

FOCUSED STUDY ACTIVITY WORK PLAN

General Information

Work Plan Unique Identifier:	A-RC-44-1718																																																																		
Focused Study Activity Title:	Airborne GHG Emission Measurements (NASA-NOAA)																																																																		
Focused Study Category:	Investigation of Cause or Potential Ecological Impact																																																																		
Geographic Location (choose from drop-down menu. If Project Location is in more than one area choose from second drop-down)	Athabasca Oil Sands Region More than 2 Locations (Described in Detailed Monitoring Plan)																																																																		
Monitoring Site(s) Coordinates (latitude and longitude)	<p>22 oil sands related specified gas emitters, including mining, upgrading, and/or <i>in situ</i> extraction field, are included in the NOAA-partnered GHG emissions determination plans:</p> <table style="width: 100%; border-collapse: collapse;"> <tbody> <tr><td>Firebag</td><td style="text-align: right;">57.2297</td><td style="text-align: right;">-110.83</td></tr> <tr><td>Cold Lake</td><td style="text-align: right;">54.597</td><td style="text-align: right;">-110.4</td></tr> <tr><td>Long Lake Project</td><td style="text-align: right;">56.4135</td><td style="text-align: right;">-110.95</td></tr> <tr><td>Wolf Lake and Primrose Plant</td><td style="text-align: right;">54.6984</td><td style="text-align: right;">-110.72</td></tr> <tr><td>Foster Creek SAGD Bitumen Battery (with Cogen)</td><td style="text-align: right;">55.0695</td><td style="text-align: right;">-110.54</td></tr> <tr><td>Christina Lake SAGD Bitumen Battery</td><td style="text-align: right;">55.5827</td><td style="text-align: right;">-110.89</td></tr> <tr><td>MacKay River Power Plant</td><td style="text-align: right;">56.9361</td><td style="text-align: right;">-111.56</td></tr> <tr><td>Jackfish 1 SAGD Plant</td><td style="text-align: right;">55.5281</td><td style="text-align: right;">-110.87</td></tr> <tr><td>MEG Christina Lake Cogeneration Facility</td><td style="text-align: right;">55.6572</td><td style="text-align: right;">-110.72</td></tr> <tr><td>Surmont SAGD Commercial Battery</td><td style="text-align: right;">56.1936</td><td style="text-align: right;">-110.95</td></tr> <tr><td>Tucker Thermal</td><td style="text-align: right;">54.345</td><td style="text-align: right;">-110.33</td></tr> <tr><td>Jackfish 2 SAGD Plant</td><td style="text-align: right;">55.5281</td><td style="text-align: right;">-110.87</td></tr> <tr><td>MEG Christina Lake Regional Project</td><td style="text-align: right;">55.6572</td><td style="text-align: right;">-110.72</td></tr> <tr><td>Leismer SAGD Bitumen Battery</td><td style="text-align: right;">55.8154</td><td style="text-align: right;">-111.44</td></tr> <tr><td>Mildred Lake and Aurora North Plant Sites</td><td style="text-align: right;">57.0408</td><td style="text-align: right;">-111.62</td></tr> <tr><td>Suncor Energy Inc. Oil Sands</td><td style="text-align: right;">57.0033</td><td style="text-align: right;">-111.47</td></tr> <tr><td>Horizon Oil Sands Processing Plant and Mine</td><td style="text-align: right;">57.3</td><td style="text-align: right;">-111.9</td></tr> <tr><td>Scotford Upgrader and Upgrader Cogeneration</td><td style="text-align: right;">53.7407</td><td style="text-align: right;">-113.02</td></tr> <tr><td>Muskeg River Cogeneration