APPENDIX D:

History of the Alaska Department of Natural Resources, Tundra Travel Management 1969 -2003

Alaska Department of Natural Resources,
Division of Mining Land & Water *
Northern Regional Office

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(It is acknowledged that the Division has undergone several name changes over the years and is referred to generically throughout this report as DMLW)

About the Authors

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Executive Summary

Since the late 1960's, the Alaska Department of Natural Resources – Division of Mining, Land and Water (DMLW), Northern Region Office has managed off-road travel related to oil and gas development on the state lands of the arctic North Slope. Since this time, off-road travel has been limited largely to winter, with decisions made yearly by DMLW staff as to when conditions warrant a general work-season opening. Opening decisions have been based on determinations about the presence of adequate ground frost/hardness and snow cover to limit disturbance to the tundra.

Under DMLW's management, the length of the winter season has declined from an average of 200 days in the 1970s to less than 120 days over the past five years. This shortening work window has become the center of a debate about management protocols at the DMLW, access to the tundra for oil and gas development, and the effects of climate change on the arctic environment. To provide a background for future DNR decisions about managing access to the tundra, this report documents the history of DMLW oversight of off-road tundra travel and analyzes the evolution of DMLW management decisions. The main findings of this report are outlined below:

- The methods employed by DMLW in making the decision to open and close the tundra have evolved substantially between the 1970s and 2004. While variants of a "12-and-6" standard (12 inches of hard ground/frost and 6 inches of snow) for determining when to open the tundra to off-road travel have influenced DMLW tundra management since the early 1970's, the methods used to measure ground frost/hardness and snow depth have changed. Specifically, DMLW has changed the tools, locations, and protocols for determining the 12-and-6 standard.

- Although many have cited the shrinking tundra work season as evidence of climate change, it's important to recognize that the collapse of the tundra travel season is likely a result of a number of factors, including both climate change and management change. While both the shortening winter work season and climate and tundra active layer data collected by researchers in the Alaskan arctic exhibit a downward trend, the variety of methods used over the years by DMLW to measure the hardness of the tundra makes it difficult to conclude exactly what portion of the shrinking season is due to climate change, and what portion is due to changes in DMLW measuring techniques.

- The evolution of DMLW decision-making is not well documented, and appears largely directed by professional judgment. The application of repeatable experiments and systematic observation of results has been weak. However, documentation, systematic protocols for data collection, scientifically driven monitoring approaches, and the utilization of outside scientific expertise have improved considerably in recent years.

- The protection-level provided to tundra vegetation by the DMLW is thought to be conservative, but evidence is largely anecdotal. There is little baseline information and spotty monitoring data on state lands to verify this conclusion. The most comprehensive studies to evaluate the impacts of oil and gas related travel across the tundra were done on federal lands in the 1980's, and indicate significant impacts to vegetation but generally high rates of recovery and resiliency. Spatial and ecological variability substantially influence the degree of initial impact and recovery, with tussock and shrub-dominated vegetation more prone to significant disturbance.

Introduction

For nearly 35 years, seismic exploration and the drilling of test wells on the tundra has been largely limited to winter, when the tundra's surface is deemed sufficiently hard and snow cover adequate to provide a level of protection to tundra vegetation and the thermal stability of the underlying permafrost. But during the last three decades, the length of this season has dwindled from an average of about 200 days in the 1970s to about 120 days over the last 5 years (see Figure 1). While it is unclear how much of this dramatic trend is attributable to climate change and how much to changes in management protocols over the timeframe, the shrinking season highlights future challenges of managing oil and gas development in a warming arctic environment.

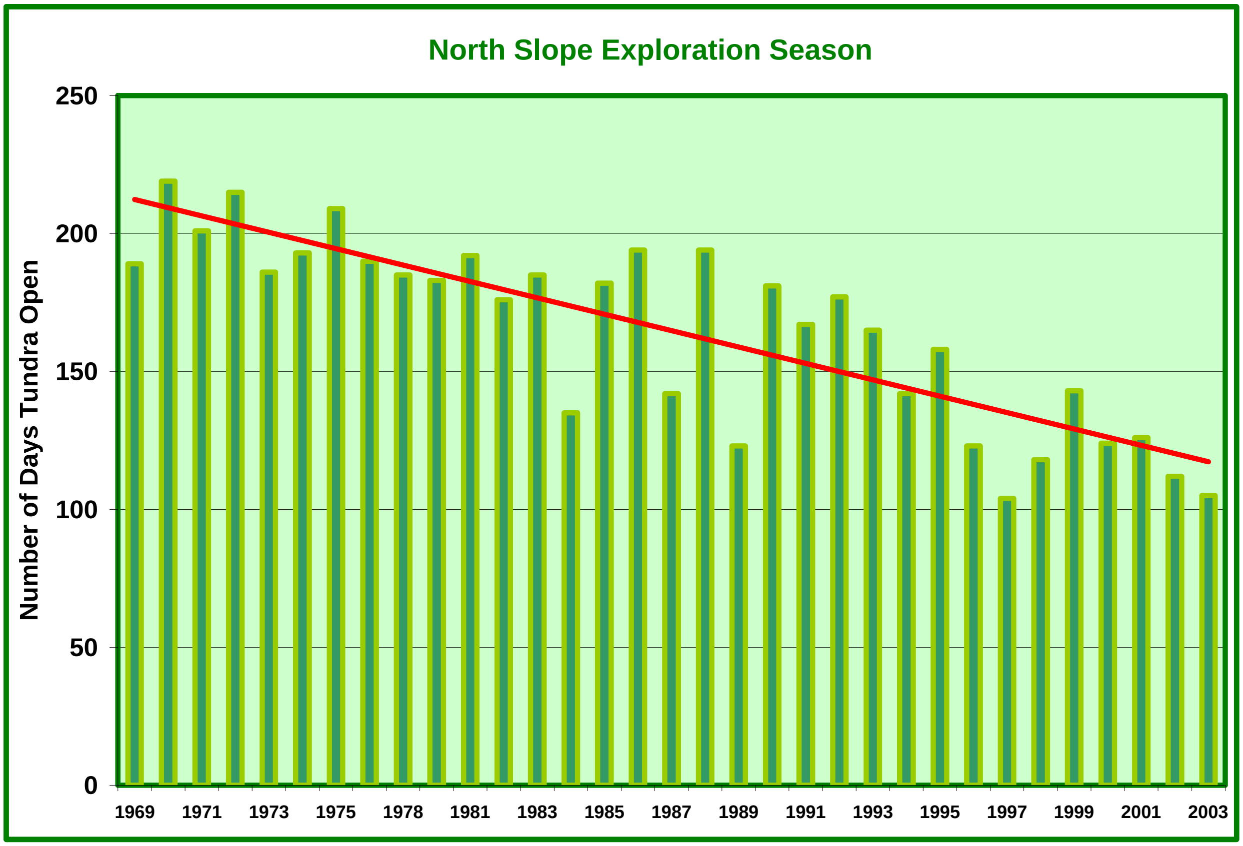

Figure 1- Length of the winter tundra travel season, as determined by the DNR-Division of Lands, Northern Regional Office

As the primary agency that manages the surface estate of Alaska's public lands, the Alaska Department of Natural Resources - Division Mining, Land and Water, Northern Region Office (DMLW) is responsible for managing many of the impacts associated with oil and gas exploration outside lease tracts on the North Slope. One part of this management is deciding when to open the tundra to off-road travel.[1]

[1] DNR Commissioner to DNR Division Directors, memorandum, 27 November 2000, *Department Order North Slope Management*, (Anchorage, 2000).

