FOCUSED STUDY ACTIVITY WORK PLAN

General Information

Work Plan Unique Identifier:	*WL-MD-6-1718*	
Focused Study Activity Title:	**Remote Sensing Wetland Ecosystem Change Detection Method Development**	
Focused Study Category:	Monitoring Design and Method Improvement	
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	Regional Municipality of Wood Buffalo
Monitoring Site(s) Coordinates *(latitude and longitude)*	Potential monitoring sites (for Hydrologic Alteration) include: 1) Poplar Road Fen (56° 56' 22" N 111° 33' 03"W) 2) Pauciflora Fen (56° 22' 37" N 111° 14' 12" W) 3) Firebag Study Fen (57°16'33" N 110°58'36" W) Plus additional additional sites for a suite of 6 sentinel sites adjacent to oil sands mines and 6 paired reference sites. Potential monitoring sites (for N deposition) include: 4) JPH4 (57˚6'45"N; 111˚25'23"W) 5) McKay (57˚13"41"N; 111˚42'11"W) 6) McMurray (57˚37'37"N; 111˚211'44"W) 7) Anzac (56˚28'8"N; 111˚2'34"W) 8) Mildred (note: site completely burned in 2016 Fort McMurray fire) (56˚55'49"N; 111˚28'31"W); 9) Utikuma (55˚59'9"N; 115˚11'3"W) The sites will be determined in a technical workshop in 2017-2018.	
Project Leader:	Laura Chasmer[1] and Chris Hopkinson[1], Danielle Cobbaert[2]	
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Date Study initiated:	2017	
Monitoring Category: *(From OSM long-term plan; choose from drop-down menu)*	Wetland Ecosystem Monitoring	
Strategic Objective of Focused Study: *(From OSM long-term*	Objective WE1: Detect and report changes in wetland ecosystem in	

plan; choose from drop-down menu)	relation to Oil Sands Developments and related Point and Non-point source emissions
Hypotheses: *(Briefly outline the specific hypotheses that your focused study is aiming to address)*	*Changes in vegetation structural characteristics observed using multi-temporal airborne Light Detection and Ranging (LiDAR) combined with optical imagery can be used as proxy indicators for the extent and intensity of wetland ecosystem disturbance as a result of a) ground water alteration/extraction for oil sands operations/development; and b) nitrogen (N) deposition with distance from oil sands operations based on scalar fluxes of atmospheric constituent transport.*
Deliverables: *What tangible goal (s) and/or product(s) will the monitoring produce and when?*	1. Detailed wetland classification maps of wetland extents and type for the Oil Sands area around Fort McMurray using LiDAR and optical imagery. 2. Maps, report and journal paper on the spatial distribution of wetland loss and change in condition and intensity of change from ~1982 (Landsat) and 2006 (SPOT) to present; using *in situ,* LiDAR and optical (multi-spectral) remote sensing methods. 3. Report and journal paper on the effects of Oil Sands development from hydrologic alteration and nitrogen (N) deposition with distance from oil sands mines will be determined using vegetation structural changes as proxy indicators for wetland ecosystem condition. 4. A monitoring report including optimal methodology on the use of remote sensing technology to track changes in wetland area and condition (key indications) associated with oil sands development over time and across the oil sands region. 5. Annual technical reports of progress and results, plus at least three peer-review publications of results.

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: In situ oil sands extraction; remote sensing; LiDAR, multi-spectral; wetland disturbance; Nitrogen;

wet area mapping; biomass; hydrology; pollution

Describe how you will test your hypothesis:

Background

Wetlands within the Oil Sands region are facing pressures from land use disturbance, climate change, and natural hazards resulting in alteration of some of the underlying processes and feedbacks that have historically maintained these sensitive ecosystems (de Groot et al. 2013; Phillips et al. 2014). **However, it is not known how sensitive these ecosystems are to climate change and disturbance from industry or natural hazards, such as fire.** Rapid changes in ecosystem processes and underlying conditions have the potential to create a 'tipping point' scenario of surface water and ground water drying, such that hydrological changes could increase shrubification within wetlands and further drying through transpiration (Kettridge et al. 2013; Chasmer and Hopkinson, 2016). Ecosystem recovery to pre-disturbance conditions becomes less likely with continued water use. These concerns have raised a series of profound questions that require examination over broad regions: ***Are wetlands sensitive to natural and anthropogenic disturbance? If wetlands are changing how rapidly is this occurring?*** **And** ***What are the driving mechanisms associated with wetland change?***

