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Mapping Wilderness Character in Gates of the Arctic National Park and Preserve

Natural Resource Report NPS/GAAR/NRR—2017/1446

ON THE COVER
Unnamed drainage in the northern Brooks Range, Gates of the Arctic National Park and Preserve
NPS/JEFFREY RASIC

Mapping Wilderness Character in Gates of the Arctic National Park and Preserve

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This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

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Executive Summary

The recent development of an interagency strategy to monitor wilderness character, *Keeping It Wild 2: An Updated Interagency Strategy for Monitoring Wilderness Character Across the National Wilderness Preservation System* (Landres et al. 2015), allows on-the-ground managers and decision makers to assess whether stewardship actions for an individual wilderness are fulfilling the legislative mandate to "preserve wilderness character." By using credible data that are consistently collected, one can assess how wilderness character changes over time and evaluate how stewardship actions affect wilderness character. As most of these data depict spatial or geographic features in wilderness, a Geographic Information System (GIS)-based approach was developed to depict impacts to wilderness character in the Gates of the Arctic National Park and Preserve (GAAR) wilderness.

A set of measures was identified by the project team to capture impacts to the five qualities of wilderness character (untrammeled, natural, undeveloped, solitude or primitive and unconfined recreation, and other features of value). These measures were depicted using a variety of spatial datasets, which were normalized using a common relative scale such that disparate metrics could be analyzed together. Each measure was "weighted" by the project team to reflect its relative impact to wilderness character. Maps generated for each of the weighted measures were then added together to produce a composite map of impacts to wilderness character. Additionally, maps were generated to depict positive features of value within GAAR and impacts posed by the potential development of an industrial road corridor through the southern portion of GAAR. The map products presented in this report delineate the spatial pattern and variation of impacts to wilderness character across the GAAR wilderness.

These maps will be used by GAAR staff to inform and support park planning documents, Wilderness Stewardship Performance planning, Wilderness Character Monitoring and management decision-making. The maps, and this approach, do not represent a determination of significant effects, nor do they endorse specific management decisions or trigger management action. Instead, this project provides managers with a tool to better understand the extent and magnitude of impacts to wilderness character across GAAR, holistically evaluate tradeoffs associated with decisions and actions in wilderness, and ultimately improve wilderness stewardship.

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Acronyms and Abbreviations

AIDEA	Alaska Industrial Development and Export Authority
ANCSA	Alaska Native Claims Settlement Act
ANILCA	Alaska National Interest Lands Conservation Act
DEM	Digital Elevation Model
DSM	Digital Surface Model
EPA	Environmental Protection Agency
FSM	Forest Service Manual
GAAR	Gates of the Arctic National Park and Preserve
GIS	Geographic Information System
MODIS	Moderate Resolution Imaging Spectroradiometer
NNIS	Non-Native Invasive Species
NPS	National Park Service
NWPS	National Wilderness Preservation System
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RAWS	Remote Automated Weather Stations
SNOTEL	Snowpack Telemetry
TIFF	Tagged Image File Format
USGS	U.S. Geological Survey
VFR	Visual Flight Reconnaissance

Introduction

The Wilderness Act of 1964 (Public Law 88-577) established the National Wilderness Preservation System (NWPS) "for the protection of these areas, [and] the preservation of their wilderness character" (Section 2(a)). In congressional testimony clarifying the intent of wilderness designation, Howard Zahniser (1962) said, "The purpose of the Wilderness Act is to preserve the wilderness character of the areas to be included in the wilderness system, not to establish any particular use". Legal scholars (Rohlf and Honnold 1988; McCloskey 1999) subsequently confirmed that preserving wilderness character is the Act's primary legal mandate. Furthermore, the policies of all four wilderness managing agencies state that they are to preserve wilderness character in all areas designated as wilderness.

The condition of wilderness character varies across a wilderness based on the intensity and distribution of human influences that degrade it. Just as variation in other landscape features can be depicted spatially, so too can the condition of wilderness character. Maps depicting spatial variation in wilderness attributes have been produced at a variety of scales: globally (Sanderson et al. 2002), continentally (Carver 2010), nationally (Aplet et al. 2000), and locally (Carver et al. 2008). Adding to this body of work, a recent study for Death Valley National Park (Tricker et al. 2012; Carver et al. 2013) provided a spatially explicit description of how impacts to wilderness character vary across the Death Valley Wilderness. This approach has been strongly supported by the National Park Service (NPS), and impacts to wilderness character have now been mapped for the wildernesses within Olympic, Denali, Sequoia and Kings Canyon, and Saguaro national parks. Gates of the Arctic National Park and Preserve (GAAR) now becomes the sixth NPS wilderness to develop a map of impacts to wilderness character. It also is the first wilderness within the National Wilderness Preservation System (NWPS) to develop a map of the positive features related to wilderness character. Finally, it is the first wilderness within the NWPS to model future scenarios that could alter attributes of wilderness character by mapping the potential impacts of two proposed industrial road routes through Gates of the Arctic National Park and Preserve.

Gates of the Arctic Wilderness

Gates of the Arctic became federally protected in 1978, when President Jimmy Carter signed a law designating the 8.22 million acres of diverse arctic ecosystems as a national monument. In 1980, President Carter signed the Alaska National Interest Lands Conservation Act (PL 96-487, also known as ANILCA), creating the 8.4-million-acre Gates of the Arctic National Park and Preserve. More than 7 million acres of the park are designated wilderness (GAAR Wilderness) – part of the NWPS – wherein wilderness character is to be preserved (Figure 1). Approximately 914,000 acres of land within GAAR remains eligible for wilderness designation and is managed as wilderness per National Park Service policy (DO-41). The GAAR Wilderness abuts additional designated wilderness in the Noatak National Preserve. Together, these two areas equal more than 12.7 million acres and comprise the largest contiguous area of designated wilderness in the National Park System (Figure 2) and the NWPS.

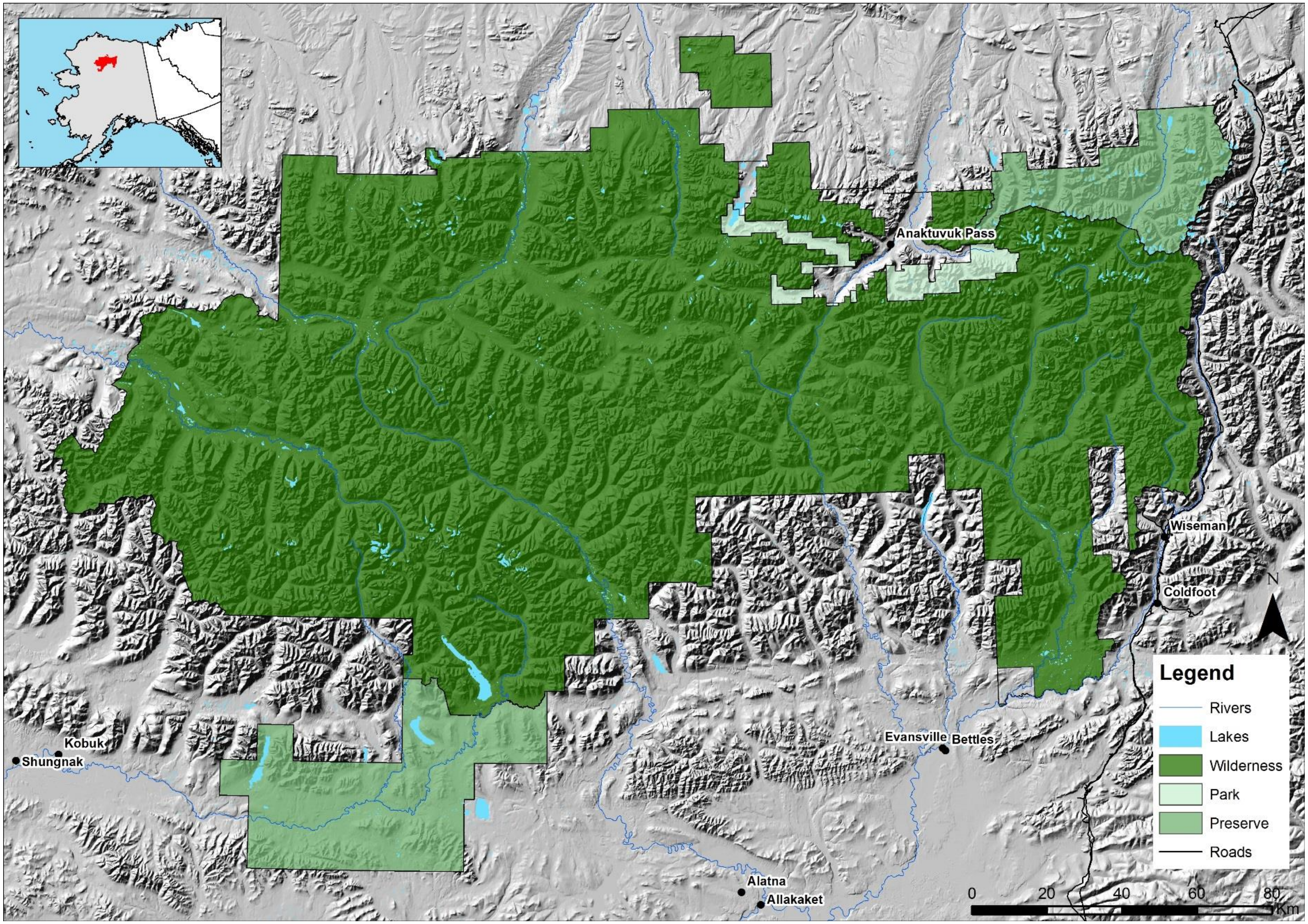

Figure 1. GAAR park, preserve and wilderness lands.

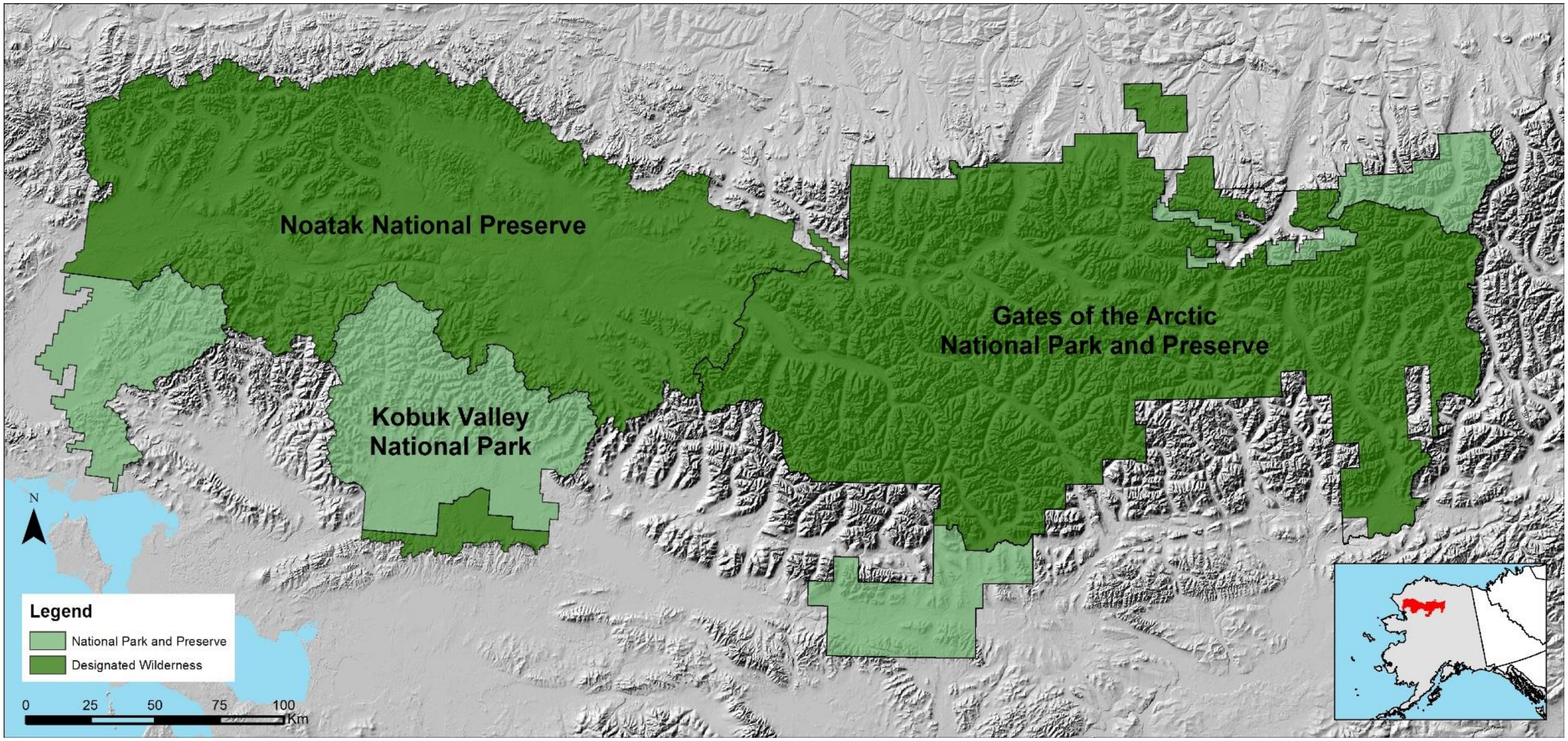

Figure 2. GAAR and surrounding protected areas.

The entirety of GAAR lies north of the Arctic Circle. The park's natural arctic ecosystem is functional and intact. Within GAAR are the mountains of the central Brooks Range, large tracts of boreal forest, huge expanses of tundra, and six designated Wild and Scenic Rivers. Wandering through the rugged landscape are significant grizzly bear, wolf, moose and raptor populations, migrating caribou, migratory bird and fish species and a substantial population of Dall's sheep. Humans do not dominate the landscape but are deeply connected with these places as evidenced by an 11,000-year archaeological record. In GAAR, people and nature continue to weave a story of mutual existence through thriving subsistence use. A living culture is preserved within a large, intact ecosystem.

Managers at GAAR balance several existing mandates and administrative commitments. Before ANILCA designated GAAR, the likelihood of rich mineral deposits in the Ambler Mining District, to the west of the park, had already been identified. Congress, in considering the establishment of GAAR, recognized that a transportation corridor to the Ambler Mining District might become desirable, and might connect with the Dalton Highway to the east of the Park. The upper Kobuk River area was included in GAAR. However, Congress made allowances for a transportation corridor across that area (known as the Kobuk Preserve) in order to provide access for future development of mineral resources in the Ambler area. (Additional information about the Ambler transportation corridor can be found in the "3. Proposed Ambler road impacts to GAAR wilderness character" section of this report.)

GAAR managers recognize and protect opportunities for subsistence use of park resources by local rural residents. Subsistence uses by local residents are permitted in GAAR, where such uses are traditional, in accordance with the provisions of ANILCA Title VIII, wherein Congress declared that "the continuation of the opportunity for subsistence uses by rural residents of Alaska, including both Natives and non-Natives, on the public lands and by Alaska Natives on Native lands is essential to Native physical, economic, traditional, and cultural existence and to non-Native physical, economic, traditional, and social existence."

Congress also found that, "in order to fulfill the policies and purposes of the Alaska Native Claims Settlement Act (ANCSA) and as a matter of equity, it is necessary for the Congress to invoke its constitutional authority over Native affairs and its constitutional authority under the property clause and the commerce clause to protect and provide the opportunity for continued subsistence uses on the public lands by Native and non-Native rural residents; and the national interest in the proper regulation, protection and conservation of fish and wildlife on the public lands in Alaska and the continuation of the opportunity for a subsistence way of life by residents of rural Alaska require that an administrative structure be established for the purpose of enabling rural residents who have personal knowledge of local conditions and requirements to have a meaningful role in the management of fish and wildlife and of subsistence uses on the public lands in Alaska."

In addition to these provisions within ANILCA and ANCSA, GAAR managers also recognize provisions within the Anaktuvuk Pass Land Exchange and Wilderness Redesignation Act of 1995[1]. The village of Anaktuvuk Pass, located in the highlands of the central Brooks Range, is virtually surrounded by GAAR park and wilderness lands and is the only Native village located within the boundary of the National Park System in Alaska. Unlike most other Alaskan Native communities, the village of Anaktuvuk Pass is not located on a major river, lake, or coastline that can be used as a means of access. This act ratifies access agreements made in conjunction with the National Park Service, Nunamiut Corporation, the City of Anaktuvuk Pass, and Arctic Slope Regional Corporation.

GAAR recognizes the preservation and continuation of subsistence lifestyles as a positive feature of wilderness character and an essential part of the natural ecology of the area, as this way of life has existed for thousands of years.

GAAR contains two sites with National Natural Landmark (NNL) designations. These are natural areas that have been designated by the Secretary of the Interior in recognition that each site contains significant examples of the nation's biological and/or geological features. Besides fostering the basic NNL program goals of protecting natural heritage and advancing science and education, some NNLs are the best remaining examples of a type of feature in the country and sometimes in the world.

GAAR safeguards six Wild and Scenic Rivers, which are protected under the 1968 Wild and Scenic Rivers Act (WSR Act). The WSR Act preserves certain rivers with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations. The Act is notable for preserving the special character of these rivers, while also recognizing the potential for their appropriate use and development. It encourages river management that crosses political boundaries and promotes public participation in developing goals for river protection.

In GAAR, each of these management responsibilities is considered along with the preservation of wilderness character. GAAR managers have viewed this mapping project as a unique opportunity to embrace wilderness as an inclusive, multi-cultural concept – a goal of the 2020 Action Plan for Alaska Wilderness Stewardship identified by the NPS Alaska Region.

Purpose of this mapping project

The many purposes of this project include:

- Showing the current extent and magnitude of impacts to wilderness character and how they vary across GAAR.
- Providing a baseline from which future monitoring can show how impacts to wilderness character change over time.

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[1] "H.R. 400 — 104th Congress: Anaktuvuk Pass Land Exchange and Wilderness Redesignation Act of 1995". www.GovTrack.us. 1995. October 23, 2016 <https://www.govtrack.us/congress/bills/104/hr400>

- Allowing GAAR staff to analyze the potential impacts of different management actions on wilderness character.

- Identifying areas within GAAR where resource managers should make an effort to control or mitigate impacts. These efforts may include monitoring conditions, establishing thresholds, or taking direct action.

- Identifying specific activities or impacts outside GAAR that may pose a substantial risk of degrading wilderness character inside the park and preserve.

- Improving internal staff communication about wilderness and wilderness character and improving external communication between GAAR and the public on related issues.

- Identifying and filling data gaps by collecting information from local staff and digitizing new spatial data.

- Showing the current extent and magnitude of the positive aspects of GAAR wilderness character, including management actions that improve wilderness character.

- Analyzing the potential future impacts to GAAR wilderness character by two proposed road corridors (to the Ambler Mining District) through the Kobuk Preserve area of GAAR.

- Producing three distinct wilderness character maps: Baseline, Positive Features, and Proposed Ambler Road Impacts.

In addition to the immediate benefits described above, this project improved and consolidated existing spatial datasets and generated new datasets. These datasets, and the maps produced by this project, lay the groundwork for future wilderness character mapping and monitoring efforts in GAAR. When and if the park is able to conduct future iterations of wilderness character maps, the maps in this report can serve as the baseline for assessing how both impacts to wilderness character and positive features of wilderness character change spatially over time. The data gaps identified during this exercise may also be used to inform future research requests and monitoring efforts.

Concerns and cautions

There are a number of potential concerns about producing these wilderness character maps. Despite these concerns, managers have recognized these maps as the best available tool for spatially representing current impacts and future threats to wilderness character. Major cautions about this overall effort include:

- *Creating sacrifice zones* – The map may facilitate the inappropriate creation of "sacrifice zones" or internal buffers within the wilderness, directly contravening congressional and agency mandates to preserve wilderness character across an entire wilderness. For example, if the map shows that some areas are "better" or of "higher quality" than others, the tendency may be to focus efforts on preserving wilderness character only in these specific areas while allowing wilderness character to degrade in "lower quality" areas. By showing the current extent and magnitude of impacts to wilderness character and how they vary across the entire wilderness, the intent of the map is to help staff maintain high quality areas while improving lower quality areas. By showing the current extent and magnitude of high value areas in the positive features map and how they vary across the entire wilderness, the intent of the map is to help staff recognize changes to those areas over time.

- *Comparing wilderness character among wildernesses* – Since this approach has been used for other wilderness areas, the map may facilitate inappropriate comparisons of wilderness character among different wildernesses. These maps show the extent and magnitude of current impacts and future threats to wilderness character in different colors (representing pixel values), and it would be easy for users to compare the quantity of a given color from one wilderness to another. Comparing these maps among different wildernesses, however, is neither valid nor appropriate because each map is built with data from the unique context of a particular wilderness.

- *Assuming that the resulting map completely describes wilderness character* – The map may be misconstrued as an accurate and precise description of wilderness character. Instead, the maps are only an estimate of selected impacts to, threats to and positive features of wilderness character for which spatial data were available for this particular wilderness. As an approximate representation of current impacts and future threats to wilderness character, as well as of the positive aspects of wilderness character, the map should not be considered an absolute and complete description. In addition, the map does not portray the impacts and threats to the symbolic, intangible, spiritual, or experiential values of wilderness character. In short, while this map is useful for the purposes outlined above, it cannot fully describe the complexity, richness, or depth of wilderness character.

- *Updating spatial datasets in future maps may prevent the baseline map from being used to evaluate change over time* – As datasets are updated over time, future iterations of the map may not be comparable with the original map. Each map is a product of both the best available spatial data and the locally defined methods for processing those data. As with all long-term monitoring efforts, changes in the type and quality of data or in the data processing techniques can make comparisons between original and subsequent data invalid. Therefore, proposals to use new or altered data, or to change data processing methods, need to be assessed carefully to ensure the comparability of map products over time.

Report outline

A team approach was used to develop the map products for GAAR, tapping the experience and knowledge of GAAR staff (see page x for a full list of staff involved). Together, the project team and other GAAR staff have more than 85 person-years of on-the-ground experience in and with GAAR. The project team, and other GAAR and Alaska Region NPS staff as required, conducted multiple face-to-face meetings and had numerous phone and email conversations while developing the map products described in this report. All decisions about developing the maps were made by project team consensus.

This report provides an in-depth discussion of how the map products were developed. It is divided into five major sections:

- Overview of the process for developing the maps of current impacts and future threats to wilderness character – describes the conceptual foundation for how the map was developed.
- Methods – describes the measures that were used to represent the degradation of wilderness character, along with the data sources, data processing methods, data and measure cautions, and the rationale for measure weighting.
- Baseline map of current impacts to wilderness character – discusses some of the patterns revealed in the map, approaches to improving map development in the future, and final caveats about the overall process.
- Positive Features map – describes the measures used to represent the positive aspects of wilderness (including data sources, data processing methods, data and measure cautions, and the rationale for measure weighting) and discusses some of the patterns revealed in the map.
- Proposed Ambler Road impacts to GAAR wilderness character – analyzes the potential future threats of each of the two proposed road corridors to wilderness character in the Kobuk Preserve unit of GAAR. This section describes the new and existing measures used to examine current and potential threats (including data sources, data processing methods, data and measure cautions, and the rationale for measure weighting) and discuss the changes between the baseline map and the two proposed road corridor maps in the Kobuk Preserve.

Overview of the process for mapping wilderness character

This wilderness character mapping project used a Geographic Information System (GIS) to spatially describe and assess current impacts and future threats to wilderness character in GAAR, as well as to depict positive features of wilderness character. With this approach, it is essential to understand the variety of activities and influences that currently impact wilderness character or could threaten it in the future, as well as the role of wilderness managers in mitigating or responding to such changes. National Park Service policy acknowledges that "Day-to-day management decisions and actions made within a park can significantly affect or be influenced by wilderness character" (NPS Director's Order 41). Only by understanding the myriad human influences that affect wilderness character can managers meet wilderness stewardship goals.

For this report, "impacts" to wilderness character are defined as a combination of:

- Historical activities that continue to degrade wilderness character (e.g. noise impacts from overflights, locations of contaminated sites).
- Current actions or influences that degrade wilderness character (e.g. non-native invasive species, administrative installations).

For this report, "threats" to wilderness character are defined as:

- Impending issues that are likely to degrade wilderness character into the future (e.g. the development of the proposed Ambler road).

By identifying and depicting both current impacts and future threats to wilderness character, as well as positive features of wilderness character, the maps produced in this report provide managers with a tool to better understand the extent and magnitude of changes to wilderness character in GAAR and thereby improve wilderness stewardship.

For two of the three wilderness character maps produced (the Baseline map and the Proposed Ambler Road Impacts map), this project adheres to the interagency strategy for monitoring wilderness character, as described in *Keeping it Wild 2: An Updated Interagency Strategy to Monitor Trends in Wilderness Character Across the National Wilderness Preservation System* (Landres et al. 2015). This interagency strategy was formally endorsed in the fall of 2015 by the Interagency Wilderness Policy Council (which is composed of the highest policy-level personnel responsible for wilderness in each of the four wilderness managing agencies). Therefore, by adhering to the interagency strategy, this project is consistent with National Park Service and interagency policies, terminology[2], and monitoring protocols for wilderness character.

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[2] Terminology used in this report to describe threats to wilderness character—including "degraded," "negative impact," "significant," etc.—reflects common vocabulary used in laws, policies, and interagency wilderness character monitoring documents. These terms do not imply an analysis of impacts or determination of significant effects, such as required by the National Environmental Policy Act or other agency decision-making processes.

The five qualities of wilderness character

Keeping It Wild 2 provides a tangible definition of wilderness character and identifies four qualities of wilderness character that apply uniquely to every wilderness: untrammeled, natural, undeveloped, and solitude or primitive and unconfined recreation. These qualities apply to all designated wilderness areas because they are based on the legal definition of wilderness from the Wilderness Act (Section 2(c)). In addition to these four qualities, a fifth quality—other features of value—was also used for this project based on the last clause of Section 2(c) in the Wilderness Act: a wilderness "may also contain ecological, geological, or other features of scientific, educational, scenic or historical value" (Landres et al. 2012; Landres et al. 2015).

Actions managers choose to take—or not take—in wilderness have the potential to degrade or improve these qualities and affect wilderness character. Challengingly, actions taken to protect or improve one quality of wilderness character may often result in the degradation of another quality (Landres et al. 2015). For example, although maintaining latrines at campsites protects natural resources and benefits the natural quality, the latrines are also facilities that decrease opportunities for primitive recreation and installations that diminish the undeveloped quality. These types of tradeoffs are inherent to many aspects of wilderness stewardship, and understanding how a single action may have different effects on the qualities of wilderness character is essential for evaluating management decisions and actions in wilderness.

In addition to the actions, inaction, or purposeful restraint of managers, wilderness character may also be affected by factors outside the jurisdiction of the National Park Service. For example, air pollution, night sky light pollution, and climate change are not under the direct control of wilderness managers but can still have substantial effects on the qualities of wilderness character. The inclusion of these types of external impacts in the interagency wilderness character monitoring strategy (and, consequently, in this mapping project) does not constitute an application of wilderness laws, policies, and restrictions to non-wilderness areas (i.e. the creation of a "buffer" around wilderness); instead, it is an acknowledgement that broad-scale social and ecological changes may affect wilderness character (Landres et al. 2015). As stated in National Park Service policy, "The goal of wilderness stewardship is to keep these areas as natural and wild as possible in the face of competing purposes and impacts brought on by activities that take place elsewhere in the park and beyond park boundaries" (NPS DO-41).

Certain activities may be legally allowed in wilderness and yet also impact wilderness character. Although the Wilderness Act prohibits "nonconforming" uses (such as motorized use, mechanical transport, or the installation of permanent developments), specific exceptions have been permitted through special provisions in the Wilderness Act itself and in subsequent wilderness legislation such as ANILCA. The Wilderness Act states that nonconforming uses or activities may be permitted only "as necessary to meet minimum requirements for the administration of the area for the purpose of this Act (including measures required in emergencies involving the health and safety of persons within the area)" (Section 4(c)). Additional special provisions may also be legislated for a specific wilderness to allow, or require, nonconforming activities by managers or visitors. For example, provisions in ANILCA allow motorized use for traditional activities (such as village to village travel and native allotment access), and for the continuation of pre-existing private use cabins. Additionally, in its administration of GAAR, the NPS employs the use of motorized tools, helicopter access and installations. Even in situations where such uses are both legal and justifiable, however, nonconforming activities still degrade wilderness character (Landres et al. 2005; Landres et al. 2015). Over time, the cumulative effects of these legal yet nonconforming uses may cause a substantial impact to wilderness character, which emphasizes the need to carefully weigh future decisions related to such activities. ANILCA-designated parks like GAAR are governed by a law that adds another layer of complexity by providing for a multitude of nonconforming uses that GAAR managers are required to allow.

