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Evaluating Potential Impacts of Proposed Industrial Access Road Routes on Wilderness Character in Gates of the Arctic National Park and Preserve, Alaska

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ABSTRACT. Northern Alaska is home to the largest designated wilderness landscape in the United States and among the world's largest remaining roadless regions. Under the 1980 Alaska National Interest Lands Conservation Act, the Alaska Industrial Development and Export Authority, a semi-public corporation of the state of Alaska, proposed an industrial road to access the Ambler Mining District that would run approximately 320 km along the southern edge of the western Brooks Range, crossing federal, state, and Native Corporation lands. Two alternative routes are being considered that cross the Kobuk Preserve portion of Gates of the Arctic National Park and Preserve, with the northern route running outside of but adjacent to Gates of the Arctic Wilderness. Both Kobuk Preserve and Gates of the Arctic Wilderness are managed by the National Park Service to preserve wilderness character under existing federal law and agency policy. This study evaluates the potential impacts of both routes on wilderness character in the Kobuk Preserve and adjacent Gates of the Arctic Wilderness. We use a hierarchical conceptual framework to identify spatially explicit measures that show the potential impacts of the road on wilderness character. The impacts from each measure are combined using a weighting scheme to generate a series of maps that quantify the potential impacts of these two proposed routes. Our results show that both routes would degrade wilderness character within the Kobuk Preserve, and that the northern route, which is the state's preferred alternative for the road corridor, would have a significantly greater impact in terms of degrading wilderness character in the adjacent Gates of the Arctic Wilderness.

Key words: Alaska; mining; roads; wilderness; wilderness character; National Parks; development; solitude

RÉSUMÉ. Le nord de l'Alaska abrite la plus grande zone sauvage désignée des États-Unis et fait partie des plus grandes régions du monde qui n'ont toujours pas de routes. En vertu de la loi *Alaska National Interest Lands Conservation Act* de 1980, l'Alaska Industrial Development and Export Authority, société d'État semi-publique de l'Alaska, a proposé l'aménagement d'une route industrielle donnant accès au district d'exploitation minière d'Ambler. Cette route s'étendrait sur environ 320 km le long de la lisière sud de l'ouest de la chaîne de Brooks et traverserait des terres fédérales, d'État et de sociétés autochtones. Deux autres routes sont en voie de considération. Une d'entre elles traverse la partie de la réserve de Kobuk du parc national et de la réserve de Gates of the Arctic, tandis que la route plus au nord se trouverait à l'extérieur de la zone sauvage de Gates of the Arctic, mais adjacente à celle-ci. La réserve de Kobuk et la zone sauvage de Gates of the Arctic sont toutes deux gérées par le Service national des parcs afin de favoriser la conservation de leur caractère sauvage, en vertu des lois fédérales et des politiques de l'organisme. Cette étude évalue les incidences potentielles des deux routes sur le caractère sauvage de la réserve de Kobuk et de la zone sauvage de Gates of the Arctic adjacente. Nous avons recouru à un cadre conceptuel hiérarchique pour déterminer les mesures spatialement explicites illustrant les incidences potentielles de la route sur le caractère sauvage de ces lieux. Les incidences de chaque mesure sont combinées à l'aide d'une méthode de pondération qui permet de produire une série de cartes quantifiant les incidences potentielles de ces deux routes proposées. Nos résultats montrent que ces deux routes auraient pour effet de dégrader le caractère sauvage de la réserve de Kobuk, et que la route plus au nord, soit l'option privilégiée par l'État pour l'aménagement du corridor routier, aurait des incidences beaucoup plus grandes en matière de dégradation du caractère sauvage de la zone sauvage de Gates of the Arctic adjacente.

Mots clés : Alaska; exploitation minière; routes; zone sauvage; caractère sauvage; parcs nationaux; aménagement; solitude

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INTRODUCTION

Northern Alaska is one of the largest remaining undeveloped and roadless regions globally and in North America (Sanderson et al., 2002; Watson et al., 2018). The region is renowned for its large, intact habitats and abundant wildlife, including a large portion of North America's remaining wild caribou (*Rangifer tarandus*) of the Western Arctic caribou herd, a herd with the longest known terrestrial migration of any species in the world. The region is also home to one of the world's largest populations of grizzly bear (*Ursus arctos*), Dall sheep (*Ovis dalli*), and hundreds of migratory bird species. Alaska's Indigenous peoples (Inupiaq, Koyukon) have lived on these landscapes for millennia and rely on the region's resources for their cultural and subsistence traditions (e.g., Wolfe and Walker, 1987; Wolfe, 2004; Magdanz et al., 2016). Tourism has also grown by 4% per year in Alaska (McDowell Group, 2020) over a 10-year period, with many visitors drawn to the region's iconic national parks and vast wilderness areas.

Large portions of the northern Alaska landscape were formally protected in 1980 with passage of the Alaska National Interest Lands Conservation Act (ANILCA, 1980). ANILCA was the single largest expansion of protected lands in U.S. history, creating most of the national parks in Alaska and adding 56 million acres of designated wilderness to the National Wilderness Preservation System (NWPS). This system provides the highest level of protection for federally managed lands (Dawson and Hendee, 2008; Aycrigg et al., 2016) in the United States and is considered the world's largest highly protected conservation network. Regulations for designated wilderness prohibit many human activities such as road-building, logging, energy development, off-road motor vehicle use, developed tourism facilities, and permanent structures (Wilderness Act, 1964: Section 4c). The primary legal mandate for all designated wilderness regardless of location, size, or any other site-specific attribute is to preserve the wilderness character of these areas (Landres et al., 2015).