Monitoring of wetlands is exceedingly difficult due to issues of inaccessibility, the logistical constraints associated with field validation across broad regions of vast wetland areas, and the need for repeat monitoring (Halsey et al. 2003; Ozesmi and Bauer, 2002). The recent availability of freely available (e.g. Landsat), and relatively inexpensive long-term remote sensing data archives can provide a means for wetland identification and monitoring over time (Chasmer et al. in review) and over broad geographic areas, as long as wetland land cover types are accurately classified. Classification accuracy of wetland area extent, therefore, is fundamentally important for quantifying the drivers of wetland change, when and where they occur, and the implementation of sound land-use decisions regarding wetland management including disturbance, mitigation and reclamation (Chasmer et al. 2014; 2016). While long-term historical remote sensing archives from Landsat and other sensors provide important observations of changes that have occurred across the landscape over the last few decades (~40 years), these records may not have the spatial fidelity to observe highly localised changes in wetland area extent or species characteristics associated with disturbance (Krankina et al. 2008). Other remote sensing methods, such as airborne Light Detection And Ranging (LiDAR) are more expensive to acquire, but provide high resolution vegetation structural characteristics and topography that, when integrated within a remote sensing classification, can be used to create accurate estimates of wetland extent and type (Chasmer et al. 2014, 2016). The province of Alberta has been highly proactive in terms of LiDAR data acquisitions over broad regions. ***These acquisitions and long-term multi-spectral remote sensing data archives have the potential to be utilized to characterize 'baseline' (defined and constrained by the historic remote sensing archives) current and future wetland condition (aerial extent and wetland classification) within an integrated wetland monitoring framework.*** Currently, no such framework for wetland monitoring in the Province of Alberta exists.

Objectives

The proposed Focused Study Activity Work Plan will create a methodological framework for scaling of LiDAR remote sensing data using lower spatial resolution optical image archives for a) wetland classification, and b) wetland change within the Oil Sands region of Alberta. The research will focus on utilizing long-term wetland monitoring sites, *in situ* field validation and instrumentation records. Key objectives are as follows:

Objective 1: Develop a remote sensing-based wetland classification methodology for sentinel (intensive long-term monitoring sites) and synoptic (one-time monitoring sites with subset of core monitoring variables) monitoring site wetlands outlined in the OSM Long-Term Monitoring Wetland Program using the available Province of Alberta LiDAR dataset with reference to underlying surficial geology, digital elevation models, and vegetation structural characteristics by expanding upon methods described in Chasmer et al. (2016), specific to the Oil Sands region.

Objective 2: Assess the ability of LiDAR technology to accurately identify the effects of natural disturbance (e.g. inter-annual variation in climate, fires) versus effects of oil sands development due to a) hydrological alteration and b) N-deposition on wetland ecological condition (primarily changes in open water area and depth, and vegetation change over time).

Objective 3: Use LiDAR-based methods as a "lots of plots" methodology to reduce costs associated with in situ field validation, and as a means for scaling to lower resolution historical remote sensing archives and continuous (future) data collection frameworks such as the Landsat Data Continuity Mission based on 'hot spot' analysis of ecosystem change. This includes recommendations on how frequently to acquire imagery and monitor for wetland change using LiDAR and optical imagery.

Methods

Objective 1: Develop a remote sensing-based wetland classification methodology for sentinel (intensive long-term monitoring sites) and synoptic (one-time monitoring sites with subset of core monitoring variables) monitoring site wetlands outlined in the OSM Long-Term Monitoring Wetland Program using the available Province of Alberta LiDAR dataset with reference to underlying surficial geology, digital elevation models, and vegetation structural characteristics by expanding upon methods described in Chasmer et al. (2016), specific to the Oil Sands region*:*

The wetland classification provides a baseline from which all ecosystem changes can be assessed and verified.

Core sites: Core sites will include 3 sentinel sites from which the hypothesis will be tested, and 6 additional sentinel sites for methods application and validation (Validation Sites) outlined in the complimentary OSM Long-term Wetland Monitoring Program:

Sentinel sites (for Hydrologic Alteration) include:

1) Poplar Road Fen (56° 56' 22" N 111° 33' 03"W)

2) Pauciflora Fen (56° 22' 37" N 111° 14' 12" W)
3) Firebag Study Fen (57°16’33” N 110°58’36” W)

Plus additional 6 additional sites to be determined in 2016-2017 winter workshop.

