams in the region may also be potentially acid-sensitive.

Predicted Potential Acid Input associated with Project Millennium and existing and approved oil sands operations exceeds the interim critical load of 0.25 keq/ha/y for highly sensitive environments in an approximately 90 by 150 km area. Since most lakes in the region are not sensitive to acidification, it is unlikely that oil sands operations would cause large-scale acidification in surface waters. However, modelling suggests that the potential exists for acidification of a small number of lakes in the RSA. Additionally, even in the absence of a large number of acid-sensitive lakes in the RSA, long-term effects of acid deposition remain a concern in the oil sands area.

In summary, acid deposition from oil sands operations is not expected to cause large-scale acidification of lakes in the RSA, but sensitive lakes may be at risk. Changes in the occurrence and severity of spring pH depression in rivers cannot be evaluated using the available information, but also cannot be ruled out.

The impact of acidification of lakes is classified as low in magnitude, long-term in duration, regional in geographic extent and possibly reversible. The environmental consequence of the impact is therefore low.

C3.3.3 Monitoring

Monitoring programs will include:

- participation in the Regional Aquatic Monitoring Program (RAMP);
- evaluation of the potential for muskeg drainage waters to cause declines in dissolved oxygen levels in receiving streams and sedimentation ponds;
- monitoring of thermal regimes for McLean Creek and Shipyard Lake;
- monitoring, on an intensive, short-term basis during the critical snowmelt period to evaluate the sensitivity of selected rivers and streams to spring acid pulses; and
- monitoring the end pit lake, once established, for PAHs and other constituents.

C4 FISHERIES AND FISH HABITAT

C4.1 BASELINE/ENVIRONMENTAL SETTING

C4.1.1 Introduction

This section provides a description of fish and fish habitat in the Project Millennium local study area (LSA). Section C4.1.2 describes traditional knowledge and uses of fish by the Fort McKay people. The traditional knowledge section is based on information provided by Fort McKay in a number of reports.

Benthic invertebrates, fish populations and fish habitat for the Athabasca and Steepbank rivers are presented in Sections C4.1.3 and C4.14, respectively. Fish habitat and utilization of Shipyard Lake and small Athabasca River tributaries is discussed in Section C4.1.5. Baseline information on fish and fish habitat in the Project Millennium LSA is presented in more detail in the following reports:

- Aquatic Baseline Report for the Athabasca, Steepbank and Muskeg Rivers in the Vicinity of the Steepbank and Aurora Mines (Golder 1996c).
- Addendum to Suncor Steepbank Mine Environmental Impact Assessment: Spring 1996 Fisheries Investigations (Golder 1996b).
- Shipyard Lake Environmental Baseline Study (Golder 1996p).
- Reference Wetlands Reconnaissance Survey (Hamilton 1992).
- Winter Aquatic Surveys: Steepbank River, Shipyard Lake, and Leases 19, 25 and 29 (Golder 1997m).
- Project Millennium: Fall Fisheries Investigations (Golder 1998j).
- Oil Sands Regional Aquatics Monitoring Program: 1997 Report (Golder 1998h).

Fish species or guilds from each watercourse were selected as key indicator resources (KIRs) for the fish and fish habitat impact assessment. Descriptions of the KIRs and their habitat requirements are presented in Section C4.1.6.

C4.1.2 Fisheries Traditonal Knowledge

Fisheries Traditional Environmental Knowledge of the of the Fort McKay aboriginal people includes 12 fish species: goldeye, lake whitefish, Arctic grayling, pickerel (walleye), chub (lake chub), sucker (longnose and white), lingcod (burbot), jack fish (northern pike), trout (lake and rainbow) and yellow perch. Fish are a food source and a commercial commodity. In the Fort McKay area there are several important rivers such as the Athabasca, Clearwater, Firebag, Richardson and Chelsea rivers. Important lakes are Namur Lake, Gardiner Lake, Sand Lake, Eaglenest Lake and the Chipewyan Lakes (Fort McKay 1994).

Fish are an important food source and are consumed fresh, frozen or dry-cured. The fish eggs are eaten fried or raw and are sometimes added to bannock (Fort McKay 1994). The most common fish species consumed in the Fort McKay community are lake whitefish and jackfish (northern pike). A survey of the Fort McKay people showed that the percentage of people who ate the various species of fish is as follows: lake whitefish (73%), jackfish (58%), walleye (47%), lake trout and rainbow trout (35%), goldeye (8%), lingcod (8%) and sucker (8%). Walleye are also sold in quantity to the Freshwater Fish Marketing Board for distribution to larger population centres. Chub may be caught and used as bait (Fort McKay 1997a). Lake whitefish, chub and lingcod are used for animal food (Fort McKay 1994, 1997a). Yellow perch are not caught for food (Fort McKay 1997a). The fat from fish stomachs and bones can be rendered and used for cooking (Fort McKay 1994). Also fish scales can be used to decorate artifact and clothing accessories and fish skin makes a delicate fabric.

Fish can be captured in a number of ways. Fish traps are built by opening a beaver dam or by damming a stream. Fish are also captured with snares or fish hooks made of wood with a bone barb attached by sinew. In the winter, fish are caught by setting nets under the ice (Fort McKay 1994). Some angling occurs on the Athabasca and Steepbank rivers (Fort McKay 1996a).

Larger quantities of fish are captured during spawning runs in the spring and fall. The pickerel spawning run is in June and the lake whitefish run in early fall. Arctic grayling are fished in streams and rivers when the water is open. It is reported that pickerel spawn in Richardson Lake. Lingcod are caught in lakes and the Athabasca River. It is thought that there are no perch in the Athabasca River (Fort McKay 1994). Currently the majority of fish eaten, lake whitefish and jackfish (northern pike), are harvested from Namur and Moose (Gardiner) lakes. Gardiner and Namur lakes are also where the majority of walleye and trout are caught (Fort McKay 1997a). Fish caught in the Steepbank River are walleye, Arctic grayling and jackfish (northern pike) (Fort McKay 1996a).

Traditionally fish camps were formed as meeting places for fishing and drying the flesh. For example, the winter meat supply would be caught and preserved in the fall (Fort McKay 1994). Tar Island and Mildred Lake were used as gathering areas for catching fish (Fort McKay 1996c). These areas are no longer available for use. Some members of the Fort McKay community feel the elimination of the gathering site and polluting of the Athabasca River led to the end of subsistence fishing (Fort McKay 1996c).

C4.1.3 Athabasca River

C4.1.3.1 Benthic Invertebrates

The Athabasca River in the oil sands area is wide and carries a considerable silt load during the summer months. It provides relatively low quality, largely depositional habitat for benthic invertebrates.

Bottom sediments of the lower Athabasca River support a relatively homogeneous benthic fauna, characterized by low density and number of species, consisting largely of chironomid midge larvae, oligochaete worms and nematode worms (Anderson 1991). More diverse communities were documented on artificial substrate samplers used for monitoring oil sands-related discharges (McCart et al. 1977, Noton 1979, Noton and Anderson 1982, Golder 1996c). Since artificial substrate provides ideal colonization habitat for invertebrates, this finding is consistent with expectations. These samplers were colonized by representatives of several pollution-sensitive invertebrate groups (e.g., Ephemeroptera, Plecoptera and Trichoptera), in addition to invertebrates found in bottom sediments.

Benthic invertebrate studies of the Athabasca River, carried out in the 1970s and 1980s, documented minor, localized effects of water releases from oil sands operations. Reductions were found in invertebrate density and taxonomic richness below Suncor's Tar Island Dyke, below the outfalls from the refinery wastewater treatment system and the plant sewage treatment system (Noton 1979, Noton and Anderson 1982, Boerger 1983). Results of recent benthic surveys suggest that such effects are now absent below Tar Island Dyke and in the area immediately below all discharges from existing oil sands operations (Golder 1994b, 1996c). As well, differences found in 1997 between benthic communities upstream and downstream of the oil sands reach were not attributed to oil sands operations (Golder 1998h). However, because the studies carried out in the 1990s did not sample immediately below individual discharges, localized effects reported by Noton (1979), Noton and Anderson (1982), and Boerger (1983) cannot be ruled out, with the exception of those below Tar Island Dyke.

To minimize biological effects in surface waters, Suncor has implemented a series of activities to improve control of potential seepage from its site to the Athabasca River. Additionally, the wastewater treament system has been upgraded to improve control and water quality. The seepage control and quality improvements have included enhancement of collection systems at the base of Tar Island Dyke and the coke storage area, as well as reclamation of the sulphur storage area.

C4.1.3.2 Fish Habitat

Fish habitat in the Athabasca River near Project Millennium was mapped in 1996 and 1997 (Golder 1996c, 1998h). The most recent habitat maps of this reach of the river are presented in the Regional Aquatics Monitoring Program (RAMP) report (Golder 1998h).

The Athabasca River provides turbid cool-water habitat and dynamic shifting-sand channels (Golder 1996c). In the local study area (LSA), single channels are the major channel type, but near islands and sand bars, multiple channels are present (Golder 1998h). Major habitat features include backwaters and snyes associated with islands and sandbars. The substrate is almost entirely sand. Minimal instream cover is present except that provided by depth and turbidity. River banks are mainly armored or erosional with some depositional areas and cliffs.

Fish habitat in the Athabasca River is relatively poor due to the homogeneous habitat and shifting-sand bottom. Fish are usually associated with distinct habitat features such as backwaters, snyes and tributary mouths (Golder 1996c, 1998h). The Athabasca River is an important migration corridor for fish that move from overwintering and feeding areas to spawning areas in tributaries or rapids (e.g., lake whitefish, longnose sucker) (Golder 1996c).

C4.1.3.3 Fish Communities

Several fish surveys conducted on the Athabasca River provide information for the LSA. These include:

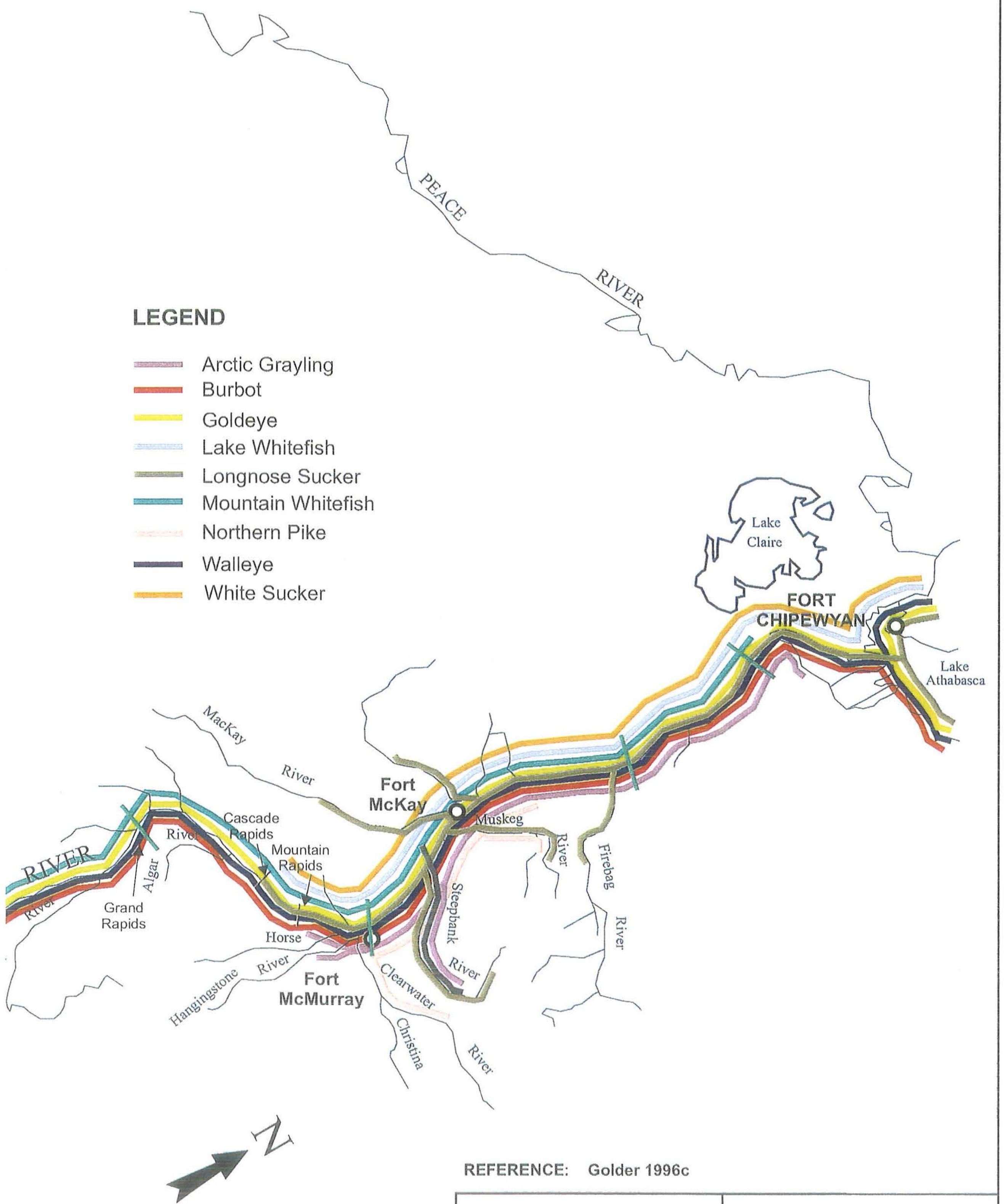
- the Regional Aquatics Monitoring Program (RAMP) of 1997 (Golder 1998h);
- aquatic baseline study for the Steepbank and Aurora Mines (Golder 1996c);
- inventories conducted by Syncrude in 1996 and from 1989 to 1991 (Golder 1996a, Syncrude unpublished data);
- the Northern River Basins Study (NRBS) fish inventories (R.L.&L. 1994); and
- the Alberta Oil Sands Environmental Research Program (AOSERP) (McCart et al. 1977, Bond 1980, Tripp and McCart 1979, Tripp and Tsui 1980).

Fish species occurrence and habitat use of the Athabasca River is presented in Table C4.1-1 and shown in Figure C4.1-1. Fish species scientific and common names are shown in Appendix II.

Table C4.1-1 Fish Species Use of the Athabasca River in the LSA

Species	1997 Ramp Study [b]	1996 Study [c]	Past Studies [d]	Spawning	Rearing	Feeding	Over-wintering	Migrating
[a] Arctic Grayling	●		●			✓	✓	✓
[a] Burbot	●	●	●	✓	✓	✓		✓
[a] Emerald Shiner	●	●	●	✓	✓	✓	✓?	✓
[a] Flathead Chub	●	●	●	✓	✓	✓	✓?	
[a] Goldeye	●	●	●	✓	✓	✓		✓
[a] Lake Chub	●	●	●	✓	✓	✓	✓	
[a] Lake Whitefish	●	●	●			✓	?	✓
[a] Longnose Sucker	●	●	●		✓	✓		✓
[a] Northern Pike	●	●	●	?		✓	✓	
[a] Spottail Shiner	●	●	●	✓	✓	✓	✓	
[a] Trout-Perch	●	●	●		✓	✓	✓	
[a] Walleye	●	●	●		✓	✓		✓
[a] White Sucker	●	●	●		✓	✓		✓
Brassy Minnow			●			✓		
Brook Stickleback		●	●			✓		
Bull Trout			●			✓		
Fathead Minnow			●			✓		
Finescale Dace			●			✓		
Iowa Darter			●			✓		
Longnose Dace			●			✓		
Mountain Whitefish	●	●	●			✓		✓
Ninespine Stickleback			●			✓		
Northern Redbelly Dace			●			✓		
Pearl Dace			●			✓		
River Shiner	●					✓		
Slimy Sculpin			●	✓	✓	✓	✓	
Spoonhead Sculpin			●			✓		
Yellow Perch	●	●	●			✓		

(a) Common, widespread species in the Athabasca River. Note that Arctic grayling are mainly found in the tributaries during the open-water season.
(b) Golder 1998h.
(c) Golder 1996c.
(d) Data from Bond 1980, McCart et al. 1977, Tripp and McCart 1979, Tripp and Tsui 1980, R.L.&L. 1994. Syncrude's unpublished fish inventories 1989-91 and Golder 1996a.
● Present in study area.
✓ Kind of habitat use.
? May use habitat but use not confirmed.



REFERENCE: Golder 1996c

SUNCOR ENERGY		
Fish Use of the Athabasca River		
12 March 1998	Figure C4.1-1	DRAWN BY: RPunzalan

Twenty-seven species of fish have been reported historically from the Athabasca River in the LSA (Bond 1980). In the 1997 RAMP fisheries inventories, a total of 16 species were captured in the vicinity of Project Millennium between McLean Creek and the Steepbank River (Table C4.1-1) (Golder 1998h).

The species composition was similar in 1996 (Golder 1996c). Species abundance and distribution patterns are similar to those reported by the AOSERP studies of the late 1970s (McCart et al. 1977, Bond 1980, Tripp and McCart 1979, Tripp and Tsui 1980) and the recent NRBS fish inventories (R.L.&L. 1994).

Fish species that use the Athabasca River near the LSA fall into two categories: migratory populations and resident fish species. Most of the large fish species are migratory. The resident populations are those which overwinter in the river or its tributaries (Table C4.1-1).

Recent and historical studies indicate that goldeye, walleye and lake whitefish are the most abundant sport fish species in the Athabasca River in the LSA (Bond 1980, Golder 1996c, 1998h). Other species include mountain whitefish, Arctic grayling, burbot, northern pike and yellow perch. White sucker and longnose sucker are the most abundant forage fish species near the LSA (Bond 1980, Golder 1996c, 1998h).

Sport Fish

Goldeye is a common migratory species in the Athabasca River. Historical studies report that immature goldeye migrate from Lake Athabasca to feed in the lower reaches of the Athabasca River in the spring (Bond 1980). Abundance data from 1995 indicate that goldeye enter the LSA in April and May and largely migrate out of the LSA by the end of October (Golder 1996c). In 1995 and 1997, a small proportion (<1%) of goldeye captured in the LSA were in spawning condition (Golder 1996a, 1996c). However, goldeye spawning areas have not been identified in the LSA.

Walleye are fall spawners that also migrate in the Athabasca River. Walleye were found in the Athabasca River during the spring, summer and fall of 1997 (Golder 1998h). Most of the adults captured in 1995 and 1997 were caught in the spring season and were ripe or spent males (Golder 1996c, 1998h). Similar results were obtained in previous studies with the percentage of ripe or spent males ranging from 63 to 97%, while no females were found in spawning condition (Tripp and McCart 1979, Golder 1996c). Walleye spawning locations have not been located with certainty but there is evidence that they spawn at the rapids upstream of Fort McMurray (Tripp and McCart 1979). A radiotelemetry study, currently underway as part of the RAMP program, may provide information on walleye spawning areas (Golder 1998h).

Lake whitefish are residents of Lake Athabasca where they overwinter and spend the summer feeding (Bond 1980). Most lake whitefish spawn in lakes, but some populations such as those from Lake Athabasca migrate upstream to spawn in the Athabasca River and some of its tributaries (McCart et al. 1977). Radiotelemetry data from the fall of 1997 indicate that lake whitefish spawn in the rapids upstream of Fort McMurray in the fall (Golder 1998h). The mouths of tributaries such as the Steepbank River are important feeding and resting areas during this migration (Golder 1998h).

Mountain whitefish also migrate within the Athabasca River system. Recent studies show they are found in low abundance in the Athabasca River with most fish captured near or at the mouth of large tributaries such as the Steepbank River (Golder 1996c, 1998h). Feeding migrations of mountain whitefish often occur in the tributaries, but spawning and overwintering locations are unknown (Bond 1980).

Arctic grayling migrate upstream in the Athabasca River in the spring and move into the tributaries to spawn (Tripp and McCart 1979, McCart et al. 1977, Golder 1996a). They remain there until late fall when most return to the Athabasca River to feed for the rest of the open-water season (Machniak and Bond 1979, Golder 1996c). A total of four Arctic grayling were captured in the Athabasca River in 1997 (Golder 1998h). These fish were found in the vicinity of Wood Creek and the Muskeg and McKay rivers.

Burbot spend part of the winter in Lake Athabasca but also migrate into the Athabasca River to spawn during late winter (January or February) (Bond 1980). Burbot spawning has been documented in the Athabasca River near the Suncor mine (Bond 1980). In the summer some burbot are thought to migrate back to Lake Athabasca to avoid warm-water temperatures; however, they are found in the mainstream Athabasca River in low abundance throughout the open-water season (Bond 1980, Golder 1996c, 1998h).

Northern pike do not move as far afield as other large fish species in the Athabasca River (Tripp and McCart 1979). They spawn in the tributaries and in a few areas of the Athabasca River that have flooded vegetation. Northern pike are thought to overwinter in the Athabasca River (Tripp and McCart 1979). Summer fish inventories in 1995 indicated that northern pike tend to be associated with the mouths of tributaries (Golder 1996c). Northern pike were also consistently present in the 1996 and 1997 fish surveys but in relatively low numbers (Golder 1996a, 1998h).

Yellow perch are uncommon in the Athabasca River but reside in some of the tributaries (Tripp and Tsui 1980). Very few yellow perch were captured in the LSA in 1997 (Golder 1998h).

Forage Fish

Longnose sucker migrate upstream in the Athabasca River in the spring and move into the tributaries to spawn (Tripp and McCart 1979, McCart et al. 1977, Golder 1998h). Shortly after spawning, they return to the Athabasca River, and remain there to feed for the rest of the open-water season (Golder 1996c, 1998h). In 1997, the majority (42%) of the longnose sucker adults captured in the Athabasca River were found downstream of the LSA, in the vicinity of the Muskeg River.

White sucker make wide use of the Athabasca River during their life cycle. This species spawns in the tributaries, including the Muskeg, Steepbank and McKay rivers (Tripp and McCart 1979). White sucker have not been documented to spawn in the Athabasca River in past studies (Tripp and McCart 1979, Golder 1996c). They return to the Athabasca River shortly after spawning, and are thought to overwinter in Lake Athabasca and in the lower part of the Athabasca River (Tripp and Tsui 1980).

The most common small fish species in the Athabasca River near the LSA are flathead chub, spottail shiner, lake chub, trout-perch, slimy sculpin and emerald shiner. Most of these species are found in the Athabasca River year-round, except for emerald shiner, which are thought to overwinter in Lake Athabasca and then migrate into the Athabasca River to spawn (Bond 1980).

Flathead chub is one of the most common small fish species in the Athabasca River (McCart et al. 1977, Golder 1998h). They are generally confined to the mainstem and rarely enter the tributaries. Spottail shiner also reside primarily in the mainstem Athabasca River. In contrast, lake chub are common in both the mainstem Athabasca River and in the tributaries. They likely spawn in the lower reaches of the tributaries and overwinter in both the tributaries and the Athabasca River. Trout-perch also spawn in the tributaries but feed and overwinter in the Athabasca River (McCart et al. 1977). Slimy sculpin are found in both the tributaries and the Athabasca River (Golder 1998h).

C4.1.4 Steepbank River

C4.1.4.1 Benthic Invertebrates

Benthic communities in the Steepbank River were most recently studied at three sites in 1995 (Golder 1996j). The results of this survey documented diverse communities with low to moderate densities of invertebrates, which is characteristic of the erosional habitats sampled. Benthic communities varied moderately among sites, most likely as a result of differences in habitat characteristics. There was a trend of decreasing abundance and taxonomic richness from upstream to downstream, as well as a gradual decline in the proportion of chironomid larvae. The relative proportions of different functional feeding groups were similar at all sites. Overall, the changes in benthic communities with distance downstream appeared to parallel the variation in current velocity and substratum composition.

Levels of metals and organic compounds in benthic invertebrates were examined in 1995. Concentrations of most metals analyzed were detectable in benthic invertebrate tissues. Concentrations of several organic compounds, particularly substituted phenanthrenes, anthracenes and dibenzothiophenes, were elevated relative to other areas sampled (i.e., Athabasca River, Muskeg River) (Golder 1996j). However, in absolute terms, the measured concentrations were relatively low. These results probably reflect differences in the amount of oil sands present in the substratum in the rivers sampled.

C4.1.4.2 Fish Habitat

The Steepbank River is one of the main tributaries of the Athabasca River in the oil sands area. Through most of its length it cuts sharply through oil-sands-rich hills resulting in the steep banks for which it is named. The 28.5 km of river within the LSA has an average channel width of 25 m (Golder 1996c). Detailed habitat maps of representative areas of the Steepbank River are found in Golder (1996c).

The fish habitat in the Steepbank River is of high quality, and consists mainly of gravel/cobble/boulder substrate with pool/riffle and run/riffle sequences. In the upper reach, riffles are the most common habitat type, followed by moderate quality runs. Pools are infrequent and occur on meander bends. Both stream gradient and the length of riffle areas decrease with distance downstream.

The middle reach of the river has defined meanders and the riffles have less boulder and more cobble/gravel substrate than the other reaches. The run/pool areas between the riffles are also slower in the middle reach with more fines and less instream cover from boulders than other reaches.

The lower reach of the Steepbank River consists of swift, armored riffles separated by run sections with the occasional pool occurring on meander bends. Riffles are less common than upstream. Moderate to low quality runs are the most common habitat type in this section of the river. Pools are moderate quality and fairly deep with good instream and overhead cover from boulders and fallen trees.

C4.1.4.3 Fish Communities

The Steepbank River supports an abundant and diverse fish fauna. Twenty-five species of fish have been recorded from the Steepbank River, of which ten (Arctic grayling, northern pike, longnose sucker, white sucker, lake chub, pearl dace, longnose dace, trout-perch, brook stickleback and slimy sculpin) are common and widespread (Sekerak and Walder 1980).

Fish species that use the Steepbank River fall into three main categories: migratory populations that rely on the Steepbank River for an important part of their life cycle (e.g., spawning), occasional migrants which use the Steepbank River for resting or feeding, and residents which live in the Steepbank River year-round.

In the spring, longnose sucker, white sucker and Arctic grayling move into the Steepbank River to spawn (Golder 1996c). As well, spring feeding migrations of mountain whitefish are common (Golder 1996c). In the spring of 1995, mountain whitefish was the most abundant species in the river, followed by Arctic grayling and longnose sucker (Golder 1996c). The largest numbers of all three species were found in the upper section of the Steepbank River LSA where riffle habitat is common and boulders provide excellent instream cover. Numbers of white sucker were also higher in the upper Steepbank River. In 1995, longnose sucker and Arctic grayling spawning sites were documented throughout the study area on the Steepbank River but they were more common in the upper study reach (Golder 1996c). White sucker spawning was not recorded.

Fisheries sampling in February, 1997 indicated that some of the pools in the Steepbank River were of sufficient depth and had oxygen concentrations high enough to provide overwintering habitat for adults of larger fish species (e.g., Arctic grayling, longnose sucker) (Golder 1997m). However, no fish were captured at these sites in 1997 and historical reports indicate that large numbers of fish vacate the Steepbank River in the fall (Machniak and Bond 1979, Golder 1997m). Juvenile white and longnose sucker and young-of-the-year Arctic grayling possibly overwinter in the Steepbank River (Machniak and Bond 1979, Golder 1997m).

Several other species occasionally use the lower portion of the Steepbank River. In 1995, goldeye, lake whitefish, longnose dace, northern pike and walleye were captured near the mouth of the river (Golder 1996c). Post-spawning feeding migrations of northern pike have also been reported in the lower reaches of the Steepbank River (Machniak and Bond 1979). Lake whitefish use the mouth of the river as a staging and resting area on their upstream spawning migration (Bond 1980, Golder 1996c).

Several small fish species (lake chub, pearl dace, longnose dace, slimy sculpin, trout-perch and brook stickleback) are thought to be year-round residents of the Steepbank River (Machniak and Bond 1979). In 1995, lake chub, longnose dace, and spoonhead sculpin were the most common small fish species captured during the open-water season (Golder 1996c).

Spoonhead sculpin was more common in 1995 than reported in previous studies (Golder 1996c).

C4.1.5 Shipyard Lake and Small Athabasca River Tributaries

C4.1.5.1 Shipyard Lake

Shipyard Lake is a shallow wetland located on the east side of the Athabasca River floodplain, south of the Steepbank River (Figure C1-2). It has one outlet, Shipyard Creek, connecting the wetland to the Athabasca River. Floating aquatic vegetation borders the open-water area in Shipyard Lake and emergent vegetation, primarily cattail, occurs along the perimeter of the wetland. Water depths in the wetland during the summer of 1996 ranged from 1.5 m to 2.3 m (Golder 1996p). Hydrological studies indicate that the Athabasca River floods Shipyard Lake for several days a year on a frequent basis (Golder 1996p).

Shipyard Lake is suitable habitat for sport fish species such as northern pike and yellow perch, both of which use aquatic vegetation for spawning and rearing (Scott and Crossman 1973). Overwintering habitat in Shipyard Lake, which was assessed in February 1997, is classified as relatively poor due to low dissolved oxygen levels (1.8 to 3.4 mg/L) and shallow water depths (about 0.6 m) (Golder 1997m). However, fish species which are relatively tolerant to low dissolved oxygen (e.g., fathead minnow, yellow perch and northern pike) could possibly overwinter in Shipyard Lake (Barton and Taylor 1996).

Northern pike that had recently spawned were captured in Shipyard Lake in spring 1996 (Golder 1996b). No fish were captured in this wetland in winter 1997 (Golder 1997m). It is not clear if northern pike captured in spring 1996 represented a resident population, or if these fish originated from the Athabasca River prior to 1996. In either case, it is likely that northern pike from the Athabasca River use Shipyard Lake for spawning when flow and passage conditions permit. Spawning habitat for this species is limited in the mainstem Athabasca River (R.L.&L. 1994) and northern pike would be expected to use any suitable waterbodies, tributaries or side channels in the Athabasca River floodplain when accessible. The presence of yellow perch in Shipyard Creek downstream of the lake suggests that this species may also use Shipyard Lake for spawning activity when conditions permit (Golder 1996b).

It is likely that Shipyard Lake also supports forage fish since brook stickleback were captured in Creek Two (one of the inlets to Shipyard Lake) (Golder 1998j).