In an effort to improve future management of the tundra, this report aims to document the history of the Department of Natural Resources' management of off-road tundra travel since the late 1960s, and to discuss some of the related scientific, economic, land management and institutional issues the recent trends have brought into focus.

This report is divided into two broad sections:

1) History of tundra travel management.

2) An analysis of tundra travel policy.

Research Objectives and Methods

One of primary challenges in compiling a history of DMLW's management of the tundra is the lack of a written record of the agency's decision-making process. While DMLW has been grappling with environmental issues related to oil exploration and development since its formation in DNR, the high degree of attention given to the impact of off-road tundra travel and the length of the oil exploration season is a relatively recent phenomenon.[2] For much of the agency's history, decisions regarding when to open the tundra to off-road travel have been left to the discretion of DMLW land managers who often left little record of the rationale behind their decisions. Another potential reason for the lack of documentation of the methods used to determine the opening of tundra travel season has to do with changing perceptions of the tundra itself. Over the years, perception of the tundra within the Department of Natural Resources has changed from that of a vast, barren wasteland to that of a complex, and potentially fragile ecosystem.

Perhaps the best explanation for the lack of documentation, however, is that prior to the 1990's, the length of the tundra travel season on the North Slope was simply not a matter of controversy. There are two likely reasons for this. 1) The season was sufficiently long to allow oil companies to implement their exploration and development programs, many of which were proximal to permanent infrastructure.[3] In recent years, in contrast, exploration activities have extended farther east, away from the early development near Prudhoe Bay, giving oil companies less time to cover greater distances;[4] 2) Climate change and variability has become an issue of great concern in Alaska and across the country. These two factors have increased pressure from the oil industry to extend the oil exploration season and increased public concern over the environmental impact of tundra travel.

To address the challenge of documenting the largely anecdotal history of DMLW's tundra management, we have conducted a series of interviews with past DMLW land managers, members of DMLW's North Slope operations team, oil industry engineers, and decision-makers from a variety of state and federal agencies who have been involved with issues surrounding transportation on the tundra. When available, internal memos, formal and informal study

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[2] Id.
[3] Northern Regional Land Manager to DNR Deputy Director, memorandum, 7 April 2003, *Winter off-road travel season and other factors that affect oil exploration*, (Fairbanks, 2000).
[4] Id.

reports, field notes, policy papers and letters provide the written documentation for the history and the analysis of past DMLW decision-making. Sources are cited as internal footnotes, and in the case of material from the scientific literature, footnotes refer to references in the *Sources and References* section at the end of the report.

The evolution of DMLW's management of off-road tundra travel

Summary

The "12-and-6" standard – 12 inches of hard ground or ground frost and 6 inches of snow – currently employed in making the decision to open the tundra is a source of controversy on the North Slope. Variants of the 12-and-6 standard have influenced DNR tundra management in some form or another since the early 1970's. However, the methods used to measure the 12-and-6 standard have varied considerably over the decades, and contrary to popular conception, ground frost/hardness was not directly measured by the DMLW until 1985. Until this point, air temperature on the Coastal Plain and snow depths were the main determinant for opening the tundra. Prior to the mid-1990's, ground frost was measured as a threshold depth at which a steel rod broke through frozen soil and into melted permafrost.

Since at least 1991, DMLW has interpreted the phrase "adequate ground frost and snow cover" - the language contained in the Alaska Coastal Management Program's General Concurrence-19, internal DMLW guidelines and land use permits - to mean more strictly an average of 12 inches of hard ground or frost (depending on the time-period) and about 6 inches of snow at testing sites (today, this means 30 sampling sites along a geographically diverse transect). Starting in 1993, field measurements of ground frost and ground hardness were made on an inch-by-inch basis, although they were not recorded consistently until 1998. In 1995, a new testing rod – a slide hammer penetrometer, was created and began to be employed by field staff to measure both frost depth and ground hardness over a 12 inch profile (hardness in the units of "hits per inch"). Since 1998, methods of using the slide hammer penetrometer have become more standardized, data recording more systematic, and rationale behind decision-making more transparent.

Today, DMLW announces separate tundra openings in 4 different management units, based on an assessment of the hardness of the ground to 12 inches (in "drops per inch" of a standard weight from a standard height), snow cover, and snow type. DMLW has exercised the right to open certain areas early (such as road corridors in which the snow has been "pre-packed" by industry to quicken freeze-up of the tundra below), to allow certain light-weight vehicles early access to the tundra, and to close other areas of the tundra as needed to protect tundra vegetation. DMLW staff also monitors the impacts of the season's work through field checks in the winter and spring, and requires rehabilitation of areas where damage was not prevented.

Introduction

The DMLW is today responsible for issuing land use permits, which are required for most off-road travel on the North Slope. For all oil and gas-related work (with the exception of work with light-weight, DMLW-approved vehicles), off-road travel is limited to the winter, and in each land use permit, the DMLW exercises the right to determine the opening and closing of this winter work season in order to limit damage to the tundra surface.

Figure 3 - Right, 1959 D-8 Caterpillar; left, tracks left by a summer cat-train near Prudhoe Bay.

The following sections document the evolution of DNR and DMLW oversight and decision-making regarding off-road tundra travel and the length of the travel season. Because the season has shortened asymmetrically, with more days lost on the front end of the season than in spring (an average of 85 days later in winter and 15 days earlier in spring since the 1970's), this document is slanted somewhat toward the history of DMLW tundra opening protocols.

As will become clear in the sections that follow, the methodology used to open and close the tundra to winter travel has evolved considerably since the 1970s. Because it is the source of some of the controversy regarding tundra-opening decisions, the history section begins with a description of the origin of the 12-and-6 standard.