Sentinel Sites (for N deposition) include:

4) JPH4 (57˚6’45”N; 111˚25’23”W)
5) McKay (57˚13”41”N; 111˚42’11”W)
6) McMurray (57˚37’37”N; 111˚211’44”W)
7) Anzac (56˚28’8”N; 111˚2’34”W)
8) Mildred (note: site completely burned in 2016 Fort McMurray fire) (56˚55’49”N; 111˚28’31”W);
9) Utikuma (55˚59’9”N; 115˚11’3”W)

Data Already Acquired

- Province of Alberta/Airborne Imaging Inc. airborne Light Detection And Ranging (LiDAR) data from which a ‘baseline’ (circa 2008) wetland land cover classification will be derived (*in kind contribution ~$200,000*).
- Field data collection of land cover type, species, and vegetation structural characteristics at sentinel (1-3) and synoptic sites (6, 8 and 9) completed in 2016 (*in kind contribution ~$4000*).

Data Required

- Classification validation data required for sites 4, 5, 7.

Brief Methods

LiDAR and optical/multi-spectral remote sensing data processing will follow methods of Chasmer et al. (2016). This will include:

- Derivation of LiDAR-based data products, including a 1 m x 1 m digital elevation model (DEM) of the ground surface topography, maps of vegetation structural characteristics including a canopy height model (CHM), foliage fractional canopy cover, and indicators of biodiversity using foliage structural complexity
- Wetland areas will be classified based on their location and extent, and type (Chasmer et al. 2016; Chasmer et al. in progress).

Deliverables

- **High resolution (1 m) maps** including ground surface elevation (DEM), vegetation characteristics, and a detailed wetland classification map of extent and type. The framework used to develop these maps will be tested and validated at sentinel and synoptic sites.
- **Annual report** including the data processing, product, and classification methodologies. These will also be presented in a peer-reviewed journal publication on classification scaling methodology and accuracy for wetland assessment.

- **Manuscript** for submission on state of the science in Wetland Remote Sensing in Alberta.

Objective 2: Assess the ability of LiDAR technology to accurately identify the effects of natural disturbance (e.g. inter-annual variation in climate, fires) versus effects of oil sands development due to a) hydrological alteration and b) N-deposition on wetland ecological condition (primarily changes in open water area and depth, and vegetation change over time):

Hypothesis: Hydrologic alteration of surface water and groundwater associated with Oil Sands development may be accelerating wetland changes beyond what occurs naturally within this environment.

The primary objective is to determine the utility of remote sensing technologies to quantify wetland vegetation structure and species changes associated with a) hydrologic alterations and b) N-deposition associated with oil sands industry development within Long-term wetland monitoring program study sites following wetland structure assessment and change detection examples of Hopkinson et al. (2005); Phillips et al. (2014); Hopkinson et al. (2016); Chasmer and Hopkinson (2016). To do this, a drought severity/frequency map and long-term changes in inputs and outputs to the water balance will be used as a baseline from which additional (industrial) point source emissions and water use will be examined against.

Data Already Acquired

Objective 2 will concentrate on sentinel Sites 1-3 and synoptic Site 9, where we currently have multi-temporal LiDAR data, and will update remaining sites with new LiDAR data collections in 2018.

- LiDAR data collected at multiple time periods, including 2008 (provincial dataset) (*in kind contribution of* ~$200,000) and 2016 (collected by the ARTeMiS Lab at the University of Lethbridge) for Sites 1, 2 (plus surrounding areas) (*in kind contribution of ~$10,000*) and in 2008, 2011, 2015, and 2016 at Site 9 (*in kind contribution of ~$10,000 - $30,000 per year of acquisition).*
- Validation of LiDAR data products from Objective 1 using vegetation mensuration (tree plot, shrub plot, peat clip plots) at sites acquired in 2010, 2016 (*in kind contribution of ~$4,000)*. Validation of new LiDAR data collection in 2018 as per budget.
- Hydrometric and meteorological data at sites acquired by Petrone and Devito (University of Alberta) (*in kind contribution exceeding $200,000*).
- Water chemistry (N) required for deposition concentration of N in ground water.

Data Required

- Airborne LiDAR data collection in summer 2018 in collaboration with the ARTeMiS Lab to continue observations of vegetation structural changes at sentinel sites, and Site 9, plus additional local validation sites.
- Field validation of vegetation structure (height, basal area, foliage area (leaf area index)) and species distribution within variable sized (11.3 m tree; 5 m shrub; 1 m grass) plots coincident with LiDAR surveys at sites in 2018 used to verify ecosystem change. All data need to be

geo-located using survey-grade GPS.