ANILCA (1980) contains numerous provisions for Alaska Native land claims and subsistence access, along with specific mandates that enable access to Alaska's remote natural resources. Although ANILCA allows certain activities, such as landing of fixed-wing aircraft, which are otherwise prohibited in designated wilderness outside of Alaska (see Dawson and Hendee, 2008 for detailed discussion), the legal mandate from the 1964 Wilderness Act to preserve wilderness character still applies to Alaskan wilderness (Landres et al., 2015), including Gates of the Arctic Wilderness within Gates of the Arctic Park and Preserve.

The Ambler Mining District, containing deposits of copper, zinc, lead, cobalt, gold, and silver, lies in the heart of Alaska's southern Arctic region. This district is considered one of the largest undeveloped copper-zinc mineral belts in the world, without any current access to these resources (Nokleberg et al., 1988). Recognition of this ore deposit and access to it were provided in ANILCA to allow the state or other authorities to develop surface transportation access across Gates of the Artic National Park and Preserve to the Ambler Mining District from the Alaska Pipeline Haul Road (ANILCA Section 201(4)(b)). Per ANILCA, these development plans must go through Secretarial review in the U.S Department of Interior and Department of Transportation and alternative routes considered, along with the environmental, social, and economic impacts of each route, but only for portions of the route that cross federal lands and waters. The Ambler Mining District also includes state and private land allotments, which would be accessed if a road was built but are not accessible without infrastructure. For all portions of the road that cross federal lands, analyses must consider routes "to avoid or minimize negative impacts and enhance positive impacts" on "wildlife, fish, and their habitat, and rural and traditional lifestyles including subsistence activities" (ANILCA, 1980: Section 201(4)).

To access the Ambler Mining District, the Alaska Industrial Development and Export Authority (AIDEA), a semi-public corporation of the state of Alaska, is proposing the Ambler Mining District Industrial Access Project (hereinafter Ambler Mining Road). This proposed road, approximately 320 km along the southern edge of the western Brooks Range, would cross federal, state, and Native Corporation lands. The proposed road includes two alternative routes through the Kobuk Preserve portion of Gates of the Arctic National Park and Preserve.

Previous studies have documented a range of impacts from the construction and continued use of three roads in remote regions of Alaska. A portion of the 84 km Delong Mountains Transportation System (commonly referred to as the Red Dog Mine Road) goes through Cape Krusenstern National Monument, and impacts from heavy metals and road dust pollutants were documented on vegetation (Hasselbach et al., 2005; Neitlich et al., 2017) and small mammal and bird species (Brumbaugh et al., 2010, 2011). The 577 km Dalton Highway, constructed initially as a private industrial access road in 1974 for the Trans-Alaska pipeline and opened to public access in 1994, caused long-lasting ecological impacts to the surrounding landscape (e.g., Myers-Smith et al., 2006) and uneven ground collapse of permafrost in proximity to the road (Connor and Harper, 2013). Use of the 148 km Denali Park Road was shown to cause the degradation of wilderness character along the road and in adjacent portions of the Denali Wilderness (Burrows et al., 2016). In addition, wilderness character was used as the organizing framework in analyzing potential impacts in Alaska from the proposed Izembek Road on the Izembek Wilderness (USFWS, 2012) and from the proposed Angoon Airport on the Kootznoowoo Wilderness (Federal Aviation Administration, 2016).

In this paper, we present an analysis of the potential impacts on wilderness character of the two alternative routes for the Ambler Mining Road that cross the Kobuk

Preserve portion of Gates of the Arctic Park and Preserve. The analysis is based on the methods, data, and results in Pace et al. (2017), a report produced for the NPS (see APPROACH section for discussion of our use of this report). The analysis is structured using the conceptual framework of wilderness character developed by a collaboration of the four U.S. federal agencies with nationwide administrative responsibility for managing wilderness (Landres et al., 2015): the U.S. Department of Agriculture, Forest Service (FS), U.S. Department of Interior, National Park Service (NPS), the Bureau of Land Management (BLM), and Fish and Wildlife Service (FWS). This framework is used to develop a spatially explicit analysis of potential impacts on wilderness character from both proposed alternative routes of the Ambler Mining Road based on mapping techniques developed from 10 years of research in eight U.S. designated wildernesses (Carver et al., 2013; Tricker and Landres, 2018). The analysis of potential impacts to wilderness character presented here complements recent analyses of potential impacts of the proposed Ambler Mining Road on the Western Arctic caribou herd (Wilson et al., 2014) and on subsistence (Guettabi et al., 2016).

STUDY AREA

The proposed Ambler Mining Road would cross the Kobuk Preserve portion of Gates of the Arctic Park and Preserve and provide access to the Ambler Mining District in the southern foothills of the central Brooks Range (Fig. 1). Surrounding the district are a number of wildlife refuges and national parks and preserves, which include federally designated wilderness areas. To the north of the mining district is the largest contiguous area managed as wilderness in the United States, composed of the Noatak Wilderness (23,331 km^2) and Gates of the Arctic Wilderness (29,004 km^2), and to the west is the Kobuk Valley Wilderness (712 km^2) and Selawik Wilderness (971 km^2). Because of their remoteness and proximity to one another, together these wildernesses present a vastness that is unique in the United States and offer outstanding opportunities for visitors to experience solitude, primitive and unconfined recreation, and interactions with a variety of wildlife. This region of Alaska represents one of the largest remaining roadless areas in North America and a significant portion of globally important roadless areas (Watson et al., 2018).

The Ambler Mining Road corridor would be the first development of its size in the region and would run approximately 320 km along the southern edge of the Brooks Range, crossing federal, state, and Native Corporation lands (Fig. 1). Additionally, the road would cross or border six designated Wild and Scenic Rivers, intersect summer, winter, and migration habitat for barren-ground caribou (*Rangifer tarandus groenlandicus*; Wilson et al., 2014), and connect remote villages and rural communities currently accessible by only boat or plane to a road network. The road will require special infrastructure due to subsurface permafrost and low elevation muskeg (i.e., northern bog) on which much of the road will be built, including large volumes of fill material and drainage structures. These actions will alter the hydrology across wetlands systems in the region (BLM, 2020). Examples of hydrologic impacts include the placement of fill in wetlands and the addition of culverts to streams. Snow removal off the highway will encourage hydrologic movement in new directions and may provide challenges for managing seasonal runoff. Many areas in the Ambler road corridor experience seasonal flooding, and these events may cause additional challenges for road surfaces (BLM, 2020).