Plant</td><td style="text-align: right;">57.2498</td><td style="text-align: right;">-111.51</td></tr> <tr><td>Shell Albian Sands Jackpine Mine</td><td style="text-align: right;">57.2444</td><td style="text-align: right;">-111.52</td></tr> <tr><td>Kearl Oil Sands Processing Plant and Mine</td><td style="text-align: right;">57.3969</td><td style="text-align: right;">-111.07</td></tr> <tr><td>Shell Albian Sands Muskeg River Mine</td><td style="text-align: right;">57.2444</td><td style="text-align: right;">-111.52</td></tr> </tbody> </table>	Firebag	57.2297	-110.83	Cold Lake	54.597	-110.4	Long Lake Project	56.4135	-110.95	Wolf Lake and Primrose Plant	54.6984	-110.72	Foster Creek SAGD Bitumen Battery (with Cogen)	55.0695	-110.54	Christina Lake SAGD Bitumen Battery	55.5827	-110.89	MacKay River Power Plant	56.9361	-111.56	Jackfish 1 SAGD Plant	55.5281	-110.87	MEG Christina Lake Cogeneration Facility	55.6572	-110.72	Surmont SAGD Commercial Battery	56.1936	-110.95	Tucker Thermal	54.345	-110.33	Jackfish 2 SAGD Plant	55.5281	-110.87	MEG Christina Lake Regional Project	55.6572	-110.72	Leismer SAGD Bitumen Battery	55.8154	-111.44	Mildred Lake and Aurora North Plant Sites	57.0408	-111.62	Suncor Energy Inc. Oil Sands	57.0033	-111.47	Horizon Oil Sands Processing Plant and Mine	57.3	-111.9	Scotford Upgrader and Upgrader Cogeneration	53.7407	-113.02	Muskeg River Cogeneration Plant	57.2498	-111.51	Shell Albian Sands Jackpine Mine	57.2444	-111.52	Kearl Oil Sands Processing Plant and Mine	57.3969	-111.07	Shell Albian Sands Muskeg River Mine	57.2444	-111.52
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Project Leader:	Bill Donahue
Organization and contact information:	Alberta Environment and Parks (AEP)
Date Study initiated:	Spring 2017
Monitoring Category: <i>(From OSM long-term plan; choose from drop-down menu)</i>	Atmospheric Monitoring
Strategic Objective of Focused Study: <i>(From OSM long-term plan; choose from drop-down menu)</i>	Objective A3: Investigate Sources and Atmospheric Transport Pathways
Hypotheses: <i>(Briefly outline the specific hypotheses that your focused study is aiming to address)</i>	<ol style="list-style-type: none"> 1) There are significant uncertainties in conventional, facility-based GHG emission estimation methods. This will contribute to uncertainty in Alberta meeting its GHG-reduction goals, which depend on having a clear understanding of actual emissions, and accurate estimation and reporting of emissions and associated reductions. 2) Aircraft-based direct measurement of GHG emissions from major oil sands sources will improve accuracy of reported values and conclusions of whether provincial GHG emissions policies are working or need amendment. And, 3) Comparison of NOAA aircraft-based direct measurement of total emissions to other methods (e.g., satellite, stack, ground-based optical, and ECCC flight-based measurements) will identify or confirm significant differences in values of emissions estimates.
Deliverables: <i>What tangible goal (s) and/or product(s) will the monitoring produce and when?</i>	<p>Completion of field study flights (November 2017).</p> <p>Data sheet of measured emission rates of the facilities and fields studied (March 2018).</p> <p>Technical report on full project results (March 2018).</p> <p>Scientific publication(s) on GHG emissions for oil sands facilities and comparisons to reported, directly measured, and remote-sensed GHG emissions data and estimates (March 2019).</p>