- Soil moisture and temperature (Campbell Scientific Inc. Hydrosense II) collected using along transects across riparian and wetland boundaries and across plots. All data need to be geo-located using survey-grade GPS.

Brief Methods

- Derive aboveground biomass based on shrub allometry (estimated from *in situ* geographically located measurement (height, basal area, stem diameter at ground) plots) (Falster et al. 2015) based on the relationship between LiDAR-derived shrub heights from multi-temporal LiDAR data plot data (Hopkinson et al. 2015) for 2008 and planned data collected in 2018.
- Map Palmer Drought Severity Index (or similar) and frequency for site areas from 1970 to present using Environment Canada precipitation and air temperature data.
- Compare changes in biomass with proximal depth to water table at key sites required for Objective 2a, providing linkages between changes in ground water regime and ecosystem response.
- Objective 2b, prevailing wind directions will be determined using long-term hydro-meteorological monitoring stations at Sentinel and Synoptic sites, used to quantify advection of N from Syncrude and Suncor stacks.
- Footprint or dispersion modelling (Chasmer et al. 2008; 2011) will be used to quantify the probability of deposition with distance of wetlands from the source and impacts on biomass change using LiDAR and optical vegetation indices as indicators of vegetation change, all else (e.g. hydrology) remaining relatively unchanged since 2000.

Deliverables

- **Annual report** on wetland ecological condition using vegetation change as an indicator of the underlying processes affecting wetlands within the Oil Sands region. This report will be divided into historical climate variability affecting hydrology, hydrological impacts of water extraction (Objective 2a) and the implications of N deposition (Objective 2b).
- **Two manuscripts** on the effects of a) hydrological alteration on wetland ecological condition and b) N deposition effects with distance from oil sands activities.
- **Develop a framework** for identifying ecosystem sensitivity to changes in depth to water table associated with industry-based resource extraction.

Objective 3: Use LiDAR-based methods as a "lots of plots" methodology to reduce costs associated with in situ field validation, and as a means for scaling to lower resolution historical remote sensing archives and continuous (future) data collection frameworks such as the Landsat Data Continuity Mission based on 'hot spot' analysis of ecosystem change. This includes recommendations on how frequently to acquire imagery and monitor for wetland change using LiDAR and optical imagery.

Objective 3 will compare results of Objective 2a and b derived from multi-temporal LiDAR data with vegetation change indices determined from lower resolution (2.5 m, 5 m SPOT and 30 m Landsat TM) less expensive (SPOT) and freely available (Landsat) multispectral remote sensing data. We propose that LiDAR data can be used as a sampling tool similar to *in situ* validation of vegetation characteristics and change over time. However, LiDAR data are expensive to acquire, therefore it is critically important to identify applications where low- or no-cost optical remote sensing can take the place of wide area mapping using LiDAR for wetland inventory and change assessment.

Data Already Acquired

- High resolution (2.5 m, 5 m) SPOT optical imagery acquired from ~2006 to 2016 (obtained through a collaboration between the University of Lethbridge and Planet Inc. *in kind contribution to UL is ~$100,000 for all sites*).
- Landsat TM 30 m resolution multispectral data from 1986 to 2016 (freely available via the United States Geological Survey (http://landsat.usgs.gov/CDR_LSR.php, high level data products; and http://glovis.usgs.gov/, spectral data).
- Validation of optical imagery from Objectives 1 and 2 for sentinel and synoptic sites.
- LiDAR data acquisition from 2017 or 2018 (acquired for Objective 2).

Data Required

- No data are required for this component

Methods

- Processing of optical images from the SPOT and Landsat TM satellites collected over the last 10-25 years (e.g. Chasmer et al. in review).
- Detection of vegetation and land surface changes using remote sensing imagery at various pixel resolutions. This will provide quantitative analysis of the range and magnitude of changes that can be observed using optical imagery based on spectral proxy indicators of wetland ecological condition over broad regions.
- Determining optimal time period for re-acquisition of remote sensing data used for change detection.
- Vegetation change will be compared over time and related to water extents and extraction (Objective 2a) and N-deposition with distance from Syncrude and Suncor stacks (Objective 2b).

Deliverables

- **Annual report** on the optimal resolution and cost of remote sensing data for mapping wetland and forest extents and change, including a spatially distributed assessment of error within these datasets compared with LiDAR data at synoptic and sentinel sites. The cost effectiveness of *in situ* validation, LiDAR and optical imagery will also be discussed for wetland assessment, limitations and benefits. Report will summarize the Focused Study Activities, outcomes and recommendations.
- **One manuscript** on the effects of pixel resolution on the accuracy of wetland change

detection using *in situ* field data collection, LiDAR and optical remote sensing methods; also optimal time period between acquisition dates (sensitivity analysis).

