# 60 Years of Landscape Change within an Arctic Oilfield, Prudhoe Bay, Alaska

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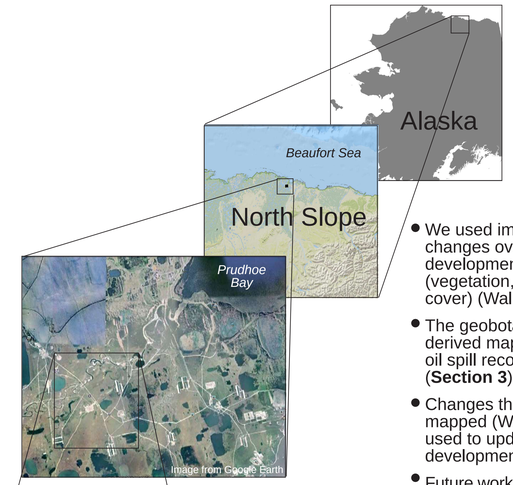
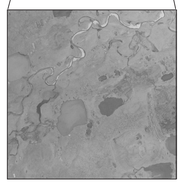
## 1. Introduction

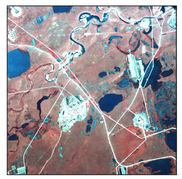



We present an update of the integrated geobotanical and historical disturbance maps (Walker et al. 1986a) for a 2100-hectare portion of Prudhoe Bay Oilfeld, Alaska.33% of the area has been affected by industrial development and an additional 14% of the area shows surface effects of permafrost degradation.

- We used imagery from 1949-2010 to quantify changes over time. Aerial photos from before development were used to map the geobotany (vegetation,soils, landform, surface form, water cover) (Walker et al. 1986b) (**Section 2**).
- The geobotanical mapping was used to create derived maps, such as breeding bird density and oil spill recovery potential (Walker et al. 1980) (**Section 3**).
- Changes through 1983 were photointerpreted and mapped (Walker et al 1987). Recent imagery was used to update the map, including oil field development and other changes (**Sections 4 & 5**).
- Future work will focus on quantifying surface effects of changes in permafrost (**Section 6**).



**1955 black & white**

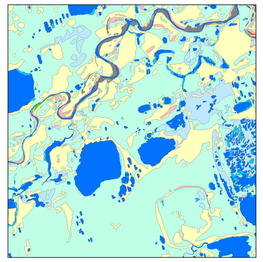


**1982 color-infrared**

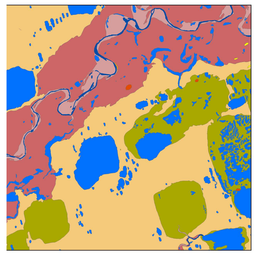
**2010 true color digital**

**Digitized polygon outlines**

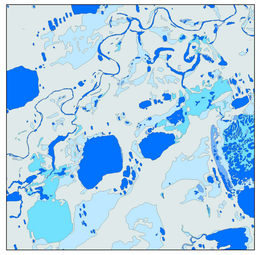
## 2. Geobotanical mapping of conditions in 1968, before industrial development



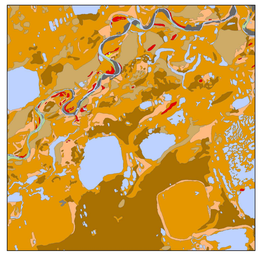
Primary Vegetation
- Water
- Aquatic grass marsh
- Aquatic sedge marsh
- Wet sedge, moss tundra
- Moist nontussock-sedge, dwarf-shrub moss tundra
- Moist low shrubland
- Dry prostrate dwarf-shrub, lichen tundra
- Dry prostrate dwarf-shrub, forb, grass tundra
- Barren



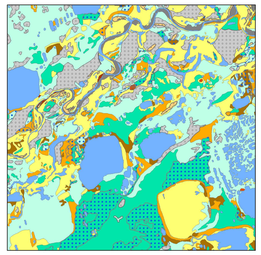
Landform
- Drained thaw-lake basin
- Inter-thaw-lake area
- Pingo
- Stabilized floodplain
- Active floodplain
- Sand dune
- Lake or pond
- River or stream