Two alternate route options for the portion of the Ambler Mining Road that passes through the Kobuk Preserve are being considered in management planning processes—a shorter 27 km northern route and a longer 42 km southern route (Fig. 1). These routes were determined with surveys, input from industrial development authorities, the state of Alaska and the federal government, available infrastructure support, accessibility to local communities, and total distance. The route options are limited by the vast wetland complexes and river systems that characterize western Alaska's boreal forest. The northern route, the preferred alternative selected by the BLM (2020), runs adjacent to the boundary of Gates of the Arctic Wilderness, with potential impacts to wilderness character inside this designated wilderness. The northern route is the preferred alternative for both the BLM and AIDEA because its overall length is shorter even though its length through the Kobuk Preserve is longer.

From its outset, the Kobuk Preserve was considered for inclusion within the National Wilderness Preservation System. The park's first general management plan (NPS, 1986) denoted this area as "suitable wilderness" meeting the initial screening criteria for being designated as wilderness. The NPS later changed the name of this category (to avoid confusion with use of the word "suitability" in the 1964 Wilderness Act) to "eligible wilderness" (Southwould et al., 2016). As eligible wilderness, the Kobuk Preserve possesses wilderness character and value but requires further study to determine whether it would be recommended by the agency to be included in the NWPS. Importantly, as eligible wilderness, the Kobuk Preserve is to be managed to preserve its wilderness character; the NPS will not take any action that would diminish its wilderness eligibility until a legislative determination has been completed (NPS, 2006, 2013).

Although a right-of-way for surface transportation is allowed under ANILCA (1980), the potential impacts associated with developing this right of way and its use must still be evaluated in the Kobuk Preserve and adjacent Gates of the Arctic Wilderness. In addition, while the Ambler Mining Road will be built for industrial use and thus closed to public access, Wilson et al. (2014) describe how eventual public access cannot be ruled out, especially considering the precedent set by the Dalton Highway (Farber and

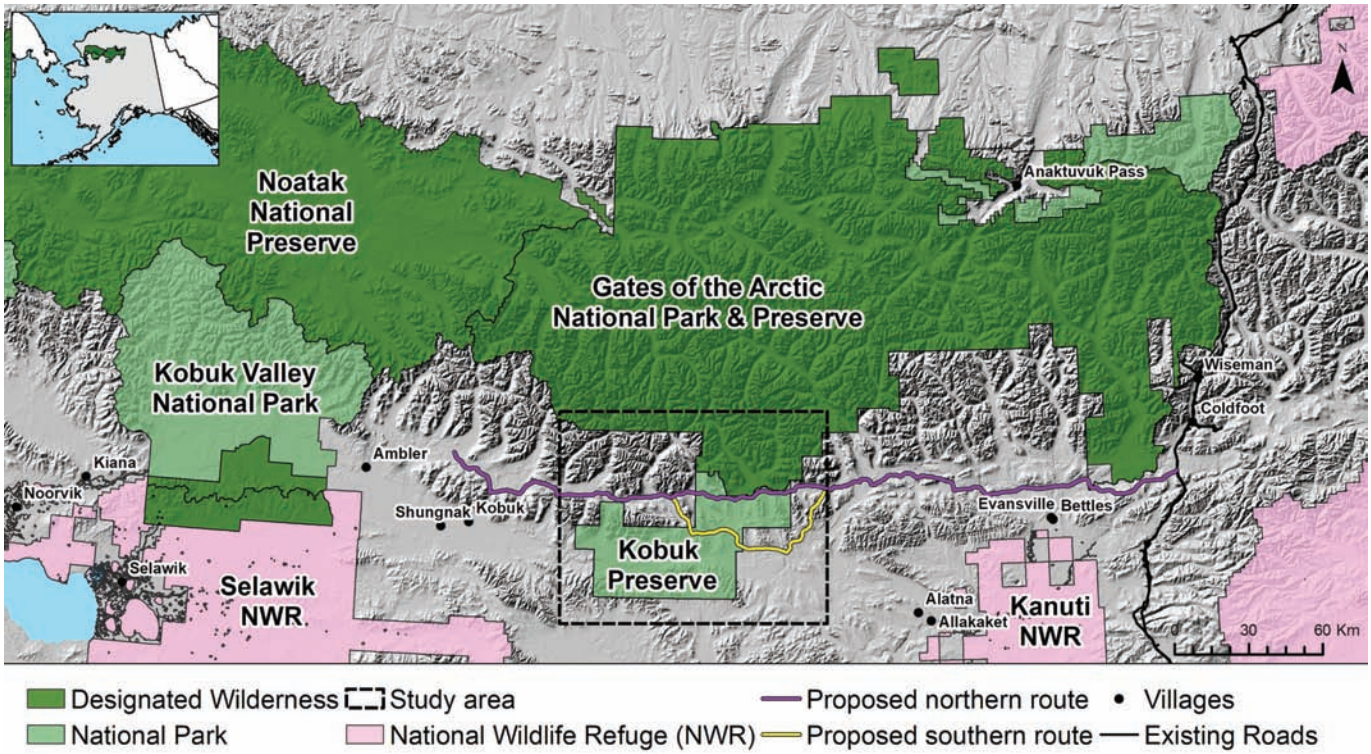

FIG. 1. Study area depicting wilderness areas and the two proposed Ambler Mining Road routes. Inset map indicates the area of focus in northern Alaska.

