



2006 Technical Report



REGIONAL AQUATICS MONITORING PROGRAM

2006 Technical Report

FINAL

Prepared for:

RAMP STEERING COMMITTEE

Prepared by:

The RAMP 2006 Implementation Team

Consisting of:

**HATFIELD CONSULTANTS
STANTEC CONSULTING LTD.
MACK, SLACK & ASSOCIATES INC.
and WESTERN RESOURCE SOLUTIONS**

APRIL 2007

1245.2

TABLE OF CONTENTS

LIST OF TABLES	v
LIST OF FIGURES.....	xviii
LIST OF APPENDICES	xxix
ACKNOWLEDGEMENTS.....	xxx
EXECUTIVE SUMMARY.....	xxxix
1.0 INTRODUCTION.....	1-1
1.1 ATHABASCA OIL SANDS REGION BACKGROUND	1-1
1.2 OVERVIEW OF RAMP	1-2
1.2.1 RAMP Objectives.....	1-3
1.2.2 Organization of RAMP	1-3
1.3 RAMP STUDY AREA.....	1-4
1.4 GENERAL RAMP MONITORING AND ANALYTICAL APPROACH.....	1-10
1.4.1 Focal Projects	1-10
1.4.2 Overall RAMP Monitoring Approach	1-10
1.4.3 RAMP Components	1-11
1.4.4 Monitoring Approaches for RAMP Components	1-11
1.4.5 Overall Analytical Approach for 2006.....	1-17
1.4.6 Definition of Terms	1-21
1.5 ORGANIZATION OF THE RAMP 2006 TECHNICAL REPORT.....	1-21
2.0 ACTIVITIES IN THE RAMP FOCUS STUDY AREA IN 2006.....	2-1
2.1 BACKGROUND	2-1
2.2 FOCAL PROJECT ACTIVITIES IN 2006	2-1
2.2.1 Suncor Energy Inc.	2-1
2.2.2 Syncrude Canada Ltd.	2-3
2.2.3 Albion Sands Energy Inc.	2-4
2.2.4 Shell Canada Ltd.	2-4
2.2.5 Canadian Natural Resources Ltd.....	2-4
2.2.6 Petro-Canada Oil and Gas	2-5
2.2.7 OPTI Canada Ltd./Nexen Inc.....	2-6
2.2.8 Deer Creek Energy Ltd.	2-6
2.2.9 Birch Mountain Resources Ltd.....	2-6
2.3 OTHER APPROVED RAMP-FUNDER PROJECTS.....	2-6
2.4 RAMP-FUNDER PROJECTS UNDER APPLICATION.....	2-6
2.5 NON-RAMP MEMBER OIL SANDS PROJECTS.....	2-7
2.6 LAND CHANGE EFFECTS OF DEVELOPMENT ACTIVITIES IN 2006	2-7
3.0 2006 RAMP MONITORING ACTIVITIES.....	3-1
3.1 CLIMATE AND HYDROLOGY COMPONENT.....	3-1
3.1.1 Summary of 2006 Monitoring Activities	3-1
3.1.2 Summary of Field Methods.....	3-2
3.1.3 Changes in Monitoring Network from 2005	3-6
3.1.4 Challenges Encountered and Solutions Applied.....	3-6

3.1.5	Other Information Obtained	3-6
3.1.6	Summary of Component Data Now Available.....	3-7
3.1.7	Analytical Approach	3-7
3.2	WATER QUALITY COMPONENT	3-11
3.2.1	Summary of 2006 Monitoring Activities	3-11
3.2.2	Summary of Field Methods and Sample Analysis	3-11
3.2.3	Changes in Monitoring Network from 2005	3-18
3.2.4	Challenges Encountered and Solutions Applied.....	3-18
3.2.5	Other Information Obtained	3-18
3.2.6	Summary of Component Data Now Available.....	3-18
3.2.7	Analytical Approach	3-20
3.3	BENTHIC INVERTEBRATE COMMUNITIES AND SEDIMENT QUALITY	3-32
3.3.1	Benthic Invertebrate Community Component.....	3-32
3.3.2	Sediment Quality Component.....	3-42
3.4	FISH POPULATION COMPONENT	3-51
3.4.1	Overview of 2006 Monitoring Activities	3-51
3.4.2	Summary of Field Methods.....	3-51
3.4.3	Changes in Monitoring Network from 2005 Field Program.....	3-64
3.4.4	Challenges Encountered and Solutions Applied.....	3-64
3.4.5	Other Information Obtained	3-64
3.4.6	Summary of Component Data Now Available.....	3-64
3.4.7	Analytical Approach	3-67
3.5	ACID-SENSITIVE LAKES.....	3-72
3.5.1	Overview of 2006 Monitoring Activities	3-72
3.5.2	Summary of Field Methods.....	3-72
3.5.3	Changes in Monitoring Network from 2005	3-76
3.5.4	Challenges Encountered and Solutions Applied.....	3-76
3.5.5	Other Information Obtained	3-76
3.5.6	Summary of Component Data Now Available.....	3-76
3.5.7	Analytical Approach	3-78
4.0	CLIMATIC AND HYDROLOGIC CHARACTERIZATION OF THE ATHABASCA OIL SANDS REGION IN 2006.....	4-1
5.0	ASSESSMENT OF 2006 RESULTS	5-1
5.1	ATHABASCA RIVER	5-2
5.1.1	Development Status	5-4
5.1.2	Hydrologic Conditions.....	5-4
5.1.3	Water Quality	5-6
5.1.4	Benthic Invertebrate Communities and Sediment Quality	5-8
5.1.5	Fish Populations	5-8
5.1.6	Summary of Conditions	5-13
5.2	ATHABASCA RIVER DELTA.....	5-52
5.2.1	Development Status	5-54
5.2.2	Hydrologic Conditions.....	5-54
5.2.3	Water Quality	5-54
5.2.4	Benthic Invertebrate Communities and Sediment Quality	5-54
5.2.5	Fish Populations	5-54
5.3	MUSKEG RIVER WATERSHED	5-56
5.3.1	Development Status	5-58

5.3.2	Hydrologic Conditions.....	5-58
5.3.3	Water Quality.....	5-59
5.3.4	Benthic Invertebrate Communities and Sediment Quality	5-63
5.3.5	Fish Populations	5-67
5.3.6	Summary of Conditions	5-73
5.4	STEEP BANK RIVER WATERSHED.....	5-120
5.4.1	Development Status	5-122
5.4.2	Hydrologic Conditions.....	5-122
5.4.3	Water Quality.....	5-123
5.4.4	Benthic Invertebrate Communities and Sediment Quality	5-125
5.4.5	Fish Populations	5-126
5.4.6	Summary of Conditions	5-130
5.5	TAR RIVER WATERSHED.....	5-158
5.5.1	Development Status	5-160
5.5.2	Hydrologic Conditions.....	5-160
5.5.3	Water Quality.....	5-161
5.5.4	Benthic Invertebrate Communities and Sediment Quality	5-163
5.5.5	Fish Populations	5-165
5.5.6	Summary of Conditions	5-165
5.6	MACKAY RIVER WATERSHED	5-180
5.6.1	Development Status	5-182
5.6.2	Hydrologic Conditions.....	5-182
5.6.3	Water Quality.....	5-182
5.6.4	Benthic Invertebrate Communities and Sediment Quality	5-184
5.6.5	Fish Populations	5-185
5.6.6	Summary of Conditions	5-186
5.7	CALUMET RIVER WATERSHED	5-204
5.7.1	Development Status	5-206
5.7.2	Hydrologic Conditions.....	5-206
5.7.3	Water Quality.....	5-206
5.7.4	Benthic Invertebrate Communities and Sediment Quality	5-208
5.7.5	Fish Populations	5-209
5.7.6	Summary of Conditions	5-210
5.8	FIREBAG RIVER WATERSHED.....	5-222
5.8.1	Development Status	5-224
5.8.2	Hydrologic Conditions.....	5-224
5.8.3	Water Quality.....	5-225
5.8.4	Benthic Invertebrate Communities and Sediment Quality	5-226
5.8.5	Fish Populations	5-227
5.8.6	Summary of Conditions	5-227
5.9	ELLS RIVER WATERSHED.....	5-240
5.9.1	Development Status	5-242
5.9.2	Hydrologic Conditions.....	5-242
5.9.3	Water Quality.....	5-243
5.9.4	Benthic Invertebrate Communities and Sediment Quality	5-244
5.9.5	Fish Populations	5-245
5.9.6	Summary of Conditions	5-245
5.10	CLEARWATER-CHRISTINA RIVER SYSTEM	5-258
5.10.1	Development Status	5-260
5.10.2	Hydrologic Conditions.....	5-260
5.10.3	Water Quality.....	5-261

5.10.4	Benthic Invertebrate Communities and Sediment Quality	5-262
5.10.5	Fish Populations	5-264
5.10.6	Summary of Conditions	5-268
5.11	HANGINGSTONE RIVER WATERSHED.....	5-302
5.11.1	Development Status	5-304
5.11.2	Hydrologic Conditions.....	5-304
5.11.3	Water Quality	5-305
5.11.4	Benthic Invertebrate Communities and Sediment Quality	5-306
5.11.5	Fish Populations	5-306
5.11.6	Summary of Conditions	5-306
5.12	MISCELLANEOUS AQUATIC SYSTEMS	5-318
5.12.1	Development Status	5-320
5.12.2	Hydrologic Conditions.....	5-320
5.12.3	Water Quality	5-322
5.12.4	Benthic Invertebrate Communities and Sediment Quality	5-330
5.12.5	Fish Populations	5-333
5.12.6	Summary of Conditions	5-334
5.13	ACID-SENSITIVE LAKES.....	5-406
5.13.1	Between-Year Comparison of ASL Measurement Endpoints.....	5-406
5.13.2	Critical Loads of Acidity and Critical Load Exceedances	5-407
5.13.3	Trends in ASL Measurement Endpoints	5-408
5.13.4	Summary of Conditions	5-409
6.0	CONCLUSIONS AND RECOMMENDATIONS.....	6-1
6.1	CONCLUSIONS.....	6-1
6.1.1	Climate and Hydrology Component.....	6-1
6.1.2	Water Quality Component	6-2
6.1.3	Benthic Invertebrate Communities and Sediment Quality Component.....	6-3
6.1.4	Fish Populations Component	6-4
6.1.5	Acid-Sensitive Lakes Component.....	6-7
6.2	RECOMMENDATIONS	6-8
6.2.1	Climate and Hydrology Component.....	6-8
6.2.2	Water Quality Component	6-8
6.2.3	Benthic Invertebrate Community and Sediment Quality Component	6-8
6.2.4	Fish Population Component	6-9
6.2.5	Acid-Sensitive Lakes Component.....	6-9
7.0	REFERENCES.....	7-1
8.0	GLOSSARY AND LIST OF ACRONYMS.....	8-1
8.1	GLOSSARY	8-1
8.2	LIST OF ACRONYMS AND ABBREVIATIONS.....	8-11

