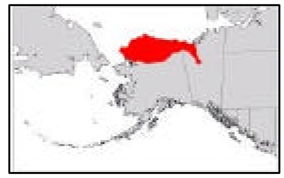


Alaska - Yukon Arctic Ecoregional Assessment
Update #9: Cost Suitability Index

Introduction

One of the objectives of ecoregional assessments is to evaluate different configurations of areas that would comprise a robust conservation network. A robust conservation network is one that is both representative of the range of biodiversity and efficient—meaning that the habitat needs of the greatest number of species and systems are represented in the least amount of "suitable" land. The suitability factor, expressed as a cost suitability index, is the focus of this update.[1]

The cost suitability index is a mechanism for integrating economic, socio-political and biological factors in the conservation network design process to identify areas of least conservation cost. Used in this context, cost refers not only to financial considerations, but also refers to *likelihood of success,* especially in terms of species viability. In other words, our conservation investment (whether it be financial or effort-based) has a higher return if it sustains biodiversity for the long-term. The odds are higher in some places than others for maintaining healthy biodiversity. In general, viability is more likely in natural vs. developed settings, in areas that are managed for conservation values, in areas where natural ecological processes can occur unimpeded, and in areas that have little human impact.

Purpose of a Cost Suitability Index

In order to maximize the success of conservation efforts, it is important to identify areas that contain the most viable occurrences of species and systems. Because the information required to judge the persistence of each element of biodiversity (e.g., species occurrence, population, ecosystem unit) is unavailable across the ecoregion[2], we created the cost suitability index as a surrogate to estimate viability of the ecoregion's biodiversity as a whole.

The cost suitability index has three functions: (1) to guide the design of a conservation network toward areas where there is a higher chance for long-term viability of conservation targets[3]; (2) to avoid areas of high conservation cost; and, (3) all else being equal, to preferentially select for areas of high species richness over lower richness. For each of these functions, we made basic assumptions:

Table 1. Fundamental assumptions of the cost suitability index

function	assumption
preferentially select areas likely to support long-term viability of target	given a choice, lands already managed for conservation (e.g., wilderness areas, wild and scenic rivers, national parks) are more suitable for conservation than areas not managed for conservation.
avoid areas of high conservation cost	given a choice, areas with existing human impacts are less suitable for biodiversity conservation investments.
preferentially select places with higher species richness	given a choice, conserving areas of higher species richness results in greater return on conservation investment.

[1] The concepts of representation and design of the conservation network are addressed in Update #10.
[2] In most cases, the information required to assess the viability of a species occurrence, population, or ecosystem unit is at a much finer resolution than is consistently available throughout this ecoregion.
[3] Please see Update #5 for more information about conservation targets.

Each of these assumptions is general and exceptions for each can be found; nevertheless for the ecoregion overall, these assumptions can guide the design of a conservation network toward areas where conservation stands a greater chance of success.

Building the Cost Suitability Index

We built two similar cost suitability indices—one for terrestrial and marine areas, and one for freshwater areas—by compiling spatial data relating to the human use footprint (e.g., road density, villages, development infrastructure, etc.), current management, and certain biological values. The spatial data used to develop the cost suitability index fell into one of the three categories listed in Table 2 and described in detail below.

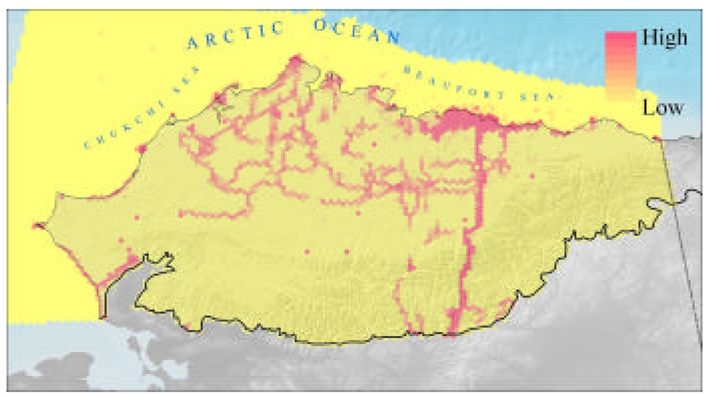
Table 2. Primary components of the cost suitability index and their functions

component	description	function*
1. infrastructure	describes existing human footprint	avoid areas of high conservation cost
2. management status	identifies existing level of conservation management using GAP methods**	select areas likely to support long-term viability
3. species richness	identifies areas of co-occurring species and habitat use	select places with higher species richness