The mapping framework

The five qualities of wilderness character form the foundation of the interagency monitoring strategy, and are the first level of the hierarchical monitoring framework. As described in *Keeping it Wild 2*, this framework divides wilderness character into successively finer components: the qualities of wilderness character are divided into a standard set of indicators[3], which are monitored in turn through a set of locally relevant measures[4]. For this project, measures were selected by the multidisciplinary project team to represent impacts to, threats to, and positive features of wilderness character in GAAR. The *Keeping it Wild 2* framework was only used for the baseline map and the proposed Ambler Road corridor map and not for the positive features map. For all three maps, individual measures were mapped using spatial datasets and weighted to reflect their respective influences on wilderness character. Maps of the measures were then added accumulatively using these weights to create maps of the indicators and qualities, as well as an overall map of either impacts to, threats to, or positive features of wilderness character in GAAR. Figure 3 shows the framework used for both the baseline map and the proposed Ambler Road corridor map:

[3] Indicators are distinct and important elements within each quality of wilderness character. They have measurable attributes that can be the focus of wilderness character monitoring efforts.

[4] Measures are specific and tangible aspects of an indicator that can be measured to gain insight into the status of the indicator and to assess trends over time.

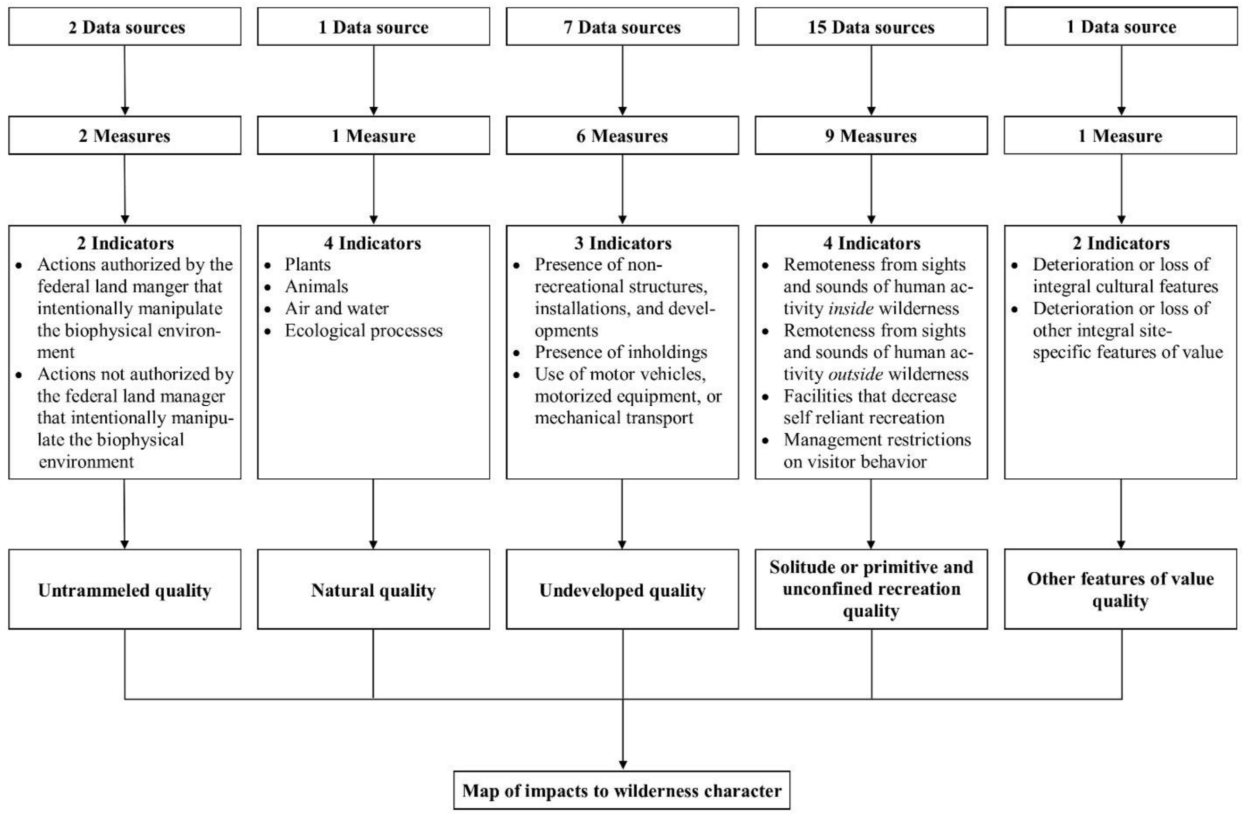

Figure 3. Flow chart of the framework used for mapping current impacts to wilderness character in the baseline wilderness character map.

For this mapping project, baseline and proposed Ambler Road corridor measures were selected to represent features, conditions, and actions that stand to alter wilderness character in GAAR. For example, the NPS emergency use shelters measure depicts where the undeveloped quality has been degraded by the presence of permanent installations. While some actions, conditions, or features in wilderness may have a positive influence on wilderness character (such as the preservation of an endangered keystone species), such "value added" features are not encompassed by the selected measures for the baseline and proposed Ambler Road maps. Similarly, when actions or features have a mix of both positive and negative effects (such as management regulations that confine visitors in order to protect natural resources), the selected measures only quantify the negative impacts in the baseline and proposed Ambler Road corridor maps. The GAAR project team decided to adopt this "negative mapping" approach for the baseline and the proposed Ambler Road corridor maps because it allows the full magnitude of current impacts and future threats to be depicted. The "negative mapping" approach also is the standard approach for all other wilderness character mapping efforts throughout the NWPS to date. In contrast, simultaneously displaying positive and negative impacts on a single map would result in these opposing influences being mutually offset or cancelled out, thereby obscuring the true extent of their individual effects on wilderness character. Therefore, two of the three map products presented in this report only depict current impacts or future threats to wilderness character and do not capture management activities that benefit or improve wilderness character. Because the GAAR project team intended to clearly convey the positive aspects of wilderness character (including beneficial management activities), they decided to develop a third map product – the positive features map. This positive mapping effort is the first ever attempted within the NWPS.

At first glance, it could appear inappropriate or meaningless to combine measures into a single overall map since each measure captures a unique and distinct impact to wilderness character. For example, it may seem counterintuitive to combine the locations of emergency use shelters with the noise impacts of motorized use. However, since all measures for both the baseline and proposed Ambler Road corridor maps quantify either impacts or threats to wilderness character, combining measures is both appropriate and important for understanding and recording the magnitude of their cumulative effects. Additional information on the rationale and methods for accumulatively combining disparate measures to produce an overall map of impacts or threats to wilderness character are described by Carver et al. (2013). While data and maps for individual measures are relevant for local management purposes, the intent of this mapping project is also to understand and report on the big picture—to represent the cumulative spatial pattern and variation of both current impacts and future threats to wilderness character, as well as the myriad positive aspects of wilderness character. This big picture is a powerful and effective tool for communicating wilderness issues within the agency and with external audiences (Landres et al. 2008).

Mapping current impacts or future threats to wilderness character differs from wilderness character monitoring in a key way. While monitoring efforts focus on assessing change in wilderness character over time by producing a single overall trend direction (i.e. improving/upward, stable, or degrading/downward), this mapping project examined the current (baseline) extent and magnitude of impacts to wilderness character and how those cumulative impacts vary across the wilderness. Both the baseline and Ambler Road corridor maps of current impacts and future threats to wilderness character were therefore generated directly from the weighted measures, and did not undergo a standardization process at each level of the hierarchical framework (as is the case when deriving trends for wilderness character monitoring). This approach allowed the magnitude of impacts or threats, depending on the map, to be depicted so that qualities with few or lightly weighted measures (i.e. fewer or milder impacts) had a proportionally smaller influence on the overall map of impacts to wilderness character than qualities with many or heavily weighted measures (i.e. more or greater impacts.)

The baseline and proposed Ambler Road corridor maps produced through this project depict GAAR's current degree of departure or degradation from an "optimal condition" of wilderness character. This optimal condition reflects a manifestation of wilderness character as expressed in the Wilderness Act—in other words, a state in which there are no or minimal impacts to wilderness character. Each measure is depicted across GAAR on a scale from its "optimal condition" (i.e. no impact) to its most "degraded condition" (i.e. highest current impact level). When the measures are combined accumulatively, therefore, the overall map of impacts to wilderness character is similarly depicted on a scale from its optimal condition (i.e. no impacts to wilderness character) to its most degraded condition (i.e. highest cumulative impact level from all measures). The optimal conditions depicted in the map products do not represent the condition of wilderness character in GAAR in 1964 (passage of The Wilderness Act) or in 1980 (passage of ANILCA), and therefore cannot be used to determine if impacts to wilderness character have increased or decreased since the time of designation; instead, the map products show the state of wilderness character when the maps were produced.

The positive features map produced through this project depicts GAAR's current richness in positive aspects of wilderness character. It shows no departure from an "optimal condition" of wilderness character like the baseline and proposed Ambler Road maps. Rather, it displays the positive aspects of wilderness character in GAAR as well as management actions that benefit or improve wilderness character.

Methods

For the baseline and proposed Ambler Road corridor maps, selecting measures under each indicator of the five qualities was an iterative and collaborative decision-making process. Possible measures were first identified by the project team and then evaluated for both their relevance to the indicator and the availability and quality of the required data. GAAR staff assessed data quality for each dataset using two metrics: accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the wilderness). In general, only measures that were relevant, that were spatially explicit, and that had readily available data of sufficient quality, were included. For certain measures, this involved developing new datasets based on institutional knowledge (i.e. documenting known locations of impacts onto paper maps, which were then digitized). In some cases, potential measures had insufficient or non-existent data but were acknowledged by the project team for their significance to their respective indicators; these "data gap" measures are noted below each applicable quality. As data improve or become available, the data gap measures should be reevaluated for inclusion in future iterations of the maps.

For the positive features map, the same iterative and collaborative decision-making process was employed by the project team, but measures weren't categorized into *KIW2* framework indicators. Currently no procedure or framework exists for creating a positive features map, so the GAAR project team identified three logical indicators and multiple underlying measures. The team used the same assessment for data quality as the other two maps and likewise identified data gap measures, which were noted below each applicable quality.

Weighting measures

For all three maps, once a final list of measures was determined, each measure was evaluated independently to determine the magnitude of its effect on wilderness character. Some measures had a greater impact on wilderness character than others; for example, the bear collaring measure had a relatively smaller impact (because it rarely occurs and minimally affects the ecological patterns of wildlife), whereas the human-started fires measure had a relatively greater impact (because human-started fires are unnatural and cause a significant manipulation of the biophysical environment). To accurately portray the variable magnitudes of the measures' effects, each measure was assigned a "weight"—a value from 1 (low impact) to 10 (high impact)—by the project team. The project team then reviewed the map outputs and modified the weighting scheme to reflect their knowledge of the condition of wilderness character on the ground. While this interactive process runs the risk of subjectively producing a desired outcome, staff experience has been shown to be highly accurate in judging resource conditions (Cook et al. 2009). The project team used caution and consensus-driven oversight to ensure accuracy in the maps produced and the assumptions made by the project team have been explicitly outlined in the rationale tables for each indicator.

Specific rationales for weights assigned to each measure can be found in tables 2, 4, 6, 10, 12, 14 and 16 under their respective qualities. The following questions were used to help determine weights for all measures:

- Is the measure spread throughout the wilderness (higher weight) or specific to a particular area (lower weight)?

- Does the measure represent a major management issue, e.g. the development of the proposed Ambler Road (higher weight), or is it something relatively benign, e.g. social trails (lower weight)?

- Is the measure an issue year-round (higher weight) or relevant to a particular time of year or season (lower weight)?

- Are the data quantitative (higher weight) or qualitative (lower weight)?

- Does the measure depict an emerging threat that requires intensive management, e.g. the development of the proposed Ambler Road (higher weight), or does it depict an issue that has largely been solved and is no longer of high concern to management, e.g. non-native plant treatments (lower weight)?

- Are the data representing the measure accurate and complete (higher weight) or are they of poorer quality (lower weight)?

Data sources and processing techniques

Measures were mapped by applying GIS-based techniques to their respective datasets. A total of 28 datasets were used for measuring and delineating impacts to wilderness character in GAAR. These datasets were obtained from a variety of sources and comprised local, regional, and national spatial data at varying scales, accuracy, and completeness. This variation placed limitations on how the map products were developed and necessitated the use of adaptable data processing methods, as described below. Metadata were developed for each data layer used in this mapping project, and include documentation of processing flows, quality/completeness, editing, development, and cautionary notes. All data and metadata were organized and stored on a NPS network drive to ensure accessibility and facilitate use in future analyses. Datasets included:

- Commonly used data layers that are part of the NPS Alaska Region GIS Permanent Dataset.

- Existing data layers associated with previous or on-going GAAR projects.

- Existing datasets that were edited, combined, or refined as a prerequisite for use in this project.

- Original datasets that were developed from local sources (including records, reports, and expert knowledge) and converted into a geospatial format.

A number of basic processing tasks were performed using ArcGIS[5] for datasets before they were used as measures to create the map of impacts to wilderness character. All datasets were projected in

[5] GIS software developed by Environmental Systems Research Institute.

ArcGIS using the Alaska Albers Equal Area Conic coordinate system. For vector[6] datasets, a value was assigned to each feature by the project team to represent its spatial impact in GAAR. Some of the vector datasets had features with a range of values because of the data they represent; for example, under the condition of archaeological and historic sites measure, sites in fair condition were ranked with a value of 1, poor condition sites with a value of 2, and destroyed sites with a value of 3. The vector datasets were then converted to raster grids[7] whereby locations of the features or their associated effects were represented by the assigned values; unaffected areas of the wilderness (i.e. where no degradation occurs) were set to a value of 0.

The values for all raster grid layers were normalized[8] by stretching them to a standardized range of values (0–255). This normalized range of values allows datasets, and therefore measures, to be evaluated together on a common relative scale (Carver et al. 2008). For example, the noise from roads and travel time measures use different units (decibels vs. meters per second) and cannot be directly compared without normalization. Lower values of normalized measures were used to represent optimal conditions (i.e. no impact) and higher values to represent degraded conditions (i.e. high impact level).

In the following sections, the measures and datasets used are described for each of the five qualities of wilderness character for the baseline[9] and proposed Ambler Road maps. Measures are organized by their weight within each quality, with higher weighted measures listed first. For each measure included in this analysis, the specific data sources, processing, and cautions are also described. All datasets and measures used the units of the original data source(s); throughout this report, metric units (e.g. kilometers) and imperial units (e.g. miles) are used interchangeably. The maps represent a grid of values (approximately 3.25 million pixels at a 100 m resolution) and use a green-brown color ramp and the “minimum-maximum” stretch method[10] to enhance the color contrast; areas of optimal condition (no impact) are shown in green, while areas of degraded condition (high impact level) are shown in brown.

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[6] Vector data type uses points, lines, and polygons to represent features.

[7] Raster data type consists of rows and columns of cells, with each cell storing a single value.

[8] Normalization of measures was achieved using a linear rescaling of the input values (slicing) onto a 0–255 scale on an equal interval basis.

[9] Anaktuvuk Pass, a Nunamiut Inupiat village and surrounding village corporation lands lie within the boundaries of GAAR but are not managed by the NPS. Only lands managed by the NPS will be projected in these map products.

[10] The stretch method defines the type of histogram stretching that was applied to raster datasets to enhance their appearance. The minimum-maximum stretch applies a linear stretch on the output minimum and output maximum pixel values, which were used as endpoints for the histogram (ESRI 2016).

1. Baseline map of impacts to wilderness character

Untrammeled Quality

The untrammeled quality focuses on the degree to which wilderness is unhindered and free from modern human control or manipulation. The untrammeled quality is degraded by actions that intentionally manipulate or control ecological systems (in contrast to the natural quality, which is degraded by the *effects* of modern civilization) (Landres et al. 2015).

To spatially depict the baseline of impacts to the untrammeled quality in the GAAR wilderness, the project team provided a cumulative summary of all trammeling actions from 2010 to 2016.

Indicators and measures

Keeping it Wild 2 delineates two indicators under the untrammeled quality. The measures selected for the GAAR wilderness are described below for each of these indicators.

<u>Indicator: Actions authorized by the federal land manager that manipulate the biophysical environment</u>

- <u>Bear collaring</u> – Locations in GAAR where bears were captured and collared.
- <u>Non-native plant treatments</u> – Locations of non-native plant treatments within GAAR. To date there have been very few treatments, but this is expected to be an issue in the future and is a measure GAAR staff would like to monitor over time.

<u>Indicator: Actions not authorized by the federal land manager that manipulate the biophysical environment</u>

- None.

<u>Data gap measures</u>

Additional measures under this quality were identified by GAAR staff but were excluded for a variety of reasons. For each data gap measure, the indicator, description, and rationale for their dismissal are listed below.

Human-started fires

- *Indicator:* Actions not authorized by the federal land manager that manipulate the biophysical environment.
- *Description:* There have been only two human-started fires since 2010 (both on Native corporation land in the vicinity of Anaktuvuk Pass), and the previous four span from 1959 through 1993.
- *Rationale for dismissal:* All human-started fires occurred on lands not managed by the NPS.

Restrictions on subsistence opportunities

- *Indicator:* Actions authorized (and not authorized, i.e. policies dictated by State Game Management Units) by the federal land manager that manipulate the biophysical environment.

- *Description:* Locations where restrictions on subsistence opportunities exist. The project team asserted that subsistence activities are part of natural ecosystem processes, so any restrictions placed on subsistence constrains or manipulates these processes. GAAR sees any restriction on local residents' ability to pursue subsistence opportunities as a trammeling action.

- *Rationale for dismissal:* Could not determine how to measure this. The project team decided to pursue positive aspects of subsistence in Positive Features map, since we had pertinent data to inform that aspect of subsistence and its importance in GAAR.

Data sources, processing, and cautions

The datasets used to create the untrammeled quality map are all vector data, of fine scale, and generally of moderate to high accuracy and completeness (Table 1). The data sources, data processing information, and cautions are listed below for each measure.

Table 1. Untrammeled quality datasets. Accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the wilderness) were evaluated for each measure by GAAR staff familiar with these data.

Measure	Source	Type	Scale	Accuracy	Completeness
Bear collaring	BearCollaringPnts	Point	—	High	High
Non-native plant treatments	InvasivePlants	Polygon	—	High	High

<u>Bear collaring</u>

- *Sources:* Point dataset of locations where brown bears (Ursus arctos) where captured and collared from 2014 to 2016, generated from the bear collaring excel spreadsheet (Kyle Joly, GAAR Wildlife Biologist).

- *Processing:* Locations of bear collaring locations were assigned a value of 1. The layer was converted to raster and values were normalized to 0–255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. Original datasets were used to derive value-added products whose accuracy may differ from original datasets. All collars are scheduled to drop off in July 2017.

<u>Non-native plant treatments</u>

- *Sources:* Point dataset of treatment locations where NNIS treatments occurred from 2010 to 2016.

- *Processing:* Locations of non-native plant treatments were assigned a value of 1. The layer was converted to raster and values were normalized to 0–255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Weighting

The assigned weight (on a scale of 1 to 10) and the corresponding rationale for each measure under the untrammeled quality are described below (Table 2).

Table 2. Measure weights and rationales for the untrammeled quality.

Indicator	Measure	Weight	Rationale
Actions authorized by the federal land manager that manipulate the biophysical environment	Bear collaring	2	This action happens rarely. Wildlife biologists say it minimally affects the ecological patterns of wildlife.
	Non-native plant treatments	2	To date these actions have rarely occurred and have been relegated to several square feet of park land.

Maps

The weighted measures were added together using a raster calculator to create the untrammeled quality map (Figure 4).

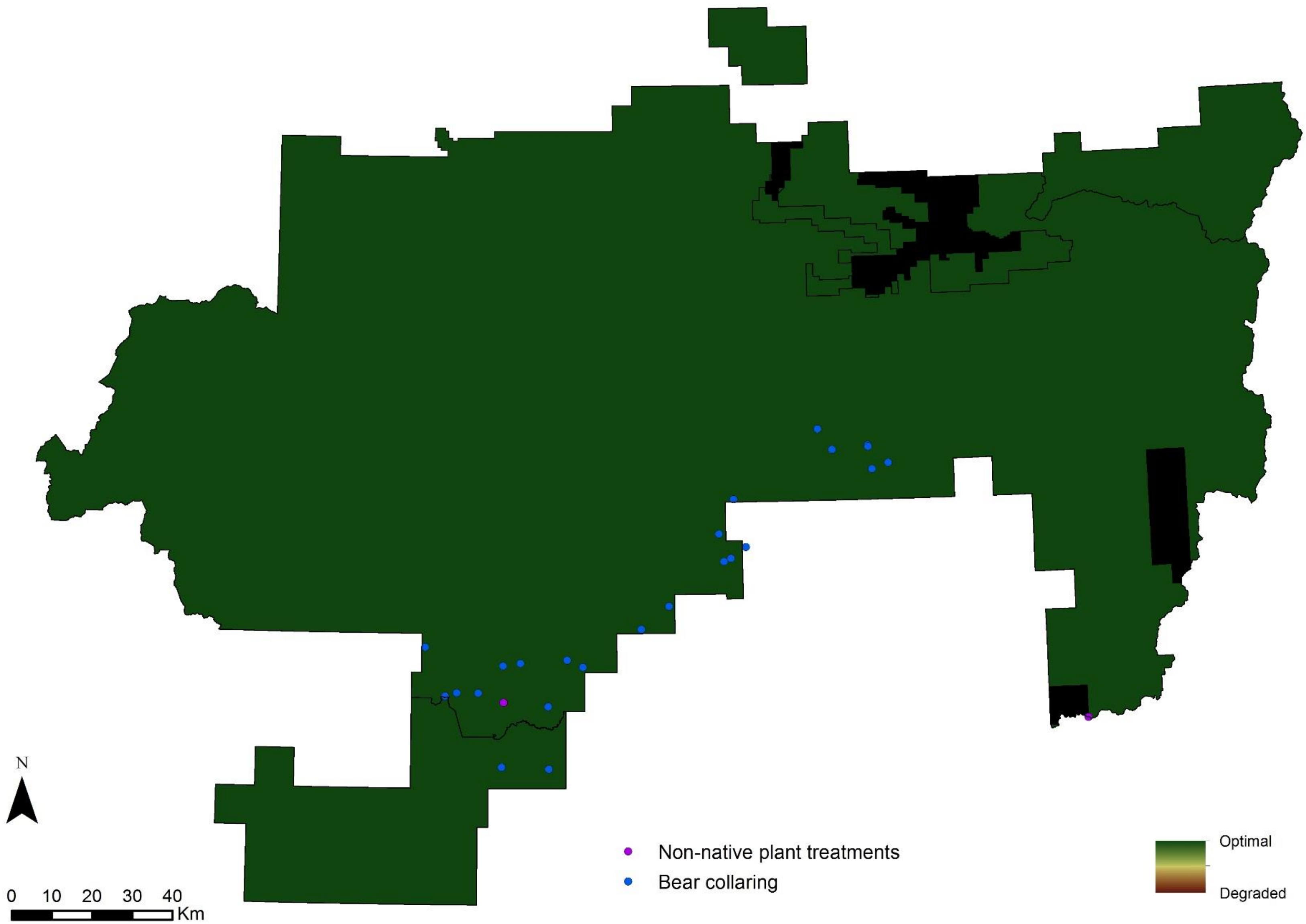

Figure 4. Map of the untrammeled quality of wilderness character. Green depicts optimal condition and brown depicts degraded condition.

Natural Quality

The natural quality centers on the idea that wilderness contains ecological systems that are substantially free from the effects of modern civilization. This quality is degraded by the intended or unintended effects of modern people on ecological systems inside wilderness (Landres et al. 2015).

Indicators and measures

Keeping it Wild 2 delineates four indicators under the natural quality, of which two were used for the baseline map. The measures selected for GAAR are described below for each of these indicators.

<u>Indicator: Air and water</u>

- <u>Contaminated sites</u> – Locations of sites where terrestrial industrial pollutants, contaminants and debris are present in GAAR.

<u>Data gap measures</u>

Additional measures under this quality were identified by GAAR staff but were excluded for a variety of reasons. For each data gap measure, the indicator, description, and rationale for their dismissal are listed below.

Air quality – wet/dry

- *Indicator:* Air and water.
- *Description:* For GAAR staff, dust was the biggest concern for both air and water quality. Air quality is a global measure that affects every single user, and GAAR staff wanted to be able to show changes to this quality over time. However, only one data point existed within the entire 8.5 million-acre area being mapped.
- *Rationale for dismissal:* Insufficient data exists for mapped area.

River and lake water quality

- *Indicator:* Air and water.
- *Description:* A project proposal was developed to collect data on 20 lakes and 57 rivers scattered throughout the Brooks Range. This information would have allowed GAAR staff to learn more about water quality in the park and determine if any changes in lake and river water quality could be attributed to human causes.
- *Rationale for dismissal:* The data for this proposed project did not get collected because the installation of water quality measurement devices was denied in order to preserve wilderness character.

Night sky

- *Indicator:* Air and water.
- *Description:* A baseline map of night sky could be used to show a significant change if the development of a mining district or road occurred adjacent to the park.

- *Rationale for dismissal:* No scalable data exists; there are continental and global models.

Woody vegetation advance

- *Indicator:* Ecological Processes.
- *Description:* Changes to vegetation patterns on a landscape scale such as woody vegetation advance are likely due to climate change.
- *Rationale for dismissal:* No data exists.

Condition of permafrost

- *Indicator:* Ecological processes.
- *Description:* Changes to permafrost layer due to climate change.
- *Rationale for dismissal:* Not enough data exists to determine the causes of changes to the permafrost layer. GAAR staff do not want to make unfounded assumptions about these changes.

Data sources, processing, and cautions

Only two datasets were used to create the natural quality map. These datasets included both vector and raster data and had medium to high levels of accuracy and completeness (Table 3). The data sources, data processing information, and cautions are listed below for each measure.

Table 3. Natural quality datasets. Accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the wilderness) were evaluated for each measure by GAAR staff familiar with these data.

Measure	Source	Type	Scale	Accuracy	Completeness
Contaminated sites	Contaminated_Sites_AK	Point	—	High	Medium

<u>Contaminated sites</u>

- *Sources:* Point dataset of contaminated sites in Alaska. (Jobe Chakuchin, GAAR NEPA Specialist & Park Planner)
- *Processing:* Dataset was clipped to the GAAR wilderness boundary and all active sites were selected and assigned a value of 1. The layer was converted to raster and values were normalized to 0–255.
- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Weighting

The assigned weight (on a scale of 1 to 10) and the corresponding rationale for each measure under the natural quality are described below (Table 4).

Table 4. Measure weights and rationales for the natural quality.

Indicator	Measure	Weight	Rationale
Air and water	Contaminated sites	4	Contaminated sites are serious threats to wilderness character but very few exist within the GAAR wilderness

Maps

The weighted measures were added together using a raster calculator to create the natural quality map (Figure 5).

