Esso Imperial Oil

WorleyParsons
resources & energy
EcoNomics™

Arctic Sites Phase 1 ESA & Remote Sensing Pilot Project

Reagen Stoddart, Imperial Oil & Steve Adam, WorleyParsons

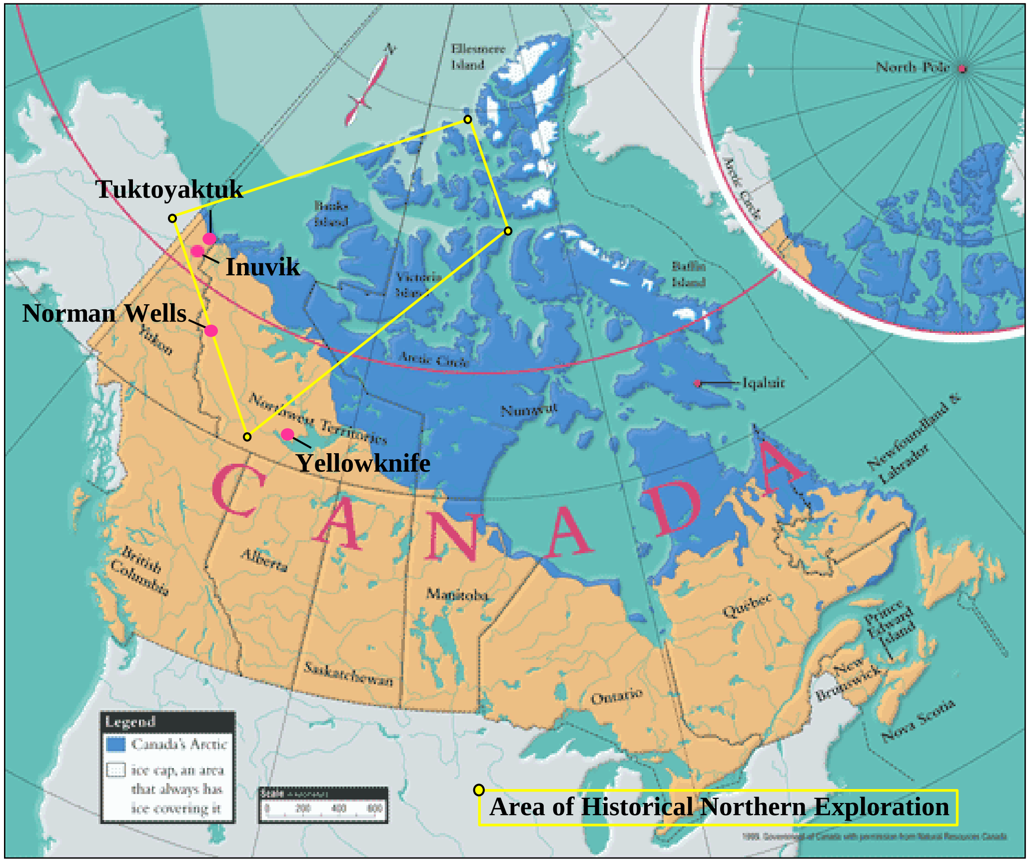
RemTech - October 19th, 2012

Outline

- The Northern legacy
  - Extent of exploration
  - Site conditions
- Assessment challenges
- Remote sensing potential
- Project overview
  - Analysis
  - Interpretation
  - Conclusions

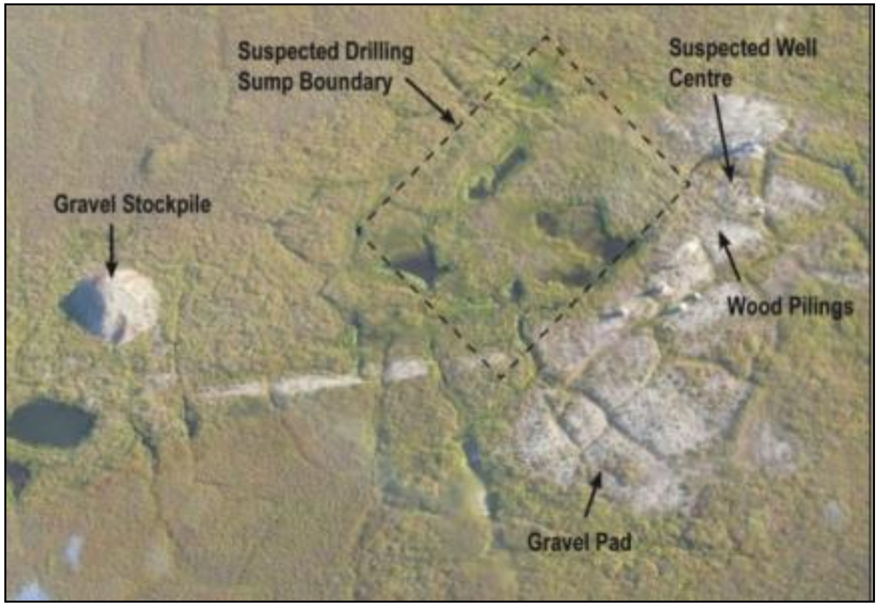
Northern Sites

- 80+ years of oil & gas exploration in Canada's North
- Legacy sites distributed over 1.5 million km^2
- Sites include:
    - Exploratory wellsites: onshore & offshore
    - Sumps: typically 1 drilling & 1 camp sump for each wellsite
    - Others: staging areas, camps, quarries, airstrips



Site Conditions

- Sites decommissioned to historical regulatory standards
- Sumps capped, major structures removed → post-abandonment inspection → comfort letters from regulators
- Visual indicators of post-abandonment sump integrity failure:
  - subsidence, ponding, potential lateral migration