* see Table 1
** see Update 3 *GAP Analysis of Terrestrial Ecosystems*

1. Infrastructure

Figure 1. Infrastructure component



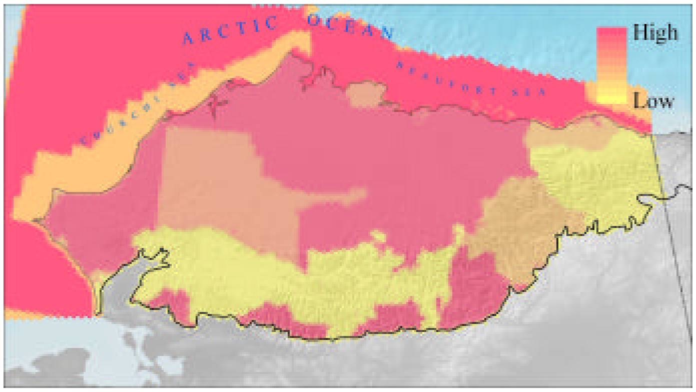
Thirty separate data layers were used to create the infrastructure component of the index, including existing roads, towns, oil and mineral development areas and related infrastructure, and power lines. The footprints of several of these data were extended, or buffered, to account for their ecological effect beyond the immediate footprint. We assessed the effect of each type of infrastructure on the Arctic environment and ranked the data layers as having low, medium, or high impacts. These ranks were translated into weighting factors 1, 2, or 3, respectively. See Appendix 1 for descriptions of the environmental effects of each infrastructure type and justification of ranks.

2. Management Status

In the cost suitability index, management status influences conservation network design by steering design toward areas already explicitly managed for conservation. Generally, these are publicly-owned lands and waters managed by an organization with a conservation mandate, such as the National Park Service. Preferentially selecting existing conservation lands lowers conservation cost in two ways. First, because these lands are actively managed for conservation values, they are likely to support viable species and ecosystems. Healthy and persistent species and ecosystems improve the likelihood of conservation success. Second, the financial and social costs of conservation are lessened; if adequate conservation can be achieved on lands already managed for conservation, other areas are available for alternate uses, such as development. Of course, as we illustrated in Update #3, the existing conservation network in the Alaska-Yukon Arctic leaves several significant gaps in the representative coverage of biodiversity in the ecoregion.

To integrate management status in the cost suitability index, we assigned one of four status ranks to lands and waters across the ecoregion. Ranks were based on the scale developed by the Gap Analysis Program (see Update #3). Status 1 lands are managed with an emphasis on conservation, such as wilderness areas and national parks. Status 4 lands have no mandated conservation management or are used primarily for human activity. Although development of status 4 lands may be currently minimal, these lands are open to future development and other human impacts. To account for differences in management of marine areas, we considered an area's availability for oil and gas leasing. Areas open to leasing were ranked 4, and all other marine waters were ranked 2 (Figure 2).