Summary of Proposed Next Steps and Deliverables:

1. **Workshop in 2017-2018** (preliminary working session in March 2017, Toronto plus additional technical workshop in 2017-2018 Q1): Participants to coordinate approved OSM (pending) focus study work plans for 2017-2018 including site selection criteria, stressor and biotic indicator selection, SOPs. Participants to develop TOC and assign tasks for peer-review manuscript and Technical Reports (listed below).

2. **Peer reviewed manuscript** (in addition to 4 manuscripts proposed above) submitted to an international journal on "State of Science: Wetland Remote Sensing in the Oil Sands Mining Region, Alberta. Content will include:
   a) Synthesis of various remote sensing projects completed or underway in the Oil Sands Region (OSR), including the Peace Athabasca Delta;
   b) Development of a wetland remote sensing strategy based on key monitoring objectives (e.g. local scale stressor-response assessment, classification of wetland disturbance/impairment, identification of wetlands sensitive to hydrologic alteration);
   c) Recommendations for next steps for application of conceptual framework to develop a wetland remote sensing Monitoring, Evaluation and Reporting plan including testing and developing wetlands, and scaling up within an operationalized regional framework. Timeline Autumn 2019-2020.

3. **Final Technical Report:** "Oil Sands Region Wetland Remote Sensing Monitoring, Evaluation and Reporting Plan (2019-2023) Draft. The technical report will outline a 5-year Wetland Monitoring, Evaluation and Reporting (MER) Plan for wetland remote sensing in the OSR. This will include key science questions, a monitoring program plan, a plan to develop standard operational procedures, and specific MER objectives and deliverables for each year of the 5-year plan. Appendices will detail SOPs or plans to further develop SOPs where appropriate" Timeline: 2018-2020 (to commence in 2017 with completion planned for 2020).

Assumptions and Constraints behind the hypothesis and the testing method:

This proposal relates to development of infrastructure associated with oil sands development, in the Athabasca oil sands region near Fort McMurray, AB. Vegetation in Boreal Plain peatlands are assumed to exist in a near persistent state of moisture stress as precipitation (P) is generally exceeded by potential evapotranspiration (PET) in most years (Chasmer et al. in review). As such landscape disturbance features associated with the oil and gas, and oil sands industries such roads, well pads, seismic lines and aggregate extraction have the potential to significantly alter ecosystem productivity since they interrupt the subtle hydrological flows and stores of water and dissolved minerals and nutrients to which the system has evolved (Carrera-Hernández et al. 2011). Current investigations by members of this group of proponents are currently examining localized impacts to evaluate the local processes causing change, however, a regional approach is needed to identify and document the range of locations and magnitude of impacts to wetlands. This can be achieved by coupling remotely sensed change detection methods with hydrological and ecological surveys, with the intent of refining remote detection capabilities for more effective large-scale ecosystem risk assessments.

References:

Carrera-Hernández, JJ., C.A. Mendoza, K.J. Devito, R.M. Petrone and B.D. Smerdon . 2011. "Effects of Aspen Harvesting on Groundwater Recharge and Water Table Dynamics in a Subhumid Climate". *Water Resources Research*, 47, doi:10.1029/2010WR009684

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Chasmer, L., C. Hopkinson, J. Montgomery*, R. Petrone, 2016. A Physically-based terrain morphology and vegetation structural classification for wetlands of the Boreal Plains, Alberta Canada. *Canadian Journal of Remote Sensing.* Special Issue on Advanced Forest Inventory. 42(5):521-540 . http://dx.doi.org/10.1080/07038992.2016.1196583

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Chasmer, L., A, Paluck*, C. Mahoney, C. Hopkinson and W. Quinton. Morphological and tree structure influences on permafrost thaw using a spatio-temporal random forest predictive model. *Permafrost and Periglacial Processes.* In progress.

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Chasmer, L., N. Kljun, A. Barr, A. Black, C. Hopkinson, H. McCaughey, and P. Treitz, 2008. Influences of vegetation structure and elevation on CO_2 uptake within a mature jack pine forest in

Saskatchewan, Canada. *Canadian Journal of Forest Research*. 38:2746-2761.

de Groot, W. J., Flannigan, M.D., and Cantin, A. S. 2013. Climate change impacts on future boreal fire regimes. *Forest Ecology and Management.* 294:35-44.