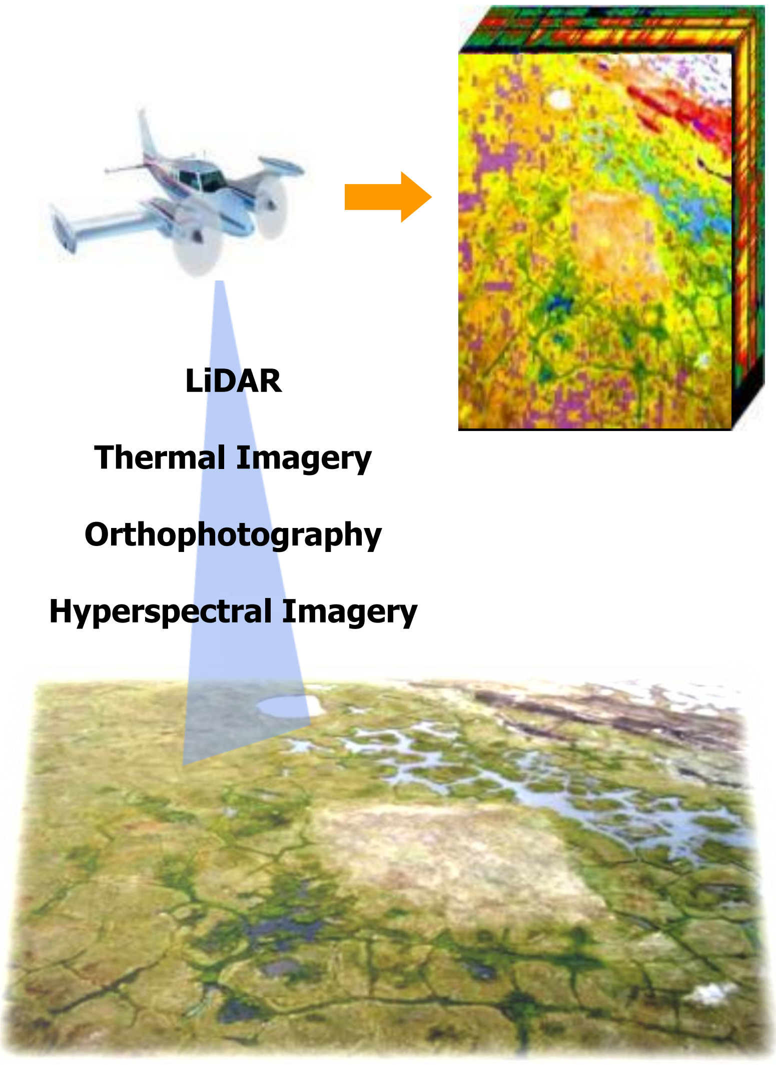
Northern Challenges

- No regulatory closure in North
- Stakeholders expectations not aligned
- Resurgence of Arctic exploration
- Unique characteristics
  - remote site access logistics
  - delicate permafrost
  - re-disturbance issues
  - waste disposal is challenging
  - substantial cost to execute work

Remote Monitoring Rationale

- Site assessment not practical (nor required)
- Stakeholders recommend long-term monitoring
- Need to assess many remote Arctic sites in a safe, timely & cost-effective manner

- Chose a modified Phase I approach: traditional file review & remote sensing data in lieu of individual site visits
- Remote sensing as initial review to categorize sites and establish risk based management