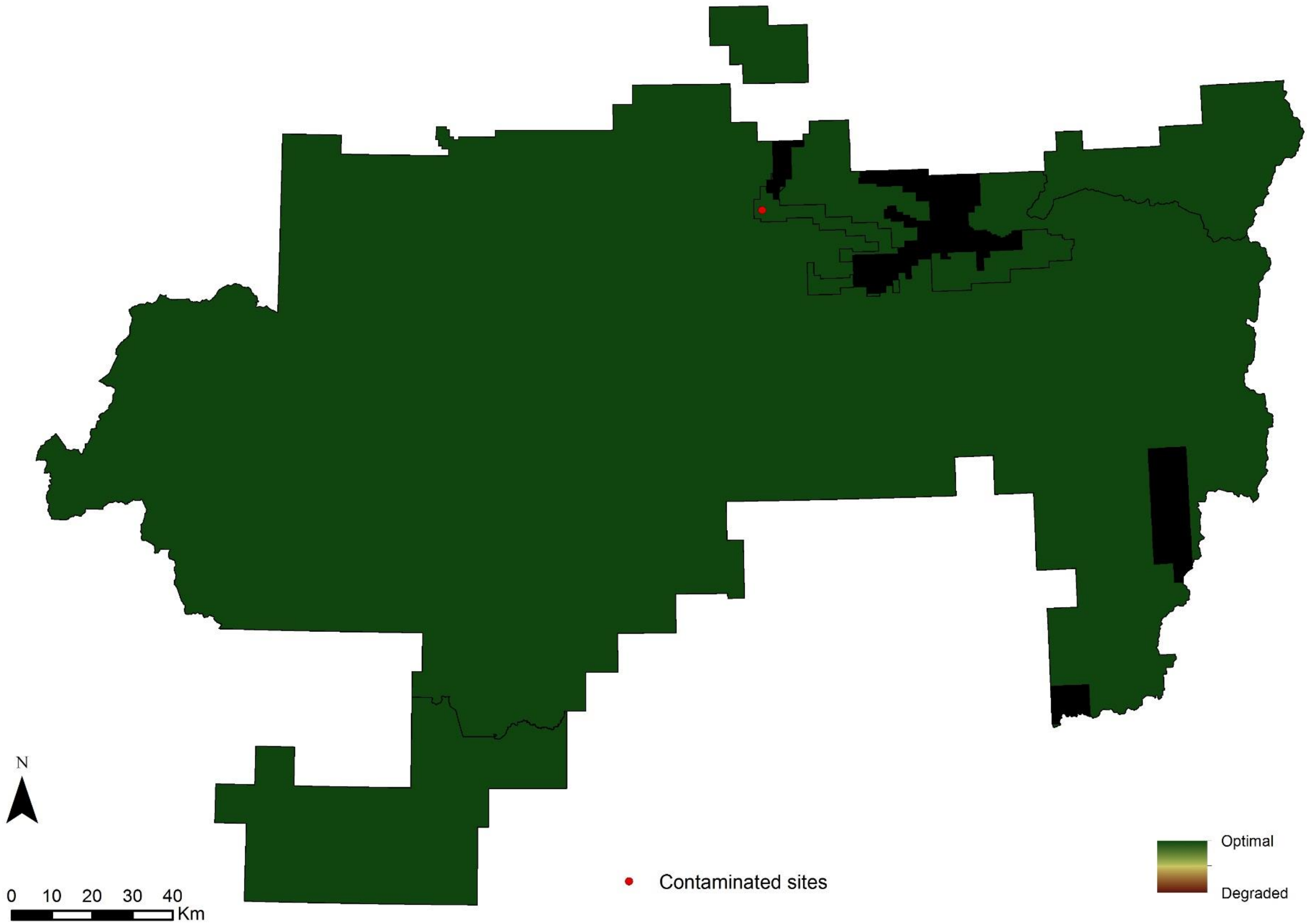

Figure 5. Map of the natural quality of wilderness character. Green depicts optimal condition and brown depicts degraded condition.

Undeveloped Quality

The undeveloped quality centers on the idea that wilderness is without permanent improvements or modern human occupation. This quality is degraded by the presence of structures and installations, as well as the use of motor vehicles, motorized equipment, and mechanical transport, because these increase people's ability to occupy or modify the environment (Landres et al. 2015).

Indicators and measures

Keeping it Wild 2 delineates three indicators under the undeveloped quality. The measures selected for the GAAR are described below for each of these indicators. No data gap measures were identified for this quality.

Indicator: Presence of non-recreational structures, installations, and developments

- Motorized use trails – Locations of motorized use trails on both federal lands and native corporation lands.
- NPS research installations – Locations of climate stations, stream monitoring stations and communications towers.
- NPS emergency use shelters – Locations of emergency use shelters throughout GAAR.
- Collared animals – Distribution of collared animals (specifically grizzly bear and caribou).

Indicator: Presence of inholdings

- Private inholdings – Locations of private inholdings subject to development.

Indicator: Use of motor vehicles, motorized equipment, or mechanical transport

- ATV motorized use – Impacts associated with the use of ATVs.
- Plane landing sites – Locations of bush plane landing sites on both land and water.

Data sources, processing, and cautions

The datasets used to create the undeveloped quality map are all vector data of fine scale, and generally high accuracy and completeness (Table 5). The data sources, data processing information, and cautions are listed below for each measure.

Table 5. Undeveloped quality datasets. Accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the wilderness) were evaluated for each measure by GAAR staff familiar with these data.

Measure	Source	Type	Scale	Accuracy	Completeness
Motorized use trails	GAAR_linear_features	Polyline	—	High	High
NPS research installations	NPS_Instrumentation_Installations	Point	—	High	High
NPS emergency use shelters	GAAR_NPS_Emergency_Shelters	Point	—	High	High
Collared animals	BearCollar_Locations; All_GAAR_Caribou	Point	—	High	High
Private inholdings	All_GAAR_Inholdings	Polygon	—	High	High
ATV motorized use	GAAR_linear_features	Polyline	—	High	High
Plane landing sites	Landing_Sites; National Hydrography Dataset	Point	—	High	Medium

Motorized use trails

- *Sources:* Polyline dataset of all linear features occurring in or adjacent to the GAAR wilderness (Andy Baltensperger, GAAR GIS Specialist; Tracy Asicksik, GAAR Resource Technician).
- *Processing:* Selected all features representing motorized use trails. Trails still in use regular use were assigned a value of 2 and trails no longer in use (i.e. the Hickel Highway) were assigned a value of 1. The layer was converted to raster and values were normalized to 0–255.
- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

NPS research installations

- *Sources:* Point dataset of NPS research installations (NPS Theme Manager).
- *Processing:* Locations of installations were assigned a value of 1. The layer was converted to raster and values were normalized to 0–255.
- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

NPS emergency use shelters

- *Sources:* Point dataset of NPS emergency use shelters (NPS Theme Manager).

- *Processing:* Locations of emergency use shelters were assigned a value of 1. The layer was converted to raster and values were normalized to 0–255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Collared animals

- *Sources:* Collar locations for bears (2014-2015; representing 57,332 locations from 19 collared individuals) and caribou (2010-2015; representing 24,128 locations from 94 collared individuals; Kyle Joly, GAAR Wildlife Biologist; Mathew Sorum, GAAR Wildlife Biologist).

- *Processing:* A density map was generated for each species using the Kernel Density[11] tool in ArcGIS. The output for each species was normalized to 0-255, added together in a raster calculator and then renormalized to 0-255.

- *Cautions:* The kernel density analysis was run using the default settings. A number of collar points were located outside the GAAR wilderness but were included in the analysis to avoid edge effects[12]. The information contained in these data is dynamic and may change over time. The data are not better than the original sources from which they were derived. All current bear collars are scheduled to drop off and be removed from GAAR in July 2017.

Private inholdings

- *Sources:* Polygon dataset of private inholdings (NPS Theme Manager).

- *Processing:* Locations of private inholdings were assigned a value of 1. The layer was converted to raster and values were normalized to 0–255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

ATV motorized use

- *Sources:* Polyline dataset of all linear features occurring in or adjacent to the GAAR wilderness (Andy Baltensperger, GAAR GIS Specialist; Tracy Asicksik, GAAR Resource Technician).

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[11] Kernel density calculates a magnitude-per-unit area from point features using a kernel function to fit a smoothly tapered surface to each point (ESRI 2016).

[12] A problem created during spatial analysis when patterns of interaction or interdependency across borders of the bounded region are ignored or distorted (ESRI 2016).

- *Processing:* All trails used for motorized use were assigned a value of 1. The layer was converted to raster and values were normalized to 0–255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Plane landing sites

- *Sources:* Point dataset of commonly used plane landing sites on gravel bars and water bodies (Scott Sample, GAAR Chief Ranger).

- *Processing:* Queried the point dataset to just depict water landings, and ran an intersect analysis to select all lakes (using National Hydrography Dataset [NHD] data) where water landings occur. Locations of landings (both gravel bars and lakes) were assigned a value of 1. The layer was converted to raster and values were normalized to 0–255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Weighting

The assigned weight (on a scale of 1 to 10) and the corresponding rationale for each measure under the undeveloped quality are described below (Table 6).

Table 6. Measure weights and rationales for the undeveloped quality.

Indicator	Measure	Weight	Rationale
Presence of non-recreational structures, installations, and developments	Motorized use trails	7	Motorized use trails have an obvious linear impact over large areas in GAAR and are therefore weighted highly.
	NPS research installations	6	Research installations are temporary features on the landscape but they moderately impact the Undeveloped quality.
	NPS emergency use shelters	4	NPS emergency use shelters impact the Undeveloped quality but are rare throughout GAAR.
	Collared animals	2	The project team determined that the impact of collared animals is minimal on a landscape scale within GAAR.
Presence of inholdings	Private inholdings	1	Private inholdings (not native allotments) have the potential for commercial development in the future. However, these inholdings are currently difficult to access and have not been commercially developed at this time, and so are weighted low.
Use of motor vehicles, motorized equipment, or mechanical transport	ATV motorized use	6	ATV use takes place mostly within the AKP Land Exchange boundary and thus is not weighted very heavily, though it does still have an impact on wilderness character.
	Plane landing sites	4	While planes landing within wilderness are a significant impact to wilderness character, this use is provided for in ANILCA and is seen as an essential way to access remote Alaskan parks.

Maps

The weighted measures were added together using a raster calculator to create the undeveloped quality map (Figure 6).

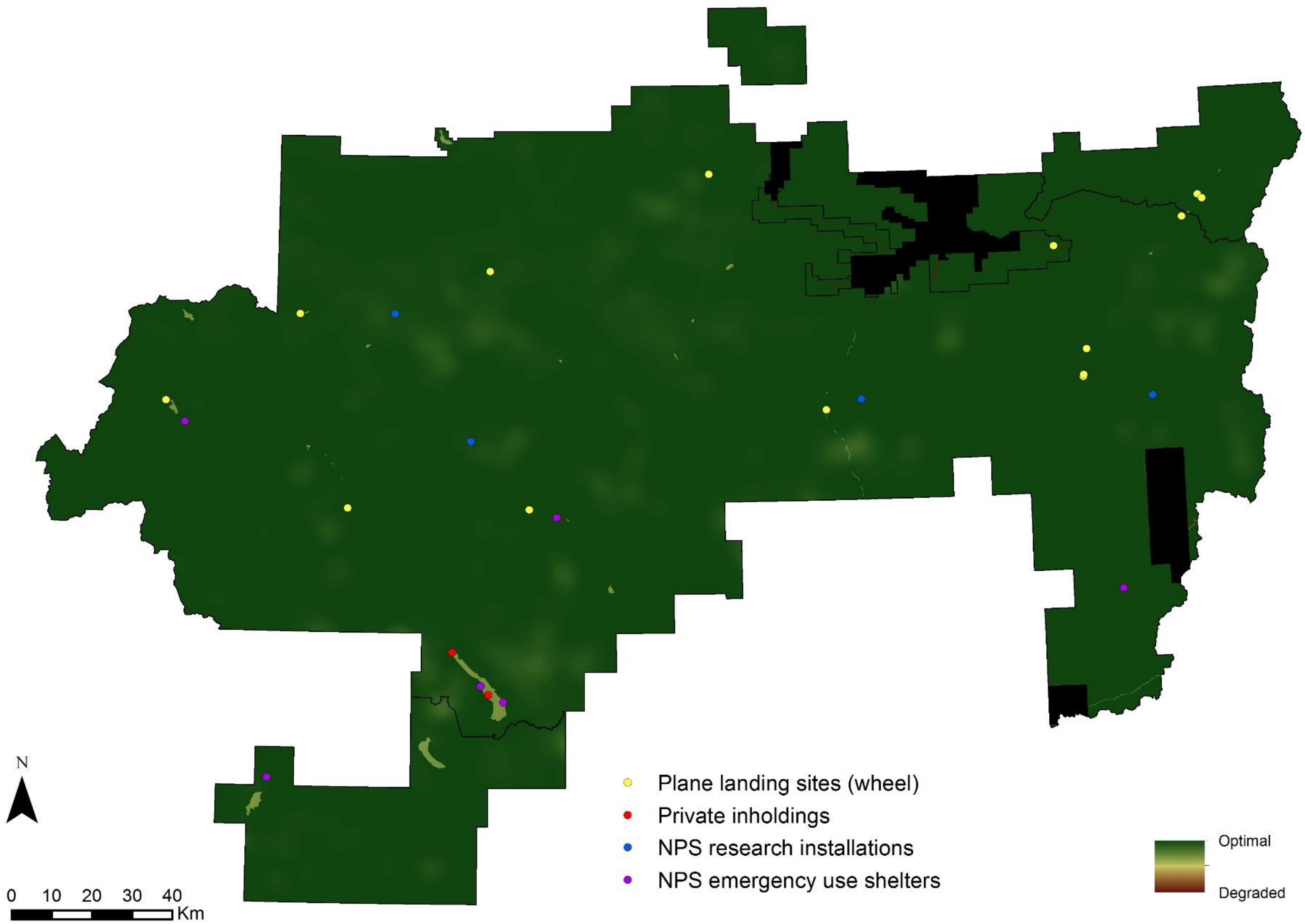

Figure 6. Map of the undeveloped quality of wilderness character. Green depicts optimal condition and brown depicts degraded condition.

Solitude or Primitive and Unconfined Recreation Quality

The solitude or primitive and unconfined recreation quality focuses on the outstanding opportunities that exist in wilderness to experience solitude, remoteness, and primitive recreation free from the constraints of modern society. This quality is degraded by tangible attributes of the setting that reduce these opportunities, such as visitor encounters, signs of modern civilization, recreation facilities, and management restriction on visitor behavior (Landres et al. 2015).

Indicators and measures

Keeping it Wild 2 delineates four indicators under the solitude or primitive and unconfined recreation quality of which three were used for the baseline map. The measures selected for the GAAR are described below for each of these indicators.

Indicator: Remoteness from sights and sounds of people inside the wilderness

- Features inside wilderness impacting viewshed – Viewshed impacts from developments located inside GAAR, including installations, cabins, and ATV trails.

- Travel time – This measure serves as a proxy for remoteness by calculating the time it takes a person of average fitness to travel across the landscape from various access points (Dalton Highway, Anaktuvuk Pass, and popular bush plane landing sites), taking into account cost surfaces[13] (elevation and land cover) and barrier features (steep ground and water).

Indicator: Remoteness from occupied and modified areas outside the wilderness

- Noise impacts from roads outside of wilderness – Noise impacts generated by a soundscape model based on Department of Transportation traffic data for the Dalton Highway.

- Noise impacts from overflights – Noise impacts generated by flights 1) servicing destinations inside the wilderness based on commercial bush flight itineraries, and 2) commercial flights over the GAAR wilderness based on Federal Aviation Administration (FAA) flight paths.

- Noise impacts from ATVs – Noise impacts inside GAAR from motorized use occurring outside the park.

- Features outside wilderness impacting viewshed – Viewshed impacts from developments outside GAAR, including the Dalton Highway, Anaktuvuk Pass Land Exchange Area, 17b easements[14], and travel corridors outside NPS lands.

Indicator: Facilities that decrease self-reliant recreation

- Cell phone coverage – Areas in the GAAR wilderness that have cell phone coverage.

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[13] Cost surfaces are used in surface modeling to establish the impedance for crossing each individual cell in a grid.

[14] Reserves easements across Native corporation land for access to public lands or major waterways.

- Social trails – No official trails exist in the GAAR wilderness but social trails do occur in certain areas from concentrated visitor use.

Data gap measures

Additional measures under this quality were identified by GAAR staff but were excluded for a variety of reasons. For each data gap measure, the indicator, description, and rationale for their dismissal are listed below.

Number of visitors, and locations of visitation

- *Indicator:* Remoteness from sights and sounds of people inside wilderness.
- *Description:* Number of visitors coming to GAAR and the locations to which they are traveling.
- *Rationale for dismissal:* GAAR does not currently collect this data. One possible way to begin collecting this data could be to survey CUA usage.

Visitor-created impacts

- *Indicator*: Remoteness from sights and sounds of people inside wilderness.
- *Description:* Visitor-generated campsite impacts and visitor-generated trash.
- *Rationale for dismissal:* Metadata on these data points was not consistent within the database that tracks these impacts, making it very difficult to interpret.

Data sources, processing, and cautions

A wide variety of data sources were used to create the solitude or primitive and unconfined recreation quality map. These datasets included both vector and raster data in a range of different scales and with high variability in accuracy and completeness (Table 7). The data sources, data processing information, and cautions are listed below for each measure.

Table 7. Solitude or primitive and unconfined recreation quality datasets. Accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the wilderness) were evaluated for each measure by GAAR staff familiar with these data.

Measure	Source	Type	Scale	Accuracy	Completeness
Viewshed inside	See Table 8.				
Travel time	(1) ARCN_ecotypes_2009; (2) Clip_Alaska_30meter_NED; (3) National Hydrography Dataset; (4) linear_features; (5) Plane_landing_sites	Raster, polyline & point	(1) (2) 30 m (3) 1:24,000 (4) (5)	—	—
Noise impacts from roads outside wilderness	Dalton1_public65_LAeq; Dalton2_public65_LAeq	Raster	100 m	High	High
Noise impacts from overflights	Bush_flight_Routes_Albers; FAA_Overflights	Polyline	—	Medium	Medium
Noise impacts from ATVs	GAAR_linear_features	Polyline	—	High	High
Viewshed outside	See Table 8.				
Cell phone coverage	FCC_Antenna_Structures	Point	—	Medium	High
Social trails	GAAR_linear_features	Polyline	—	Medium	High

Viewshed inside wilderness and viewshed outside wilderness

The line of sight visual impacts of modern anthropogenic features inside and outside the GAAR wilderness were modeled using a custom-built software tool. This tool analyzed a variety of inputs—including terrain, land cover, road networks, and all modern human developments occurring in and around the wilderness—to delineate the impacts of modern human features on visitor solitude. To account for edge effects[15] from visible human features immediately outside the wilderness boundary, the viewshed analysis was extended into a 15 km buffer zone around the wilderness.

Viewshed analyses such as these have traditionally been extremely costly in terms of computer processing time. Detailed analyses can take weeks, months, or even years to process depending on the number of anthropogenic features in the database. Previous work on the effects of human features on perceptions of wilderness, carried out at national and global scales, has focused on simple distance measures (Lesslie 1993; Carver 1996; Sanderson et al. 2002). Recent improvements to viewshed modelling algorithms have utilized measures of the visibility of anthropogenic features in 3D landscapes using digital terrain models[16] (Fritz et al. 2000; Carver and Wrightham 2003). These

[15] A problem created during spatial analysis when patterns of interaction or interdependency across borders of the bounded region are ignored or distorted (ESRI 2015).

[16] Digital terrain models are 3D representations of the earth's surface that contain elevation data.

algorithms calculate the line of sight between a person standing anywhere on a landscape and a particular feature (e.g. a building or radio antennae), and account for places where this line of sight is interrupted by intervening higher ground.

Incorporating these improvements, Washtell (2007) has shown that it is possible to both dramatically decrease processing times and improve overall accuracy through judicious use of a voxel-based landscape model[17] and a highly optimized ray-casting algorithm. This algorithm, which is similar to those used in real-time rendering applications and in some computer games, was designed to perform hundreds of traditional point viewshed operations per second. By integrating this approach into a custom-built software tool that has been designed to work directly with GIS data, it is possible to estimate the visibility between every pair of cells in a high-resolution landscape model utilizing only moderate computing resources. With this approach (called a "viewshed transform") an inverse square distance function is used in calculating the significance of visible cells. Put simply, this tool determines the relative viewshed value for each cell by calculating the proportion of the features that can be seen and the distance between the cell and the particular features. Thus, the smaller the proportion of the feature in view and the further away it is, the lower the viewshed value for the particular cell. The greater the proportion of the feature in view and the closer it is, the higher the viewshed value of the particular cell.

In summary, the approach described above represents a maturation of traditional cumulative viewshed techniques (Carver et al. 2008) and is used to:

1. Calculate the viewshed for every single feature.
2. Incorporate estimations of the proportional area of each feature that is visible.
3. Run separate viewshed calculations for categories of features with different viewshed distances, which can then be combined together to create overall viewshed maps.

Sources: The viewshed transform tool was used to conduct the viewshed analyses for modern human features inside and outside the GAAR wilderness. Viewshed analyses rely on the ability to calculate the line of sight from one point on a landscape to another. It has been shown that the accuracy of a viewshed analysis produced in GIS is strongly dependent on the accuracy of the terrain model used and the inclusion of intervening features or "terrain clutter" (Fisher 1993). While previous studies have made use of a digital surface model (DSM)[18] for obtaining terrain clutter data (Carver et al. 2008), the large spatial extent of the GAAR wilderness and the relative lack of anthropogenic features allows feature information to be collated and formatted manually. A resolution of 30 m for feature inputs was considered adequate for this analysis. The USGS 30 m Digital Elevation Model (DEM) provides the base terrain elevation data. The DEM was then augmented with surface data,

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[17] A voxel is a volumetric pixel.

[18] Digital surface models are a type of terrain model that include objects on the surface of the earth, such as buildings, vegetation, or other features.

including both land cover data and anthropogenic features. The land cover data were created by assigning heights (provided by David Swanson, GAAR Terrestrial Ecologist) to the different classes in the original land cover dataset. Modern anthropogenic features in and adjacent to the GAAR wilderness were identified by the project team; viewshed distance and height information were then assigned for each feature (Table 8).

Processing: Two data inputs are required for the viewshed model: (1) a terrain layer and (2) a viewshed feature layer. The terrain layer is a model of the environment being analyzed. The feature layer is used to identify the features being analyzed in the terrain model and sets their associated viewshed distances.

The major processing tasks performed for the terrain layer are summarized chronologically below:

1. The height values for the USGS 30 m DEM were converted from feet to meters.

2. The height information for different vegetation types was related to the land cover dataset.

3. All viewshed features (listed in Table 8) were converted to raster at 30 m, setting the pixel values to the height information.

4. The viewshed features were combined together using the MOSAIC TO NEW RASTER tool. The mosaic priority order was set from the tallest features to the shortest (such that taller features are given priority when features overlap).

5. The combined viewshed features were added to the land cover raster using the MOSAIC TO NEW RASTER tool, giving priority to the viewshed features (such that features always override the land cover heights wherever they occur).

6. The above raster was added to the DEM using a raster calculator.

7. The raster was converted to a floating point grid (as required by the viewshed software).

The major processing tasks performed for the viewshed feature layer are summarized chronologically below:

1. All viewshed features (listed in Table 8) were converted to raster at 30 m, setting the pixel values to the height information.

2. The viewshed features were combined together for each viewshed distance category (1 km and 15 km) using the MOSAIC TO NEW RASTER tool.

3. Each of the rasters for the viewshed distance categories was converted to a floating point grid (as required by the viewshed software).

The software was used to analyze the viewshed distance categories for both features inside wilderness (1 km) and features outside wilderness (15 km) (see Table 8). When necessary for the analysis of a distance category, the viewshed landscape was split into a number of overlapping tiles such that they could be simultaneously analyzed by a cluster of desktop computers.

The model outputs for the different viewshed distances were combined together using the MINIMUM function in the MOSAIC TO NEW RASTER tool to produce grids of viewshed impacts for features inside and adjacent to the wilderness. Raster values were normalized to 0–255. The normalized values were then inverted to reflect high degradation of solitude near human features and lower degradation further away from those features (Figure 7).

Cautions: The viewshed model replicates the natural environment using a number of rules and compromises. While necessary for the purposes of this analysis, these compromises should be carefully considered when discussing results.

1. For this analysis, a "pessimistic" re-sampling was done to generate the 30 m feature inputs guaranteeing that features smaller than this area were included[19] and that the viewsheds produced an accurate representation of the visual impacts of these features.

2. Categorizing the anthropogenic features in and adjacent to the GAAR wilderness into specific viewshed distances requires careful consideration as to how well each type of feature may blend in with the local background. For example, emergency cabins are largely unnoticeable at a distance because of their small size and how well they blend into the landscape; they were therefore assigned a maximum viewshed distance of 1 km. Larger and more prominent features, such as roads or the community of Anaktuvuk Pass, were assigned a maximum viewshed distance of 15 km.

3. The viewshed analysis may not realistically represent certain re-sampled feature inputs and instead emphasizes worst case scenarios. For example, road traffic on the proposed road corridors are represented in the model as a solid 5 m high continuous "wall", even though road traffic would only occur along the road at a rate of 12 vehicles an hour.

4. The current version of the viewshed tool places the "person" in the analysis on top of all the viewshed features (such as vegetation or buildings), as opposed to placing them in among those features. Areas where the vegetation exceeds 3 m must therefore be removed manually from the output. This limitation is being addressed for future versions of the software.

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[19] Re-sampling of feature layers in GIS is normally carried out on a "majority class" basis wherein the value of a grid cell takes on the value of the largest feature by area that it contains. Using this rule, a 10 x 10 m building in a 30 x 30 m grid cell that was otherwise not classified as a feature would not be recorded on re-sampling. The "pessimistic" re-sampling used here operates on presence/absence basis such that any grid cell containing a human feature will be classified as such even though the actual area or footprint of the feature may not cover the majority of the grid cell.

Table 8. Modern human features impacting viewshed.

Measure	Data source	Viewshed distance (km)	Height (m)	Accuracy	Completeness
Features INSIDE wilderness					
NPS emergency use cabins	GAAR_NPS_Emergency_Shelters	1	4	High	High
NPS research stations	NPS_Instrumentation_Installations	1	3	High	High
ATV trails	GAAR_linear_features	1	1	High	High
Historic structures	GAAR_historic_structures	1	3	High	High
Features OUTSIDE wilderness					
Dalton highway	GAAR_linear_features	15	5	High	High
Trans-Alaska Oil Pipeline	GAAR_linear_features	15	5	High	High
Anaktuvuk Pass buildings and infrastructure	GAAR_linear_features	15	5	High	High

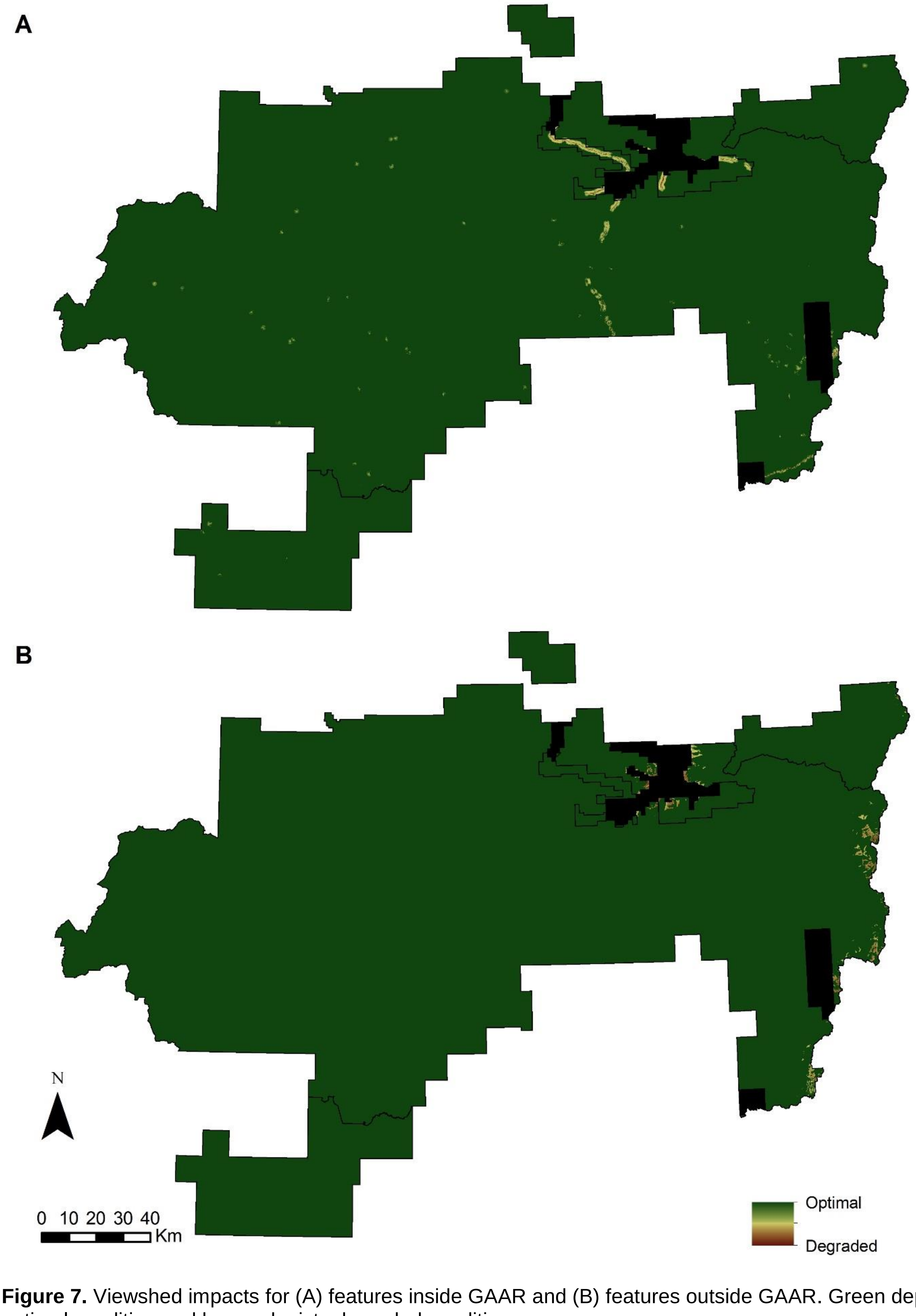

Figure 7. Viewshed impacts for (A) features inside GAAR and (B) features outside GAAR. Green depicts optimal condition and brown depicts degraded condition.