Origin of the 12-and-6 standard

The 12-6 standard was first developed by Dr. Max Brewer, an arctic geologist, engineer and permafrost expert, who was a leading scientific figure in Alaska throughout the l960s and 1970s.[5] Brewer is probably best known for his work with the Naval Arctic Research Laboratory (NARL) in Barrow, where he served as director from 1956 to 1971. During the two decades that Brewer served as director, the agency's focus expanded from mostly biological studies to include the physical sciences, oceanography, atmospheric studies and social sciences.[6]

In addition to his contributions to arctic ecology, Brewer was instrumental in developing engineering techniques used in the Navy's early oil exploration on the North Slope, and later in the construction of the trans-Alaska Pipeline. Brewer developed a standard of "12 inches of frozen ground and 6 inches of snow" while advising the U.S. Geological Survey (USGS) on the construction of roads, airstrips, and drilling pads on permafrost. The guidelines were based upon his professional judgment about the amount of solid ground and snow cover necessary to support the weight of moving vehicles on the tundra and to protect the surface vegetation from damage. During Brewer's work for USGS and NARL, he observed that 12 inches of frozen ground was sufficient to provide a "cement-like" surface, capable of supporting the weight of winter

[5] Kenai Peninsula Online, *The Voice of the Times supports research on global warming*, April 29, 2002, http://peninsulaclarion.com/stories/050602.shtml
[6] Karen Brewster's interview with Max Brewer, Byrd Polar Research Center Archival Program (2001).

exploration vehicles in the meadows of the Coastal Plain. He also determined, through professional experience, that 6 inches of snow provided adequate protection for tussocks on drier ridges above the Plain, where early snowfall is often blown away by the wind. Brewer explained that, "as an engineer, you always want to design for the worst-case scenario. That's what I did, and it has worked for nearly forty years."[7]

In 1975, Brewer incorporated the 12 inches of frozen ground and 6 inches of snow standard into the environmental impact statement ("EIS") he wrote for the Navy's exploration of Naval Petroleum Reserve No. 4 (now NPRA).[8] Like the guidelines that DMLW uses today, the report does not specify a preferred method for measuring the depth of frozen ground.[9] When asked about how to verify when the standard is met, Brewer stated that he envisioned a variety of possible techniques. "You could dig a hole in the ground and take a temperature reading. You could also measure the ice layer on nearby lakes and streams."[10] However, Brewer suggested that in his opinion, the method of measurement was irrelevant because, "you could almost always hang your hat on November 1st."[11]

These comments are consistent with the language of Brewer's 1975 EIS. Unlike the current DMLW policy requiring 12 inches of hard ground and 6 inches of snow, Brewer's original EIS stipulations provided an explicit estimate of when the off-road travel season was likely to begin.[12] This suggests that Brewer's 12-6 standard was less of a scientific standard as it was a precautionary measure intended to prevent vehicle access to the tundra before mid-October.

It is interesting to note that while Brewer's 1975 EIS estimates that the conditions necessary for off-road tundra travel should be present sometime between October 15 and November 1, there have only been three years since 1969 in which DNR has opened the tundra to off-road travel before November 1.[13] Although the variety of techniques DMLW has used to measure tundra frost and hardness since 1985 makes the correlation between hardness and opening date difficult to unravel, these direct measurements of the tundra illustrate the difficulty in pinpointing a specific date after which the ground conditions will always be adequate to prevent tundra damage.

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[7] Max Brewer, personal communication.
[8] *Stipulations Concerning Winter Seismic and Related Geophysical Operations Within Naval Petroleum Reserve No. 4*, 5 September 1975 (Anchorage, 1975).
[9] DMLW's guidelines for winter cross-country travel state that all vehicle travel is allowed when there is 12 inches of hard ground. The distinction between "frozen" and "hard" ground has become important in recent years. In many instances, DMLW has found that while the ground temperature at 12 inches may be at or below zero, the tundra is still not hard enough to open to prevent damage.
[10] See Supra, note 34
[11] Id.
[12] In the section of the 1975 EIS entitled, Stipulations Concerning Winter Seismic and Related Geophysical Operations within Naval Petroleum Reserve No. 4 states "Seismic survey operations are to begin after the seasonal frost in the tundra and underlying mineral soils has reached a depth of 12 inches; the average snow cover a depth of 6 inches. Normally these conditions will not prevail until about 15 October, occasionally not until 1 November."
[13] DMLW records, North Slope Opening and Closing Dates For Tundra Travel

DMLW tundra management, 1963-1980

While the DNR has been responsible for managing tundra travel since 1963, DMLW oversight evolved gradually between 1963 and 1980. This transition is not neatly documented, and was pieced together to the greatest extent possible through interviews, internal memos and letters, and some field notes.

Impacts of early off-road travel increases general State oversight

Although the problems associated with off-road travel in Alaska did not receive extensive media attention during the late '60s, the impact of vehicles on environmentally sensitive tundra was well documented.[14] During the mid-'40s and '50s, large bulldozers provided much of the horsepower necessary to haul equipment used in the Navy's exploration of the North Slope.[15] Bulldozer-pulled sleds known as "cat-trains" were used during the summer months to carve away the surface vegetation, allowing the sled loaded with equipment to slide directly on top of a slick layer of mud.[16] The impact of this type of vehicle activity was dramatic and many of these bulldozed trails are still visible today.[17] They often appear as linear paths of shallow ponds, or as Dr. Brewer put it, "a trail of swamp that will last as long as Hadrians' Wall."[18] Cat-trains continued to be employed during the '60s and '70s - before the completion of the Dalton Highway that now connects Fairbanks with Prudhoe Bay. A 1969 report published by the BLM presents a photographic tour of the early impacts of oil exploration vehicles on the tundra and describes these disturbances in relation to the vegetation and topography of the region.[19]

Despite the evidence of harm to the tundra which was available at the time, interviews with former DMLW employees and DNR records indicate that during the '60s and early '70s, the DMLW did not play an active role in preventing environmental damage to the tundra. Throughout the period of construction for the Trans-Alaska Pipeline and the development of the Prudhoe Bay oil field, DNR's Division of Minerals and Energy Management (DMEM became the Division of Oil and Gas in 1984) had oversight authority over all activities related to oil and gas leases, including the transportation of equipment to and from oil and gas lease tracts.[20]

In contrast to the current management scheme, the Division of Forests, Land, and Water Management (DFLWM, now the Division of Mining, Land, and Water) advised DMEM regarding surface land uses related to oil and gas development, but did not issue off-road travel permits for vehicle access.[21] Throughout the 1970s, DMEM managed vehicle access to the tundra through the stipulations it included on oil and gas leases, but had no direct mechanism for ensuring that these stipulations were met.

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14 Reed, J.C., 1958
15 Fredrick, C., 1991.
16 Max Brewer, personal communication.
17 McKendrick, J. D. et. al., 2000.
18 See Supra, note 43.
19 Hok, J., 1969.
20 DNR Leasing Manager to DNR Leasee, letter, 17 October, 1979, (Anchorage 1979)
21 Former DMEM Director, Pedro Denton, personal communication.