LIST OF TABLES

Table 1.1-1	Status of bitumen reserves in the Athabasca oil sands region.	1-1
Table 1.4-1	Measurement endpoints and criteria for determination of change used in the analysis for the RAMP 2006 Technical Report.	1-18
Table 2.2-1	Status and activities of developments owned by 2006 RAMP- funders in the RAMP Focus Study Area.	2-2
Table 2.5-1	Approved Athabasca oil sands development projects within the RAMP study area operated by non-RAMP members, as of 2006.	2-7
Table 2.6-1	Area of watersheds with land change in 2006.	2-13
Table 2.6-2	Percent of total watershed areas with land change in 2006.	2-14
Table 3.1-1	RAMP climate and hydrology stations operating in 2006.	3-5
Table 3.1-2	Summary of RAMP data available for the Climate and Hydrology component.	3-8
Table 3.2-1	RAMP water quality sampling field campaigns, 2006.	3-11
Table 3.2-2	Summary of sampling for the RAMP 2006 Water Quality component.	3-13
Table 3.2-3	RAMP water quality composite sample sub-groups.	3-17
Table 3.2-4	Locations of 2006 continuous water temperature monitoring stations.	3-17
Table 3.2-5	OPTI Lakes sample station locations, 2006.	3-17
Table 3.2-6	RAMP standard variables.	3-19
Table 3.2-7	Sublethal toxicity tests of ambient river water.	3-19
Table 3.2-8	Summary of RAMP data available for the Water Quality component.	3-21
Table 3.2-9	Potential key water quality measurement endpoints.	3-26
Table 3.2-10	Classification of groups of RAMP water quality monitoring stations with similar water quality, from 1997 to 2006 data.	3-28
Table 3.2-11	Regional baseline water quality data groups and station comparisons.	3-29
Table 3.2-12	Number of observations for determination of baseline regional water quality.	3-30

Table 3.2-13	Summary of 2006 focal projects that are <i>in situ</i> oil sands operations.	3-31
Table 3.3-1	Summary of sampling for the RAMP 2006 Benthic Invertebrate Community component.	3-35
Table 3.3-2	Summary of RAMP data available for the Benthic Invertebrate Community component.	3-40
Table 3.3-3	Summary of sediment quality sampling for RAMP, September 2006.	3-44
Table 3.3-4	RAMP sediment quality variables analyzed in 2006.	3-45
Table 3.3-5	Summary of RAMP data available for the Sediment Quality component.	3-47
Table 3.3-6	Potential sediment quality measurement endpoints.	3-50
Table 3.4-1	Summary of Fish Population component monitoring studies in 2006.	3-52
Table 3.4-2	Fish inventory sampling areas for Athabasca and Clearwater rivers, 2006.	3-55
Table 3.4-3	Methods of analyses and detection limits for metals and tainting compounds.	3-57
Table 3.4-4	Equipment used during the Muskeg River spring fish fence, April and May 2006.	3-58
Table 3.4-5	Tributary sentinel fish species monitoring sites, 2006.	3-62
Table 3.4-6	Location of MacKay River sentinel fish species reconnaissance sites.	3-63
Table 3.4-7	Summary of RAMP data available for the Fish Population component.	3-65
Table 3.4-8	Fish population measurement endpoints for non-lethal sentinel species monitoring.	3-68
Table 3.4-9	Concentrations of metals that have lethal, sublethal or no effect on freshwater fish.	3-69
Table 3.5-1	Lakes sampled in 2006 for the Acid-Sensitive Lakes component.	3-75
Table 3.5-2	Water quality variables analyzed in 2006 in lake water sampled under the ASL component.	3-76
Table 3.5-3	Summary of lakes sampled during RAMP, 1999 to 2006.	3-77

Table 4.1-1	A summary of 2006 streamflow variables compared to historical values measured in the Athabasca oil sands region.	4-4
Table 5-1	Page number guide to watersheds and RAMP component reports.....	5-1
Table 5.1-1	Inputs for calculation of baseline hydrograph at RAMP Station S24, Athabasca River below Eymundson Creek.	5-15
Table 5.1-2	Calculated changes in hydrologic measurement endpoints for the Athabasca River, focal projects case.....	5-16
Table 5.1-3	Calculated changes in hydrologic measurement endpoints for the Athabasca River, cumulative effects case.	5-16
Table 5.1-4	Concentrations of water quality measurement endpoints, Athabasca River mainstem, fall 2006.	5-17
Table 5.1-5	Seasonal exceedances of water quality guidelines in the Athabasca River mainstem, downstream of development (ATR-DD), 2006.	5-26
Table 5.1-6	Trend analysis of water quality measurement endpoints for Athabasca River mainstem stations.	5-27
Table 5.1-7	Athabasca River fish inventory results, spring 2006.	5-36
Table 5.1-8	Athabasca River fish inventory results, fall 2006.	5-36
Table 5.1-9	Results of multi-year (1997-2006) comparisons of weight-length relationship (condition) for four key indicator fish species, Athabasca River.	5-47
Table 5.1-10	Summary of external pathology indices, Athabasca River, 1995-2006.....	5-48
Table 5.1-11	Fish species presence-absence summary for reaches 19A and 19B resulting from the Athabasca River Inventory, 2003 to 2006.	5-48
Table 5.1-12	Seasonal total CPUE for reaches 19A and 19B.....	5-48
Table 5.1-13	Results of RAMP fish tag return analysis, 2006.....	5-51
Table 5.1-14	Results of RAMP fish tag return analysis, 1999 to 2006.....	5-51
Table 5.3-1	Inputs for calculation of baseline hydrograph at RAMP/WSC Station S7, Muskeg River near Fort McKay (07DA008).	5-76
Table 5.3-2	Calculated changes in hydrologic measurement endpoints for the Muskeg River watershed.	5-76

Table 5.3-3	Concentrations of selected water quality measurement endpoints, Muskeg River mouth (station MUR-1), fall 2006.	5-77
Table 5.3-4	Concentrations of selected water quality measurement endpoints, Jackpine Creek (station JAC-1), fall 2006.	5-78
Table 5.3-5	Concentrations of selected water quality measurement endpoints, Stanley Creek (station STC-1), fall 2006.	5-79
Table 5.3-6	Concentrations of selected water quality measurement endpoints, Shelley Creek (station SHC-1), fall 2006.	5-80
Table 5.3-7	Concentrations of selected water quality measurement endpoints, Muskeg River upstream of Wapasu Creek (station MUR-6), fall 2006.	5-81
Table 5.3-8	Concentrations of selected water quality measurement endpoints, Muskeg Creek (station MUC-1), fall 2006.	5-82
Table 5.3-9	Concentrations of selected water quality measurement endpoints, Wapasu Creek (station WAC-1), fall 2006.	5-83
Table 5.3-10	List of all 2006 water quality guideline exceedances, Muskeg River.	5-84
Table 5.3-11	Habitat characteristics of benthic invertebrate community sampling reaches in the Muskeg River, fall 2006.	5-90
Table 5.3-12	Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the Muskeg River.	5-92
Table 5.3-13	Results of Analysis Of Variance (ANOVA) between the lower (MUR-E-1) and upper (MUR-D-3) reaches of the Muskeg River.	5-93
Table 5.3-14	Analysis of variance (ANOVA) between middle (MUR-D-2) and upper (MUR-D-3) reaches of the Muskeg River.	5-96
Table 5.3-15	Habitat characteristics of benthic invertebrate community sampling reaches in Jackpine Creek, fall 2006.	5-99
Table 5.3-16	Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in Jackpine Creek.	5-100
Table 5.3-17	Analysis of variance between lower (JAC-D-1) and upper (JAC-D-2) reaches of Jackpine Creek.	5-101
Table 5.3-18	Concentrations of selected sediment quality measurement endpoints in middle reach of the Muskeg River, near the Canterra Road crossing (reach MUR-D-2), fall 2006.	5-104

Table 5.3-19	Concentrations of selected sediment quality measurement endpoints in upper reach of the Muskeg River (reach MUR-D-3), fall 2006.	5-105
Table 5.3-20	Concentrations of selected sediment quality measurement endpoints in lower reach of the Jackpine River (reach JAC-D-1), fall 2006.	5-106
Table 5.3-21	Concentrations of selected sediment quality measurement endpoints in upper reach of the Jackpine River (reach JAC-D-2), fall 2006.	5-107
Table 5.3-22	Daily fish counts at the Muskeg River counting fence, spring 2006.	5-108
Table 5.3-23	Summary of mark/recapture data for dominant fish species captured at the Muskeg River fish fence, spring 2006.	5-109
Table 5.3-24	Summary of residency time of fish tagged at the Muskeg River fish fence, spring 2006.	5-111
Table 5.3-25	Number of fish with specific external abnormalities for the three dominant fish species captured at the Muskeg River fish fence, spring 2006.	5-118
Table 5.3-26	Data on incidental fish species caught at the Muskeg River fish fence, spring 2006.	5-119
Table 5.4-1	Inputs for calculation of the baseline hydrograph at WSC Station 07DA006, Steepbank River near Fort McMurray.	5-132
Table 5.4-2	Calculated change in hydrologic measurement endpoints for the Steepbank River watershed for 2006.	5-132
Table 5.4-3	Concentrations of water quality measurement endpoints in the lower Steepbank River (STR-1), fall 2006.	5-133
Table 5.4-4	Concentrations of water quality measurement endpoints in the Steepbank River upstream of Steepbank Mine/Project Millennium (STR-2), fall 2006.	5-134
Table 5.4-5	Concentrations of water quality measurement endpoints in the upper Steepbank River (STR-3), fall 2006.	5-135
Table 5.4-6	Concentrations of water quality measurement endpoints in the North Steepbank River (NSR-1), fall 2006.	5-136
Table 5.4-7	List of water quality guideline exceedances, Steepbank River watershed, 2006.	5-137
Table 5.4-8	Average habitat characteristics of benthic invertebrate community reaches in the Steepbank River, fall 2006.	5-141

