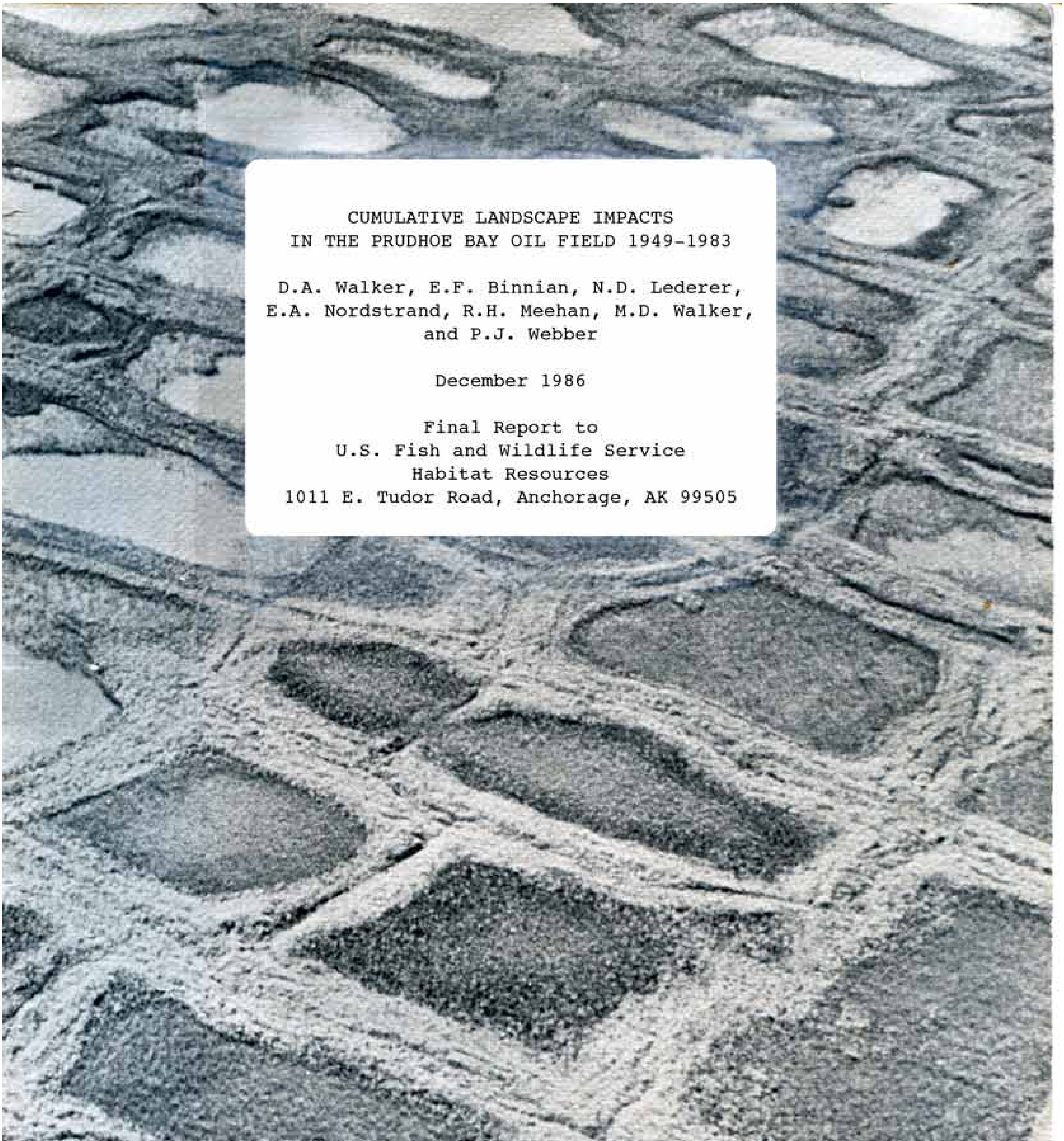

CUMULATIVE LANDSCAPE IMPACTS IN THE PRUDHOE BAY OIL FIELD 1949-1983

D.A. Walker, E.F. Binnian, N.D. Lederer,
E.A. Nordstrand, R.H. Meehan, M.D. Walker,
and P.J. Webber

December 1986

Final Report to
U.S. Fish and Wildlife Service
Habitat Resources
1011 E. Tudor Road, Anchorage, AK 99505

Institute of Arctic and Alpine Research
University of Colorado, Boulder

ARCO Alaska, Inc.
Post Office Box 360
Anchorage, Alaska 99510
Telephone 907 277 5637

December 16, 1981

John Katz, Commissioner
State Department of Natural Resources
Juneau, Alaska

Re: Kuparuk River Unit Application

Dear Commissioner Katz:

Pursuant to AS 38.05 and 11 AAC 83.300-395 ARCO Alaska, Inc., BP Alaska Exploration Inc., Sohio Alaska Petroleum Company, and Union Oil Company of California, (the "Applicants"), submit for your review and approval the proposed Kuparuk River Unit Agreement. The Applicants proposing the Kuparuk River Unit Agreement are all lessees and owners of state oil and gas leases within the State of Alaska. The Applicants believe that the materials submitted with this application address the criteria listed in 11 AAC 83.303 upon which the Commissioner must base his finding that the Kuparuk River Unit Agreement is necessary and advisable to protect the public interest. The following items are submitted as a part of this application:

1. Kuparuk River Unit Agreement, including all Exhibits, executed by the Applicants.

2. The Kuparuk River Unit Operating Agreement executed by the Applicants.

3. Exhibit A is the testimony of ARCO Alaska, Inc., Sohio Alaska Petroleum Company, and BP Alaska Exploration Inc. given at the Alaska Oil and Gas Conservation Commission hearing on Conservation Order No. 73, held on March 25, 1981 which indicates the pertinent geological, geophysical, engineering and well data and interpretations of this data in support of the application. In addition, supplemental information obtained subsequent

to the hearing is provided. Confidential maps and data have been supplied to the Division of Minerals Energy and Management, Department of Natural Resources, by ARCO Alaska, Inc. These maps are incorporated in this application by reference. Representatives of the Applicants are available to discuss the matters submitted in this application. Finally, copies of an application to the Alaska Oil and Gas Conservation Commission to initiate additional recovery pursuant to 20 AAC 25.400 (Increment I Application) is also included.

4. Exhibit B is the Applicants' explanation and justification of the differences between the standard State unit form and the Kuparuk River Unit Agreement form.

5. Exhibit C is a request by the Applicants to the Commissioner to certify the Kuparuk River Reservoir as capable of producing hydrocarbons in commercial quantities.

The Applicants are submitting this application pursuant to Title 38 of Alaska Statutes and regulations (11 AAC 300-395) adopted under that statute requiring agreement of the Working Interest Owners having reasonably effective control of Unit Operations and approval of the Commissioner to form a voluntary unit. Pursuant to Title 31 of the Alaska Statutes the Applicants are concurrently furnishing a copy of the Kuparuk River Unit Agreement and Kuparuk River Unit Operating Agreement to the Alaska Oil and Gas Conservation Commission, requesting a finding that the Kuparuk River Unit Plan of Development is in the interest of conservation and will not result in waste. The proposed Kuparuk River Unit Area includes approximately 237,776 acres. It is located on the North Slope of Alaska and adjacent to the

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Habitat Resources,
1011 E. Tudor Road, Anchorage AK 99505
Funded by U.S. Environmental Protection Agency and Cold Climate
Environmental Research Program under U.S. Department of Energy
Interagency Agreement No.
DE-A106-84RL10584

[1] Plant Ecology Laboratory, Institute of Arctic and Alpine
Research (INSTAAR), University of Colorado, Boulder, Colorado
80309

[2] North Slope Borough GIS, 508 W. 2nd Street, Room 310,
Anchorage, Alaska 99501

[3] Plant Ecology Laboratory, Institute of Arctic and Alpine
Research (INSTAAR) and Department of Environmental, Population
and Organismic Biology, University of Colorado, Boulder, Colorado
80309

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EXECUTIVE SUMMARY

Cumulative impacts due to oil-field development threaten the integrity of ecosystems on the North Slope of Alaska. New techniques are needed to monitor the growth that is occurring and to plan for future developments with minimum disturbance to the natural wildlife resources. This report is a history of the growth of the Prudhoe Bay Oil Field. It is a contribution toward the development of a comprehensive method of assessing cumulative impacts in the region.

The objectives are to answer several specific questions regarding the history of development: (1) Prior to development, what was the spatial arrangement and relative cover of natural geobotanical features (vegetation, percent water cover, landforms, surface forms, soils, and landscape units)? (2) What were the rates of growth of the major disturbance types (roads, gravel pads, flooding)? (3) Were certain geobotanical features selected for construction sites or other disturbances? (4) Were the patterns of anthropogenic disturbances related to broad landscape units? (5) How do the rates of anthropogenic disturbances compare to natural changes? (6) Is there any evidence of synergistic impacts?

The history of the region is examined using maps at two scales: (1) 1:24,000 to determine the historical changes of roads, gravel pads, and flooding for the entire field, and (2) 1:6000 to determine the effects of anthropogenic changes on the natural geobotany. Three 22km^2, heavily impacted areas are analyzed in the second part of this study. At this larger scale, we examined the progression of roads, pads, flooding, thermokarst, road dust, construction debris, and vehicle trails.

A new mapping method was needed to portray periodic historical changes to a landscape consisting of a complicated network of roads, pipelines, facilities, and other anthropogenic disturbances overlaid on two major landscape units, and an intricate matrix of periglacial geobotanical features that are subject to relatively rapid natural disturbance cycles. The method we developed utilizes the latest geobotanical knowledge of the region and the ARC/INFO geographic information system (GIS) software, which resides with the North Slope Borough's Planning Department. The project was feasible because of a fortuitous combination of factors: (1) an aerial photographic record that portrays the complete history of development from the wilderness state to the present-day industrial complex, (2) the existing excellent geobotanical data base for the region, and (3) the commitment by the local government (the North Slope Borough) to build a superior GIS data base.

The basic information is contained on a computer file called an Integrated Geobotanical and Historical Disturbance Map (IGHDM), which consists of three basic categories of information,

natural geobotanical data, natural disturbance data, and anthropogenic disturbance data. This report contains 67 maps (6 in color) that were derived from the IGHDM data files for the three maps. The maps portray the geobotany in 1949 and the status of disturbances in 1968, 1970, 1973, 1977, 1979, and 1983. Area summaries are included for all variables and for several combinations of disturbance and geobotanical data.

Analysis of the maps and area summaries resulted in the following conclusions:

1. The oil field has grown at a constant pace during the 15 years of this study. By 1983, the oil field occupied about 500 km^2 with over 350 km of roads, 21 km^2 of tundra covered by gravel, and another 14 km^2 flooded. The road network of the nearby Kuparuk Oil Field has grown at nearly the same pace during the first 6 years of its development.

2. Total indirect (unplanned) impacts averaged for the three maps was about equal to the area covered by direct impacts (roads, pads, excavations). However, the ratio of direct to indirect impacts varied considerably depending on the terrain and impact types. In the very wet tundra of Map 22, the indirect impacts (primarily flooding) were more than double the direct impacts. On Map 34, where there was a large excavated area, the indirect impacts were less than half the direct impacts.

3. There was a selection for relatively well-drained microsites for road and pad construction in the wetter maps. In wet areas, the moist and dry sites are particularly important components of intricate wetland complexes. If such wet areas are developed, the well drained microsites are likely to be built on because of their value as construction sites. Building in the wet microsites of such areas creates other problems caused by anthropogenic flooding.

4. The distribution of geobotanical types and anthropogenic disturbance types were distinctly different in the two primary landscape units, 'flat thaw-lake plains' and 'floodplains and terraces'. Gravel pads and flooding were the most abundant impact on the 'flat thaw-lake plains' and excavations were most common in the floodplains. There was a lack of anthropogenic thermokarst in the floodplain landscape unit although this was a common indirect impact on the 'flat thaw-lake plains'.

5. The areas affected by natural disturbances were about two orders of magnitude less than those affected by anthropogenic disturbances. Our erosion data from Map 22 indicate a landscape turnover period for this area of about 11,000 years due to the thaw-lake cycle assuming the present constant rate of erosion for the entire period.

6. Anthropogenic thermokarst was increasing at a more rapid rate in 1983 than during the early years of the study. The area covered by anthropogenic thermokarst in 1983 was about equal to the area covered by roads. Thermokarst is an example of a synergistic impact that is increasing due to a combination of the effects of road dust, impoundments, and other sources of heat within the oil field. This conclusion is based on close

examination of numerous small mapped areas along the Spine Road. There is generally a delay between the construction of a road or pad and the onset of widespread thermokarst around the feature. The thermal effects are most noticeable where there is a combination of disturbance factors such as large amounts of road dust, flooding, or heat from flaring operations. At present, it is unlikely that the existence of the oil field would lead to widespread thermal disintegration of the landscape; however, we cannot rule out the possibility that heat generated by the field operations combined with climatic warming could lead to a regional thawing of ground ice. Thermokarst is an example of a cumulative effect that should be closely watched.

7. In hindsight, we can now see that there were basic geobotanical characteristics of the three sites that foretold the types of impacts that were likely to occur during development. For example, development in Map 22 occurred in one of the wettest areas of the region with numerous drained thaw-lake basins and a predominance of aquatic and wet tundra types. This area experienced the most severe anthropogenic flooding. Also, anthropogenic thermokarst was most widespread in areas that exhibited natural thermokarst features in 1949.

8. Had the IGHDM techniques been available and used during development, they would have provided a thorough ecological reconnaissance and mapping of the region. Sites of exceptional ecological quality and areas of high wildlife value such as well-developed polygon complexes, pingos and riparian habitat could have been treated as special no-impact zones, and tragedies such as the mining in the Putuligayuk River floodplain and the leveling of a pingo near the Arco Base Camp could have been prevented. Now that the mapping system is available, it should be used to prevent the recurrence of such events.

The study resulted in several major accomplishments:

1. <u>Geobotanical mapping legends</u>. These are applicable over broad regions of the Arctic Coastal Plain. The vegetation legends are part of a hierarchical scheme that is also appropriate for maps using Landsat data and for detailed community-level studies.

2. <u>A practical approach to long term monitoring of oil field development</u>. The approach utilizes available topographic maps and aerial photographs. The method could also be an important tool for minimizing impacts for new developments. The method is now sufficiently developed that a team of trained botanists and photointerpreters could map even a very large development area within a few months given good aerial photographs, proper training in the methods, and time to obtain the necessary ground truth.

3. <u>A detailed historical analysis of the growth of the Prudhoe Bay Oil Field</u>. The results should be useful for extrapolating the effects of future oil fields and other developments that are planned in northern Alaska. The three IGHDM areas are sufficient for future monitoring of the Prudhoe Bay Oil Field.

4. <u>A long-term ecological experiment to study anthropogenic</u>

landscape change in an arctic region. This is an important opportunity to develop and apply new theories and concepts of landscape ecology to the arctic.

Specific recommendations regarding planning and construction practices include:

1. The IGHDM techniques are an appropriate planning tool that should be used in new areas of development. The techniques should be used to identify areas that require special planning or that should be avoided. Areas of high biotic diversity such as complex wetlands, narrow floodplains, coastal areas, and pingos demand special attention, and development in these areas should be avoided if at all possible.
2. If development in complex wetlands is unavoidable, then special attention should be paid to avoid flooding large drained thaw-lake basins. Placing too many culverts would be preferable to destroying valuable waterfowl habitat.
3. Mining in floodplains may be appropriate in areas that have extensive unvegetated gravel resources that are not bounded by valuable wildlife habitat. If properly planned these areas are likely to be rehabilitated naturally by the large rivers. There are, however, very few rivers where such mining could be conducted without extensive damage to adjacent riparian habitat. Mining in narrow floodplains is likely to completely destroy the riparian ecosystem.
4. Special attention needs to be paid to the spread of thermokarst along roads and near impoundments. The control of dust by desiccants may be appropriate on roads with high volumes of traffic. Controls of flooding would also help to control the spread of thermokarst in many areas.

Recommendations for future studies of this nature are:

1. Continue the monitoring the Prudhoe Bay Oil Field through both the 1:24,000-scale maps and the IGHDM techniques at 1:6000 scale. Three year monitoring intervals are appropriate.
2. New developments in other landscape units should be monitored using the same methods. Sites in the 'gently rolling thaw-lake plains' of the Kuparuk Oil Field and new developments in the Colville River delta are high-priority areas for similar projects.
3. 1986 is the planned year for the completion of the Prudhoe Bay Oil Field and marks an appropriate time to produce an atlas that traces the history of the development of the first large industrial complex in the North American Arctic. Such an atlas should include the maps and analyses of this report plus the updated information for 1986. These data should be linked to the history of exploration, political decisions, past construction practices and environmental regulations that shaped the present-day landscape.

CUMULATIVE LANDSCAPE IMPACTS IN THE PRUDHOE BAY OIL FIELD 1949-1983

INTRODUCTION

The rapid expansion of the Prudhoe Bay Oil Field and the recent discovery of several new oil fields along the coast of northern Alaska has left many of us with the discomforting vision of the destruction of the Arctic Coastal Plain by "insignificant increments" (Lopez 1986). A vast complex of roads, pipelines, and service centers could be devastating for several wildlife species, unless enlightened planning procedures are used to help shape the course of oil-field development. There is an urgency to develop cumulative impact assessment methods for the large impacts that are sure to affect this region in the next few years.

Unfortunately, the concept of cumulative impacts is still sufficiently new that we do not presently have a national comprehensive method or policy regarding cumulative impacts. A report of a recent U.S. Fish and Wildlife Service (USFWS) project entitled "Methods for Determining Cumulative Effects of Coal Activities on Fish and Wildlife Resources" begins by noting:

> Despite all the writing and the myriad of environmental impact statements (EIS's), a key problem remains, namely, the frustrating task of specifying some generally agreed upon methodologies for carrying out a more comprehensive assessment mandate and for accounting for the far-reaching, aggregative effects of public projects. This task becomes particularly difficult in view of the lack of existing appropriate literature and of the paucity of concrete methods for carrying out an effective cumulative impact assessment. (Cline et al. 1983).

Even though we lack specific methods, we can begin approaching the problem in northern Alaska through the analysis of past actions. One of the conclusions of the above project was:

> A good strategy at this point is to concentrate on case studies in order to illustrate current challenges, on-going practices and how pragmatic questions are answered in the field. In the context of realistic problems, it may be easier--inductively--to arrive at agreed upon procedures. Operational models need to be developed through interdisciplinary and interagency planning and funding. The cumulative issue is too large for one agency to efficiently and effectively manage. (Horak et al. 1983)

The authors of the above report recommend that historical case studies would be useful for developing cumulative impact methods, particularly if the studies are combined with analysis of methods of development, success of those methods, and what other methods could have been used (Cline et al. 1983).

This document is intended as the basis for such an historical analysis. It is a preliminary atlas summarizing the growth of the Prudhoe Bay Oil Field from 1968 to 1983. This project was stimulated by collaboration between the Environmental Protection Agency (EPA) and the USFWS to address their responsibility under law (Section 404, Clean Water Act) to assess the cumulative impacts of planned and ongoing developments in wetlands. Impacts in wetlands are a major consideration in the permitting process on the North Slope. The Prudhoe Bay development offers a unique opportunity because of the historical documentation to examine some of the mechanisms of cumulative impacts and to contribute to better understanding of the problem.

We use the words "cumulative <u>landscape</u> impacts" in the title because the scope of this work is limited to impacts that are visible on aerial photographs. Cumulative impacts in the broad sense are "the total interactive impacts over time, i.e., the sum incremental, synergistic effects on fish and wildlife <u>populations and habitats</u> caused by all current and future actions over time and space" (Horak et al. 1983, italics are ours). We feel that it is virtually impossible to determine the full suite of cumulative impacts that have occurred in the region because of the lack of baseline wildlife data, so we have limited the scope of this research to the visible landscape.

OBJECTIVES

The overall objective of this project was to examine the aerial-photograph record for the Prudhoe Bay Oil Field in order to answer the following questions: What kinds of vegetation and surface forms (and by implication wildlife habitat) existed before development? What were the rates of growth for roads, pads, impoundments, and other disturbance types? Was there selection for certain types of geobotanical features for construction sites? Are the patterns and types of anthropogenic disturbances related to major landscape units? How do the rates of anthropogenic disturbance change compare to natural changes? And is there any evidence for synergistic impacts? Synergistic impacts are those that have interactive reinforcement over time and distunguish cumulative impacts from simple aggregation of impacts (Horak et al. 1983).

The specific goals were: (1) examine the historical progression of road and pad construction within the entire oil field; (2) develop a mapping method to portray the complex interaction of natural geobotanical features, natural disturbances, and anthropogenic disturbances through time; and (3) examine the details of natural and anthropogenic changes within three areas of intensive oil-field development.

A previous report (Walker et al. 1984) described the basic methods we used for making 1:6000-scale Integrated Geobotanical and Historical Disturbance Maps (IGHDMs) and summarized the information from our first IGHDM. We also mapped the major disturbances for the entire oil field at 1:24,000 scale. That work was summarized in an article published in Environmental Conservation (Walker et al. 1986), (Appendix A), and at an international conference (Webber and Walker 1986). At the conclusion of that work, we felt that we had insufficient data to draw conclusions regarding anthropogenic disturbances within the oil field as a whole, and we recommended making two more IGHDMs. This report is a follow-up on that recommendation and contains all the map data and analysis from the 1:24,000-scale map and the three IGHDMs. We now have sufficient information for a proper analysis of cumulative landscape impacts within the oil field. With respect to our purposes, little would be gained by mapping other areas within the Prudhoe Bay Oil Field, but such mapping would definitely be beneficial in new oil fields, particularly in landscape units not represented at Prudhoe Bay.

METHODS

Location of Study Areas

Fig. 1 shows the Prudhoe Bay Oil Field and its location within Alaska. The three squares (Maps 22, 32, and 34) are the areas of intensive analysis using the IGHDM method. These maps are part of a series of 47 topographic maps of the Prudhoe Bay Unit [1:6000 scale, 1.52-m (5 ft) contour interval, Air Photo Tech 1979]. The IGHDM locations were chosen to represent areas of intensive development within the two primary landscape units of the oil field, 'flat thaw-lake plains' and 'floodplains and terraces' (Walker et al. 1985). Place names of oil field facilities are in Fig. 2.

Map 22 contains the Sohio Base Operations Center (BOC), Gathering Center 1 (GC-1), Well Pads A, C, and D, Frontier Camp, Construction Camps 1 and 3 (CC-1 and 3), and a large storage pad. This is one of the wettest portions of the oil field; it is located entirely within a 'flat thaw-lake-plain' landscape unit and contains some of the most extensive areas of roadside flooding.

Map 32 contains Pump Station 1 (PS-1, the northern terminus of the trans-Alaska pipeline), Flow Station 3 (FS-1), Drill Sites 7 and 14, the BP discovery well, and a portion of the North Slope Borough Land Fill. It is mostly within a 'flat thaw-lake plain' landscape unit, but also contains a large section of 'floodplains and terraces' of the Putuligayuk River. Two unique disturbances on this map are the large artificially drained lake where Pump Station 1 is now located and the gravel mine on the narrow floodplain of the Putuligayuk River northeast of the Spine Road.

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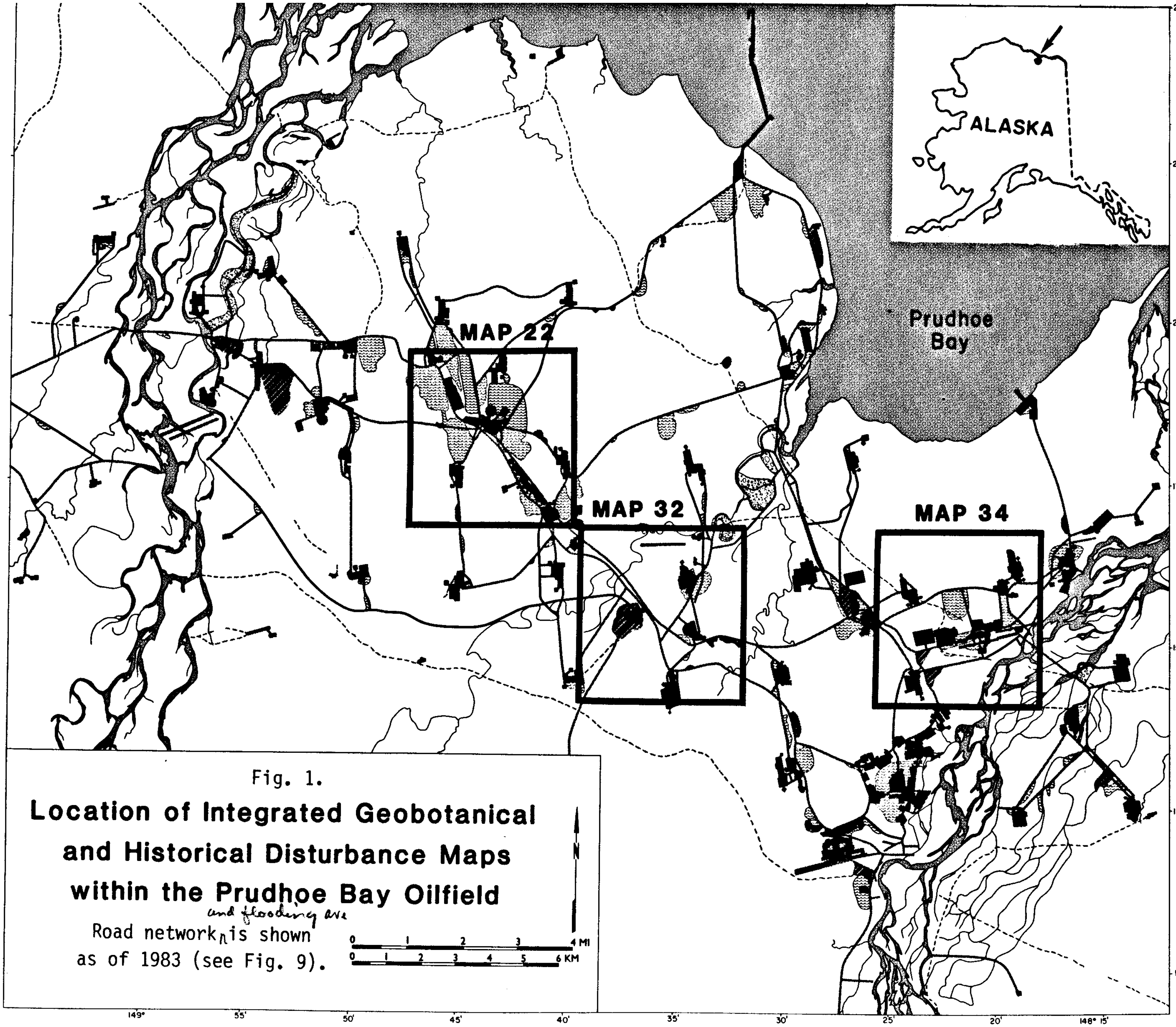

Fig. 1.

Location of Integrated Geobotanical and Historical Disturbance Maps within the Prudhoe Bay Oilfield

Road network and flooding are is shown as of 1983 (see Fig. 9).

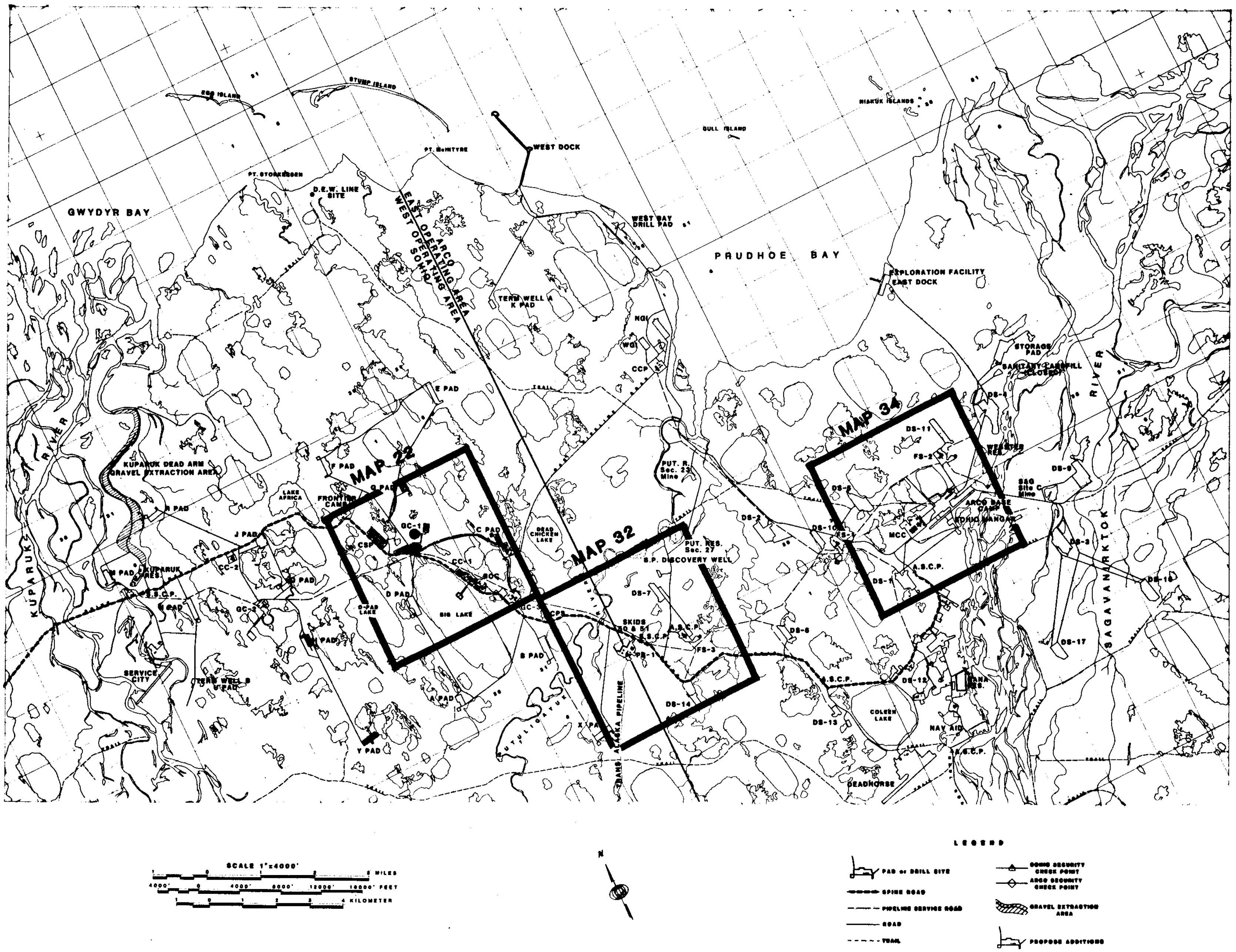

Fig. 2. Facilities map of the Prudhoe Bay Oil Field. (Modified from Sohio Alaska Petroleum Co., 1979.)

Map 34 contains the Arco base camp and airfield, Flow Station 2 (FS-2), Drill Sites 1, 5, and 11, Arco Prime Camp (MCC), and a storage pad. It is also dominated by 'flat thaw-lake plains' with a large area of Sagavanirktok River floodplain. Gravel mining is a major disturbance on the floodplain of the Sagavanirktok River.

1:24,000-scale Map

The methods for making the 1:24,000-scale map of cumulative development of the Prudhoe Bay Oil Field are described in Walker et al. (1986) (Appendix A). The first version of the map showed all roads, pads and flooded areas with the date that a given feature first appeared on aerial photographs. That information has now been separated into a series of maps that portray the development of the oil field for the years 1968, 1970, 1973, 1977, 1980, and 1983.

The areas covered by pads, excavations, and flooding were measured using an electronic digital planimeter. Road lengths were also planimetered and placed in one of four categories: Spine Road (the main highway through the oil field), other primary roads, secondary access roads, and pipeline construction roads. The area covered by roads was calculated by using the engineering specifications of 15.2-m basal width for the Spine Road and other primary roads, and 13.4-m width for secondary roads and pipeline construction roads.

The data for the road lengths by year in the Prudhoe Bay Oil Field were compared to similar data from the Kuparuk Oil Field. The data from the Kuparuk field were obtained from aerial photographs and expert knowledge within USFWS regarding the dates of construction for various segments of the road system.

1:6000-scale IGHDMs

An IGHDM contains three basic types of data, geobotanical, historical natural disturbances, and historical anthropogenic disturbances. The steps involved in making the IGHDM for Map 22 are summarized in Fig. 3 and described in Appendix A. For Maps 32 and 34 there were four modifications to the methods:

1. The geobotanical legends have been slightly modified to account for new information encountered since 1984. The new legends are in Table 1. The numbering scheme for the vegetation has been changed to permit easier expansion of the legends while maintaining the hierarchical construction of the classification. The computer file for Map 22 was updated with the new classification to maintain consistency for all three maps.

2. Maps 32 and 34 were mapped according to landscape units (Walker et al. 1985). All of Map 22 is within a single unit (flat thaw-lake plains). Area statistics were generated for the landscape units as well as the entire maps.

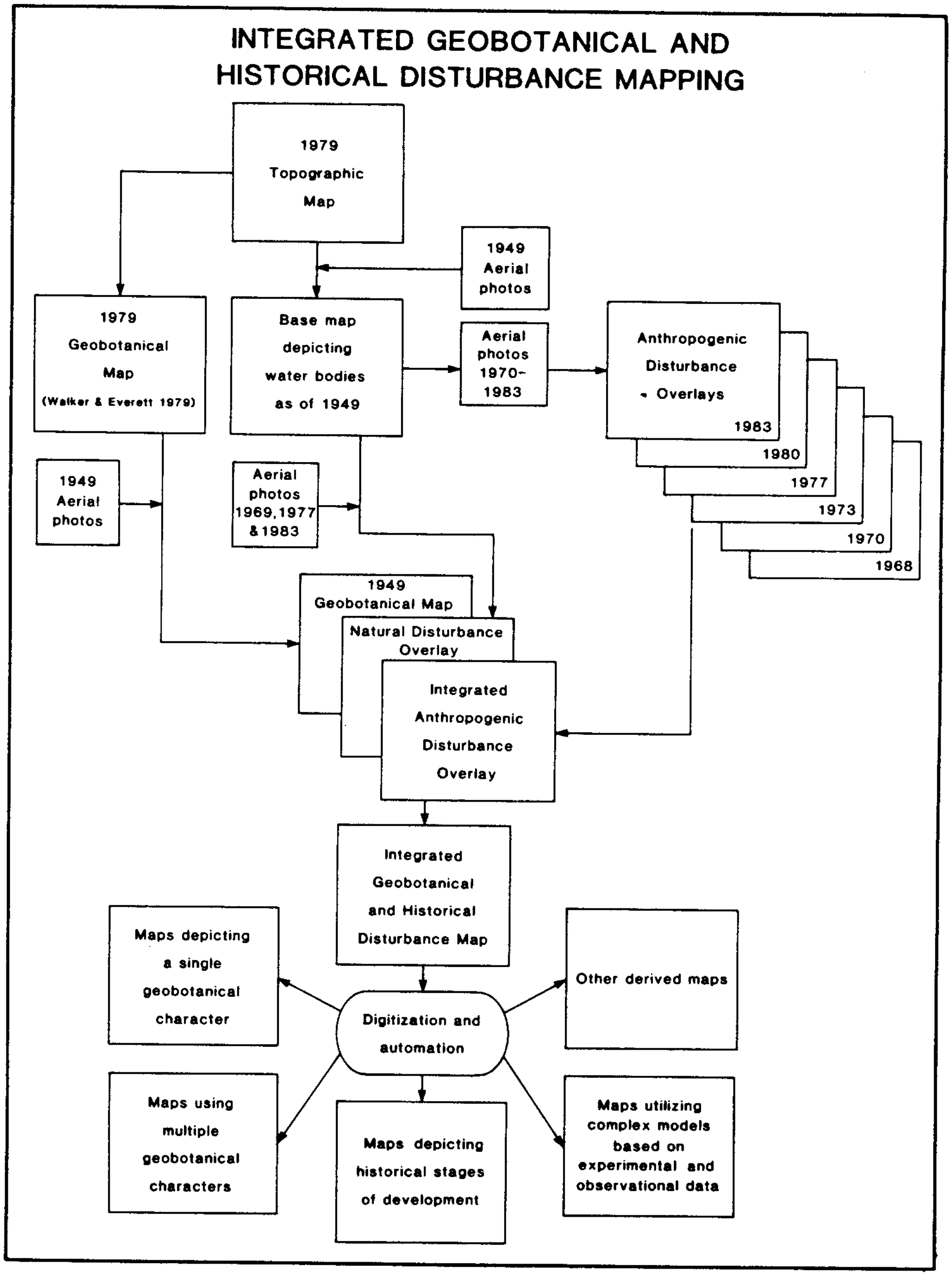

Fig. 3. Steps involved in making a 1:6000-scale IGHDM. (From Walker et al. 1986).

Table 1. Geobotanical and disturbance codes used for the IGHDMs (modified from Walker et al., 1984).

Code	Description
VEGETATION	The alphanumeric codes in the first set of parentheses following the vegetation type names are the codes used in the hierarchical classification (Walker and Acevedo, in press). The numeric codes in the bracket following each vegetation type are the codes used in the geobotanical and historical disturbance map of Map 22 (Walker et al. 1984).
1 to 19, Water and Aquatic Types	
1 *	Water (Ia) [1]
2 *	Aquatic grass marsh (Ib) [2]
3 *	Aquatic sedge marsh (IIa) [3]
4	Aquatic forb marsh (Ic) [4]
5 *	Aquatic moss marsh (no code) [no code]
20 to 39, Wet Types	
21 *	Wet sedge tundra (IIb) [5]
22 *	Wet sedge tundra (saline areas) (IId) [6]
23	Wet, sedge, low-shrub tundra (IIe) [7]
24	Wet, sedge, dwarf-shrub, moss tundra (IIc) [no code]
25	Wet low-shrub tundra (Vc) [8]
40 to 59, Moist Types	
41 *	Moist, nontussock-sedge, dwarf-shrub tundra (IIIa) [9]
42 *	Moist, tussock-sedge, dwarf-shrub tundra (IIIb) [10]
43 *	Moist, tussock-sedge, mixed-shrub tundra (IVa) [11]
44	Moist, nontussock-sedge, mixed-shrub tundra (IVb) [no code]
45 *	Moist or dry, dwarf-shrub, fruticose-lichen tundra (snowbeds) (IIIf) [13]
46	Moist, dwarf-shrub, moss tundra (Va) [14]
47	Moist low-shrub tundra (Vb) [15]
48 *	Moist low shrubland (riparian areas) (Vd) [16]
49	Moist, open-tall-shrub, sedge, mixed-shrub tundra (older savannas, foothills and terraces of the Colville River) (IVc) [17]
60 to 79, Dry Types	
61	Dry, dwarf-shrub, fruticose-lichen tundra (acidic dry exposed sites) (IIId) [no code]
62 *	Dry, dwarf-shrub, crustose-lichen tundra (IIIc) [19]
63 *	Dry, dwarf-shrub, forb, lichen tundra (Dryas river terraces) (IIIe) [20]
64 *	Dry, dwarf-shrub, forb, grass tundra (river bars and stabilized dunes near sea coast) (VIc) [21]
65 *	Dry, open-low-shrub, forb, grass tundra (river bars inland) (VId) [22]
66	Dry, low-shrub, fruticose-lichen tundra (dwarf-birch, lichen tundra, mainly river bars) (Ve) [23]
80 to 99, Barren Types	
81 *	Dry forb barren (river bars, beaches, barrier islands) (VIIa) [24]
82	Dry, crustose- and foliose-lichen barren (talus and blockfields) (VIIb) [25]
83 *	Dry grassland (dunes) (VIa) [26]
84 *	Dry shrubland (dunes) (VIb) [27]
99 *	Barren (VIIc) [28]

*Common units on the Beechey Point Quadrangle

Code	Description
PERCENT OPEN WATER	From Walker et al. (1986).
1	0-5%
2	5-30%
3	30-60%
4	60-90%
5	90-100%
ANTHROPOGENIC DISTURBANCE CODES	Modified from Walker et al. (1986).
1	Gravel roads
2	Peat roads
3	Gravel pads
4	Continuous flooding, more than 75% open water
5	Discontinuous flooding, less than 75% open water
6	Construction-induced thermokarst
7	Vehicle tracks-deeply rutted and/or with thermokarst
8	Vehicle tracks-not deeply rutted
9	Winter road
10	Gravel and construction debris (more than 75% cover)
11	Gravel and construction debris (less than 75% cover)
12	Heavy dust or dust-killed tundra
13	Excavations of river gravels or other gravel sources, roadcuts or construction excavations
14	Barren tundra caused by oil-spills, burns, blading, etc.
15	Barren tundra caused by previous flooding
16	Construction-induced eolian deposits

NATURAL DISTURBANCE

Natural disturbance was coded according to the vegetation type that was present after the disturbance. For example, shoreline erosion would be coded "1" showing that the area was now water. A drained lake would be coded "99" showing that the area was now barren.

Code	Description
LANDSCAPE UNIT	From Walker et al. (1985).
1	Flat thaw-lake plains
2	Floodplains and terraces
LANDFORM	Modified from Walker et al. (1986).
1	Distinct drained thaw-lake basin, or developing basins in residual surfaces of the coastal plain
2	Basin associated with hilly terrain often with thermokarst features
3	Residual surface unaffected by thaw lakes (gently rolling thaw-lake plains)
4	Inter-thaw-lake area (gently rolling and flat thaw-lake plains; may include some very old, indistinct thaw-lake basins)
5	Hill slope
6	Hill crest
7	Talus slope
8	Moraine
9	Kame
10	Elevated marine terrace
11	Pingo
12	Active floodplain
13	Stabilized or ancient floodplain
14	empty code
15	Stream drainage
16	Sand dunes (both active and stabilized dunes)
17	Beach
18	Spit
19	Bluff steep slope
20	Bluff crest
21	Alluvial fan
22	Colluvial deposits, including mudflows and solifluction deposits
23	Tidal flat
24	River delta
25	Island
51	Lake or pond
52	River or stream
53	Ocean
54	Artificial impoundment
SURFACE FORM	Modified from Walker et al. (1986).
1	High-centered polygons, center-trough relief greater than 0.5 m
2	High-centered polygons, center-trough relief less than 0.5 m
3	Low-centered polygons, center-rim relief greater than 0.5 m
4	Low-centered polygons, center-rim relief less than 0.5 m
5	Mixed high-centered and low-centered polygons
6	Frost scars
7	Strangmoor and/or disjunct polygon rims (generally well-defined features visible on 1:6000 photographs)
8	Hummocky terrain
9	Pingo
10	Nonpatterned ground
11	Reticulate pattern
13	Floodplain alluvium
14	Thermokarst pits (density greater than 4 pits per 3/8 in. circle on 1:6000-scale photograph)
15	Steep non-eroding bank
16	Actively eroding bank
17	Sand or gravel beach
21	Water
SOIL	From Walker et al. (1986).
1	Pergelic Cryoborolls
2	Pergelic Cryaquolls or Cryosaprists
3	Complex of: a) Pergelic Cryohemists or Cryofibrists b) Histic Pergelic Cryaquepts c) Pergelic Cryaquepts
4	Association of: a) Pergelic Cryohemists or Cryofibrists or Histic Pergelic Cryaquepts b) Pergelic Cryosaprists or Cryaquolls
5	Association of: a) Pergelic Cryaquolls or Cryosaprists b) Pergelic Cryaquepts
6	Pergelic Cryorthents
7	Perγelic Cryopsamments
8	Pergelic Cryaquepts
9	Denotes soil covered by a thin layer of wind-blown sand
10	No soil

3. River channel changes were a new phenomenon not encountered on Map 22. In areas of gravel mining it was often difficult to decide if river channel changes should be considered natural or anthropogenic disturbances. On Map 32, the Putuligayuk River course has been completely altered within its floodplain, so most of the floodplain northeast of the Spine Road was mapped as a gravel mine. No attempt was made to determine yearly changes to the stream course because constant activity in the ox-bow gravel mines and the NSB Land Fill caused numerous small changes to the river channels that made the IGHDMs unnecessarily complex. On Map 34, we mapped the changes to the channels because the gravel mining was essentially a single event, and the channels appeared to reestablish themselves in a more or less natural pattern. This logic was not altogether consistent on the two maps and should be kept in mind when comparing disturbance data for the two areas.

4. Map automation utilized a newly developed scanning digitizer made by Northern Video Graphics of Minneapolis, Minnesota. This procedure reduced the time required to digitize each map from approximately 6 days using the former manual methods to 2 days using the scanning digitizer.

Data Analysis for the IGHDMs

Geobotanical Characterization of the Study Areas

Area summaries were produced for all primary and secondary geobotanical attributes (vegetation, percent water cover, landform, surface form, soil, landscape unit), and natural disturbances (lake erosion, lake drainage, river channel changes). The summaries were made of each map and for the total study area (Map 22 + Map 32 + Map 34). Summaries were also made for the two major landscape units ('flat thaw-lake plains' and 'floodplains and terraces') for each map and for the total study area.

Geobotanical comparison of the three map areas was done by comparing the information in the tables and by bar graphs of the distribution of primary vegetation and surface-forms. The progression of natural disturbances was analyzed using line graphs.

Analysis of Anthropogenic Disturbances

Tabular summaries of the anthropogenic disturbances were prepared for each map and the total study area. The summaries were broken down by the mapped categories of disturbance (see Table 1) for the seven years of the study (1968, 1970, 1972, 1973, 1977, 1979, and 1983). The history of disturbance was portrayed on line graphs showing: (1) the area covered by five major disturbance types (roads, pads, flooding, thermokarst, and excavations) for the seven years of data, and (2) the disturbance types classified according to 'direct disturbances' [gravel pads, roads, winter roads and excavations (mainly gravel mines)] and 'indirect disturbances' (flooding, thermokarst, vehicle tracks, dust-killed tundra, construction debris, barren tundra caused by flooding, oil spills and other causes). The analysis in (1) included both primary and secondary disturbance. Flooding included both continuous and discontinuous flooding; roads included gravel and peat roads.

Analysis of the vegetation types affected by the various categories of disturbance was accomplished by using tabular breakdowns of disturbance type by vegetation type. The area of vegetation types affected by flooding and gravel placement were summarized in bar graphs and compared to the natural distribution of vegetation types using a chi-square analysis.

RESULTS

1:24,000-scale Maps - Historical Development of the Prudhoe Bay Oil Field

The historical development of the oil field is shown for the years 1968, 1970, 1973, 1977, 1980, and 1983 in Figs. 4 to 9. On each map, the roads, pads, flooded areas, and gravel mines constructed during the given time interval are shown in black; disturbances from earlier time intervals are shown in dark grey. The new roads for each year are on separate overlays and could be printed in red for easier interpretation. Planimetry data from these maps are summarized in Table 2. Historical progressions of the major anthropogenic disturbances (gravel pads, road length, total gravel-covered area, and flooded areas) are shown in Fig. 10.

The comparison of the rate of growth of the road networks in the Prudhoe Bay Oil Field with that in the Kuparuk Oil Field shows that the rate of growth is similar for both fields (Fig. 11).

1:6000-scale Maps - IGHDMs

Computer-drawn Maps

Table 3 is a list of the 6 colored maps and 61 black and white maps produced from the IGHDMs of Maps 22, 32, and 34. Reduced copies of the maps are in Appendix B. [See Fig. 4, in Walker et al. (1986) (Appendix A) for example of an uncoded IGHDM.] Color plots were produced for 1949 primary vegetation, and 1983 anthropogenic disturbances overlaid on the 1949 vegetation. Black and white plots were produced for all the variables in the IGHDM GIS data file, but tertiary vegetation and tertiary anthropogenic disturbance maps were not reproduced for this report because of the minimal amount of information on these maps. Also, anthropogenic disturbance maps for 1972 were not reproduced because there was little difference from 1973.

Area Summaries

Appendix C contains area summaries of all primary and

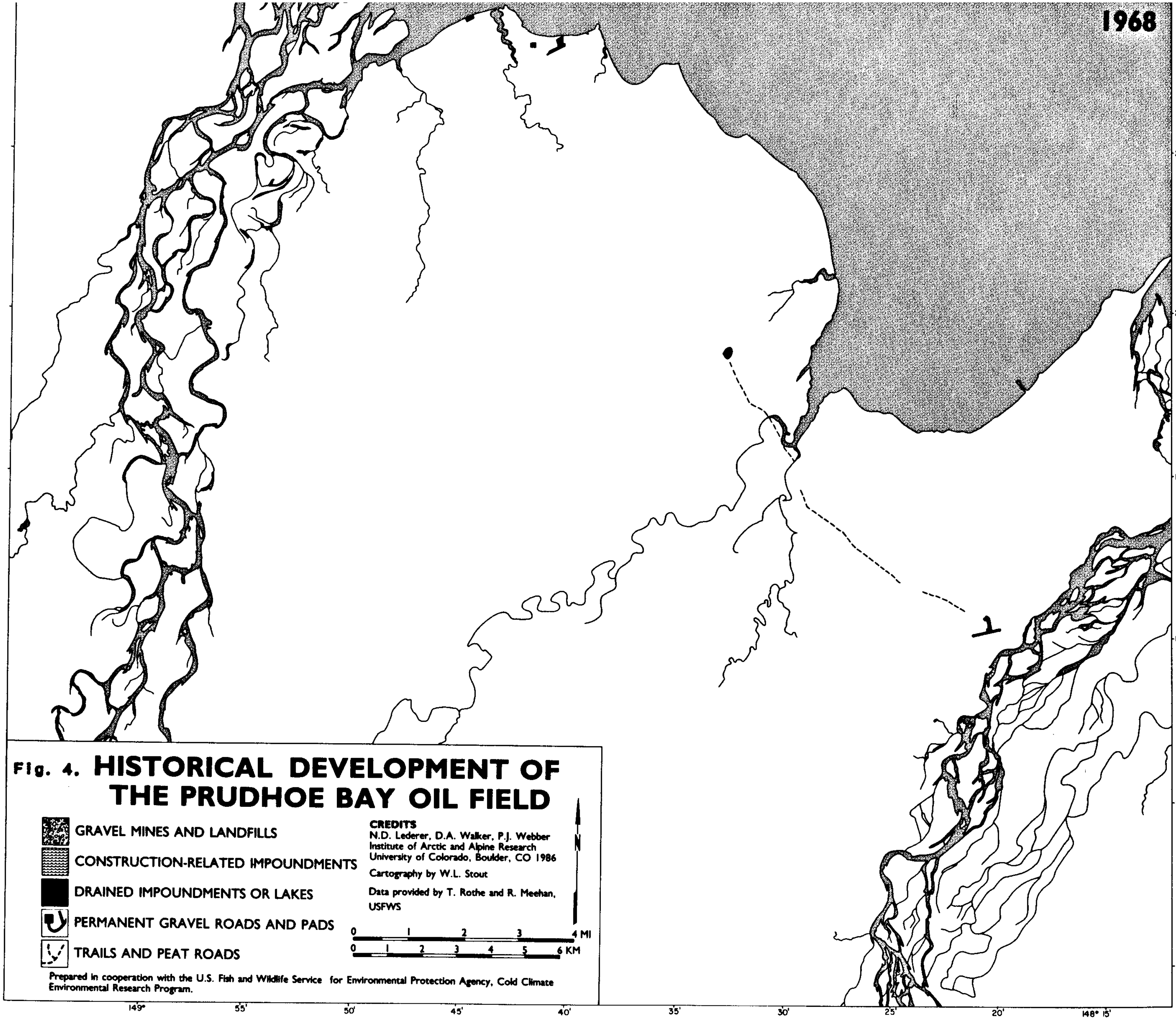

Fig. 4. HISTORICAL DEVELOPMENT OF THE PRUDHOE BAY OIL FIELD

CREDITS
N.D. Lederer, D.A. Walker, P.J. Webber
Institute of Arctic and Alpine Research
University of Colorado, Boulder, CO 1986
Cartography by W.L. Stout
Data provided by T. Rothe and R. Meehan, USFWS

Prepared in cooperation with the U.S. Fish and Wildlife Service for Environmental Protection Agency, Cold Climate Environmental Research Program.

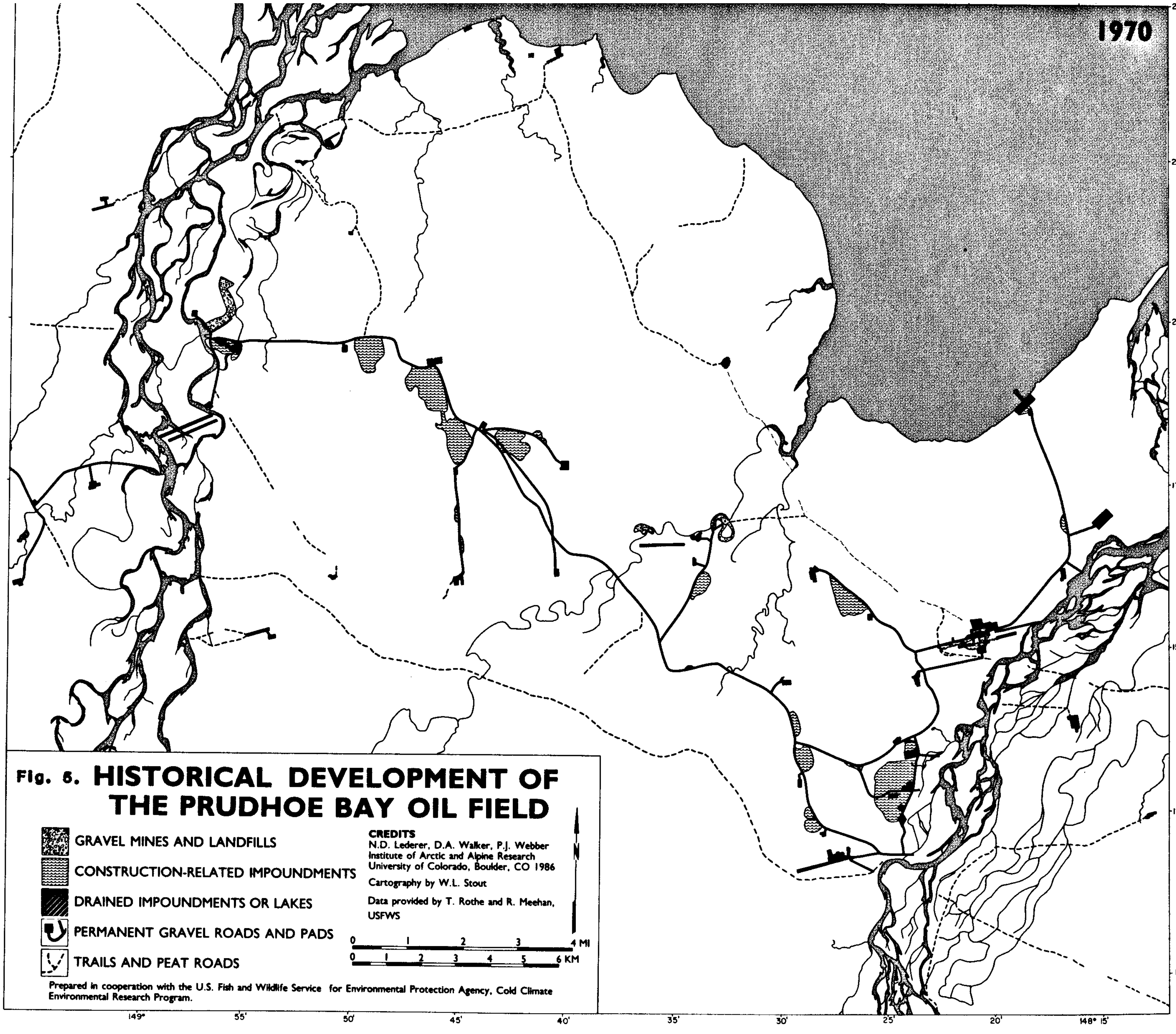

Fig. 6. HISTORICAL DEVELOPMENT OF THE PRUDHOE BAY OIL FIELD

CREDITS
N.D. Lederer, D.A. Walker, P.J. Webber
Institute of Arctic and Alpine Research
University of Colorado, Boulder, CO 1986
Cartography by W.L. Stout
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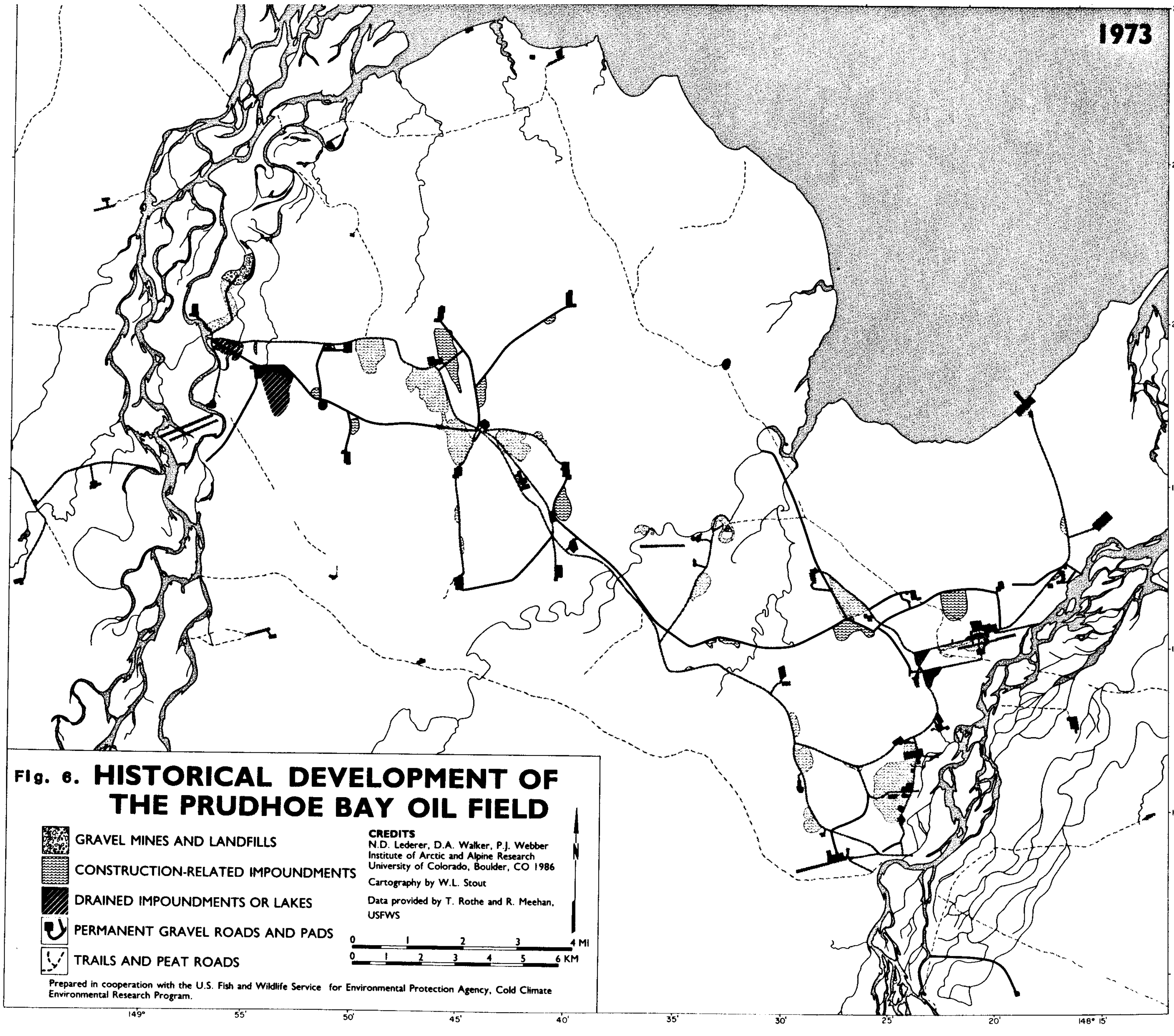

Fig. 6. HISTORICAL DEVELOPMENT OF THE PRUDHOE BAY OIL FIELD

CREDITS
N.D. Lederer, D.A. Walker, P.J. Webber
Institute of Arctic and Alpine Research
University of Colorado, Boulder, CO 1986
Cartography by W.L. Stout
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Prepared in cooperation with the U.S. Fish and Wildlife Service for Environmental Protection Agency, Cold Climate Environmental Research Program.

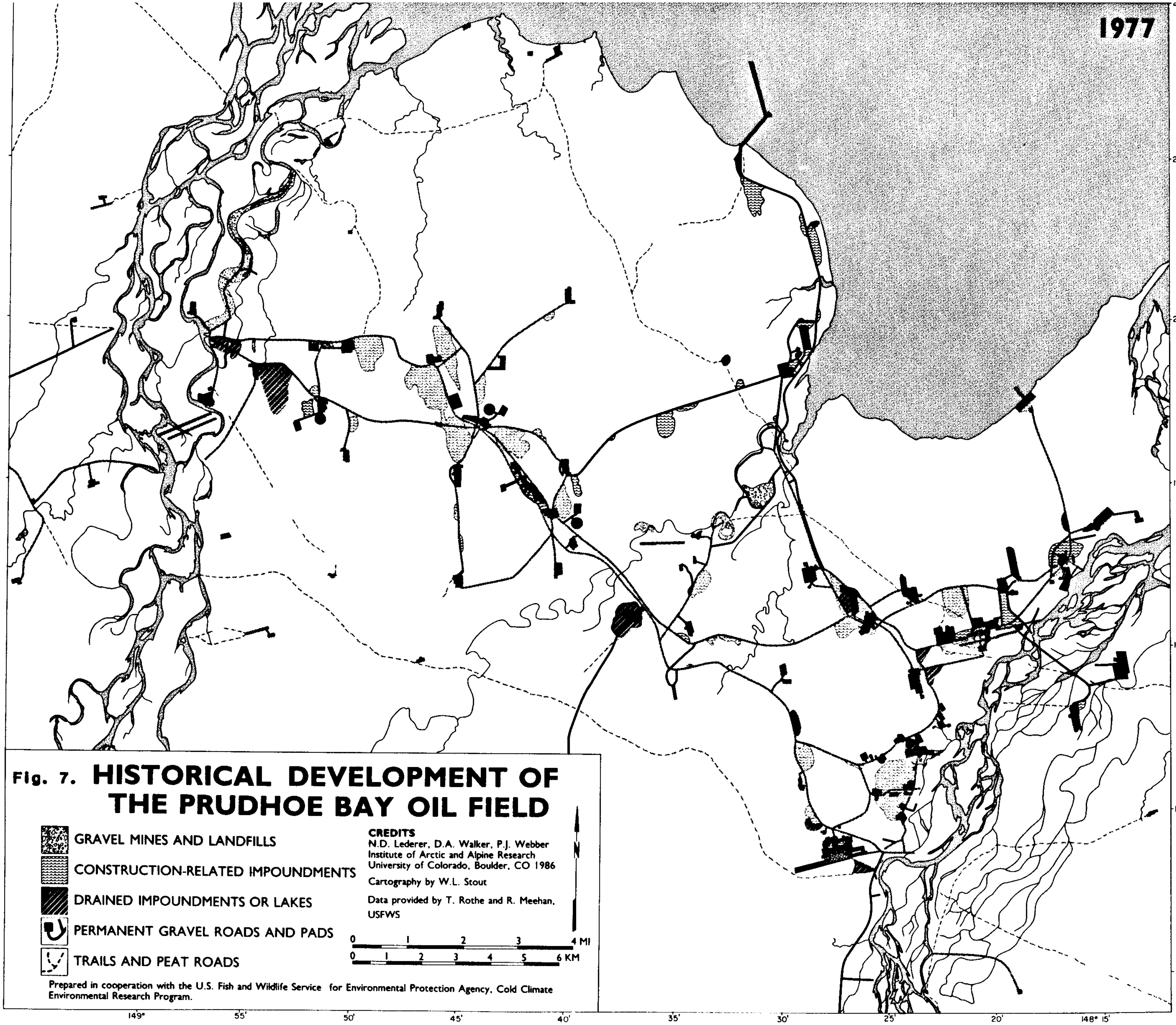


Fig. 7. HISTORICAL DEVELOPMENT OF THE PRUDHOE BAY OIL FIELD

CREDITS
N.D. Lederer, D.A. Walker, P.J. Webber
Institute of Arctic and Alpine Research
University of Colorado, Boulder, CO 1986
Cartography by W.L. Stout
Data provided by T. Rothe and R. Meehan, USFWS

Prepared in cooperation with the U.S. Fish and Wildlife Service for Environmental Protection Agency, Cold Climate Environmental Research Program.

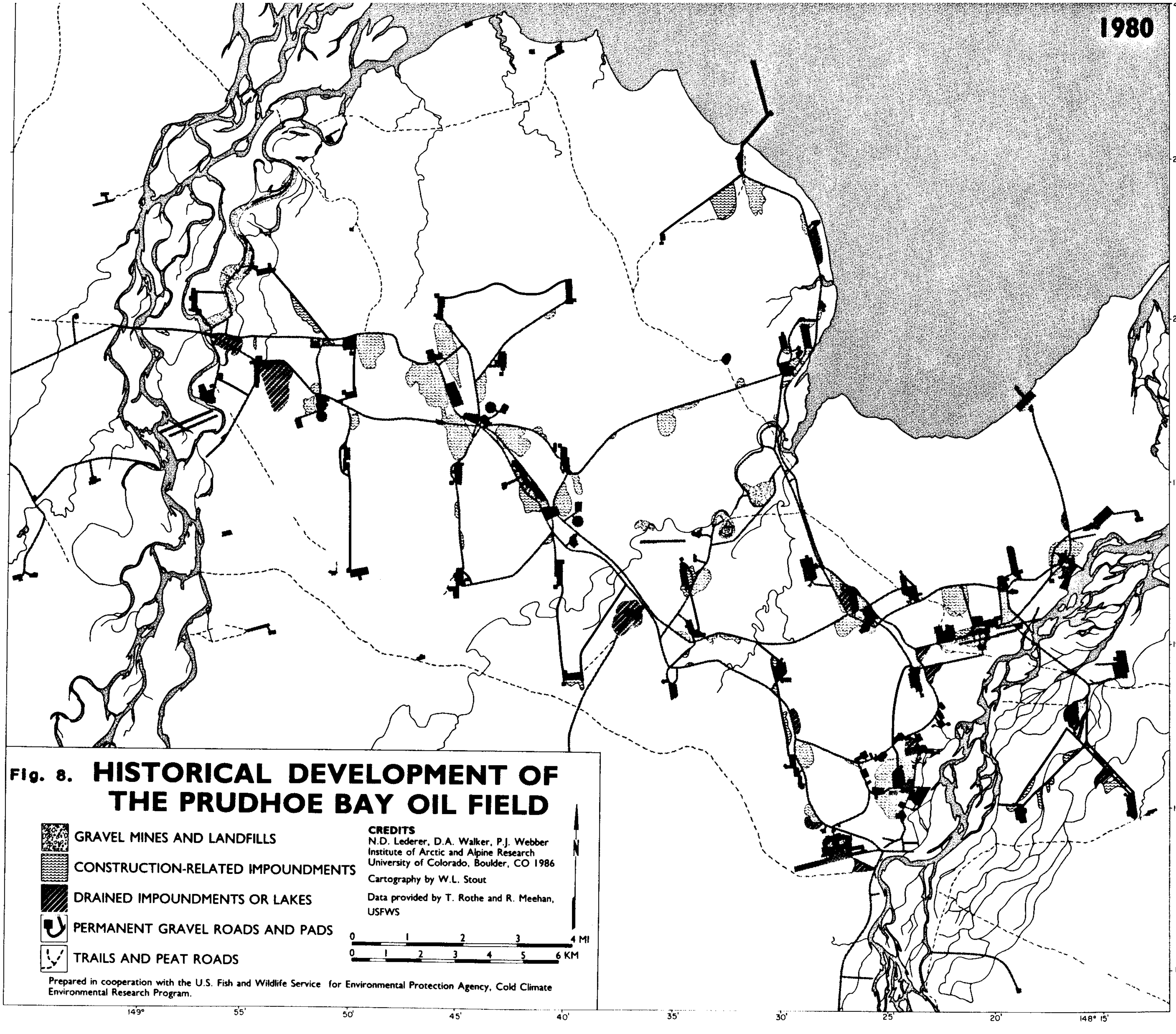


Fig. 8. HISTORICAL DEVELOPMENT OF THE PRUDHOE BAY OIL FIELD

CREDITS
N.D. Lederer, D.A. Walker, P.J. Webber
Institute of Arctic and Alpine Research
University of Colorado, Boulder, CO 1986
Cartography by W.L. Stout
Data provided by T. Rothe and R. Meehan, USFWS

Prepared in cooperation with the U.S. Fish and Wildlife Service for Environmental Protection Agency, Cold Climate Environmental Research Program.

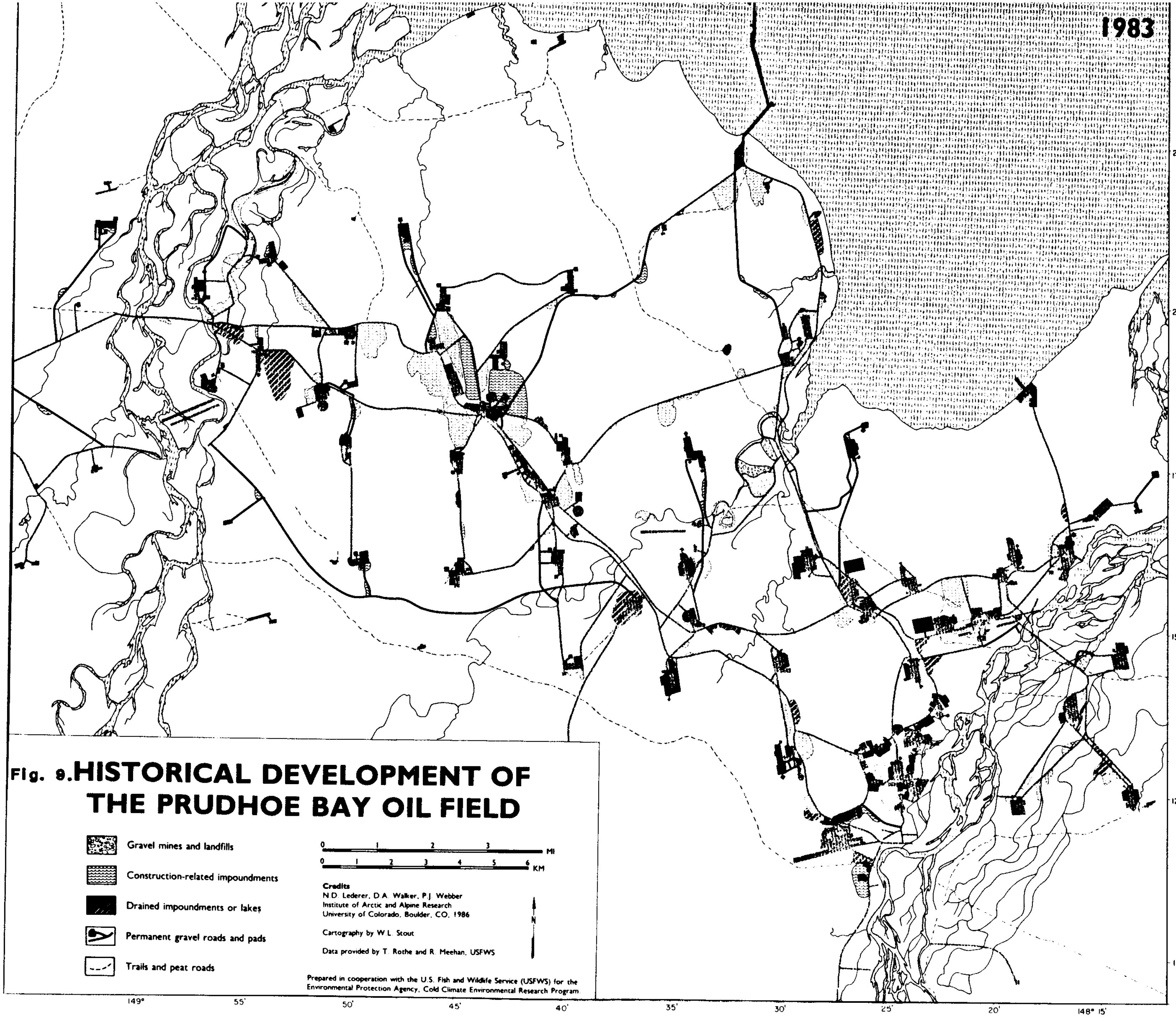


Fig. 9. HISTORICAL DEVELOPMENT OF THE PRUDHOE BAY OIL FIELD

Credits
N.D. Lederer, D.A. Walker, P.J. Webber
Institute of Arctic and Alpine Research
University of Colorado, Boulder, CO, 1986

Cartography by W.L. Stout

Data provided by T. Rothe and R. Meehan, USFWS

Prepared in cooperation with the U.S. Fish and Wildlife Service (USFWS) for the Environmental Protection Agency, Cold Climate Environmental Research Program.