Hall, 2007). Public use of this road could cause additional ecological and sociological impacts to wilderness character. Proponents of the road state that the road will connect remote villages, but the road will only connect a portion of the villages in the region, and it is unclear whether local traffic will be allowed on the road and in what ways this will be managed with mining traffic.

APPROACH

As stated in the Introduction, the approach used in this paper is based on the data, methods, and results in Pace et al. (2017). This report is focused almost entirely on Gates of the Arctic Wilderness with only a short appendix on the Kobuk Preserve. Furthermore, this report does not interpret the results or place them in a broader conservation or societal context. While the analysis we present is based on the Pace et al. (2017) report, here we place this analysis in the context of the Kobuk Preserve and potential impacts of the Ambler Mining Road on wilderness character and discuss broader implications of these impacts on the conservation values of the region. We provide here only an overview of relevant methods and results from the Pace et al. (2017) report and cite the report whenever we draw explicitly from it. Readers should refer to the Pace et al. (2017) report for details of data sources, methods, and results.

We use the concept of wilderness character as a hierarchical organizational framework to identify and categorize potential impacts of the two alternative Ambler Mining Road routes (Fig. 2) within the Kobuk Preserve and adjacent Gates of the Arctic Wilderness. The U.S. federal wilderness managing agencies (BLM, FS, FWS, NPS) collaborated to operationally define wilderness character (Landres et al., 2015) as a unique and holistic resource composed of five "qualities" that directly link on-the-ground activities to the statutory language of the 1964 Wilderness Act:

- Untrammeled—wilderness ecological systems are unhindered and free from intentional actions of modern human control or manipulation.
- Natural—wilderness ecological systems are substantially free from the effects of modern civilization.
- Undeveloped—wilderness is essentially without structures or installations, the use of motors, or mechanical transport.
- Solitude or primitive and unconfined recreation—wilderness provides outstanding opportunities for solitude or primitive and unconfined recreation.
- Other features of value—wilderness may have unique features of ecological, geological, scientific, educational, scenic, or historical value.

Each of these five qualities is divided into component indicators; qualities and indicators are nationally consistent across the four wilderness managing agencies and across all wildernesses regardless of geographic location, ecosystem, and size. Measures, the specific elements for which data are collected to assess trends in an indicator, are site-specific

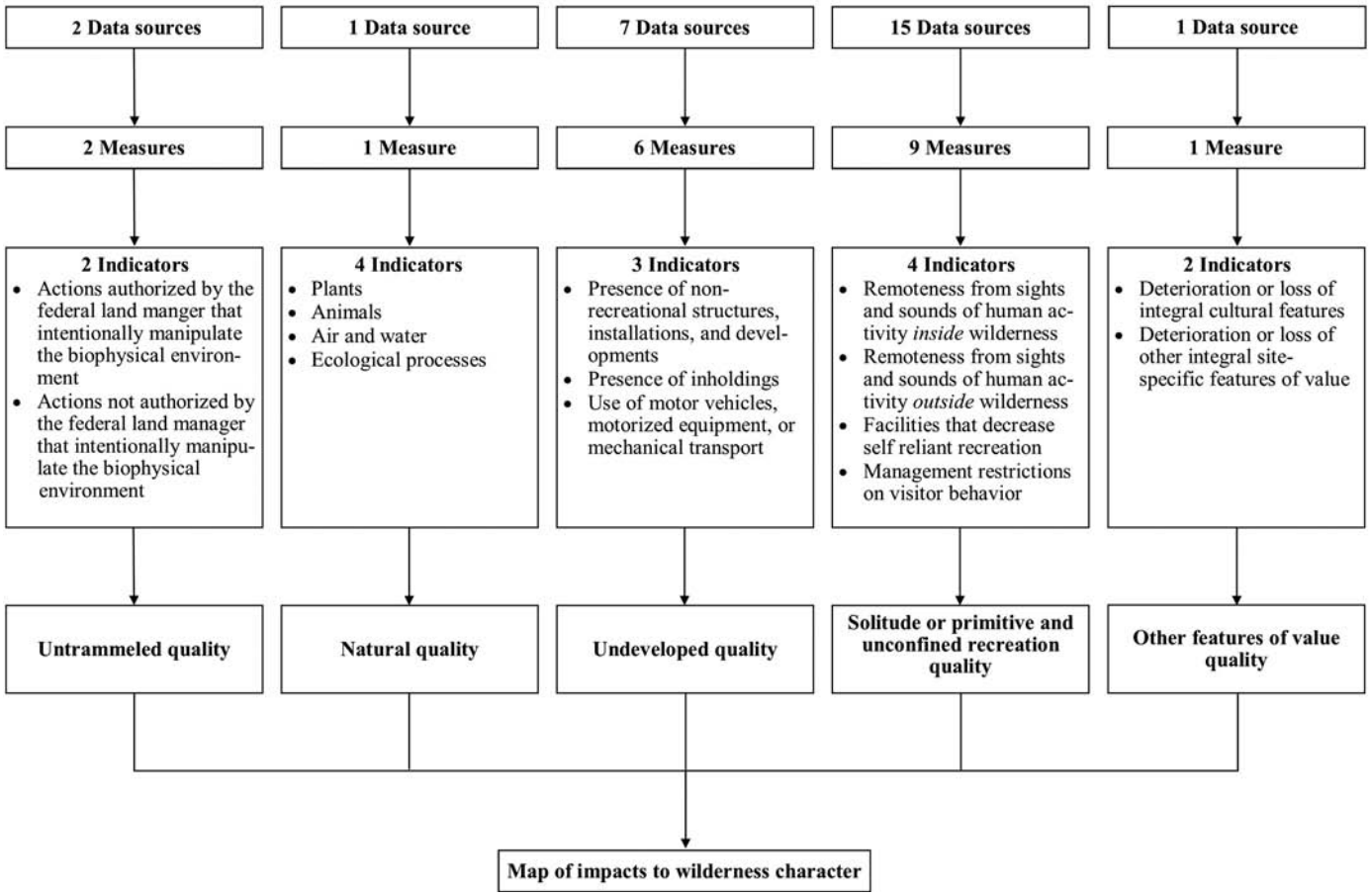

FIG. 2. Flow chart of the framework used for mapping impacts to wilderness character for the baseline wilderness character map.

to each wilderness based on local impacts and threats, management concerns, and data availability and quality. See Landres et al. (2015) for a detailed description of the qualities and indicators, and Tables 1 and 2 in this paper for the measures used in this study of potential impacts to these qualities and indicators from the Ambler Mining Road.