Esso Imperial Oil

WorleyParsons
resources & energy
EcoNomics

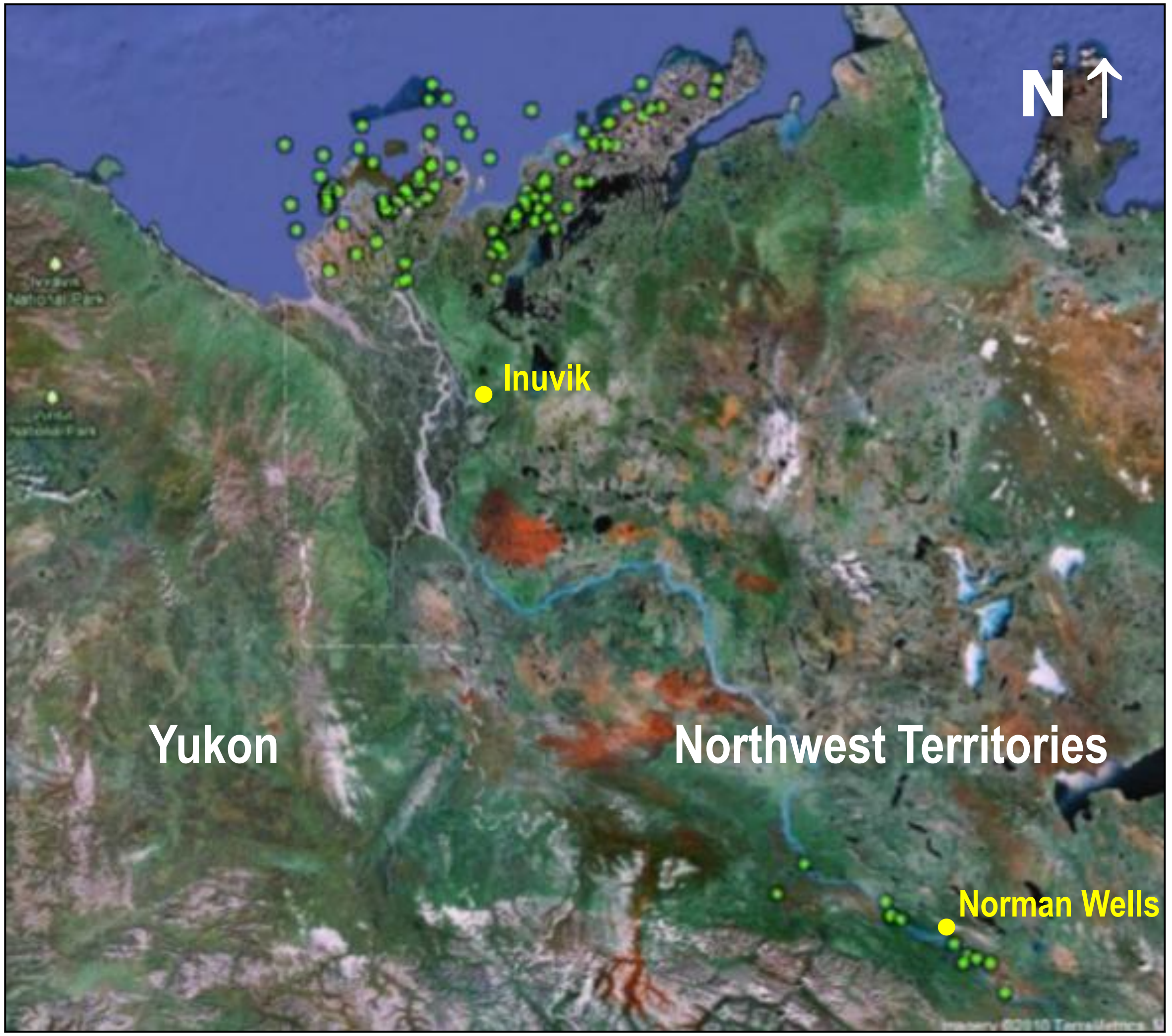
Project Milestones

2008 – Planning

- Site selection
- Consultation
- Permitting

2009 – Field Execution

- Award contract
- Only onshore sites surveyed
- Data acquired for 77 sites
- Successful after 3 flights

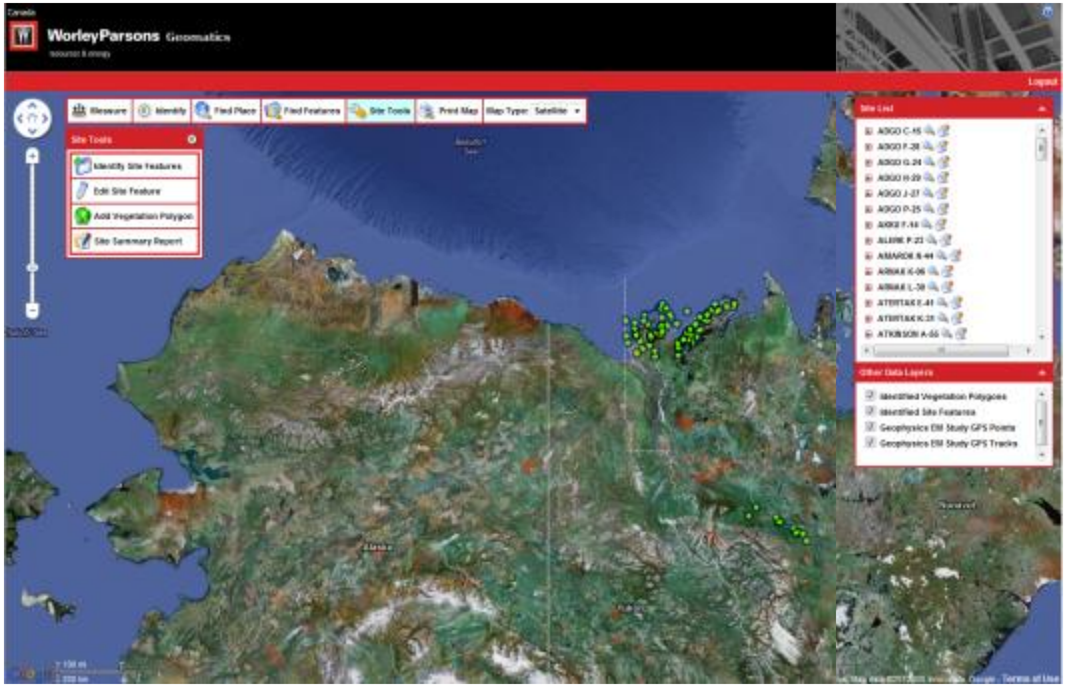


Sites selected during initial project planning

Project Milestones

2010 – Post-Field Processing

- Collaborated with University of Victoria scientists
- Data processing, calibration, rectification
- Developed site attributes against hyperspectral imagery
- Preliminary interpretation of processed data



- Compilation of data into Geomatics web portal:
  - Access point for all historical files, photos & remote sensing data files

Esso Imperial Oil

WorleyParsons resources & energy EcoNomics

Project Milestones

2011 – Imagery Comparison

- Collaborated with University of Calgary
- Advanced data interpretation for identifying Phase I ESA related features
- Compared remote sensing imagery to high resolution satellite imagery
    - multispectral vs. hyperspectral
- Assigned each site a “vulnerability” rating to develop a prioritized site list

Project Objectives

1. **Analyze remote sensing data** for information on environmental variables

2. Use **Source > Pathway > Receptor model** to evaluate potential risk

Source
- Distressed Vegetation
- Sumps
- Debris

→

Pathway
- Flow lines
- Drainage basins

→

Receptor
- Open water bodies or wet areas

3. Create a **lower and higher priority scheme** to categorize sites (i.e. for future monitoring or remediation purposes)

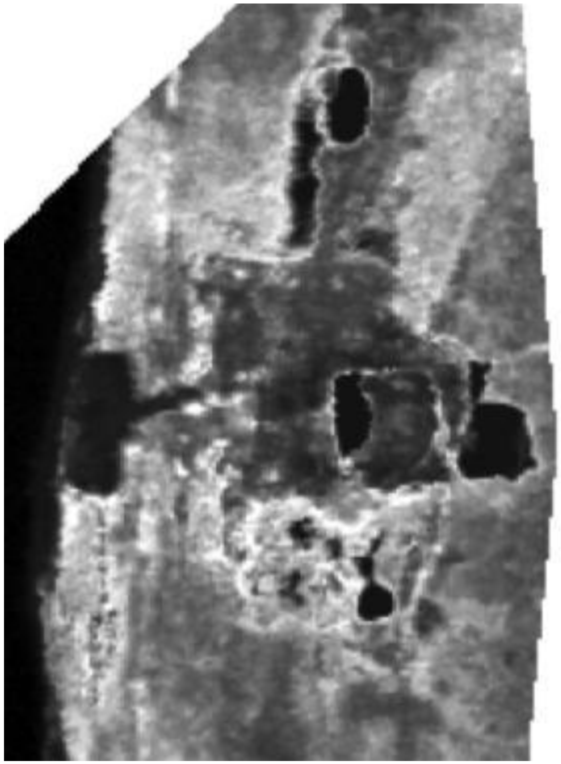
Project Datasets

- Hyperspectral from Aerial (492 bands)
- Multispectral from Satellite (GeoEye 4 band and WorldView 8 band)
- Lidar from Aerial (topography)
- Thermal from Aerial (emissivity)
- Aerial images (high resolution natural color)
- Field data