Halsey, L. A., Vitt, D. H., Beilman, D., Crowand, S., and Wells, S. M. R., 2003. Alberta Wetlands Classification System, v. 2.0. *Government of Alberta, Alberta Sustainable Resource Development,* Edmonton, AB.

Hopkinson, C. J. Montgomery, et al. Defining standing water areas using Synthetic Aperture Radar within the Alberta Water Portal. In progress.

Hopkinson, C., L. Chasmer, G. Sass, I. Creed, M. Sitar, W. Kalbfleisch, and P. Treitz, 2005. Vegetation class dependent errors in lidar ground elevation and canopy height estimates in a boreal wetland environment. *Canadian Journal of Remote Sensing*. 31(2):191-206.

Hopkinson, Chasmer, L., A. Barr, N. Kljun, T. A. Black and J. H. McCaughey 2016. Monitoring forest biomass and carbon storage change by integrating airborne laser scanning and eddy covariance data. *Remote Sensing of Environment.* 181:82-95.

Krankina, O.N., Pflugmacher, D., Friedl, M., Cohen, W. B., Nelson, P., and Baccini, A., 2008. Meeting the challenge of mapping peatlands with remotely sensed data. *Biogeosciences.* 5:1809-1820.

Ozesmi, S. L. & Bauer, M. E., 2002. Satellite remote sensing of wetlands. *Wetlands Ecology and Management*. 10:381-402.

Phillips T, Petrone RM, Wells CM, Price JS., 2015. Characterizing dominant controls governing evapotranspiration within a natural saline fen in the Athabasca Oil Sands of Alberta, Canada. Ecohydrology. 9(5):817-829.

Data Management

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

Deliverables	Timeframe	
Data Collection Period: *Field work*	Start : 2018-05-01	End: 2018-10-31
Data Analysis Period: *Laboratory analysis and QA/QC of data*	Start : 2018-09-01	End: 2020-03-30
Data Release Date: *Metadata and data consistent, complete and meet basic standard format for publication in Open Data; on or linked to JOSM portal*	2020-03-30	

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
Workshop	Coordination of focus study work plans for 2017-2018. Participants will develop TOC and assign tasks for the peer-review manuscript and technical reports	2017-2018. Preliminary meeting in Toronto, March 2017
Manuscript 1 for peer review	State of the Science: Wetland Remote Sensing in the Oil Sands Mining region	Autumn 2017 (if review only; additional manuscripts on methods described below)
Annual Report #1	Description of LiDAR-based Oil Sands wetland	March 31, 2018

	classification methodology	
Manuscript 2 for peer review	Spatial distribution of wetlands using Landsat, SPOT and LiDAR Comparison of classification methodology and repeat times using LiDAR data analysis, optical imagery and *in situ* validation at sentinel and synoptic sites	October 2018
Manuscript 3 for peer review	Effects of wetland loss associated with oil sands mine development on downstream water quality using wetland change products	December 2018
Annual Report #2	Report on work so far including statistics on wetland areas, methodologies and applications	March 31, 2019
Manuscript 4 for peer review	Quantifying impacts of hydrologic alteration by Oil Sands industry with distance from mine sites using multi-spectral LiDAR data of structural vegetation changes	May 2019
Manuscript 5 for peer review	Impacts of the effects of nitrogen (N) deposition with distance from oil sands mine sites based on structural characteristics	November 2019
Annual Report #3	Report on research observations during final year. Also discussion on the implications and best practices associated with using LiDAR data as a sampling strategy and optical imagery, plus economic advantages and disadvantages. Nesting of data products in the Alberta Water Portal will also be described.	March 31, 2020

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
Co-Principal Investigator	- Coordination and integration between various Wetland Monitoring Focus Studies (e.g. LTM wetland monitoring program development, PAD wetland focus study, ABMI Biodiversity project, PAD remote sensing study). - Program lead for JOSM Long-term wetland monitoring program development Focus Study including remote sensing component (site selection, stressor and bioindicator selection, development of SOPs). - Co-PI on vegetation indicator criteria and vegetation methods.	Danielle Cobbaert, Wetland Scientist, Alberta Environment and Parks
Co-Principal Investigator	- Remote sensing data analysis and integration at sites, including LiDAR and optical remote sensing data analysis - Collaboration with lead scientists in other projects, such that remote sensing initiatives are comparable across sites, and for best practices research - Graduate student supervising and HQP development	Laura Chasmer, Assistant Professor, Department of Geography, University of Lethbridge
Co-Investigator	- LiDAR data collections, operations and processing, integration with RADAR imagery (possible), field logistics and graduate student support. - Access to high power computing resources and measurement instrumentation including survey-grade GPS - Access and integration of results within the Alberta Water Portal	Chris Hopkinson, Associate Professor and CAIP Chair in Ecosystem Remote Sensing, Department of Geography, University of Lethbridge
Collaborator:	Sentinel site, hydro-meteorology and validation lead	Dr. Richard Petrone, Professor, University of Waterloo
Collaborator:	Sentinel site, hydro-meteorology and validation datasets	Dr. Jonathan Price, Professor, University of Waterloo
Collaborator:	Synoptic site: long-term hydrology and	Dr. Kevin Devito, Professor,