Table 5.4-9	Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the Steepbank River.....	5-143
Table 5.4-10	Analysis of variance (ANOVA) between reach STR-E-1 and reach STR-E-2.....	5-145
Table 5.4-11	Summary of habitat characteristics of sentinel species monitoring sites, August 2006.	5-147
Table 5.4-12	Results of fish sampling efforts during August and October 2004 and 2006 sentinel species monitoring programs.	5-147
Table 5.4-13	Statistical comparison of length-frequency distributions between Steepbank River sites and other sentinel species sites, 2006.....	5-148
Table 5.4-14	Seasonal comparison of size of captured slimy sculpin, August and October 2006.	5-152
Table 5.4-15	Estimated growth rates of young-of-the-year sculpin, 2006.....	5-155
Table 5.4-16	Proportion of slimy sculpin populations represented by young-of-year individuals, August and October 2006.	5-156
Table 5.4-17	Mean condition factor of slimy sculpin (excluding YOY fish), 2006.....	5-156
Table 5.4-18	Effect summary for condition factor of adult slimy sculpin from the lower Steepbank River (site SR-E <i>potentially influenced</i>) relative to each <i>reference</i> site, 2006.....	5-157
Table 5.4-19	Effect summary for condition factor of adult slimy sculpin from the lower Muskeg River (site MR-E, <i>potentially influenced</i>) relative to each <i>reference</i> site, 2006.....	5-157
Table 5.5-1	Summary of inputs to the calculation of the Tar River baseline hydrograph at RAMP/WSC Station S15, Tar River near the Mouth (07DA015).	5-167
Table 5.5-2	Calculated change in hydrologic measurement endpoints for the Tar River watershed.	5-167
Table 5.5-3	Concentrations of water quality measurement endpoints, lower Tar River (station TAR-1), fall 2006.	5-168
Table 5.5-4	Concentrations of water quality measurement endpoints, upper Tar River (station TAR-2), fall 2006.	5-169
Table 5.5-5	List of all 2006 water quality guideline exceedances, Tar River.	5-170
Table 5.5-6	Average habitat characteristics of benthic invertebrate community sampling reaches in the Tar River, fall 2006.	5-174

Table 5.5-7	Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the Tar River.	5-175
Table 5.5-8	Results of Analysis of Variance (ANOVA) on Tar River, reaches TAR-D-1 and TAR-E-2, with planned comparisons.	5-176
Table 5.5-9	Sediment quality measurement endpoints, lower reach of Tar River near the mouth (reach TAR-D-1), fall 2006.	5-179
Table 5.6-1	Inputs to calculation of MacKay River baseline hydrograph at RAMP/WSC Station S26, MacKay River near Fort McKay (07DB001).	5-188
Table 5.6-2	Calculated change in hydrologic measurement endpoints for the MacKay River watershed.	5-188
Table 5.6-3	Concentrations of water quality measurement endpoints, mouth of MacKay River (station MAR-1), fall 2006.	5-189
Table 5.6-4	Concentrations of water quality measurement endpoints, upstream MacKay River (station MAR-2), fall 2006.	5-190
Table 5.6-5	List of water quality guideline exceedances, MacKay River watershed, 2006.	5-191
Table 5.6-6	Average habitat characteristics of benthic invertebrate community sampling reaches in the MacKay River, fall 2006.	5-195
Table 5.6-7	Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the MacKay River.	5-197
Table 5.6-8	Results of analysis of variance (ANOVA) on MacKay River, reaches MAR-E-1 and MAR-E-2, with planned comparisons.	5-199
Table 5.6-9	Results of the MacKay River sentinel reconnaissance fish sampling program, September 2006.	5-203
Table 5.6-10	CPUE for the two electrofishing sites on the MacKay River sentinel reconnaissance, September 2006.	5-203
Table 5.7-1	Inputs to calculation of Calumet River baseline hydrograph at CNRL Station CR-1, Calumet River near the Mouth.	5-211
Table 5.7-2	Calculated change in hydrologic measurement endpoints for the Calumet River watershed.	5-211
Table 5.7-3	Concentrations of water quality measurement endpoints, mouth of Calumet River (station CAR-1), fall 2006.	5-212
Table 5.7-4	Concentrations of water quality measurement endpoints, upper Calumet River (station CAR-2), fall 2006.	5-213

Table 5.7-5	List of all 2006 water quality guideline exceedances, Calumet River.	5-214
Table 5.7-6	Habitat characteristics of upper Calumet River reach, fall 2006.	5-218
Table 5.7-7	Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the Calumet River.	5-219
Table 5.7-8	Concentrations of sediment quality measurement endpoints, upper Calumet River (reach CAL-D-2), fall 2006.	5-221
Table 5.8-1	Inputs to calculation of Firebag River baseline hydrograph at RAMP/WSC Station S27, Firebag River near the Mouth (07DC001).	5-229
Table 5.8-2	Calculated change in hydrologic measurement endpoints for the Firebag River watershed.	5-229
Table 5.8-3	Concentrations of water quality measurement endpoints, mouth of Firebag River (station FIR-1), fall 2006.	5-230
Table 5.8-4	Concentrations of water quality measurement endpoints, Firebag River above the Suncor Firebag project (station FIR-2), fall 2006.	5-231
Table 5.8-5	List of all 2006 water quality guideline exceedances, Firebag River.	5-231
Table 5.8-6	Average habitat characteristics of benthic invertebrate community sampling reaches in the Firebag River, fall 2006.	5-235
Table 5.8-7	Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the Firebag River.	5-237
Table 5.8-8	Sediment quality measurement endpoints, lower reach near mouth of Firebag River (reach FIR-D-1), fall 2006.	5-239
Table 5.9-1	Summary of inputs to the calculation of the Ells River baseline hydrograph at RAMP Station S14, Ells River above Joslyn Creek.	5-246
Table 5.9-2	Calculated change in hydrologic measurement endpoints for the Ells River watershed.	5-247
Table 5.9-3	Concentrations of water quality measurement endpoints, mouth of Ells River (ELR-1), fall 2006.	5-247
Table 5.9-4	Concentrations of water quality measurement endpoints, upper Ells River (ELR-2), fall 2006.	5-248
Table 5.9-5	Water quality guideline exceedances, Ells River watershed, 2006.	5-249

Table 5.9-6	Average habitat characteristics of benthic invertebrate sampling reaches in the Ells River, fall 2006.	5-253
Table 5.9-7	Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the Ells River, fall 2006.	5-255
Table 5.9-8	Sediment quality measurement endpoints, lower reach of Ells River near the mouth (reach ELR-D-1), fall 2006.	5-257
Table 5.10-1	Estimated changes in annual discharge in the Christina River watershed as a result of focal projects and other active oil sands projects in the watershed.	5-271
Table 5.10-2	Concentrations of water quality measurement endpoints, mouth of Clearwater River (CLR-1), fall 2006.	5-272
Table 5.10-3	Concentrations of water quality measurement endpoints, upper Clearwater River (CLR-2), fall 2006.	5-273
Table 5.10-4	Concentrations of water quality measurement endpoints, mouth of Christina River (CHR-1), fall 2006.	5-274
Table 5.10-5	Concentrations of water quality measurement endpoints, upper Christina River (CHR-2), fall 2006.	5-275
Table 5.10-6	Water quality guideline exceedances, Clearwater-Christina River watersheds, 2006.	5-276
Table 5.10-7	Average habitat characteristics of benthic invertebrate community sampling reaches in the Christina River, fall 2006.	5-280
Table 5.10-8	Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the Christina River, fall 2006.	5-281
Table 5.10-9	Sediment quality measurement endpoints, lower reach near mouth of Christina River (reach CHR-D-1), fall 2006.	5-283
Table 5.10-10	Sediment quality measurement endpoints, upper Christina River (reach CHR-D-2), fall 2006.	5-284
Table 5.10-11	Clearwater River fish inventory results, spring 2006.	5-285
Table 5.10-12	Clearwater River fish inventory results, fall 2006.	5-285
Table 5.10-13	Seasonal comparison of total catch per unit effort (captured fish only) in the Clearwater River, 2003 to 2006.	5-285
Table 5.10-14	Comparison of external pathology indices for fish captured during the Clearwater River (2004 to 2006) and Athabasca River (1995 to 2006) inventories.	5-292

Table 5.10-15	Metrics and mercury concentrations in northern pike collected from the Clearwater River, fall 2006.	5-293
Table 5.10-16	Correlations between mercury concentration in northern pike muscle from Clearwater River versus length, and age, fall 2006.....	5-293
Table 5.10-17	Screening of metals and tainting compounds in northern pike composite samples collected in 2006 from the Clearwater River against criteria fish consumption for the protection of human health.	5-296
Table 5.10-18	Screening of mercury concentrations in northern pike from the Clearwater River against criteria for fish consumption for the protection of human health, fall 2006.....	5-298
Table 5.10-19	Screening of mercury concentrations in northern pike from the Clearwater River against criteria for the protection of fish, fall 2006.....	5-299
Table 5.10-20	Screening of metals and tainting compounds in northern pike composite samples collected in 2006 from the Clearwater River against criteria for the protection of fish.....	5-300
Table 5.11-1	Inputs for calculation of the baseline hydrograph at WSC Station 07CD004, Hangingstone River at Fort McMurray.....	5-308
Table 5.11-2	Calculated change in hydrologic measurement endpoints for the Hangingstone River watershed for 2006.	5-308
Table 5.11-3	Concentrations of water quality measurement endpoints, mouth of Hangingstone River (station HAR-1), fall 2006.....	5-309
Table 5.11-4	List of all 2006 water quality guideline exceedances, Hangingstone River (station HAR-1).	5-310
Table 5.11-5	Average habitat characteristics of benthic invertebrate community sampling reaches in the Hangingstone River, fall 2006.....	5-314
Table 5.11-6	Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in the lower reach of the Hangingstone River (reach HAR-E-1).	5-316
Table 5.12-1	Inputs for calculation of the baseline hydrograph at RAMP Station S11, Poplar Creek at Highway 63 (07DA007).	5-337
Table 5.12-2	Calculated change in hydrologic measurement endpoints for the Poplar Creek watershed for 2006.	5-337
Table 5.12-3	Inputs for calculation of the baseline hydrograph at RAMP Station S12, Fort Creek at Highway 63.	5-338