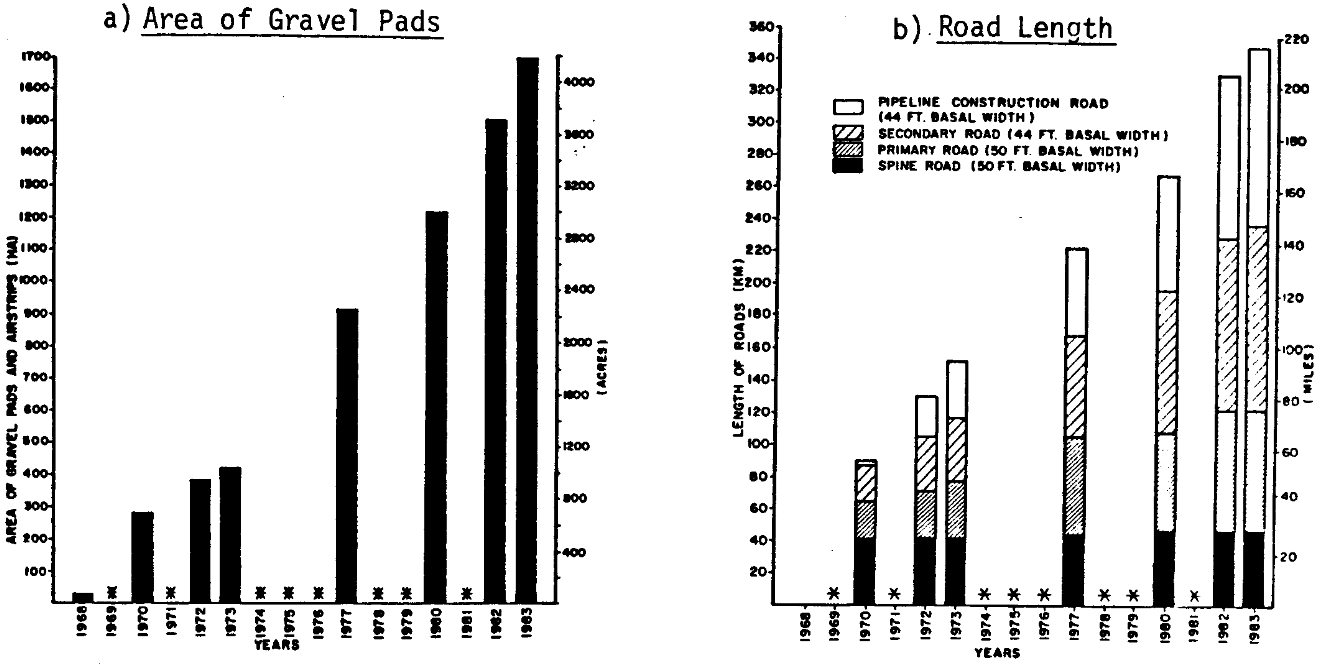
Table 2. Additions to the major disturbance types for the years of record in the Prudhoe Bay Oil Field (Figs. 4 through 9). (From Walker et al. 1986).

Year	Gravel Pads	Spine Road		Primary Roads		Secondary Roads		Pipeline Construction Roads		Total Roads		Total Gravel-covered	Construction-related Flooding
	Area (ha)	Length (km)	Area (ha)	Length (km)	Area (ha)	Length (km)	Area (ha)	Length (km)	Area (ha)	Length (km)	Area (ha)	Area (ha)	Area (ha)
1968	28.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.6	0.0
1970	253.0	40.8	62.3	24.1	36.7	22.1	29.6	2.8	3.8	89.8	132.4	385.4	568.9
1972	103.0	0.0	0.0	6.4	9.7	12.2	10.2	21.3	28.6	39.9	48.5	151.5	309.1
1973	36.1	0.0	0.0	5.9	9.0	5.4	7.2	11.6	15.6	22.9	31.8	67.9	−122.5
1974*	91.0	0.0	0.0	9.2	14.0	2.0	2.6	6.7	9.0	17.9	25.6	116.6	74.4
1975*	31.5	0.0	0.0	11.4	17.4	2.2	2.9	4.3	5.7	17.9	26.0	57.5	23.5
1976*	59.5	0.0	0.0	0.4	0.6	4.4	6.0	3.7	4.9	8.5	11.5	71.0	0.0
1977	312.5	3.3	5.1	3.6	5.5	14.8	19.9	4.0	5.3	25.7	35.8	348.3	105.3
1978*	57.8	0.0	0.0	0.0	0.0	11.1	14.9	6.4	8.6	17.5	23.5	81.3	0.0
1979*	115.0	2.8	4.3	0.4	0.7	2.4	3.3	4.3	5.8	9.9	14.1	129.1	56.1
1980	128.8	0.0	0.0	0.0	0.0	11.3	15.2	5.8	7.8	17.1	23.0	151.8	121.3
1981*	106.5	0.0	0.0	4.2	6.4	7.1	9.5	22.6	30.4	33.9	46.3	152.8	1.1
1982	183.7	0.0	0.0	9.5	14.4	11.8	15.8	8.5	11.5	29.8	41.7	225.4	232.9
1983	186.0	0.0	0.0	0.0	0.0	7.8	10.5	9.4	12.6	17.2	23.1	209.1	10.9
Total	1,693.0	46.9	71.7	75.1	114.4	114.6	147.6	111.4	149.6	348.0	483.3	2,176.3	1,381.0

* Years with incomplete or missing aerial photographic coverage.
Available information from unpublished draft map by T. Rothe.

a) Area of Gravel Pads

b) Road Length



c) Gravel-covered Area

d) Construction-related Impoundments

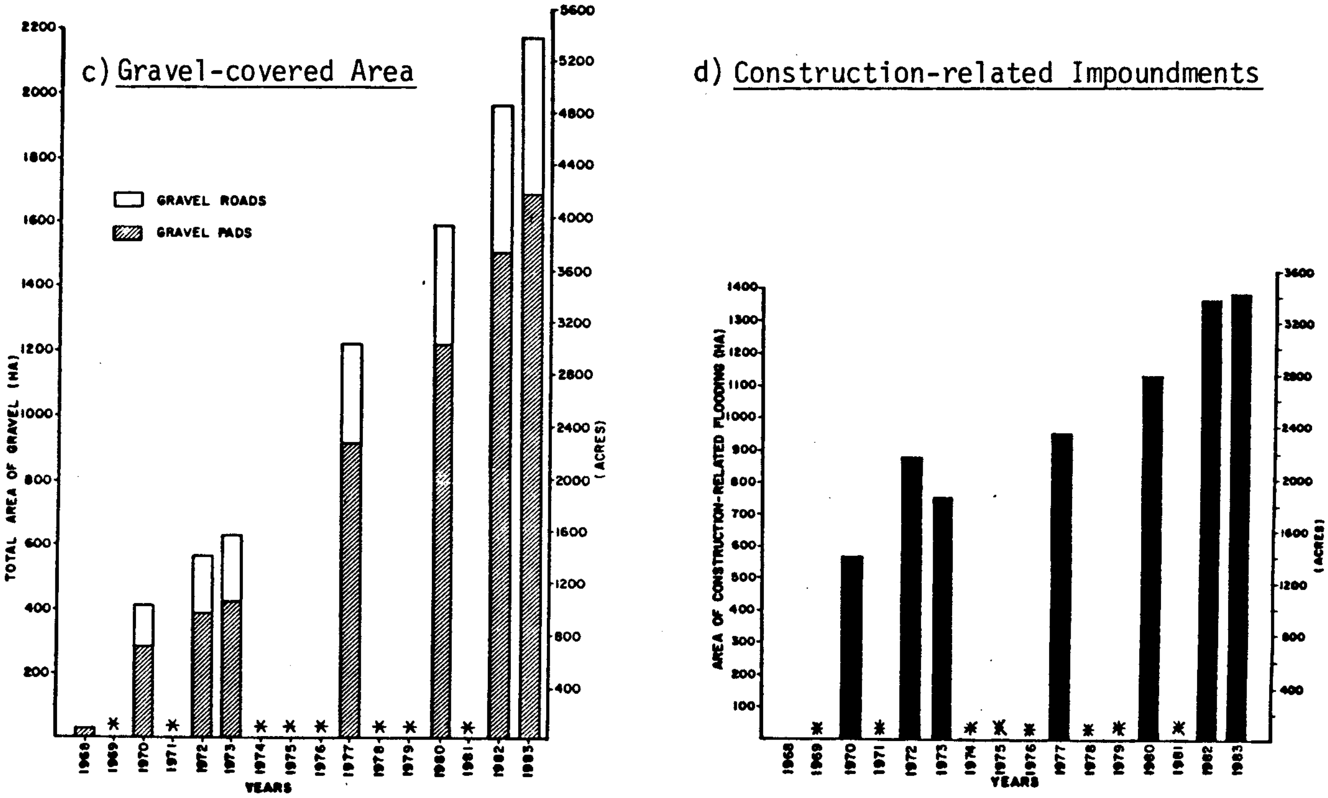


Fig. 10. Area of anthropogenic disturbances within the Prudhoe Bay Oil Field for years of available photo coverage. Data are from Figs. 4 through 9. Starred (*) columns are years of missing or incomplete data. Regression equations for the respective data sets are as follows:

a) $Y = 107.9X - 124.8$ ($r = .99$), b) $Y = 21.2X + 10.2$ ($r = .99$),
c) $Y = 132.2X - 51.2$ ($r = .99$), d) $Y = 74.5X + 237.9$ ($r = .93$).

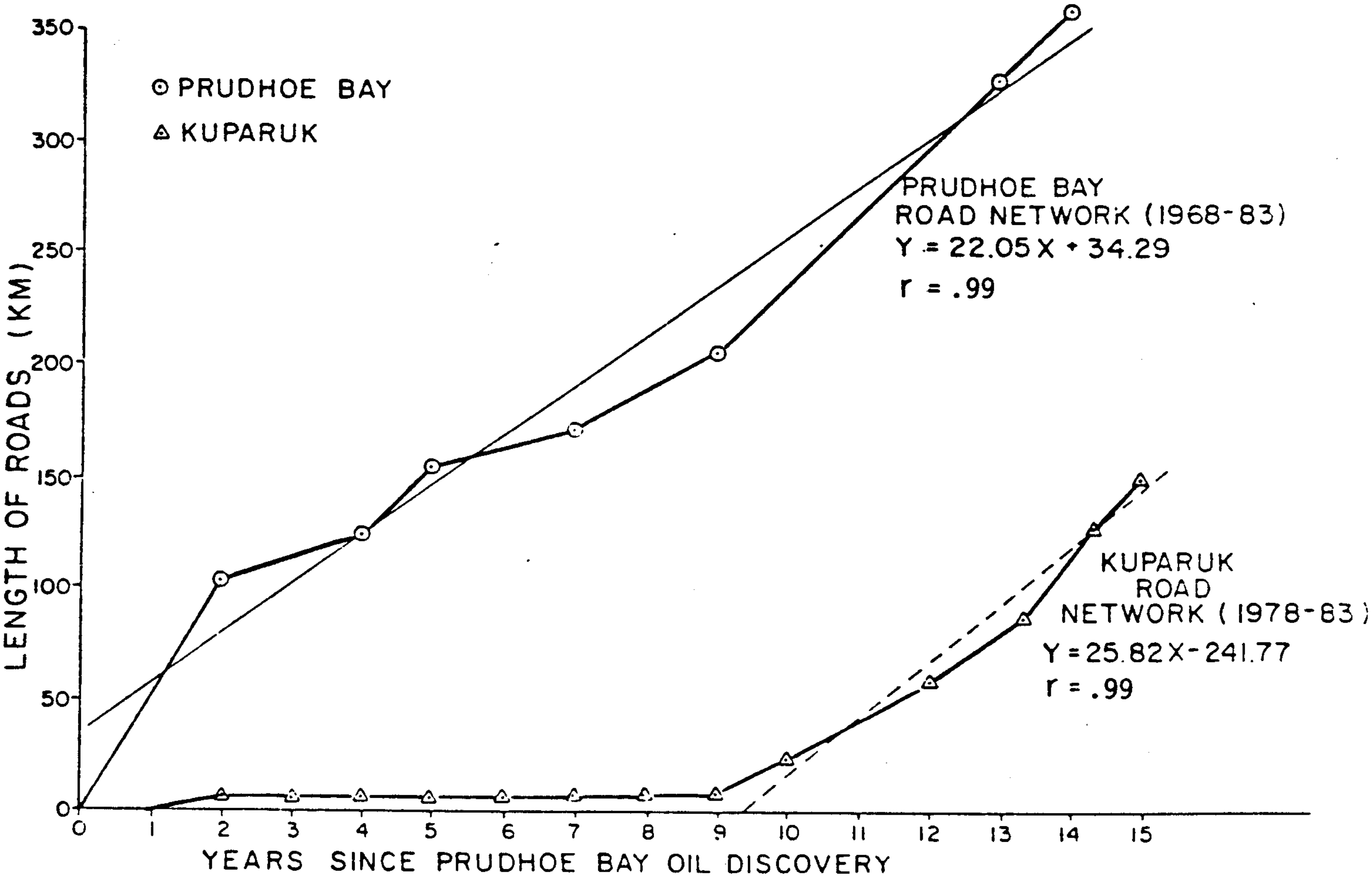


Fig. 11. Comparison of growth of the Prudhoe Bay and Kuparuk oil field road networks. Top straight fine line is the regression for the Prudhoe Bay road network since the discovery of oil in 1968. Bottom dashed regression line shows the growth of the Kuparuk road network since 1978 when development began to expand.

Table 3. List of maps produced from the IGHDMs for Maps 22, 32, and 34.

	Map 22	Map 32	Map 34
6 Color Maps			
Primary Vegetation 1949	X	X	X
Primary Vegetation 1949 with 1983 Anthropogenic Disturbances	X	X	X
61 Black and White Maps			
Primary Vegetation 1949	X	X	X
Secondary Vegetation 1949	X	X	X
Percent Water Cover 1949	X	X	X
Landscape Unit 1949		X	X
Landform 1949	X	X	X
Primary Surface Form 1949	X	X	X
Secondary Surface Form 1949	X	X	X
Primary Soil 1949	X	X	X
Secondary Soil 1949	X	X	X
Primary Anthropogenic Disturbance 1968			X
Secondary Anthropogenic Disturbance 1968			X
Primary Anthropogenic Disturbance 1970	X	X	X
Secondary Anthropogenic Disturbance 1970	X	X	X
Primary Anthropogenic Disturbance 1973	X	X	X
Secondary Anthropogenic Disturbance 1973	X	X	X
Primary Anthropogenic Disturbance 1977	X	X	X
Secondary Anthropogenic Disturbance 1977	X	X	X
Primary Anthropogenic Disturbance 1979	X	X	X
Secondary Anthropogenic Disturbance 1979	X	X	X
Primary Anthropogenic Disturbance 1983	X	X	X
Secondary Anthropogenic Disturbance 1983	X	X	X
Natural Disturbance 1968, 1977, and 1983	X	X	X
	21	22	24

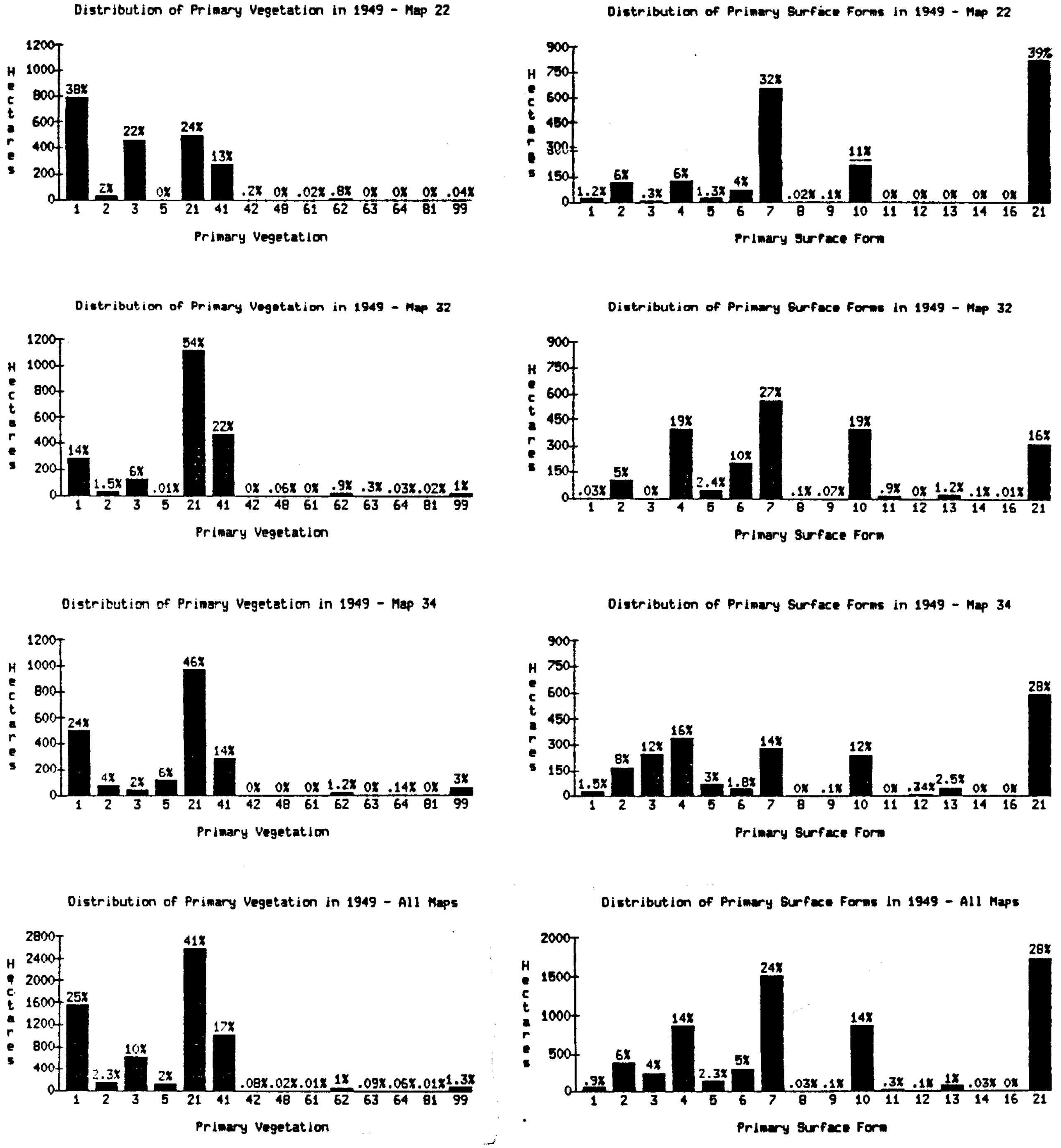
secondary attributes in the IGHDM data file for all three maps and for the total study area (Map 22 + Map 32 + Map 34) for the seven years of the study. Fig. 12 compares the distribution of the primary vegetation and surface-form types for the three maps and for the total study area. Comparison of the geobotany (vegetation and surface forms) for the 'flat thaw-lake plains' and the 'floodplains and terraces' landscape units is in Fig. 13.

Historical progression of the major disturbance types (flooding, roads, pads, thermokarst, and excavations) are shown for the three maps and the total study area in Fig. 14. Note that the amount of disturbance on the three maps varies considerably and the scale of the vertical axis is different for each map. The ranking of the major disturbances also varies between maps. For example, on Map 22, which is located entirely within a 'flat thaw-lake plain' landscape unit, flooding covers more area than all other disturbances combined, but on Maps 32 and 34, which have large components of 'floodplains and terraces', excavations (= gravel mines) cover large areas. On Map 34, pads cover the largest area. A strict comparison of disturbance on 'flat thaw-lake plains' and 'floodplains and terraces' (Fig. 15) shows the major differences between the types of impacts that have occurred in each unit. The impacts on the floodplains were caused chiefly by gravel mining, whereas on the 'flat thaw-lake plains', the primary impacts were flooding and pads. For all maps combined, thermokarst surprisingly covered about as much area as roads (Fig. 14).

The comparison of direct vs. indirect impacts (Fig. 16) shows that the area of indirect impacts just exceeds that of direct impacts (889 ha of total indirect impacts vs. 839 ha of direct impact for all maps combined). Total impacts (direct + indirect) expressed as percentages of the total map areas were: 35.7% on Map 22, 21.4% on Map 32, 26.6% on Map 34, and 28.6% for all maps combined.

The analysis of vegetation types affected by the various types of impacts is summarized in Tables C3, C6, C9, and C12 of Appendix C. Fig. 17 shows the distribution of vegetation types affected by flooding and gravel placement. Chi-square analysis of these data (Table 4) reveals that the distribution of vegetation types covered by flooding is significantly different from that of the natural distribution of vegetation on all maps and for the total study area. This is to be expected since flooding is concentrated in the thaw-lake basins and the wetter vegetation types. Flooding as defined should not occur in an area that was already coded as water on the geobotanical overlay. However, some instances of flooding in lakes do appear in the data. For example, 7% of the flooding on Map 32 was in water areas (Fig. 17). These were most likely oversights that occurred during the map-integration process.

The chi-square analysis comparing the distribution of vegetation types covered by gravel to the natural vegetation distribution shows a significant difference on maps 22 and 32 but



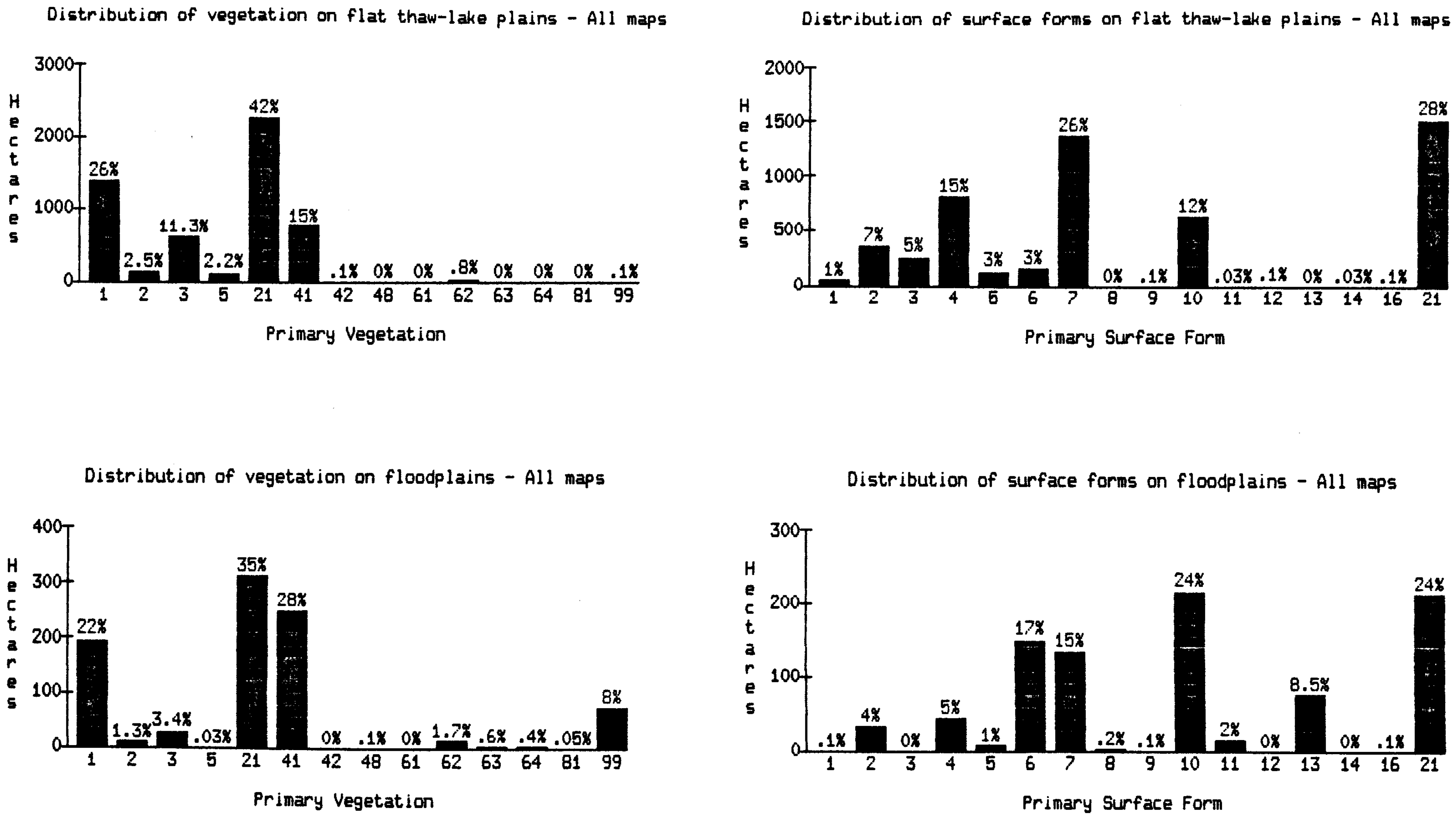
Vegetation Legend

1	Water
2	Aquatic grass marsh
3	Aquatic sedge marsh
5	Aquatic moss marsh
21	Wet sedge tundra
41	Moist, nontussock-sedge, dwarf-shrub tundra
42	Moist, tussock-sedge, dwarf-shrub tundra
48	Moist low shrubland
61	Dry, dwarf-shrub, fruticose-lichen tundra
62	Dry, dwarf-shrub, crustose-lichen tundra
63	Dry, dwarf-shrub, forb, lichen tundra
64	Dry, dwarf-shrub, forb, grass tundra
81	Dry forb tundra
99	Barren

Surface-form Legend

1	High-centered polygons, greater than 0.5 m relief
2	High-centered polygons, less than 0.5 m relief
3	Low-centered polygons, greater than 0.5 m relief
4	Low-centered polygons, less than 0.5 m relief
5	Mixed high-centered and low-centered polygons
6	Frost scars
7	Strangmoor
8	Hummocky terrain
9	Pingo
10	Nonpatterned ground
11	Reticulate pattern
12	Sand dunes
13	Floodplain alluvium
14	Thermokarst pits
16	Actively eroding bank
21	Water

Fig. 12. Distribution of natural vegetation and surface forms in 1949 on the three IGHDMs and for all maps combined.



Distribution of vegetation on flat thaw-lake plains - All maps

Distribution of surface forms on flat thaw-lake plains - All maps

Distribution of vegetation on floodplains - All maps

Distribution of surface forms on floodplains - All maps

Fig. 13. Distribution of vegetation and surface forms in the two primary landscape units. (See Fig. 12 for legends).

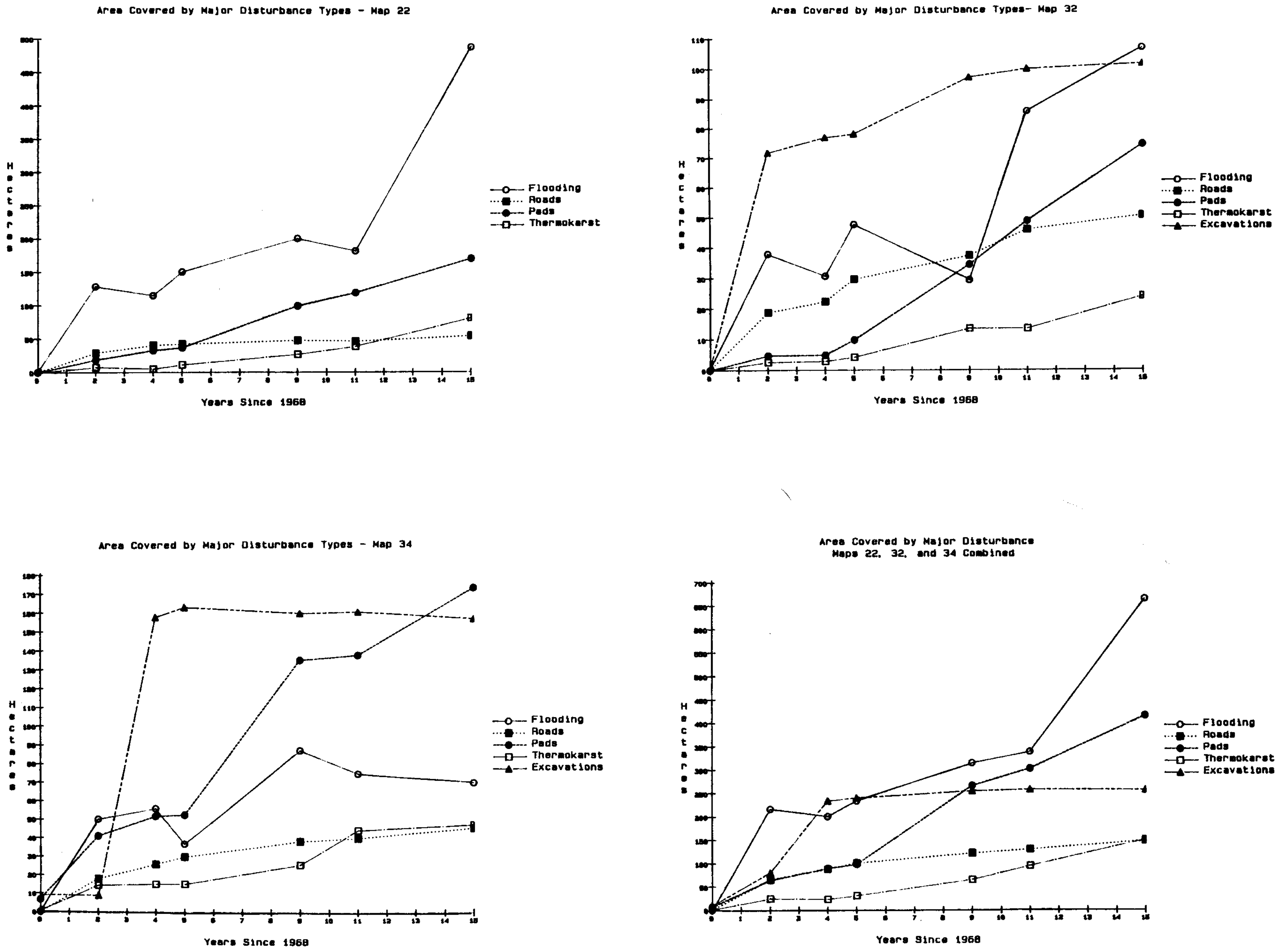
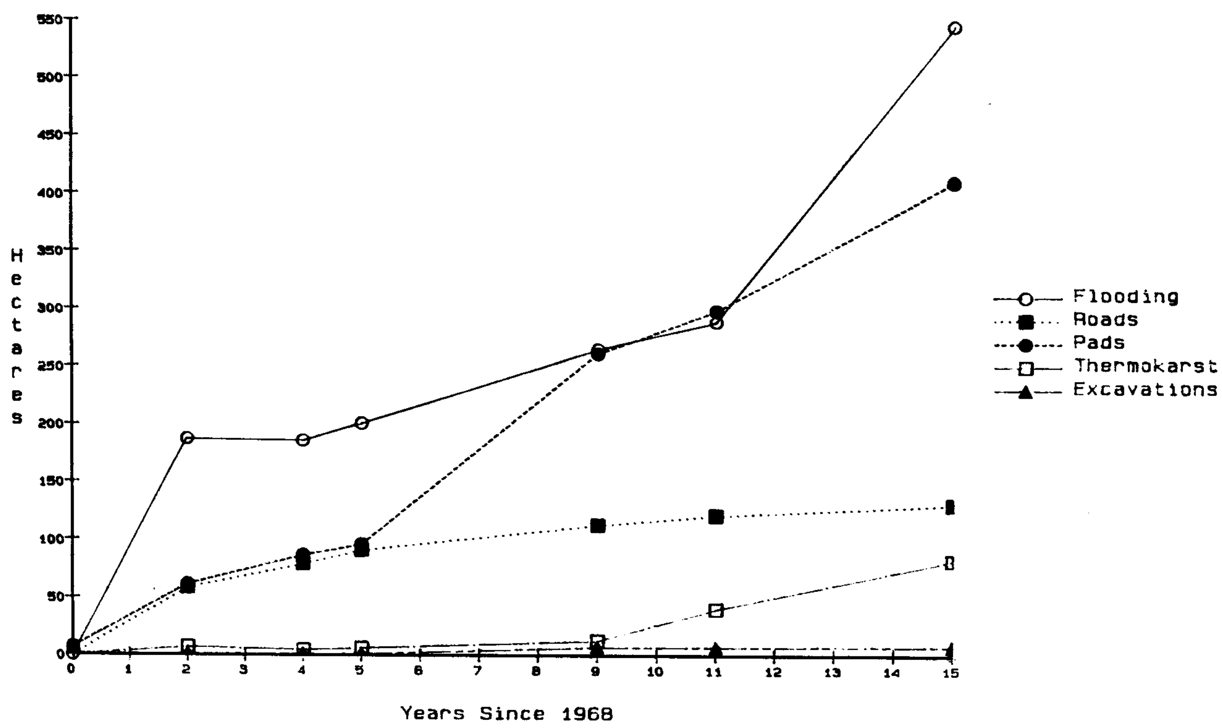
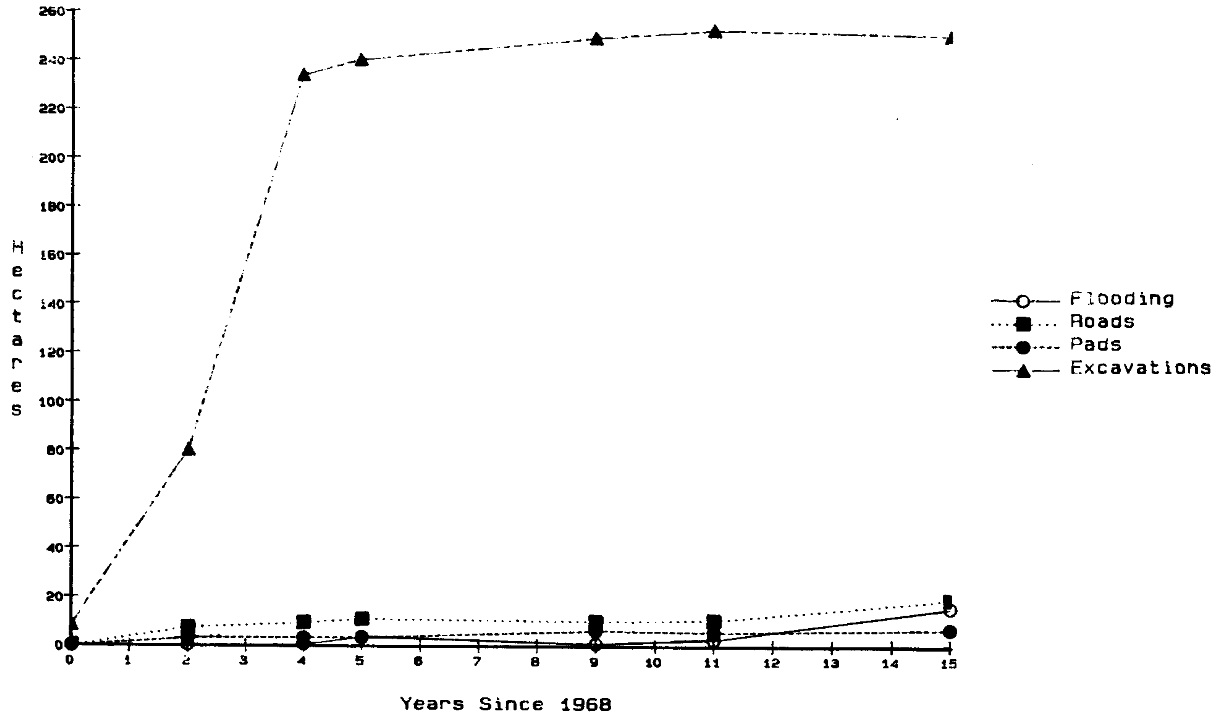


Fig. 14. Historical progression of anthropogenic disturbances on the three IGHDMs and for all maps combined.



Area of Flat Thaw-Lake Plains Covered by Major Disturbances
Maps 22, 32, and 34 Combined



Area of Floodplain Covered by Major Disturbances
Maps 32 and 34 Combined

Fig. 15. Historical progression of anthropogenic disturbances on 'flat thaw-lake plains' and 'floodplains and terraces'.

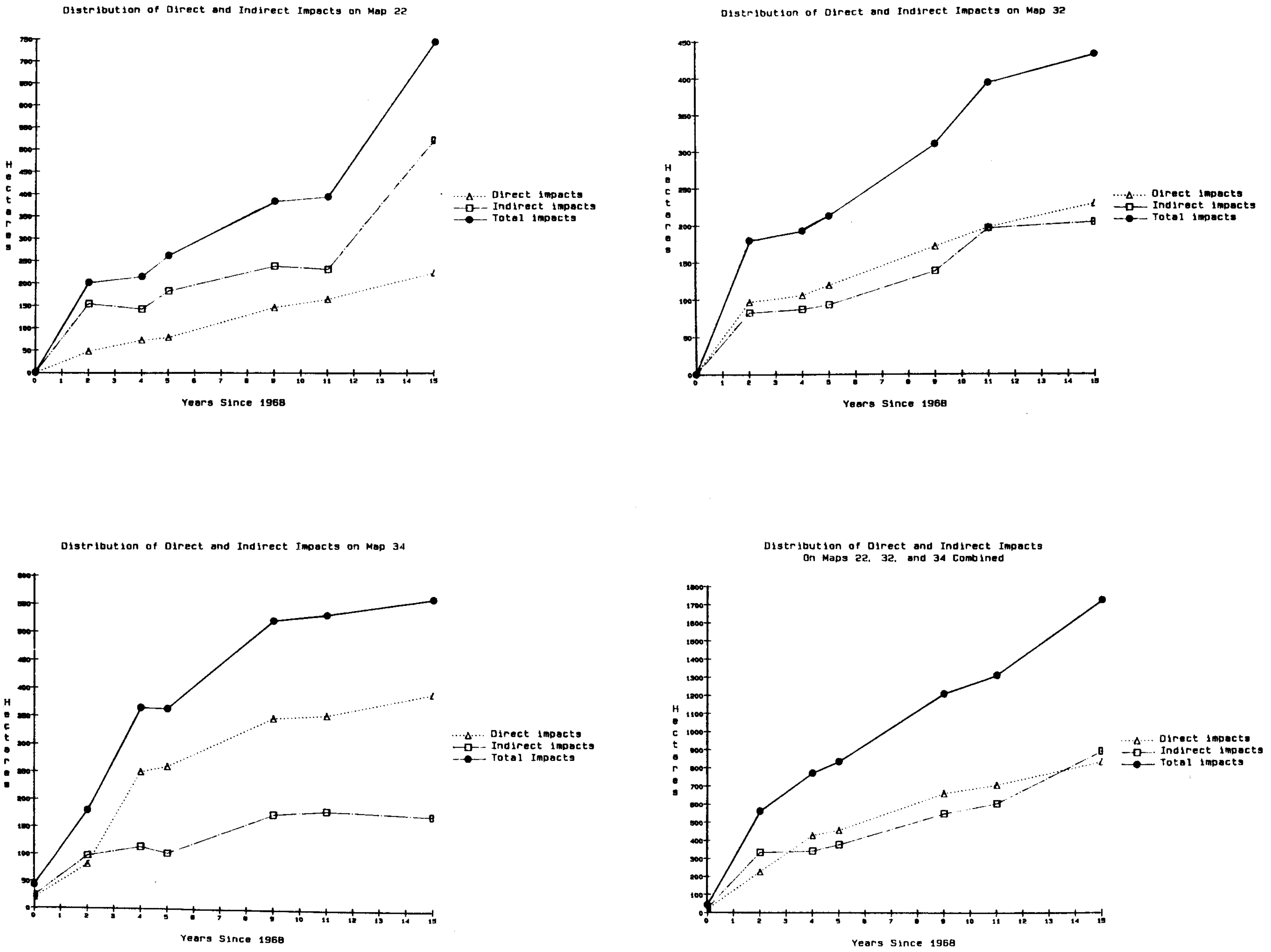
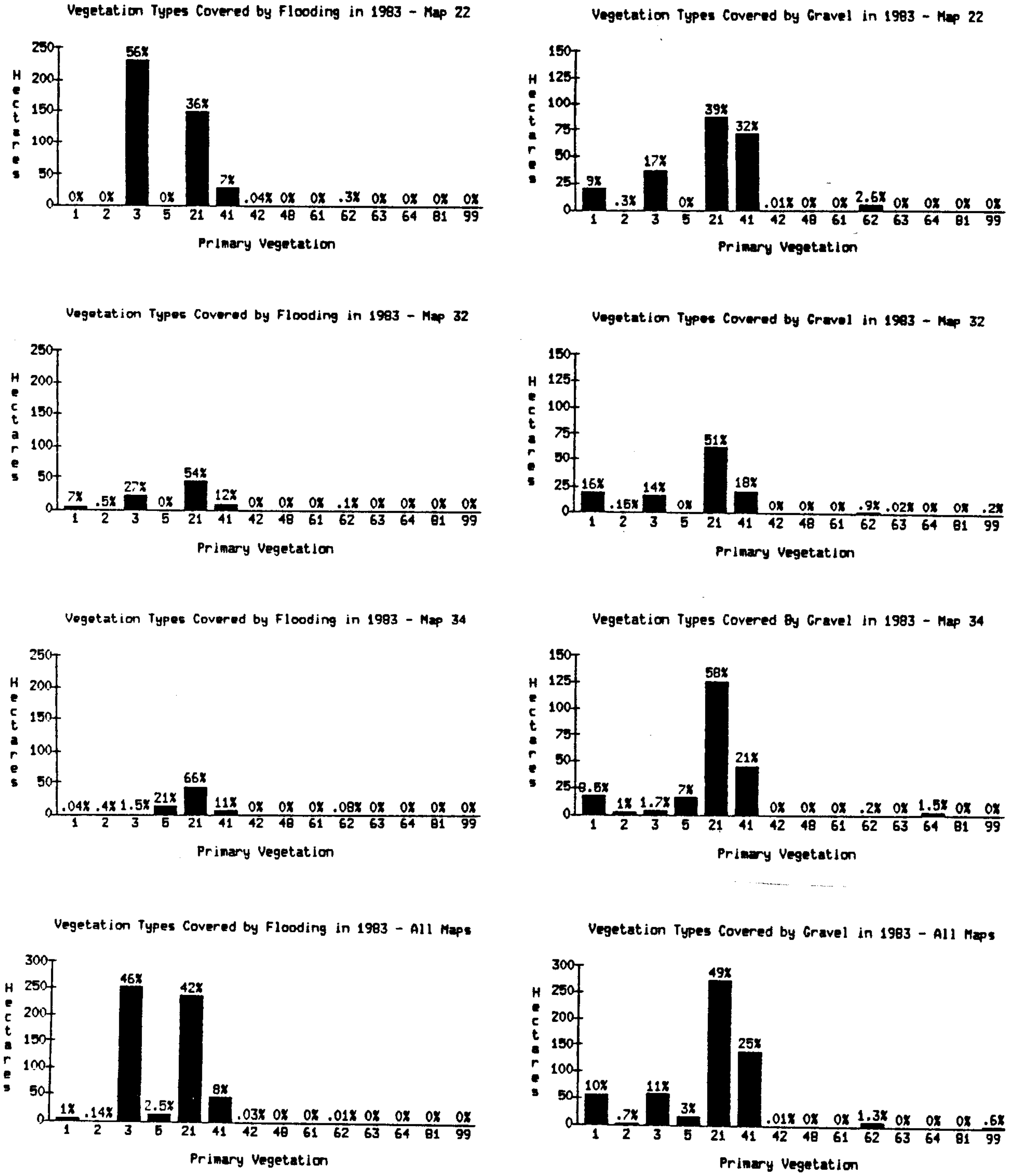


Fig. 16. Direct and indirect impacts on the three IGHDMs and for all maps combined.



<u>Vegetation Legend</u>

1	Water
2	Aquatic grass marsh
3	Aquatic sedge marsh
5	Aquatic moss marsh
21	Wet sedge tundra
41	Moist, nontussock-sedge, dwarf-shrub tundra
42	Moist, tussock-sedge, dwarf-shrub tundra
48	Moist low shrubland
61	Dry, dwarf-shrub, fruticose-lichen tundra
62	Dry, dwarf-shrub, crustose-lichen tundra
63	Dry, dwarf-shrub, forb, lichen tundra
64	Dry, dwarf-shrub, forb, grass tundra
81	Dry forb tundra
99	Barren

Fig. 17. Distribution of vegetation types covered by flooding and gravel in 1983. Compare with natural distribution of vegetation types in 1949 (Fig. 12).

Table 4. Chi-square values comparing distribution of vegetation types covered by flooding and gravel to the natural distribution of the vegetation types. The varying degrees of freedom are due to the absence of certain vegetation types on some maps. Moist sedge tundra types (41 and 42) were combined into a single category, as were dry tundra types (61 through 64). Percentages were adjusted to exclude water.

	Flooding	Gravel
Map 22		
χ^2	45.36***	22.55***
df	4	4
Map 32		
χ^2	77.37***	15.85**
df	5	5
Map 34		
χ^2	35.84***	8.74
df	6	6
All Maps		
χ^2	100.59***	3.73
df	6	6

***$p<.005$
**$p<.01$

not on 34 nor for all maps combined. This implies that the gravel placement was not selective for certain vegetation types on Map 34, and that other than for water bodies, no other types were selectively avoided. The chi-square values were adjusted to exclude water, as roads and pads are generally built to avoid water bodies (although this does not appear to be the case on Map 32. See Fig. 17, Vegetation types covered by gravel 1983 - Map 32).

DISCUSSION

The maps and tabular summaries presented in this report describe the growth of the Prudhoe Bay Oil Field. The maps prepared from the 1:24,000-scale data base portray the growth of the entire field, while the data from the IGHDMs give more detailed information for three of the most intensely developed areas within the field. In particular, the IGHDMs portray how the development impacted the natural geobotanical features of these areas.

Historical Development of the Prudhoe Bay Oil Field

The history of development in the Prudhoe Bay region was strongly controlled by industrial decisions regarding how to best tap the oil reservoirs. A full discussion of these decisions and the political climate that helped to pace the development are beyond the scope of this report. Here we are concerned only with the history of the anthropogenic changes to the landscape. However, we write this with the hope that it will later be connected to the history of exploration, political decisions, past construction practices, and environmental regulations in the region.

Overview of Major Construction Activities

In 1968 the only permanent structures in the region were the DEW Line facility at Point Storkerson, a small airstrip and camp built by Arco near the Sagavanirktok River, and a peat road to an exploration well (Fig. 4).

By 1970 (Fig. 5), after the confirmation of a major oil field, most oilfield equipment arrived via air at the Arco Camp and at three new airstrips, the principal one at Deadhorse, one near the Putuligayuk River and another on the Kuparuk River floodplain. Equipment also arrived during the summer at a temporary port facility at East Dock. The Spine Road was built as the major road through the oil field from East Dock to the Kuparuk River. On the west side of the Kuparuk River there was a small road system, which was isolated from the rest of the field during the summer. Along the Spine Road there were already numerous access roads to drill sites and camp facilities. One access road went to a gravel mine on an oxbow of the Putuligayuk River and the British Petroleum (BP) discovery well. Other gravel mines were in the active floodplain of the Sagavanirktok River and a dead channel of the Kuparuk River. Service facilities on the west side of the field were mainly those at Service City and Frontier Camp. The center of service activities for most of the field was established on the east side of the field, just north of the Deadhorse airstrip. There were also a few peat roads that preceded the gravel road network. One paralleled the Spine Road to the south and another connected the Arco base camp with Point Storkerson. Numerous other trails connected the more remote drill sites.

In 1973 (Fig. 6), drilling was proceeding at numerous new drill sites, and the oil-field pipeline network was under construction including several gathering centers and flow stations. British Petroleum had built the pad for its base camp facility near Big Lake, and gravel mining had impacted large areas of the three principal rivers in the oil field.

By 1977 (Fig. 7), the trans-Alaska pipeline was in place, and oil was being pumped through Pump Station 1, which was built on an artificially-drained lake basin. Numerous new drill sites had been built and old ones had been expanded, particularly on the Arco side of the field. There was also a major expansion of the Deadhorse airport facilities. A bridge now spanned the Sagavanirktok River, linking several drill sites in the Sagavanirktok floodplain to the rest of the oil field. The gravel mining operations on the Putuligayuk and Kuparuk rivers had expanded dramatically to meet the need for the pad additions throughout the oil field. The road network had expanded with a new gas pipeline road between C Pad and the Central Compression Plant (CCP), and a new coastal road to the West Dock. And a new highway, the pipeline haul road (which eventually was named the Dalton Highway), linked Prudhoe Bay to the outside world.

By 1980 (Fig. 8), the complexity of the road network had increased with the addition of several new pads (e.g. K, N, Q, R, X, and Y pads, and Drill Sites 7, 12, 16, and 17). These facilities plus major expansion of most other drill pads required enormous volumes of gravel from the open pit mines in the river systems. To the west, the Kuparuk Oil Field was beginning to expand in a manner very similar to that of the Prudhoe Bay field and the two were now linked by a bridge across the Kuparuk River.

1983 was the last year of this historical analysis (Fig. 9), and the oil field continued to grow with several major construction projects including the Waterflood project and the oil pipeline linking the Kuparuk field to the trans-Alaska pipeline. The West Dock facilities were now complete and the West Road linked the West Dock to E Pad and the west side of the oil field. New pads included S and T pads, Drill Sites 15 and 18, and major expansion of the service facilities in the Deadhorse vicinity.

Analysis of Area Covered by Major Impacts

The area covered by roads and pads increased in a linear fashion throughout the study period, closely following the regression equations in Fig. 11. By 1983, over 2100 ha of tundra were covered by roads and pads and there were about 350 km of road within the oil field. In the later years of the study, most of the new road construction was for secondary roads and pipeline construction roads, which carry considerably less traffic than the Spine Road or roads in the main service area near Deadhorse. Most secondary roads have less roadside impacts from dust, construction debris and off-road-vehicle trails, but flooding is a major problem with all roads in the field. Flooding was the only indirect impact that we could map at the 1:24,000 scale, and we found that approximately 1400 ha had been flooded due to construction. In summary, a total of about 21 km^2 have been completely covered by either roads or pads, and another 14 km^2 have been flooded.

Detailed Analysis of Three Heavily Impacted Areas

The following discussion examines the geobotanical character and the history of natural and anthropogenic impacts for the three areas covered by the IGHDMs.

Geobotanical Character of the Mapped Areas Prior to Development

The three maps could all be primarily characterized as 'wet tundra' prior to development. However, the details of the distribution of the natural geobotanical features varied considerably between the maps (Fig. 12). Map 22 was, by far, the wettest with over 38% of the map covered by open-water lakes and ponds and another 24% covered by aquatic vegetation. Maps 32 and 34 had less open water than Map 22 (14% and 24% respectively) and considerably less aquatic vegetation (7.5% and 12% respectively). Only 14% of Map 22 was relatively well drained (either moist or dry vegetation types). This compares with about 23% on Map 32 and 19% on Map 34, or about 19% for all maps combined.

The distributions of landscape units, landforms, and surface forms were also markedly different for the three maps. Map 22 was entirely within a 'flat thaw-lake plain' landscape unit with 39% percent cover of lakes, 38% cover of drained lake basins, and only 21% cover of the area outside of lake basins. The dominant surface form on Map 22 was 'strangmoor or disjunct polygon rims' (32% of the map).

Map 32 was bisected by the Putuligayuk River and consequently had a large portion (34%) covered by 'floodplains and terraces'. However, most of this was not an active floodplain, but part of an old alluvial surface dominated by oxbow lakes and terrace features, with no true thaw lakes. Only about 4% of the map was classed as an 'active floodplain'. Field observations in the region of the river that was unimpacted indicate that it was a floristically rich area, as are most gravel-bottomed floodplains in the region (Walker 1985). Map 32 had the least number of lakes of the three maps (16%) and the most area classed as 'inter-thaw-lakes' [i.e. areas apparently unaffected by thaw-lake processes (37%)]. The surface forms on this map were primarily 'strangmoor or disjunct polygon rims' (27%), 'low-centered polygons' (19%), and 'non-patterned' (19%). Much of the map area was also covered by 'frost scars' (14%), which were concentrated along the terraces of the Putuligayuk River

Map 34 had about 10% active floodplain of the Sagavanirktok River. The remainder was a 'flat thaw-lake plain' with 21% cover of lakes, 35% cover of 'drained lake basins', and 34% 'inter-thaw-lakes'. This map had the best developed polygonal features with 28% of the map covered by low-centered polygons; about half of these were polygons with more than 0.5-m relief. Many of these latter polygons were pond complexes with deep water in the polygon basins. These areas are particulary valuable waterfowl and shorebird habitat (Troy 1982). There was also a high percentage of high-centered polygons (9.5% compared to 7.2% on Map 22 and 5.3% on Map 32). Map 34 also had the highest percentage of natural 'thermokarst pits' (17% compared to 6% on Map 22 and 13% on Map 32.

Judging from the base geobotanical information we could have predicted several things about the susceptibility of these areas to impacts. For example, Map 32 was most susceptible to anthropogenic flooding because of its flatness and abundance of drained lake basins. Good construction sites were limited on Map 22 because of the scarcity of moderately drained areas. Maps 32 and 34 had important gravel resources in their floodplains and were likely to be mined; Map 32 was particularly susceptible to damage because of its narrow floodplain and the difficulty of removing gravel without destroying rich bluff and gravel bar habitat. Also, thermokarst was likely to be a major indirect impact on Maps 22 and 34 because of the abundance of naturally occurring thermokarst pits. With good experimental information regarding the sensitivity of certain vegetation and habitat types to disturbance, we could have made very specific predictions regarding the resistance and resilience of the vegetation and wildlife habitats to some of the major disturbances that were likely to affect the region.

Anthropogenic Disturbances

Comparison of the history and types of disturbances on the three IGHDMs. The historical patterns of anthropogenic change are summarized here by comparing three major classes of direct disturbance: roads, pads, and excavations, and two classes of indirect disturbance: flooding and thermokarst (Fig. 14). The specific details of other elements of indirect disturbance (vehicle tracks, construction debris, dust, and other miscellaneous impacts) are not discussed here, but are summarized as total indirect impacts in Fig. 15. The following discussion is based primarily on Figs. 14 and 15 and Table C3, C6, and C9 (see Appendix C).

Roads showed numerous similarities on all three maps. The area covered by gravel and peat roads in 1983 was nearly equal in the three study areas (2.6% on Map 22, 2.5% on Map 32, and 2.8%

on Map 34). However, peat roads occurred only on Maps 32 and 34 and covered 0.1% and 0.6% of the maps respectively. The rate of growth of the road networks leveled off after about 5 years on Maps 22 and 32, but continued to grow at a steady pace on Map 32. Map 32 is the least densely developed area, and several new access roads to pads have been constructed in recent years. This pattern was noted in our earlier paper (Walker et al. 1986) where we commented that in the densely developed portions of the field, most of the roads are in place within a few years, whereas road construction continues in the less developed portions of the field and around the perimeters of the field.

Pads also showed similar patterns of growth on all three maps. For example, all three areas showed a steady increase in pad construction throughout the 15 year period of study with an inflection point at about 5 years with more rapid pad construction in the later years. This point reflects a decision in 1974 to increase the well spacing within the field from 1 well per square mile to 4 wells per square mile, which required much larger drill pads to accomodate the larger number of wells. The total area covered by pads in 1983 is quite similar on Maps 22 and 34, but Map 32 has less than half the pad area of the other two maps (8.1% of map 22, 3.5% of Map 32 and 8.2% of Map 34).

On Map 34, we find an occurrence of pad construction with complete disregard for the landscape whereby a pingo was leveled in order to construct Prime Camp. This was also a site of scientific interest because of the selection of this site by D. Richardson (1974) for monitoring air pollution by the use of lichens.

Excavations occurred on Maps 32 and 34, both of which contain large areas of easily mined gravel on river floodplains. Gravel mining within Map 34 peaked after 5 years. Thereafter, the Sagavanirktok River slowly reclaimed portions that were excavated, and the total area of recognizable mining impact declined somewhat. On Map 32 the entire channel of the Putuligayuk river northeast of the Spine Road has been affected by mining activity. The most intense mining occurred in two oxbows of the river. The total area affected by excavation in 1983 was 4.8% of Map 32 and 7.5% of Map 34.

Flooding was most severe on Map 22, affecting over 22% of the map by 1983. This compared to 4.7% of Map 32 and 3.2% of Map 34. The most severe flooding occurred in drained lake basins on all three maps, particularly in areas that were surrounded by roads or pads. The sudden increase in flooding that occurred in 1983 on Map 22 was due largely to the construction of a new road which totally enclosed a portion of a drained lake basin thereby preventing its drainage. Flooding also increased this year in several other lake basins on the same map. On Map 34, however, there was a decline in flooding during this same year. Flooding showed several declines over the period of study, but there was no consistent pattern of declines that could be easily related to dry summers; the declines are most likely related to a variety of factors including summer precipitation, new culverts, and the timing of the aerial photographs (i.e. early vs. late July).

On Map 32, we find an occurrence of the opposite impact of flooding where a large lake was drained for the construction of Pump Station 1. This resulted in an interesting indirect impact whereby a small area downwind of the drained lake was subsequently covered with windblown lake sediments. This phenomenon is also common along the shores of naturally drained lake basins, and we could expect much larger areas to be affected by eolian materials if large lakes are drained in the future. The lake basin should now be protected as a dated site on which to study natural succession in a drained thaw lake.

Thermokarst affected about 3.7% of Map 22, 1.1% of Map 32, and 2.2% of Map 34. The amount of thermokarst actually just exceeds the area covered by roads on Maps 22 and 34, but is considerably less than road-covered areas on Map 32. In Fig. 14, the graphs of thermokarst for Maps 32 and 34 nearly parallel those of pad growth, and on Map 22 thermokarst follows that of road growth. Thus, we might conclude that the rate of growth of thermokarst closely follows that of gravel placement. However, the occurrence of thermokarst is a delayed reaction. We have noted that there has been a noticeable increase in the amount and severity of thermokarst along some of the older roads during the last few years. This is evident on the anthropogenic disturbance maps of all three study areas. In many areas along the Spine Road, thermokarst was not mapped during the early years of the study but occurs in the later years (For example, compare the anthropogenic disturbance near the Spine Road on Map 22 in 1979 and 1983, Appendix B, Figs. B21 and B23). One problem with following thermokarst through time on the IGHDMs is that many of the areas with thermokarst eventually become completely flooded, and thus the anthropogenic disturbance code may change. Also, thermokarst can be masked during times of exceptionally high flooding.

In our earlier report (Walker et al. 1986), we suggested that thermokarst is an example of a synergistic impact and is increasing due to a combination of the effects of road dust, impoundments, and other sources of heat within the oil field. This conclusion is based on close examination of numerous small mapped areas along the Spine Road. There is generally a delay between the construction of a road or pad and the onset of widespread thermokarst around the feature. The thermal effects are most noticeable where there is a combination of disturbance factors such as large amounts of road dust, flooding, or heat from flaring operations. At present, it is unlikely that the existence of the oil field would lead to widespread thermal disintegration of the landscape; however, we cannot rule out the possibility that heat generated by the field operations combined with climatic warming could lead to a regional thawing of ground ice. Thermokarst is an example of a cumulative effect that should be closely watched. Methods of reducing thermokarst along roads should be examined including the use of desiccants to decrease road dust.

Comparison of disturbances among landscape units. Excavations totally dominated the anthropogenic disturbances within the 'floodplains and terraces' landscape unit (Fig. 15) accounting for about 83% of the total disturbance. It is also interesting that there was no anthropogenic thermokarst within the floodplain landscape unit. This is likely a function of the low ground-ice volumes in this unit.

Within the 'flat thaw-lake plains' unit, flooding exceeded all other forms of disturbance and in 1983 covered about 11% of the total mapped area of this landscape unit. The sudden increase in 1983 was due to the very large increase on Map 22. Pads showed a steady increase with the major inflection point at 5 years as noted previously, and in 1983 covered about 9% of the mapped unit. Roads followed a saturation curve, leveling off at about 130 ha or about 2.7% of the mapped unit. Thermokarst showed a major inflection point at about 9 years, which may be related to the synergistic effects that we noted above. In 1983, anthropogenic thermokarst covered about 1.7% of the mapped flat thaw-lake plains.

Comparison of direct vs. indirect impacts. We consider direct impacts to be those that are planned and include pads, roads, and excavations. Indirect impacts are a result of the direct impacts and are often not easily predictable. Indirect impacts in this study included flooding, thermokarst, construction debris, vehicle trails, road dust, and other miscellaneous impacts. The relative importance of these two classes of impact varied between maps (Fig. 16). On Map 22 indirect impacts covered more than twice the area of direct impacts; whereas on Map the 34 the opposite pattern occurred, and on Map 32 the two classes were quite close throughout the period of study. Within this study, the relative importance of indirect impacts was heavily weighted by anthropogenic flooding.

Comparison of natural vs. anthropogenic disturbances. The coastal plain is a relatively active region of geomorphic activity. Thaw lakes are constantly forming and draining, coastal shore erosion is rapid, and braided rivers regularly change their channels. These actions are at a scale large enough to map within the time period of this study. Other natural disturbances such as those of wildlife, frost activity, succession related to climatic change, and development of natural thermokarst occur at much larger scales or over longer time periods and could not be detected within this project.

Here we consider only the effects of the thaw-lake cycle. River channel changes were also evident in this study (see Appendix B, Fig. B67 for map of historical changes to the channels of the Sagavanirktok River on Map 34), but natural channel changes could not be separated from those related to gravel mining in the rivers.

Thaw-lake erosion was most evident on Map 22 (Fig. B25) where over 8 ha were affected by either thaw-lake expansion or drainage between 1949 and 1983. Most of this activity occurred along the shoreline of Big Lake. This is clearly minor in comparison to the anthropogenic disturbances in the region. On this same map, there were 746 ha of anthropogenic disturbance which occurred in a shorter time period from 1968 to 1983.

The natural disturbance data also lend some insight to the time periods required to completely alter the tundra surface by thaw-lake processes. The erosion of lake shorelines on Map 22 has taken place at a remarkably constant rate during the period of 1949-1983 (Fig. 18). 0.38% of the map area has been affected within the 34 years of the study. If we assume the same rate of erosion occurs over much longer time periods and extrapolate the present rate over a period of time sufficient to erode the entire area of the map (20.8 km^2), it will take approximately 11,000 years to disturb the entire map surface by thaw lake processes. This figure would, of course, vary depending on the climate, size of lakes and the substrate characteristics. Even within the Prudhoe Bay field, there appears to be considerable difference between erosion rates in the eastern and western portions of the field. There was less area affected by thaw-lake processes on Maps 32 (0.8 ha) and 34 (0.14 ha), probably because of the slower lake erosion that is associated with smaller lakes and perhaps more stable inter-thaw-lake areas due to larger grain size of eolian materials from the Sagavanirktok River (Walker 1985).

SUMMARY AND CONCLUSIONS

Geobotanical Character of the Oil Field Before Development

The basic geobotany of the region has been described in other reports (Walker et al. 1980, Walker and Acevedo, in press). What we are concerned with here is the previous nature of the terrain that now is covered by gravel pads, roads, and impoundments. Large areas have been so altered by the presence of the oil field that it is difficult in many instances to determine, on the basis of the present day landscape, what previously existed. By using the historical record of aerial photographs and GIS technology, we can, in essence, strip away the development to see the original landscape. This is perhaps best illustrated with the color maps in Appendix B (Figs. B1 to B6) that depict the vegetation in 1949 prior to development and then again in 1983 with the anthropogenic changes.

In our comparison of the geobotany of the three intensively developed areas, we found that there were basic characteristics of the sites that foretold the types of impacts that were likely to occur during development. For example, on Map 22, we could see from the vegetation and landform maps that

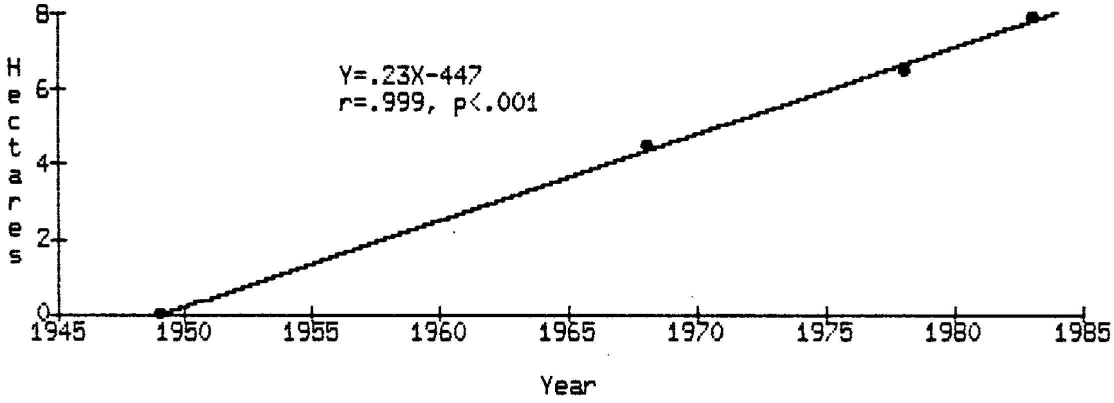


Fig. 18. Historical natural lake bank erosion on Map 22.

this area was exceptionally wet, with numerous drained thaw-lake basins, and valuable waterfowl habitat. Flooding was likely to be a major problem. The cobweb of roads that eventually formed here prevented proper management of the drainage through these wetlands. We also saw that anthropogenic thermokarst occurred primarily in areas that were already marked by natural thermokarst pits.

If the geobotanical mapping methods had been available and used prior to development, a thorough ecological reconnaissance and mapping of the region would have noted sites of exceptional ecological quality. Areas of high wildlife value such as the well-developed polygon complexes on Map 34, pingos, and riparian habitat could have been treated as special no-impact zones, and tragedies such as the total elimination of the Putuligayuk River floodplain and the leveling of the pingo near Arco Base Camp could have been prevented.

Growth of the Oil Field

The Prudhoe Bay Oil Field has completely altered the terrain north of Deadhorse between the Sagavanirktok and Kuparuk rivers within 15 years. By 1983, the field occupied about 500 km^2 with over 350 km of roads, 21 km^2 of tundra covered by gravel, and another 14 km^2 flooded. The pace of development has proceeded at a nearly constant rate throughout the 15 years since discovery of the field. If the same pace continues it will take only about 90 years to completely cover a 10 by 300 km coastal strip from the Colville River to Demarcation Point with oil fields as densely developed as Prudhoe Bay. This, of course, depends on many factors, but it could be a conservative estimate because it assumes that there is only one oil field at a time growing at this pace. Even now, the growth of the road network within the relatively new Kuparuk Oil Field is simultaneously proceeding at a very similar rate as that at Prudhoe Bay, thus doubling the rate of impact.

Indirect vs. Direct Impacts

The total indirect (unplanned) impacts averaged for the three IGHDMs was about equal to the area covered by direct impacts (roads, pads, and excavations). However, in the very wet tundra of Map 22 the indirect impacts were more than double the direct impacts, and on Map 34, where there was a large excavated area and little flooding, the indirect impacts were less than half the direct impacts.

Relationship of Impacts to Vegetation

There was selection for relatively well-drained construction sites on Maps 22 and 32 where roads and pads were routed around many drained lake basins. This selection was strongest on Map 22 where there was a scarcity of suitable construction sites. On Map 34, which was not nearly as wet, there was no statistically significant difference between the natural distribution of vegetation types and the distribution of types covered by gravel. This interesting result indicates that the moist sites are most likely to be selected for construction where they are relatively rare. The wettest areas are often highly heterogeneous with high biotic diversity as is the case in most areas with complex landscapes and large amounts of habitat edges (Forman and Godron 1986). In these areas, moist and dry sites are rare and are valuable waterbird habitat (Troy and Burgess 1983). If these complex wetlands are developed, the moist and dry sites are likely to be selected for roads and pads.

The distribution of flooded vegetation types was, as expected, different from the natural distribution of vegetation types on all maps. Flooding was confined mainly to lake basins and wet or aquatic vegetation types, although about 8% of the total flooding did occur in moist or dry vegetation types. A more thorough analysis of this sort could produce "susceptibility to disturbance" indices for the most common disturbance and vegetation combinations.

Relationship of Impacts to Landscape Units

Landscape units are logical ecological units that, to a large degree, define the regional distribution of plants and wildlife. Some landscape units have special qualities that make them more susceptible to certain types of impact. In this analysis we could compare only two landscape units, and it was clear that the distribution of impacts on the 'flat thaw-lake plains' unit was distinctly different from the impacts in the 'floodplains and terraces' unit. We would expect the floodplains to be more susceptible to excavations (unless regulations prevent mining of narrow riparian ecosystems) and less likely to have pads constructed on them. We might also anticipate less drainage problems in floodplains. Thermokarst is less likely on floodplains because of low ground ice volumes in these relatively new landscape units (Lawson 1986).

Natural Disturbance Rates

We determined the rates of natural disturbance for only the 'flat thaw-lake plain' landscape unit because of the anthropogenically altered channel patterns in the floodplains. We found that the amount of thaw-lake disturbance varied considerably between different areas, and that erosion was greatest around the margins of the larger lakes. Our erosion data from Map 22 indicate a landscape turnover period of about 11,000 years for this site assuming the present constant rate of erosion for the entire period.

Synergistic Impacts

Thermokarst is an example of a synergistic impact that is increasing at a more rapid rate now than during the early years of the oil field. Field observations and detailed examination of the maps show many areas where thermokarst was absent during early years of the study but appeared recently, particularly in heavily dusted areas along roads, flooded areas, and near flaring facilities. Some thermokarst areas eventually become completely flooded, and their classification on the IGHDM consequently changes. Thermokarst is also often masked by flooding; so the true extent of thermokarst may be greater than portrayed on the maps.

Major Accomplishments of the Project

The mapping program for the Prudhoe Bay field has made several important contributions toward the problem of cumulative impacts in northern Alaska. It has resulted in an approach that is useful for long-term monitoring of oil field growth and impacts that can be related to the natural geobotanical character of the landscape. Although a few types of small impacts were not mapped for this project (e.g. narrow linear features such as power lines, off-road vehicle trails, and fences), the scale of the IGHDM method (1:6000) is a practical one that utilizes the topographic maps which are produced by the oil industry for their field operations. The method could also prove useful in the planning process for new developments. The automated mapping methods lend themselves well to creative planning, whereby roads, pads, and even anticipated indirect impacts, can be overlain against the background of the natural terrain. The procedures are appropriate for analysis of high-impact projects that cover relatively small areas. For very large projects such as long utility corridors or a comprehensive plan for the entire North Slope, the IGHDM methods could be integrated into planning procedures at smaller scales. Planning at this scale would require different data bases such as Landsat-derived classifications (e.g. Walker et al. 1982, Walker and Acevedo, in press) and small-scale GIS data bases.

