National Park Service
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Natural Resource Stewardship and Science

Fire Monitoring Protocol for the Arctic Network

Fire Extent, Severity, and Effects

Natural Resource Report NPS/ARCN/NRR—2018/1716





ON THIS PAGE
The tussock cottongrass (*Eriophorum vaginatum*) bloom intensely one year after the 2010 Lake Tutusirok fire in Noatak National Preserve.
NPS/HEATHER BRADSHAW

ON THE COVER
A lightning-caused tundra fire in Noatak National Preserve, Sidik Lake Fire June 6, 2010. The fire burned 18,189 acres.
NPS/DAN STEVENSON

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Natural Resource Report NPS/ARCN/NRR—2018/1716

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Executive Summary

Fire was selected as a “vital sign” for long-term monitoring in the Arctic Inventory and Monitoring Network (ARCN) of the National Park Service. Fire affects all of the parks in the Arctic Network. Fire exerts strong landscape and micro-scale effects on vegetation composition and distribution, and can also influence wildlife habitat, soil parameters (e.g., permafrost and nutrient cycling), hydrology, water quality and air quality. In addition, the natural fire regime (fire frequency, fire extent and severity) and fire succession are likely to respond to global climate changes. Wildfires are dynamic in nature, and are a reflection of the environmental conditions at a specific time and space on a landscape. Wildfires are influenced by weather, vegetation (fuels), ignitions and human interactions (fire suppression). All of these have the potential to change over time. This protocol presents methods for acquiring data to monitor the extent, severity and effects of fires in the ARCN parks. Baseline monitoring of fire parameters such as the number of fires, fire extent (area burned) and burn severity will provide explanatory variables for ecological changes detected through the I&M program, while long term monitoring of fire effects on vegetation will provide a foundation to elucidate the complex relationship between fire and the landscape. This I&M protocol narrative describes the plan for monitoring and reporting wildfire activity and effects within the ARCN parks. Fire and lightning data collected by the NPS Fire Management and other fire agencies will be used to summarize statistics on fire extent, number of fires, and lightning within the parks. Burn severity data from remote sensing and ground-based plots will be used to assess changes in burn severity over time. Fire effects will be monitored using legacy plot data sets and establishing a framework for future monitoring sites in the parks if additional funding becomes available.

List of Terms and Definitions

AICC ArcIMS site: web site that uses a mapping program called ArcIMS to display and distribute current and historic fire locations and perimeters, lightning data, fire management layers, etc. in Alaska. Site is maintained by Alaska Interagency Coordination Center and BLM-Alaska Fire Service. Data is provided by multiple agencies and cooperators.

AICC Fire History Perimeters since 1940: Alaska statewide fire history geospatial data set of fire perimeters based on fire records and active fire mapping, maintained by Bureau of Land Management – Alaska Fire Service. Data is stored on the AICC ArcIMS site, here: http://afsmaps.blm.gov/imf_firehistory/imf.jsp?site=firehistory

AICC Statewide Fires/Fire Information Map: This map shows fire points of origin and fire perimeters for the current fire season and is updated in near real time as new fires start and new perimeters are submitted. It is hosted on the AICC ArcIMS site available here: http://afsmaps.blm.gov/imf_fire/imf.jsp?site=fire

Alaska Interagency Coordination Center (AICC): The AICC will be the interagency focal point for coordinating the mobilization of resources for wildland fire and other incidents throughout Alaska and nationally.

Alaska Interagency Wildland Fire Management Plan (AIWFMP): The interagency plan and reference for wildland fire operational information in Alaska.

Alaska Statewide Annual Operating Plan (AOP): The Alaska Statewide AOP tiers to the Alaska Master Cooperative Wildland Fire Management and Stafford Act Response Agreement and further defines statewide interagency working relationships, roles, responsibilities, standards and expectations.

Alaska Region GIS Team Permanent Data Set (AKR GIS PDS): Collection of GIS data compiled and served out by the Alaska NPS Regional GIS team and collaborators available on the Alaska Region network X drive.

Burn severity: A qualitative assessment of the impacts of fire.

Fire frequency: The number of fires occurring within a defined area and time period.

Fire extent: The area burned by a fire or several fires over a defined area and time period.

Fire perimeter: The entire outer edge or boundary of a fire.

Fire reporting system (FRS): Generic term for a database that holds information on fire incidents that occur on parklands.

Jurisdictional Agency: The agency having overall land and resource management responsibility for a specific geographical or functional area as provided by federal or state law.

Management Option: A fire management classification assigned by jurisdictional agency that determines the initial response to a wildfire. Responses range from full fire suppression to managing fires for resource benefits.

Monitoring Trends in Burn Severity (MTBS): A multi-year project designed to map burn severity and perimeters for fires across all lands of the United States from 1984 and beyond. A partnership between the U.S. Geological Survey National Center for Earth Resources Observation and Science (EROS) and the USDA Forest Service Remote Sensing Applications Center (RSAC).

NPS fire points: general reference for geospatial point data set of fire locations for Alaska NPS fire records stored on the Alaska Region GIS Team Permanent Data Set. (Theme name in GIS PDS as of 2016 is "Fires-NPS Alaska")

NPS fire perimeters: general reference for statewide fire perimeter geospatial data stored on the Alaska Region NPS GIS Team Permanent Data Set. (Theme name on AKR GIS PDS as of 2016 is "Fires- Historic Wildland Fire Perimeters 1940-2015").

Protection/Protecting Agency: The agency responsible for providing and coordinating safe, cost-effective emergency wildland fire suppression services within a specific geographical area pursuant to its responsibility as specified and provided by law, policy, or this cooperative agreement. Suppression is defined as a management action intended to protect identified values from a fire, extinguish a fire, or alter a fire's direction of spread.

1. Background and Objectives

1.1. Background

Fire exerts landscape and micro-scale effects on vegetation composition and distribution, wildlife habitat, soil parameters (e.g., permafrost and nutrient cycling), hydrology, and air quality. In addition, the natural fire regime (fire frequency, fire extent, and severity) and fire succession are likely to respond to local and global climate changes. For these reasons, fire was selected as one of the vital signs to be monitored by the National Park Service (NPS) Arctic Network Inventory and Monitoring Program (Lawler et al. 2009). The Arctic Network Inventory and Monitoring program (ARCN) is one of the 32 inventory and monitoring networks established for the National Park Service (NPS) nationwide. The Arctic Network is comprised of five large land units in northwest Alaska that includes Noatak National Preserve, Kobuk Valley National Park, Bering Land Bridge National Preserve, Cape Krusenstern National Monument, and Gates of the Arctic National Park and Preserve. Wildfire affects all of the parks in the Arctic Network (Figure 1). The purpose of this document is to describe the objectives and methods used to monitor the extent, severity and effects of wildfires within the Arctic Network parks.

This protocol provides a narrative and SOPs for wildfire monitoring and reporting within ARCN. Fire and lightning data collected by the NPS Fire Management and other fire agencies will be used to summarize statistics on fire extent, number of fires, and lightning within the parks. Burn severity data from remote sensing and ground-based plots will be used to assess changes in burn severity over time. Fire effects will be monitored using legacy plot data sets and establishing a framework for future monitoring sites in the parks if additional funding becomes available.

1.2. Fire History of the Parks

Weather, terrain, and vegetation strongly influence the occurrence and extent of fires within ARCN. The subarctic boreal forests and low arctic tundra biomes are subject to periodic fires. NPS fire records indicate that between 1955 and 2015 at least 1,968,741 acres have burned within and into the ARCN park units. An average of 32,274 acres (SE 9,542) have burned per year and 97% of the fires were caused by lightning within ARCN (NPS Fire Records 1955-2015). The frequency and extent of fires varies within each park unit, as described below.

The southern third of Gates of the Arctic NP/Pr (GAAR) lies within the northernmost belt of Interior Alaska, and has the greatest average number of lightning strikes/year within ARCN (Table 1). GAAR is on the periphery of interior weather patterns and is occasionally subject to large lightning storms associated with low precipitation and high temperatures in June and July. The spruce lichen woodlands, black spruce feather moss and low shrub-tussock tundra types south of the Brooks Range are the most common fuel types burned. Large fires are common in the southern portion of GAAR and adjoining lands. Between 1955 and 2015 the records indicate that a total of 631,358 acres have burned within and adjacent to Gates of the Arctic, the largest area burned of the five parks (Table 1). Fires are less frequent in the northernmost two-thirds of GAAR likely due to the lack of fuels associated with the barren or sparse alpine tundra on the Brooks Range. A study near and within the southern portion of Gates of the Arctic using lake sediment cores indicated that the average fire

return interval over the last 5,000 years has been approximately 145 years, which corresponds to the onset of black spruce (*Picea mariana*) on the landscape (Higuera et. al. 2009).

Table 1. Fire statistics for wildfires that have burned in and around ARCN from 1955-2015. Fire data is based on NPS wildfire records from 1955-2015 in the Wildland Fire Management Information database (WFMI) and AKRO GIS permanent data sets (Fire-NPS Alaska (2015) and Fires-Historic Wildland Fire Perimeters 1940-2015). Lightning strike data is from AICC ArcIMS site (AICC 2012).

Park	Number of Fires Affecting[1] Park (n)	Total Acres Burned Affecting[1] Park	Total Acres Burned in Park[2] Boundary	Average Acres Burned per Year Affecting[1] Park (Standard Error)	Average Fire Size in Acres Affecting[1] Park (Standard Error)	Average Number of Lightning Strikes/Yr (1986-2012)
BELA	47	293,982	138,676	4,819 (4,595)	6,255 (5478)	46
CAKR	4	4,277	893	70 (66)	1,069 (997)	12
GAAR	167	631,358	278,852	10,350 (4,364)	3,781 (1456)	1,174
KOVA	69	440,983	135,203	7,229 (3,775)	6,391 (3197)	146
NOAT	222	598,142	535,143	9,806 (3,710)	2,707 (774)	399
ARCN Total	**508**	**1,968,749**	**1,089,624**	**32,274 (9,542)**	**3,875 (885)**	**603**

[1] Fires that have burned in the park, but fire area may have extended beyond the park boundary are designated as "Affecting Park."

[2] Fires that occurred only within the park boundary or were clipped to the park boundary are designated "In Park."

Bering Land Bridge NPr (BELA) is located on the northern part of the Seward Peninsula. This area is a cold, wind-swept landmass jutting out into the Bering Sea. Vegetation is primarily tundra, with moist sedge-tussock shrub communities at lower elevations and alpine dryas-lichen communities in the high mountains. Vegetation is primarily composed of sedge tussocks interspersed with scattered stringers of willows and dwarf birch. Patches of low-growing ericaceous and willow-birch shrubs occur on better-drained areas. Isolated pockets of balsam poplar occur within the region. These vegetation communities are susceptible to fire, but low frequency of lightning (Dissing and Verbyla 2003) and/or higher precipitation near coastal areas likely reduce the number of fires within BELA. The majority of acres burned within the preserve occurred during 1977, in which several large fires burned within and around the Preserve. Fire return intervals are not known for the preserve, however fire cycles based on data from 50 years of fire records within the Seward Peninsula ecoregions indicate that the fire cycle is approximately 418 years (Joly et al. 2009).

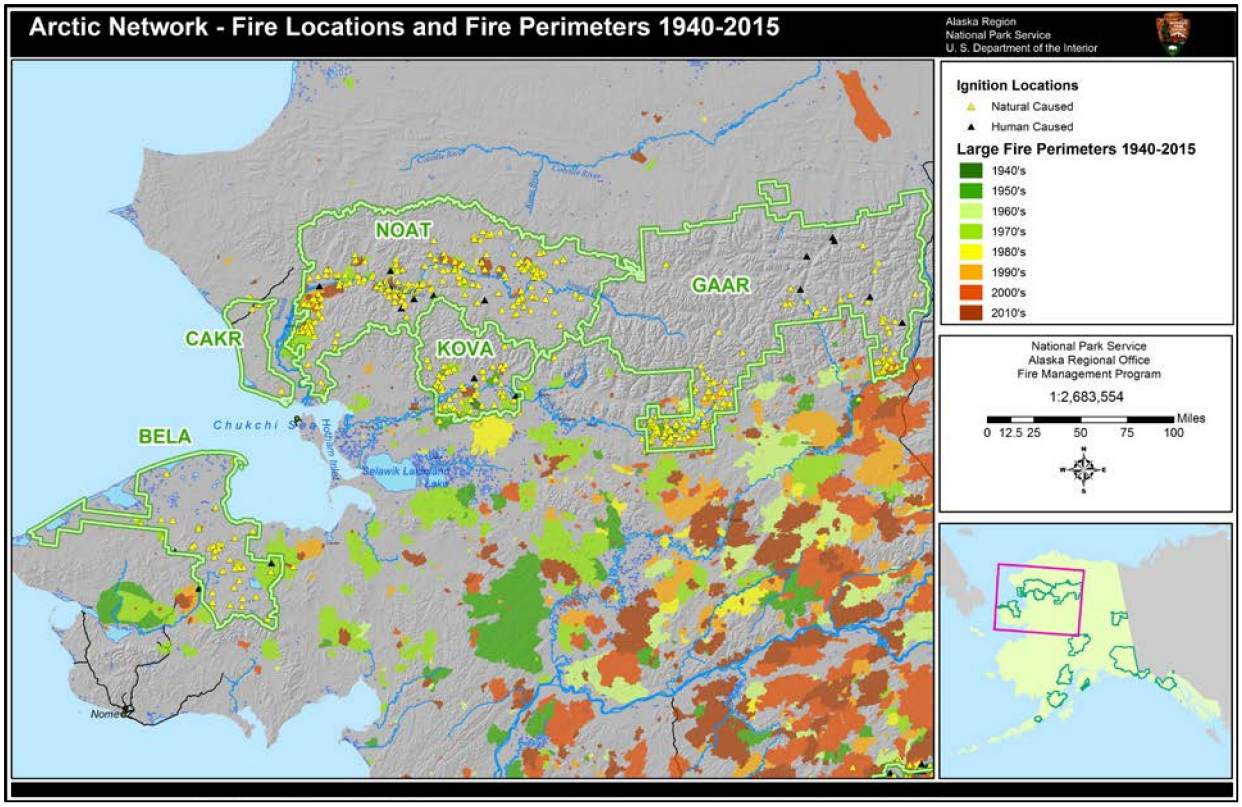


Figure 1. Map of fire history from 1940-2015 within the NPS Arctic Network Inventory and Monitoring parks. Parks include: BELA – Bering Land Bridge National Preserve, CAKR – Cape Krusenstern national Monument, GAAR – Gates of the Arctic National Park and Preserve, KOVA – Kobuk Valley National Park, NOAT – Noatak National Preserve. Fire ignition locations (triangles) indicate the start location of fires directly affecting NPS lands. Fire perimeter data is statewide for fires generally over 100 acres.

The lowlands of the Noatak National Preserve (NOAT) are subject to periodic large fires and frequent small fires from late May until early August. Fires commonly occur in shrub-tussock tundra, sedge/graminoid lowlands, and shrub thickets of dwarf birch/ericaceous, alder (*Alnus crispa*) or willow (*Salix* spp). Of all the parks in ARCN, Noatak has burned the most acreage (535,143 acres) within the park boundaries and has the greatest number of fires over the last 61 years (Table 1). Recent studies indicate that over the past 2000 years in Noatak, the fire return interval has ranged from a median of 150 years down valley to 195 years up valley in the Noatak drainage (Higuera et al. 2011). More than 95% of Noatak's fires are caused by lightning. Thunderstorm development in the valley can result from synoptic widespread storms or localized air-mass storms controlled by local topography. Warm dry air masses within the Noatak Valley can encounter coastal low pressure systems from the west, leading to significant thunder cell development and lightning. When ignitions are accompanied by dry windy conditions, fires in the shrub-tussock tundra and low shrub birch/ericaceous can spread rapidly and burn thousands of acres in a few days.

Kobuk Valley NP (KOVA) is in the transition zone between the interior Alaska forests and northern and western tundra. Of the ARCN parks, KOVA has the greatest percentage of forested lands, with a majority of the needleleaf forest mapped as white spruce (Table 2). Fires are most frequent in lower

elevation forests south of the Baird Mountains within open and woodland spruce forests. As is typical of boreal forest fires, the fires tend to have longer duration than tundra fires. No studies have been completed on the fire return intervals within KOVA.

Table 2. Percent of park units by vegetation classes as defined in the Jorgenson ARCN 2009 landcover map. Sorted by most common vegetation type for all ARCN Parks combined.

Vegetation ARCN Map 2009	% NOAT	% BELA	% CAKR	% KOVA	% GAAR	ARCN Sum of percentages
120: Dwarf Birch-Tussock Shrub	33.3	35.0	30.1	8.5	6.6	113.6
110: Dwarf Birch-Ericaceous-Willow Low Shrub	15.9	10.8	27.6	20.5	12.5	87.4
010: Partially Vegetated	15.3	4.3	4.6	6.1	20.5	50.8
020: Sedge-Dryas Meadow	6.3	21.2	13.8	3.0	4.3	48.6
060: Dryas Dwarf Shrub	8.4	3.0	3.4	5.2	25.8	45.7
150: Alder or Willow Tall Shrub	4.4	0.9	1.7	20.2	6.6	33.9
310: White Spruce Forest	1.3	0.0	0.4	18.1	9.6	29.4
140: Willow Low Shrub	5.3	7.4	7.9	4.5	0.3	25.3
400: Fresh Water	1.0	5.5	0.9	0.9	0.9	9.2
040: Sedge Fen	2.0	3.1	1.4	1.2	0.1	7.8
410: Coastal Water	0.0	3.1	4.2	0.0	0.0	7.2
100: Ericaceous Shrub Bog	1.0	4.6	1.4	0.1	0.1	7.2
320: Black Spruce Forest	0.0	0.0	0.0	4.0	2.7	6.6
070: Ericaceous Dwarf Shrub	2.2	0.0	0.0	1.3	2.8	6.3
030: Sedge Wet Meadow	2.5	0.0	0.0	2.0	0.3	4.8
130: Dwarf Birch-Willow Low Shrub	0.9	0.5	1.4	0.4	0.3	3.6
230: Spruce-Paper Birch Forest	0.0	0.0	0.0	1.9	0.5	2.4
210: Paper Birch Forest	0.1	0.0	0.0	0.8	0.6	1.5
090: Crowberry Dwarf Shrub	0.0	0.3	0.6	0.0	0.0	0.9
050: Brackish Sedge-Grass Wet Meadow	0.0	0.4	0.5	0.0	0.0	0.9
200: Balsam Poplar Forest	0.0	0.0	0.0	0.5	0.0	0.6
500: Snow	0.0	0.0	0.0	0.0	0.6	0.6
300: White Spruce-Lichen Woodland	0.1	0.0	0.0	0.4	0.0	0.6
220: White Spruce-Balsam Poplar Forest	0.0	0.0	0.0	0.3	0.0	0.4
015: Dunegrass Meadow	0.0	0.1	0.2	0.0	0.0	0.2

Cape Krusenstern National Monument (CAKR) is dominated by moist dwarf shrub-tussock tundra. The boreal forest reaches its north-western most limits in North America in the vicinity of the eastern border of Cape Krusenstern National Monument. The number of fires in CAKR is much lower than the other park units, likely due to the wet maritime conditions and lack of ignition sources. Only four fires have been detected in CAKR over the past 60 years. No studies have been completed on the fire return intervals within CAKR.

1.3. Rational for Monitoring Wildfires

The boreal forest and tundra of Alaska are fire-adapted ecosystems, and are characterized by a mosaic of different aged landscapes that have been maintained by fire for thousands of years (Hu et al. 2006; Brubaker et al. 2009; Higuera et al. 2009, 2011; Chipman et al. 2015). Wildfire is a dominant natural disturbance process within Alaska and the Arctic Network. Fires influence vegetation composition and distribution, permafrost dynamics, nutrient cycling, carbon gain or loss, and primary productivity for wildlife. Fires are dynamic in nature, and are a reflection of the environmental conditions at a specific time and space on a landscape. They are regulated by weather, vegetation (fuels), ignitions and human interactions (fire suppression). All of these have the potential to change over time.

Current and future climatic changes are expected to impact the occurrence, extent, and severity of fires in Alaska (e.g., Rupp et al. 2000; Goetz et al. 2005; Kasischke et al. 2010; Young et al. 2016). Although many of these studies focus on interior boreal forest, the interest in tundra fires has increased over the years and several studies address climate change and tundra fires (e.g., Hu et al. 2015; Chipman et al. 2015; Young et al. 2016). Predicted changes in weather, vegetation, fuels and ignition sources will likely influence fire and fire effects in the Arctic Network parks. Baseline monitoring of fire parameters such as the number of fires, fire extent and burn severity will provide explanatory variables for ecological changes detected through the I&M program, while long term monitoring of fire effects on vegetation will provide a foundation to elucidate the complex relationship between fire and the landscape.

Fire Frequency and Extent

The most basic information for monitoring fires is the location, size of a fire, and cause of a fire. Within Alaska, fire records have generally been kept since the early 1940s by fire management organizations (Lutz 1956; Kasischke et al. 2002; Todd and Jewkes 2006). The methods utilized and quality of data have changed over time (Kasischke et al. 2002). Permanent records of fires are maintained by the *fire protection* and *jurisdictional agencies*. Although fire records are available, in general there are no standardized summaries or statistics being produced for Alaska parks or networks. Trends on fire frequency and area burned will provide essential information on how our parks may change in response to climate, vegetation changes, fuel moisture, and ignition sources.

The size of fires can also be influenced by human intervention and fire suppression. Prior to 1980 the policy for fire in Alaska required the immediate suppression of all wildfires (Todd and Jewkes 2006). This policy was costly, of questionable effectiveness, and had a negative effect on the diversity and productivity of the fire-dependent ecosystems in some regions of Alaska. In addition, during periods of high fire activity it was not possible to provide immediate or effective suppression on many fires because of the shortage of personnel, equipment, supplies or aircraft. It was soon recognized by all land agencies that an improved system was needed for establishing response priorities. In 1984, the NPS cooperated with the Alaska Department of Fish and Game (ADF&G), Bureau of Indian Affairs (BIA), Bureau of Land Management (BLM), Department of Natural Resources (DNR), U.S. Forest Service (USFS), U.S. Fish and Wildlife Service (FWS), and Regional and Village Native Corporations to produce Interagency Fire Management Plans for the Kobuk and

Seward/Koyukuk Planning Areas. These plans provided direction for fire management activity for WEAR and GAAR until 1998. Several progressions of fire management planning documents evolved over the years until finally, in 1998, the Alaska Interagency Wildland Fire Management Plan (AIWFMP) was signed into action as the official response plan. Under the AIWFMP, fire protection needs are determined by the land manager/owner and reviewed annually. Land areas are categorized as Critical, Full, Modified, or Limited fire *management options*. The management options establish priorities for allocating fire-fighting resources with the Critical category being the highest priority and Limited the lowest. These categories are based on values to be protected, as well as the managing agency's resource management objectives, policies and mandates. These categories are discussed in detail in the AIWFMP (Alaska Wildland Fire Coordinating Group 2016).

As of 2015, 90% of the park areas in ARCN are managed under Limited Fire Management Option, in which most fires are monitored and are generally not suppressed (see WEAR and GAAR Fire Management Plans (NPS 2010; NPS 2014b)). In 2015, three percent of the lands are managed under "Full" and 7% are under "Modified", where fires are generally suppressed or kept to minimal size if firefighting resources are available. Modified has a conversion date, generally in mid-July in which these lands will convert to "Limited" and fires will not be suppressed unless requested by the land manager.

Burn Severity

As fires burn under varying weather conditions across landscapes characterized by varying topography and fuel types, their behavior and effects also dramatically change (Johnson 1992; Allen and Sorbel 2008). Thus, within any given fire, some areas are radically changed due to intense scorching or sustained burning of surface organic layers, while other areas remain untouched. This heterogeneous pattern or 'fire mosaic' is the result of varying burn severity on the landscape.