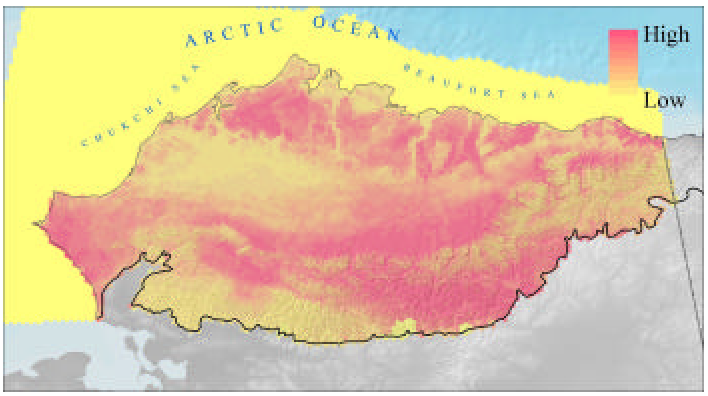
Figure 2. Management Status Component



3. Species Richness

The role of the species richness component in the cost suitability index is to preferentially select areas of higher species richness when all else is equal. Richness maps[4] for birds, terrestrial mammals, and vascular plants guide conservation network design toward areas in the ecoregion that support a greater number of species. Because species richness indicates "suitability" rather than "cost," the darker values in Figure 3 actually indicate greater richness/lower costs (in contrast to Figures 1 and 2 where darker values indicate greater cost). Overall 'costs' associated with infrastructure and management status were reduced in places where there is higher species richness.

Figure 3. Species richness component



Integrating the Cost Suitability Index

Calculations

For each of the three components of the cost suitability index, we combined multiple data layers. For example, the infrastructure component includes data for roads, towns, and industrial development. All data was attributed to planning units (hexagons for terrestrial and marine, and watersheds for freshwater). The areal extent of each data layer within a planning unit was calculated and normalized for comparison across planning units and among components.

[4] See Update #5 for more about the species richness maps and a list of species included. Also note that the richness maps are more correctly referred to as *target richness* maps rather than *species richness* maps, since not all species in the ecoregion are represented.

For the infrastructure and management status components, weights were assigned to the individual data layers based on their ecological effect relative to other data layers within the component (Appendix 1). We then doubled the weight of the infrastructure component to emphasize its tangibility relative to management and richness. For the terrestrial/marine index, the cost suitability index was calculated as the sum of twice infrastructure plus management status divided by the species richness. This is expressed by the following equation:

$$\text{COST}_{\text{Terrestrial/Marine}} = \frac{(2 * \text{normalized infrastructure}) + \text{normalized management status}}{\text{normalized species richness}}$$

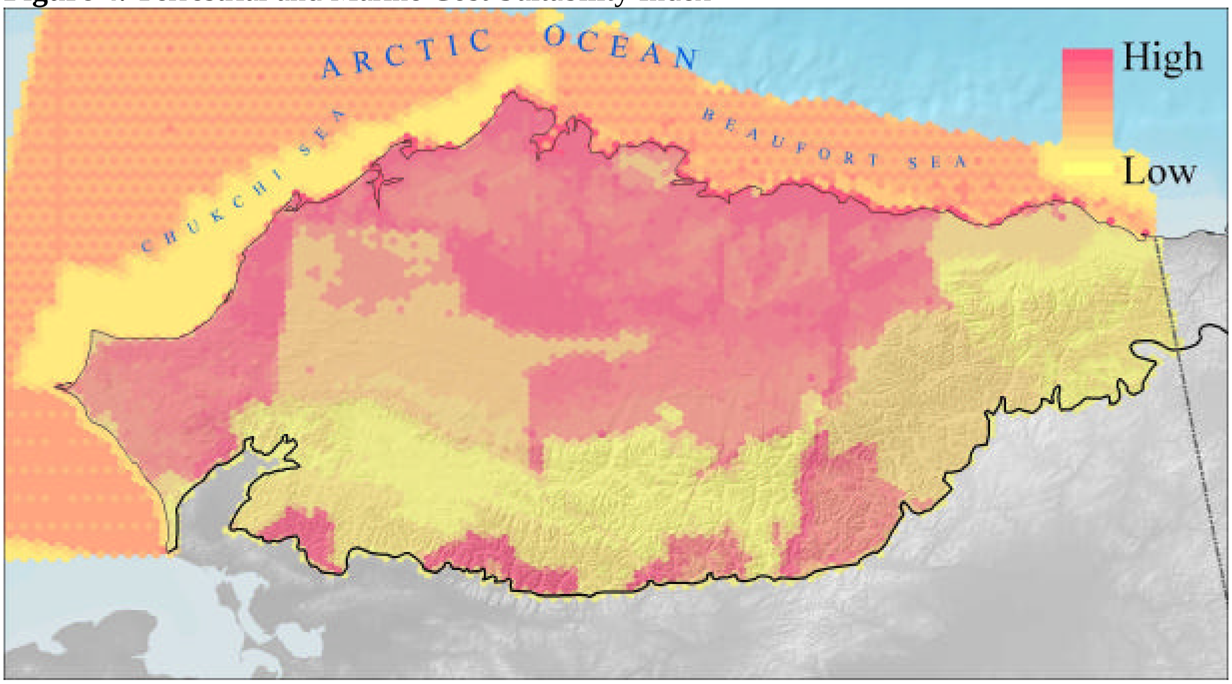
Because there was no freshwater species richness information, the freshwater cost suitability index was not divided by normalized species richness; this index is expressed as:

$$\text{COST}_{\text{Freshwater}} = (2 * \text{normalized infrastructure}) + \text{normalized management status}$$

Cumulative Cost Suitability Index

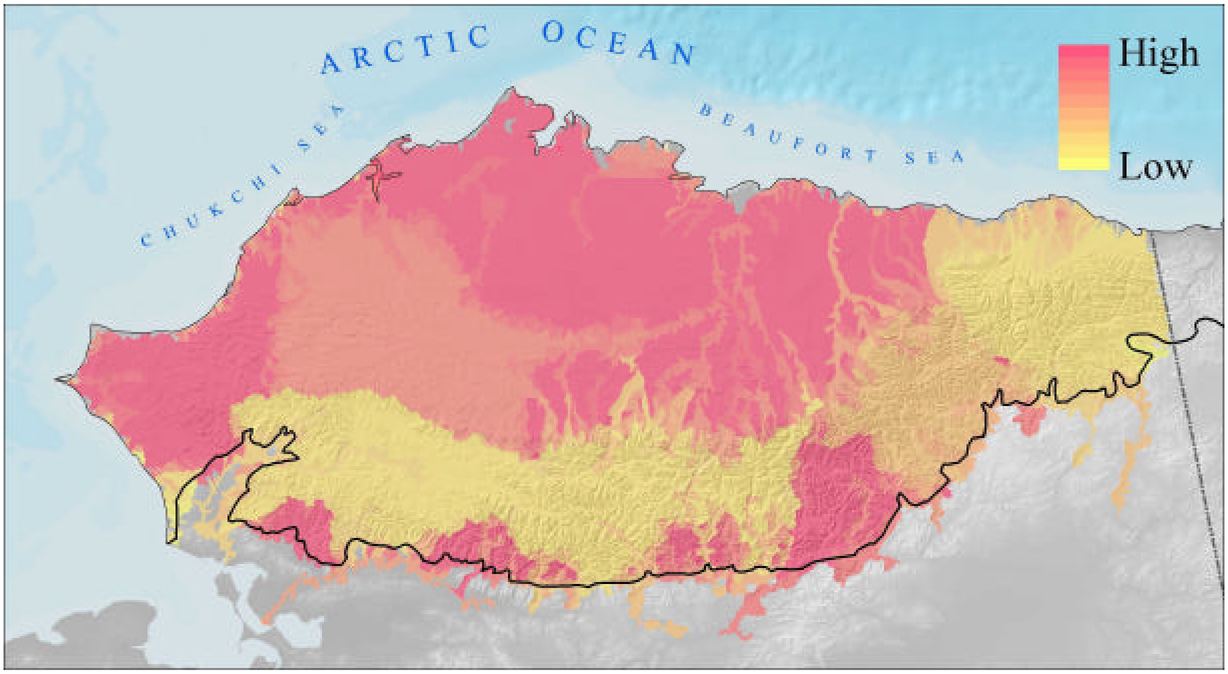
Cumulative cost suitability indices for terrestrial/marine and freshwater are mapped in Figures 4 and 5, respectively. Red colors indicate high cost areas, while yellow colors indicate low cost. The slight differences between the two indices are due to two things. First, management status costs are calculated differently for each. For the terrestrial/marine planning units, costs are calculated for land management inside the boundaries of the hexagon. But for nested watersheds (the freshwater planning units[5]), costs are based on the land management of the watershed and upstream watersheds. Second, no species richness data was available to reduce costs in the freshwater index.