Benthic invertebrate density and diversity were generally low in Shipyard Lake in fall 1996 (Golder 1996p). The resultant data are representative of open-water sites with soft sediments. Field observations and water quality profile data suggest that the bottom sediments were anoxic (e.g., dissolved oxygen level was very low) at the benthic sampling sites, which accounts for low density and diversity. Areas of the lake closer to shore, in the zone of aquatic vegetation, likely support a more diverse benthic invertebrate fauna.

C4.1.5.2 Shipyard Creek

Shipyard Creek drains from the northern end of Shipyard Lake and flows into the Athabasca River (Figure C1-2). The mouth of Shipyard Creek was examined in 1995 and 1996 for potential use by fish (Golder 1996b, 1996c). In 1995 the lower portion of the creek was dry (Golder 1996c). Therefore, during the spawning season of 1995, fish passage into this creek and Shipyard Lake was not possible. In May 1996, a discharge of 0.5 m^3/s was present in the lower portion of the creek. At this time the creek was passable to large fish from the Athabasca River for approximately 2 km, to a point where a large beaver dam extended across the channel. Later that season, water levels in Shipyard Creek were elevated above the beaver dam (Ken Manly, Klohn-Crippen, pers. comm.). Hence it is likely that fish use of Shipyard Creek varies with flow conditions. In 1996, the average monthly flow from July to October was 0.34 m^3/s (Klohn-Crippen 1996c).

Habitat in Shipyard Creek is composed entirely of low quality runs with sand/silt substrate (Golder 1996b). Some instream cover is available from wood debris and breached beaver dams.

Most fish captured in Shipyard Creek in May 1996 were forage fish species including spottail shiner, lake chub, trout-perch, brook stickleback and emerald shiner (Golder 1996b). The only sports fish captured were four yellow perch, which were collected about 350 m from the confluence with the Athabasca River.

C4.1.5.3 Unnamed Creek

Unnamed Creek is a small upland stream that enters Shipyard Lake from the northeast (Figure C1-2). Only the lower 1.5 to 2 km of the creek, where it runs down the escarpment, has a well defined channel. The remainder of the catchment consists of wetlands and ponded areas (Golder 1996b).

In 1996, the average monthly flow of Unnamed Creek from July to October was 0.04 m^3/s (Klohn-Crippen 1997). In May 1996, near the confluence with Shipyard Lake, the creek was 1.2 m wide and had a flow of 0.1 m^3/s (Golder 1996b). In this region the creek was comprised mainly of run habitats (about 70%) with some riffle areas (about 20%) and pools (about 10%) also present. The substrate in the lower portion of the stream was primarily silt.

On the escarpment where a defined channel exists, riffles are the dominant habitat type. The average stream gradient in the escarpment area is about 8 to 10% (Golder 1996b). The substrate consists of cobble and gravel substrate in riffles, and fines are present in the lower velocity run and pool areas.

Several beaver dams are present in the upper reaches of the creek (i.e., above the escarpment), causing ponding and potentially affecting fish passage. No fish were captured in Unnamed Creek during fish inventories in May 1996 (Golder 1996b). The depth and flow of Unnamed Creek is too low to provide significant habitat for sports fish species. Numerous obstructions such as instream debris and beaver dams would limit or preclude fish movements within the creek.

C4.1.5.4 Creek Two

Creek Two is a small stream that enters Shipyard Lake from the southeast (Figure C1-2). Its average monthly flow from July to October 1997 was 0.09 m^3/s (Klohn-Crippen 1997). In October 1997, at the confluence with Shipyard Lake, it had a defined channel which was about 2 m wide and 0.7 m deep (Golder 1998j). In this area it has a low stream gradient, stable stream banks and consists almost entirely of low quality runs (Golder 1998j). Pools comprise the remaining available habitat. The substrate consists of fines. Woody debris and inundated riparian vegetation provide instream and overhead cover and beaver dams are present throughout the creek.

In the upper reaches, on the escarpment, the stream gradient is steep (8 to 10%). Here the creek consists of faster flowing runs with gravel substrate and less instream cover. Above the escarpment, there is no defined creek channel.

In fall 1997, brook stickleback were the only fish captured in Creek Two. They were found in still water within 400 m of the creek mouth (Golder 1998j).

C4.1.5.5 Leggett Creek

Leggett Creek is a small tributary (about 5.6 m wide near the mouth) to the Athabasca River located south of Shipyard Lake (Figure C1-2). Leggett Creek was examined in 1995 and 1996 for potential use by fish from the Athabasca River. Similar to other small tributaries in the area, Leggett Creek showed very little flow in spring 1995 (Golder 1996c). In 1996, more flow was present in the mouth of the creek (discharge 0.28 m^3/s) (Golder 1996a). In 1996, the average flow from April to November has been estimated at 0.15 m^3/s (Klohn-Crippen 1996c).

Fish habitat varies in the lower, middle and upper reaches of Leggett Creek. In the lower reach, medium quality runs are the most common habitat type but pools and riffles are also present (Golder 1996b). The substrate is dominated by fines. The middle and upper portions of the creek (i.e., above the escarpment) are narrow, with stream discharges similar to the lower reach. In the middle segment, riffles are the dominant habitat type and low quality runs were also present.

Habitat is more diverse in the upper segment of Leggett Creek, where riffles, runs and pools are present (Golder 1996b). Substrate is composed of fines in the lower velocity areas and gravel and cobble in areas of faster flow. Instream debris and overhead cover are abundant throughout Leggett Creek. Log jams and beaver dams are common and may restrict passage of sport fish.

In 1995 and 1996, forage fish species such as spottail shiner, lake chub, emerald shiner and pearl dace were the only fish species captured in Leggett Creek (Golder 1996b, 1996c). These species were only found in the lower portions of the creek.

C4.1.5.6 Wood Creek

Wood Creek is a moderately sized tributary of the Athabasca River located south of Leggett Creek (Figure C1-2). The average flow in Wood Creek from April to November 1996 has been estimated at 0.17 m^3/s (Klohn-Crippen 1996c). Habitat in representative reaches of the creek was mapped in spring 1996 (Golder 1996b). At that time the creek was about 4.6 m wide and the discharge was 0.54 m^3/s. The lower and middle portions of the creek have a moderately high gradient and the creek consists primarily of riffles with some low quality run habitat. A portion of the riffle areas consists of boulder gardens, which provide good instream cover and velocity breaks. The substrate of Wood Creek is dominated by cobble and gravel with some bedrock intrusions. In low velocity areas the substrate is dominated by fines. Cover for fish is abundant from undercut banks, instream debris and overhanging vegetation.

The portion of Wood Creek above the escarpment has numerous beaver dams, ponds and wetland areas. Low quality runs and occasional riffles occur where a defined channel exists. The substrate is composed mainly of fines, with cobble present only in riffle areas.

As with Shipyard Creek, Creek Two and Leggett Creek, fish in Wood Creek were found to be present only in the lower reaches. In 1996, three immature mountain whitefish were captured in the lower segment of Wood Creek near its confluence with the Athabasca River, indicating that this portion of the creek is being used to a limited extent as a rearing area for this species (Golder 1996b). Forage fish species such as spoonhead sculpin, longnose sucker and brook stickleback were also captured near the mouth of Wood Creek. No fish were captured from the upper section of Wood Creek, as fish passage is likely precluded by physical barriers from beaver dams and debris piles.

C4.1.5.7 McLean Creek

McLean Creek is a small stream (3.0 m wide and 0.6 m deep near the mouth) located south of Wood Creek (Figure C1-2). In 1995, the mouth of McLean Creek had very little flow making fish passage into the creek unlikely (Golder 1996c). Flow was greater in 1997 with the average annual stream flow estimated at 0.12 m^3/s (Klohn-Crippen 1997).

Habitat surveys in 1997 indicated the lower reach of McLean Creek had a moderate-to-high stream gradient and fish habitat consisted of riffle-run-pool sequences and occasional backwaters (Golder 1998j). The substrate is dominated by small boulders, cobble and gravel, and fines in backwaters. The stream is also characterized by unstable and undercut banks. There is abundant instream debris and overhanging vegetation to provide cover for fish. Woody debris piles and chutes present in McLean Creek pose potential barriers to the upstream migration of fish.

The upper portion (above the escarpment) of McLean Creek has a low stream gradient and no defined channel. Fish habitat and substrate is similar to the lower reaches, except where flooded beaver ponds are present. The stream banks are generally stable, vegetated and not undercut. Woody debris and aquatic plants provide overhead and instream cover. Beaver dams, chutes and debris piles would possibly prevent fish movement.

In October 1997, three young-of-the-year Arctic grayling were captured in the lower section of McLean Creek, near the confluence of the Athabasca River (Golder 1998j). The presence of young-of-the-year Arctic grayling indicates lower McLean Creek may provide spawning habitat for this species in spring. No fish were captured in the upper section, indicating that this area is likely inaccessible to fish.

C4.1.6 Key Indicator Resource Descriptions and Habitat Requirements

Key Indicator Resources (KIRs) are fish species or guilds chosen as a means to focus the fisheries and fish habitat impact assessment. The rationale for their selection is explained in Section C4.2.3. KIR descriptions and habitat requirements are discussed below.

C4.1.6.1 Walleye

Walleye are piscivores and feed on a variety of fish species (Scott and Crossman 1973). Adult and juvenile walleye generally feed in turbid waters where forage fish are abundant. In rivers, walleye spawn on rocky shoals downstream of rapids and falls and along shallow shorelines. Lake populations spawn on cobble/boulder shoals. Spawning occurs in spring when water temperatures range from 5.6 to 11.1°C (Scott and Crossman 1973). Walleye fry remain close to the substrate for about 10 days after hatching. They enter the water column to feed on zooplankton until they reach 1.5 to 2.5 cm in length (about six weeks), at which point they begin feeding on fish. Overwintering habitat is similar to summer feeding habitat except that in winter, walleye will avoid strong currents (Scott and Crossman 1973).

Preferred water temperatures are 10 to 18°C in spring and fall and 20 to 24° C in summer (McMahon et al. 1984). Juvenile walleye have a temperature tolerance range of 15 to 34°C with 22 to 28°C providing optimal growth (Ford et al. 1995). Adult walleye have a temperature tolerance range of 0 to 34°C, with 20 to 24°C providing optimal conditions for growth (Ford et al. 1995). The preferred oxygen concentrations for juvenile and adult walleye is greater than 5 and 3 mg/L, respectively; concentrations below 3 mg/L are likely to result in physiological impairments and mortality (Ford et al. 1995).

C4.1.6.2 Lake Whitefish

In Alberta, lake whitefish are most abundant in the eastern portion of the province, in the drainages of the Hay, Slave, Peace, Athabasca, Beaver, North Saskatchewan, and upper Battle rivers. Their presence in southern drainages is the result of introductions. Lake whitefish are characteristically a lake-dwelling species, but in Alberta they do sometimes occur in rivers (Nelson and Paetz 1992).

Lake whitefish are fall-spawners, with spawning occurring in lakes, rivers and streams from October to December when water temperatures are 8°C or less. The longest spawning migrations usually occur when lake whitefish ascend rivers, while shorter migrations occur for lake spawning populations. Age of maturity varies depending on fishing pressure, but 4 to 9 years is typical. No nest is built and in rivers, the eggs are broadcast over cobble and gravel in shallow running water. In lakes, eggs are broadcast over sand, gravel, cobble and boulders in depths from 0.3 to 30.0 m. Spawning occurs at night. Eggs incubate over the winter for approximately 20 to 23 weeks, hatching in April or May. Eggs require water temperatures between 0.5 to 12°C for incubation; 4 to 6°C has been found to be the optimal water temperature (Scott and Crossman 1973, Ford et al. 1995).

After hatching, the young move downstream from spawning areas to river margins. Larval lake whitefish begin feeding on small zooplankton species 1 to 3 days after hatching. They may also remain in adjacent, backwater areas where they stay for several weeks feeding on planktonic (e.g., cladocerans) and then benthic (e.g., dipteran larvae) organisms (Ford et al. 1995). Towards late summer the young move from the warmer epilimnetic waters to the cooler metalimnetic waters, where their diet begins to resemble adult lake whitefish. The upper lethal temperature for young lake whitefish is estimated at 26.6°C with the preferred temperature ranging from 12 to 16°C (Taylor and Barton 1992, Ford et al. 1995).

During the summer months lake whitefish descend into deeper, cooler waters, while in the fall and winter they are found in shallower waters. The preferred temperature range of adult lake whitefish is estimated to be between 8 to 14°C, while the preferred oxygen concentrations are greater than 7.0 mg/L. The acute temperature for adults is estimated at greater than 23°C while the minimum short term exposure for oxygen is estimated at 4.25 mg/L (Taylor and Barton 1992, Ford et al. 1995).

Adults are almost entirely benthic feeders and consume aquatic insect larvae (e.g., chironomids and caddisflies), clams, snails and amphipods. Zooplankton, fish and fish eggs are occasionally consumed by adults, in lesser amounts (Nelson and Paetz 1992, Ford et al. 1995). The major predators of lake whitefish are lake trout, northern pike, walleye, burbot, and even lake whitefish which will consume their own eggs (Scott and Crossman 1973). Yellow perch and ciscoes will also feed on larval lake whitefish. Lake whitefish on average have a maximum observed age of 16 years.

C4.1.6.3 Goldeye

Goldeye are surface feeding fish that occupy warm turbid lakes and rivers. They are opportunistic and survive on a wide variety of food types including invertebrates (terrestrial and aquatic), fish, mammals and fish eggs (Scott and Crossman 1973). Spawning occurs during May and June in firm bottomed pools and backwaters of turbid rivers when water temperatures range from 10 to 13°C. Since goldeye spawn in turbid water, spawning activity is difficult to observe (Scott and Crossman 1973). In contrast to other freshwater fishes in North America, goldeye eggs are semi-buoyant. Young fry float near the surface and drift downstream. Goldeye overwinter in deep areas of rivers and lakes.

C4.1.6.4 Longnose Sucker

Longnose sucker are the most widespread sucker in northern Canada and are found in large numbers in most waterbodies with clear and cool waters (Lee et al. 1980). Longnose sucker spawning normally occurs in tributary streams rather than in lakes or in large rivers (Brown and Graham 1953).

Longnose sucker require riffle habitats for spawning, where water velocities range from 0.3 to 1.0 m/s and clean gravel or cobble (1 to 20 cm in diameter) is present. Peak spawning occurs in June when water temperatures range from 10 to 15°C (Edwards 1983).

The fry of longnose sucker drift downstream following emergence. Fry seek shelter from predation and swift flows in shallow areas of reduced velocity and vegetation. Fry have been reported to congregate near the water surface (within 150 mm of surface) and within 2 m of the shore or river bank (Hayes 1956). As young-of-the-year longnose sucker become larger (juveniles), they frequent shallow weedy areas and will seek out areas with some current velocity (Johnson 1971).

Longnose sucker feed on zooplankton and diatoms as fry, and shift to larger organisms such as benthic macroinvertebrates as they become larger (Edwards 1983). Adult longnose suckers in general feed on a wide range of food items based on availability; dominant items in the diet include amphipods, cladocerans, aquatic insect larvae and other invertebrates. The preferred temperature range of adult longnose suckers is 10 to 15°C with the upper lethal limit estimated at 27°C (Edwards 1983). No specific information exists for dissolved oxygen criteria but concentrations above 5 mg/L is assumed to be adequate (Edwards 1983).

In areas with prolonged and extensive ice cover, overwintering habitats are critical to longnose suckers. The principle requirements for longnose sucker winter habitat are an adequate oxygen supply and sufficient water depth to allow for ice cover and refugia from high water velocities (Edwards 1983).

C4.1.6.5 Arctic Grayling

Arctic grayling inhabit cold water streams, rivers and lakes that support aquatic vegetation (Hubert et al. 1985). They are found almost exclusively in pools but can tolerate a current of 0.26 m/s (Kreuger 1981). Arctic grayling overwinter in large streams and rivers or in deep holes (>1.0 m) in smaller streams (Nelson and Wojcik 1953). Spring-fed reaches that do not completely freeze in winter also provide suitable overwintering habitat (Kreuger 1981).

Arctic grayling are spring spawners and may migrate long distances to reach tributary spawning streams. Once spawning is completed, adult Arctic grayling may move upstream or downstream, or migrate to larger streams for summer feeding (Tack 1971). By late summer or fall, the adults have moved downstream to wintering areas (Kratt and Smith 1977).

Spawning usually occurs over gravel substrate in the transition area between a riffle and a pool (Bishop 1971). Spawning typically occurs in May to early June when water temperatures may range from 4 to 10°C (Scott and

Crossman 1973; Northcote 1995). Current velocities at spawning sites range from 0.34 to 1.46 m/s (Kreuger 1981). Arctic grayling do not typically spawn over silt or clay, as this substrate type does not provide optimal conditions for egg survival (Bishop 1971). Many eggs commonly drift downstream soon after spawning occurs (Warner 1955).

Newly hatched fry spend a few days buried under 2 to 3 cm of gravel, protected from water currents and wave action (Kratt and Smith 1977). After fry emerge from the gravel they remain in quiet backwaters and sheltered areas of the spawning stream throughout the summer (Craig and Poulin 1975). In contrast, juveniles will use pool and slough habitat in the spawning stream most or all of the growing season, and may feed in riffles (Kreuger 1981). Fry depend on interstitial spaces and shadows of boulders for cover from predators (Kreuger 1981). Juveniles will commonly use overhanging vegetation, logs, boulders and turbulence for instream cover (Kreuger 1981).

Juvenile Arctic grayling have a temperature tolerance of 2 to 24.5°C and an optimal temperature for growth of 10 to 12°C. Adult Arctic grayling have a temperature tolerance of 1 to 20°C and an optimal temperature for growth of 10°C. Juvenile and adult Arctic grayling have lower lethal oxygen concentrations of 1.4 and 2.0 mg/L, respectively (Ford et al. 1995).

C4.1.6.6 Mountain Whitefish

Mountain whitefish are common in medium and large clear, cold rivers (Nelson and Paetz 1992). In Alberta, they are found in the Peace, Athabasca, North Saskatchewan, Red Deer, Bow, Oldman, and the North Fork of the Milk River drainages (Nelson and Paetz 1992). Mountain whitefish reside in both lakes and rivers.

Mountain whitefish are generally autumn spawners (Brown 1952), although spawning has been noted as late as January or mid-February (Hildebrand and English 1991). Spawning has been reported at temperatures as high as 9°C and as low as near 0°C, but usually in the 3°C to 5°C range (Hildebrand and English 1991).

Mountain whitefish use a wide range of habitats for spawning. Mainstem river resident populations commonly move upstream into small tributaries to spawn (Bruce and Starr 1985). But they may also move from the upper reaches to middle and lower reaches of the same river (Davies and Thompson 1976). Mountain whitefish are broadcast spawners (i.e., their eggs are dispersed). Stream populations spawn over rubble and gravel riffle areas (Stuart and Chislett 1979) with a wide range in particle size from coarse rubble to fine gravel (Brown 1952). Stream and river spawning occur in shallow depths (13 to 122 cm), within areas of fast or slow current (Brown 1952).

Mountain whitefish eggs hatch early in spring, usually about the time of ice breakup on rivers (Roberts 1988). Mountain whitefish prefer protected backwaters, pools and side channels as rearing habitat. Juveniles largely use mainstem riffles and runs for rearing but are sometimes found in pools (Stuart and Chislett 1979). Adults are found in pools, mainstem runs and riffles. Mountain whitefish overwinter in deep pools (Stuart and Chislett 1979).

Very little is known about large scale migratory patterns of mountain whitefish but individuals can exhibit a wide variation in movement within the same river, such as migrations to different areas for spring feeding, summer feeding, prespawning, spawning, postspawning and overwintering (Thompson and Davies 1976).

Mountain whitefish are primarily bottom feeders consuming a variety of organisms. Thompson and Davies (1976) found that aquatic insect larvae were the primary item in their diet.

C4.1.6.7 Northern Pike

Northern pike in Alberta are widely distributed and occur almost everywhere except for higher elevation and steeper gradient watercourses in the Rocky Mountains and foothills (Nelson and Paetz 1992). Typical northern pike habitat is characterized by vegetated, nutrient-rich shallow waters. Northern pike are not adapted to survive in strong currents, therefore they predominantly occur in lakes or in slow-moving rivers and streams, where they inhabit backwaters and pools (Inskip 1982).

Northern pike are spring spawners, spawning immediately after ice melt in April to early May when water temperatures range from 4 to 11°C (Scott and Crossman 1973). They may migrate long distances to reach appropriate spawning areas (Inskip 1982). Both lake and river populations of northern pike tend to migrate up tributaries to find favourable spawning habitat such as wetlands, shallow pools, and the vegetated floodplains of rivers, marshes and bays of lakes (Scott and Crossman 1973, Casselman and Lewis 1996). No nest is built and the semi-adhesive eggs are broadcast over submerged vegetation (Inskip 1982, Casselman and Lewis 1996). The vegetation must provide abundant surface area for eggs and newly hatched fry to attach and allow the circulation of water for oxygenation (Inskip 1982).

Northern pike typically spawn in calm waters less than 0.5 m deep, that contain moderately dense mats of short vegetation (e.g. grasses and sedges). They avoid spawning in channelized reaches and prefer spawning in pools with low velocities and fine substrate. Absence of instream cover and flows greater than 1.5 m/s may inhibit spawning (Inskip 1982). Dissolved oxygen concentrations which fall below 3.2 mg/L usually result in greatly reduced survival of northern pike eggs and larvae (Barton and Taylor 1996). High water levels at spawning time with stable levels after the incubation period are associated with large year-classes of northern pike. Thus, it is critical that water levels are maintained throughout the egg and fry life stages (Hassler 1970). Water temperature decreases and/or silt deposition have been found to cause significant mortality of incubating eggs (Hassler 1970).

Eggs hatch approximately two weeks after spawning, and the emerging post-hatch larvae attach themselves to aquatic vegetation for 6 to 10 days as they absorb their yolk reserves. After they detach, the fry remain in the vicinity of the spawning grounds for 2 to 3 weeks, feeding on zooplankton and aquatic invertebrates (Ford et al. 1995). The young aggressively defend a territory in shallow areas, seeking cover amongst vegetation as they are photo-sensitive. At 20 mm in length they become free ranging and move to other parts of the lake or river.

Casselman and Lewis (1996) estimated young northern pike require more than 10 times the area of nursery habitat compared to spawning habitat, and optimally this habitat will contain 40 to 80% coverage by submergent and emergent aquatic plants. Young northern pike grow rapidly, and shift to piscivory at a length of 50 to 60 mm. As they grow older, an ambush style of feeding is adopted; therefore, the presence of submerged cover (e.g., aquatic vegetation or logs) is important (Ford et al. 1995; Casselman and Lewis 1996). The optimal temperature for northern pike young-of-the-year is 25.6°C (Casselman and Lewis 1996).

Juvenile and adult northern pike prefer shallow, littoral areas (< 4 m deep) with moderate densities of vegetation (> 30% coverage), and usually stay within 100 m of the shore (Inskip 1982, Casselman and Lewis 1996). They are known to move short distances in summer or winter, and rarely make long migrations (Ford et al. 1995). However, shallow, heavily vegetated lakes that were favorable for most of the year frequently develop low dissolved oxygen concentrations during winter. Northern pike counter the effects of lowered oxygen concentrations by seeking areas of increased oxygen concentrations higher up in the water column, decreasing their activity levels, and reducing or ceasing to feed. Northern pike generally avoid oxygen concentrations of less than 3 to 4 mg/L, with the lower incipient lethal oxygen concentration estimated at 0.5 to 1.5 mg/L. Smaller northern pike are more tolerant of oxygen depression than larger individuals. The optimal temperature for adult northern pike is 19°C, while the lethal water temperature is 30°C for subadults (Casselman and Lewis 1996).

Adult northern pike are a strictly predatory and opportunistic feeder, primarily feeding on fish, but crayfish, waterfowl and even small mammals may contribute to the diet (Scott and Crossman 1973, Ford et al. 1995).

C4.1.6.8 Forage Fish Species

Brook stickleback, pearl dace and lake chub comprise the forage fish guild. These species have generally similar habitat requirements and life histories. Lake chub and pearl dace are closely related and are known to hybridize with each other (Scott and Crossman 1973, Nelson and Paetz 1992).

These forage fish species are typically found in a wide range of habitats including streams, rivers, ponds and lakes. Brook stickleback, pearl dace and lake chub are usually found in still waters associated with aquatic vegetation (Scott and Crossman 1973, Nelson and Paetz 1992).

These species spawn from April to August when water temperatures range from 8 to 18°C (Scott and Crossman 1973, Nelson and Paetz 1992). Maturity occurs as early as one year for brook stickleback to as late as 3 to 4 years for lake chub. Brook stickleback are unique in that a small nest of detritus and fibres is constructed on aquatic vegetation into which eggs are deposited. Pearl dace deposit their eggs in shallow water over sand and gravel in weak to moderate current, and lake chub spawn among rocks and over silt and detritus (Brown et al. 1970). Eggs generally hatch in 5 to 9 days (Scott and Crossman 1973, Nelson and Paetz 1992).

The diet of these forage species is typical of other forage fish and consists of aquatic insects (e.g., chironomids), crustaceans (e.g., cladocerans) and algae. Larger lake chub will consume small fish, while brook stickleback will eat fish eggs and larval fish (Scott and Crossman 1973, Nelson and Paetz 1992). These species are short-lived, ranging from three years (brook stickleback) to five years (lake chub). Maximum sizes range from 87 mm (brook stickleback) to 200 mm (lake chub) (Scott and Crossman 1973, Nelson and Paetz 1992). Dissolved oxygen requirements for these forage species are less critical than for salmonid species. They are tolerant to low dissolved oxygen concentrations, with acutely lethal concentrations of dissolved oxygen ranging from less than 1 to 2 mg/L (Barton and Taylor 1996).

C4.2 FISHERIES AND FISH HABITAT PROJECT IMPACT ASSESSMENT

C4.2.1 Introduction

The overall approach to impact analysis and classification is presented in Section A2. The fish and fish habitat impact analysis is based on issues identified by Project stakeholders and the study team. These issues can be combined into the following broad categories:

- effects on fish habitat;
- effects on aquatic biota; and
- effects on fish tissue quality.

This section includes:

- presentation of potential linkages between Project activities and fisheries and fish habitat;
- a list of key questions regarding potential impacts on fisheries and fish habitat;
- rationale for key indicator resource (KIR) selection;
- fisheries and fish habitat impact analysis methods; and
- analysis of key questions:
    - analysis of potential linkages,
    - analysis of key question,
    - residual impact classification and environmental consequence,
    - uncertainty and follow-up studies, and
    - monitoring.

C4.2.2 Potential Linkages and Key Questions

Potential linkages between Project activities and fish and fish habitat are illustrated in Figures C4.2-1 and C4.2-2. Key questions and the main issues associated with them are described below.