Burn severity has many definitions, but in general is a measure of the ecological impacts of the fire (Keeley 2009). This can be measured in terms of plant survivorship or mortality, depth of the burn in organic layers, or amount of biomass consumed. Burn severity strongly influences vegetation patterns, succession after fire, carbon emissions, and a suite of other variables. Burn severity within northern regions is often addressed in terms of surface organic matter consumption, particularly within boreal forests (e.g., Viereck 1983; Kasischke and Johnstone 2005; Johnstone and Chapin 2006). The reduction of soil organic materials influences plant reproductive capabilities (Zasada et al. 1986; Johnstone and Kasischke 2005; Johnstone and Chapin 2006), carbon loss and emissions (Turetsky et al. 2011; Mack et al. 2011; Kasischke and Hoy 2012; Hu et al. 2014), and permafrost (Yoshikawa et al. 2003; Jorgeson et al. 2010).

Burn severity is important not only at the site level but also at a landscape scale. Determining whether fires are burning more severely has become an important topic in light of climate change (Flannigan et. al. 2013; Loboda et al. 2013). The scale of fires in Alaska are so large (thousands of hectares), that remote sensing is often the most viable method to assess burn severity. Methods have been developed to map burn severity utilizing Landsat imagery (Key and Benson 2006; Allen and Sorbel 2008; Soverel et al. 2010; Loboda et al. 2013). Monitoring burn severity will provide a more

comprehensive view on wildfire trends, and also relates to fire effects on fuels, vegetation and other factors such as thermokarst development or carbon emissions in the parks.

Fire Effects

Wildfire produces a rapid change in the physical, chemical and biological properties of an ecosystem changing both above and below ground conditions (Figure 2). There is immediate change in the vegetation and soils (organics, nutrients, temperatures and microbial activity). In permafrost terrain, thawing of ice-rich permafrost, subsidence and thermal erosion may result in complete ecosystem change. Ecosystem response begins immediately following fire, involves a great many processes and is dependent on initial fire severity, climate, soils, topography, or herbivore during this period.



Figure 2. Vegetation changes one year post fire in tussock tundra in Noatak (left) and black spruce forest in Gates of the Arctic (right). The depth of consumption of the organic matter will influence the vegetation response post fire. In both photos, tussock cotton grass, *Eriophorum vaginatum*, has survived the fire, although the inter-tussock spaces have had a major change in species composition of shrubs and bryophytes. Photos courtesy of the National Park Service.

The successional vegetation changes after fire in the boreal ecosystems have been studied more intensively than tundra ecosystems, in Alaska (for example see: Viereck 1973; Viereck 1983; Foote 1983; Johnstone and Chapin 2006). Historically, the effects of fire on tundra ecosystems and vegetation succession trajectories have been less studied (Wein and Bliss 1973; Racine et al. 2004), although there has been increasing interest in tundra fire interactions (Bret-Harte et al. 2013; Jones et al. 2013). There are only a few long-term monitoring studies pertaining to tundra fires and two of the sites are in the Arctic Network parks - Bering Land Bridge (Racine et. al. 2004) and Noatak (Racine

et al. 2006). Several studies have looked at the impacts of fire on lichen and caribou habitat (e.g., Holt et al. 2008; Joly et al. 2009; Joly et al. 2010). Recent fire events on the North Slope arctic tundra has brought about additional tundra fires studies in this region (Mack et al. 2011; Bret-Harte et al. 2013; Jones et al. 2013).

Burn severity influences the vegetation succession and establishment of plants post fire. In both boreal and tundra ecosystems, many of the vascular plants (herbaceous, shrubs and non-coniferous trees) will re-sprout after a low or moderate severity fire (Figure 2). The non-vascular plant (bryophyte and lichen) communities generally have the greatest amount of change after a fire because of the changes in species composition (Jean et al. 2017) and slow recovery of lichens (Holt et al. 2008; Nelson et al. 2015). The severity of fires will influence the establishment of trees on site (Johnstone et al. 2006) and the availability of mineral soil for other seedling establishment after a fire. As fires become more frequent or severe, a better understanding of post-fire successional trajectories will become even more essential to understand potential impacts to the landscape, wildlife habitat, permafrost degradation, carbon release, or range expansion of species into newly formed biophysical settings.

Climate Change Impacts

Climate models presented by the Scenarios Network for Alaska Planning (SNAP) predict continued strong warming in Alaska, with increases reaching 1.5-5.0 ºF by 2030, and 5-18 ºF by 2100. Temperature increases are expected to be most pronounced in the interior and northern regions, and average winter temperatures are expected to have greater increases than the averages for the other seasons. Continued precipitation changes are also projected, with increases of 20-25% projected in the north and northwest, and decreases expected along the south coast of Alaska. Changes in temperature and precipitation will alter disturbance regimes; with fire being a key disturbance regime that will change (Chapin et al. 2003; Kasischke et al. 2010; Flannigan et al. 2013). The trend of increased tundra burning is anticipated to accelerate as a result of climate change in the 21st century, with the potential to result in novel fire regimes (Hu et al. 2015; Young et al. 2016) relative to the past 6,000-35,000 years (Chipman et al. 2015). These authors also suggest that increased evaporation from warming is projected to more than offset the increased precipitation, making soil drier in most of the state (see also Flannigan et al. 2016).

Experiments and remote sensing suggest that the response of arctic tundra vegetation to increased nutrients and warmer soils result in an increase in graminoids, deciduous shrubs, decreased plant diversity and loss of lichens (Chapin et al. 1995, 1996; Sturm et al. 2001; Sturm et al. 2005; Hollister et al. 2005). Changes in plant functional types (increased deciduous shrub abundance and size) are important to the surface energy balance (summer sensible heat flux), carbon balance (increase carbon storage in wood), forage for herbivores, and winter snow depth (deeper snow due to shrub trapping of blowing snow).

Climate change and the subsequent effects on fire frequency, extent and severity, as well as potential changes in the vegetation, distribution of permafrost and hydrologic regimes, are of interest and concern to park managers and the public. With these concerns in mind, we propose to monitor fire parameters and their associated impacts. We expect the fire monitoring program will provide the

broad-based, scientific information necessary to help make sound management decisions and support research, education, and public awareness regarding the parks that is required of the Inventory and Monitoring program.

1.4. Protocol Objectives

Monitoring Questions to be Addressed by the Protocol

Based on needs identified through scoping meetings, discussions, and data gaps identified for the Arctic Network, the following are a subset of the monitoring questions developed during the planning phases for the ARCN Network Monitoring Program (Lawler et al. 2009):

- *What are the long-term trends and natural level of variation in the frequency, extent, and burn severity of fires?*
- *How does the time since fire and burn severity affect the species composition, vegetation structure, and ground cover among varying vegetation types?*

Monitoring base-line fire parameters such as the number of fires, fire extent, and burn severity will provide information on the long-term changes in fire regimes that influence many other ecological factors in ARCN. Long-term monitoring of fire effects will provide information on vegetation changes post-fire, which can influence wildlife habitat, soils and hydrology. In order to measure the effects of fires, data will be collected with on-site ground vegetation measurements utilizing pre-existing fire plots. The purpose of these ground-based permanently marked plots are to detect major changes in structure and composition of vegetation within the representative areas in response to fire. Additional monitoring plots may be established in conjunction with the burn severity plots that are established by the network and fire program.

In order to address the long-term trends in fire extent, burn severity and fire effects the following monitoring objectives were developed.

Monitoring Objectives

1. Determine the variability and decadal-scale trends in fire frequency (number of fires/year), average fire size, maximum fire size, and total area affected by fire in ARCN network parks.
2. Detect the variability and decadal-scale trends in number of lightning strikes by park and ecoregions for ARCN.
3. Detect decadal-scale trends and variability in burn severity on fires larger than 1000 acres in ARCN.
4. Detect changes in species composition, vegetation structure, and ground cover due to time since fire and burn severity.

This protocol provides a narrative on how wildfires and effects will be monitored and reported for the Arctic Network. This protocol narrative provides information on methods, analysis and specific data management for three major aspects of the fire monitoring protocol. The document is divided into the following chapters: Chapter 2 - fire frequency, extent and lightning; Chapter 3 - burn severity; and Chapter 4 - fire effects. Centralized data management is addressed in Chapter 5.

2. Fire Frequency and Extent

2.1. Sampling Design

Rationale for Sampling Design Selection

Data on wildfire occurrence, location and size are required to be collected for all known fires that occur within the boundaries of all National Park Service units (NPS RM-18, 2014). Within Alaska this is a combined effort of the NPS fire management program in conjunction with Alaska *fire protection agencies* (Bureau of Land Management - Alaska Fire Service; State of Alaska - Division of Forestry; United States Forest Service) (Alaska Master Agreement 2015, DM-620 Chapter 2 (DOI 1998). The National Park Service is a *jurisdictional agency* in the fire management role for Alaska. Utilizing datasets that are being generated on a state and park wide basis through the NPS fire program and other agencies is the preferred method for collecting data on fire extent and frequency.

The basic approach will be to work with the Alaska Region NPS fire management program to utilize existing datasets. Through support from the I&M program, fire datasets will be improved through data quality control, as errors are identified or improved data becomes available, this information will be provided back to the fire management program. ARCN's primary role will be to provide timely reports on fire statistics for the parks and analyze trends in the fire frequency and extent over time.

The fire extent and frequency datasets are park wide and sample the full population of fires that are known to have occurred, therefore traditional sampling design information (e.g., site selection, replication, number of sampling sites, sample size) are not relevant. The protocol narrative section 2.2 Methods of Data Acquisition and Development and standard operating procedures (SOPs) provide a description of data acquisition, data properties, and data processing for the fire frequency and extent datasets. A brief description of the datasets are provided below.

Fire Frequency

Fire frequency or the number of fires occurring within the parks will be determined utilizing fire records that are collected for the origin of fires that start within park lands or burn onto park lands. As of 2016, the wildland fire occurrence data has been stored electronically in a national fire reporting database called WFMI (Wildland Fire Management Information) for all fires on National Park Service lands as described in Reference Manual 18 (NPS 2014). Because national systems can change over time, the database will be referred to as the "fire reporting system" (FRS) database within this narrative.

Data collected for all fires detected include: location, year, start/end date, fire number, fire cause (natural/human caused), acreage by land ownership, final fire acreage, vegetation types, closest weather station, and fire management activities. Data from the fire reporting system database are incorporated into a GIS point layer of fire locations (referred to in the narrative as the *NPS fire points*) and are stored on the Alaska Region GIS Team Permanent Data Set (GIS PDS). For Alaska, the data is generally available from 1950s to current.

Fire Extent

Fire extent or the area burned by wildfires will be determined using one or two data sources, depending on the variable or extent being calculated. The data sources are the final acres reported in the FRS database and a geospatial layer of fire perimeters. Fire perimeters are the entire outer edge or boundary of a fire. GPS collected or digitized fire perimeters are the preferred method for determining the final area burned by a fire. For Alaska, final fire perimeters are generally mapped for all fires greater than 10 acres in size (Alaska Statewide Annual Operating Plan 2016), while smaller fires may be visually estimated to determine the final size of the fire. Fire perimeters are created by or submitted to the BLM Alaska Fire Service during the fire season. Historic and current statewide fire perimeter data is available on the Alaska Interagency Coordination Center Statewide Fires/Fire Information ArcIMS sites (http://fire.ak.blm.gov/predsvcs/maps.php accessed 21 April 2016). Statewide fire perimeter geospatial data is downloaded annually by NPS fire management staff and incorporated into the GIS PDS. This statewide fire perimeter geospatial layer stored on the Alaska GIS PDS will be referred to as the *NPS fire perimeters* in the narrative.

Fire Season

The fire season can be defined by many different variables. Fire season may be defined by the date of the first fire start and the last fire start in a park or unit. This measure of fire season is dependent on fires occurring and which is partially dependent on ignition sources (lightning or human caused starts). The fire season can also be defined by the availability of vegetation/fuels to burn. Currently the start and end dates of the last fires within the parks will be used to assess fire season length. Future work could consider variables such as: snow free dates, green-up dates (NDVI), or fire danger indices.

Lightning Frequency

Lightning data is available through the BLM and stored on the Alaska Interagency Coordination Center (AICC) ArcIMS Historical Lightning Information map: http://afsmaps.blm.gov/imf_customlight/imf.jsp?site=customlight. Data will be downloaded and summarized for the park areas to determine the number of lightning strikes within a park unit and strikes/area for the parks and ARCN total.

Sampling Frequency

Information on active fires will be collected throughout the duration of the fire season. Basic fire statistics for the number of fires and area burned for wildfires occurring within or adjacent to park administrative boundaries will be collected annually. Generally fire reports are generated in the fall of each year by the fire protection agencies and are provided to the National Park Service. Data is entered into the fire reporting system database over the winter. GIS data layers of NPS fire points and NPS fire perimeters are generally updated in April of the following fire season.

Detectable Level of Change

Data will be summarized annually for each park within ARCN to present the number of fires/year, the total area burned/year, average fire size/year and presented graphically within a report provided to ARCN. Additional summaries of fire cause (human versus natural) and fire season duration will

be calculated. The detectable level of change will dependent on the data variability and the fire frequency.

Limitations of the Data

The fire history data sets in Alaska have varying quality of data (Kasischke et al. 2002). Fire location data stored in the Alaska NPS fire reporting system database are generated from fire records from 1950 until present day, although there are some records that are earlier than 1950. The early records of fire locations were often estimated using maps and fire sizes were visually estimated. More recently fire locations are generally taken with a GPS, however due to the remote nature of the parks, sometimes fire points are taken in a fixed wing aircraft and the fire point may not be precise, for example see Figure 3.

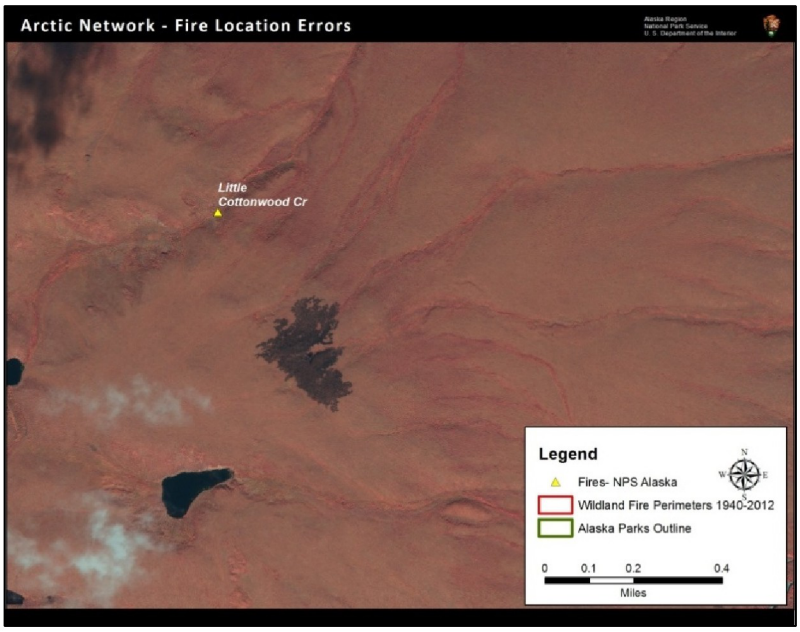


Figure 3. Example of a fire location point that does not accurately represent the actual location of the fire. Errors such as these will be identified during the data QC process and corrections will be submitted to the fire reporting database.

During the early 1990s a large effort was put forth to digitize fire record perimeter maps to create what was called the Alaska large-fire database (Kasischke et al. 2002). The objective was to compile and standardize fire perimeter information for large fires dating back to 1950. The data was compiled from historical fire reports. Some of these reports had very rough fire perimeters hand drawn, so the quality of the data was variable. In addition, many fire reports were lost in the 1960s. The Alaska large-fire database has since been stored on the AICC ArcIMS site and is referred to as the *"Perimeters Since 1940"* layer under the "Fire History" map on the ArcIMS site. Since the mid-1990s, the practice of mapping fire perimeters with a GPS or utilizing satellite imagery to digitize perimeters has improved the data quality. The database has continued to be maintained by the Alaska Fire Service.

Between 2007 and 2008 partial funding from a Joint Fire Science Program research study was used to update, improve, and digitize missing fire perimeters on the AICC ArcIMS site "Perimeters Since 1940" layer (Olson et al. 2011). As a result of the project, 417 fire perimeters were improved through the use of Landsat imagery and other sources. Over 112 perimeters were updated in this process on NPS Alaska lands. With the improved mapping, fire acreages changed for many of the fires. It is a continual process to quality check and update the fire datasets. In order to adjust for potential discrepancies between data sources and to improve the datasets, a process was developed to quality check the fire data within the fire reporting system and the fire perimeter data sets (SOP 1.3).

2.2. Methods of Data Acquisition and Development

The main goal of the fire frequency and extent vital sign is to provide accurate data on the number of fires, types of fires, and area burned within and adjacent to the park boundaries. The general data acquisition and data handling methods are described briefly here; more details are provided in the Fire Extent and Frequency SOPs 1.1 – 1.9 and under the data management section. The general methods are shown graphically in Figure 4.

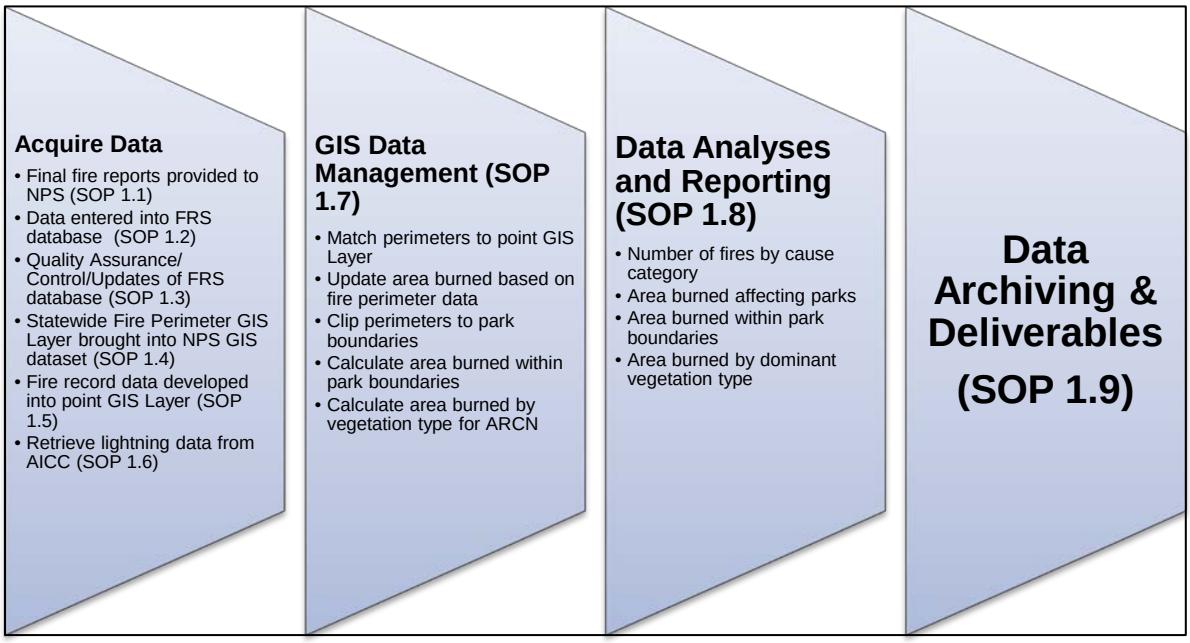


Figure 4. General methods overview of how fire occurrence data is acquired and utilized to calculate fire statistics for ARCN network.

Sequence of Events During the Fire Season

This protocol does not cover the process and actions taken during an active fire, such as tactical or strategic decisions. However, a brief overview of the process for mapping and recording fire information during an active fire is provided as general background for the acquisition of the data at the end of the fire season. Much of this information is directly out of the Alaska Statewide Annual Operating Plan Exhibit C as part of the Master Cooperative Agreement Wildland Fire Management

Agreement 2015 (AOP Exhibit C 2017, http://fire.ak.blm.gov/content/aicc/asma/Exhibit%20C%20AOP.pdf accessed 24 October 2017).

In Alaska, the primary responsibility for wildland fire protection is divided among the Alaska Department of Natural Resources (DNR), the US Forest Service (USFS), and the Bureau of Land Management Alaska Fire Service (BLM-AFS). The BLM-AFS carries the primary responsibility for suppression actions on lands within the Arctic Network parks. Part 620 Departmental Manual 2.4 states "BLM will maintain and operate the Department of the Interior wildland fire suppression organization in Alaska with the primary intention of providing cost-effective suppression services and minimize unnecessary duplication of suppression systems for Department of Interior agencies." (DOI 1998)

The BLM Alaska Fire Service – Galena and Tanana Zones provide fire detection for the five parks in ARCN based on lighting activity levels, human use or at the request of the NPS. Upon discovery of a fire, the BLM-AFS Zone will verify and document fire location, fire management option, and cause of fire. Initial response will be implemented according to the Alaska Interagency Wildland Fire Management Plan and the Jurisdictional Fire Management Officer (FMO) or designated NPS Duty Officer will be notified. Likewise, when a Jurisdictional Agency discovers a fire, they will promptly notify the appropriate Protection Agency. Notification standards are listed in the Alaska Interagency Wildland Fire Management Plan (AIWFMP) and the Statewide Annual Operating Plan (AOP).

Throughout the duration of the fire the protection agency and NPS FMO will communicate fire suppression actions and/or monitoring status of the fire activity. Periodic surveillance will continue for the duration of the wildfire to evaluate fire behavior and threats. Surveillance frequency will be coordinated between the Protecting Agency and the Jurisdictional Agency.

The protection agency is responsible for fulfilling daily interagency incident reporting requirements and will complete the final fire report which will be provided to the Jurisdictional Agencies. Throughout the duration of the fire, current fire information is provided through the Alaska Interagency Coordination Center web page (http://fire.ak.blm.gov/) on the AICC Situation Report.

Locations of fires and fire perimeters are generally mapped and updated on the AICC ArcIMS site throughout the duration of the fire. The interagency fire community in Alaska has developed a set of procedures for submitting digital fire perimeters to the AICC ArcIMS website (AOP 2016). GIS shape files of fire perimeters (10 acres and greater) are to be submitted to this website when perimeters are created, updated, and finalized. For ongoing fires being monitored, the agencies will negotiate a timeline for fire surveillance updates and perimeter map submissions. The final fire perimeters submitted with the final fire reports are added to the *"Perimeters Since 1940"* layer under the "Fire History" map on the AICC ArcIMS site. The perimeter data on the AICC ArcIMS site is downloaded by NPS fire staff annually in April to update the fire perimeter dataset on the AKRO X: drive.

Jurisdictional Agencies have the option to update an incident perimeter after fire season by submitting annual updates to the AFS GIS division prior to March 1. AICC will incorporate those

updates into historical fire data and perimeter files. This is to ensure the most accurate information for the historical databases.

The following recommendations are provided to encourage the best available data is available for the final fire reports and GIS data for NPS fires.

- Fires that are greater than 10 acres should have a fire perimeter drawn or mapped by GPS.
- Fire origins should have an accuracy of at least 200 meters of the actual fire. Locations should be taken from a stationary platform, such as a helicopter or drawn based on good geographic markers. Assure that fire locations fall within the perimeter or vice versa.
- If adequate fire information is not provided due to resource constraints on the fire protection agencies, the NPS may monitor and map fires to provide fire perimeters, photos and fire behavior information.
- Fire perimeters that are mapped by hand or with a fixed wing aircraft should be reviewed upon receiving the final fire perimeter and compared to Landsat imagery to determine if the fire perimeter could be improved to provide more detail and for increased accuracy of location.