Figure 4. Terrestrial and Marine Cost Suitability Index



[5] See Update #4 for a complete description of nested watersheds and their derivation.

Figure 5. Freshwater Cost Suitability Index



Use of the Cost Suitability Index

In the ecoregional assessment of the Alaska-Yukon Arctic, we use an optimal site selection algorithm known as SITES to generate and evaluate different configurations of areas that might comprise a robust conservation network. A robust conservation network is one that is both representative of the range of biodiversity and efficient—meaning that the habitat needs of the greatest number of species and systems are represented in the least amount of "suitable" area.

The cost suitability index helps steer SITES towards robust designs in which:

- conservation cost is decreased because developed areas are avoided;
- conservation cost is decreased because areas already managed for conservation are preferentially selected; and,
- return on investment is increased because areas of high species richness are preferentially selected.

It is important to note that the SITES algorithm will still select areas of high cost / low suitability if they are required to meet representation objectives. For example, rare species or those with limited range will have fewer places for SITES to choose and may force the selection of "high cost" areas. The cost suitability index simply ensures that, if there is a high suitability / low cost alternative, it will be preferentially selected. A future update will provide more information about the influence of the cost suitability index on conservation network design.

Contacts

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Previous Updates on the Alaska-Yukon Arctic Ecoregional Assessment

Update #1: Project Description
Update #2: Predictive Terrestrial Ecosystem Model
Update #3: Gap Analysis of Terrestrial Ecosystems
Update #4: Freshwater Ecosystem Model
Update #5: Conservation Targets
Update #6: Nearshore Ecosystem Model
Update #7: Environmental Change Model
Update #8: Assessment Limitations and Data Gaps

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See *Update #3: Gap Analysis of Terrestrial Ecosystems* for Input Data related to Management Status

See *Update #5: Conservation Targets* for Input Data related to Species Richness

The Nature Conservancy

The Nature Conservancy is an international non-profit conservation organization that seeks to preserve the plants, animals, and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive. Ecoregional assessments employ a science-based approach to evaluate the biodiversity significance of landscapes. For the Alaska-Yukon Arctic, our goal is to gather sufficient information to identify areas of biological significance, evaluate current and potential stresses to biodiversity, and develop appropriate and constructive conservation strategies to ameliorate threats in special areas.

Appendix 1. Ranks Assigned to Data Layers in the Infrastructure Component

Individual Layer	Terrestrial / Marine Rank	Rationale for Rank	Sources	Freshwater Rank	Rationale for Rank	Sources	Spatial Data Source*
Airstrips	High	Constructed on tundra permafrost with a minimum of five foot thick gravel pads--inhibits vegetation, source of erosion and dust production, and interferes with snow distribution patterns.	Ambrosious 2002	Low	Alteration of hydrologic flow patterns. This is limited due to the limited number of airstrips.	Walters 1996	ADNR
Causeways	High	Affects migration of young of the year Arctic cisco and most species of diadromous fish; causes changes to temperature and salinity of nearshore habitat affecting broad whitefish population levels. Some of these effects have been mitigated by breaches designed for causeways that extend across the nearshore zone, but additional research is necessary.	Ross 1988; NRC 2003	Medium	Require large quantities of gravel that is mined from river channels and riparian zones.	NRC 2003	BP
DEW line sites	High	Disturb various habitats predominantly in the nearshore environment; PCB, DDT, and hydrocarbon contamination resulting from DEW lines have entered the terrestrial and marine food chains through air/plant and animal contaminant pathways.	McKendrick 2000; Thomas 1992	Medium	PCB, DDT, and hydrocarbon contamination of Arctic systems.	Thomas 1992	NSB
Exploration airstrips thin gravel/tundra scar	Medium	Tundra scarring and long term loss of vegetation; many are severely thermocarsted and unusable.	Ambrosious 2002	N/A	N/A		BP
Exploration site: disturbed area around gravel pad	High	Vegetation disturbance and formation of thermocarst--these sites cumulatively cover relatively large areas of the North Slope. These areas were unprotected by gravel and have thus resulted in greater damage to the permafrost than areas protected by gravel pads.	Ambrosious 2002; NRC 2002	Medium	Alteration of hydrologic pathways of cumulatively relatively large extent.	Gilders et al 2000; NRC 2002	BP