To map potential impacts to wilderness character from the Ambler Mining Road, we follow the approach first identified by Carver et al. (2013) and used for a number of wildernesses throughout the NWPS (Tricker and Landres, 2018). First, the hierarchical framework is used to identify and organize specific measures that represent impacts to wilderness character for a given area. Corresponding weights are assigned to each measure to reflect their respective influence on wilderness character. A variety of spatial data are then used to depict the spatial impact of the individual measures on wilderness character in a geographical information system (GIS). The data representing each measure are converted to grids at a specified resolution, and the grid values are normalized to a standardized scale so they can be evaluated together (Carver et al., 2012). Finally, the standardized grids are combined using the weighting scheme to create composite raster-based maps for the indicators and qualities; these maps are then combined to create an overall map of impacts to wilderness character (Tricker and Landres, 2018).

Using this approach, we first quantify the existing condition of wilderness character throughout Kobuk Preserve and Gates of the Arctic Wilderness and then use this condition as a baseline from which to evaluate the potential impacts of both routes (Pace et al., 2017). Throughout this analysis, we define potential impacts as the effects that will likely occur from the construction and industrial use of the road on all the qualities of wilderness character. Following established terminology for monitoring and mapping wilderness character (Landres et al., 2015; Tricker and Landres, 2018), we refer to impacts that adversely affect wilderness character from its existing, pre-road baseline condition as degrading wilderness character.

METHODS

A multidisciplinary team of NPS staff identified the site-specific measures used to evaluate both the existing baseline condition of wilderness character throughout Gates of the Arctic National Park and Preserve as well as the potential impacts of the Ambler Mining Road (Pace et al., 2017). Potential 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. Seasonal differences were considered when selecting measures, however the wilderness character maps were developed to reflect summer conditions in the park (i.e., when visitation to the park is highest and impacts on the measures most prevalent). The project team 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 project area). In general, only measures that were relevant, that were spatially explicit, and that had readily available data of sufficient quality, were included. Existing data included tabular, vector, and raster data from local, regional, and national sources. In addition, new data for certain measures were generated based on institutional knowledge (i.e., locations of existing impacts were drawn on printed maps and then digitized in a GIS).

A total of 19 measures were identified for the baseline map (Table 1), and 12 existing or new measures were used for assessing impacts from the two alternative Ambler Mining Road routes (Table 2). The project team assigned a weight (on a scale of 1 to 10) to each selected measure to reflect its respective influence on wilderness character (Tables 1 and 2). Considerations for each measure weight included how pervasive the measure is across the wilderness, if the measure represents major management issues or constitutes an emerging threat, if the measure is a seasonal or year-round issue, and if the data used to represent the measure is accurate and complete (Pace et al., 2017). Although localized areas depicting multiple measures may be more sensitive to weighting uncertainty (Carver et al., 2013), staff experience has been shown to be highly accurate in judging resource conditions (Cook et al., 2010). Therefore, the project team used consensus-driven oversight when assessing the influence of all measures on wilderness character and recorded the rationale for each weighted measure in Tables 1 and 2.

Individual measures were mapped by applying GIS processing techniques to their respective datasets using ArcGIS (ESRI, 2016). Initial tasks involved projecting all data to the Alaska Albers Equal Area Conic coordinate system, joining tabular records to spatial data, and clipping data to the mapping extent. For vector-based data, features representing threats to wilderness character were assigned values to represent their spatial impact on the landscape. This task used either a simple binary approach for features such as contaminated sites (i.e., presence = 1; absence = 0) or a range of values for datasets representing different types of features such as research installations where the size of the feature dictated the assigned value. Certain vector data, such as point locations of collared animals (which are considered moving installations under the undeveloped quality; see Landres et al., 2015) required additional processing techniques using density analysis to provide for more intuitive interpretation of the raw data. Finally, specific GIS models were used to analyze viewshed impacts or identify areas that are more remote than others due to the time cost of travelling across the landscape from frequently used plane landing locations. All vector data were then converted to gridded rasters at 100 m resolution. See Tricker and Landres (2018) for a general discussion of these techniques and Pace et al. (2017) for how they were applied in deriving the baseline maps of wilderness character in Gates of the Arctic Park and Preserve and in deriving potential impacts from the two proposed routes for the Ambler Mining Road.

Using standard GIS techniques, each raster was normalized by linear rescaling (i.e., slicing) the input values onto a standardized scale of 0–255 on an equal interval basis (Eastman et al., 1995). The normalized range of values allow measures to be evaluated together on a common relative scale (Carver et al., 2008) whereby the "polarity" of the individual map layers are maintained so lower values represent better conditions and higher values represent degraded conditions (Carver et al., 2012). For example, noise from roads and travel time measures use different units (decibels vs. meters per second) and cannot be analyzed together if they are not normalized. The normalized measures are added together after being multiplied by their respective weights (i.e., simple weighted linear summation, Malczewski, 2006) to produce a series of maps for each indicator. The indicator maps were added together to produce maps for each quality, which in turn were added together to produce the baseline wilderness character map (Pace et al., 2017).