Figure C4.2-1 Construction and Operations Linkages for Fisheries and Fish Habitat

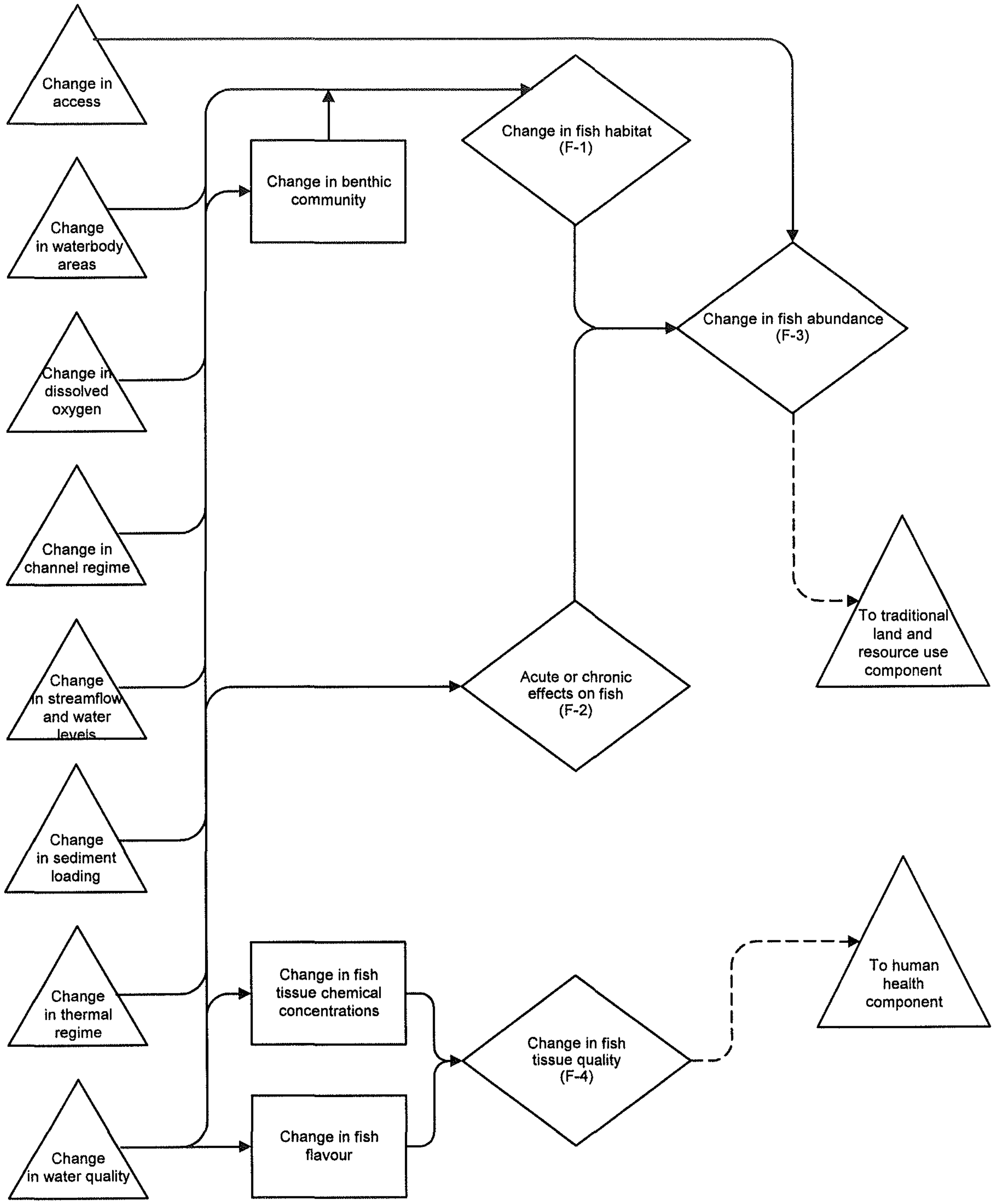
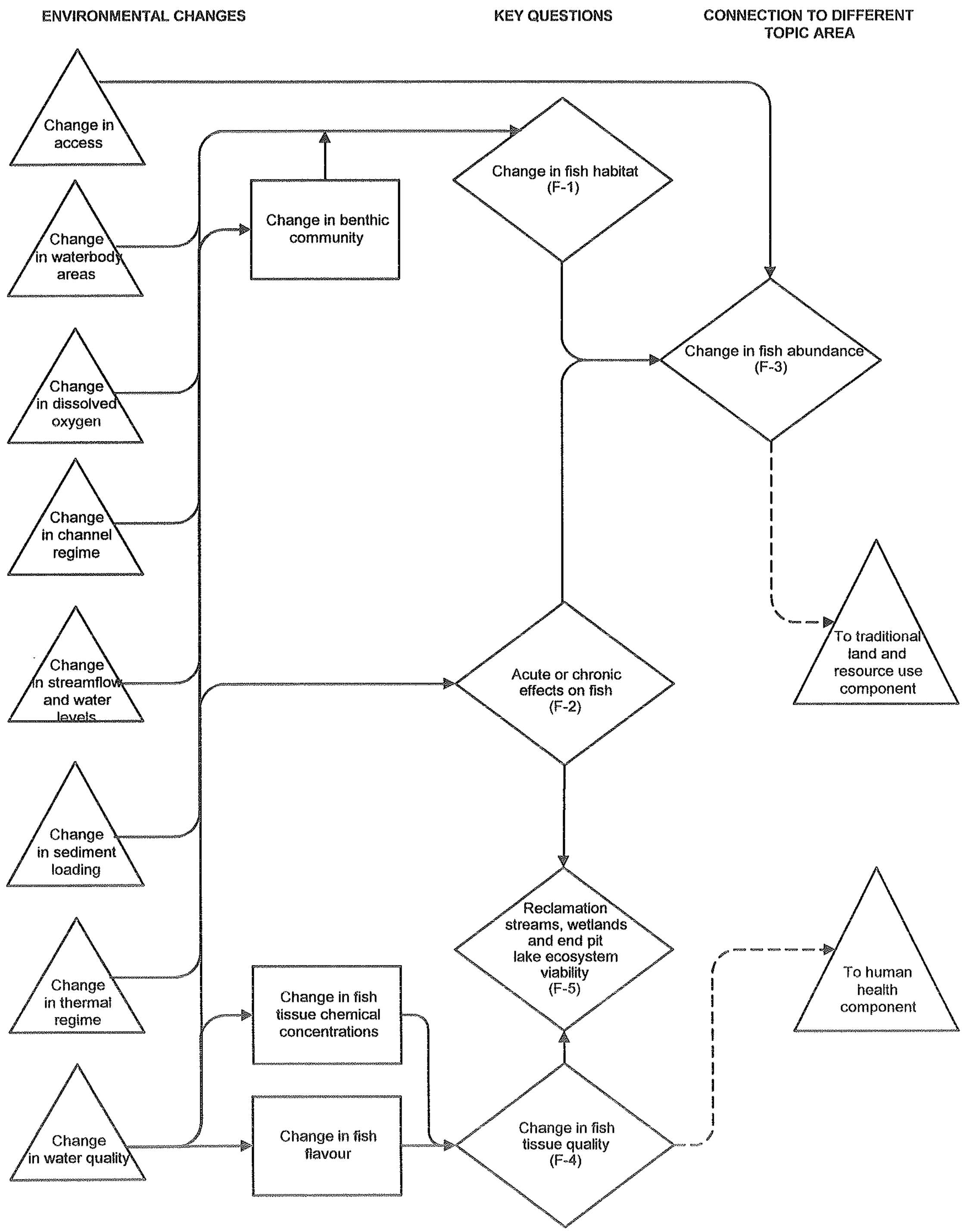


Figure C4.2-2 Closure Linkages for Fisheries and Fish Habitat



F-1: What impact will development and closure of Project Millennium have on fish habitat?

Stakeholder concerns were addressed as part of this key question and include:

- direct loss of habitats (change in waterbody areas);
- increases in suspended solids;
- changes in dissolved oxygen levels;
- changes in flows and water levels in watercourses;
- increased bank erosion and channel instability (channel regime);
- changes in the thermal regime; and
- changes in benthic invertebrate communities.

F-2: What impact will development and closure of Project Millennium have on levels of acute or chronic toxicity to fish?

The potential for water releases from the Project (particularly consolidated tailings (CT) and tailings sand seepage water) to cause acute or chronic effects on fish was assessed.

F-3: What impact will development and closure of Project Millennium have on fish abundance?

Fish abundance can be affected by changes in habitat, acute or chronic effects on fish and changes in harvest. Each of these linkages are assessed within this key question.

F-4: What changes to fish tissue quality will result from development and closure of Project Millennium?

The potential was assessed for tainting (flavour impairment) of fish flesh and bioaccumulation of chemicals in fish tissue as result of exposure to CT and tailings sand seepage water. Both tainting and bioaccumulation have been raised as concerns by Alberta Environmental Protection (AEP), Department of Fisheries and Oceans (DFO) and aboriginal people from the region.

F-5: What type of aquatic ecosystems are expected in Project Millennium reclamation streams, wetlands and the end pit lake?

The potential for the reclamation streams, wetlands and end pit lake to support viable ecosystems has been raised as an issue by regulators. Issues related to the reclamation drainage system include viability of an aquatic ecosystem, potential for establishment of a fishery and fish tissue quality.

C4.2.3 Key Indicator Resources

Key Indicator Resources (KIRs) were selected to assess impacts on fish and fish habitat. For this component of the analysis, KIRs are fish species or guilds and their respective habitats. Fish species selected as KIRs act as "sentinels" for the aquatic ecosystem. Therefore, KIRs should be chosen to provide adequate information within a relatively short time frame about responses to environmental changes expected as a result of Project Millennium.

KIRs for this assessment differ by waterbody to reflect differences in species composition and habitat availability. Waterbodies in the Local Study Area (LSA) are shown in Figure C1-2. Life history and habitat requirements for each of the KIRs are described in Section C4.1.6.

KIRs were selected according to the matrix that was developed and used for the Steepbank and Aurora EIAs (Golder 1996j, BOVAR 1996e). The system involves ranking each potential species for each waterbody according to the criteria shown in Table C4.2-1. The criteria were adapted from those designed for environmental effects monitoring investigations (Environment Canada and Department of Fisheries and Oceans 1993) and from a receptor screening process suggested for ecological risk assessments (Suter 1993). At the request of stakeholders consulted during the Steepbank Mine environmental assessment process, a weighting factor of two was applied to criteria considered to be of primary importance (e.g., residence/abundance, recreational importance).

The results of the candidate species rating for the Athabasca River are shown in Table C4.2-2. The species with the highest scores in the Athabasca River were selected as KIRs. Goldeye and northern pike had the same rating. However, goldeye were chosen over northern pike since northern pike are far less abundant than goldeye in the mainstem Athabasca River (Golder 1996c, 1998h). The Athabasca River KIRs are:

- walleye;
- lake whitefish;
- longnose sucker; and
- goldeye.

Table C4.2-1 Scoring Criteria for Fish KIRs

1. residence and relative abundance: (determined from catch-per-unit effort data from watercourse) 1 = uncommon 2 = moderately abundant 3 = common
2. provincial importance: (or status, measure of the relative abundance and degree of management concern or aesthetic value) 0 = species abundant, no concern (green-listed) 1 = species rare, but not threatened or special status (yellow-listed) 2 = threatened or vulnerable species (blue-listed) 3 = endangered species (or red-listed)
3. commercial economic importance: (importance to guides, outfitters, fisheries) 0 = no importance 1 = low importance 2 = moderate importance 3 = high importance
4. subsistence economic importance: (fish species important for subsistence) 0 = not fished for food 1 = low 2 = moderate 3 = high
5. recreational importance: (fish species important for recreational fishing) 0 = non-game species 1 = low 2 = moderate 3 = high
6. habitat niche/sediment exposure: (benthic habitat niche) 0 = no 1 = yes
7. spawning in watercourse: 0 = no 1 = yes
8. benthic food preference: 0 = no 1 = yes
9. important as prey: 0 = no 1 = yes
10. fecundity: (number of eggs produced) 1 = low fecundity 2 = moderate fecundity 3 = high fecundity
11. growth rate: 1 = slow growth rate 2 = fast growth rate
12. age to maturity: 1 = long age to maturity 2 = moderate age to maturity 3 = short age to maturity
13. feasibility of studying: 0 = none 1 = low 2 = medium 3 = high
14. availability of information: (the amount of information available for each species or species group) 0 = none 1 = limited 2 = moderate 3 = abundant

Table C4.2-2 Weighted Potential Athabasca River KIRs for Project Millennium

Species	Residence/ Abundance [a]	Provincial Importance	Present Commercial Importance	Subsistence Importance [b]	Recreational Importance in LSA	Sediment Exposure	Spawning in Mainstem Athabasca River (LSA) [c]	Benthic Food Preference	Important as Prey	Fecundity [d]	Growth Rate [d]	Age to Maturity [d]	Feasibility to Study	Information Availability	Total [e]
Weighting Factor	2	2	2	2	2	1	1	1	1	1	1	1	2	2	
goldeye	6	0	0	2	0	no	unknown	yes	yes	2	1	2	4	4	23
longnose sucker	4	0	0	2	0	yes	no	yes	yes	2	1	2	6	4	24
northern pike	2	0	0	4	4	no	no	no	no	2	2	3	2	4	23
walleye	6	0	4	4	6	no	unknown	no	no	3	1	2	4	4	34
lake whitefish	4	0	6	6	0	no	unknown	yes	yes	2	1	2	4	4	31
yellow perch	2	0	0	0	0	no	no	yes	yes	3	1	3	0	4	15
white sucker	2	0	0	2	0	yes	no	yes	yes	2	1	3	4	4	21
flathead chub	4	0	0	0	0	no	yes	yes	yes	unknown	2	3	2	2	16
emerald shiner	2	0	0	0	0	no	yes	yes	yes	unknown	2	3	2	2	14
trout-perch	4	0	0	0	0	no	yes	yes	yes	unknown	2	3	2	2	16
lake chub	2	0	0	0	0	no	yes	yes	yes	1	2	3	2	2	15
mountain whitefish	2	0	0	0	2	no	no	yes	yes	2	1	2	0	4	15
burbot	2	0	0	2	0	yes	yes	no	no	3	1	2	0	2	14
Arctic grayling	2	2	0	0	2	no	no	yes	no	2	1	2	0	4	16
bull trout [f]	2	4	0	0	0	no	no	no	no	2	1	2	0	2	13

[a] Determined from catch-per-unit effort (Golder 1996c, 1998h).
[b] Fort Mckay (1994).
[c] Willow Island to Saline Lake (Figure C-2).
[d] Scott and Crossman (1973), Nelson and Paetz (1992).
[e] Scores are multiplied by the weighting factor to arrive at weighted potentials.
no = 0; yes = 1; unknown = 0.
See Table C4.2-1 for scoring criteria.
[f] Bull trout have not been captured or observed in recent studies (Golder 1996c, 1998h).

The species chosen for the Athabasca River are consistent with the KIRs used for the recent Shell Canada's Muskeg River Mine project. As well, they are consistent with the Aurora and Steepbank Mine EIAs with the exception of lake whitefish. This species was included for Project Millennium because it scored high on the KIR matrix and because of input from regional communities and regulators. The Fort Chipewyan community has expressed concern about the potential for Project impacts on lake whitefish. As well, regulators at a Water Workshop for the Shell Muskeg River Mine Project held on October 7, 1997 indicated that lake whitefish should be considered a KIR for oil sands EIAs due to their socio-economic importance regionally and their seasonal abundance in the Regional Study Area (RSA) (Golder 1997u).

Steepbank River KIR ratings are shown in Table C4.2-3. The species with the highest scores (and thus the highest suitability as KIRs) for the Steepbank River are:

- Arctic grayling; and
- longnose sucker

Potential KIRs were also rated for Shipyard Lake and small creeks in the LSA (Table C4.2-4). In most cases, only a few species use these habitats. The KIRs for Shipyard Lake are northern pike and the forage fish guild. Shipyard Lake provides spawning habitat for northern pike, which is relatively uncommon in the lower Athabasca River. Forage fish are included as a KIR because they are a potential food source for northern pike.

The forage fish guild consists of small fish species that have generally similar life histories and habitat preferences. These species are year-round residents of the Steepbank River and also reside in the small creeks in the LSA (Golder 1996c, Sekerak and Walder 1980). The forage fish guild includes lake chub, brook stickleback and pearl dace.

The forage fish guild is the KIR for Leggett Creek and Creek Two since these are the only species that have been documented in this creek. The forage guild is also the KIR for Shipyard Creek since it scored highest on the KIR matrix and these species are likely year round residents of the creek.

Wood Creek KIRs are the forage fish guild and mountain whitefish. Forage fish guild are present in low abundance and they are likely to be permanent residents of the stream. Mountain whitefish was selected as a KIR since it is a sport fish species and was identified by DFO and AEP as important to examine in this stream. Wood Creek has been documented to support rearing (juvenile) mountain whitefish, but no other life stages of this

Table C4.2-3 Weighted Potential Steepbank River KIRs for Project Millennium

Species	Residence/ Abundance [a]	Provincial Importance	Recreational Importance in LSA	Subsistence Importance [b]	Sediment Exposure	Spawning in Mainstem Steepbank River [c]	Benthic Food Preference	Important as Prey	Fecundity [d]	Growth Rate [d]	Age to Maturity [d]	Feasibility to Study	Information Availability	Total [e]
Weighting Factor	2	2	2	2	1	1	1	1	1	1	1	2	2	
goldeye	2	0	0	0	no	no	yes	yes	2	1	2	0	4	13
longnose sucker	6	0	0	0	yes	yes	yes	yes	2	1	2	6	4	25
northern pike	2	0	0	2	no	no	no	no	2	2	3	0	4	15
walleye	2	0	0	2	no	no	no	no	2	1	2	0	4	13
lake whitefish	2	0	0	0	no	no	yes	yes	2	1	2	0	4	13
white sucker	2	0	0	0	yes	yes	yes	yes	1	1	3	4	4	19
trout-perch	2	0	0	0	no	yes	yes	yes	1	2	3	2	2	15
forage fish guild [f]	4	0	0	0	no	yes	yes	yes	1	2	3	2	2	17
mountain whitefish	6	0	2	0	no	unknown	yes	yes	2	1	2	4	4	23
burbot	2	0	0	0	yes	no	no	no	3	1	2	0	2	11
Arctic grayling	6	2	2	2	no	yes	yes	no	2	1	2	4	4	27
bull trout[g]	2	4	0	0	no	unknown	no	no	2	1	2	0	2	13

[a] Determined from catch-per-unit effort data (Golder 1996c).
[b] Fort McKay (1994).
[c] Study area is 25 km long, from upper reaches to confluence with Athabasca River.
[d] Scott and Crossman (1973), Nelson and Paetz (1992).
[e] Scores are multiplied by the weighting factor to arrive at weighted potentials.
no = 0; yes = 1; unknown = 0.
See Table C4.2-1 for scoring criteria.
[f] Includes brook stickleback, pearl dace, lake chub.
[g] Bull trout have not been captured or observed in recent studies (Golder 1996c, 1998h).

Table C4.2-4 Weighted Potential KIRs for Shipyard Lake and Small Creeks in the Project Millennium Local Study Area

Species	Residence/ Abundance [a]	Sediment Exposure	Recreational importance in LSA	Spawning in Study Area	Benthic Food Preference	Important as Prey	Fecundity [b]	Growth Rate [b]	Age to Maturity [b]	Feasibility to Study	Information Availability	Total [c]
Weighting Factor	2	1	2	1	1	1	1	1	1	2	2	
Shipyard Lake												
northern pike	2	no	0	yes	no	no	2	1	3	2	4	15
forage guild [d]	2	no	0	unknown	yes	yes	1	2	3	2	4	16
Shipyard Creek												
yellow perch	2	no	0	no	yes	yes	1	2	2	2	2	13
spottail shiner	2	no	0	no	yes	yes	1	2	3	2	4	16
emerald shiner	2	no	0	no	yes	yes	1	2	3	2	4	16
trout-perch	2	no	0	unknown	yes	yes	1	2	3	2	2	14
forage guild [d]	2	no	0	yes	yes	yes	1	2	3	2	4	17
Creek Two												
forage guild [d]	2	no	0	yes	yes	yes	1	2	3	2	4	17
Leggett Creek												
forage guild [d]	2	no	0	yes	yes	yes	1	2	3	2	4	17
Wood Creek												
spoonhead sculpin	2	yes	0	unknown	yes	yes	1	2	2	0	2	12
longnose sucker	2	yes	0	no	yes	yes	2	1	2	0	4	14
forage guild [d]	2	no	0	yes	yes	yes	1	2	3	2	4	17
mountain whitefish	2	no	2	unknown	yes	yes	2	1	2	2	4	17
McLean Creek												
Arctic grayling	2	no	2	unknown	yes	no	2	1	2	2	4	16

(a) Determined from catch-per-unit effort (Golder 1996b, 1998j).
(b) Scott and Crossman (1973), Nelson and Paetz (1992).
(c) Scores are multiplied by the weighting factor to arrive at weighted potentials.
no = 0; yes = 1; unknown = 0.
See Table C4.2-1 for scoring criteria.
(d) Includes brook stickleback, pearl dace, lake chub.

species. Juvenile mountain whitefish were captured in Wood Creek in fall 1997; however, the same survey reported no evidence of spawning by this species which is a fall spawner (Golder 1998j). Therefore, although mountain whitefish is a KIR for Wood Creek, the impact assessment has been restricted to the juvenile life stage of this species.

The McLean Creek KIR is Arctic grayling. Three young-of-the-year Arctic grayling were captured in McLean Creek in the fall of 1997, indicating that this creek provides rearing habitat for this species (Golder 1998j). The presence of yearling Arctic grayling also indicates that this species may have spawned in McLean Creek in the spring. In the spring of 1995, McLean Creek had very little flow and was not accessible to Arctic grayling. However, in years with higher water levels it is possible that this species may spawn in the creek since the habitat is suitable for this purpose. Hence, Arctic grayling spawning will be surveyed in the spring of 1998. Using a conservative approach, the spawning, incubation and fry life stages of Arctic grayling will be considered as a KIR for McLean Creek.

No fish were captured in Unnamed Creek (Golder 1998j), therefore this watercourse does not have a KIR.

C4.2.4 Fish and Fish Habitat Impact Evaluation Methods

C4.2.4.1 Approach

The impact analysis was facilitated by evaluating linkages between Project Millennium activities and key questions based on expected modes of action and information generated from computer modelling. Invalid linkages were eliminated by using screening arguments derived from modelling results, or based on Project design features and mitigation that will remove the mode of action or pathway.

If a link between Project activities and KIRs was deemed valid (i.e., if there was a plausible mode of action or pathway), then impacts were quantified and, where possible, compared with water quality or toxicity guidelines. The impacts were classified according to the criteria outlined in Table A2-8, and the environmental consequence was rated.

For changes in measurement endpoints such as habitat area, the criteria are: negligible (no measurable change), low (<10% change), moderate (10 to 20% change) and high (> 20% change).

For parameters where water quality (e.g., toxicity) guidelines exist, the criteria are: negligible (releases do not cause exceedance of guideline), low (releases contribute to existing background exceedances), moderate (releases cause marginal exceedance of guideline) and high (releases cause substantial exceedance of guideline).

Following classification of the potential impact, uncertainty of the assessment, follow-up studies (if necessary because of uncertainty in the assessment) and proposed monitoring are described.

Follow-up studies are special projects designed to address uncertainty in the impact assessment, and are in addition to routine monitoring programs. These studies would occur prior to the start-up of the Project (or the particular Project activity that may affect a specific component of the aquatic ecosystem) to generate information that would reduce the uncertainty in impact predictions. The data may also result in adjustments to the mitigation plan and will contribute to a more extensive baseline against which future monitoring data can be compared.

Monitoring programs are routine environmental programs that focus on key indicators of the well-being of the aquatic environment. These data are gathered at regular intervals. The data are compared with baseline data and are examined for trends over time. Monitoring data provide feedback on the effectiveness of mitigation measures, and contribute to any necessary adjustments in mitigation measures if existing measures are not having the desired effect.

C4.2.4.2 Assessment of Fish Habitat

Fish habitats assessed within the LSA include:

- Athabasca River;
- Steepbank River;
- Shipyard Lake;
- inlets of Shipyard Lake (Unnamed Creek and Creek Two);
- Shipyard Creek (outlet of Shipyard Lake); and
- small Athabasca River tributaries (Leggett, Wood and McLean creeks).

Each of these waterbodies was considered separately since they differ in habitat characteristics and types of potential Project impacts.

Potential effects on fish habitat include physical factors such as loss of habitat area, changes in sediment loading, dissolved oxygen levels, streamflow (e.g., discharge, velocity and water levels), thermal regime or channel regime. Impacts can also occur due to changes in the quality or quantity of fish food (e.g., benthic invertebrates) (Figure C4.2-1).

Most changes in physical habitat variables have been analyzed in the Surface Hydrology and Hydrogeology (C2) and Water Quality (C3) sections. The Hydrology section contains an assessment of changes in streamflow, channel regime and sediment concentrations. Water quality and thermal regime changes are described in the Surface Water Quality section.

Habitat Area

Fish habitat loss (in hectares) was estimated by calculating waterbody areas no longer available for use by fish. The length of creek affected (determined through the use of GIS) was multiplied by the average creek wetted width (measured in the field) and converted to hectares.

Hydrologic and Thermal Regime

Changes to the hydrologic and thermal regime in Shipyard Lake and McLean Creek were compared to habitat suitability indices (HSIs) for Arctic grayling and northern pike developed by the U.S. Fish and Wildlife Service (Hubert et al. 1985, Inskip 1982). The habitat suitabilities reported by these authors have been reviewed by the study team and are considered adequate for this level of assessment.

The HSI model estimates the relationship between habitat variables considered to be important to the well-being of the fish population and habitat suitability. Habitat suitability is based on a scale of 0 to 1, where 0 is unsuitable and 1 is ideal habitat. Changes in physical habitat variables (e.g., velocity) were compared with these habitat suitability indices to quantify habitat change.

No HSI information was available for the forage fish guild. For this KIR, information from the literature on habitat requirements was compared with predicted changes in habitat. Descriptions of habitat requirements for each of the KIRs are found in Section C4.1.

Benthic Invertebrates

Benthic invertebrates may also be affected by physical factors such as changes in sediment loading, streamflows and substratum characteristics. Changes in water quality may also affect the suitability of habitats for benthic invertebrates.

Predicted changes in physical habitat variables applicable to invertebrate habitat (i.e., suspended sediment concentration, water velocity) were compared with baseline ranges to assess impacts. Potential changes in substratum characteristics were evaluated qualitatively, based on changes in other related physical variables. Because predicted changes were typically small, no quantitative analysis was conducted.

The potential for acute and chronic effects on benthic invertebrates, caused by changes in water quality, were evaluated by comparing water quality modelling results against water quality guidelines for the protection of aquatic life (AEP 1996b).

C4.2.4.3 Assessment of Acute and Chronic Toxicity to Fish

Changes in thermal regime, sediment loading and water quality can potentially cause acute (i.e., short-term, usually lethal) or chronic (i.e., long-term, sublethal or lethal) effects on fish (Figures C4.2-1 and C4.2-2).

Thermal Regime

The magnitude of predicted changes in thermal regimes of McLean Creek and Shipyard Lake were examined to determine whether they are sufficiently large to cause physiological stress in fish. Since Project-related changes in the thermal regime of the Athabasca and Steepbank rivers are unlikely, this analysis was not conducted for these waterbodies.

Sediment Loading

Information from the Hydrology Section (C2) was used to assess potential impacts of sediment on fish.

Water Quality

The methods used to assess potential acute and chronic impacts on fish caused by changes in water quality were the same as those used to evaluate impacts of changes in water quality on benthic invertebrates, specifically:

1. Predicted concentrations of water quality parameters in the Athabasca River, McLean Creek and Shipyard Lake were compared with water quality guidelines for protection of aquatic life (AEP 1996b); and

2. Predicted toxic units (TUs) in these waterbodies were compared with toxicity guidelines (AEP 1996b).

The methods used for the prediction of water quality parameters and TUs are explained in the Water Quality section (Section C3). Detailed background information on the use of toxicity data as the basis for impact predictions is provided in Appendix V.

In 1997, samples of CT water from Suncor were tested for potential impacts on representative species of the major trophic levels in aquatic systems (i.e., microbes, plants, invertebrates and fish). The goal was to add to the existing toxicity database, using tests with fresh CT water and samples of CT water aged for three and six weeks respectively. A synthesis of existing information on consolidated tailings (CT) toxicity is provided in the report entitled "1997 Synthesis of Environmental Information on Consolidated/Composite Tails (CT)" (Golder 1998a).

Although toxicity data were not available for the KIRs selected for the impact assessment, using laboratory toxicity data for the most sensitive test organisms was considered to result in a conservative analysis (Appendix V). Furthermore, Environment Canada (1996) states that there has been sufficient research carried out to show that toxicity tests are usually predictive of impacts on natural aquatic communities.

Fish Health

The impacts of CT water on fish health (e.g., gonad size, liver size, internal pathology, fecundity) cannot be estimated directly because there have been no experimental studies of the effects of CT water on fish health. Such studies are planned for 1998. This assessment relies on data from acute and chronic toxicity tests using CT water, plus the evidence from previous field and laboratory studies. In previous work, there was good agreement between acute and chronic toxicity tests and combined field and laboratory studies on fish health and fish population parameters (Golder 1996d, HydroQual 1996a, 1996b). The results of previous fish health studies and the relationship between acute and chronic toxicity tests and fish health are described below.

Previous work on TID seepage water and upgrader outfall wastewater included acute and chronic toxicity testing of both waters, plus laboratory studies of fish health. Acute and chronic toxicity testing produced no effect levels (NOELs) and lowest effect levels (LOELs). These were in good agreement with NOELs and LOELs derived for biochemical and physiological indicators from the laboratory fish health studies (Golder 1996d, HydroQual 1996a, 1996b). A comparison of the NOELs and LOELs derived during the experimental exposures with modelled concentrations of operational waters in the Athabasca River showed that it was unlikely that exposure to operational water releases would cause biochemical or physiological responses in fish in the Athabasca River (Golder 1996d). Therefore, it was also unlikely that there would be adverse effects on whole organism or population-level indicators.

Field studies confirmed the lack of adverse effects on whole organism or population-level parameters. Walleye, goldeye and longnose sucker showed physiological responses to exposure to oil sands materials, but no evidence of deleterious whole organism or population-level effects. The physiological response was an elevation in mixed function oxidase (MFO) activity in liver and a possible increase in glucose levels in blood plasma (Golder 1996d). The increase in MFO activity was an expected response to PAHs present in oil sands. The blood glucose result was difficult to interpret because of the lack of reference data. There were no adverse changes in whole organism indicators, including indicators of reproductive performance such as gonad size. Growth rates were higher for all three species, relative to growth rates recorded 180 km upstream (Golder 1996j). Condition factor was higher in longnose sucker and walleye relative to upstream. In summary, fish populations in the vicinity of oil sands activities were viable, with good growth rates, no indication of reproductive impairment, and no change in community composition and habitat use from what had been recorded prior to development of the area.

Analysis of Regional Aquatic Monitoring Program (RAMP) data from 1997 showed that there continues to be no evidence of deleterious effects on fish population parameters in the oil sands area (Golder 1998h). RAMP fish population monitoring increases the reliability of the fish population database by increasing sample sizes and recording year-to-year variability.

The weight of evidence provided by the acute and chronic toxicity tests, laboratory fish health studies and field observations indicated that fish populations would not be adversely affected by exposure to TID seepage or upgrader wastewater.

The relationship between acute and chronic toxicity and fish health has been well established for oil sands waters tested to date. Therefore, this assessment assumes that there will also be good agreement between acute and chronic toxicity tests of CT water and effect thresholds for fish health and fish population parameters. Follow-up studies will conducted to ensure that the same relationship between acute and chronic toxicity and other fish health parameters for CT water.

C4.2.5 Key Question F-1: What Impact Will Development and Closure of Project Millennium Have on Fish Habitat?

C4.2.5.1 Analysis of Potential Linkages

Linkage Between Changes in Waterbody Areas and Fish Habitat

The Project does not impinge on the Athabasca River, Steepbank River, Shipyard Lake, Shipyard Creek or McLean Creek. Mine operations will be setback above the 1-in-100 year ice-flood level of the Athabasca River and at least 100 m from the Steepbank River escarpment as recommended by the Oil Sands Subregional Integrated Resource Plan (AEP 1996a). Setbacks from Shipyard Lake, Shipyard Creek and McLean Creek will be at least 100 m from their banks.

The areas of two tributaries of the Athabasca River, Leggett Creek and Wood Creek, will be affected by Project Millennium. The middle and upper portions of Leggett and Wood creeks will be lost during construction and operation, resulting in dewatering of the lower portions of the creeks near the confluence of the Athabasca River (Figure C1-1). The upper portions of the tributaries to Shipyard Lake, Unnamed Creek and Creek Two, will also be eliminated during the construction and operation phases.