Fire Report Acquisition and Review (SOP 1.1)

The NPS is required by Reference Manual 18 to have a completed wildland fire report and any additional fire reporting information for all fires that occur on NPS lands (NPS 2014). The hardcopy wildland fire reports are considered the permanent record of wildland fires on NPS lands (NPS 2014). In Alaska, the final fire reports are provided by the fire protection agencies through AICC for all fires that occur on park lands in the fall of each year. These reports include the following data about individual fires: fire name, fire number, fire code, fire type (wildfire, prescribed fire, natural out or false alarm), protection type, cause category (natural or human), start or discovery date, declared out date, fire origin (latitude/longitude), final fire acreage, acres by land ownership, closest weather station, dominant fuel types, topography, aspect, slope class, and elevation of the origin of the fire. Example fire reports provided by the protection agencies to NPS are shown in SOP 1.1. The fire reports are reviewed by park fire management officers (FMO) or staff for accuracy. The process for corrections or revisions are described in SOP 1.1. Hard copies of final fire reports and maps of fires are maintained at the NPS Alaska regional office.

Fire Report Data Entry (SOP 1.2)

The final fire reports or fire occurrence data are entered into a fire reporting system database (FRS) (See SOP 1.2). For example, WFMI (Wildland Fire Management Information) a web-based system-of-record for fire occurrence data, has been used by some agencies within the Department of Interior, including the National Park Service. Data entry and access to the data or reports is only allowed by authorized users. Authorized users may enter (create), edit, and view fire reports; as well as create data-sets for export to fire analysis programs and to generate summaries of the fire occurrence data.

Within Alaska, the NPS fire occurrence data has historically been entered into a FRS database during November and December by the NPS Alaska Fire GIS specialist or other designee. The SOP for data

entry is provided in SOP 1.2. Data entered into the FRS database will be reviewed by a process of printing outputs of the data entry and checking for consistency with the hard copy final fire reports.

Quality Control and Verification of Fire Data (SOP 1.3)

New (and old) data entered into the FRS database will be reviewed and verified through a GIS process of quality control for the fire locations and acreages reported. Older fire records may have errors in fire size and locations that can be improved with remote sensing methods for mapping perimeters and locations (Olson et al. 2011). Most of these errors are in older NPS fire records, although even in current records errors can occur. In order to adjust for these discrepancies, a process was developed to QC and update fire acreage data and fire origin locations in the FRS (SOP 1.3). Landsat imagery or other imagery will be utilized to verify perimeter accuracy. Over time the process will simply be a verification of the point location within the perimeter and check the acreage as reported in the protection agency fire report versus the fire perimeter acreage if available.

Develop Geospatial Layer – NPS Statewide Fire Perimeters (SOP 1.4)

Statewide fire perimeters are submitted throughout the fire season to the BLM Alaska Fire Service and are maintained on the Alaska Interagency Coordinating Center web page (http://fire.ak.blm.gov/predsvcs/maps.php). The final fire perimeters are downloaded annually at the end of the fire season and are incorporated into the NPS Alaska Regional Office (AKRO) GIS permanent dataset and maintained within a geodatabase maintained on the regional GIS X: drive.

Develop Geospatial Layer – NPS Fire Location Points (SOP 1.5)

The NPS fire GIS staff maintains a fire "points" GIS layer that includes the point of origin for all fires that originate or burn into park unit boundaries. This geospatial layer can be created from the FRS database and has generally been updated annually after all fire reports have been entered and quality control has been completed on the FRS dataset. A unique identifier that links the WFMI database to the perimeter data is added to the NPS fire point dataset in order to match the fire perimeters to the fire point datasets. The final geospatial layer for the NPS fire points is incorporated into the Alaska Region GIS Team PDS. Details on this process are provided in SOP 1.5.

Acquire Lightning Data (SOP 1.6)

Lightning strike data in Alaska are available as a prebuilt compressed shape file and as a compressed File Geodatabase available online. This geodatabase contains lightning data from 1986 through the current year and stores it in two separate feature classes, one for the old lightning data (from 1986 to 2012) and another for strikes detected with the new Time of Arrival (TOA) system (from 2012 to present). Both systems collected data in 2012. There are distinct differences between the two lightning detection systems making the data incomparable. Lightning data prior to 2012 will not be used unless explicitly noted.

2.3. Data Analysis and Reporting

The following sections provide information on the data summaries, analyses and reporting for fire extent and frequency monitoring vital sign. The details of data management are provided in a combined chapter for data management for fire extent, burn severity and fire effects monitoring in

Chapter 5 Data Management. Descriptions and details for data analyses and reporting are in SOP 1.8.

Routine Data Summaries (SOP 1.8)

The data will be summarized to provide a set of fire statistics to assess the 10 year trends in fire frequency and extent. Because fires can burn across multiple land jurisdictions or may start outside the park boundaries but ultimately burn on to park lands (see Figure 5), data will be summarized to show the number of fires and area burned affecting the parks and within the park administrative boundaries. In addition, even within a park's administrative boundaries there are non-NPS lands, for instance in Figure 5, the fire on the left shows a portion of the fire burned on Native lands within the NPS administrative boundaries of Gates of the Arctic National Park and Preserve. A decision was needed to determine whether the acres reported for ARCN parks were on NPS land ownership or within the administrative boundaries of the parks. Since this data set is more concerned with ecological effects and trends of fires, not changing landownership, it was decided that the administrative boundary for parks will be used for data analyses rather than NPS landownership.

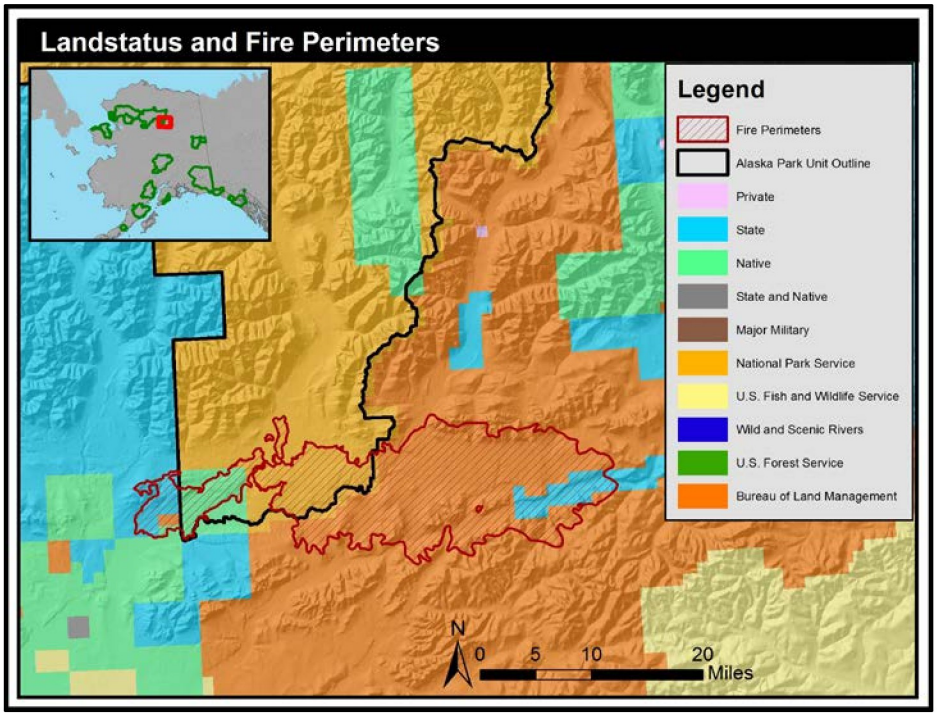


Figure 5. Map showing how fires can cross multiple land jurisdictional boundaries near Gates of the Arctic National Park and Preserve, Alaska. The two fire perimeters in red hatch show large fires crossing multiple land jurisdictions outside the park boundary (black outline). The fire on the left also burned on Native lands within the park boundary.

A set of variables will be calculated utilizing the two datasets (point and polygon fire history) shown in Table 3. Detailed methods for the GIS process and calculation of these variables are provided in SOP 1.7.

Table 3. Description of variables to be potentially calculated for fire frequency, extent and seasonality of wildfires. Prescribed fires will not be included in the analysis[1].

Variable	Variable Detail	Data sources	Calculation or Comment
Total Fire Frequency – Number of total wildfires affecting the park/year	Number of natural and human caused fires that have burned in or onto park lands per year.	Fires-NPS Alaska	Count by park unit and year.
Park Fire Frequency Natural – Number of natural fires within park/year	Number of natural caused fires started	Fires-NPS Alaska Park Boundaries	Count of the number of fires inside park boundary where WFMI Data * and "CauseCategory" = "Natural"
Park Fire Frequency Human – Number of human caused fires within park/year	Number of human caused fires started	Fires-NPS Alaska Park Boundaries	Count of the number of fires inside park boundary where WFMI Data * and "CauseCategory" =" Human"
Total Area Burned (Acres) – Total area burned within and adjacent to park boundary by year.	Acres burned "affecting" the parks for time measured.	Fires-NPS Alaska "ContrAcres".	Sum of Fire-NPS Alaska "ContrAcres".
Total Park Area Burned (Acres) - within park boundaries	Acres burned per year within park boundary. Fire perimeters clipped to park boundary.	Fires-NPS Alaska - "ContrAcres" Fires-Historic Wildland Fire Perimeters XXXX – XXXX (clipped to park boundary).	Current method: Fire Perimeter data clipped to Park boundaries, and adding in ContrAcres for all other fires without perimeters with assumption that fire burned within park boundary.
Average fire size/year	Average of fire acreage of fires that started within the park boundary.	Fires-NPS Alaska Park Boundaries	Mean of "ContrAcres" of fires that started within the park boundary.
Maximum fire size/year	Maximum fire size of fires	Fires-NPS Alaska Park Boundaries	Maximum of "ControlAcres" of fires that started within the park boundary.
Number of lightning strikes/year	Number of lightning strikes within park boundary. Or number of strikes per acre.	AICC Lightning Strike Data Park Boundaries	Discuss with AICC the stability of the data, additional lightning sensors to be installed. Determine when to start the data analysis. I.e. after 2012?
Fire Season Duration	The number of days fires are burning for a year by park.	Fires-NPS Alaska	Minimum start date of a fire and maximum end date of a fire within a park area. Calculate the number of days of active fires.

[1] Fires-NPS Alaska data not including Fire Type/Protection Types: 48 prescribed fires

The frequency of fires will be summarized annually to indicate the total number of fires affecting the park and the number of fires that started within the park boundaries. In addition the number of human caused versus natural starts will be counted. This data will be generated from the NPS Fire Point data layer generated from the FRS database.

Fire extent or area burned will be summarized annually to determine the total area burned affecting the parks and the area burned within the park boundaries. Additional information such as average fire size and range of fire sizes will be calculated utilizing the total area burned (not clipped to park boundary).

Reporting Schedule

Fire extent and frequency data will be reported in three report formats: ARCN annual report, Fire Ecology Annual Report, and 10-year trend analysis report. Basic summary statistics on the fire activity for the year will be reported in the ARCN annual report and in a Fire Ecology Annual report. A more detailed 10-year monitoring report will be completed to summarize data and identify any trends in fire extent and frequency for ARCN parks. The expected reporting schedule is shown in Table 4. Additional details on the types of tables and graphics that would be included in these reports are provided below.

Table 4. Reporting schedule for fire extent and frequency data.

Report	Report Type	Schedule	Primary Responsibility
ARCN Administrative Annual Report	Word document	October Annually	ARCN I&M Coordinator / Fire PI
Fire Ecology Annual Report	NRDS	May Annually	Fire PI (or Regional Fire Ecologist)
Fire 10 Year Trend Report	NRR	Every 10 years	Fire PI

Preliminary data on fire frequency and extent will be summarized at the end of the fire season, based on the best available data and will be provided for the ARCN annual report by October of each year. Generally the official fire record data entry and fire perimeters are not completely updated until April, therefore a final annual report will not be completed until May of the following year.

Data will be summarized annually on a regional basis for all parks in an annual fire ecology report (SOP 1.8). These annual reports provide brief summaries about the NPS Alaska fire season, fire ecology monitoring results, fire research projects, and fire ecology program activities and outreach for the Alaska Region.

A more detailed ten-year monitoring report will be completed to summarize the trends and statistics on fire occurrences and extent for ARCN (SOP 1.8). Additional details on the types of tables and graphics that would be included in this report are provided below.

Report Format with Examples of Summary Tables and Figures (SOP 1.8)

Final annual reports will be formatted using the NPS Natural Resource Data Series format (http://www.nature.nps.gov/publications/nrpm/nrds.cfm), for example: Barnes and Northway 2015 https://irma.nps.gov/DataStore/Reference/Profile/2221708 (accessed 19 February 2016). These reports may include fire statistics as listed in Table 3 and as shown with data from 2015 in Table 5. The report may also include preliminary summary results for the burn severity monitoring or fire effects monitoring (see Chapters 3 and 4). Graphics of summaries from past years of data could be included in these annual reports, such as shown in Figures 6 and 7. Further details are contained in SOP 1.8.

Table 5. Example summary table of 2015 fire statistics for wildfires that burned in and adjacent to ARCN parks. Fire data is based on NPS wildfire records from 2015 that are developed into the AKRO GIS permanent data sets (Fire-NPS Alaska (2015) and Fires-Historic Wildland Fire Perimeters 1940-2015). Lightning strike data is from AICC ARCIMS web page (AICC 2015).

Park	Total Number of Wildfires[1]	Number of Wildfires by Cause - Natural /Human[1]	Total Acres Burned Affecting Park in 2015[1]	Total Acres Burned within Park Boundary in 2015[2]	Average fire size (Acres)[1]	Minimum / Maximum fire size (acres)[1]	Number of lightning strikes detected
BELA	2	2 / 0	1595	1595	797	1 / 1594	26
CAKR	0	–	0	–	–	–	3
GAAR	1	1 / 0	79	79	79	- / 79	1487
KOVA	1	1 / 0	15,740	15,740	15,740	- / 15,740	556
NOAT	1	1 / 0	299	299	299	- / 299	413
ARCN Total	**5**	**5 / 0**	**17,713**	**17,713**	**3,543**	**1 / 15,740**	**–**

[1]Fires that have burned in the park, but fire area may have extended beyond the park boundary are designated as “Affecting Park”.

[2]Fires that occurred only within the park boundary or were clipped to the park boundary are designated “In Park”.

Ten year trend reports would be written to summarize trends in fire extent, frequency, and lightning for the network. These reports would be formatted in a NPS Natural Resource Report format (https://www.nature.nps.gov/publications/nrpm/index.cfm?tab=0#reports (accessed 24 October 2017). Further details are contained in SOP 1.8.

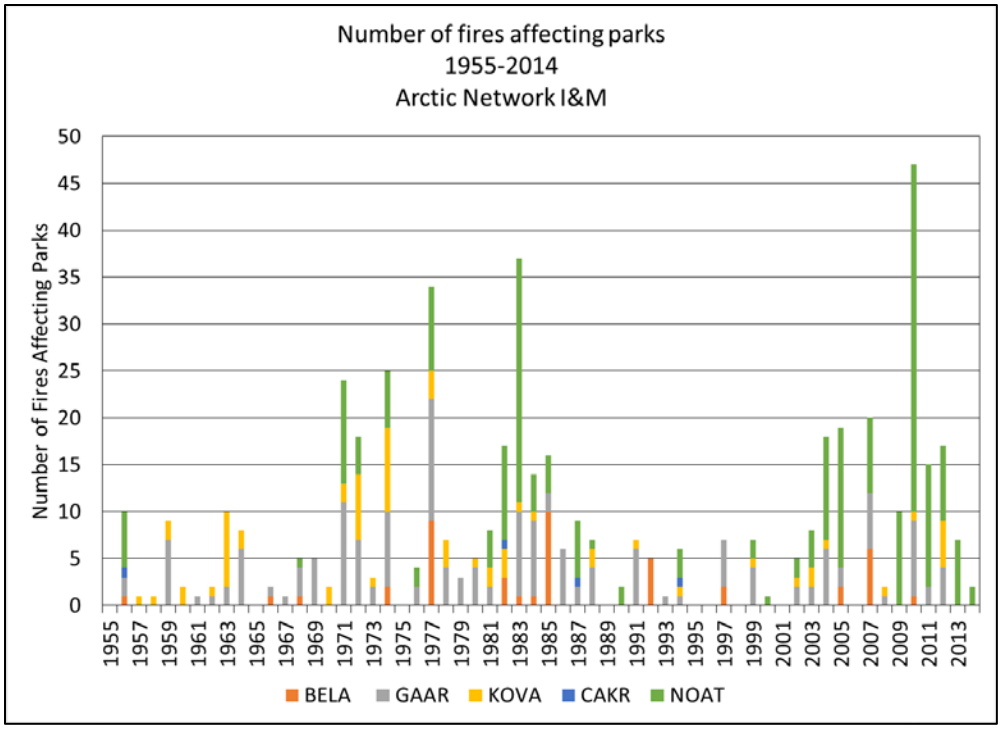


Figure 6. Summary graph example showing the number of fires each year that have burned in or on to Arctic Network parklands based on fire records from 1955 to 2014.

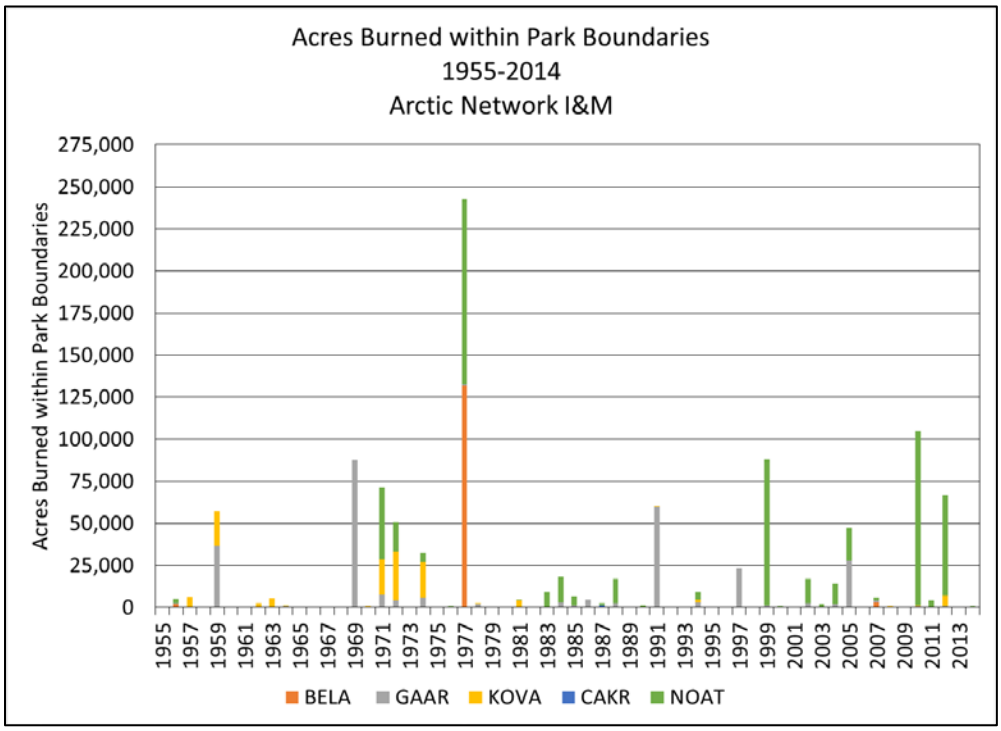


Figure 7. Summary graph example showing the area burned by year within the administrative boundaries of the Arctic Network parklands based on fire perimeter and NPS fire point records from 1955 to 2014.

Methods for Long-term Trend Analysis

Data from past and current fire years will be analyzed to detect changes in area burned and number of fires affecting the park and on NPS lands. Due to the non-normal distribution of data (high variability) non-parametric statistics will likely be utilized to detect changes with a P-value set at 0.10. The high amount of variability among years and extended fire return interval suggest that trend detection may be possible only over multiple decades unless changes are quite dramatic (i.e., orders of magnitude). Because additional sampling is not feasible (the full population is sampled), increasing the sample size to increase the power of analyses cannot be conducted. In addition, because additional samples are not possible and the long term range of variation is unknown, the most appropriate type of analysis technique is uncertain. In consultation with a biometrician/statistician, every 5-10 years exploratory analyses will be used to identify whether longer term trend analyses are appropriate, and if so, which techniques are most robust based on the data at hand. Graphs showing 5 year or 10 year running averages could be included in the report (see examples Figures 8 and 9).

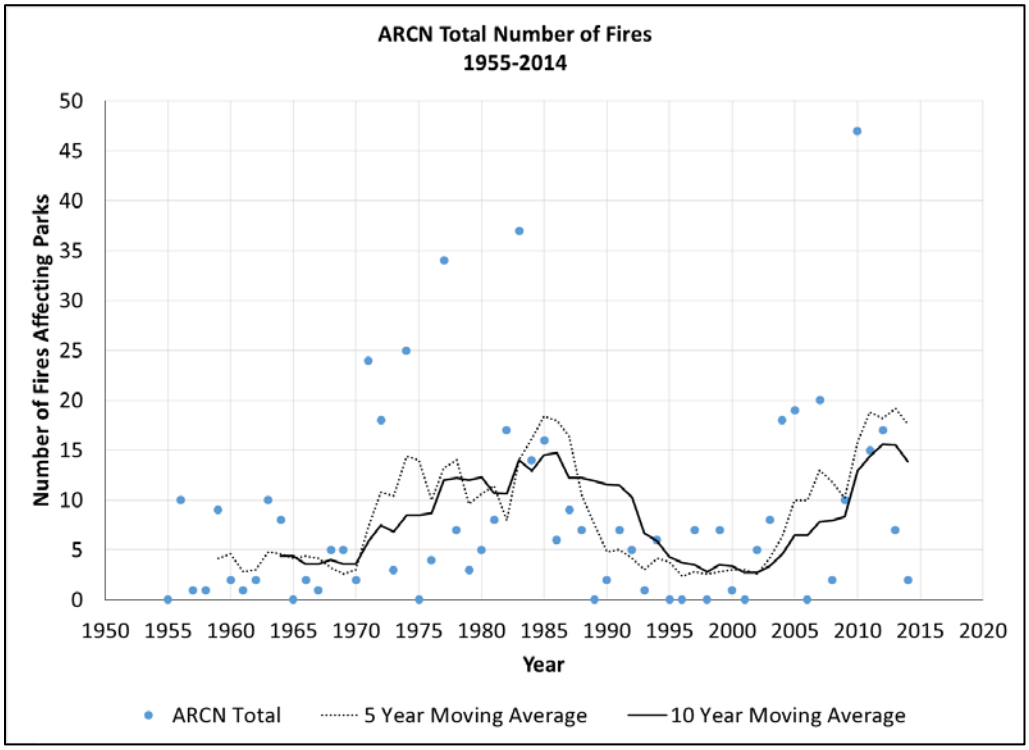


Figure 8. Example graph displaying the total number of fires affecting ARCN parks by year, with 5-year (dotted line) and 10-year (solid line) running averages.

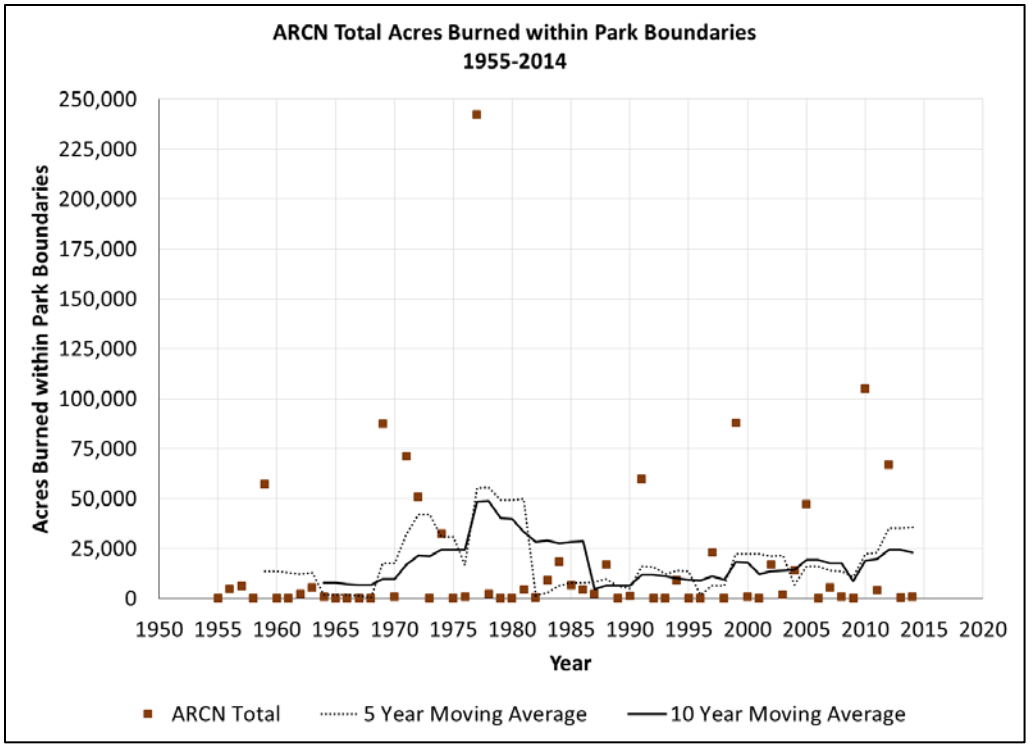


Figure 9. Example graph displaying the total acres burned within ARCN park boundaries by year, with 5-year (dotted line) and 10-year (solid line) running averages.