The legends used for mapping are sufficient for most types of terrain that are likely to be encountered on the coastal plain. The process of creating the geobotanical overlays is now sufficiently routine that a team of trained botanists and photointerpreters could reasonably map even a very large development area within a few months if they were given good aerial photographs, proper training in the methods, and time to obtain the necessary ground truth. It should be noted, however, that this mapping program has been conducted in an area with a large base of geobotanical knowledge, and caution should be applied in extrapolating the legends to new areas.

The analysis we have conducted here could be utilized in an extrapolative analysis to predict cumulative landscape impacts for future oil fields. Such an approach would likely find that within 50 years most of the North Slope coastal plain would be affected by road networks and pipeline systems. Holistic planning on the North Slope must involve much more than extrapolation from the present to some time when the entire ecosystem breaks down. It should also include a practical compromise that permits resource development for a well-developed economy while preserving as much of the natural environment of northern Alaska as possible. This is a process that Horak et al. (1983) term a 'normative' or 'teleological' approach to cumulative impact analysis. It requires "a vision of preferred futures" and a conscious movement in the planning process toward this ideal (Horak et al. 1983).

This project has established an invaluable data base for a long-term cumulative impact experiment using the Prudhoe Bay Oil Field. A recent examination of a variety of long-term ecological studies noted:

> There is a whole class of whole-ecosystem manipulations that ecosystem scientists have not begun to exploit. These manipulations can be classed broadly as real-world ecosystem management, and include, for instance, management of timber plantations, liming of lakes, exploitation or manipulation of fisheries, and even routine development of land for human use. These are ecosystem-level manipulations, and someone else is paying the bill. Furthermore, these ecosystem manipulations are important in themselves, since they are being done on large parts of the earth. We believe that poor communication and adversial attitude between ecologists and the people who do these manipulations have blocked the use of such manipulations for research. We strongly encourage ecosystem ecologists to try to integrate themselves into the design and execution of these manipulations. Although management schemes may rarely approach the ideal of controlled ecosystem experimentation, they should allow ecosystem scientists to collect experimental data in quantities and on scales that are economically infeasible in the traditional research environment (Strayer et al. 1986).

The Prudhoe Bay Oil Field offers a unique opportunity to examine and fully document modern man's alteration of a natural arctic landscape. Hopefully, such documentation will help to shape the course of development so as not to cause catastrophic consequences to either the landscape or the wildlife.

RECOMMENDATIONS

We have several recommendations related to planning and management that are based on the results of this report:

1. The IGHDM techniques are an appropriate planning tool that should be used to identify areas that require special planning or that should be avoided. Complex wetlands and other highly heterogeneous areas such as narrow floodplains, coastal areas, and pingos are areas of high biotic diversity that demand special attention, and development in these areas should be avoided if at all possible.
2. If development in complex wetlands is unavoidable, then

special attention should be paid to avoid flooding large drained thaw-lake basins. Placing too many culverts would be preferable to destroying valuable waterfowl habitat. Relatively well-drained areas within wetlands, such as high-centered polygon complexes and mixed high- and low-centered polygon complexes are particularly valuable to waterbirds and pose other problems for development in these areas because these sites are likely to be selected for construction.

3. Mining in floodplains may be appropriate in areas that have extensive unvegetated gravel resources that are not bounded by valuable wildlife habitat. If properly planned these areas are likely to be rehabilitated naturally by the large rivers. There are, however, very few rivers where such mining could be conducted without extensive damage to adjacent riparian habitat. Mining in narrow floodplains is likely to completely destroy the riparian ecosystem.

4. Special attention needs to be paid to the spread of thermokarst along roads and near impoundments. The control of road dust by desiccants may be appropriate on roads with high volumes of traffic. Controls of flooding would also help control the spread of thermokarst in many areas.

We also have three recommendations related to follow-up of this research:

1. The monitoring of the Prudhoe Bay Oil Field should be continued using both the 1:24,000-scale maps and the IGHDM methods. A three year monitoring interval is appropriate.

2. New developments in other landscape units should be monitored using the same techniques. Sites in the 'gently rolling thaw-lake plains' and the Colville River delta are high priority areas for similar analyses.

3. 1986 is the planned year for the completion of the Prudhoe Bay Oil Field and marks an appropriate time to produce an atlas that traces the history of the development of the first large industrial complex in the North American Arctic. Such an atlas should include the maps and analyses of this report plus the updated information for 1986. These data should be linked to the history of exploration, political decisions, past construction practices and environmental regulations that shaped the present-day landscape.

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The opinions and conclusions presented in this report are

those of the authors and do not reflect policies of the USFWS or EPA. This project was part of a FWS goal to develop a guidance manual for cumulative impacts. Rosa Meehan of USFWS is in charge of writing a manual for evaluation and mitigation of oil development impacts. She obtained much of the aerial photography and was a valuable source of information for this project, playing a large role in a number of aspects of this document.

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APPENDICES

Appendix A.	"Use of Geobotanical Maps and Automated Mapping Techniques to Examine Cumulative Impacts in the the Prudhoe Bay Oil Field, Alaska." Reprint of paper published in <u>Environmental Conservation</u>, 1986, Vol. 13, pp. 149-160.
Appendix B.	Computer-drawn geobotanical and disturbance maps
Appendix C.	Area summaries for geobotanical and disturbance data

APPENDIX A

Use of Geobotanical Maps and Automated Mapping Techniques to Examine Cumulative Impacts in the Prudhoe Bay Oilfield, Alaska

by

DONALD A. WALKER, M.A., Ph.D.(Colorado)
Research Associate, Institute of Arctic & Alpine Research,
University of Colorado, Boulder, Colorado 80309,
PATRICK J. WEBBER, M.Sc., Ph.D.(Queen's, Canada)
Professor, Institute of Arctic & Alpine Research and Department of
Environmental, Population & Organismic Biology,
University of Colorado, Boulder, Colorado 80309,
MARILYN D. WALKER, M.A.(Colorado)
Graduate Research Assistant, Institute of Arctic & Alpine Research and
Department of Environmental, Population & Organismic Biology,
University of Colorado, Boulder, Colorado 80309,
NANCY D. LEDERER
Professional Research Assistant, Institute of Arctic & Alpine Research,
University of Colorado, Boulder, Colorado 80309,
ROSA H. MEEHAN, M.S.(Alaska)
Graduate Research Assistant, Institute of Arctic & Alpine Research and
Department of Environmental, Population & Organismic Biology,
University of Colorado, Boulder, Colorado 80309;
also *U.S. Fish and Wildlife Service, Special Studies, 1011 E. Tudor Avenue,*
Anchorage, Alaska 99503,
&
EARL A. NORDSTRAND, M.A.(Minnesota)
North Slope Borough GIS, 508 W. 2nd Street, Room 310, Anchorage, Alaska 99501, USA.

INTRODUCTION

Importance of Cumulative Impact Research in the Arctic

In the past 20 years, great strides have been made in the understanding and protection of arctic ecosystems, but the rate, extent, and intensity, of development on the Arctic Coastal Plain of Alaska is so unprecedented that grave loss of regional environmental quality and habitat, wildlife, and subsistence values, is certain unless steps are taken to avoid such consequences. Those steps should include continued ecological research, improved engineering methods, revised regulatory policies, and better-than-formerly management implementation. The study of cumulative impacts on terrestrial ecosystems is a leading aspect of the required ecological research.

Cumulative impacts are defined here as the total current and future interactive impacts on fish and wildlife populations and habitats (Horak *et al.*, 1983). Although environmental legislation in the United States requires evaluation of cumulative impacts (Council on Environmental Quality, 1978), very few US environmental impact statements treat the problem adequately, because agreed methods and a comprehensive approach to address it are largely lacking. Most evaluations and reviews only address impacts in generalities, because the details of subsequent development are not precisely known, and hence associated impacts are difficult to predict. Such evaluations usually fail to consider indirect or induced effects which may occur even years after the direct disturbance.

The first step towards predicting the future effects of development must be based on our knowledge of what has already occurred. One approach is through the development of models which depend on determination of the rate and extent of the impacts that have already occurred, and analysis of the effects of such impacts on various components of the immediate ecosystem. The present paper analyses past physical disturbances in the Prudhoe Bay region. Recent advances in computerized cartography and geographic information systems (GISs) lend themselves well to such 'historical' studies of changes in terrain. This analysis combines detailed geobotanical mapping 'legends' that have been developed for the Prudhoe Bay region (Walker *et al.*, 1980) with automated mapping techniques.

The Prudhoe Bay region of northern Alaska (Fig. 1) is the site of the largest oilfield in the United States. This field, which now covers an area of approximately 300 km^2, has been developed entirely within the past 16 years on a remote arctic site that, prior to development, was virtually unknown except to the native Inuit (Eskimo) population. The oilfield now consists of a vast network of roads and

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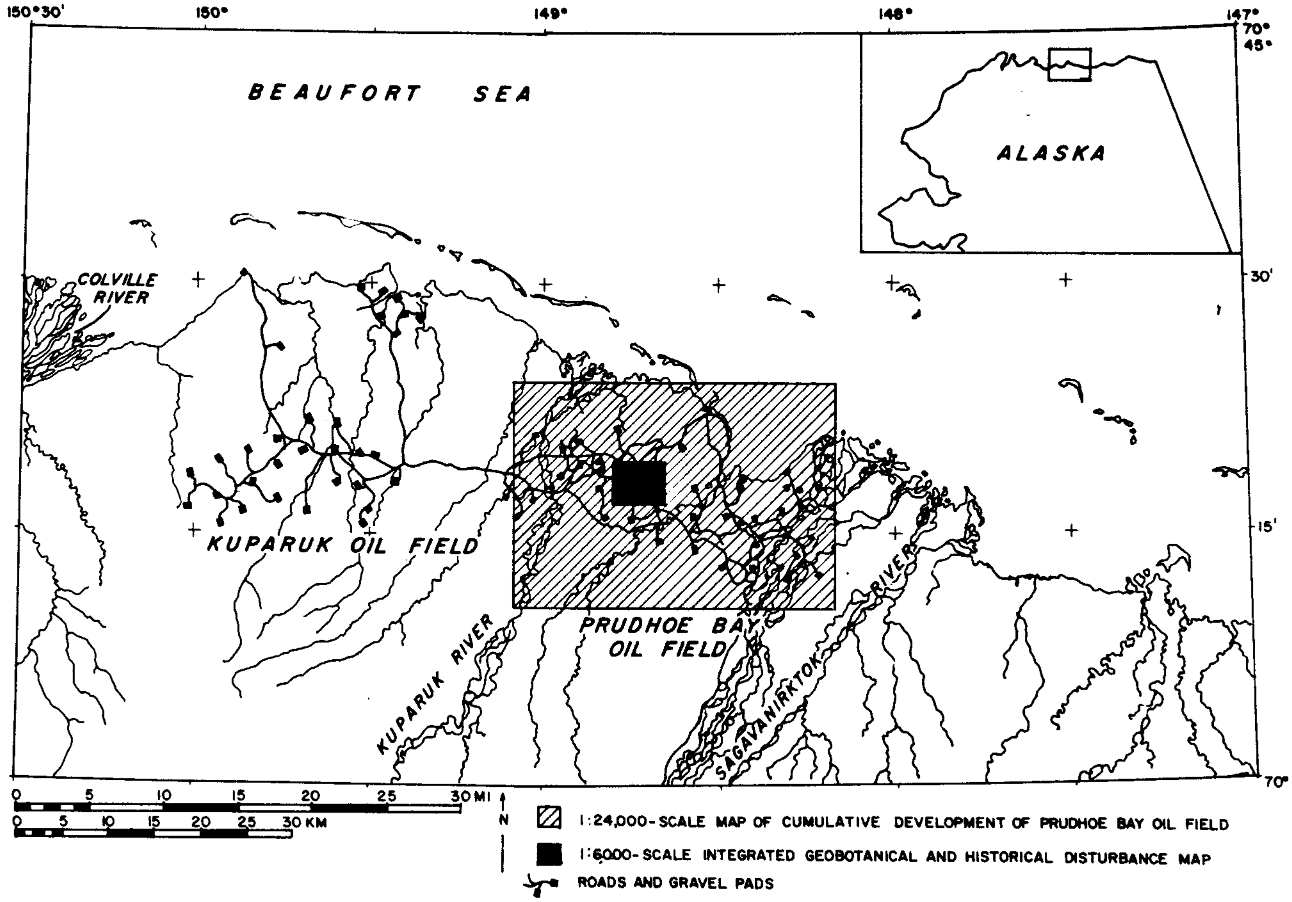

FIG. 1. *Location of the map areas within the Prudhoe Bay region, Alaska, USA.*

pipelines that connect oil-wells and other facilities within the field. Two airports and numerous other facilities support many contractors and the two principal developers of the field, Arco Oil & Gas Company and Sohio Alaska Petroleum Company. The Dalton Highway parallels the trans-Alaska pipeline system and links Prudhoe Bay to Fairbanks, providing road access to this area which was previously accessible only by 'bush plane' or boat.

Development of the field has occurred at an extraordinary pace, and similar development is likely to occur in nearby areas where oil has recently been discovered. This is of particular concern to those natives who rely on the wildlife of the Alaskan Arctic Coastal Plain for subsistence. Various government agencies oversee development in areas of valuable national wildlife resources. The Environmental Protection Agency and the US Army Corps of Engineers are chiefly responsible for environmental regulatory surveillance of such wetland regions and, through the US Fish and Wildlife Service, have encouraged research regarding regional cumulative impacts.

Suitability of the Prudhoe Bay Data-set for Cumulative Impact Analysis

The Prudhoe Bay region is particularly well suited for the application of GIS technology to the problem of cumulative impact. The North Slope Borough, which is the local government authority, has made a long-term commitment to develop a geographic information system that will include the 'historical' development of the land. They have purchased a state-of-the-art GIS facility and data-base developed by the Environmental Systems Research Institute, of Redlands, California. The data-base of the system includes extensive and detailed terrain mapping capability at three scales: 1:250,000, 1:63,360, and 1:6,000. Most of the North Slope Borough (an area of about 225,000 km^2, or slightly smaller than Great Britain), is mapped at the 1:250,000 scale for soils, vegetation, geology, and several other terrain features. Smaller areas of specific interest are mapped at the larger scales. The 1:6,000 scale is most appropriate for analysing many of the terrain impacts related to development.

The landscape of the region is well known because of a heritage of geobotanical research that began in 1972 with the selection of Prudhoe Bay as a study area for the International Biological Programme (IBP) (Webber & Ives, 1978; Walker *et al.*, 1980). The IBP research included an extensive mapping programme which has continued up to the present with funding from many additional sources—including the oil industry, Cold Regions Research and Engineering Laboratory (CRREL) of the US Army Corps of Engineers, US Geological Survey (USGS), US Fish and Wildlife Service, and the North Slope Borough.

The Prudhoe Bay region may be the only large industrial complex in the world where the complete history of development can be traced in detail with the help of an excellent aerial-photographic record (Table I). The record began with US military photo flights in 1948, 1949, and 1955, that

TABLE I

Aerial Photographs used for 'Historical' Disturbance Mapping.

Date	*Source**	*Scale*	*Type†*	*Quality*	*Any Disturbances Visible*
?/7/49	US Navy	1:24,000	BW	Excellent	No disturbance
28/7/68	Arco	1:12,000	TC	Very good to excellent	No disturbance
26/6/70	US Geological Survey	1:76,000	BW	Excellent	Roads, gravel pads**, large flooded areas
15/7/72	CRREL	1:3,000	BW	Excellent	All types of disturbance are easily visible
15/7/72	US-IBP Tundra Biome	1:24,000	BW	Excellent	Roads, gravel pads**, flooding, debris >50 ft (15.2 m), excavations
26/7/73	Sohio	1:6,000	BW	Variable, somewhat fuzzy to very sharp	All types of disturbance are visible
26/7/73	Sohio (US-IBP study)	1:18,000	BW	Good—not crisp	Roads, gravel pads**, trails, flooding, thermokarst‡, debris
27/6/74	NASA U2	1:120,000	CIR	Very good	Roads, gravel pads**, major flooding
17/7/77	NASA U2	1:120,000	CIR	Very good	Roads, major flooding, gravel pads** are visible but may be difficult to map
24/7/77	Prudhoe Bay Unit	1:18,000	BW	Good—not crisp in all areas	All types of disturbance visible but vehicle tracks; some long strips next to roads difficult to map
13/7/79	Prudhoe Bay Unit	1:18,000	TC	Excellent	All types of disturbance are visible, but linear features associated with roads (i.e. debris) difficult to map
17/7/80	Prudhoe Bay Unit	1:18,000	TC	Very good—not crisp in some areas	*Idem*
23/7/81	Prudhoe Bay Unit	1:18,000	TC	Very good—not crisp in some areas	*Idem*
?/7/82	NASA	1:60,000	CIR	Excellent	Roads, gravel pads**, major flooding, large areas of debris
4/7/83	Prudhoe Bay Unit	1:18,000	TC	Excellent	All types of disturbance are visible; debris associated with roads may be difficult to map

* Identities indicated in Introduction except for US-IBP = US International Biological Program, and NASA = National Aeronautic and Space Administration.

† Film types: TC = true colour; BW = black and white; CIR = colour infrared.

** Gravel pads are areas where gravel has been laid to depths of 2 m or more and compacted for the purpose of establishing a firm base for construction of oil drilling rigs, airstrips, and other oilfield facilities. These are constructed to prevent subsidence of the terrain in this marshy permafrost region.

‡ *See* footnote to this page. — Ed.

show the region prior to any development. In addition, aerial photographs have been taken of the Prudhoe Bay oilfield by the oil industry almost yearly during its development from 1968 to 1983. This series of photographs displays the rapid transformation of the Prudhoe Bay region from a remote undeveloped wilderness in 1949 to the most-developed area in the North American Arctic by 1983.

Objectives of the Study

This study had two major objectives. The first was to map the general sequence of development of the entire oilfield at a scale of 1:24,000 and to analyse the map data for trends regarding the rate of growth of the road system, gravel placement, and artificial impoundments. The second objective was to select an area of intense development for a more comprehensive analysis at the 1:6,000 scale. This included the production of a map showing geobotanical features as well as the progression of 'historical' anthropogenic and natural disturbances, anthropogenic disturbance being defined as any change to the landscape due to human activity.

This map, termed an Integrated Geobotanical and Historical Disturbance Map (IGHDM), permitted a detailed time-series analysis of areas covered by natural and anthropogenic disturbances. The anthropogenic disturbances included direct impacts—such as roads and gravel pads—and indirect effects, such as dust-covered areas, construction debris, flooding, and thermokarst.* The map was constructed on a geobotanical base that depicted the terrain prior to any anthropogenic disturbance, thus permitting an analysis of the distribution of geobotanical features affected by each type of disturbance. The methods of making

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* Defined as 'topographic depressions resulting from thawing of ground-ice' (cf. page 158).—Ed.

an IGHDM were developed during this study. Only one map has been analysed at this point, but others are planned in order to compare development within different parts of the oilfield. Analysis of the map data gives insight regarding the patterns and rates of development, and also yields data on the amount that each geobotanical feature has been affected by the various types of impacts.

METHODS

Map of Cumulative Development of the Prudhoe Bay Oilfield (1:24,000 scale)

A map depicting the 'historical' development of the Prudhoe Bay oilfield was prepared directly on the 1970 USGS orthophoto topographic maps (1:24,000-scale series), namely sheets B-4NE, B-3NW, B-4SE, B-3SW, A-3NW, and A-3NE, of the Beechey Point Quadrangle. (This last is a 1:250,000-scale USGS map defined by the 147° and 150° longitude lines and the 70° and 71° latitude lines [*see* Fig. 1].) Table I gives details of the aerial photographs that were available for mapping the growth of development.

Each photograph was projected onto the orthophoto base-map with an Artograph DB300 projector, and the scale of the photographs was matched exactly to that of the base-map. All roads, airstrips, gravel pads (*see* third footnote to Table I, above), gravel mines, and areas of construction-related flooding, were transferred onto the base-map. The minimum size of a facility or flooded area mapped was 0.60 ha (1.5 acres). All construction appearing in a given year was coded with a colour and an alphabetic code. As photographs were not available for every year, the date given on the map for a constructed facility indicates the first year that it appeared on available photographs—rather than, necessarily, the actual year of its construction.

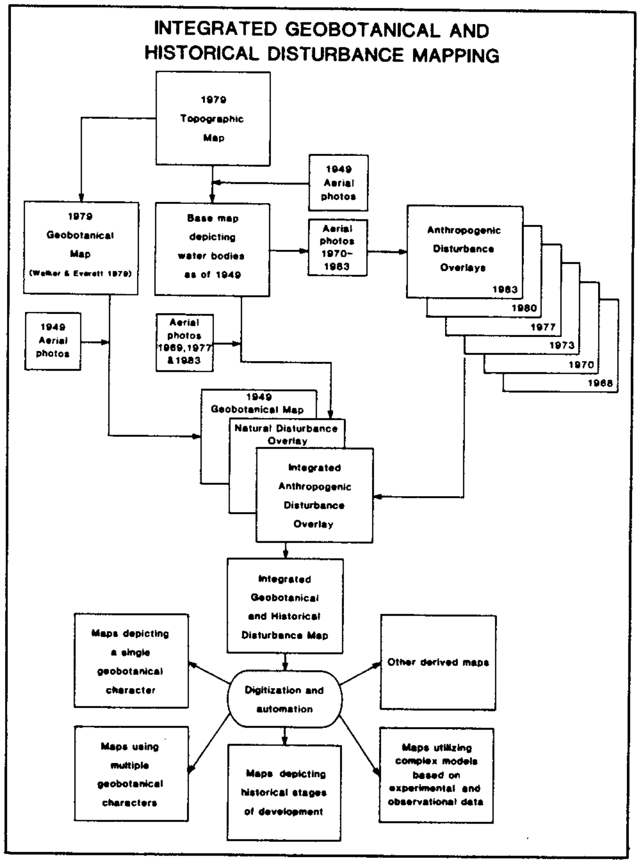

FIG. 2. *Steps involved in production of the 1:6,000-scale integrated geobotanical and historical disturbance map and its derivatives.*

The map was planimetred by hand to obtain areal measurements of gravel pads, airstrips, flooding, and gravel extraction areas, as well as linear measurements of the roads, for each year. Roads were classified as primary roads, secondary roads, Spine Road, and pipeline construction roads. The Spine Road is the major transportation corridor through the oilfield. To determine the total area covered by each type of road, the primary roads and the Spine Road were assumed to have basal widths of 15.2 m (50 ft), and other roads were assumed to be 13.4 m (44 ft) wide. Those are the standard road-widths used within the oilfield. Based on these assumptions, the total area covered by gravel was calculated for each year.

Integrated Geobotanical and 'Historical' Disturbance Map (1:6,000 scale)

The area selected for the IGHDM was Map 22 of a series of 47 topographic maps of the Prudhoe Bay Unit (Air Photo Tech 1979). These maps have a scale of 1:6,000 and a 1.52 m (5 ft) contour interval. Map 22 is of one of the more heavily developed areas within the field, and includes the location of the Sohio Base Operations Camp. The production of the IGHDM involved the prior production of three principal overlays: 1) geobotanical features, 2) natural disturbance, and 3) anthropogenic disturbances, which were integrated together to form the IGHDM (Fig. 2).

Geobotanical maps:—A base-map showing the pre-disturbance shapes of water-bodies was prepared from the 1949 photographs and the 1979 topographic map, and located accurately the positions of lakes and streams. Each photograph was projected onto a mylar (frosted plastic drafting film) surface by means of an Artograph DB300 projector. The geobotanical information included vegetation, soils, landforms, surface forms, and percentage of open water. Much of this information came from an earlier geobotanical map (Everett *et al.*, 1981) and was transferred directly onto the new map, the major exceptions being areas which were significantly changed since 1949. These latter areas were mapped from the 1949 and 1968 aerial photographs. The minimum 'polygon' diameter on this map is 3 mm (≈ 0.15 ha, 0.38 acre). (Map 'polygons' are areas of maps enclosed by line boundaries.) Each such 'polygon' was coded with a nine-parts code in fraction form as follows:

$$\frac{\text{1° vegetation, 2° vegetation, 3° vegetation; percentage of open water}}{\text{landform; 1° surface form, 2° surface form; 1° soil, 2° soil}}$$

In addition to primary (1°) cover types and features, secondary (2°) and tertiary (3°) features were mapped if they covered more than 30% of a given map-polygon. Table II contains the legends for the geobotanical characters. The vegetation legend is a modified version of Level C of the

TABLE II

Geobotanical Codes Used in the Prudhoe Bay Region, Alaska.
(Codes are modified from Walker *et al.* [1980, 1983].)

Code	*Description*
VEGETATION	
1	Water
2	Aquatic grass tundra
3	Aquatic sedge tundra
5	Wet sedge tundra
6	Wet graminoid tundra (saline areas)
9	Moist sedge, dwarf-shrub tundra
10	Moist tussock-sedge, dwarf-shrub tundra
13	Moist or dry dwarf-shrub, fructicose-lichen tundra (snow beds)
16	Moist shrubland (riparian areas)
19	Dry dwarf-shrub, crustose-lichen tundra
21	Dry dwarf-shrub, forb, grass tundra
22	Dry low-shrub, forb, grass tundra
24	Dry forb tundra
26	Dry grassland (dunes)
PERCENTAGE OPEN WATER	
1	0−5%
2	6−30%
3	31−60%
4	61−90%
5	91−100%
LANDFORM	
1	Distinct drained thaw-lake basin, or developing basins in residual surfaces of the coastal plain
2	Basin associated with hilly terrain often with thermokarst features
3	Residual surface (gently rolling thaw-lake plains)
4	Inter-thaw-lake area (gently rolling and flat thaw-lake plains; may include some very old, indistinct thaw-lake basins)
11	Pingo
12	Active braided floodplain
13	Stabilized braided floodplain
14	Meander floodplain
15	Stream drainage
16	Sand dunes
17	Beach
18	Spit
25	Island
51	Lake or pond
52	River or stream
53	Ocean
54	Artificial impoundment

Code	*Description*
SURFACE FORM	
1	High-centred polygons*, centre-trough relief greater than 0.5 m
2	High-centred polygons*, centre-trough relief less than 0.5 m
3	Low-centred polygons*, centre-rim relief greater than 0.5 m
4	Low-centred polygons, centre-rim relief less than 0.5 m
5	Mixed high- and low-centred polygons*
6	Frost scars
7	Strangmoor** and/or discontinuous low-centred polygon rims (generally well-defined features visible on 1:6,000-scale photographs)
8	Hummocky terrain associated with steep slopes
9	Pingo, with undefined or varied surface forms
10	Non-patterned ground or with pattern occupying less than 20% (includes some areas with aligned hummocks that are not visible on photographs)
11	Reticulate pattern
12	Active sand-dune
13	Active floodplain alluvium
14	Thermokarst pits (density greater than 4 pits per 1 cm circle on 1:6,000-scale photograph)
21	Water
SOIL**	
1	Pergelic Cryoborolls
2	Pergelic Cryaquolls or Cryosaprists
3	Complex of: *a)* Pergelic Cryohemists or Cryofibrists *b)* Histic Pergelic Cryaquepts *c)* Pergelic Cryaquepts
4	Association of: *a)* Pergelic Cryohemists or Cryofibrists or Histic Pergelic Cryaquepts *b)* Pergelic Cryosaprists or Cryaquolls
5	Association of: *a)* Pergelic Cryaquolls or Cryosaprists *b)* Pergelic Cryaquepts
6	Pergelic Cryorthents
7	Pergelic Cryopsamments
8	Pergelic Cryaquepts
9	Soil covered by a thin layer of wind-blown sand
10	No soil

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* Ice-wedge polygons have two basic forms: high-centred and low-centred polygons. High-centred forms consist of an elevated 'centre', usually about 5–10 m wide surrounded by a 'trough' which delineates the locations of the ice wedges and separates one polygon from the adjacent ones. Low-centered forms consist of a central 'basin' surrounded by an elevated 'rim' and a 'trough'.

** United States Soil Survey nomenclature (7th approximation, Soil Survey Staff, 1975).

Walker (1983) hierarchical vegetation mapping classification system. This system is appropriate for mapping Alaskan tundra ecosystems with either photo-interpretation or Landsat methods. Percentages of water, surface forms, and landforms, were mapped according to the legends used in the North Slope Borough's geographic information system (GIS). Soils were mapped according to K.R. Everett's legend (in Walker *et al.*, 1983).

'Historical' natural disturbance overlay:—The purpose of the natural disturbance overlay is to quantify rates of natural change by mapping observable changes for the years 1968, 1977, and 1983. Examples of natural change are lake-boundary erosion, lake drainage, and stream-channel changes. Each set of photographs was projected onto the map surface, one photo at a time. Areas that had changed were coded with the year of the photograph on which the disturbance was noted and the vegetation type after disturbance.

'Historical' anthropogenic disturbance overlay:—Preparation of the anthropogenic disturbance overlay involved

TABLE III

Disturbance Codes for the Anthropogenic Disturbance Overlay.

Code	*Disturbance Type*
1	Gravel roads and pipeline construction roads
2	Peat roads
3	Gravel pads
4	Continuous flooding, more than 75% open water
5	Discontinuous flooding, less than 75% open water
6	Construction-induced thermokarst
7	Vehicle tracks—deeply rutted and/or with thermokarst
8	Vehicle tracks—not deeply rutted
9	Winter road
10	Gravel and construction debris (more than 75% cover)
11	Gravel and construction debris (less than 75% cover)
12	Heavy dust or dust-killed tundra
13	Excavations of river gravels or other gravel sources, road-cuts or construction excavations
14	Barren tundra caused by oil-spills, burns, blading, etc.
15	Barren tundra caused by previous flooding

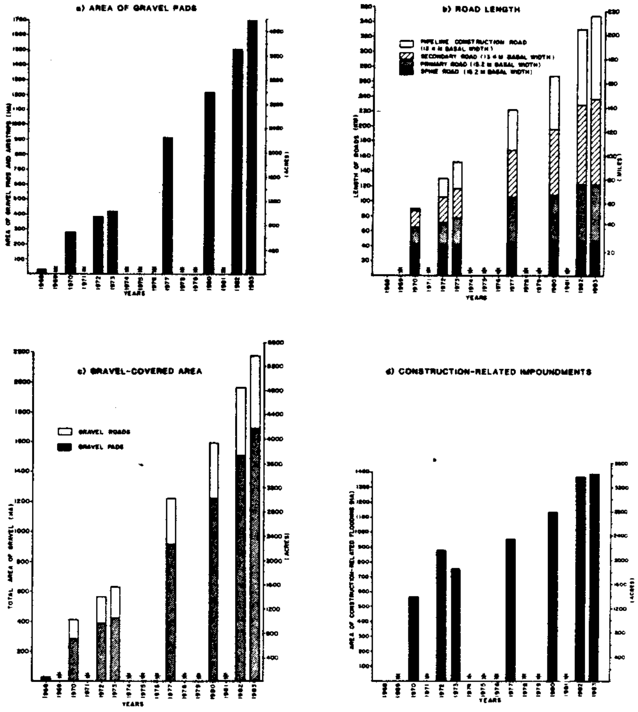


FIG. 3. *Area of anthropogenic disturbances within the Prudhoe Bay oilfield for years of available photo coverage. Starred (*) columns are years of missing or incomplete data. Regression equations for the respective data-sets are as follows: a) Y = 107.9X - 124.8 (r = .99), b) Y = 21.2X + 10.2 (r = .99), c) Y = 132.2X - 51.2 (r = .99), d) Y = 74.5X + 237.9 (r = .93).*

compiling disturbances for the years 1970, 1972, 1973, 1977, 1979, and 1983, onto a single map-sheet. Separate overlays were prepared for each year from the respective photography in the manner employed for the natural disturbance overlay. Table III lists the anthropogenic disturbance codes. The final, anthropogenic disturbance overlay was prepared by registering the overlays for all six years and tracing all the resulting 'polygons' onto a seventh sheet.

Map integration:—The final step prior to automation of the maps was to integrate the geobotanical, natural disturbance, and anthropogenic disturbance, overlays onto a single sheet. This integration process is the same as that developed by the Enviromental Systems Research Institute for making integrated terrain-unit maps (Dangermond *et al.*, 1982). The three overlays were registered and all boundaries were traced onto a fourth sheet of mylar. A final copy of the uncoded IGHDM was drafted with ink, to provide a clean copy for digitization. This version of the IGHDM contained all the 'polygon' boundaries but no codes. The 'polygon' information was contained in an attribute file stored in the computer. There were 30 attributes for each 'polygon', which included geobotanical, natural disturbance, and anthropogenic disturbance, information. A sequential identification number was assigned to each 'polygon'. The sequence numbers were written on formatted coding sheets, and attribute codes for each 'polygon' were recorded by reference to the appropriate overlays. Coded data were recorded and verified on magnetic tape. Copies of the tape, code sheets, and drafted IGHDM, were sent to the North Slope Borough GIS for automation.

Digitization and automation:—The IGHDM was automated, using the ARC/INFO software of the Environmental Systems Research Institute. The ARC/INFO software consists of two primary components. The ARC component manages cartographic (locational) information and is a topologically structured coordinate file made up of 'graphic entities'. The INFO portion of the software is the data-base management system that handles tabular (non-locational) information associated with geographic features. A detailed description of the software is available by writing to the Environmental Systems Research Institute, Inc., 380 New York Street, Redlands, California 92373, USA.

The digital file of coded attribute data contained a unique identifier for each 'polygon' and a list of codes describing the geobotanical and disturbance information for each 'polygon'. This information was used to create an attribute file within ARC/INFO, and was related to the digital geographic data by the unique sequence-number identifier. Final quality review and editing of the data-base were accomplished by producing verification plots and by review of tabular summaries. The INFO software was used to calculate the total area for each attribute, and to generate tabular reports of areas in hectares and percentage of total area.

RESULTS

Cumulative Development of the Prudhoe Bay Oilfield

The map of cumulative development of the oilfield was drawn to a scale of approximately 1:24,000 and was not appropriate for reproduction here. Planimetry data from this map (Table IV and Fig. 3) document the growth of the oilfield—including areas covered by gravel pads, roads, gravel, and flooding.

Integrated Geobotanical and 'Historical' Disturbance Map (IGHDM)

The basic uncoded IGHDM (Fig. 4) was used to make all other derived maps, such as the maps of surface-water

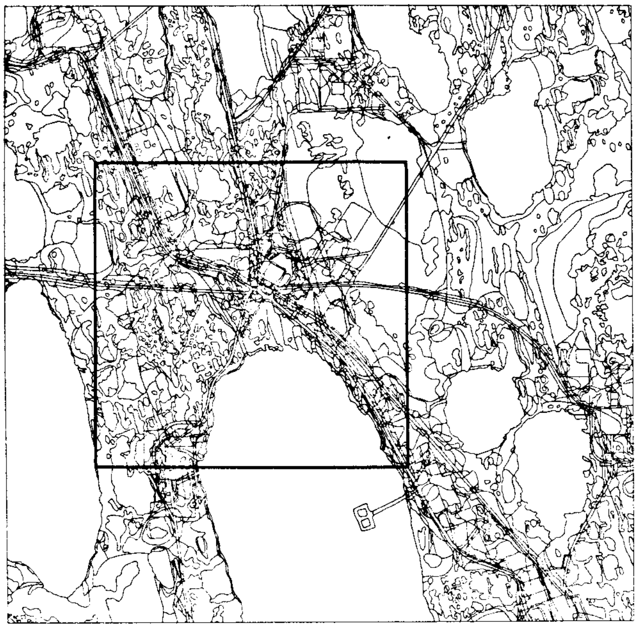


FIG. 4. *'Polygon' map for the integrated geobotanical and historical disturbance map. The map 'polygons' are small areas of the map enclosed by line boundaries. Large square is the portion of the map depicted in Fig. 7.*

PERCENTAGE COVER OF WATER IN 1949

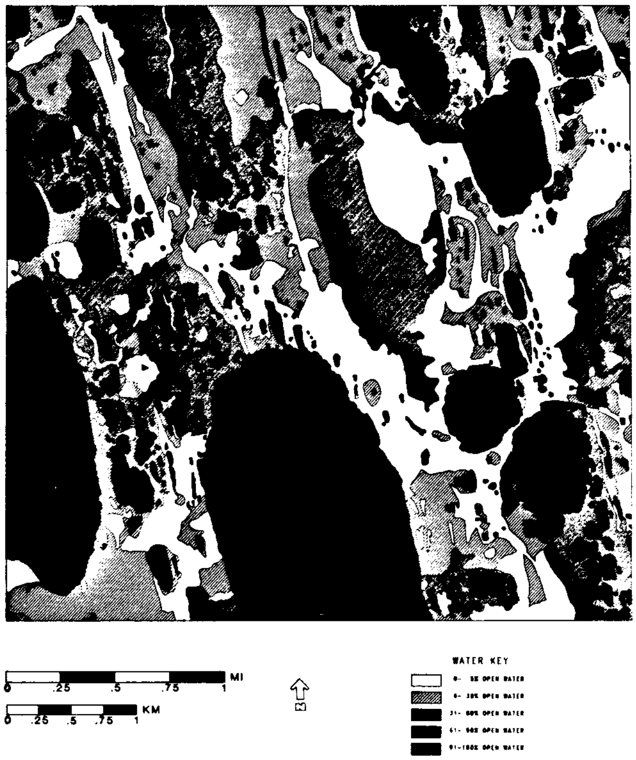


FIG. 5. *Percentage of open water on the IGHDM in 1949.*

DOMINANT VEGETATION IN 1949

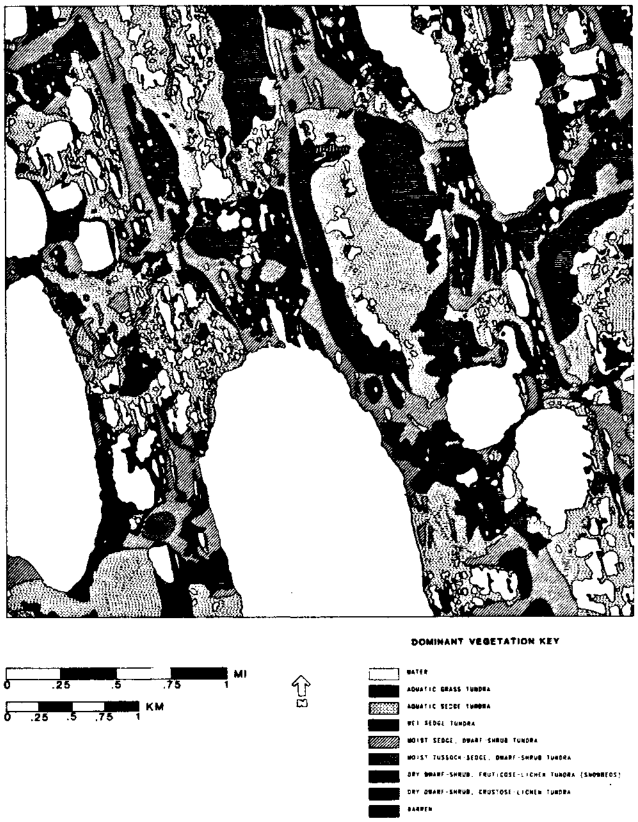
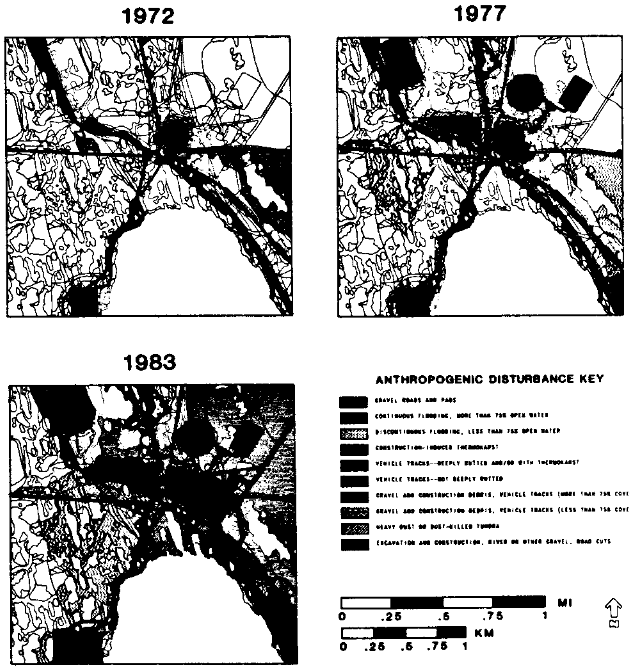


FIG. 6. *Dominant vegetation on the IGHDM in 1949.*


1972

1977

1983

FIG. 7. *Anthropogenic disturbance for three years of the study on a portion of the IGHDM.* See *Fig. 4 for location of this map's area.*

distribution (Fig. 5) and of vegetation (Fig. 6). Similar maps were made for soils, landforms, and surface forms. The progression of anthropogenic change was also mapped (Fig. 7). The anthropogenic disturbances affect the vegetation types differentially, and are not distributed randomly across the landscape; instead they are concentrated within

TABLE IV

Additions to the Major Disturbance Types for the Years of Record in the Prudhoe Bay Oilfield.

Year	Gravel Pads	Spine Road		Primary Roads		Secondary Roads		Pipeline Construction Roads		Total Roads		Total Gravel-covered	Construction-related Flooding
	Area (ha)	Length (km)	Area (ha)	Length (km)	Area (ha)	Length (km)	Area (ha)	Length (km)	Area (ha)	Length (km)	Area (ha)	Area (ha)	Area (ha)
1968	28.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.6	0.0
1970	253.0	40.8	62.3	24.1	36.7	22.1	29.6	2.8	3.8	89.8	132.4	385.4	568.9
1972	103.0	0.0	0.0	6.4	9.7	12.2	10.2	21.3	28.6	39.9	48.5	151.5	309.1
1973	36.1	0.0	0.0	5.9	9.0	5.4	7.2	11.6	15.6	22.9	31.8	67.9	−122.5
1974*	91.0	0.0	0.0	9.2	14.0	2.0	2.6	6.7	9.0	17.9	25.6	116.6	74.4
1975*	31.5	0.0	0.0	11.4	17.4	2.2	2.9	4.3	5.7	17.9	26.0	57.5	23.5
1976*	59.5	0.0	0.0	0.4	0.6	4.4	6.0	3.7	4.9	8.5	11.5	71.0	0.0
1977	312.5	3.3	5.1	3.6	5.5	14.8	19.9	4.0	5.3	25.7	35.8	348.3	105.3
1978*	57.8	0.0	0.0	0.0	0.0	11.1	14.9	6.4	8.6	17.5	23.5	81.3	0.0
1979*	115.0	2.8	4.3	0.4	0.7	2.4	3.3	4.3	5.8	9.9	14.1	129.1	56.1
1980	128.8	0.0	0.0	0.0	0.0	11.3	15.2	5.8	7.8	17.1	23.0	151.8	121.3
1981*	106.5	0.0	0.0	4.2	6.4	7.1	9.5	22.6	30.4	33.9	46.3	152.8	1.1
1982	183.7	0.0	0.0	9.5	14.4	11.8	15.8	8.5	11.5	29.8	41.7	225.4	232.9
1983	186.0	0.0	0.0	0.0	0.0	7.8	10.5	9.4	12.6	17.2	23.1	209.1	10.9
Total	1,693.0	46.9	71.7	75.1	114.4	114.6	147.6	111.4	149.6	348.0	483.3	2,176.3	1,381.0

* Years with incomplete or missing aerial photographic coverage.
Available information from unpublished draft map by T. Rothe.

TABLE V

Distribution of Disturbance Types Within the Various Vegetation Units on the IGHDM.

Disturbance types for 1983	Vegetation Types																			
	Water		Aquatic Grass Tundra		Aquatic Sedge Tundra		Wet Sedge Tundra		Moist Sedge, Dwarf-shrub Tundra		Moist Tussock-sedge, Dwarf-shrub Tundra		Dry Dwarf-shrub Fruticose-lichen Tundra		Dry Dwarf-shrub, Crustose-lichen Tundra		Barren		Total	
	ha	% Area	ha	% Area	ha	% Area	ha	% Area	ha	% Area	ha	% Area	ha	% Area	ha	% Area	ha	% Area	ha	% Area
Gravel roads	3.77	0.18	0.16	0.01	15.14	0.73	19.55	0.94	14.15	0.67	0	0	0	0	0.73	0.03	0	0	53.50	2.56
Gravel pads	16.16	0.77	0.62	0.03	23.01	1.10	67.43	3.23	57.14	2.74	0.03	0.00	0	0	5.04	0.24	0	0	169.43	8.11
Continuous flooding (>75% open water)	0.13	0.01	0.83	0.04	163.91	7.85	104.89	5.02	18.54	0.89	0.18	0.01	0	0	1.20	0.06	0	0	289.68	13.88
Discontinuous flooding (<75% open water)	0.01	0.00	0.11	0.00	67.08	3.22	43.69	2.09	10.34	0.48	0	0	0	0	0	0	0	0	121.23	5.79
Construction-induced thermokarst	0.14	0.01	0	0	3.26	0.16	29.77	1.43	24.02	1.16	0	0	0	0	2.10	0.10	0	0	59.29	2.86
Vehicle tracks, deeply rutted	0	0	0	0	0.25	0.01	1.42	0.07	1.00	0.04	0	0	0	0	0	0	0	0	2.67	0.12
Vehicle tracks, not deeply rutted	0	0	0	0	2.12	0.10	0.25	0.01	1.21	0.06	0	0	0	0	0	0	0	0	3.58	0.17
Gravel and debris (>75% cover)	0.22	0.01	0	0	2.66	0.13	7.28	0.35	6.52	0.30	0.50	0.02	0	0	0	0	0	0	17.18	0.81
Gravel and debris (<75% cover)	0	0	0	0	5.23	0.26	6.73	0.32	9.08	0.44	0	0	0	0	0	0	0	0	21.04	1.02
Heavy dust or dust-killed tundra	0	0	0	0	1.82	0.09	1.31	0.06	1.18	0.05	0	0	0	0	0	0	0	0	4.31	0.20
Previously-flooded areas with dead vegetation	0	0	0	0	2.91	0.14	1.53	0.07	0	0	0	0	0	0	0	0	0	0	4.44	0.21
No mapped disturbance	770.59	36.90	29.53	1.42	183.23	8.78	212.45	10.17	133.89	6.42	4.35	0.21	0.34	0.02	6.53	0.31	0.78	0.04	1,341.69	64.27
TOTAL	791.02	37.88	31.25	1.50	470.62	22.57	496.30	23.76	277.07	13.25	5.06	0.24	0.34	0.02	15.60	0.74	0.78	0.04	2,088.04	100.00

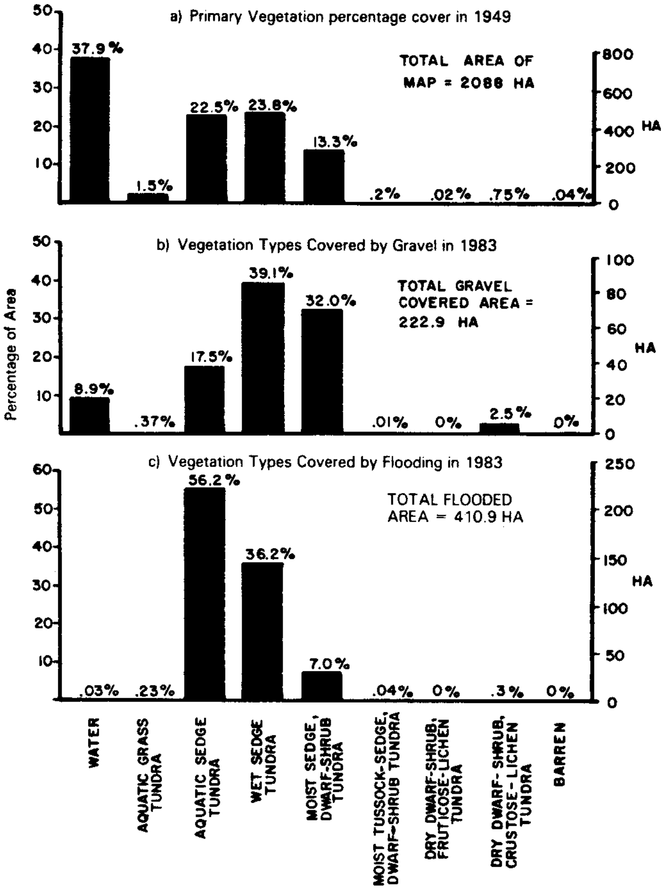


FIG. 8. a) *Percentage distribution of primary vegetation types as of 1949 on the IGHDM (Fig. 4);* b) *distribution of vegetation types impacted as of 1983 by gravel placement, and* c) *by impoundments. Note: if the water areas are subtracted from the total area available for gravel placement, the percentages in* a) *are as follows: water, 0%; aquatic grass tundra, 2.4%; aquatic sedge tundra, 36.2%; wet sedge tundra, 38.3%; moist sedge, dwarf-shrub tundra, 21.4%; moist tussock-sedge, dwarf-shrub tundra, 0.3%; dry dwarf-shrub, fruticose-lichen tundra, 0.03%; dry dwarf-shrub, crustose-lichen tundra, 1.2%; barren, 0.06%.*

particular vegetation-types (Fig. 8). For example, 'moist sedge, dwarf-shrub tundra' occupied 13.3% of the undisturbed landscape in 1949. Even if the water areas are subtracted as areas unavailable for gravel replacement (*see* caption of Fig. 8), only 21.4% of the remaining area is of this 'moist sedge, dwarf-shrub tundra'. However, 32% of the area covered by gravel roads and pads occurs on this type. A similar pattern exists for 'dry dwarf-shrub, crustose-lichen tundra'. The distribution of gravel and impoundments on the various vegetation-types is significantly different from the distribution of undisturbed vegetation ($\chi^2 = 43.33$, $p < .01$ for gravel; $\chi^2 = 97.85$, $p < .01$ for flooding). The chi-square values were adjusted to exclude water, as roads and pads are generally built to avoid lakes. Also, flooding as defined cannot occur in an area that has already been coded as water on the geobotanical overlay. Table V gives a summary of the impact of all mapped anthropogenic disturbances as they affect the primary vegetation-types. Natural disturbances are clearly minor when compared with areas affected by anthropogenic disturbances (Tables V and VI).

TABLE VI

Summary of Natural Disturbances for the Period 1968 to 1983 on the IGHDM.

Year	*Disturbance type*	*Cumulative area disturbed since 1949* *ha*	 *%*
1968	Lake erosion	4.43	0.21
1977	Lake erosion	6.47	0.31
	Drained pond	0.13	0.01
1983	Lake erosion	7.91	0.38
	Drained pond	0.13	0.01

DISCUSSION

The 1:24,000-scale map contains data regarding the whole field, whereas the IGHDM (Fig. 4) covers a smaller area but yields more detailed information regarding the effects of indirect impacts, such as roadside disturbances and thermokarst, which could not be mapped at the 1:24,000 scale. Also, the effects on the geobotany which are important for wildlife considerations can only be determined from the IGHDM.

The Entire Oilfield

Regression analysis of the yearly additions for four major disturbance types—length of roads, area of gravel pads, total gravel-covered areas, and areas of flooding—shows that there has been a linear increase in all these factors during the first 15 years of development (Fig. 3). Information such as this is beneficial for determining the accumulated impacts for the oilfield as a whole, or for small subareas such as individual drill-sites. Comparison with other oilfields can help us to determine whether there are general patterns of development that are repeated in other large oilfields. For example, the rate of growth of the road network within the Prudhoe Bay oilfield is very similar to that in the nearby Kuparuk oilfield (Fig. 9). This is somewhat surprising considering the number of variables that could conceivably affect those rates.

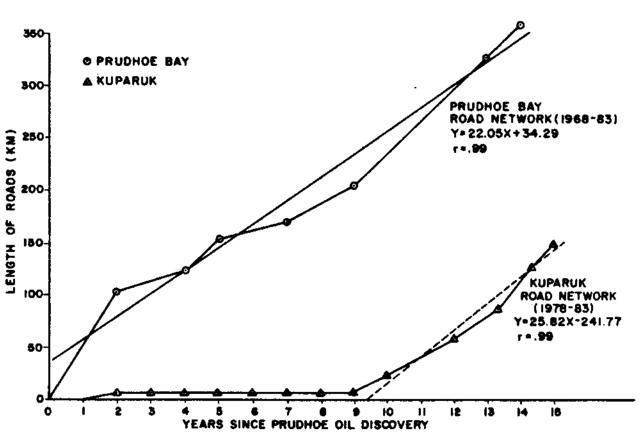


FIG. 9. *Comparison of growth of the Prudhoe Bay and Kuparuk oilfield road networks. Top straight fine line is the regression for the Prudhoe Bay road network since the discovery of oil in 1968. Bottom dashed regression line shows the growth of the Kuparuk road network since 1978 when development began to expand. Kuparuk data are unpublished data of the Authors.*

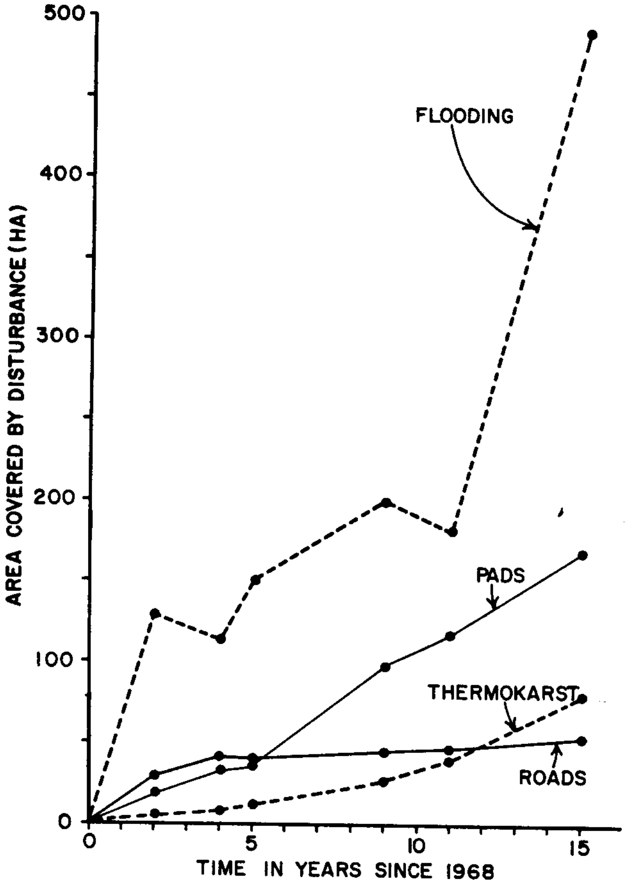


Fig. 10. *The progression of the direct impacts of gravel road and pad placement (continuous lines) and of indirect and induced impacts (dashed lines) for the area of the IGHDM. Data are for the small area blacked in Fig. 1 which is about 22 km² in extent.*

Heavily-developed Portion of the Oilfield (1: 6,000-scale map)

Within the area of the large-scale map we examined the 15-years' history for two direct impacts, roads and total gravel-covered area, and two indirect impacts, flooding and thermokarst (Fig. 10). The area covered by roads levelled off within five years, while the area covered by gravel showed a linear increase throughout the period. This indicates that all the roads which were found necessary for full development of the area were built fairly soon, but that gravel pads continued to increase in size and number as development proceeded. In contrast, roads in the entire oilfield increased linearly for a much longer period of time (*see* Fig. 3), due to expansion of the oilfield perimeter and increased road access within the field.

The total area affected by indirect impacts, particularly flooding, now far exceeds that of direct impacts (Fig. 10). This is partially due to a dramatic rise in flooding in 1983. Whether or not this rise was due to the somewhat earlier-in-the-year photographs taken in 1983 (early July in 1983 as opposed to mid-July in other years), which would be likely to show larger areas flooded from the spring runoff, is unknown to us. Also, 1983 was a generally wetter year with a later-than-usual breakup. However, the rest of the oilfield as a whole did not show a similar dramatic increase in flooding in 1983, even though the photographs for the whole field were also from early July. The sudden rise could be unique to this particular area—possibly the result of a few new areas of gravel placement that resulted in large new areas of flooding.

Also unknown is whether this pattern has been repeated in other areas of the flat coastal plain with very high densities of roads and gravel pads. IGHDM mapping in other similar areas will help to determine the extent and causes of this phenomenon. The Prudhoe Bay field is located in an extraordinarily flat and wet portion of the Alaskan Arctic Coastal Plain. Oilfields developed in somewhat more hilly portions of the coastal plain are not likely to have such severe flooding problems.

The rate of increase of the area covered by thermokarst appears to be accelerating with time (Fig. 10). Thermokarst is defined as topographic depressions resulting from thawing of ground-ice (Webber & Ives, 1978; Washburn, 1980). We might expect that the area of anthropogenic thermokarst would increase exponentially as the number of roads and the thermal effects of dust, impoundments, and other oilfield activities, combined synergistically to melt the subsurface ice.

The IGHDM is also useful for determining how specific types of impact are distributed among the various geobotanical units (Fig. 8). For example, the relatively dry vegetation-types are being selected for road and gravel-pad construction because they offer firmer substrates and present less of a flooding problem than do moister ones. In contrast, flooding is generally restricted to wetter areas, for example in aquatic sedge tundra or wet sedge tundra.

The amount and type of habitat that is impacted and lost can be determined from the IGHDM and compared with the original habitat composition for species with specific habitat preferences, provided that the habitat classification can be related to the geobotanical classification. For example, Troy *et al.* (1982) derived a waterbird habitat classification from the geobotanical classification (Table VII); it was based on combinations of vegetation, surface forms, and demonstrated habitat preferences of the common waterfowl and shorebirds. The most common shorebird species preferred moist tundra classes, which are disproportionately covered by gravel (Fig. 8). Gravel cover can be considered a complete habitat loss but some impacts (e.g. flooding) are similar to natural features and may be utilized

Table VII

Waterbird Habitat Types Used by Troy et al. *(1982).*

Habitat
Moist tundra/high-centred polygon
Moist tundra/frost-scar
Moist tundra/low relief high-centred polygons
Wet tundra/low relief low-centred polygons
Wet tundra/strangmoor
Wet tundra/non-patterned ground
Aquatic, moist tundra/strangmoor
Aquatic sedge/strangmoor
Water/pond with emergent plants
Water/pond without emergent plants
Impoundments (flooded)

by some species. The full effect of the various impacts on bird-use is beyond the scope of this paper, other than emphasizing the point that maps of this nature can be a major tool for assessing cumulative impacts on wildlife habitat as they show losses of, and changes to, habitats which may be distinguished by the geobotanical classification.

The value of the geobotanical mapping method for habitat evaluations is currently being studied in the Prudhoe Bay region by the Environmental Protection Agency and the US Fish and Wildlife Service. These studies will lead to a comprehensive method for evaluating and mitigating oil development impacts on the coastal tundra of northern Alaska, and, it is hoped, comparable areas elsewhere.

CONCLUSIONS

This report demonstrates some of the flexibility of the automated geobotanical map data-base. The data-base has obvious potential for day-to-day planning and record-keeping within the oilfield. It also has many scientific applications. Bird habitat, ground-ice, plant distribution patterns, and many other features, can all be related to the basic data-set. The data-set can also be readily expanded to include other factors such as geology and habitat attributes. It must be emphasized, however, that derived maps and models produced from the base-data are only as good as the understanding of the processes involved. They will remain 'blunt tools' for land-use planning until there are thorough studies of tundra response to disturbance that are specifically related to the various geobotanical units.

Maps can only depict relatively major physical changes to the terrain. They cannot depict total cumulative impact, which includes other factors such as the actual effects on wildlife populations (although the effects on wildlife habitat can be displayed on a map). They do, however, depict the accumulated sum of development and the associated visual impacts. In this regard it should be recognized that, in spite of the clear need to examine cumulative impact in the face of massive development occurring on the North Slope, there exists very little theory or methodology regarding cumulative impact.

The method presented here for depicting complex 'historical' change is a necessary first step towards a comprehensive methodology for evaluating cumulative impact. Although there is uncertainty as to whether site-specific 'histories' and dynamics can be extrapolated to other areas, 'historical' studies can point out the flaws of past practices and help in the development of more effective regulatory methods.

The automation of the geobotany and historical development of the Prudhoe Bay region allows for the quick analysis of the historical changes, and permits the display of the data in a wide variety of map formats. Within this study there are several specific conclusions regarding the historical development of the Prudhoe Bay oilfield:

1. The growth of the Prudhoe Bay road network increased in a linear manner during the period 1968–83. The area covered by gravel pads and flooding also increased linearly.

2. The Kuparuk oilfield road network is showing a growth-rate similar to that in the Prudhoe Bay field.

3. The growth of the road network within a small, heavily developed portion of the field levelled-off within five years, while the area covered by gravel continued to expand linearly for the length of the study.

4. The total area covered by the indirect impacts of flooding and thermokarst was more than double that of the primary impacts. The rate of growth of the area covered by flooding fluctuated from year to year, and was partially controlled by the date of the photograph and yearly precipitation. There was, however, clearly a steady increase in flooding during the period of study. There appears to be an accelerating rate of increase of thermokarst.

5. The anthropogenic impacts within this area from 1968 to 1983 were two orders of magnitude greater than the natural disturbances within the same area from 1949 to 1983 (746 *versus* 8 ha).

6. Disturbance types affect the geobotanical units differentially. On flat and wet thaw-lake plains, moist and dry sites tend to be selected for gravel placement, whereas artificial impoundments occur primarily in the naturally wet or aquatic tundra types. Both of these disturbance distribution patterns have important implications regarding waterfowl and shorebird habitat.

7. A robust link between the cumulative effects of oilfield development and the effects on wildlife habitat still requires much additional research. The creation of habitat models for a wide variety of species, and their integration with appropriate geobotanical map data, will require close cooperation between landscape-oriented ecologists and wildlife specialists.

ACKNOWLEDGEMENTS

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This project would not have been possible without the input from numerous individuals who played major roles in developing the geobotanical mapping methods and securing funding for the early phases of the research. These individuals include Dr Kaye R. Everett, Institute of Polar Studies, the Ohio State University, Dr Jerry Brown, formerly Chief of Earth Sciences at the US Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, and Patrick Webb, Resource Dynamics, Inc., Fort Collins, Colorado. The Environmental Systems Research Institute (ESRI), of Redlands, California, helped in adapting the geobotanical mapping system to GIS technology.

SUMMARY

A comprehensive approach to the problem of examining impacts on tundra landscapes is presented, using the Prudhoe Bay oilfield as a model. Development of the oilfield is

documented, utilizing a series of 'historical' disturbance maps for the period 1949–83. Cumulative development of the entire field was mapped at a scale of 1:24,000, and an intensely developed portion of the field was mapped at 1:6,000, using an integrated geobotanical and historical disturbance map (IGHDM). The IGHDM data were automated, and a series of maps was made which depict a variety of information—including geobotany of the area as of 1949, and the historical sequence of development from 1968 to 1983.

The region is ideal for the application of automated GIS technology for studying cumulative impacts because of (1) a commitment by the local government to build a GIS, (2) an existing excellent geobotanical data-base, and (3) an aerial photographic record of the complete history of development from the wilderness state to the present-day industrial complex.

The map data show numerous aspects of the growth of the oilfield, including rates of growth of the road network, total gravel-covered area, and areas covered by flooded impoundments. Within the heavily-developed region (1:6,000-scale map), 0.39% of the area was affected by natural disturbances from 1949 to 1983, whereas 35.74% of the area was affected by anthropogenic physical disturbances from 1968 to 1983. The area covered by indirect impacts of flooding and thermokarst shows an exponential rate of growth, and the total area covered by these indirect impacts is more than double the area affected by the direct impacts of roads and gravel pads. The exponential increase in thermokarst is an example of a synergistically increasing impact within the oilfield. Disturbances are not distributed randomly within the various geobotanical units; they tend to occur within specific moisture-regime categories depending on the type of disturbance.

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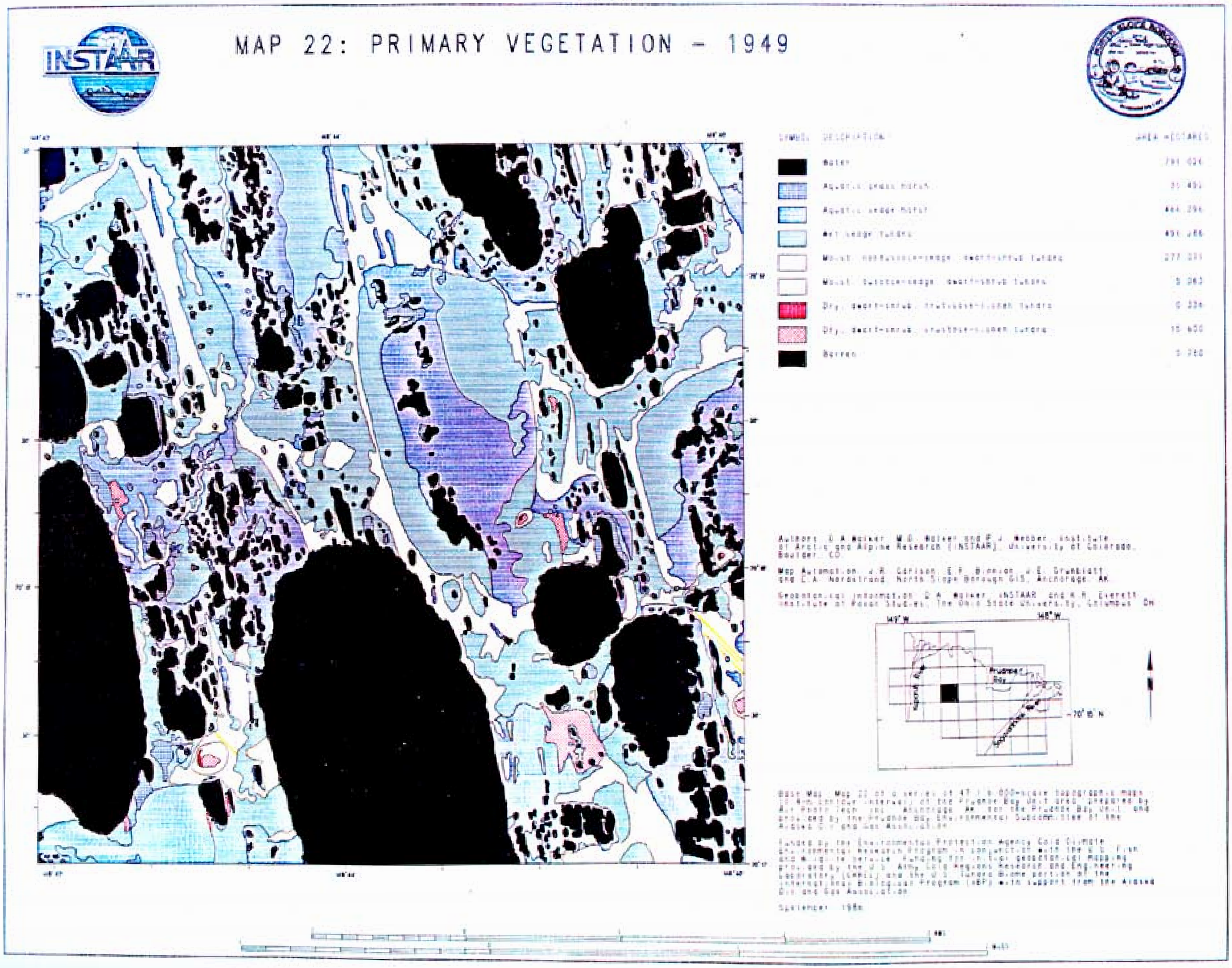
Appendix B. Computer-drawn geobotanical and disturbance maps

Fig. No.	
	Color Maps
B1	Map 22, Primary Vegetation 1949
B2	Map 22, Primary Vegetation 1949 with 1983 Primary Anthropogenic Disturbances
B3	Map 32, Primary Vegetation 1949
B4	Map 32, Primary Vegetation 1949 with 1983 Primary Anthropogenic Disturbances
B5	Map 34, Primary Vegetation 1949
B6	Map 34, Primary Vegetation 1949 with 1983 Primary Anthropogenic Disturbance
	Black and White Maps
B7	Map 22, Primary Vegetation 1949
B8	Map 22, Secondary Vegetation 1949
B9	Map 22, Percent Water Cover 1949
B10	Map 22, Landform 1949
B11	Map 22, Primary Surface Form 1949
B12	Map 22, Secondary Surface Form 1949
B13	Map 22, Primary Soil 1949
B14	Map 22, Secondary Soil 1949
B15	Map 22, Primary Anthropogenic Disturbance 1970
B16	Map 22, Secondary Anthropogenic Disturbance 1970
B17	Map 22, Primary Anthropogenic Disturbance 1973
B18	Map 22, Secondary Anthropogenic Disturbance 1973
B19	Map 22, Primary Anthropogenic Disturbance 1977
B20	Map 22, Secondary Anthropogenic Disturbance 1977
B21	Map 22, Primary Anthropogenic Disturbance 1979
B22	Map 22, Secondary Anthropogenic Disturbance 1979
B23	Map 22, Primary Anthropogenic Disturbance 1983
B24	Map 22, Secondary Anthropogenic Disturbance 1983
B25	Map 22, Natural Disturbance 1968, 1977, and 1983
B26	Map 32, Primary Vegetation 1949
B27	Map 32, Secondary Vegetation 1949
B28	Map 32, Percent Water Cover 1949
B29	Map 32, Landscape Unit 1949
B30	Map 32, Landform 1949
B31	Map 32, Primary Surface Form 1949
B32	Map 32, Secondary Surface Form 1949
B33	Map 32, Primary Soil 1949
B34	Map 32, Secondary Soil 1949
B35	Map 32, Primary Anthropogenic Disturbance 1970
B36	Map 32, Secondary Anthropogenic Disturbance 1970
B37	Map 32, Primary Anthropogenic Disturbance 1973
B38	Map 32, Secondary Anthropogenic Disturbance 1973
B39	Map 32, Primary Anthropogenic Disturbance 1977
B40	Map 32, Secondary Anthropogenic Disturbance 1977
B41	Map 32, Primary Anthropogenic Disturbance 1979
B42	Map 32, Secondary Anthropogenic Disturbance 1979

B43	Map 32, Primary Anthropogenic Disturbance 1983
B44	Map 32, Secondary Anthropogenic Disturbance 1983
B45	Map 32, Natural Disturbance 1968, 1977, and 1983
B46	Map 34, Primary Vegetation 1949
B47	Map 34, Secondary Vegetation 1949
B48	Map 34, Percent Water Cover 1949
B49	Map 34, Landscape Unit 1949
B50	Map 34, Landform 1949
B51	Map 34, Primary Surface Form 1949
B52	Map 34, Secondary Surface Form 1949
B53	Map 34, Primary Soil 1949
B54	Map 34, Secondary Soil 1949
B55	Map 34, Primary Anthropogenic Disturbance 1968
B56	Map 34, Secondary Anthropogenic Disturbance 1968
B57	Map 34, Primary Anthropogenic Disturbance 1970
B58	Map 34, Secondary Anthropogenic Disturbance 1970
B59	Map 34, Primary Anthropogenic Disturbance 1973
B60	Map 34, Secondary Anthropogenic Disturbance 1973
B61	Map 34, Primary Anthropogenic Disturbance 1977
B62	Map 34, Secondary Anthropogenic Disturbance 1977
B63	Map 34, Primary Anthropogenic Disturbance 1979
B64	Map 34, Secondary Anthropogenic Disturbance 1979
B65	Map 34, Primary Anthropogenic Disturbance 1983
B66	Map 34, Secondary Anthropogenic Disturbance 1983
B67	Map 34, Natural Disturbance 1968, 1977, and 1983

Fig. B1



MAP 22: PRIMARY VEGETATION - 1949

SYMBOL	DESCRIPTION	AREA HECTARES
■	Water	791.026
▦	Aquatic grass marsh	35.493
▤	Aquatic sedge marsh	464.294
▤	Wet sedge tundra	491.486
☐	Moist, nontussock-sedge, dwarf-shrub tundra	277.331
☐	Moist, tussock-sedge, dwarf-shrub tundra	5.063
▩	Dry, dwarf-shrub, fruticose-lichen tundra	0.336
▨	Dry, dwarf-shrub, crustose-lichen tundra	15.600
■	Barren	0.760

Authors: D.A. Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: J.R. Carlson, E.F. Binnian, J.E. Grunblatt and C.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical information: D.A. Walker, INSTAAR, and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.