To understand how the two proposed road corridors would impact wilderness character in the Kobuk Preserve and adjacent Gates of the Arctic Wilderness, the project team re-ran the baseline map with the adjusted and new measures that capture the potential impacts of the two routes (Pace et al., 2017). These maps include impacts to wilderness character from the developments explicitly described in the Ambler Mining Road right-of-way application (AIDEA, 2009) and also estimated additional impacts to wilderness character that could occur should the Ambler Mining Road become a public access route. The project team chose to map both known (e.g., the presence of the road) and estimated (e.g., increased visitation) impacts to wilderness character to foster consideration of reasonably foreseeable outcomes of road access being introduced through large tracts of public (both state and federal) lands. To calculate the total area of impact the two proposed road corridors would have on existing wilderness character, the baseline map was subtracted from the northern and southern route maps respectively, and the number of cells depicting new degradation for each route was summed and converted to square kilometres.

RESULTS

The existing, pre-road baseline map of wilderness character and the potential impacts of the two proposed routes are displayed using a green-brown color ramp (with the "minimum-maximum" stretch method to enhance the

TABLE 1. List of measures, their associated weights (on a scale of 1 to 10), and the rationale for this assigned weight, used to create maps depicting current and potential impacts to wilderness character. Qualities and indicators are the higher categories in the national hierarchical framework operationally defining wilderness character (Landres et al., 2015). See Pace et al. (2017) for a detailed discussion of why each measure is appropriate for representing current and potential impacts to wilderness character and inclusion in the maps.

Quality	Indicator	Measure	Weight	Rationale
Untrammeled	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.
Natural	Air and water	Contaminated sites	4	Contaminated sites are serious threats to wilderness character but very few exist within the GAAR wilderness.
Undeveloped	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.
Solitude or primitive and unconfined recreation	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 (e.g., 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.

TABLE 1. List of measures, their associated weights (on a scale of 1 to 10), and the rationale for this assigned weight, used to create maps depicting current and potential impacts to wilderness character. Qualities and indicators are the higher categories in the national hierarchical framework operationally defining wilderness character (Landres et al., 2015). See Pace et al. (2017) for a detailed discussion of why each measure is appropriate for representing current and potential impacts to wilderness character and inclusion in the maps – *continued*:

Quality	Indicator	Measure	Weight	Rationale
	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.
Other features of value	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.

color contrast; ESRI, 2016). This method yields areas of optimal condition (no impact) shown in green and areas of degraded condition (high impact level) shown in brown. Interpreting the maps requires understanding the measures selected, the datasets that represent them, the methods used in developing the map, and a grounding in location-specific factors such as topography, visitor trends, and management issues (Tricker and Landres, 2018). As discussed in the Introduction, details of methods and results are in Pace et al. (2017); here, we summarize those results for the potential impacts of the two alternative Ambler Mining Road routes on wilderness character.

The baseline map of wilderness character shows the Kobuk Preserve and adjacent Gates of the Arctic Wilderness as largely unaffected by any impacts (Fig. 3). This result is understandable since Gates of the Arctic National Park and Preserve receives relatively few visitors, and even fewer visitors plan trips in the Kobuk Preserve because they are typically drawn to more popular areas within the Gates of the Arctic wilderness. The only noticeable degradation of the Kobuk Preserve and adjacent Gates of the Arctic Wilderness baseline map occurs from occasional overflights through this area, usually to access Walker and Nutuvukti Lakes. While fixed-wing aircraft are allowed in Alaskan wildernesses by ANILCA, they nonetheless degrade wilderness character by the incursion of motorized and mechanized transport and degrade the soundscape (Landres et al., 2015; Pace et al., 2017).

Potential impacts from the two Ambler Mining Road routes are shown in Figure 4, with noticeable degradation to wilderness character from both routes within the Kobuk Preserve. The northern route is 12.8 km longer through the Kobuk Preserve than the southern (NPS, 2019). This greater distance contributes to a greater total area of impact to wilderness character from the northern corridor (3141 km^2) compared to the southern route (2494 km^2). Importantly, the northern route would also degrade wilderness character within Gates of the Arctic Wilderness because of proximity of the road to this wilderness (150 m at its closest point). This proximity would likely increase walk-in access to the wilderness; easier access in turn would likely increase recreational impacts and then developments within the designated wilderness to manage these impacts. In addition, the proximity of the northern road would degrade the wilderness experience for visitors within the designated wilderness, for example, from sights and sounds of haul trucks and dust plumes from the road.

Another difference between the two routes is that the northern option is relatively close to two large lakes, Walker Lake to the north within Gates of the Arctic Wilderness and Nutuvukti Lake to the south within the Kobuk Preserve. The proximity of the northern route to these lakes has significant implications for wilderness character because float plane access to lakes, combined with proximity to a road, would likely be a significant means of access into the area. This increased access likely would eventually require facilities such as campsites, restrooms, and trails, along with management restrictions to protect resources, which will in turn degrade wilderness character.

DISCUSSION

Both of the alternative routes for the Ambler Mining Road would have an adverse impact on wilderness character. The southern route will degrade wilderness character in the Kobuk Preserve, while the northern route will degrade wilderness character both in the Kobuk Preserve and the adjacent Gates of the Arctic Wilderness. Of the two alternative routes, the northern route will have a greater overall adverse impact on wilderness character than the southern route because of the northern route's longer length within the Kobuk Preserve and proximity to Gates of the Arctic Wilderness.

The analysis presented here complements other recent studies that showed how the Ambler Mining Road could have a substantial impact on subsistence activities within and near Indigenous peoples' communities (Guettabi et al., 2016), adversely affect up to about 9% of the high-value winter habitat for caribou (Wilson et al., 2014), and adversely impact the caribou migration corridor that spans the western half of the proposed road right-of-way (Wilson et al., 2016).