Travel time

Travel time was modeled for the GAAR wilderness based on a GIS implementation of Naismith's Rule[20], with Langmuir's correction[21]. Terrain and land cover information were used to delineate the relative time necessary to walk into a roadless area from the nearest point of legal motorized access, taking into account the effects of distance, relative slope, ground cover, and barrier features such as very steep ground. The travel time (or "remoteness") model, developed by Carver and Fritz (1999), assumes a person can walk at a speed of 5 km/hr over flat terrain and adds a time penalty of 30 minutes for every 300m of ascent and 10 minutes for every 300m of descent for slopes greater than 12 degrees. When descending slopes between 5 and 12 degrees, a time bonus of 10 minutes is subtracted for every 300m of descent. Slopes between 0 and 5 degrees are assumed to be flat. The angle at which terrain is crossed (i.e., the horizontal and vertical relative moving angles[22]) was used to determine the relative slope and height lost/gained. These values are input into the model using a simple lookup table as shown in Table 9. Ancillary data layers were used to modify walking speeds according to ground cover (e.g., Naismith's 5 km per hour on the map can be reduced to 1 km per hour or less when walking through dense vegetation). They also include barrier features that force a detour as "null" values[23]. Finally, to account for edge effects[24] from access outside the wilderness boundary, the travel time analysis was extended into a 15 kilometers (km) buffer zone around the wilderness.

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[20] Naismith's Rule is a simple formula that helps to plan a hiking expedition by calculating how long it will take to walk the route, including ascents. Devised by Scottish mountaineer, William Naismith, the basic rule states: "Allow…an hour for every three miles on the map, with an additional hour for every 2,000 feet of ascent" (1892: 136).

[21] Langmuir's correction acknowledges the need to descend slowly in steep terrain as it is necessary to take shorter steps, or reduce slope angle and extend path length by zig-zagging.

[22] Vertical and horizontal factors determine the difficulty of moving from one cell to another while accounting for vertical or horizontal elements that affect movement. These include slope and aspect as they determine the relative angle of the slope in the direction traveled and hence the elevation gained or lost.

[23] NoData or null values in a raster grid contain no data and so are disregarded in most calculations unless the model explicitly references these. NoData values are useful in building access models in that they can be used to describe the location of barrier features that cannot be crossed.

[24] A problem created during spatial analysis when patterns of interaction or interdependency across borders of the bounded region are ignored or distorted (ESRI 2015).

Table 9. Naismith's Rule expressed in the vertical relative moving angle (VRMA) field.

VRMA (Degrees)	Vertical Factor
-40	2.40
-30	1.87
-20	1.45
-12	0.29
-11	0.33
-10	0.37
-9	0.44
-8	0.47
-6	0.51
-5	0.72
0	0.72
10	1.78
20	2.90
30	4.19
40	5.75

Sources: Calculating travel time based on Naismith's rule requires a range of data including a detailed terrain model, land cover data, and information on the location of barrier features, roads, and other access features. The USGS 30 m Digital Elevation Model (DEM) provided the terrain elevation data, the ARCN ecotypes 2009 dataset provided the land cover data, and the USGS National Hydrologic Dataset (NHD) provided the hydrology data. All other datasets, including road and plane access, were provided by GAAR.

Processing: A macro program implementing the PATHDISTANCE function in ArcGIS is used to model Naismith's rule. This estimates walking speeds based on relative horizontal and vertical moving angles across the terrain surface together with appropriate cost or weight factors incurred by crossing different land cover types and the effects of barrier features. The model is applied using the following conditions:

1. *Source grid:* The Dalton Highway (outside the wilderness) and plane landing sites (inside the wilderness) provide access to the GAAR wilderness.
2. *Cost surface:* Travel speeds were assigned to the different land cover classes to represent vegetation impedance across the GAAR wilderness. Alder and willow tall shrub were considered the most difficult vegetation type to travel through and was assigned a walking speed of 1 km/hr. Conversely, dwarf shrub and partially vegetated areas were considered the

easiest vegetation types to travel through and were assigned a walking seed of 5 km/hr. For a full list of land cover impedance values that represent off-trail travel, see Appendix A. Finally, rivers were integrated into the cost surface to represent both decreased travel speeds when crossing rivers on foot (small rivers were coded to take 7.5 minutes to cross and large rivers to take 30min to cross) and increased speeds when floating rivers (8 km/hr).

3. *Barriers to movement:* These are areas in GAAR that are considered impassable on foot and include all lakes and any areas where slope angles exceed 40 degrees. The barrier features are coded as NoData (null values) in the cost surface, which forces the model to seek a solution that involves walking around the obstacle.

Because of the difficulty in coding rivers to provide both impedance values for crossing on foot and increased speeds for floating in watercraft, road access and plane access (representing river trips) analyses were run separately and the output grids were combined together using the MINIMUM function in the MOSAIC TO NEW RASTER tool. Raster values were then normalized to 0-255. The normalized values were inverted to reflect high degradation of solitude values near access points, and lower degradation further away from these features (Figure 8).

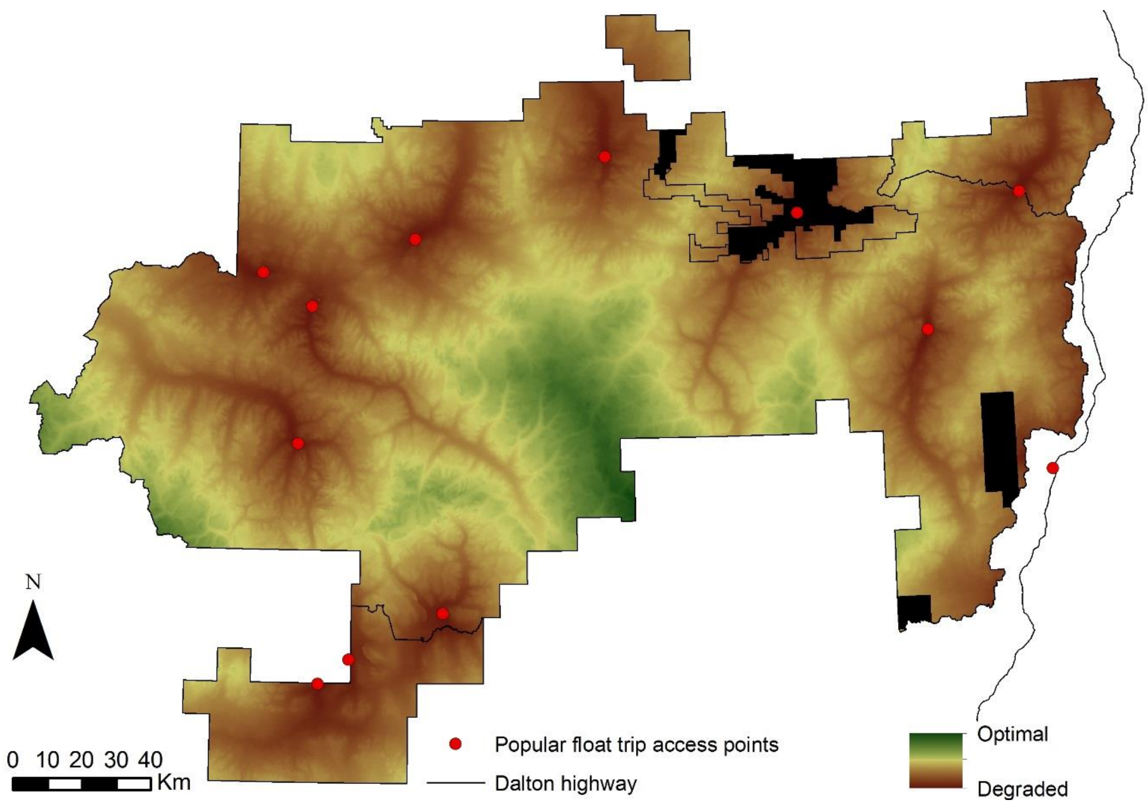

Figure 8. Travel time model. Green depicts optimal condition and brown depicts degraded condition.

Noise impacts from roads outside of wilderness

- *Sources:* Raster datasets depicting road related noise impacts from the Dalton Highway. For more information on how these dataset were generated see Appendix A

- *Processing:* The road noise grids were combined together using the MAXIMUM[25] function in ArcGIS. Ambient noise was removed by reclassing all negative values to 0. Grid values were normalized to 0-255.

- *Cautions:* Documentation within ISO 9613-2:1996 gives limits on the error of the model based on two factors, the mean height between source and receiver, *h*, and the distance between the source and receiver, *d*. Error in any grid cell is ± 1 dB when *d* is less than 100 m and *h* is greater than 5 meters but less than 30 meters. For other situations such that d is less than 1000 meters and h is less than 30 meters, the error is ± 3 dB. The standard does not define error values when d is greater than 1000 meters or h is greater than 30 meters, but they are greater than ± 3 dB.

    - All acoustical calculations were conducted according to ISO 9613-2:1996 *'Acoustics -- Attenuation of sound during propagation outdoors -- Part 2: General method of calculation'*.

    Documentation within ISO 9613-2:1996 suggests the following error range (adapted from table 5):

Height (h) *	**Distance (d) between source and receiver**	
	0 m < d < 100 m	*100 m < d < 1000 m*
0 m < d < 5 m	± 3 dB	± 3 dB
5 m < d < 30 m	± 1 dB	± 3 dB

    * Mean height of source and receiver.

    Data for traffic inputs were based off of State of Alaska and NPS observations on the Dalton Highway. The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Noise impacts from overflights

- *Sources:* Polyline dataset depicting 1) direct and low elevation[26] bush flights to destinations inside the GAAR wilderness (Scott Sample, GAAR Chief Ranger), and 2) Polyline dataset

[25] The output cell value of the overlapping areas will be the maximum value of the overlapping cells.

depicting low and high elevation commercial flight paths above the GAAR wilderness (NPS Theme Manager).

- *Processing:* Flight paths for the different types of overflights were assigned the following values:

    - VFR (visual flight reconnaissance) bush flights – 4
    - Straight line bush flights – 3
    - Low elevation commercial flights – 2
    - High elevation commercial flights – 1

  A density map was generated for the flight paths using the Line Density[27] tool in ArcGIS. The search radius was set to 10 km and the population field was used to add model bias to flights with a higher noise impact. The output values were normalized to 0-255.

- *Cautions:* The 10 km search radius was suggested by Davyd Betchkal (Alaska Region Soundscape Specialist) based on his experience of monitoring Alaskan bush flights. The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

<u>Noise impacts from ATVs</u>

- *Sources:* Polyline dataset of all linear features occurring in or adjacent to the GAAR wilderness (Andy Baltensperger, GAAR GIS Specialist; Tracy Asicksik, GAAR Resource Technician).

- *Processing:* All features representing current ATV use were selected. ATV trails were buffered to 1 km to account for the distance sounds travels over the landscape. The buffered ATV trails were assigned a value of 1. The layer was converted to raster and values were normalized to 0-255.

- *Cautions:* The buffer distance was determined by input from several GAAR staff who are familiar with the areas where ATV use occurs. The information contained in these data is

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[26] Lower elevation bush flights occur when meteorological conditions prevent pilots from flying directly to a destination. Therefore, the pilot must operate the aircraft with visual reference to the ground (i.e. flying through valleys), and by visually avoiding obstructions and other aircraft (Section 91.155 14 CFR Part 91 - General Operating and Flight Rules - FAA).

[27] Line density calculates a magnitude-per-unit area from polyline features that fall within a radius around each cell (ESRI 2016).

current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Cell phone coverage

- *Sources:* Point dataset depicting the location of the cell tower at Anaktuvuk Pass. The viewshed tool was utilized to identify areas inside the wilderness that Anaktuvuk Pass cell tower can be 'viewed' from. The output serves as a proxy for areas of available cellular service, i.e. cell coverage is determined by line of sight, and is impeded by topography (NPS Theme Manager).

- *Processing:* The 11.9 m high Anaktuvuk Pass cell tower was evaluated in the viewshed model to a maximum distance of 15 km. The output area was reclassed to 1 then normalized to 0-255.

- *Cautions:* The decision to use the line of sight analysis was based on the experiences GAAR staff observing cellular coverage on their phones in and around Anaktuvuk Pass. Generally speaking, staff were unable to receive cellular service if their line of sight to Anaktuvuk Pass was obscured by topography.

Social trails

- *Sources:* Polyline dataset of all linear features occurring in or adjacent to the GAAR wilderness (Bob Maurer, GAAR Backcountry Ranger; Al Smith, GAAR Backcountry Ranger).

- *Processing:* All features representing social trails were selected. Social trails with regular use were assigned a value of 2, and social trails no longer in use were assigned a value of 1. The layer was converted to raster and values were normalized to 0-255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Weighting

The assigned weight (on a scale of 1 to 10) and the corresponding rationale for each measure under the solitude or primitive and unconfined recreation quality are described below (Table 10).

Table 10. Measure weights and rationales for the solitude or primitive and unconfined recreation quality.

Indicator	Measure	Weight	Rationale
Remoteness from sights and sounds of people inside the wilderness	Viewshed inside	6	The visibility of modern human features that lie within wilderness has a moderate impact on wilderness character within GAAR.
	Travel time	5	Visitor expectations for solitude in GAAR increase with the amount of time and effort it takes to reach a certain location on foot. However, because GAAR is so big and remote, it is often accessed by air, making the travel time measure less weighty in terms of conveying expectations for solitude in GAAR.
Remoteness from occupied and modified areas outside the wilderness	Noise impacts from roads	8	Noise from adjacent roads has a significant impact on the solitude quality.
	Noise impacts from overflights	8	The presence of overflights removes the sense of isolation and disconnectedness from modern civilization.
	Noise impacts from ATVs	7	Motorized use for accessing inholdings and for traditional uses (i.e. subsistence) is provided for in ANILCA but is a non-conforming activity that has a moderate impact on the Solitude quality.
	Viewshed outside	6	The visibility of modern human features that lie outside the wilderness have a moderate impact on wilderness character within GAAR.
Facilities that decrease self-reliant recreation	Cell phone coverage	9	Cell phone coverage decreases self-reliance significantly.
	Social trails	3	Social trails decrease self-reliance but they are rare in GAAR and often originate from animal paths.

Maps

The weighted measures were added together using a raster calculator to create the solitude or primitive and unconfined recreation quality map (Figure 9).

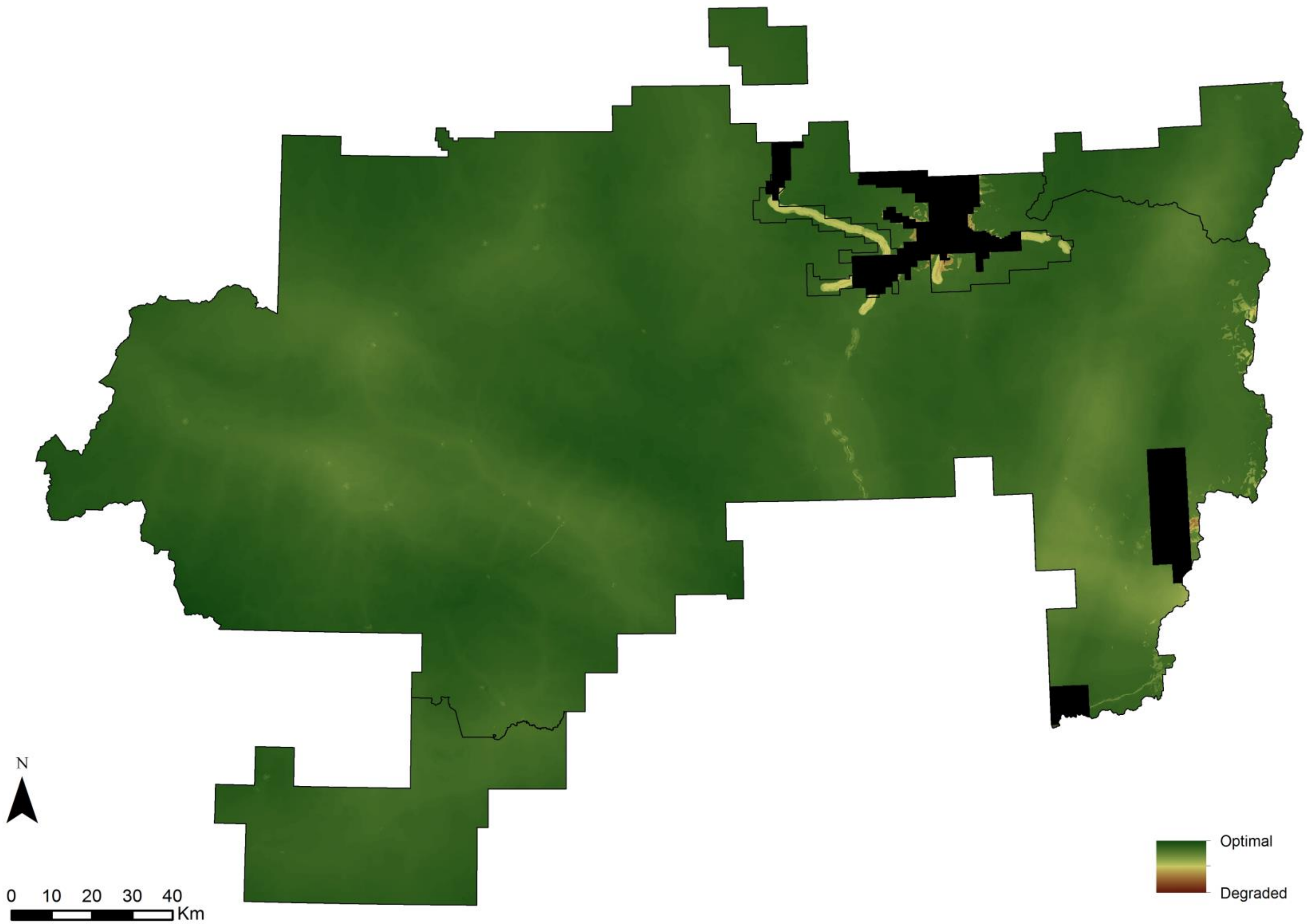

Figure 9. Map of the solitude or primitive and unconfined recreation quality of wilderness character. Green depicts optimal condition and brown depicts degraded condition.

Other Features of Value Quality

The other features of value quality centers on unique and tangible features of a wilderness that are integral to the wilderness character of that place. These features may include cultural resource sites, paleontological sites, or any other features not included under the other four qualities that have ecological, geological, scientific, educational, scenic, or historical value (Landres et al. 2012; Landres et al. 2015). This quality is degraded by loss or damage to other features integral to wilderness character.

Indicators and measures

Keeping it Wild 2 delineates two indicators under the other features of value quality, of which one was used for the baseline map. The measure selected for the GAAR wilderness is described below.

<u>Indicator: Deterioration or loss of integral cultural features</u>

- <u>Condition of archaeological and historic sites</u> - These sites hold intrinsic value and preserve cultural knowledge important to the history of American people.

<u>Data gap measures</u>

Additional measures under this quality were identified by GAAR staff but were excluded for a variety of reasons. For each data gap measure, the indicator, description, and rationale for their dismissal are listed below.

Documentation of place names and associated cultural place-based knowledge

- *Indicator*: Prehistoric cultural resources integral to wilderness.
- *Description:* Traditional place names represent very long-term connections between people and places and resources in the park, and they document intimate and detailed familiarity and knowledge about resources, natural features, and places of cultural significance. This knowledge represents a thing of high value in a wilderness character context, however the transfer of this knowledge from old to new generations is occurring less frequently in recent decades and this loss of knowledge can be seen as a degradation to wilderness character.
- *Rationale for dismissal:* The project team could not represent the degradation of this knowledge, only the positive documentation of this knowledge. Therefore, the project team decided to exclude this measure from the baseline threats map and instead show the proliferation of this knowledge as a positive measure on the positive features map.

Condition of Reed River Hot Spring

- *Indicator:* Deterioration or loss of integral geological or paleontological features.
- *Description:* This is a unique and likely sensitive geothermal feature within GAAR. Impacts to this important geological feature could occur due to visitor use, impacts to plants and impacts to water quality.
- *Rationale for dismissal:* While GAAR staff recognize this is a unique feature, there is little detailed data on the condition of the hot spring and its surroundings. It is also a single,

relatively small area within a massive park and would have limited value as an indicator of broad, landscape-scale trends. This is potentially a topic for future research.

Condition of Fen System at Nutuvukti Lake

- *Indicator:* Deterioration or loss of integral geological or paleontological features.
- *Description:* The fen system is a unique hydrological feature in GAAR.
- *Rationale for dismissal:* While GAAR staff recognize this is a unique feature, there is little data on the condition of the fen system at Nutuvukti Lake, making it difficult to quantify as an indicator.

Data sources, processing, and cautions

The other features of value quality utilizes one vector dataset, of fine scale, with a medium accuracy and high completeness (Table 11). The data sources, data processing information, and cautions are listed below for each measure.

Table 11. Other features of value quality datasets. Accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the wilderness) were evaluated for each measure by GAAR staff familiar with these data.

Measure	Source	Type	Scale	Accuracy	Completeness
Condition of archaeological and historic sites	ArchSite_Condition	Point	—	Medium	High

<u>Condition of archaeological and historic sites</u>

- *Sources:* Point dataset of archaeological and historic sites.
- *Processing:* The condition rankings used for assessing each site were assigned the following values:
  - Fair = 1
  - Poor = 2
  - Destroyed = 3

  The layer was converted to raster and values were normalized to 0-255.
- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Weighting

The assigned weight (on a scale of 1 to 10) and the corresponding rationale for each measure under the other features of value quality are described below (Table 12).

Table 12. Measure weights and rationales for the other features of quality.

Indicator	Measure	Weight	Rationale
Deterioration or loss of integral cultural features	Condition of archaeological and historic sites	5	These sites are especially significant in GAAR as they preserve a concrete link to the history of people upon this landscape.

Maps

The single weighted measure serves as the other features of value quality map (Figure 10).

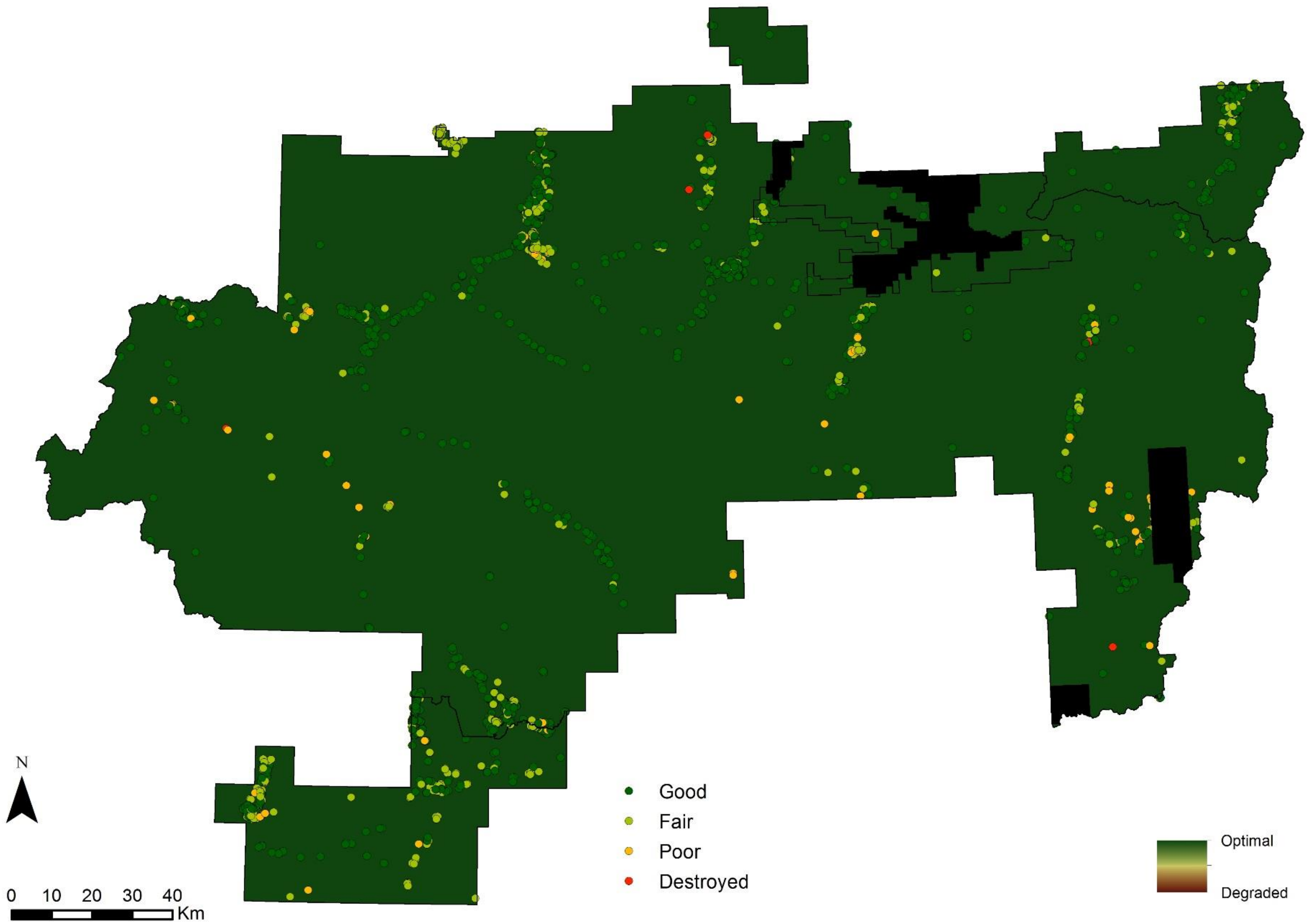

Figure 10. Map of the other features of value quality of wilderness character. Green depicts optimal condition and brown depicts degraded condition.

Discussion for baseline map of impacts to wilderness character

Interpreting the map products generated by this project requires a clear understanding of the methods that were used and their associated limitations. For example, the map for the solitude or primitive and unconfined recreation quality used both vector and continuous raster data sources and is distinctly different in appearance from the maps for the other qualities that only used vector data sources. In addition, it is important to bear in mind that the maps were generated through the analysis of a multitude of datasets: to understand why certain areas are degraded one must "drill down" into the individual qualities, indicators, and measures.

The methodology described in the previous sections produced maps for each of the 21 weighted measures; these were then added together accumulatively to produce a single map of impacts to wilderness character in GAAR (Figure 11). The map of impacts to wilderness character represents a grid of values (approximately 3.3 million pixels at a 100 m resolution), and uses a green-brown color ramp and the "minimum-maximum" stretching technique to best represent those values for display and discussion. An equal interval reclassification[28] of the overall map was performed to transform the range of values for all pixels onto a scale of 0 (most degraded condition, highest cumulative impact level from all measures) to 100 (optimal condition, no impacts to wilderness character). These values were then split into ten equal categories (i.e. 0-10, 11-20, 21-30, etc.) to clearly emphasize the variation in the magnitude of impacts to wilderness character across the GAAR wilderness (Figure 12).

The histogram of the distribution of pixel values (Figure 13) indicates that over 98% of the pixels fall within the top 2 categories (81-90 and 91-100), signifying that the majority of the park has very high quality wilderness character that has not been substantially impacted by degradations. On the map, the highest category (91-100) covers areas of the park that receive little to no visitation, and are rarely impacted by low flying bush flights. The second largest category (81-90) covers river drainages that are typically floated by visitors, and areas of the park that provide "walk in" access (Anaktuvuk Pass and the Dalton Highway). These river drainages are also impacted by bush planes dropping off or picking up visitors for float trips or commercial flights servicing native villages. The third largest category (71-80) includes small pockets of landscape in the south east of the park that are affected by air planes taking off from Bettles and Coldfoot airports, lakes and gravel bars that are frequently used for dropping off or picking up visitors for floating or hiking trips, and areas in the east of the park with viewshed impacts from the Dalton Highway. The majority of the remaining categories represent impacted areas surrounding Anaktuvuk Pass, from either the viewshed impacts of the village itself, or from the presence and use of ATV trails (and the associated soundscape and viewshed impacts) both on or adjacent to NPS lands.