Individual Layer	Terrestrial / Marine Rank	Rationale for Rank	Sources	Freshwater Rank	Rationale for Rank	Sources	Spatial Data Source*
Exploration site: tundra covered by gravel	Low	Raised gravel pads cause vegetation disturbance due to thickness of gravel covering. Many of these sites have resumed some level of native vegetation growth.	Ambrosious 2002	Low	Alteration of hydrologic flow patterns in limited areas.	Gilders et al 2000	BP
Gravel exploration islands	Medium	Affects the quality of marine waters and flow patterns thus affecting marine habitats. Oil spills on islands have great effects due to poor clean up methods that remove a small fraction of the oil, especially in broken ice.	NRC 2002	n/a	Require large quantities of gravel that is mined from river channels and riparian zones.	NRC 2003	BP
Gravel mine: tundra	High	Create nutrient and moisture limited areas to revegetate. These tundra scars essentially become thermokarst lakes with nutrient poor waters.	Walker 1996	High	The mines also create overburden piles next to rivers that remain unvegetated and provide a continuous source of excess sediment to the river channel.	Walker 1997	BP
Gravel mine: riverbed	Medium	Loss of bank stability and changes in riparian and upland vegetation.	Reynolds et al. 1996	High	Gravel mine in channel and within the floodplain causes increased braiding and spreading of flow across the channel--this is equivalent to alteration of the channel and of the riparian vegetation and habitat. The growth rate of fish and food organisms is affected by these changes in the drainage and erosion patters of the system.	Reynolds et al 1996	BP
Gravel pad: drill site	High	Cause vegetation disturbance because pads are greater than 2m thick, creating dry, elevated sites that are difficult to revegetate once they are abandoned. These sites can remain unaltered for hundreds of years after abandonment and therefore represent a permanent change to the tundra environment. They also cause large alteration of snow drift patterns.	Walker 1996	Low	Block natural flow patterns and require gravel mining.	Walker 1997	BP

Individual Layer	Terrestrial / Marine Rank	Rationale for Rank	Sources	Freshwater Rank	Rationale for Rank	Sources	Spatial Data Source*
Gravel pad: process facilities	Medium	The entire process facility many contain several well sites, drill houses, etc. The effects are similar to those imposed by gravel pad drill sites and are equally as damaging.	Walker 1996	Low	Block natural flow patterns and require gravel mining.	Walker 1997	BP
Gravel pad: support facilities	High	Cause vegetation disturbance because pads are greater than 2m thick, creating dry, elevated sites that are difficult to revegetate once they are abandoned. These sites can remain unaltered for hundreds of years after abandonment and therefore represent a permanent change to the tundra environment. They also cause large alteration of snow drift patterns.	Walker 1996	Low	Block natural flow patterns and require gravel mining.	Walker 1997	BP
Gravel production islands offshore	Medium	Affects the quality of marine waters and flow patterns thus affecting marine habitats. Oil spills on islands have great effects due to poor clean up methods that remove a small fractions of the oil, especially in broken ice.	NRC 2002	N/A			BP
Culverts	Medium	Bank erosion and riparian habitat loss due to undersized and blocked culverts.	Moulton et al. 2000	High	Impede fish passage; cause channel erosion both down cutting, channel widening, and aggradation that result in changes in channel form, function, and available habitat.	Moulton et al. 2000	BP
Pipelines - includes Trans-Alaska Pipeline	High	Pollution source in the form of oil spills, which affect terrestrial mammals, birds, vegetation, marine mammals, and terrestrial systems. Elevated pipeline may deflect, delay, or prevent caribou passage of caribou through oil fields.	Walker 1996; Cronin et al. 1997	Medium	Pollution source in the form of oil spills affecting freshwater systems.	Walker 1996	BP
Power lines	Low	Rank based on comparison to similar layers.	Pers. Comm B.S. 2004	Low	Rank based on comparison to similar layers.	Pers. Comm B.S. 2004	BP