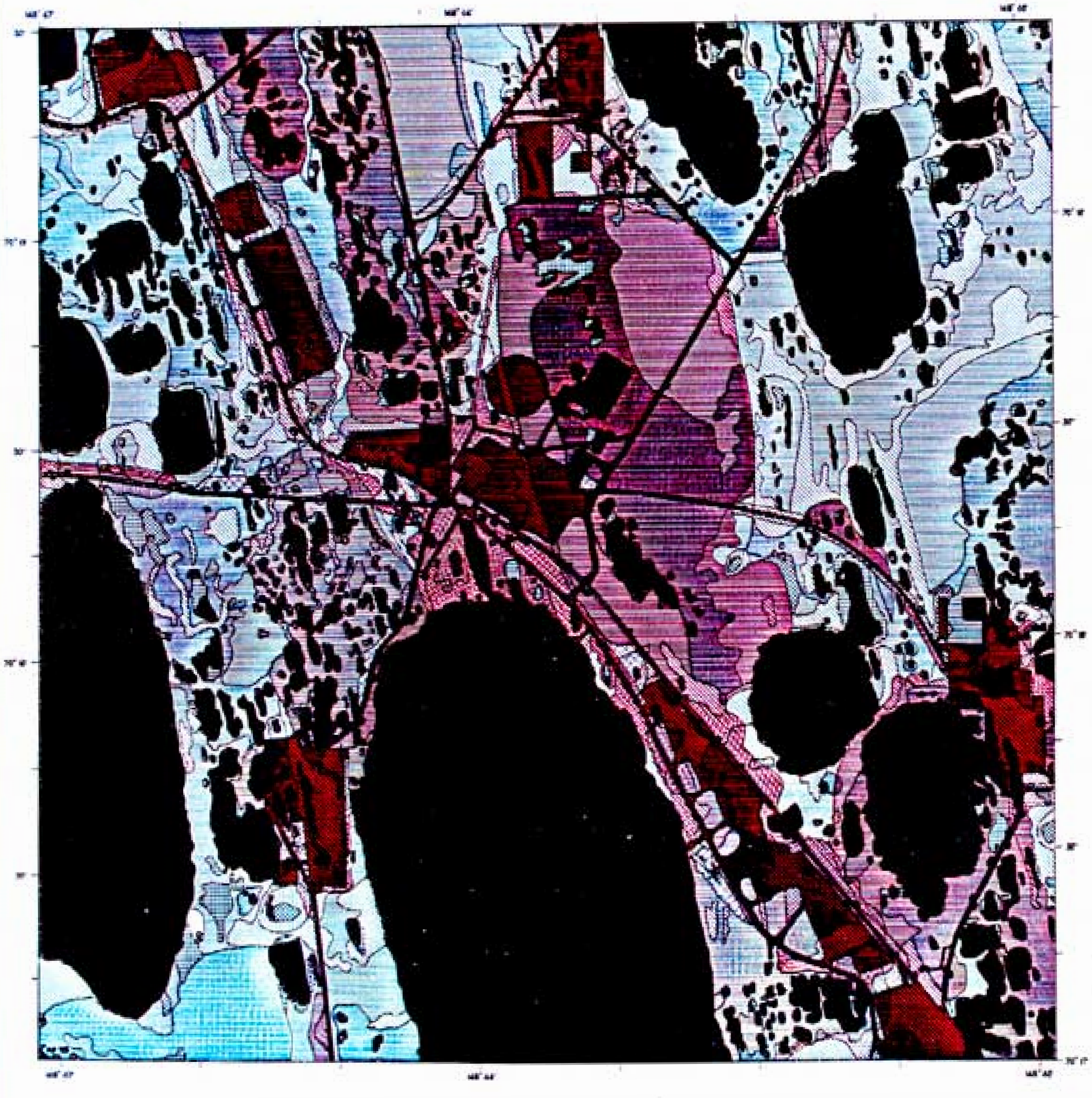
Base Map: Map 22 of a series of 47 1:6,000-scale topographic maps (1.5-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

Funded by the Environmental Protection Agency Cold Climate Environmental Research Program in conjunction with the U.S. Fish and Wildlife Service. Funding for initial geobotanical mapping provided by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) and the U.S. Tundra Biome portion of the International Biological Program (IBP) with support from the Alaska Oil and Gas Association.

September 1986

Fig. B2

MAP 22: PRIMARY ANTHROPOGENIC DISTURBANCE - 1983 AND PRIMARY VEGETATION - 1949



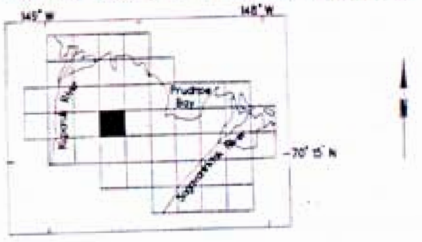
- ■ Water
- ▦ Aquatic grass marsh
- ▤ Aquatic sedge marsh
- ▤ Wet sedge tundra
- ▢ Moist nontussock-sedge dwarf-shrub tundra
- ▢ Moist tussock-sedge dwarf-shrub tundra
- ■ Dry dwarf-shrub fruticose-lichen tundra
- ▩ Dry dwarf-shrub crustose-lichen tundra
- ☐ Barren

- ■ Gravel roads
- ■ Gravel pads
- ▦ Continuous flooding more than 75% open water
- ▤ Discontinuous flooding less than 75% open water
- ▩ Construction-induced thermokarst
- ▤ Vehicle tracks, deeply rutted or with thermokarst
- ▦ Vehicle tracks not deeply rutted
- ▩ Gravel and construction debris (more than 75% cover)
- ▨ Gravel and construction debris (less than 75% cover)
- ▢ Dust or dust-killed tundra
- ▣ Barren tundra caused by previous anthropogenic impoundments

Authors: D.A. Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO

Map Automation: J.R. Carlson, E.F. Binnian, J.E. Grunblatt, and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR, and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH



Base Map: Map 22 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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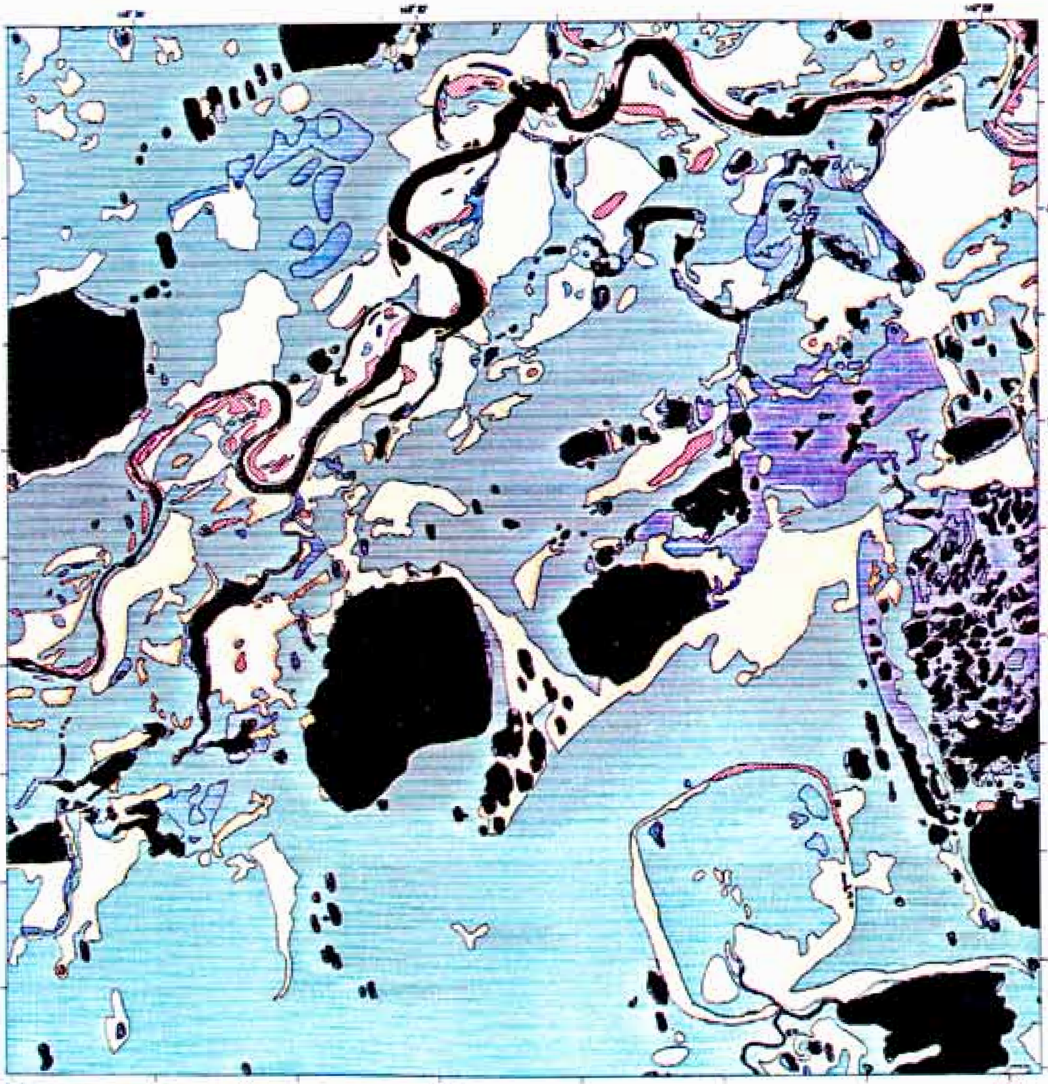
September 1986

Fig. B3

MAP 32: PRIMARY VEGETATION - 1949

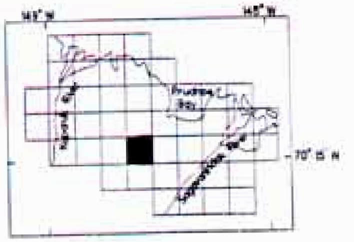


SYMBOL	DESCRIPTION	AREA HECTARES
■	Water	287.904
▨	Aquatic grass marsh	30.498
▨	Aquatic sedge marsh	128.842
■	Aquatic moss marsh	0.291
▨	Wet sedge tundra	1122.682
□	Moist, nontussock-sedge, dwarf-shrub tundra	468.895
▨	Moist low shrubland	1.240
▨	Dry, dwarf-shrub, crustose-lichen tundra	18.543
▨	Dry, dwarf-shrub, forb, lichen tundra	8.443
▨	Dry, dwarf-shrub, forb, grass tundra	0.581
▨	Dry forb barren	0.438
■	Barren	22.978

Authors: D.A. Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK

Geobotanical Information: D.A. Walker, INSTAAR, and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH



Base Map: Map 32 of a series of 47 1:6,000-scale topographic maps (1 m contour intervals) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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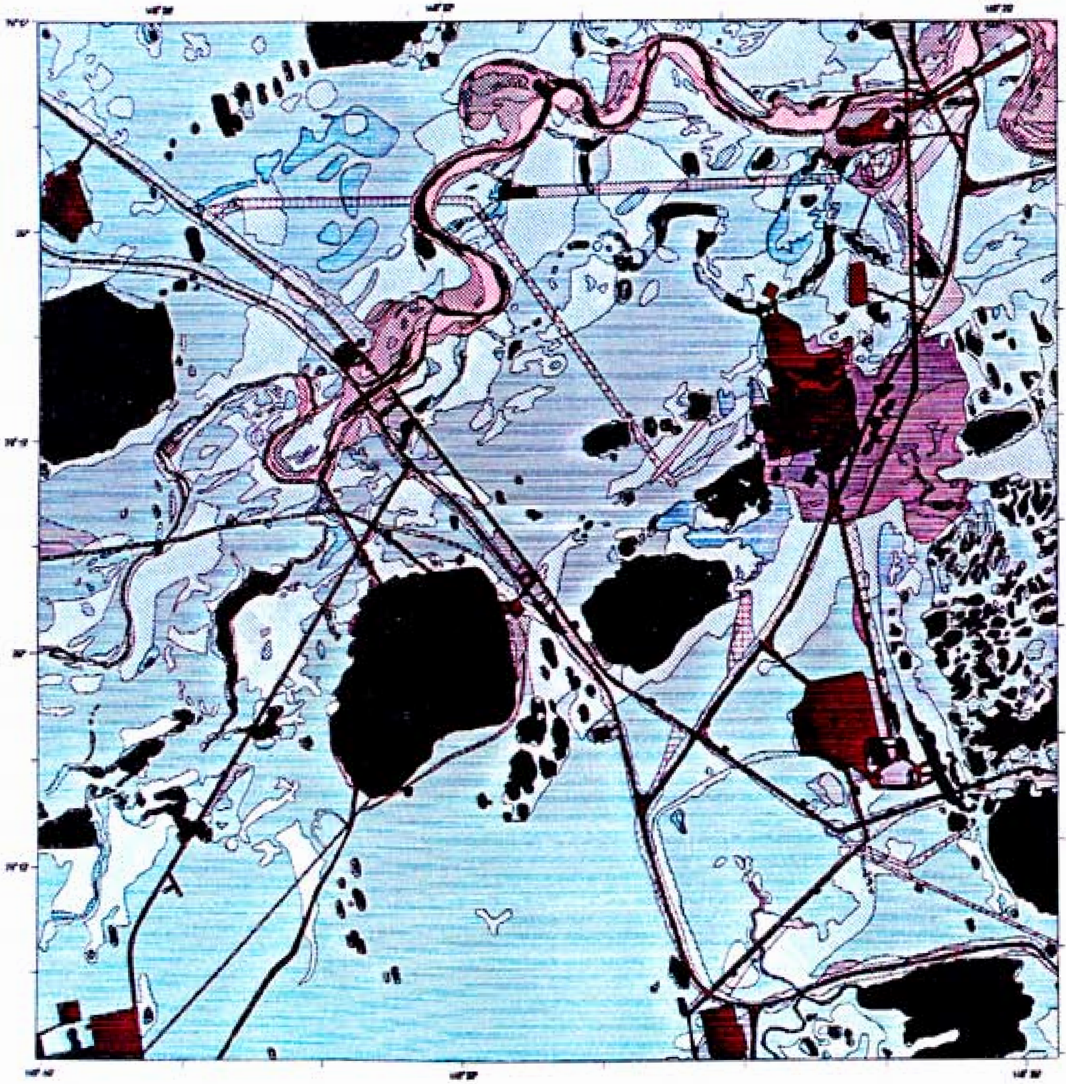
September 1986

Fig. B4

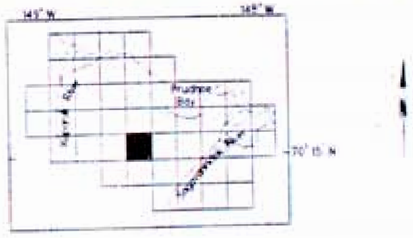
MAP 32: PRIMARY ANTHROPOGENIC DISTURBANCE – 1983 AND PRIMARY VEGETATION – 1949



Authors: D.A. Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical information: D.A. Walker, INSTAAR, and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH



Base Map: Map 32 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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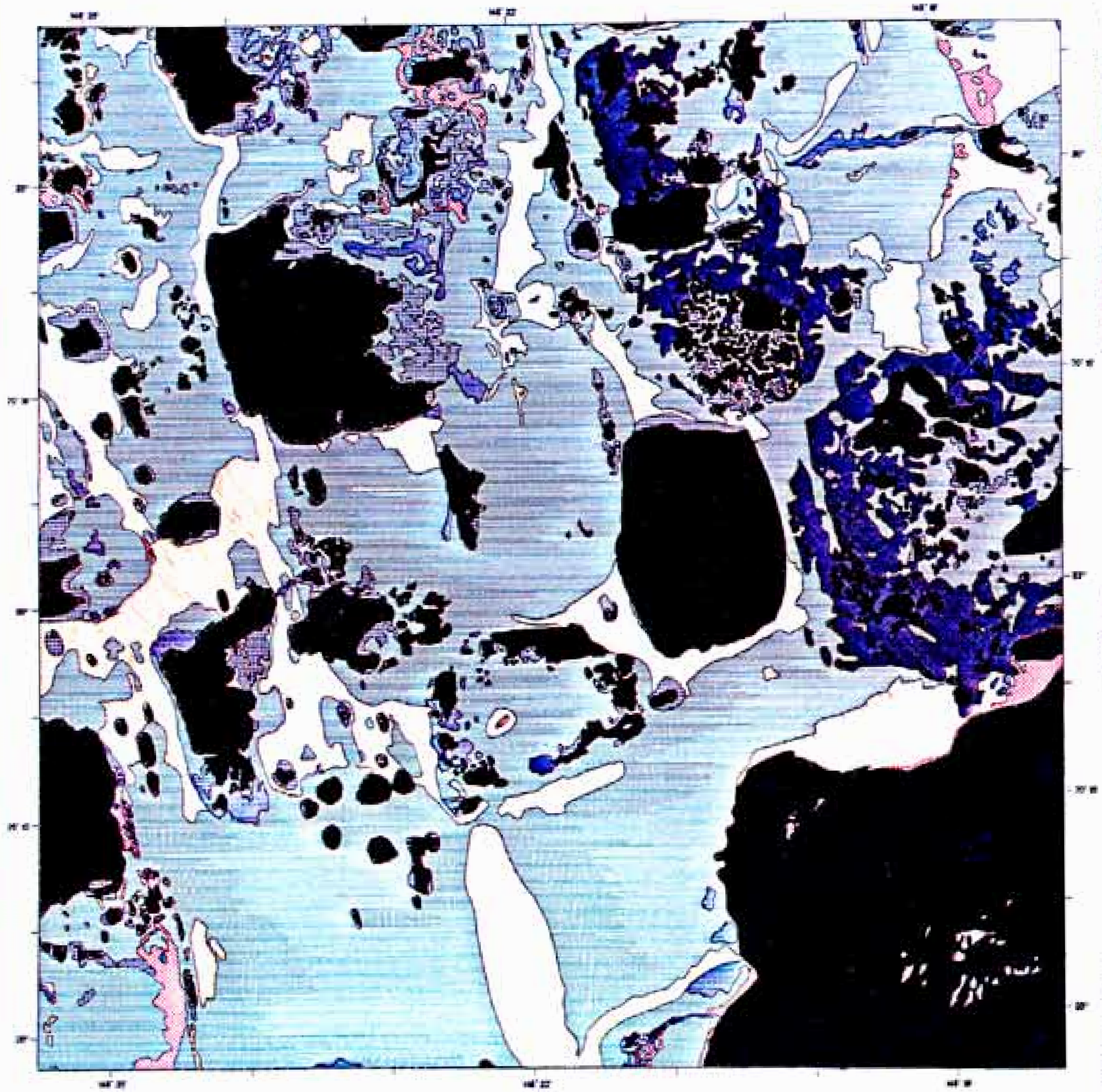
September 1986

Fig. B5

MAP 34: PRIMARY VEGETATION - 1949

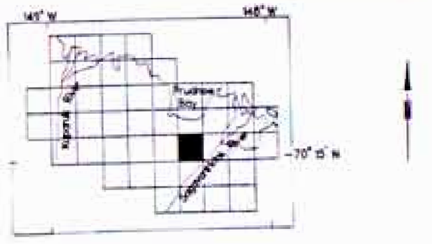


SYMBOL	DESCRIPTION	AREA HECTARES
■	Water	502.750
▦	Aquatic grass marsh	80.558
▤	Aquatic sedge marsh	42.004
■	Aquatic moss marsh	116.155
▤	Wet sedge tundra	968.316
□	Moist, nontussock-sedge, dwarf-shrub tundra	286.705
▩	Dry, dwarf-shrub, crustose-lichen tundra	24.794
▒	Dry, dwarf-shrub, forb, grass tundra	2.906
■	Barren	59.571

Authors: D.A. Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical information: D.A. Walker, INSTAAR, and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 34 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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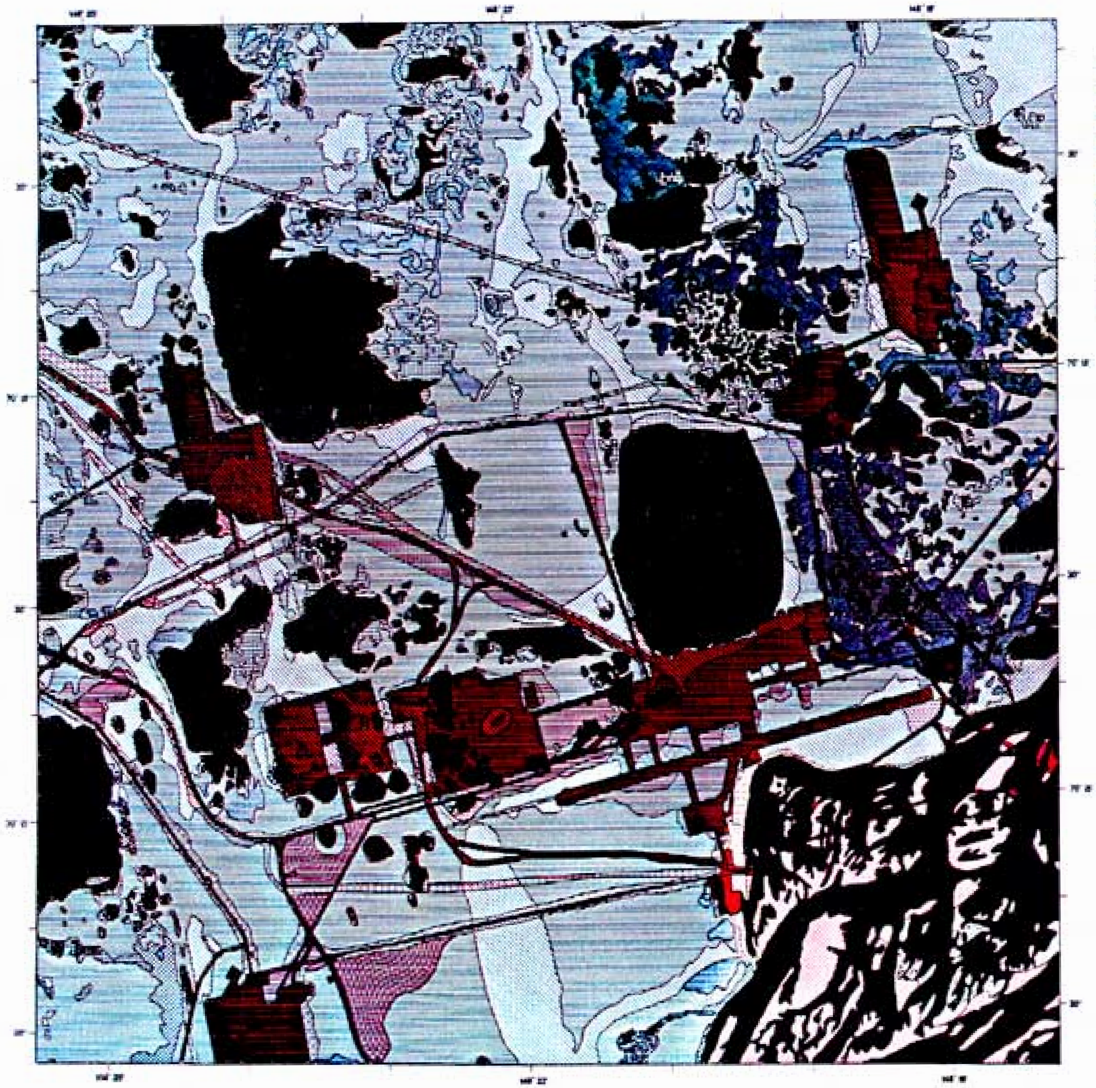
September 1986

km

mile

Fig. B6

MAP 34: PRIMARY ANTHROPOGENIC DISTURBANCE – 1983 AND PRIMARY VEGETATION – 1949



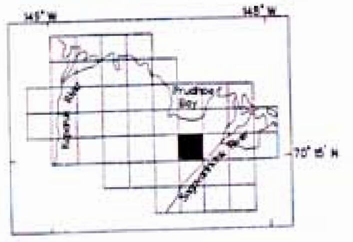
- ■ Water
- ▦ Aquatic grass marsh
- ▦ Aquatic sedge marsh
- ■ Aquatic moss marsh
- ▤ Wet sedge tundra
- ▨ Moist, nontussock-sedge, dwarf-shrub tundra
- ▩ Dry, dwarf-shrub, crustose-lichen tundra
- ▧ Dry, dwarf-shrub, forb, grass tundra
- □ Barren

- ■ Gravel roads
- ■ Peat roads
- ■ Gravel pads
- ▦ Continuous flooding, more than 75% open water
- ▦ Discontinuous flooding, less than 75% open water
- ▦ Construction-induced thermokarst
- ▦ Vehicle tracks, deeply rutted or with thermokarst
- ▦ Vehicle tracks, not deeply rutted
- ▨ Gravel and construction debris (more than 75% cover)
- ▧ Gravel and construction debris (less than 75% cover)
- ▩ Excavations

Authors: D.A. Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK

Geobotanical Information: D.A. Walker, INSTAAR, and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH



Base Map: Map 34 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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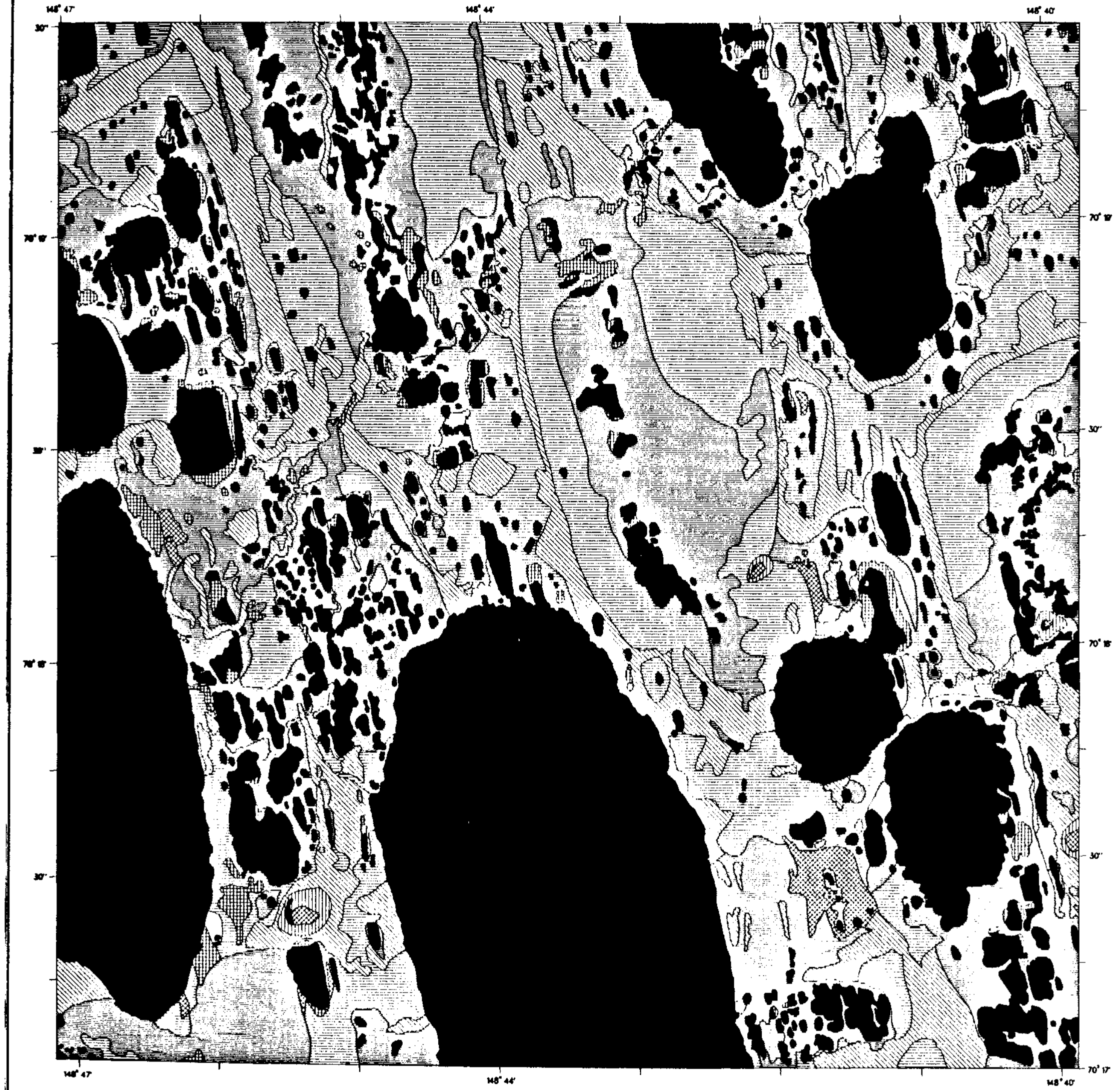
September, 1988

Fig. B7

MAP 22: PRIMARY VEGETATION - 1949

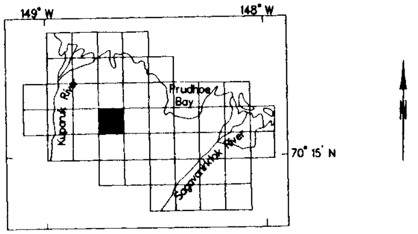


SYMBOL	DESCRIPTION	AREA HECTARES
■	Water	791.026
▦	Aquatic grass marsh	35.492
▩	Aquatic sedge marsh	466.396
▤	Wet sedge tundra	496.286
▧	Moist, nontussock-sedge, dwarf-shrub tundra	277.071
▥	Moist, tussock-sedge, dwarf-shrub tundra	5.063
■	Dry, dwarf-shrub, fruticose-lichen tundra	0.336
▩	Dry, dwarf-shrub, crustose-lichen tundra	15.600
□	Barren	0.780

Authors: D.A.Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: J.R. Carlson, E.F. Binnian, J.E. Grunblatt, and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 22 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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September, 1986

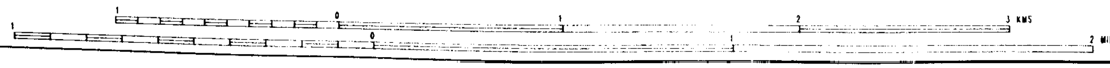
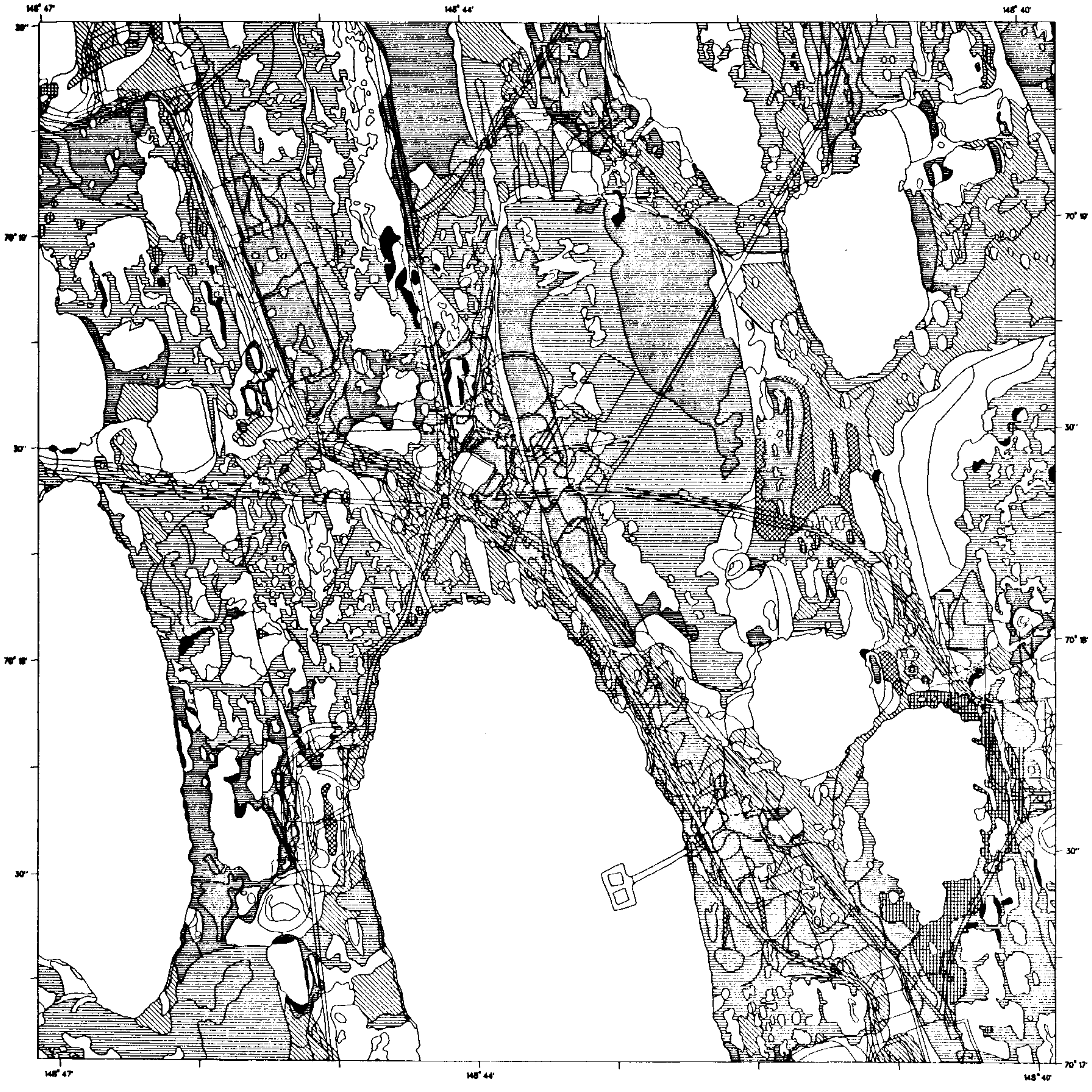


Fig. B8

MAP 22: SECONDARY VEGETATION - 1949

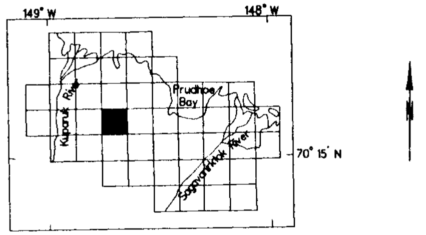


SYMBOL	DESCRIPTION	AREA HECTARES
■	Water	6.798
▦	Aquatic grass marsh	23.405
▒	Aquatic sedge marsh	237.777
▤	Wet sedge tundra	528.539
▨	Moist, nontussock-sedge, dwarf-shrub tundra	184.267
▩	Dry, dwarf-shrub, crustose-lichen tundra	13.951

Authors: D.A.Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: J.R. Carlson, E.F. Binnian, J.E. Grunblatt, and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR, and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 22 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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September, 1986

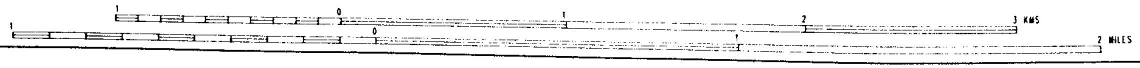
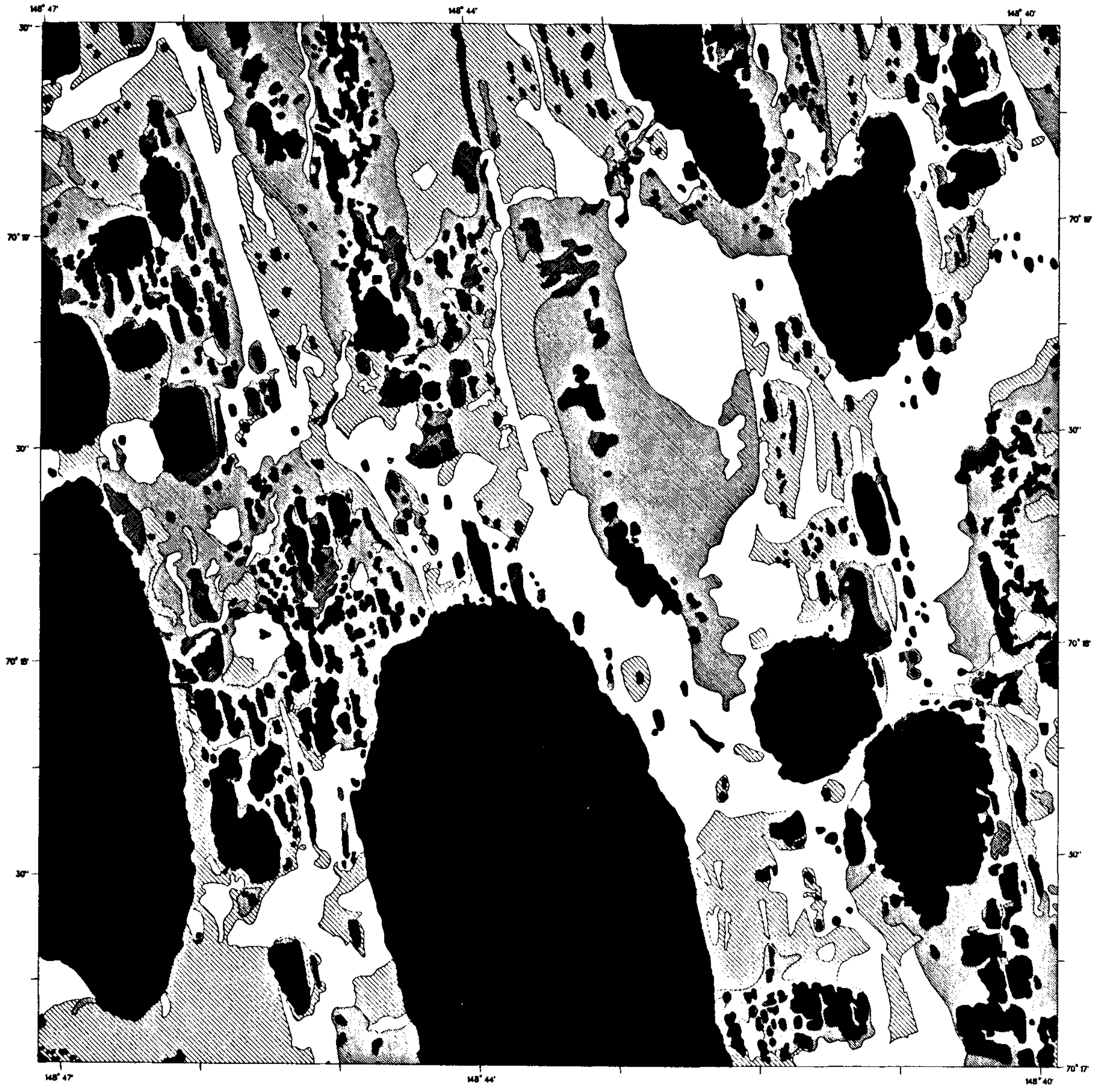


Fig. B9

MAP 22: PERCENT OF WATER COVER - 1949



SYMBOL	DESCRIPTION	AREA HECTARES
☐	0-5%	496.351
▨	6-30%	373.405
▩	31-60%	385.191
■	61-90%	42.022
■	91-100%	791.082

Authors: D.A.Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

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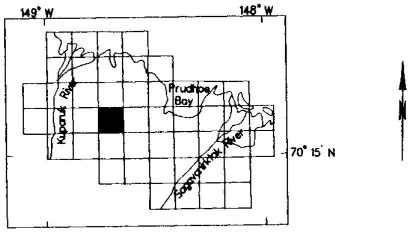
Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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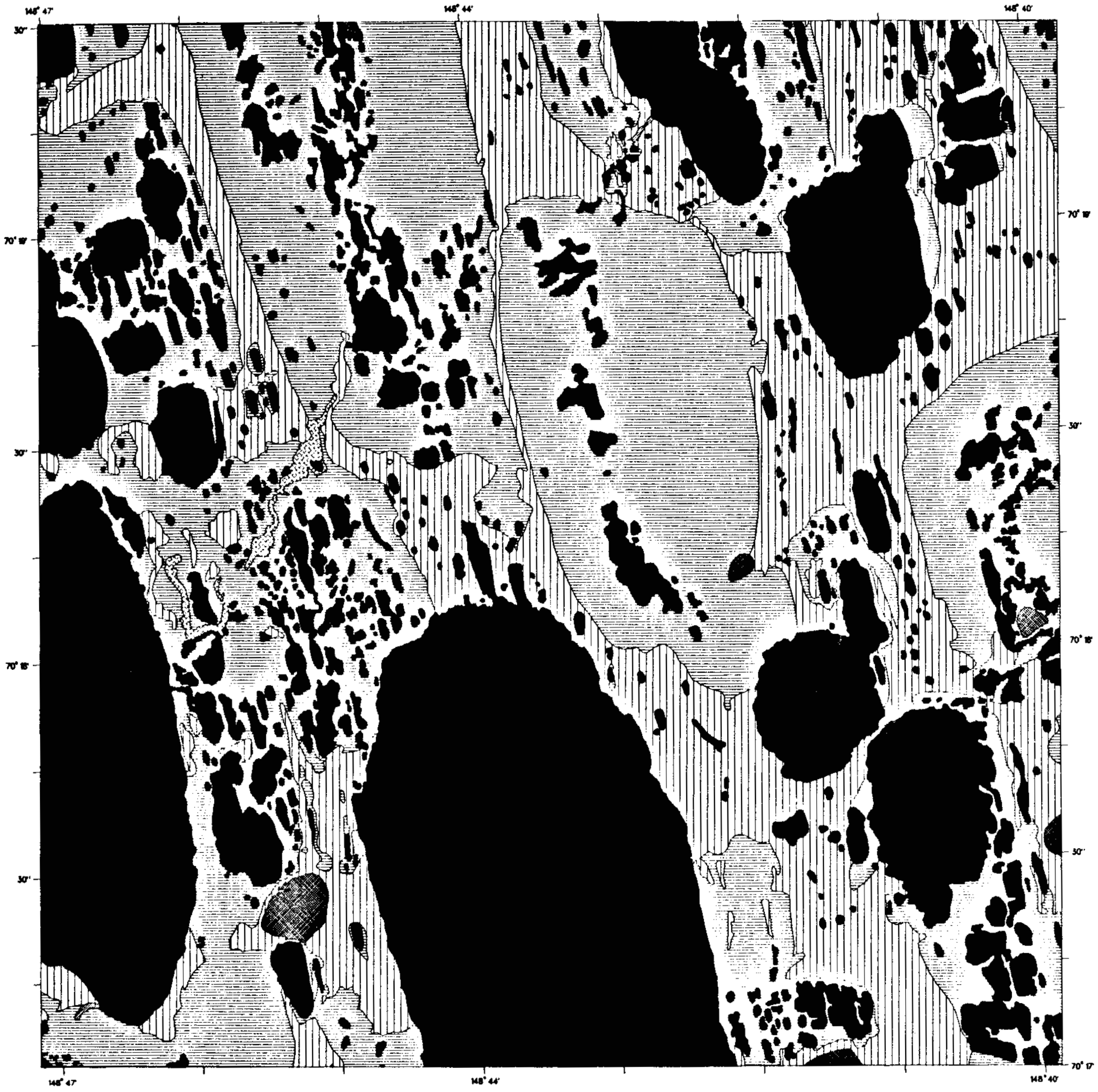
September, 1986

Fig. B10

MAP 22: LANDFORM - 1949

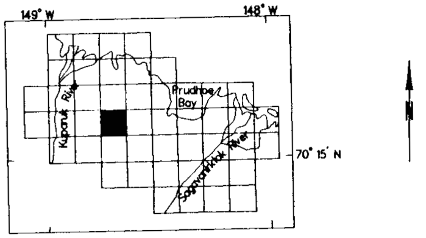


SYMBOL	DESCRIPTION	AREA HECTARES
▤	Drained thaw-lake basin	792.346
▥	Inter-thaw-lake area	455.492
■	Pingo	10.992
▩	Stabilized floodplain	6.605
▨	Small stream drainage	0.562
▦	Island	0.031
■	Lake or pond	821.821
■	River or stream	0.201

Authors: D.A.Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: J.R. Carlson, E.F. Binnian, J.E. Grunblatt, and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 22 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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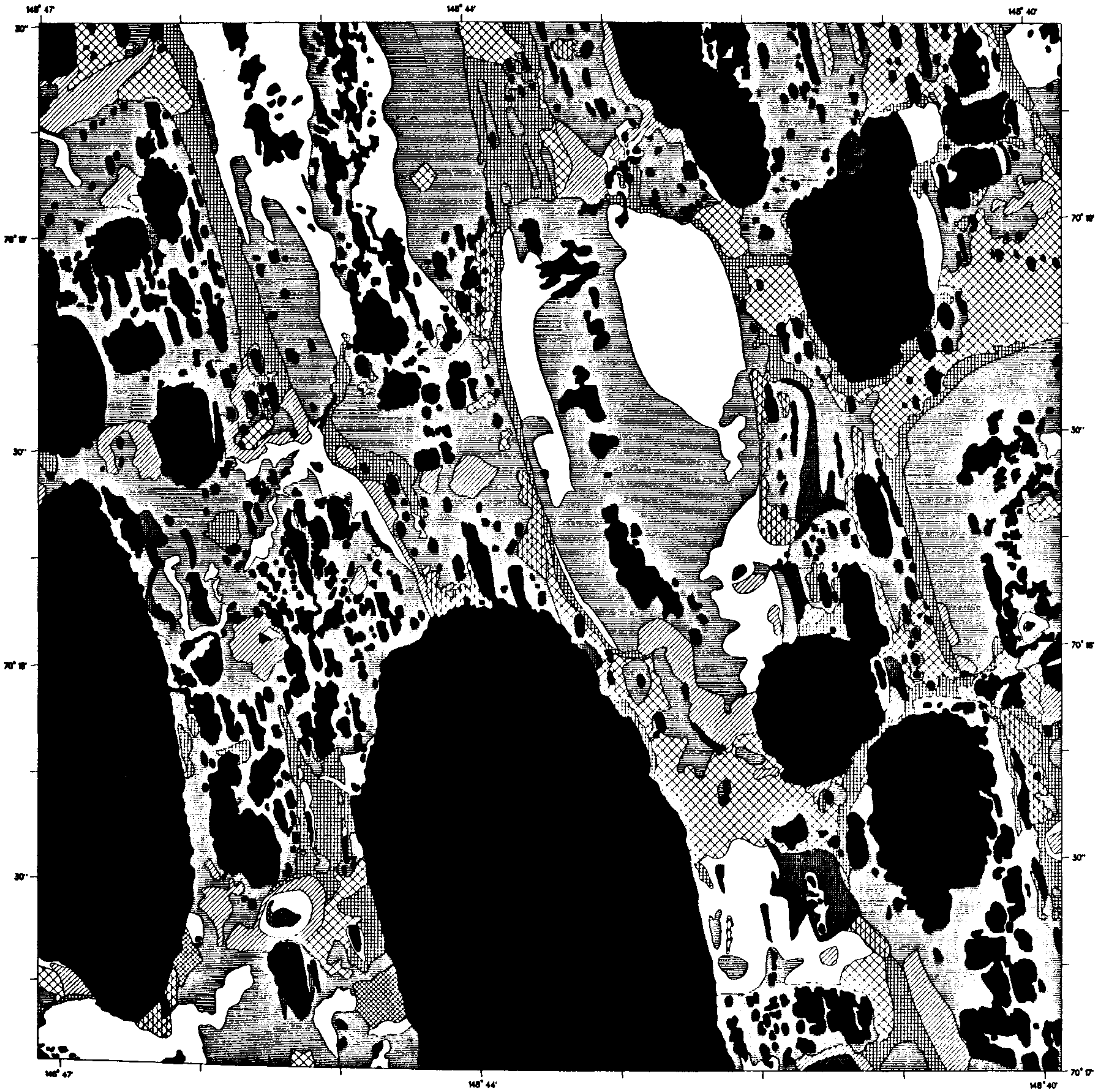
September, 1986

Fig. B11

MAP 22: PRIMARY SURFACE FORM - 1949

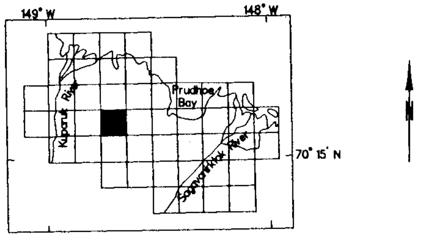


SYMBOL	DESCRIPTION	AREA HECTARES
■	High-centered polygons, center-trough relief greater than 0.5 m	24.551
▦	High-centered polygons, center-trough relief less than 0.5 m	119.503
▩	Low-centered polygons, center-rim relief greater than 0.5 m	5.896
▧	Low-centered polygons, center-rim relief less than 0.5 m	128.386
▦	Mixed high-centered and low-centered polygons	27.345
▨	Frost scars	76.541
▤	Strangmoor or disjunct polygon rims	660.199
▩	Hummocky terrain	0.336
■	Pingo with varied or undefined surface forms	2.336
□	Nonpatterned ground	220.595
■	Water	822.363

Authors: D.A.Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: J.R. Carlson, E.F. Binnian, J.E. Grunblatt, and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 22 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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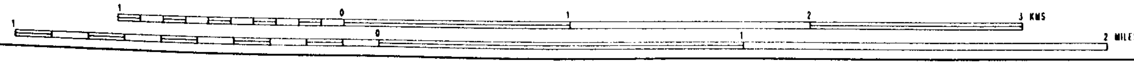
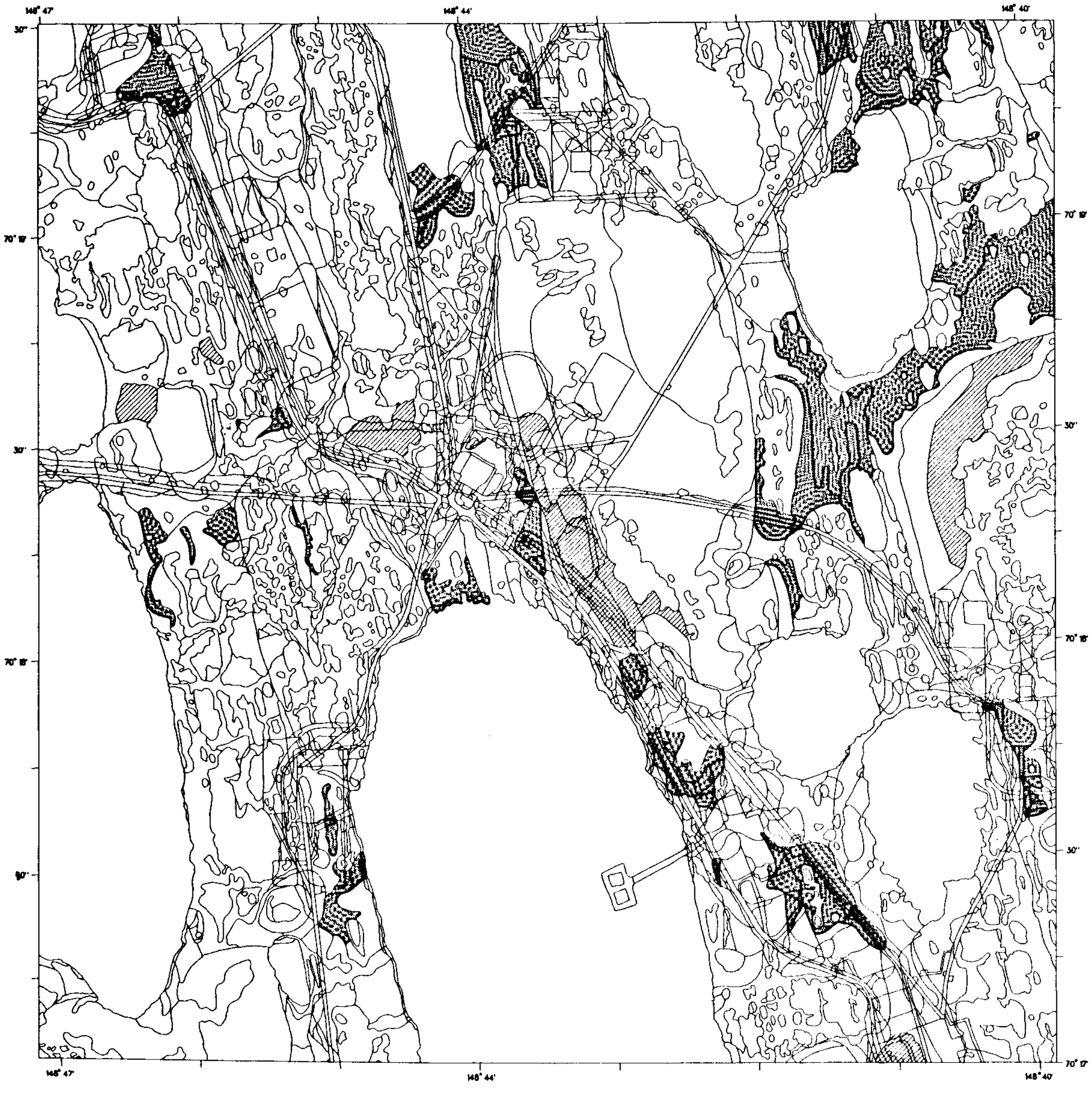


Fig. B12

MAP 22: SECONDARY SURFACE FORM - 1949

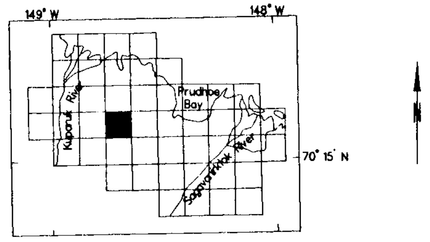


SYMBOL	DESCRIPTION	AREA HECTARES
▨	Frost scars	40.280
▨	Thermokarst pits	134.138

Authors: D. A. Walker, M. D. Walker and P. J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: J. R. Carlson, E. F. Binnian, J. E. Grunblatt, and E. A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D. A. Walker, INSTAAR; and K. R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 22 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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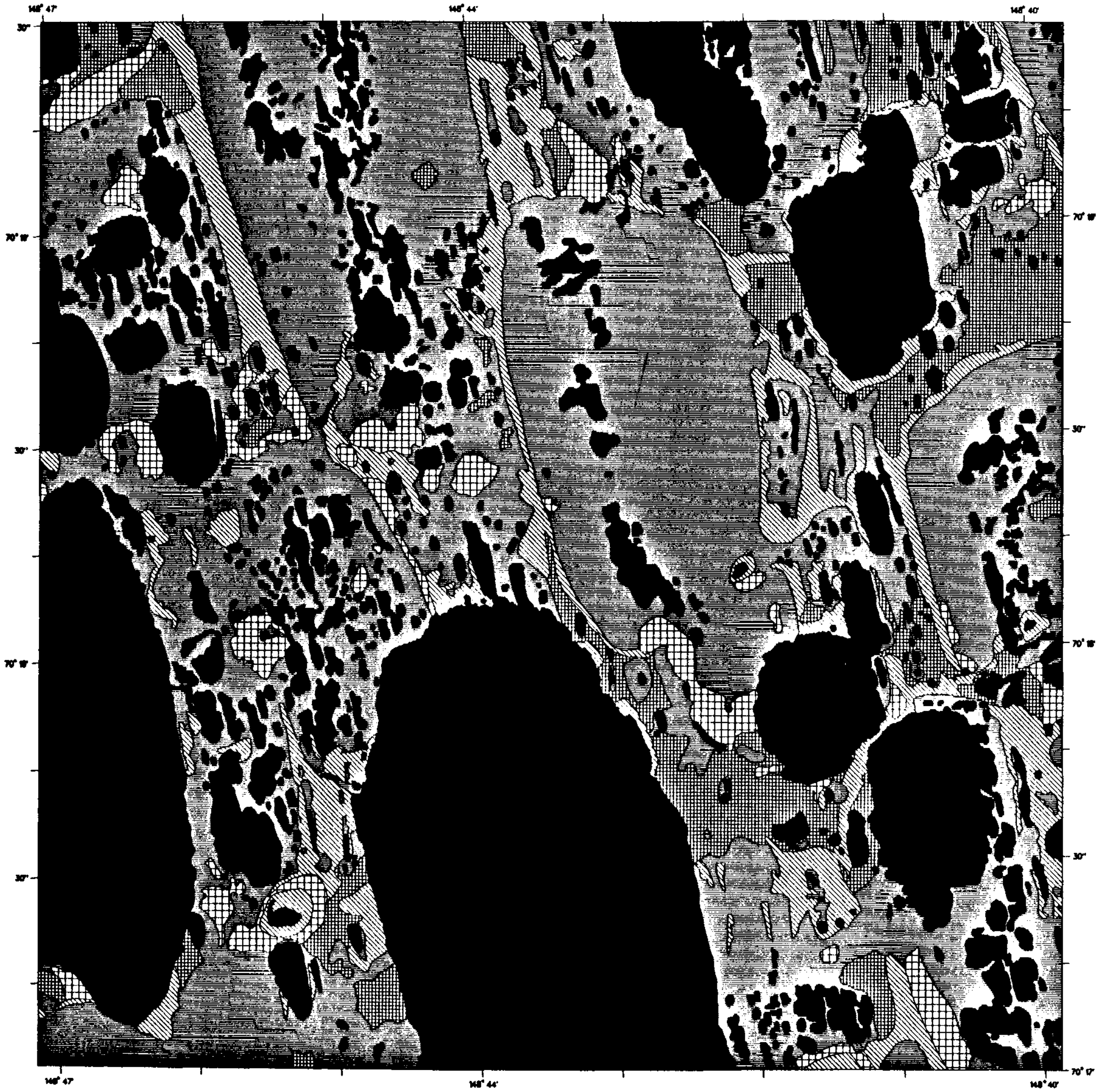
Fig. B13

MAP 22: PRIMARY SOIL - 1949

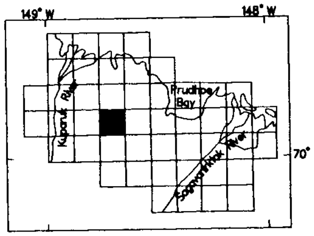


SYMBOL	DESCRIPTION	AREA HECTARES
■	Pergelic Cryoborolls	2.455
▨	Pergelic Cryaquolls or Cryosaprists	176.112
▤	Complex of: a) Pergelic Cryohemists or Cryofibrists, b) Histic Pergelic Cryaquepts, and c) Pergelic Cryaquepts	872.520
▩	Association of: a) Pergelic Cryohemists or Cryofibrists or Histic Pergelic Cryaquepts and b) Pergelic Cryosaprists or Cryaquolls	137.022
▦	Association of: a) Pergelic Cryaquolls or Cryosaprists and b) Pergelic Cryaquepts	77.167
■	Water	822.775

Authors: D.A.Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: J.R. Carlson, E.F. Binnian, J.E. Grunblatt, and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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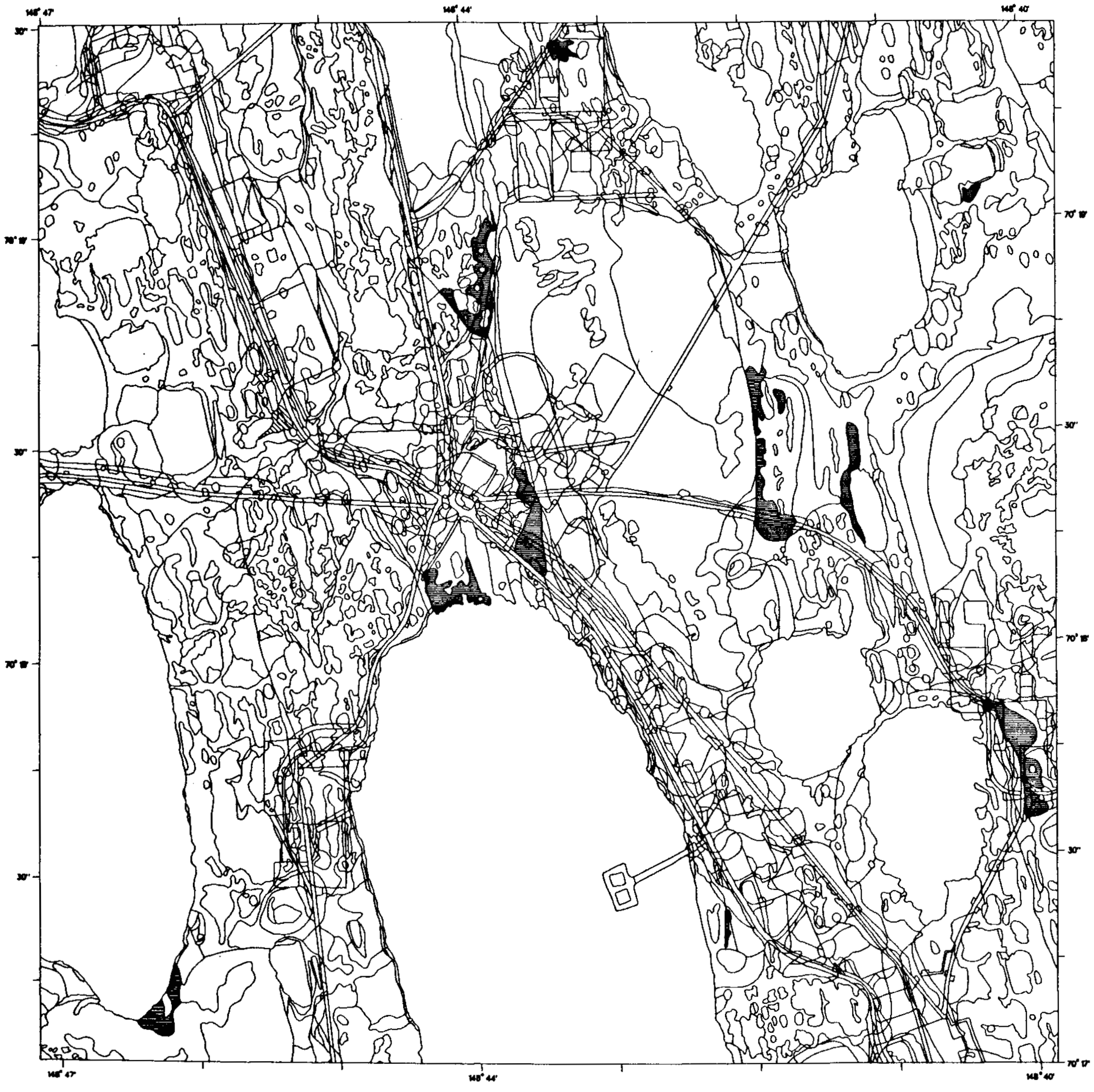
September, 1986

Fig. B14

MAP 22: SECONDARY SOIL - 1949

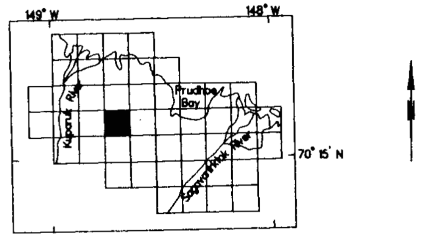


SYMBOL	DESCRIPTION	AREA HECTARES
▨	Pergelic Cryaquolls or Cryosaprists	0.905
■	Complex of: a) Pergelic Cryohemists or Cryofibrists b) Histic Pergelic Cryaquepts, and c) Pergelic Cryaquepts	25.817

Authors: D.A.Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: J.R. Carlson, E.F. Binnian, J.E. Grunblatt, and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 22 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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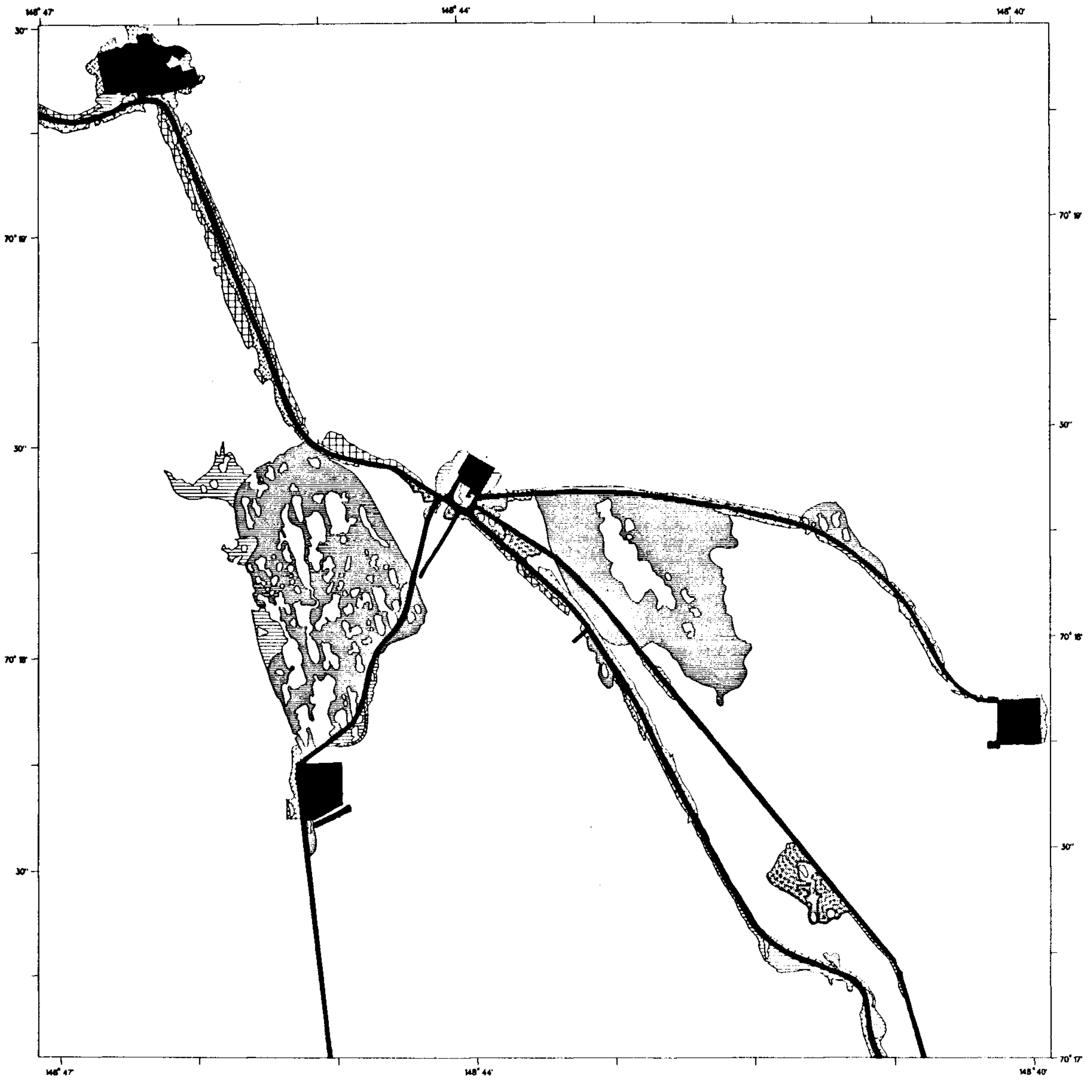
September, 1986

Fig. B15

MAP 22: PRIMARY ANTHROPOGENIC DISTURBANCE - 1970

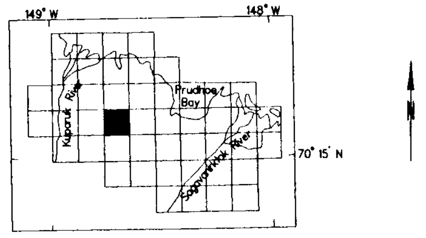


SYMBOL	DESCRIPTION	AREA HECTARES
■	Gravel roads	28.720
■	Gravel pads	18.517
▒	Continuous flooding, more than 75% open water	96.851
▤	Discontinuous flooding, less than 75% open water	18.380
▩	Construction-induced thermokarst	6.491
▦	Vehicle tracks, not deeply rutted	9.955
▨	Gravel and construction debris (more than 75% cover)	9.441
▧	Gravel and construction debris (less than 75% cover)	12.397

Authors: D.A.Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: J.R. Carlson, E.F. Binnian, J.E. Grunblatt, and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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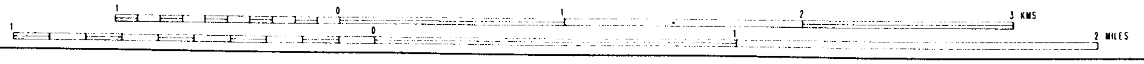
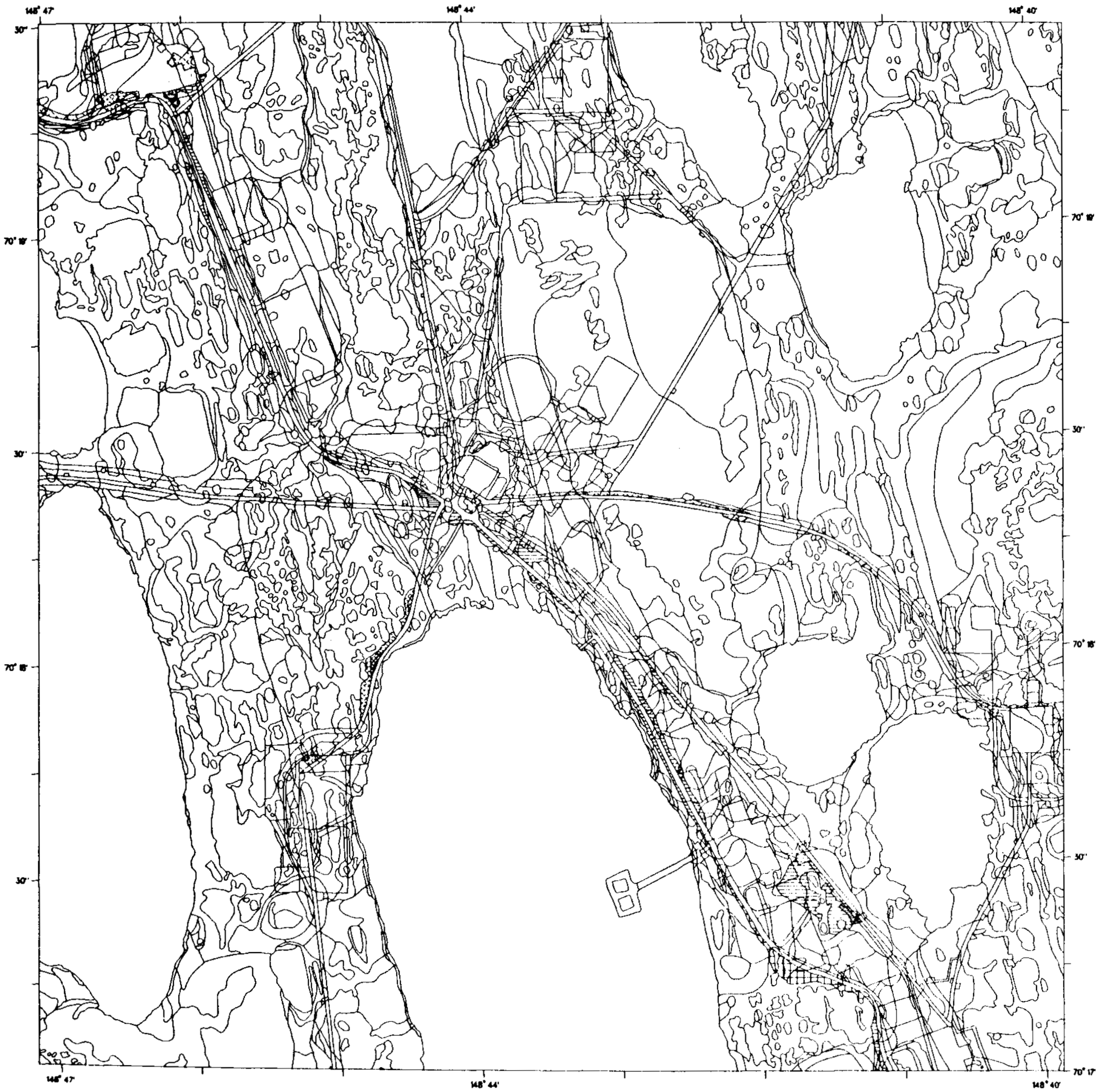