Water Cover
- 0 - 5 %
- 5 - 30 %
- 30 - 60 %
- 60 - 90 %
- 90 - 100 %

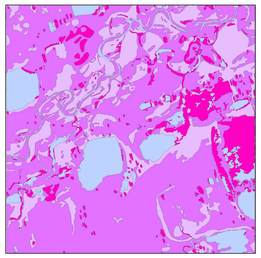


Soil
- Pergelic Cryoborolls
- Pergelic Cryaquolls or Cryosaprists
- Complex of a) Pergelic Cryohemists or Cryofibrists, b) Histic Pergelic Cryaquepts, c) Pergelic Cryaquepts
- Association of a) Pergelic Cryohemists or Cryofibrists or Histic Pergelic Cryaquepts, b) Pergelic Cryosaprists or Cryaquolls
- Association of a) Pergelic Cryaquolls or Cryosaprists, b) Pergelic Cryaquepts (frost boils)
- Pergelic Cryorthents
- Pergelic Cryopsamments
- Pergelic Cryaquepts
- Floodplain Alluvium
- Water



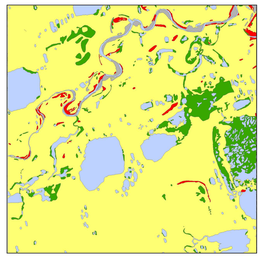
Surface Form
- Low-centered polygons relief > 0.5 m
- Low-centered polygons relief < 0.5 m
- Low-centered polygons with thermokarst pits
- Strangmoor
- Mixed high- and low-centered polygons
- High-centered polygons
- Pingo
- Non-patterned ground
- Reticulate patterned ground
- Frost scars
- Floodplain alluvium
- Water

## 3. Example maps derived from geobotanical mapping



Breeding Bird Density
- 0 to 2 birds/ha
- 2 to 4 birds/ha
- 4 to 6 birds/ha
- Water

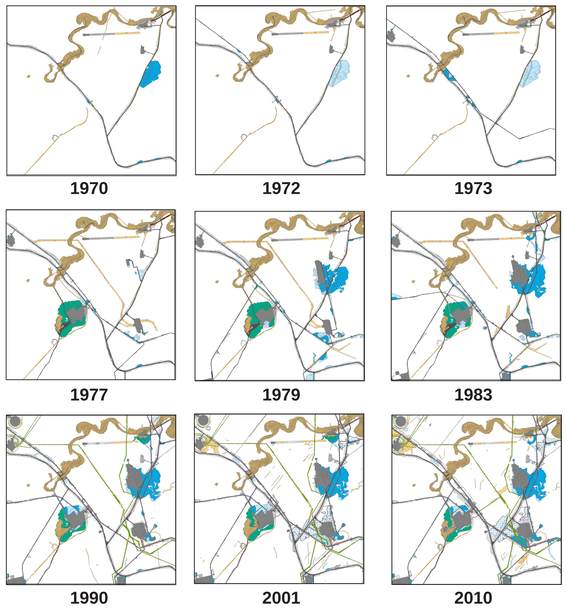
Average densities of breeding birds in various vegetation types were sampled in the third week of June.



Oil Spill Recovery Potential
- Good to excellent
- Moderate
- Poor
- River gravel
- Water

Experiments showed that sedges and willows recovered substantially following spills of moderate intentsity. Dryas intergrifolia, common on dry sites, was more sensitive (Walker et al. 1978).

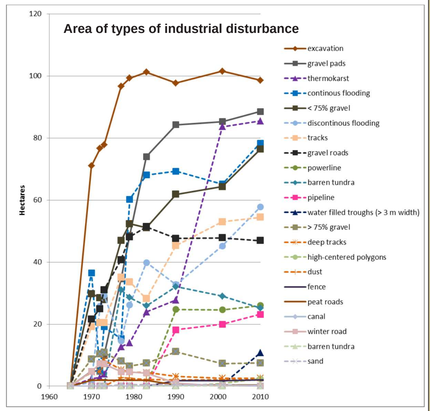
## 4. Oilfield Development 1972 to 2010




- Gravel road
- Peat road
- Gravel pad
- Continuous flooding
- Discontinuous flooding
- Increase thermokarst pits
- Deep tracks
- Shallow tracks
- >75% gravel debris
- < 75% gravel debris
- Excavation
- Drained lake bed
- Pipeline
- Powerline

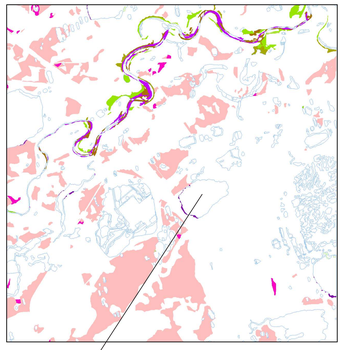
A total of 689 hectares were affected by industrial development by 2010, 33% of the study area.