TABLE 2. List of measures, their associated weights (on a scale of 1 to 10), and the rationale for this assigned weight, used to create maps depicting potential impacts to wilderness character from the two proposed Ambler Mining Road routes. Qualities and indicators are the higher categories in the national hierarchical framework operationally defining wilderness character (Landres et al., 2015). See Pace et al. (2017) for a detailed discussion of why each measure is appropriate for representing potential impacts to wilderness character from the proposed road routes, as well as data sources, data processing, and data cautions for each measure. New measures are denoted with an asterisk.

Quality	Indicator	Measure	Weight	Rationale
Untrammeled	Actions authorized by the federal land manager that manipulate the biophysical environment	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.
Natural	Plants	Fugitive dust*	5	Fugitive dust can cause changes 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.
Undeveloped	Presence of non-recreational structures, installations, and developments	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.
	Presence of 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.
	Use of motor vehicles, motorized equipment, or mechanical transport	Proposed Ambler Road corridor motorized use*	10	Motorized use along the proposed Ambler Road corridors would have a significant impact on wilderness character.
Solitude or primitive and unconfined recreation	Remoteness from sights and sounds of people inside the wilderness	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.
	Remoteness from occupied and modified areas outside the wilderness	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 that decrease self-reliant recreation	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 on visitor behaviour	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.

Analysis of potential impacts to wilderness character from the proposed Ambler Mining Road uses existing, pre-road conditions of the Kobuk Preserve and Gates of the Arctic Wilderness landscape as the baseline for understanding these impacts. In contrast, some people believe that the road right-of-way created by ANILCA in 1980 set a new baseline condition that includes the road and its ecological and social effects. This belief, however, conflates a legal right-of-way with the changing environmental and societal impacts of actual road development. Concern about these impacts was expressed in the first general management plan written for Gates of the

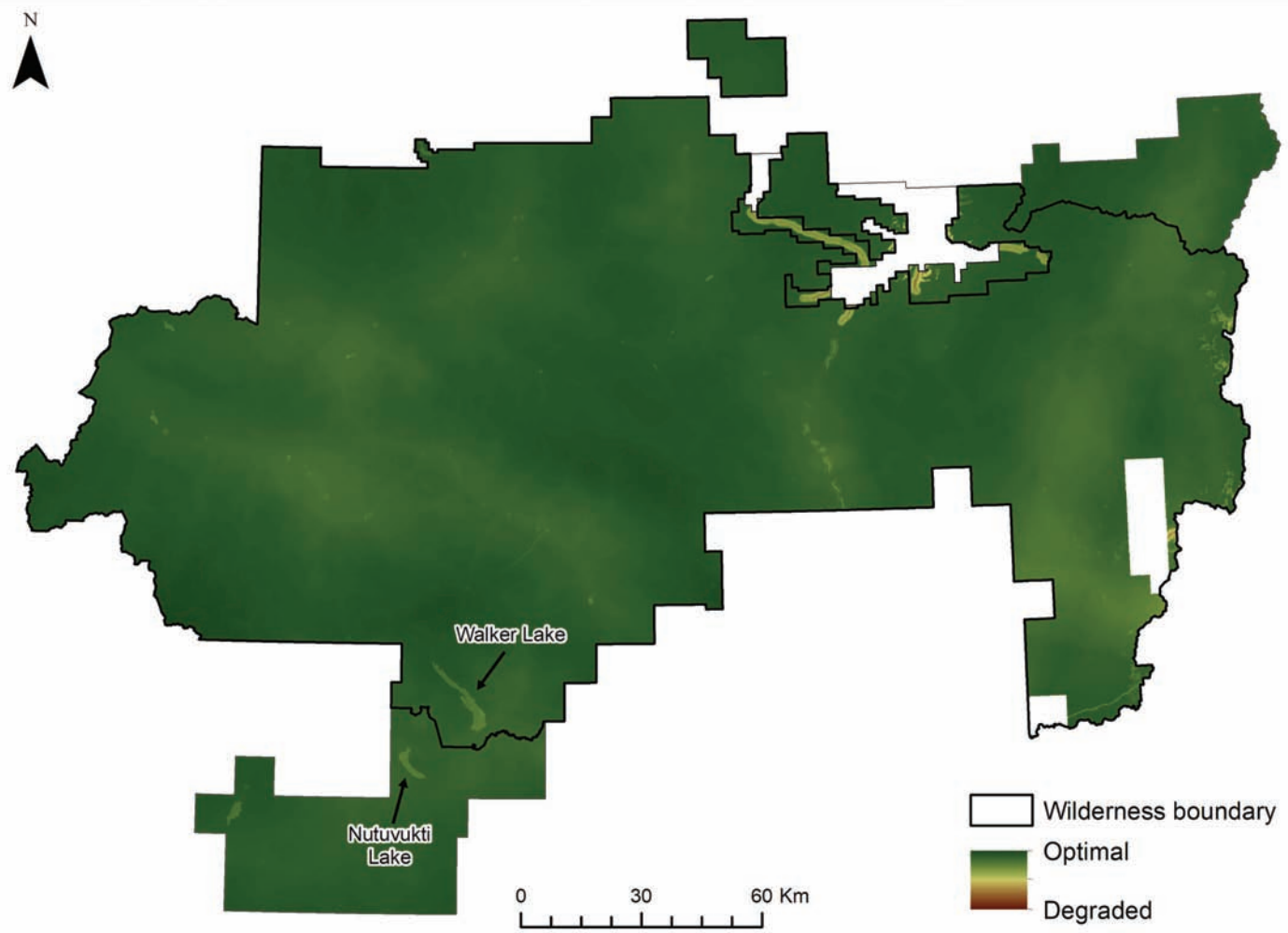

FIG. 3. Baseline map of current impacts to wilderness character in GAAR. Green depicts optimal condition and brown depicts degraded condition.