Fig. B16

MAP 22: SECONDARY ANTHROPOGENIC DISTURBANCE - 1970

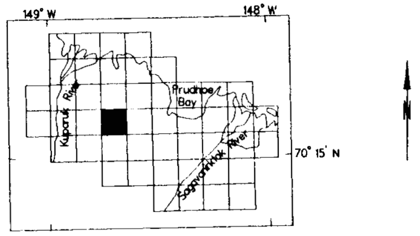


SYMBOL	DESCRIPTION	AREA HECTARES
▓	Continuous flooding, more than 75% open water	0.798
▤	Discontinuous flooding, less than 75% open water	12.447
▩	Construction-induced thermokarst	0.315
▦	Vehicle tracks, not deeply rutted	3.007
▨	Gravel and construction debris (more than 75% cover)	2.739
▧	Gravel and construction debris (less than 75% cover)	3.895

Authors: D.A.Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: J.R. Carlson, E.F. Binnian, J.E. Grunblatt, and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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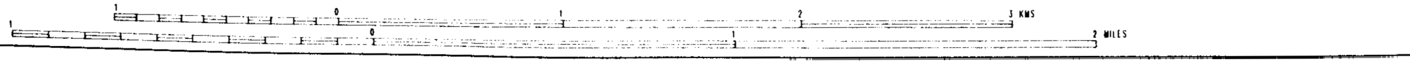
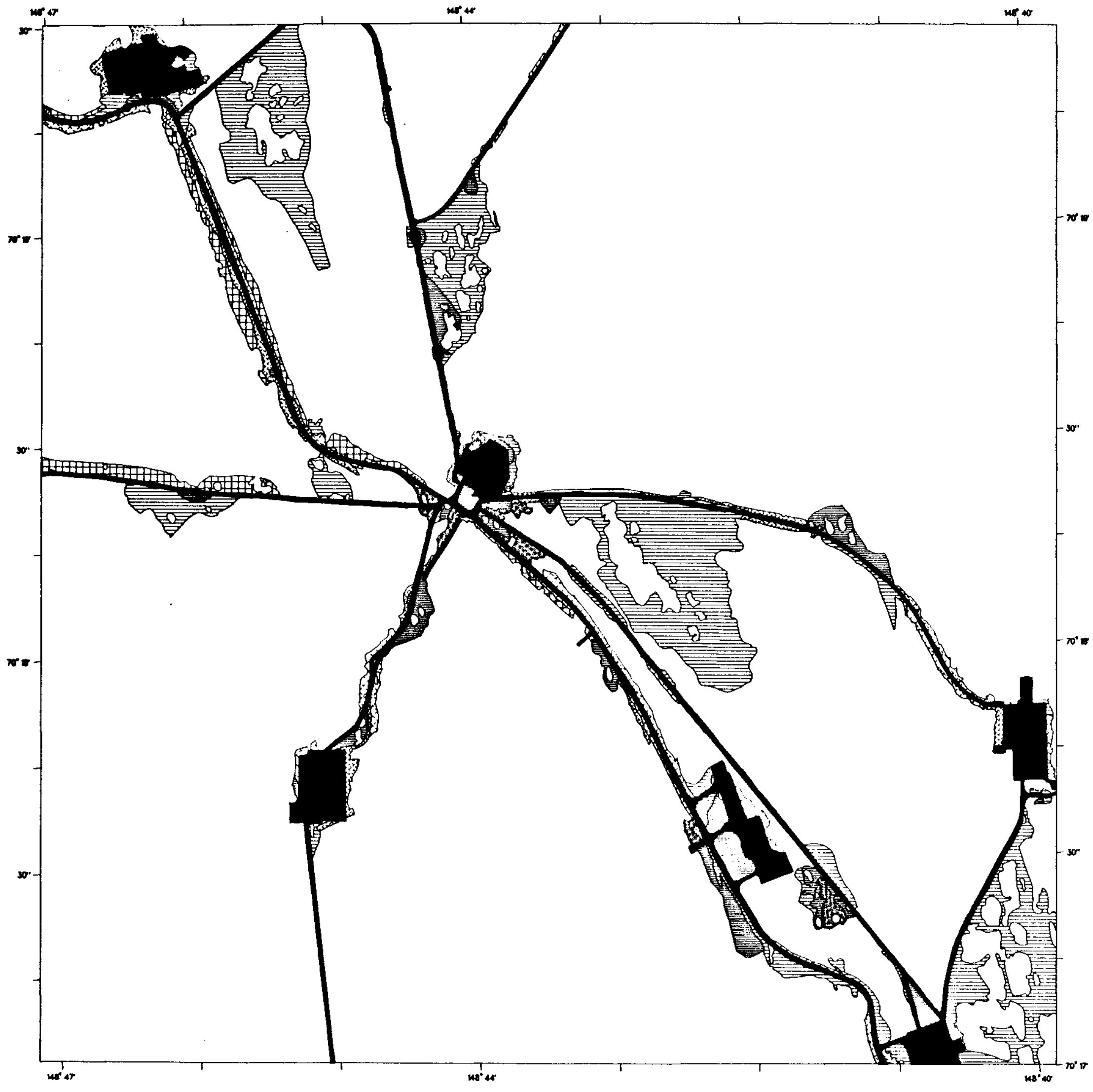


Fig. B17

MAP 22: PRIMARY ANTHROPOGENIC DISTURBANCE - 1973

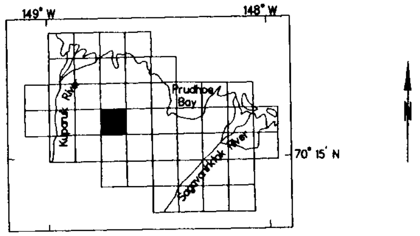


SYMBOL	DESCRIPTION	AREA HECTARES
■	Gravel roads	41.778
■	Gravel pads	36.560
▓	Continuous flooding, more than 75% open water	23.227
▤	Discontinuous flooding, less than 75% open water	110.775
▩	Construction-induced thermokarst	5.752
▦	Vehicle tracks, not deeply rutted	14.733
▧	Gravel and construction debris (more than 75% cover)	11.731
░	Gravel and construction debris (less than 75% cover)	15.628

Authors: D.A.Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: J.R. Carlson, E.F. Binnion, J.E. Grunblatt, and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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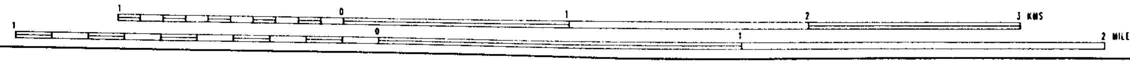
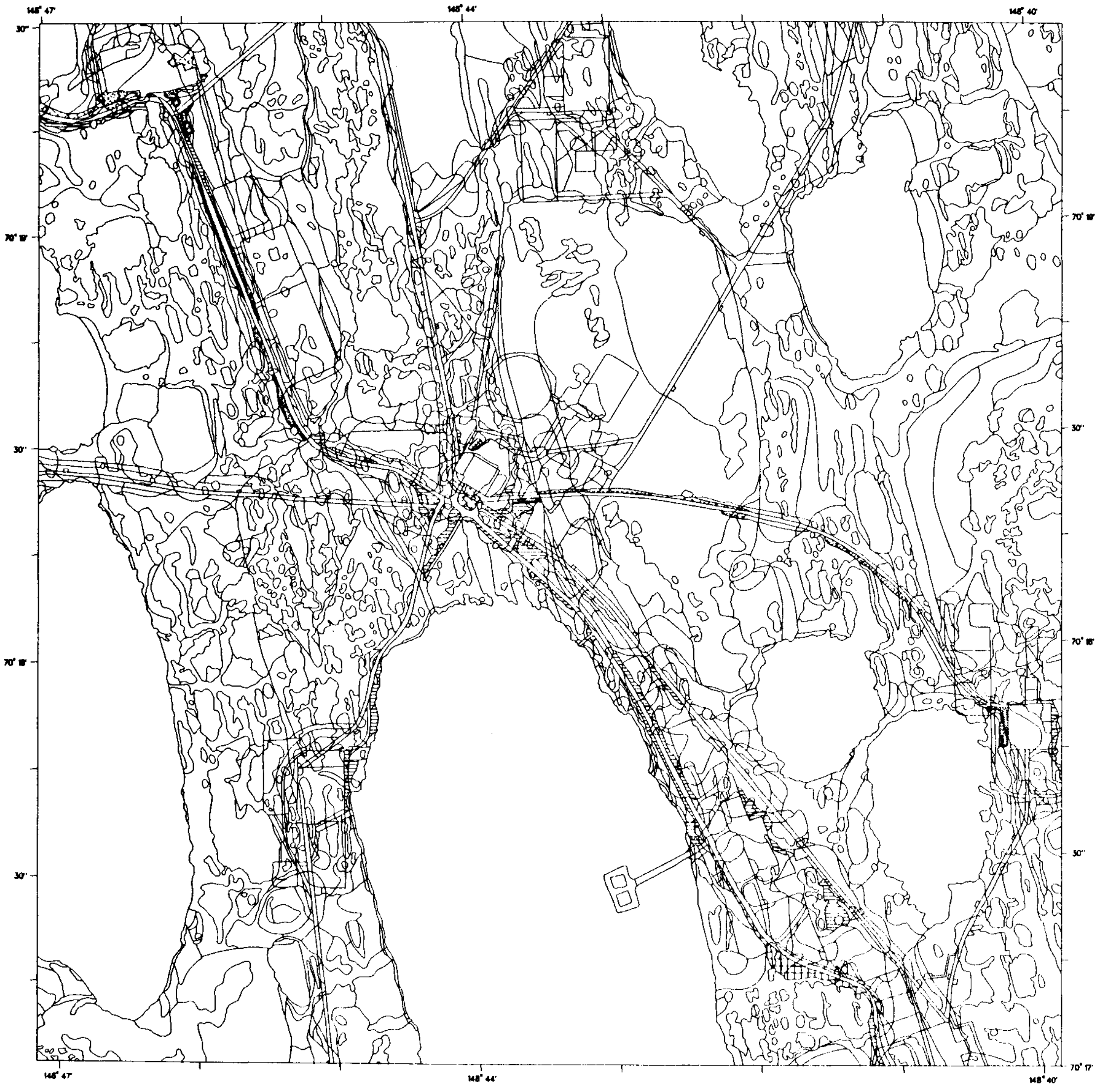


Fig. B18

MAP 22: SECONDARY ANTHROPOGENIC DISTURBANCE - 1973

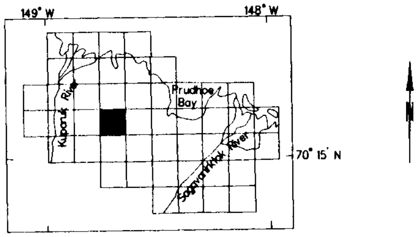


SYMBOL	DESCRIPTION	AREA HECTARES
▤	Discontinuous flooding, less than 75% open water	15.081
▩	Construction-induced thermokarst	4.060
▦	Vehicle tracks, not deeply rutted	3.346
▩	Gravel and construction debris (more than 75% cover)	3.072
▨	Gravel and construction debris (less than 75% cover)	3.310

Authors: D.A. Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: J.R. Carlson, E.F. Binnian, J.E. Grunblatt, and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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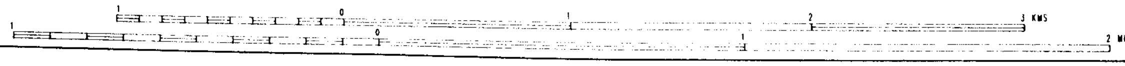
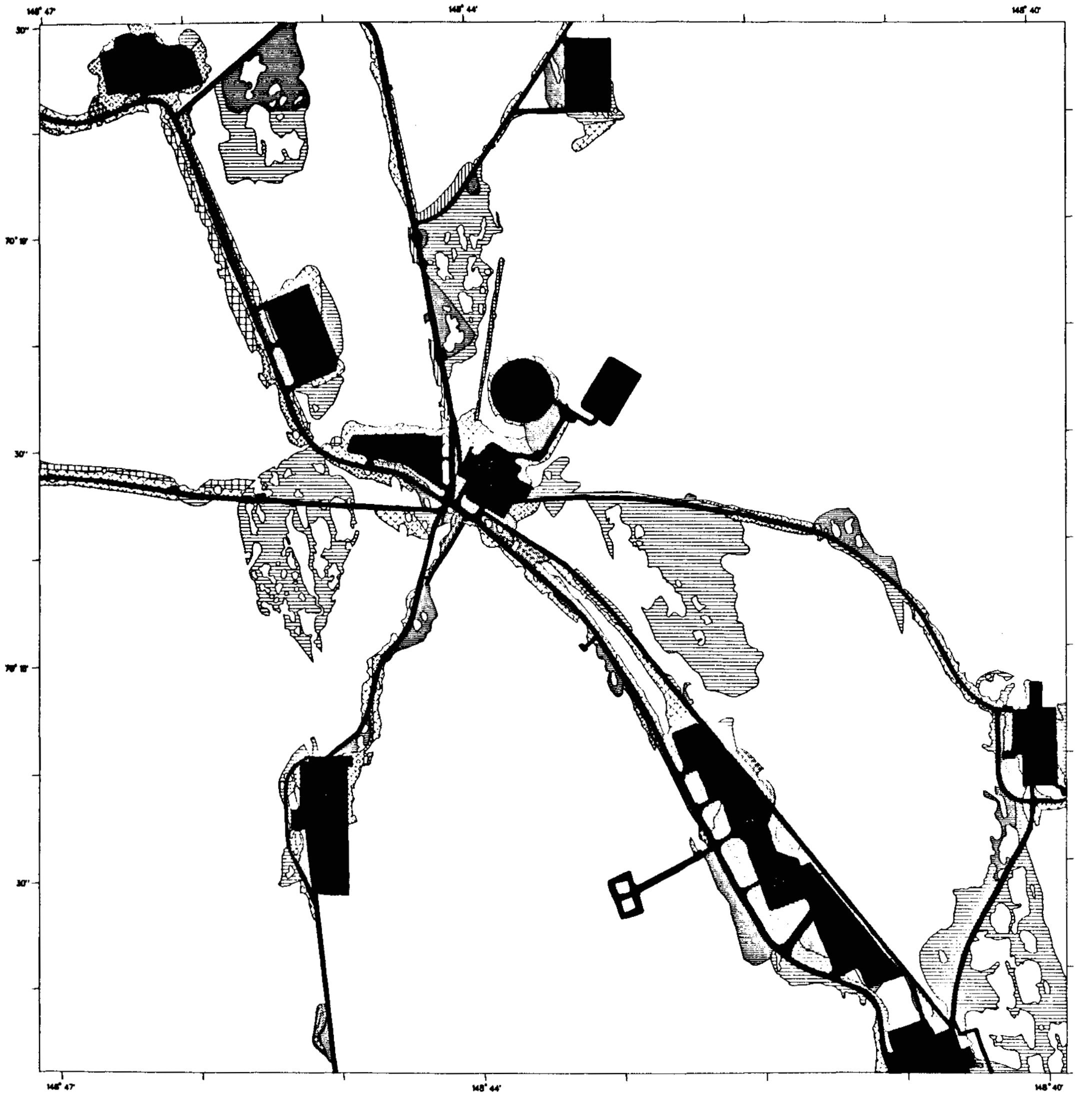


Fig. B19

MAP 22: PRIMARY ANTHROPOGENIC DISTURBANCE - 1977



SYMBOL	DESCRIPTION	AREA HECTARES
■	Gravel roads	47.041
■	Gravel pads	98.410
▓	Continuous flooding, more than 75% open water	46.086
▤	Discontinuous flooding, less than 75% open water	118.444
▩	Construction-induced thermokarst	8.550
▦	Vehicle tracks, deeply rutted or with thermokarst	1.251
⊞	Vehicle tracks, not deeply rutted	7.742
▩	Gravel and construction debris (more than 75% cover)	13.653
▨	Gravel and construction debris (less than 75% cover)	39.512
▥	Dust or dust-killed tundra	2.706

Authors: D.A.Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

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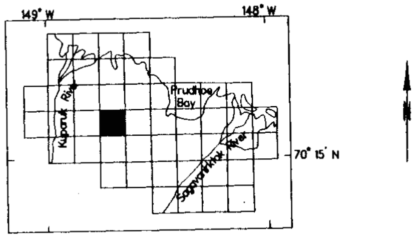
Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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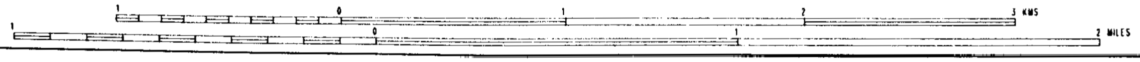
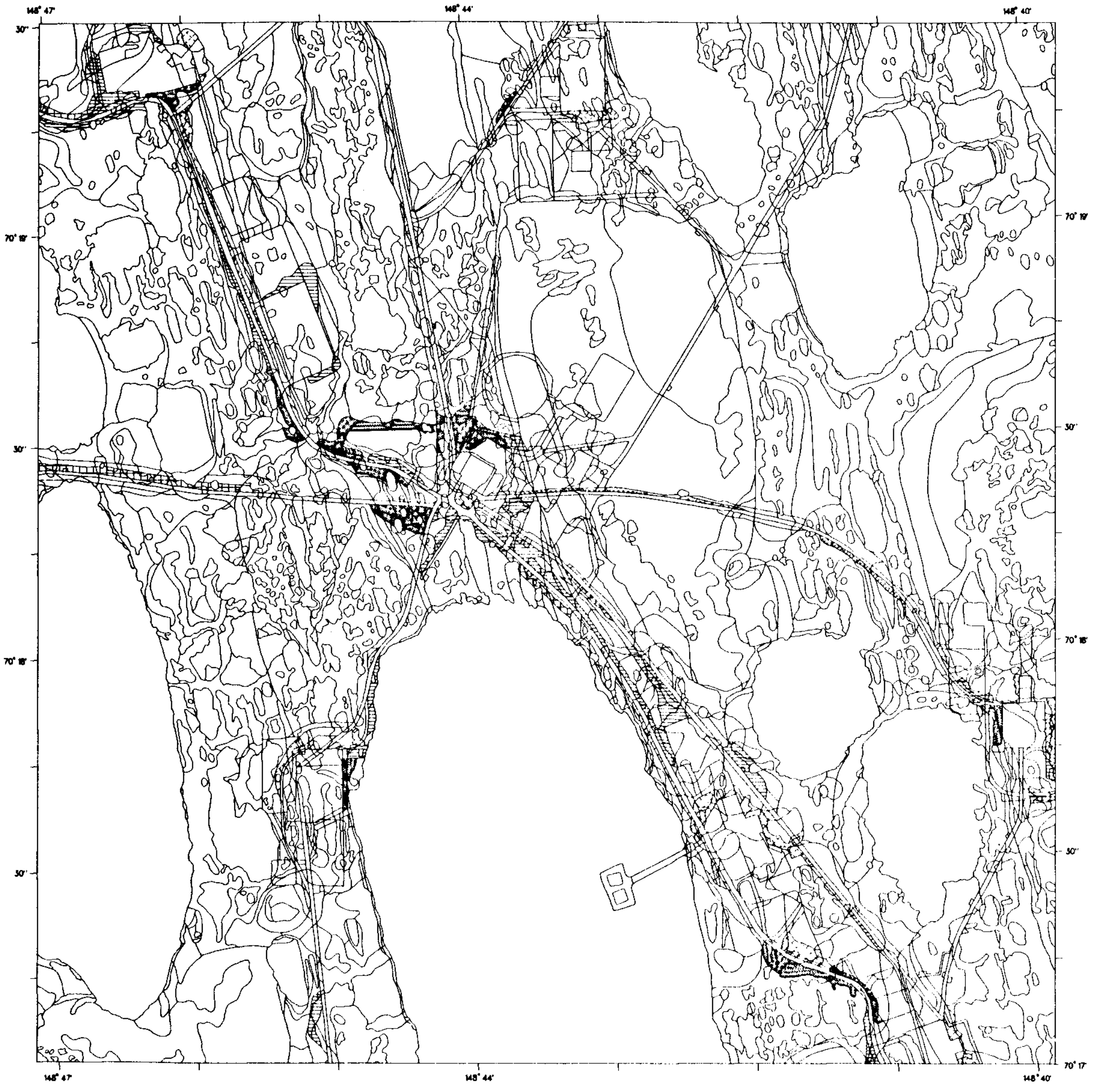


Fig. B20

MAP 22: SECONDARY ANTHROPOGENIC DISTURBANCE - 1977



SYMBOL	DESCRIPTION	AREA HECTARES
▤	Discontinuous flooding, less than 75% open water	23.005
▩	Construction-induced thermokarst	14.443
▦	Vehicle tracks, not deeply rutted	4.263
▨	Gravel and construction debris (more than 75% cover)	1.730
▧	Gravel and construction debris (less than 75% cover)	11.838

Authors: D.A Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO

Map Automation: J.R. Carlson, E.F. Binnion, J.E. Grunblatt, and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

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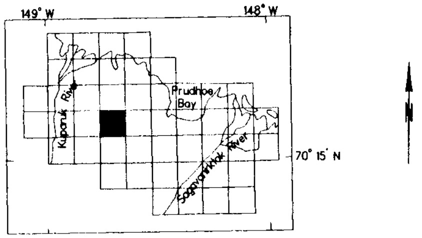

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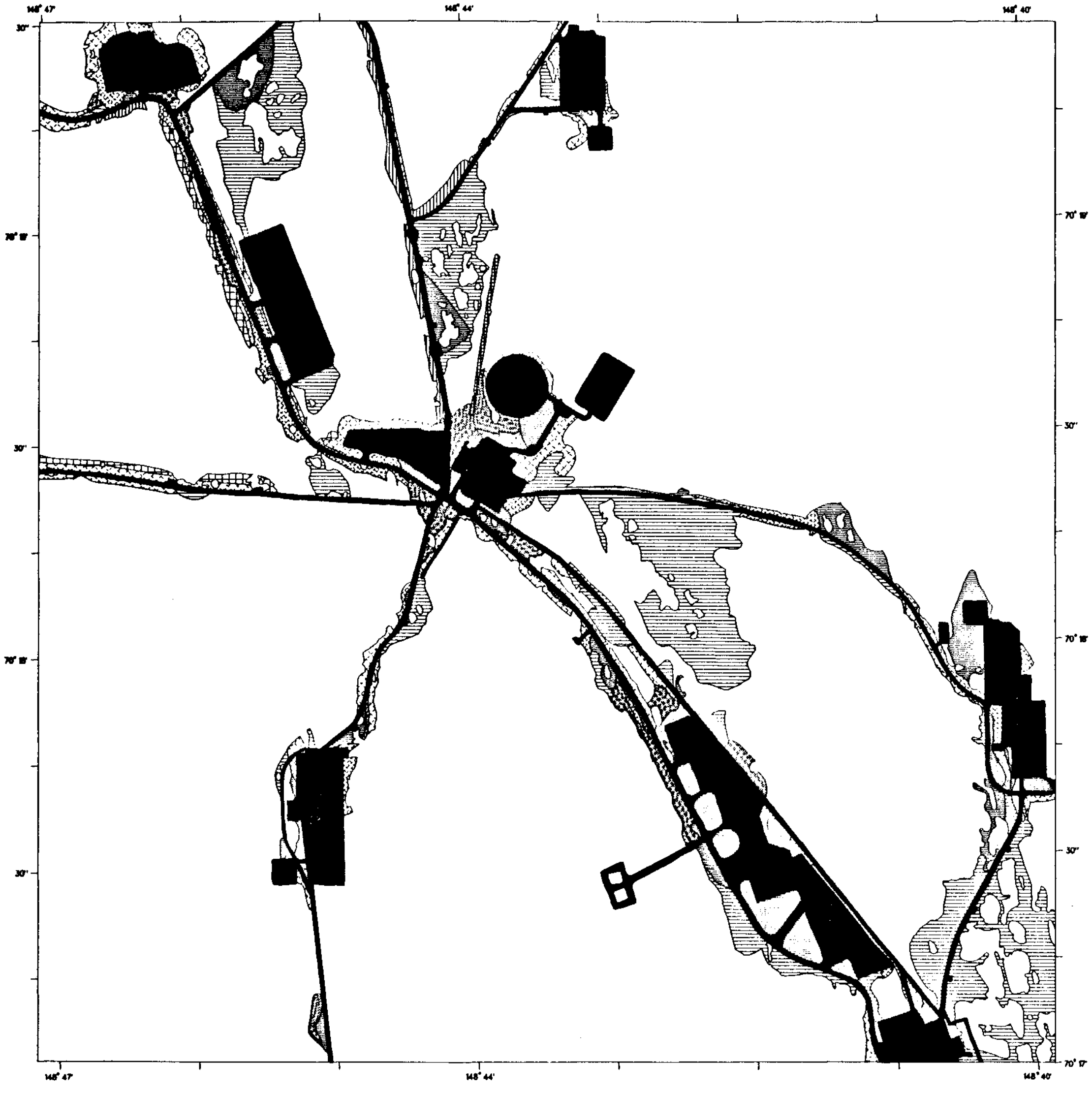
September, 1986

Fig. B21

MAP 22: PRIMARY ANTHROPOGENIC DISTURBANCE - 1979

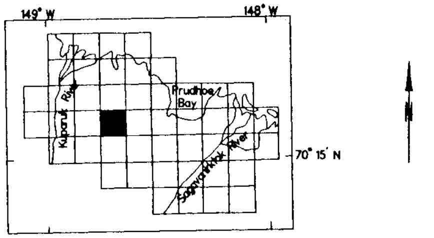


SYMBOL	DESCRIPTION	AREA HECTARES
■	Gravel roads	45.386
■	Gravel pads	117.905
▨	Continuous flooding, more than 75% open water	39.301
▤	Discontinuous flooding, less than 75% open water	110.439
▨	Construction-induced thermokarst	18.478
▦	Vehicle tracks, deeply rutted or with thermokarst	1.251
▦	Vehicle tracks, not deeply rutted	6.812
▩	Gravel and construction debris (more than 75% cover)	14.548
▩	Gravel and construction debris (less than 75% cover)	33.470
▥	Dust or dust-killed tundra	6.169

Authors: D.A. Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: J.R. Carlson, E.F. Binnian, J.E. Grunblatt, and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 22 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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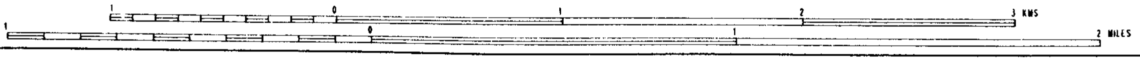
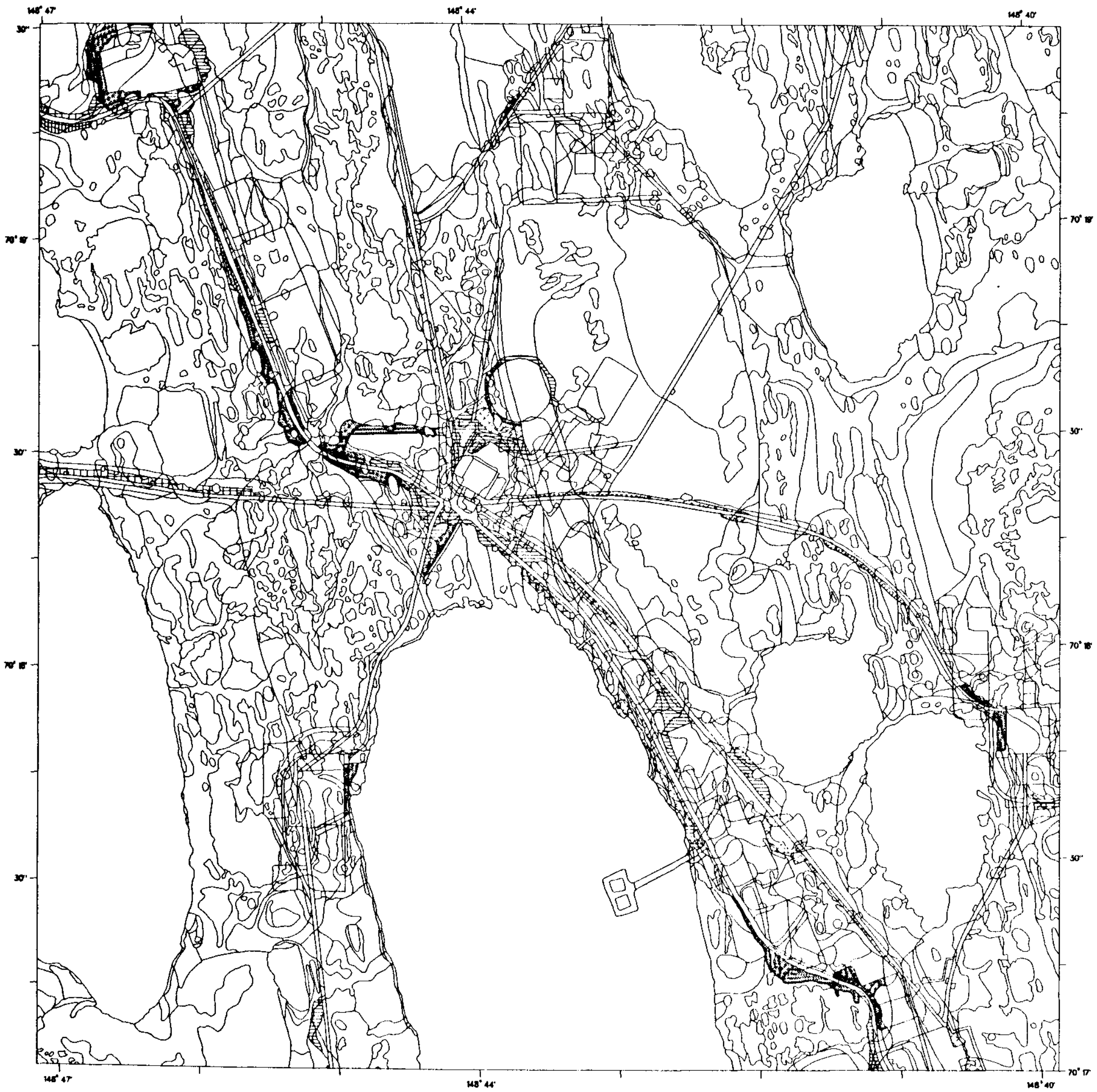


Fig. B22

MAP 22: SECONDARY ANTHROPOGENIC DISTURBANCE - 1979



SYMBOL	DESCRIPTION	AREA HECTARES
▤	Discontinuous flooding, -less than 75% open water	18.792
▩	Construction-induced thermokarst	17.402
▦	Vehicle tracks, not deeply rutted	4.341
▩	Gravel and construction debris (more than 75% cover)	2.767
▧	Gravel and construction debris (less than 75% cover)	10.633
▥	Dust or dust-killed tundra	0.870

Authors: D.A.Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: J.R. Carlson, E.F. Binnian, J.E. Grunblatt, and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

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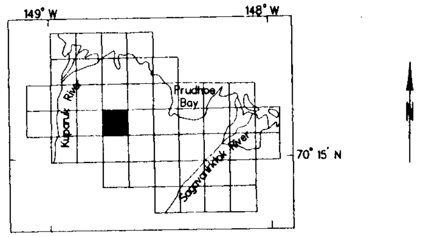

Base Map: Map 22 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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September, 1986

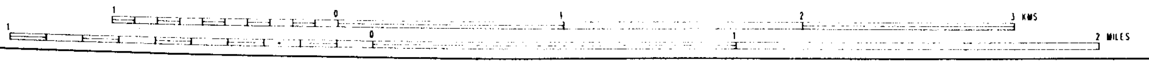
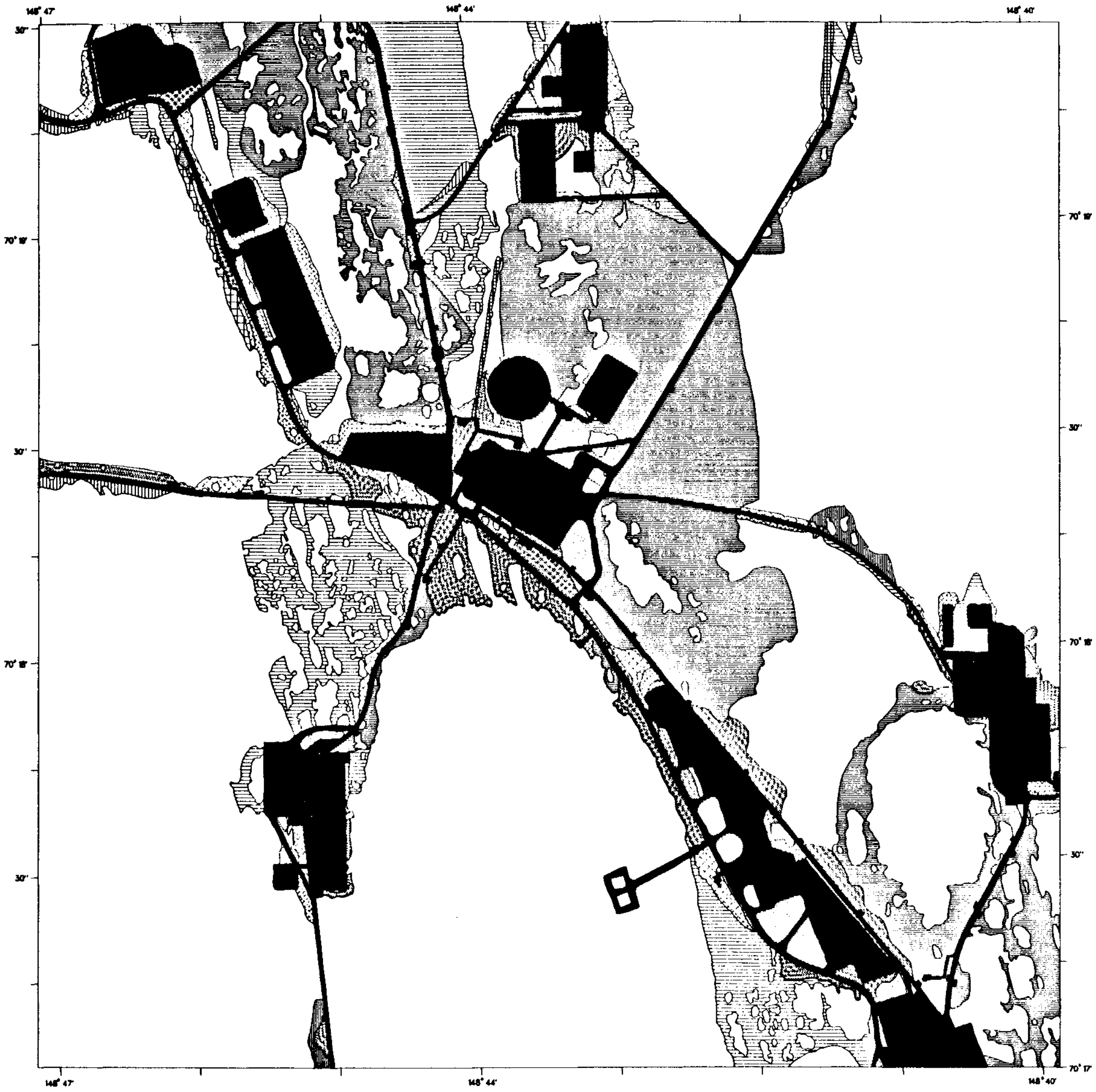


Fig. B23

MAP 22: PRIMARY ANTHROPOGENIC DISTURBANCE - 1983



SYMBOL	DESCRIPTION	AREA HECTARES
■	Gravel roads	· 53.495
■	Gravel pods	169.518
▒	Continuous flooding, more than 75% open water	288.645
▤	Discontinuous flooding, less than 75% open water	121.184
▩	Construction-induced thermokarst	59.292
▦	Vehicle tracks, deeply rutted or with thermokarst	2.673
⊞	Vehicle tracks, not deeply rutted	3.578
▩	Gravel and construction debris (more than 75% cover)	17.188
▨	Gravel and construction debris (less than 75% cover)	21.041
▥	Dust or dust-killed tundra	4.321
▓	Barren tundra caused by previous anthropogenic impoundments	4.437

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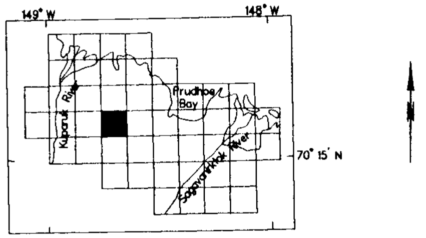

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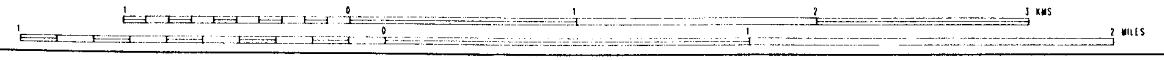
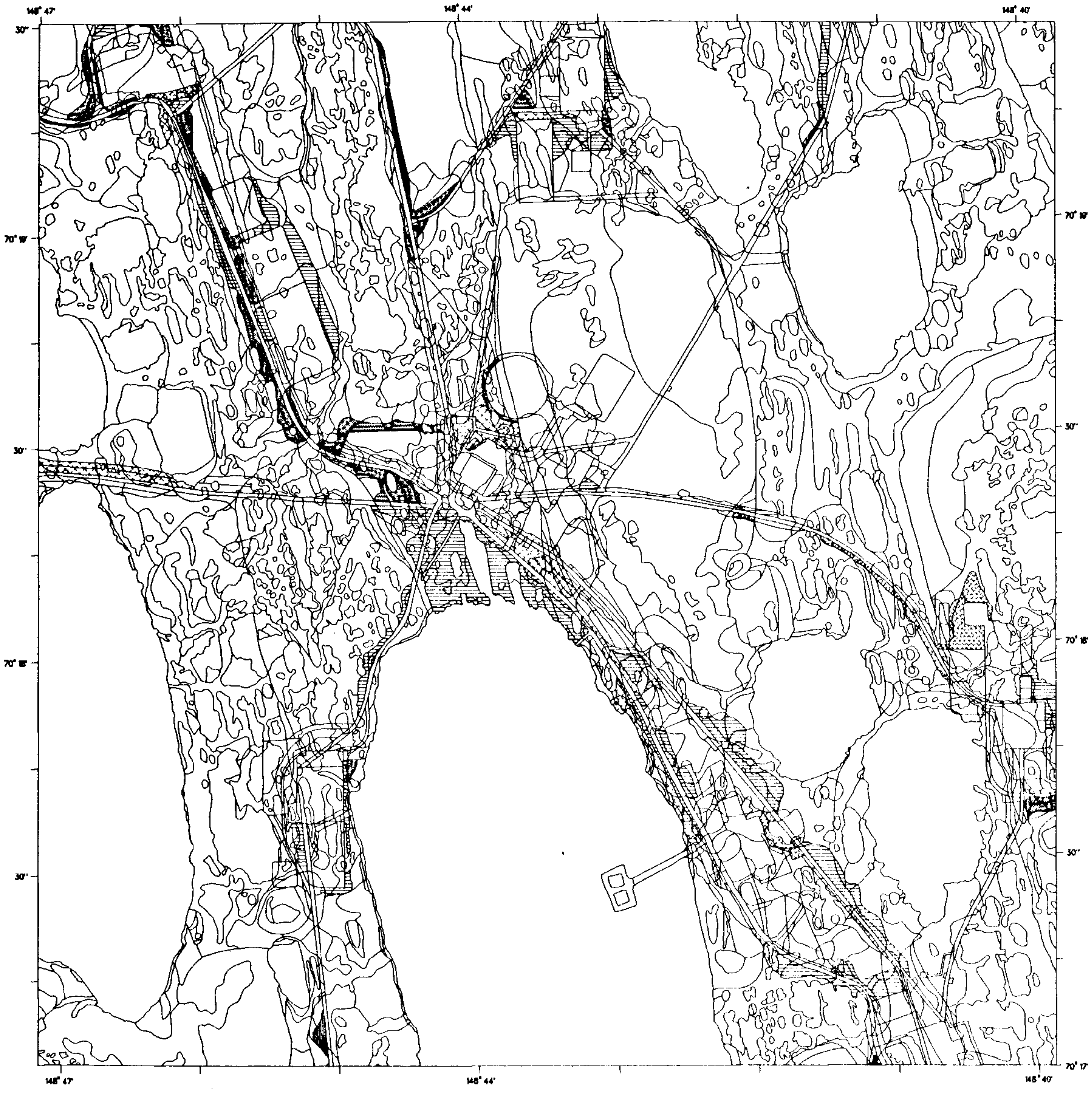


Fig. B24

MAP 22: SECONDARY ANTHROPOGENIC DISTURBANCE - 1983



SYMBOL	DESCRIPTION	AREA HECTARES
▤	Discontinuous flooding, less than 75% open water	50.400
▩	Construction-induced thermokarst	19.322
▦	Gravel and construction debris (more than 75% cover)	6.772
▨	Gravel and construction debris (less than 75% cover)	17.899
▥	Barren tundra caused by previous anthropogenic impoundments	0.705

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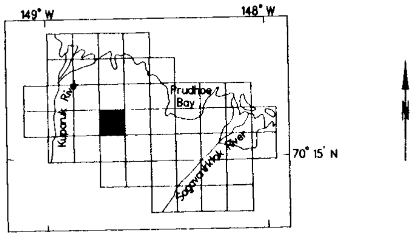

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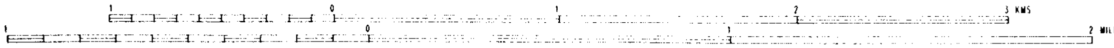
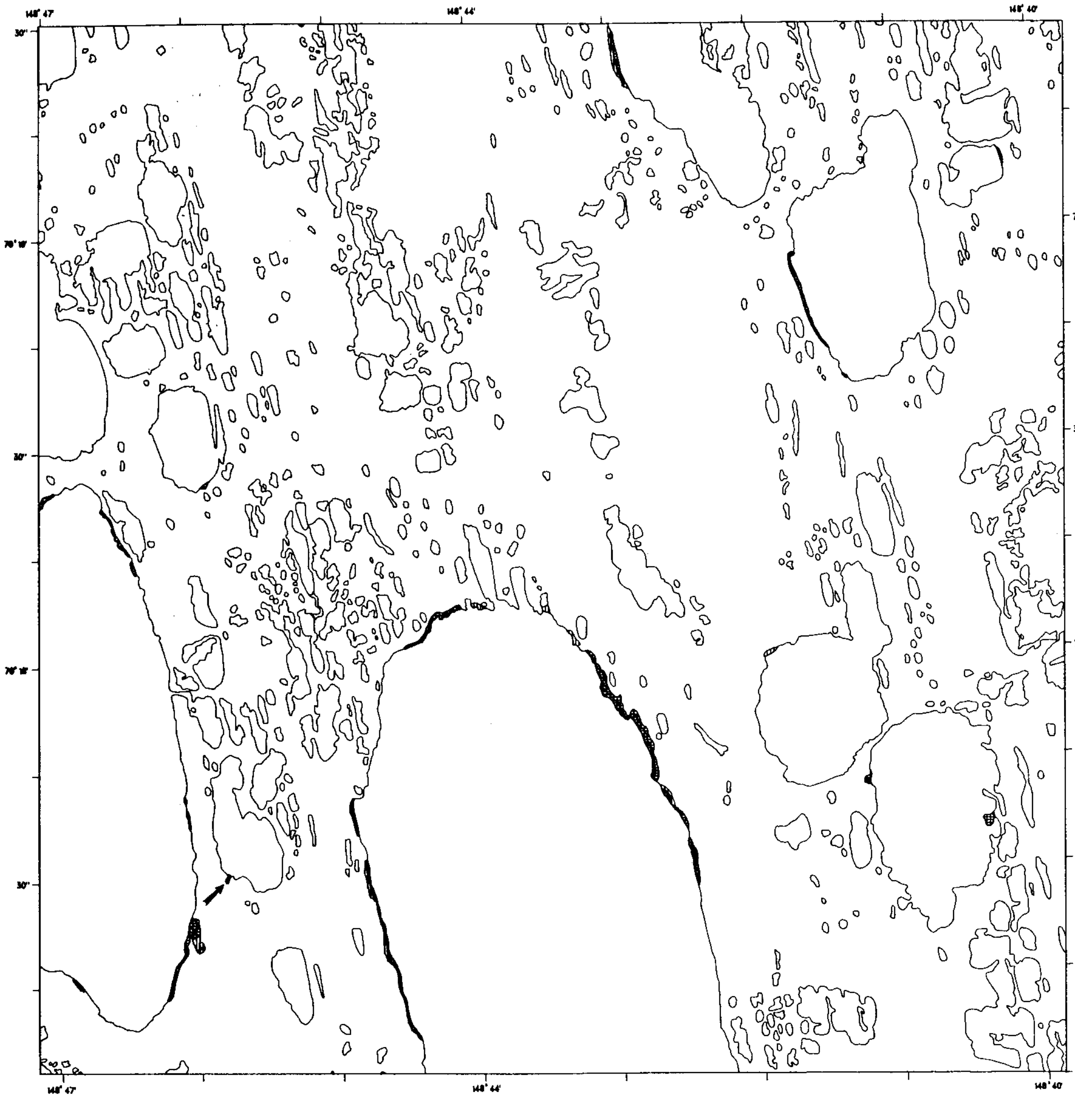


Fig. B25

MAP 22: NATURAL DISTURBANCES - 1968, 1977, & 1983



SYMBOL	DESCRIPTION	AREA HECTARES
▨	Lake erosion - 1968	4.433
▤	Lake erosion - 1977	6.466
▥	Lake erosion - 1983	7.905
■	Lake drainage - 1977, 1983	0.129

Authors: D.A.Walker, M.D. Walker and P.J. Webber, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

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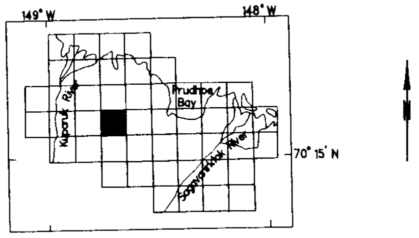

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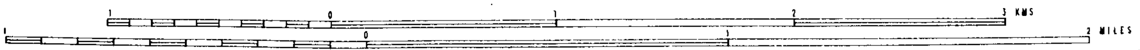
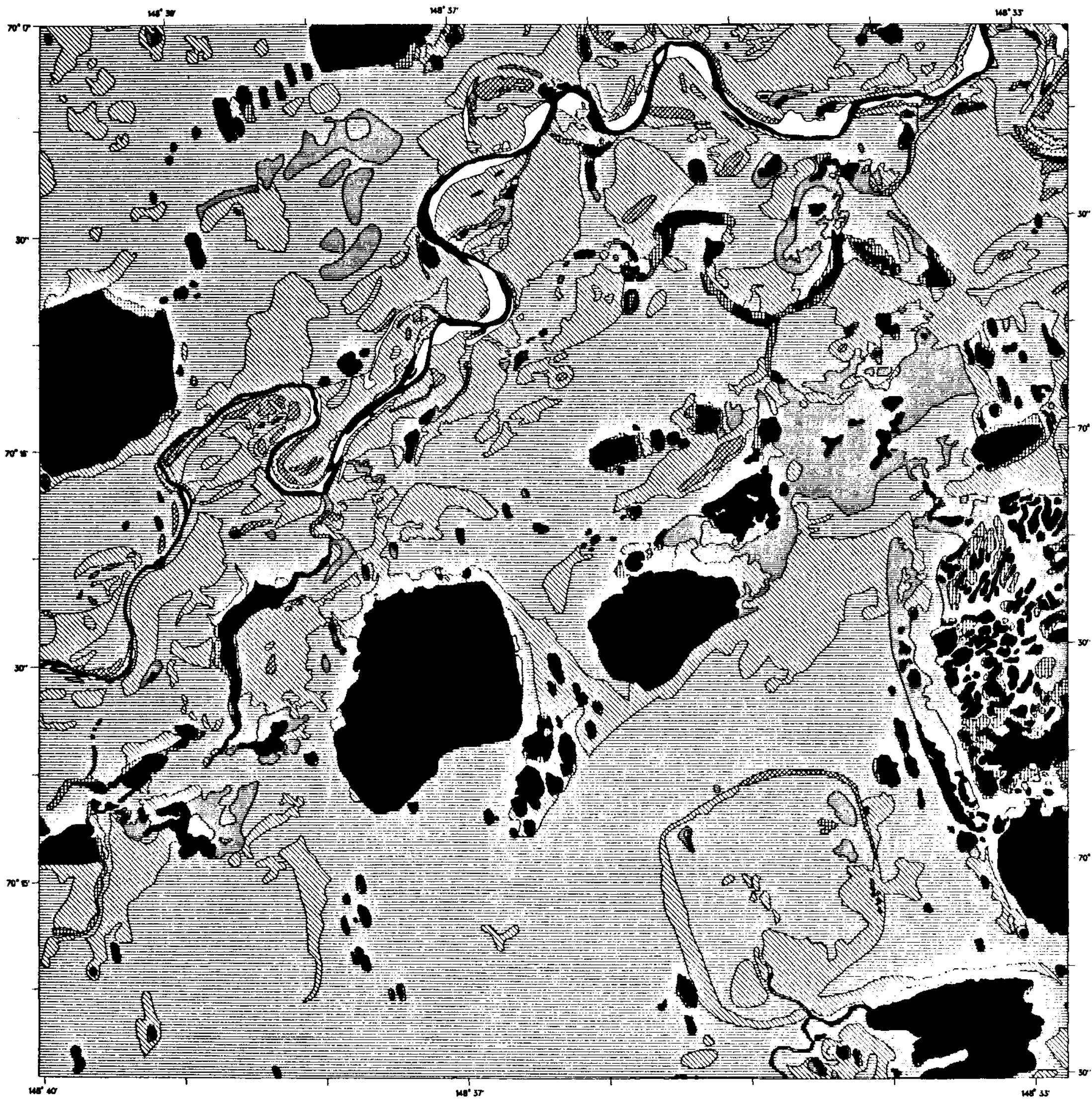


Fig. B26

MAP 32: PRIMARY VEGETATION - 1949



SYMBOL	DESCRIPTION	AREA HECTARES
■	Water	287.904
▦	Aquatic grass marsh	30.498
▒	Aquatic sedge marsh	128.842
■	Aquatic moss marsh	0.291
▤	Wet sedge tundra	1123.662
▨	Moist, nonlussock-sedge, dwarf-shrub tundra	468.895
▩	Moist low shrubland	1.240
▩	Dry, dwarf-shrub, crustose-lichen tundra	19.543
░	Dry, dwarf-shrub, forb, lichen tundra	5.645
▧	Dry, dwarf-shrub, forb, grass tundra	0.561
░	Dry forb barren	0.436
□	Barren	22.978

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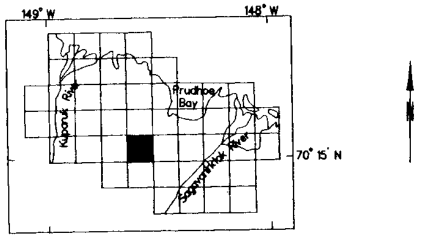

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September, 1986

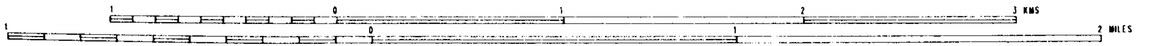
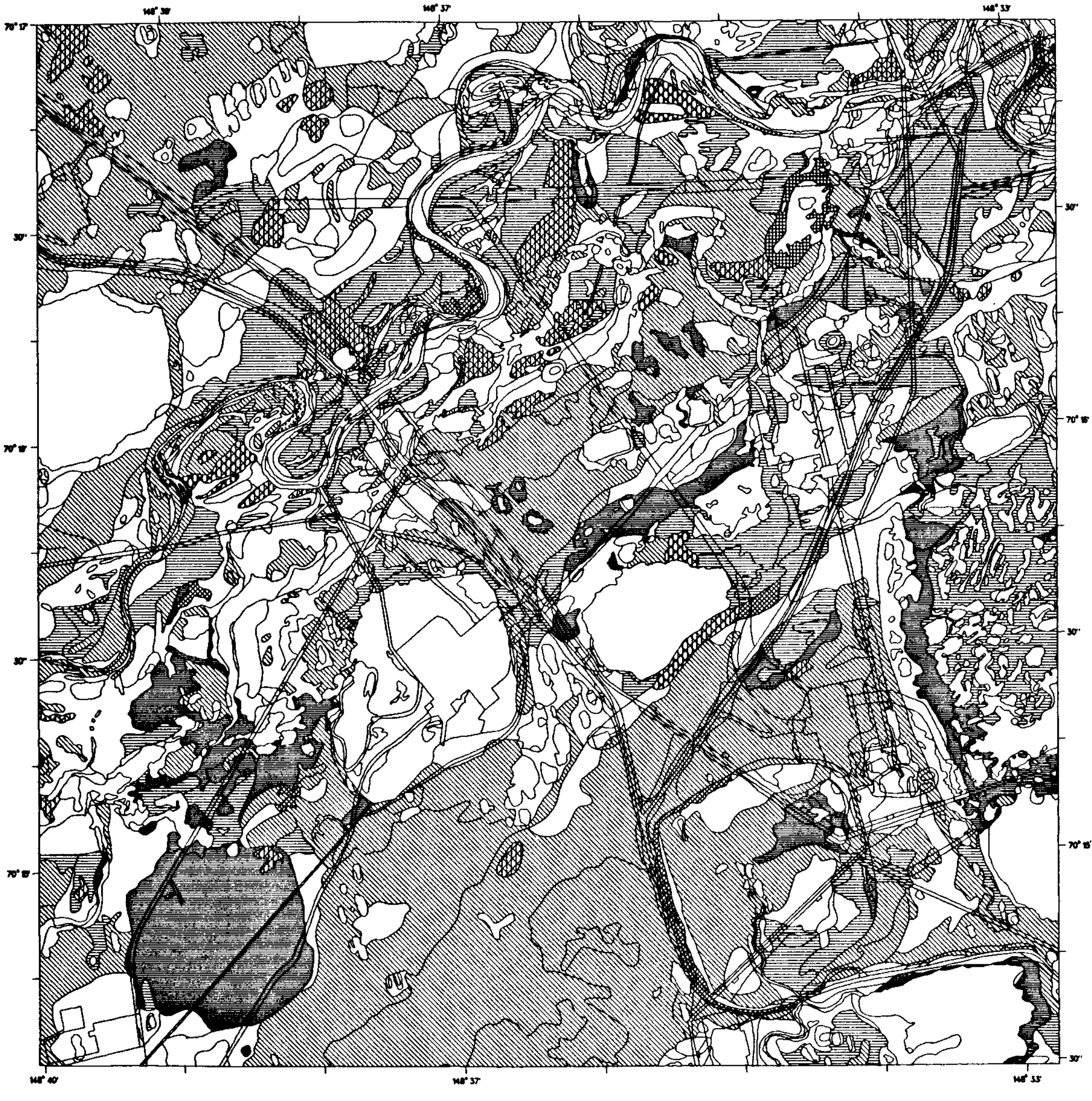


Fig. B27

MAP 32: SECONDARY VEGETATION - 1949



SYMBOL	DESCRIPTION	AREA HECTARES
▦	Aquatic grass marsh	5.016
■	Aquatic sedge marsh	145.381
▤	Wet sedge tundra	289.835
▨	Moist, nontussock-sedge, dwarf-shrub tundra	658.559
▥	Moist low shrubland	0.683
▩	Dry, dwarf-shrub, crustose-lichen tundra	10.424
░	Dry, dwarf-shrub, forb, lichen tundra	3.232
▩	Barren	55.121

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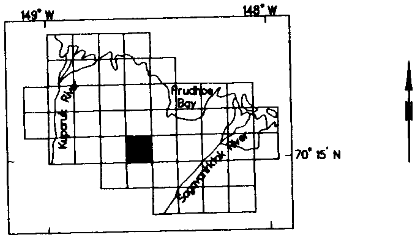

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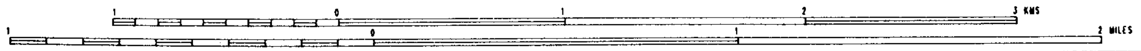
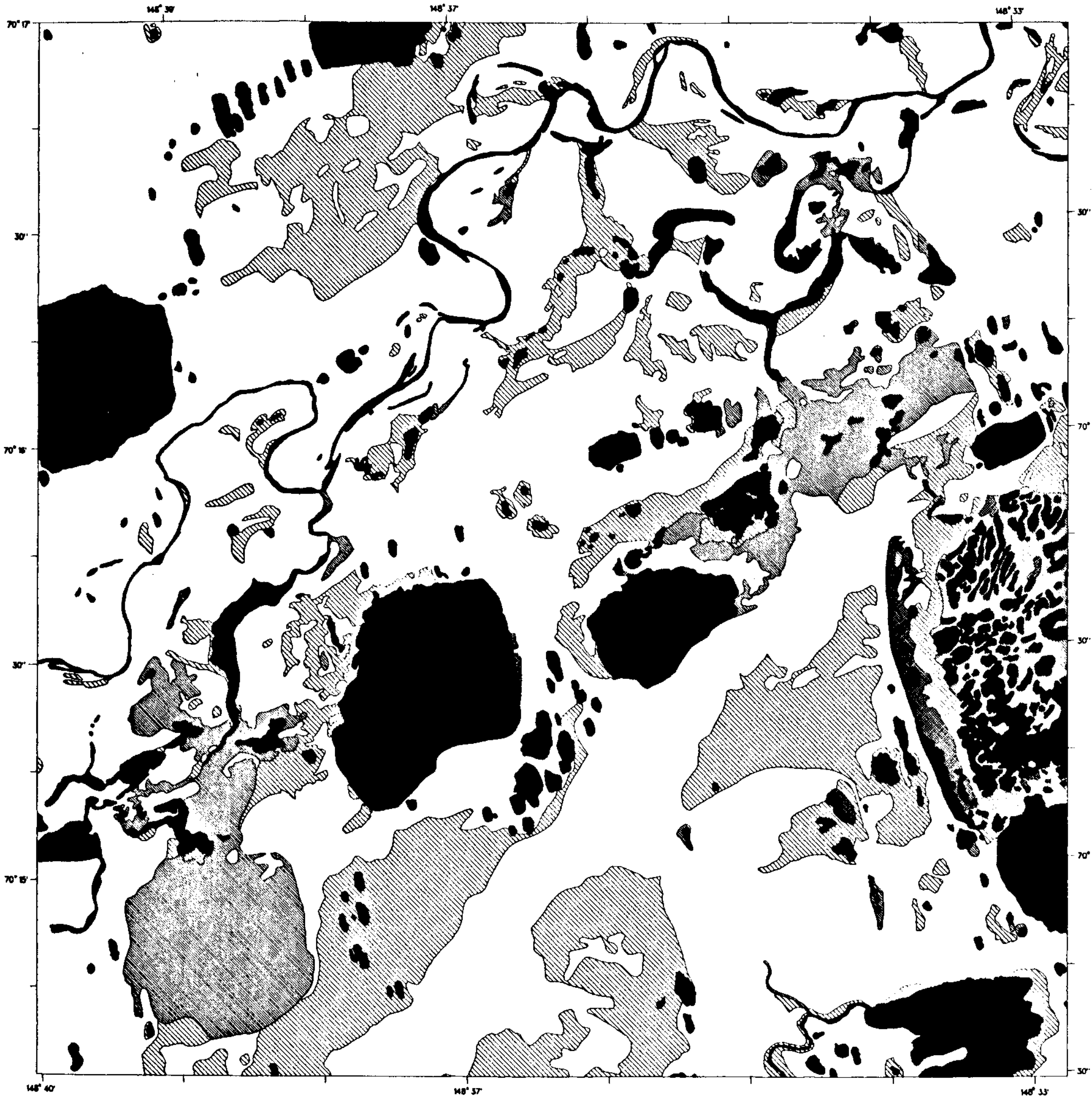


Fig. B28

MAP 32: PERCENT OF WATER COVER - 1949



SYMBOL	DESCRIPTION	AREA HECTARES
☐	0-5%	1240.850
▨	6-30%	354.516
▩	31-60%	154.394
■	61-90%	16.552
■	91-100%	324.183

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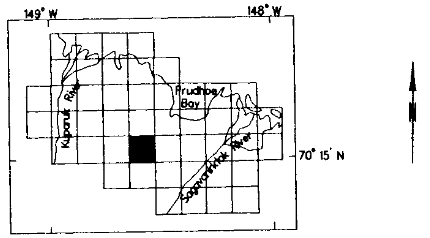

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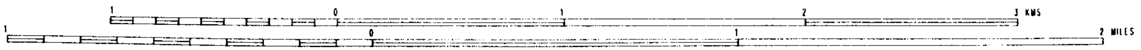
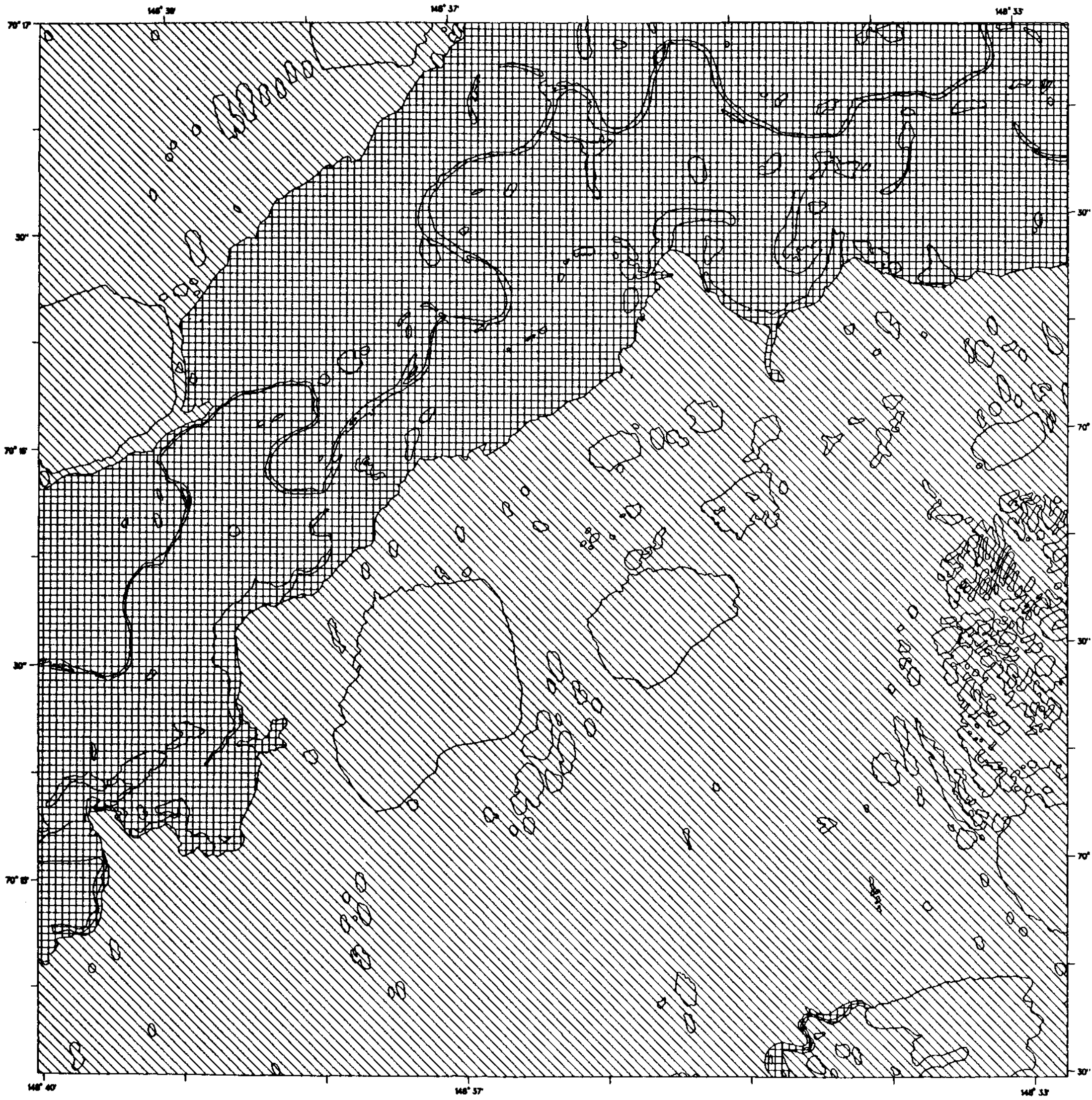


Fig. B29

MAP 32: LANDSCAPE UNITS



▨	Flat thaw-lake plains	1386.668
▦	Floodplains and terraces	703.827

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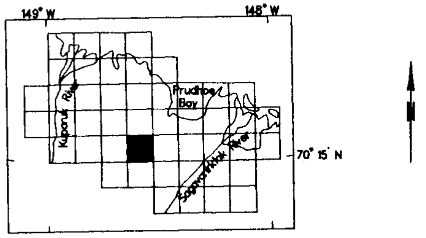

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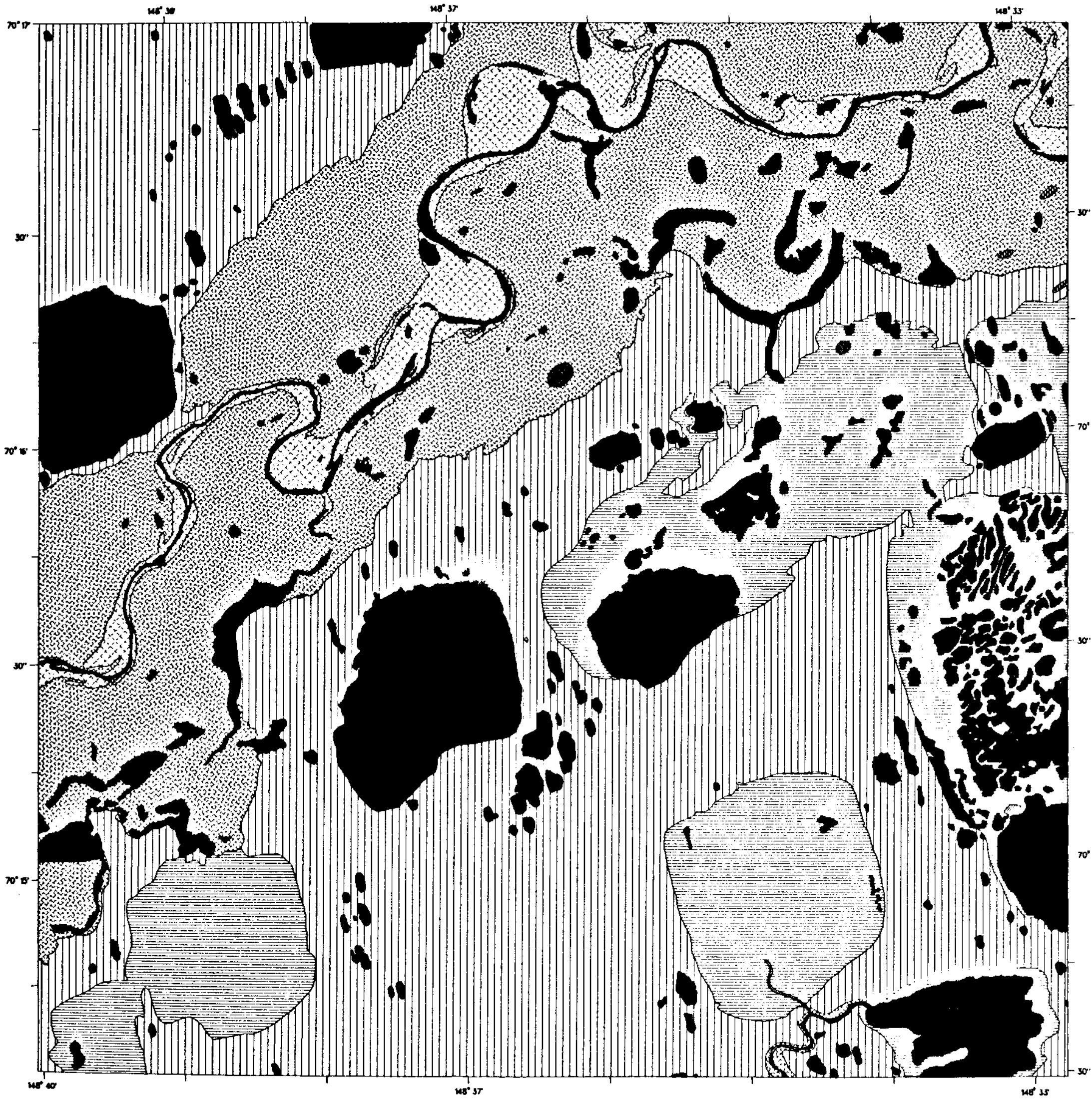
September, 1986

1 0 1 2 3 KMS

1 0 1 2 MILES

Fig. B30

MAP 32: LANDFORM - 1949



SYMBOL	DESCRIPTION	AREA HECTARES
▤	Drained thaw-lake basin	347.700
▥	Inter-thaw-lake area	782.805
■	Pingo	1.430
░	Active floodplain	85.053
▒	Stabilized floodplain	548.054
▨	Small stream drainage	0.461
▩	Sand dunes	0.552
▦	Bluff crest	0.257
■	Lake or pond	306.268
■	River or stream	17.915

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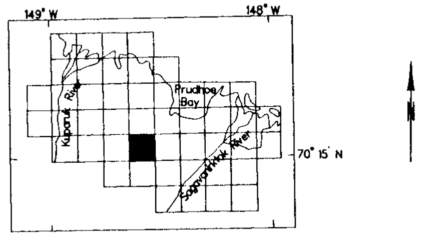

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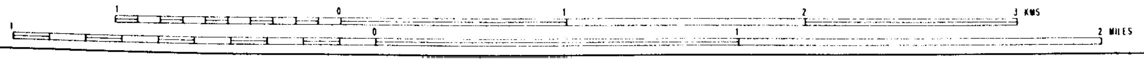
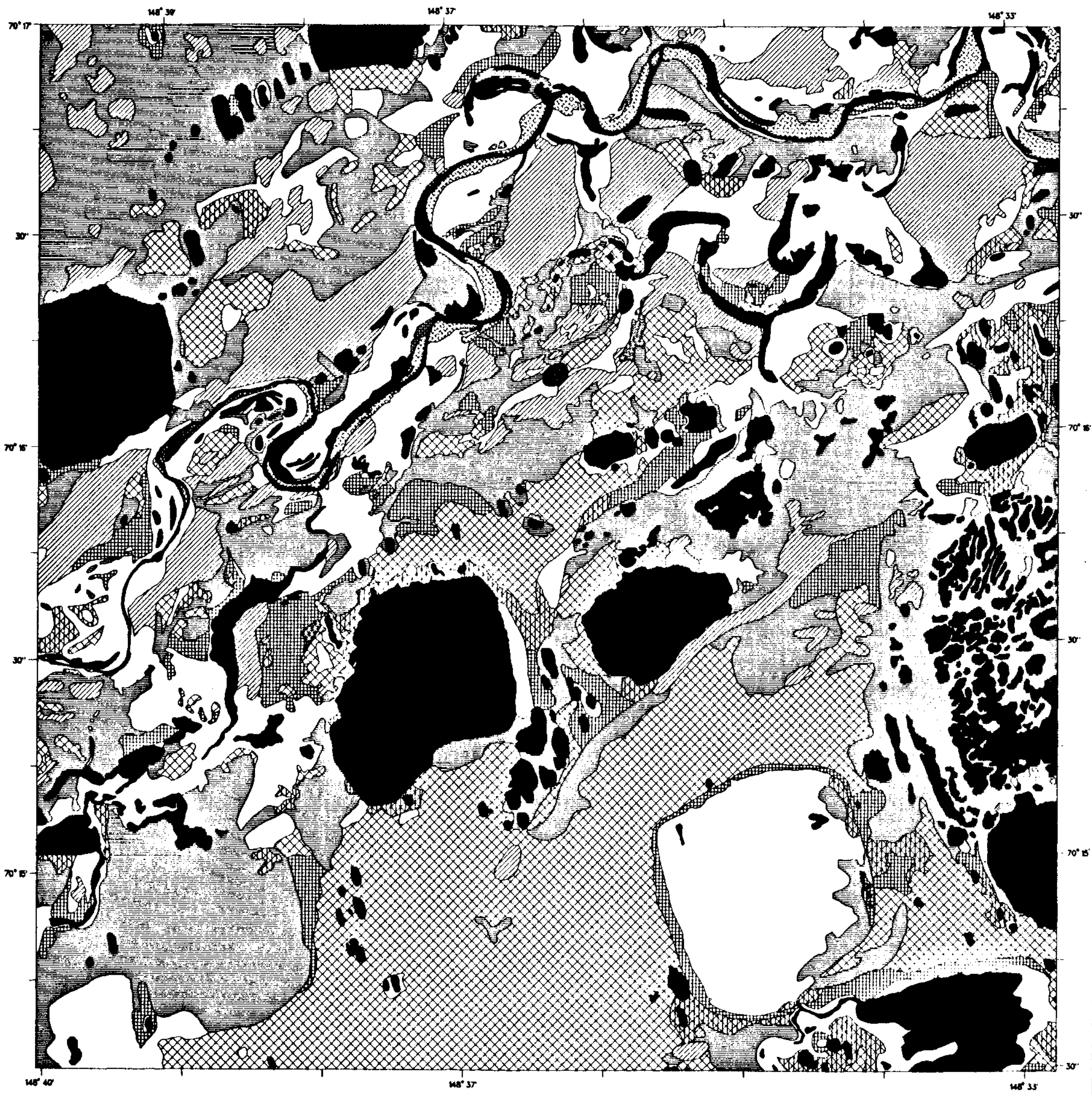