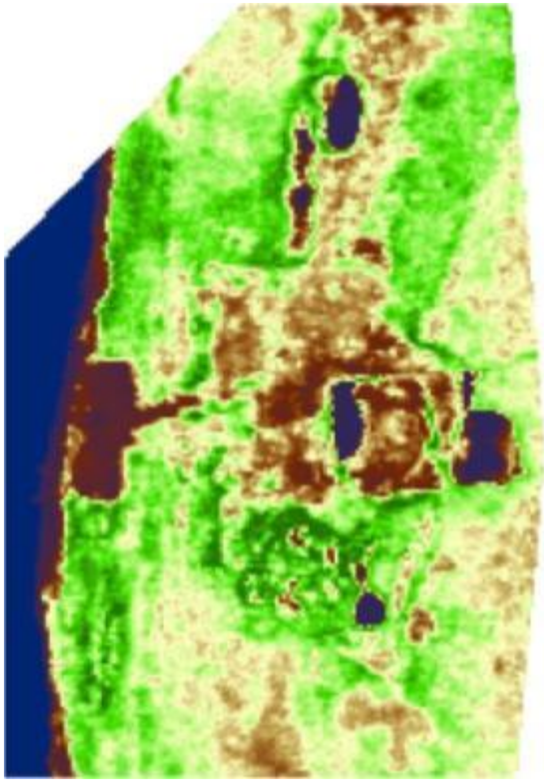
Source #1 – Vegetation Density and Vigor