In the early 70s, when DMEM issued a lease for the construction of a drilling pad, it would include a stipulation that prohibited "blading" (traveling across the tundra in a bulldozer with the blade down to scrape off uneven surfaces), or disturbance of the tundra vegetative cover. However, DNR never established a policy to explain this language – for example, did it also prohibit damage to the tundra that occurred while hauling equipment to and from the drilling pad tract?[22] Confusion over this policy is illustrated in a letter written by an Alaska Department of Fish &Game (ADF&G) employee to DMLW. It states, "On a recent trip to the Slope, I noticed that X is doing a considerable amount of travel on thawed tundra with a bulldozer. . . I don't know if this falls within his lease stipulations or not but thought you should know."[23]

In addition to confusion regarding the precise area covered by lease stipulations, DNR's policy regarding the length of the off-road travel season was open to broad interpretation. Until 1969, there is no written documentation about the start of the tundra travel season, and interviews with DMLW employees and oil industry engineers indicate that during the 60s and early 70s, DNR generally allowed all off-road travel as soon as the tundra was hard enough for vehicles to drive on it without getting stuck.

DMLW's increasing role in travel management

According to George Hollett, who served as Director of North Slope operations from 1963 to 1973, the DMLW management of the tundra increased during the early 1970s, after the impact of off-road vehicles began to generate criticism from both ADF&G and the media. Mr. Hollett recalled one incident in which an off-duty employee working for an oil development project used a bulldozer to carve the company's initials into a 360 square foot stretch of tundra.[24] The incident generated a great deal of negative publicity and helped to convince the DNR commissioner that the agency needed to be more involved in managing tundra travel from an ecological standpoint.

In 1970, DMEM Chief Pedro Denton asked DMLW staff and members of ADF&G to begin monitoring snow and weather conditions for the purpose of determining the opening and closing dates of the tundra travel season.[25] Although DMEM continued to issue miscellaneous land use permits for off-road tundra travel directly from the DNR office in Anchorage, decisions regarding opening and closing of the off-road travel season were now based on observations and recommendations of DMLW and ADF&G staff working on the North Slope.[26]

DMLW resources for fieldwork were severely limited during this period.[27] For half of the period between 1963 and 1989, DMLW had only one staff member responsible for permitting and field operations for 12 million acres of state land, land that contained hundreds of oil wells, pads and pipelines. Under these circumstances, DMLW land managers also relied heavily upon

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[22] Id.
[23] Letter from Bob Wienhold of ADF&G to George Hollett of the Alaska Division of lands dated September 10, 1971.
[24] *A Handbook for Management of Oil and Gas Activities on Lands in Alaska*, U.S. Fish and Wildlife Service, August 1983, FWS/OBS-80/23.
[25] DMEM Director Pedro Denton to DMLW employee George Hollett, letter, 20 April 1970, (Anchorage, 1970).
[26] There are no records that clearly indicate when DMLW began to issue miscellaneous land use permits directly from the Fairbanks office.
[27] Former DFLWM employee George Hollett personal communication.

information from oil industry engineers and Department of Environmental Conservation (DEC) agents stationed near Deadhorse to make tundra-opening decisions.[28] And while DMLW was able to conduct some summer monitoring operations by borrowing aircraft owned by BLM or the oil industry, budgetary constraints and a lack of personnel support often limited the division's ability to enforce the terms of the permits it issued until after the damage had already occurred.

Role of ADF&G in transitioning authority from DMEM to DMLW

Members of the ADF&G were instrumental in convincing DNR to base its decision of when to open the tundra on the observations and judgment of DMLW field staff.[29] In the late '60s, DMLW and ADF&G staff informally tested the protections provided by Brewer's 12-and-6 standard by observing the effects of driving vehicles over areas with different snow and "frost depth".[30] They measured the depth of compression left by the vehicle tracks and retuned to the site the following summer to see whether the places where the vehicles had driven looked different from the surrounding area.[31] The group found that 12" of frozen ground and 6" of snow resulted in "flattening" of the tundra vegetation but didn't "tear up the surface." Mr. Hollett acknowledged that methods used in these tests were not particularly scientific. The group did not attempt to make repeatable tests or to conduct a detailed survey of changes to the vegetation, nor did they conduct tests in different vegetation types. It is unclear how they measured frost depth.[32]

The effect of these trials, however, began to influence tundra opening and closing beginning in the early 1970s. DMLW staff soon began to fly to the sites where off-road travel was to occur, and make measurements to determine that there was adequate snow depth to protect the tundra.[33] However, ground frost was still not measured directly in the field.

During this time period, monitoring of off-road travel occurred in the summer following activities. Companies that conducted off-road activities would provide DMLW with a precise map of the territory where they had driven and would arrange to have a DMLW field officer fly over the route to verify that no damage had occurred. DMLW records from this period indicate that when problems were identified, companies would generally fulfill the terms of their lease agreements by paying to restore damaged areas. However, limited resources available for monitoring during this period make it difficult to assess the extent of damage to the tundra or how it was remedied.

Methods for determining tundra travel opening and closing dates, 1969-1980

Opening

DMLW records between 1969 and 1980, and interviews with former staff members responsible for field operations, indicate that the DMLW used a variety of measurement techniques to determine the opening date of the tundra travel season during its early management. While it appears that snow depth was measured ad hoc in areas where activity was planned, ground frost

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[28] Id.
[29] Former ADF&G Director Al Ott personal communication.
[30] See Supra, note 57.
[31] Id.
[32] Id.
[33] Id.

depth or ground hardness was not measured directly. In other words, while DMLW staff may have known of and even loosely followed a 6-and-12 rule of thumb during the early '70's, they did not attempt to systematically measure for ground frost and snow depth parameters. Instead they relied heavily upon weather station information regarding cumulative snowfall and air temperature to estimate when the standard was likely met. For example, when 12 inches of snow had fallen in Deadhorse, DMLW assumed that the tundra was frozen up to 12 inches.[34]

DMLW staff also sometimes attempted to approximate the depth of frost on the tundra by taking measurements of the depth of ice on the Colville River.[35] Using a sledgehammer, a DMLW staff person would pound a graduated metal rod into the ice and record the point at which it broke through into the water below. Once it had been determined that the ice layer on the river was thick enough to support the weight of vehicles loaded with equipment, DMLW assumed that the tundra was hard enough to open for off-road travel.