No fish have been captured in Unnamed Creek; however, the habitat in the lower portions could support forage fish (Golder 1998j). The lower reaches (near the mouth) of Leggett Creek, Wood Creek and Creek Two are documented to support forage fish (Golder 1996b, Golder 1996c, Golder 1998j). Three immature mountain whitefish were documented in the lower segment of Wood Creek, indicating that this portion of the creek is being used to a limited extent as rearing habitat for this species (Golder 1996b). No fish were captured in the upper portions of any of these creeks, and fish passage is likely precluded by natural physical barriers in these streams.

Although the upper reaches (above the escarpment) of Creek Two and Unnamed Creek will be removed, the fish habitat of these creeks will not be affected by Project Millennium, since fish habitat is only present in the lower portion. However, dewatering the lower portions of Leggett and Wood creeks will affect fish habitat.

Therefore the linkage between changes in waterbody areas and fish habitat is invalid for Shipyard Lake, Shipyard Creek, Unnamed Creek and Creek Two, but valid for Leggett and Wood creeks. Analysis of this linkage is presented in Section C4.2.5.2.

Elimination of fish habitat in Leggett and Wood creeks affects the forage fish guild. Elimination of fish habitat in Wood Creek also affects a mountain whitefish rearing area. No other KIRs are affected as a result of habitat loss.

Linkage Between Change in Sediment Loading and Fish Habitat

Athabasca River

The Project will not involve instream activities in the Athabasca River. Project activities associated with mine development that could potentially cause an increase in sedimentation in the Athabasca River include surface disturbance during construction and operations. The interception and mine drainage systems include provisions to control sediment discharge from the site as discussed in Section C2.2.4.2. In addition, an increase in sediment concentration in runoff to receiving waterbodies, such as the Athabasca River tributaries, could cause an increase in sediment load in the Athabasca River.

Mitigation measures to prevent possible sedimentation of the Athabasca River are described in detail in Section C2.2.4.2. Mitigation measures to control increased sediment concentrations in receiving waterbodies are described below.

Steepbank River

The Project will not involve instream activities in the Steepbank River. However, sediment loading in the Steepbank River could be affected by construction of the northeast overburden dump and materials reclamation stockpile near the southern boundary of the river. Mining at the north end of Pit 1 could also cause an increase in sediment loading in the Steepbank River (Figure C1-2).

Mitigation measures to prevent possible sediment loading of the Steepbank River are described in detail in Section C2.2.4.2. Mitigations include a mining setback of at least 100 m from the river escarpment. During construction the potential increase in sediment yield will be managed by temporary controls including silt fencing and cross-berms. In addition, the dump and stockpile will be reclaimed as soon as activities allow.

Shipyard Lake and Other Small Creeks

Project activities that could potentially cause changes in sediment loading of Shipyard Lake and Shipyard Creek, Creek Two and McLean Creek are clearing, muskeg drainage and overburden dewatering, diversions, pre-stripping and mine infrastructure construction (e.g., roads, powerlines, pipeline installation). The potential for these activities to cause changes in sediment loading of these watercourses was discussed in the Hydrology section (Key Question SHH-4; Section C2.2.4.2).

Mitigation measures to prevent increase of sediment in Shipyard Lake Unnamed Creek, Creek Two and McLean Creek are described in detail in Section C2.2.4.2. Mitigation measures include the routing of muskeg drainage water through an interception drainage system and sedimentation ponds prior to the point where they enter Shipyard Lake and McLean Creek. The sedimentation ponds will be sized to ensure that the sediment concentration released during the 1-in-10 year flood will not be greater than baseline sediment concentrations in Shipyard Lake and McLean Creek.

Sediment loads to Shipyard Lake may be reduced to below baseline levels as a result of the construction of upstream ponds. Hence, there will no increase in sediment loading to Shipyard Lake.

The results of the hydrology assessment indicate that there will be no changes in sediment loading to the receiving watercourses during all phases of the Project (Section C2.2.4.2). Therefore, no impacts on fish habitat are expected and this linkage is deemed invalid.

Linkage Between Change in Dissolved Oxygen Levels and Fish Habitat

The potential for muskeg and overburden dewatering to cause changes in dissolved oxygen levels in Shipyard Lake and McLean Creek was evaluated in Section C3.2.7 (Key Question WQ-3). Muskeg drainage waters have elevated organic matter concentrations. Aerobic bacteria consume dissolved oxygen while decomposing organic matter; therefore the potential for lowered dissolved oxygen levels in Shipyard Lake and McLean Creek theoretically exists.

Negligible changes in dissolved oxygen levels are expected in these watercourses, since discharge of muskeg drainage waters will be very low or will cease in the winter. Mitigation measures will include aeration of muskeg drainage waters in sedimentation ponds if potential problems develop (Section C3.2.7). Hence, the linkage between dissolved oxygen levels and fish habitat is invalid.

Linkage Between Changes in the Streamflow and Water Levels of Receiving Streams and Fish Habitat

Change in the streamflow and water levels of the Athabasca and Steepbank rivers, Shipyard Lake, Unnamed, Creek Two, Leggett, Wood and McLean creeks were assessed in Section C2.2.3.1 (Hydrology and Hydrogeology). Potential linkages between changes in flows and water levels and fish habitat are assessed separately for each waterbody.

Athabasca River

Project activities that could potentially change flows and water levels in the Athabasca River are muskeg dewatering and mine pit construction in the vicinity of the river. Groundwater seepage and surface water inputs to the Athabasca River will be slightly reduced during construction and operation. However, the portion of the drainage basin affected is negligible (Table C2.2-9) and will not result in measurable changes in flow (<0.01%).

Suncor will not increase water withdrawals from the Athabasca River for Project Millennium. Therefore no effects on fish habitat from water withdrawals as a result of the proposed Project are expected.

Since changes in flows of the Athabasca River are negligible, there is no linkage between changes in flows and fish habitat in the Athabasca River.

Steepbank River

The only potential linkage between Project activities and potential changes in flows and water levels in the Steepbank River is construction of an overburden dump and reclamation stockpile within a portion of the Steepbank River watershed (Figure C1-1). This will result in a very small

(1%) reduction of the drainage area of the Steepbank River (Table C2.2-9). The small decrease in drainage area size will result in a negligible (<0.1%) change in Steepbank River flow.

Since changes in flows of the Steepbank River are negligible, there is no linkage between changes in flows and fish habitat in the Steepbank River.

Shipyard Lake and Shipyard Creek

Changes in the hydrologic regime of Shipyard Lake and Shipyard Creek are described in the Hydrology and Hydrogeology section (Section C2.2.3.1, Table C2.2-10 and Figure C2.2-6).

Shipyard Lake and Shipyard Creek will not be directly affected by mining. However, since they are adjacent to mining activity their watershed will be altered. Strategies for maintaining inflows to Shipyard Lake will be implemented to compensate for changes to the surface and groundwater flow. Strategies used to maintain Shipyard Lake levels include:

- diverting natural runoff and muskeg drainage water from upland areas through Unnamed Creek during the early stages of mining (1998 to 2015);
- if monitoring indicates that additional inflow to Shipyard Lake is required to maintain lake levels or water quality, additional make-up water from the Athabasca River may be used (2015 to 2033); and,
- routing surface runoff to Shipyard Lake from the reclaimed landscape during closure (after 2033).

Strategies for how fish habitat can be maintained in Shipyard Lake are further discussed in the Project Millennium Conceptual Plan for "No Net Loss" of Fish Habitat (Golder 1998i).

Since changes in the hydrologic regime of Shipyard Lake and Shipyard Creek are predicted to occur, this linkage is valid for fish and fish habitat. Analysis of this linkage is presented in Section C4.2.5.2.

Unnamed Creek

The upper portions of Unnamed Creek will be lost during construction and operation of Project Millennium. Therefore, the hydrologic regime of Unnamed Creek will be altered (Table C2.2-10). An interception drainage system will replace the upper portions of Unnamed Creek. However, an upstream sedimentation pond and a diversion system will be used to regulate flows to the mouth of Unnamed Creek so existing fish habitat can be maintained (Figure C2.2-5). Thus, this linkage is invalid for fish and fish habitat.

Creek Two

Most of Creek Two will be lost during construction and operation of Project Millennium (Section C2.2.3.1). However, fish habitat is only present at the mouth of this creek (near Shipyard Lake) and this area will not be impacted by mine activities.

Leggett Creek

Leggett Creek will be lost early in the Project. A dyke and mine pit will be constructed within its catchment basin (Figures C2.2-5 and C2.2-8). This will eventually eliminate flow in the lower reaches of the creek.

The linkage between changes in flows and water levels and fish habitat is valid for Leggett Creek. Elimination of flow in this waterbody affects the forage fish guild KIR. Analysis of this linkage is presented in Section C4.2.5.2.

Wood Creek

A tailings pond will be located west of east bank mining area Pit 2, within Wood Creek (Figure C1-1). The end pit lake also is within the catchment basin of Wood Creek. The locations of these mine features will require rerouting the flow of water from the upper portion of the Wood Creek catchment to McLean Creek, which will eliminate flow in Wood Creek.

The linkage between changes in flows and water levels and fish habitat is valid for Wood Creek. Elimination of flow in this waterbody affects the forage fish guild and mountain whitefish (juvenile life stage) KIRs. Analysis of this linkage is presented in Section C4.2.5.2.

McLean Creek

There will not be any direct physical alterations of McLean Creek as a result of mining activities. Some effects are predicted on the hydrologic regime of McLean Creek as a result of diverting Wood Creek upper catchment to McLean Creek during operations. In addition, flows from muskeg and overburden dewatering will be directed to an interception drainage system located on the McLean Creek escarpment, which will also increase flows in McLean Creek (Table C2.2-10 and Figure C2.2-7). Flows will approximately double from 2002 to 2012. After 2012, flows will likely triple in comparison to pre-mine development. This diversion will occur during operations until the end pit lake in begins filling. Water from the Wood Creek diversion will be routed to the end pit lake and flows in McLean Creek will decline to slightly. Once the end pit lake is full, water from the lake will be routed to the Athabasca River. When the water quality in the end pit lake improves to acceptable levels, the end pit lake outflow will be routed back to McLean Creek.

Since flow will change in McLean Creek, the linkage between changes in flow and water levels and fish habitat is valid. This linkage is analysed in Section C4.2.5.2.

Linkage Between Changes in Channel Regime and Fish Habitat

Changes in channel regime are described in the Hydrology and Hydrogeology section (Section C2.2.4.2). Since there will be no measurable changes in flows in the Athabasca and Steepbank rivers, Shipyard Creek, Unnamed Creek and Creek Two, no changes in channel regime in these waterbodies are expected. However, there is potential for changes in channel regime in McLean Creek because flows are expected to increase during construction and operation phases of Project Millennium. Mitigation measures to prevent changes in channel regime in McLean Creek are described in detail in Section C2.2.4.2. Mitigation measures include instream erosion protection designed on the basis of the maximum increase in flow, expected in about year 2012. Strategies for how fish habitat can be maintained in McLean Creek are further discussed in the Project Millennium Conceptual Plan for "No Net Loss" of Fish Habitat (Golder 1998i).

Since changes in channel regime of McLean Creek will be mitigated, this linkage is invalid for fish and fish habitat.

Linkage Between Changes in Thermal Regime and Fish Habitat

Predicted changes in the thermal regime of McLean Creek and Shipyard Lake are described in the Water Quality section (Section C3.2.6, Key Question WQ-2). There is a potential that the temperature regime of McLean Creek will be affected by Project activities.

McLean Creek

A slight reduction in water temperature is predicted in McLean Creek during the open-water season in 2025, when highest inflows of muskeg and overburden drainage water are expected. A maximum decline of 1.2°C from average water temperature in July and August is predicted (Figure C3.2-3). In addition, there is a potential that thermal regime of McLean Creek will be affected by end pit lake discharges (predicted maximum decline of 4°C in the far future). This predicted temperature is above the Alberta Ambient Surface Water Quality Interim Guideline. However, results of temperature modelling for McLean Creek are conservative and are subject to a high degree of uncertainty. The predicted changes in water temperature of McLean Creek represent worst case estimates which could not be refined due to lack of data.

Studies to date have only documented fish in the lower reaches of McLean Creek, below the escarpment (Golder 1998j). The anticipated point of discharge of mine related waters is located at least 1 km upstream of fish habitat. This distance may allow for water temperature to increase to near ambient. Temperature will be monitored in the stream under baseline conditions and during the life of the Project. If monitoring indicates potential changes in thermal regime, mitigation will be employed to prevent impacts to fish habitat in McLean Creek (Section C3.2.6.3). Since temperature changes will be mitigated to prevent impacts on fish habitat in McLean Creek, the linkage between thermal regime and fish habitat in McLean Creek is invalid.

Shipyard Lake

It is unlikely that the temperature regime of Shipyard Lake would be cooled by muskeg and overburden drainage water inflows (Section C3.2.6.3). The lake is shallow and surrounded by wetlands, which facilitate warming of incoming waters. Hence, the linkage between thermal regime and fish habitat is invalid for Shipyard Lake.

Linkages to Benthic Invertebrate Communities

The following environmental changes are linked to benthic invertebrate communities in Figure C4.2-1 and are evaluated below:

- change in dissolved oxygen concentration;
- change in channel regime;
- change in streamflow and water levels;
- change in sediment loading;
- change in thermal regime; and
- change in water quality.

Change in Dissolved Oxygen Concentration

Discharges of muskeg and overburden drainage waters are not expected to result in unacceptable declines of dissolved oxygen levels in receiving waters (Key Question WQ-3, Section C3.2.7). Therefore, the linkage between change in dissolved oxygen concentration and benthic invertebrate communities is invalid.

Change in Channel Regime

Since negligible changes were predicted in flows in the Athabasca and Steepbank rivers, Shipyard Creek, Unnamed Creek and Creek Two, no changes in channel regime are expected in these waterbodies (Key Question SHH-3, Section C2.2.3.1). There is potential for changes in channel regime in McLean Creek because flows are expected to increase during the Project period. However, since changes in the channel regime of McLean Creek will be mitigated, this linkage is invalid.

Changes in Streamflow and Water Levels

Predicted changes in flows in the Athabasca and Steepbank rivers are negligible and water level would be maintained in Shipyard Lake (Key Question SHH-3, Section C2.2.3.1). Project activities were predicted to cause changes in flow in McLean Creek, Shipyard Creek, Creek Two and Unnamed Creek. These changes may affect benthic invertebrate communities if they are of sufficient magnitude to permanently alter substratum composition and change current velocity beyond the natural range in these streams.

Predicted flow changes are small in Shipyard Creek, Creek Two and Unnamed Creek. The largest predicted increase in discharge would occur in McLean Creek, where an approximately three-fold increase in flow is predicted, beginning during mine construction (Section C2.2.3, Table C2.2-10). Mitigation applied to offset impacts to fish habitat will ensure that current velocity will remain within the baseline range. Bottom material in redesigned stream reaches will be selected to provide high quality fish habitat, which will also favour benthic invertebrates. Therefore, the linkage between changes in streamflow and water levels and benthic invertebrate communities is invalid.

Change in Sediment Loading

Results of the hydrology assessment indicate that there will be no changes in sediment loading to watercourses during all phases of the Project (Key Question SHH-4, Section C2.2.4.2). Therefore, this linkage is invalid.

Change in Thermal Regime

Predicted changes in the thermal regime of McLean Creek and Shipyard Lake are described under Key Question WQ-2 (Section 3.2.6). Other waterbodies will not receive discharge waters at sufficient flow rates to affect their thermal regime.

There is a potential that thermal regime of McLean Creek will be affected by end pit lake discharges during the far future (i.e., a cooling effect during the open-water period), but results of the temperature analysis are very conservative. Because temperature is an important feature of fish habitat, potentially deleterious temperature changes identified by future monitoring of McLean Creek will be mitigated and hence not affect benthic invertebrates.

The effects of muskeg and overburden drainage water inputs on the thermal regime of Shipyard Lake would be negligible. Only a small proportion of inflows to this lake will originate from dewatering. In addition, Shipyard Lake is shallow and surrounded by wetlands, which facilitate warming of incoming waters.

Based on the above information, the linkage between change in thermal regime and benthic invertebrate communities is invalid.

Change in Water Quality

Results of the water quality analysis conducted under Key Question WQ-1 (Section C3.2.5) indicate that few exceedances of water quality guidelines would result from Project activities in the Athabasca River, McLean Creek and Shipyard Lake, other than those caused by naturally elevated levels of metals. No changes in water quality are expected in the Steepbank River. Toxicity guidelines would be met throughout the life of the project and thereafter. Therefore, Project-related changes in water quality are not expected to influence benthic invertebrate communities in these waterbodies and this linkage is invalid.

C4.2.5.2 Analysis of Key Question

In the analysis of potential linkages between the Project and fish habitat, the following linkages were deemed invalid:

- habitat loss in Shipyard Lake, Shipyard Creek, Unnamed Creek, Creek Two and McLean Creek;
- sediment loading;
- changes in dissolved oxygen;
- changes in the streamflow and water levels (hydrologic regime) of the Athabasca and Steepbank rivers;
- changes in the thermal regime in Shipyard Lake; and
- changes in benthic invertebrate communities.

Hence, the following linkages to fish habitat require assessment:

- Leggett and Wood creeks: the effects of direct habitat loss through elimination of flow; and
- Shipyard Lake, Shipyard Creek and McLean Creek: the effects of changes in streamflow and water levels (hydrologic regime).

Valid linkages to fish habitat are assessed separately for each waterbody and are discussed below.

Leggett and Wood Creeks

Changes to Leggett and Wood creeks as a result of the Project include a total area loss of 1.2 ha (Leggett Creek = 0.96 ha, Wood Creek = 0.23 ha) and elimination of flow. These physical changes to these waterbodies are analyzed relative to the KIRs for each watercourse.

Mountain Whitefish

Mountain whitefish is a KIR for Wood Creek. In 1996, three immature mountain whitefish were captured in the lower segment of Wood Creek, near the confluence with the Athabasca River (Golder 1996b). It appears that this portion of the creek is being used to a limited extent as rearing area for this species. Hence, 0.23 ha of mountain whitefish rearing habitat will be lost as a result of Project Millennium.

Forage Fish Guild

The forage fish guild is a KIR for Leggett and Wood creeks. No other fish species were captured in Leggett Creek (Golder 1996c). In Wood Creek, other forage fish species were also captured (spoonhead sculpin, longnose sucker) (Golder 1998j). All fish were found in the lower portions of these creeks, near the confluence with the Athabasca River. Hence, the habitat area lost as a result of Project Millennium will be 1.2 ha of forage fish habitat from the lower portion of these creeks.

Arctic Grayling

It is possible that Arctic grayling occasionally use the habitat in lower Wood Creek for spawning and rearing, when flows are suitable for these habitat uses. No such habitat uses were found in 1995, which was a low run-off year (Golder 1996c) or in spring 1996 which was an average run-off year (Golder 1996b). However, Wood Creek will be re-examined in 1998. If spawning or rearing of Arctic grayling are documented in Wood Creek, habitat compensation will include Arctic grayling habitat.

Habitat Compensation

Suncor is committed to a fish habitat compensation program. Fish habitat will be replaced concurrently with habitat lost during the Project. There are several options available to compensate for habitat lost in Leggett and Wood creeks, as discussed in Project Millennium's Conceptual Plan for "No Net Loss" of Fish Habitat (Golder 1998i). These include:

- create side channels in the Athabasca River floodplain;
- create additional habitat in the lower portion of McLean Creek;
- enhance habitat in Shipyard Lake;
- create habitat in the end pit lake outlet channel; or
- enhance or create habitat off-site.

The end pit lake will not be considered as fish habitat compensation since its viability will need to be established.

The amount of habitat created or enhanced to compensate for habitat losses in Wood and Leggett Creek will be determined in consultation with Alberta Environmental Protection (AEP) and Department of Fisheries and Oceans (DFO). At least 1.2 ha of forage fish habitat and 0.23 ha of mountain whitefish habitat will be created.

Therefore, no negative impacts on mountain whitefish, Arctic grayling and the forage fish guild are expected, and thus no net loss of the productive capacity of fish habitats is anticipated.

Shipyard Lake and Shipyard Creek

Changes to flows in Shipyard Lake and Shipyard Creek are described in the Surface Water Hydrology and Hydrogeology section (Section C2.2.3.1, Table C2.2-10). Changes in the hydrologic regime of Shipyard Lake are predicted to occur during the life of the Project and after closure. This potential physical change to Shipyard Lake is analyzed for northern pike and the forage fish guild KIRs.

Northern Pike

Northern pike spawn in Shipyard Lake when access allows. Both the embryo and fry life stages of northern pike are sensitive to water level fluctuations (Casselman and Lewis 1996). Two aspects of Shipyard Lake's habitat could be affected by changes in lake level: access to and from the lake through Shipyard Creek for spawners, as well as an emigration route for fry, and suitability for the embryo and fry life stages. Access to the lake from the Athabasca River is likely related to both the lake level and Athabasca River flow. During periods when flows are low, beaver dams and debris likely prevent access to the lake. During periods of high flow in the Athabasca River when water depths exceed the height of the beaver dams or when beaver dams are breached, northern pike can access the lake through Shipyard Creek and have also been able to leave the lake after spawning.

The second way that hydrological changes could affect habitat in the lake is by decreasing the suitability or amount of habitat for embryo and fry life stages. Northern pike spawn in shallow vegetated areas, and eggs are attached to vegetation. Hence, a drop in water level after spawning and before hatching could affect embryo survival (Casselman and Lewis 1996). Similarly, a sudden drop in water levels affect fry behavior, potentially triggering emigration from rearing habitat.

Hydrological assessments indicate that levels of Shipyard Lake from Unnamed Creek can be maintained to pre-development conditions (Section C2.2.3.1). Mitigation measures will be incorporated to ensure flows and water levels in Shipyard Lake are maintained. Hence no negative impacts on northern pike are expected.

Forage Fish

Brook stickleback have been captured in Creek Two, which is a tributary of Shipyard Lake (Golder 1998j). Therefore, it is assumed that forage fish also reside in Shipyard Lake. The potential for changes in lake water levels and flows will not impact forage fish habitat. Hence no negative impacts on forage fish are expected.

McLean Creek

Changes to flows in McLean Creek are described in detail in Surface Water Hydrology and Hydrogeology (Section C2.2.3.1, Table C2.2-10). Flows in McLean Creek are predicted to double during 2002 to 2012 and triple after 2012. This potential physical change to McLean Creek is analyzed for the Arctic grayling KIR.

Flow regulation through use of water retention structures, ponds and wetlands above the escarpment and appropriate in-channel works will be implemented to control potential channel degradation in McLean Creek as a result of flow increases. The water retention structures will be sized appropriately to eliminate potential increases in flood peaks.

Average annual discharge in McLean Creek is about 150 L/s (Figure C2.2-7). The results of hydrological monitoring of McLean Creek indicate that velocity at this discharge is 0.42 m/s which is within the preferred range for Arctic grayling (HSI = 1) (Hubert et al. 1985). Mitigation will be implemented to ensure that velocities in McLean Creek remain within the preferred range for Arctic grayling spawning (i.e., between 0.2 to 0.55 m/s; Hubert et al. 1984).

Other impacts to McLean Creek as a result of increased flow (e.g., unstable banks or loss of instream cover) will be mitigated by standard stream rehabilitation methods.

C4.2.5.3 Residual Impact Classification and Environmental Consequence

Negligible impacts on habitats of KIRs in the Athabasca and Steepbank rivers are predicted and the environmental consequence is considered negligible.

Negligible impacts and environmental consequence on mountain whitefish, northern pike, Arctic grayling or the forage fish guild are expected from habitat alteration in the Project Millennium LSA. Mitigations will be in place to ensure no net loss of fish habitat. These have been discussed throughout the analysis of potential linkages and impact analysis and are summarized in Table C4.2-5.

Table C4.2-5 Summary of Project Mitigation Features to Achieve No Net Loss of Fish Habitat

Design Feature/Mitigation	Result
Mining setbacks at least • above the 1-in-100 year ice-flood level along the Athabasca River • 100 m from the escarpment along the Steepbank River • 100 m from the banks of Shipyard Creek and McLean Creeks, Shipyard Lake	No impact on fish habitat
Habitat compensation for habitat lost in Wood and Leggett creeks	Impact on fish habitat mitigated
Mitigations for sediment loading including: • temporary erosion control and rapid reclamation • sedimentation ponds to facilitate sediment settling and flow regulation (Shipyard Lake, Shipyard Creek and McLean Creek).	Negligible increase in sediment levels
Strategies to maintain the hydrological regime in McLean Creek: • instream erosion protection • sizing of sedimentation ponds to control peak flows	Hydrological regime maintained and no impact on fish habitat
Strategies to maintain the hydrologic regime in Shipyard Lake: • sedimentation pond and diversion to Shipyard Creek to regulate flow from upland areas • use of make-up water from the Athabasca River if necessary	Hydrological regime maintained and no impact on fish habitat
Mitigation to prevent impacts to water quality as described in (Section C3.2; Table C3.2-2)	No impacts on fish habitat from changes in water quality

C4.2.5.4 Uncertainty

The uncertainty of these predictions is moderate since there is some uncertainty in the effectiveness of fish habitat mitigation and creation. However, fish habitat mitigation/enhancement has been implemented successfully in other projects and there are several tools available for fish habitat design and enhancement (e.g., Ontario Ministry of Natural Resources 1994; Natural Channel Systems: An Approach to Management and Design).

C4.2.5.5 Monitoring

Monitoring of mitigation/compensation measures will be conducted, the results of which will provide feedback on the suitability of the mitigation/compensation.

Suncor has initiated a program to monitor the Shipyard Lake ecosystem. This is an integrated program and includes assessment of:

- water levels in the wetlands;
- inflows and outflows;
- water and sediment quality;
- aquatic vegetation; and
- fish resources.

Suncor has established flow monitoring stations at the inlets (Unnamed Creek, Creek Two) and the outlet (Shipyard Creek) of Shipyard Lake which have been in operation during the open-water season since 1996. Similarly, aquatic vegetation, fish utilization, water quality and sediment quality have been documented (Hamilton 1992, Golder 1996b, 1996p). Shipyard Lake monitoring was initiated in 1997 as part of the RAMP and will continue to be done within this program (1998h).

Monitoring of McLean Creek habitat will include hydrological monitoring as well as monitoring water quality, benthic invertebrates and the thermal regime. Fish utilization of the lower reaches will also be documented.

Monitoring of Shipyard Lake, Shipyard Creek, Creek Two and McLean Creek will be done to measure the effectiveness of mitigation (e.g., diversions, sedimentation ponds, flow control) and ensure that there are no negative impacts on fish habitat. If monitoring indicates the potential for impacts on habitat to occur, additional mitigation will be applied.

Habitat created or enhanced to compensate for the loss of Leggett and Wood Creeks will be monitored to evaluate both physical characteristics and fish utilization. Habitat monitoring will include hydrological monitoring to ensure that the physical characteristics of the stream are maintained. Habitat improvements would be implemented if the new habitat is not providing the required habitat components for the target fish species (e.g., mountain whitefish rearing, forage fish feeding).

Monitoring results will be used in a feedback loop to adjust, if necessary, mitigation measures and make design improvements as required. Habitat monitoring will be the key to ensure that the "no net loss" objective will be achieved.

C4.2.6 Key Question F-2: What Impact Will Development and Closure of Project Millennium Have on Levels of Acute or Chronic Toxicity to Fish?

C4.2.6.1 Analysis of Potential Linkages

Linkage Between Changes in Suspended Sediment Levels and Acute or Chronic Effects on Fish

The potential for Project Millennium to cause changes in sediment loading was discussed in the Surface Hydrology and Hydrogeology section (Key Question SHH-4; Section C2.2.4.2). Results of the analysis of this issue indicate that changes in sediment levels will be minimal in the Athabasca and Steepbank rivers, Shipyard Lake and McLean Creek. Water retention structures (e.g., sedimentation ponds) that will intercept sediments will be used at all sites. Therefore, the linkage between changes in sediment levels in surface waters and acute or chronic impacts on fish is invalid.

Linkage Between Changes in the Thermal Regime of Small Streams and Acute or Chronic Effects on Fish

The potential of Project Millennium to cause changes in the thermal regime of McLean Creek and Shipyard Lake was discussed in Section C3.2.6 and the fish habitat key question (C4.2.6). Results indicate that changes in the thermal regime of McLean Creek, during the open-water season in 2025 would not exceed 1.2°C. Similar changes are predicted for the far future when end pit lake water would be discharged to McLean (predicted maximum decline of 4°C). However, these results are subject to a high degree of uncertainty (Section C3.2.6.3). Monitoring will be conducted to determine thermal regime. If necessary, Suncor will implement mitigation to prevent changes in thermal regime (e.g., increased retention time in sedimentation ponds).

Releases of muskeg and overburden drainage waters are not anticipated to cause measurable changes in the thermal regime of Shipyard Lake (Section C3.2.6).

Based on the above evaluation, the linkage between a change in the thermal regime of small streams and acute or chronic impacts on fish is invalid.

Linkage Between Changes in Water Quality and Acute or Chronic Effects on Fish

The potential for operational and reclamation water releases to reach the Steepbank River was discussed in Section C3.2.5. The only waters to reach the Steepbank River will be seepage from the groundwater divide. Hence, no exceedances of water quality guidelines are expected in this watercourse.

Furthermore, previous studies of Tar Island Dyke (TID) seepage and upgrader wastewaters showed that effect thresholds derived from acute and chronic toxicity tests were in good agreement with effect thresholds observed during experimental fish health studies in the laboratory, and with results of field studies on fish health and fish populations (Golder 1996d, HydroQual 1996a, 1996b). If the same relationship exists for CT water, no effects on fish health of fish population parameters are expected at the modelled concentrations of CT water in the Athabasca River.

Since no exceedances of acute or chronic toxicity guidelines are predicted for the Athabasca River, Shipyard Lake and McLean Creek this linkage is invalid.

C4.2.6.2 Analysis of Key Question

Changes in suspended sediment levels, thermal regime and water quality were identified on the linkage diagram as factors that may contribute to acute or chronic impacts on fish. Results of the analyses summarized above indicate there are no valid linkages between Project activities and potential acute or chronic effects on fish.