2.4. Operational Requirements

Personnel Requirements and Training

Fire report data entry and GIS data layer development for the base fire datasets will usually be performed by the Regional Fire GIS specialist or designated person with knowledge of GIS skills required for the work (GS-9 Assistant Fire Ecologist or PI). Data entry and access to the FRS database or reports is generally only allowed by authorized users.

The principle investigator (PI, a GS-11 or GS-12 NPS permanent employee) or a GS-9 term or permanent employee, under the supervision of the PI, will analyze the data and prepare reports on the fire statistics.

Annual Workload and Data Acquisition

Data entry generally occurs during the late fall after the fire season. The GIS data layers are generally not finalized until April. The PI or assistant will spend about 1 month in midwinter preparing datasets and 1 month in the spring preparing graphs and reports. Table 6 provides an overview of annual tasks, responsibilities, and expected schedule for the fire extent and frequency data.

Table 6. Annual workload tasks and responsible personnel for fire extent, frequency and lightning data.

Task	Responsible Personnel	Annual Schedule
Acquire final fire reports from fire protection agencies (SOP 1.1)	Fire GIS Specialist or Park FMOs	October
Download lightning data (SOP 1.7)	PI (Fire Ecologist)	November
Review fire reports for accuracy (SOP 1.1)	Park FMOs	November
Input fire reports into FRS database (SOP 1.2)	Fire GIS Specialist or Assistant Fire Ecologist	December
QC data in FRS database (SOP 1.3)	Fire GIS Specialist or Assistant Fire Ecologist	December
Annual update of fire point location data is developed into a GIS layer for Alaska Region GIS PDS X drive or other location as identified in SOP 1.4	Fire GIS Specialist	April
Annual update of fire perimeter data is made available on Alaska Region GIS PDS X drive or other location other location as identified in SOP 1.5.	Fire GIS Specialist	April
Process fire extent, frequency, and lightning data (SOP 1.6)	PI	April
Summarize fire extent, frequency and lightning data annually (SOP 1.7)	PI	April
Annual Resource Brief or Report	PI	May

Software and Hardware

Currently there are three primary software packages which will be required to meet the goals of this protocol.

- Standard internet browser for evaluating and ordering satellite imagery from the U.S Geological Survey Earth Resources Observation (EROS) Center website
- Geographic Information System software package: ArcGIS is the current package used by the NPS
- Microsoft Office (word processing, spreadsheet preparation, presentations preparation)
- R-stats software, SPSS, or other statistical program

The hardware requirements include a personal computer with a processing speed and memory adequate to run GIS analyses. To achieve maximum performance in processing and manipulation of imagery, more powerful processors and memory are preferred. A minimum hard drive capacity of 2 Tb is recommended for imagery processing.

Budget Considerations

The workload associated with data acquisition, data entry and GIS layer development will be approximately six weeks annually. Startup costs include 2 months of salary for assistant Fire Ecologist (GS-9) for data clean up and fire perimeter map improvements. The annual data analysis and report writing will take approximately 3-4 weeks of the PIs time. Currently the regional fire

ecologist (GS-11/12) is funded full time by the fire program, but if this workload needs to be completed by the assistant, additional funding may be needed. Estimated time and costs are provided in Table 7.

Table 7. Budget, responsible personnel and costs for fire extent, frequency and lightning data.

Task or Item	Responsible Personnel	Cost/Unit	Number of Units	Estimated Cost in 2017
Data entry and/or QC of fire occurrence data	Assistant Fire Ecologist (GS-9)	$3300/Pay Period	1	$3300
QC fire perimeter data	Assistant Fire Ecologist (GS-9)	$3300/Pay Period	1	$3300
Annual Data Analysis	PI Fire Ecologist or Assistant Fire Ecologist	$3300/Pay Period	1	$3300
Annual Report Writing	PI Fire Ecologist	NA	1	$0
Total				**$9,900**

3. Burn Severity

3.1. Sampling Design

Rationale for Sampling Design Selection

The heterogeneous pattern of fire (or 'fire mosaic') on the landscape results from varying burn severity within a fire (Figure 10). Burn severity is a measure of the ecological impacts of the fire, in terms of plant survivorship or mortality, depth of burn in the organic layers, or amount of biomass consumed. Due to the large size and the remote location of most fires in Alaska, it is recommended to use remote sensing as a method to monitor burn severity. A method for mapping burn severity with Landsat satellite imagery was developed to provide landscape level burn severity maps (Key and Benson 2006). Burn severity maps are produced by applying the Differenced Normalized Burn Ratio (dNBR) to pre and post fire Landsat imagery (Key and Benson 2006, Allen and Sorbel 2008). The dNBR is calculated using an index of Landsat bands 4 and 7, the two bandwidths that show greatest response to fire disturbances (Figure 11). In 2006, the Wildland Fire Leadership Council sponsored a multi-year project to map the burn severity for fires greater than 500 acres for the east and 1000 acres for the west in the United States for the period of 1984 through 2010 (Eidenshink et al. 2007), and has continued through to present time. The project is referred to as the Monitoring Trends in Burn Severity (MTBS) project and is implemented jointly by the U.S. Geological Survey (USGS) Center for Earth Resources Observation and Science (EROS) and the U.S. Department of Agriculture Forest Service, Geospatial Technology and Applications Center (GTAC).



Figure 10. Patterns of varying burn severity can be seen in this photo of a tundra fire taken shortly after the fire burned this area of the 2012 Uvgoon #1 fire in Noatak National Preserve. Photo courtesy of BLM-Alaska Fire Service.

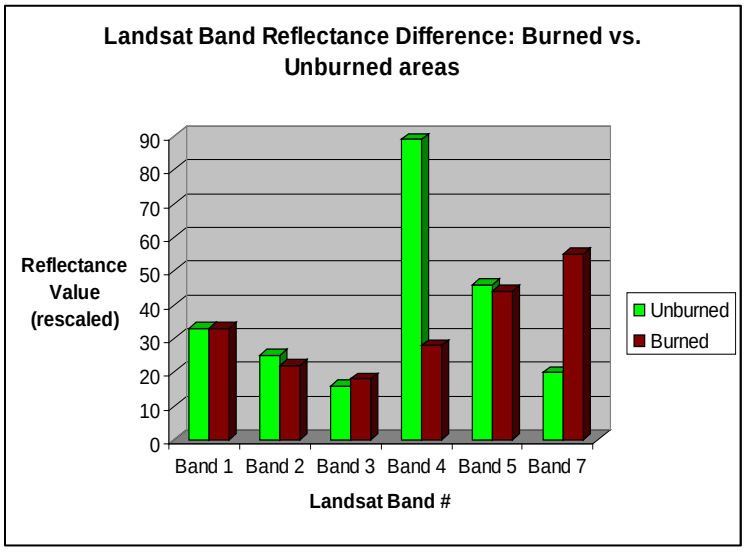


Figure 11. Landsat band reflectance graph shows the response of bands 4 and 7 in burned and unburned areas. Bands 4 and 7 are used in the calculations of the Normalized Burn Ratio to estimate burn severity.

We propose to monitor burn severity for the ARCN parks using data available from the Monitoring Trends in Burn Severity (MTBS) datasets (Eidenshink et al. 2007). MTBS provides Landsat-based,

30 m resolution fire severity data and fire perimeters for wildfires generally larger than 1,000 acres in the US from 1984 to present. MTBS acquires and processes appropriate pre and post fire Landsat imagery to generate the following dNBR burn severity products: grid based dNBR severity data set, satellite-derived final fire perimeter, pre and post fire Landsat imagery, and associated metadata. The burn severity datasets are made available on the MTBS website: http://www.mtbs.gov/ (accessed 24 October 2017). It is recommended that burn severity datasets be acquired for all fires occurring within ARCN that are greater than 1,000 acres.

The dNBR datasets can be used to develop maps of burn severity for fires within the parks (Figure 12) and can provide a measure of the likely effect of fire on the vegetation and soils. The dNBR value is a continuous variable and generally the higher the dNBR value indicates increased fire effects or severity. The raster dataset of dNBR values can be used to statistically compare the burn severity across fires, years or decades. The MTBS datasets also include threshold classified burn severity maps that could be used to detect changes in area burned by burn severity classification.

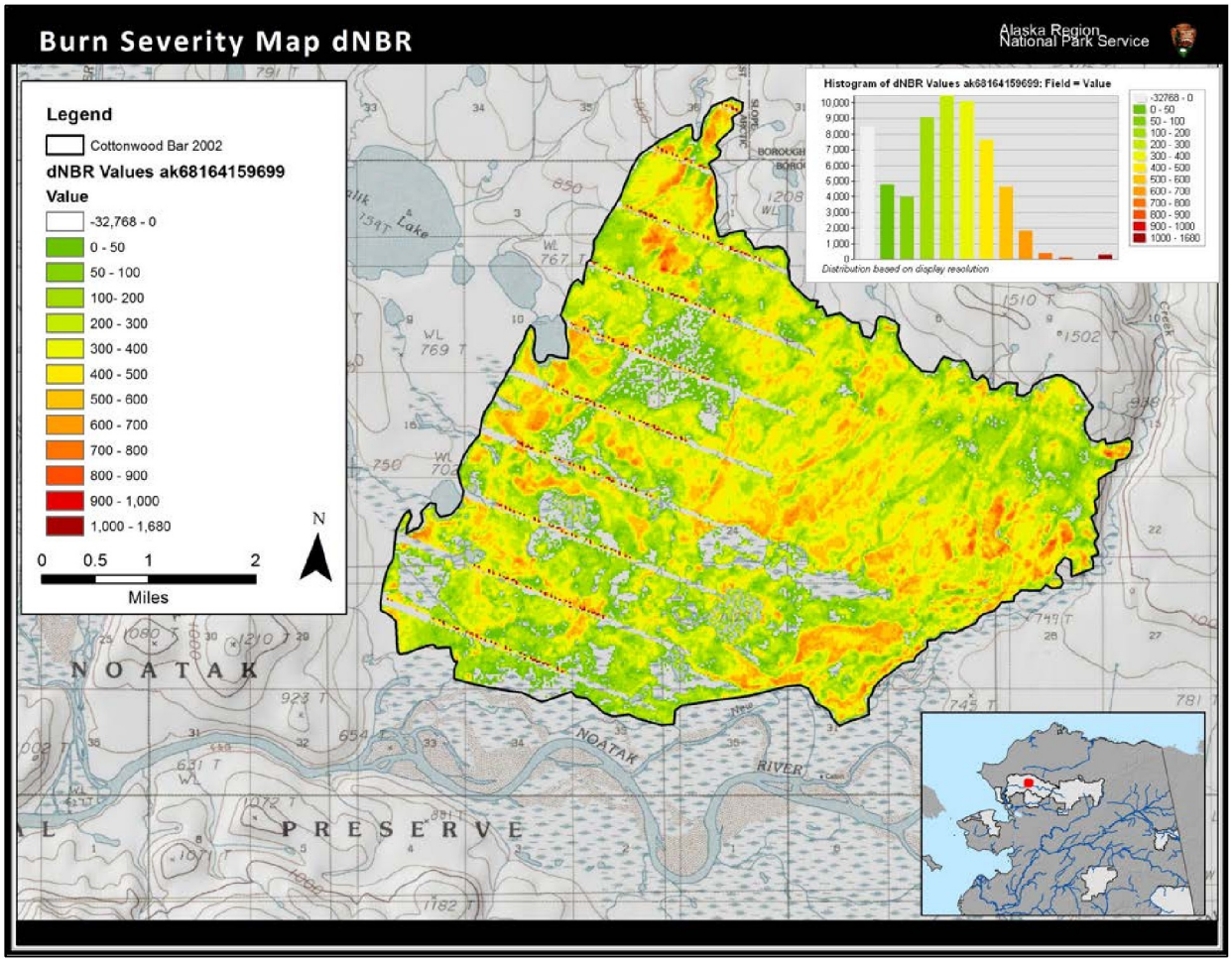


Figure 12. Burn severity map produced from differencing the pre and post fire Landsat imagery. This Monitoring Trends and Burn Severity extended assessment dNBR map was scaled to 100 increments of

dNBR values. The higher the dNBR value the more severe the burn. The histogram shows that most dNBR values were less than 500.

The remotely sensed burn severity products should be periodically validated with ground based plots. On the ground verification methods, called the Composite Burn Index (CBI), have been developed to compare ground based burn severity to remote sensed burn severity (Key and Benson 2006, Sorbel and Allen 2005, Allen and Sorbel 2008). Since protocols for CBI plot methods have already been developed and published, they will only be briefly described and cited where appropriate. Ground truth data will be collected approximately every 10 years (dependent of fire occurrences) to validate the burn severity map outputs in the ARCN parks.

Sampling Frequency and Sample Size

Remotely sensed burn severity datasets are dependent on fire occurrence and the ability to acquire good satellite imagery, therefore traditional sampling design information (e.g., site selection, replication, number of sampling sites, and sample size) are not relevant for the remote sensed burn severity maps. All fires greater than 1000 acres that are mapped with dNBR and of quality processing/imagery (see limitations below) will be included in the sample.

Burn severity maps are typically produced by the MTBS program 18 months to 2 years following the fire occurrence, depending on satellite imagery availability and national data processing load. Due to limitations of good Landsat imagery (clouds, smoke, or seasonality), not all fires over 1000 acres can or will be mapped (see https://www.mtbs.gov/mapping-methods, accessed 24 October 2017). As of 2014, 37 of the 50 fires in ARCN over 1000 acres since 1984 have been mapped by MTBS. A majority of these fires that were not mapped appear to be due to poor Landsat scenes available for analyses. The remotely sensed data will be acquired from the MTBS data site each year that the data is available for the ARCN parks.

Change Detection

Data will be summarized annually for each park within ARCN to present the area burned under severity classifications when burn severity is available. Tests of analysis will need to be conducted to determine if average burn severity (dNBR) will provide a detectable level of change.

Limitations of the Data

The remote sensed burn severity value of dNBR and the threshold severity data (dNBR6) have some limitations which may include: the spatial georeferencing of the imagery pairs, landsat scene clarity (smoke, cloud, scan lines), seasonality of imagery and variations in phenology, slope, aspect. Additional limitations of the data set include the following:

- Not all fires are mapped due to limitations of good imagery.
- The same value of dNBR may not be equal severity on another fire. This may be corrected by not mixing initial and extended assessment values. Further testing and ground truthing is needed.
- Severity threshold classifications (dNBR6) are completed by individual analysts at MTBS and may vary due to variations in analysts.

- Scan line issues in Landsat 7 result in no data for portions of fires.

Burn severity ground truth data has shown relatively good agreement between ground and satellite derived burn severity in Alaska with linear regression R^2 values ranging of from 0.45 to 0.88 from nine fires in Alaska parks (Allen and Sorbel 2008). Other studies have found poor correlations when sampled at high severity sites between 2004 and 2005 in Alaska (e.g., French et al. 2008). Therefore, it is recommended that ground truth verification continue sporadically to confirm the values produced by the remote sensed data. As new methods or remote sensing platforms for mapping burn severity are developed, these methods will be assessed as a potential means for providing landscape level burn severity. For instance Jenkins et al. (2014) tested the use of Synthetic Aperture Radar (SAR) to detect burns and monitor post-fire recovery in tundra, and had good success.

3.2. Methods

Burn Severity Mapping Methods

The following provides a brief description of the methods utilized to develop burn severity map products from Landsat imagery by the Monitoring Trends and Burn Severity program (Eidenshink et al. 2007). Additional details on the methods can be found on the MTBS website http://www.mtbs.gov/ (accessed 24 October 2017).

The burn severity data products are derived from Landsat Thematic Mapper data. A pre-fire scene and a post-fire scene are analyzed to create a Differenced Normalized Burn Ratio (dNBR) image. The dNBR image portrays the variations of burn severity within the fire.

The Landsat images are terrain corrected and geometrically rectified to an Albers Conical Equal Area map projection using the National Landsat Archive Production System (NLAPS). The images are further processed to convert bands 1-5 and 7 to at-satellite-reflectance. The Normalized Burn Ratio (NBR) is computed for each date of imagery using the following formula:

((Band 4 - Band 7) / (Band 4 + Band 7)) x 1000 = NBR

The differenced NBR is computed by subtracting the post-fire NBR from the pre-fire NBR:

PreNBR - PostNBR = dNBR

Higher dNBR values are correlated with more severe burns (Allen and Sorbel 2008). Values further away from zero represent greater change as a result of both first and second order fire effects (within the fire perimeter). Negative values indicate a positive vegetation response (growth) and positive values indicate a negative vegetation response (mortality). The dNBR image is evaluated to determine the threshold value between burned and unburned areas. The perimeter of the fire is delineated using the dNBR and/or post-fire reflectance image. The dNBR image, the pre-fire and post-fire TM images, a fire perimeter vector file, thematic burn severity depicting burn severity in classes, and masks of areas not processed are provided in digital format.

There are two main types of burn severity assessments that can be produced: initial assessments or extended assessments (Key and Benson 2006). For initial assessments post-fire satellite data are

typically acquired at the first opportunity after fire to capitalize on the maximum post-fire data signal; typically in biophysical settings where post-fire vegetation response is rapid. For extended assessments post-fire satellite data are typically acquired during the growing season following a fire in order to include delayed first order effects and dominant second order effects. Generally in tundra fires, the initial assessment values will be higher than the extended assessment, due to the rapid post-fire regeneration of vegetation within a year of the fire (Allen and Sorbel 2008). In some cases single scene assessments (SS) are produced. A single scene (SS) assessment uses only the post-fire satellite data if appropriately matching pre-fire satellite data is not available. The single scene assessments provide the NBR rather than dNBR, the raw pixel values of NBR are not comparable to the initial or extended assessment dNBR.

MTBS also provides burn severity threshold classifications depicting severity as: 1) unburned to low, 2) low severity, 3) moderate severity, 4) high severity, and 5) increased greenness. In addition a mask for clouds, shadows and large bodies of water are depicted as non-processed area masks. The threshold classifications are provided in a map with summary table of acres by each classification for each fire. The threshold classifications are determined by analysts for each individual fire and the type of assessment is considered in the threshold classifications. For instance the threshold for high severity in an initial assessment might have a value of 850 (example from Uvgoon Creek 1 fire), while a high severity threshold for an extended assessment might have a value of 510 (example from Cottonwood Bar fire).

Burn Severity Data Acquisition

Burn severity data is acquired from the MTBS website (https://mtbs.gov/) through the MTBS Data Interactive Viewer and Direct Download tools. The Interactive Viewer allows one to search and download data by using a bounding box and filter by region, area, year, and fire type. Direct Data Download provides download options for individual fire data bundles, annual state and national-level burn severity mosaics or national shapefiles for burned area boundaries and fire occurrences.

Burn severity data produced by MTBS will be downloaded from the MTBS data source website annually for all fires that occur on NPS lands as described in SOP 2.1. The data will be stored on an external hard drive and on the O drive (dependent on space) and organized by park unit/year/fire name.

The original format of the MTBS dNBR maps are the complete satellite scene size that fit the fire area. The data is not clipped to the fire perimeter extent (see Figure 13). In order to analyze the data sets, the dNBR maps need to be clipped to the extent of the fire perimeter and masked for areas of clouds or scan lines when Landsat 7 imagery is used. Data processing will occur each year that fires are mapped as described in SOP 2.2.

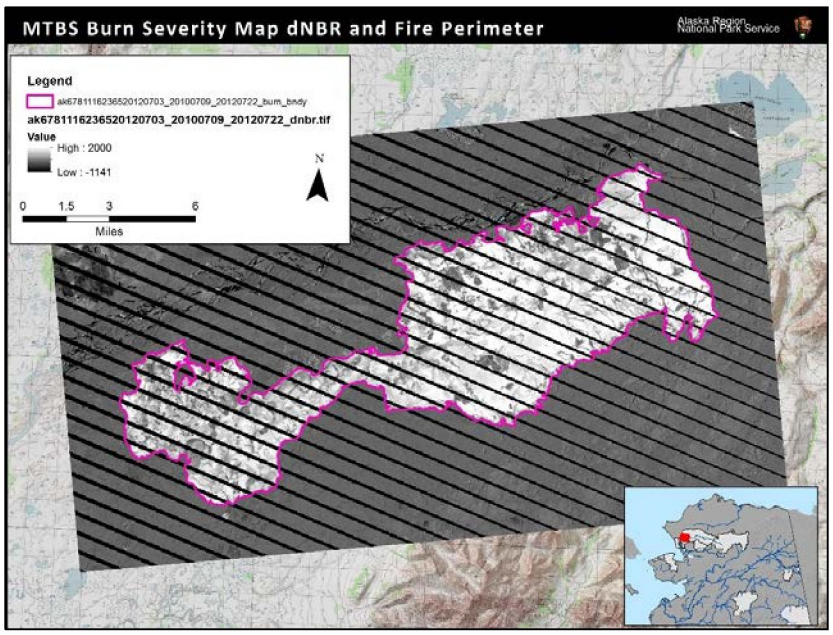


Figure 13. Example of burn severity dNBR map provided by MTBS. For analysis and display purposes, the fire area would be clipped to the fire perimeter and masked for clouds etc.

Burn Severity Field Assessment (CBI)

Field Season Preparations (SOP 2.4)

As part of the fire monitoring program, the remotely sensed burn severity maps would be assessed periodically with ground-truth CBI plots to calibrate the satellite based burn severity maps with field data. Burn severity ground assessments need to occur 1-2 years after the fire. MTBS generally produces burn severity maps 18 months to 2 years after the fire occurred. Therefore it is necessary to request burn severity maps ahead of regular production through MTBS in order to complete ground assessments. The USGS EROS representative at MTBS can be contacted and a request for burn severity maps can be made (SOP 2.4).

Approximately 40-50 burn severity plots should be established for each fire assessment (Key and Benson 2006). Methodologies have been developed to select a representative number of plots in a range of burn severity classes (Key and Benson 2006). These methods are described in SOP 2.4. GPS coordinates of selected plot locations will be uploaded to GPS units and field maps will be created for aircraft and foot navigation.

Compliance and sampling permits will be submitted during the winter prior to the field season. Access frequently involves helicopter transportation due to the remote sites. Task orders for flights and project aviation safety plans will be completed 4 weeks prior to fieldwork. Backcountry plans will be submitted 1 week prior to fieldwork.