All of the early field reports from this period consist of tabulations of snow depth and the daily maximum and minimum air temperatures from Barrow and Barter Island. According to Bill Copeland, who worked for DNR during the mid to late '70s, this temperature data was primarily used to predict the beginning of the opening season.[36] If a company's exploration or drilling crew was particularly concerned about having enough time to complete their operations, DMLW would provide them with an estimate of when the off-road season was likely to begin. Records from this period indicate that tundra travel generally occurred when the daily high temperatures dropped below zero. However, in 1971 and 1972 opening occurred despite high temperatures of 20 and 28°F respectively.[37]

Closing

DMLW's tundra closure procedure during this period is documented in a memo by former DMEM chief Pedro Denton. The memo indicates that decisions regarding the closing date were based upon the judgment of DMLW staff.[38] Beginning in early April, a field officer would make several trips to the North Slope to monitor ice and snow break-up. When it appeared that the melting snow cover would soon be inadequate to protect surface vegetation from damage, DNR gave seismic and development crews 72 hours in which to demobilize and return to the Dalton Highway. While in recent years oil companies have instructed their crews to demobilize over a month before the official end of the tundra travel season, several memos from ADF&G during this period show seismic crews continuing to work up until the middle of May.[39]

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[34] Id.
[35] Id.
[36] Natural Resource Specialist to Northern Regional Land Manager, memorandum, *Tundra Opening History*, 10 June 2004, (Fairbanks, 2004).
[37] DMLW North Slope field records.
[38] See Supra, note 55
[39] In a letter dated May 15, 1970 from Robert Pegau of ADF&G to Bruce Hinsman of DNR, Pegau wrote, "Spring has already arrived from the Amatusuk Hills southward. . .There is so little snow in the area that the tracked vehicles, when they are on land are running on the vegetation rather than snow. I would suggest closing off the operation as soon as possible."

Year	Opening Date	Snow Depth in Inches
1969	November 13	4
1970	October 20	2
1971	November 1	4
1972	November 1	7
1973	November 15	7
1974	November 18	5
1975	November 1	5
1976	No opening date available	
1977	November 25	3
1978	November 4	3
1979	No opening date available	

Table 1 - Snow depth data from Barrow, 1969-1979, as reported by NOAA. The data indicate that DNR often opened the tundra before the snow depth reached 6 inches at Barrow.

Methods for determining tundra travel opening and closing dates, 1980 -1992

The 1980's were the most active years of seismic exploration and oil production in Alaska's history.[40] [41] At the height of oil production, resource management specialist Greg Zimmerman was DMLW's primary field presence on the North Slope.[42] In addition to making decisions regarding the opening and closing dates for the tundra travel season, Mr. Zimmerman monitored leasing operations on the North Slope and kept track of the enormous volume of paperwork associated with land use permits, lease operations, and gravel sales. Although the implementation of the Alaska Coastal Management Program on the North Slope in 1979 brought some additional funding for field operations, DMLW's budget was still limited.[43] DMLW staff provided their own protective clothing for winter fieldwork and there were no funds available for radio communication devices or other safety equipment.[44]

Both DMLW field records and interviews with former staff suggest that during the '80s, the 12 inches of frost or hard ground and 6 inches of snow standard was understood as a rule-of-thumb

[40] See Supra, note 12
[41] Figure 3 is from, Myers, Mike, *Alaska's Oil & Gas Future – New Frontiers, Expanding Opportunities*, prepared at the request of the DNR (Anchorage, 2004).
[42] Former DMLW Natural Resource Specialist, Greg Zimmerman, personal communication.
[43] Former DEC employee, Brad Fristoe personal communication.
[44] See Supra, Note 71

more than a strict guideline. As in the previous decade, there are no concise records explaining the methods DMLW used to determine the general opening date for the tundra travel season. Mr. Zimmerman recalled that he would begin calling oil companies with crews stationed on the North Slope in early October to find out how much ice had formed on the Colville River. When he received reports that the ice layer was sufficiently thick, he would drive up the Dalton Highway and "kick the snow around."

Based upon his impressions of the snow cover, temperature data from the U.S. Weather Service, and reports of the thickness of ice on the Colville River, he would use professional judgment to determine when the tundra was ready to permit off-road travel. Field records from this period are similar to those kept during the '70's. However, beginning in 1982, DMLW expanded its catalogue of air temperature data from Barter Island and Barrow to include information from Umiat and Deadhorse.[45]

In 1985, DMLW made its first attempt to directly measure the thickness of the frozen tundra layer.[46] A graduated steel spike with a steel eye welded to the top was pounded with a sledgehammer into the ground, and the point at which the spike met little resistance or "broke through" was observed but not recorded.

This practice apparently continued through 1990, and although it has been generally assumed that DMLW actually measured and waited until there were 12 inches of frozen/hard ground before opening the tundra, there is virtually no mention of this standard in documents prior to 1991.[47] Throughout the '80s, it appears that the amount of snowfall was the major limiting factor in tundra opening. Memos documenting the January openings, which occurred in 1985 and 1990 each, attribute the delay to late snowfall.[48]

DMLW tundra management, 1993 – 2003

A review of the trip files from 1993 to 2004 indicates that the decision making process for opening the tundra has evolved considerably over the past ten years. The reports from the 1993 season provide indication that Brewer's 6:12 standard, with frost depth (measured as a function of resistance felt using a sledgehammer to drive a rod into the tundra) was used in making the determination to open the tundra. Measurements were taken for a literal 12 inches of frost, without documentation of specific "hardness" determinations.

Later, in the 1990's, with the adoption of a slide hammer, DNR started recording how many "hits" and then "drops" of a slide hammer it took to penetrate an inch (HPI, DPI) of frozen tundra. Frost depth measurements were still reported; however, they were not "literal"

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[45] Beginning in 1986 files documenting the opening and closing season includes a report entitled, *Alaska Snow Survey* published by the U.S. Department of Agriculture which contains snow depth and density data from the previous year; however it's unclear how this data was incorporated into the decision-making process for tundra opening.

[46] Id.

[47] The only reference made to the standard in the '80's field reports appears in a handwritten note on a file from 1981 which states, "Needed to open: over 6 inches of snow, one week below zero, and 8 plus inches of frozen ground."

[48] See Supra, note 66

measurements of depth. Instead, they were a manager's assessment of "hard frost" which was a function of DPI and probe tip conditions.

The adoption of the slide hammer in 1995-1996, and specifically the change to measuring "ground hardness" instead of a literal "frost depth" left managers with the task of assessing how many hits or drops of the slide hammer correlated with adequate frost hardness within the soil profile to permit winter tundra travel. Between 1993 and 2003, it appears that 15-20 HPI was considered sufficiently hard. In 2003, using a new, slimmer probe, the DMLW determined that 10 DPI is sufficient for tundra opening (takes less DPI to penetrate tundra than the older probe).[49]

Beginning with the 1999 – 2000 season, tip conditions were recorded in the reports with documentation of observations of the number of inches of crystals, frost, dirt, and mud on the tip as it was removed from the tundra. This would affect the determination of calculated frost depth. For example, if 12 inches of frost were present and 3 inches of ice or mud appeared on the tip, frost depth would be recorded as 9 inches. Subsequent seasons reveal how mud/dirt/ice on the probe increasingly factored into the actual decision making process.