	hydrometric measurements	University of Alberta

Deliverables (Year 1) If your Focus Study is longer than 1 year then complete **Appendix 3** 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
Technical workshop in Edmonton for planning 2017-2018 field campaigns and reporting deliverables (peer-review manuscript and technical reports); hire and train graduate student, PDF.
Q2 – July to September
Field data collection
Acquire airborne LiDAR data (summer 2018) at sites.
Q3 – October to December
Quality control of new field data.
LiDAR classification using provincial LiDAR dataset
LiDAR data processing of provincial dataset and data acquired in 2018
Validation of LiDAR-based classification using field data collected in June to August.
Programming of methodology to classify wetlands using LiDAR data over broad regions to be incorporated in Yr 3 Alberta Water Portal
Q4 – January to March
Writing of Journal Articles
Writing of Annual Reports
Plan for next field campaign, and hire/train required students.

Detailed Financial Breakdown – Year 1 of 3 (2017-2020)

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:		
Remote sensing data (already collected)	**$0**	**$350,000**
Computer equipment	**$10,000**	**$5,000**
Data Management	**$6,000**	**$0**
Long term monitoring data	**$0**	**$200,000**
Consumable Materials & Supplies	**$865**	**$0**
Publications and reports	**$500**	**$0**
Sub-Total	**$16,865**	**$555,000**
O&M – Travel		
Field Work	**$0**	**$4000**
Conferences (*Canadian Remote Sensing Symposium*)	**$2,000**	**$0**
Meeting (*AEP-ECCC*)	**$2,000**	**$0**
Sub-Total	**$4,000**	**$0**
O&M - External Contracts :		
Goods and Services Contract (*describe contractor*): Airborne services retainer/standing offer LiDAR system retainer/standing offer (up to 1 month of LiDAR system access	**$30,000** **$40,000**	**$0**
External Lab Analysis	**$0**	**$0**
Sub-Total	**$70,000**	**$0**
Salaries:		
Principal Investigator	**$50,000**	**$19,500**
Technical / Professional Assistants	**$31,700**	**$0**
Field Staff	**$0**	**$0**
Sub-Total	**$81,700**	**$19,000**
Total Salaries	**$81,700**	**$19,500**

Budget requirements – List areas that require budget expenditures: (ADD OR DELETE BUDGET CATEGORIES AS REQUIRED)	OS Funding	External Funding (*outside JOSM*)
Total O&M	**$173,065**	**$578,500**
Total University Overhead (@15%)	**$25,905**	
2017-2018 GRAND TOTAL*	**$198,970**	**$578,500**

Appendix 1 – Approvals

Project Submitted by:

Name: Laura Chasmer		
Organization: University of Lethbridge	Signature:	Date: 15/11/2016

Project Approved by:

Dr. Monique Dubé (AEP)	**Dr. Kevin Cash (ECCC)**
Signature	Signature
Date	Date

APPENDIX 2 – Detailed Multi-year Financial Breakdown (Complete the following detailed financial breakdown; add or delete categories as required)