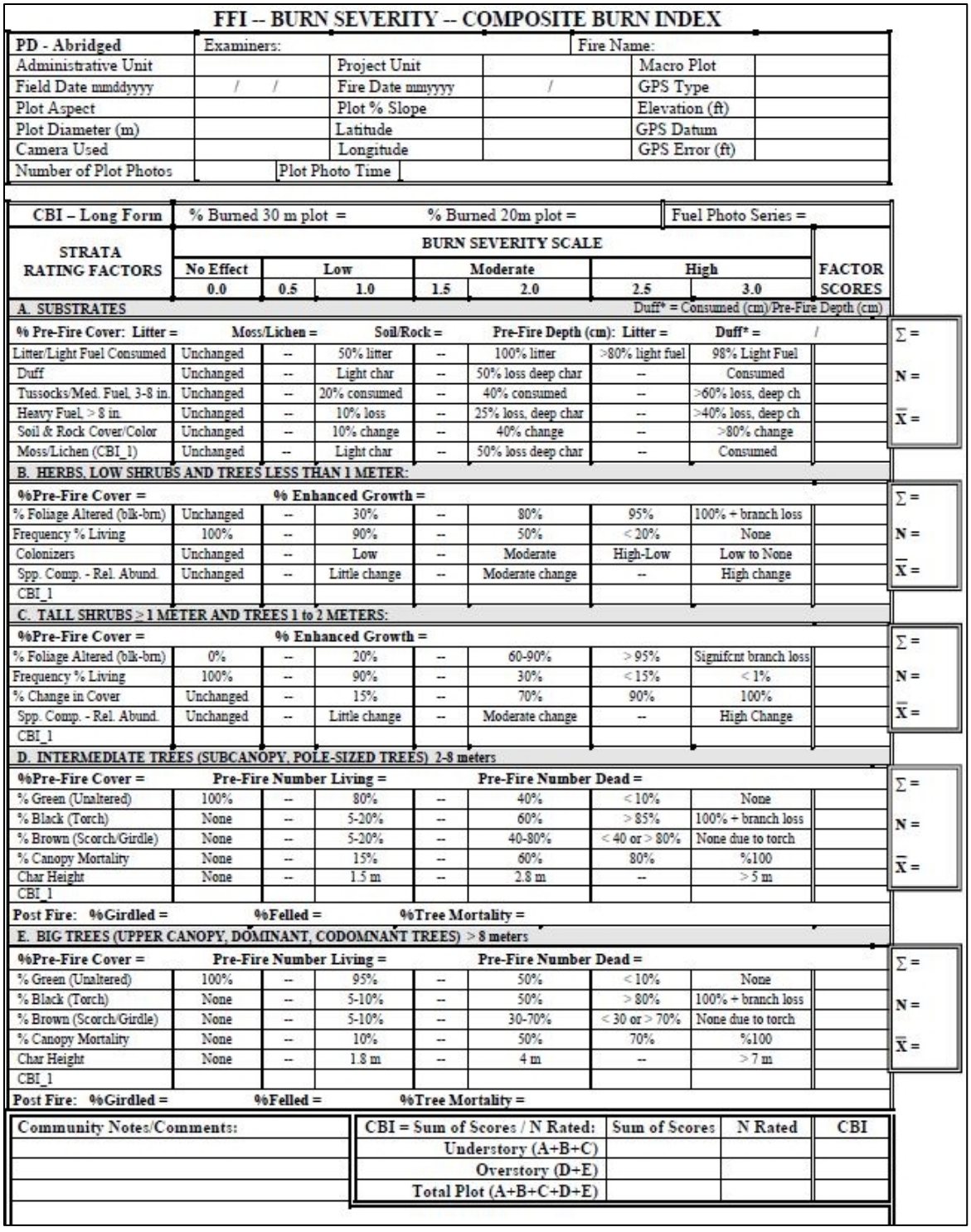
Field methods (SOP 2.5)

Composite Burn Index (CBI) plot methods were developed to field validate the accuracy and applicability of mapping burn severity with remotely sensed data (Key and Benson 2004). The plots

are 30 meter diameter circular plots. The burn severity of a plot is assessed by scoring the degree of change from the pre-burn state for a subset of variables within five vegetation/substrate strata, as shown in Figure 14. A score ranging from 0.0 to 3.0 is recorded for each variable, where 0 indicates unburned and 3 indicates the highest burn severity (i.e., the component has either been completely consumed or radically changed by fire). As an example, crews categorize the change caused by fire to the duff layer with possible options being: unchanged (0); light char (1); 50% loss with deep char (2); or consumed (3). In all, up to 22 severity scores are recorded for a variety of variables including: soil cover/color change, duff and litter consumption, % of colonizers, % of foliage altered, and % canopy mortality. These scores are then averaged to yield CBI ratings for the understory, overstory, and the total plot. The overall CBI plot score is compared with the satellite measure of severity at that location to determine the degree of correlation, and to help determine thresholds for levels of burn severity (SOP 2.7).

Physical attributes recorded at each plot include slope, aspect, elevation, topographic position, and disturbance regime. At each plot, photographs are taken in cardinal directions from the center point of the plot. GPS locations of the plot center are recorded.

Both pre- and post-fire ocular vegetation and ground cover estimates are made for the plot area utilizing a form as shown in Figure 15. Average height of trees and shrubs are recorded by species. For more quantitative method of vegetation and ground cover, a thirty meter transect can be set up for point intercept methods. Along the 30-m transect, the point intercept method will be used to determine plant and ground cover. Every 50 cm along the 30-m transect, all plant species and types of surface cover (e.g. mosses, lichens, substrate) intercepted at that point are recorded.



FFI -- BURN SEVERITY -- COMPOSITE BURN INDEX

PD - Abridged	Examiners:			Fire Name:	
Administrative Unit		Project Unit		Macro Plot	
Field Date mmddyyyy	/ /	Fire Date mmyyyy	/	GPS Type	
Plot Aspect		Plot % Slope		Elevation (ft)	
Plot Diameter (m)		Latitude		GPS Datum	
Camera Used		Longitude		GPS Error (ft)	
Number of Plot Photos		Plot Photo Time			

CBI – Long Form	% Burned 30 m plot =	% Burned 20m plot =	Fuel Photo Series =

STRATA RATING FACTORS	BURN SEVERITY SCALE							FACTOR SCORES
	No Effect	Low		Moderate		High		
	0.0	0.5	1.0	1.5	2.0	2.5	3.0	
A. SUBSTRATES							Duff* = Consumed (cm)/Pre-Fire Depth (cm)	
% Pre-Fire Cover: Litter =	**Moss/Lichen =**		**Soil/Rock =**		**Pre-Fire Depth (cm): Litter =**	**Duff* =**	/	
Litter/Light Fuel Consumed	Unchanged	--	50% litter	--	100% litter	>80% light fuel	98% Light Fuel	
Duff	Unchanged	--	Light char	--	50% loss deep char	--	Consumed	
Tussocks/Med. Fuel, 3-8 in.	Unchanged	--	20% consumed	--	40% consumed	--	>60% loss, deep ch	
Heavy Fuel, > 8 in.	Unchanged	--	10% loss	--	25% loss, deep char	--	>40% loss, deep ch	
Soil & Rock Cover/Color	Unchanged	--	10% change	--	40% change	--	>80% change	
Moss/Lichen (CBI_1)	Unchanged	--	Light char	--	50% loss deep char	--	Consumed	
B. HERBS, LOW SHRUBS AND TREES LESS THAN 1 METER:								
%Pre-Fire Cover =	**% Enhanced Growth =**							
% Foliage Altered (blk-brn)	Unchanged	--	30%	--	80%	95%	100% + branch loss	
Frequency % Living	100%	--	90%	--	50%	< 20%	None	
Colonizers	Unchanged	--	Low	--	Moderate	High-Low	Low to None	
Spp. Comp. - Rel. Abund.	Unchanged	--	Little change	--	Moderate change	--	High change	
CBI_1								
C. TALL SHRUBS > 1 METER AND TREES 1 to 2 METERS:								
%Pre-Fire Cover =	**% Enhanced Growth =**							
% Foliage Altered (blk-brn)	0%	--	20%	--	60-90%	> 95%	Signifcnt branch loss	
Frequency % Living	100%	--	90%	--	30%	< 15%	< 1%	
% Change in Cover	Unchanged	--	15%	--	70%	90%	100%	
Spp. Comp. - Rel. Abund.	Unchanged	--	Little change	--	Moderate change	--	High Change	
CBI_1								
D. INTERMEDIATE TREES (SUBCANOPY, POLE-SIZED TREES) 2-8 meters								
%Pre-Fire Cover =	**Pre-Fire Number Living =**				**Pre-Fire Number Dead =**			
% Green (Unaltered)	100%	--	80%	--	40%	< 10%	None	
% Black (Torch)	None	--	5-20%	--	60%	> 85%	100% + branch loss	
% Brown (Scorch/Girdle)	None	--	5-20%	--	40-80%	< 40 or > 80%	None due to torch	
% Canopy Mortality	None	--	15%	--	60%	80%	%100	
Char Height	None	--	1.5 m	--	2.8 m	--	> 5 m	
CBI_1								
Post Fire: %Girdled =	**%Felled =**		**%Tree Mortality =**					
E. BIG TREES (UPPER CANOPY, DOMINANT, CODOMNANT TREES) > 8 meters								
%Pre-Fire Cover =	**Pre-Fire Number Living =**				**Pre-Fire Number Dead =**			
% Green (Unaltered)	100%	--	95%	--	50%	< 10%	None	
% Black (Torch)	None	--	5-10%	--	50%	> 80%	100% + branch loss	
% Brown (Scorch/Girdle)	None	--	5-10%	--	30-70%	< 30 or > 70%	None due to torch	
% Canopy Mortality	None	--	10%	--	50%	70%	%100	
Char Height	None	--	1.8 m	--	4 m	--	> 7 m	
CBI_1								
Post Fire: %Girdled =	**%Felled =**		**%Tree Mortality =**					

Community Notes/Comments:	CBI = Sum of Scores / N Rated:	Sum of Scores	N Rated	CBI
	Understory (A+B+C)			
	Overstory (D+E)			
	Total Plot (A+B+C+D+E)			

Figure 14. Example Composite Burn Index (CBI) field form to assess burn severity.

General Vegetation Information

Park Unit: _____ **Project:** _____ **Plot ID:** _____ **Pre or Post** ____ yrs
Field Date: _____ **Field Crew:** _____ **Plot Dimensions**: _____

Record plant status (superscript): **D** (dead), **C** (charred), **S** (scorched). Also record if collected (* next to spp. code) or trace (t = trace) <1% cover. If tree density and tree measurements not recorded at plot, then record average ladder fuel height and DBH for tree species. If a single species forms two or more distinct sub-layers or a substantial proportion of species is burned or damaged then, list on separate rows (e.g. PIGL-sapling, PIGL-overstory, PIGL-scorched). If estimating pre-fire cover, record estimated value.

Species	Common Name			Cover Class											
Tree Layer		Avg. DBH (cm)	Avg. Ladder Fuel Hgt (cm)	Pre-Fire Cover	1-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%	Avg. Height (m)
PIGL	White spruce														
PIMA	Black spruce														
POTR5	Aspen														
BEPA	Paper birch														
POBA2	Balsam poplar														
LALA	Larch														
Shrub Layer	Common Name	Seedling	Resprout	Pre-Fire Cover	1-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%	Avg. Height (m)
ALVIC	Green alder														
SALIX	Unknown willow														
SAGL	Glaucous willow														
SAPU15	Diamond Leaf willow														
SABE2	Bebb willow														
BENA	Dwarf birch														
BEGL	Tall shrub birch														
DAFL3	Shrubby cinquefoil														
LEPA11	Labrador tea														
CHCA2	Leatherleaf														
SHCA	Soapberry														
ROAC	Prickly Rose														
VAUL	Blueberry														
VAVI	Lowbush cranberry														
EMNI	Crowberry														
ARRU	Bearberry														
RUCH	Cloudberry														
COCA13	Dwarf dogwood														
LIBO3	Twinflower														
Herbs & Graminoids	Common Name	Seedling	Resprout	Pre-Fire Cover	1-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%	
EQUIS	Unknown Horsetail														
EPAN2	Fireweed														
GELI2	Pumpkinberry														
CABI5	Bigelow's sedge														
CAREX	Unknown carex														
CACA4	Bluejoint grass														
GRASS	Unknown Grass														
ERVA4	Tussock grass														
Non-vascular	Common Name			Pre-Fire Cover	1-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%	
MOSS*	Unidentified moss														
SPHAG2	Sphagnum moss														
FMOSS	Unknown feather moss														
HYSP70	Stair-step moss														
PLSC70	Big red stem moss														
CEPU12	Ceratadon moss														
POJU70	Common juniper moss														
AULAC2	Unk. Aulacomnium moss														
MAPO12	Marchantia liverwort														
CLADI3	Cladina unknown														
CLADO3	Cladonia unknown														
LICHEN*	Unknown lichen														
PEAP60	Freckle pelt lichen														
Ground Cover	Common Name			Pre-Fire Cover	1-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%	
LTRNDL	Needle Litter														
LTRH	Leaf Litter														
DUFF	Duff														
1Hr	0 to 0.25 inch														
10Hr	0.25 to 1 inch														
100Hr	1 to 3 inches														
1000Hr	> 3 inches														
DM	Dead Moss														
UD	Upper Duff														
LD	Lower Duff														
MIN	Mineral Soil														
W	Water														
ROCK	Rocks														

Figure 15. Ocular vegetation form used to record vegetation and ground cover at burn severity plots.

Data Entry CBI Field Plots (SOP 2.6)

Data from the burn severity plots will be entered into an interagency database called FFI (FEAT/FIREMON Integrated; www.frames.gov/ffi). FFI is a plot-level monitoring software tool that provides data entry, storage and summary report tools. Data is stored in a Microsoft SQL Server database (Lutes et al. 2015). Details of data entry and verification are in SOP 2.6.

3.3. Data Analysis and Reporting

The following sections provide information on the data summaries, analyses and reporting for fire burn severity vital sign. The details of data management are provided in a combined chapter for data management for fire extent, burn severity and fire effects monitoring in Chapter 5 Data Management.

Routine Data Summaries

For each fire a set of summaries and statistics will be produced from the burn severity datasets. Utilizing the threshold burn severity maps for the fire areas, the amount of area classified by burn severity level will be summarized and entered into a data table. The percent of the fire area mapped as moderate and high severity will be calculated for each fire. The following statistics will be generated for each fire from the clipped and masked dNBR burn severity maps (SOP 2.2): average dNBR, standard deviation, minimum and maximum raster values.

A preliminary comparison of the average dNBR values in comparison to the percent of area by fire mapped as moderate and high severity, indicate a strong correlation of the mean dNBR value to the percent area mapped as moderate or high severity based on the MTBS severity threshold classifications, as shown in Figure 16. These graphs also show the differences in dNBR values between initial versus extended assessments in tundra ecosystems.

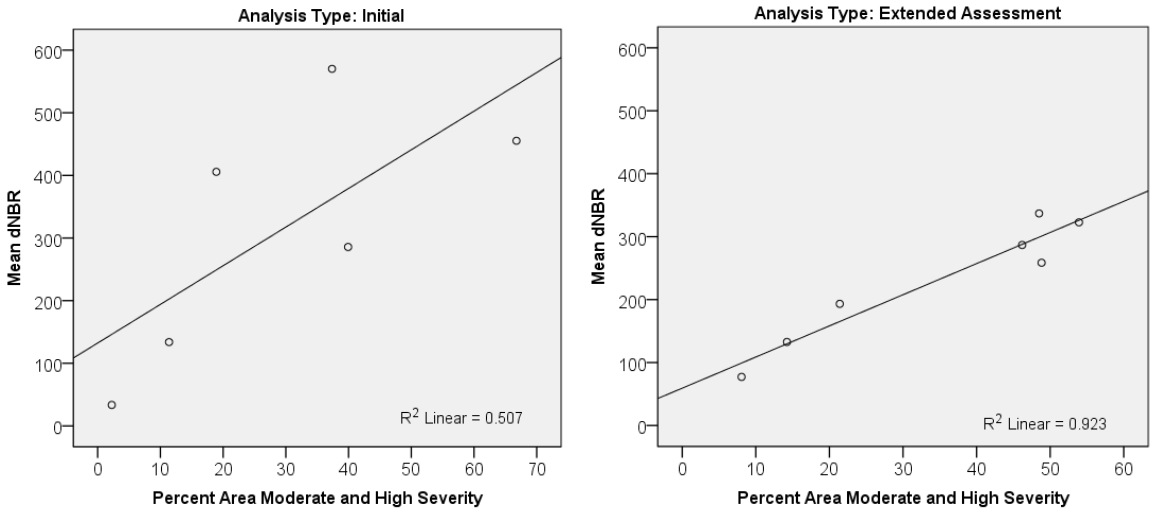


Figure 16. Preliminary data comparing average dNBR values by fire to percent area mapped as moderate and high severity. Graphs are shown by assessment type (Initial and Extended).

Reporting Schedule

Burn severity data will be reported in two formats – annual reports when burn severity field data are collected and a 10-year summary report for remotely sensed burn severity data. If burn severity ground plots are completed then the results will be reported in the Fire Ecology Annual report. A more detailed 10-year monitoring report will be completed to summarize data and identify any trends in burn severity for ARCN parks. The expected reporting schedule is shown in Table 8. Additional details on the types of tables and graphics that would be included in this report are provided below.

Table 8. Recommended reporting schedule for fire extent and frequency data.

Report	Report Type	Schedule	Primary Responsibility
Fire Ecology Annual Report	NRDS	May Annually (if ground based data are collected)	Fire PI (Regional Fire Ecologist)
Burn Severity 10 Year Trend Report	NRR	Every 10 years	Fire PI (Regional Fire Ecologist)

Report Format with Examples of Summary Tables and Figures

Annual reports will be formatted using the NPS Natural Resource Data Series format and the 10-year summary reports will be formatted using the NPS Natural Resource Report format (http://www.nature.nps.gov/publications/nrpm/).

Burn severity maps can be displayed as shown in Figure 17 for individual fires. In the case of multiple fires during a year, the data can be presented graphically as in Figure 18 and in a table format of area burned by severity classification (Table 9). Ground based burn severity plot data (CBI values) can be compared to satellite severity dNBR values using linear regressions (Figure 19) as described in SOP 2.7. Data from the field based severity measures can be used to adjust the threshold values for burn severity classifications. For example the data from the fire assessed in Figure 19 was used to set the burn severity classifications in Figure 17.

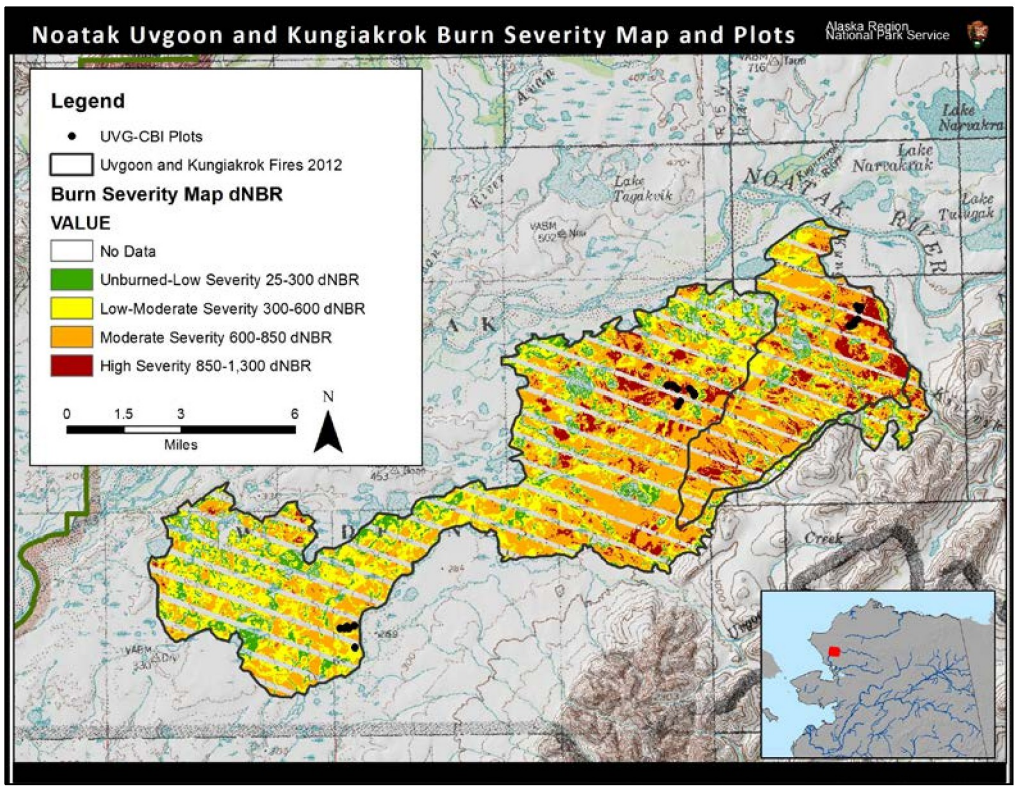


Figure 17. Map of remote sensed burn severity data categorized by burn severity classifications.

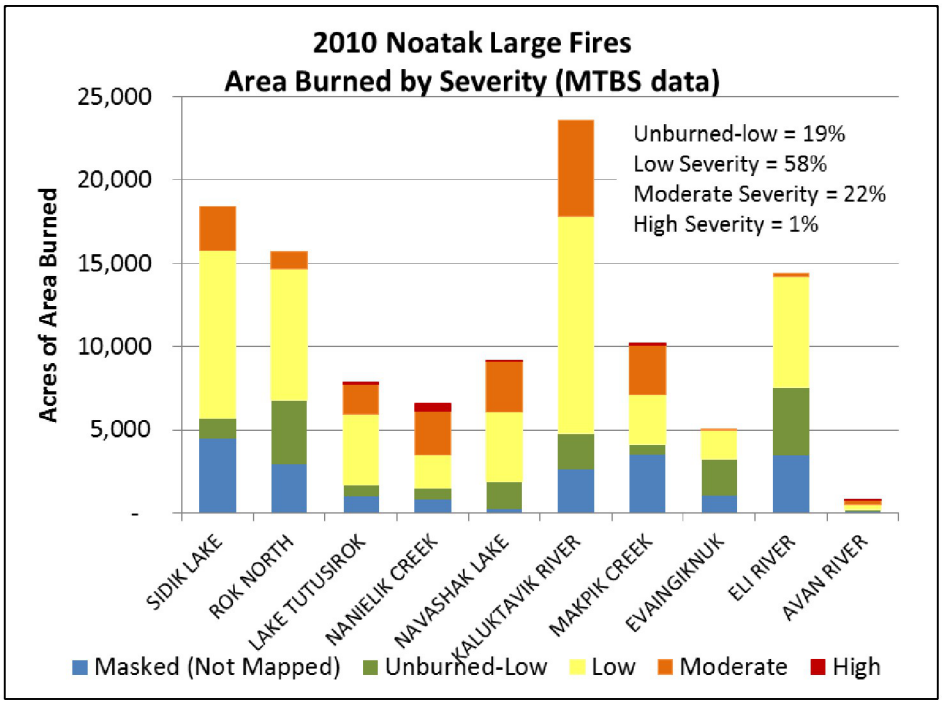


Figure 18. Example graph of the area burned by dNBR threshold burn severity classes provided by MTBS for individual fires in Noatak during 2010.

Table 9. Example of area burned by burn severity classification from MTBS threshold data for fires.