Table 5.12-4	Calculated change in hydrologic measurement endpoints for the Fort Creek watershed for 2006.	5-338
Table 5.12-5	Concentrations of water quality measurement endpoints, lower Beaver River, (BER-1), fall 2006.	5-341
Table 5.12-6	Water quality guideline exceedances in the Beaver River (station BER-1), Poplar Creek (station POC-1), and McLean Creek (station MCC-1), 2006.	5-342
Table 5.12-7	Concentrations of water quality measurement endpoints, Poplar Creek (POC-1), fall 2006.	5-346
Table 5.12-8	Concentrations of water quality measurement endpoints, McLean Creek (MCC-1), fall 2006.	5-347
Table 5.12-9	Concentrations of water quality measurement endpoints, Isadore's Lake (ISL-1), fall 2006.	5-348
Table 5.12-10	Concentrations of water quality measurement endpoints, Shipyard Lake (SHL-1), fall 2006.	5-352
Table 5.12-11	Concentrations of water quality measurement endpoints, lower Fort Creek (FOC-1), fall 2006.	5-353
Table 5.12-12	Concentrations of water quality measurement endpoints, Kearl Lake (station KEL-1), fall 2006.	5-357
Table 5.12-13	Water quality guideline exceedances, Kearl Lake (station KEL-1) and McLelland Lake (station MCL-1), fall 2006.	5-357
Table 5.12-14	Concentrations of water quality measurement endpoints, McClelland Lake (station MCL-1), fall 2006.	5-361
Table 5.12-15	Concentrations of water quality measurement endpoints (fall data), Birch Lake (BIL-1), 2000 to 2006.	5-364
Table 5.12-16	Concentrations of water quality measurement endpoints (fall data), Long Lake (LOL-1), 2000 to 2006.	5-365
Table 5.12-17	Concentrations of water quality measurement endpoints (fall data), Poison Lake (POL-1), 2000 to 2006.	5-366
Table 5.12-18	Concentrations of water quality measurement endpoints (fall data), Pushup Lake, 2000 to 2006.	5-367
Table 5.12-19	Concentrations of water quality measurement endpoints (fall data), Rat Lake (RAL-1), 2000 to 2006.	5-368
Table 5.12-20	Concentrations of water quality measurement endpoints, (fall data) Canoe Lake (CANL-1), 2000 to 2006.	5-369

Table 5.12-21	Concentrations of water quality measurement endpoints (fall data), Caribou Horn Lake (CARL-1), 2000 to 2006.	5-370
Table 5.12-22	Concentrations of water quality measurement endpoints (fall data), Frog Lake (FRL-1), 2000 to 2006.	5-371
Table 5.12-23	Concentrations of water quality measurement endpoints (fall data), Gregoire Lake (GRL-1), 2000 to 2006.	5-372
Table 5.12-24	Concentrations of water quality measurement endpoints (fall data), Kiskatinaw Lake (KIL-1), 2000 to 2006.	5-373
Table 5.12-25	Concentrations of water quality measurement endpoints (fall data), Sucker Lake (SUL-1), 2000 to 2006.	5-374
Table 5.12-26	Concentrations of water quality measurement endpoints (fall data), Unnamed Lake 1 (UNL-1), 2000 to 2006.	5-375
Table 5.12-27	Concentrations of water quality measurement endpoints (fall data), Unnamed Lake 2 (UNL-2), 2000 to 2006.	5-376
Table 5.12-28	Concentrations of water quality measurement endpoints (fall data), Unnamed Lake 3 (UNL-3), 2000 to 2006.	5-377
Table 5.12-29	Water quality guideline exceedances, OPTI lakes, spring and fall 2006.	5-378
Table 5.12-30	Average habitat characteristics of benthic invertebrate sampling locations in Kearl, McClelland, and Shipyard lakes, fall 2006.	5-391
Table 5.12-31	Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in Kearl, Shipyard, McClelland, and Isadore's lakes.	5-392
Table 5.12-32	Results of analysis of variance (ANOVA) testing for effects in Shipyard Lake (SHL-1) relative to Kearl and McClelland lakes.	5-393
Table 5.12-33	Results of analysis of variance (ANOVA) testing for effects in Isadore's Lake (SHL-1) relative to Kearl and McClelland lakes.	5-394
Table 5.12-34	Average habitat characteristics of lower Fort Creek, reach FOC- D-1, fall 2006.	5-396
Table 5.12-35	Relative abundance of major taxa, and benthic invertebrate community measurement endpoints in lower Fort Creek, 2001 to 2006.	5-397
Table 5.12-36	Analysis of variance (ANOVA) of benthic invertebrate community measurement endpoints in reach FOC-D-1 between <i>reference</i> and <i>potentially influenced</i> years.	5-398

Table 5.12-37	Concentrations of sediment quality measurement endpoints, Shipyard Lake (SHL-1), fall 2006.....	5-401
Table 5.12-38	Concentrations of sediment quality measurement endpoints, Kearl Lake (KEL-1), fall 2006.....	5-402
Table 5.12-39	Concentrations of sediment quality measurement endpoints, Isadore's Lake (ISL-1), fall 2006.....	5-403
Table 5.12-40	Concentrations of sediment quality measurement endpoints, McClelland Lake (MCL-1), fall 2006.	5-404
Table 5.12-41	Concentrations of sediment quality measurement endpoints, lower Fort Creek (reach FOC-D1), fall 2006.....	5-405
Table 5.13-1	Summary Statistics for RAMP ASL lakes, 2002 to 2006.....	5-410
Table 5.13-2	RAMP ASL lakes with chemical characteristics either below 5 th or above 95 th percentile of 2006 values, 2006 data.....	5-410
Table 5.13-3	Critical loads of acidity in the RAMP ASL lakes, 2002 to 2006.	5-413
Table 5.13-4	Summary of critical loads and exceedance rates (2002-2006).	5-415
Table 5.13-5	Characteristics of lakes with predicted critical load exceedances, 2006.....	5-415
Table 5.13-6	Results of Mann-Kendall trend analyses on ASL measurement endpoints.	5-416
Table 6.1-1	Summary of 2006 hydrologic assessment for RAMP FSA watersheds.	6-1

LIST OF FIGURES

Figure 1.2-1	RAMP organizational structure.	1-4
Figure 1.3-1	RAMP study areas.	1-7
Figure 1.3-2	Hydrologic schematic of RAMP Focus Study Area.	1-9
Figure 1.4-1	Overall analytical approach for RAMP 2006.	1-20
Figure 2.6-1	Land change areas for the RAMP FSA north of Fort McMurray, derived from SPOT5 imagery taken in June 2006.	2-9
Figure 2.6-2	Land change areas for the RAMP FSA south of Fort McMurray, derived from SPOT5 imagery taken in June 2006.	2-11
Figure 3.1-1	Locations of RAMP climate and hydrology stations, and snowcourse survey sites, 2006.	3-3
Figure 3.2-1	RAMP water quality sampling locations, 2006.	3-15
Figure 3.3-1	RAMP benthic invertebrate community and sediment quality sampling locations, 2006.	3-33
Figure 3.4-1	Location of sampling areas used for inventory, fish tissue, and sentinel species monitoring studies in the RAMP Fish Population component, 2006.	3-53
Figure 3.4-2	The Muskeg River, showing potential fish fence sites, and location of the 2003 and 2006 fence installation.	3-59
Figure 3.4-3	View of full-span Muskeg River Fish Fence, Spring 2006.	3-60
Figure 3.5-1	Location of RAMP lakes surveyed for the ASL component in 2006.	3-73
Figure 4.1-1	Historical annual precipitation at Fort McMurray (1946 to 2006).	4-3
Figure 4.1-2	Monthly precipitation at Fort McMurray in the 2006 water year (November 1, 2005 to October 31, 2006).	4-3
Figure 4.1-3	Cumulative total precipitation at climate stations in the Athabasca oil sands region in 2006.	4-4
Figure 4.1-4	Historical annual runoff in the Athabasca River basin (1974 to 2006).	4-5
Figure 4.1-5	The 2006 Athabasca River hydrograph compared to historical values.	4-5

Figure 4.1-6	Historical annual runoff in the Muskeg River basin (1974 to 2006).....	4-6
Figure 4.1-7	The 2006 Muskeg River hydrograph compared to historical values.	4-6
Figure 4.1-8	Historical annual runoff in the MacKay River basin (1974 to 2006).....	4-7
Figure 4.1-9	The 2006 MacKay River hydrograph compared to historical values.	4-7
Figure 4.1-10	Historical annual runoff in the Christina River basin (1983 to 2006).....	4-8
Figure 4.1-11	The 2006 Christina River hydrograph compared to historical values.	4-8
Figure 5.1-1	Athabasca River.....	5-3
Figure 5.1-2	Athabasca River: 2006 hydrograph and historical context.....	5-14
Figure 5.1-3	Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem, upstream of Donald Creek (ATR-DC).	5-18
Figure 5.1-4	Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem, upstream of the Steepbank River (ATR-SR).	5-20
Figure 5.1-5	Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem, upstream of the Muskeg River (ATR-MR).	5-22
Figure 5.1-6	Concentrations of selected water quality measurement endpoints (fall data) relative to regional baseline fall concentrations, Athabasca River mainstem, downstream of development (ATR-DD) and upstream of the Firebag River (ATR-FR).	5-24
Figure 5.1-7	Water quality measurement endpoints (physical variables), 1997 to 2006 AENV data, Athabasca River mainstem stations.....	5-28
Figure 5.1-8	Water quality measurement endpoints (nutrients, set No. 1), 1997-2006 AENV data, Athabasca River mainstem stations.	5-29
Figure 5.1-9	Water quality measurement endpoints (nutrients, set No. 2), 1997-2006 AENV data, Athabasca River mainstem stations.	5-30