Budget requirements	Year 1 (2017- 2018)		Year 2 (2018- 2019)		Year 3 (2019- 2020)	
	Cash	In-kind	Cash	In-kind	Cash	In-kind
1) Salaries and benefits						
a) Investigator Salary for L.Chasmer (0.5 FTE)	$50,000		$50,750		$51,500	
b) Investigator Salary for D. Cobbaert (0.25 FTE)		$5,500		$27,500		$27,500
c) Investigator Salary for C. Hopkinson (0.1 FTE)		$14,000		$14,000		$14,000
d) Technical/professional assistants (x 1, FTE)	$16,700		$50,000		$25,000	
e) Graduate students (x 1, FTE)	$15,000		$15,000		$15,000	
f) Undergraduate research assistants (x 1, FTE)			$3,200			
g) Programmer				$11,667	$70,000	
Salaries and benefits sub-total	**$81,700**	**$19,500**	**$118,950**	**$53,167**	**$161,500**	**$41,500**
2) Operations and maintenance						
a) Remote Sensing data already acquired (GOA LiDAR 200 K; U of L LiDAR 50K; SPOT 100k)		$350,000				
b) Computer Equipment (in kind network and data storage; computing resources	$10,000	$5,000		$5,000		$5,000
c) Field Data already collected		$4,000				
d) Data management and licensing (access to terrascan, ENVI, PCI)	$6,000		$1,000	$5,000		$6,000
e) Long-term monitoring data, hydrology datasets from Richard Petrone and Kevin		$200,000				

Devito						
f) GPS equipment rental (Geo 7x Cansel) and other miscellaneous field supplies			$4,000			
Operations and maintenance sub-total	**$16,000**	**$559,000**	**$5000**	**$10,000**		**$11,000**
3) Consumable Materials and supplies						
a) Office supplies	$865		$500		$500	
Consumable materials and supplies sub-total	**$865**		**$500**		**$500**	
4) Travel						
a) Conferences and workshops	$2,000		$4,000		$6,000	
b) Field work (including truck rental, accommodations, per diem for 4 people)			$10,000			
c) OSM Wetland team meetings	$2,000		$2,000		$2,000	
Travel sub-total	**$4,000**		**$16,000**		**$8,000**	
5) Dissemination & Engagement						
a) Publications/Reports	$500		$2,000		$2,000	
b) Communications					1500	
Dissemination sub-total	**$500**		**$2,500**		**$3,000**	
6) External Contracts						
a) LiDAR system retainer/standing offer (up to 1 month of LiDAR system access)	$40,000					
b) Airborne services retainer/standing offer	$30,000		$30,000			
External contracts sub-total	**$70,000**		**$30,000**			

Sub-total	**$173,065**	**$578,500**	**$172,950**	**$63,167**	**$173,000**	**$52,500**
University overhead (15%)	**$25,905**		**$25,943**		**$25,950**	
Grand Total	**$198,970**	**$578,500**	**$198,893**	**$63,167**	**$198,950**	**$52,500**

APPENDIX 3 –Years 2 and 3 Deliverables (Complete the following detailed breakdown. Provide a summary of tangible quarterly deliverables. Identify major project areas (deliverables) and results that can be identified as a tangible goal.)

Year 2 (2018- 2019)
Deliverable(s) (please provide enough information to support status reporting)
Q1 – April to June
Investigator salary (Chasmer) + graduate student and technician salary)
LiDAR data collection and field work planning for July-September surveys
Submission of numerous LiDAR and remote sensing data products + wetland classification
Software for data processing annual update
Consumable office supplies
Conference presentations at Canadian Remote Sensing Symposium
OSM Team meeting
Q2 – July to September
Investigator salary (Chasmer) + graduate student and technician salary)
Field data collection, including measurements of soil moisture and temperature along transects
Acquire airborne LiDAR data at sites
Summer student for field assistance
GPS rental for fieldwork
Q3 – October to December
Data analysis by personnel
Submission of manuscript #2: Spatial distribution of wetlands and wetland changes
Map of spatial distribution of wetland change using Landsat and SPOT imagery
Sensitivity analysis determined from differences in pixel resolution
Determine recommended repeat times for remote sensing data acquisition to monitor wetland change over time
Maps of water mask layers and pseudo-depth analysis
Submission of Manuscript #3: Effects of wetland loss on water quality

Q4 – January to March
Investigator salary (Chasmer) + graduate student and technician salary)
Writing of Annual Report (2019)
University overhead @ 15%

Year 3 (2019- 2020)
Deliverable(s) (please provide enough information to support status reporting)
Q1 – April to June
Investigator salary (Chasmer) + graduate student, technician and programmer salary)
Manuscript 4: Quantifying wetland structure changes associated with hydrological alteration with distance from oil sands companies
Q2 – July to September
Continued data analysis, writing and integration of data products within the Alberta Water Portal
Q3 – October to December
Manuscript 5 Submission: Impacts of N deposition with distance from oil sands mines and wetland condition
Conference attendance and presentation of results
OSM Wetland team meeting and communications
Q4 – January to March
Completion of Report #3
Dissemination of Water Portal with Wetland classification with change detection addition
Maps of drying trends in the Oil Sands region
University overhead @ 15%