Wellsite #1

Ortho-image



Vegetation Density

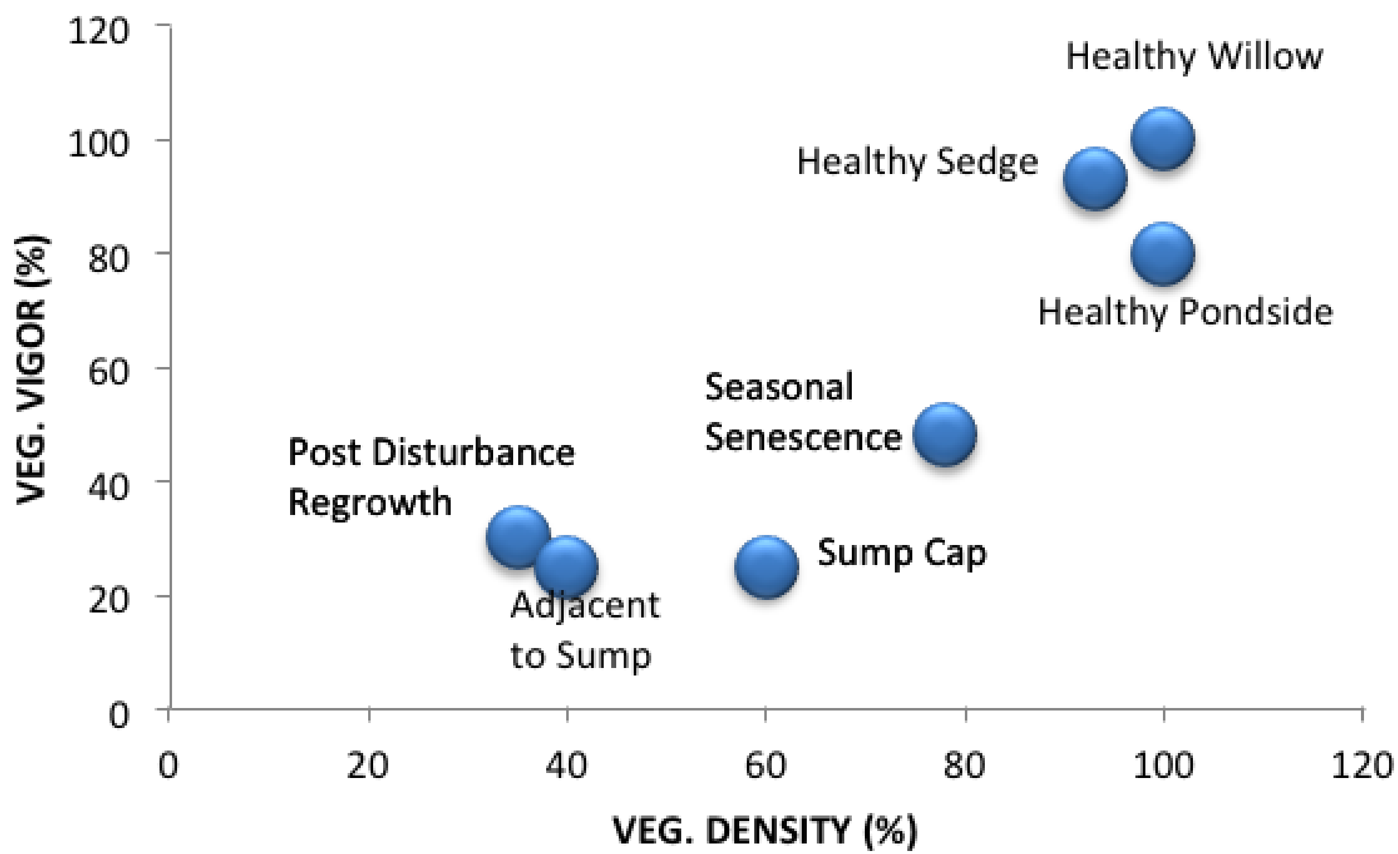


Vegetation Vigour

Esso Imperial Oil

WorleyParsons
resources & energy
EcoNomics

Vegetation Density and Vigor



Vegetation Vigor – Hyperspectral vs. Satellite

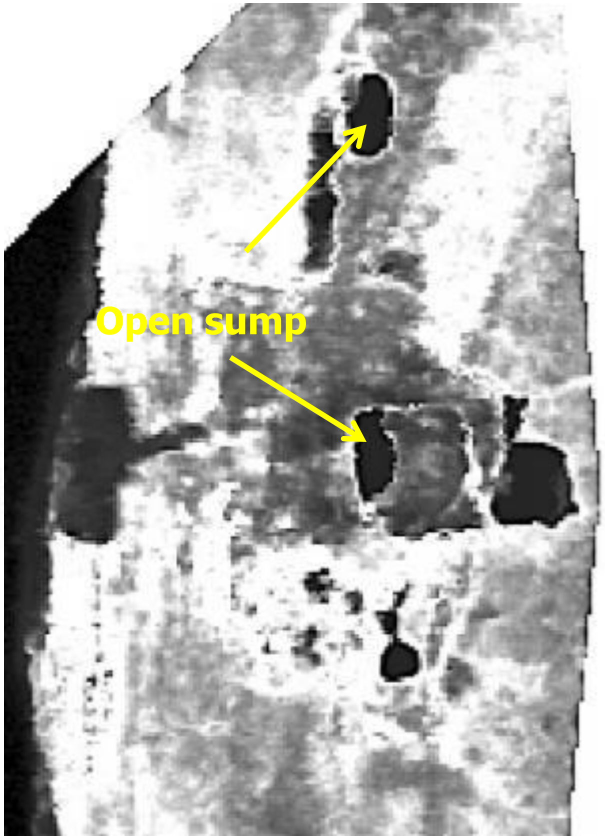
Hyperspectral

WorldView 2

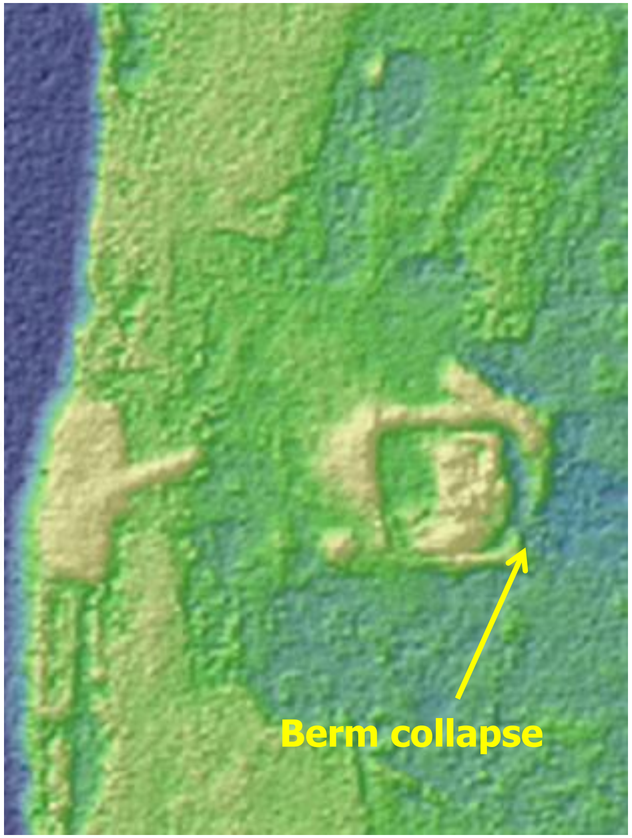
Source #2 – Sumps

- looking for open water and sump collapse