Frost Depth
Reported: 0 to 10" – 15 to 16 dpi 10 to 12" – 8 dpi ***Total: 12*** *Deduct for:* 2" of ice crystals on tip
Frost Depth Recorded: 10"

Finally, in 2003, the column for "frost depth" was no longer included in the reports, and only DPI down to 12 inches was recorded. However, the 2003 season covered by this report indicates that managers still factor tip conditions into their opening decision, interpreting their presence as a soft layer.

[49] Internal DMLW report, H. Bader & M. Wishnie, 2003.

Season	Date of Trip	Average HPI or DPI through Frozen Active Layer
1997 – 1998	**January 5 – 8, 1998**	21.97 HPI
1998 – 1999	**December 14 -17, 1998**	13.61 HPI
	December 28-31, 1998	17.009 HPI
	January 4-7, 1999 (opened January 14, 1999)	19.72 HPI
2000 – 2001	**December 26-29, 2000**	10.98 HPI
2001 – 2002	**January 25, 2002**	6.03 DPI
2002 – 2003	**January 27, 2003**	9.4 DPI
2003 – 2004	**December 15, 2003**	Approximately 7 DPI[50]

Table 7 – Average HPI or DPI for field reports 1997-2004.

In 2002, DNR made attempts to ascertain the impact of snow density on vehicle impacts. Accordingly, during the season information on average snow depth and the density of snow in grams per cubic inch at each test site were collected. As a result of the samples taken, snow was classified as slab, hoar frost, or surface snow. A further improvement in data collection occurred when 30 permanent sites were selected that are located along the road system for systematic sampling. Prior to this, staff sampled the same general areas, but not the same locations. By sampling at the same locations, changes in ground hardness at specific sites started to be evaluated over the course of the winter.

By the year 2003, DMLW engaged in a rapid series of attempts to further standardize their methods. The staff at DMLW and industry representative identified a problem with data collection due to operator variability in using the slide hammer. For example, a large and fit person could potentially drive the probe tip into the ground with fewer blows per inch than a smaller person. To eliminate this sampling variability, DMLW implemented the following three procedures:

1. The probes were standardized as follows so that they were all the exact same size and weight.

Total weight	20 lbs
Slide weight	15 lbs
Drop distance	24 in
Total length	45 in
Shaft diameter	9/16 in
Handle length	14 in
Tip diameter	3/8 in
Tip length	13 in

[50] Decision Spreadsheet, December 15, 2003

2. Use of the slide hammer was standardized by mandating that the weight be dropped from a known distance. Gravity is thus the force that drives the tip into the ground.

3. The tip size was reduced from 9/16 inch to 3/8 inch to facilitate penetration.

DMLW also made a decision to divide the North Slope into different management units. Until 2002, all State land on the North Slope was treated as one unit. With the recognition that coastal areas may freeze up faster than the foothills, four geographic areas were established called Tundra Opening Areas (TOA's). This decision was a consensus decision amongst industry representatives, scientists and agency representatives, and distinctions between the Eastern Coastal TOA, Western Coastal TOA, Lower Foothills TOA and Upper Foothills TOA were based on factors such as elevation and vegetation cover. The southern boundary for the two coastal areas was taken from the Alaska Coastal Management Plan.[51]

A memo dated December 19, 2003, describes the factors used by DMLW managers to "determine if conditions are adequate to open the tundra." As recorded in the memo, the following five factors are listed as weighing into the decision:

1. Is the tundra consistently hard throughout the vertical profile?

2. Is there a soft layer? If so, how soft is it?

3. Is there ice or mud on the probe tip? We have found in the past that this is a good indication of a thawed layer. We see this often in the early winter, but we never see it later when we find the ground to be hard enough to open the tundra. (Anecdotally, it seems that on the 9/16" tip it is easier to see these things, but we still do get them on the 3/8" tip.)

4. Based on the above, I estimate the depth of hard frozen ground.

5. Bader & Wishnie (2003) compared the 9/16" tip with the 3/8" tip. This document states that adequate hardness for opening is achieved with an average of 10 drops per inch. (Note that on the decision spread sheet, I estimated a rough mean DPI for each site.

[51] Leon Lynch memo June 2004.

Analysis of Tundra travel Policy

Introduction

Much of the current concern surrounding management of tundra travel by the DMLW has centered on methods for determining when the tundra can be safely opened for off-road travel by oil and gas company vehicles. It is clear from the *History* section of this report that DMLW's decision-making related to tundra travel has evolved over time. The next section of this report analyzes the reasons for past decisions.

Protocols and techniques used to determine tundra readiness

The 12-and-6 standard

Dr. Brewer's original standard for protecting the tundra from significant impacts (12 inches of frost and 6 inches of snow cover) appears to be a rule of thumb based on years of experience managing infrastructure in the arctic environment. As an engineering-based standard, it was formulated as a conservative estimation, with margins of error built in informally by Dr. Brewer. While it may make intuitive sense, the standard's scientific underpinnings are unclear, and the standard was not based on extensive or direct testing to understand the specific relationship between two environmental variables (snow and ground frost) and tundra disturbance levels from off-road travel.

Based on an interview with Dr. Brewer, however, it is clear that the standard is based on years of valuable experience gained from scientific research on permafrost dynamics, arctic engineering and tundra ecology. As such, the standard is likely reliable guideline of one threshold condition under which tundra disturbance will be low. Indeed, based on it's varied implementation over the past 30 years, this 'rule-of-thumb' has proven effective in protecting tundra from the level of impact observed in the early days of oil and gas development.[52] It has also kept impacts in more recent years to anecdotally low levels on State lands. In the Arctic Refuge, the standard as applied in the mid 1980's resulted in generally low, but sometimes-significant impacts, with greater impact observed in higher, drier sites dominated by tussock vegetation[53].

Despite it's subjective origins, the standard is attractive as a management guideline because of its simple, rule-of-thumb approach. The standard would become more scientifically credible if it were tied to specific impacts and disturbance levels across different types of tundra vegetation.

DMLW's tundra opening methodology and the application of the 12-and-6 standard

As is clear from the *History* section of this report, the DMLW's has used the 12-and-6 standard as a guideline but not a hard and fast rule for opening the tundra. The application of this guideline has evolved significantly over the past three decades. This evolution has been hampered by the lack of scientific information and by a methodical and consistent approach to data collection. Instead, it seems to have been guided somewhat by incremental efforts DMLW field staff to understand tundra dynamics and standardize methods of for making decisions. The evolution is punctuated by changes in staffing resource levels, and changes in the tools used to measure ground frost and ground hardness. The informal nature of these decisions to modify

[52] Id.
[53] Felix & Reynolds 1989a, 1989b, Jorgenson 2003, Emers & Jorgenson 1997, Reynolds & Felix 1989

decision-making may not have been scrutinized or particularly important because when season lengths were much longer, opening the tundra was not considered controversial. It may also have been due to a lack of staff and budget.