C4.2.6.3 Residual Impact Classification and Environmental Consequence

Negligible acute or chronic impacts are predicted on fish in the Athabasca and Steepbank rivers, Shipyard Lake and McLean Creek.

C4.2.6.4 Uncertainty and Follow-up Studies

The conclusions regarding the potential for effects on fish are based on acute and chronic toxicity testing of CT waters and TID seepage waters. There are limited data on the effects of CT water on fish health. The only tests conducted to date with Suncor CT water are survival and growth of fathead minnow and survival of juvenile rainbow trout. Results are presented in Appendix V.

Suncor plans to conduct studies on the effects of CT water on fish health to reduce the uncertainty associated with impact predictions. These studies will be conducted before the Project is operational, to ensure that results can be incorporated into mitigation and future monitoring plans, if necessary. These studies will include three elements:

- laboratory exposures of fish to CT water (i.e., fish health studies that will include an analysis of tissue residues in fish);
- chemical characterization of CT water used for the tests; and
- toxicity testing at different trophic levels. These tests will be conducted in conjunction with fish tainting studies discussed in Section C4.2.8.

Laboratory Exposures of Fish to CT Water

The overall approach would be very similar in design to the studies already carried out on TID water and upgrader outfall wastewater from Suncor's current operations (HydroQual 1996a, 1996b). Studies would include fish health and challenge tests, which are designed to measure potential effects on the general health and condition of fish following prolonged exposure to wastewaters. The study design includes exposures of approximately one month in duration and a dilution series representative of concentrations predicted to occur in the receiving environment. The following fish health indicators will be examined:

- survival and growth of rainbow trout juveniles and sac fry (i.e., fry transition from sac to swim-up phase) and walleye juveniles (if available);

- suborganismal indicators: mixed function oxidases, blood chemistry, hematology, DNA adducts;
- whole organism indicators: liver size, fat content, condition factor, growth, gross pathology, histopathology, embryo survival, embryo deformities, swimming stamina, resistance to bacterial infection; and
- tissue analysis for metals and PAHs (whole fish).

Chemical Characterization of Wastewaters

In conjunction with the fish health studies, a representative number of samples of CT water will be submitted for analyses of oil sands related parameters and routine water quality parameters. The analyses will be comparable to those performed in 1997 (i.e., will include fresh and aged CT water to further examine potential differences with ageing). Parameters examined in conjunction with the CT water testing conducted in 1997 are listed in Appendix V.

Trophic Level Toxicity Testing

Suncor has conducted tests on the potential chronic effects of CT water on representative species of the major trophic levels in aquatic systems (microbes, plants, invertebrates and fish). In 1995, one fresh CT water sample was tested. In 1997, fresh, 3-week and 6-week old CT water was tested. The objective of additional trophic level tests will be to increase the existing toxicity database. Samples of the CT waters collected for the fish health studies will be tested as follows:

- bacterial luminescence (Microtox ®);
- algal growth inhibition;
- survival of *Daphnia magna*;
- survival and reproduction of *Ceriodaphnia*;
- survival and growth of fathead minnows; and
- survival of rainbow trout.

The chemistry, fish health data and toxicity test information will be interpreted together. The complete data set will be evaluated for consistency (i.e. the chemistry, toxicity and health data should provide complimentary, not contradictory information). The new data will also be added to the existing chemistry and toxicity data on CT water to enhance the existing information regarding the potential for environmental impacts from CT water.

C4.2.6.5 Monitoring

Monitoring for impacts on fish health in the Athabasca River and tributaries is part of the RAMP. Goldeye, walleye, longnose sucker and lake whitefish will be sampled from standard reaches within the oil sands operating area and from an upstream reference area if a suitable reference area can be found. Longnose sucker from the Steepbank River will also be included.

Fish health parameters will be collected from a sub-sample of fish captured during electrofishing. The fish health parameters included in the RAMP are: gonad weight; liver weight; fecundity; fat content; external pathology; and internal pathology. Fillets will be taken for analysis of metals and PAHs. Fish population parameters will also be monitored, including: species composition; relative abundance; condition factor; length-at-age; length-frequency; and age-to-maturity.

C4.2.7 Key Question F-3: What Impact Will Development and Closure of Project Millennium Have on Fish Abundance?

C4.2.7.1 Analysis of Potential Linkages

There are three potential linkages between Project Millennium and changes in fish abundance: change in access (i.e., increased harvest), acute or chronic impacts on fish and changes in fish habitat.

Linkage Between Change in Access and Fish Abundance

The bridge across the Athabasca River which was constructed for the Steepbank Mine project provides access to the Steepbank River and Shipyard Lake and the potential for increased fishing pressure. The bridge will not be open to the public during the operational phases of the mine. Suncor employees will have access to Steepbank River from the bridge; however, access for recreational activities will be prohibited. Thus, this linkage is restricted to post-reclamation conditions when the public may have access to the Steepbank River and Shipyard Lake by the bridge.

Increased fishing in the post-reclamation phase may result from use of the bridge to access the Steepbank River area if the bridge is maintained. An increase in fishing could cause a decrease in fish abundance. However, regulation of angling is the responsibility of Fisheries Management Division, AEP. It is assumed that decreases in fish abundance would be prevented by appropriate enforcement of legislation by Fisheries Management Division. Therefore, the linkage between change in access and fish abundance is invalid.

Linkage Between Acute and Chronic Effects on Fish and Fish Abundance

No acute or chronic effects on fish are expected as a result of the Project; hence, this linkage is invalid. However, there is some uncertainty associated with this prediction which will be investigated and confirmed with follow-up studies and monitoring (Sections C4.2.6.4 and C4.2.6.5).

Linkage Between Change in Fish Habitat and Fish Abundance

Fish habitat will be lost in Leggett and Wood creeks and could potentially be altered in Shipyard Lake, Shipyard Creek, Unnamed Creek, Creek Two and McLean Creek. However, Suncor is committed to habitat compensation and will ensure the objective of no net loss of fish habitat is attained (Section C4.2.6.2). Hence, no impacts on fish abundance are expected, therefore this linkage is invalid.

C4.2.7.2 Analysis of Key Question

None of the linkages between the Project and fish abundance are valid. Therefore, no further analysis is required.

C4.2.7.3 Residual Impact Classification and Environmental Consequence

Negligible impacts are predicted on fish abundance in the Athabasca and Steepbank rivers, Shipyard Lake and its tributaries, Shipyard Creek and McLean Creek. The environmental consequence is negligible.

C4.2.7.4 Uncertainty

The uncertainty of conclusions about fish abundance is influenced by the uncertainty associated with habitat mitigation and predictions about acute and chronic impacts on fish described in Sections C4.2.5.4 and C4.2.6.4 respectively.

C4.2.7.5 Monitoring

Fish abundance in the Steepbank and Athabasca Rivers will be monitored as part of the RAMP program as described in the monitoring section of Section C4.2.7.5.

C4.2.8 Key Question F-4: What Changes to Fish Tissue Quality Will Result From Development and Closure of Project Millennium?

C4.2.8.1 Potential Linkages

Changes in fish tissue quality are linked to water quality. The two main concerns are: 1) a change in chemical concentrations in fish tissue; and 2) a change in fish flavor (tainting). The first concern is linked to possible effects on human health from consumption of fish tissue with elevated chemical levels. The second concern is linked to the aesthetic effect of off-flavors. Both concerns are linked to a possible decline in the use of the fish resource.

Linkage Between Water Quality and Fish Tissue Chemical Concentration

The potential for Project Millennium to produce changes in chemical concentrations in fish tissue was evaluated by examining the bioaccumulative potential of the chemicals of concern and by interpreting available data on chemical levels in fish tissue from the area.

Walleye, goldeye and longnose sucker were collected as part of the Steepbank and Aurora Mines aquatic baseline studies (Golder 1996c). These fish were captured in the Athabasca and Muskeg rivers. Composite samples (by sex and species) of fish tissue (fillets) were analyzed for organic compounds and metals.

Uptake of oil sands related compounds into fish tissue was also investigated as part of a laboratory fish health study, using Athabasca River water and a dilution series of Tar Island Dyke (TID) and wastewater treatment system effluent waters, with a maximum concentration of 10% which is greater than predicted concentrations in the river (Appendix V). Juvenile walleye and rainbow trout were held for 28 days, sacrificed and their tissues analyzed for polycyclic aromatic hydrocarbons (PAHs) and trace metals (HydroQual 1996a, 1996b).

The results indicate that there is very limited uptake of PAHs or PANHs in fish (Table C4.2-6). Longnose sucker composite samples showed detectable naphthalene levels of 0.40 µg/g and methyl naphthalene levels of 0.03 µg/g; however, all other PAH parameters were not detectable (detection limits range from 0.02 to 0.04 µg/g). PAH/PANH compounds were not detectable in walleye and goldeye, the species more likely to be consumed by humans. In the laboratory, PAH concentrations for fish exposed to TID and upgrader effluent were below detection limit for nearly all compounds except naphthalene and methyl naphthalene in rainbow trout exposed to 10% TID, which were at, or just above the detection level (0.02 to 0.05 µg/g). Hence, both field and laboratory studies indicate that uptake of PAH/PANH compounds is limited to naphthalene and methyl naphthalene. Levels of the two compounds are below risk-based concentrations for consumption by humans or wildlife (Section F1.3).

Heavy metals such as cadmium and lead were not detected in juvenile walleye and rainbow trout exposed to 10% TID water, 10% upgrader effluent, Athabasca River water or in three species of fish captured in the field (Table C4.2-6). Mercury levels were detectable and of low magnitude in laboratory fish exposed to TID, wastewater treatment system effluent and Athabasca River waters.

Measurable levels of mercury were also found in fillets or liver of fish species examined in the Athabasca River under the Northern River Basin Study (NRBS) (Donald et al. 1996). The decreasing order for concentrations of mercury in fish, according to these studies, was walleye > goldeye > northern pike > longnose sucker > mountain whitefish. Levels of mercury exceeded human consumption guidelines for 25% of the walleye captured in the Athabasca River. However, it was noted that mercury levels have been relatively stable since the 1980's (Donald et al. 1996).

In general, metal levels in laboratory controls (exposed to Athabasca River water from upstream of oil sands operations) were similar to levels in fish exposed to oil sands waters (Table C4.2-6). Therefore, no significant incremental accumulation of metals, related to oil sands operations, is indicated by either the laboratory studies or from fish collected from the LSA.

Since there are no available laboratory or field data on the chemical accumulation of CT water residues in fish tissue, the potential for bioaccumulation was evaluated by using the available data from TID seepage water. Levels of PAH/PANH and metals in CT water (i.e., mean values for samples analysed to date) are comparable to those of TID seepage water (Golder 1998a) and hence it is reasonable to assume that fish tissue accumulation levels related to CT water would be comparable to those observed in the previous TID water studies (Table C4.2-6). Thus no significant incremental accumulation of metals or organic compounds would be expected from CT water.

Based on existing data from field and laboratory analyses, significant bioaccumulation of chemicals sufficient to cause direct effects on fish health or to cause exceedances of guidelines for human consumption is not expected to occur. However, since fish tissue quality is an issue that directly relates to the consumption of fish in the LSA, Suncor is committed to follow-up studies to confirm this prediction. Studies on the levels of metals and organic compounds in tissues of fish species exposed to different concentrations of CT water in the laboratory will be conducted.

Levels of organic compounds and metals in lake whitefish (identified KIR species) will also be measured to add to the existing knowledge of field level exposures of fish from the Athabasca River (Table C4.2-6).

Table C4.2-6 Comparison of Chemical Concentrations in Fish Tissue Samples

Chemical	Field Exposure			Laboratory Exposure-Oil Sands Wastewaters			Laboratory Exposure-Athabasca River Water Upstream of Suncor	
	Muskeg River[a] Longnose Sucker (µg/g) Max	Athabasca River[a] Walleye (µg/g) Max	Athabasca River[a] Goldeye (µg/g) Max	10% TID[b] Walleye (µg/g) Max - Lab	10%TID[b] Rainbow trout (µg/g) Max - Lab	10% Upgrader Effluent [c] Rainbow Trout (µg/g) Max - Lab	Athabasca River[d] Walleye (µg/g) Max - Lab	Athabasca River[d] Rainbow trout (µg/g) Max - Lab
PAHS AND SUBSTITUTED PAHs[e]								
Naphthalene	0.4	<0.02[f]	<0.02	<0.02	0.03	<0.02	<0.02	0.02
Methyl naphthalene	0.03	<0.02[f]	<0.02	<0.02	0.03	<0.02	<0.02	0.03
METALS								
Aluminum	11	3	2	12	12	4.1	14	18
Arsenic	<0.5	<0.5	<0.5	1.1	<0.1	0.4	2.3	<0.1
Barium	<0.5	<0.5	<0.5	0.9	<0.5	0.18	0.9	<0.5
Beryllium	<0.5	<0.5	<0.5	<1	<1	<0.2	<1	<1
Boron	<5	<5	<5	<5	<5	<2	<5	<5
Calcium	880	662	627	7660	261	261	7090	2260
Cadmium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.08	<0.5	<0.5
Chromium	<0.5	<0.5	<0.5	<0.5	<0.5	0.5	<0.5	<0.5
Cobalt	<0.5	<0.5	<0.5	<1	<1	<0.08	<1	<1
Copper	<1	1	2	<1	<1	0.91	<1	<1
Iron	16	12	12	<1	4	5	8	23
Lead	<2	<2	<2	<5	<5	0.19	<5	<5
Magnesium	661	321	377	371	302	289	457	380
Manganese	0.9	1.2	<0.5	6.1	0.2	0.21	5.1	0.9
Mercury	-[g]	-[g]	-[g]	0.44	0.03	0.02	0.45	0.04
Nickel	<1	<1	2	<2	<2	0.14	<2	<2
Phosphorus	2,960	2,880	2,590	5,820	2,640	2,130	6,060	3,620
Potassium	5,190	4,880	4,380	4,390	4,880	3,700	5,090	4,840
Selenium	0.3	<0.5	<0.5	0.4	<0.4	0.3	0.4	0.3
Silicon	12	4	7	<50	<50	-[g]	<50	<50
Silver	<0.2	<0.2	<0.2	<1	<1	0.08	<1	<1
Sodium	409	440	360	748	480	452	635	471
Strontium	0.9	0.6	<0.5	8	<1	0.8	8	2
Thallium	<1	<1	<1	<1	<1	<0.04	<1	<1
Tin	<2	<2	<2	<5	<5	<0.08	<5	<5
Vanadium	<1	<1	<1	<1	<1	0.11	<1	<1
Zinc	6	9	6	17.5	10.3	17.7	17.2	8.9

(a) Data from fish sampled by Golder during 1995 (Golder 1996c).
(b) Data from fish exposed to Tar Island Dyke Water (10%) in laboratory (HydroQual 1996a).
(c) Data from fish exposed to upgrader effluent in laboratory (HydroQual 1996b).
(d) Data from fish exposed in laboratory to Athabasca River water taken upstream of Fort McMurray (HydroQual 1996a). These are considered to be background samples.
(e) All other PAHs nondetectable (detection levels range from 0.02 to 0.04 µg/g).
(f) Not detected above detection limits.
(g) No data.

Linkage Between Water Quality and Fish Flavour

Previous investigations conducted for the Steepbank Mine (Golder 1996f, HydroQual 1996b) produced information on the tainting potential of operational and reclamation waters. The studies included Suncor's wastewater treatment system effluent, TID seepage water and Athabasca River water. No tainting was evident in fish exposed to TID seepage water or Athabasca River water (Golder 1996f).

Waters from the upgrader wastewater treatment system were tested twice with varying results. The first test showed upgrading wastewaters could cause tainting at a concentration of 0.5% (Golder 1996f). However, a second study indicated that the wastewater treatment system effluent did not cause tainting in concentrations of 0.01, 0.1 and 1% or after 14-day depuration (HydroQual 1996b). The difference in the results of these two studies is likely due to variability in the quality of the wastewaters.

Wastewater treatment system effluent is currently released from Lease 86/17 in the Athabasca River. However, over the life of the project Suncor plans to reduce the amount of wastewater released to the Athabasca River by at least 50%. Hence, any potential for tainting from the wastewater treatment system waters would be reduced by Project Millennium.

TID seepage water, the reclamation water tested by Suncor, showed no potential to taint. Compounds with the potential to cause tainting (notably PAHs) are expected to be present in CT water. However, concentrations are likely to be below those required to produce off-flavors in fish because CT water has similar levels of organic compounds to TID water (Appendix V). Hence, tainting from CT water is not expected.

There is no evidence to suggest that CT water will cause tainting; therefore, this linkage is considered invalid. However, since tainting has been raised repeatedly as a concern by aboriginal groups and regulators and since there have been no tainting studies on CT water to date, Suncor is committed to follow-up studies to confirm this prediction.

C4.2.8.2 Analysis of Key Question

Based on existing information on levels of chemicals in fish tissue, no accumulation in fish tissue, sufficient to exceed guidelines for human consumption, is expected. Flavour impairment is also not expected. Therefore, no impacts on fish tissue quality are expected.

C4.2.8.3 Residual Impact Classification and Environmental Consequence

Impacts on fish tissue quality are predicted to be negligible in magnitude and of negligible environmental consequence.

C4.2.8.4 Uncertainty and Follow-up Studies

Conclusions regarding the potential for chemical bioaccumulation in fish tissues and tainting of fish tissue via exposure to CT waters are based on previous investigations and the presence of very low concentrations of potential tainting compounds in CT water. Suncor is planning specific testing of representative CT water from Project Millennium to increase the level of confidence in these conclusions.

Tainting studies will be conducted using exposure tanks in a laboratory facility to be established in Fort McMurray. Rainbow trout will be exposed to a series of dilutions of CT water that are representative of a range of possible conditions in the field (i.e., 10%, 1%, 0.1% and 0.01%). After a ten day exposure period, a number of fish will be removed and processed for assessment of tainting.

Taste panels will consist of Fort McMurray and region residents who have been trained in the testing protocol. This procedure involves the following steps:

- initial recruitment of 30 to 40 people;
- selection of participants based on ability to detect taint;
- further training of selected participants (20 total); and
- selection of panelists for the taint assessment (10 people).

The fish tainting protocol that will be used for this study was written by HydroQual Laboratories Ltd. and reviewed by the Department of Fisheries and Oceans. The test was designed to determine the presence and intensity of taint. This procedure will also comply with ASTM Method E 1810-96 and the Pulp and Paper EEM; Recommendation for Cycle 2 (Environment Canada 1997).

C4.2.8.5 Monitoring

Monitoring for bioaccumulation of chemicals in fish tissue will focus on metals and PAHs. Chemical levels in KIRs for the Athabasca River (walleye, lake whitefish, goldeye and longnose sucker) and the Steepbank River (longnose sucker) will be monitored to confirm the predicted negligible impacts on fish tissue chemical levels. Data will also be collected from an upstream reference site for comparison. Since the potential for impacts is low and expected instream concentrations of bioaccumulative chemicals are also low, fish tissue monitoring will be confirmatory only and will be done infrequently (e.g., once every five years).

Fish tainting in the Athabasca River will not be monitored unless results of the CT water tainting test indicate that CT water causes tainting.

C4.2.9 Key Question F-5: What Type of Aquatic Ecosystem is Expected in Project Millennium Reclamation Streams, Wetlands and the End Pit Lake?

C4.2.9.1 Conceptual Design

Design of the end pit lake is described in Section E3.2.6. The lake will be about 883 ha size including the littoral zone which is about 191 ha. The average depth will range from 65 to 100 m (Figure E-4). The end pit lake will receive runoff from streams and wetlands from the reclaimed landscape (Figure E-2). At closure, its outlet will connect to McLean Creek by a channel that is several kilometres long.

The end pit lake will be designed to evolve into a productive, self-sustaining aquatic ecosystem. To achieve this goal, the following parameters will be incorporated into the design:

- use of upslope runoff (Wood Creek drainage) to maintain water levels after closure;
- inclusion of approximately 20% of the surface area as a littoral zone composed of shallow wetlands and shoreline areas; and
- wetlands/fish habitat areas will be incorporated into locations where streams discharge into the lake (e.g., Wood Creek, drainage stream from the reclaimed tailings pond area and drainage streams from reclaimed CT deposit areas.

The inclusion of shallow littoral areas into the design of end pit lake should allow for the establishment benthic invertebrate populations and aquatic vegetation, which would be important for populations of vegetation-dependent fish species. Once the water of the end pit lake is determined to be productive, non-toxic to aquatic biota and to support benthic invertebrates, stocking of fish species into the lake could be initiated by Suncor. The species that would be stocked would be dictated by the limnological characteristics of the waterbody, the habitat requirements of the candidate fish species and consultation with regulatory authorities and other interested stakeholders.

Constructed wetlands will also form part of the closure landscape (Figure C2.2-12). These wetlands will be shallow open water areas about 1.5 to 2 m deep with a littoral zone. The wetlands range in size from 33 to 88 ha, which includes about 30% littoral zone. Three of these wetlands will be connected to the end pit lake through small intermittently flowing streams. There will also be three constructed wetlands that will connect to Unnamed Creek by intermittent streams. The design of these wetlands will allow for the eventual development of productive aquatic ecosystems.

It is doubtful that fish from watercourses in the local study area will utilize the constructed wetlands since the wetlands are located on the escarpment. Fish access to the escarpment is usually prevented by natural barriers such as beaver dams. However, if fish were stocked into the end pit lake they would be able to utilize these wetland habitats when connecting streams were flowing.

C4.2.9.2 Potential for Long-Term Viability of the Aquatic Ecosystem

Water quality in the end pit lake is described in Section C3.2. Water quality predictions indicate that the lake will not be acutely or chronically toxic to aquatic biota once it is full (by 2044) (Section C3.2). Two parameters were examined with respect to aquatic biota: naphthenic acids and total dissolved solids. Naphthenic acids are expected to drop to non-toxic levels by 2044. Total dissolved solids concentrations are expected to vary from 335 mg/L to over 1180 mg/L. These salt levels would not be expected to affect lake productivity or the potential diversity of aquatic macrophytes (Section C3.3).

A number of issues with respect to long-term viability of an ecosystem in the lake were identified in the Surface Water Quality Section C3.2, including stratification potential, nutrient status, and the period of time over which water quality will improve.

Design criteria would be established for the desired fish species. Habitat would be designed to increase the suitability of the lake for the target sports fish and non-sports fish species. Appropriate amounts of spawning, rearing, feeding and overwintering habitat need to be established to provide for self-sustaining fish populations. Features such as peninsulas, islands and spawning shoals could be incorporated into the design of the lake.

Before establishing fish in the lake, the potential for effects on fish health, tainting and bioaccumulation would have to be further assessed. Available information indicates that it is unlikely that exposure to CT water will cause significant bioaccumulation or tainting. However, the follow-up studies identified in Section C4.2.6 and C4.2.8 will provide information to confirm these predictions.

The conceptual features of the lake (i.e., littoral zone, development of a non-toxic aquatic environment) indicate that it is likely that an aquatic ecosystem would be viable. However, the following issues require further evaluation (in addition to those discussed in Section C3.2):

- naphthenic acid degradation rate;
- potential for health effects, bioaccumulation and tainting in fish; and
- sources of toxicity in CT water.

Suncor is committed to participate in research to ensure that the end pit lake meets regulatory and stakeholder goals. This is an issue facing all oil sands operators and will be addressed through a coordinated effort.

C4.2.9.3 Residual Impact and Environmental Consequence

The end pit lake is likely to support a viable aquatic ecosystem and provide a positive benefit in terms of aquatic habitat. However, there are several issues that require further evaluation. Hence this impact is rated as undetermined.

C4.2.9.4 Monitoring

The monitoring program for the end pit lake will be developed once a detailed design is produced.

C4.3 FISHERIES AND FISH HABITAT CONCLUSION

C4.3.1 Introduction

Project Millennium has been designed to mitigate fisheries and fish habitat impacts by:

- avoidance of habitat impacts in the Athabasca River, in part by ensuring a minimum 100 m setback from the river;
- avoidance of impacts in the Steepbank River (minimal disturbance of watershed, 100 m setback from the escarpment);
- recycling of all process-affected waters throughout construction and operation of the Project, thereby reducing any additional raw water withdrawal from the Athabasca River;
- using water retention structures to regulate flows and control sediment in muskeg drainage and other water diversions;
- reducing by at least 50%, the existing discharge from the wastewater treatment system;
- distributing muskeg drainage and overburden dewatering evenly throughout the life of the mine to avoid a large increase in flows to receiving streams;
- developing a sustainable closure landscape and drainage systems by:
  - vegetating reclaimed surfaces to minimize surface erosion,
  - building drainage systems to minimize gully and channel erosion,
  - constructing wetlands and lakes to reduce flood peak discharges and sediment loadings to receiving streams; and
- developing wetlands systems on the reclaimed CT deposit areas, the reclaimed tailings pond area as well as in conjunction with reclamation drainage systems to provide retention and bioremediation of operational and reclamation waters.

The removal of Wood and Leggett creeks and alteration of Shipyard Lake and McLean Creek fish habitats is addressed through a "No Net Loss" plan for fish habitat.

The fisheries and fish habitat impact assessment predicted the incremental effects of the Project on top of existing and approved oil sands operations. The assessment considered the issues, as addressed through the key question approach in Section C4.2 of the EIA. The issues and environmental consequences are summarized in Table C4.3-1.

Table C4.3-1 Fisheries and Fish Habitat Issues and Environmental Consequences

Issue	Environmental Consequence
Fish habitat	Negligible
Levels of acute or chronic toxicity to fish	Negligible
Fish abundance	Negligible
Fish tissue quality	Negligible
Aquatic ecosystems in reclamation streams, wetlands and the end pit lake	Undetermined

C4.3.2 Impact Assessment

Fish Habitat

No effects on fish or fish habitat in the Steepbank River are expected from Project Millennium. The Project occupies a very small portion of the Steepbank River watershed and will not affect the hydrology of this river. Overburden dumps and Pit 1 are located just south of the Steepbank River. However, erosion protection will be put in place to prevent sedimentation and the area will be reclaimed rapidly. There will be a minimum 100 m setback of all mining activities from the Steepbank River escarpment.

Fish habitat in the Athabasca River will not be affected by Project Millennium. Very small changes in flow will occur in the Athabasca River, which are not expected to influence fish habitat. All project facilities located near the Athabasca River will be placed above the 1-in-100 year floodline. As well, erosion protection will be put in place to prevent sediment from entering the river.

No impacts on northern pike and forage fish habitat in Shipyard Lake are predicted. Suncor will monitor water quality and quantity in Shipyard Lake and adjust the inflows to the lake to maintain fish habitat.

McLean Creek will receive increased flows from diversion of the upper catchment of Wood Creek, as well as waters from muskeg and overburden dewatering operations. However, mitigation such as water retention structures and creek stabilization procedures will be incorporated into the project design to prevent impacts to fish habitat in this creek. Hence, no impacts on Arctic grayling habitat in McLean Creek are expected to result from the Project. Suncor will monitor habitat in McLean Creek and implement additional mitigation if necessary.

Two small Athabasca River tributaries, Leggett and Wood creeks, will be lost due to Project Millennium. This will result in about 1.2 ha of fish habitat loss since the lower portions of these creeks (below the escarpment) are used by fish from the Athabasca River. The habitat in these creeks is used by forage fish, juvenile mountain whitefish and possibly Arctic grayling. Suncor is committed to a fish habitat compensation program. Fish habitat will be replaced concurrent with habitat loss and monitored to ensure that the "No Net Loss" objective is achieved.

Therefore, the environmental consequences of impacts of the Project on fish habitat was assessed as negligible because of no net loss of fish habitat.

Acute and Chronic Effects on Fish

Water quality modelling indicates that no toxic effects on fish or other aquatic organisms will result from Project Millennium because modelled concentrations of acute and chronic toxicity are less than guidelines for the protection of aquatic life. These results are based on recent laboratory testing of CT water toxicity, which included different levels of the aquatic food chain: bacteria, algae, invertebrates and fish. These tests have provided information on growth and survival of fish exposed to CT water. Other aspects of CT effects on fish health (e.g., disease resistance, embryo survival) have not been examined. However, it is assumed that the acute and chronic toxicity tests are adequate predictors of effects on fish health parameters. This assumption was shown to be valid for TID seepage waters, which have comparable characteristics. Suncor plans to conduct further studies on the effect of CT water on fish health to confirm this assumption. The studies will be conducted in Fort McMurray, and will include exposure of fish to concentrations of CT water that are representative of concentrations predicted to occur in the local study area.

Therefore, the environmental consequences of residual impacts of the Project on acute or chronic toxicity was assessed as negligible.

Fish Abundance

The Project is not predicted to have any impact on fish habitat or on increased acute or chronic toxicity to fish, thus it will not have any impact on fish abundance.

As well, changes in fishing are not anticipated during operations since access to the Steepbank River via the Suncor bridge will be restricted. At closure access may be increased if the bridge remains. However, it is assumed that decreases in fish abundance from angling will be prevented by appropriate enforcement of legislation by Fisheries Management Division of Alberta Environmental Protection.

Therefore, the environmental consequence of the Project on fish abundance is negligible.

Fish Flavour

People living in the oil sands region have expressed concern that Project Millennium will negatively affect (i.e., taint) the flavour of fish from the Athabasca and Steepbank rivers. Suncor has conducted studies on various waters from their operation to determine if they cause tainting in fish. Wastewater treatment system effluent and seepage from Tar Island Dyke (TID) were tested along with Athabasca River water from upstream of Suncor. The tests showed that TID seepage and Athabasca River water did not cause tainting (Golder 1996f). Waters from the wastewater treatment system were tested twice with varying results. The first test showed upgrader wastewaters could cause tainting at a concentration of 0.5% (HydroQual 1996b). However, a second study indicated that the upgrader wastewater did not cause tainting (HydroQual 1996b). The difference in the results of these two studies is likely due to variability in the quality of the wastewaters. As part of Project Millennium, Suncor plans to reduce, by at least 50%, the amount of wastewaters released to the Athabasca River. Hence, any potential for tainting from the wastewater treatment system waters would be reduced by Project Millennium.