Figure 5.1-10	Water quality measurement endpoints (ions, set No. 1), 1997-2006 AENV data, Athabasca River mainstem stations.....	5-31
Figure 5.1-11	Water quality measurement endpoints (ions, set No. 2), 1997-2006 AENV data, Athabasca River mainstem stations.....	5-32
Figure 5.1-12	Water quality measurement endpoints (metals, set No. 1), 1997- 2006 AENV data, Athabasca River mainstem stations.....	5-33
Figure 5.1-13	Water quality measurement endpoints (metals, set No. 2), 1997- 2006 AENV data, Athabasca River mainstem stations.....	5-34
Figure 5.1-14	Piper diagram of ion concentrations in Athabasca River mainstem, fall 1997 to 2006.....	5-35
Figure 5.1-15	Percent composition of captured large-bodied species, Athabasca River spring and fall inventories, 1997 to 2006.....	5-37
Figure 5.1-16	Seasonal CPUE for all species combined (captured fish only), Athabasca River spring inventory, 1997 to 2006.	5-38
Figure 5.1-17	Seasonal walleye CPUE (captured fish only), Athabasca River inventory, 1997 to 2006.	5-38
Figure 5.1-18	Seasonal goldeye CPUE (captured fish only), Athabasca River inventory, 1997 to 2006.	5-39
Figure 5.1-19	Seasonal longnose sucker CPUE (captured fish only), Athabasca River, 1997 to 2006.	5-39
Figure 5.1-20	Seasonal white sucker CPUE (captured fish only), Athabasca River, 1997 to 2006.	5-40
Figure 5.1-21	Seasonal northern pike CPUE (captured fish only), Athabasca River, 1997 to 2006.	5-40
Figure 5.1-22	Relative length-frequency distributions for walleye captured in the Athabasca River, spring and fall, 1997 to 2006.	5-41
Figure 5.1-23	Relative length-frequency distributions for goldeye captured in the Athabasca River, spring and fall, 1997 to 2006.	5-42
Figure 5.1-24	Relative length-frequency distributions for longnose sucker captured in the Athabasca River, spring and fall, 1997 to 2006.	5-43
Figure 5.1-25	Relative length-frequency distributions for white sucker captured in the Athabasca River, spring and fall, 1997 to 2006.	5-44
Figure 5.1-26	Relative length-frequency distributions for northern pike captured in the Athabasca River, spring and fall, 1997 to 2006.	5-45

Figure 5.1-27	Ratio of undersize to legal size walleye captured from the Athabasca River, spring 2006.....	5-46
Figure 5.1-28	Ratio of undersize to legal size northern pike captured from the Athabasca River, spring 2006.....	5-46
Figure 5.1-29	Mean condition factor for key indicator fish species in the Athabasca River, 1997-2006.	5-47
Figure 5.1-30	Fish tag recovery locations, 2006.	5-49
Figure 5.2-1	Athabasca River Delta.	5-53
Figure 5.3-1	Muskeg River watershed.....	5-57
Figure 5.3-2	Muskeg River: 2006 hydrograph and historical context.	5-75
Figure 5.3-3	Selected water quality measurement endpoints in the Muskeg River at the mouth (station MUR-1) and upstream of Wapasu Creek (station MUR-6), fall data, relative to regional baseline fall concentrations.	5-85
Figure 5.3-4	Selected water quality measurement endpoints in Muskeg River tributaries, fall data, relative to regional baseline fall concentrations.	5-87
Figure 5.3-5	Piper diagram of fall ion concentrations in the Muskeg River and its tributaries, 1997 to 2006.	5-89
Figure 5.3-6	Annual variation in periphyton chlorophyll <i>a</i> in the lower Muskeg River (reach MUR-E-1).	5-91
Figure 5.3-7	Annual variation in benthic invertebrate community measurement endpoints in the lower (MUR-E-1) and upper (MUR-D-3) reaches of the Muskeg River.	5-94
Figure 5.3-8	Ordination biplot for the lower reach of the Muskeg River (reach MUR-E-1).....	5-95
Figure 5.3-9	Annual variation in benthic invertebrate community measurement endpoints in the middle (MUR-D-2) and upper (MUR-D-3) reaches of the Muskeg River.	5-97
Figure 5.3-10	Ordination biplot for the middle reach (reach MUR-D-2) of the Muskeg River.....	5-98
Figure 5.3-11	Annual variation in benthic invertebrate community measurement endpoints in lower (JAC-D-1) and upper (JAC-D-2) reaches of Jackpine Creek.	5-102
Figure 5.3-12	Ordination biplot for the lower reach (reach JAC-D-1) of Jackpine Creek.	5-103

Figure 5.3-13	Timing of the longnose sucker migration in the Muskeg River, spring 2006.	5-110
Figure 5.3-14	Timing of white sucker migration in relation to water temperature in the Muskeg River, May 2006.	5-110
Figure 5.3-15	Timing of the northern pike migration in the Muskeg River fish fence, spring 2006.	5-111
Figure 5.3-16	Length-frequency distribution of longnose sucker caught at the Muskeg River fish fence, spring 2006.....	5-112
Figure 5.3-17	Weight-length relationship for male and female longnose sucker, Muskeg River fish fence program, spring 2006.	5-113
Figure 5.3-18	Age composition for longnose sucker sampled at the Muskeg River fish fence, spring 2006.	5-113
Figure 5.3-19	Length-at-age relationship by gender for longnose sucker sampled at the Muskeg River fish fence, spring 2006.	5-114
Figure 5.3-20	Length-frequency distribution of white sucker caught at the Muskeg River fish fence, spring 2006.....	5-114
Figure 5.3-21	Weight-length relationships for male and female white sucker, Muskeg River fish fence, spring 2006.....	5-115
Figure 5.3-22	Age composition of white sucker sampled at the Muskeg River fish fence, spring 2006.....	5-115
Figure 5.3-23	Length-at-age relationship by gender for white sucker sampled at the Muskeg River fish fence, spring 2006.....	5-116
Figure 5.3-24	Length-frequency distribution for northern pike caught at the Muskeg River fish fence, spring 2006.....	5-116
Figure 5.3-25	Weight-length relationships for male and female northern pike, Muskeg River fish fence, spring 2006.....	5-117
Figure 5.3-26	Age composition for northern pike sampled at the Muskeg River fish fence, spring 2006.....	5-117
Figure 5.3-27	Length-at-age relationship by gender for northern pike sampled at the Muskeg River fish fence, spring 2006.....	5-118
Figure 5.4-1	Steepbank River watershed.	5-121
Figure 5.4-2	Steepbank River: 2006 hydrograph and historical context.....	5-131
Figure 5.4-3	Selected water quality measurement endpoints in the Steepbank River (fall data) relative to regional baseline fall concentrations.....	5-138

Figure 5.4-4	Piper diagram of fall concentrations in the Steepbank River watershed, fall 1997-2006.	5-140
Figure 5.4-5	Annual variation in periphyton chlorophyll a in the lower reach of the Steepbank River (reach STR-E-1) and the upper reach of the Steepbank River (reach STR-E-2).....	5-142
Figure 5.4-6	Annual variation in benthic invertebrate community measurement endpoints in the lower (STR-E-1) and upper (STR-E-2) reaches of the Steepbank River.	5-144
Figure 5.4-7	Benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for reach STR-E-1.....	5-146
Figure 5.4-8	Cumulative length-frequency distributions for slimy sculpin populations at upper Steepbank River (site SR-R2), 2006.....	5-149
Figure 5.4-9	Cumulative length-frequency distributions for slimy sculpin populations at lower Steepbank River (site SR-E), 2006.....	5-150
Figure 5.4-10	Mean length of slimy sculpin captured in the 2006 sentinel fish species fish survey.	5-151
Figure 5.4-11	Mean weight of slimy sculpin captured in the 2006 sentinel fish species survey.	5-151
Figure 5.4-12	Length-frequency distributions of slimy sculpin from the Steepbank River, August and October 2006.	5-153
Figure 5.4-13	Length-frequency distributions of slimy sculpin from the Dunkirk, Horse and Muskeg rivers, August and October 2006.....	5-154
Figure 5.5-1	Tar River watershed.....	5-159
Figure 5.5-2	Tar River: 2006 hydrograph and historical context.	5-166
Figure 5.5-3	Concentrations of selected water quality measurement endpoints in the Tar River (fall data) relative to regional baseline fall concentrations.....	5-171
Figure 5.5-4	Piper diagram of fall ion concentrations in the Tar River watershed.	5-173
Figure 5.5-5	Annual variation in periphyton chlorophyll a biomass in the upper reach of the Tar River (reach TAR-E-2).....	5-174
Figure 5.5-6	Annual variation in benthic invertebrate community measurement endpoints in the lower Tar River, reach TAR-D-1 and the upper Tar River, reach TAR-E-2.....	5-177