Year / Name	Unit	Unburned to Low Severity	Low Severity	Moderate Severity	High Severity	Increased Greenness	Nodata/ Non-Processing Mask
1986 / Eureka	Ac	2,730	9,212	4,178	15,213	228	1,044
	Ha	1,105	3,728	1,691	6,156	92	422
	% composition	8.4	28.3	12.8	46.7	0.7	3.2
1991 / 132339	Ac	8,414	14,188	10,649	1,235	1,225	891
	Ha	3,405	5,742	4,309	500	496	361
	% composition	23.0	38.8	29.1	3.4	3.3	2.4
1993 / CEMSE34	Ac	4,075	4,002	7,009	4,950	10	240
	Ha	1,649	1,620	2,837	2,003	4	97
	% composition	20.1	19.7	34.6	24.4	0.1	1.2
1999 / Witch	Ac	9,316	14,174	9,158	15,044	NA	134
	Ha	3,770	5,736	3,706	6,088	NA	54
	% composition	19.5	29.6	19.1	31.5	NA	0.3

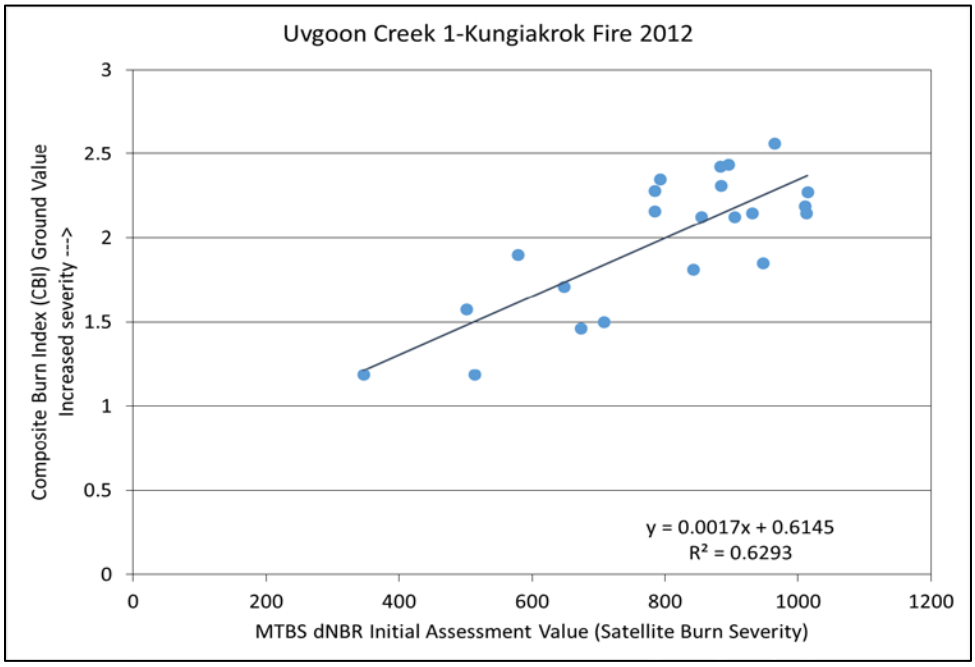


Figure 19. Ground-based CBI burn severity plots compared to remote sensed burn severity values (dNBR) for a fire sampled in Noatak. Regression analysis indicates good agreement between ground-based severity and satellite measures of severity for the same location.

Methods for Long-term Trend Analysis

The remotely sensed data will be summarized to provide a set of fire statistics to assess the trends in burn severity. The primary data used will be the percent of area by fire with moderate or high

severity. The average dNBR value may be used to detect trends, but based on preliminary data analyses, the satellite assessment types (initial, extended and single scene) should not be mixed. However, separating the assessment types reduces the number of data points.

Data from past and future fire years will be analyzed to detect changes in percent area burned in moderate or high severity classifications. Due to the non-normal distribution of data (high variability), non-parametric statistics will likely be utilized to detect changes with a P-value set at 0.10. Currently the data summarized for Noatak shows a high degree of variability among years and even within a single year (Figure 20). For example in 2010 nine fires were mapped by MTBS and the percent of area burned with moderate-high severity ranged from 1.8% to 54%. With the current natural range of burn severity a trend may be difficult to detect. However utilizing mock data for the next decade with increased area of burn severity, there is an ability to detect a significant change in burn severity (Figure 21). In this example, data is organized by decade and analyzed using non-parametric independent sample tests showed a significant difference in the medians across decade groups. In consultation with a biometrician/statistician, every 5-10 years exploratory analyses will be used to identify whether longer term trend analyses are appropriate, and if so, which techniques are most robust based on the data at hand.

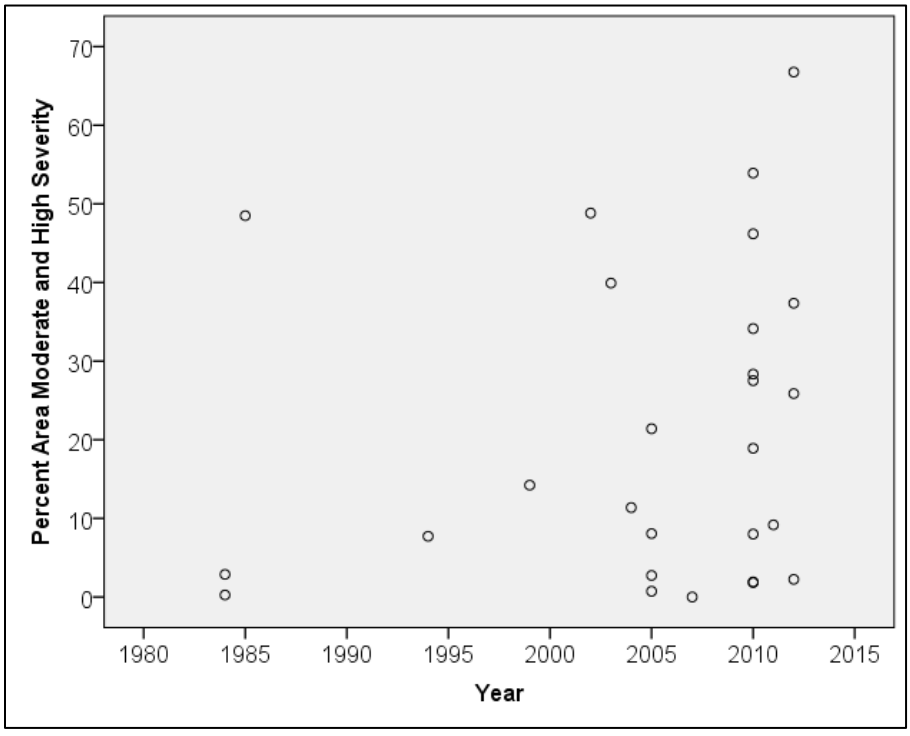


Figure 20. Graph of the percent of area with moderate to high burn severity for individual fires from Noatak shown by year.

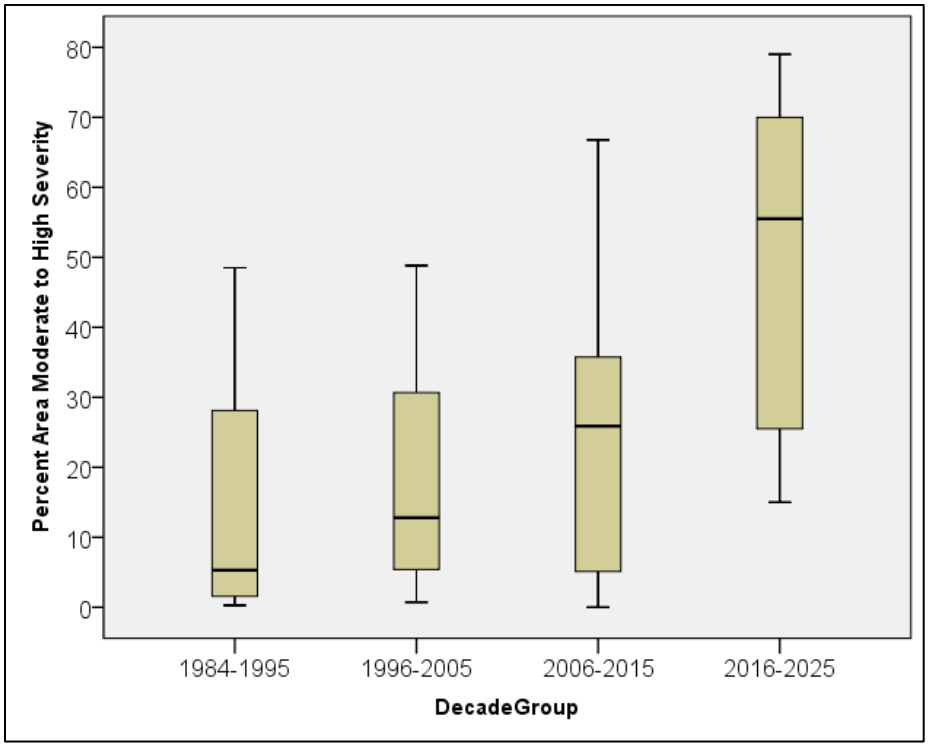


Figure 21. Example of boxplots by decade for percent of area burned in moderate to high severity for Noatak. The data shown for **2016-2025 are mock data** to show how a trend could be detected with an increase in percent area.

3.4. Operational Requirements

Personnel Requirements and Training

The MTBS burn severity data acquisition and download can be accomplished by a technician or assistant by following the SOP 2.1 instructions. The GIS extraction and analysis would be best performed by the principle investigator (Regional Fire Ecologist) or a person with knowledge of the GIS skills required for the work (GS-9 Assistant Fire Ecologist).

For the burn severity field data collection, the PI (a NPS employee GS-9, -11, or -12) would be responsible for planning and organizing field logistics, field sampling, and post-season database management. The PI provides training on the sampling routine and, as necessary, burn severity methods and plant identification.

The burn severity field data collection is best accomplished with 2 crews of 2 people. Each crew would have a field lead, familiar with the burn severity rating methods and local flora in Alaska, and a second crew member that can be trained in burn severity methods and data collection. One crew member should also be qualified as a project helicopter manager when access by helicopter is required. All crew members need to complete routine safety training common to all NPS field employees (bear safety and shotgun certification, basic aviation safety, first aid, CPR, and safety check-in procedures of the NPS units involved).

Data entry into the FFI database would be accomplished by the assistant fire ecologist or technicians if hired. Quality control and data verification would be completed by the regional fire ecologist and assistant. The principle investigator or a GS-9 term or permanent employee, under the supervision of the PI, will analyze the data and prepare reports on the burn severity statistics.

Annual Workload and Data Acquisition

Data entry during the late fall after the fire season. The GIS data layers are generally not finalized until April. The PI or assistant will spend about 1 month in midwinter preparing datasets and 1 month in the spring preparing graphs and reports. Table 10 provides an overview of annual tasks, responsibilities, and expected schedule for the burn severity data.

Table 10. Workload tasks and responsible personnel for burn severity remote sensed data.

Data Set	Tasks	Responsible Personnel	Schedule (dependent on data availability)
Remote Sensed Burn Severity Data*	Acquire burn severity data from MTBS site (SOP 2.1)	Assistant Fire Ecologist	October and April
	Process new burn severity maps and update data tables (SOP 2.2)	Assistant Fire Ecologist or PI (Fire Ecologist)	November
	Analyze datasets (SOP 2.3)	PI (Fire Ecologist)	January
	Write 10 Year Burn Severity Trend Report (SOP 2.3)	PI (Fire Ecologist)	February every 10 years
	Data archiving (SOP 2.8)	PI (Fire Ecologist)	April
Burn Severity Field Assessment**	Request burn severity products from MTBS for focal fire or fires (SOP 2.4)	PI (Fire Ecologist)	November
	Select plot locations (SOP 2.4)	PI (Fire Ecologist)	April
	Prepare compliance documents for fieldwork and prepare aircraft acquisition paperwork (SOP 2.4)	PI or Assistant	February
	Fieldwork – burn severity plots (SOP 2.5)	Field crew, PI	Late June to Early August
	CBI and plot data entry, photo labeling, GPS processing (SOP 2.6)	Technician or Assistant Fire Ecologist	September or October
	Data analyses and summaries (SOP 2.7)	Assistant Fire Ecologist or PI (Fire Ecologist)	January
	Annual Resource Brief or Report (SOP 2.7)	Assistant Fire Ecologist	May as needed
	Data archiving & Deliverables (SOP 2.8)	PI (Fire Ecologist)	April

* Schedule for data collection and analyses of remote sensed burn severity data will depend on when fires occur and are mapped. **Schedule for burn severity ground assessments is completed only for years that data is collected.

Software and Hardware

Listed below are the primary computer software and equipment needs to meet the goals of this protocol.

- Geographic Information System software package: ArcGIS is the current package used by the NPS
- FFI Database
- Microsoft Office (word processing, spreadsheet preparation, presentations preparation)
- R-stats software or SPSS statistical program
- GPS – Trimbles and Garmin

Budget Considerations

The workload associated with data acquisition, data entry and GIS processing will be approximately two weeks annually. The annual data analysis and report writing will take approximately 3-4 weeks of the PIs time. Currently the regional fire ecologist (GS-11/12) is funded full time by the fire program, but if this workload needs to be completed by the assistant, additional funding may be needed. Annually the burn severity data acquisition would cost approximately $3200 for one pay period of a GS-9 assistant fire ecologist.

The cost of the ground-based field assessments for burn severity are shown in Table 11. These costs would be approximately every 10 years. The costs include estimates for OAS costs for fixed wing and helicopter access to the field sites. The cost of two GS-5 bio-techs working 2 pay periods each and travel costs including commercial airfare to Kotzebue for 4 field personnel. For ground-based severity assessments, the estimated cost in 2018 would be $41,300 every 10 years.

Table 11. Budget, responsible personnel and costs for burn severity field data collection, every 10 years.

Description	Item	Cost/Unit	Number of Units	Estimated Cost in 2018
Fixed-wing flights	Fixed wing flights	$600/hr flight time	10	$6,000
Helicopter	Helicopter flight time availability	$1,350/hr flight time	10	$13,500
Fieldwork	GS-5 Technicians	$1700/Pay Period	4	$6,800
Fieldwork	Overtime	$40/hr	60	$2,400
Travel Costs	4 people to Kotzebue, 8 day field work	$1,500/person	4	$6,000
Data Entry and Analysis	Assistant Fire Ecologist	$3,300/Pay Period	2	$6,600
Annual Report Writing	PI Fire Ecologist	NA	1	$0
Total				**$41,300**

4. Fire Effects Monitoring

4.1. Sampling Design

Rationale for Sampling Design Selection

Numerous vegetation sampling designs have been established within the National Park Service Inventory and Monitoring programs and even within the Alaska Networks (e.g., Roland et al. 2004, Miller et al. 2010, Swanson and Neitlich 2016). The decision between using extensive or intensive sampling; probabilistic sampling schemes (gridded or GRTS - Generalized Random-Tesselation Stratified (Stevens and Olsen 2004) or representative sites; and sampling methods are addressed in these protocols.

As in any vegetation monitoring program, an ideal strategy for sampling fire effects would involve an extensive number of ground-based plots to sample the range of vegetation that has or could be burned. In addition, due to the strong effects of burn severity on vegetation succession and soil impacts, a range of burn severity would also need to be sampled. As addressed in Miller et al. (2010) and Swanson and Neitlich (2016), there are many constraints to ground-based monitoring in Alaska: 1) the costs and risks of accessing remote, roadless areas, 2) potential damage to fragile ecosystems and wilderness values, and 3) the costs of sampling such vast areas and staffing needs.

Due to the constraints listed above, the fire effects ground-based data collection will focus on pre-existing fire effects plots with a history of monitoring (Racine et al. 2004, Racine et al. 2006). The monitoring program would not be limited to solely utilizing these pre-existing plots, in the event that additional funding becomes available in conjunction with the need to gain additional information on fire effects. The establishment of ground-truth burn severity plots as identified in Chapter 3 can provide a framework for future monitoring sites (and have been used in other Alaska park units for monitoring). Likewise, sites that have been established by the ARCN Terrestrial Vegetation Monitoring program (Swanson and Neitlich 2016) may burn over time and will also provide long-term monitoring sites to assess the effects of fire.

<u>Existing Fire Monitoring Plots Overview</u>

There are two sets of fire effects monitoring plots that have been established in the Arctic Network that provide a long-term dataset for the effects of fire. The purpose of these ground-based permanently marked fire effects plots are to detect major changes in structure and composition of vegetation within the representative areas. This includes changes in the cover of vascular plants by species or lifeform, changes in cover of non-vascular plants by selected species or groupings, changes in density of trees and heights of shrubs, and changes in active layer depth over time. A brief description of the history and methods utilized at these plots are provided below.

Dr. Charles Racine and colleagues established a series of tundra post-fire vegetation and permafrost monitoring sites within two of the Arctic Network parks - Bering Land Bridge (Racine et. al. 2004) and Noatak (Racine et al. 2006) during the late 1970s and early 1980s. These sites have been monitored several times over the past 40 years and provide the longest set of monitoring data for tundra fire effects study in Alaska (Racine et al. 2006). The National Park Service has acquired the

data from earlier monitoring measurements and has continued to monitor these sites over the past 12 years.

In 1978 Racine and others established 8 permanently marked plots in a 1977 fire along a topographic gradient on Nimrod Hill, on the east side of Imuruk Lake in Bering Land Bridge. Pre-fire data was available from a 1973 soils and vegetation survey. The Nimrod Hill BELA plots were re-measured in 1979, 1981, 1983, 2001, and 2002 (Racine et al. 2004). As part of the Arctic Network Inventory & Monitoring Program, Racine and NPS fire personnel re-measured the plots in 2009.

Following the study in BELA, the same researchers established tundra fire plots in Noatak NPr (NOAT) during 1981 and 1982. Eight sites were established in areas of varying time since fire, ranging from 2-4 weeks post fire, 4-5 years and 10 years post fire (1972, 1977 and 1982 fires). These sites were not re-measured again until 2005. As part of the Arctic Network Inventory & Monitoring Program, Racine and NPS personnel relocated and re-measured the Noatak fire plots in 2005 (Racine et al. 2006). These plots were monitored again in 2017 by ARCN and NPS fire staff.

For both study areas, ten 1-m x 1-m quadrats were sampled per plot. Data collected within the quadrats include: ocular estimates of vascular and non-vascular species cover, maximum height and stem density estimates of selected shrubs, tree density, active layer depth measurements, site descriptions (soil samples in 1981-82), and photographs.

The use of pre-existing monitoring sites precludes many of the sampling design parameters addressed in the NPS I&M protocols, such as site selection, procedures for selecting sampling locations, spatial design and number of plots. The use of legacy plots and constraints of the sampling design will limit the applicability of the data beyond the sites being monitored. However the plots will provide long-term fire effects monitoring at representative tundra sites in two parks.

Site Locations and Sample Size

Noatak Racine Sites

Eight fire monitoring plots were located near the confluence of Noatak and Kugururok Rivers (Figure 22) in Noatak National Preserve. The vegetation in the study area is generally dominated by tussock-shrub tundra, birch-ericaceous shrub tundra or willow shrub types. The area is at the upriver limit of spruce along the Noatak, however scattered patches of spruce and alder are present in the area. Both spruce and alder appear to have expanded in this area during the past 50 years (Suarez et al. 1999 and Sturm, Racine and Tape 2001). The plots vary in the time since fire and pre-fire vegetation type, and some plots have burned again since the initial establishment of the plots (see Table 12). Four of the 8 plots were established in a 1977 fire, two other sites burned different years (1972 and 1982), two sites were established as control plots and one of the control plots burned in 2012. A majority of the plots (5 of 8) are classified as tussock-low shrub tundra which is the most dominant vegetation type in ARCN (Table 2 120: Dwarf Birch-Tussock Shrub). The 3 Noatak River sites have more diverse pre-fire vegetation due to the influence of the Noatak river floodplain and are quite distinct in terms of soils and vegetation from the other more typical tussock-shrub tundra sites.

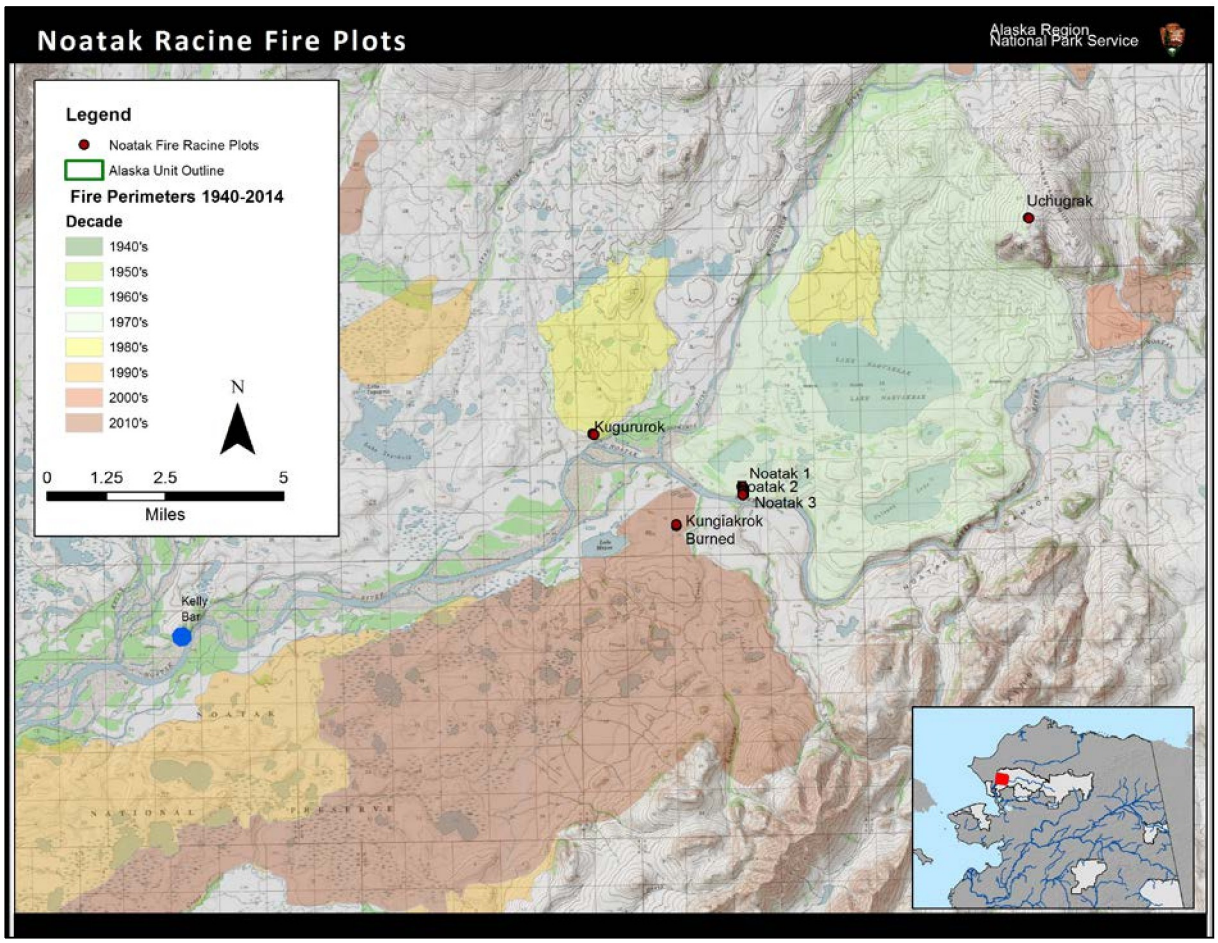


Figure 22. Location of 8 fire effects plots in Noatak National Preserve and the fire history between 1940-2015 in the area. Note that Kungiakrok and Uchugrak sites have two plots each.

Table 12. List of Racine fire effect plots in Noatak National Preserve, estimated pre-fire vegetation types, fire years and estimated burn severity for each plot.

Site Name	Plot ID	Pre-fire Vegetation	Fire Year(s)	Burn Severity
Kugururok	KUG-B	Tussock-Low Shrub Tundra	1972 and 1984	Moderate/Uknown
Kungiakrok Burned	KNG-B	Tussock-Low Shrub Tundra	1982 and 2012	Moderate/Moderate
Kungiakrok Unburned	KNG-U	Tussock-Low Shrub Tundra	Unburned, 2012	Unburned/Moderate
Noatak 1	NOAT1	Shrub tundra	1977	Moderate-High
Noatak 2	NOAT2	Low centered polygons	1977	Low
Noatak 3	NOAT3	Willow-Sedge	1977	Low
Uchugrak Burned	UCH-B	Tussock-Low Shrub Tundra	1977	Moderate
Uchugrak Unburned	UCH-U	Tussock-Low Shrub Tundra	Unburned	Unburned

Bering Land Bridge Racine Sites

In Bering Land Bridge on the Seward Peninsula eight fire effects monitoring plots were established where a portion of a large 1977 tundra fire burned hillslope (Nimrod Hill) off Imuruk Lake

(Figure 23 and Table 13). Vegetation was sampled before the fire in 1973 and the plots were established one year after the fire in 1978 (Racine et al. 2004). Pre-fire vegetation and soils along this slope ranged from moist tussock-shrub tundra on the lower slopes to dwarf shrub tundra on the steeper upper-slope (12%) and wet sedge meadow on the ridgetop. At each sample site two stakes were placed 10 m apart oriented in a magnetic N-S direction roughly parallel to the slope contours. Between the 10-m stakes, ten 1-m x 1-m quadrats were sampled on the downslope side of the line between the stakes starting at the south end.