Since the levels of tainting compounds in CT water are similar to those in TID water, it is unlikely that CT water from the Project would cause tainting in fish. However, to confirm this prediction and to address concerns voiced by aboriginal people and Fort McMurray residents, Suncor will conduct a tainting study of CT water in conjunction with the planned fish health study. The tainting study will be conducted in Fort McMurray with a taste panel consisting of people from the region.

Therefore, the environmental consequences of residual impacts of the Project on fish tissue flavour are predicted to be negligible because any impacts are negligible in magnitude.

Chemicals in Fish Tissue

Fish exposed to oil sands waters in the laboratory, as well as fish captured from the Athabasca River near Suncor showed very limited uptake of organic chemicals such as polycyclic aromatic hydrocarbons (PAHs). Very few heavy metals were detectable in fish flesh. Mercury was present in low levels in fish exposed to oil sands waters but not in levels higher than those in fish from the Athabasca River. These studies show that the potential for bioaccumulation of chemicals in fish is low. It is unlikely that the Project will result in direct effects on fish or cause exceedances of guidelines for human consumption of fish.

No studies have been conducted on the potential for chemicals from CT water to accumulate in fish. Levels of PAHs and metals in CT water are similar to those found in TID water, which has already been tested. However, since fish tissue quality is an issue that directly relates to people's use of this resource from the local study area, Suncor is committed to follow-up studies to confirm this prediction. Bioaccumulation studies on CT water will be conducted in conjunction with the fish health studies.

Chemical levels in fish from the Athabasca and Steepbank rivers will also be monitored by Suncor. This will likely be done in cooperation with other oil sands operators as part of the oil sands Regional Aquatics Monitoring Program (RAMP).

The residual impacts of the Project on chemicals in fish tissue was assessed as negligible in magnitude. Therefore, the environmental consequence is rated as negligible.

Reclamation Streams, Wetlands and End Pit Lake

The end pit lake and reclamation drainage system will be designed to evolve into a productive, self-sustaining ecosystem. A 20% littoral zone, consisting of shallow wetlands and shoreline areas, will be incorporated in the end pit lake to enhance productivity and provide fish habitat. Several constructed wetlands will also provide aquatic habitat. As discussed in Water Quality impact assessment, the end pit lake will be managed so that once it is filled, it is non-toxic to aquatic life. Research conducted to date indicates it is likely that the reclamation drainage systems will support aquatic ecosystems.

Suncor recognizes that there are a number of issues that will need to be addressed to demonstrate long-term ecological viability of the end pit lake and reclamation streams. For example, potential for tainting, bioaccumulation and effects on fish health would have to be addressed prior to fish being introduced to the lake. Suncor is committed to participate in research to ensure that the end pit lake meets regulatory and stakeholder end land use goals. Since these issues are common to all oil sands operators, Suncor will cooperate with other companies to address them.

The end pit lake is likely to support a viable aquatic ecosystem. However, because of uncertainties about the design and functioning of this system, the environmental consequence is rated as undetermined.

Monitoring

The Fisheries and Fish Habitat impact assessment was based on mitigation inherent in the Project Millennium design. Negligible impacts are expected on fisheries and fish habitat. However, there are some uncertainties. Suncor will address these uncertainties by further studies or monitoring as appropriate. Follow-up studies and monitoring include:

- survey of Arctic grayling spawning in the mouths of Wood and McLean creeks to determine fish utilization of these creeks;

- evaluation of compensation options, and habitat design and construction to 1 of a fish health laboratory study on CT water using trophic level toxicity testing and chemical analyses of CT water to confirm:
  - no acute or chronic effects on fish,
  - determine links between acute and chronic effects and other fish health parameters, and
  - confirm prediction of no bioaccumulation in fish tissue;
- monitoring of fish health and abundance, including fish tissue chemical residue analyses, as part of RAMP; to include walleye, goldeye, longnose sucker and lake whitefish in the Athabasca River and longnose sucker in the Steepbank River; and
- development of a plan to confirm end pit lake ecosystem viability once the design for the lake is finalized.

C5 AQUATICS CUMULATIVE EFFECTS ASSESSMENT

C5.1 INTRODUCTION

This CEA predicts the effects of Project Millennium plus existing, approved and planned developments on surface water quality in the RSA. The following developments were included in this analysis (Figure A2-8):

- Suncor Lease 86/17
- Suncor Steepbank Mine/Fixed Plant Expansion
- Suncor Project Millennium
- Shell Muskeg River Mine
- Shell Lease 13 East
- Syncrude Mildred Lake
- Syncrude Aurora Mine
- SOLV-EX
- Mobil Kearl Oil Sands Mine
- upstream water quality

Descriptions of these developments and the assumptions applicable to each for this CEA are provided in Section A2.3. The water quality predictions presented in this section are used to assess cumulative effects on terrestrial resources (Section D6) and human health (Section F1.4).

The following overall key question is addressed in this CEA:

CA-1: What impacts to the Athabasca River will result from changes in hydrogeology, surface water hydrology, surface water quality, and fisheries and fish habitat associated with Project Millennium and the combined developments?

Additional questions (sub-key questions) were formulated to address individual issues pertaining to this overall key question. Results of analyses to address each sub-key question were then combined to address the overall key question.

The CEA assessed the impacts of discharges from oil sands operations on the Athabasca River only. This is consistent with the approach outlined in Section A2.3, since the Athabasca is the only waterbody in the RSA that will receive discharge waters from the Project and other developments.

C5.2 SURFACE HYDROLOGY AND HYDROGEOLOGY

No additional water withdrawal from the Athabasca River is required for Project Millennium during operations. Therefore, there will be no effect on the river hydrology beyond the existing levels. Similarly, the impacts from hydrogeology are minor.

The change in flow to the Athabasca River for various times in the Project life cycle from both surface water and groundwater sources by basin and year is presented in Table C5-1. As shown, the maximum change in flow is less than 0.03% of the mean annual flow in the Athabasca River throughout the mine life. Low flows from surface water in the local study area are estimated to be zero for all periods rarer than the 1 in 10 year drought.

Table C5-1 Summary of Changes in Flow to Athabasca River

Year	Shipyard Lake (L/s)	Unnamed Creek (L/s)	Leggett Creek (L/s)	Wood Creek (L/s)	McLean Creek (L/s)	Total (L/s)	Net Change (L/s)	Net Change / Athabasca River[a] (%)
Baseline	154	142	70	205	154	725	-	
2002	238	222	-	-	344	804	79	0.01%
2012	121	107	-	-	459	686	-39	-0.01%
2018	63	49	-	-	445	557	-168	-0.03%
2025	64	49	-	-	439	551	-174	-0.03%
2033	64	49	-	-	366	479	-246	-0.04%
Far Future	154	142	1	1	420	730	-5	0.00%

(a) Athabasca River mean annual flow: 655,000 L/s

These changes are low magnitude, local geographic extent, long-term and irreversible. The environmental consequence is negligible. There is no cumulative impact from these sources.

C5.3 WATER QUALITY

C5.3.1 Sub-Key Questions

The following sub-key questions apply to the water quality CEA:

WQCEA-1: **What impacts will water releases from Project Millennium and the combined developments have on water quality and toxicity guideline attainment in the Athabasca River?**

WQCEA-2: **What impacts will Project Millennium and the combined developments have on levels of PAHs in sediments in the Athabasca River?**

WQCEA-3: **What impacts will acidifying emissions from Project Millennium and the combined developments have on regional waterbodies?**

Some of the Impact Assessment key questions are not relevant for the CEA. Questions related to thermal regimes of waterbodies (WQ-2), dissolved oxygen levels in small streams (WQ-3) and end pit lake (EPL) water quality (WQ-5) are not relevant for this CEA for the following reasons:

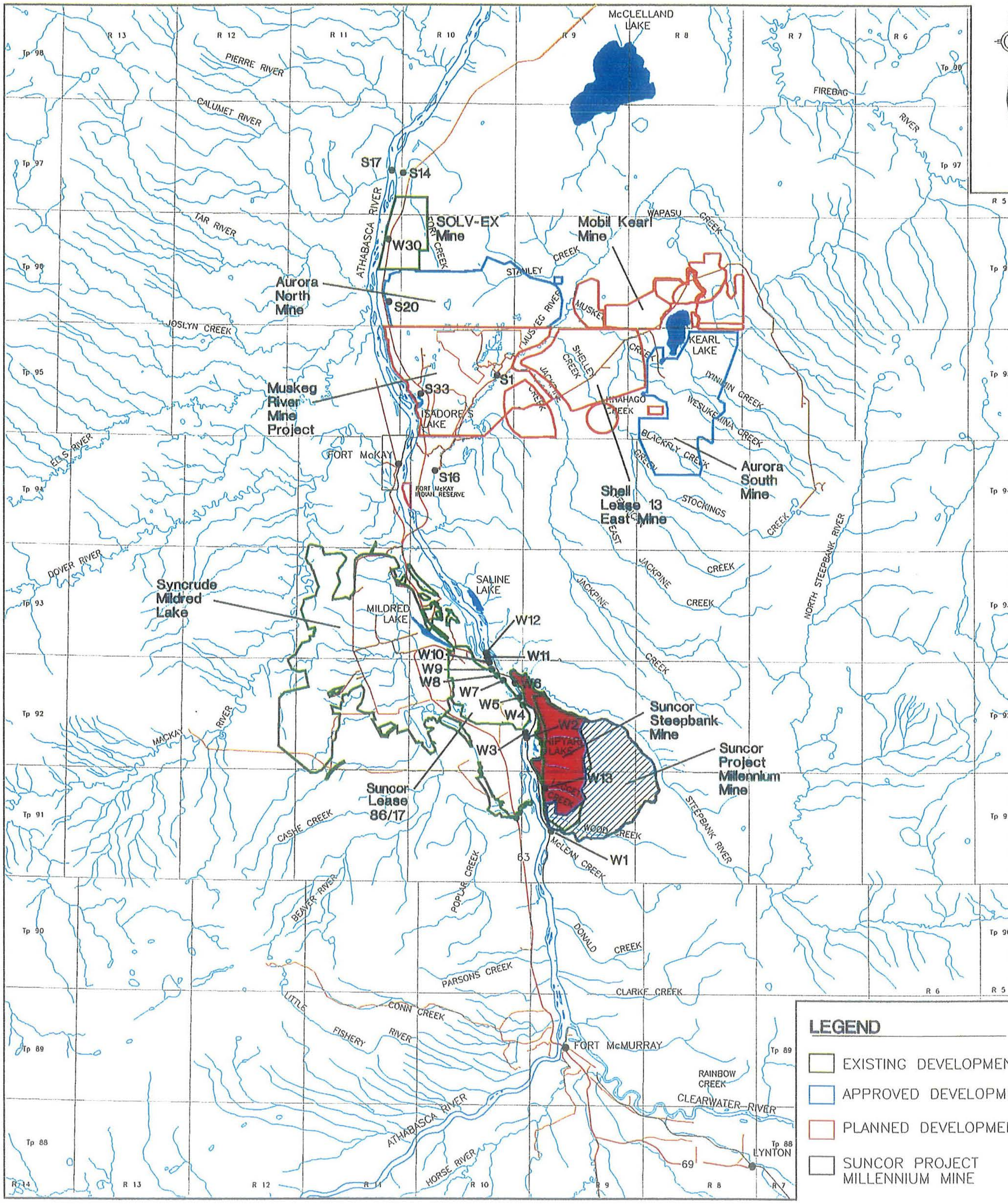
- Additional developments included in the CEA will not affect thermal regimes or dissolved oxygen levels in waterbodies influenced by the Project; and
- Water quality of the Project EPL will not be affected by additional developments included in the CEA. However, future discharges from all EPLs in the RSA were considered during the CEA, under sub-key question WQCEA-1, to predict combined effects on water quality of the Athabasca River.

C5.3.2 Methods

The approach used to assess cumulative effects on water quality was the same as that described in the Water Quality Impact Assessment (Section C3.2).

To model cumulative effects on water quality in the Athabasca River, Project-related activities and water releases that may affect surface water quality were considered to apply to the additional developments included in the CEA (Figure C5-1), in the form of additional discharges to the river. The same time snapshots were used for the CEA as for the Impact Assessment (Section C3.2.4.3). Model input data (flow rates and water chemistry) for additional developments were consistent with the Steepbank, Aurora and Muskeg River Mine EIAs (Golder 1996d, BOVAR 1996a, Shell 1998). Additional details of the Athabasca River model are provided in Appendix V.

Sub-key questions related to accumulation of PAHs in sediments and acidification of surface waters were addressed based on results of air quality modelling, available information in the scientific literature and information presented in the Impact Assessment (Section C3.2).



SUNCOR ENERGY

Project Millennium
Taking Suncor into the 21st Century

WATER QUALITY MODELLING NODES FOR CUMULATIVE EFFECTS ASSESSMENT

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

16 Apr. 1998	Figure C5-1	DRAWN BY: RFM/TM

C5.3.3 Sub-Key Question: WQCEA-1: What Impacts Will Water Releases From Project Millennium and the Combined Developments Have on Water Quality and Toxicity Guideline Attainment in the Athabasca River?

C5.3.3.1 Analysis of Key Question

Results are presented in Appendix V for each substance modelled during each snapshot and flow condition in the Athabasca River. Summary tables, as discussed below, provide results for toxicity concentrations and

exceedances of water quality guidelines, the majority of which are due to background levels of the substances in question. The values shown in the summary tables represent the highest concentrations predicted in all snapshot years simulated. Contour plots of substance concentrations predicted to exceed guidelines in the Athabasca River are presented in Appendix V. Results are subsequently discussed under "Significance of Water Quality Guideline Exceedances." Summary tables for the Athabasca River provide the following information for acute and chronic toxicity and for substances that would exceed water quality guidelines:

- the existing concentration upstream of Fort McMurray, as measured during baseline studies or monitoring;
- predicted concentration at 10% river width (on both sides of the river), resulting from existing and approved oil sands developments;
- the effects of Project Millennium at 10% river width (on both sides of the river), in combination with existing and approved oil sands developments;
- the combined effects at 10% river width (on both sides of the river), of existing, approved and proposed oil sands developments (Figure C5-1 illustrates all operations included in the CEA analysis); and
- the water quality guidelines associated with each substance.

Mean Open-Water Flow in Athabasca River

Model results indicate that during mean open-water flow, most water quality guidelines are maintained during all time snapshots (Appendix V, Table V-14). Table C5-2 provides the concentrations of substances that would exceed water quality guidelines. Acute and chronic toxicity values shown in Table C5-2 represent the highest concentrations predicted for all snapshot years simulated; no exceedances of toxicity guidelines would occur. Dispersion model contour plots of all substances discussed in Table C5-2 are presented in Appendix V, Figures V-30 to V-40.

Table C5-2 Predicted Substance Concentrations Compared With Water Quality Guidelines at Mean Open-Water Flow in the Athabasca River

Substance	Upstream Fort McMurray[a]	Existing plus Approved[b]	Project Millennium[c]	CEA[d]	Guideline[e]	Comments on CEA[f]
aluminum (mg/L)	0.68 (<0.005 - 11.4)	0.68	0.68	0.68	0.1 C	exceedance of C guideline is a result of existing river conditions; concentrations are the same in all time snapshots
arsenic (mg/L)	0.001 (0.0003 - 0.0125)	0.002	0.002	0.002	0.01 C 0.000018 HC	exceedance of HC guideline is a result of existing river conditions; concentrations are the same in all time snapshots
benzo(a) anthracene (mg/L)	n.d.	0.0000048	0.0000057	0.0000066	0.0000028 HC	highest concentrations projected from 2044 to far future, primarily due to sand and CT seepage from downstream operations
iron (mg/L)	3.0 (0.25 - 10.7)	3.0	3.0	3.0	1.0 C 0.3 HNC	exceedance of C and HNC guidelines are a result of existing river conditions; concentrations are the same in all time snapshots
manganese (mg/L)	0.4	0.4	0.4	0.4	0.05 HNC	exceedance of HNC guideline is a result of existing river conditions; concentrations are the same in all time snapshots
mercury (mg/L)	0.0001 (<0.00004 - 0.0001)	0.0001	0.0001	0.0001	0.000012 C 0.00014 HNC	exceedance of C and HNC guidelines are a result of existing river conditions; concentrations are the same in all time snapshots
acute toxicity (TUa)	0	0.008	0.004	0.004	0.3 A	acute toxicity guideline maintained; projected drop in acute toxicity levels results from CT water previously released from Steepbank Mine now being used in Project operations
chronic toxicity (TUc)	0	0.05	0.03	0.03	1.0 C	chronic toxicity guideline maintained; projected drop in chronic toxicity levels results from CT water previously released from Steepbank Mine now being used in Project operations and reduced upgrader wastewater flows from Suncor Lease 86/17 Mine Site

NOTES:

[a] Upstream concentrations taken from Golder (1997d); n.d. = non-detectable.

[b] Concentrations at 10% river width resulting from Suncor Lease 86/17, Steepbank, Syncrude Mildred Lake, Aurora Mine and SOLV-EX.

[c] Concentrations at 10% river width resulting from Suncor Lease 86/17, Steepbank, Syncrude Mildred Lake, Aurora Mine, SOLV-EX plus Project Millennium.

[d] Concentrations at 10% river width resulting from Suncor Lease 86/17, Steepbank, Syncrude Mildred Lake, Aurora Mine, Project Millennium plus Muskeg River Mine, Shell East, Mobil Kearl Oil Sands Mine.

[e] A = Aquatic Life Acute, C = Aquatic Life Chronic, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen.

[f] Comments refer to CEA results.

Annual 7Q10 Flow in Athabasca River

Model results indicate that during 7Q10 flow, most water quality guidelines are maintained during all time snapshots (Appendix V, Table V-15). Table C5-3 provides the concentrations of substances that would exceed water quality guidelines. Acute and chronic toxicity values shown in Table C5-3 represent the highest concentrations predicted for all snapshot years simulated; no exceedances of toxicity guidelines would occur. Dispersion model contour plots of all substances discussed in Table C5-3 are presented in Appendix V, Figures V-30 to V-40.

Table C5-3 Predicted Substance Concentrations Compared With Water Quality Guidelines at Annual 7Q10 Flow in the Athabasca River

Substance	Upstream Fort McMurray[a]	Existing plus Approved[b]	Project[c]	CEA[d]	Guideline[e]	Comments on CEA[f]
mercury (mg/L)	0.0001 (<0.00004 - 0.0001)	0.0001	0.0001	0.0001	0.000012 C	exceedance of C guideline is a result of existing river conditions; concentrations are the same in all time snapshots
acute toxicity (TUa)	0	0.02	0.01	0.01	0.3 A	acute toxicity guideline maintained; projected drop in acute toxicity levels results from CT water previously released from Steepbank Mine now being used in Project operations
chronic toxicity (TUc)	0	0.14	0.07	0.07	1.0 C	chronic toxicity guideline maintained; projected drop in chronic toxicity levels results from CT water previously released from Steepbank Mine now being used in Project operations and reduced upgrader wastewater flows from Suncor Lease 86/17 Mine Site

NOTES:
(a) Upstream concentrations taken from Golder (1997d).
(b) Concentrations at 10% river width resulting from Suncor Lease 86/17, Steepbank, Syncrude Mildred Lake, Aurora Mine and SOLV-EX.
(c) Concentrations at 10% river width resulting from Suncor Lease 86/17, Steepbank, Syncrude Mildred Lake, Aurora Mine, SOLV-EX plus Project Millennium.
(d) Concentrations at 10% river width resulting from Suncor Lease 86/17, Steepbank, Syncrude Mildred Lake, Aurora Mine, Project Millennium plus Muskeg River Mine, Shell East, Mobil Kearl Oil Sands Mine.
(e) A = Aquatic Life Acute, C = Aquatic Life Chronic.
(f) Comments refer to CEA results.

Significance of Water Quality Guideline Exceedances

There are several lines of evidence that suggest that these exceedances are of limited environmental consequence. These are briefly discussed below.

Of the substances identified above, aluminum, arsenic, iron, manganese and mercury frequently exceed water quality guidelines under natural, background conditions in the RSA. Predicted concentrations of these metals from combined developments generally fall into the natural ranges in watercourses in the RSA, as summarized in Section C3.1. Naturally elevated levels of metals are usually not considered to be of concern in surface waters.

As discussed in Section C3.2.5.2, available metals data suggest that for the majority of metals that would exceed water quality guidelines, the bioavailable fraction would likely be considerably lower than suggested by predicted total metal concentrations. The predicted concentrations of substances that tend to be bound to particulates are conservative, since no reduction in these metals was assumed during modelling, even though most of the particulates would settle in sedimentation ponds, EPLs and wetlands, or would be trapped as seepage waters traveling through the ground. As well, modelling was carried out using conservative, worst-case assumptions regarding concentrations of substances in release waters and flows of release waters. Therefore, actual concentrations will likely be lower than those predicted, with the exception of periods of extreme low flow.

The benzo(a)anthracene group would exceed the human health water quality guideline. However, it is anticipated that these PAHs would also be tightly bound to particulates and would settle out in EPLs, or be trapped by soil particles as seepage moves through the ground. As in Section C3.2.5.2, the predicted guideline exceedance by the benzo(a)anthracene group was brought forward for further screening under the human health section (F1.4). The analysis in Section F1.4 indicates that the risks posed to human health by these compounds would be very low.

Based on the above information, it is concluded that operational and reclamation water releases from the combined developments have limited potential to affect the environmental quality of the Athabasca River, despite the water quality guideline exceedances predicted by modelling.

C5.3.3.2 Uncertainty

Substance concentrations described in this EIA were predicted using available information and conservative assumptions. As a result, there is some uncertainty inherent in the reported values.

C5.3.3.3 Residual Impact Classification

The predicted impacts of operational and reclamation water releases during mean open-water flow and annual 7Q10 flow are classified as negligible in magnitude, long-term in duration, moderate in frequency, regional in geographic extent and irreversible, with a low degree of scientific uncertainty (Table C5-4). The environmental consequence of these impacts is low.

Table C5-4 Residual Impact Classification for Water Quality Guideline Exceedances

Impact	Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Scientific Uncertainty	Environmental Consequence
Mean open-water flow in the Athabasca River	Negligible	Long-Term	Moderate	Regional	Irreversible	Low	Low
Annual 7Q10 flow in the Athabasca River	Negligible	Long-Term	Moderate	Regional	Irreversible	Low	Low

C5.3.3.4 Monitoring

The proposed monitoring plan for the Athabasca River will be finalized upon review by regulatory agencies and acceptance by the joint industry Regional Aquatic Monitoring Program (RAMP).

C5.3.3.5 Mitigation

In the event that monitoring detects unacceptable changes in water quality caused by water releases from the Project, mitigation would be applied in the form of increasing the retention time of sedimentation ponds and wetlands. This would enhance degradation or settling of chemicals that may affect aquatic life in the Athabasca River.

C5.3.4 Sub-Key Question WQCEA-2: What Impacts Will Project Millennium and the Combined Developments Have on Levels of PAHs in Sediments in the Athabasca River?

C5.3.4.1 Analysis of Key Question

There is no additional information to that presented under Key Question WQ-4 (Section C3.2.8) in the Impact Assessment to address this sub-key question. However, the information in Section C3.2.8 also applies to the CEA.

Based on the weight of evidence provided in under Key Question WQ-4, it is unlikely that PAHs released from combined oil sands developments will result in substantial accumulation in sediments of surface waters.

C5.3.4.2 Uncertainty

Understanding of this issue is limited at this time, which highlights the necessity of further studies. Because this is a regional issue, these studies should be cooperative, sponsored by all oil sands developments in the RSA.

C5.3.4.2 Uncertainty

Understanding of this issue is limited at this time, which highlights the necessity of further studies. Because this is a regional issue, these studies should be cooperative, sponsored by all oil sands developments in the RSA.

C5.3.4.3 Residual Impact Classification

The predicted impact of PAH releases resulting from the combined developments on sediment levels is classified as negligible in magnitude, long-term in duration, high in frequency, regional in geographic extent and irreversible (Table C5-5). The environmental consequence of this impact is low.

Table C5-5 Residual Impact Classification for PAH Accumulation in Sediments

Impact	Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Environmental Consequence
PAH accumulation in sediments	Negligible	Long-Term	High	Regional	Irreversible	Low

C5.3.4.4 Monitoring

The accumulation of PAHs in sediments will be monitored as part of the RAMP. Specific aspects of sediment monitoring will be finalized upon program approval by regulatory agencies.

C5.3.5 Sub-Key Question WQCEA-3: What Impacts Will Acidifying Emissions From Project Millennium and the Combined Developments Have on Regional Waterbodies?

C5.3.5.1 Analysis of Key Question

Analysis presented in the Impact Assessment under Key Question WQ-6 (Section C3.2.10) also applies to the CEA. The difference between air quality model results for the CEA and those presented in the Impact Assessment consists of an increase in the area of exceedance of the Critical Load under the CEA (from 90 x 150 km to 120 x 170 km; Section B4 - Air Quality CEA).

C5.3.5.2 Uncertainty

This analysis is subject to a high degree of uncertainty. Sources of uncertainty are identified in Section C3.2.10.

C5.3.5.3 Residual Impact Classification

Acidification of lakes is classified as low in magnitude, long-term in duration, high in frequency, regional in geographic extent and reversible (Table C5-6). The environmental consequence of this impact is low.

Spring pH depression in streams is classified as low in severity, long-term in duration, moderate in frequency, regional in geographic extent and reversible (Table C5-6). The environmental consequence of this impact is low.

Table C5-6 Residual Impact Classification for Changes in Water Quality Caused by Acidifying Emissions

Impact	Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Environmental Consequence
Acidification of lakes	Low	Long-Term	High	Regional	Reversible	Low
Spring pH depression in streams	Low	Long-Term	Moderate	Regional	Reversible	Low

C5.3.5.4 Monitoring

Monitoring will be undertaken under the RAMP to strengthen the available baseline database and to assess long-term trends in water quality. Intensive, short term monitoring during the critical snowmelt period will evaluate the sensitivity of selected rivers and streams to spring acid pulses. Details of the monitoring program will be finalized upon review by regulatory agencies.

C5.4 FISHERIES AND FISH HABITAT

C5.4.1 Sub-Key Questions

The following sub-key questions apply to the fisheries and fish habitat CEA:

FCEA-1: What impacts to fish habitat will result from Project Millennium and the combined developments?

FCEA-2: What impacts will Project Millennium and the combined developments have on levels of acute or chronic toxicity to fish?

reclamation streams, wetlands and EPL does not apply to the CEA since it is site specific. However, water quality of the EPL and its potential effect on fish in the Athabasca Rivers is addressed through inclusion in the water quality modelling.

Figures C4.2-1 and C4.2-2 are the linkage diagrams for potential changes in fisheries and fish habitat for the Project. The linkages that apply to the CEA include change in access, waterbody areas, streamflow, sediment loading, water quality and benthic invertebrates.

C5.4.2 Methods

The approach used to assess cumulative effects on fisheries and fish habitat was the same as that described in Section C4.2.1.

The fisheries and fish habitat CEA is focused on potential impacts to the Athabasca River since there are no additional developments within the Steepbank River, Shipyard Lake or small Athabasca River tributary watersheds. The only question that addresses potential impacts outside of the Athabasca River is FCEA-1, which addresses regional fish habitat impacts.

C5.4.3 Sub-Key Question FCEA-1: What Impacts to Fish Habitat Will Result From Project Millennium and the Combined Developments?

C5.4.3.1 Analysis of Key Question

Athabasca River

Flow, sediment loading and benthic invertebrates (through changes in water quality) are aspects of Athabasca River fish habitat that could be affected by Project Millennium and the combined developments.

No impacts on sediment loads in the Athabasca River are expected from Project Millennium (Section C4.2). Hence, no further analysis of sediment loads from the combined developments is required.

No additional water withdrawal from the Athabasca River is required for Project Millennium during operations. Other changes in hydrology and hydrogeology from the Project result in less than 0.03% change in the Athabasca River mean annual flow and no change in low flow (Section C5.2). Hence, no effects on fish habitat in the Athabasca River are expected from Project Millennium. Since there are no effects on Athabasca River flow from the Project, no further analysis of the combined developments is required.

As well, results of water quality analyses show no acute or chronic effects on aquatic biota as a result of Project Millennium and the combined developments. Therefore, no impacts on Athabasca River benthic invertebrates would be expected.

No effects on fish habitat in the Athabasca River are expected in relation to Project Millennium and the combined developments.

Habitat Loss From Small Tributaries in RSA

Impacts on fish habitat in Shipyard Lake, Shipyard Creek and McLean Creek from Project Millennium will be prevented through mitigation. No other planned or approved developments are expected to impact these waterbodies.

As described in Section C4.2.5, approximately 1.2 ha of fish habitat in the lower reaches of Wood and Leggett creeks will be lost as a result of project Millennium. However, Suncor will mitigate for habitat loss in these creeks by creating new habitat or enhancing existing habitat. The quality and quantity of habitat created/enhanced will be determined in consultation with Department of Fisheries and Oceans (DFO) to ensure that the "no net loss" objective is achieved. Habitat creation/enhancement will occur at the same time as habitat loss so that there will be no net loss of fish habitat at any given time. Therefore, since Project Millennium will not result in any net loss of fish habitat, no cumulative effects on fish habitat will result from Project Millennium and no further analysis is required.

C5.4.3.2 Residual Impact Classification

Cumulative impacts on fish habitat as a result of Project Millennium and the combined developments are rated as negligible in magnitude and of negligible environmental consequence.

C5.4.3.3 Uncertainty

Negligible cumulative impacts on habitat are predicted from Project Millennium. The certainty of these predictions is moderate since there is some uncertainty regarding the effectiveness of fish habitat mitigation and creation. However, fish habitat mitigation/enhancement has been implemented successfully in other projects and there are several tools available for fish habitat design and enhancement (e.g., Ontario Ministry of Natural Resources 1994; Natural Channel Systems: An Approach to Management and Design).

There is also uncertainty related to water quality predictions as described in Section C5.3.3.2.