In conclusion, the two main issues degrading wilderness character in GAAR are overflights and the presence and use of ATV trails. The areal extent of overflights is considerably larger than that of

[28] This reclassification scheme divides the range of attribute values into equal-sized sub-ranges, allowing the user to specify the number of intervals while ArcMap determines where the breaks should occur (ESRI 2015).

ATV's in GAAR, but they don't have the permeant presence that ATV trails create on the landscape. Additionally, the accumulated impacts of the trails and the ATV's that use them (depicted using four separate measures under two qualities) result in higher levels of degradation to wilderness character than overflights. The use of these two modes of transport in wilderness are legislated in ANILCA, and they facilitate recreational and subsistence use to areas that would otherwise be largely unreachable. However, motorized use remains a non-conforming use of wilderness and provides a strong connection to modern civilization, eroding the undeveloped and solitude qualities of the landscape.

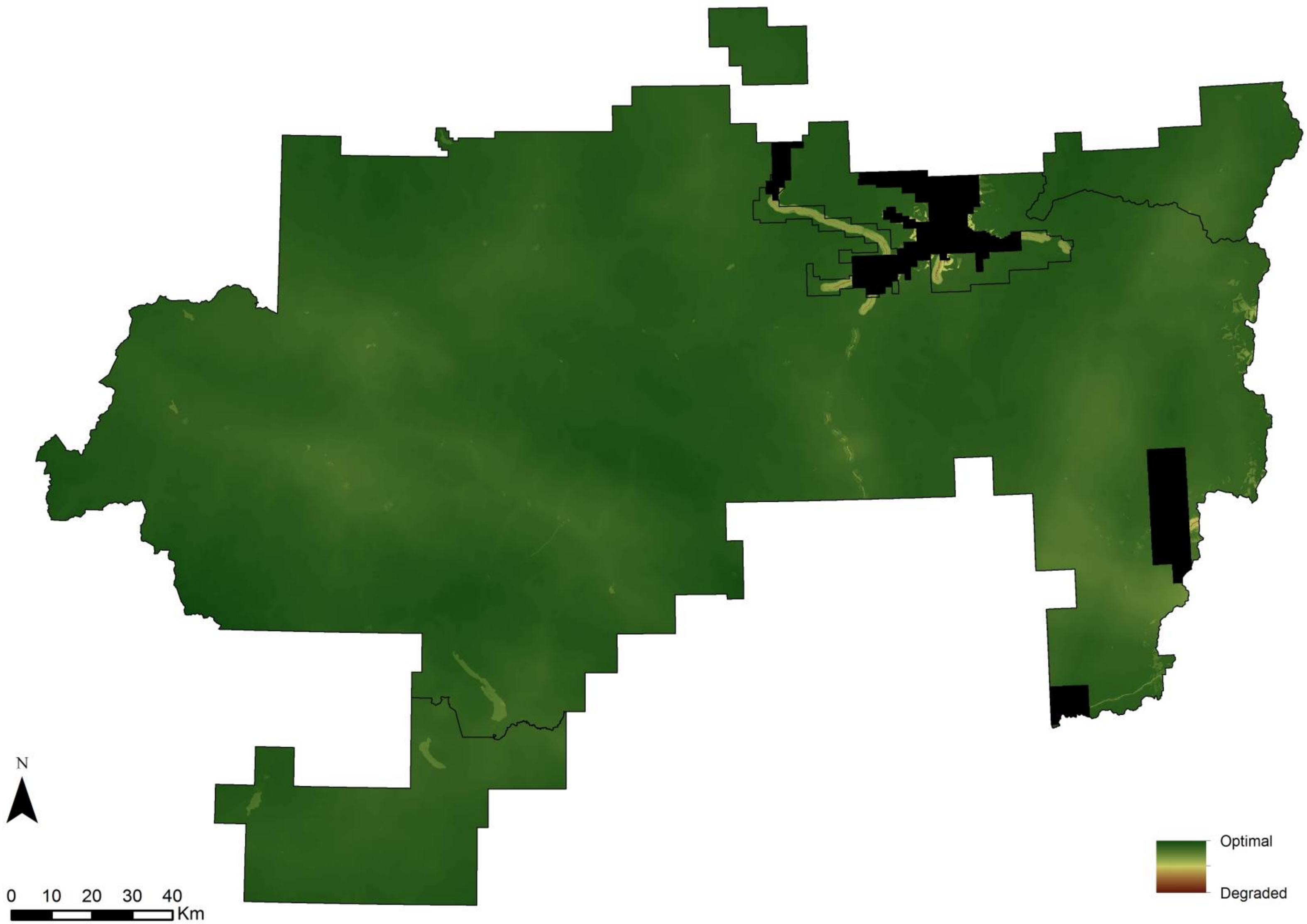

Figure 11. Map of impacts to wilderness character in GAAR. Green depicts optimal condition and brown depicts degraded condition.

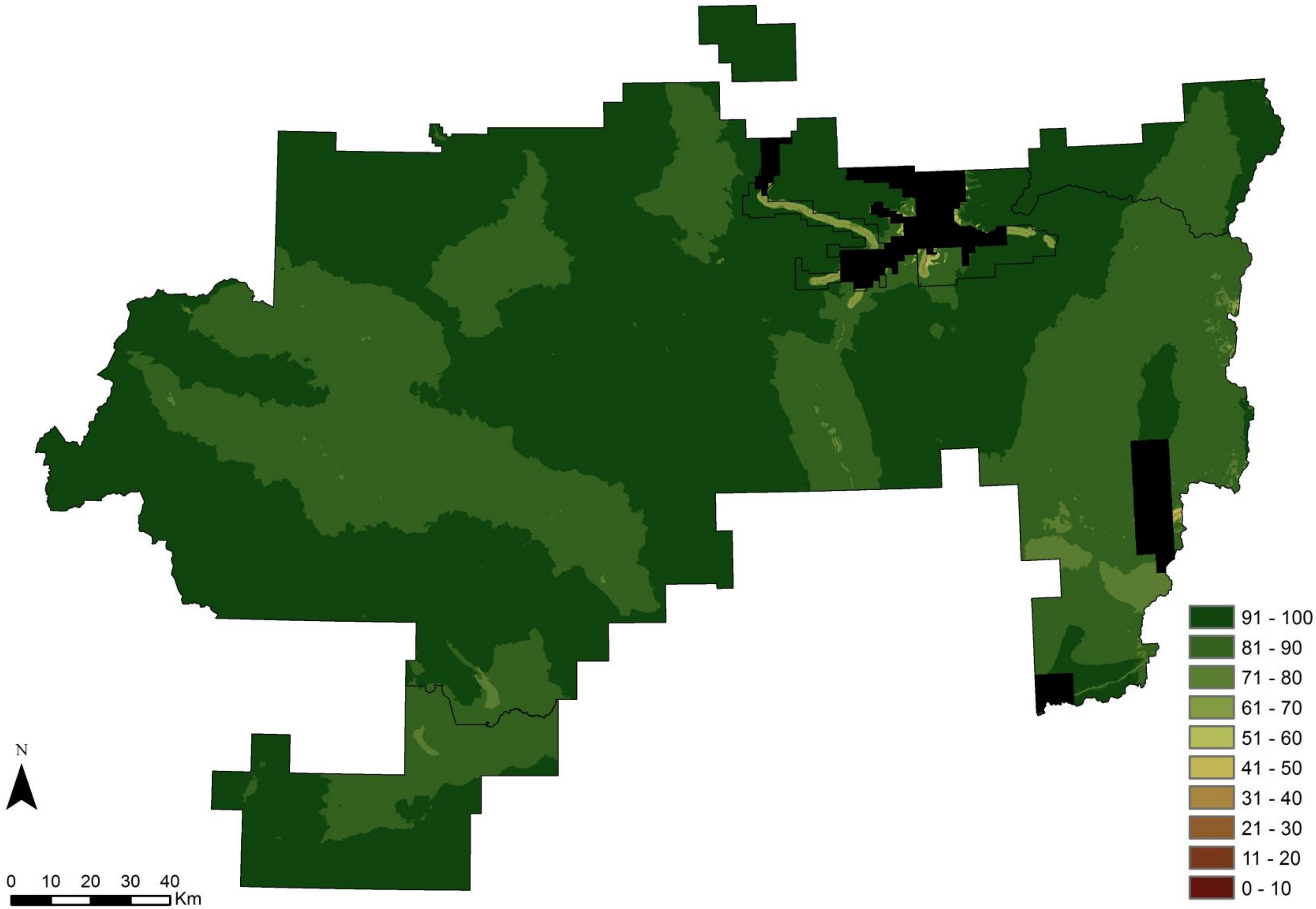

Figure 12. Map of impacts to wilderness character in GAAR reclassed into ten equal categories. Green depicts optimal condition and brown depicts degraded condition.

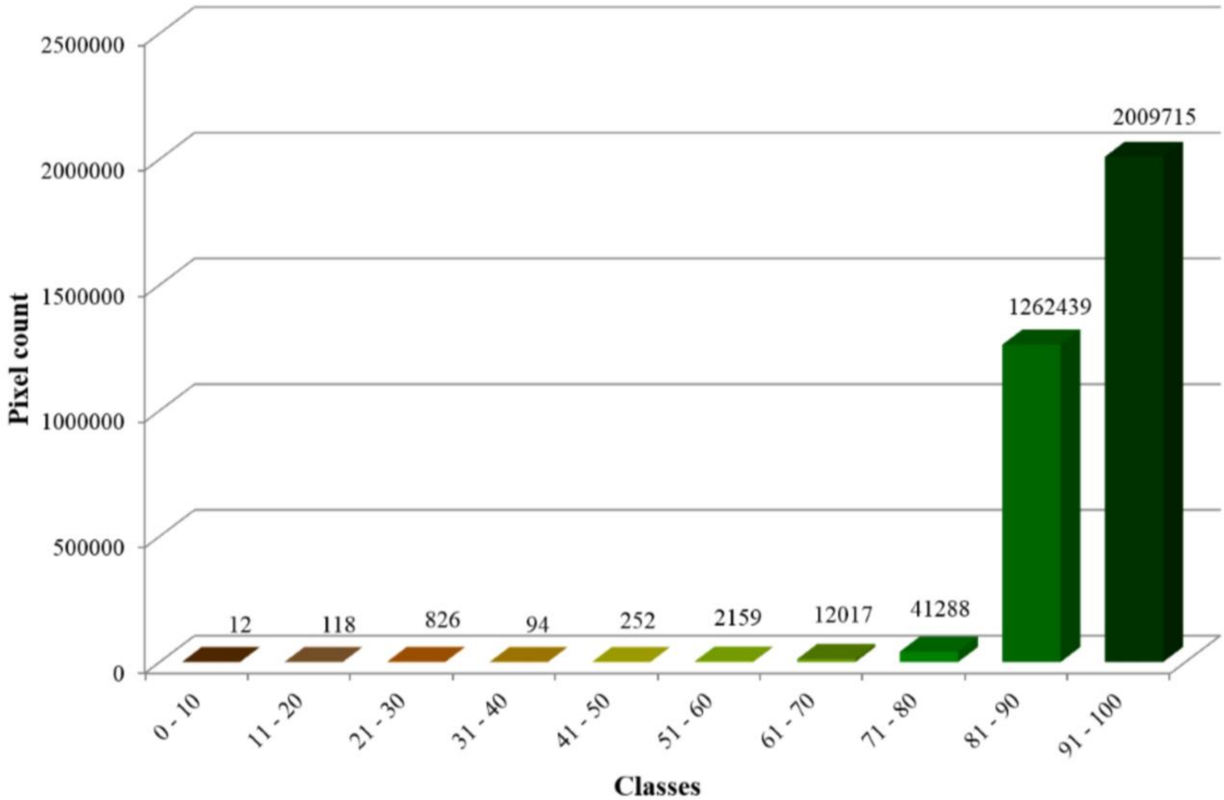

Figure 13. Histogram of the values of the map of impacts to wilderness character. Green depicts optimal condition and brown depicts degraded condition.

Recommendations to improve map products

The map products presented in this report could be improved in a number ways. The maps are highly dependent on the wide range of spatial datasets that depict impacts to wilderness character. Improving the data quality of the existing datasets (by improving data accuracy or completeness) or adding datasets for the data gap measures would benefit future iterations of the maps. For example, a wider availability of improved land cover maps and a higher resolution DSM would increase the accuracy and effectiveness of the viewshed model, and thereby improve future maps of the solitude or primitive and unconfined recreation quality.

The issue of data quality also highlights the need for effective and holistic management of GAAR spatial data. Clear communication among staff, as well as with external agencies, researchers, and others working in wilderness, would allow for improvements in the quality and availability of wilderness datasets; this in turn would result in more effective and efficient wilderness stewardship. By raising awareness of data needs among field staff and encouraging the use of GPS units to record spatial data, new datasets could be created and existing datasets could be ground-truthed for accuracy or otherwise improved. It would be particularly useful, for example, to test the output of the viewshed models against observations in the field. Furthermore, regular meetings between GIS specialists and wilderness staff would ensure the preservation of institutional knowledge in the form of spatial datasets. While generally successful in these areas, increased collaboration and involvement would allow GAAR staff and partner organizations to better realize how they can contribute to—and benefit from—spatial data and GIS applications.

Final concerns about mapping impacts to wilderness character

A major concern of this work is that end-users will ascribe false levels of accuracy to the map products. The tendency to attribute higher levels of reliability and precision to maps because they look accurate is common to almost all GIS analyses. The maps produced through this project are only an estimate of selected measures of wilderness character and their spatial variability and pattern; they are not a final determination of wilderness character in GAAR. Underscoring this point, the maps do not portray the symbolic, intangible, spiritual, and experiential values of wilderness character that are unique to individual persons, locations, and moments. Wilderness researchers and managers have debated the merits of even attempting to quantify or map impacts and threats to wilderness character; while some emphasize the need to develop indicators that can be used to aid wilderness monitoring, management, and long-term planning (e.g. Landres 2004), others point out that quantitative analyses do not reflect important qualitative attributes of wilderness character, such as how wilderness affects each of us in different ways (e.g. Watson 2004). Although the maps do not depict all nuances of wilderness character, they still provide useful information on tangible impacts and threats. Ultimately, the maps should be viewed as a tool that wilderness stewards can use to further refine the effectiveness of their efforts to “preserv[e] the wilderness character of the area” and perpetuate the “enduring resource of wilderness” (Wilderness Act of 1964).

2. Positive features map

When selecting measures for a baseline map of degradations to wilderness character in GAAR, it became apparent to the project team that GAAR has very few degradations to wilderness character. The team was concerned that the wilderness character of GAAR would not be adequately represented solely by showing degradations, and key information about GAAR's wilderness character would be lost using this approach. Therefore, the project team developed a Positive Features map for wilderness character. When used together, the Baseline degradations map and the Positive Features map more completely represent the condition of wilderness character in GAAR.

This positive approach to mapping wilderness character has never been attempted before in the NWPS, so the project team was able to think creatively and flexibly in determining indicators for such a map. The project team identified three logical indicators, of which their respective measures are listed underneath:

Indicator: Natural features

- Biomass – Presence of diverse plant species within GAAR. It is difficult to interpret whether change to biomass is positive or negative since not all of the factors and processes underlying the change are well understood. Following from this fact, it is difficult to assert what change in such a complex measure indicates in regard to changing wilderness character. Nonetheless, diversity of plant species and biomass stand to be useful indicators of the function of natural systems and relevant to wilderness character, even if the precise relationship to wilderness character is not fully understood. With these considerations in mind, it was decided to include biomass data in the positive map to show presence/absence of species.

- Wild and Scenic Rivers – Six Wild and Scenic Rivers are located within the GAAR wilderness. The rivers and their immediate environments in GAAR are nationally recognized for their outstanding natural, cultural and recreational values and are of clear positive importance in a wilderness character context. Currently, all rivers in GAAR are free flowing and no dams, bridges or culverts exist in the park.

- Wildlife biodiversity –The GAAR wilderness is a refuge for a considerable amount of wildlife biodiversity. The distribution of thirteen threatened, endangered and iconic species are used as a proxy to represent overall wildlife biodiversity in GAAR.

- Special areas – Locations of National Natural Landmarks and nationally significant cultural landscapes. These special areas include Arrigetch Peaks, Walker Lake, Agiak Lake Cultural Landscape and Itkillik Lake Archaeological District. Like Wild and Scenic Rivers, these landmarks and districts have clear positive importance relative to wilderness character and also exhibit no meaningful degradations. Showing these features on the positive features map provides a way to recognize these wilderness character attributes and maintain their good condition.

- Areas of permanent ice and snow – Locations and extent of permanent ice and snow fields in GAAR represent one of the most proximal indicators of a rapidly changing climate. As these relics of the last ice age melt and shrink in size, a unique component of the Brooks Range montane physiography is disappearing. Currently, these patches serve as reminders of a primordial wilderness.

Indicator: Cultural features

- Subsistence – Areal extent of the different types of subsistence harvest occurring in the GAAR wilderness. This measure is based on data collected in a 2011 survey, but serves as a proxy for long-term patterns of use. Subsistence activities in GAAR are an allowable use and provide the opportunity for local residents to continue a traditional way of life. The project team acknowledges that patterns of subsistence use will evolve over time to match the changes in distribution of flora and fauna in GAAR.

- Existence of archaeological sites/traditional place names – Locations of archaeological sites and traditional native place names. Native place names and archaeological sites represent peoples' ties to places in the park over a significant amount of recorded history. Traditional place names and archaeological sites hold special significance within GAAR, as peoples' ties to the land continue to live into modern times. This aspect of preserving a lifestyle inextricably tied to the landscape sets GAAR apart and GAAR managers see including this particular measure in the Positive Features map as a way to represent that significance spatially.

- Existence of native allotments – Locations of native allotments in the GAAR wilderness. Native allotments acknowledge and represent the strong and long-lived cultural connections that local residents and specific families have to places on the landscape in GAAR. Native allotments are not allowed to be commercially developed. These are positive aspects of wilderness character that cannot be adequately conveyed on a scale framed only in terms of degradations.

Indicator: Management actions

- Remediated sites – Locations of remediated sites. GAAR has been proactive in the cleanup of contaminated sites that once held toxic industrial byproducts leftover from military exercises. By remediating these sites, often through the use of human and dog power, GAAR is improving the natural, undeveloped and solitude qualities of wilderness character.

- Non-Native Invasive Species (NNIS) removal – Locations of NNIS removal projects. While considered a trammeling action in the baseline map, the removal of non-native species restores landscapes to their natural state and improves the natural quality of wilderness character.

- Naturally started fires – Areal extent of natural fires allowed to burn within GAAR. GAAR has a policy of allowing naturally started fires to burn and run their natural course. As a consequence, there is currently no deviation from the natural fire regime parkwide.

- Research – Research activities provide information that GAAR managers use to improve their understanding and management of the natural environment in GAAR. For this measure, the locations of RAWS (Remote Automatic Weather Stations) stations and radio collar kernel density maps represent the positive effects of research in the GAAR wilderness. The goal of utilizing this measure in the Positive Features map has nothing to do with visitor experience, rather it is to indicate that without this research, our knowledge is diminished. Additionally, these installations are tracked as degradations on the baseline wilderness character map.

Data sources, processing, and cautions

A wide variety of data sources were used to create the positive features map. These datasets included both vector and raster data in a range of different scales and with mostly high accuracy and completeness (Table 14). The data sources, data processing information, and cautions are listed below for each measure.

Table 13. Positive features datasets. Accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the wilderness) were evaluated for each measure by GAAR staff familiar with these data.

Measure	Source	Type	Scale	Accuracy	Completeness
Biomass	meanndvi2000	Raster	1000 m	High	High
Wild and Scenic Rivers	National Hydrography Dataset	Polyline	—	High	High
Areas of permanent ice and snow, incl. glaciers & snow patches	GAAR_binary_Snow_Patches_tif1	Raster	30 m	High	High
Special areas (Arrigetch Peaks National Natural Landmark, etc.)	Special_Areas	Polygon	—	Medium	High
Wildlife Biodiversity	AlaskaTinyShrew_AnnualDistribution; ArcticPeregrineFalcon_BreedingDistribution; BlackBackedWoodpecker_AnnualDistribution; BlackScoter_BreedingDistribution; HudsonianGodwit_BreedingDistribution; RingNeckedDuck_BreedingDistribution; RustyBlackbird_BreedingDistribution; SmithsLongspur_BreedingDistribution; Surfbird_BreedingDistribution; SwainsonsHawk_BreedingDistribution; TrumpeterSwan_BreedingDistribution; Whimbrel_BreedingDistribution; YellowBilledLoon_BreedingDistribution	Raster	60 m	Medium	High

Table 13 (continued). Positive features datasets. Accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the wilderness) were evaluated for each measure by GAAR staff familiar with these data.

Measure	Source	Type	Scale	Accuracy	Completeness
Existence of traditional place names and Archaeological sites (ASMIS)	Anthro_kernel	Raster	100 m	High	Medium
Subsistence	GAAR_Subsistence	Polygon	—	Medium	Medium
Existence of Native allotments	NativeAllotment_2015	Polygon	—	High	High
Remediated sites (Clean contaminated sites)	Impacts_Albers; Contaminated_Sites_AK	Point	—	High	Medium
Research	BearCollar_Locations; All_GAAR_Caribou; NPS_Instrumentation_Installa tions	Point	—	High	High
Non-native plant treatments	InvasivePlants	Polygon	—	High	High
Naturally started fires	Fire_Origins; akfirehist_2015	Point & Polygon	—	High	High

Biomass

- *Sources:* Normalized Difference Vegetation Index (NDVI)[29] raster dataset.
- *Processing:* The dataset was re-projected and clipped to the GAAR wilderness boundary. Raster values were then normalized to 0-255.
- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Wild and Scenic Rivers

- *Sources:* Polyline dataset depicting river systems.
- *Processing:* The following wild and scenic rivers were selected from the dataset:
    - Alatna River
    - John River

[29] NDVI is a simple graphical indicator that can be used to analyze remote sensing instruments and assess whether the target being observed contains live green vegetation or not.

  - Kobuk River
  - Noatak River
  - North Fork of the Koyukuk River
  - Tinayguk River

  Wild and scenic rivers were assigned a value of 1. The layer was converted to raster and values were normalized to 0-255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Wildlife biodiversity

- *Sources:* Raster datasets depicting the distribution (presence/absence) of 13 threatened, endangered and iconic species in GAAR (Alaska Gap Analysis Project).
- *Processing:* All datasets were clipped to the GAAR wilderness boundary and added together using a raster calculator. The output raster values were then normalized to 0-255.
- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Special areas (Arrigetch Peaks National Natural Landmark, etc.)

- *Sources:* Polygon dataset depicting special areas (Andy Baltensperger, GAAR GIS Specialist).
- *Processing:* Special areas were assigned a value of 1. Layer was converted to raster and values were normalized to 0-255.
- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Areas of permanent ice and snow, including glaciers and snow patches

- *Sources:* Raster dataset depicting areas of permanent ice and snow.
- *Processing:* The dataset was clipped to the GAAR wilderness boundary and raster values were normalized to 0-255.
- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Subsistence

- *Sources:* Polygon dataset depicting areas of different types of subsistence use in the GAAR wilderness by 9 local communities (Annette Watson, Associate Professor, College of Charleston).

- *Processing:* New polygon datasets were created for each type of subsistence use (37 different types) from the original dataset. The subsistence use in each dataset was assigned a value of 1. All layers were converted to rasters and added together in a raster calculator. The output raster values were then normalized to 0-255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Existence of traditional place names and Archaeological sites (ASMIS)

- *Sources:* Point dataset depicting traditional place names and archaeological sites.

- *Processing:* Point datasets were combined together and a value of 1 was assigned to each site. A density map was then generated using the Kernel Density[30] tool in ArcGIS. The output raster values were then normalized to 0-255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Existence of Native allotments

- *Sources:* Native allotment polygon dataset (NPS Theme Manager)

- *Processing:* Locations of native allotments were assigned a value of 1. Layer was converted to raster and values were normalized to 0-255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Remediated sites (clean contaminated sites)

- *Sources:* Point dataset of contaminated sites in Alaska (Jobe Chakuchin, GAAR NEPA Specialist & Park Planner).

[30] Kernel density calculates a magnitude-per-unit area from point features using a kernel function to fit a smoothly tapered surface to each point (ESRI 2016).

- *Processing:* Dataset was clipped to the GAAR wilderness boundary and all remediated sites were selected and assigned a value of 1. The layer was converted to raster and values were normalized to 0–255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Naturally started fires

- *Sources:* Fire origins point dataset and Alaska fire history polygon dataset (NPS Theme Manager).

- *Processing:* Naturally started fire points were selected from the fire origins dataset, which were then used to select the fire polygons that were naturally ignited. The naturally started fire polygons were assigned a value of 1. The layer was converted to raster and values were normalized to 0–255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Non-native plant treatments

- *Source:* Point dataset of treatment locations where non-native plant treatments occurred from 2010 to 2016 (NPS Theme Manager).

- *Processing:* Locations of non-native plant treatments were assigned a value of 1. The layer was converted to raster and values were normalized to 0–255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Research

- *Sources:* Collar locations for bears (2014-2015; representing 57,332 locations from 19 collared individuals) and caribou (2010-2015; representing 24,128 locations from 94 collared individuals); point dataset of NPS research installations (Kyle Joly, GAAR Wildlife Biologist; Mathew Sorum, GAAR Wildlife Biologist).

- *Processing:* A density map was generated for each collared species using the Kernel Density[31] tool in ArcGIS. The output for each species was normalized to 0-255, added together in a raster calculator, and then renormalized to 0-255. Locations of installations were

[31] Kernel density calculates a magnitude-per-unit area from point features using a kernel function to fit a smoothly tapered surface to each point (ESRI 2016).

assigned a value of 1. The layer was converted to raster and values were normalized to 0–255. The two research layers were then added together and values were renormalized to 0-255.

- *Cautions:* The kernel density analysis was run using the default settings. A number of collar points were located outside the GAAR wilderness but were included in the analysis to avoid edge effects[32]. The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Weighting

The assigned weight (on a scale of 1 to 10) and the corresponding rationale for each measure under the positive features map are described below (Table 14).

Table 14. Measure weights and rationales for the positive features map.

Indicator	Measure	Weight	Rationale
Natural features	Biomass	7	Biomass is an important measurement of ecosystem health in GAAR
	Wild and Scenic Rivers	7	The presence of natural and free-flowing rivers is significant in GAAR as there are currently no dams, bridges and culverts in the wilderness.
	Wildlife Biodiversity	7	Wildlife biodiversity is an important measurement of ecosystem health and is thus weighted moderately high.
	Special areas (Arrigetch Peaks National Natural Landmark, etc.)	5	The presence of these areas enhances the overall uniqueness of the GAAR wilderness.
	Areas of permanent ice and snow, incl. glaciers & snow patches	5	Areas of permanent ice and snow are particularly valued during a time when climate is causing them to diminish statewide.
Cultural features	Subsistence	9	This measure has a high weight because subsistence use is a defining positive feature of the GAAR wilderness.

[32] A problem created during spatial analysis when patterns of interaction or interdependency across borders of the bounded region are ignored or distorted (ESRI 2016).

Table 14 (continued). Measure weights and rationales for the positive features map.

Indicator	Measure	Weight	Rationale
Cultural features, cont.	Existence of traditional place names and Archaeological sites (ASMIS)	7	This measure depicts the continuing ancient connection between humans and the land.
	Existence of Native allotments	7	This measure spatially represents the continued existence of people on the land.
Management actions	Remediated sites (Clean contaminated sites)	7	The removal of industrial toxins from sites within GAAR represents a management decision that improves/restores wilderness character in the area.
	Naturally started fires	7	Allowing naturally started fires to burn freely is a management decision that significantly improves/preserves wilderness character.
	Non-native plant treatments	3	The removal of non-native species improves the natural quality of wilderness character.
	Research	3	Research projects within GAAR contribute to the preservation or improvement of wilderness character.

Maps

The weighted measures were added together using the ArcGIS raster calculator to create the positive features map (Figure 14).

Discussion for positive features map

The positive features map (Figure 14) depicts GAAR's current richness in positive aspects of wilderness character. The project team wanted to highlight particular aspects of GAAR that are not only positive, but also crucial to understanding the wilderness character of GAAR as a whole. Unlike the baseline and proposed Ambler Road maps, it shows no departure from an "optimal condition" of wilderness character. Instead, the "value-added" approach for this map depicts the accumulation of positive features or management actions across the entire park.