Detailed Study Plan

(Please provide detailed information on the specifics of your focused study including – (**keywords, hypothesis and the assumptions and constraints behind your hypothesis**)

Provide a maximum of 10 key words that describe this project. Use commas to separate them:

Greenhouse gases, emission measurement, aircraft-based mass balance method, oil sands facilities, specified gas emitters, *in situ* oil sands field

Describe how you will test your hypothesis:

Alberta Environment and Parks (AEP) will collaborate with U.S. National Oceanic and Atmospheric Administration (NOAA) on airborne Greenhouse Gas (GHG) emission measurements in Alberta from May to November, 2017 (up to 6 monthly research periods, typically 10 – 12 days each period), using an instrumented high-performance light aircraft (operated by Scientific Aviation) that will quantify total facility or field GHG emissions, with accessory VOC determinations.

The aircraft will measure *in situ* methane (CH₄), carbon dioxide (CO₂), ethane (C₂H₆), carbon monoxide (CO), ozone (O₃), water vapour (H₂O), temperature and wind. Flask air sample measurements (analyzed later in a laboratory; up to 12 flasks each flight) will include more than 50 different species including sulfur hexafluoride (SF₆), and a variety of hydrocarbons, halocarbons and isotopes of carbon. The emission measurements will follow the methodology (a mass balance method) described in Karion et al. (2013) and the wind measurements will follow the protocol given in Conley et al. (2014). Emission rates are determined based on the measured concentration and wind data, via flight-based, enveloped upwind and downwind mass-balance determinations. Full facility emissions for select major oil sands specified GHG emitters extracting via mining or *in situ* methods will be measured. The hypotheses will be tested by comparing the airborne measurement results with those derived from other methods and the reported emissions values.

Overview

Under the Specified Gas Emitters Regulation, major GHG emitters in Alberta must reduce their emissions intensities, either via real reductions in emissions or by paying a per-tonne fee. Under the Climate Leadership Plan, methane (CH₄) emissions in Alberta will be reduced by 45% by 2025 and total GHG emissions caps for the province and oil sands industry have been identified. However, there are significant uncertainties in conventional GHG emission estimation methods, and any determination of success or failure of Alberta to meet its GHG-reduction goals will depend on having a clear understanding of actual emissions, and whether reported emissions and associated reductions are accurate. Establishing clear emissions baselines and periodic direct measurements of GHGs as a form of quality assurance check will help Alberta to assess both accuracy of reported values and whether provincial GHG emissions policies are working or need amendment. The proposed direct and more accurate aircraft-based measurement of GHG emissions at a very large scale will contribute greatly to reducing the uncertainties in CH₄ emission measurement and reporting currently in place in Alberta.

With the extensive research experience of the project staff and more than CAN\$2 million of in-kind contribution in hardware and labor from NOAA/NASA, this opportunity is of great value to GHG emissions reduction and achieving Alberta's priorities and goals under the Climate Leadership Plan.

Monitoring Locations

As given in Section "Monitoring Site(s) Coordinates (*latitude and longitude*)" under General Information, the monitoring locations include about 22 major specified GHG emitters and one *in situ* oil sands extraction field.

Monitoring Duration

The first airborne GHG emission measurement flight is expected to begin May 13, 2017. Subsequent flights could begin June 26, August 1, August 26, September 23 and November 5. Each of the up to 6 study periods may include up to 10 – 12 days of flights.

Monitoring Frequency

Data will be collected both continuously (GHG, temperature and wind) and discretely (flask samples) during the flights. Each facility or field will be monitored once per monthly flight study period.

Parameters to be Monitored

Flight plans are designed to encircle and envelope a facility, with continuous monitoring of real-time methane (CH₄), carbon dioxide (CO₂), ethane (C₂H₆), carbon monoxide (CO), ozone (O₃), water vapour (H₂O), temperature and wind during flights. Up to 12 discrete flask air samples will be taken per flight, for subsequent lab analyses of more than 50 different chemical species, including sulfur hexafluoride (SF₆), and a variety of hydrocarbons, halocarbons and isotopes of carbon. This technique will permit mass-balance-based calculation of facility fluxes at the time of flights.

Monitoring Equipment

The Mooney M20M TLS aircraft is equipped with Picarro Greenhouse gas analyzers, Aerodyne Ethane TDL Analyzer, horizontal wind system, temperature and relative humidity analyzers as well as whole air sampling system, and data integration and analysis systems.

Evaluation and Reporting

AEP will develop a series of technical reports and peer-reviewed research papers summarizing and interpreting the results, including the total emissions rates of the facilities and sites measured directly, emissions patterns among major industrial sectors, the utility of this approach as a means by which Alberta may confirm the accuracy of reported emissions rates from major emitters, and a comparison of this aerial technique with other means by which GHG emissions in Alberta are or can be quantified. A similar proposal for using this approach for measuring GHG emissions from non-oil sands specified emitters in Alberta is also being considered by the Alberta Climate Change Office. If this second proposal is approved, then we will be able to leverage the data and results from that study program to enhance the information gained under this OSM project.