The area excavated for gravel rose quickly as the oilfield was developed. The gravel was used for roads and pads on the tundra. These facilities often impeded the drainage across the relatively flat landscape, creating flooding. Permafrost degradation adjacent to industrial facilities, resulting from the thawing of ice-rich soils has been particularly evident since 1983. Powerlines and pipelines were only possible to map on the most recent, detailed imagery (1990, 2001, 2010).

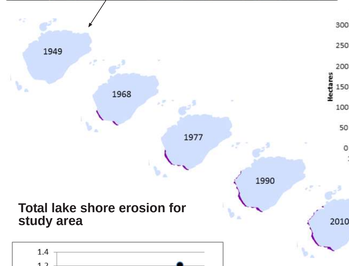



## 5. Other Changes

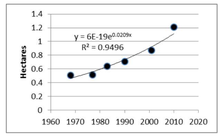
The main non-industrial disturbance mapped by this project was an increase in the standing water in the troughs between polygons due to permafrost degradation and melting of ice wedges and ice-rich frozen soils. This effect was noticeable away from industrial facilities, and affected 287 hectares in 2010, 14% of the study area. Erosion of lake shores (see figure below left), erosion and deposition of river gravel, and revegetation were also noted.



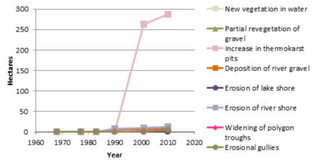
Other Historical Changes
- Increase in thermokarst pits
- Partial revegetation of gravel
- Erosion of river shore
- Erosion of lake shore
- Widening of polygon troughs
- Deposition of river gravel
- Erosional gullies
- New vegetation in water



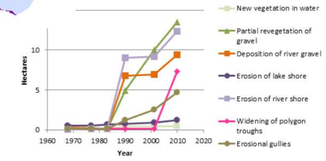

Total lake shore erosion for study area




Area of changes not directly related to oilfield

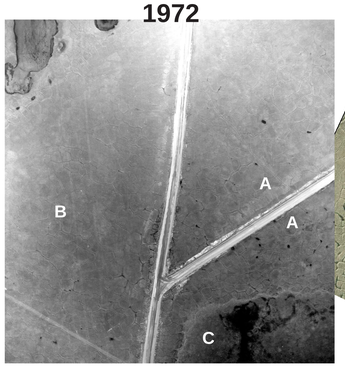



Area of changes not directly related to oilfield, excluding thawing of ice-wedges




## 6. Future research

**1972**




**2010**

Note increase in water along polygons troughs next to roads (A), less common but still noticeable increase in water in troughs away from roads, (B) and lack of change in ice-poor soils of drained thaw lake basin (C)

Plans for future analysis include:
- Develop more quantitative techniques to measure changes in thermokarst features
- Assess the relationship of thermokarst to infrastructure and various geobotanical features
- Apply similar methods to the other two map areas at Prudhoe Bay and several North Slope villages
- Partner with Indigenous Knowledge holders to document local-scale observations and implications of change
- Assess the utility of Landsat and Quickbird imagery to provide broad-area assessments of infrastructure and landscape changes that could be applied to the entire area of development on the North Slope

## Major Findings

- The integrated geobotanical and historical disturbance mapping can be brought into geodatabase format and updated with recent imagery to extend the time-span of the change analysis.
- Most of the oilfield infrastructure was built between 1972 and 1983, but indirect impacts such as flooding and permafrost degradation continued to expand over the next 27 years.
- Lake shore erosion continues to increase, non-linearly.
- There was a large increase in the area showing surface effects of permafrost degradation between 1990 and 2001, possibly the result of reaching some "tipping point".

**References**

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