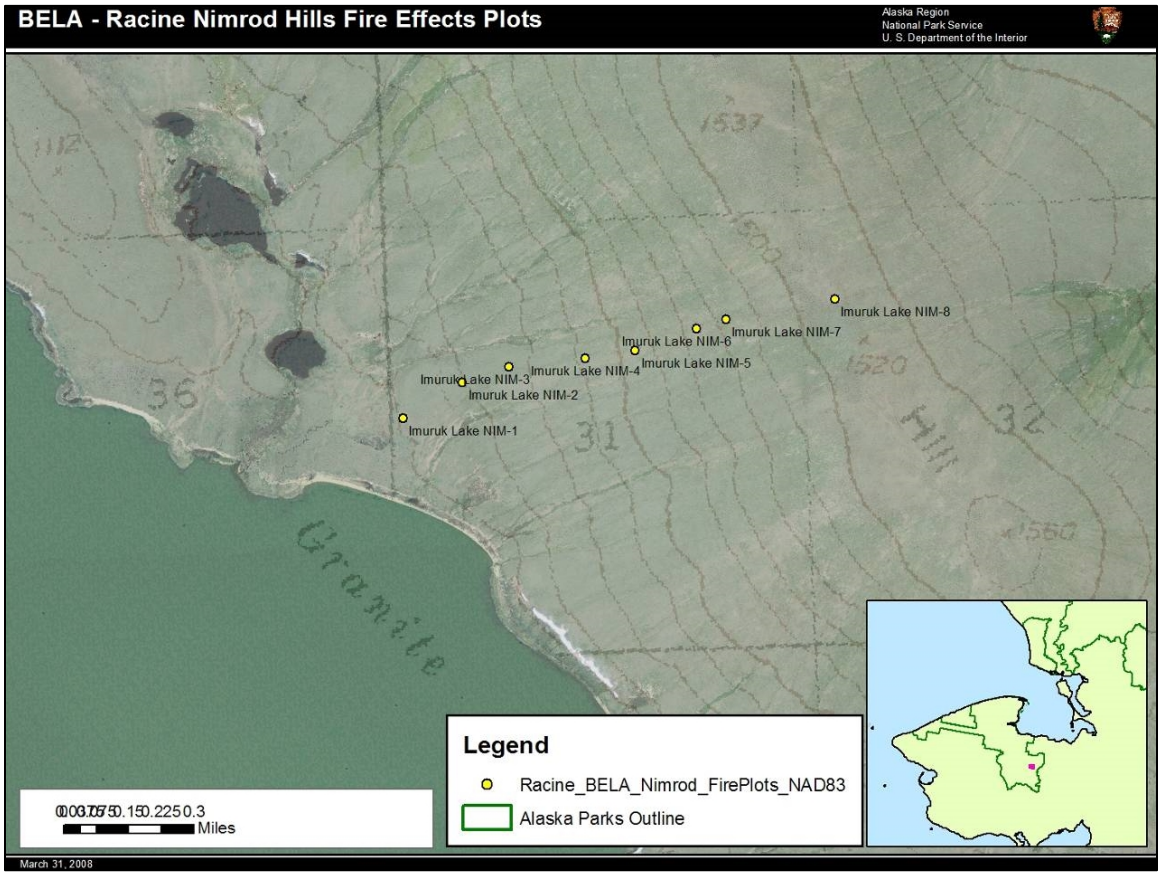


Figure 23. Location of 8 fire effects plots from the 1977 Kuguruk Hi Fire (BLM Fire #8623) in Bering Land Bridge.

Table 13. List of Racine fire effect plots in Bering Land Bridge National Preserve, estimated pre-fire vegetation types, fire year, and estimated burn severity for each plot.

Plot ID	Pre-fire Vegetation	Fire Year	Burn Severity
BELA-NIM-1	Tussock-Low Shrub Tundra	1977	Unknown
BELA-NIM-2	Tussock-Low Shrub Tundra	1977	Moderate-High?
BELA-NIM-3	Tussock-Low Shrub Tundra	1977	Moderate
BELA-NIM-4	Tussock-Low Shrub Tundra	1977	Moderate
BELA-NIM-5	Tussock-Low Shrub Tundra	1977	Moderate?
BELA- NIM-6	Dwarf Shrub Tundra	1977	High
BELA-NIM-7	Dwarf Shrub Tundra	1977	High
BELA-NIM-8	Wet Sedge	1977	Mod-High

Sampling Frequency and Replication

Vegetation change in the arctic is generally slow, although can be accelerated by disturbances such as fire or significant warming. Following the guidelines for the ARCN Terrestrial Vegetation monitoring program (Swanson and Neitlich 2016) and discussions with technical committee members, a sample return interval of 10 to 15 years, would provide a foundation for detecting major vegetation structure and composition changes. In the event that these plots (or others established) burn again, 1 year post-fire monitoring should be completed to document the severity of the fire and impacts to the soils and surrounding vegetation (see Figure 24). Due to the rapid changes immediately following fire, it would also be recommended to follow up 5 year post fire and then continue to monitor every 10 to 15 years. These sites have previously been sampled in mid to late July, and continued sampling at this time of year will provide consistency for phenology and active layer depth measurements.



Figure 24. Rapid changes in vegetation post-fire are shown at the Kungiakrok unburned plot which burned in 2012. Photos from right to left are 2005 ("pre-fire"), 2013 (1 year post-fire) and 2017 (5 years post-fire).

A majority of the Racine plots (10 of 16) are classified as tussock-low shrub tundra pre-fire (Table 14), which is the most dominant vegetation type in ARCN (Table 2 - 120: Dwarf Birch-Tussock Shrub). The three Noatak River sites have more diverse pre-fire vegetation due to the influence of the Noatak river floodplain and are distinct in terms of soils and vegetation from the

other more typical tussock-shrub tundra sites (Racine et al. 2006). Likewise, three sites from the BELA Nimrod plots were classified as either shrub tundra or wet sedge pre-fire likely due to the soils on the upper portions of the slope (Racine et al. 2004). Only one plot remains as a control "unburned" at the Uchugrak site. With the plots sampled there are 7 replicates of Tussock-Low Shrub tundra with one fire event. Severity would be used as a co-variate at sites for analyses.

Table 14. Number of fire effects plots by fire history and pre-fire vegetation for Noatak and Bering Land Bridge.

General Pre-Fire Vegetation Type	Fire History	Number of plots	Plot IDs
Tussock-Low Shrub Tundra	1977	6	NIM1, NIM2, NIM3, NIM4, NIM5, UCH-B
	2012	1	KNG-U
	Twice Burned	2	KNG-B, KUG-B
	Unburned	1	UCH-U
Shrub Tundra	1977	3	NIM6, NIM7, NOAT1
Low Centered Polygons/ Sedge-Herb	1977	3	NIM8, NOAT2, NOAT3

Level of Change that Can Be Detected

Long-term monitoring will provide vascular and non-vascular cover estimates and active layer depths at these sites after fire. Data that has been collected has been utilized to detect changes in lifeform cover between sample years. A power analysis to calculate sample size to detect changes with an alpha of 0.05 and power at 0.80 was completed utilizing average cover by lifeform from two sample periods for the Noatak sites. The average cover and standard deviation by life form was compared from the 6 burned plots sampled in 2005 and the 1980s (Table 15). The 6 plots used for the analysis combined various pre-fire vegetation classes (Table 12) which adds to the variability of the data. The test also assumed a normal distribution, which is often uncommon for vegetation data. Table 16 shows the number of plots needed to detect change by life form cover based on a power analysis applying a one-sided, paired t-test with significance level of 0.05 to obtain a power of 0.8. The results indicated that the ability to detect changes for deciduous shrub cover was near the plot numbers sampled (6 plots), while detecting significant changes for forbs or sedge cover would require significantly more plots (37 – 138). Data from the Bering Land Bridge sites were not included in this analysis and would provide a more complete look at the sample size adequacy to detect changes.

Table 15. Average and standard deviation of cover by life form for the six burned plots sampled in Noatak by year sampled. Data was utilized to calculate a power analysis for sample size.

Plot Type	Sample Year	Life Form	Average	SD	N Plots
Burned	1981-82	Deciduous Shrub	12.66	7.41	6
Burned	1981-82	Evergreen Shrub	0.9667	1.088	6
Burned	1981-82	Grass	8.07	8.62	6
Burned	1981-82	Sedge	21.27	14.93	6
Burned	1981-82	Forb	5.7	4.01	6
Burned	2005	Deciduous Shrub	33.78	9.94	6
Burned	2005	Evergreen Shrub	11.27	16.65	6
Burned	2005	Grass	0.67	0.65	6
Burned	2005	Sedge	32.49	22.89	6
Burned	2005	Forb	7.12	5.67	6

Table 16. Average and standard deviation of cover by life form for the burned plots sampled in Noatak. Results of the recommended plot number based on a power analysis applying the one-sided, paired t-test with significance level of 0.05 to obtain a power of 0.8.

Life Form	Average	SD	N	Power Analysis Sample Size
Deciduous Shrub	23.22	13.84	12	6
Evergreen Shrub	6.12	12.47	12	19
Grass	4.37	6.99	12	12
Sedge	26.88	19.34	12	37
Forb	6.41	4.74	12	138

Limitations of the Data

The non-probabilistic sampling scheme of the Racine fire effects plots limits the applicability of the results beyond the sites being monitored. However, in conjunction with other monitoring sites in ARCN and in tundra ecosystems it can provide additional data points to examine the trends in fire effects. In addition, these sites best represent lowland tundra ecosystems and the current design does not provide data on the effects of fire in the forested areas of the ARCN parks. Additional monitoring sites would need to be added to adequately sample more vegetation types.

4.2. Field Methods

Field Season Preparations (SOP 3.1)

Project planning and field preparation will begin in late fall/early winter and continue through to the time of actual field sampling the following summer season. Details are provided in SOP 3.1. A general timeline of the major logistical and field preparation tasks are provided in Table 17 (adapted from SOP 3.1). Project planning begins with compliance documentation is completed in early winter to allow for revisions or additional planning. NPS compliance requirements and deadlines vary

slightly between park units but are generally due mid-March to early April. These sites require access via fixed wing aircraft and helicopter for some sites, therefore aviation tasks will be needed. Details on field preparation of data sheets, copies of past data, maps, and GPS unit steps are outlined in SOP 3.1.

Table 17. Planning and preparations tasks for field season preparations for fire effects monitoring.

Planning Task	General Timeline/Due Dates[1]
Budget/Acquire Project Funding	Late fall/early winter
Compliance	Early-March/Mid-April
Aircraft Requests (Fixed-Wing and/or Helicopter)	Late Spring
Task Orders (if applicable)	Late Spring
Lodging/Facility/Vehicle Reservations	Late Spring
Project Aviation Safety Plan (if applicable)	Minimum 21 days prior to project
Field data, maps and GPS unit preparations	1-2 months prior to project
Travel Arrangements to Kotzebue	2-3 weeks prior to project
Final Field Crew Determination	2-3 weeks prior to project
Backcountry Itinerary	1-2 weeks prior to project
Float Plan (if applicable)	1-2 weeks prior to project
Flight Plan (if applicable)	1-2 weeks prior to project
Field Gear Packing	1-2 weeks prior to project

Sequence of Events During the Field Season

All backcountry, safety and aviation policies will be followed during the field season. All required training will be taken prior to going the field and supervision/support will be provided throughout the field season.

Plot Layout and Methods

At each site ten 1-m x 1-m quadrats were sampled. For all of the sites, except NOAT1, NOAT2, and NOAT3, the quadrats are laid out along a 10 m transect in a row as shown in Figure 25 from the Bering Land Bridge Nimrod Hills site. The details of each plot layout are described in SOP 3.2.

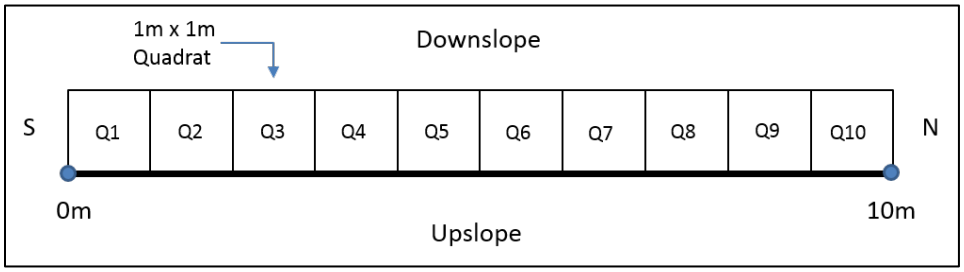
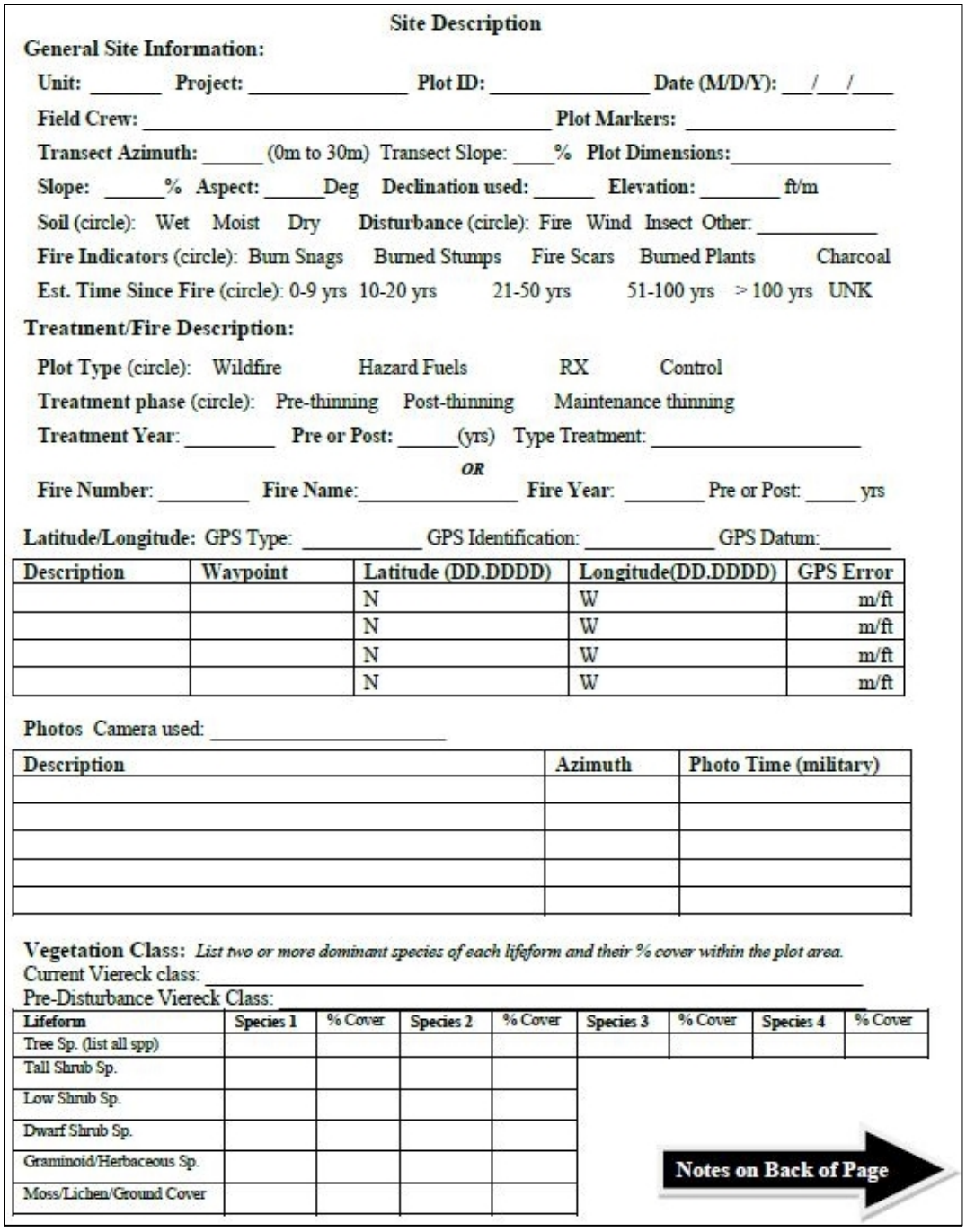


Figure 25. Plot layout for all Nimrod Hill plots in Bering Land Bridge.

A brief overview of the methods are provided here, see SOP 3.2 for details on methods and data sheet explanations. A site description form is utilized to record site topographic information, transect descriptions, disturbance information, photo information, and GPS data collected (see Figure 26). Vegetation and ground cover, density and height of selected species, and active layer depth measurements are recorded in each quadrat. Figure 27 shows the data form to collect the cover, density and height data. All living vascular and non-vascular plant species are recorded and an ocular estimate of percent cover for each species within each of the 1-m x 1-m quadrat is recorded. A density count of all trees, tall shrubs (willow/alder) and tussock forming sedges are recorded in each quadrat. The maximum height of each shrub species is recorded in each quadrat. Active layer depths are measured at the center and each corner of each quadrat for a total of 5 measurements per quadrat, surface code and additional information is collected for each depth measurement (see Figure 28). Detailed tree measurements are made at each site – recording the locations, height, crown measurements and diameter. Previously the detailed tree data was only collected at one site (Kugururok), but will be expanded to all sites in the future. See SOP 3.2 for the data sheets and detailed information on the tree density and measurement methods. If plots are burned in the future the Composite Burn Index (CBI) plot methods as described in Chapter 3 and SOPs 3.2 will be used to describe the burn severity overall for the site. Burn severity codes for substrate and vegetation will be recorded for each quadrat.



Site Description

General Site Information:

Unit: _____ **Project:** _____ **Plot ID:** _____ **Date (M/D/Y):** __/__/____

Field Crew: _____ **Plot Markers:** _____

Transect Azimuth: _____ (0m to 30m) **Transect Slope:** ____% **Plot Dimensions:** _____

Slope: _____% **Aspect:** _____Deg **Declination used:** _____ **Elevation:** _____ ft/m

Soil (circle): Wet Moist Dry **Disturbance** (circle): Fire Wind Insect Other: _____

Fire Indicators (circle): Burn Snags Burned Stumps Fire Scars Burned Plants Charcoal

Est. Time Since Fire (circle): 0-9 yrs 10-20 yrs 21-50 yrs 51-100 yrs > 100 yrs UNK

Treatment/Fire Description:

Plot Type (circle): Wildfire Hazard Fuels RX Control

Treatment phase (circle): Pre-thinning Post-thinning Maintenance thinning

Treatment Year: _____ **Pre or Post:** _____(yrs) Type Treatment: _____

OR

Fire Number: _____ **Fire Name:** _____ **Fire Year:** _____ Pre or Post: _____ yrs

Latitude/Longitude: GPS Type: _____ GPS Identification: _____ GPS Datum: _____

Description	Waypoint	Latitude (DD.DDDD)	Longitude(DD.DDDD)	GPS Error
		N	W	m/ft
		N	W	m/ft
		N	W	m/ft
		N	W	m/ft

Photos Camera used: _____

Description	Azimuth	Photo Time (military)

Vegetation Class: *List two or more dominant species of each lifeform and their % cover within the plot area.*

Current Viereck class: _____

Pre-Disturbance Viereck Class: _____

Lifeform	Species 1	% Cover	Species 2	% Cover	Species 3	% Cover	Species 4	% Cover
Tree Sp. (list all spp)								
Tall Shrub Sp.								
Low Shrub Sp.								
Dwarf Shrub Sp.								
Graminoid/Herbaceous Sp.								
Moss/Lichen/Ground Cover								

Notes on Back of Page

Figure 26. Site description form used for the Racine fire effects plots.

Vegetation Cover/Density/Height – 1m x 1m Quadrats

Park Unit: _____ Project: _____ Plot ID: _____ Field Crew: _____ Field Date: _____

Record percent vegetation cover (CV), count the density (DN) and max height (Ht) by species within the 1m x 1m quadrat. Canopy cover (%) estimates are made for each species of trees, shrubs, herbs, bryophytes, and lichens. Density counts are for tall willows, alder, trees and tussock forming plants. Maximum height (cm) of shrubs by species (all) in each quadrat.

SPECIES	Cv/Dn/Ht 1			Cv/Dn/Ht 2			Cv/Dn/Ht 3			Cv/Dn/Ht 4			Cv/Dn/Ht 5			Cv/Dn/Ht 6			Cv/Dn/Ht 7			Cv/Dn/Ht 8			Cv/Dn/Ht 9			Cv/Dn/Ht 10		

Figure 27. Vegetation cover, density, and height quadrat form example for the Racine fire effects plots.

Active Layer Depths

Park Unit: _____ Project: _____ Plot ID: _____

Field Date: _____ Field Crew: _____

Record depth (cm) of active layer in the four corners and center of each 1-m x 1-m quadrat. For each location record ***active layer boundary type*** and ***surface code***. Record if probe is in ***intertussock (IT)*** or on ***top of tussocks (T)***. Example: 43, PF, LM, IT.

Active Layer Depths (cm)					
Quadrat	NW Corner	NE Corner	SW Corner	SE Corner	Center
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Active Layer Boundary Types: Permafrost (PF), Rock (R), Seasonal Frost (SF), Unknown (UNK).

Surface Layer Fuel Codes: LC = lichen, FM = feather moss, SM = sphagnum moss, DM = dead moss, UD = upper duff, LD = lower duff, MIN = mineral, LTRH = Litter herbaceous, LTRNDL = Litter needle litter, other species codes as needed

Probe Location: Intertussock (IT), Top of Tussock (T)

Figure 28. Active layer measurement form and instructions for the Racine fire effects plots.

Data Entry Field Plots (SOP 3.3)

Data from the fire effects plots will be entered into an interagency database called FFI (FEAT/FIREMON Integrated; www.frames.gov/ffi). FFI is a plot-level monitoring software tool that provides data entry, storage and summary report tools. Data is stored in a Microsoft SQL Server database (Lutes et al. 2015). Details of data entry and verification are in SOP 3.3. All photos and GPS data will be processed and stored as described in SOP 3.3.

Post-collection Processing of Samples

Any voucher plant specimens collected at the plots for identification will be prepared in standard plant specimen voucher collection methods, as outlined by Murray and Parker from the University of Alaska Museum-Herbarium (Miller et al. 2010 Appendix H). Collections will be dictated by collection permits from the park and the curation process will be identified by park curatorial managers.

End-of-season Procedures

Field season close-out should include an inventory of equipment to replace damaged or perishable items that need to be replaced. All data sheets will be scanned to keep a digital backup of datasheets. An after action review should take place to provide suggestions for improvements or recommendations for future sampling.

4.3. Data Analysis and Reporting

The following sections provide information on the data summaries, analyses and reporting for fire effects vital sign. The details of data management are provided in a combined chapter for data management for fire extent, burn severity and fire effects monitoring in Chapter 5 Data Management.

Routine Data Summaries (SOP 3.4)

When data entry and quality control has been completed basic summary statistics will be produced for the fire effects data sets. Data will be presented in quantitative and visual format with tables and graphs. Data will be summarized by each plot with the frequency (percent of quadrats containing a species) and average cover for each species by plot (Tables 18a, b). Data summaries will emphasize plant functional types (Chapin et al. 1996) based on their growth form (i.e. graminoids, forbs, evergreen shrubs, deciduous shrubs, lichens, mosses etc.) and response to disturbance. Table 15 provides an example of the average and standard deviation of cover by growth form for the 6 Noatak burn plots in the 1980s and 2005. Graphical display of average cover and 80% CI by growth forms grouped by fire history and pre-fire vegetation will be made (see Figure 29). Summary data on active layer depths, tree density and shrub heights will be provided in tables and graphs by plot and summarized by fire history and pre-fire vegetation. The repeat photography are often some of the most compelling data and will be utilized in reports, presentations and resource briefs.