Darker colors on the positive features map indicate areas of higher values, where either individual measures have high values themselves, or where two or more measures have combined to emphasize high positive values for particular areas. The overall trend for the positive features map is that the southern portions of the park and the river systems have higher positive values, whereas low values exist for much of the higher terrain. The burn areas of naturally started fires within GAAR occur in the park's southern regions and GAAR's policy of allowing them to burn freely is highlighted as a positive management action. The effects of latitude on a large wilderness such as GAAR also contribute to its southern portions and lower elevation river corridors containing more biomass and wildlife biodiversity than the northern portions and higher ground across the park. Additionally, an abundance of cultural features exists in the Kobuk Preserve area of GAAR. Finally, the area around Anaktuvuk Pass stands out as having high values for cultural features, largely due to the different types of subsistence use available to the local population.

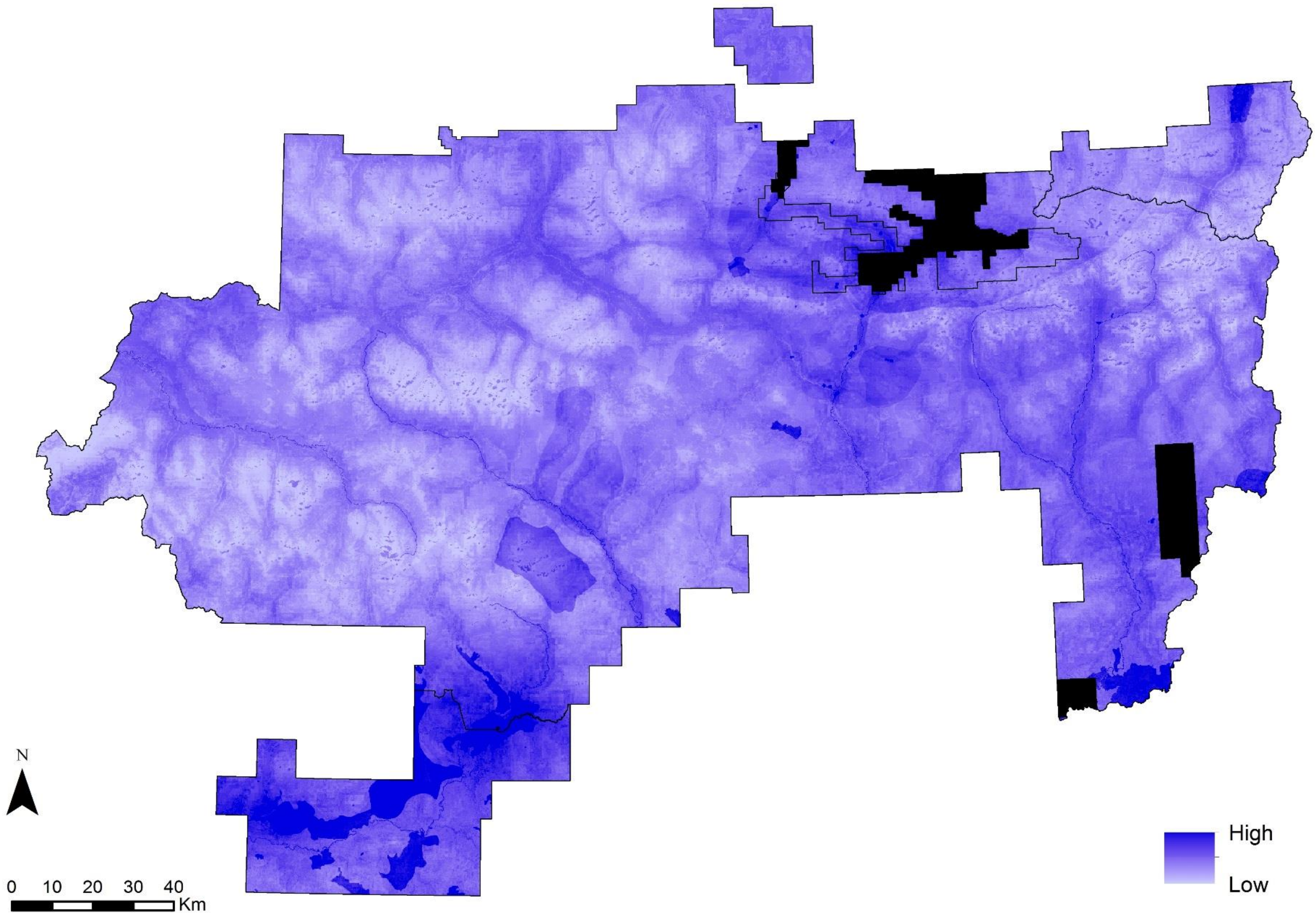

Figure 14. Positive features map for GAAR. Darker colors indicate higher values for positive features

3. Proposed Ambler road impacts to GAAR wilderness character

Before ANILCA designated GAAR, the likelihood of rich mineral deposits in the Ambler Mining District, to the west of the park, had already been identified. Congress, in considering the establishment of GAAR, recognized that a transportation corridor to the Ambler Mining District might become desirable, and could connect with the Dalton Highway to the east of the Park. The upper Kobuk River area was included in Gates of the Arctic National Park as a Preserve. However, Congress made allowances for a transportation corridor across the area, known as the Kobuk Preserve, in order to provide access for future development of mineral resources in the Ambler area.

In November 2015, an SF-299 application was filed by the Alaska Industrial Development and Export Authority (AIDEA) with the NPS for the above-specified right-of-way. In the application, AIDEA proposes the construction of a 211-mile road from the Dalton Highway to the Ambler Mining District. Two alternative right-of-ways have been proposed and would traverse either 18 or 26 miles of Gates of the Arctic National Preserve. As part of meeting the requirements of ANILCA Section 401 (d), GAAR managers are responsible for assessing the potential impacts of the two routes and recommending the option with fewer impacts to park resources and values.

The management direction of GAAR is to maintain the wild and undeveloped character of the area, provide continued opportunities for wilderness recreational activities, protect park resources and values, and provide continued opportunities for subsistence uses by local residents, where such uses are traditional. To prepare for a possible right-of-way application, GAAR has initiated projects designed to provide necessary information for an environmental and economic analysis (EEA). Information on wilderness and recreational values of GAAR and potential effects of a road on those values will be needed to inform the EEA. A map of wilderness character for GAAR would provide relevant information, and assist the park in evaluating potential effects on park resources and values.

The project team took a proactive approach to anticipating these impacts to wilderness character by evaluating each proposed route (both a northern route and a southern route) as if they were open to public access. Although the current application submitted by AIDEA proposes a private industrial route, there are a number of examples of infrastructure from similar industrial projects in Alaska becoming open to public use. The Dalton Highway on the eastern border of GAAR is one such example. In the current application submitted by AIDEA, the stated purpose for the road is to support a mining operation, and access would be limited to vehicles engaged in that activity: the road would not be open to the public. The Dalton Highway, which lies on the eastern edge of GAAR and leads to the oil fields on Alaska's North Slope, was initially developed as an industry-only road, but it was opened to public use in relatively short order. So, while the initial right-of-way application has called for the proposed Ambler Road to be open for industrial use only and not to the general public, the precedent set by the Dalton Highway makes public access on the road to the Ambler Mining District reasonably foreseeable, especially since the route accesses public lands. Moreover, the project's proponents have noted that there are multiple options to increase public access on the road (Brehmer, 2014). Given that public access to the road cannot be ruled out, GAAR's project team assessed the potential impacts of this alternative. Impacts of public access were a specific concern expressed by some rural residents within the study area (Guettabi et al. 2016). Therefore, the project team evaluated the routes as publicly accessible to help proactively discern management issues in the area that could arise from increased visitor use.

Given the large size of the GAAR wilderness and locality of the proposed impacts, the project team agreed to focus the results of this analysis on a specific area – the Kobuk Preserve (Figure 15). This decision was made in order to better understand the discrete impacts that the proposed Ambler road will have on wilderness character in the area.

Evaluating the anticipated impacts of the proposed Ambler Road corridors to wilderness character required amending existing baseline measures and developing new measures. Listed below are the measures (and their associated indicators and qualities) that would be impacted by the development of a road corridor through the Kobuk Preserve.

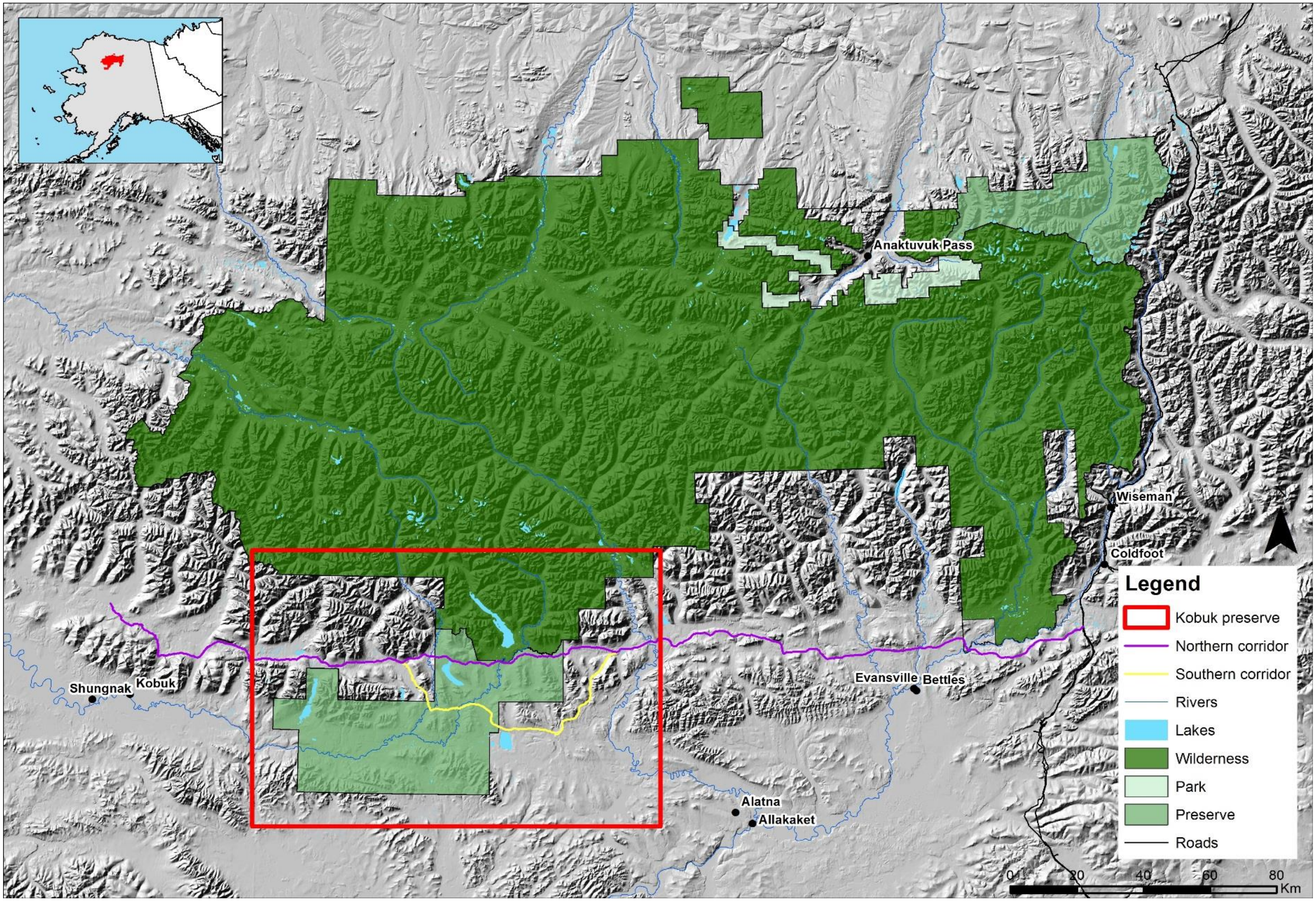

Figure 15. Map depicting proposed Ambler Road corridors.

Untrammeled

Indicator: Actions authorized by the federal land manager that intentionally manipulate the biophysical environment

- Construction of the proposed Ambler Road – Locations of proposed road corridor routes. The act of constructing the proposed road corridor directly degrades the untrammeled quality of wilderness across an extensive swath of the biophysical environment. Free-flowing waterways, sheet flow of wetlands and migratory routes of animals are likely to be impacted by the construction of the Ambler Road (van der Ree 2011).

Natural

Indicator: Plants

- Fugitive dust – Anticipated changes to species composition and plant health through the dispersal of fugitive dust (including mining particulates) from trucks transporting ore along the road corridor. Fugitive dusts enriched with heavy metals Cu, Zn, Pb and Cd are likely to cause some plant and lichen mortality along the road corridor and eliminate more sensitive lichens and mosses. These contaminants are also likely to decrease the health of certain plants in the corridor. Specific effects will depend on the extent of dust control measures. Numerous studies on similar Alaskan mining projects have concluded that soils and mosses adjacent to industrial roads have become contaminated with dust and metals originated from hauling activities (Red Dog Mine Operations Alaska, 2008).

Indicator: Animals

- Hunting along proposed Ambler Road corridor – Areal extent along road corridors and river courses in the Kobuk Preserve that may be impacted by increased hunting activities. The Kobuk Preserve provides rich habitat for moose and bears, and has historically been an important winter caribou range (Guettabi et al. 2016).

Undeveloped

Indicator: Presence of non-recreational structures, installations, and developments

- Developments along proposed Ambler Road corridors – Locations of the proposed road corridors. The construction of a road corridor through the Kobuk Preserve constitutes a major industrial development.

Indicator: Presence of inholdings

- Private inholdings – Locations of private inholdings in GAAR. The proposed road corridors would improve access to private inholdings around Walker Lake and could result in new developments for commercial activities.

Indicator: Use of motor vehicles, motorized equipment, or mechanical transport

- Trucks driving proposed Ambler Road corridor routes – Locations of the proposed road corridors. Motorized use along the proposed road corridors will have a significant impact the undeveloped quality.

Solitude

Indicator: Remoteness from sights and sounds of human activity inside the wilderness

- Travel time – This measure serves as a proxy for remoteness by calculating the time it takes a person of average fitness to travel across the landscape from various access points (Dalton Highway, Anaktuvuk Pass, and popular bush plane landing sites), taking into account cost surfaces[33] (elevation and land cover) and barrier features (steep ground and water). The baseline measure is amended to include access into the GAAR wilderness from the proposed road corridors.

Indicator: Remoteness from sights and sounds of human activity outside the wilderness

- Noise from roads – Noise impacts generated by a soundscape model based on Alaska Department of Transportation traffic data for the Dalton Highway. This baseline measure was amended to include the noise impacts of traffic along the two proposed road corridors.

- Features outside wilderness impacting viewshed – Viewshed impacts from developments outside GAAR, including the Dalton Highway, Anaktuvuk Pass Land Exchange Area, 17b easements[34], and travel corridors outside NPS lands. The baseline measure is amended to include the viewshed impacts of the two proposed road corridors.

Indicator: Facilities that decrease self-reliant recreation

- Visitor Facilities and Interpretation – Locations of potential visitor hotspots along proposed road corridors. Due to the proximity of the proposed road corridors to natural viewing areas, the project team identified potential hotspots of visitor use that may require visitor services and interpretation. GAAR managers want to maintain management flexibility in the future and this measure could assist in controlling management efficiency from one route or another.

- Trails – Locations of new trails potentially constructed to provide visitor access to the GAAR wilderness and protect adjacent resources. Currently, no developed or maintained trails exist in GAAR. A public access road through the Kobuk Preserve would create a significant increase in backcountry use for this area of the park due to the decrease in access costs. The project team acknowledge that increased visitor use in the Kobuk Preserve could press GAAR staff to develop maintained trails that concentrate use to protect local resources and prevent a proliferation of social trails.

Indicator: Management restrictions on visitor behavior

- Camping restrictions – Areas adjacent to the proposed road corridors that may require management restrictions on visitor activities. If visitor use in the Kobuk Preserve exceeded an agreed carrying capacity, management restrictions on visitors could be enacted. Using

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[33] Cost surfaces are used in surface modeling to establish the impedance for crossing each individual cell in a grid.

[34] Reserves easements across Native corporation land for access to public lands or major waterways.

Denali National Park and Preserve's backcountry permit and quota system as an example, camping restrictions would be delineated by drainage just for the areas that intersect the proposed Ambler Road routes. Denali is the only NPS unit in Alaska with a quota system for backcountry use, and the system is predicated upon maintaining management goals for social indicators (such as encounters with other parties or large groups) and resource indicators (such as the development of user-created sites and trails due to concentrated use) outlined in the park's Backcountry Management Plan.

Data gap measures

Additional measures under this quality were identified by GAAR staff but were excluded for a variety of reasons. For each data gap measure, the quality and indicator, description, and rationale for their dismissal are listed below.

Disrupted species migrations due to proposed Ambler Road corridors

- *Quality/Indicator:* Natural/Animals

- *Description:* The proposed road corridors could have a significant impact on species migrations in the Kobuk Preserve. A recent study in a northwest Alaska park indicates that a single road can disrupt caribou movements and delay their migrations (Wilson et al. 2015). GPS data from collared caribou revealed that individuals in the Western Arctic Herd (235,000 caribou) and Teshekpuk Herd (32,000 caribou) were delayed during their autumn migrations, on average 30 days, by the Red Dog Mine Road in northwest Alaska. Delayed caribou increased their migration speeds after eventually crossing the road adding additional stresses to the animals as they try to gain body fat for the ensuing winter.

- *Rationale for dismissal:* The caribou migration in GAAR primarily takes place west of the terminus of the proposed Ambler Road corridors and at a different time of the year. Therefore, it would be inappropriate to infer impacts to caribou in the Kobuk Preserve based on studies from different locales.

- *Future research and monitoring:* The Western Arctic Herd has undergone a > 50% reduction in numbers over the past 10 years. These natural population shifts result in changes to the size of range required for these animals – as herd numbers decline, so too does their range, especially on the peripheries. Currently, the area through which the proposed road corridors will be routed is experiencing less use owing to low herd numbers. However, if herd numbers were to increase, so too would the use of caribou in this area. Should increased use by caribou occur, park wildlife biologists would conduct further study in the area.

Animal mortality due to vehicle collisions on proposed Ambler Road corridors

- *Quality/Indicator:* Natural/Animals

- *Description*: Animal collisions from vehicles travelling along the proposed Ambler Road corridors could alter population numbers for a variety of species in the Kobuk Preserve. A study of caribou mortality along the Red Dog Mine road from vehicle collisions indicates that although the road traffic is heavily regulated (i.e. traffic is supposed to stop when they see caribou, and if the entire herd comes through, shut down the road for an entire week) significant road collision mortality still happens with caribou

- *Rationale for dismissal*: Different abundances of caribou and moose exist between the Red Dog Mine Road area and the proposed Ambler Road corridor.
- *Future research and monitoring*: A trend in this measure could not be monitored until a road was built and being used.

Spread of invasive species

- *Quality/Indicator:* Natural/Plants
- *Description:* Spread of non-native species along the proposed Ambler Road corridor.
- *Rationale for dismissal:* No data exists.
- *Future research and monitoring*: A trend in this measure could not be monitored until a road was built and being used.

Illegal harvest and collection

- *Quality/Indicator:* Untrammeled/Actions not authorized by the federal land manager that intentionally manipulate the biophysical environment
- *Description:* GAAR staff anticipate an increase in unauthorized/illegal harvest along the proposed Ambler Road corridor.
- *Rationale for dismissal:* No data exists.
- *Future research and monitoring*: GAAR staff have acknowledged that a monitoring plan is required to combat illegal harvest and collection in GAAR. The need for this plan would increase with the development of a proposed road corridor

Increased river usage

- *Quality/Indicator:* Solitude/ Remoteness from sights and sounds of human activity inside wilderness
- *Description:* The proposed road corridors would create a logical and inexpensive terminus for river trips starting in the GAAR wilderness. Therefore, the project team anticipates that river usage could potentially increase in GAAR as the associated logistics and expenses decrease.

- *Rationale for dismissal:* No data exists for popular floating trips[35].

- *Future research and monitoring:* A trend in this measure could not be monitored until a road was built and being used.

Visitor impacts

- *Quality/Indicator:* Solitude/Remoteness from sights and sounds of human activity inside wilderness

- *Description:* Visitor-generated campsites and trash in the Kobuk Preserve.

- *Rationale for dismissal:* Dataset is incomplete.

- *Future research and monitoring*: Currently, data collection on visitor impacts is sporadic and incomplete. Future wilderness character monitoring plans need to be more comprehensive and involve consistent data collection and storage.

Data sources, processing, and cautions

A wide variety of data sources were used to create the proposed road corridor maps. These datasets included both vector and raster data in a range of different scales and with high variability in accuracy and completeness (Table 15). The data sources, data processing information, and cautions are listed below for each measure that would be impacted by the development of a road corridor through the Kobuk Preserve.

[35] The only usable data for this measure is from hunting patrols in the late 1990s and early 2000s – earlier than the baseline date for this mapping effort (2010).

Table 15. Datasets for the road impacted measures. Accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the wilderness) were evaluated for each measure by GAAR staff familiar with these data.

Measure	Source	Type	Scale	Accuracy	Completeness
Construction of the proposed Ambler Road	Southern_alternative; Northern_alternative	Polyline	—	High	High
Fugitive dust	Southern_alternative; Northern_alternative	Polyline	—	—	—
Hunting along road corridor	Southern_alternative; Northern_alternative; National Hydrography Dataset	Polyline	—	Medium	Medium
Road corridor development	Southern_alternative; Northern_alternative	Polyline	—	High	Medium
Private inholdings	All_GAAR_Inholdings	Polygon	—	High	High
Road corridor motorized use	Southern_alternative; Northern_alternative	Polyline	—	High	High
Travel time	ARCN_ecotypes_2009; Clip_Alaska_30meter_NED; National Hydrography Dataset; linear_features; Southern_alternative; Northern_alternative; Plane_landing_sites	—	—	—	—
Noise impacts from roads outside of wilderness	Dalton1_public65_LAeq; Dalton2_public65_LAeq; KobukSouthAlt_public65_DALTONMIX_LAeq; KobukNorthAlt_public65_DALTONMIX_LAeq; Narvak_public65_DALTONMIX_LAeq; NorthForkKoyukuk_public65_DALTONMIX_LAeq.tif	Raster	—	—	—
Viewshed	See table 8				
Interpretation/Visitor Center	Kobuk_visitor_facilities	Point	—	—	—
Trails	Kobuk_trails	Polyline	—	Medium	Medium
Camping restrictions	Kobuk_camping_restrictions	Polygon	—	—	—

Construction of the proposed Ambler Road

- *Sources:* Polyline datasets for the two proposed road corridors.
- *Processing:* Locations of each proposed road corridor were assigned a value of 1. The layers were converted to rasters and values were normalized to 0–255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Fugitive dust

- *Sources:* Polyline datasets for the two proposed road corridors.

- *Processing:* Locations of each proposed road corridor were buffered to a distance of 2 km, based on recommendations by Peter Neitlich (Western Arctic National Parklands Plant Ecologist). Each buffered corridor was assigned a value of 1, the layers were converted to rasters, and then their values were normalized to 0–255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived. The data used to derive this measure are based on studies completed on a shorter haul road associated with the transport of less caustic ore than the proposed Ambler Road corridor.

Hunting along road corridor

- *Sources:* Polyline datasets for the two proposed road corridors and the national hydrography dataset.

- *Processing:* The two proposed road corridors and the large, navigable rivers they intersect (Kobuk, Reed and Beaver Rivers) were buffered to 1 km to represent increased hunting pressures on game animals along these travel corridors, based on recommendations by Kyle Joly (GAAR Wildlife Biologist). Each buffered travel corridor was assigned a value of 1, the layers were converted to rasters, and then their values were normalized to 0–255.

- *Cautions:* The 1 km buffer for the roads and rivers is based on the assumption that the majority of hunters will not track and shoot an animal beyond this distance owing to the difficulty of retrieval in challenging terrain/vegetation. The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Road corridor development

- *Sources:* Polyline datasets for the two proposed road corridors.

- *Processing:* Locations of each proposed road corridor were assigned a value of 1. The layers were converted to rasters and values were normalized to 0–255.

- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Private inholdings

- *Sources:* Polygon dataset of private inholdings (NPS Theme Manager).
- *Processing:* Locations of private inholdings were assigned a value of 1. The layer was converted to raster and values were normalized to 0–255.
- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Road corridor motorized use

- *Sources:* Polyline datasets for the two proposed road corridors.
- *Processing:* Locations of each proposed road corridor were assigned a value of 1. The layers were converted to rasters and values were normalized to 0–255.
- *Cautions:* The information contained in these data is current for the time of this report and may change over time. The data have not been manipulated from the original source from which they were derived.

Travel time

See page 40 of the report for a full description of the approach, data sources, processing notes, and associated caveats for producing the travel time layer. For evaluating the impacts of the proposed road corridors on travel time in the GAAR wilderness, the two road corridors were added to source grid and output was produced for both alternatives.

Noise impacts from roads outside of wilderness

- *Sources:* Raster datasets depicting combined road related noise impacts from the Dalton Highway and the two proposed road corridors. For more information on how these dataset were generated see Appendix B.
- *Processing:* The road noise grids were combined together using the MAXIMUM[36] function in ArcGIS. Ambient noise was removed by reclassing all negative values to 0. Grid values were normalized to 0-255.
- *Cautions:* Documentation within ISO 9613-2:1996 gives limits on the error of the model based on two factors, the mean height between source and receiver, *h*, and the distance between the source and receiver, *d*. Error in any grid cell is ± 1 dB when *d* is less than 100 m and *h* is greater than 5 meters but less than 30 meters. For other situations such that d is less than 1000 meters and h is less than 30 meters, the error is ± 3 dB. The standard does not define error values when d is greater than 1000 meters or h is greater than 30 meters, but they are greater than ± 3 dB.

[36] The output cell value of the overlapping areas will be the maximum value of the overlapping cells.

- All acoustical calculations were conducted according to ISO 9613-2:1996 *'Acoustics -- Attenuation of sound during propagation outdoors -- Part 2: General method of calculation'*.

Documentation within ISO 9613-2:1996 suggests the following error range (adapted from table 5):

Height (h) *	**Distance (d) between source and receiver**	
	0 m < d < 100 m	*100 m < d < 1000 m*
0 m < d < 5 m	± 3 dB	± 3 dB
5 m < d < 30 m	± 1 dB	± 3 dB

* Mean height of source and receiver.

Data for traffic inputs were based off of State of Alaska and NPS observations on the Dalton Highway. The information contained in these data is dynamic and may change over time. The data are not better than the original sources from which they were derived.

Viewshed

See page 34 of the report for a full description of the approach, data sources, processing notes, and associated caveats for producing the viewshed layer. For evaluating the impacts of the proposed road corridors on viewshed inside the GAAR wilderness, the two road corridors were added to the 15 km feature category using a height of 5 m and output was produced for both alternatives.

Visitor facilities and Interpretation

- *Sources:* Point dataset depicting anticipated visitor facilities in the Kobuk Preserve, including visitor interpretation, toilets, and camping.
- *Processing:* Locations of visitor facilities were assigned a value of 1. The layer was converted to raster and values were normalized to 0–255.
- *Cautions:* The information contained in these data is dynamic and may change over time. The data are not better than the original sources from which they were derived. The data is based on assumptions and experiences from other Alaskan national parks with road access.

Trails

- *Sources:* Polyline dataset depicting anticipated trails in the Kobuk Preserve.
- *Processing:* Locations of trails were assigned a value of 1. The layer was converted to raster and values were normalized to 0–255.
- *Cautions:* The information contained in these data is dynamic and may change over time. The data are not better than the original sources from which they were derived. The data is based on assumptions and experiences from other Alaskan national parks with road access.

Camping restrictions

- *Sources:* Polygon dataset representing anticipated camping restrictions in the Kobuk Preserve and adjacent wilderness.

- *Processing:* Camping restriction zones are mapped using watershed data (from the National Hydrography Dataset) that intersect the two proposed road corridors. Locations of camping restriction zones for each proposed road corridor were assigned a value of 1. The layers were converted to rasters and values were normalized to 0–255.

- *Cautions:* The information contained in these data is dynamic and may change over time. The data are not better than the original sources from which they were derived. The data is based on assumptions and experiences from other Alaskan national parks with road access.

Weighting

The assigned weight (on a scale of 1 to 10) and the corresponding rationale for the road specific measures are described below (Table 16). New measures are denoted with an asterisk.

Table 16. Weights and rationales for the road impacted measures.