Figure 5.5-7	Benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for reach TAR-D-1 (designated as <i>potentially influenced</i> as of summer 2004).....	5-178
Figure 5.6-1	Mackay River watershed.	5-181
Figure 5.6-2	Mackay River: 2006 hydrograph and historical context.	5-187
Figure 5.6-3	Concentrations of selected water quality measurement endpoints in the Mackay River (fall data) relative to regional baseline fall concentrations.	5-192
Figure 5.6-4	Piper diagram of fall ion concentrations in the Mackay River watershed.	5-194
Figure 5.6-5	Annual variation in periphyton chlorophyll a biomass in the lower Mackay River (reach MAR-E-1) and upstream Mackay River (reach MAR-E-2).....	5-196
Figure 5.6-6	Annual variation in benthic invertebrate community measurement endpoints in the lower Mackay River (reach MAR-E-1) and upstream Mackay River (MAR-E-2).	5-198
Figure 5.6-7	Benthic invertebrate community sample scores based on a Correspondence Analysis (CA) of taxon abundances for lower Mackay River (reach MAR-E-1), designated as <i>potentially influenced</i> as of summer 2002.....	5-200
Figure 5.6-8	Location and stream habitat details of lower (<i>potentially influenced</i>) sampling location for the 2006 Mackay River non-lethal sentinel reconnaissance study.	5-201
Figure 5.6-9	Location and stream habitat details of upper (<i>reference</i>) sampling location for the 2006 Mackay River non-lethal sentinel reconnaissance study.	5-202
Figure 5.7-1	Calumet River watershed.....	5-205
Figure 5.7-2	Calumet River: 2006 hydrograph and historical context.	5-210
Figure 5.7-3	Concentrations of selected water quality measurement endpoints in the Calumet River (fall data) relative to regional baseline fall concentrations.	5-215
Figure 5.7-4	Piper diagram of fall ion concentrations in Calumet River watershed.	5-217
Figure 5.7-5	Annual variation in benthic invertebrate community measurement endpoints in the Calumet River, reach CAL-D-1 and reach CAL-D-2.....	5-220

Figure 5.8-1	Firebag River watershed.	5-223
Figure 5.8-2	Firebag River: 2006 hydrograph and historical context.	5-228
Figure 5.8-3	Concentrations of selected water quality measurement endpoints in the Firebag River watershed (fall 2006) relative to regional baseline fall concentrations.	5-232
Figure 5.8-4	Piper diagram of fall ion concentrations in the Firebag River watershed.	5-234
Figure 5.8-5	Annual variation in periphyton chlorophyll a in the upper reach of the Firebag River (reach FIR-E-2).	5-236
Figure 5.8-6	Annual variation in benthic invertebrate community measurement endpoints in the Firebag River, reach FIR-D-1 and reach FIR-E-2.	5-238
Figure 5.9-1	Ells River watershed.	5-241
Figure 5.9-2	Ells River: 2006 hydrograph and historical context.	5-246
Figure 5.9-3	Selected water quality measurement endpoints in the Ells River (fall data) relative to regional baseline fall concentrations.	5-250
Figure 5.9-4	Piper diagram of fall ion concentrations in the Ells River watershed.	5-252
Figure 5.9-5	Annual variation in periphyton chlorophyll a in the upper reach of the Ells River (reach ELR-E-2).	5-254
Figure 5.9-6	Annual variation in benthic invertebrate community measurement endpoints in the lower Ells River (reach ELR-D-1) and upstream Ells River (reach ELR-E2-2).	5-256
Figure 5.10-1	Clearwater-Christina River watershed.	5-259
Figure 5.10-2	Clearwater River: 2006 hydrograph and historical context.	5-270
Figure 5.10-3	Christina River: 2006 hydrograph and historical context.	5-270
Figure 5.10-4	Concentrations of selected water quality measurement endpoints in the Clearwater and Christina watersheds (fall data) relative to regional baseline fall concentrations.	5-277
Figure 5.10-5	Piper diagram of fall ion concentrations in the Clearwater-Christina River system.	5-279
Figure 5.10-6	Annual variation in benthic invertebrate community measurement endpoints in the Christina River, reach CHR-D-1 and reach CHR-D-2.	5-282

Figure 5.10-7	Comparison of seasonal northern pike and walleye CPUE, 1999 to 2006.....	5-286
Figure 5.10-8	Relative length-frequency distribution for walleye captured during fish inventories on the Clearwater River, spring and fall, 2003 to 2006.....	5-287
Figure 5.10-9	Relative length-frequency distribution for goldeye captured during fish inventories on the Clearwater River, spring and fall, 2003 to 2006.....	5-288
Figure 5.10-10	Relative length-frequency distribution for longnose sucker captured during fish inventories on the Clearwater River, spring and fall, 2003 to 2006.	5-289
Figure 5.10-11	Relative length-frequency distributions for white sucker captured during fish inventories on the Clearwater River, spring and fall, 2003 to 2006.....	5-290
Figure 5.10-12	Relative length-frequency distribution for northern pike captured during fish inventories on the Clearwater River, spring and fall, 2003 to 2006.....	5-291
Figure 5.10-13	Mean condition factor (± 1 SE) for key indicator fish species in the Clearwater River, spring 2003 to 2006.	5-292
Figure 5.10-14	Scatterplot of mercury concentration in northern pike muscle versus length, Clearwater River, 2006.....	5-294
Figure 5.10-15	Scatterplot of mercury concentration in northern pike muscle versus age, Clearwater River, 2006.	5-294
Figure 5.10-16	Regression analysis of mercury concentration in fish muscle versus length and age for northern pike from the Clearwater River, fall 2006.....	5-295
Figure 5.10-17	Temporal comparison of mercury concentration in northern pike from the Clearwater River, 2004 and 2006.....	5-301
Figure 5.11-1	Hangingstone River watershed.	5-303
Figure 5.11-2	Hangingstone River: 2006 hydrograph and historical context.....	5-307
Figure 5.11-3	Concentrations of selected water quality measurement endpoints at the mouth of Hangingstone River (station HAR-1) (fall 2006) relative to regional baseline fall concentrations.	5-311
Figure 5.11-4	Piper diagram of fall ion concentrations, mouth of Hangingstone River (station HAR-1).....	5-313
Figure 5.11-5	Annual variation in chlorophyll <i>a</i> in the lower reach of the Hangingstone River (reach HAR-E-1).	5-315

Figure 5.11-6	Annual variation in benthic invertebrate community measurement endpoints in the lower reach of the Hangingstone River (reach HAR-E-1).....	5-317
Figure 5.12-1	Miscellaneous aquatic systems.....	5-319
Figure 5.12-2	Isadore's Lake: 2006 hydrograph and historical context.	5-335
Figure 5.12-3	Mills Creek: 2006 hydrograph and historical context.	5-335
Figure 5.12-4	Poplar Creek: 2006 hydrograph and historical context.	5-336
Figure 5.12-5	Fort Creek: 2006 hydrograph and historical context.	5-336
Figure 5.12-6	Kearl Lake: 2006 hydrograph and historical context.	5-339
Figure 5.12-7	Kearl Lake outlet: 2006 hydrograph and historical context.	5-339
Figure 5.12-8	McClelland Lake: 2006 hydrograph and historical context.....	5-340
Figure 5.12-9	Susan Lake Outlet: 2006 hydrograph.	5-340
Figure 5.12-10	Concentrations of selected water quality measurement endpoints in the Beaver River (station BER-1), Poplar Creek (station POC-1), and McLean Creek (station MCC-1) (fall 2006) relative to regional baseline fall concentrations.	5-343
Figure 5.12-11	Piper diagram of ion balance in McLean Creek, Beaver River and Poplar Creek, 1999-2006.....	5-345
Figure 5.12-12	Concentrations of selected fall water quality measurement endpoints, Shipyard Lake (SHL-1) and Isadore's Lake (ISL-1) (fall 2006), relative to regional fall baseline concentrations.	5-349
Figure 5.12-13	Piper diagram of ion balance in Shipyard Lake and Isadore's Lake, 1999-2006.....	5-351
Figure 5.12-14	Concentrations of selected water quality measurement endpoints in Fort Creek (fall 2006) relative to regional baseline fall concentrations.....	5-354
Figure 5.12-15	Piper diagram of fall ion balance in Fort Creek, 2000 to 2006.	5-356
Figure 5.12-16	Concentrations of selected water quality measurement endpoints in Kearl Lake (station KEL-1, fall data) relative to regional baseline fall concentrations.....	5-358
Figure 5.12-17	Piper diagram of fall concentrations in Kearl Lake (station KEL-1) and McClelland Lake (station (MCL-1).	5-360

Figure 5.12-18	Concentrations of selected water quality measurement endpoints in McClelland Lake (station MCL-1, fall data) relative to regional baseline fall concentrations.....	5-362
Figure 5.12-19	Concentrations of selected water quality measurement endpoints in Birch (BIL-1), Long (LOL-1), Poison (POL-1), Pushup (PUL-1), and Unnamed Lake 3 (UNL-3) (fall data) relative to regional baseline fall concentrations.	5-379
Figure 5.12-20	Concentrations of selected water quality measurement endpoints in Rat (RAL-1), Canoe (CANL-1), Caribou Horn (CARL-1), and Frog (FRL-1) lakes (fall data) relative to regional baseline fall concentrations.	5-381
Figure 5.12-21	Concentrations of selected water quality measurement endpoints in Gregoire (GRL-1), Kiskatinaw (KIL-1), and Sucker (SUL-1) lakes (fall data) relative to regional baseline fall concentrations.	5-383
Figure 5.12-22	Concentrations of selected water quality measurement endpoints in Unnamed Lake 1 (UNL-1), Unnamed Lake 2 (UNL-2), Reference Lake 2 (REF-2), and Reference Lake 4 (REF-4) (fall data) relative to regional baseline fall concentrations.....	5-385
Figure 5.12-23	Piper diagram of spring, summer and fall ion concentrations in Birch, Long, Poison, Pushup lakes and Unnamed Lake 3.....	5-387
Figure 5.12-24	Piper diagram of spring, summer and fall ion concentrations in Rat, Canoe, Caribou Horn and Frog lakes.	5-388
Figure 5.12-25	Piper diagram of spring, summer and fall ion concentrations in Gregoire, Kiskatinaw and Sucker lakes.	5-389
Figure 5.12-26	Piper diagram of spring, summer and fall ion concentrations in Unnamed 1, Unnamed 2, Reference 2 and Reference 4 lakes.	5-390
Figure 5.12-27	Annual variation in benthic invertebrate community measurement endpoints in Kearl, McClelland, Shipyard and Isadore's lakes.....	5-395
Figure 5.12-28	Annual variation in benthic invertebrate community measurement endpoints in lower Fort Creek, reach FOC-D-1.	5-399
Figure 5.12-29	Ordination biplot for the lower reach (FOC-D-1) of Fort Creek.	5-400
Figure 5.13-1	RAMP acid-sensitive lakes with calculated Potential Acid Input exceeding calculated Critical Load, 2006.	5-411

LIST OF APPENDICES

Appendix A	Land Change Area Estimation for RAMP Focus Study Area
Appendix B	Quality Assurance and Quality Control Procedures for 2006
Appendix C	Climate and Hydrology Component
Appendix D	Water Quality Component
Appendix E	Benthic Invertebrate Community Component
Appendix F	Sediment Quality Component
Appendix G	Fish Population Component
Appendix H	Acid-Sensitive Lakes Component

ACKNOWLEDGEMENTS

Funding for RAMP in 2006 was provided by Suncor Energy Inc. (Suncor), Syncrude Canada Ltd. (Syncrude), Albion Sands Energy Inc. (Albian Sands), Shell Canada Limited (Shell), Canadian Natural Resources Limited (CNRL), Imperial Oil Resources (Imperial Oil), Petro-Canada Oil and Gas (Petro-Canada), OPTI Canada Inc. (OPTI)/Nexen Inc. (Nexen), Husky Energy (Husky), Deer Creek Energy Ltd. (Deer Creek), Synenco Energy Inc. (Synenco), and Birch Mountain Resources Ltd. (Birch Mountain).