Air photo



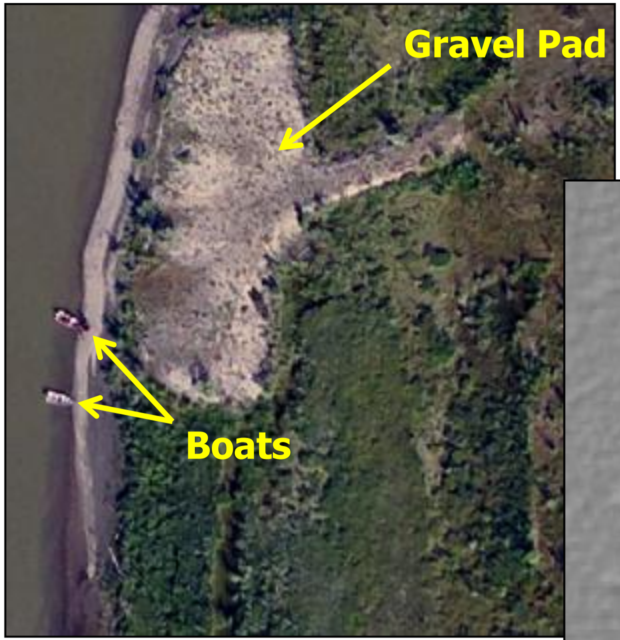
Infrared Image



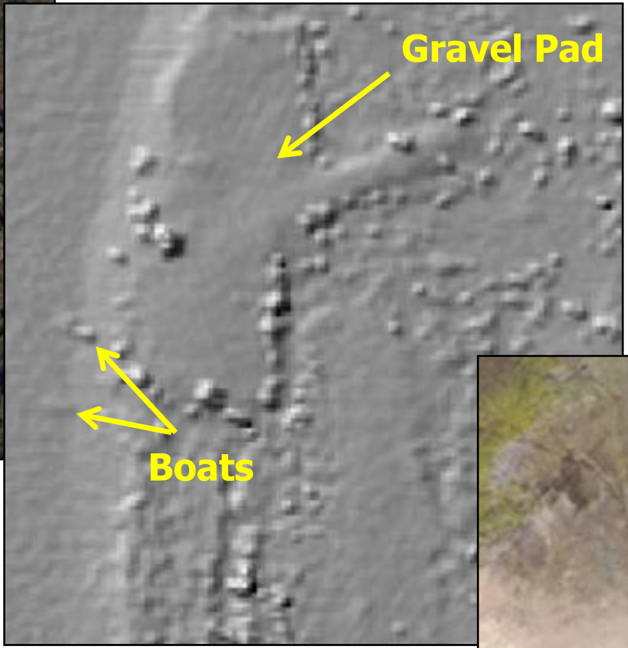
LiDAR Topographical Image

Wellsite #1

Source #3 – Debris



Wellsite #1 – Ortho image



Wellsite #1 – LiDAR

Staging Area #1 – Air photo

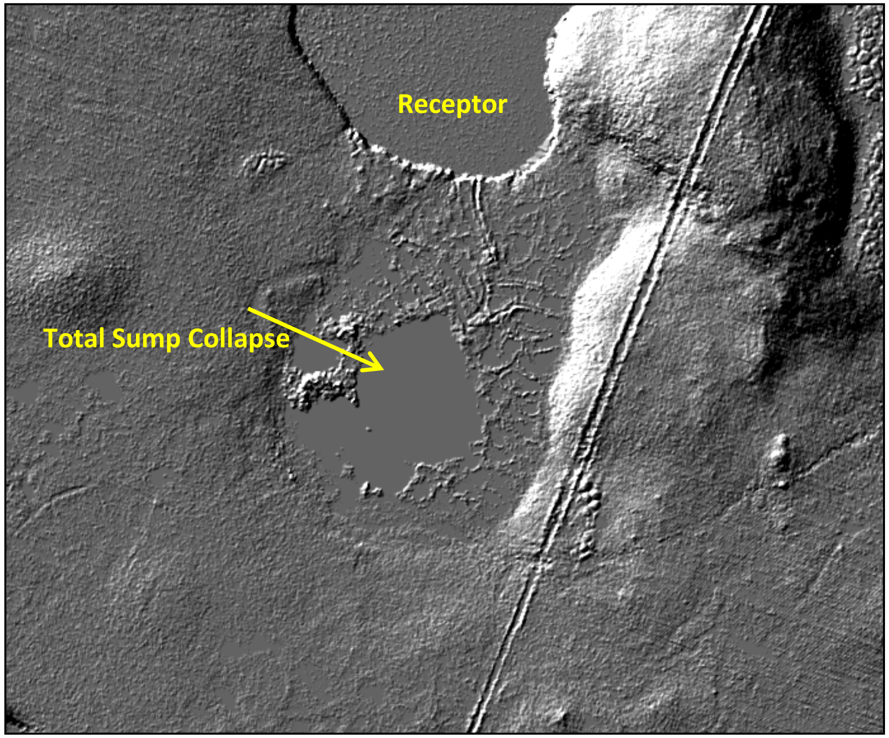
Imperial Oil

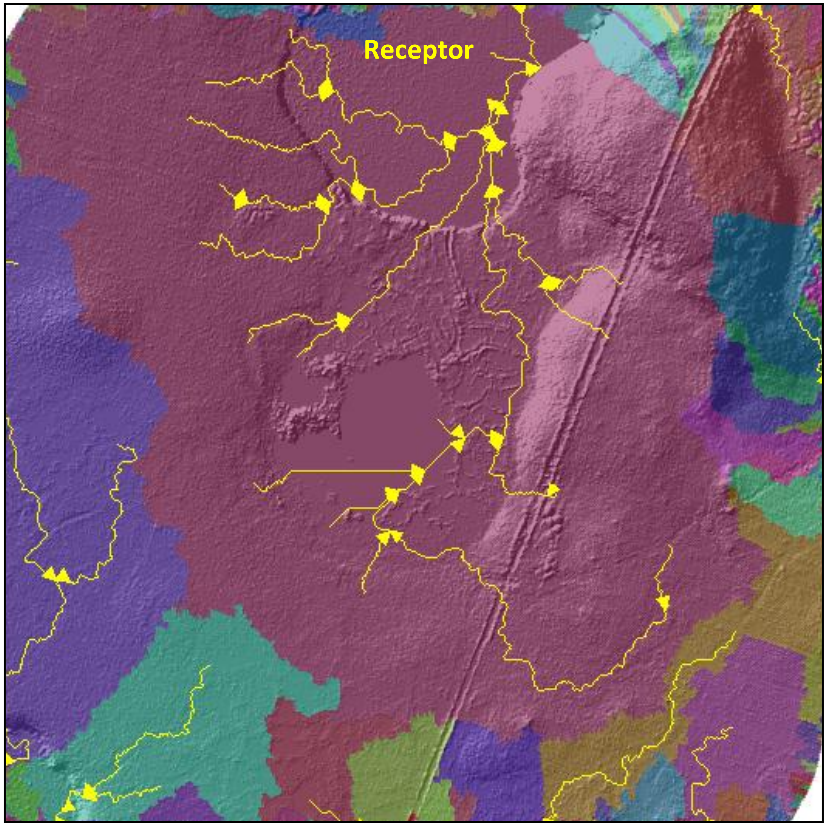
WorleyParsons
resources & energy
EcoNomics