Indicator	Measure	Weight	Rationale
Authorized	Construction of the proposed Ambler Road*	10	The act of constructing the Ambler Road would be the most significant trammeling action ever to occur in GAAR, and thus is given the highest possible weight.
Plants	Fugitive dust*	5	Fugitive dust can cause change in species composition along the proposed road corridor and a decrease in plant health.
Animals	Hunting along proposed Ambler Road corridor*	7	Public access along the proposed road corridor may alter wildlife populations due to new hunting pressures.
Non-rec	Proposed Ambler Road corridor development*	10	Highest weight because the proposed construction of an industrial road through the Kobuk Preserve is considered a significant development in an otherwise pristine environment.
Inholdings	Private inholdings	7	Improved access to private inholdings at Walker Lake via the proposed road corridors could increase potential for commercial development. Commercial developments are a significant impact to wilderness character in GAAR.
Motorized	Proposed Ambler Road corridor motorized use*	10	Motorized use along the proposed Ambler Road corridors would have a significant impact on wilderness character.

Table 16 (continued). Weights and rationales for the road impacted measures.

Indicator	Measure	Weight	Rationale

Indicator	Measure	Weight	Rationale
Remote in	Travel time	5	While the proposed road corridors would improve access to the Kobuk Preserve, GAAR is often accessed by bush planes and the expectation for remoteness is lower in Alaska because of this popular and often necessary access method. As a consequence, this layer does not carry a significant weight.
Remote out	Noise from proposed Ambler Road corridor	8	Noise generated from the proposed Ambler Road corridor would significantly impact the solitude quality of wilderness character within the GAAR wilderness.
	Viewshed	6	The viewshed impacts from the proposed road corridors would have a significant effect on the solitude quality in the Kobuk Preserve.
Facilities	Visitor Facilities and Interpretation*	9	Visitor facilities adjacent to the proposed Ambler Road corridor would have a significant impact on self-reliant recreation in the Kobuk Preserve.
	Trails*	8	The development of trails off the proposed road corridors would have a significant impact on self-reliant recreation. Currently no formal trails exist in the 7.1 million acres of designated wilderness.
Management restrictions	Camping restrictions*	7	Predicated on the scenario that the proposed Ambler Road corridor becomes open to public, a significant increase in visitor use to the area could require camping restrictions. Currently no management restrictions on visitor use exist in the 7.1 million acres of designated wilderness.

Maps

Existing measures from the baseline map, along with the new and amended measures depicting the predicted impacts of the proposed road corridors, were added together using their associated weights in a raster calculator. Figure 16 depicts the baseline impacts to wilderness character in the Kobuk Preserve (i.e. the current state of wilderness character), and Figures 17 and 18 depict the anticipated impacts of the two proposed road corridors.

Figure 16. Baseline map of impacts to wilderness character for Kobuk Preserve. Green depicts optimal condition and brown depicts degraded condition.

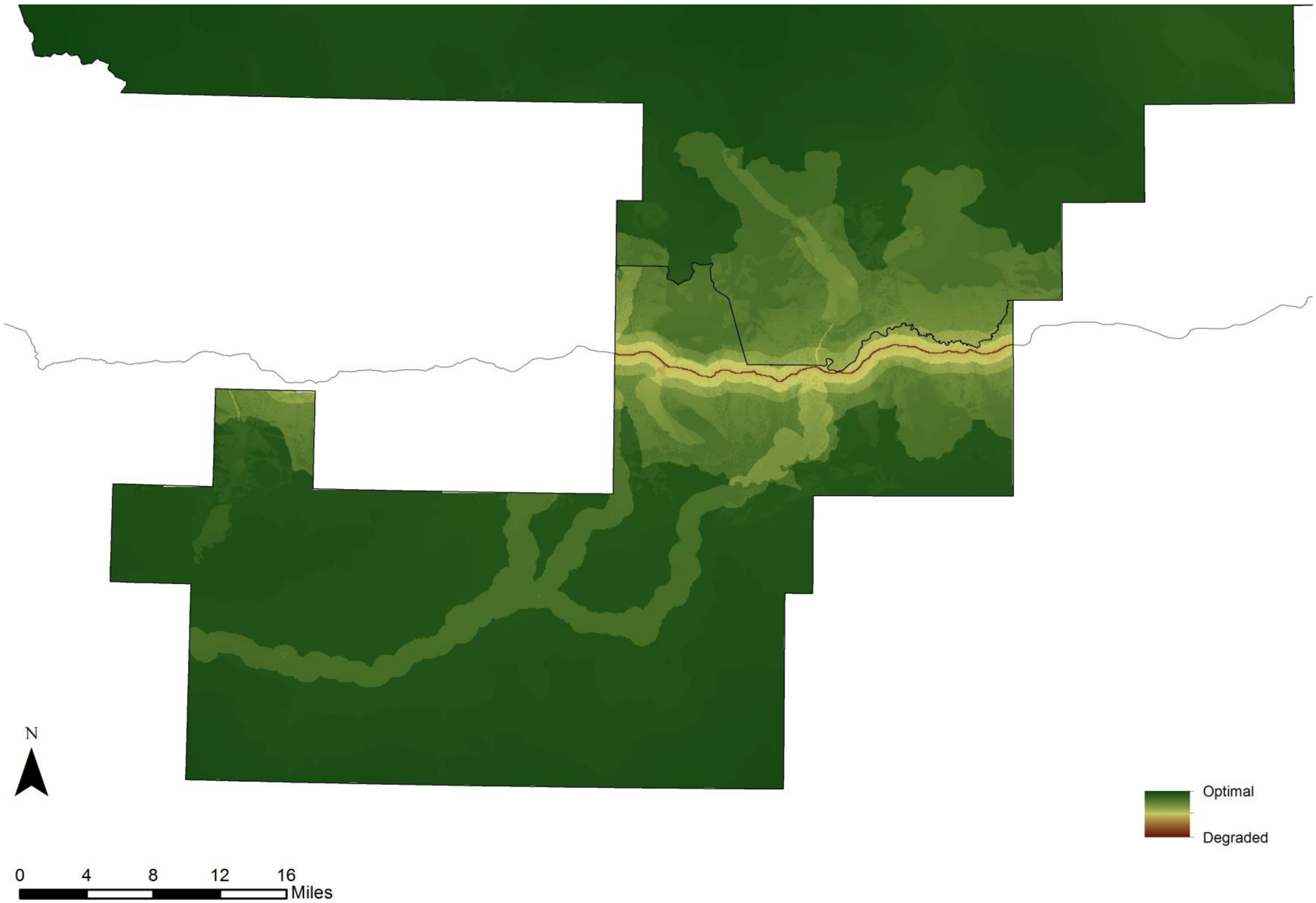

Figure 17. Proposed northern Ambler Road corridor map of potential threats to wilderness character for the Kobuk Preserve. Green depicts optimal condition and brown depicts degraded condition. (See Appendix B for full map.)

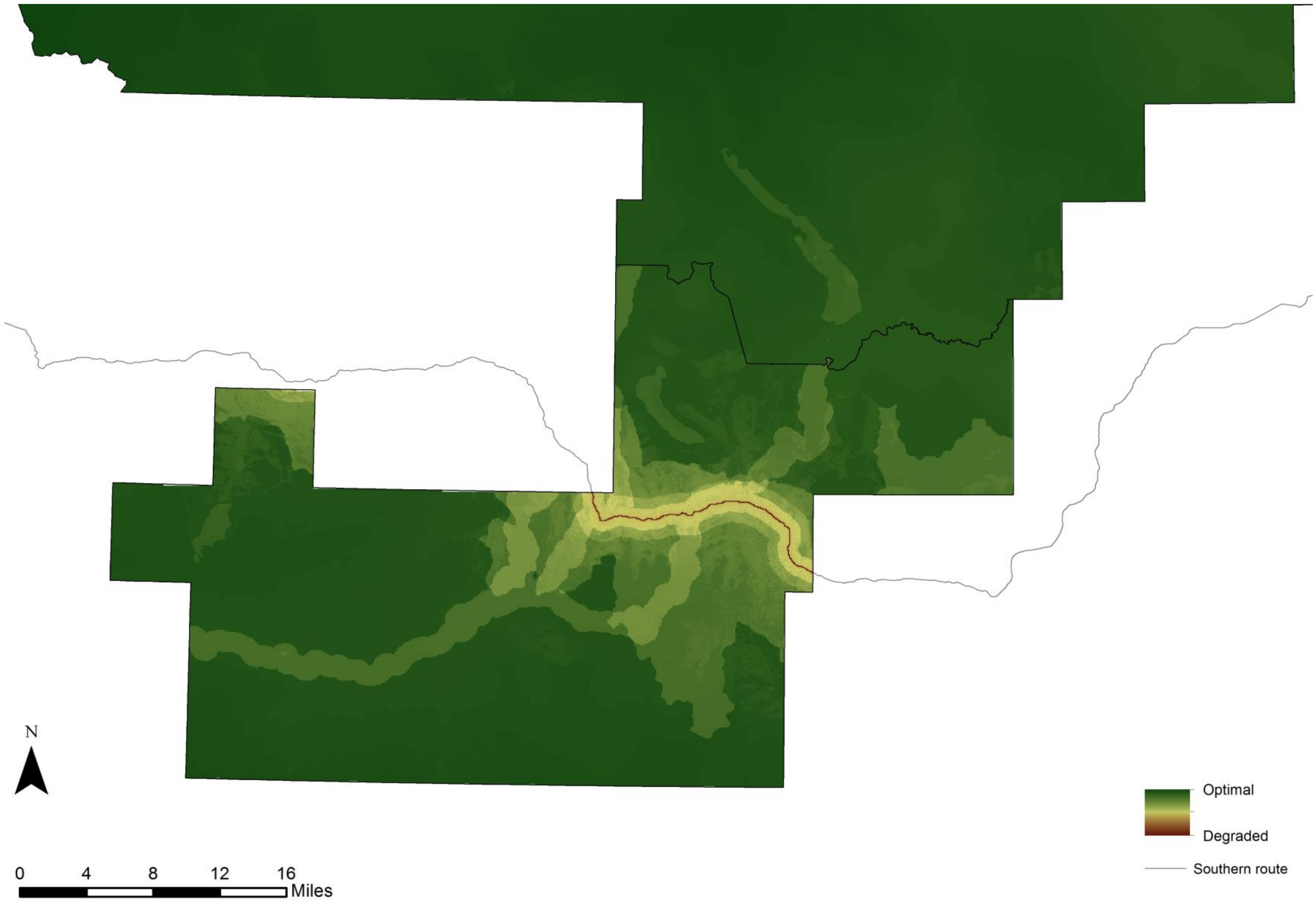

Figure 18. Proposed southern Ambler Road corridor map of potential threats to wilderness character for Kobuk Preserve. Green depicts optimal condition and brown depicts degraded condition. (See Appendix B for full map.)

Discussion of proposed Ambler road impacts to GAAR wilderness character

Interpreting the map products generated by this project requires a clear understanding of the methods that were used and their associated limitations. To create the maps depicting the impacts that the proposed road corridors will have on wilderness character in GAAR, the project team re-ran the baseline map with the adjusted and new measures that capture the impacts of the two routes. These maps include degradations of wilderness character from the developments explicitly described in AIDEA's Ambler Road right-of-way application, and also estimated additional degradations of wilderness character that could occur should the Ambler Road become a public access route. The project team chose to map both explicit and estimated degradations of wilderness character to foster consideration of reasonably foreseeable outcomes of road access being introduced through large tracts of public (both state and federal) lands, which include public access to and increased recreational visitation of National Park Service lands within GAAR. This approach also allows managers to foresee impacts from types of visitor use previously unseen in the area.

On paper, the proposed northern road corridor will have a larger footprint through the Kobuk Preserve and thus a greater impact on wilderness character in the area. The impacted area of the proposed northern route is 3,141 sq. km. and the unaffected area for that route is 30,148 sq. km. (For the proposed southern route, the impacted area is 2,494 sq. km and the unaffected area is 30,796 sq. km.[37]) This is especially true when considering that road construction is an intentional action that degrades the untrammeled quality and that the two routes are tracked twice in the undeveloped quality (as a non-recreational development and as a proxy for motorized use). Similarly, under the solitude quality, the length of the northern corridor results in a larger area of impacts to outstanding opportunities for solitude. However, the effect of local environmental factors, such as topography and vegetation adjacent to each route, can also affect the overall footprint of measures such as viewshed, soundscape and travel time. One clear difference between the two routes is the northern corridor is in close proximity to two large lakes (Walker Lake and Nutuvukti Lake) which may have implications for opportunities for primitive and unconfined recreation. Walker Lake is a National Natural Landmark depicted on the positive features map. The project team acknowledged that visitors along the northern route would be drawn to stopping at these natural features, which may eventually require facilities (such as campsites, restrooms and trails) and management restrictions to protect resources.

Finally, the area of analysis for the maps in this report includes both designated wilderness and the two national preserves (which are managed as wilderness). If only analyzing the impacts of the two

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[37] Using raster calculator, GIS analyst subtracted the baseline map from each road map. He then reclassified those difference values by whether they were greater or less than 0. Those values that were greater than 0 indicated areas where the wilderness quality had declined with the addition of the road. Those values less than or equal to 0 indicated areas that were unaffected by the road. 519 false positive pixels were incorrectly identified as being greater than 0 (as a result of differences in normalization) but should have been negative. These 519 pixels were added to the total number of pixels in the unaffected areas and subtracted from the total number of pixels in the impacted areas. GIS analyst then multiplied the number of pixels in both categories by the area of each pixel (100 m x 100 m= 10,000 sq m) and then converted these values to sq km by dividing by 1,000,000.

proposed corridors on current designated wilderness, it is clear that the northern corridor will have a greater impact on wilderness character than the southern corridor

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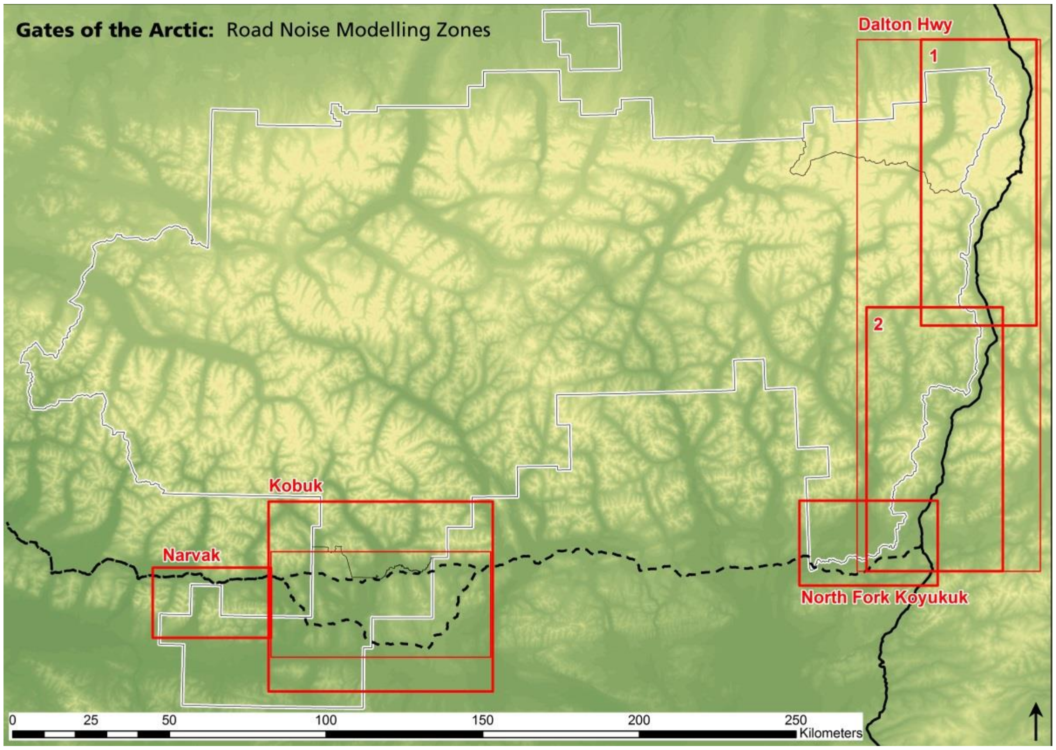
Appendix A. GAAR wilderness character spatial model: road noise modelling methodology

This methodology builds upon – and documents deviations from – the technique employed by Big Sky Acoustics in developing a noise model for the *Ambler Mining District Industrial Access Project Department of the Interior Permit Application Supplemental Narrative, Appendix 4-H: Ambler Mining District Industrial Access Road Environmental Sound Analysis*. For a full description of the basic assumptions of these models, please see the original documentation within the supplemental narrative. A basic overview of assumptions is as follows:

- Calculations by International Organization for Standardization (ISO) 9613-2 *Attenuation of Sound during Propagation Outdoors, Part 2: General Method of Calculation.*
- Vehicles assumed to operate during the day at a certain hourly rate.
- Atmospheric conditions: 55° F, relative humidity 70% - mean conditions in Ambler, June through August 2014 (Weather Underground data)
- Ground factor assumed to be G = 1.0 (porous ground) everywhere except large lakes, where G = 0.0 (acoustically reflective) (ISO 9613-2)

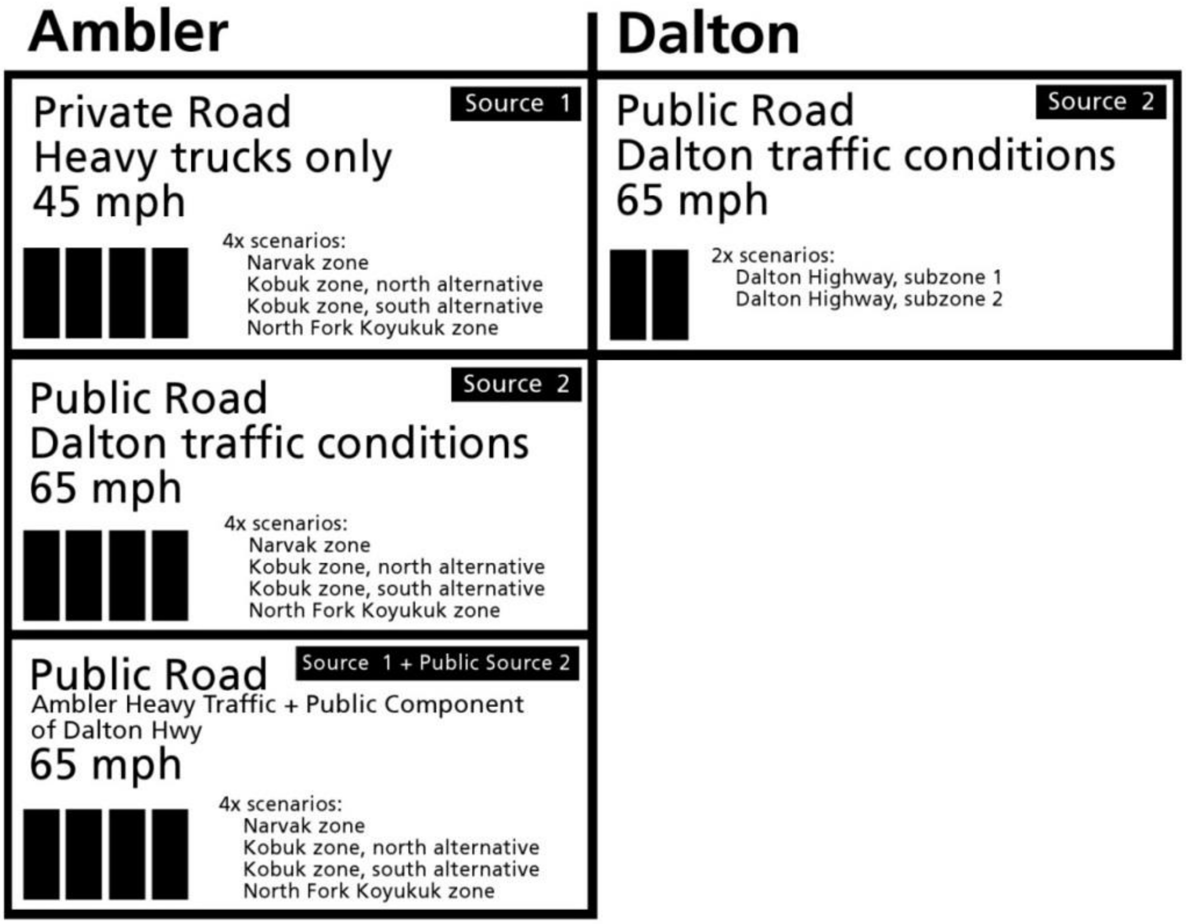
A. Preparing spatial inputs:

1. The model prepared in CadnaA required the following spatial data, clipped to the bounds of a rectangular study area:
    a. digital elevation model (Alaska 30 meter NED) for *'height points'* exported as ascii grid
    b. road route for '*line source'* exported as shapefile
    c. park or preserve outline for '*calculation area'* exported as shapefile
    d. lake surface polygons for *'ground effect'* exported as shapefile
2. Study areas were defined such that noise could be calculated separately for the extant road (Dalton Highway), and proposed road (Ambler Road). Due to the large area influenced by the Dalton Highway, two separate study areas were defined. The Ambler Road has three unique routing situations close enough to influence the park – a combined easterly portion near the North Fork Koyukuk River which splits into two routing alternatives within the Kobuk portion, and then recombines in a westerly portion near Narvak Lake.



3. Given these study areas, a number of modelling scenarios were designed. First was the Ambler Road route as described in the State of Alaska right-of-way application - a private mining road with heavy trucks travelling 45 miles per hour. The second scenario describes the Dalton Highway with its current mixed traffic conditions and median speed of 65 miles per hour (State of Alaska 2015a). A third scenario applies Dalton Highway traffic conditions to the Ambler Road, and the fourth extends that condition to one of maximum use – the full proposed volume of mining traffic (12 heavy trucks per hour) added to the public component of the Dalton Highway.

   The following graphic describes the 14 unique model runs in CadnaA:



B. Preparing vehicle line sources:

An initial challenge of the project was to develop line source information for mixed traffic conditions using methodology of the Department of Transportation Traffic Noise Model. This approach was adopted for consistency with the original models included in the right of way application.

1. Curves showing broadband A-weighted sound pressure levels for automobiles, medium trucks, and heavy trucks as a function of vehicle speed are shown in figures 8, 10, and 12 of FHWA Traffic Noise Model Technical Manual, Appendix A (FHWA 1998). Given a median measured traffic speed of 65 miles per hour on the Dalton Hwy and a given traffic speed of 45 miles per hour on the private Ambler Road, broadband levels were determined for each vehicle type.

2. The 1/3rd octave band emission spectra for each vehicle type are given in figures 17, 21, and 26 of the TNM Technical Manual, Appendix A. These spectra are referenced to unity (0 dB), so a numeric offset must be added such that the broadband level of the spectrum matches the broadband level of the vehicle travelling at a given speed. For vehicles travelling 65 mph, these offsets were determined to be 62.1 dBA for automobiles/light vehicles, 70.6 dBA for medium trucks, and 86.9 dBA for heavy trucks. For heavy trucks at 45 mph, the offset was 72.3 dBA.

3. Adjusted 1/3rd octave band levels are then summed to 1/1 octave band levels for the 63, 125, 250, 500, 1000, 2000, 4000, and 8000 Hz bands.

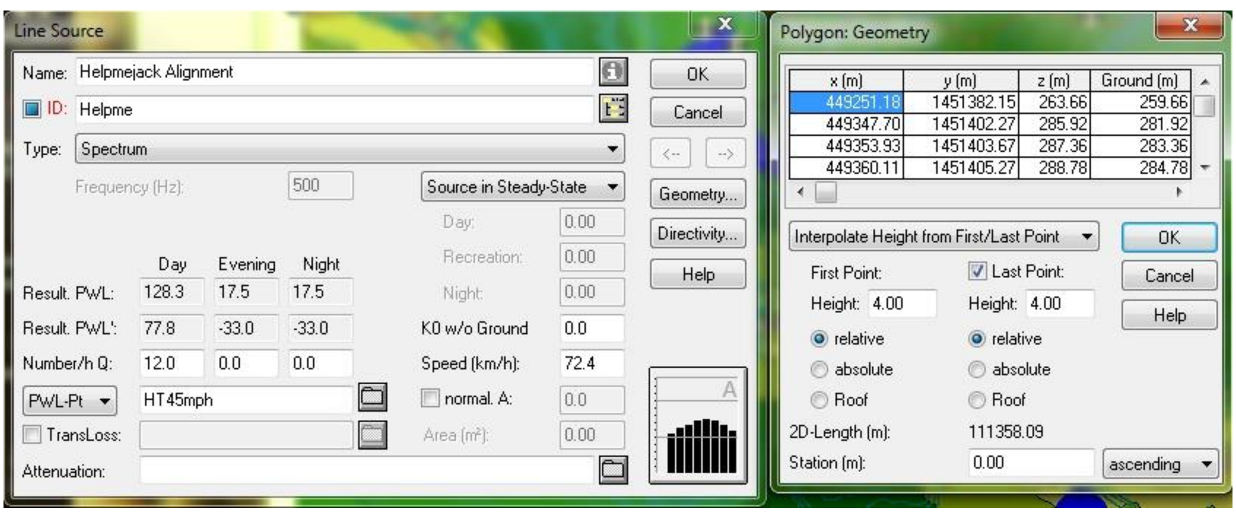
4. The weighted 1/1 octave spectrum can then be input into the global library of sound pressure levels in CadnaA. They are used to create independent, overlapping line sources that are calculated simultaneously.

C. Settings within the CadnaA environment:

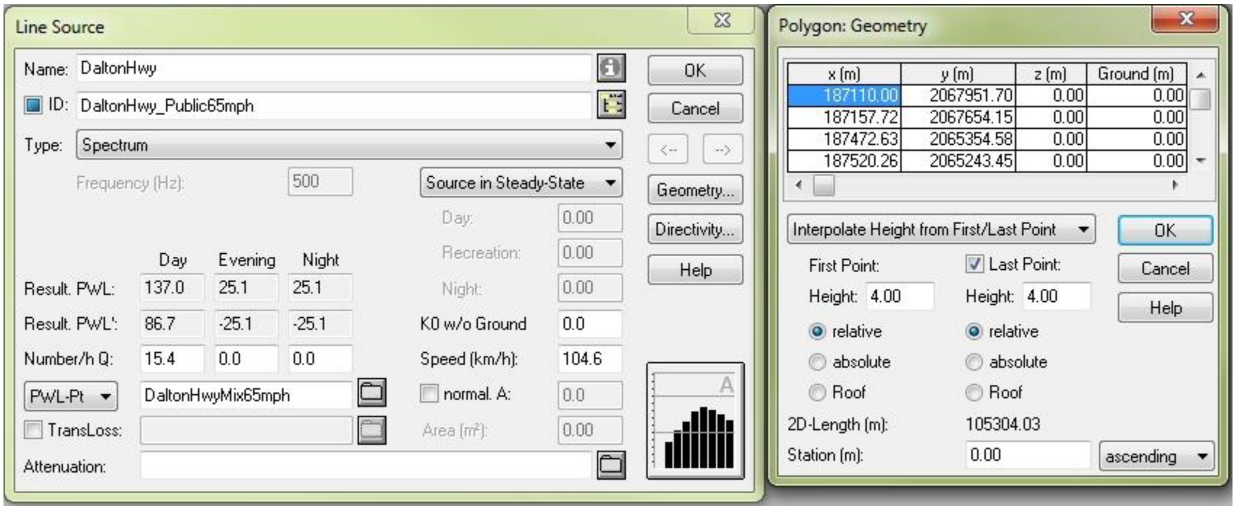
The following images detail the parameters used within the CadnaA environment:

Grid Properties

Line Source, 45 mph private



Line Source, 65 mph public



NOTE: the 'Number/h Q' parameter varies by scenario and vehicle type in the following way:

Table A1. '*Number/h Q*' parameter values for line source by scenario and source.

Scenario	**'Number/h Q' (by source)**
Ambler: Private Road	Heavy = 12.0
Dalton: Public Road	Heavy = 6.6, Medium = 3.9, Light = 4.9
Ambler: Public Road, Dalton traffic mix	Heavy = 6.6, Medium = 3.9, Light = 4.9
Ambler: Public Road, Ambler heavy traffic + Dalton public	Heavy = 12.0, Medium = 3.9, Light = 4.9

Parameters used for the *Calculation Configuration* dialog were identical to those used for the right of way application. These parameters were saved as a preset, '*AmblerRoad_CalcConfiguration.cnf*' if future variants of the model are to be run.

Table A2. Non-default parameters used for *Calculation Configuration* dialog.