Because of its mostly informal nature, DMLW decision-making before the 1990s was characterized by a reliance on proxy weather information, and a lack of actual testing of conditions in the field. When conditions were tested, data were not always recorded, and were not collected in a manner that could easily be repeated or validated. For example, varying locations were used for testing and methods for measuring ground frost and snow depth varied from year to year and person-to-person.

Anecdotally, it appears that testing was focused in areas where development activities were to occur. This informal constraining of the extent of the management area is a potentially good way to limit variability in measurements, but it makes comparing opening dates from year to year difficult. Furthermore, prior to 2002, it is not clear that attempts were made to ensure the data collected was representative of conditions in either informal ‘management units’, or of conditions overall.

Additional early limitations in DMLW protocol include lack of a clear decision-making framework for opening the tundra (not always clear how the collected data factored into decision-making).

In the mid-1990s, records switch from documenting the depth of ground frost to recording ground hardness over a depth profile in “hits per inch” or “drops per inch.” Here, a slide hammer probe measures ground hardness. “Hardness” is both a more sensitive and less precise measure of ground conditions than “frost depth.” Ground hardness allows an incremental measurement of conditions over a depth profile, whereas ground frost is recorded as a single threshold depth. However, while frost depth is theoretically an actual physical parameter, ‘ground hardness’ is a qualitative description with units that depend on the instrument used to measure it (units in the case of DMLW have been “blows per inch,” “hits per inch,” or “drops per inch”).

After 1985, when DMLW field staff started to actually measure ground conditions, a steel rod was used to crudely estimate hardness over a profile (although this isn’t recorded), and based on intuition, the depth at which hardness (resistance) lessened significantly was recorded as the threshold frost depth.

Measuring ground hardness through a probe test is not necessarily an untested approach to understanding the properties of a freezing surface. According to a Cold Regions Research Engineering Laboratory (CRREL) report on Snow Roads and Runways, the probe hardness test is one of three typical measurements used in cold region engineering: surface load, sample strength, and probe. A surface load test, such as a plate indentation test, applies a vertical load to the snow surface and has the highest degree of reality in simulating load application. In a sample strength test, a core sample is removed from the snow and subjected to a strength test, and is less accurate in its correlation to load bearing strength. A probe measuring technique, such as the DMLW has used, is the easiest method, but does not simulate load application. The 1990 report CRREL on Snow Roads and Runways states the following about probe testing:

"These tests are the most convenient and least time consuming; in addition they provide a vertical hardness profile of a snow layer or a snow pavement. The hardness values, however, have no real physical meaning; they are simply indices of the 'relative hardness' of snow and have to be correlated empirically with more meaningful or familiar strength properties or actual bearing capacity."[54]

Tom Krzewinski, a geotechnical engineer with Golder Associates[55] in Anchorage, Alaska, stated that these methods for testing snow road and runway strength are also "all used frequently" for measuring frost depth of the active layer.[56]

Thus the DMLW's probe test has always been limited by the fact that "hardness" has not been systematically correlated with more meaningful environmental variables such as impacts to vegetation, ground temperature over the profile, final-freeze up, or load-bearing strength.

Consultation with experts in permafrost dynamics and engineering earlier on in management history could have improved staff understanding of the meaning of measurements and perhaps tightened measurement protocols used by field staff. Consultation could have also illuminated other factors that are potentially important in describing permafrost conditions or in predicting disturbance levels.

For example, according to Dr. Hinzman, an arctic scientist at UAF, the top inches of frozen active layer receive the most pressure from equipment, and the force is spread out below. This would suggest that the hardness of the upper inches is critical in determining the load-bearing strength of the tundra.[57] As noted in the *History* section, hardness measurements were often not recorded for the first few inches, and no regression has been attempted to relate the relative importance of hardness at different depths over the standard 12-inch profile.

Another instance in which consultation could provide important insight is in the case of measuring mud streaking and ice crystals on probe tips starting in the 1990s. While this observation has been used by DMLW staff as indication of soft layers in the permafrost, it is not clear that this assumption is consistent with current knowledge of permafrost characteristics. Even though tundra can be frozen solid, liquid water is always present in some quantity, and can lead to streaking. Testing would be needed to determine whether this DMLW assumption is valid.

Within the "ground hardness" regime, the use of scientific information and methods in DMLW management has improved dramatically in the last few years. Recent efforts have lead to increased standardization and repeatability of tundra readiness measurements, and new staff studies are investigating the sensitivity of current methods to testing location and number of testing replications at each location. Furthermore, a clear decision-making framework has been

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[54] Abeles, G, 1990.
[55] Golder Associates is an international group of consulting companies that specializes in ground engineering and environmental science.
[56] Personal communication, September 3, 2004.
[57] Personal Interview August 5, 2004.

established so that the rationale behind yearly decisions (including supporting data) is clearly documented in agency files.

Recent consultation with scientists and stakeholders has also led to the adoption of four tundra-opening areas. The divisions are based on current understanding of tundra ecosystem types and elevation gradients, and allow managers more flexibility in determining when to open each area to oil and gas activities. Informal and formal studies by DMLW and industry (e.g. an Ice Road Demonstration Project & the tundra modeling effort) have increased understanding of tundra systems on the part of DMLW staff, and have for the first time systematically documented disturbance levels related to certain activities and certain initial conditions. The most successful internal studies take care to set out hypotheses or research objectives, to develop good ways of testing the hypotheses, and then use data collected in the experiment to confirm or reject the hypotheses in a statistically informed manner.

Tundra Closing

While considerable effort has gone into increasing the use of science in tundra opening procedures, tundra-closing procedures have remained relatively constant for the past three decades. Closing the tundra is primarily a pragmatic decision, as vehicles need a few days notice to return the existing infrastructure from remote areas. The closing decision is based on observations of snow cover and short and long term weather forecasts. Once the insulating snow layer is gone, warming air temperatures begin to melt the permafrost active layer. Permafrost freezes each winter from both the surface in and the edge of the active layer out, and the same is true in spring. This means that after snow is gone, the surface of the permafrost is the first part to thaw.