C5.4.3.4 Monitoring

As described in Section C4.2, existing fish habitat will be monitored to ensure that mitigation is working. If monitoring indicates that changes to fish habitat are occurring, additional mitigation will be put in place to prevent habitat impacts.

Created and enhanced fish habitat will also be monitored to evaluate fish utilization throughout all phases of the project. Habitat improvements would be implemented if the new habitat is not found to be providing required habitat components for the target fish species lifecycle requirements (e.g., mountain whitefish rearing).

C5.4.4 Sub-Key Question FCEA-2: What Impacts Will Project Millennium and the Combined Developments Have on Levels of Acute or Chronic Toxicity to Fish?

C5.4.4.1 Analysis of Key Question

Results of analyses of potential water quality changes related to regional developments were presented in Section C5.3. They indicate that acute and chronic toxicity predictions are not expected to exceed guidelines in the Athabasca River under either mean open-water or annual 7Q10 flows.

C5.4.4.2 Residual Impact Classification

No acute and chronic impacts on fish are predicted. Therefore, the impact is rated as negligible in magnitude and of negligible environmental consequence.

C5.4.4.3 Uncertainty and Follow-up Studies

Conclusions regarding the potential for effects on fish are based on a number of assumptions, each of which affects the level of certainty. There is uncertainty related to water quality modelling predictions as described in Section C5.3.3.2. As well, it is assumed that acute and chronic toxicity tests are adequate predictors of effects on fish health parameters from CT water. This assumption was shown to be valid for TID seepage waters, which have comparable characteristics to CT water. However, this assumption will need to be confirmed.

Further studies on the effects of CT water on fish health are planned by Suncor as described in Section C4.2.6.4. These studies would include assessments of fish health, chemical characterization of wastewaters, and trophic level toxicity testing; and would expand on the existing database. Studies would be conducted in Fort McMurray, with the participation of other oil sands operators. Results would be incorporated in mitigation and future monitoring plans, if necessary.

C5.4.4.4 Monitoring

Water quality, toxicity and benthic invertebrate monitoring of surface waters will continue to be part of RAMP. Fish population monitoring will also be included in RAMP.

C5.4.5 Sub-Key Question FCEA-3: What Impacts Will Project Millennium and the Combined Developments Have on Fish Abundance?

C5.4.5.1 Analysis of Key Question

There are three potential linkages to fish abundance: change in fish habitat, acute and chronic effects on fish and change in fishing pressure (Figure C4.2-1).

No cumulative impacts on fish habitat are expected in relation to Project Millennium since habitat impacts from the Project will be mitigated (Sub-key Question FCEA-1).

As described under Sub-key Question FCEA-2, no acute and chronic effects on fish are expected from Project Millennium and the combined developments.

Similarly, change in fishing on a regional basis is not expected to impact fish abundance. Regulation of angling is within the jurisdiction of Fisheries Management Division of Alberta Environmental Protection (AEP). It is assumed that decreases in fish abundance would be prevented by appropriate enforcement of legislation by AEP.

C5.4.5.2 Residual Impact Classification

Changes in fish abundance are predicted to be negligible in magnitude and of negligible environmental consequence.

C5.4.5.3 Uncertainty and Follow-up Studies

The certainty of conclusions about fish abundance is limited by certainty of habitat and acute and chronic impact predictions as described in Sections C5.4.3.3 and C5.4.4.3, respectively.

C5.4.5.4 Monitoring

Fish abundance in the Athabasca River will be monitored as part of the RAMP.

C5.4.6 Sub-Key Question FCEA-4: What Changes to Fish Tissue Quality Will Result From Project Millennium and the Combined Developments?

C5.4.6.1 Analysis of Key Question

There is no additional information to that presented under Key Question F-4 to address this sub-key question. Based on existing data from field and laboratory analyses, sufficient bioaccumulation of chemicals to cause direct effects on fish health, or to cause exceedances of guidelines for human consumption is not expected to occur (Section C.4.2.6). Flavour impairment (i.e., tainting) is also not expected (Section C.4.2.8).

C5.4.6.2 Residual Impact Classification

No impacts on fish tissue quality are expected. The impact is rated as negligible in magnitude and of negligible environmental consequence. However, since fish tissue quality and tainting are issues that directly relate to consumption of fish in the RSA, Suncor is committed to conduct follow-up studies to confirm these predictions.

C5.4.6.3 Uncertainty and Follow-up Studies

As described in Section C4.2.6, studies on the levels of metals and organic compounds in tissues of fish exposed to different concentrations of CT water in the laboratory will be conducted in conjunction with the fish health studies. These studies will also be coordinated with other regional oil sands operators.

Fish tainting studies with CT water will also be conducted in Fort McMurray (Section C4.2.8). They will involve the training and selection of a taste panel with individuals from the RSA. These studies will also be coordinated with other regional oil sands operators.

C5.4.6.4 Monitoring

Monitoring of fish tissue chemical levels in the RSA will be conducted as part of the RAMP.

Regional monitoring for tainting will only be implemented if the results of the tainting tests indicate the potential for tainting from CT water.

C5.5 CONCLUSION

Sub-key questions were developed to address the overall question of whether impacts to the Athabasca River will result from changes in hydrogeology, surface water hydrology, surface water quality, fisheries and fish habitat associated with Project Millennium and the combined developments. The following brief summaries characterize the effects of existing, approved and planned developments on aquatics in the RSA.

Surface Hydrology and Hydrogeology

The change in flow to the Athabasca River from both surface water and groundwater sources for various times in the Project life cycle, by basin and year is less than 0.03% of the mean annual flow in Athabasca River. Low flows from surface water in the LSA are estimated to be zero for all periods less frequent than the 1 in 10 year drought. These changes are low in magnitude, regional in geographic extent, long-term in duration and irreversible. The environmental consequence is negligible.

Water Quality/PAH's

Combined developments will not cause exceedances of acute or chronic toxicity guidelines for aquatic life. A number of metals exceed water quality guidelines in the Athabasca River naturally and the combined developments would not contribute an appreciable, additional load of these metals. These metals are not considered to be of concern, because they are largely associated with suspended particulate matter and are thus not in a bioavailable form. The predicted impacts of operational and reclamation water releases during mean open-water flow and annual 7Q10 flow are negligible in magnitude, long-term in duration, moderate in frequency, regional in geographic extent and irreversible. The environmental consequence of these impacts is low.

Based on the weight of evidence provided in the Water Quality impact assessment on PAHs, it is unlikely that PAHs released from combined oil sands developments will result in substantial accumulation in sediments of surface waters. The predicted impact of PAH releases resulting from the combined developments on sediment levels is negligible in magnitude, long-term in duration, high in frequency, regional in geographic extent and irreversible, with a high degree of uncertainty. The environmental consequence of this impact is low.

Acidification

Analysis of potential waterbody acidification presented in the impact assessment also applies to the CEA. The difference between air quality model results for the CEA and those presented in the impact assessment consists of an increase in the area of exceedance of the interim critical load under the CEA (from 90 x 150 km to 120 x 170 km). Acidification of lakes is low in magnitude, long-term in duration, high in frequency, regional in geographic extent and reversible, with a high degree of uncertainty. The environmental consequence of this impact is low.

Spring pH depression in streams is low in magnitude, long-term in duration, moderate in frequency, regional in geographic extent and reversible, with a high degree of uncertainty. The environmental consequence of this impact is low.

Fish and Fish Habitat

No effects on fish habitat in the Athabasca River from changes in sediment loading or flow are expected in relation to Project Millennium. Hence, further analysis of combined developments was not done. No impacts to benthic invertebrates (from changes in water quality) are predicted. Hence, no impacts to fish habitat in the Athabasca River are expected from Project Millennium and the combined developments.

Since Project Millennium will not result in any net loss of fish habitat in small tributaries, no cumulative effects on small stream fish habitat in the RSA will result from Project Millennium, and no further analysis was done. Project Millennium is not expected to contribute to regional habitat impacts to small streams.

Cumulative impacts on fish habitat as a result of Project Millennium and the combined developments are negligible in magnitude and of negligible environmental consequence.

Results of water quality modelling indicate that acute and chronic guidelines are not expected to exceed guidelines in the Athabasca River under either mean open-water or annual 7Q10 flows. Hence, no impact on fish health as measured by acute or chronic guidelines is expected. Therefore, the impact is negligible in magnitude and of negligible environmental consequence.

Fish Abundance/Tainting

Conclusions relative to fish abundance are as follows:

- No cumulative impacts on fish habitat are expected in relation to Project Millennium since habitat impacts from the Project will be mitigated.
- No acute and chronic effects on fish are expected from Project Millennium and the combined developments.

- Change in fishing pressure on a regional basis is not expected to impact fish abundance. Regulation of angling is within the jurisdiction of the Fisheries Management Division of AEP. It is assumed that decreases in fish abundance would be prevented by appropriate enforcement of legislation.

Changes in fish abundance are negligible in magnitude and of negligible environmental consequence.

Based on existing data from field and laboratory analyses, no impacts on fish tissue quality (i.e. bioaccumulation or tainting) are expected. Therefore, the environmental consequence is predicted to be negligible.

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GLOSSARY

Abiotic Non-living factors that influence an ecosystem, such as climate, geology and soil characteristics.

Activity Area A limited portion of a site in which a specialized cultural function was carried out, such as hide scraping, tool manufacture, food preparation and other activities.

Acute Exposures Exposures occurring over a short period of time, usually at high concentrations.

Adverse Effect An undesirable or harmful effect to an organism (human, animal or plant), indicated by some result such as mortality, growth inhibition, reproductive abnormalities, altered food consumption, altered body and organ weights, altered enzyme concentrations, visible pathological changes or carcinogenic effects.

Age-to-maturity Most often refers to the age at which more than 50% of the individuals of a particular sex within a population reach sexual maturity. Age-to-maturity of individuals within the same population can vary considerably from the population median value. In fish species, males often reach sexual maturity at a younger age than female.

Airshed Describes the geographic area requiring unified management for achieving air pollution control.

Alkalinity A measure of water's capacity to neutralize an acid. It indicates the presence of carbonates, bicarbonates and hydroxides, and less significantly, borates, silicates, phosphates and organic substances. It is expressed as an equivalent of calcium carbonate. The composition of alkalinity is affected by pH, mineral composition, temperature and ionic strength. However, alkalinity is normally interpreted as a function of carbonates, bicarbonates and hydroxides. The sum of these three components is called total alkalinity.

Alluvium Sediment deposited in land environments by streams.

Ambient The conditions surrounding an organism or area.

AOSERP Alberta Oil Sands Environmental Research Program.

Aquifer A body of rock or soil that contains sufficient amounts of saturated permeable material to yield economic quantities of water to wells or springs.

Archaeology The scientific discipline responsible for studying the unwritten portion of man's historic and prehistoric past.

Armouring Channel erosion protection by covering with protection material.

Artifact Any portable object modified or manufactured by man.

ASL Above sea level.

Aspect Compass orientation of a slope as an inclined element of the ground surface.

ASWQO Alberta Surface Water Quality Objectives. Numerical concentrations or narrative statements established to support and protect the designated uses of water. These are minimum levels of quality, developed for Alberta watersheds, below which no waterbody is permitted to deteriorate. These objectives were established as minimum levels that would allow for the most sensitive use. These concentrations represent a goal to be achieved or surpassed.

Available Drawdown The vertical distance that the equipotential surface of an aquifer can be lowered; in confined aquifers, this is to the top of the aquifer; in unconfined aquifers, this is to the bottom of the aquifer.

Background An area not influenced by chemicals released from the site under evaluation.

Background Concentration (environmental) The concentration of a chemical in a defined control area during a fixed period before, during or after data-gathering.

Backwater Discrete, localized area exhibiting reverse flow direction and, generally lower stream velocity than main current; substrate similar to adjacent channel with more fines.

Baseline A surveyed condition that serves as a reference point on which later surveys are coordinated or correlated.

Beaver River Sandstone A light gray, medium to fine-grained quartz sandstone cemented in a silica matrix.

Bedrock The body of rock which underlies gravel, soil or other superficial material.

Benthic Invertebrates Invertebrate organisms living at, in or in association with the bottom (benthic) substrate of lakes, ponds and streams. Examples of benthic invertebrates include some aquatic insect species (such as caddisfly larvae) that spend at least part of their lifestages dwelling on bottom sediments in the river. These organisms play several important roles in the aquatic community. They are involved in the mineralization and recycling of organic matter produced in the open water above, or brought in from external sources, and they are important second and third links in the trophic sequence of aquatic communities. Many benthic invertebrates are major food sources for fish.

Bile An alkaline secretion of the vertebrate liver. Bile, which is temporarily stored in the gall bladder, is composed of organic salts, excretion products and bile pigments. It primarily functions to emulsify fats in the small intestine.

Bioaccumulation A general term meaning that an organism stores within its body a higher concentration of a substance than is found in the environment. This is not necessarily harmful. For example, freshwater fish must bioaccumulate salt to survive in intertidal waters. Many toxicants, such as arsenic, are not included among the dangerous bioaccumulative substances because they can be handled and excreted by aquatic organisms.

Bioavailability The amount of chemical that enters the general circulation of the body following administration or exposure.

Bioconcentration A process where there is a net accumulation of a chemical directly from an exposure medium into an organism.

Biodiversity The variety of organisms and ecosystems that comprise both the communities of organisms within particular habitats and the physical conditions under which they live.

Biological Indicators Any biological parameter used to indicate the response of individuals, populations or ecosystems to environmental stress. For example, growth is a biological indicator.

Biomarker Biomarker refers to a chemical, physiological or pathological measurement of exposure or effect in an individual organism from the laboratory or the field. Examples include: contaminants in liver enzymes, bile and sex steroids.

Biome A major community of plants and animals such as the boreal forest or tundra biome.

Biotic The living organisms in an ecosystem.

Bitumen A highly-viscous, tarry, black hydrocarbon material having an API gravity of about 9° (specific gravity about 1.0). It is a complex mixture of organic compounds. Carbon accounts for 80% to 85% of the elemental composition of bitumen, hydrogen - 10%, sulphur - 5%, and nitrogen, oxygen and trace elements the remainder.

BOD The biochemical oxygen demand (BOD) determination is an imperical test in which standardized laboratory procedures are used to determine the relative oxygen requirements of wastewaters, effluents and polluted waters.

Bottom Sediments Substrates that lie at the bottom of a body of water. For example, soft mud, silt, sand, gravel, rock and organic litter, that make up a river bottom.

Bottom-feeding Fish	Fish that feed on the substrates and/or organisms associated with the river bottom.
Cancer	A disease characterized by the rapid and uncontrolled growth of aberrant cells into malignant tumours.
Canopy	An overhanging cover, shelter or shade; the tallest layer of vegetation in an area.
Carcinogen	An agent that is reactive or toxic enough to act directly to cause cancer.
Carrying capacity	The maximum population size that can be supported by the available resources.
Centre Reject	A non bituminous baring material found within a central zone of the oil sand ore body.
Cervid	Of the family Cervidae, which includes elk, deer, moose, and caribou.
Chert	A fine-grained siliceous rock. Impure variety of chalcedony which is generally light-coloured.
Chronic Exposure	Exposures occurring over a relatively long duration of time (Health Canada considers periods of human exposure greater than three months to be chronic while the U.S. EPA only considers human exposures greater than seven years to be chronic).
Chronic Toxicity	The development of adverse effects after an extended exposure to relatively small quantities of a chemical.
Chronic Toxicity Unit (TU_c)	Measurement of long duration toxicity that produces an adverse effect on organisms.
Climax	The culminating stage in plant succession for a given site where the vegetation has reached a stable condition.
Cline	A gradual change in a feature across the distributional range of a species or population.
Closure	The point after shutdown of operations when regulatory certification is received and the area is returned to the Crown.
Community	Pertaining to plant or animal species living in close association or interacting as a unit.
Composite Tailings (CT)	A non-segregating mixture made by Syncrude Canada Ltd. of oil sands extraction tailings that consolidates relatively quickly in deposits. Composed of sand tailings, mature fine tailings and a chemical stabilizer (e.g., $CaSO_4$).
Concentration	Quantifiable amount of a chemical in environmental media.

Conceptual Model	A model developed at an early stage of the risk assessment process that describes a series of working hypotheses of how the chemicals of concern may affect potentially exposed populations. The model identifies the populations potentially at risk along with the relevant exposure pathways and scenarios.
Condition Factor	A measure of the relative "fitness" of an individual or population of fishes by examining the mathematical relationship between length and weight. The values calculated show the relationship between growth in length relative to growth in weight. In populations where increases in length are matched by increases in weight, the growth is said to be isometric. Allometric growth, the most common situation in wild populations, occurs when increases in either length or weight are disproportionate.
Conditioning Drums	Large, inclined cylindrical tumblers that rotate slowly, used for preparing (conditioning) oil sand for primary extraction by mixing it with hot water and steam.
Conductivity	A measure of a waterbody's capacity to conduct an electrical current. It is the reciprocal of resistance. This measurement provides the limnologist with an estimation of the total concentration of dissolved ionic matter in the water. It allows for a quick check of the alteration of total water quality due to the addition of pollutants to the water.
Confined Aquifer	An aquifer in which the potentiometric surface is above the top of the aquifer.
Conifers	White and black spruce, balsam fir, jack pine and tamarack.
Conservative Approach	Approach taken to incorporate protective assumptions to ensure that risks will not be underestimated.
Consolidated Tailings (CT)	Consolidated Tailings (CT) is a non-segregating mixture made by Suncor Energy Inc., Oil Sands of plant tailings which consolidates relatively quickly in tailings deposits. At Suncor, Consolidated Tailings are prepared by combining mature fine tails with thickened (cycloned) fresh sand tailings. This mixture is chemically stabilized (to prevent segregation of fine and coarse mineral solids) using gypsum ($CaSO_4$).
Consolidated Tailings Release Water	Water is expelled from Consolidated Tailings mixtures during the course of consolidation. The water is referred to as Consolidated Tailings (or CT) release water.
Consolidation	The gradual reduction in volume of a soil or semi-solid mass.
Contaminant Body Burdens	The total concentration of a contaminant found in either whole-body or individual tissue samples.

Contaminants A general term referring to any chemical compound added to a receiving environment in excess of natural concentrations. The term includes chemicals or effects not generally regarded as "toxic," such as nutrients, colour and salts.

Control A treatment in a toxicity test that duplicates all the conditions of exposure treatments but contains no test material. The control is used to determine basic test conditions in the absence of toxicity (e.g., health of test organisms, quality of dilution water).

Cratering The act of creating depressions, or craters, in the snow when foraging for food. Usually done by elk or other ungulates.

Crop Tree Regeneration The renewal of a forest or stand of trees by natural or artificial means, usually white spruce, jack pine or aspen.

Culture The sum of man's non-biological behavioural traits: learned, patterned and adaptive.

CWQG Canadian Water Quality Guidelines. Numerical concentrations or narrative statements recommended to support and maintain a designated water use in Canada. The guidelines contain recommendations for chemical, physical, radiological and biological parameters necessary to protect and enhance designated uses of water.

Cyclofeeder A cyclofeeder is a vertical, open-topped cylindrical vessel with a conical bottom. The purpose of a cyclofeeder is to mix oil sand with warm water to form a slurry which can be pumped via a pipeline to Extraction. Warm water is introduced through horizontal ports situated at the bottom of the vertical portion to produce a vortex inside the vessel, into which incoming oil sands falls. The energy imparted to the oil sand forms a slurry, which is withdrawn at the bottom of the cone.

Darcy's Law A law describing the rate of flow of water through porous media. (Named for Henry Darcy of Paris who formulated it in 1856 from extensive work on the flow of water through sand filter beds.)

DEM (Digital Elevation Model) A three-dimensional grid representing the height of a landscape above a given datum.

Dendritic Drainage Pattern A drainage pattern characterized by irregular branching in all directions with the tributaries joining with the main stream at all angles.

Deposit Material left in a new position by a natural transporting agent such as water, wind, ice or gravity, or by the activity of man.

Depressurization The process of reducing the pressure in an aquifer, by withdrawing water from it.

Depuration Loss of accumulated chemical residues from an organism placed in clean water or clean solution.

Detection Limit (DL) The lowest concentration at which individual measurement results for a specific analyte are statistically different from a blank (that may be zero) with a specified confidence level for a given method and representative matrix.

Deterministic Risk approach using a single number from each parameter set in the risk calculation and producing a single value of risk.

Detoxification To decrease the toxicity of a compound. Bacteria decrease the toxicity of resin and fatty acids in mill effluent by metabolizing or breaking down these compounds; enzymes like the EROD or P4501A proteins begin the process of breaking down and metabolizing many "oily" compounds by adding an oxygen atom.

Development Area Any area altered to an unnatural state. This represents all land and water areas included within activities associated with development of the oil sands leases.

Diameter at Breast Height (DBH) The diameter of a tree 1.5 m above the ground on the uphill side of the tree.

Discharge In a stream or river, the volume of water that flows past a given point in a unit of time (i.e., m^3/s).

Disclimax A type of climax community that is maintained by either continuous or intermittent disturbance to a severity that the natural climax vegetation is altered.

Disturbance (Historic) A cultural deposit is said to be disturbed when the original sequence of deposition has been altered. Examples of agents of disturbance include erosion, plant or animal activity, cultivation and excavations.

Disturbance (Terrestrial) A force that causes significant change in structure and/or composition of a habitat.

Disturbance coefficient The effectiveness of the habitat within the disturbance zone of influence in fulfilling the requirements of a species.

Disturbance zone of influence The maximum distance to which a disturbance (e.g., traffic noise) is felt by a species.

Diversity The variety, distribution and abundance of different plant and animal communities and species within an area.

Dose A measure of integral exposure. Examples include (1) the amount of chemical ingested, (2) the amount of a chemical taken up, and (3) the product of ambient exposure concentration and the duration of exposure.

Dose Rate	Dose per unit time, for example in mg/day, sometimes also called dosage. Dose rates are often expressed on a per-unit-body-weight basis, yielding units such as mg/kg body weight/day expressed as averages over some period, for example a lifetime.
Dose-Response	The quantitative relationship between exposure of an organism to a chemical and the extent of the adverse effect resulting from that exposure.
Drainage Basin	The total area that contributes water to a stream.
Dry Landscape Reclamation	A reclamation approach that involves dewatering or incorporation of fine tailings into a solid deposit capable of being reclaimed as a land surface or a wetland.
Ecological Land Classification	A means of classifying landscapes by integrating landforms, soils and vegetation components in a hierarchical manner.
Ecoregion	Ecological regions that have broad similarities with respect to soil, terrain and dominant vegetation.
Ecosection	Clearly-recognizable landforms such as river valleys and wetlands at a broad level of generalization.
Ecosite	Ecological units that develop under similar environmental influences (climate, moisture and nutrient regime). Ecosites are groups of one or more ecosite phases that occur within the same portion of the moisture/nutrient grid. Ecosite is a functional unit defined by the moisture and nutrient regime. It is not tied to specific landforms or plant communities, but is based on the combined interaction of biophysical factors that together dictate the availability of moisture and nutrients for plant growth.
Ecosite Phase	A subdivision of the ecosite based on the dominant tree species in the canopy. On some sites where the tree canopy is lacking, the tallest structural vegetation layer determines the ecosite phase.
Ecosystem	An integrated and stable association of living and non-living resources functioning within a defined physical location.
Edaphic	Referring to the soil. The influence of the soil on plant growth is referred to as an edaphic factor.
Edge	Where plant communities meet; and where plant communities meet a disturbance.
Effluent	Stream of water discharging from a source.
Environmental Impact Assessment	A review of the effects that a proposed development will have on the local and regional environment.

Environmental Media	One of the major categories of material found in the physical environment that surrounds or contacts organisms (e.g., surface water, groundwater, soil, food or air) and through which chemicals can move and reach the organism.
Ephemeral	A phenomenon or feature that last only a short time (i.e., an ephemeral stream is only present for short periods during the year).
EROD	Ethoxyresorufin-O-deethylase (EROD) are enzymes that can increase in concentration and activity following exposure of some organisms to chemicals such as polycyclic aromatic hydrocarbons. EROD measurement indirectly measures the presence of catalytical proteins that remove a CH_3CH_2-group from the substrate ethoxyresorufin.
Escarpment	A cliff or steep slope at the edge of an upland area. The steep face of a river valley.
Exposure	The contact reaction between a chemical and a biological system, or organism.
Exposure Assessment	The process of estimating the amount (concentration or dose) of a chemical that is taken up by a receptor from the environment.
Exposure Concentration	The concentration of a chemical in its transport or carrier medium at the point of contact.
Exposure Limit or Toxicity Reference Value	For a non-carcinogenic chemical, the maximum acceptable dose (per unit body weight and unit of time) of a chemical that a specified receptor can be exposed to, without the development of adverse effects. For a carcinogenic chemical, the maximum acceptable dose of a chemical to which a receptor can be exposed to, assuming a specified risk (e.g., 1 in 100 000). May be expressed as a Reference Dose (RfD) for non-carcinogenic (threshold-response) chemicals or as a Risk Specific Dose (RsD) for carcinogenic (non-threshold response) chemicals. Also referred to as a toxicity reference value.
Exposure Pathway or Route	The route by which a receptor comes into contact with a chemical or physical agent. Examples of exposure pathways include: the ingestion of water, food and soil; the inhalation of air and dust; and dermal absorption.
Exposure Ratio (ER) or Hazard Quotient (HQ)	A comparison between total exposure from all predicted routes of exposure and the exposure limits for chemicals of concern. This comparison is calculated by dividing the predicted exposure by the exposure limit. Also referred to as hazard quotient (HQ).
Exposure Scenario	A set of facts, assumptions and inferences about how exposure takes place, that helps the risk assessor evaluate, estimate and quantify exposures.

Fate — In the context of the study of contaminants, fate refers to the chemical form of a contaminant when it enters the environment and the compartment of the ecosystem in which that chemical is primarily concentrated (e.g., water or sediments). Fate also includes transport of the chemical within the ecosystem (via water, air or mobile biota) and the potential for food chain accumulation.

Fauna — An association of animals living in a particular place or at a particular time.

Fecundity — The most common measure of reproductive potential in fishes. It is the number of eggs in the ovary of a female fish. It is most commonly measured in gravid fish. Fecundity increases with the size of the female.

Filter-Feeders — Organisms that feed by straining small organisms or organic particles from the water column.

Filterable Residue — Materials in water that pass through a standard-size filter (often 0.45 µm). This is a measure of the "total dissolved solids" (TDS), i.e., chemicals that are dissolved in the water or that are in a particulate form smaller than the filter size. These chemicals are usually salts, such as sodium ions and potassium ions.

Fine Tailings — A suspension of fine silts, clays, residual bitumen and water that forms in the course of bitumen extraction from oil sands using the hot water extraction process. This material segregates from coarse sand tailings during placement in tailings ponds and accumulates in a layer (referred to as fine tailings) that dewaters very slowly. The top of the fine tailings deposit is typically about 85% water, 13% fine minerals and 2% bitumen by weight.

Fines — Silt and clay particles.

Fish Health Parameters — Parameters used to indicate the health of an individual fish. May include, for example, short-term response indicators such as changes in liver mixed function oxidase activity and the levels of plasma glucose, protein and lactic acid. Longer-term indicators include internal and external examination of exposed fish, changes in organ characteristics, hematocrit and hemoglobin levels. May also include challenge tests such as disease resistance and swimming stamina.

Fisheries Act — Federal legislation that protects fish habitat from being altered, disrupted or destroyed by chemical, physical or biological means. Destruction of the habitat could potentially undermine the economic, employment and other benefits that flow from Canada's fisheries resources (DFO 1986).

Floodplain — Land near rivers and lakes that may be inundated during seasonally high water levels (i.e., floods).

Flue Gas Desulphurization (FGD)	A process involving removal of a substantial portion of sulphur dioxide from the combustion gas (flue gas) formed from burning petroleum coke. Desulphurization is accomplished by contacting the combustion gases with a solution of limestone. Gypsum ($CaSO_4$) is formed as a byproduct of this process.
Fluvial	Relating to a stream or river.
Food Chain Transfer	A process by which materials accumulate in the tissues of lower trophic level organisms and are passed on to higher trophic level organisms by dietary uptake.
Forage Area	The area used by an organism for hunting or gathering food.
Forage Fish	Small fish that provide food for larger fish (e.g., longnose sucker, fathead minnow)
Forb	Broadleaved herb, as distinguished from grasses.
Forest	A collection of stands of trees that occur in similar space and time.
Forest Fragmentation	The change in the forest landscape, from extensive and continuous forests.
Forest Landscape	Forested or formerly forested land not currently developed for non-forest use.
Forest Succession	The orderly process of change in a forest as one plant community or stand condition is replaced by another, evolving toward the climax type of vegetation.
Fragmentation	The process of reducing size and connectivity of stands of trees that compose a forest.
Froth	Air-entrained bitumen with a froth-like appearance that is the product of the primary extraction step in the hot water extraction process.
Fugitive Emissions	Contaminants emitted from any source except those from stacks and vents. Typical sources include gaseous leakages from valves, flanges, drains, volatilization from ponds and lagoons, and open doors and windows. Typical particulate sources include bulk storage areas, open conveyors, construction areas or plant roads.
Genetic diversity	Describes the range of possible genetic characteristics found within a species and amongst different species (e.g., variations in hair colour, eye colour, and height in humans).
Geomorphic	Pertaining to natural evolution of surface soils and landscape over long periods.
Geomorphical Processes	The origin and distribution of landforms, with the emphasis on the nature of erosional processes.