Arctic National Park and Preserve (NPS, 1986:119), which stated that approval for future transportation systems under Title XI of ANILCA "requires that a proposal is compatible with purposes for which the [Park] unit was established and that no economically feasible and prudent alternative route exists. The National Park Service is concerned about adverse effects of future transportation and utility systems on the wild and undeveloped character of the area, natural values, and valid uses of Gates of the Arctic."

This study has implications for understanding broad-scale ecological and societal effects of road development in remote areas and on wilderness. Increasing pressure from infrastructure development such as roads, especially in remote areas, presents some of the greatest challenges for the world's protected areas and their managers (Watson et al., 2018). Distance from roads, for example, is often used as a surrogate to evaluate areas for their ecological integrity, landscape protection, and future wilderness designation (e.g., Theobald, 2013; Belote, 2018). The degradation of wilderness character shown in the analysis presented here can broadly be considered a degradation of the conservation value (sensu Capmourteres and Anand, 2016) in the Kobuk Preserve and Gates of the Arctic Wilderness landscape.

Similarly, degradation of wilderness character indicates a degradation of the broader societal values derived from wilderness (Schuster et al., 2004). These societal values include outstanding opportunities for solitude and primitive and unconfined recreation, the traditional and cultural uses of resources by Indigenous peoples, and the general social value of wilderness to visitors and to people who may never visit the area but who nonetheless derive meaning from knowing that they exist (Bengston et al., 2010; Ashley et al., 2015). Finally, this analysis of potential impacts to wilderness character is limited to what would likely occur, but as Wilson et al. (2014) describe, a new road in a remote area will allow a host of unforeseeable future changes, such as changing spatial patterns of subsistence, sport hunting, and recreational activities that are difficult to quantify yet may have significant, cumulative, and long-lasting ecological and social effects.

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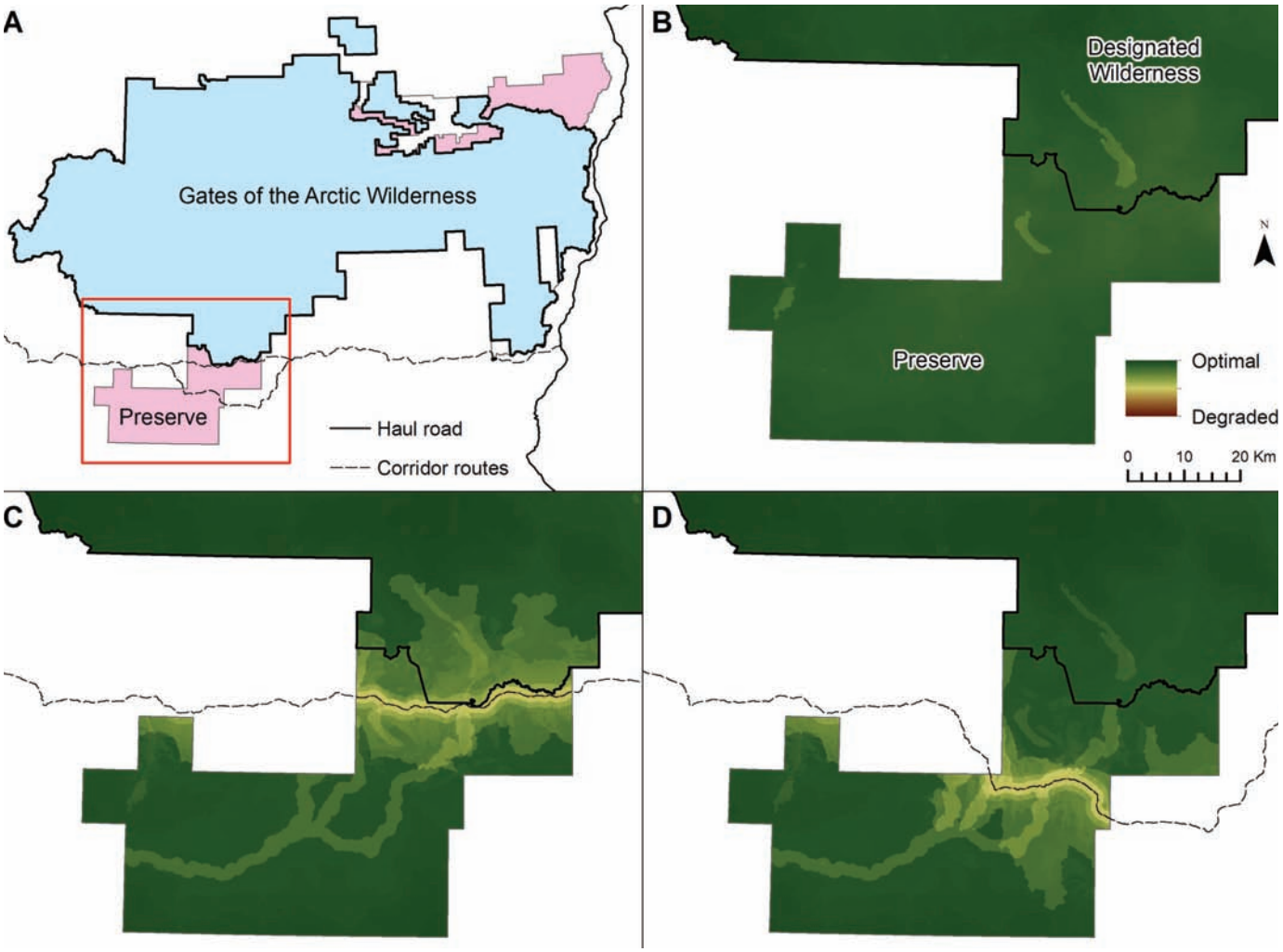

FIG. 4. Impacts of the proposed Ambler Mining Road routes on wilderness character in GAAR: (A) red box indicates area of focus, (B) baseline maps depict current impacts, (C) impacts of the proposed northern route, (D) impacts of the proposed southern route. Green depicts optimal condition and brown depicts degraded condition.

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