The RAMP chairperson during the 2006 program year was Fred Kuzmic (Albian Sands). Stephen Full (Petro-Canada) was chair of the Technical Program Committee, Neil Rutley (Syncrude) was chair of the Finance Sub-committee and Melissa Pennell was the Communications Coordinator for RAMP and the Joint Communications Committee held jointly with CEMA and WBEA.

RAMP is a multi-stakeholder environmental monitoring program that is composed of representatives from industry; municipal, provincial and federal governments; local aboriginal groups and environmental organizations. Effective implementation of the RAMP requires a number of contributors. We would like to thank the following:

- Members of the RAMP Steering Committee, Technical Program Committee, Finance Sub-committee and the Communications Committee;
- Syncrude, Suncor, CNRL, OPTI/Nexen, and ASRD for in-kind contribution towards the fish inventory program;
- Nexen Inc. for assistance monitoring the Muskeg River fish fence;
- Alberta Environment (AENV), Syncrude, CNRL, and Albion Sands for providing water quality data from their ongoing monitoring programs for inclusion in RAMP;
- AENV for conducting field work required for the Acid-Sensitive Lakes component; and
- Local residents/anglers who provided information for the Fish Tag Return Program.

In addition, the 2006 RAMP Implementation Team would like to acknowledge the following contractors who assisted with the program in 2006:

- ALS Laboratory Group (chemical analyses);
- AXYS Analytical Services Ltd. (chemical analyses);
- University of Alberta Limnological Laboratory (chemical analyses);
- Alberta Research Council (chemical analyses);
- HydroQual Laboratories Ltd. (toxicity testing);
- Dr. Jack Zloty (benthic invertebrate taxonomy);
- North/South Consultants Inc. (fish ageing and fish fence installation assistance); and
- Flett Research Ltd (non-lethal fish tissue analyses).

EXECUTIVE SUMMARY

OVERVIEW

The Regional Aquatics Monitoring Program (RAMP) was initiated in 1997 in association with mining development in the Athabasca oil sands region near Fort McMurray, Alberta. RAMP is an industry-funded, multi-stakeholder initiative that monitors aquatic environments in the region. The intent of RAMP is to integrate aquatic monitoring activities so that long-term trends, regional issues and potential cumulative effects related to oil sands development can be identified and assessed. In 2006, RAMP was funded by Suncor Energy Inc., Syncrude Canada Ltd., Albion Sands Energy Inc., Shell Canada Limited, Canadian Natural Resources Limited, Imperial Oil Resources, Petro-Canada Oil and Gas, OPTI Canada Inc./Nexen Inc., Husky Energy, Deer Creek Energy Ltd., Synenco Energy Inc., and Birch Mountain Resources Ltd.

The Regional Municipality of Wood Buffalo in northeastern Alberta is the RAMP Regional Study Area (RSA). Within this area, a Focus Study Area (FSA) has been defined and includes watersheds where oil sands and other developments are occurring or planned, including:

- Lower Athabasca River and Athabasca River Delta;
- Major tributary watersheds/basins of the lower Athabasca River including the Clearwater-Christina rivers, Hangingstone River, Steepbank River, Muskeg River, MacKay River, Ells River, Tar River, Calumet River, and Firebag River;
- Select minor tributaries of the lower Athabasca River (McLean Creek, Mills Creek, Beaver River, Poplar Creek, and Fort Creek);
- Specific wetlands and shallow lakes in vicinity of current or planned oil sands and related developments; and
- A selected group of 50 regional acid-sensitive lakes.

RAMP incorporates both stressor- and effects-based monitoring approaches. Using impact predictions from the various oil sands environmental impact assessments, specific potential stressors have been identified that are monitored to document baseline conditions, as well as potential changes related to development. Examples include specific water quality variables and changes in water quantity. In addition, there is a strong emphasis in RAMP on monitoring sensitive biological indicators that reflect the overall condition of the aquatic environment. By combining both monitoring approaches, RAMP strives to achieve a more holistic understanding of potential effects on the aquatic environment related to oil sands development.

The scope of RAMP focuses on key components of boreal aquatic ecosystems, including:

- Climate and hydrology – monitors changes in the water level of selected lakes and in the quantity of water flowing through rivers and creeks in the Athabasca oil sands area;
- Water quality in rivers, lakes and the delta – reflects potential exposure of fish and invertebrates to organic and inorganic chemicals;
- Benthic invertebrate communities and sediment quality in rivers, lakes and the delta – reflect habitat quality, serve as biological indicators, and are important components of fish habitat;
- Fish populations in rivers and lakes – biological indicators of ecosystem integrity and are a highly valued resource in the region; and
- Water quality in regional lakes sensitive to acidification – early warning indicator of potential effects related to acid deposition.

With the addition in 2006 of Birch Mountain as a member of RAMP, RAMP is now funded by companies that are not exclusively constructing and operating oil sands projects in the RAMP FSA. Therefore, the term “focal projects” has been introduced to the RAMP 2006 Technical Report; focal projects are defined as those projects owned and operated by the 2006 RAMP funders listed above which were under construction or operational in 2006 in the RAMP FSA. For 2006, these projects include a number of oil sands projects and a limestone quarry project (in the case of Birch Mountain).

2006 RAMP funders do have other projects in the RAMP FSA that were in the application stage as of 2006 (e.g., Imperial’s Kearn project), or which received approval in 2006 (or earlier), but were not in the construction phase as of 2006 (e.g., Suncor’s Voyageur project). These projects are noted throughout the 2006 Technical Report, but are not designated as focal projects, as these projects in 2006 would not have potentially influenced aquatic resources covered by RAMP components.

The overall analytical approach for the 2006 RAMP Technical Report builds on the methodology used in previous years and the RAMP Technical Design and Rationale document. The analysis:

- Is conducted at the watershed/river basin level, with an emphasis on watersheds in which development has already occurred, as well as the lower Athabasca River at the regional level;
- Uses a set of measurement endpoints representing the health and integrity of valued environmental resources within the component;
- Uses where possible, specific criteria (e.g., criteria used in focal project EIAs, AENV, CCME guidelines, generally-accepted EEM effects criteria) for determining whether or not a change in the measurement endpoints has occurred and is significant with respect to the health and integrity of valued environmental resources; and
- Uses an analysis of land change to determine which RAMP stations and monitoring years are to be designated as operational or baseline for the purposes of data analysis.

Satellite imagery was used in 2006 in conjunction with more detailed maps of Athabasca oil sands operations provided by a number of RAMP industry members to estimate the type, location, and amount of land changed by oil sands and other development activities. It is estimated that there were approximately 58,000 ha of land change attributable to focal projects within the RAMP FSA as of 2006. The percentage of the watersheds with land change from focal project activities varies from less than 1% for many watersheds (Steeptank, MacKay, Ells, Christina, Firebag, Horse, and Hangingstone), slightly more than 1% for the Calumet and Poplar Rivers, 5% to 10% for the Muskeg River and Fort Creek, and more than 10% for the McLean, and Tar watersheds, as well as the smaller lower Athabasca River tributaries from Fort McMurray to the mouth of the Firebag River taken together.

The following sub-sections summarize results of the monitoring assessment for each watershed evaluated as part of the 2006 RAMP. Results are also presented for the Acid-Sensitive Lakes component, which focuses on regional lakes.

Lower Athabasca River

Monitoring activities on the Athabasca River mainstem in 2006 consisted hydrology, water quality, and Athabasca River fish inventories.

The large size and flow of the lower Athabasca River means that there is high year-to-year variation in aquatic resources represented by the RAMP components, much of which is due to natural factors; the much lower than average flow year for the lower Athabasca River in 2006 was no exception in this regard. The differences between hydrologic measurement endpoints for estimated baseline

hydrologic conditions and measured operational hydrologic conditions were greater in 2006 than in 2005. This was due almost completely to the lower overall flows in the lower Athabasca River in 2006. It is estimated that focal project activities as of 2006 decreased 2006 mean open-water season discharge by 0.45%, lowered 2006 mean winter discharge by 1.5%, decreased annual maximum daily discharge by 0.21%, and lowered open-water season minimum daily discharge in 2006 by 0.76%. The cumulative effects of focal project activities plus all other active oil sands projects in the RAMP FS are estimated to be only marginally greater. Based on criteria used in previous oil sands project EIAs, these differences would have been assessed as negligible, with the exception of the incremental mean winter discharge which would have been assessed as a low effect. There were no discernable changes in water quality conditions due to focal project activities in 2006 and there is little evidence to suggest that characteristics of key indicator fish populations have changed during the period of increasing focal project activity in the RAMP FSA.

Athabasca River Delta

There was no monitoring conducting in the Athabasca River Delta in 2006. There were no plans to conduct water quality sampling in the Athabasca River Delta in 2006 and, while there were plans to conduct benthic invertebrate community and sediment quality monitoring in the Athabasca River Delta in 2006, very low water levels during the benthic invertebrate community sampling campaign prevented access to the sampling sites.

Muskeg River Watershed

Monitoring activities in the Muskeg River basin in 2006 included hydrology, water quality, benthic invertebrate community surveys, sediment quality, the Muskeg River fish fence, and part of the 2006 sentinel fish species survey for the Athabasca River tributaries.