Assumptions and Constraints behind the hypothesis and the testing method:

- It is assumed that the instrumented aircraft system will function properly as usual, during the flight

periods.

- It is assumed that weather conditions will permit emission measurement flights for the majority of the days.

References:

Conley, S. A., et al. (2014). *A Low-Cost System for Measuring Horizontal Winds from Single-Engine Aircraft.* *Journal of Atmospheric and Oceanic Technology* 31(6): 1312-1320.

Karion, A., et al. (2013), Methane emissions estimate from airborne measurements over a western United States natural gas field, *G.R.L.*, 40, 1-5, *doi:10.1002/grl.50811*.

Data Management

If this work generates data please summarize your project-level data management plan.

Deliverables	Timeframe
Data Collection Period: <i>Field work</i>	Start : 2017-05-13 End: 2017-11-30
Data Analysis Period: <i>Laboratory analysis and QA/QC of data</i>	Start : 2017-05-14 End: 2018-03-31
Data Release Date: <i>Metadata and data consistent, complete and meet basic standard format for publication in Open Data; on or linked to JOSM portal</i>	2018-03-31

Reporting and Publications

Provide information on the anticipated reports / publications. (Insert additional rows if needed)

Expected Subject/Titles of Publications or Reports	Short Description of Publication or Report	Expected Year of Publication
GHG emission measurements using an instrumented aircraft	Report: A summary of the emissions rates of the facilities and sites directly measured, emissions patterns among major industrial sectors, the utility of this approach as a means by which Alberta may confirm the accuracy of reported emissions rates from major emitters, and a comparison of this aerial technique with other means by which GHG emissions in Alberta could be quantified.	2018
GHG emissions of oil sands activities measured by an instrumented aircraft	Peer-reviewed paper(s): The analysis of the emission data collected using the instrumented aircraft, including a summary of the measured emission rates and comparison between	2018

	measured and reported values.	
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Technical / Professional Roles and Responsibilities

Identify members of the monitoring team/organization, their roles and responsibilities. Identify monitoring organization leads if different from overall monitoring activity lead. (Insert additional rows if needed)

Role	Responsibilities	Resource Name/Organization
Chief pilot and airborne scientist	Planning, field operations, data processing and analysis	Dr. Stephen Conley (Scientific Aviation, Boulder, CO 80305)
Chief scientist	Planning, office support, data processing and analysis	Dr. Gabrielle Petron (NOAA/CIRES, Boulder, CO 80305)
Aircraft instrument maintenance and calibrations	Aircraft instrument maintenance and calibrations	Sonja Wolter (NOAA/CIRES, Boulder, CO 80305)
Data processing and analysis (NOAA)	Data processing and analysis (NOAA)	Dr. Stefan Schwietzke (NOAA/CIRES, Boulder, CO 80305)
Air Scientists (EMSD)	Planning, field and office support, data analysis and report writing.	Lucas Zhang and a second air scientist (TBD) (AEP)
Meteorological and logistics coordination	Meteorological and logistics coordination	One NOAA staff (TBD) (NOAA/CIRES)
Meteorological support	Meteorological support	Two EMSD or ECCC staff (EMSD or ECCC)
NOAA oversight and project administration	NOAA oversight and project administration	Dr. Russell Schnell (NOAA, Boulder, CO 80305, 3 man months) (In kind contribution at no cost valued at CA\$118 K to the project).
EMSD oversight and project administration	EMSD oversight and project administration	Dr. Bill Donahue (AEP)
Aircraft instrumentation, calibration gases, laboratory facilities and data processing computers, software, IT staff and publication provided by NOAA	N/A	(In-kind contribution valued at ~CA\$2.1 M in hardware and 229 K in labor)

Deliverables (Year 1) If your Focus Study is longer than 1 year then complete **Appendix C** for multi-year deliverables breakdown

Provide a summary of tangible quarterly deliverables. Identify major project areas (deliverables) and results that can be identified as a tangible goal. This could include: field work, lab work/ analysis, evaluation, data, reports, publications, SOPs etc. Do not define process as your Deliverable e.g. ‘fly to Ft. McMurray to conduct fieldwork’ or ‘seek Director approval for report’.