Fig. B31

MAP 32: PRIMARY SURFACE FORM - 1949



SYMBOL	DESCRIPTION	AREA HECTARES
■	High-centered polygons, center-trough relief greater than 0.5 m	0.678
▦	High-centered polygons, center-trough relief less than 0.5 m	103.319
▩	Low-centered polygons, center-rim relief greater than 0.5 m	0.062
▩	Low-centered polygons, center-rim relief less than 0.5 m	398.902
▦	Mixed high-centered and low-centered polygons	49.900
▨	Frost scars	200.824
▤	Strangmoor or disjunct polygon rims	564.661
▩	Hummocky terrain	1.822
■	Pingo with varied or undefined surface forms	1.430
☐	Nonpatterned ground	399.772
■	Reticulate pattern	18.374
▒	Floodplain alluvium	24.616
▦	Thermokarst pits	1.815
▥	Actively eroding bank	0.137
■	Water	324.183

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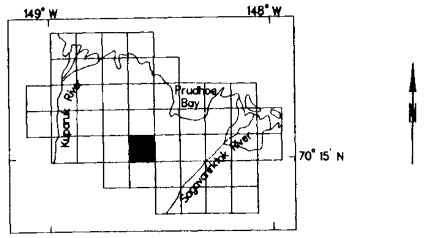

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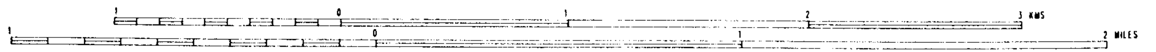

Fig. B32

MAP 32: SECONDARY SURFACE FORM - 1949

SYMBOL	DESCRIPTION	AREA HECTARES
▨	Frost scars	3.244
■	Reticulate pattern	1.035
▩	Thermokarst pits	182.395

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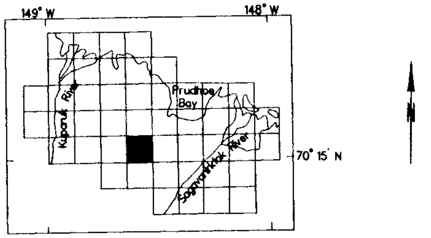

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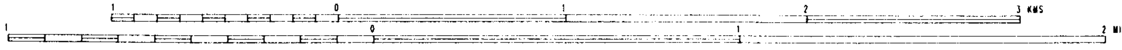
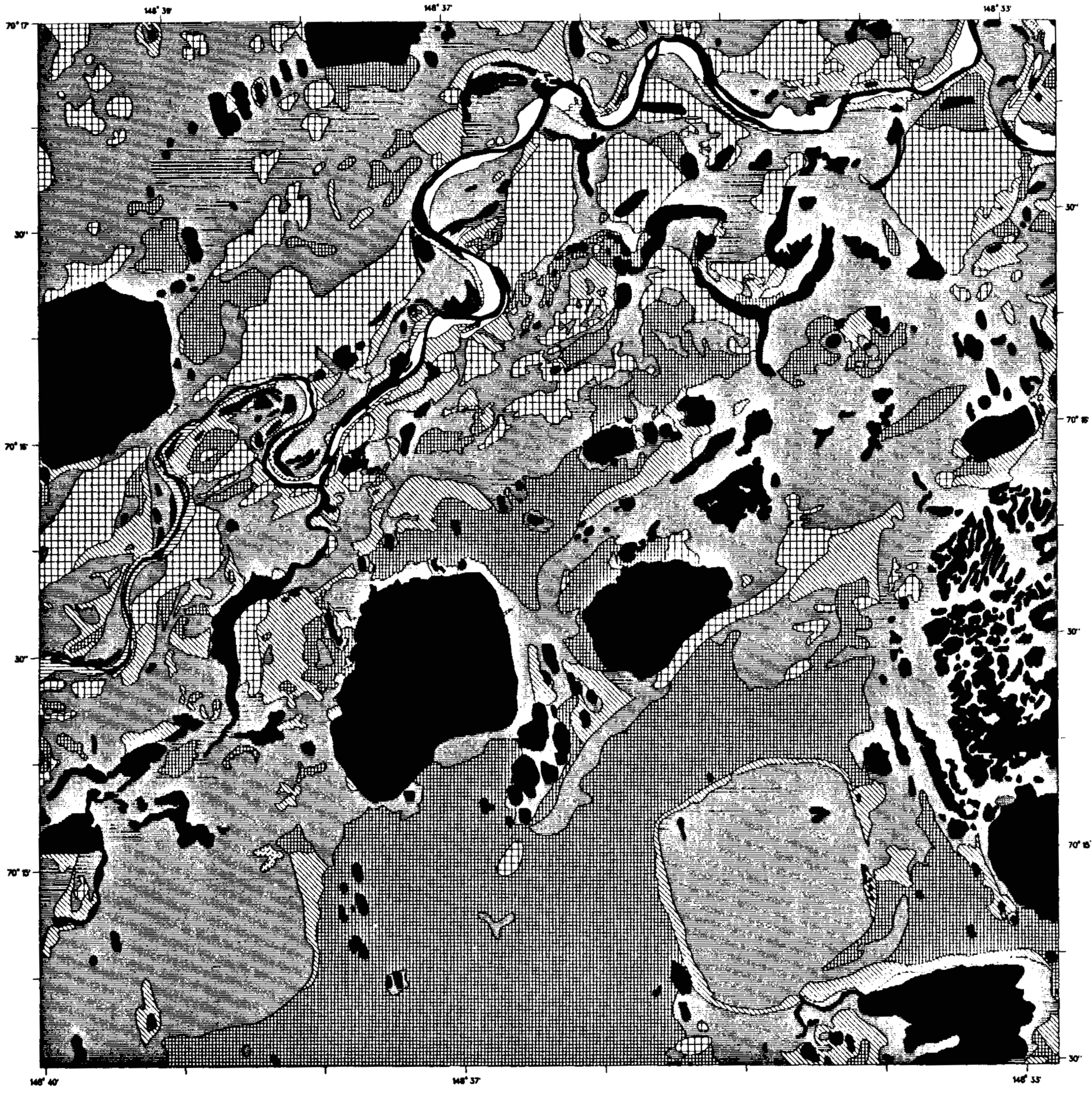


Fig. B33

MAP 32: PRIMARY SOIL - 1949

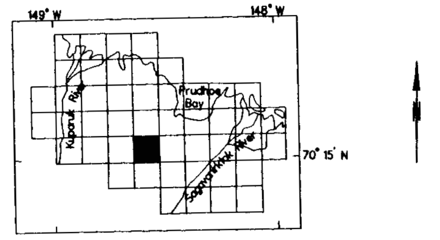


SYMBOL	DESCRIPTION	AREA HECTARES
■	Pergelic Cryoborolls	16.715
▧	Pergelic Cryaquolls or Cryosaprists	163.844
▒	Complex of: a) Pergelic Cryohemists or Cryofibrists, b) Histic Pergelic Cryaquepts, and c) Pergelic Cryaquepts	945.104
▦	Association of: a) Pergelic Cryohemists or Cryofibrists or Histic Pergelic Cryaquepts and b) Pergelic Cryosaprists or Cryaquolls	398.693
▦	Association of: a) Pergelic Cryaquolls or Cryosaprists and b) Pergelic Cryaquepts	202.748
▩	Pergelic Cryorthents	3.049
▨	Pergelic Cryopsamments	0.463
▤	Pergelic Cryaquepts	11.934
□	No soil	23.762
■	Water	324.183

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 32 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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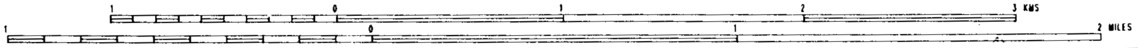
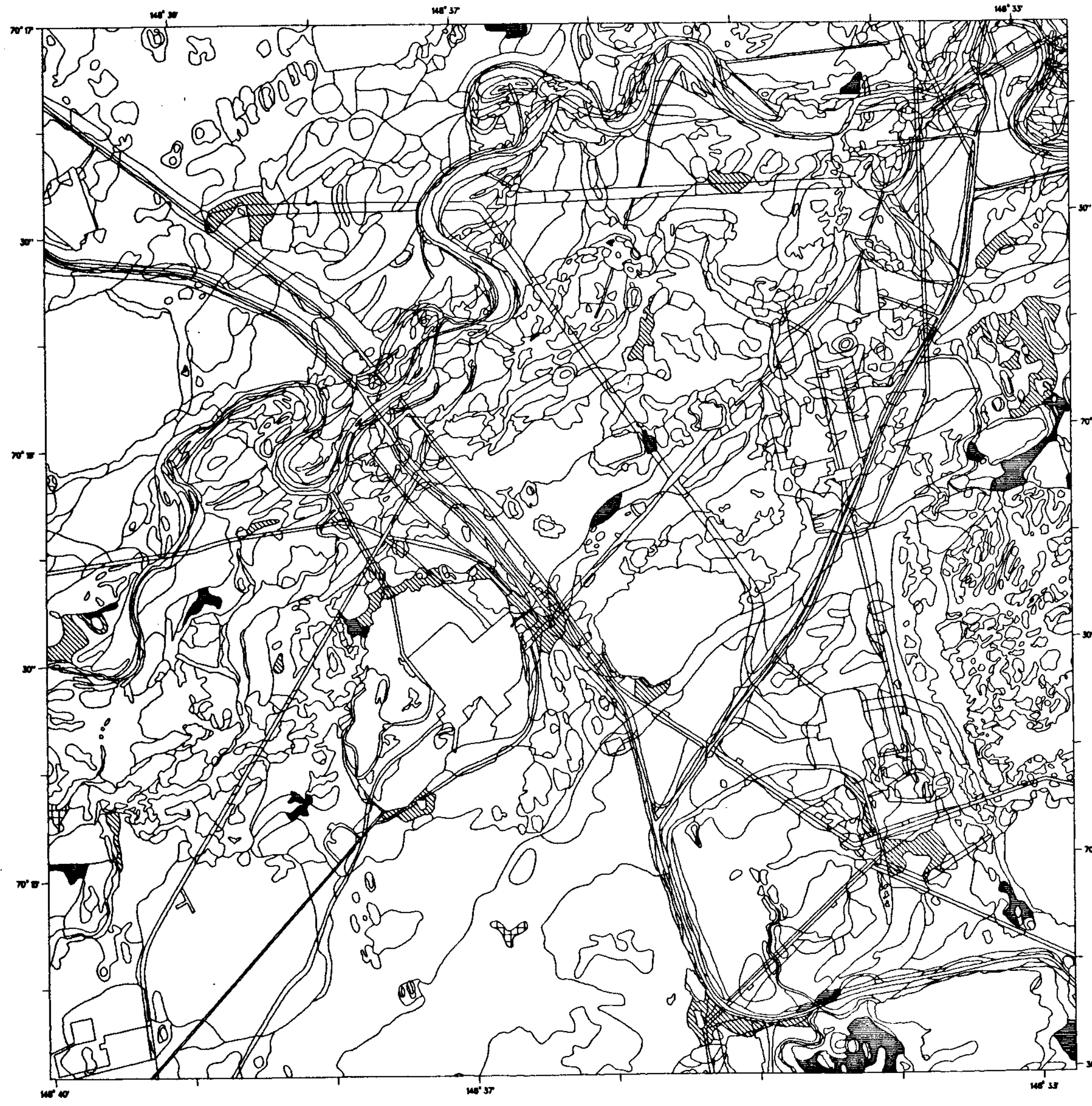


Fig. B34

MAP 32: SECONDARY SOIL - 1949

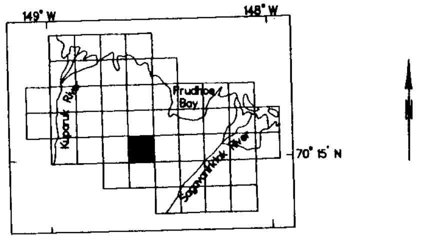


SYMBOL	DESCRIPTION	AREA HECTARES
▨	Pergelic Cryaquolls or Cryosaprists	34.000
■	Complex of: a) Pergelic Cryohemists or Cryofibrists b) Histic Pergelic Cryaquepts, and c) Pergelic Cryaquepts	16.506
▦	Association of: a) Pergelic Cryaquolls or Cryosaprists and b) Pergelic Cryaquepts	1.320

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 32 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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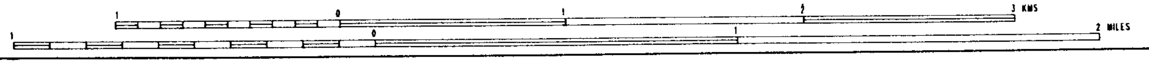
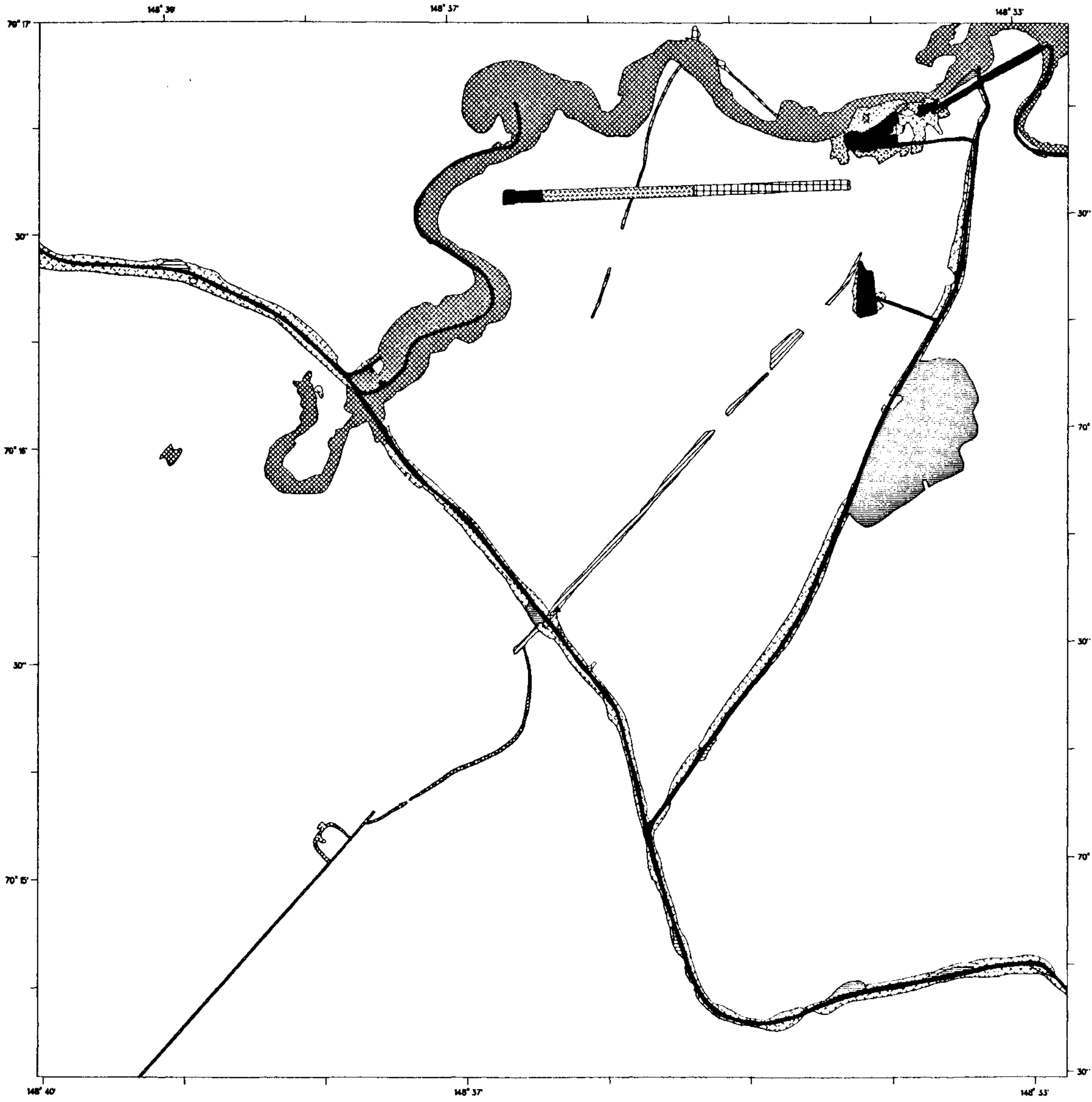


Fig. B36

MAP 32: PRIMARY ANTHROPOGENIC DISTURBANCE - 1970

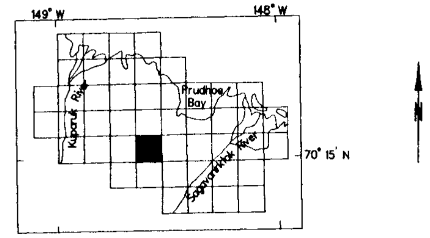


SYMBOL	DESCRIPTION	AREA HECTARES
■	Gravel roads	18.760
■	Peat roads	1.882
■	Gravel pads	4.664
▒	Continuous flooding, more than 75% open water	25.497
▤	Discontinuous flooding, less than 75% open water	1.239
▦	Vehicle tracks, deeply rutted or with thermokarst	2.965
⊞	Vehicle tracks, not deeply rutted	7.811
▨	Winter road	4.740
▩	Gravel and construction debris (more than 75% cover)	8.563
▧	Gravel and construction debris (less than 75% cover)	31.919
▩	Excavations	71.649

Authors: D.A Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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September, 1986

Fig. B36

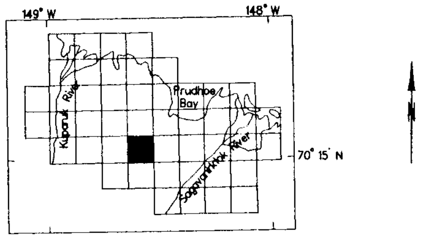
MAP 32: SECONDARY ANTHROPOGENIC DISTURBANCE - 1970

SYMBOL	DESCRIPTION	AREA HECTARES
▤	Continuous flooding, more than 75% open water	11.107
▩	Construction-induced thermokarst	2.551
▦	Vehicle tracks, deeply rutted or with thermokarst	1.248
⊞	Vehicle tracks, not deeply rutted	12.471

Authors: D.A Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 32 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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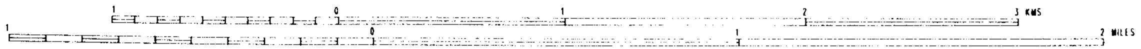
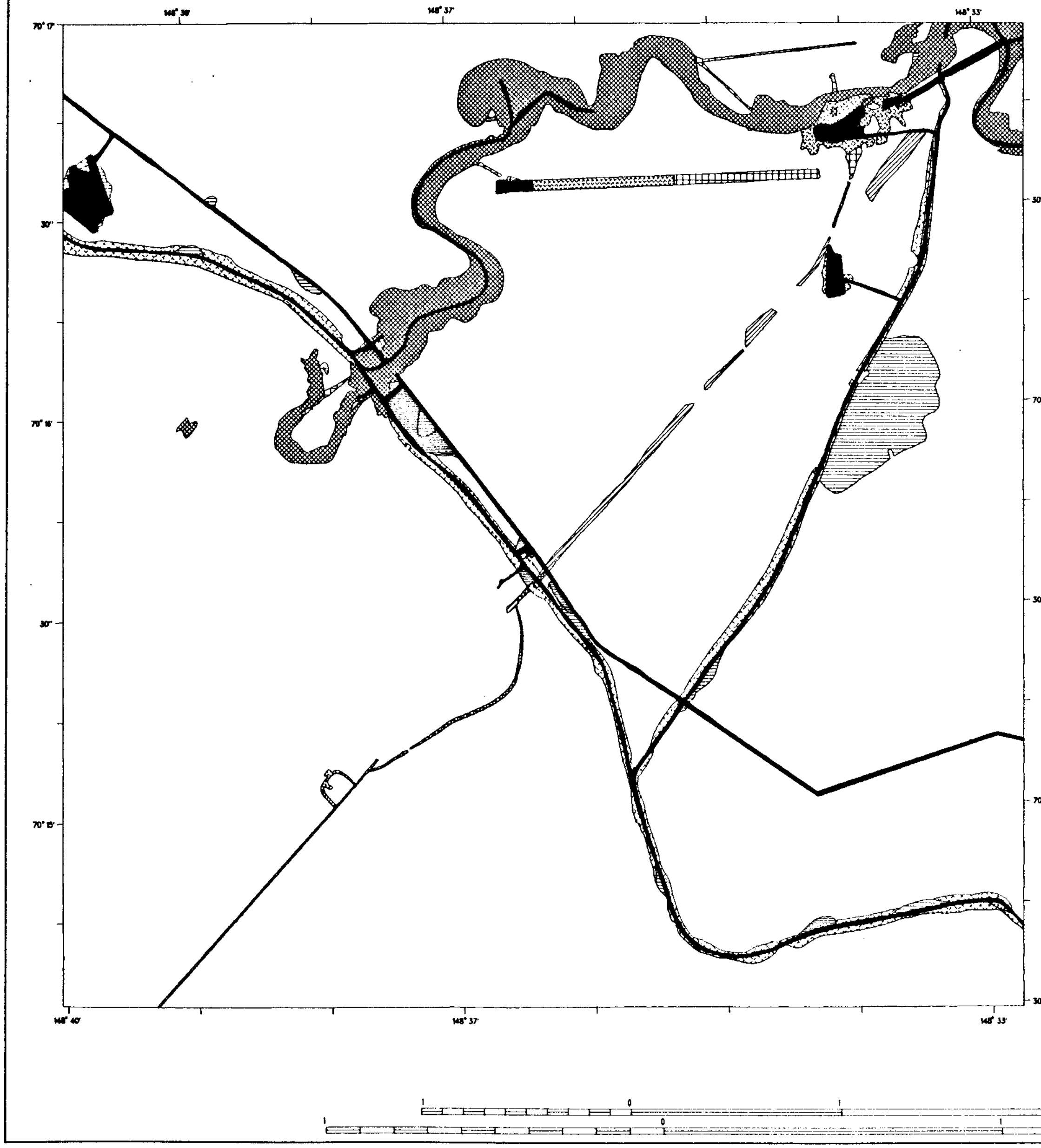


Fig. B37

MAP 32: PRIMARY ANTHROPOGENIC DISTURBANCE - 1973



SYMBOL	DESCRIPTION	AREA HECTARES
■	Gravel roads	29.590
■	Peat roads	1.882
■	Gravel pads	9.831
▒	Continuous flooding, more than 75% open water	5.334
▤	Discontinuous flooding, less than 75% open water	28.143
▦	Vehicle tracks, deeply rutted or with thermokarst	3.095
▦	Vehicle tracks, not deeply rutted	9.272
▨	Winter road	7.002
▩	Gravel and construction debris (more than 75% cover)	10.417
▩	Gravel and construction debris (less than 75% cover)	29.901
▩	Excavations	77.952

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.

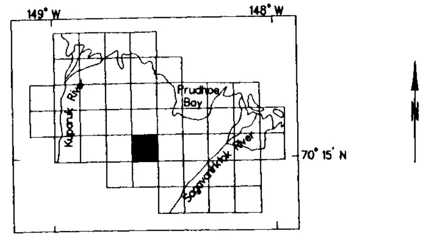


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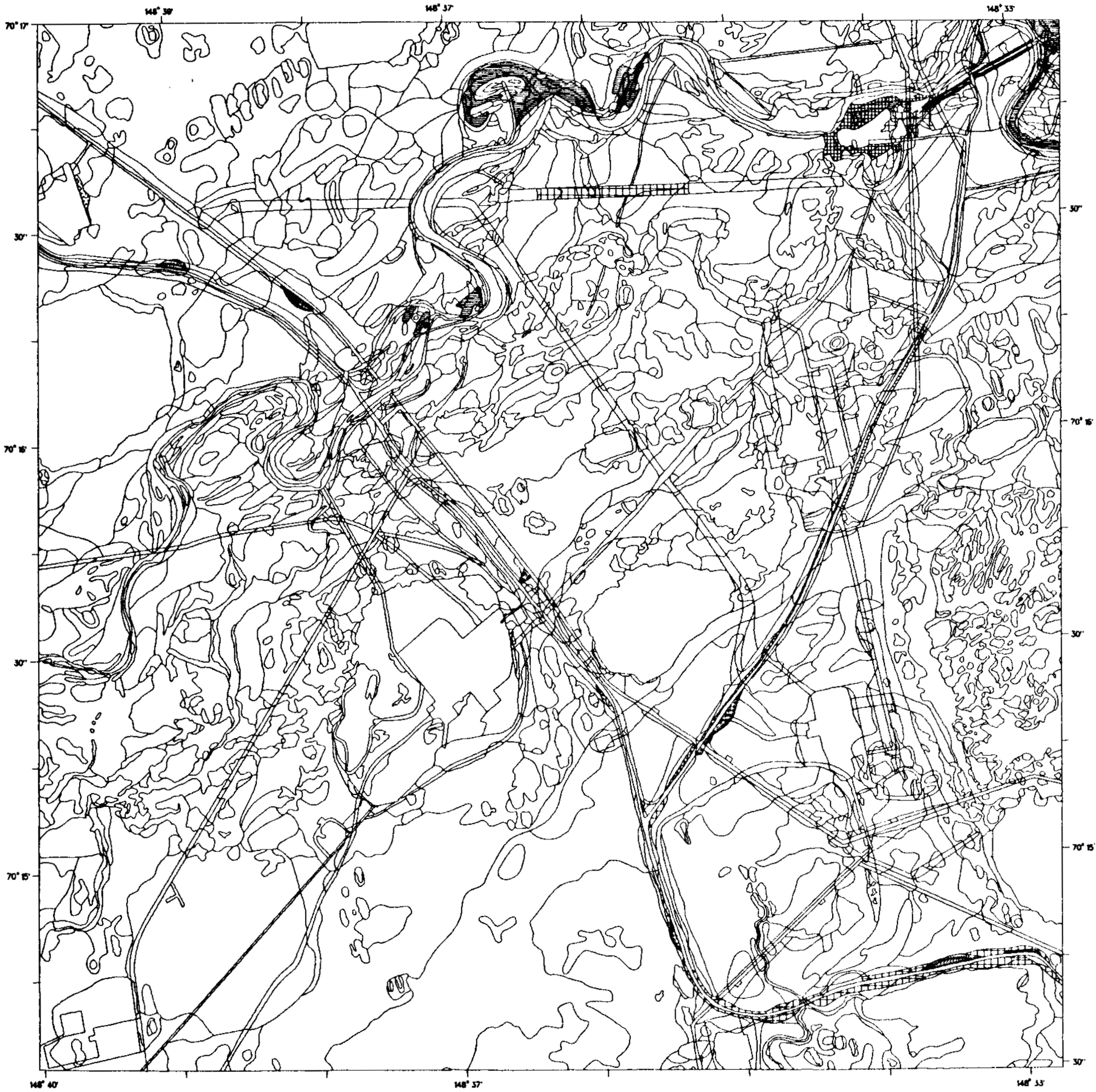
Fig. B38

MAP 32: SECONDARY ANTHROPOGENIC DISTURBANCE - 1973

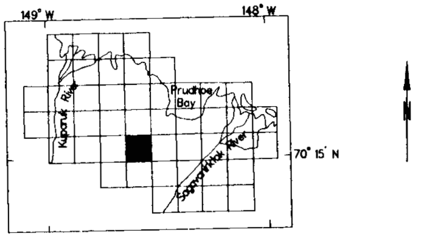


SYMBOL	DESCRIPTION	AREA HECTARES
▓	Continuous flooding, more than 75% open water	13.315
▤	Discontinuous flooding, less than 75% open water	0.888
▩	Construction-induced thermokarst	4.124
▦	Vehicle tracks, deeply rutted or with thermokarst	4.985
⊞	Vehicle tracks, not deeply rutted	12.208
▒	Gravel and construction debris (more than 75% cover)	0.419

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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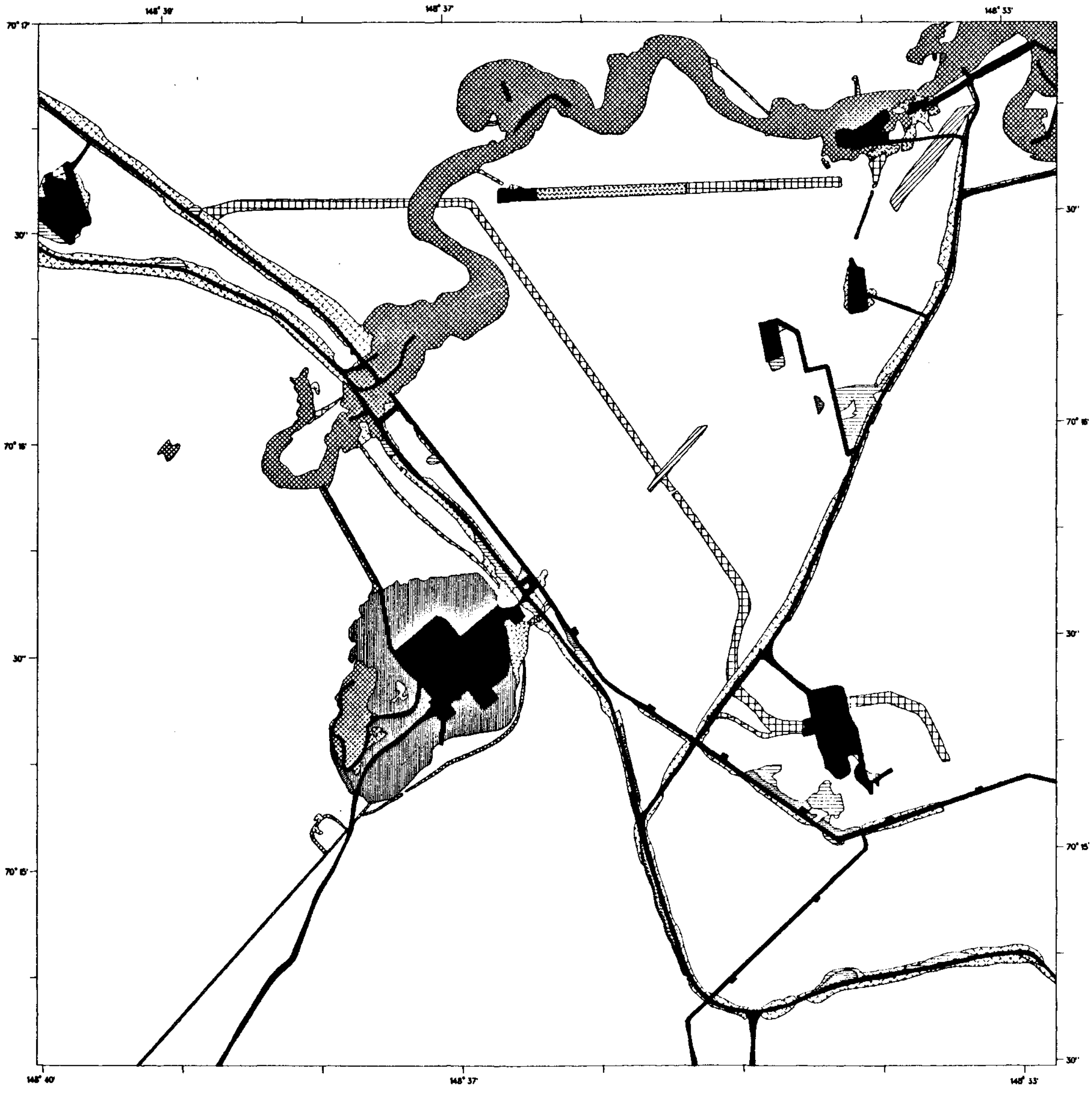
September, 1986

Fig. B39

MAP 32: PRIMARY ANTHROPOGENIC DISTURBANCE - 1977

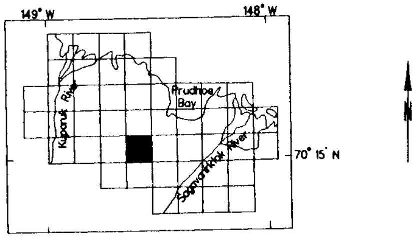


SYMBOL	DESCRIPTION	AREA HECTARES
■	Gravel roads	37.295
■	Peat roads	1.882
■	Gravel pads	34.432
▩	Continuous flooding, more than 75% open water	3.756
▤	Discontinuous flooding, less than 75% open water	10.606
▩	Construction-induced thermokarst	2.471
▦	Vehicle tracks, deeply rutted or with thermokarst	3.063
▦	Vehicle tracks, not deeply rutted	25.284
▨	Winter road	4.514
▩	Gravel and construction debris (more than 75% cover)	8.011
▧	Gravel and construction debris (less than 75% cover)	45.874
▩	Excavations	96.882
▥	Barren tundra caused by previous anthropogenic impoundments	33.951
▩	Construction-induced eolian deposits	0.491

Authors: D.A Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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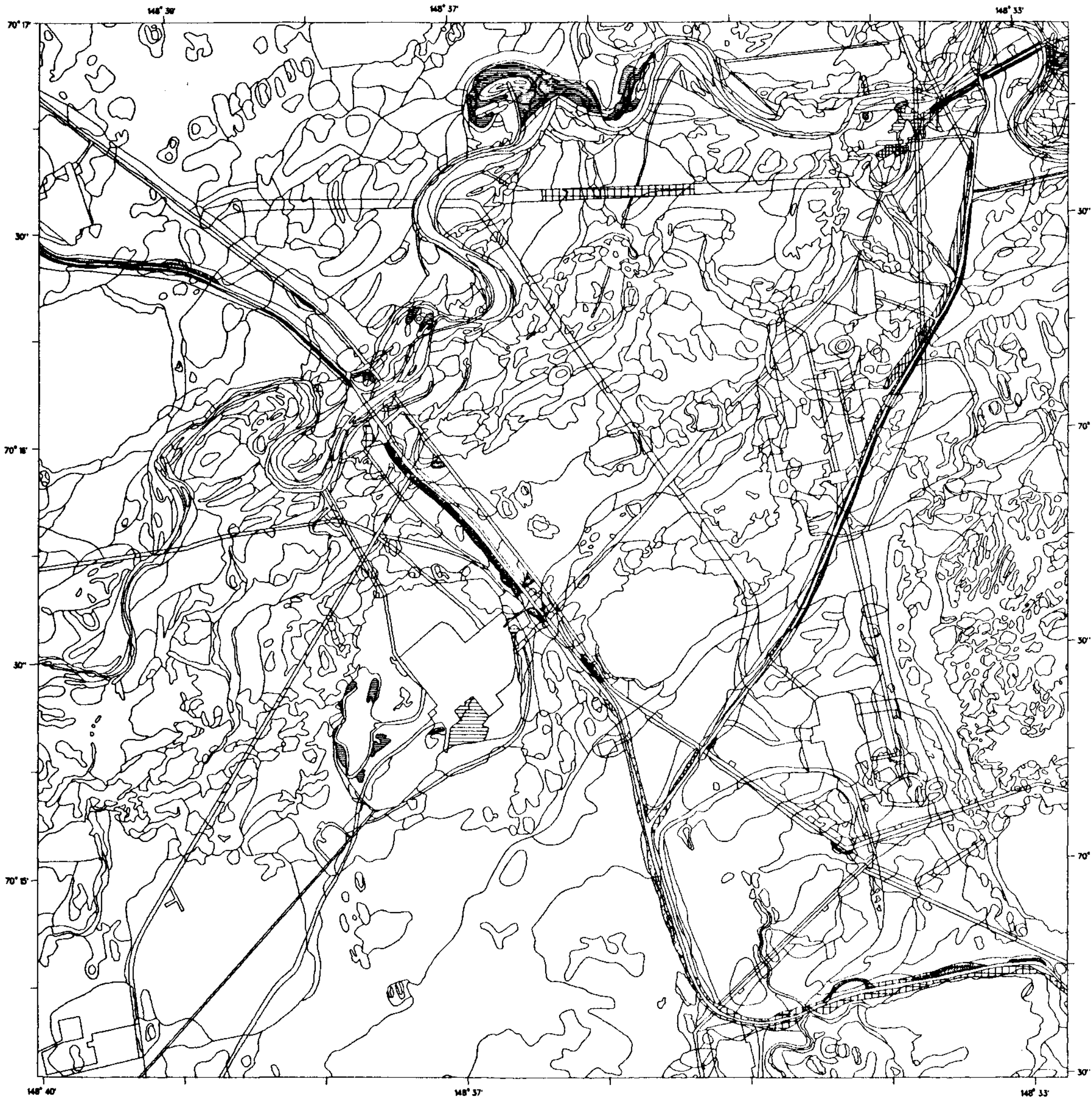
September, 1986

Fig. B40

MAP 32: SECONDARY ANTHROPOGENIC DISTURBANCE - 1977

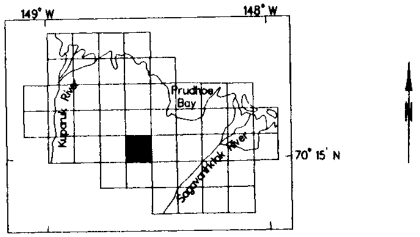


SYMBOL	DESCRIPTION	AREA HECTARES
▩	Continuous flooding, more than 75% open water	11.494
▤	Discontinuous flooding, less than 75% open water	3.428
▩	Construction-induced thermokarst	11.149
▦	Vehicle tracks, deeply rutted or with thermokarst	1.990
▦	Vehicle tracks, not deeply rutted	10.928
▨	Gravel and construction debris (less than 75% cover)	2.256
▥	Dust or dust-killed tundra	2.764

Authors: D.A Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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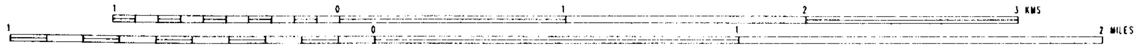
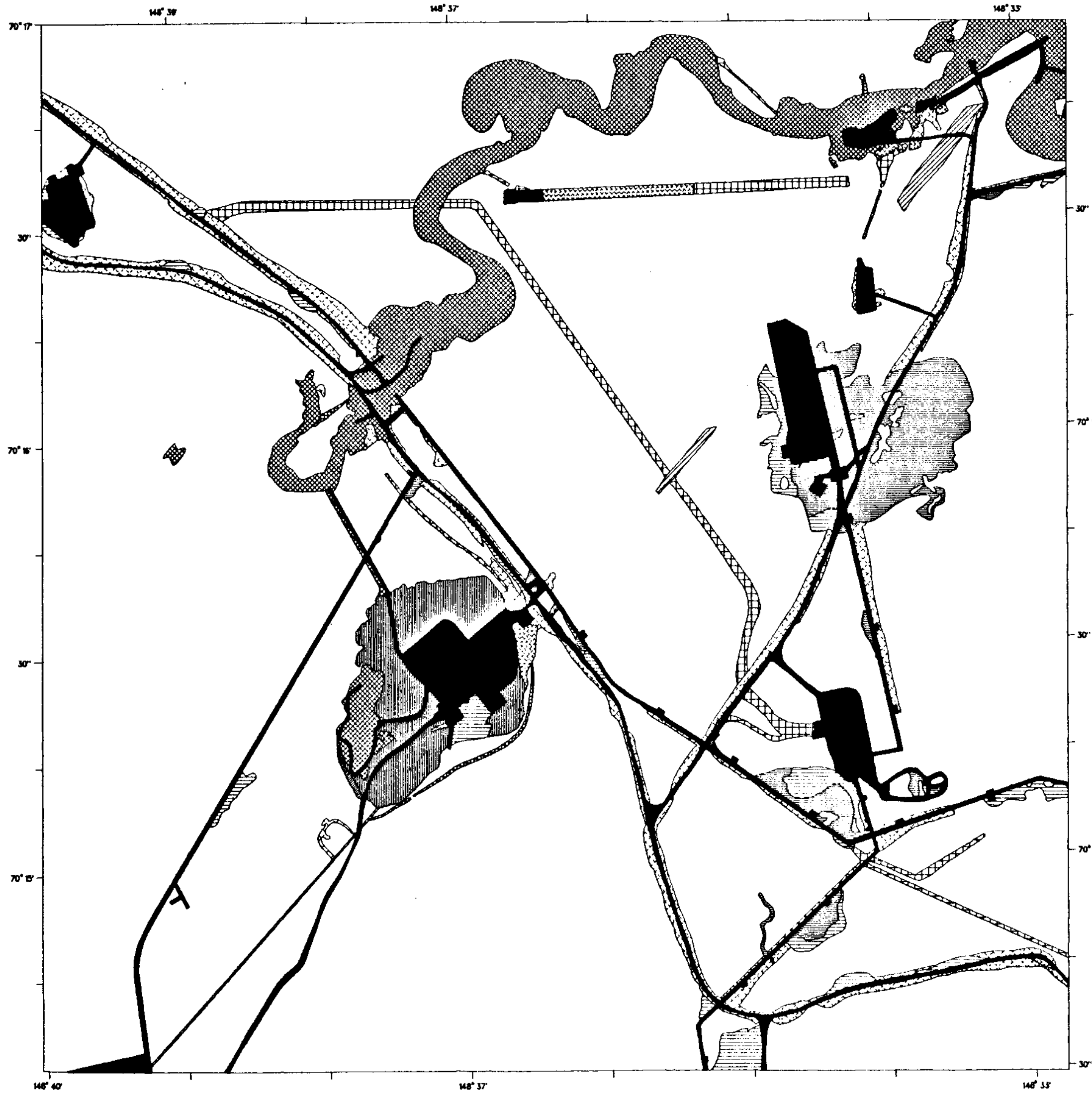


Fig. B41

MAP 32: PRIMARY ANTHROPOGENIC DISTURBANCE - 1979

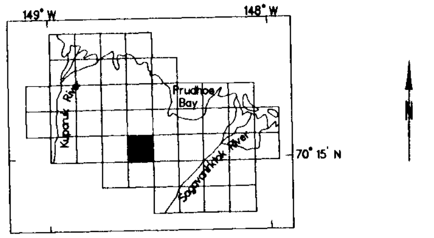


SYMBOL	DESCRIPTION	AREA HECTARES
■	Gravel roads	45.746
■	Peat roads	1.882
■	Gravel pads	48.666
▨	Continuous flooding, more than 75% open water	44.992
▤	Discontinuous flooding, less than 75% open water	24.193
▨	Construction-induced thermokarst	0.653
▦	Vehicle tracks, deeply rutted or with thermokarst	3.210
▦	Vehicle tracks, not deeply rutted	25.319
▨	Winter road	4.485
▨	Gravel and construction debris (more than 75% cover)	6.537
▨	Gravel and construction debris (less than 75% cover)	53.450
▨	Excavations	99.559
▥	Barren tundra caused by previous anthropogenic impoundments	31.461
▨	Construction-induced eolian deposits	0.491

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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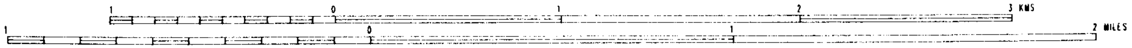
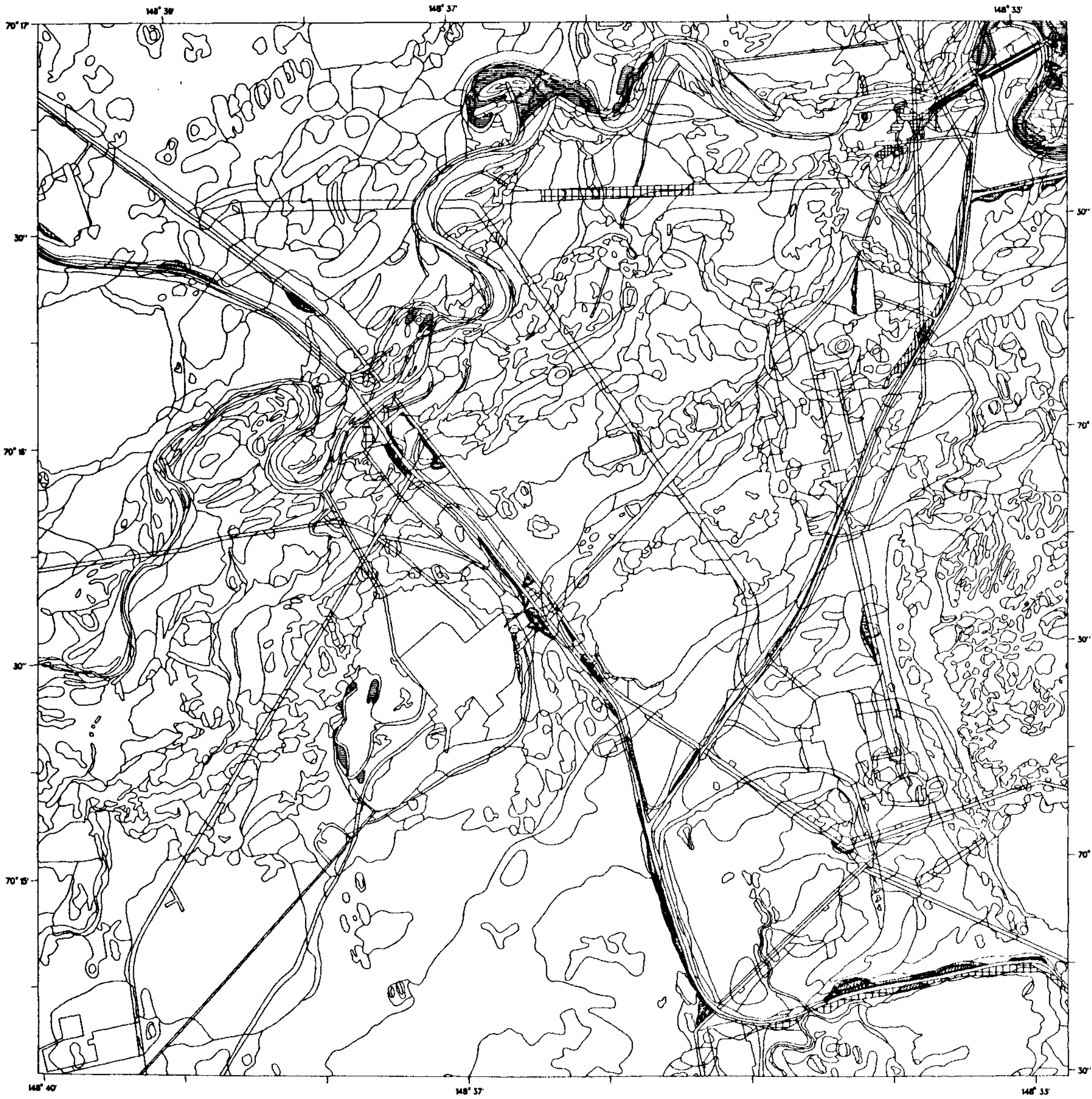


Fig. B42

MAP 32: SECONDARY ANTHROPOGENIC DISTURBANCE - 1979



SYMBOL	DESCRIPTION	AREA HECTARES
▩	Continuous flooding, more than 75% open water	15.000
▤	Discontinuous flooding, less than 75% open water	1.127
▩	Construction-induced thermokarst	12.931
▦	Vehicle tracks, deeply rutted or with thermokarst	0.869
▦	Vehicle tracks, not deeply rutted	8.906
▨	Gravel and construction debris (less than 75% cover)	0.163
▥	Dust or dust-killed tundra	2.569

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

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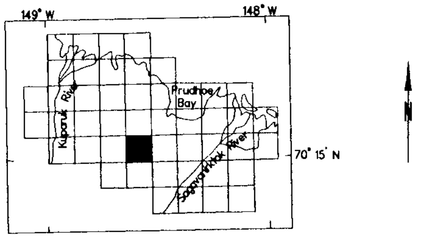

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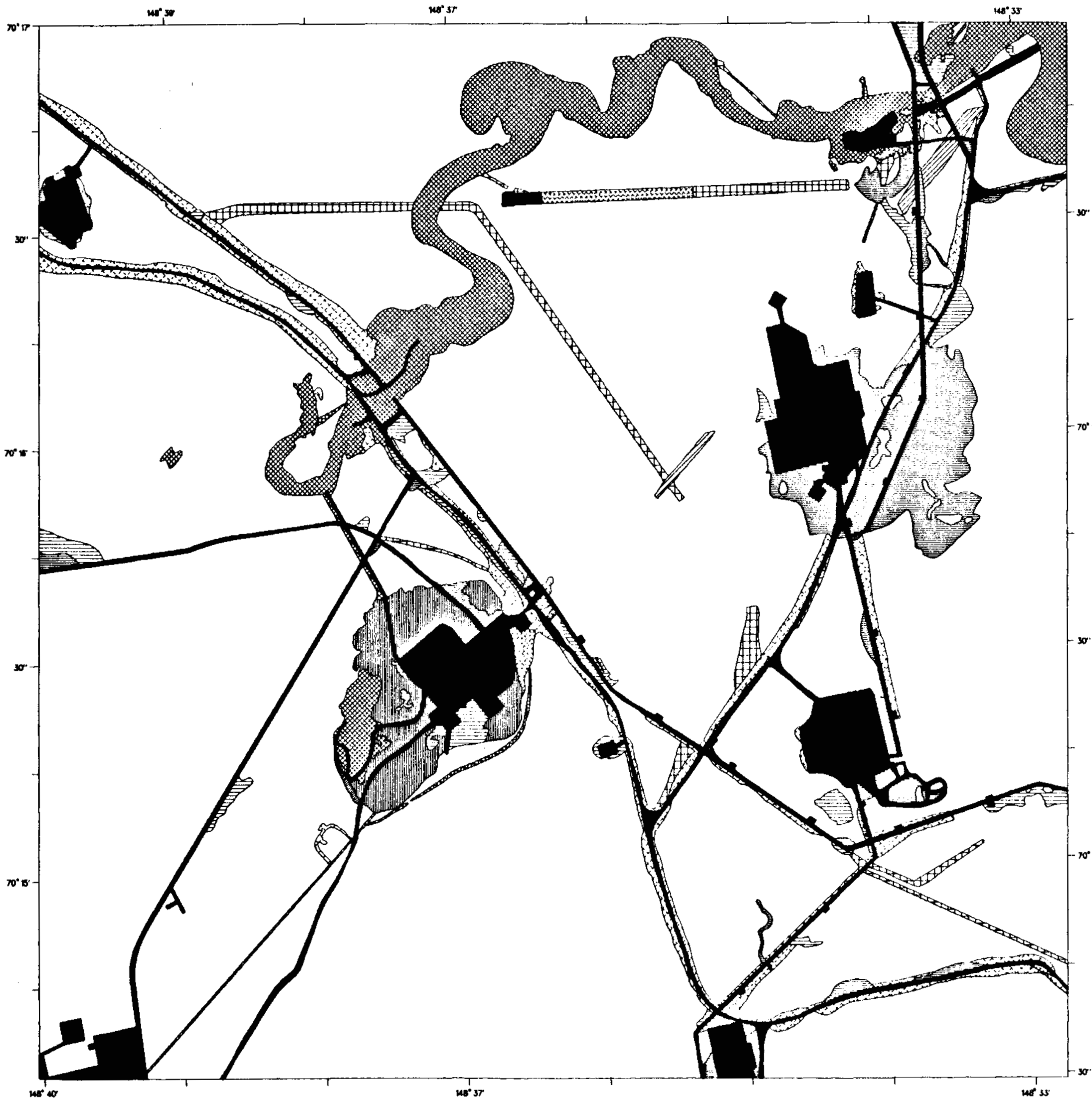
September, 1986

Fig. B43

MAP 32: PRIMARY ANTHROPOGENIC DISTURBANCE - 1983

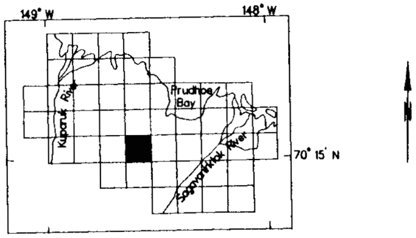


SYMBOL	DESCRIPTION	AREA HECTARES
■	Gravel roads	50.306
■	Peat roads	1.811
■	Gravel pads	73.880
▒	Continuous flooding, more than 75% open water	55.023
▤	Discontinuous flooding, less than 75% open water	28.359
▩	Construction-induced thermokarst	0.653
▦	Vehicle tracks, deeply rutted or with thermokarst	3.143
▦	Vehicle tracks, not deeply rutted	22.218
▨	Winter road	4.077
▩	Gravel and construction debris (more than 75% cover)	7.518
▩	Gravel and construction debris (less than 75% cover)	52.272
▩	Excavations	101.210
▩	Barren tundra caused by previous anthropogenic impoundments	28.596
▨	Construction-induced eolian deposits	0.491

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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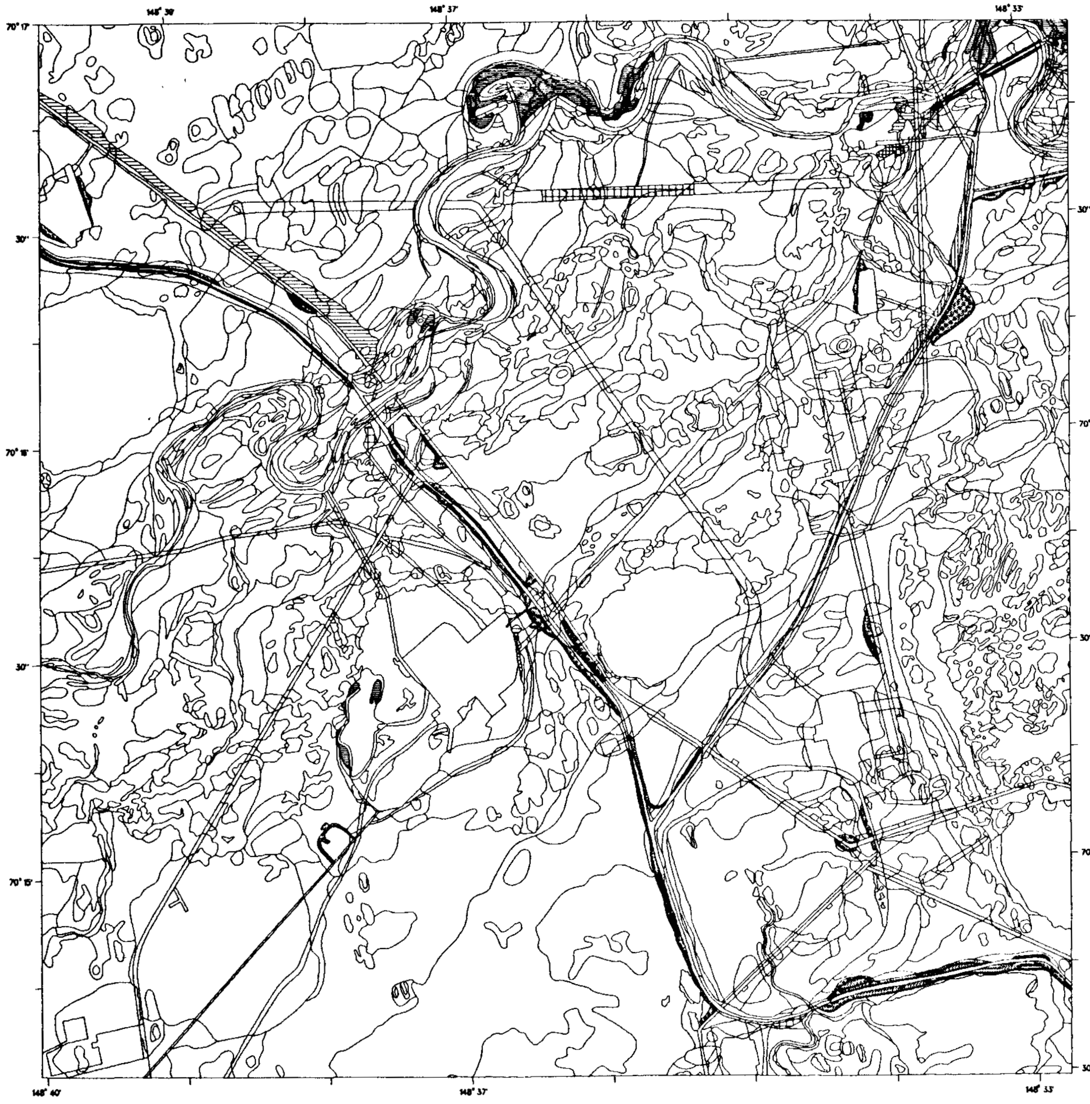
September, 1986

Fig. B44

MAP 32: SECONDARY ANTHROPOGENIC DISTURBANCE - 1983

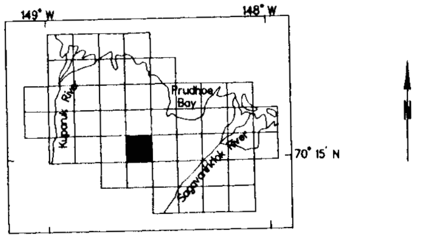


SYMBOL	DESCRIPTION	AREA HECTARES
▤	Continuous flooding, more than 75% open water	13.352
▤	Discontinuous flooding, less than 75% open water	9.906
▩	Construction-induced thermokarst	23.403
▦	Vehicle tracks, deeply rutted or with thermokarst	0.869
▦	Vehicle tracks, not deeply rutted	6.120
▨	Gravel and construction debris (less than 75% cover)	0.163
▥	Dust or dust-killed tundra	2.102

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnion and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 32 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

Funded by the Environmental Protection Agency Cold Climate Environmental Research Program in conjunction with the U.S. Fish and Wildlife Service. Funding for initial geobotanical mapping provided by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) and the U.S. Tundra Biome portion of the International Biological Program (IBP) with support from the Alaska Oil and Gas Association.

September, 1986

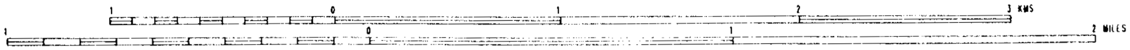
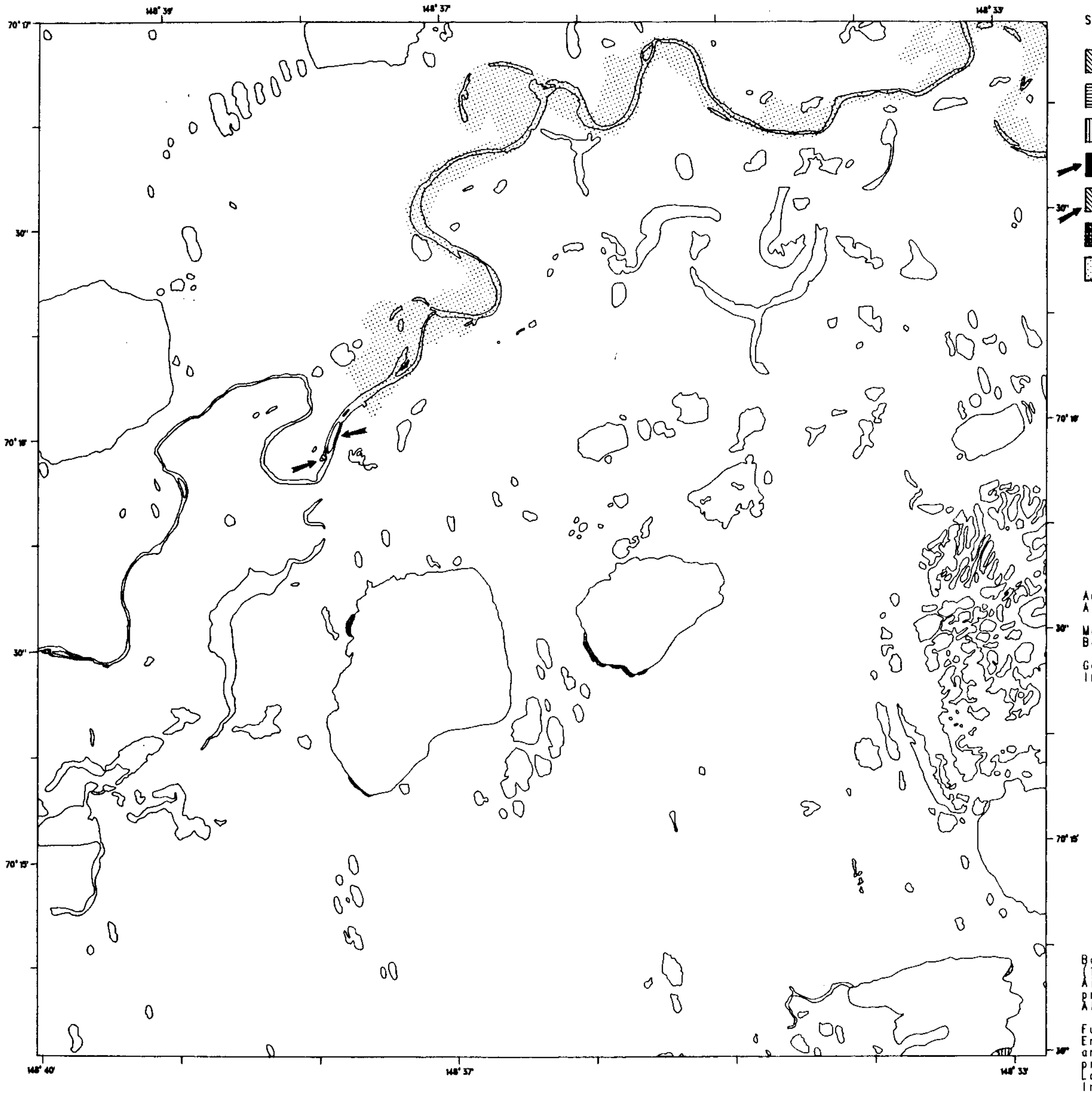


Fig. B45

MAP 32: NATURAL DISTURBANCES - 1968, 1977, & 1983

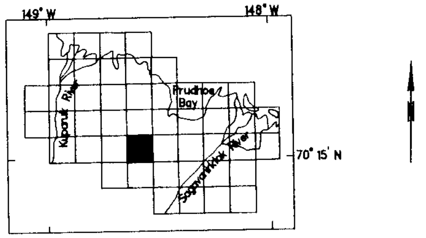


SYMBOL	DESCRIPTION	AREA HECTARES
▨	Lake erosion - 1968	0.574
▤	Lake erosion - 1977	0.622
▥	Lake erosion - 1983	0.858
■	Gravel bar - 1949, river channel - 1968 only	0.080
▨	River channel - 1949, gravel bar - 1968 only	0.280
▩	River channel - 1949, gravel bar - 1968, 1977, 1983	0.343
░	Channel changes not mapped because of anthropogenic disturbance in this area	

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 32 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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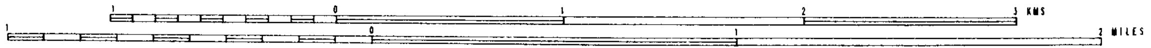
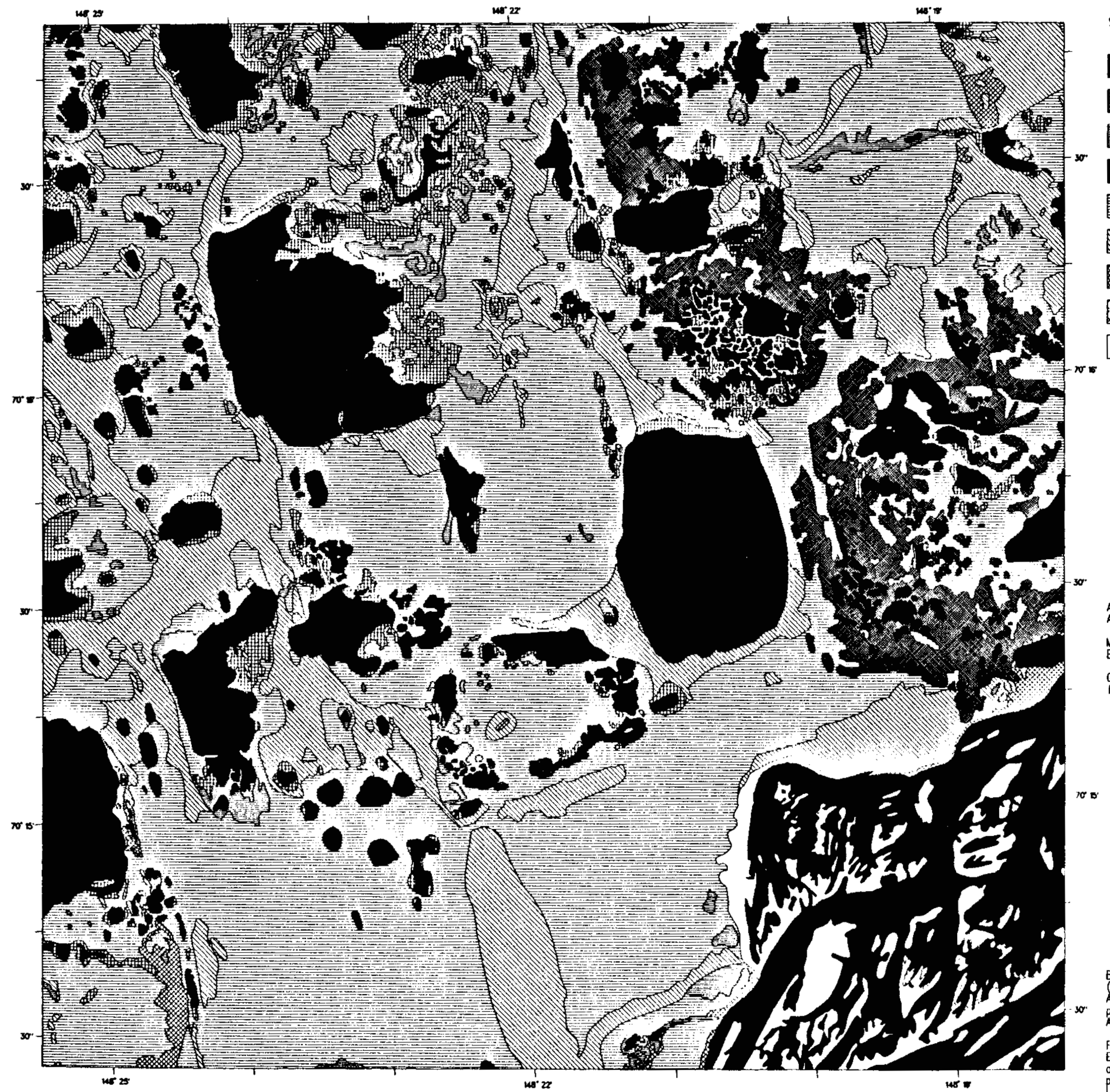


Fig. B46

MAP 34: PRIMARY VEGETATION - 1949

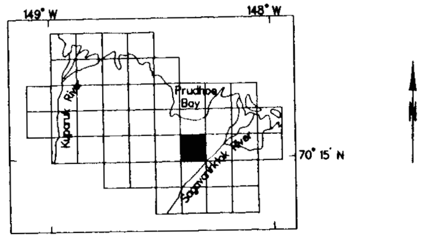


SYMBOL	DESCRIPTION	AREA HECTARES
■	Water	502.750
▦	Aquatic grass marsh	80.558
▒	Aquatic sedge marsh	42.004
■	Aquatic moss marsh	119.155
▤	Wet sedge tundra	968.316
▨	Moist, nontussock-sedge, dwarf-shrub tundra	289.705
▩	Dry, dwarf-shrub, crustose-lichen tundra	24.794
░	Dry, dwarf-shrub, forb, grass tundra	2.906
□	Barren	59.571

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 34 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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September, 1986

Fig. B47

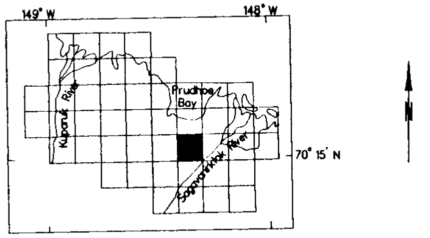
MAP 34: SECONDARY VEGETATION - 1949

SYMBOL	DESCRIPTION	AREA HECTARES
■	Water	8.037
▦	Aquatic grass marsh	3.921
▒	Aquatic sedge marsh	121.419
■	Aquatic moss marsh	6.139
▤	Wet sedge tundra	208.738
▨	Moist, nontussock-sedge, dwarf-shrub tundra	737.121
▩	Dry, dwarf-shrub, crustose-lichen tundra	24.683
▩	Barren	35.464

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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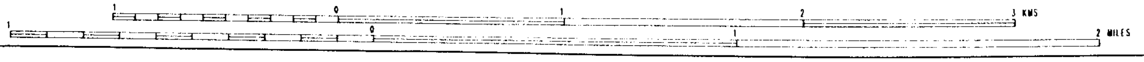
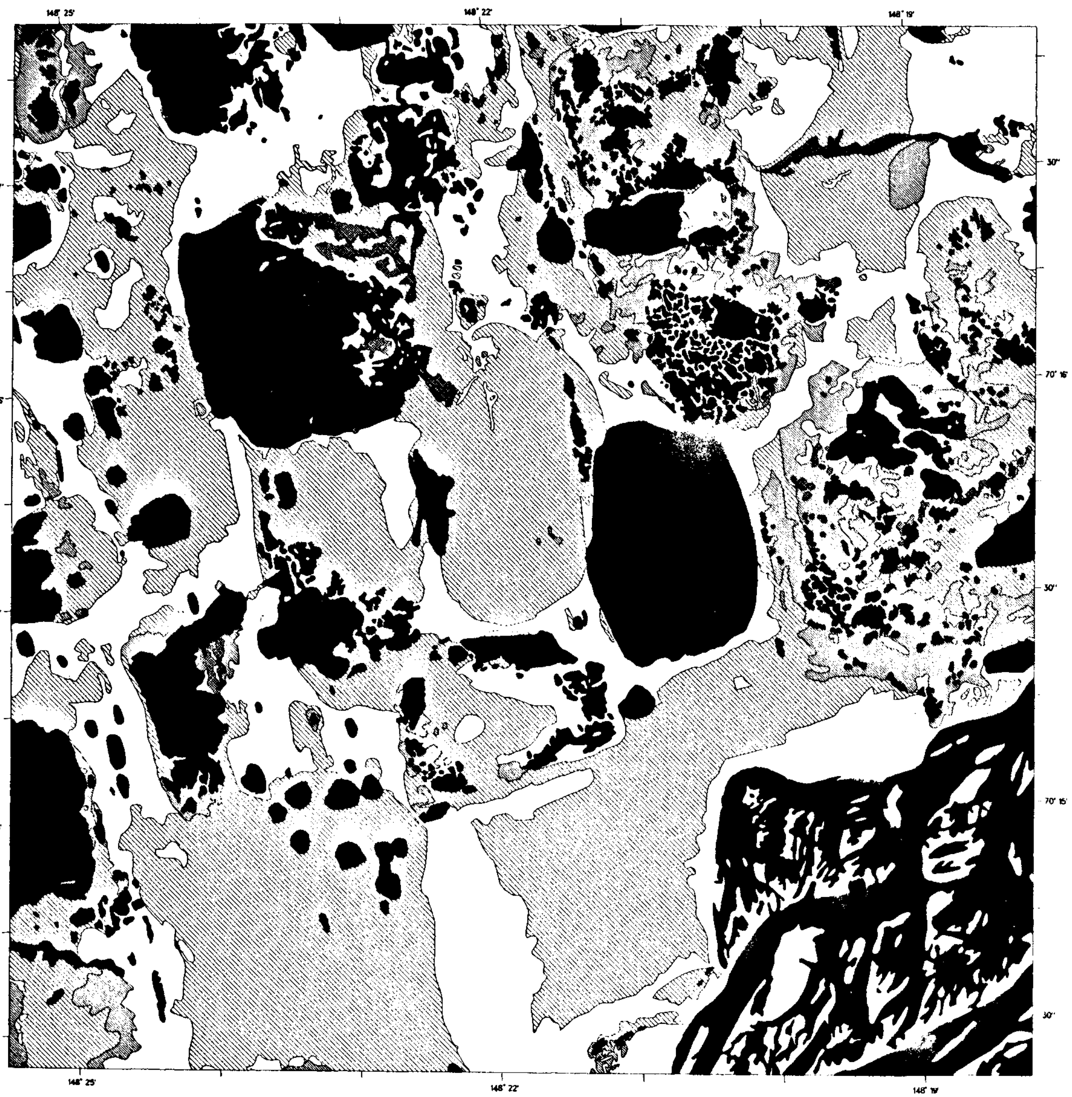