The cumulative effects of focal projects in the Muskeg River watershed for 2006 are assessed as follows:

- There appear to be some effects on watershed hydrology, with large differences in two of the four hydrologic measurement endpoints (mean winter discharge and open-water season minimum daily discharge) between potentially influenced conditions and estimated reference conditions. It must be noted that these differences have been estimated under the assumption that all Aurora Clean Water Diversion discharge waters would not have entered the Muskeg River under *reference* conditions;
- Water quality remains largely unaffected by focal project activities, with few exceedances of water quality guidelines throughout the watershed and concentrations of most water quality measurement endpoints throughout the watershed that remained within historical regional baseline ranges. The exceptions to these overall results for water quality is an indication of greater variability of water quality in fall 2006 in *potentially influenced* areas of the Muskeg River watershed than in *reference* areas, as well as elevated concentrations of a number of water quality measurement endpoints in measured in Stanley Creek in fall 2006 as a results of the Aurora Clean Water Diversion discharge;
- There is little evidence of effects of focal project activities on benthic invertebrate communities. Values of all benthic invertebrate community measurement endpoints in 2006 at all reaches sampled in the Muskeg river watershed were within the normal range of values observed from regional baseline reaches, and there continues to be consistency across years in values of all benthic invertebrate community measurement endpoints with respect to regional baseline reaches. In addition, there may be little contribution of changes in sediment quality to differences in benthic invertebrate communities in the Muskeg River watershed;

- Any influence of focal project activities on fish utilizing the Muskeg River during the spring spawning season remains largely undetectable and unknown, given the few years of information available from Muskeg River fish fence studies; and
- The results of the sentinel fish species survey indicate there are no clear differences in sculpin population measurement endpoints between reference and potentially *influenced* sites that would suggest possible effects of focal project activities on these populations.

Steepbank River Watershed

Monitoring activities in 2006 in the Steepbank River watershed included hydrology (Water Survey of Canada station), water quality, a benthic invertebrate community survey, and a major component of the 2006 sentinel fish species survey for the Athabasca River tributaries.

There is little evidence in 2006 of watershed-level effects of focal project activities on RAMP aquatic resources in the Steepbank River watershed. Cumulative, watershed-level changes in hydrologic conditions in the Steepbank River caused by focal project activities in the watershed as of 2006 have been negligible. In 2006, there were few exceedances of water quality guidelines throughout the watershed, concentrations of almost all water quality measurement endpoints in the watershed were within historical regional baseline ranges, and ion balance in fall 2006 was generally consistent throughout the watershed with ion balance in previous years. There were some significant, though statistically weak differences in some benthic invertebrate community measurement endpoints between sampled reaches designated as *potentially-influenced* and *reference*, but values of all benthic invertebrate community measurement endpoints in 2006 at all reaches sampled were within the normal range of values observed from regional reference reaches. Finally, similar to results for the Muskeg River, the results of the sentinel fish species survey indicate there are no clear differences in sculpin population measurement endpoints between *reference* and *potentially influenced* sites that would suggest possible effects of focal project activities on these populations.

Tar River Watershed

Monitoring activities in the Tar River watershed in 2006 included hydrology, water quality, as well as a benthic invertebrate community survey and sediment quality.

The Tar River watershed in 2006 continued to show some effects of focal project activities. The effects of focal project activities on hydrologic conditions in 2006 was assessed as low to moderate based on effects criteria used in oil sands EIAs for mean open-water season discharge, annual maximum daily discharge, and open-season minimum daily discharge. Concentrations of water quality measurement endpoints in fall 2006 were generally within regional ranges of concentrations for baseline conditions and there were few instances of concentrations of water quality measurement endpoints exceeding water quality guidelines, although there was some evidence of possible effects on water quality in the lower Tar River of wastewater treatment facility discharge. Finally, generally lower values of benthic invertebrate community measurement endpoints in 2006, and recent downward trends in a number of these measurement endpoints in areas of the watershed designated as *potentially influenced*, indicate possible effects of focal project activities on benthic invertebrate communities in the lower parts of the Tar River watershed.

MacKay River Watershed

Monitoring activities in the MacKay River watershed in 2006 included hydrology, water quality, a benthic invertebrate community survey, and a sentinel fish species reconnaissance.

Data collected in the MacKay River watershed in 2006 indicated negligible changes in hydrological conditions as a result of focal project activities, little measurable change in water quality and possible subtle effects on benthic invertebrate communities. These results indicate that focal project

activities have had, to 2006, little effect on RAMP aquatic resources at the watershed level in the MacKay River watershed. Results from the 2006 reconnaissance sampling suggest suitable conditions for a non-lethal sentinel program do not exist on the MacKay River.

Calumet River Watershed

Monitoring activities in the Calumet River watershed in 2006 included hydrology, water quality, a benthic invertebrate community survey, and sediment quality.

RAMP aquatic resources were measured in the Calumet River watershed in 2006 as being similar to previous years. Values of few measurement endpoints in 2006 exceeded existing environmental guidelines, and few selected measurement endpoints were outside the range of expected reference conditions for similar river systems and habitats in the RAMP FSA. Effects of focal project activities in the watershed were negligible in 2006 in the case of hydrologic conditions, and any effects of focal project activities on water quality were not detected.

Firebag River Watershed

Monitoring activities in the Firebag River watershed in 2006 included hydrology, water quality, a benthic invertebrate community survey, and sediment quality.

At a watershed level, the conditions of RAMP aquatic resources of the Firebag River watershed were similar in 2006 relative to previous years. There were few exceedances of water quality environmental guidelines in 2006, and almost all water quality and benthic invertebrate community measurement endpoints for RAMP aquatic resources that were sampled in 2006 were within the range of expected reference conditions for similar river systems and habitats in the RAMP FSA.

Ells River Watershed

Monitoring activities in the Ells River watershed in 2006 included hydrology, water quality, a benthic invertebrate community survey, and sediment quality.

Conditions in the Ells River in 2006 were generally similar to previous years. Cumulative, watershed-level changes in hydrologic conditions caused by focal project activities in the Ells River watershed as of 2006 have been negligible. Water quality conditions were similar in 2006 to water quality conditions in previous years. Conditions in the two reaches at which benthic invertebrate communities were sampled in fall 2006, one depositional and one erosional, were representative and typical of depositional and erosional reaches in the RAMP FSA, and values of benthic invertebrate community measurement endpoints were generally consistent with values measured in previous years in the watershed. Values of most sediment quality measurement endpoints were within the range of previously-measured values for the watershed.

Clearwater-Christina River System

Monitoring activities in the Clearwater River and Christina River watershed in 2006 consisted of hydrology, water quality, benthic invertebrate community surveys sediment quality, fish inventories, and fish tissue quality assessment.

While hydrologic measurement endpoints for the Christina River watershed could not be estimated because there is no hydrometric station at the mouth of the Christina River, estimated effects of focal project activities in 2006 were to remove 0.075 mm of runoff depth from the watershed. Estimated effects of focal project activities plus oil sands projects in the Christina River watershed that were under construction or operation in 2006 but which were not owned by 2006 RAMP funders were to remove 0.128 mm of runoff depth from the watershed. Water quality measurement endpoints were generally within historical ranges and within the range for regional

reference stations. Guideline exceedance of selected water quality measurement endpoints was restricted to nutrients and metals. Values of benthic invertebrate community measurement endpoints were similar to previous years and there have been no unusual trends in these measurement endpoints since sampling began in 2002.

A fourth year of fish inventory work on the Clearwater River was conducted to expand the baseline dataset for this river. Fish community composition, length-frequency relationships external fish health indices, and condition factors were similar to what was found in previous years. Mercury tissue concentrations in northern pike from the Clearwater River measured in 2006 are consistent with the natural range of concentrations observed in this region of northern Alberta and, as in previous years, mercury and arsenic levels in sampled northern pike fish tissue exceeded USEPA screening criteria. No fish tissues effects thresholds for fish and fish health were exceeded and all potential tainting compounds in sampled Clearwater River fish tissue were present at concentrations well below the 1 mg/kg threshold for palatability.

Hangingstone River Watershed

Monitoring activities in the Hangingstone River watershed in 2006 included hydrology, water quality, and a benthic invertebrate community survey.

2006 results confirm that the Hangingstone River is a typical Athabasca River basin watershed, with RAMP aquatic resources in 2006 within the range of regional baseline conditions for similar watersheds and habitat types. As of 2006, there have been no detectable effects of focal projects or cumulative, watershed-level changes in the Hangingstone River watershed.

Miscellaneous Aquatic Systems

Miscellaneous aquatic systems designated as *potentially influenced* in 2006 included Mills Creek, Poplar Creek, McLean Creek, Fort Creek, Beaver River, Isadore's Lake, and Shipyard Lake, while miscellaneous aquatic systems designated as *reference* in 2006 included Kearl Lake, McClelland Lake, and the Susan Lake outlet. The OPTI lakes were also sampled in 2006. The effect of focal project activities on the hydrology of Poplar Creek is assessed as High, due to the hydrologic effects of the Poplar Creek spillway, while the effect of focal project activities on the hydrology of Fort Creek is assessed as Negligible. There was little to distinguish 2006 water quality conditions in these aquatic systems from previous years, with the exception of possible increased influence of groundwater on water quality due low precipitation in the RAMP FSA and reduced surface runoff north of Fort McMurray in 2006. There was little evidence of effects on focal project activities on water quality conditions in these aquatic systems in 2006. Benthic invertebrate communities in miscellaneous aquatic systems that were sampled in 2006 had values of benthic invertebrate measurement endpoints that were in the range of regional baseline conditions. The exception was Isadore's Lake, in which lower diversity and the absence of sensitive faunal species in 2006 is indicative of a stressed benthic community.

Acid-Sensitive Lakes

These results of the analysis of 2006 RAMP ASL lake data in conjunction with historical RAMP ASL lake data suggest that there has been no significant change in the overall chemistry of the 50 RAMP ASL lakes in 2006 compared to previous years. In addition, the inconsistent results of the trend analysis with respect to any conceivable regional acidification scenario indicate there is no evidence of any significant changes in lake chemistry in the RAMP ASL lakes over the period of the ASL component of RAMP.