Deliverable(s) (please provide enough information to support status reporting)
Q1 – April to June
-Completion and commencement of the field work scheduled for the May 13 (~3 weeks) and June 26 (10 – 12 days) flight windows, respectively.
-Data sheet of emission rates measured during the field work.
-Lab analysis of flask air samples.
Q2 – July to September
-Completion of the field work scheduled for the June 26, August 1 and August 26 flight windows (10 – 12 days each window). Commencement of the field work scheduled for the September 23 flight window (10 – 12 days).
-Data sheet of emission rates measured during the field work.
-Lab analysis of flask air samples.
Q3 – October to December
-Completion of the field work scheduled for the September 23 and November 5 flight windows (10 – 12 days each window).
-Data sheet of emission rates measured during the field work.
-Lab analysis of flask air samples.
Q4 – January to March
-Final project report
-Final QA/QCed data sheet
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Detailed Financial Breakdown – Year 1 of 1 (2017-2018)

Also complete **Appendix B** for the multi-year financial breakdown

Budget requirements – List areas that require budget expenditures: (ADD OR DELETE BUDGET CATEGORIES AS REQUIRED)	OS Funding	External Funding (outside JOSM)
O&M - Operations and Maintenance:		
Helicopter Costs	\$	\$
Field Costs	\$162,000	\$275,800
Data Management	\$	\$
Internal Lab Analysis	\$	\$
Consumable Materials & Supplies	\$	\$
Sub-Total	\$162,000	\$275,800
O&M - Travel		
Field Work	\$4,200	\$7,200
Conferences (<i>Air & Waste Management Association Annual Conference or International Conference on Climate Change or International Conference on Greenhouse Gas Technologies or Air Quality Measurement Methods and Technology</i>)	\$3,700	\$6,300
Meeting (<i>identify meeting</i>)	\$	\$
Sub-Total	\$7,900	\$13,500
O&M - External Contracts :		
Goods and Services Contract (<i>Fort McKay Sustainability Department</i>)	\$74,000	\$126,000
External Lab Analysis	\$72,700	\$123,800
Sub-Total	\$146,700	\$249,800
Salaries:		
Principal Investigator (<i>inclusive of salaries, benefits, overheads, office support</i>)	0.10 FTE (\$23,310)	\$0.17 FTE (\$39,690)
Technical / Professional Assistants (<i>inclusive of salaries, benefits, overheads, office support</i>)	1.19 FTE (\$194,580)	\$2.03 FTE (\$331,320)
Field Staff	0.00 FTE (\$)	\$
Sub-Total	1.29 FTE (\$217,890)	2.2 FTE (\$371,010)

Budget requirements – List areas that require budget expenditures: (ADD OR DELETE BUDGET CATEGORIES AS REQUIRED)	OS Funding	External Funding <i>(outside JOSM)</i>
Total Salaries	1.29 FTE (\$217,890)	\$2.2 FTE (\$371,010)
Total O&M	\$316,600	\$539,100
2017-2018 GRAND TOTAL *	\$534,490	\$910,110

Appendix A – Approvals

Project Submitted by:		
Name: Bill Donahue		
Organization: EMSD	Signature:	Date:
Project Approved by:		
Dr. Monique Dubé (AEP)		Dr. Kevin Cash (ECCC)
Signature 		Signature 
Date		Date

APPENDIX B – Detailed Multi-year Financial Breakdown (Complete the following detailed financial breakdown; add or del

Budget requirements	Year 1 (2017- 2018)		Year 2 (2018- 2019)		Cash
	Cash	In-kind	Cash	In-kind	
1) Salaries and benefits					
a) Investigators					
b) Technical/professional assistants					
c) Field Staff					
d)					
2) Operations and maintenance					
a) Facilities					
b) Equipment					
c) Lab analysis					
d) Data management					
e) Field work					
3) Consumable Materials and supplies					
a)					
b)					
4) Travel					
a) Conferences and meetings					
b) Field work					
c) Project-related travel					
5) Dissemination & Engagement					
a) Publications/Reports					
b) Translation (if required)					
c) Communications					
d) Stakeholder Engagement					
e) Indigenous Peoples Engagement					
6) External Contracts					

a)					
Grand Total					