Individual Layer	Terrestrial / Marine Rank	Rationale for Rank	Sources	Freshwater Rank	Rationale for Rank	Sources	Spatial Data Source*
Recovered site: gravel pad removed	Low	Some revegetation over 15 year period in some cases. Tundra scars do not remain visible from aerial photos using aerial visibility index. A different index at a finer scale could reveal different results.	Ambrosious 2002; Emers et al 1997	Low	Alteration of hydrologic flow patterns in limited areas.	Gilders et al 2000	BP
Recovery in process site: gravel pad removed	Medium	Rank based on comparison to similar layers.	No Source	Low	Rank based on comparison to similar layers.	No Source	BP
Red Dog Mine	High	Rank based on comparison to similar layers.	No Source	High	Rank based on comparison to similar layers.	No Source	ADNR
Roads: exploration access of thin gravel and frozen tundra	High	Tundra scaring, disturbance of natural vegetation patterns, dust-killed tundra and creation of thermokarst. Cumulative effects of exploration and off road vehicular travel are extensive.	NRC 2003; Auerbach et al. 1997; Ambrosious 2002	Medium	Destruction of wetlands and riparian habitat; disturbance of hydrologic pattern.	Walters 1996; Gilders et al. 2000	BP
Roads: gravel	High	Effects beyond road footprint. Elevated gravel roads constructed on the open tundra likely to remain unaltered for hundreds of years and represent a permanent change to the environment unless intensive site preparation provides adequate soils. Loss of hydrologic connection with adjacent tundra causes inability to revegetate these affected areas. Road dust may alter soil pH from acid to alkaline, eliminating vegetation within 5m of heavily traveled roads. In general, roads may displace wildlife, impede wildlife movement, increase human access to an area.	Walker 1996; Ercelawn 1999; Jorgenson 1997; Walker 1997; Auerbach et al. 1997	Medium	Alteration of hydrologic pattern, disturbance of channel and riparian habitat for gravel mining, and installation of culverts and bridges associated with road construction.	Walker 1996; Gilders et al. 2000; NRC 2003	BP

Individual Layer	Terrestrial / Marine Rank	Rationale for Rank	Sources	Freshwater Rank	Rationale for Rank	Sources	Spatial Data Source*
Roads : peat	Medium	Formed by scooping the active layer of the permafrost from two sides of an area to form an elevated road surface. Result is a mound with shallow ditches on either side, altering native vegetation pattern and drainage patterns. Extensive thermokarst damage.	Walker 1996; NRC 2003	Medium	Highly visible, deeply rutted and often flooded, so change to permafrost and physical hydrology	Walker 1996; NRC 2003	BP
Roads: Red Dog Road and Dalton Hwy	High	Rank based on comparison to similar layers.	No Source	High	Rank based on comparison to similar layers.	No Source	ADNR
Tractor trails/tundra scars	Medium	Scars and depressions caused by driving directly on permafrost. Creation of thermokarst and loss of vegetation result. Affected areas in low lying wet areas are marked by well defined water filled depressions or ditches.	Ambrosious 2002	Medium	Formation of thermokarst lakes and alteration of the natural hydrologic pattern.	Ambrosious 2002; Gilders et al. 2000	BP
Villages	High	Off-road travel causes loss of native vegetation patterns, tundra scarring, and damage to wetlands. Source of pollution and garbage.	NRC 2003	High	Off-road vehicular travel harms to wetlands and alters natural hydrologic patterns.	NRC 2003	ADNR
Wells: in production	Medium	Rank based on comparison to similar layers.	No Source	Medium	Rank based on comparison to similar layers.	No Source	ADNR and DOG
Wells: abandoned	Low	Rank based on comparison to similar layers.	No Source	Low	Rank based on comparison to similar layers.	No Source	ADNR and DOG

- ADNR: Alaska Dept. of Natural Resources;
- BP: British Petroleum;
- DOG: Alaska Division of Oil and Gas;
- NSB: North Slope Borough