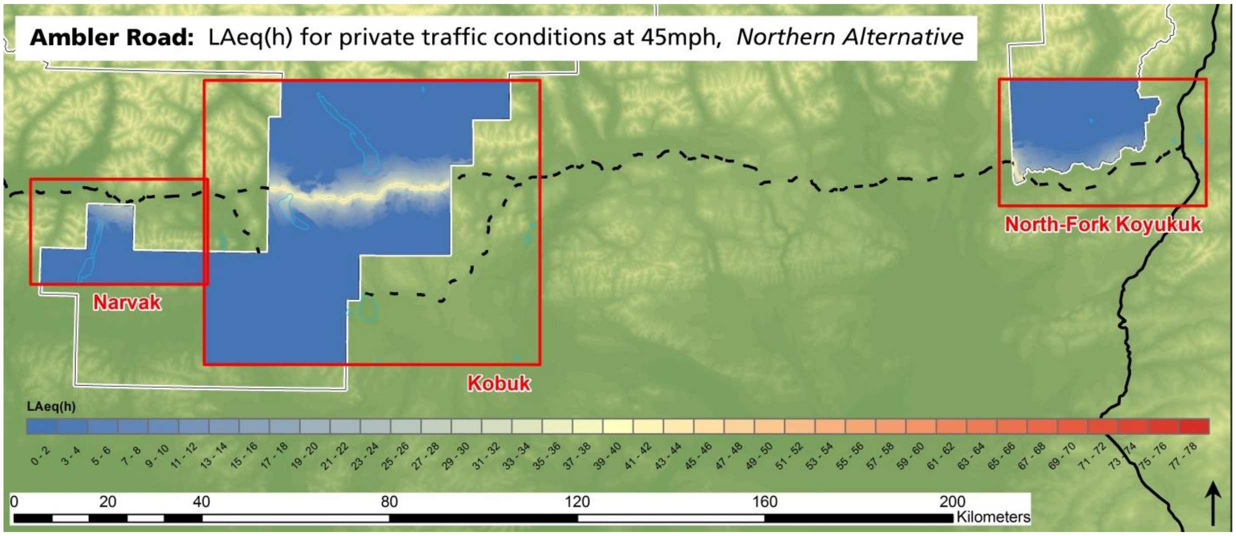
Tab / parameter	**Value**
Country / Road	TNM
General / Max. Search Radius	30000.0
General / Extrapolate Grid 'under' Buildings	N
Partition / Max. Dist. Source-Rcvr	40000.0
Partition / Search Radius Source	40000.0
Partition / Search Radius Receiver	40000.0

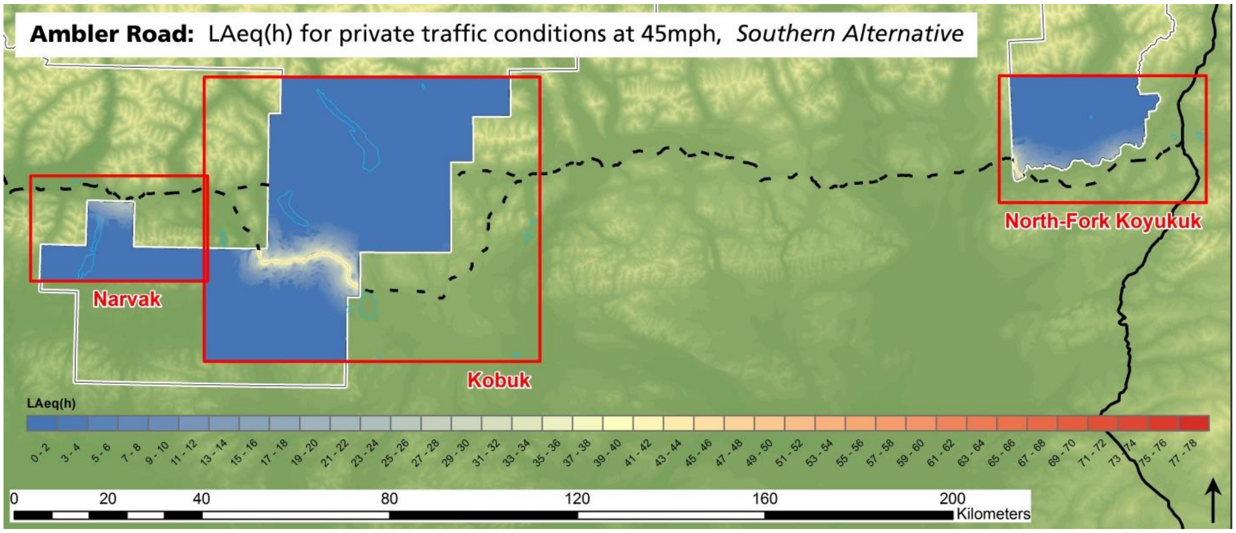
Tab / parameter	Value
Eval. Param. / 1	Ld
Eval. Param. / 2	=f(x), totd_l
Ground Abs. / Resolution	10.00
Industry / No sub. Of neg. Ground Att.	Y
Industry / Temperature	12
Industry / rel. Humidity	70

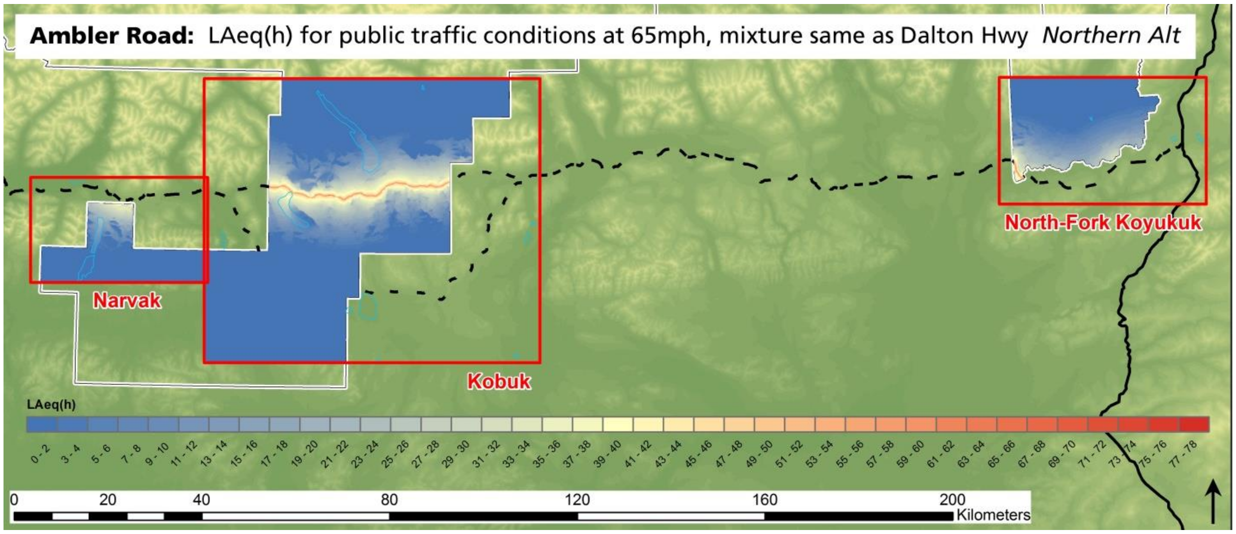
D. Description of final results:

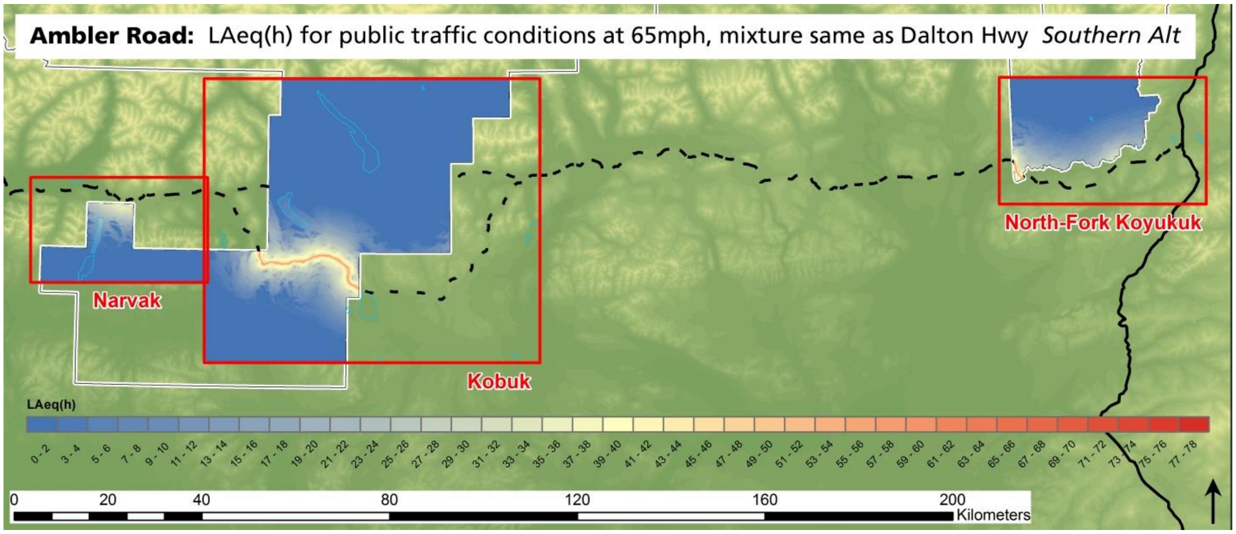
Running each CadnaA scenario results in a 100x100 meter grid of 1-hour equivalent sound pressure levels. Both A-weighted (*LAeq, 1hr*) and flat-weighed (*LZeq, 1hr*) levels were calculated, but only the A-weighted results are incorporated into the larger spatial model.

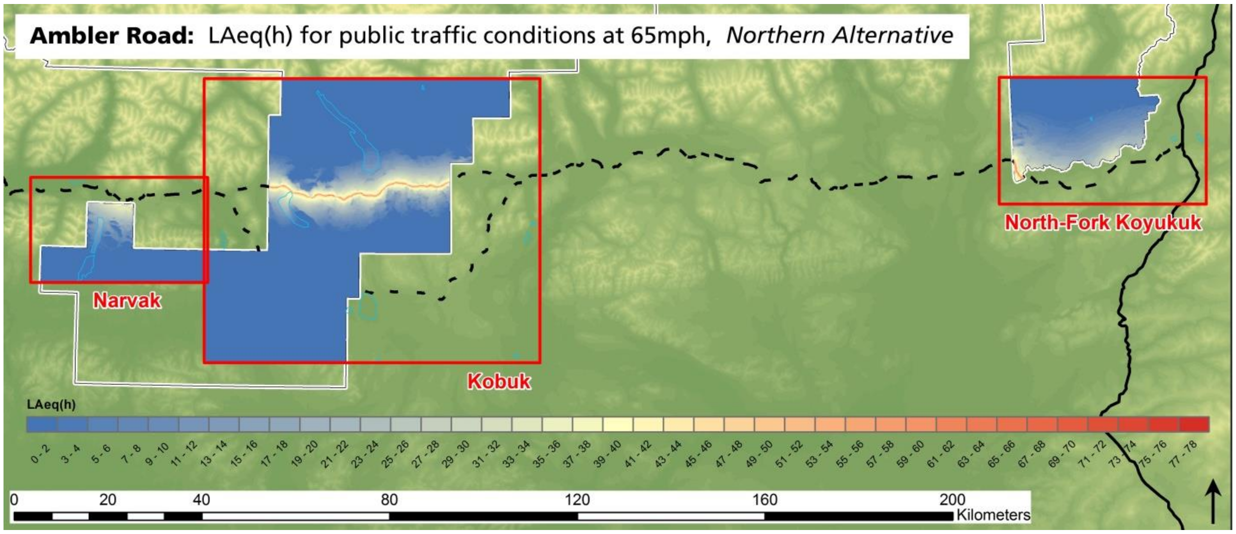
Data were exported from CadnaA as ASCII files, then converted into a raster and projected into the *Alaska Albers NAD83 2011* coordinate system using ArcMap. Finally, these rasters were exported as uncompressed TIFF files for further use and archive.

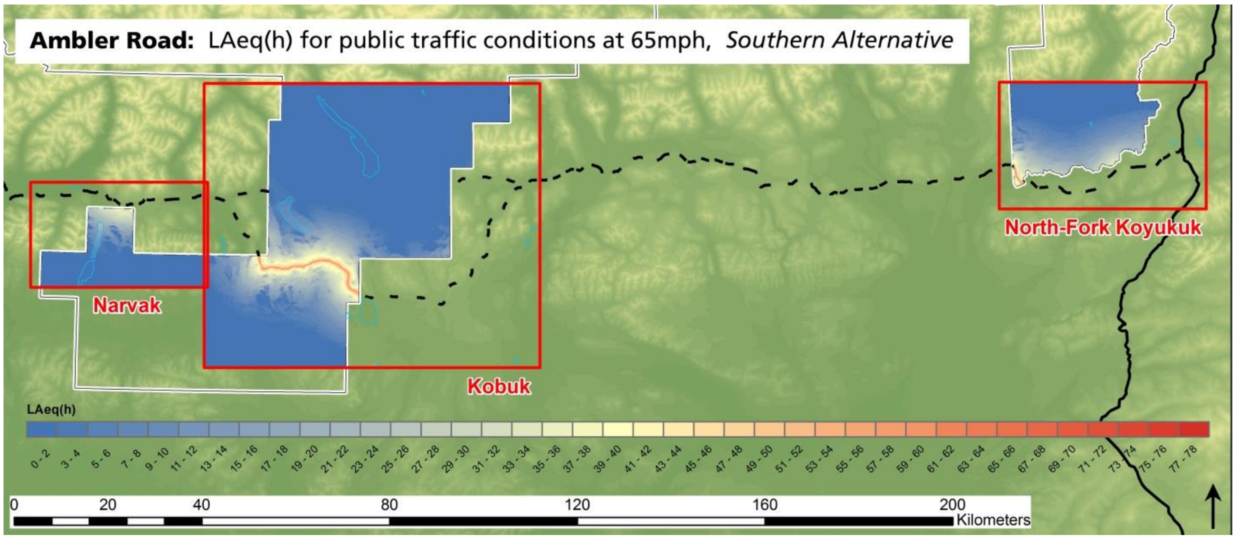


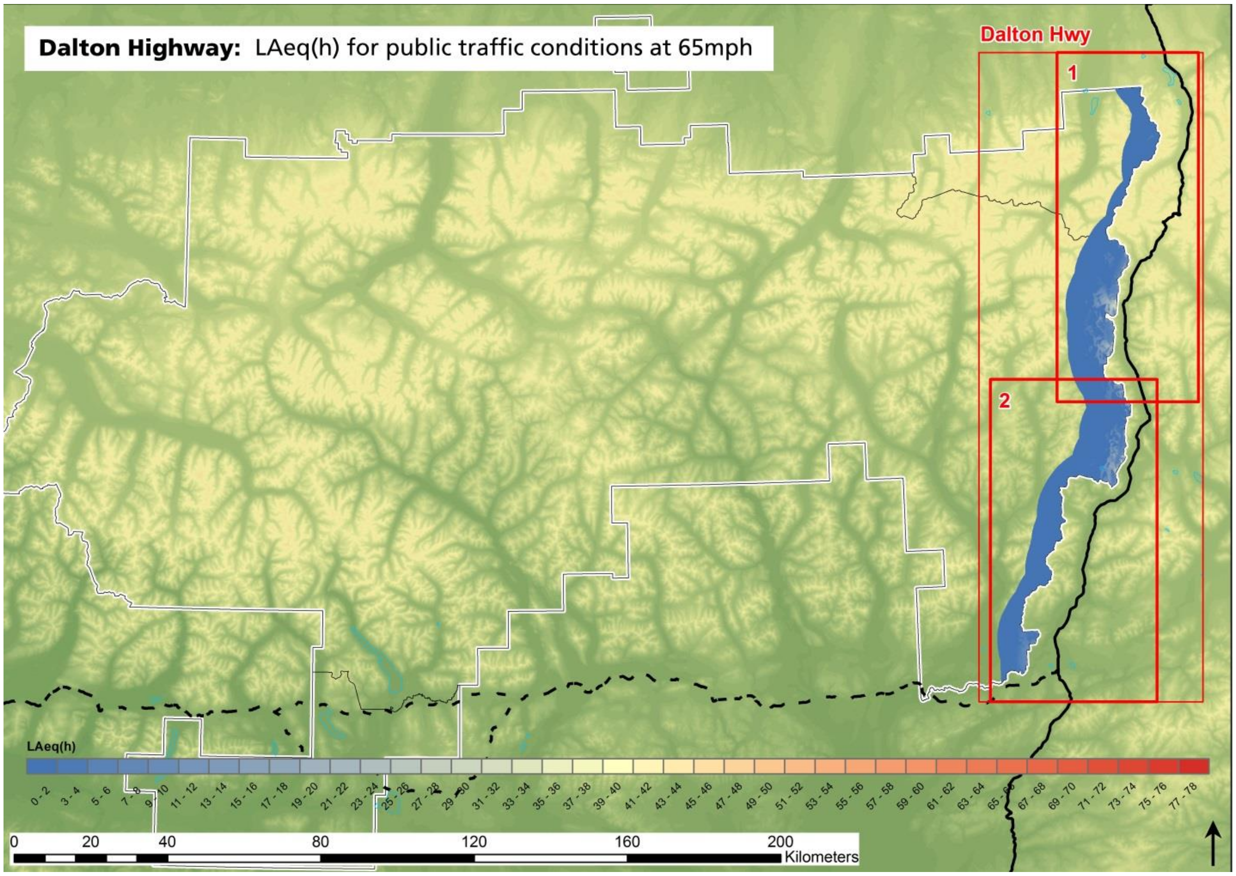

Ambler Road: LAeq(h) for private traffic conditions at 45mph, Southern Alternative
North-Fork Koyukuk
Narvak
Kobuk
LAeq(h)
0 20 40 80 120 160 200
Kilometers


Ambler Road: LAeq(h) for public traffic conditions at 65mph, mixture same as Dalton Hwy Northern Alt
North-Fork Koyukuk
Narvak
Kobuk
LAeq(h)
0 20 40 80 120 160 200
Kilometers


Ambler Road: LAeq(h) for public traffic conditions at 65mph, mixture same as Dalton Hwy Southern Alt
North-Fork Koyukuk
Narvak
Kobuk
LAeq(h)
0 20 40 80 120 160 200
Kilometers


Ambler Road: LAeq(h) for public traffic conditions at 65mph, *Northern Alternative*
Narvak
Kobuk
North-Fork Koyukuk
LAeq(h)
0 - 2 3 - 4 5 - 6 7 - 8 9 - 10 11 - 12 13 - 14 15 - 16 17 - 18 19 - 20 21 - 22 23 - 24 25 - 26 27 - 28 29 - 30 31 - 32 33 - 34 35 - 36 37 - 38 39 - 40 41 - 42 43 - 44 45 - 46 47 - 48 49 - 50 51 - 52 53 - 54 55 - 56 57 - 58 59 - 60 61 - 62 63 - 64 65 - 66 67 - 68 69 - 70 71 - 72 73 - 74 75 - 76 77 - 78
0 20 40 80 120 160 200
Kilometers


Ambler Road: LAeq(h) for public traffic conditions at 65mph, *Southern Alternative*
Narvak
Kobuk
North-Fork Koyukuk
LAeq(h)
0 - 2 3 - 4 5 - 6 7 - 8 9 - 10 11 - 12 13 - 14 15 - 16 17 - 18 19 - 20 21 - 22 23 - 24 25 - 26 27 - 28 29 - 30 31 - 32 33 - 34 35 - 36 37 - 38 39 - 40 41 - 42 43 - 44 45 - 46 47 - 48 49 - 50 51 - 52 53 - 54 55 - 56 57 - 58 59 - 60 61 - 62 63 - 64 65 - 66 67 - 68 69 - 70 71 - 72 73 - 74 75 - 76 77 - 78
0 20 40 80 120 160 200
Kilometers



Thanks to Eddie Duncan (*Resource Systems Group, Inc.*) and Katie Nuessly (*NPS Natural Sounds and Night Skies Division*) for their help with developing this model.

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State of Alaska. 2015a. Northern Region Annual Traffic Volume Report: 2015. State of Alaska Department of Transportation and Public Facilities - Northern Region. Fairbanks, Alaska.

State of Alaska. 2015b. Ambler Mining District Industrial Access Project - Department of the Interior Permit Application Supplemental Narrative, Appendix 4-H: Ambler Mining District Industrial Access Road Environmental Sound Analysis. State of Alaska, Alaska Industrial Development and Export Authority, Anchorage, AK.

Appendix B. GAAR wilderness character maps depicting the effect of the proposed northern and southern routes of the Ambler Road Corridor on wilderness character.

These maps depict the impact of the proposed Ambler Road corridor (both the northern and southern routes) to the wilderness character of GAAR as a whole.

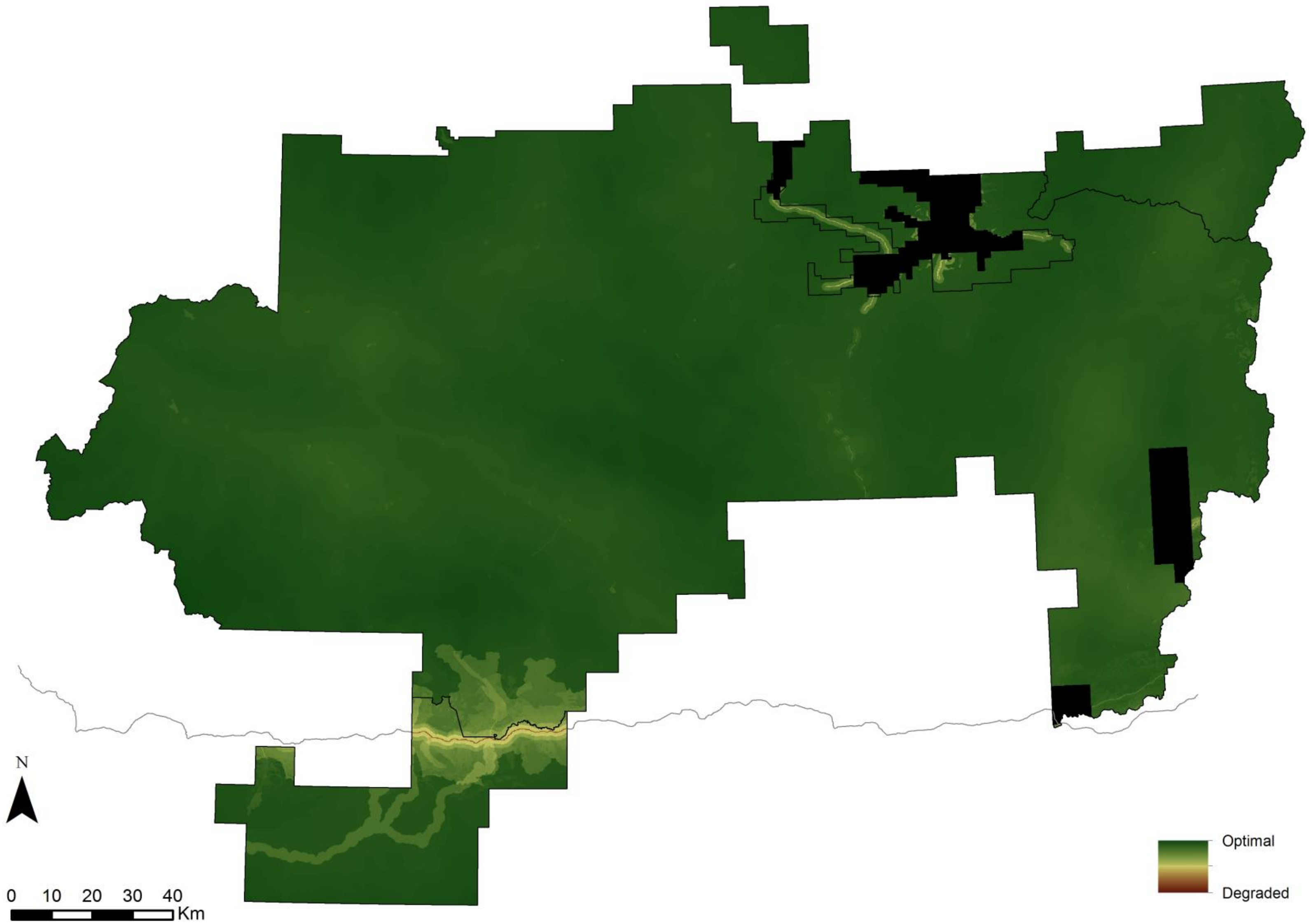

Figure B1. Wilderness character map for northern route. Map depicting the effect of the proposed northern route of the Ambler Road Corridor on wilderness character in GAAR.

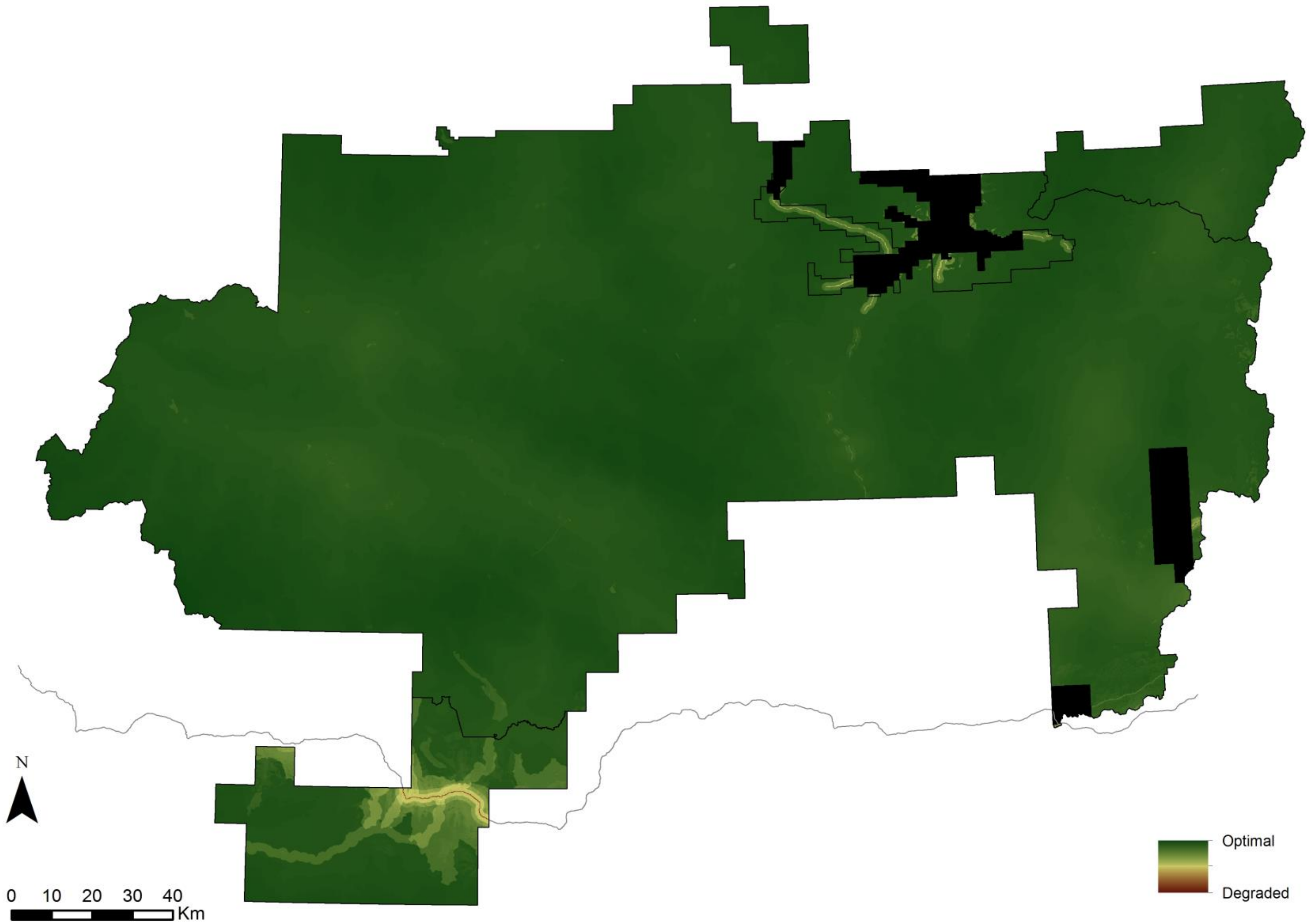

Figure B2. Wilderness character map for southern route. Map depicting the effect of the proposed southern route of the Ambler Road Corridor on wilderness character in GAAR.

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U.S. Department of the Interior

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