Tundra closing decisions have been less controversial than tundra openings, for two reasons:

1) While winter temperature and snow conditions have changed significantly in the arctic, the onset of spring has not changed as drastically.[58] This is reflected in the asymmetry of days lost on either end of the DMLW travel season over the past few decades. While 85 days on average have been lost in winter, only 15 days have been lost on average in spring ;
2) It is of great importance to industry that equipment be moved out of remote areas before they are liable to become stranded across rivers with inadequate ice depth to support crossings, or stuck in melting permafrost. Once snow begins to melt, this happens quite quickly. This dynamic may induce a more precautionary approach on the part of industry and state managers.

Some scrutiny of tundra closing methodology might be in order, however. To avoid controversy over tundra closing in the future, it becomes important to standardize approaches and document decision-making, as in the case of tundra opening. Some testing of the assumptions implicit in the decision-making protocol may be in order, as well.

[58] Smith et. al. 2003.

Vehicle Testing

It has been DMLW's policy to allow certain vehicles access to the tundra at different times of the year depending on how they perform in informal tests on the tundra surface. Over the past few decades, these tests have resulted in a list of vehicles allowed on the tundra both during the summer and when snow depth is above 6" but ground hardness has not reached the threshold for opening the tundra to general traffic. [59]

Thresholds for allowing or prohibiting a vehicle are not entirely clear, and methods used to measure these threshold disturbance levels are not clearly documented. Based on interviews with staff, the general standard is that the vehicle will not tear the vegetative mat.[60]

Standardized testing, record keeping, and data collection procedures could improve the transparency of this practice.

Monitoring disturbance and impacts

There is a noted lack of scientific study on the impacts of winter off-road travel on the North Slope tundra.[61] This scientific gap extends from peer-reviewed scientific journal articles to technical reports and informal field monitoring studies.

Years of informal monitoring of trails and rehabilitation sites have enhanced institutional understanding of the range of impacts and their specific causes. This knowledge and the transparency of the system to the public could be greatly improved by standardizing methods and measurement parameters. This could be as simple as standardizing the number of disturbed sites visited and the questions asked by monitors every year. Further steps might include establishing monitoring plots in areas where high disturbance is anticipated, or establishing a more formal program of monitoring by air or even potentially from satellite. Cumulative impacts have not been and are still not monitored.[62] Although maps of work areas are collected, they are not compiled.

Based on interviews of past and current staff, similar informal testing has informed DMLW's approach to rehabilitating the tundra in areas where it is damaged by off-road traffic. The results of these informal investigations are largely contained in case-files, and have not been compiled into a single resource or document. Again, the implementation of standard scientific practices with regard to data collection and documentation could improve future rehabilitation efforts.

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[59] DMLW memorandum from H. Bader and G. Schultz to N. Welch, April 17, 2003.
[60] DMLW staff interviews.
[61] See Appendix B.
[62] NAS 2003.

Measuring for 12-and-6: DMLW tundra management timeline

Early 1970's – DMLW, with help from DH&G, begins to play more of an active role in deciding tundra opening and closing date, taking over from Division of Minerals and Energy Management (now Division of Oil & Gas).

Early 1970's-1980 – Mean tundra season length is 200 days. DMLW relies mostly on remote weather data from Barter Island and Barrow (on the Arctic Ocean), snow depth information, river ice depth, and intelligence from people in the field to judge whether the tundra is ready to open. "Frost depth" not measured in the field. "Ground hardness" not used as a determination for opening tundra. DNR staff sometimes flies to intended work areas to measure snow depths. The 12-and-6 standard occasionally mentioned, but if used at all is only used as a guideline for determining adequate conditions are met.

Early 1980's – According to interviews with former staff, DMLW continues to rely primarily on air temperature from remote weather station data and river ice depth as proxies for frost depth. When remote station data and intelligence from people in the field indicates average snow depths are close to 6 inches, DMLW staff drives or flies to field and gauges average snow depth. 12-and-6 standard may be used for guidance, but is not a fast and hard threshold for opening.

1982 – DMLW expands weather station data to include information from stations at Umiat and Deadhorse.

1985 – DMLW makes first attempt to measure frost depth directly. Uses sledgehammer to drive a steel rod into the tundra. DMLW assumes frost depth corresponds to the depth at which resistance to rod decreases. 12-and-6 standard followed, although still as a guideline. The depth information is not recorded, field reports are spotty, and testing locations are inconsistent and sparsely distributed mostly on the coastal plain.

1985 – 1994 – Sledgehammer and steel rod technique continues, augmented by weather station data and sporadic testing of snow depth. Staff history indicates that tundra is opened if field staff determines that frost depth is to 12 inches and no significant soft layers are encountered when pounding the probe down into the tundra.

1991 – Mention of 12-and-6 guideline becomes more common in field reports and files.

1993 – Turnover in DMLW North Slope field staff. Rod now marked in one-inch increments and number of blows needed to pound in each inch is observed but not always recorded. Thus "hardness" as well as frost depth is crudely measured. Snow depth, ground frost and crude hardness in "blows per inch" measured at various locations, but blows per inch not consistently recorded. Unclear exactly how decision is made to open tundra, but 12-and-6 is still apparently a guideline as it applies to average snow depth and average frost depth as measured by the steel probe and sledgehammer technique.

1995 -1996 – New staff designs and employs new, safer probe - the slide hammer penetrometer. Penetrometers used by staff are generally similar but not standardized in hammer weight or height, or probe diameter, although the diameter is generally about 9/16". User assists hammer in driving probe into ground. Increasing number of sites sampled and additional measurements made, including "snow depth at probe site."

1996-1997 – Ground "hardness" now measured and recorded as well as frost depth. Hardness expressed in Hits per Inch (HPI) of the slide hammer. While ground frost can be present over 12 inches, a certain HPI is necessary to be considered adequately "hard frost." HPI not always recorded for first few inches of tundra.

1998 – Field observations begin to be systematically recorded in more standardized field reports, and sampling intensity is increased but not entirely standardized. Geographic area covered by sampling also increases. Observations of dirt, ice crystals and mud begin to be noticed and factored into ground hardness and frost depth assessment.

2002 –Working group formed; 4 different management units (Tundra Opening Areas or TOAs) are created for phased tundra opening. Pilot study conducted that indicates that the current method for determining tundra readiness may be conservative. Tundra modeling project begins.

2002 –2003 – New, slimmer 3/8 " probe is employed, with standardized height, weight and diameter.
Ground hardness is now measured in terms of unassisted "drops per inch" (DPI) of the slide hammer from a specified height. 'Adequately hard' determined to be 10 DPI on average over the entire 12-inch profile with new probe. Standardized testing methodology implemented, with visits to 30 permanent sample stations distributed along both an E-W and a N-S transect, scheduled every two weeks starting in November. Decision-making matrix created. Reports issued explaining each opening decision, methodology for decision, and supporting data. DMLW manager over-rides decisions influenced by observations of mud, ice and dirt on probe tip until these observations can be linked to increases in tundra impacts.

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