Pathways

- modeling drainage pathways using LiDAR imagery

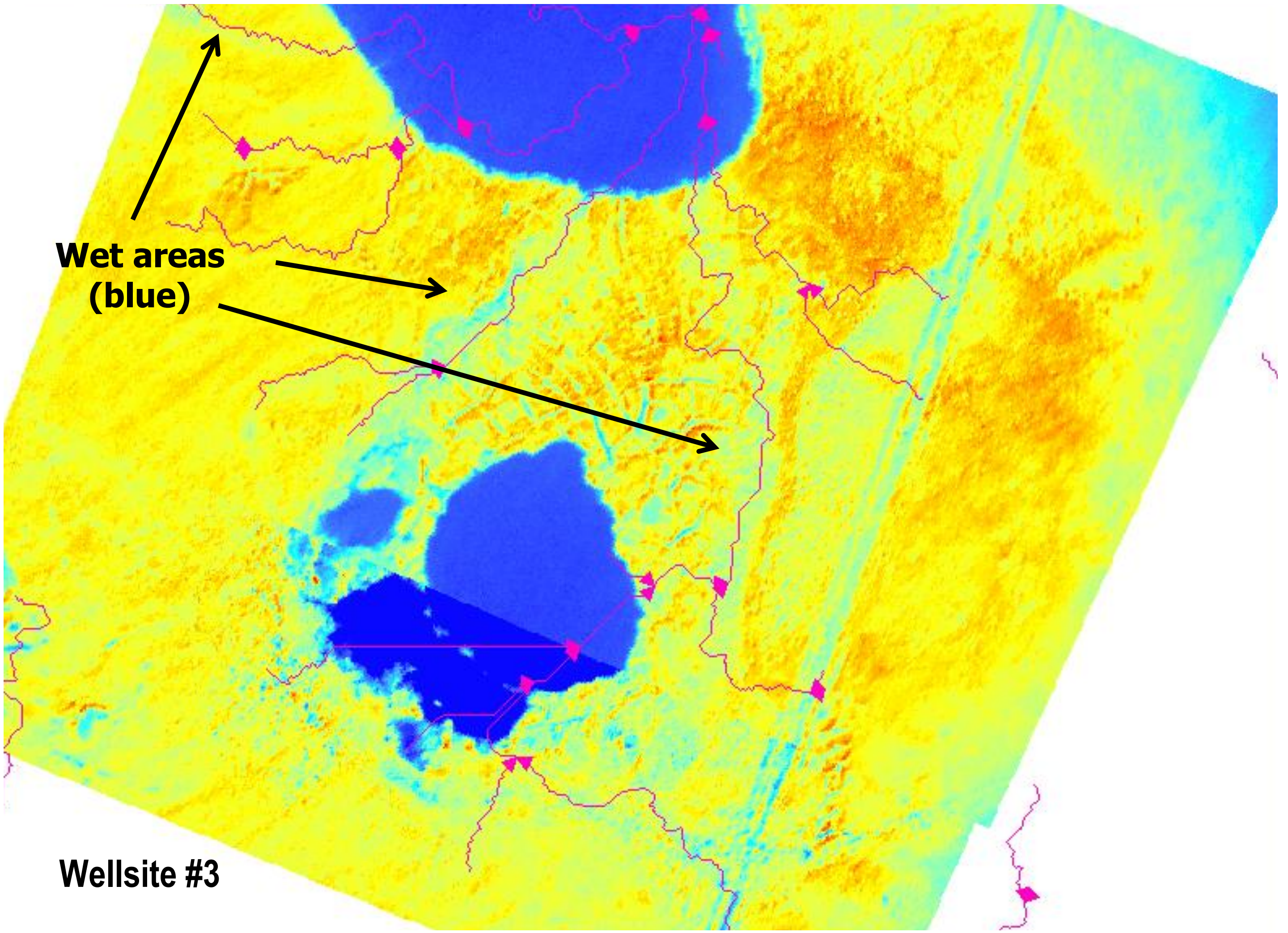
Wellsite #3





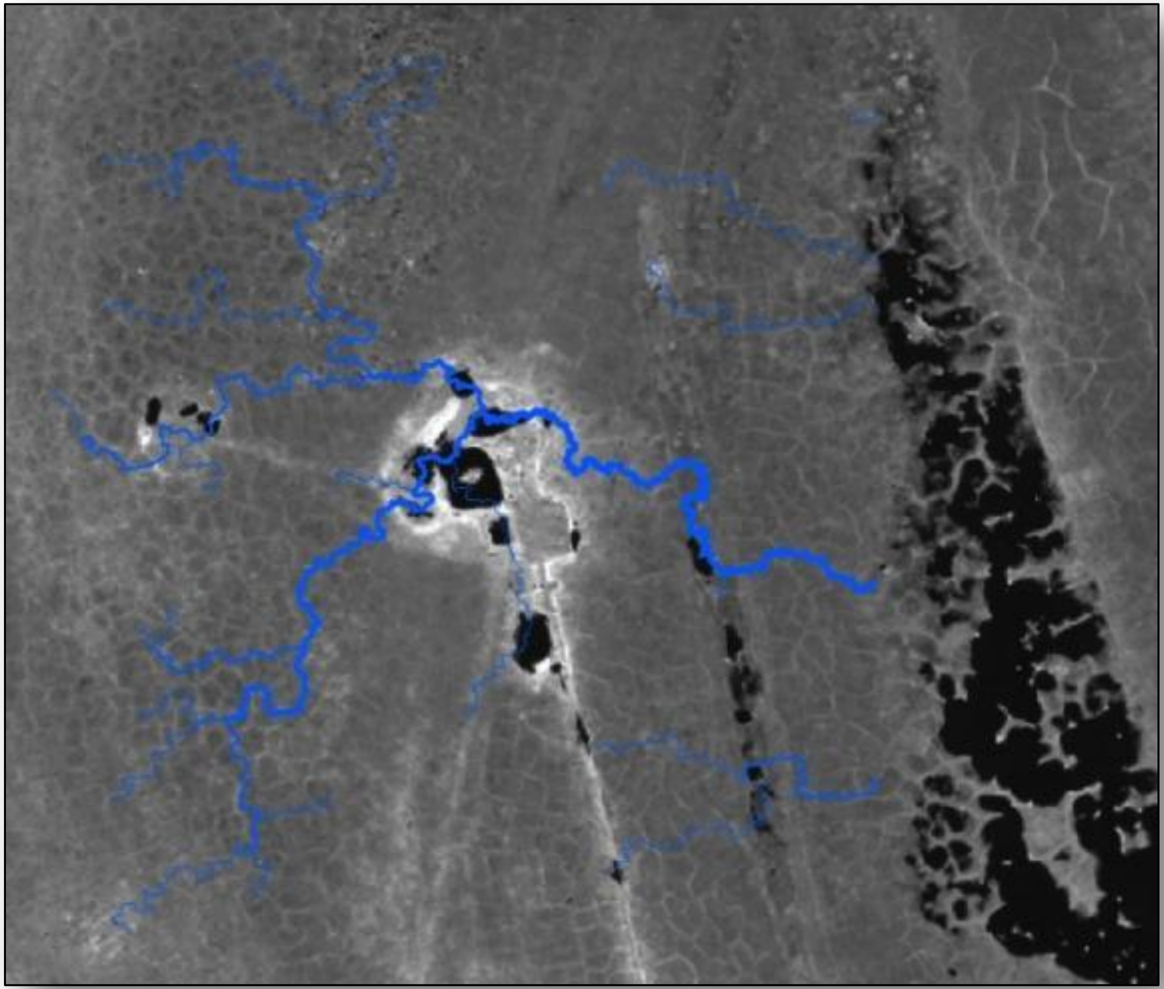
Pathways

- validating potential water pathways using thermal imagery



Receptors – determining open water and wet areas using Infrared

Wellsite #2



Flow lines on infrared multispectral image

Site Prioritization:

Lower

- no debris, physical hazards
- no hazardous materials
- no water ponding
- drilling muds not an issue
- evidence of sump freeze-back
- in a less sensitive area
- vegetation re-growth (higher density, vigour, type)
- flat slopes
- no potential for erosion

Wellsite #5 – Lower Priority

Site Prioritization:

Higher

- potential erosion by water
- sump migration / contact with the environment
- pathway receptor for drilling mud
- physical hazards (ex. pilings, debris, sump heaving)
- located in a sensitive area
- uptake potential for wildlife
- negative community perception

Wellsite #1 – Higher Priority

Conclusions

- Source-Pathway-Receptor model well supported by remote sensing data
  - requires clear data requirements for Phase I and other environmental analyses
- Useful for prioritizing sites that may require future field visits
  - Establishes database of baseline information
  - Potential use as long-term monitoring strategy
  - Advantageous to have an inventory for stakeholder inquiries
- Satellite data proves useful and cost effective vs. hyperspectral
  - Comparable results and more easily acquired
  - Aerial data has detail but expensive and logistically difficult to execute
- Certain site details only acquired by traditional site visit

Special thanks to…

- WorleyParsons project team
  - Alan MacDonald, Ann Glatiotis, Brock Snider
- North of 60 Geomatics
- Terra Remote Sensing Inc.
- University of Victoria – Department of Geography
- University of Calgary – Department of Geography
- Imperial Oil project team
  - Ron Quaife, Holly Stover, Lori Neufeld, Doug Blue, Bruce Parent, Heather Hynes
- Aurora Research Institute

Imperial Oil

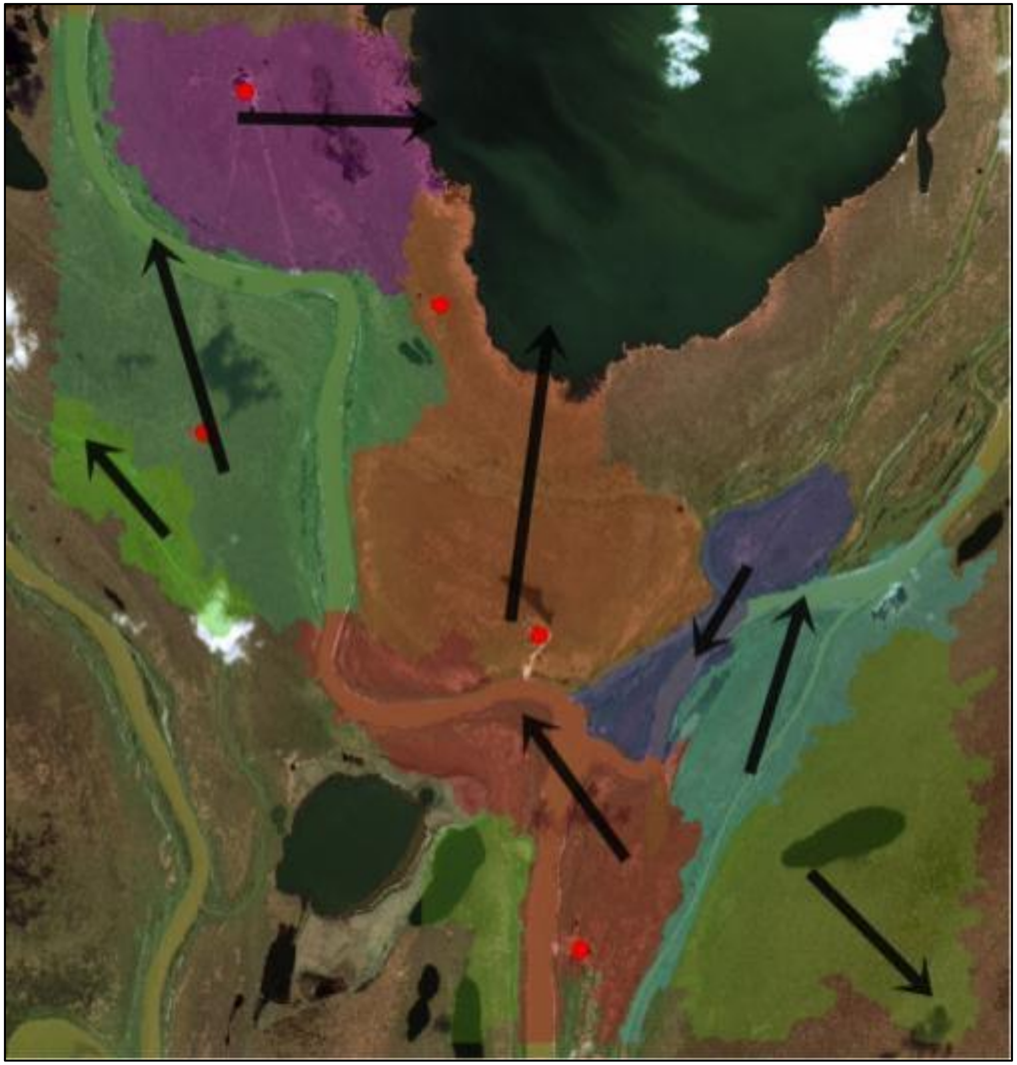
WorleyParsons
resources & energy
EcoNomics™

Backup

Esso Imperial Oil

WorleyParsons
resources & energy
EcoNomics™

Pathways – identifying regional flow basins using satellite topography



flow direction

wellsite location

Satellite derived topographical image of wellsites

Esso Imperial Oil

Source #2 – Sumps

- Assessing sump morphology using LiDAR