Geomorphology	That branch of science which deals with the form of the earth, the general configurations of its surface and the changes that take place in the evolution of landforms.
GIS	Geographic Information System. Pertains to a type of computer software that is designed to develop, manage, analyze and display spatially-referenced data.
Glacial Till	Unsorted and unstratified glacial drift (generally unconsolidated) deposited directly by a glacier without subsequent reworking by water from the glacier. Consisting of a heterogeneous mixture of clay, silt, sand, gravel and boulders (i.e., drift) varying widely in size and shape.
Glaciolacustrine (or Glacio-Lacustrine)	Relating to the lakes that formed at the edge of glaciers as the glaciers receded. Glaciolacustrine sediments are commonly laminar deposits of fine sand, silt and clay.
Golder	Golder Associates Ltd.
Gonads	Organs responsible for producing haploid reproductive cells in multi-cellular cells in multi-cellular animals. In the male, these are the testes and in the female, the ovaries.
Groundtruth	Conductive site visits to confirm accuracy of remotely sensed information.
Groundwater	That part of the subsurface water that occurs beneath the water table, in soils and geologic formations that are fully saturated.
Groundwater Level	The level below which the rock and subsoil, to unknown depths, are saturated.
Groundwater Regime	Water below the land surface in a zone of saturation.
Groundwater Velocity	The speed at which groundwater advances through the ground. In this document, the term refers to the average linear velocity of the groundwater.
GSI	Gonad-Somatic Index. The proportion of reproductive tissue in the body of a fish. It is calculated by dividing the total gonad weight by the total body weight and multiplying the result by 100. It is used as an index of the proportion of growth allocated to reproductive tissues in relation to somatic growth.
Guild	A set of co-existing species that share a common resource.
Habitat	The place where an animal or plant naturally or normally lives and grows, for example, a stream habitat or a forest habitat.
Habitat alienation	The loss of habitat effectiveness as a result of sensory disturbances from human activities at disturbed sites.

Habitat effectiveness	Including the physical characteristics suitability of a habitat, the ability of a habitat to be used by wildlife. The effectiveness of a habitat can be decreased through visual, auditory, or olfactory disturbance even though the physical characteristics of the habitat remain unchanged.
Habitat fragmentation	Occurs when extensive, continuous tracts of habitat are reduced by habitat loss to dispersed and usually smaller patches of habitat. Generally reduces the total amount of available habitat and reduces remaining habitat into smaller, more isolated patches
Habitat generalist	Wildlife species that can survive and reproduce in a variety of habitat types (e.g., red-backed vole).
Habitat specialist	Wildlife species that is dependent on a few habitat types for survival and reproduction (e.g., Cape May warbler).
Habitat Suitability Index (HSI) model	Analytical tools for determining the relative potential of an area to support individuals or populations of a wildlife species. They are frequently used to quantify potential habitat losses and gains for wildlife as a result of various land use activities.
Habitat unit	Generally, used in HSI models. A habitat is ranked in regards to its suitability for a particular wildlife species. This ranking is then multiplied by the area (ha) of the particular habitat type to give the number of habitat units available to the wildlife species in question.
Hazard	A condition with the potential for causing an undesirable consequence.
Head	The energy, either kinetic or potential, possessed by each unit weight of a liquid, expressed as the vertical height through which a unit weight would have to fall to release the average energy possessed. It is used in various compound terms such as pressure head, velocity head and loss of head.
Herb	Tender plant, lacking woody stems, usually small or low; it may be annual or perennial, broadleaf (forb) or graminoid (grass).
Heterogeneity	Variation in the environment over space and time.
Histology/ Histological	The microscopic study of tissues.
Historical Resources Impact Assessment	A review of the effects that a proposed development will have on the local and regional historic and prehistoric heritage of an area.
Historical/Heritage Resources	Works of nature or of man, valued for their palaeontological, archaeological, prehistoric, historic, cultural, natural, scientific, or aesthetic interest.

Human Health Risk Assessment The process of defining and quantifying risks and determining the acceptability of those risks to human life.

Hydraulic Conductivity The permeability of soil or rock to water.

Hydraulic Gradient A measure of the force of moving groundwater through soil or rock. It is measured as the rate of change in total head per unit distance of flow in a given direction. Hydraulic gradient is commonly shown as being dimensionless, since its units are m/m.

Hydraulic Head The elevation, with respect to a specified reference level, at which water stands in a piezometer connected to the point in question in the soil. Its definition can be extended to soil above the water table if the piezometer is replaced by a tensiometer. The hydraulic head in systems under atmospheric pressure may be identified with a potential expressed in terms of the height of a water column. More specifically, it can be identified with the sum of gravitational and capillary potentials, and may be termed the hydraulic potential.

Hydraulic Structure Any structure designed to handle water in any way. This includes retention, conveyance, control, regulation and dissipation of the energy of water.

Hydrocyclone A device for separating out sand from extraction tailings slurry by imparting a rotating (cyclone) action to the slurry. Water, fine tailings and residual bitumen report to the overflow of the device. Sand flows out the bottom of the device in a dense slurry.

Hydrogeology The study of the factors that deal with subsurface water (groundwater), and the related geologic aspects of surface water.

Hydrotransport Refers to the transport of granular materials (e.g., oil sands ore or extraction tailings) by means of a water-based slurry in a pipeline.

ICP (Metals) Inductively Coupled Plasma (Atomic Emission Spectroscopy). This analytical method is a U.S. EPA designated method (Method 6010). The method determines elements within samples of groundwater, aqueous samples, leachates, industrial wastes, soils, sludges, sediments and other solid wastes. Samples require chemical digestion before analysis.

Induction Response to a biologically active compound — involves new or increased gene expression resulting in enhanced synthesis of a protein. Such induction is commonly determined by measuring increases in protein levels and/or increases in the corresponding enzyme activity. For example, induction of EROD would be determined by measuring increases in cytochrome P4501A protein levels and/or increases in EROD activity.

Inorganics Pertaining to a compound that contains no carbon.

Integrated Resource Management	A coordinated approach to land and resource management, which encourages multiple-use practices.
Interspersion	The percentage of map units containing categories different from the map unit surrounding it.
Inversion	An atmospheric condition when temperatures increase with height above the ground. During inversion conditions the vertical mixing of emissions are restricted.
Isolated Find	The occurrence of a single artifact with no associated artifacts or features.
KIRs	Key indicator resources are the environmental attributes or components identified as a result of a social scoping exercise as having legal, scientific, cultural, economic or aesthetic value.
Landform	General term for the configuration of the ground surface as a factor in soil formation; it includes slope steepness and aspect as well as relief. Also, configurations of land surface taking distinctive forms and produced by natural processes (e.g., hill, valley, plateau).
LANDSAT	A specific satellite or series of satellites used for earth resource remote sensing. Satellite data can be converted to visual images for resource analysis and planning.
Landscape	A heterogeneous land area with interacting ecosystems.
Landscape Diversity	The size, shape and connectivity of different ecosystems across a large area.
Leaching	The removal, by water, of soluble matter from regolith or bedrock.
Lean Oil Sands	Oil bearing sands, which do not have a high enough saturation of oil to make extraction of them economically feasible.
Lesions	Pathological change in a body tissue.
Lethal	Causing death by direct action.
Linear corridor	Roads, seismic lines, pipelines and electrical transmission lines, or other long, narrow disturbances.
Lipid	One of a large variety of organic fats or fat-like compounds, including waxes, steroids, phospholipids and carotenes. Refers to substances that can be extracted from living matter using hydrocarbon solvents. They serve several functions in the body, such as energy storage and transport, cell membrane structure and chemical messengers.
Littoral Zone	The zone in a lake that is closest to the shore.

Loading Rates The amount of deposition, determined by technical analysis, above which there is a specific deleterious ecological effect on a receptor.

LOAEL Lowest Observed Adverse Effect Level. In toxicity testing it is the lowest concentration at which adverse effects on the measurement end point are observed.

LOEC Lowest Observed Effect Concentration. The lowest concentration in a medium that causes an effect that is a statistically significant difference in effect compared to controls.

LOEL Lowest Observed Effect Level. In toxicity testing it is the lowest concentration at which effects on the measurement end point are observed.

LSI Liver Somatic Index. Ratio of liver versus total body weight. Expressed as a percentage of total body weight.

m^3/s Cubic metres per second. The standard measure of water flow in rivers; i.e., the volume of water in cubic metres that passes a given point in one second.

Mature Fine Tailings (MFT) These are fine tailings that have dewatered to a level of about 30% solids over a period of about three years after deposition. The rate of consolidation beyond this point is substantially reduced. Mature fine tailings behave like a viscous fluid.

Mature Forest A forest greater than rotation age with moderate to high canopy closure; a multi-layered, multi-species canopy dominated by large overstory trees; some with broken tops and other decay; numerous large snags and accumulations of downed woody debris.

Mature Stand A stand of trees for which the annual net rate of growth has peaked.

Media The physical form of the environmental sample under study (e.g., soil, water, air).

Merchantable Forest A forest area with potential to be harvested for protection of lumber/timber or wood pulp. Forests with a timber productivity rating of moderate to good.

Mesic Pertaining to, or adapted to an area that has an intermediate supply of water; neither wet not dry.

Metabolism Metabolism is the total of all enzymatic reactions occurring in the cell; a highly coordinated activity of interrelated enzyme systems exchanging matter and energy between the cell and the environment. Metabolism involves both the synthesis and breakdown (catabolism) of individual compounds.

Metabolites	Organisms alter or change compounds in various ways, such as removing parts of the original or parent compound, or in other cases adding new parts. Then, the parent compound has been metabolized and the newly converted compound is called a metabolite.
MFO	Mixed Function Oxidase. A term for reactions catalyzed by the Cytochrome P450 family of enzymes, occurring primarily in the liver. These reactions transform organic chemicals, often altering toxicity of the chemicals.
Microclimate	The temperature, precipitation and wind velocity in a restricted or localized area, site or habitat.
Microtox©	A toxicity test that includes an assay of light production by a strain of luminescent bacteria (*Photobacterium phosphoreum*).
Mineral Soil	Soils containing low levels of organic matter. Soils that have evolved on fluvial, glaciofluvial, lacustrine and morainal parent material.
Mixing Height	The depth of surface layer in which atmospheric mixing of emissions occurs.
Modelling	A simplified representation of a relationship or system of relationships. Modelling involves calculation techniques used to make quantitative estimates of an output parameter based on its relationship to input parameters. The input parameters influence the value of the output parameters.
Movement corridor	Travel way used by wildlife for daily, seasonal, annual and/or dispersal movements from one area or habitat to another.
Multilayered Canopy	Forest stands with two or more distinct tree layers in the canopy; also called multistoried stands.
Muskeg	A soil type comprised primarily of organic matter. Also known as bog peat.
Mycorrhizal	A fungi that forms a symbiotic relationship with plants, resulting in improved nutrient uptake by the plant.
NMHC	Non-Methane Hydrocarbons is a measure of the airborne hydrocarbons, less methane.
NOAEL	No observed adverse effect level. In toxicity testing, it is the highest concentration at which no adverse effects on the measurement end point are observed.
Node	Location along a river channel, lake inlet or lake outlet where flows, sediment yield and water quality have been quantified.

NOEC No observed adverse effect concentration. The highest concentration in a medium that does not cause a statistically significant difference in effect as compared to controls.

NOEL No observed effect level. In toxicity testing, it is the highest concentration at which no effects on the measurement end point are observed.

Non-Filterable Residue Material in a water sample that does not pass through a standard size filter (often 0.45 mm). This is considered to represent "total suspended solids" (TSS), i.e., particulate matter suspended in the water column.

Noncarcinogen A chemical that does not cause cancer and has a threshold concentration, below which adverse effects are unlikely.

NO_X A measure of the oxides of nitrogen comprised of nitric oxide (NO) and nitrogen dioxide (NO_2).

Nutrients Environmental substances (elements or compounds) such as nitrogen or phosphorus, which are necessary for the growth and development of plants and animals.

Oil Sands A sand deposit containing a heavy hydrocarbon (bitumen) in the intergranular pore space of sands and fine grained particles. Typical oil sands comprise approximately 10 wt% bitumen, 85% coarse sand (>44µm) and a fines (<44µm) fraction, consisting of silts and clays.

Organic Soil Soils containing high percentages of organic matter (fibric and humic inclusions).

Organics Chemical compounds, naturally occurring or otherwise, which contain carbon, with the exception of carbon dioxide (CO_2) and carbonates (e.g., $CaCo_3$).

Overburden The soil, sand, silt or clay that overlies bedrock. In mining terms, this includes all material that has to be removed to expose the ore.

Overstory Those trees that form the upper canopy in a multi-layered forest.

Overwintering Habitat Habitat used during the winter as a refuge and for feeding.

PAH(s) Polycyclic Aromatic Hydrocarbon. A chemical byproduct of petroleum-related industry. Aromatics are considered to be highly toxic components of petroleum products. PAHs, many of which are potential carcinogens, are composed of at least two fused benzene rings. Toxicity increases along with molecular size and degree of alkylation of the aromatic nucleus.

PAI The Potential Acid Input is a composite measure of acidification determined from the relative quantities of deposition from background and industrial emissions of sulphur, nitrogen and base cations.

Paleosol A paleosol is a soil that was formed in the past. Paleosols are usually buried beneath a layer of sediments and are thus no longer being actively created by soil formation processes like organic decay.

PANH Polycyclic Aromatic Nitrogen Heterocycle. See PAH.

PASH Polycyclic Aromatic Sulphur Heterocycle.

Patch This term is used to recognize that most ecosystems are not homogeneous, but rather exist as a group of patches or ecological islands that are recognizably different from the parts of the ecosystem that surround them but nevertheless interact with them.

Pathology The science that deals with the cause and nature of disease or diseased tissues.

Peat A material composed almost entirely of organic matter from the partial decomposition of plants growing in wet conditions.

Performance Assessment Prediction of the future performance of a reclaimed lease to allow identification of potential adverse effects with respect to geotechnical, geomorphic and ecosystem sustainability.

Permit Holder The director of an Historical Resource Impact Assessment. Responsible for the satisfactory completion of all field and laboratory work and author of the technical report.

Physiological Related to function in cells, organs or entire organisms, in accordance with natural processes of life.

Pictograph Aboriginally painted designs on natural rock surfaces. Red ochre is the most frequently used pigment.

Piezometer A pipe in the ground in which the elevation of water level can be measured.

Piezometric Surface If water level elevations in wells completed in an aquifer are plotted on a map and contoured, the resulting surface described by the contours is known as a potentiometric or piezometric surface.

Plant Community An association of plants of various species found growing together.

PM_{10} Airborne particulate matter with mean diameter less than 10 μm (microns) in diameter. This represents the fraction of airborne particles that can be inhaled into the upper respiratory tract.

$PM_{2.5}$ Airborne particulate matter with mean diameter less than 2.5 μm (microns) in diameter. This represents the fraction of airborne particles that can be inhaled deeply into the pulmonary tissue.

Polishing Pond Pond where final sedimentation takes place before discharge.

Polygon The spatial area delineated on a map to define one feature unit (e.g., one type of ecosite phase).

Population A collection of individuals of the same species that potentially interbreed.

Porewater Water between the grains of a soil or rock.

Problem Formulation The initial step in a risk assessment that focuses the assessment on the chemicals, receptors and exposure pathways of greatest concern.

Productive Forest Forests on lands with a capability rating of equal to or greater than 3, and stocked with trees to meet the stocking standards of a merchantable forest.

Propagules Root fragments, seeds, and other plant materials which can develop into a plant under the right conditions.

QA/QC Quality Assurance/Quality Control refers to a set of practices that ensure the quality of a product or a result. For example, "Good Laboratory Practice" is part of QA/QC in analytical laboratories and involves such things as proper instrument calibration, meticulous glassware cleaning and an accurate sample information system.

QA/QC Plan Quality Assurance/Quality Control Plan.

Rearing Habitat Habitat used by young fish for feeding and/or as a refuge from predators.

Receptor The person or organism subjected to exposure to chemicals or physical agents.

Reclamation The restoration of disturbed or wasteland to a state of useful capability. Reclamation is the initiation of the process that leads to a sustainable landscape (see definition), including the construction of stable landforms, drainage systems, wetlands, soil reconstruction, addition of nutrients and revegetation. This provides the basis for natural succession to mature ecosystems suitable for a variety of end uses.

Reclamation Certificate A certificate issued by an Alberta Environmental Protection, Conservation, and Reclamation Inspector, signifying that the terms and conditions of a conservation and reclamation approval have been complied with.

Reclamation Unit A unique combination of reclamation conditions, namely surface shape, sub-base material, cover material and initial vegetation.

Refugia Areas of natural ecosystems within, or adjacent to, a development area from which plants or animals may move back into the development area, or to which animals may move from the development area.

Regeneration The natural or artificial process of establishing young trees.

Rejects Hard clusters of clays or lean oil sands that do not pass sizing screens in the extraction process and are rejected. Rejects contain residual bitumen and account for a portion of extraction recovery loss.

Relative Abundance The proportional representation of a species in a sample or a community.

Remote Sensing Measurement of some property of an object or surface by means other than direct contact; usually refers to the gathering of scientific information about the earth's surface from great heights and over broad areas, using instruments mounted on aircraft or satellites.

Replicate Duplicate analyses of an individual sample. Replicate analyses are used for measuring precision in quality control.

Reproductive success The production of healthy offspring which live to reproduce themselves.

RfD (Reference Dose) The maximum recommended daily exposure for a non-carcinogenic chemical exhibiting a threshold (highly nonlinear) dose-response based on the NOAEL determined for the chemical from human and/or animals studies and the use of an appropriate uncertainty factor.

Richness The number of species in a biological community (e.g., habitat).

Riffle Habitat Shallow rapids where the water flows swiftly over completely or partially submerged materials to produce surface agitation.

Riparian Area A geographic area containing an aquatic ecosystem and adjacent upland areas that directly affect it.

Risk The likelihood or probability that the toxic effects associated with a chemical or physical agent will be produced in populations of individuals under their actual conditions of exposure. Risk is usually expressed as the probability of occurrence of an adverse effect, i.e., the expected ratio between the number of individuals that would experience an adverse effect at a given time and the total number of individuals exposed to the factor. Risk is expressed as a fraction without units and takes values from 0 (absolute certainty that there is no risk, which can never be shown) to 1.0, where there is absolute certainty that a risk will occur.

Risk Analysis	Quantification of predictions of magnitudes and probabilities of potential impacts on the health of people, wildlife and/or aquatic biota that might arise from exposure to chemicals originating from a study area.
Risk Assessment	Process that evaluates the probability of adverse effects that may occur, or are occurring on target organism(s) as a result of exposure to one or more stressors.
Risk Characterization	The process of evaluating the potential risk to a receptor based on comparison of the estimated exposure to the toxicity reference value.
Risk Management	The managerial, decision-making and active hazard control process used to deal with those environmental agents for which risk evaluation has indicated the risk is too high.
Risk-Based Concentration (RBC)	Concentration in environmental media below which health risks are not expected to occur.
Robust Landscape	Landscape with either an capability to self-correct after extreme events or one with hazard triggers reducing with time.
RsD (Risk Specific Dose)	The exposure limit determined for chemicals assumed to act as genotoxic, non-threshold carcinogens. An RsD is a function of carcinogenic potency (q_1^*) and defined acceptable risk (i.e., q_1^* , target level of risk); for example, the RsD for a lifetime cancer risk of one-in-one-million would equal q_1^*, 1×10^{-6}.
Run Habitat	Areas of swiftly flowing water, without surface waves, that approximate uniform flow and in which the slope of water surface is roughly parallel to the overall gradient of the stream reach.
Run-off	The portion of water from rain and snow which flows over land to streams, ponds or other surface water bodies. It is the portion of water from precipitation which does not infiltrate into the ground, or evaporate.
Run-on	Essentially the same as runoff, but referring to water that flows onto a property, or any piece of land of interest. Includes only those waters that have not been in contact with exposed oil sands, or with oil sands operational areas.
Runoff	The portion of water from rain and snow that flows over land to streams, ponds or other surface waterbodies. It is the portion of water from precipitation that does not infiltrate into the ground, or evaporate.
Sanitary Can	Specific design of metal can also known as an open topped can. Typically consists of a lapped or locked side seam and rolled or crimped lip. Invented in 1896.

Saturation Percentage Percent water content where the soil is completely saturated with water.

Scale Level of spatial resolution.

Screening The process of filtering and removal of implausible or unlikely exposure pathways, chemicals or substances, or populations from the risk assessment process to focus the analysis on the chemicals, pathways and populations of greatest concern.

Secondary Extraction In this step, bitumen froth from the primary extraction step is diluted with light hydrocarbon, and water and fine solids are removed by centrifuges in two stages.

Sediment Sampling A field procedure relating to a method for determining the configuration of sediments.

Sedimentation The process of subsidence and deposition of suspended matter carried by water, wastewater or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material.

Sensory disturbance Visual, auditory, or olfactory stimulus which creates a negative response in wildlife species.

Separation Cells Large, cylindrical open-top vessels which are used as the primary extraction device in the hot water extraction process. Bitumen is recovered from the top of the vessel (as well as from a sidestream in a secondary circuit). Tailings are removed from the bottom.

Shell Shell Canada Limited

Silviculture The science and practice of controlling the establishment, composition and growth of the vegetation in forest stands. It includes the control or production of stand structures such as snags and down logs, in addition to live vegetation.

Site [Human Health] The area determined to be significantly impacted after the iterative evaluations of the risk assessment. Can also be applied to political or legal boundaries.

Site [Historic] Any location with detectable evidence of past human activity.

Slumps Small shallow slope failure involving relocation of surficial soil on a slope without risk to the overall stability the facility.

Snag Any standing dead, or partially-dead tree.

Snye Discrete section on non-flowing water connected to a flowing channel only at its downstream end, generally formed in a side channel or behind a peninsula (bar).

Sodium Adsorption Ratio (SAR)	Concentrations of sodium, calcium and magnesium ions in a solution.
Soil Structure	The combination or arrangement of primary soil particles into secondary particles, units or peds.
Spawning Habitat	A particular type of area where a fish species chooses to reproduce. Preferred habitat (substrate, water flow, temperature) varies from species to species.
Species	A group of organisms that actually or potentially interbreed and are reproductively isolated from all other such groups; a taxonomic grouping of genetically and morphologically similar individuals; the category below genus.
Species abundance	The number of individuals of a particular species within a biological community (e.g., habitat).
Species Composition	A term that refers to the species found in the sampling area.
Species Distribution	Where the various species in an ecosystem are found at any given time. Species distribution varies with season.
Species Diversity	A description of a biological community that includes both the number of different species and their relative abundances. Provides a measure of the variation in number of species in a region. This variation depends partly on the variety of habitats and the variety of resources within habitats and, in part, on the degree of specialization to particular habitats and resources.
Species Richness	The number of different species occupying a given area.
Sport/Game Fish	Large fish caught for food or sport (e.g., northern pike, Arctic grayling).
Stability	A measure of the atmosphere's ability to disperse emissions. Stable atmospheric conditions create poorer dispersion of plumes and increased concentrations. Unstable conditions promote dispersion and result in lower concentrations.
Stand	An aggregation of trees occupying a specific area and sufficiently uniform in composition, age, arrangement and condition so that it is distinguishable from trees in adjoining areas.
Stand Age	The number of years since a stand experienced a stand-replacing disturbance event (e.g., fire, logging).
Stand Density	The number and size of trees on a forest site.
Standard Deviation (Sd)	A measure of the variability or spread of the measurements about the mean. It is calculated as the positive square root of the variance.

Stratigraphy	The succession and age of strata of rock and unconsolidated material. Also concerns the form, distribution, lithologic composition, fossil content and other properties of the strata.
Strip Mining	Mining method in which overburden is first removed from a seam of coal, or a sedimentary ore such as oil sands, allowing the coal or ore to be removed.
Structure (Stand Structure)	The various horizontal and vertical physical elements of the forest. The physical appearance of canopy and subcanopy trees and snags, shrub and herbaceous strata and downed woody material.
Subchronic toxicity	Adverse effects occurring as a result of the repeated daily exposure to a chemical for a short time. In Canada, human exposures lasting between two weeks and three months may be termed subchronic while in the U.S., human exposures lasting between two weeks and seven years may be termed subchronic.
Succession	A series of dynamic changes by which one group of organisms succeeds another through stages leading to a climax community.
Successional Stage	A stage or recognizable condition of a forest community that occurs during its development from bare ground to climax.
Suncor	Suncor Energy Inc., Oil Sands (also Suncor Inc., Oil Sands Group)
Surficial Aquifer	A surficial deposit containing water considered an aquifer.
Surficial Deposit	A geologic deposit (clay, silt or sand) that has been placed above bedrock. (See also "Overburden")
Suspended Sediments	Particles of matter suspended in the water. Measured as the oven dry weight of the solids, in mg/L, after filtration through a standard filter paper. Less than 25 mg/L would be considered clean water, while an extremely muddy river might have 200 mg/L of suspended sediments.
Sustainable Landscape	Ability of landscape (including landforms, drainage, water bodies and vegetation) to survive extreme events and natural cycles of change, without causing accelerated erosion and environmental impacts much more severe than that of the natural environment.
Syncrude	Syncrude Canada Ltd.
Tailings	A byproduct of oil sands extraction which are comprised of water, sands and clays, with minor amounts of residual bitumen.
Tailings Ponds	Man-made impoundment structures required to contain tailings. Tailings ponds are enclosed dykes made with tailings and/or overburden materials to stringent geotechnical standards.
TDS	Total dissolved solids.

Thalweg The (imaginary) line connecting the lowest points along a streambed or valley. Within rivers, the deep channel area.

THC Total Hydrocarbons include all airborne compounds containing only carbon and hydrogen.

TID Tar Island Dyke.

Till Sediments laid down by glaciers.

TOC Total Organic Carbon. TOC is composed of both dissolved and particulate forms. TOC is often calculated as the difference between total carbon (TC) and total inorganic carbon (TIC). TOC has a direct relationship with both biochemical and chemical oxygen demands, and varies with the composition of organic matter present in the water. Organic matter in soils, aquatic vegetation and aquatic organisms are major sources of organic carbon.

Total Dissolved Solids (TDS) The total concentration of all dissolved compounds solids found in a water sample. See filterable residue.

Toxic A substance, dose or concentration that is harmful to a living organism.

Toxic Threshold Almost all compounds (except genotoxic carcinogens) become toxic at some level with no evident harm or adverse effect below that level. Scientists refer to the level or concentration where they can first see evidence for an adverse effect on an organism as the toxic threshold. Genotoxic carcinogens exhibit some toxic potential at any level.

Toxicity The inherent potential or capacity of a material to cause adverse effects in a living organism.

Toxicity Assessment The process of determining the amount (concentration or dose) of a chemical to which a receptor may be exposed without the development of adverse effects.

Toxicity Reference Value (TRV) For a non-carcinogenic chemical, the maximum acceptable dose (per unit body weight and unit of time) of a chemical to which a specified receptor can be exposed, without the development of adverse effects. For a carcinogenic chemical, the maximum acceptable dose of a chemical to which a receptor can be exposed, assuming a specified risk (e.g., 1 in 100,000). May be expressed as a Reference Dose (RfD) for non-carcinogenic (threshold-response) chemicals or as a Risk Specific Dose (RsD) for carcinogenic (non-threshold response) chemicals. Also referred to as exposure limit.

TSP A measure of the total particulate matter suspended in the air. This represents all airborne particles with a mean diameter less than 30 μm (microns) in diameter.

TSS Total suspended solids. See non-filterable residue.

U.S. EPA U.S. Environmental Protection Agency.

Uncertainty Imperfect knowledge concerning the present or future state of the system under consideration; a component of risk resulting from imperfect knowledge of the degree of hazard or of its spatial and temporal distribution.

Uncertainty Factor A unitless numerical value that is applied to a reference toxicological value (i.e., NOAEL) to account for uncertainties in the experimental data used to derive the toxicological value (e.g., short testing period, lack of species diversity, small test group, etc.) and to increase the confidence in the safety of the exposure dose as it applies to species other than the test species (e.g., sensitive individuals in the human population). RfD equals the NOAEL divided by the uncertainty factor.

Unconfined Aquifer An aquifer in which the water level is below the top of the aquifer.

Understory Those trees or other vegetation in a forest stand below the main canopy level.

Upgraded Crude Oil Often referred to as synthetic oil, upgraded crude oil is bitumen that has undergone alteration to improve its hydrogen-carbon balance to a lighter specific gravity product. At Suncor upgraded crude oil products may include:

- Oil Sands A, a blend of low sulphur (hydrotreated) naphtha, kerosene and gas oil
- Oil Sands Diesel, hydrotreated kerosene
- Oil Sands E, a sour (higher sulphur) blend of coker distillate
- Oil Sand Virgin, an uncracked vacuum tower product

Uptake The process by which a chemical crosses an absorption barrier and is absorbed into the body.

Valued Ecosystem Component (VEC) Components of an ecosystem (either plant, animal, or abiotic feature) considered valuable by various sectors of the public.

Vegetation Community See "Plant Community".

VOC Volatile Organic Compounds include aldehydes and all of the hydrocarbons except for ethane and methane. VOCs represent the airborne organic compounds likely to undergo or have a role in the chemical transformation of pollutants in the atmosphere.

Waste Area The area where overburden materials are placed that are surplus to the need of the mine. Also referred to as a "waste dump".

Water Equivalent	As relating to snow; the depth of water that would result from melting.
Water Table	The shallowest saturated ground below ground level - technically, that surface of a body of unconfined groundwater in which the pressure is equal to atmospheric pressure.
Watershed	The entire surface drainage area that contributes water to a lake or river.
Wet Landscape Reclamation	A reclamation approach that involves a lake system, whereby contained fluid tailings are capped with a layer of water of sufficient depth to isolate fine tailings from direct contact with the surrounding environment.
Wetlands	Term for a broad group of wet habitats. Wetlands are transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands include features that are permanently wet, or intermittently water-covered such as swamps, marshes, bogs, muskegs, potholes, swales, glades, slashes and overflow land of river valleys.
Worst-Case	A semi-quantitative term referring to the maximum possible exposure, dose or risk, that can conceivably occur, whether or not this exposure, dose, or risk actually occurs is observed in a specific population. It should refer to a hypothetical situation in which everything that can plausibly happen to maximize exposure, dose, or risk does happen. The worst-case may occur in a given population, but since it is usually a very unlikely set of circumstances in most cases, a worst-case estimate will be somewhat higher than what occurs in a specific population.
WSC	Water Survey of Canada
Xeric	Referring to habitats in which plant production is limited by availability of water.
YOY	Young of the year. Fish at age 0, within the first year after hatching.