Fig. B48

MAP 34: PERCENT OF WATER COVER - 1949

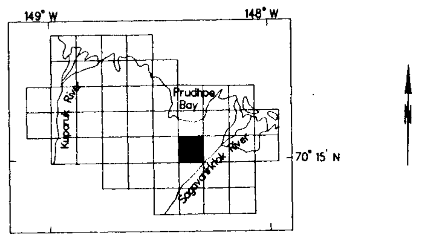


SYMBOL	DESCRIPTION	AREA HECTARES
☐	0-5%	548.597
▨	6-30%	780.977
▩	31-60%	150.090
▩	61-90%	15.733
■	91-100%	594.362

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 34 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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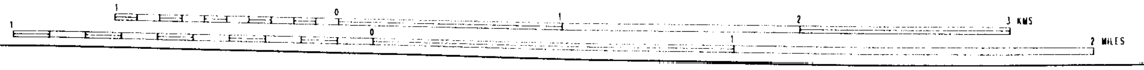
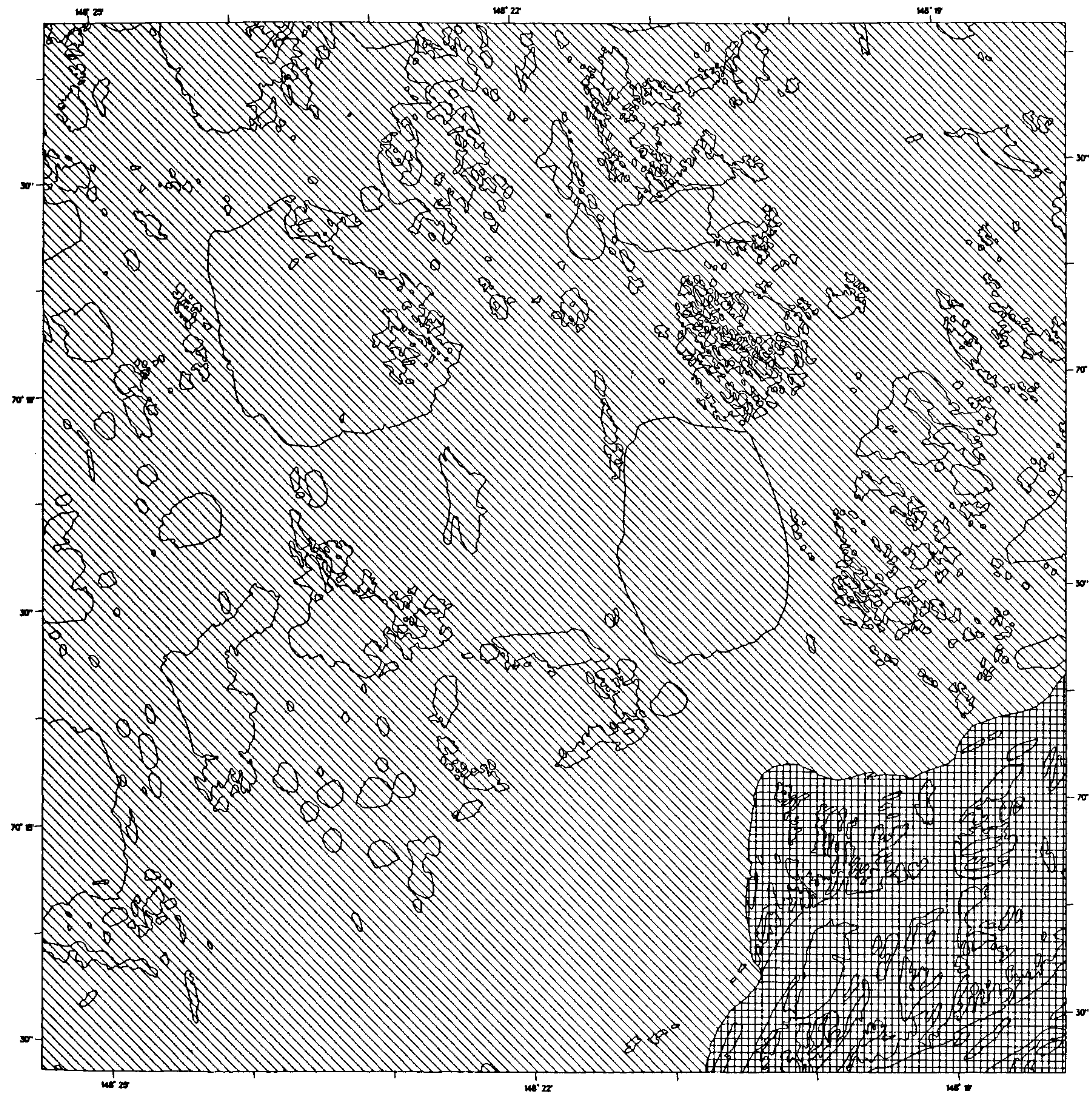


Fig. B49

MAP 34: LANDSCAPE UNITS

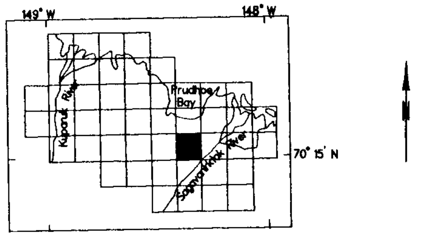


▨	Flat thaw-lake plains	1889.445
▦	Floodplains and terraces	200.314

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 34 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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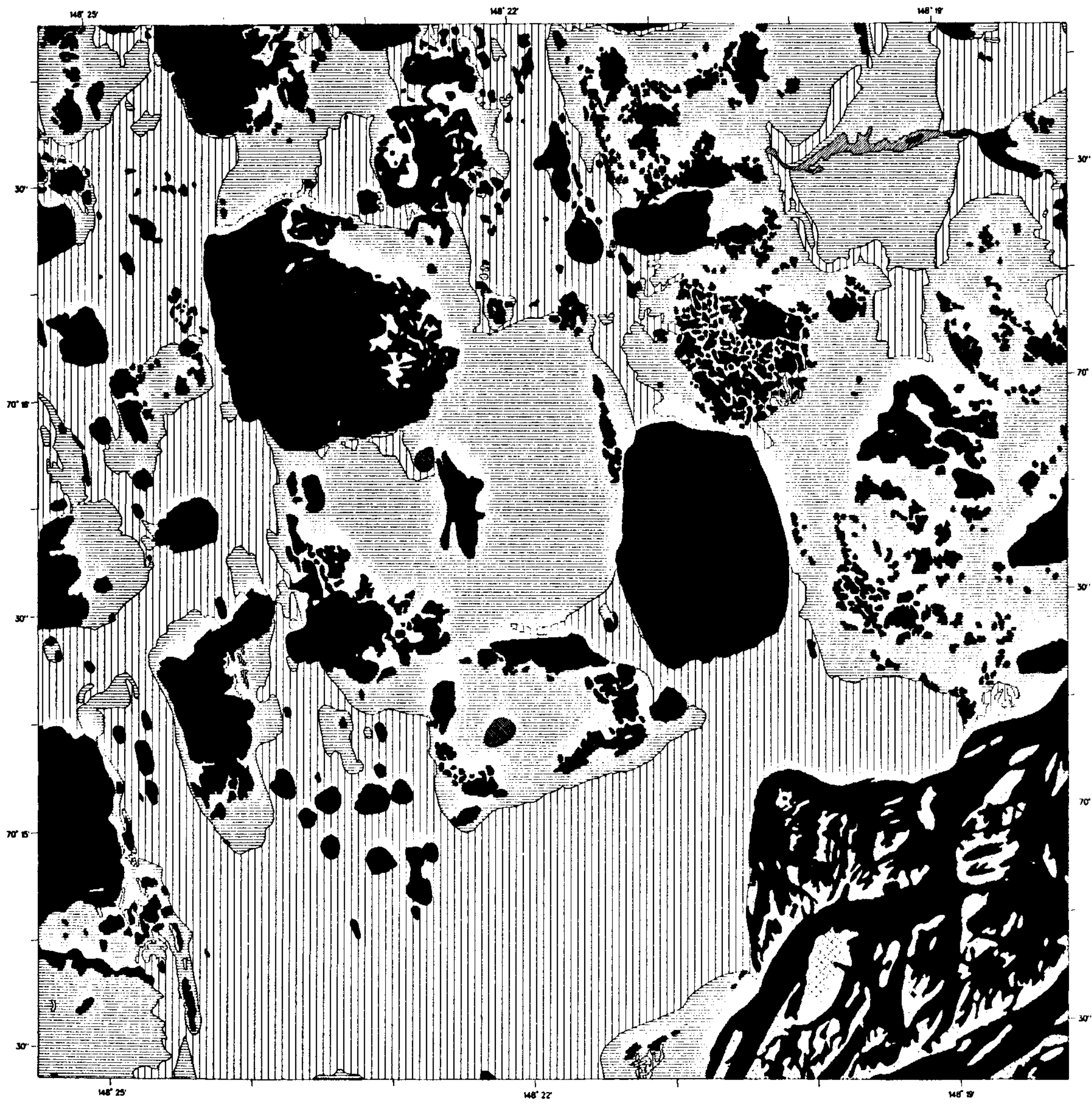
September, 1986

Fig. B50

MAP 34: LANDFORM - 1949

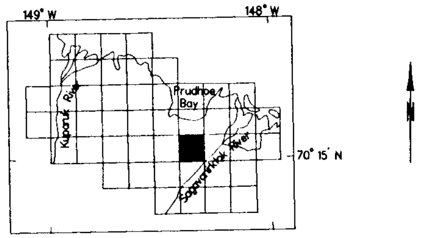


SYMBOL	DESCRIPTION	AREA HECTARES
▤	Drained thaw-lake basin	728.919
▥	Inter-thaw-lake area	701.239
■	Pingo	1.930
▒	Active floodplain	55.319
▨	Small stream drainage	3.562
▦	Island	5.158
■	Lake or pond	448.713
■	River or stream	144.919

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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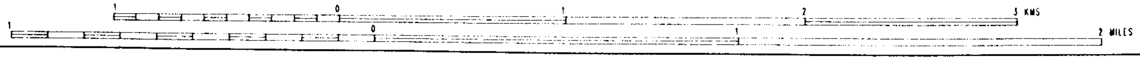
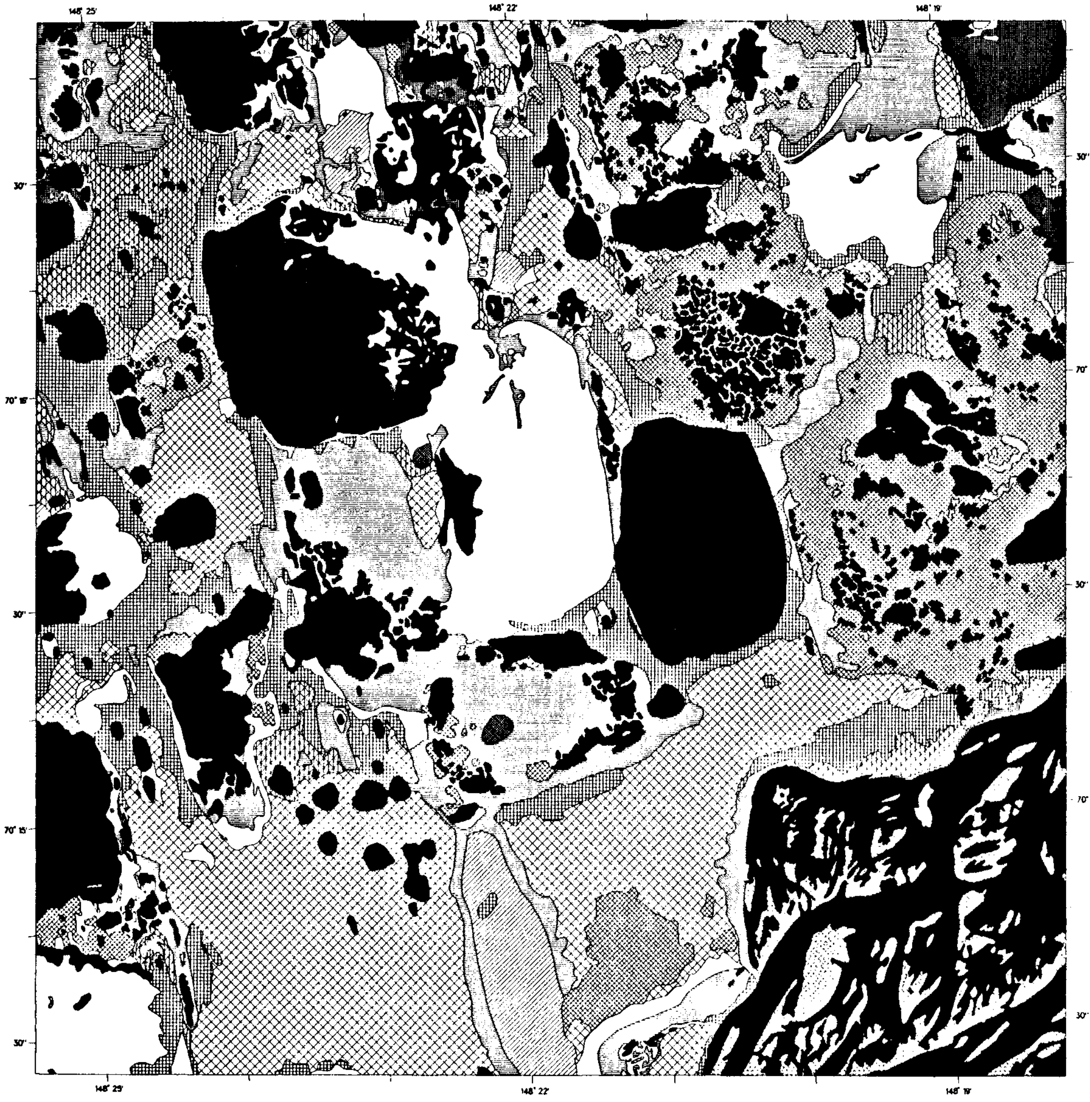


Fig. B51

MAP 34: PRIMARY SURFACE FORM - 1949

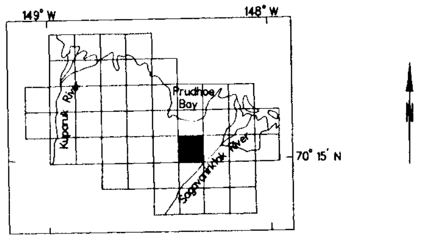


SYMBOL	DESCRIPTION	AREA HECTARES
■	High-centered polygons, center-trough relief greater than 0.5 m	30.255
▦	High-centered polygons, center-trough relief less than 0.5 m	174.422
▩	Low-centered polygons, center-rim relief greater than 0.5 m	252.044
▧	Low-centered polygons, center-rim relief less than 0.5 m	342.692
▦	Mixed high-centered and low-centered polygons	68.772
▨	Frost scars	38.222
▒	Strangmoor or disjunct polygon rims	283.151
■	Pingo with varied or undefined surface forms	1.930
□	Nonpatterned ground	245.068
▨	Sand dunes	7.158
░	Floodplain alluvium	52.413
■	Water	593.632

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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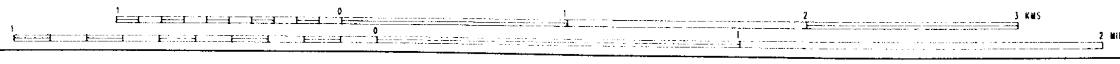


Fig. B52

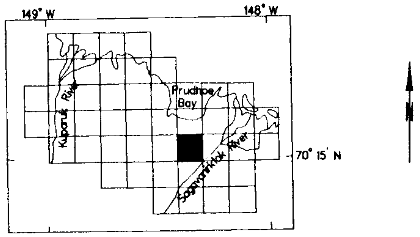
MAP 34: SECONDARY SURFACE FORM - 1949

SYMBOL	DESCRIPTION	AREA HECTARES
▩	Low-centered polygons, center-rim relief greater than 0.5 m	0.212
▨	Frost scars	20.059
■	Reticulate pattern	1.294
▦	Thermokarst pits	348.247

Authors: D.A. Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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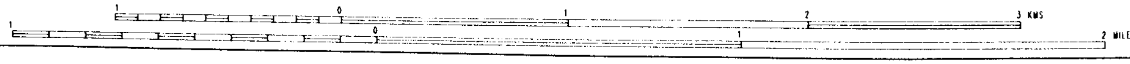
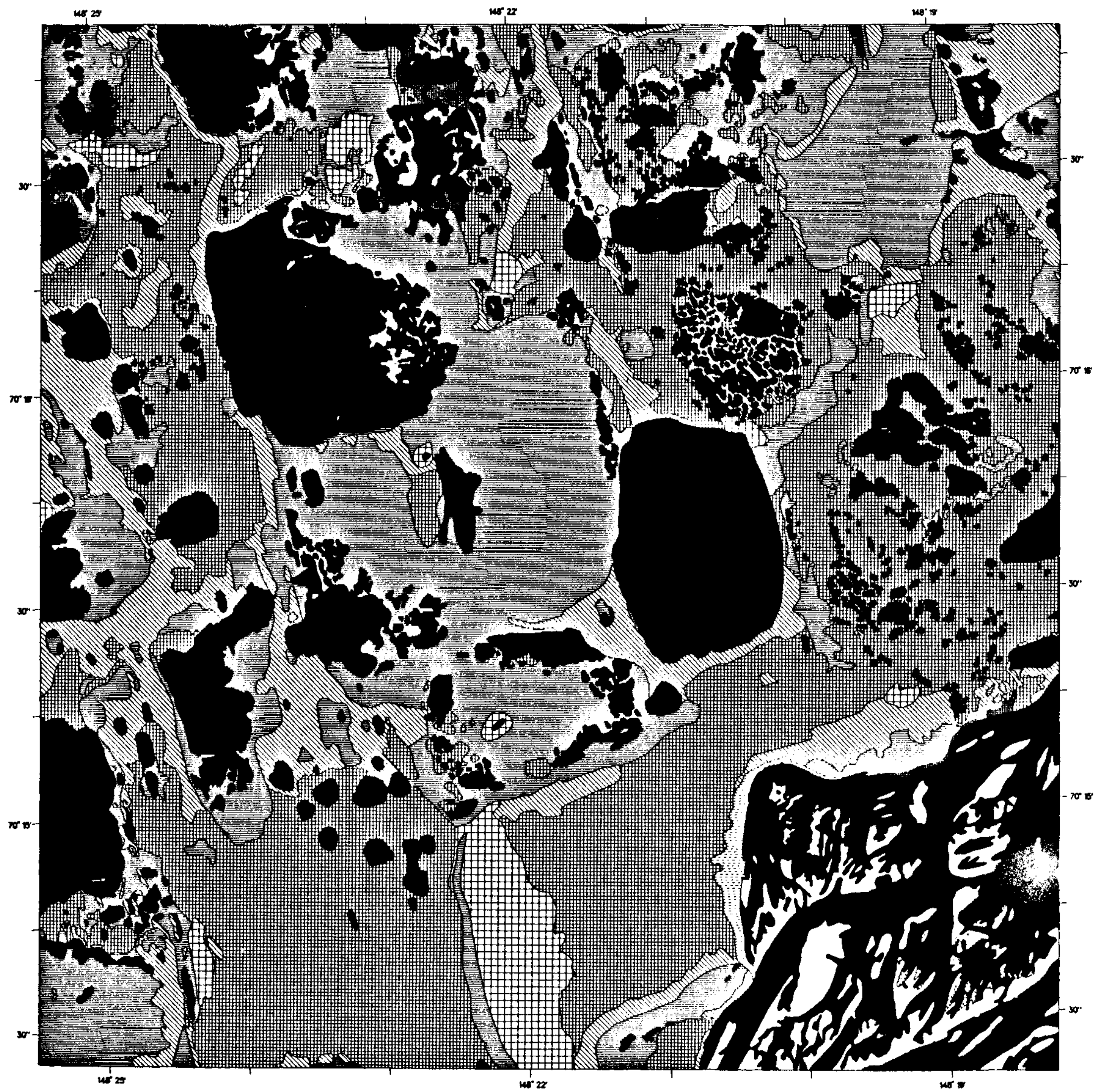


Fig. B53

MAP 34: PRIMARY SOIL - 1949

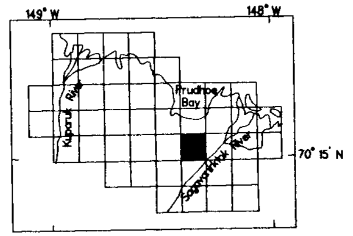


SYMBOL	DESCRIPTION	AREA HECTARES
■	Pergelic Cryoborolls	11.433
▨	Pergelic Cryaquolls or Cryosaprists	223.924
▤	Complex of: a) Pergelic Cryohemists or Cryofibrists, b) Histic Pergelic Cryaquepts, and c) Pergelic Cryaquepts	521.324
▦	Association of: a) Pergelic Cryohemists or Cryofibrists or Histic Pergelic Cryaquepts and b) Pergelic Cryosaprists or Cryaquolls	618.951
⊞	Association of: a) Pergelic Cryaquolls or Cryosaprists and b) Pergelic Cryaquepts	58.018
▩	Pergelic Cryorthents	2.906
▥	Denotes soil covered by a thin layer of wind-blown sand	7.158
□	No soil	52.413
■	Water	593.632

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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September, 1986

Fig. B54

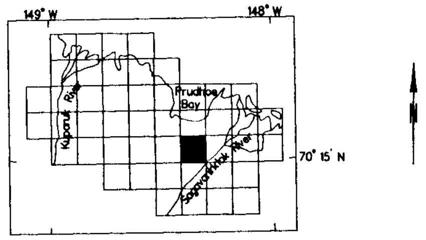
MAP 34: SECONDARY SOIL - 1949

SYMBOL	DESCRIPTION	AREA HECTARES
▨	Pergelic Cryaquolls or Cryosaprists	10.341
▩	Complex of: a) Pergelic Cryohemists or Cryofibrists b) Histic Pergelic Cryaquepts, and c) Pergelic Cryaquepts	29.544

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 34 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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September, 1986

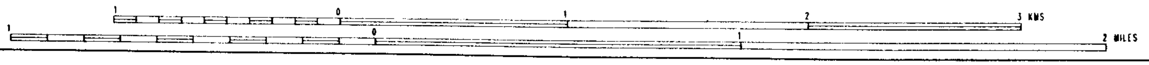
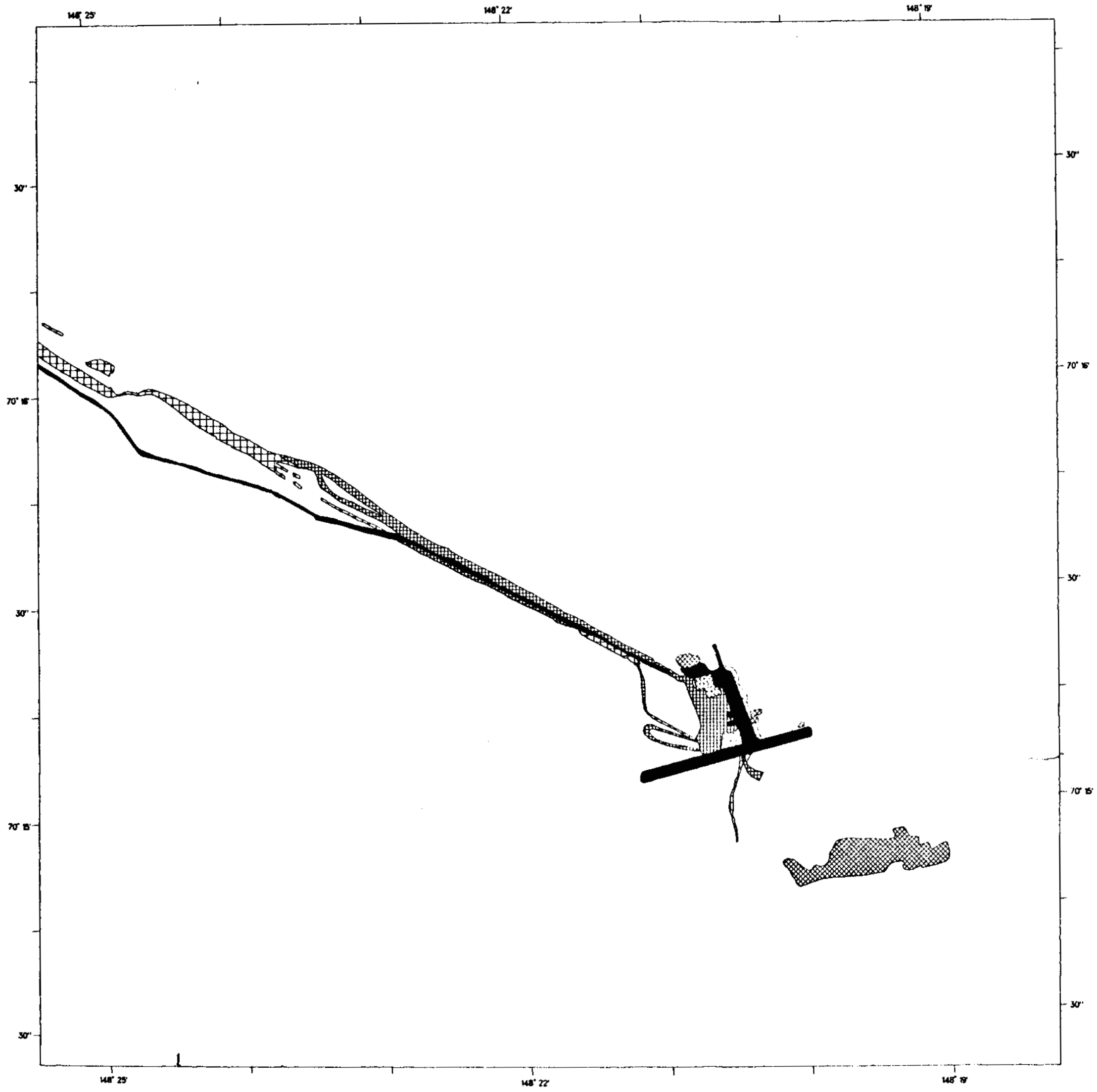


Fig. B65

MAP 34: PRIMARY ANTHROPOGENIC DISTURBANCE - 1968

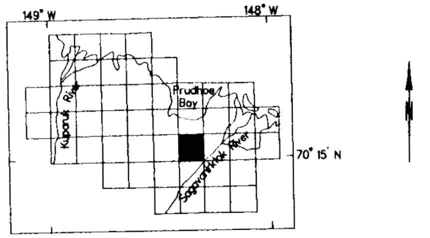


SYMBOL	DESCRIPTION	AREA HECTARES
■	Peat roads	4.096
■	Gravel pads	6.654
▦	Vehicle tracks, deeply rutted or with thermokarst	12.858
⊞	Vehicle tracks, not deeply rutted	8.005
▨	Gravel and construction debris (more than 75% cover)	1.397
▨	Gravel and construction debris (less than 75% cover)	0.720
▩	Excavations	9.161

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 34 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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September, 1986

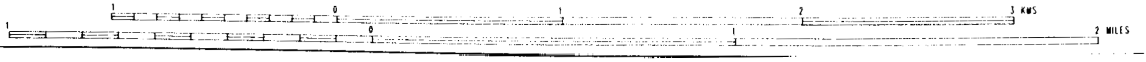


Fig. B56

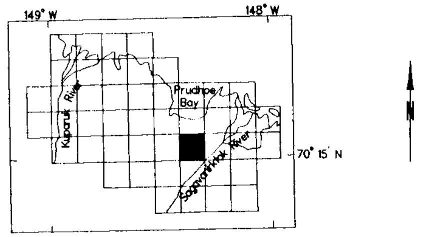
MAP 34: SECONDARY ANTHROPOGENIC DISTURBANCE - 1968

SYMBOL	DESCRIPTION	AREA HECTARES
▩	Construction-induced thermokarst	0.683
▦	Vehicle tracks, deeply rutted or with thermokarst	0.618
░	Gravel and construction debris (less than 75% cover)	3.929

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 34 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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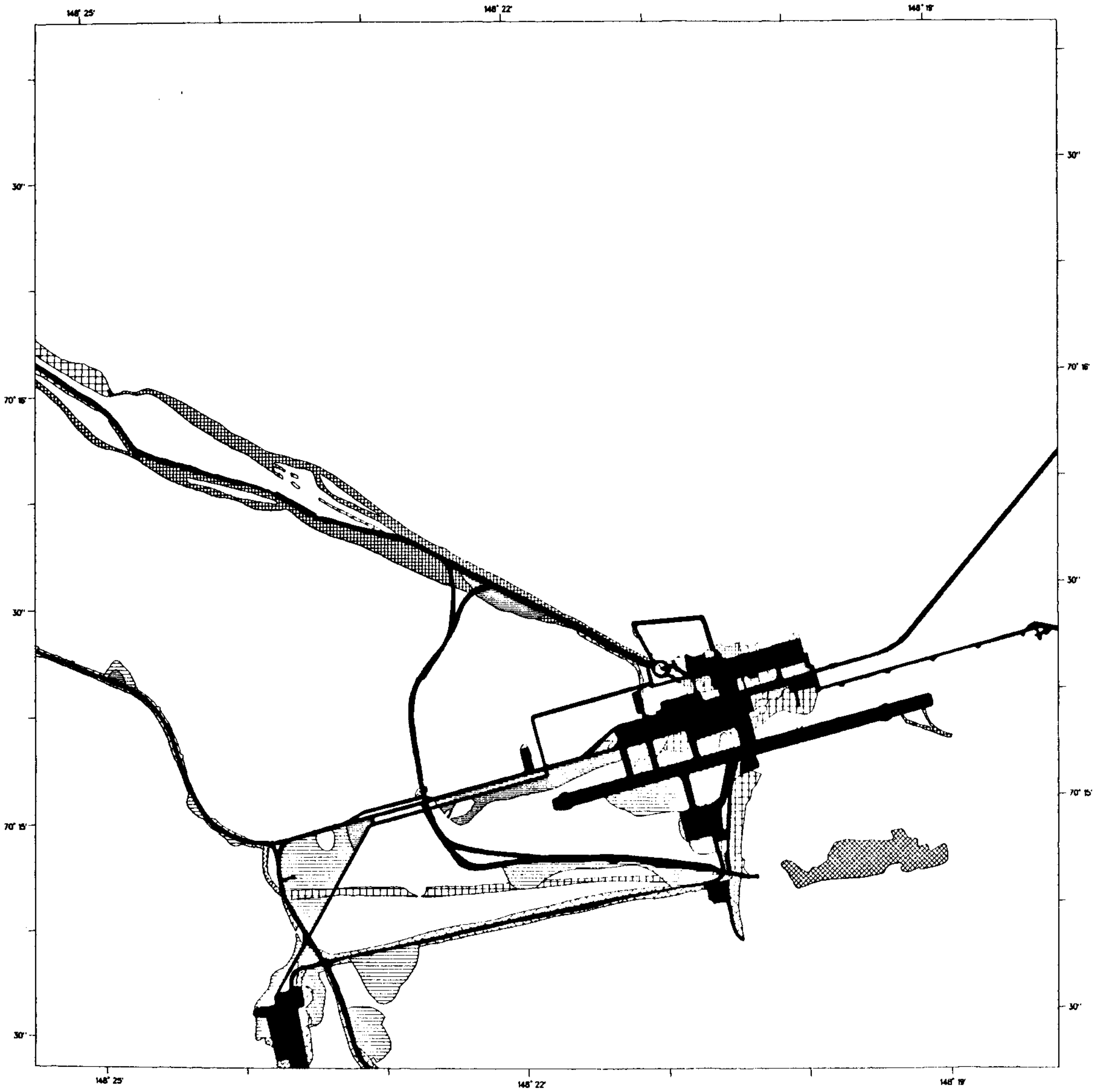
September, 1986

Fig. B57

MAP 34: PRIMARY ANTHROPOGENIC DISTURBANCE - 1970

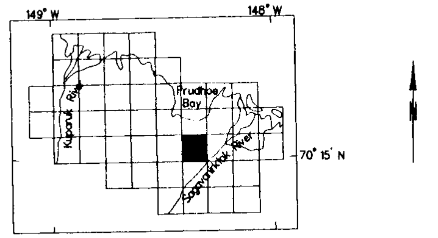


SYMBOL	DESCRIPTION	AREA HECTARES
■	Gravel roads	17.828
■	Peat roads	14.270
■	Gravel pads	41.104
░	Continuous flooding, more than 75% open water	12.244
▤	Discontinuous flooding, less than 75% open water	32.931
▦	Vehicle tracks, deeply rutted or with thermokarst	21.761
⊞	Vehicle tracks, not deeply rutted	15.346
▩	Gravel and construction debris (more than 75% cover)	2.490
▧	Gravel and construction debris (less than 75% cover)	13.698
▩	Excavations	8.775

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 34 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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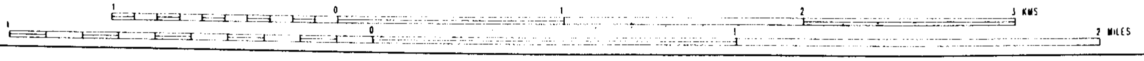
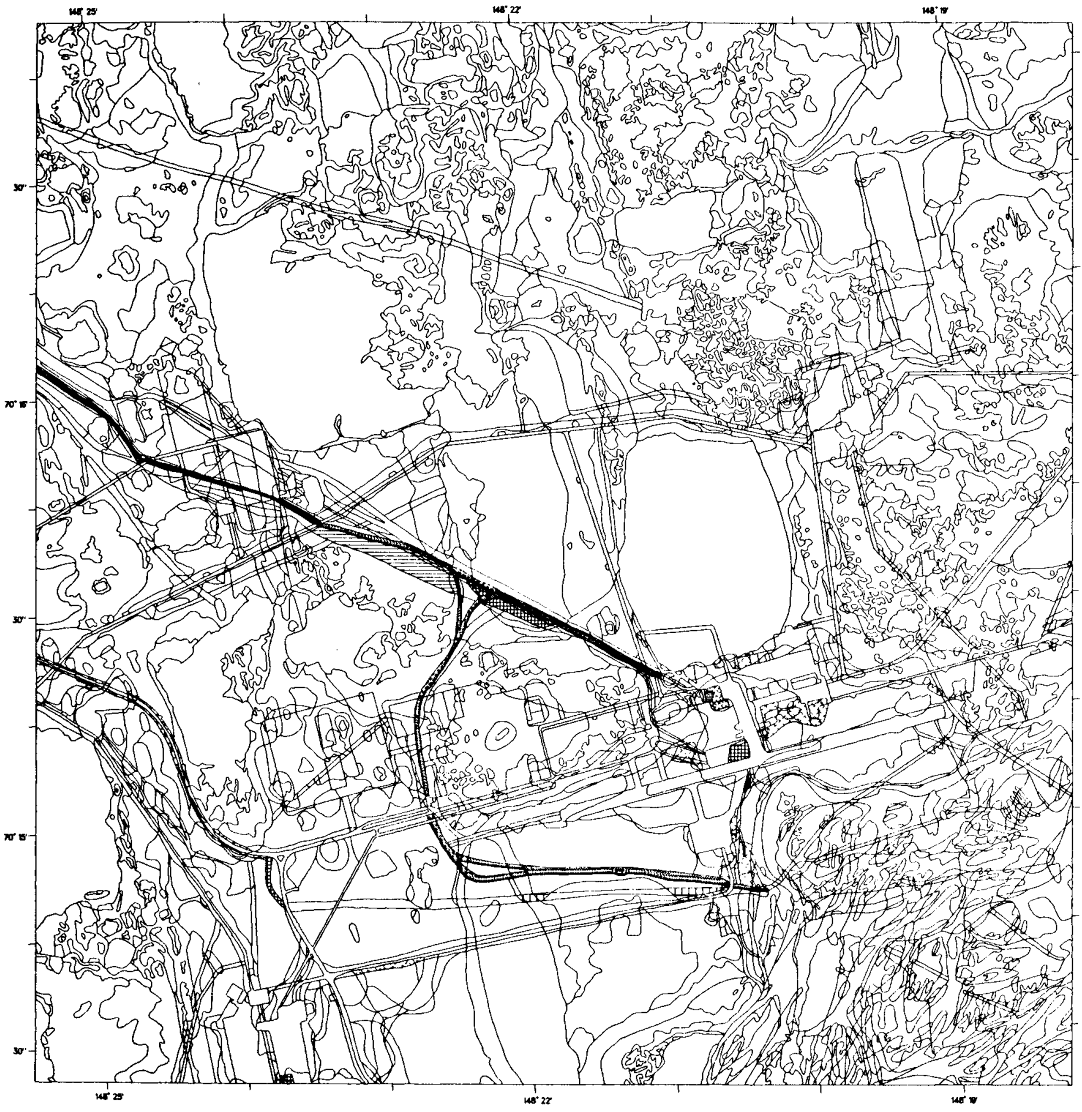


Fig. B58

MAP 34: SECONDARY ANTHROPOGENIC DISTURBANCE - 1970

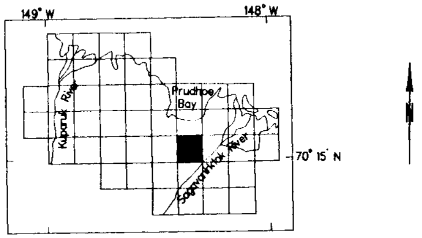


SYMBOL	DESCRIPTION	AREA HECTARES
▓	Continuous flooding, more than 75% open water	0.131
▤	Discontinuous flooding, less than 75% open water	4.867
▩	Construction-induced thermokarst	14.270
▦	Vehicle tracks, deeply rutted or with thermokarst	2.938
⊞	Vehicle tracks, not deeply rutted	3.020
▨	Gravel and construction debris (more than 75% cover)	0.604
░	Gravel and construction debris (less than 75% cover)	6.767

Authors, D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



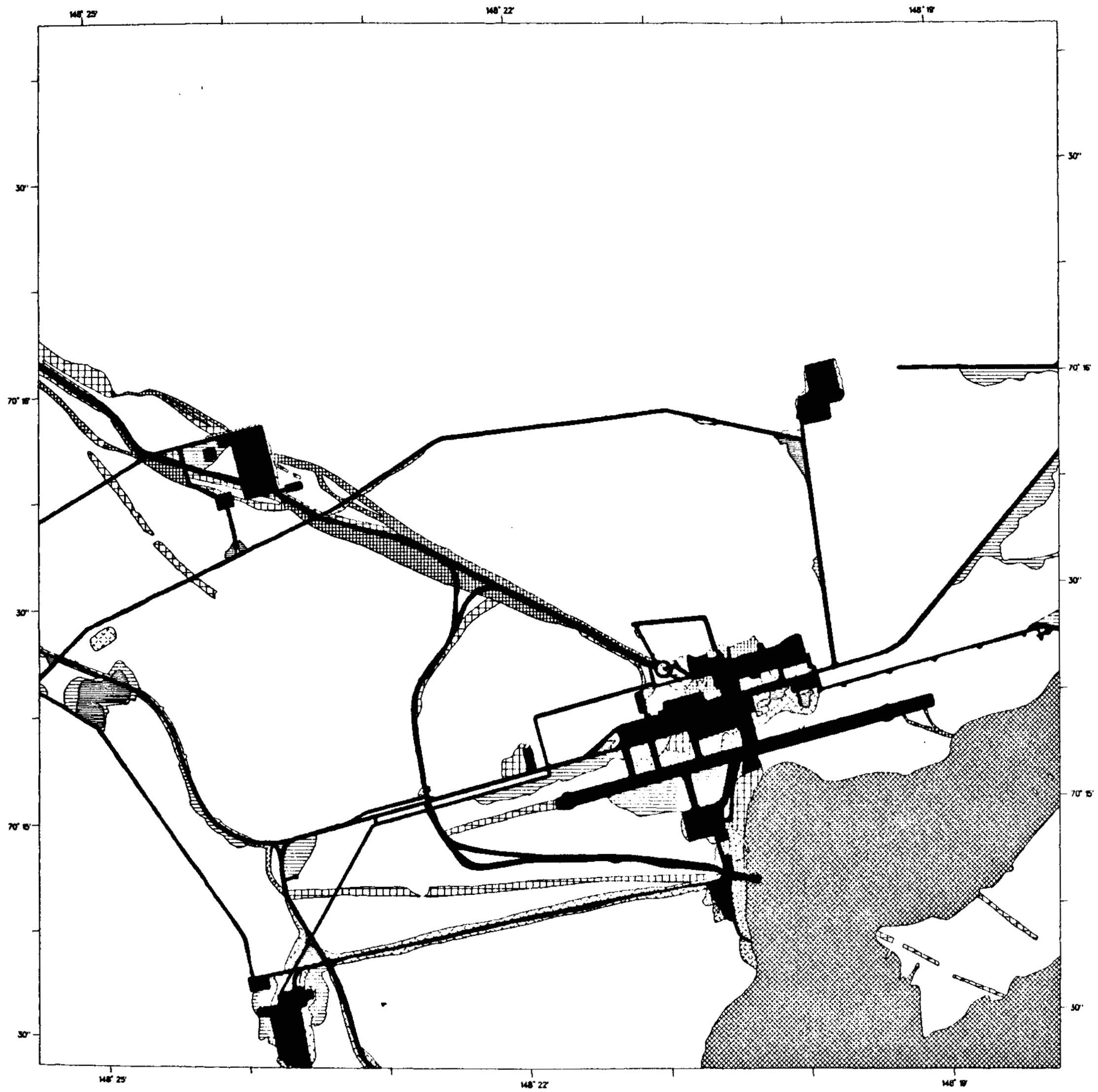
Base Map: Map 34 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

Funded by the Environmental Protection Agency Cold Climate Environmental Research Program in conjunction with the U.S. Fish and Wildlife Service. Funding for initial geobotanical mapping provided by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) and the U.S. Tundra Biome portion of the International Biological Program (IBP) with support from the Alaska Oil and Gas Association.

September, 1986

Fig. B59

MAP 34: PRIMARY ANTHROPOGENIC DISTURBANCE - 1973

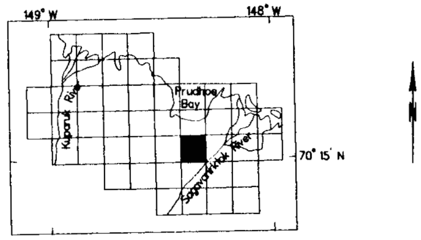


SYMBOL	DESCRIPTION	AREA HECTARES
■	Gravel roads	29.796
■	Peat roads	15.124
■	Gravel pads	52.371
▨	Continuous flooding, more than 75% open water	7.836
▤	Discontinuous flooding, less than 75% open water	28.391
▦	Vehicle tracks, deeply rutted or with thermokarst	18.413
▦	Vehicle tracks, not deeply rutted	24.493
▩	Gravel and construction debris (more than 75% cover)	5.492
▩	Gravel and construction debris (less than 75% cover)	18.604
▩	Excavations	162.488

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 34 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

Funded by the Environmental Protection Agency Cold Climate Environmental Research Program in conjunction with the U.S. Fish and Wildlife Service. Funding for initial geobotanical mapping provided by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) and the U.S. Tundra Biome portion of the International Biological Program (IBP) with support from the Alaska Oil and Gas Association.

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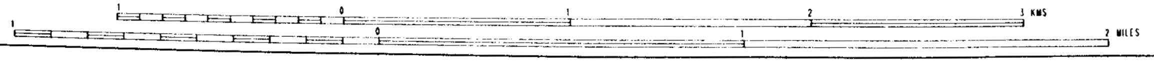
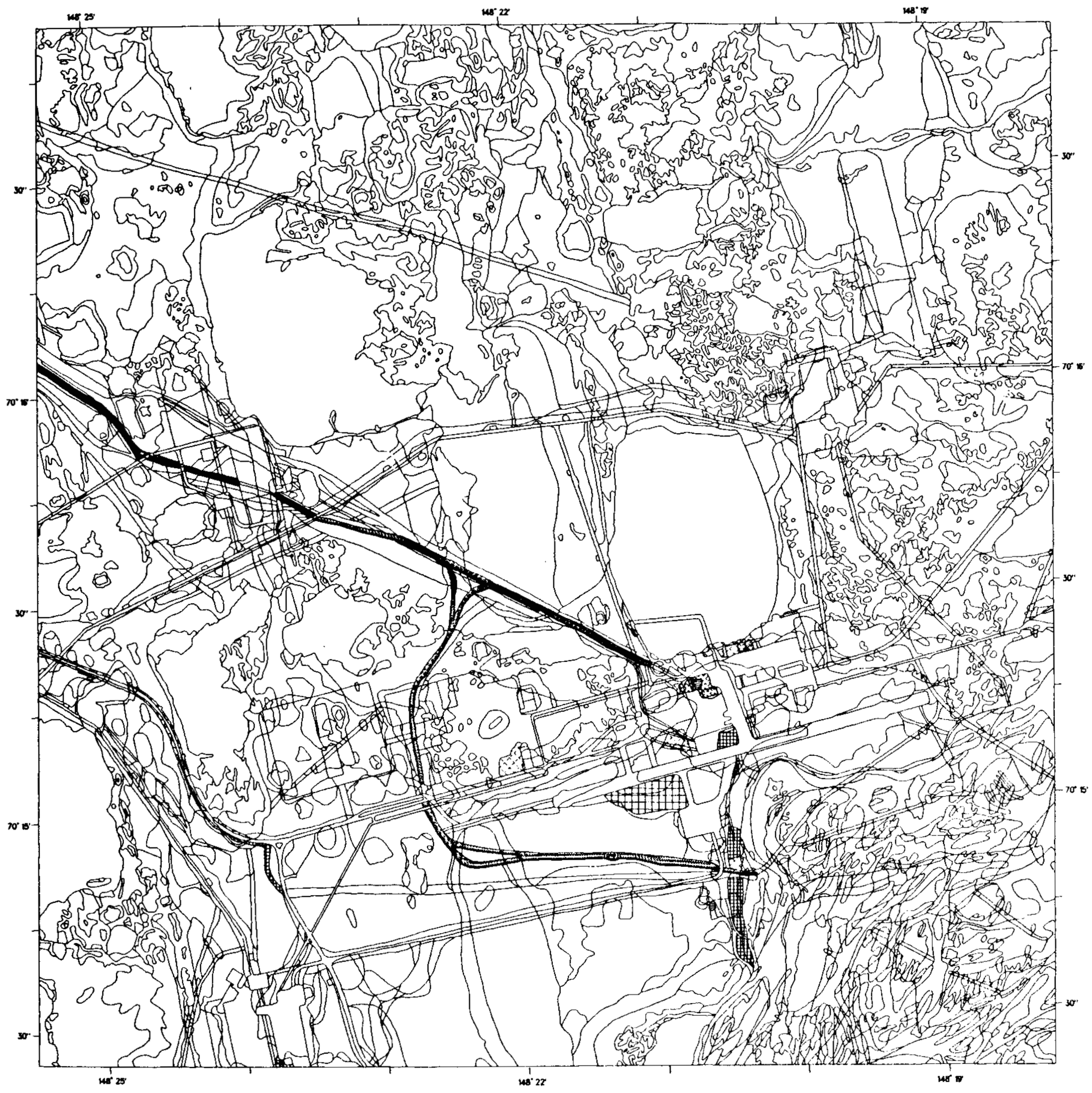


MAP 34: SECONDARY ANTHROPOGENIC DISTURBANCE - 1973



SYMBOL	DESCRIPTION	AREA HECTARES
▩	Continuous flooding, more than 75% open water	0.225
▤	Discontinuous flooding, less than 75% open water	0.341
▧	Construction-induced thermokarst	15.164
▦	Vehicle tracks, deeply rutted or with thermokarst	4.396
⊞	Vehicle tracks, not deeply rutted	5.534
▨	Gravel and construction debris (more than 75% cover)	1.325
⬚	Gravel and construction debris (less than 75% cover)	3.485

Authors: D.A. Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.

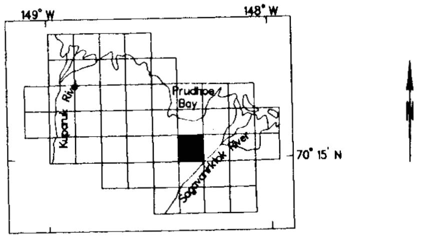


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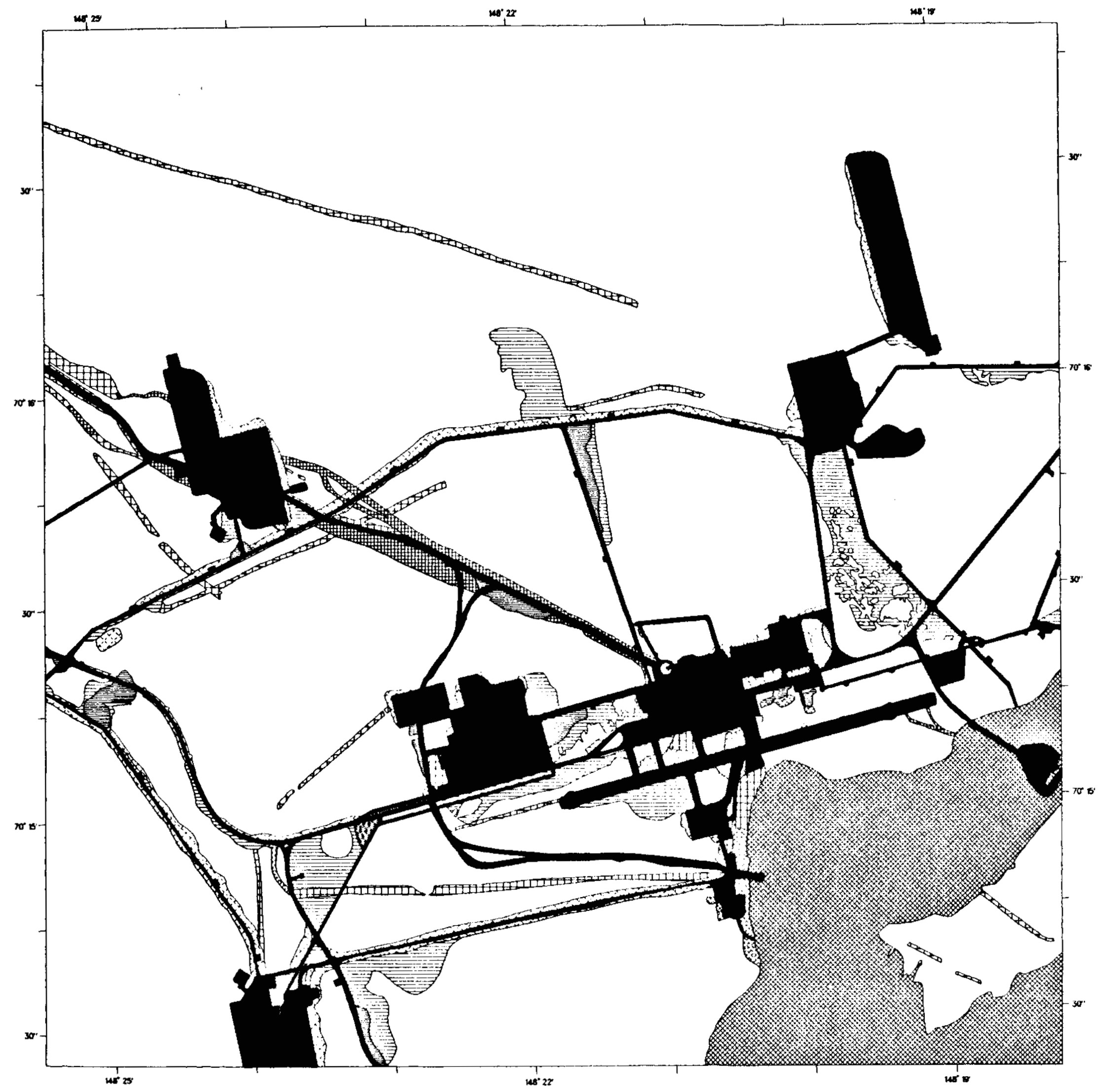
Fig. B61

MAP 34: PRIMARY ANTHROPOGENIC DISTURBANCE - 1977

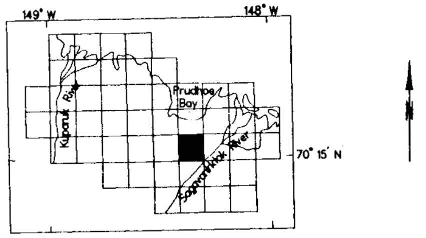


SYMBOL	DESCRIPTION	AREA HECTARES
■	Gravel roads	38.145
■	Peat roads	13.437
■	Gravel pads	134.120
▨	Continuous flooding, more than 75% open water	15.776
▤	Discontinuous flooding, less than 75% open water	70.479
▨	Construction-induced thermokarst	1.166
▦	Vehicle tracks, deeply rutted or with thermokarst	13.399
▦	Vehicle tracks, not deeply rutted	30.868
▨	Gravel and construction debris (more than 75% cover)	7.867
▨	Gravel and construction debris (less than 75% cover)	34.352
▩	Excavations	159.024

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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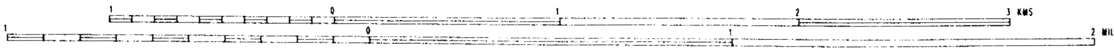
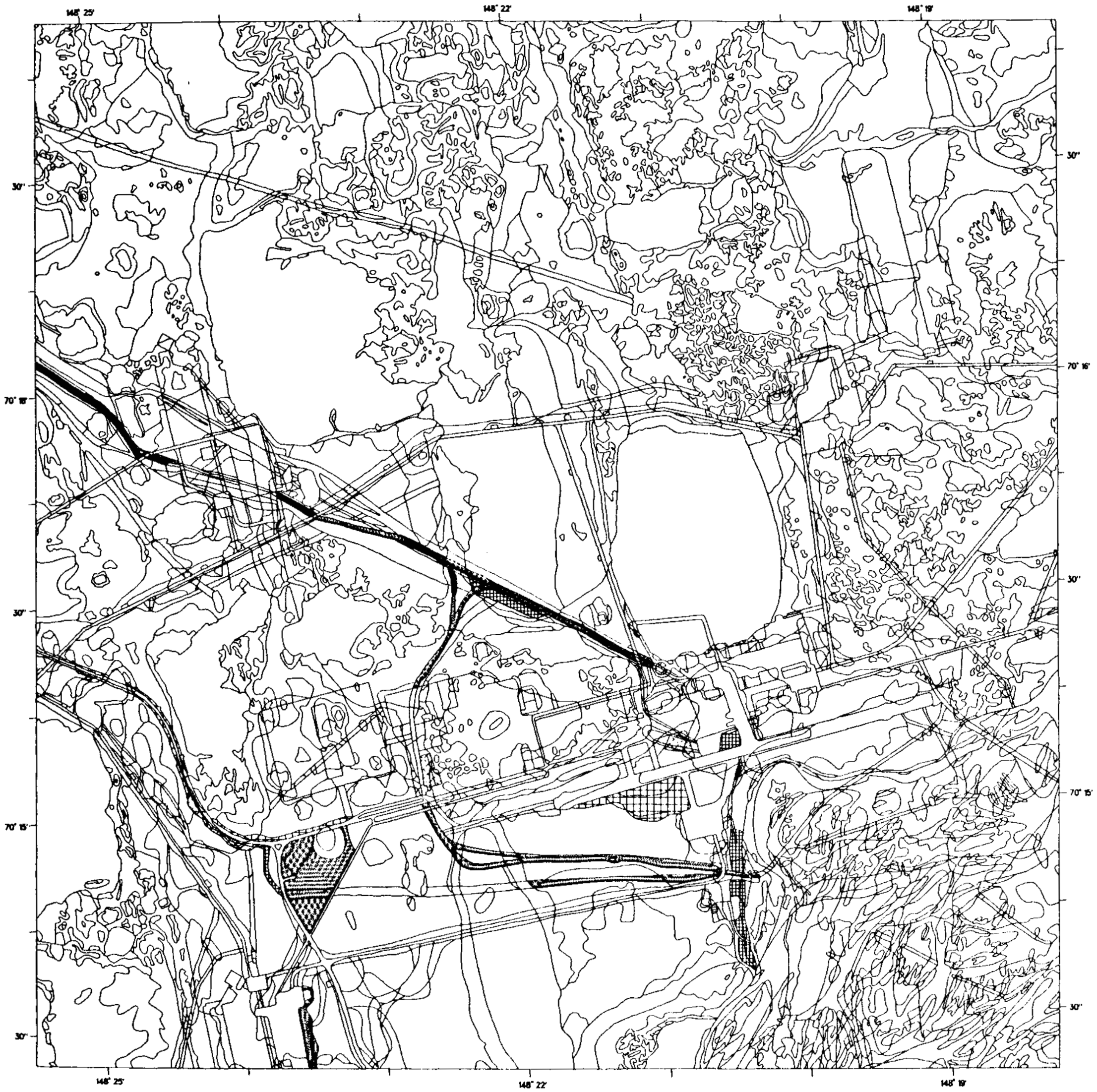


Fig. B62

MAP 34: SECONDARY ANTHROPOGENIC DISTURBANCE - 1977

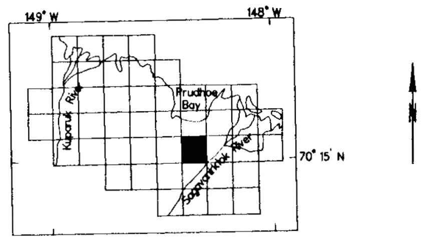


SYMBOL	DESCRIPTION	AREA HECTARES
▨	Continuous flooding, more than 75% open water	0.094
▨	Construction-induced thermokarst	24.534
▦	Vehicle tracks, deeply rutted or with thermokarst	5.555
▦	Vehicle tracks, not deeply rutted	7.407
▨	Gravel and construction debris (more than 75% cover)	0.172
▨	Gravel and construction debris (less than 75% cover)	3.926

Authors: D.A. Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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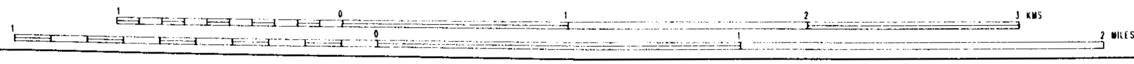
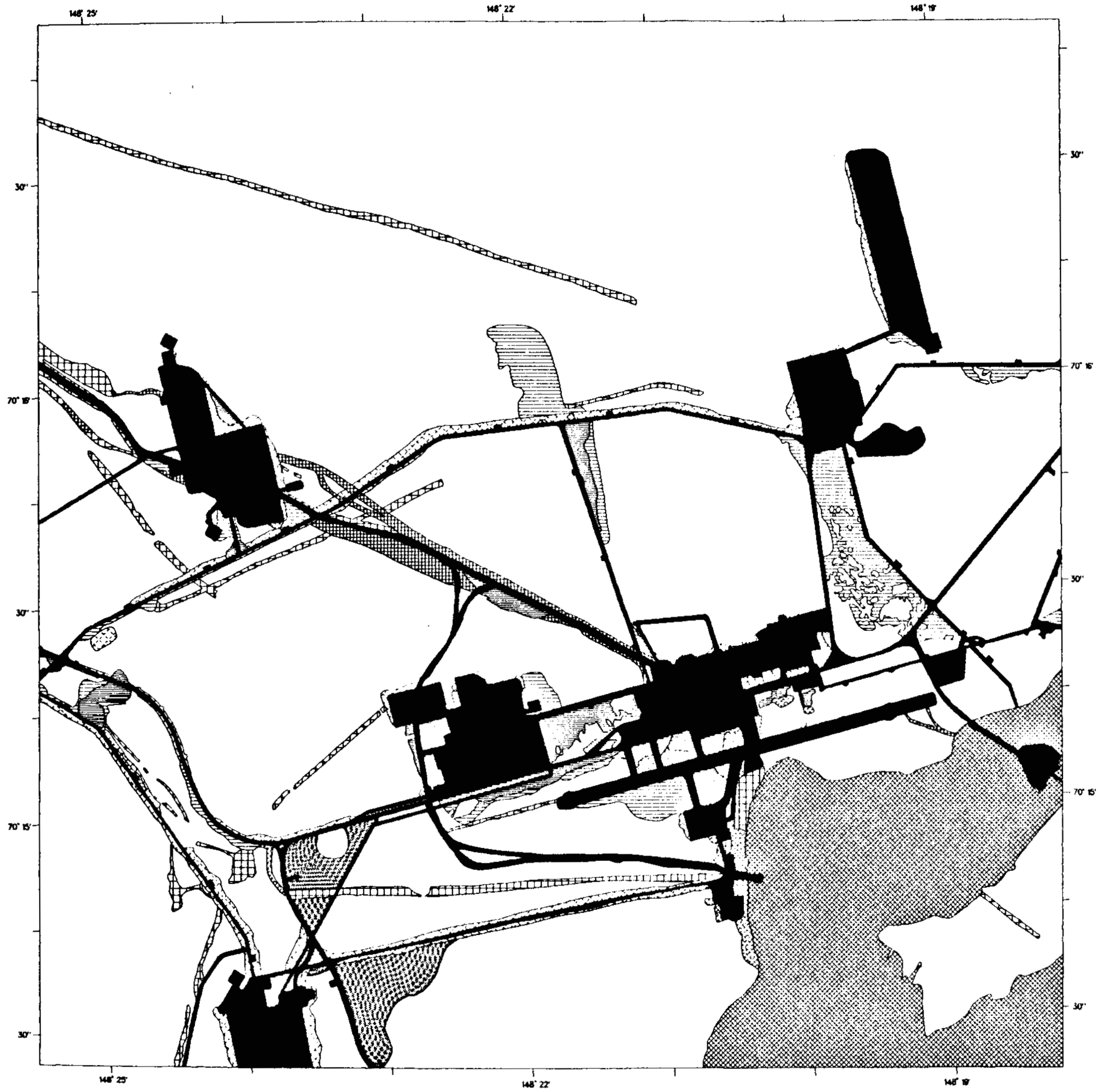


Fig. B63

MAP 34: PRIMARY ANTHROPOGENIC DISTURBANCE - 1979



SYMBOL	DESCRIPTION	AREA HECTARES
■	Gravel roads	39.487
■	Peat roads	13.437
■	Gravel pads	136.523
▒	Continuous flooding, more than 75% open water	23.534
▤	Discontinuous flooding, less than 75% open water	48.763
▩	Construction-induced thermokarst	20.635
▦	Vehicle tracks, deeply rutted or with thermokarst	12.912
⊞	Vehicle tracks, not deeply rutted	32.093
░	Gravel and construction debris (more than 75% cover)	6.392
░	Gravel and construction debris (less than 75% cover)	35.044
▩	Excavations	159.559

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.

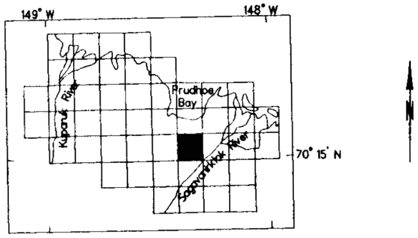


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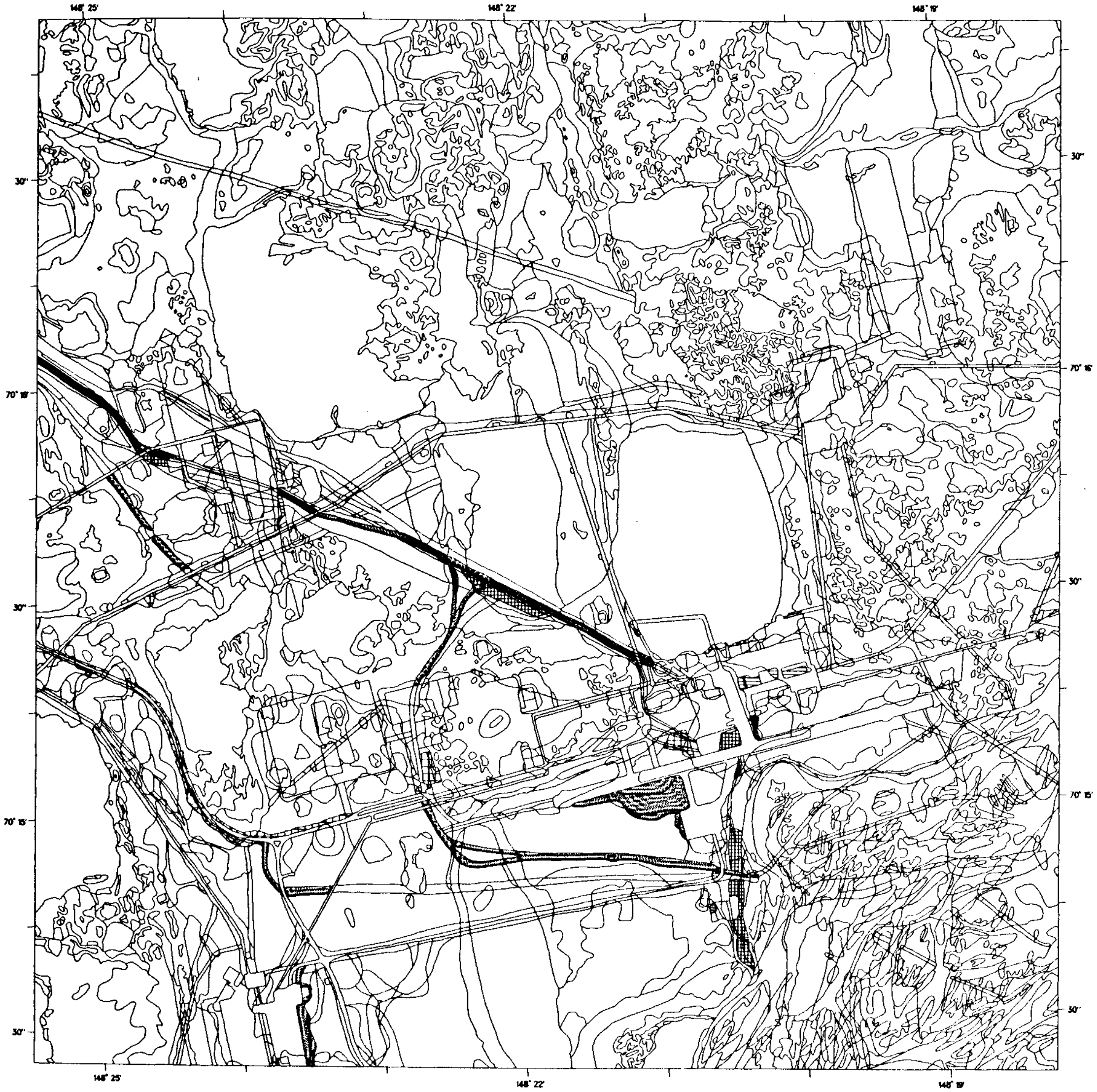
Fig. B64

MAP 34: SECONDARY ANTHROPOGENIC DISTURBANCE - 1979

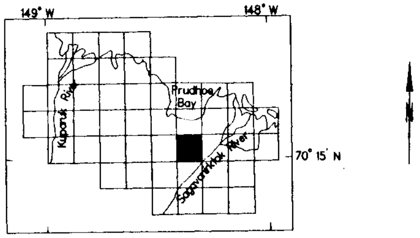


SYMBOL	DESCRIPTION	AREA HECTARES
▦	Continuous flooding, more than 75% open water	0.094
▤	Discontinuous flooding, less than 75% open water	1.187
▩	Construction-induced thermokarst	23.176
▦	Vehicle tracks, deeply rutted or with thermokarst	5.604
▦	Vehicle tracks, not deeply rutted	4.247
▨	Gravel and construction debris (more than 75% cover)	0.172
▨	Gravel and construction debris (less than 75% cover)	1.761

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



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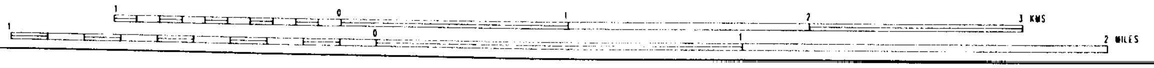
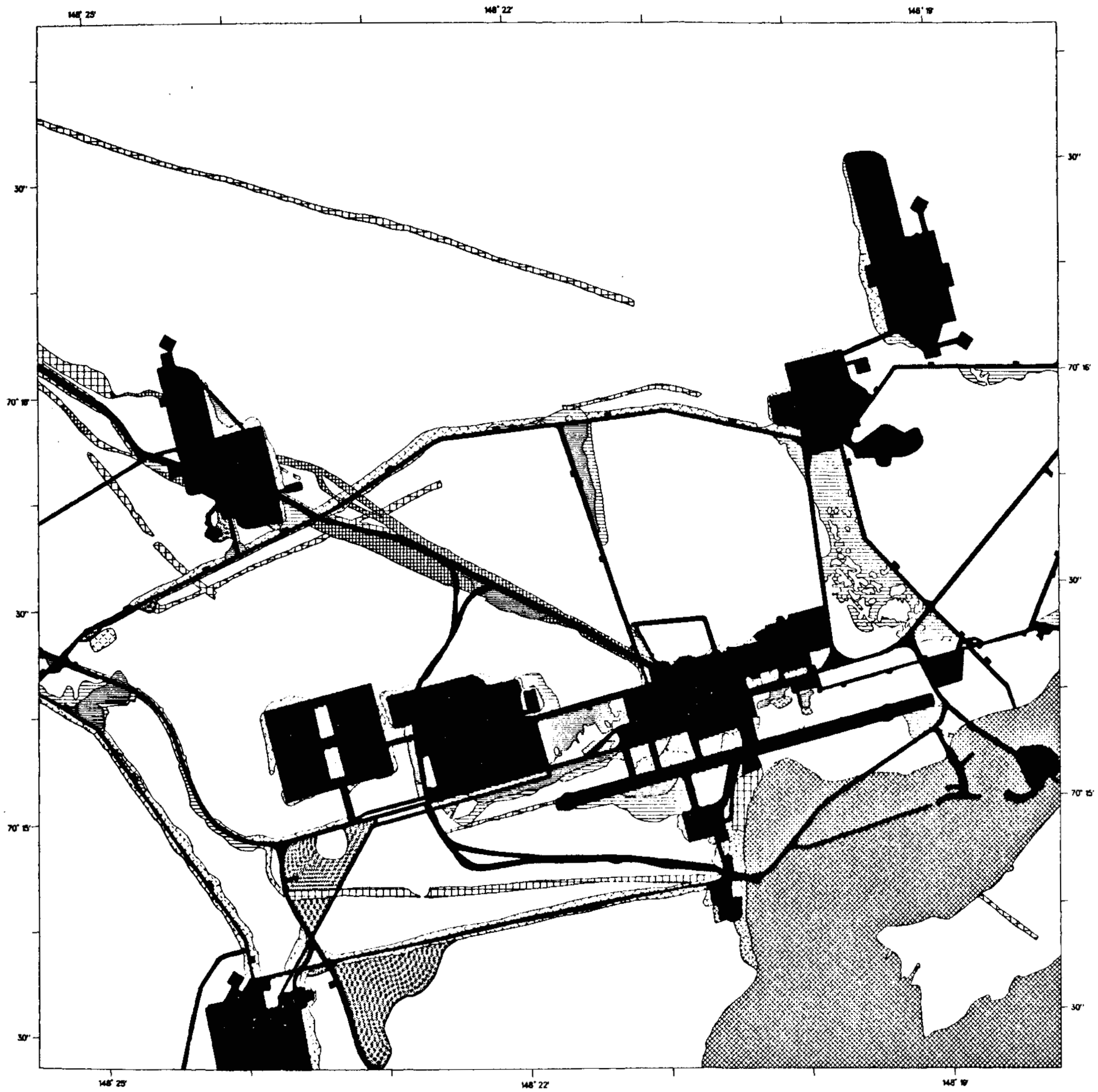


Fig. B65

MAP 34: PRIMARY ANTHROPOGENIC DISTURBANCE - 1983

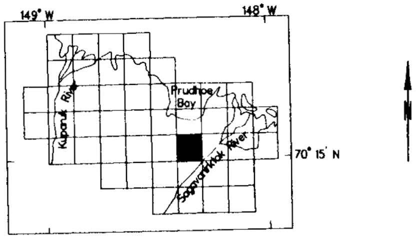


SYMBOL	DESCRIPTION	AREA HECTARES
■	Gravel roads	44.628
■	Peat roads	13.365
■	Gravel pads	172.283
▒	Continuous flooding, more than 75% open water	26.826
▤	Discontinuous flooding, less than 75% open water	39.903
▩	Construction-induced thermokarst	21.624
▦	Vehicle tracks, deeply rutted or with thermokarst	12.527
▦	Vehicle tracks, not deeply rutted	26.739
▨	Gravel and construction debris (more than 75% cover)	5.711
▨	Gravel and construction debris (less than 75% cover)	35.680
▩	Excavations	155.649

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 34 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

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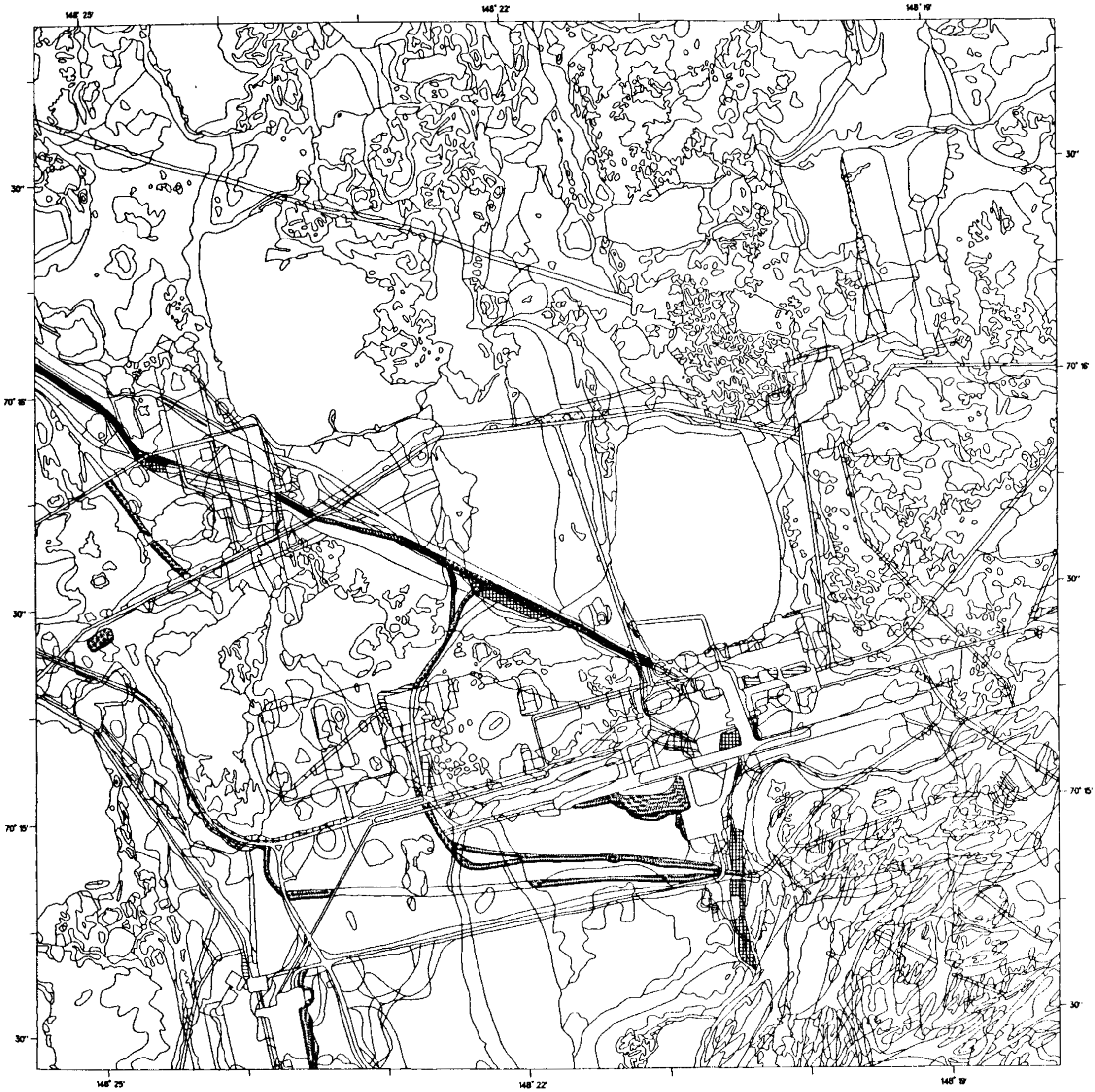
September, 1986

Fig. B66

MAP 34: SECONDARY ANTHROPOGENIC DISTURBANCE - 1983

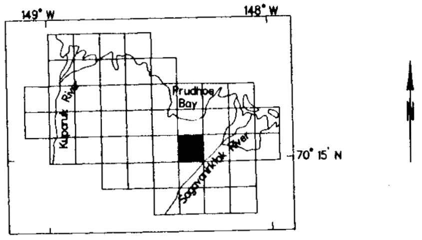


SYMBOL	DESCRIPTION	AREA HECTARES
▓	Continuous flooding, more than 75% open water	0.094
▤	Discontinuous flooding, less than 75% open water	1.822
▩	Construction-induced thermokarst	24.825
▦	Vehicle tracks, deeply rutted or with thermokarst	5.507
⊞	Vehicle tracks, not deeply rutted	3.705
▧	Gravel and construction debris (more than 75% cover)	0.347
⬚	Gravel and construction debris (less than 75% cover)	3.210

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 34 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

Funded by the Environmental Protection Agency Cold Climate Environmental Research Program in conjunction with the U.S. Fish and Wildlife Service. Funding for initial geobotanical mapping provided by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) and the U.S. Tundra Biome portion of the International Biological Program (IBP) with support from the Alaska Oil and Gas Association.

September, 1986

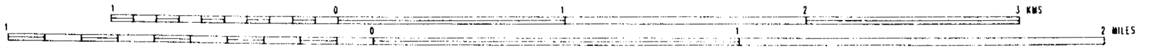
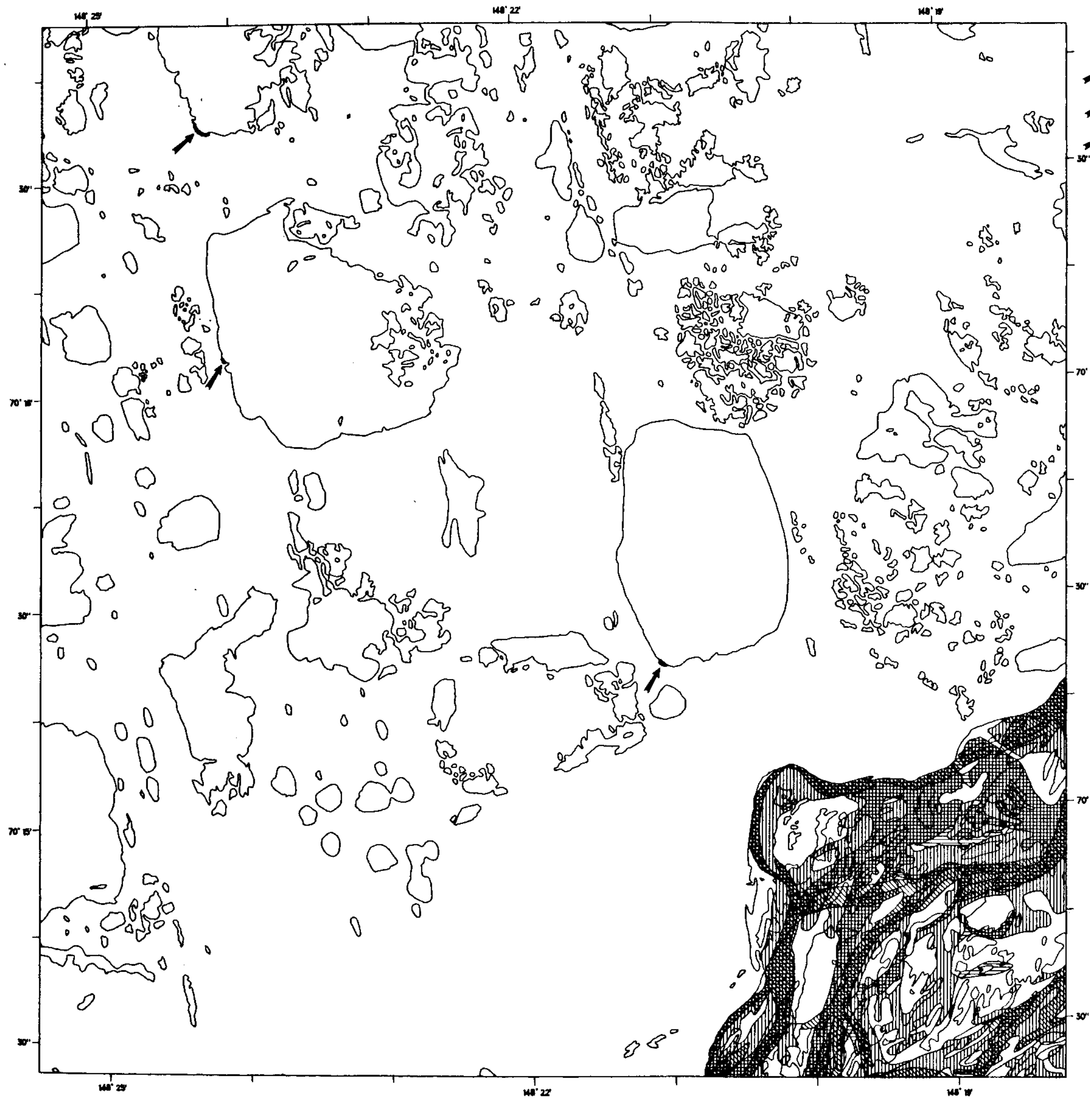


Fig. B67

MAP 34: NATURAL DISTURBANCES - 1968, 1977, & 1983

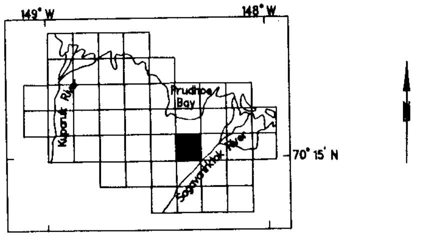


SYMBOL	DESCRIPTION	AREA HECTARES
▨	Lake erosion 1968	0.188
▤	Lake erosion 1977	0.135
▥	Lake erosion 1983	0.135
▨	River channel locations 1968	125.340
▤	River channel locations 1977	60.580
▥	River channel locations 1983	42.871

Authors: D.A.Walker and N.D. Lederer, Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, Boulder, CO.

Map Automation: E.F. Binnian and E.A. Nordstrand, North Slope Borough GIS, Anchorage, AK.

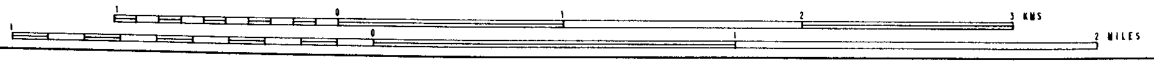
Geobotanical Information: D.A. Walker, INSTAAR; and K.R. Everett, Institute of Polar Studies, The Ohio State University, Columbus, OH.



Base Map: Map 34 of a series of 47 1:6,000-scale topographic maps (1.4-m contour interval) of the Prudhoe Bay Unit area, prepared by Air Photo Tech, Inc., Anchorage, AK, for the Prudhoe Bay Unit, and provided by the Prudhoe Bay Environmental Subcommittee of the Alaska Oil and Gas Association.

Funded by the Environmental Protection Agency Cold Climate Environmental Research Program in conjunction with the U.S. Fish and Wildlife Service. Funding for initial geobotanical mapping provided by the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) and the U.S. Tundra Biome portion of the International Biological Program (IBP) with support from the Alaska Oil and Gas Association.

September, 1986



Appendix C. Area summaries for geobotanical and disturbance data

Table C1. Area summaries for geobotanical data on Map 22.

```
       PRIMARY VEGETATION 1949

   V1    MAP AREA HA.    P T MAP APEA
----- --------------- ---------------

    1          791.03           37.88
    2           35.49            1.70
    3          466.40           22.34
    5            0.00            0.00
   21          496.29           23.77
   41          277.07           13.27
   42            5.06            0.24
   48            0.00            0.00
   61            0.34            0.02
   62           15.60            0.75
   63            0.00            0.00
   64            0.00            0.00
   81            0.00            0.00
   99            0.78            0.04
      =============== ===============
             2,088.05          100.00
```

```
      SECONDARY VEGETATION 1949

   V2    MAP AREA HA.    P T MAP AREA
----- --------------- ---------------

    0*       1,093.31           52.36
    1            6.80            0.33
    2           23.41            1.12
    3          237.78           11.39
    5            0.00            0.00
   21          528.54           25.31
   41          184.27            8.82
   48            0.00            0.00
   62           13.95            0.67
   63            0.00            0.00
   99            0.00            0.00
      =============== ===============
             2,088.05          100.00
```

```
       TERTIARY VEGETATION 1949

   V3    MAP AREA HA.    P T MAP AREA
----- --------------- ---------------

    0        2,014.65           96.48
    2            1.06            0.05
    3           32.52            1.56
    5            0.00            0.00
   21           12.09            0.58
   41           27.73            1.33
   48            0.00            0.00
   62            0.00            0.00
   63            0.00            0.00
   99            0.00            0.00
      =============== ===============
             2,088.05          100.00
```

```
       PERCENT WATER COVER 1949

    W    MAP AREA HA.    P T MAP AREA
----- --------------- ---------------

    1          496.35           23.77
    2          373.41           17.88
    3          385.19           18.45
    4           42.02            2.01
    5          791.08           37.89
      =============== ===============
             2,088.05          100.00
```

```
            LANDFORM 1949

   LF    MAP AREA HA.    P T MAP AREA
----- --------------- ---------------

    1          792.35           37.95
    4          455.49           21.81
   11           10.99            0.53
   12            0.00            0.00
   13            6.61            0.32
   15            0.56            0.03
   16            0.00            0.00
   20            0.00            0.00
   25            0.03            0.00
   51          821.82           39.36
   52            0.20            0.01
      =============== ===============
             2,088.05          100.00
```

```
         LANDSCAPE UNIT 1949

  LSU    MAP AREA HA.    P T MAP AREA
----- --------------- ---------------

    1        2,088.05          100.00
    2            0.00            0.00
      =============== ===============
             2,088.05          100.00
```

```
      PRIMARY SURFACE FORM 1949

   S1    MAP AREA HA.    P T MAP AREA
----- --------------- ---------------

    1           24.55            1.18
    2          119.50            5.72
    3            5.90            0.28
    4          128.39            6.15
    5           27.35            1.31
    6           76.54            3.67
    7          660.20           31.62
    8            0.34            0.02
    9            2.34            0.11
   10          220.60           10.56
   11            0.00            0.00
   12            0.00            0.00
   13            0.00            0.00
   14            0.00            0.00
   16            0.00            0.00
   21          822.36           39.38
      =============== ===============
             2,088.05          100.00
```

```
     SECONDARY SURFACE FORM 1949

   S2    MAP AREA HA.    P T MAP AREA
----- --------------- ---------------

    0        1,913.63           91.65
    3            0.00            0.00
    6           40.28            1.93
   11            0.00            0.00
   14          134.14            6.42
      =============== ===============
             2,088.05          100.00
```

```
          PRIMARY SOIL 1949

  SL1    MAP AREA HA.    P T MAP AREA
----- --------------- ---------------

    1            2.46            0.12
    2          176.11            8.43
    3          872.52           41.79
    4          137.02            6.56
    5           77.17            3.70
    6            0.00            0.00
    7            0.00            0.00
    8            0.00            0.00
    9            0.00            0.00
   10            0.00            0.00
   21          822.78           39.40
      =============== ===============
             2,088.05          100.00
```

```
         SECONDARY SOIL 1949

  SL2    MAP AREA HA.    P T MAP AREA
----- --------------- ---------------

    0        2,061.33           98.72
    2            0.91            0.04
    3           25.82            1.24
    5            0.00            0.00
      =============== ===============
             2,088.05          100.00
```

Table C2. Area summaries for disturbance data on Map 22.

PRIMARY ANTHROPOGENIC DISTURBANCE 1970

HD1-70	MAP AREA HA.	P T MAP AREA
0	1,887.30	90.39
1	28.72	1.38
2	0.00	0.00
3	18.52	0.89
4	96.85	4.64
5	18.38	0.88
6	6.49	0.31
7	0.00	0.00
8	9.96	0.48
9	0.00	0.00
10	9.44	0.45
11	12.40	0.59
13	0.00	0.00
	2,088.05	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1970

HD2-70	MAP AREA HA.	P T MAP AREA
0	2,064.85	98.89
4	0.80	0.04
5	12.45	0.60
6	0.32	0.02
7	0.00	0.00
8	3.01	0.14
10	2.74	0.13
11	3.90	0.19
	2,088.05	100.00

TERTIARY ANTHROPOGENIC DISTURBANCE 1970

HD3-70	MAP AREA HA.	P T MAP AREA
0	2,083.88	99.80
6	0.74	0.04
10	0.32	0.02
11	3.10	0.14
	2,088.04	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1972

HD1-72	MAP AREA HA.	P T MAP AREA
0	1,874.30	89.76
1	39.85	1.91
2	0.00	0.00
3	32.63	1.56
4	86.65	4.15
5	16.87	0.81
6	4.05	0.19
7	0.00	0.00
8	9.96	0.48
9	0.00	0.00
10	10.84	0.52
11	12.92	0.62
13	0.00	0.00
	2,088.05	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1972

HD2-72	MAP AREA HA.	P T MAP AREA
0	2,068.67	99.07
4	0.00	0.00
5	11.03	0.53
6	0.32	0.02
7	0.00	0.00
8	3.01	0.14
10	0.84	0.04
11	4.19	0.20
	2,088.05	100.00

TERTIARY ANTHROPOGENIC DISTURBANCE 1972

HD3-72	MAP AREA HA.	P T MAP AREA
0	2,083.43	99.78
1	0.15	0.01
6	0.74	0.04
10	0.62	0.03
11	3.10	0.14
	2,088.04	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1973

HD1-73	MAP AREA HA.	P T MAP AREA
0	1,827.86	87.54
1	41.78	2.00
2	0.00	0.00
3	36.56	1.75
4	23.23	1.11
5	110.78	5.31
6	5.75	0.28
7	0.00	0.00
8	14.73	0.71
9	0.00	0.00
10	11.73	0.56
11	15.63	0.75
13	0.00	0.00
	2,088.05	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1973

HD2-73	MAP AREA HA.	P T MAP AREA
0	2,059.18	98.62
4	0.00	0.00
5	15.08	0.72
6	4.06	0.19
7	0.00	0.00
8	3.35	0.16
10	3.07	0.15
11	3.31	0.16
	2,088.05	100.00

TERTIARY ANTHROPOGENIC DISTURBANCE 1973

HD3-73	MAP AREA HA.	P T MAP AREA
0	2,079.71	99.60
5	0.59	0.03
6	1.47	0.07
10	0.68	0.03
11	5.59	0.27
	2,088.04	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1977

HD1-77	MAP AREA HA.	P T MAP AREA
0	1,704.65	81.64
1	47.04	2.25
2	0.00	0.00
3	98.41	4.71
4	46.09	2.21
5	118.44	5.67
6	8.55	0.41
7	1.25	0.06
8	7.74	0.37
9	0.00	0.00
10	13.65	0.65
11	39.51	1.89
12	2.71	0.13
13	0.00	0.00
15	0.00	0.00
16	0.00	0.00
	2,088.05	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1977

HD2-77	MAP AREA HA.	P T MAP AREA
0	2,032.77	97.35
4	0.00	0.00
5	23.01	1.10
6	14.44	0.69
7	0.00	0.00
8	4.26	0.20
10	1.73	0.08
11	11.84	0.57
12	0.00	0.00
	2,088.05	100.00

TERTIARY ANTHROPOGENIC DISTURBANCE 1977

HD3-77	MAP AREA HA.	P T MAP AREA
0	2,067.06	98.99
5	11.64	0.57
6	3.06	0.14
10	0.16	0.01
11	6.12	0.29
	2,088.04	100.00

Table C2. (Continued).

PRIMARY ANTHROPOGENIC DISTURBANCE 1979

HD1-79	MAP AREA HA.	P T MAP AREA
0	1,694.29	81.14
1	45.39	2.17
2	0.00	0.00
3	117.91	5.65
4	39.30	1.88
5	110.44	5.29
6	18.48	0.88
7	1.25	0.06
8	6.81	0.33
9	0.00	0.00
10	14.55	0.70
11	33.47	1.60
12	6.17	0.30
13	0.00	0.00
15	0.00	0.00
16	0.00	0.00
	2,088.05	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1979

HD2-79	MAP AREA HA.	P T MAP AREA
0	2,033.24	97.38
4	0.00	0.00
5	18.79	0.90
6	17.40	0.83
7	0.00	0.00
8	4.34	0.21
10	2.77	0.13
11	10.63	0.51
12	0.87	0.04
	2,088.05	100.00

TERTIARY ANTHROPOGENIC DISTURBANCE 1979

HD3-79	MAP AREA HA.	P T MAP AREA
0	2,061.50	98.73
5	12.12	0.58
6	2.18	0.10
8	0.29	0.01
10	1.86	0.09
11	10.09	0.49
	2,088.04	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1983

HD1-83	MAP AREA HA.	P T MAP AREA
0	1,342.68	64.30
1	53.50	2.56
2	0.00	0.00
3	169.52	8.12
4	288.65	13.82
5	121.18	5.80
6	59.29	2.84
7	2.67	0.13
8	3.58	0.17
9	0.00	0.00
10	17.19	0.82
11	21.04	1.01
12	4.32	0.21
13	0.00	0.00
15	4.44	0.21
16	0.00	0.00
	2,088.05	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1983

HD2-83	MAP AREA HA.	P T MAP AREA
0	1,992.95	95.45
4	0.00	0.00
5	50.40	2.41
6	19.32	0.93
7	0.00	0.00
8	0.00	0.00
10	6.77	0.32
11	17.90	0.86
12	0.00	0.00
15	0.71	0.03
	2,088.05	100.00

TERTIARY ANTHROPOGENIC DISTURBANCE 1983

HD3-83	MAP AREA HA.	P T MAP AREA
0	2,033.64	97.39
5	29.51	1.41
6	1.68	0.08
10	0.17	0.01
11	23.04	0.11
	2,088.04	100.00

NATURAL DISTURBANCE 1968

ND-68	MAP AREA HA.	P T MAP AREA
0	2,083.61	99.79
28	0.00	0.00
51	4.43	0.21
52	0.00	0.00
64	0.00	0.00
99	0.00	0.00
	2,088.05	100.00

NATURAL DISTURBANCE 1977

ND-77	MAP AREA HA.	P T MAP AREA
0	2,081.45	99.68
28	0.13	0.01
51	6.47	0.31
52	0.00	0.00
64	0.00	0.00
99	0.00	0.00
	2,088.05	100.00

NATURAL DISTURBANCE 1983

ND-83	MAP AREA HA.	P T MAP AREA
0	2,080.01	99.62
28	0.13	0.01
51	7.91	0.38
52	0.00	0.00
64	0.00	0.00
99	0.00	0.00
	2,088.05	100.00

Table C3. Area summaries for breakdowns of primary anthropogenic disturbance by primary vegetation type and primary surface form on Map 22.

HD1-83	VEG1-49	AREA HECTARES	P T AREA
0	1	770.73	36.91
0	2	34.64	1.66
0	3	178.99	8.57
0	21	212.45	10.17
0	41	133.89	6.41
0	42	4.35	0.21
0	61	0.34	0.02
0	62	6.53	0.31
0	99	0.78	0.04
1	1	3.77	0.18
1	2	0.16	0.01
1	3	15.14	0.73
1	21	19.54	0.94
1	41	14.15	0.68
1	62	0.73	0.03
3	1	16.16	0.77
3	2	0.62	0.03
3	3	23.06	1.10
3	21	67.42	3.23
3	41	57.19	2.74
3	42	0.03	0.00
3	62	5.04	0.24
4	3	163.87	7.85
4	21	104.89	5.02
4	41	18.50	0.89
4	42	0.18	0.01
4	62	1.21	0.06
5	2	0.08	0.00
5	3	67.08	3.21
5	21	43.69	2.09
5	41	10.36	0.50
6	1	0.14	0.01
6	3	3.26	0.16
6	21	29.77	1.43
6	41	24.02	1.15
6	62	2.10	0.10
7	3	0.25	0.01
7	21	1.42	0.07
7	41	1.00	0.05
8	3	2.12	0.10
8	21	0.25	0.01
8	41	1.21	0.06
10	1	0.23	0.01
10	3	2.66	0.13
10	21	7.29	0.35
10	41	6.52	0.31
10	42	0.50	0.02
11	3	5.23	0.25
11	21	6.73	0.32
11	41	9.08	0.43
12	3	1.82	0.09
12	21	1.32	0.06
12	41	1.13	0.06
15	3	2.91	0.14
15	21	1.53	0.07
		=============	==========
		2,088.05	100.00

HD1-83	SF1-49	AREA HECTARES	P T AREA
0	1	13.65	0.65
0	2	56.56	2.71
0	3	5.90	0.28
0	4	79.08	3.79
0	5	10.44	0.50
0	6	34.78	1.67
0	7	271.71	13.01
0	8	0.34	0.02
0	9	2.34	0.11
0	10	66.89	3.20
0	21	801.02	38.36
1	1	0.86	0.04
1	2	6.60	0.32
1	4	6.43	0.31
1	5	1.17	0.06
1	6	3.38	0.16
1	7	23.83	1.14
1	10	7.23	0.35
1	21	4.00	0.19
3	1	5.45	0.26
3	2	26.83	1.28
3	4	19.88	0.95
3	5	6.47	0.31
3	6	13.70	0.66
3	7	63.28	3.03
3	10	16.94	0.81
3	21	16.98	0.81
4	1	1.68	0.08
4	2	8.80	0.42
4	4	3.64	0.17
4	5	0.33	0.02
4	6	11.67	0.56
4	7	160.23	7.67
4	10	102.30	4.90
5	2	2.82	0.13
5	4	1.37	0.07
5	5	2.89	0.14
5	6	1.89	0.09
5	7	93.85	4.49
5	10	18.37	0.88
6	1	2.17	0.10
6	2	7.84	0.38
6	4	14.26	0.68
6	5	4.71	0.23
6	6	5.76	0.28
6	7	20.93	1.00
6	10	3.48	0.17
6	21	0.14	0.01
7	2	0.27	0.01
7	4	0.69	0.03
7	5	0.27	0.01
7	7	1.27	0.06
7	10	0.17	0.01
8	2	0.94	0.05
8	6	0.27	0.01
8	7	2.37	0.11
10	1	0.27	0.01
10	2	2.74	0.13
10	4	0.72	0.03
10	5	0.71	0.03
10	6	2.16	0.10
10	7	7.94	0.38
10	10	2.45	0.12
10	21	0.23	0.01
11	1	0.48	0.02
11	2	6.10	0.29
11	4	2.32	0.11
11	5	0.37	0.02
11	6	2.24	0.11
11	7	7.24	0.35
11	10	2.30	0.11
12	6	0.72	0.03
12	7	3.50	0.17
12	10	0.11	0.01
15	7	4.06	0.19
15	10	0.37	0.02
		=============	==========
		2,088.05	100.00

Table C4. Area summaries for geobotanical data on Map 32.

PRIMARY VEGETATION 1949

V1	MAP AREA HA.	P T MAP AREA
1	287.90	13.77
2	30.50	1.46
3	128.84	6.16
5	0.29	0.01
21	1,123.66	53.75
41	468.90	22.43
42	0.00	0.00
48	1.24	0.06
61	0.00	0.00
62	19.54	0.93
63	5.65	0.27
64	0.56	0.03
81	0.44	0.02
99	22.98	1.10
	2,090.49	100.00

SECONDARY VEGETATION 1949

V2	MAP AREA HA.	P T MAP AREA
0	922.24	44.12
1	0.00	0.00
2	5.02	0.24
3	145.38	6.95
5	0.00	0.00
21	289.84	13.86
41	658.56	31.50
48	0.68	0.03
62	10.42	0.50
63	3.23	0.15
99	55.12	2.64
	2,090.49	100.00

TERTIARY VEGETATION 1949

V3	MAP AREA HA.	P T MAP AREA
0	1,981.52	94.79
2	0.00	0.00
3	0.00	0.00
5	0.00	0.00
21	2.30	0.11
41	1.55	0.07
48	4.53	0.22
62	1.97	0.09
63	1.24	0.06
99	97.38	4.66
	2,090.49	100.00

PERCENT WATER COVER 1949

W	MAP AREA HA.	P T MAP AREA
1	1,240.85	59.36
2	354.52	16.96
3	154.39	7.39
4	16.55	0.79
5	324.18	15.51
	2,090.49	100.00

LANDFORM 1949

LF	MAP AREA HA.	P T MAP AREA
1	347.70	16.63
4	782.81	37.45
11	1.43	0.07
12	85.05	4.07
13	548.05	26.22
15	0.46	0.02
16	0.55	0.03
20	0.26	0.01
25	0.00	0.00
51	306.27	14.65
52	17.92	0.86
	2,090.49	100.00

LANDSCAPE UNIT 1949

LSU	MAP AREA HA.	P T MAP AREA
1	1,386.67	66.33
2	703.83	33.67
	2,090.50	100.00

PRIMARY SURFACE FORM 1949

S1	MAP AREA HA.	P T MAP AREA
1	0.68	0.03
2	103.32	4.94
3	0.06	0.00
4	398.90	19.08
5	49.90	2.39
6	200.32	9.61
7	564.66	27.01
8	1.82	0.09
9	1.43	0.07
10	399.77	19.12
11	18.37	0.88
12	0.00	0.00
13	24.62	1.18
14	1.82	0.09
16	0.14	0.01
21	324.18	15.51
	2,090.49	100.00

SECONDARY SURFACE FORM 1949

S2	MAP AREA HA.	P T MAP AREA
0	1,903.82	91.07
3	0.00	0.00
6	3.24	0.16
11	1.04	0.05
14	182.40	8.72
	2,090.50	100.00

PRIMARY SOIL 1949

SL1	MAP AREA HA.	P T MAP AREA
1	16.72	0.80
2	163.84	7.84
3	945.10	45.21
4	398.69	19.07
5	202.75	9.70
6	3.05	0.15
7	0.46	0.02
8	11.93	0.57
9	0.00	0.00
10	23.76	1.14
21	324.18	15.51
	2,090.49	100.00

SECONDARY SOIL 1949

SL2	MAP AREA HA.	P T MAP AREA
0	2,038.67	97.52
2	34.00	1.63
3	16.51	0.79
5	1.32	0.06
	2,090.50	100.00

Table C5. Area summaries for disturbance data on Map 32.

PRIMARY ANTHROPOGENIC DISTURBANCE 1968

HD1-68	MAP AREA HA.	P T MAP AREA
0	2,090.50	100.00
2	0.00	0.00
3	0.00	0.00
7	0.00	0.00
8	0.00	0.00
10	0.00	0.00
11	0.00	0.00
13	0.00	0.00
	2,090.50	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1970

HD1-70	MAP AREA HA.	P T MAP AREA
0	1,910.81	91.40
1	18.76	0.90
2	1.88	0.09
3	4.66	0.22
4	25.50	1.22
5	1.24	0.06
6	0.00	0.00
7	2.97	0.14
8	7.81	0.37
9	4.74	0.23
10	8.56	0.41
11	31.92	1.53
13	71.65	3.43
	2,090.49	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1972

HD1-72	MAP AREA HA.	P T MAP AREA
0	1,897.75	90.78
1	22.27	1.07
2	1.88	0.09
3	4.86	0.23
4	1.64	0.08
5	25.50	1.22
6	0.00	0.00
7	3.14	0.15
8	8.59	0.41
9	7.17	0.34
10	10.28	0.49
11	30.67	1.47
13	76.76	3.67
	2,090.49	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1973

HD1-73	MAP AREA HA.	P T MAP AREA
0	1,878.08	89.84
1	29.59	1.42
2	1.88	0.09
3	9.83	0.47
4	5.33	0.26
5	28.14	1.35
6	0.00	0.00
7	3.10	0.15
8	9.27	0.44
9	7.00	0.33
10	10.42	0.50
11	29.90	1.43
13	77.95	3.73
	2,090.49	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1968

HD2-68	MAP AREA HA.	P T MAP AREA
0	2,090.50	100.00
6	0.00	0.00
7	0.00	0.00
11	0.00	0.00
	2,090.50	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1970

HD2-70	MAP AREA HA.	P T MAP AREA
0	2,063.12	98.69
4	11.11	0.53
5	0.00	0.00
6	2.55	0.12
7	1.25	0.06
8	12.47	0.60
10	0.00	0.00
11	0.00	0.00
	2,090.49	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1972

HD2-72	MAP AREA HA.	P T MAP AREA
0	2,069.93	99.02
4	3.19	0.15
5	0.25	0.01
6	2.90	0.14
7	1.25	0.06
8	12.98	0.62
10	0.00	0.00
11	0.00	0.00
	2,090.50	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1973

HD2-73	MAP AREA HA.	P T MAP AREA
0	2,054.56	98.28
4	13.32	0.64
5	0.89	0.04
6	4.12	0.20
7	4.99	0.24
8	12.21	0.58
10	0.42	0.02
11	0.00	0.00
	2,090.49	100.00

Table C5. (Continued).

PRIMARY ANTHROPOGENIC DISTURBANCE 1977

HD1-77	MAP AREA HA.	P T MAP AREA
0	1,781.98	85.24
1	37.30	1.78
2	1.88	0.09
3	34.43	1.65
4	3.76	0.18
5	10.61	0.51
6	2.47	0.12
7	3.06	0.15
8	25.28	1.21
9	4.51	0.22
10	8.01	0.38
11	45.87	2.19
12	0.00	0.00
13	96.88	4.63
15	33.95	1.62
16	0.49	0.02
	2,090.49	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1977

HD2-77	MAP AREA HA.	P T MAP AREA
0	2,046.49	97.90
4	11.49	0.55
5	3.43	0.16
6	11.15	0.53
7	1.99	0.10
8	10.93	0.52
10	0.00	0.00
11	2.26	0.11
12	2.76	0.13
	2,090.49	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1979

HD1-79	MAP AREA HA.	P T MAP AREA
0	1,699.85	81.31
1	45.75	2.19
2	1.88	0.09
3	48.67	2.33
4	44.99	2.15
5	24.19	1.16
6	0.65	0.03
7	3.21	0.15
8	25.32	1.21
9	4.49	0.21
10	6.54	0.31
11	53.45	2.56
12	0.00	0.00
13	99.56	4.76
15	31.46	1.50
16	0.49	0.02
	2,090.49	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1979

HD2-79	MAP AREA HA.	P T MAP AREA
0	2,048.93	98.01
4	15.00	0.72
5	1.13	0.05
6	12.93	0.62
7	0.87	0.04
8	8.91	0.43
10	0.00	0.00
11	0.16	0.01
12	2.57	0.12
	2,090.49	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1983

HD1-83	MAP AREA HA.	P T MAP AREA
0	1,660.94	79.45
1	50.31	2.41
2	1.81	0.09
3	73.88	3.53
4	55.02	2.63
5	28.36	1.36
6	0.65	0.03
7	3.14	0.15
8	22.22	1.06
9	4.08	0.20
10	7.52	0.36
11	52.27	2.50
12	0.00	0.00
13	101.21	4.84
15	28.60	1.37
16	0.49	0.02
	2,090.49	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1983

HD2-83	MAP AREA HA.	P T MAP AREA
0	2,034.58	97.33
4	13.35	0.64
5	9.91	0.47
6	23.40	1.12
7	0.87	0.04
8	6.12	0.29
10	0.00	0.00
11	0.16	0.01
12	2.10	0.10
15	0.00	0.00
	2,090.49	100.00

NATURAL DISTURBANCE 1968

ND-68	MAP AREA HA.	P T MAP AREA
0	2,089.56	99.96
28	0.28	0.01
51	0.57	0.03
52	0.08	0.00
64	0.00	0.00
99	0.00	0.00
	2,090.50	100.00

NATURAL DISTURBANCE 1977

ND-77	MAP AREA HA.	P T MAP AREA
0	2,089.68	99.96
28	0.18	0.01
51	0.62	0.03
52	0.02	0.00
64	0.00	0.00
99	0.00	0.00
	2,090.49	100.00

NATURAL DISTURBANCE 1983

ND-83	MAP AREA HA.	P T MAP AREA
0	2,089.44	99.95
28	0.16	0.01
51	0.86	0.04
52	0.04	0.00
64	0.00	0.00
99	0.00	0.00
	2,090.50	100.00

Table C6. Area summaries for breakdowns of primary anthropogenic disturbance by primary vegetation type and primary surface form on Map 32.

HD1-83	VEG1-49	AREA HECTARES	P T AREA
0	1	212.00	10.14
0	2	29.12	1.39
0	3	84.12	4.02
0	5	0.29	0.01
0	21	946.98	45.30
0	41	372.48	17.82
0	48	1.07	0.05
0	62	12.57	0.60
0	63	1.28	0.06
0	99	1.03	0.05
1	1	3.09	0.15
1	2	0.15	0.01
1	3	3.38	0.16
1	21	26.13	1.25
1	41	16.66	0.80
1	62	0.64	0.03
1	63	0.02	0.00
1	99	0.24	0.01
2	3	0.05	0.00
2	21	1.48	0.07
2	41	0.28	0.01
3	1	16.95	0.81
3	2	0.40	0.02
3	3	14.26	0.68
3	21	36.46	1.74
3	41	5.36	0.26
3	62	0.43	0.02
4	1	2.10	0.10
4	2	0.43	0.02
4	3	19.70	0.94
4	21	27.89	1.33
4	41	4.82	0.23
4	62	0.08	0.00
5	1	3.49	0.17
5	2	0.00	0.00
5	3	2.98	0.14
5	21	16.77	0.80
5	41	5.12	0.24
6	21	0.65	0.03
7	2	0.02	0.00
7	21	2.66	0.13
7	41	0.45	0.02
7	99	0.02	0.00
8	1	0.07	0.00
8	2	0.05	0.00
8	3	1.31	0.06
8	21	11.94	0.57
8	41	8.74	0.42
8	62	0.11	0.01
9	21	0.03	0.00
9	41	4.05	0.19
10	1	0.68	0.03
10	2	0.05	0.00
10	3	0.53	0.03
10	21	2.40	0.11
10	41	3.61	0.17
10	62	0.25	0.01
11	1	0.31	0.02
11	3	0.54	0.03
11	21	31.11	1.49
11	41	20.24	0.97
11	62	0.04	0.00
11	99	0.03	0.00
13	1	20.84	1.00
13	2	0.28	0.01
13	3	1.98	0.09
13	21	18.67	0.89
13	41	26.83	1.28
13	48	0.17	0.01
13	62	5.43	0.26
13	63	4.34	0.21
13	64	0.56	0.03
13	81	0.44	0.02
13	99	21.66	1.04
15	1	28.34	1.36
15	21	0.14	0.01
15	41	0.11	0.01
16	21	0.35	0.02
16	41	0.14	0.01
		=============	==========
		2,090.49	100.00

HD1-83	SF1-49	AREA HECTARES	P T AREA
0	1	0.52	0.02
0	2	81.81	3.91
0	3	0.06	0.00
0	4	349.14	16.70
0	5	41.15	1.97
0	6	164.91	7.89
0	7	445.26	21.30
0	8	1.07	0.05
0	9	1.43	0.07
0	10	317.47	15.19
0	11	10.24	0.49
0	13	0.82	0.04
0	14	1.60	0.08
0	16	0.14	0.01
0	21	245.32	11.74
1	2	6.99	0.33
1	4	8.85	0.42
1	5	1.20	0.06
1	6	5.74	0.27
1	7	16.27	0.78
1	8	0.02	0.00
1	10	7.25	0.35
1	11	0.12	0.01
1	13	0.28	0.01
1	14	0.22	0.01
1	21	3.31	0.16
2	2	0.28	0.01
2	4	0.39	0.02
2	10	1.09	0.05
2	11	0.05	0.00
3	2	1.02	0.05
3	4	12.81	0.61
3	5	1.17	0.06
3	6	1.08	0.05
3	7	27.71	1.33
3	10	12.65	0.61
3	21	17.42	0.83
4	2	1.17	0.06
4	4	5.29	0.25
4	5	0.19	0.01
4	6	2.95	0.14
4	7	30.19	1.44
4	10	12.62	0.60
4	11	0.05	0.00
4	21	2.54	0.12
5	2	0.85	0.04
5	4	3.61	0.17
5	5	1.13	0.05
5	6	3.28	0.16
5	7	10.55	0.50
5	10	5.42	0.26
5	21	3.49	0.17
6	4	0.35	0.02
6	5	0.13	0.01
6	7	0.15	0.01
7	2	0.12	0.01
7	4	0.45	0.02
7	5	0.19	0.01
7	6	0.05	0.00
7	7	1.22	0.06
7	10	1.06	0.05
7	11	0.03	0.00
7	13	0.02	0.00
8	2	1.10	0.05
8	4	4.92	0.24
8	5	1.90	0.09
8	6	3.29	0.16
8	7	4.95	0.24
8	10	5.86	0.28
8	11	0.04	0.00
8	21	0.12	0.01
9	2	1.08	0.05
9	4	0.70	0.03
9	6	2.27	0.11
9	7	0.03	0.00
10	2	0.34	0.02
10	4	0.36	0.02
10	5	0.32	0.02
10	6	2.56	0.12
10	7	0.80	0.04
10	10	2.21	0.11
10	11	0.10	0.00
10	21	0.83	0.04
11	2	6.43	0.31
11	4	11.50	0.55
11	5	2.31	0.11
11	6	11.71	0.56
11	7	15.56	0.74
11	10	4.43	0.21
11	13	0.03	0.00
11	21	0.31	0.02
13	1	0.16	0.01
13	2	1.93	0.09
13	4	0.38	0.02
13	5	0.10	0.00
13	6	2.98	0.14
13	7	11.60	0.56
13	8	0.73	0.03
13	10	29.66	1.42
13	11	7.71	0.37
13	13	23.47	1.12
13	21	22.50	1.08
15	2	0.03	0.00
15	4	0.09	0.00
15	5	0.12	0.01
15	7	0.01	0.00
15	21	28.34	1.36
16	5	0.14	0.01
16	7	0.35	0.02
		=============	==========
		2,090.49	100.00

Table C7. Area summaries for geobotanical data on Map 34.

PRIMARY VEGETATION 1949

V1	MAP AREA HA.	P T MAP AREA
1	502.75	24.06
2	80.56	3.85
3	42.00	2.01
5	119.16	5.70
21	968.32	46.34
41	289.71	13.86
42	0.00	0.00
48	0.00	0.00
61	0.00	0.00
62	24.79	1.19
63	0.00	0.00
64	2.91	0.14
81	0.00	0.00
99	59.53	2.85
	2,089.72	100.00

SECONDARY VEGETATION 1949

V2	MAP AREA HA.	P T MAP AREA
0	944.20	45.18
1	8.04	0.38
2	3.92	0.19
3	121.42	5.81
5	6.14	0.29
21	208.74	9.99
41	737.12	35.27
48	0.00	0.00
62	24.68	1.18
63	0.00	0.00
99	35.46	1.70
	2,089.72	100.00

TERTIARY VEGETATION 1949

V3	MAP AREA HA.	P T MAP AREA
0	1,918.40	91.80
2	1.04	0.05
3	24.59	1.18
5	0.87	0.04
21	10.72	0.51
41	124.16	5.94
48	0.00	0.00
62	7.15	0.34
63	0.00	0.00
99	2.80	0.13
	2,089.72	100.00

PERCENT WATER COVER 1949

W	MAP AREA HA.	P T MAP AREA
1	548.56	26.25
2	780.98	37.37
3	150.09	7.18
4	15.73	0.75
5	594.36	28.44
	2,089.72	100.00

LANDFORM 1949

LF	MAP AREA HA.	P T MAP AREA
1	728.92	34.88
4	701.24	33.56
11	1.93	0.09
12	55.28	2.65
13	0.00	0.00
15	3.56	0.17
16	0.00	0.00
20	0.00	0.00
25	5.16	0.25
51	448.71	21.47
52	144.92	6.93
	2,089.72	100.00

LANDSCAPE UNIT 1949

LSU	MAP AREA HA.	P T MAP AREA
1	1889.43	90.42
2	200.29	9.58
	2,089.72	100.00

PRIMARY SURFACE FORM 1949

S1	MAP AREA HA.	P T MAP AREA
1	30.26	1.45
2	174.42	8.35
3	252.04	12.06
4	342.69	16.40
5	68.77	3.29
6	38.22	1.83
7	283.15	13.55
8	0.00	0.00
9	1.93	0.09
10	245.07	11.73
11	0.00	0.00
12	7.16	0.34
13	52.37	2.51
14	0.00	0.00
16	0.00	0.00
21	593.63	28.41
	2,089.72	100.00

SECONDARY SURFACE FORM 1949

S2	MAP AREA HA.	P T MAP AREA
0	1,719.91	82.30
3	0.21	0.01
6	20.06	0.96
11	1.29	0.06
14	348.25	16.66
	2,089.72	100.00

PRIMARY SOIL 1949

SL1	MAP AREA HA.	P T MAP AREA
1	11.43	0.55
2	223.92	10.72
3	521.32	24.95
4	618.95	29.62
5	58.02	2.78
6	2.91	0.14
7	0.00	0.00
8	0.00	0.00
9	7.16	0.34
10	52.37	2.51
21	593.63	28.41
	2,089.72	100.00

SECONDARY SOIL 1949

SL2	MAP AREA HA.	P T MAP AREA
0	2,049.83	98.09
2	10.34	0.49
3	29.56	1.41
5	0.00	0.00
	2,089.72	100.00

Table C8. Area summaries for disturbance data on Map 34.

PRIMARY ANTHROPOGENIC DISTURBANCE 1968

HD1-68	MAP AREA HA.	P T MAP AREA
0	2,046.83	97.95
2	4.10	0.20
3	6.65	0.32
7	12.86	0.62
8	8.01	0.38
10	1.40	0.07
11	0.72	0.03
13	9.16	0.44
	2,089.72	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1968

HD2-68	MAP AREA HA.	P T MAP AREA
0	2,084.49	99.75
6	0.68	0.03
7	0.62	0.03
11	3.93	0.19
	2,089.72	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1970

HD1-70	MAP AREA HA.	P T MAP AREA
0	1,909.27	91.36
1	17.83	0.85
2	14.27	0.68
3	41.10	1.97
4	12.24	0.59
5	32.93	1.58
6	0.00	0.00
7	21.76	1.04
8	15.35	0.73
9	0.00	0.00
10	2.49	0.12
11	13.70	0.66
13	8.78	0.42
	2,089.72	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1970

HD2-70	MAP AREA HA.	P T MAP AREA
0	2,057.12	98.44
4	0.13	0.01
5	4.87	0.23
6	14.27	0.68
7	2.94	0.14
8	3.02	0.14
10	0.60	0.03
11	6.77	0.32
	2,089.72	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1972

HD1-72	MAP AREA HA.	P T MAP AREA
0	1,724.85	82.54
1	25.78	1.23
2	15.06	0.72
3	51.91	2.48
4	15.16	0.73
5	40.37	1.93
6	0.00	0.00
7	15.32	0.73
8	24.45	1.17
9	0.00	0.00
10	5.22	0.25
11	14.35	0.69
13	157.36	7.53
	2,089.72	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1972

HD2-72	MAP AREA HA.	P T MAP AREA
0	2,058.88	98.52
4	0.23	0.01
5	0.00	0.00
6	15.06	0.72
7	5.57	0.27
8	3.46	0.17
10	1.02	0.05
11	5.50	0.26
	2,089.72	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1973

HD1-73	MAP AREA HA.	P T MAP AREA
0	1,726.75	82.63
1	29.80	1.43
2	15.12	0.72
3	52.37	2.51
4	7.84	0.37
5	28.39	1.36
6	0.00	0.00
7	18.41	0.88
8	24.49	1.17
9	0.00	0.00
10	5.49	0.26
11	18.60	0.89
13	162.45	7.77
	2,089.72	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1973

HD2-73	MAP AREA HA.	P T MAP AREA
0	2,059.25	98.54
4	0.23	0.01
5	0.34	0.02
6	15.16	0.73
7	4.40	0.21
8	5.53	0.26
10	1.33	0.06
11	3.49	0.17
	2,089.72	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1977

HD1-77	MAP AREA HA.	P T MAP AREA
0	1,571.13	75.18
1	38.15	1.83
2	13.44	0.64
3	134.12	6.42
4	15.78	0.75
5	70.48	3.37
6	1.17	0.06
7	13.40	0.64
8	30.87	1.48
9	0.00	0.00
10	7.87	0.38
11	34.35	1.64
12	0.00	0.00
13	158.98	7.61
15	0.00	0.00
16	0.00	0.00
	2,089.72	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1977

HD2-77	MAP AREA HA.	P T MAP AREA
0	2,043.03	98.00
4	0.09	0.00
5	0.00	0.00
6	24.53	1.17
7	5.56	0.27
8	7.41	0.35
10	0.17	0.01
11	3.93	0.19
12	0.00	0.00
	2,089.72	100.00

Table C8. (Continued).

PRIMARY ANTHROPOGENIC DISTURBANCE 1979

HD1-79	MAP AREA HA.	P T MAP AREA
0	1,561.38	74.72
1	39.49	1.89
2	13.44	0.64
3	136.52	6.53
4	23.53	1.13
5	48.76	2.33
6	20.64	0.99
7	12.91	0.62
8	32.09	1.54
9	0.00	0.00
10	6.39	0.31
11	35.04	1.68
12	0.00	0.00
13	159.52	7.63
15	0.00	0.00
16	0.00	0.00
	2,089.72	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1979

HD2-79	MAP AREA HA.	P T MAP AREA
0	2,053.48	98.26
4	0.09	0.00
5	1.19	0.06
6	23.18	1.11
7	5.60	0.27
8	4.25	0.20
10	0.17	0.01
11	1.76	0.08
12	0.00	0.00
	2,089.72	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1983

HD1-83	MAP AREA HA.	P T MAP AREA
0	1,534.82	73.44
1	44.63	2.14
2	13.37	0.64
3	172.28	8.24
4	26.83	1.28
5	39.90	1.91
6	21.62	1.03
7	12.53	0.60
8	26.74	1.28
9	0.00	0.00
10	5.71	0.27
11	35.68	1.71
12	0.00	0.00
13	155.61	7.45
15	0.00	0.00
16	0.00	0.00
	2,089.72	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1983

HD2-83	MAP AREA HA.	P T MAP AREA
0	2,050.21	98.11
4	0.09	0.00
5	1.82	0.09
6	24.83	1.19
7	5.51	0.26
8	3.71	0.18
10	0.35	0.02
11	3.21	0.15
12	0.00	0.00
15	0.00	0.00
	2,089.72	100.00

NATURAL DISTURBANCE 1968

ND-68	MAP AREA HA.	P T MAP AREA
0	1,889.39	90.41
28	0.00	0.00
51	0.19	0.01
52	42.87	2.05
64	12.49	0.60
99	144.78	6.93
	2,089.72	100.00

NATURAL DISTURBANCE 1977

ND-77	MAP AREA HA.	P T MAP AREA
0	1,889.47	90.42
28	0.00	0.00
51	0.14	0.01
52	60.58	2.90
64	12.49	0.60
99	127.05	6.08
	2,089.72	100.00

NATURAL DISTURBANCE 1983

ND-83	MAP AREA HA.	P T MAP AREA
0	1,889.47	90.42
28	0.00	0.00
51	0.14	0.01
52	125.34	6.00
64	12.31	0.59
99	62.46	2.99
	2,089.72	100.00

Table C9. Area summaries for breakdowns of primary anthropogenic disturbance by primary vegetation type and primary surface form on Map 34.

HD1-83	VEG1-49	AREA HECTARES	P T AREA
0	1	372.38	17.82
0	2	76.78	3.67
0	3	37.25	1.78
0	5	88.86	4.25
0	21	716.32	34.28
0	41	209.64	10.03
0	62	24.25	1.16
0	64	2.48	0.12
0	99	6.88	0.33
1	1	5.03	0.24
1	2	0.29	0.01
1	3	0.43	0.02
1	5	6.68	0.32
1	21	23.51	1.13
1	41	7.42	0.36
1	62	0.24	0.01
1	99	1.03	0.05
2	21	9.80	0.47
2	41	3.38	0.16
2	99	0.19	0.01
3	1	13.49	0.65
3	2	2.19	0.10
3	3	3.14	0.15
3	5	9.15	0.44
3	21	102.97	4.93
3	41	39.05	1.87
3	62	0.14	0.01
3	99	2.14	0.10
4	1	0.03	0.00
4	3	0.04	0.00
4	5	0.28	0.01
4	21	24.35	1.17
4	41	2.13	0.10
5	2	0.27	0.01
5	3	0.95	0.05
5	5	13.80	0.66
5	21	19.70	0.94
5	41	5.14	0.25
5	62	0.05	0.00
6	21	20.25	0.97
6	41	1.38	0.07
7	21	10.92	0.52
7	41	1.61	0.08
8	1	0.97	0.05
8	2	0.87	0.04
8	3	0.01	0.00
8	5	0.14	0.01
8	21	12.92	0.62
8	41	10.01	0.48
8	99	1.81	0.09
10	1	0.61	0.03
10	2	0.02	0.00
10	5	0.04	0.00
10	21	2.17	0.10
10	41	0.26	0.01
10	62	0.01	0.00
10	99	2.59	0.12
11	1	0.17	0.01
11	2	0.13	0.01
11	3	0.18	0.01
11	5	0.20	0.01
11	21	25.32	1.21
11	41	9.67	0.46
11	99	0.02	0.00
13	1	110.07	5.27
13	21	0.09	0.00
13	41	0.03	0.00
13	62	0.11	0.01
13	64	0.42	0.02
13	99	44.92	2.15
		=============	==========
		2,089.76	100.00

HD1-83	SF1-49	AREA HECTARES	P T AREA
0	1	30.00	1.44
0	2	123.37	5.90
0	3	204.27	9.77
0	4	200.81	9.61
0	5	58.02	2.78
0	6	34.52	1.65
0	7	209.93	10.05
0	9	0.41	0.02
0	10	207.32	9.92
0	12	0.85	0.04
0	13	6.03	0.29
0	21	459.30	21.98
1	1	0.09	0.00
1	2	5.01	0.24
1	3	10.21	0.49
1	4	12.05	0.58
1	5	0.93	0.04
1	6	0.56	0.03
1	7	5.79	0.28
1	9	0.15	0.01
1	10	3.36	0.16
1	12	0.41	0.02
1	13	0.62	0.03
1	21	5.46	0.26
2	2	2.46	0.12
2	4	3.64	0.17
2	6	0.88	0.04
2	7	3.65	0.17
2	10	2.54	0.12
2	12	0.19	0.01
3	1	0.02	0.00
3	2	23.26	1.11
3	3	17.06	0.82
3	4	61.96	2.96
3	5	6.27	0.30
3	6	0.13	0.01
3	7	31.40	1.50
3	9	1.22	0.06
3	10	12.77	0.61
3	12	1.43	0.07
3	13	0.71	0.03
3	21	16.07	0.77
4	1	0.04	0.00
4	2	0.35	0.02
4	3	0.19	0.01
4	4	7.75	0.37
4	5	0.65	0.03
4	7	10.42	0.50
4	10	7.31	0.35
4	21	0.13	0.01
5	2	3.84	0.18
5	3	17.33	0.83
5	4	8.92	0.43
5	5	0.45	0.02
5	7	4.48	0.21
5	10	4.60	0.22
5	21	0.29	0.01
6	2	0.77	0.04
6	4	20.85	1.00
7	2	1.54	0.07
7	3	0.23	0.01
7	4	0.47	0.02
7	7	8.00	0.38
7	10	2.28	0.11
8	2	8.16	0.39
8	3	0.46	0.02
8	4	7.27	0.35
8	5	1.04	0.05
8	6	1.07	0.05
8	7	4.21	0.20
8	10	1.34	0.06
8	12	1.75	0.08
8	13	0.06	0.00
8	21	1.39	0.07
10	2	0.17	0.01
10	3	0.24	0.01
10	4	1.90	0.09
10	7	0.06	0.00
10	10	0.11	0.01
10	12	2.35	0.11
10	13	0.24	0.01
10	21	0.63	0.03
11	2	5.43	0.26
11	3	2.07	0.10
11	4	16.99	0.81
11	5	1.42	0.07
11	6	1.07	0.05
11	7	5.21	0.25
11	9	0.16	0.01
11	10	3.02	0.14
11	12	0.02	0.00
11	21	0.30	0.01
13	1	0.11	0.01
13	2	0.03	0.00
13	4	0.09	0.00
13	10	0.42	0.02
13	12	0.16	0.01
13	13	44.76	2.14
13	21	110.07	5.27
		=============	==========
		2,089.76	100.00

Table C10. Area summaries for geobotanical data on all maps combined.

PRIMARY VEGETATION 1949

V1	TOTAL STUDY HA.	P T STUDY AREA
1	1581.68	25.23
2	146.55	2.34
3	637.24	10.17
5	119.45	1.91
21	2588.26	41.29
41	1035.67	16.52
42	5.06	0.08
48	1.24	0.02
61	0.34	0.01
62	59.94	0.96
63	5.65	0.09
64	3.47	0.06
81	0.44	0.01
99	83.29	1.33
	===============	===============
	6,268.26	100.00

SECONDARY VEGETATION 1949

V2	TOTAL STUDY HA.	P T STUDY AREA
0	2959.75	47.22
1	14.84	0.24
2	32.34	0.52
3	504.58	8.05
5	6.14	0.10
21	1027.11	16.39
41	1579.95	25.21
48	0.68	0.01
62	49.06	0.78
63	3.23	0.05
99	90.59	1.45
	===============	===============
	6,268.26	100.00

TERTIARY VEGETATION 1949

V3	TOTAL STUDY HA.	P T STUDY AREA
0	5914.56	94.36
2	2.10	0.03
3	57.11	0.91
5	0.87	0.01
21	25.11	0.40
41	153.44	2.45
48	4.53	0.07
62	9.11	0.15
63	1.24	0.02
99	100.17	1.60
	===============	===============
	6,268.25	100.00

PERCENT WATER COVER 1949

W	TOTAL STUDY HA.	P T STUDY AREA
1	2285.75	36.47
2	1508.90	24.07
3	689.68	11.00
4	74.31	1.19
5	1709.63	27.27
	===============	===============
	6,268.26	100.00

LANDFORM 1949

LF	TOTAL STUDY HA.	P T STUDY AREA
1	1868.96	29.82
4	1939.54	30.94
11	14.35	0.23
12	140.33	2.24
13	554.66	8.85
15	4.59	0.07
16	0.55	0.01
20	0.26	0.00
25	5.19	0.08
51	1576.80	25.16
52	163.04	2.60
	===============	===============
	6,268.26	100.00

LANDSCAPE UNIT 1949

LSU	MAP AREA HA.	P T MAP AREA
1	5,364.15	85.58
2	904.12	14.42
	===========	===========
	6,268.27	100.00

PRIMARY SURFACE FORM 1949

S1	TOTAL STUDY HA.	P T STUDY AREA
1	55.48	0.89
2	397.24	6.34
3	258.00	4.12
4	869.98	13.88
5	146.02	2.33
6	315.59	5.03
7	1508.01	24.06
8	2.16	0.03
9	5.70	0.09
10	865.44	13.81
11	18.37	0.29
12	7.16	0.11
13	76.99	1.23
14	1.82	0.03
16	0.14	0.00
21	1740.18	27.76
	===============	===============
	6,268.26	100.00

SECONDARY SURFACE FORM 1949

S2	TOTAL STUDY HA.	P T STUDY AREA
0	5537.36	88.34
3	0.21	0.00
6	63.58	1.01
11	2.33	0.04
14	664.78	10.61
	===============	===============
	6,268.26	100.00

PRIMARY SOIL 1949

SL1	TOTAL STUDY HA.	P T STUDY AREA
1	30.60	0.49
2	563.88	9.00
3	2338.95	37.31
4	1154.67	18.42
5	337.93	5.39
6	5.96	0.10
7	0.46	0.01
8	11.93	0.19
9	7.16	0.11
10	76.14	1.21
21	1740.59	27.77
	===============	===============
	6,268.26	100.00

SECONDARY SOIL 1949

SL2	TOTAL STUDY HA.	P T STUDY AREA
0	6149.83	98.11
2	45.25	0.72
3	71.87	1.15
5	1.32	0.02
	===============	===============
	6,268.26	100.00

Table C11. Area summaries for disturbance data on all maps combined.

PRIMARY ANTHROPOGENIC DISTURBANCE 1968

HD1-68	TOTAL STUDY HA.	P T STUDY AREA
0	6225.37	99.32
2	4.10	0.07
3	6.65	0.11
7	12.86	0.21
8	8.01	0.13
10	1.40	0.02
11	0.72	0.01
13	9.16	0.15
	6,268.26	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1968

HD2-68	TOTAL STUDY HA.	P T STUDY AREA
0	6263.03	99.92
6	0.68	0.01
7	0.62	0.01
11	3.93	0.06
	6,268.26	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1970

HD1-70	TOTAL STUDY HA.	P T STUDY AREA
0	5707.37	91.05
1	65.31	1.04
2	16.15	0.26
3	64.29	1.03
4	134.59	2.15
5	52.55	0.84
6	6.49	0.10
7	24.73	0.39
8	33.11	0.53
9	4.74	0.08
10	20.49	0.33
11	58.01	0.93
13	80.42	1.28
	6,268.26	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1970

HD2-70	TOTAL STUDY HA.	P T STUDY AREA
0	6185.08	98.67
4	12.04	0.19
5	17.31	0.28
6	17.14	0.27
7	4.19	0.07
8	18.50	0.30
10	3.34	0.05
11	10.66	0.17
	6,268.26	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1972

HD1-72	TOTAL STUDY HA.	P T STUDY AREA
0	5496.89	87.69
1	87.89	1.40
2	16.95	0.27
3	89.30	1.42
4	103.45	1.65
5	82.74	1.32
6	4.05	0.06
7	18.46	0.29
8	42.99	0.69
9	7.17	0.11
10	26.33	0.42
11	57.93	0.92
13	234.12	3.73
	6,268.26	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1972

HD2-72	TOTAL STUDY HA.	P T STUDY AREA
0	6197.48	98.87
4	3.41	0.05
5	11.28	0.18
6	18.28	0.29
7	6.82	0.11
8	19.45	0.31
10	1.86	0.03
11	9.69	0.15
	6,268.26	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1973

HD1-73	TOTAL STUDY HA.	P T STUDY AREA
0	5432.69	86.67
1	101.16	1.61
2	17.01	0.27
3	98.76	1.58
4	36.40	0.58
5	167.31	2.67
6	5.75	0.09
7	21.51	0.34
8	48.50	0.77
9	7.00	0.11
10	27.64	0.44
11	64.13	1.02
13	240.40	3.84
	6,268.26	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1973

HD2-73	TOTAL STUDY HA.	P T STUDY AREA
0	6172.98	98.48
4	13.54	0.22
5	16.31	0.26
6	23.35	0.37
7	9.38	0.15
8	21.09	0.34
10	4.82	0.08
11	6.80	0.11
	6,268.26	100.00

Table C11. (Continued).

PRIMARY ANTHROPOGENIC DISTURBANCE 1977

HD1-77	TOTAL STUDY HA.	P T STUDY AREA
0	5057.76	80.69
1	122.48	1.95
2	15.32	0.24
3	266.96	4.26
4	65.62	1.05
5	199.53	3.18
6	12.19	0.19
7	17.71	0.28
8	63.89	1.02
9	4.51	0.07
10	29.53	0.47
11	119.74	1.91
12	2.71	0.04
13	255.87	4.08
15	33.95	0.54
16	0.49	0.01
	6,268.26	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1977

HD2-77	TOTAL STUDY HA.	P T STUDY AREA
0	6127.28	97.75
4	11.59	0.18
5	26.43	0.42
6	50.13	0.80
7	7.55	0.12
8	22.60	0.36
10	1.90	0.03
11	18.02	0.29
12	2.76	0.04
	6,268.26	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1979

HD1-79	TOTAL STUDY HA.	P T STUDY AREA
0	4955.52	79.06
1	130.62	2.08
2	15.32	0.24
3	303.09	4.84
4	107.83	1.72
5	183.40	2.93
6	39.77	0.63
7	17.37	0.28
8	64.22	1.02
9	4.49	0.07
10	27.48	0.44
11	121.96	1.95
12	6.17	0.10
13	259.08	4.13
15	31.46	0.50
16	0.49	0.01
	6,268.26	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1979

HD2-79	TOTAL STUDY HA.	P T STUDY AREA
0	6135.65	97.88
4	15.09	0.24
5	21.11	0.34
6	53.51	0.85
7	6.47	0.10
8	17.49	0.28
10	2.94	0.05
11	12.56	0.20
12	3.44	0.05
	6,268.26	100.00

PRIMARY ANTHROPOGENIC DISTURBANCE 1983

HD1-83	TOTAL STUDY HA.	P T STUDY AREA
0	4538.44	72.40
1	148.43	2.37
2	15.18	0.24
3	415.68	6.63
4	370.49	5.91
5	189.45	3.02
6	81.57	1.30
7	18.34	0.29
8	52.54	0.84
9	4.08	0.07
10	30.42	0.49
11	108.99	1.74
12	4.32	0.07
13	256.82	4.10
15	33.03	0.53
16	0.49	0.01
	6,268.26	100.00

SECONDARY ANTHROPOGENIC DISTURBANCE 1983

HD2-83	TOTAL STUDY HA.	P T STUDY AREA
0	6077.74	96.96
4	13.45	0.21
5	62.13	0.99
6	67.55	1.08
7	6.38	0.10
8	9.83	0.16
10	7.12	0.11
11	21.27	0.34
12	2.10	0.03
15	0.71	0.01
	6,268.26	100.00

NATURAL DISTURBANCE 1968

ND-68	STUDY HA.	P T STUDY AREA
0	6062.56	96.72
28	0.28	0.00
51	5.20	0.08
52	42.95	0.69
64	12.49	0.20
99	144.78	2.31
	6,268.26	100.00

NATURAL DISTURBANCE 1977

ND-77	STUDY HA.	P T STUDY AREA
0	6060.59	96.69
28	0.31	0.00
51	7.22	0.12
52	60.60	0.97
64	12.49	0.20
99	127.05	2.03
	6,268.26	100.00

NATURAL DISTURBANCE 1983

ND-83	STUDY HA.	P T STUDY AREA
0	6058.92	96.66
28	0.29	0.00
51	8.90	0.14
52	125.38	2.00
64	12.31	0.20
99	62.46	1.00
	6,268.26	100.00

Table C12. Area summaries for breakdowns of primary anthropogenic disturbance by primary vegetation type on all maps combined.

HD1-83	VG1-49	AREA HA.	P T AREA
0	1	1355.11	21.62
0	2	140.54	2.24
0	3	300.36	4.79
0	5	89.15	1.42
0	21	1875.75	29.92
0	41	716.01	11.42
0	42	4.35	0.07
0	48	1.07	0.02
0	61	0.34	0.01
0	62	43.35	0.69
0	63	1.28	0.02
0	64	2.48	0.04
0	99	8.64	0.14
1	1	11.89	0.19
1	2	0.60	0.01
1	3	18.95	0.30
1	5	6.68	0.11
1	21	69.18	1.10
1	41	38.23	0.61
1	62	1.61	0.30
1	63	0.02	0.00
1	99	1.27	0.02
2	3	0.05	0.00
2	21	11.28	0.18
2	41	3.66	0.60
2	99	0.19	0.00
3	1	46.63	0.74
3	2	3.21	0.05
3	3	40.46	0.65
3	5	9.15	0.15
3	21	206.85	3.30
3	41	101.60	1.62
3	42	0.03	0.00
3	62	5.61	0.09
3	99	2.14	0.03
4	1	2.13	0.03
4	2	0.43	0.01
4	3	183.61	2.93
4	5	0.28	0.00
4	21	157.13	2.51
4	41	25.45	0.41
4	42	0.18	0.00
4	62	1.29	0.02
5	1	3.49	0.06
5	2	0.35	0.01
5	3	71.01	1.13
5	5	13.80	0.22
5	21	80.16	1.28
5	41	20.60	0.33
5	62	0.05	0.00
6	1	0.14	0.00
6	3	3.26	0.05
6	21	50.67	0.81
6	41	25.40	0.41
6	62	2.10	0.03
7	2	0.02	0.00
7	3	0.25	0.00
7	21	15.00	0.24
7	41	3.06	0.05
7	99	0.02	0.00
8	1	1.04	0.02
8	2	0.92	0.01
8	3	3.44	0.05
8	5	0.14	0.00
8	21	25.11	0.40
8	41	19.96	0.32
8	62	0.11	0.00
8	99	1.81	0.03
9	21	0.03	0.00
9	41	4.05	0.06
10	1	1.47	0.02
10	2	0.07	0.00
10	3	3.19	0.05
10	5	0.04	0.00
10	21	11.80	0.19
10	41	10.39	0.17
10	42	0.50	0.01
10	62	0.26	0.00
10	99	2.59	0.04
11	1	0.48	0.01
11	2	0.13	0.00
11	3	5.95	0.09
11	5	0.20	0.00
11	21	63.16	1.01
11	41	38.99	0.62
11	62	0.04	0.00
11	99	0.05	0.00
12	3	1.82	0.03
12	21	1.32	0.02
12	41	1.13	0.02
13	1	130.91	2.09
13	2	0.28	0.00
13	3	1.98	0.03
13	21	18.76	0.30
13	41	26.86	0.43
13	48	0.17	0.00
13	62	5.54	0.09
13	63	4.34	0.07
13	64	0.98	0.02
13	81	0.44	0.01
13	99	66.58	1.06
15	1	28.34	0.45
15	3	2.91	0.05
15	21	1.67	0.03
15	41	0.11	0.00
16	21	0.35	0.01
16	41	0.14	0.00
		=======	======
		6268.30	100.00