Table 18a. Example table of frequency (Freq) and average cover (C) for species sampled at Kungiakrok Burned Sites in 1982 and 2005. Table information from Racine et al. 2006 report.

		1982		2005	
Category	**Species**	**Freq**	**C**	**Freq**	**C**
Graminoids	*Eriophorum vaginatum*	100	25	100	64
	Carex bigelowii	100	11	100	7
	Calamagrostis sp.	100	2	40	0.5
	Graminoid Cover Sum	**–**	**38**	**–**	**71**
Deciduous shrubs	*Betula nana*	80	3	80	10
	Salix glauca	0	0	20	1
	Salix pulchra	60	3	60	6
	Vaccinium uliginosum	30	0.2	10	0.2
	Deciduous Shrub Cover	**–**	**6**	**–**	**17**
Evergreen shrubs	*Ledum palustre*	80	3	100	10
	Vaccinium vitis-idaea	0	0	0	0
	Evergreen Shrub Cover	**–**	**3**	**–**	**10**
Forbs	Epilobium angustifolium	20	0.3	20	0.5
Bryophytes	*Sphagnum sp*	40	1.5	50	1
	Feather moss	80	5.5	50	1
	Bryophyte Cover	**–**	**7**	**–**	**2**
Lichens	*Peltigera*	0	0	20	0.2

Table 18b. Example table of frequency (Freq) and average cover (C) for species sampled at Kungiakrok Unburned Sites in 1982 and 2005. Table information from Racine et al. 2006 report.

		1982		2005	
Category	**Species**	**Freq**	**C**	**Freq**	**C**
Graminoids	*Eriophorum vaginatum*	100	39	100	25
	Carex bigelowii	100	9	100	8
	Calamagrostis sp.	0	0	0	0
	Graminoid Cover Sum	**–**	**48**	**–**	**33**
Deciduous shrubs	*Betula nana*	100	7	100	18
	Salix glauca	0	0	0	0
	Salix pulchra	70	2	90	6
	Vaccinium uliginosum	30	0.5	20	0.5
	Deciduous Shrub Cover	**–**	**9.5**	**–**	**24.5**
Evergreen shrubs	*Ledum palustre*	100	18	100	26
	Vaccinium vitis-idaea	10	0.5	30	3
	Evergreen Shrub Cover	**–**	**18.5**	**–**	**29**
Forbs	*Epilobium angustifolium*	0	0	0	0

Table 18b (continued). Example table of frequency (Freq) and average cover (C) for species sampled at Kungiakrok Unburned Sites in 1982 and 2005. Table information from Racine et al. 2006 report.

Category	Species	1982		2005	
		Freq	C	Freq	C
Bryophytes	*Sphagnum sp*	0	0	60	6
	Feather moss	50	3.5	80	2
	Bryophyte Cover	**–**	**3.5**	**–**	**8**
Lichens	*Peltigera*	20	0.2	10	0.1

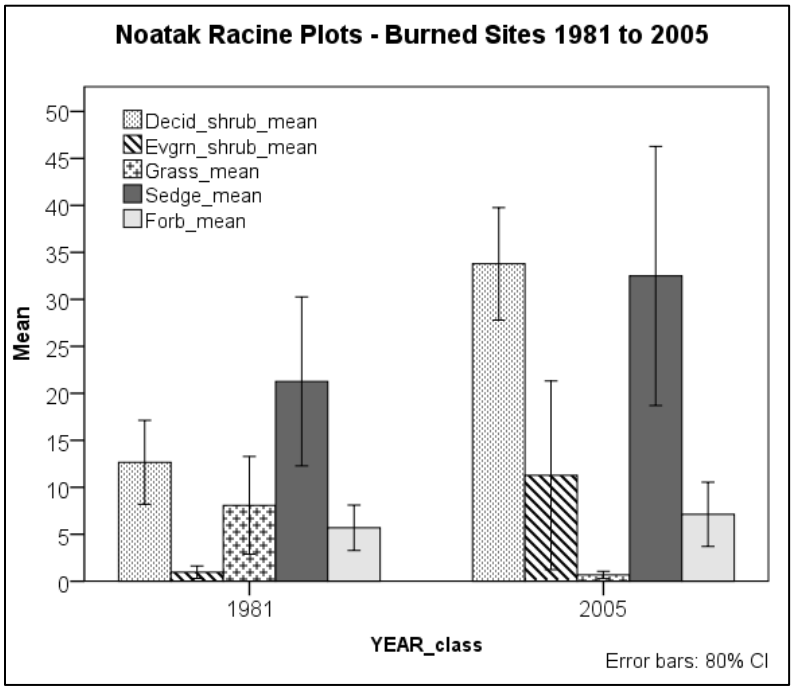


Figure 29. Example graph of the average vegetation cover and 80% CI by life form for 6 of the 8 Noatak fire effects plots measured in 1981-82 and 2005.

Reporting Schedule and Format

The fire effects data will be reported in the Fire Ecology Annual report the year that the data is collected and a full technical report one year after the data is collected at the plots. The expected reporting schedule is shown in Table 19.

Table 19. Recommended reporting schedule for fire effects data.

Report	Report Type	Schedule	Primary Responsibility
Fire Ecology Annual Report	NRDS	May Annually (if ground based data are collected)	Fire PI (Regional Fire Ecologist)
Fire Effects Trend Report	NRR	Every 10 years, 1 year after data collection	Fire PI (Regional Fire Ecologist)

Annual reports if data is collected will be formatted using the NPS Natural Resource Data Series format and the 10-year summary reports will be formatted using the NPS Natural Resource Report format (http://www.nature.nps.gov/publications/nrpm/). Reports could be similar to the report that was published in 2006 with the Noatak data (Racine et al. 2006). Examples of graphics and summary tables are provided in this report.

Methods for Long-term Trend Analysis

Long-term monitoring will provide an estimate of ecosystem response to environmental change due to fire and other factors. Summary statistics for species-level and life form cover data will be calculated by plot for each sampling date (SOP 3.4). Changes in species cover or life form cover within sampling times may be estimated between two points in time using repeated measures analysis or Bonferroni corrected paired t-tests. Changes in frequency data can be measured using nonparametric (e.g., chi-square) tests. For change detection, the difference in the measure of interest (e.g., percent cover by some group of plants) between two dates is computed for each plot, and a single-sample t-test is used to test whether the resulting change value is significantly different from zero.

4.4. Operational Requirements

Personnel Requirements and Training

For the fire effects field data collection, the PI (a NPS employee GS-9, -11, or -12) would be responsible for planning and organizing field logistics, field sampling, and post-season database management. The PI provides training on the sampling routine and, as necessary, burn severity methods and plant identification.

The field data collection is best accomplished with 2 crews of 2 people. Each crew would have a field lead, familiar with the local flora in Alaska, and a second crew member that can be trained in data collection methods. One crew member should also be qualified as a project helicopter manager when access by helicopter is required. All crew members need to complete routine safety training common to all NPS field employees (bear safety and shotgun certification, basic aviation safety, first aid, CPR, and safety check-in procedures of the NPS units involved).

Data entry into the FFI database would be accomplished by the assistant fire ecologist or technicians if hired. Quality control and data verification would be completed by the regional fire ecologist and assistant. The principle investigator or a GS-9 term or permanent employee, under the supervision of the PI, will analyze the data and prepare reports on the burn severity statistics.

Annual Workload

Annual workload portray the years that the sites are re-measured (approximately every 10 years). The PI or assistant will spend about 1 month in midwinter preparing compliance and task orders for flights, 2 weeks in the spring preparing for field logistics and approximately 1 month for data analysis and reporting. Table 20 provides an overview of annual tasks, responsibilities, and expected schedule for the burn severity data. Details for field preparations and field work are in SOP 3.1 and 3.2.

Table 20. Workload tasks and responsible personnel for fire effects data collection and analyses.

Data Set and Tasks	Responsible Personnel	Schedule
Budget/Acquire Project Funding	PI (Fire Ecologist)	November
Prepare compliance documents for fieldwork and prepare aircraft acquisition paperwork (SOP 3.1)	PI or Assistant	February
Fieldwork – burn severity plots (SOP 3.2)	Field crew, PI	Early July to Early August
Plot data entry, photo labeling, GPS processing (SOP 3.3)	Technician or Assistant Fire Ecologist	September or October
Data analyses and summaries (SOP 3.4)	Assistant Fire Ecologist or PI (Fire Ecologist)	January
Resource Brief or Report (SOP 3.4)	Assistant Fire Ecologist	May as needed
Data archiving & Deliverables (SOP 3.5	PI (Fire Ecologist)	April

Software and Hardware

Listed below are the primary computer software and equipment needs to meet the goals of this protocol.

- Geographic Information System software package: ArcGIS is the current package used by the NPS
- FFI Database
- Microsoft Office (word processing, spreadsheet preparation, presentations preparation)
- R-stats software or SPSS statistical program
- GPS – Trimble and Garmin

Budget Considerations

The workload associated with data acquisition and data entry will be approximately 3 months every 10 years. Currently the regional fire ecologist (GS-11/12) is funded full time by the fire program, but if this workload needs to be completed by the assistant, additional funding may be needed. Annually the burn severity data acquisition would cost approximately $3300 for one pay period of a GS-9 assistant fire ecologist.

The cost of the ground-based field assessments for re-measuring the fire effects plots in one park (Noatak) are shown in Table 21. These costs would be approximately every 10 years. The costs include estimates for OAS costs for fixed wing and helicopter access to the field sites. The cost of two GS-5 bio-techs working 2 pay periods each and travel costs including commercial airfare to Kotzebue for 4 field personnel. The estimated cost in 2017 would be $41,300 every 10 years. Costs for sampling in Bering Land Bridge would be less since helicopter flights are not necessary only float plane access is needed.

Table 21. Budget, responsible personnel and costs for fire effects field data collection in one park, every 10 years.

Description	Item	Cost/Unit	Number of Units	Estimated Cost in 2017
Fixed-wing flights	Fixed wing flights	$600/hr flight time	10	$6,000
Helicopter	Helicopter flight time availability	$1,350/hr flight time	10	$13,500
Fieldwork	GS-5 Technicians	$1,700/Pay Period	4	$6,800
Fieldwork	Overtime	$40/hr	60	$2,400
Travel Costs	4 people to Kotzebue, 8 day field work	$1,500/person	4	$6,000
Data Entry and Analysis	Assistant Fire Ecologist	$3,300/Pay Period	2	$6,600
Annual Report Writing	PI Fire Ecologist	NA	1	$0
Total				**$41,300**

5. Data Management

5.1. NPS Standards

Data Quality

Director's Order #11 mandates a high level of information quality from the service's scientific programs:

"The NPS will ensure that information it releases to the public or utilizes in management decisions will be developed from reliable data sources that provide the highest quality of information at each stage of information development. The NPS's methods for producing quality information will be made transparent, to the maximum extent practicable, through accurate documentation, use of appropriate internal and external review procedures, consultation with experts and users, and verification of the quality of the information. The NPS will also keep users informed about corrections and revisions.

Information will be developed only from reliable data sources based on accepted practices and policies, utilizing accepted methods for information collection and verification. To ensure high quality, information should be peer reviewed at an appropriate level and at appropriate times. Data will be reproducible to the extent possible. Influential information will be produced with a high degree of transparency about data and methods. The information should include all pertinent information to allow the public to understand the park's legislative authorities, mission, activities, organization, strategic plan, performance plan, and performance accomplishments."

Director's Order #11A section 5.8: Data Integrity Standards outlines the NPS policy for accuracy, completeness and review:

"All information owners will maintain all official NPS records and data in a manner which meets the highest data integrity standards, including timeliness, accuracy and completeness (also see DO #19). Each information owner will take what ever steps necessary to ensure that NPS systems have sufficient data quality reviews and audits from both an internal system perspective, as well as externally thorough control reviews."

Freedom of Information Act

The Network will comply with all FOIA restrictions regarding the release of data and information as instructed in NPS Director's Order #66.

Records Management

Direction for managing physical and digital materials is provided in NPS Director's Order 11D.

"The NPS has a strong business need for excellent records management, in that the Service's mission is to care for natural and cultural resources so that they are left "unimpaired" for future generations. This requirement for managing resources in perpetuity sets a high standard for record keeping. No resources can be managed well in the future without complete records of how they were managed in the past. Because the NPS manages some of America's most significant cultural and natural resources, the public also has a significant interest in our records. Section 1.9.2 of NPS

Management Policies 2006 (NPS, 2006) states that the future of the Service depends on the availability, management, dissemination, and preservation of information, and directs the agency to implement professional quality programs to manage information resources."

5.2. Data Management Life Cycle

Data management for the fire monitoring program will proceed through an ongoing life cycle as shown in Figure 30 (NPS 2008a). Major stages of the life cycle include data collection, data entry and import, quality control, data product documentation and archival, seasonal closeout, dataset certification, and data analysis and reporting as shown in Figure 31 (NPS 2008b).

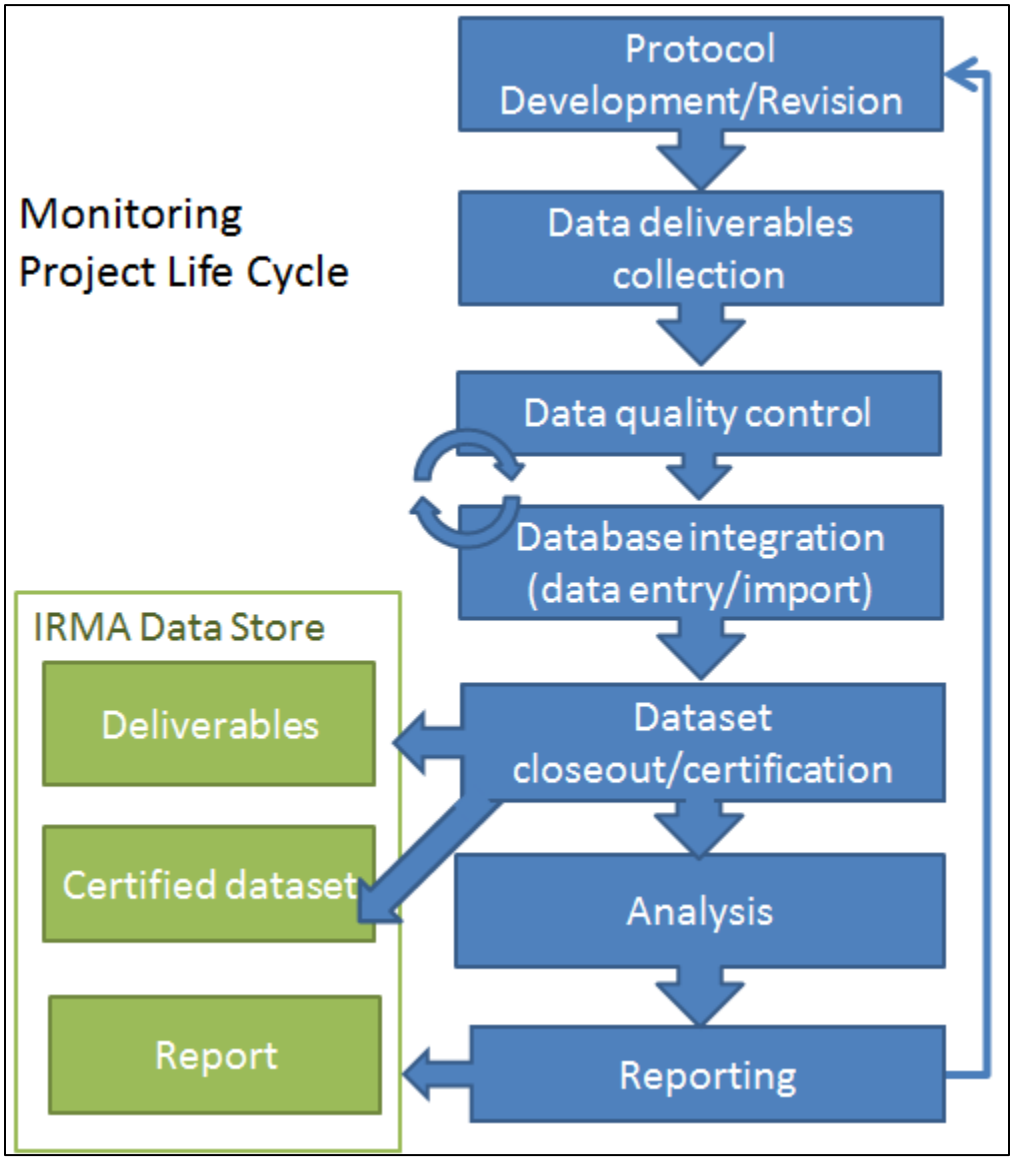


Figure 30. Long-term monitoring project data management life cycle.

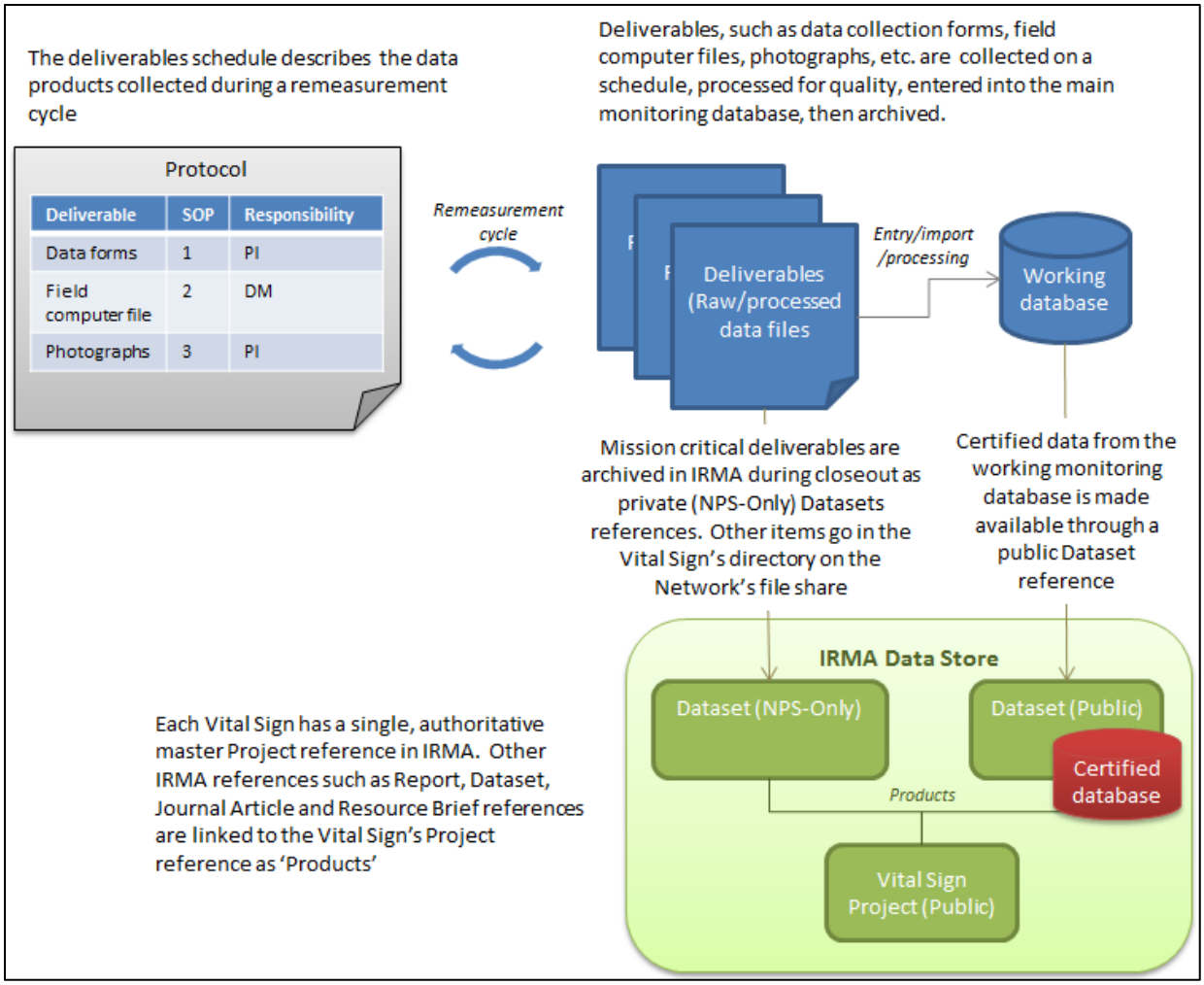


Figure 31. Overview of data collection and archival process. Data quality improves as it moves from collection of raw data deliverables through quality control and database integration procedures and into a series of well-documented IRMA Data Store references. All Data Store references are linked to a single, authoritative Vital Sign master Project Reference.

5.3. Roles and Responsibilities

The fire monitoring team members must work collaboratively to assure the quality of the communal dataset is maintained at a high level.

Project Leader

- Ensures that the fire monitoring protocol and all of its standard operating procedures are current and up to date. If methods must be changed, the project leader ensures that the standard operating procedures remain in sync with actual data management operations.
- Ensures data is collected, processed and integrated with the master database consistently and strictly according to the specifications and methods described in the standard operating procedures. Performs an annual closeout with the Network program manager and data manager.

- Certifies the fire monitoring dataset for analysis and publication and assures that the fire monitoring standard operating procedures are current.
- Performs analytical procedures and reports on findings
- Arranges technicians and budgets for data management costs, such as data entry and processing.

Data Manager

- Provides for the security, longevity and accessibility of the fire monitoring dataset.
- Maintains software and hardware for file backups and security, databases, custom and proprietary applications and GIS tools.
- Guides personnel in data processing techniques, metadata generation and product archival in NPS data stores and enterprise databases.
- The data manager is not responsible for data entry, processing, metadata generation or archiving data deliverables.

5.4. Quality Assurance

The fire Vital Sign assures high data quality by proactively deploying a standard system of quality assurance safeguards and a consistent framework of administrative and technological quality control procedures (NPS 2008a,b, Frakes et al., 2015). This system includes:

- Standard operating procedures designed to maintain consistent data collection methods and minimize the introduction of errors during data processing and database integration.
- Field crew training.
- Standard database security and integrity functions and data integrity constraints (Frakes et al., 2015) to enforce compliance with the Vital Sign's logical data model.
- Application level data entry checks and business rule enforcement.
- Periodic data quality audits and reports.

5.5. Quality Control

Ensuring high data quality as a priority for the Fire Vital Sign (NPS 2008a,b). Quality control procedures focus on verifying data as well as identifying, correcting and documenting anomalies in final data products. Quality control safeguards include:

- Visual data verification
- Spot checking
- Automated programmatic range, domain or impossible value checking
- Graphical and visual exploratory data analysis
- Statistical error or outlier identification
- Data quality audits and reporting.

5.6. Product Archival and Documentation

Director's Order 19 states that all records of natural and cultural resources and their management are considered mission-critical records (necessary for fulfillment of the NPS mission) and must be permanently archived. Mission critical deliverables are considered to be archived when they are uploaded to the IRMA Data Store. With few exceptions IRMA is the only authoritative repository for mission critical I&M products. Data archiving is done in concert with seasonal close out and data certification.

In most cases, unless specified differently in the deliverables schedule, data products generated by the Fire Extent and Severity monitoring program will be archived in the IRMA Data Store according to the standard Arctic Network archival procedures describe in ARCN/CAKN DMSOP-1 *Product Archival, Seasonal Closeout and Dataset Certification Procedures for the Arctic and Central Alaska Inventory and Monitoring Networks* (Miller 2017).

IRMA Data Store

The NPS IRMA Data Store is the primary organizational repository and publication platform for information related to the fire monitoring program (Figure 32). The fire Vital Sign has a single master IRMA project reference (https://irma.nps.gov/DataStore/Reference/Profile/2219489) to which all products are related.

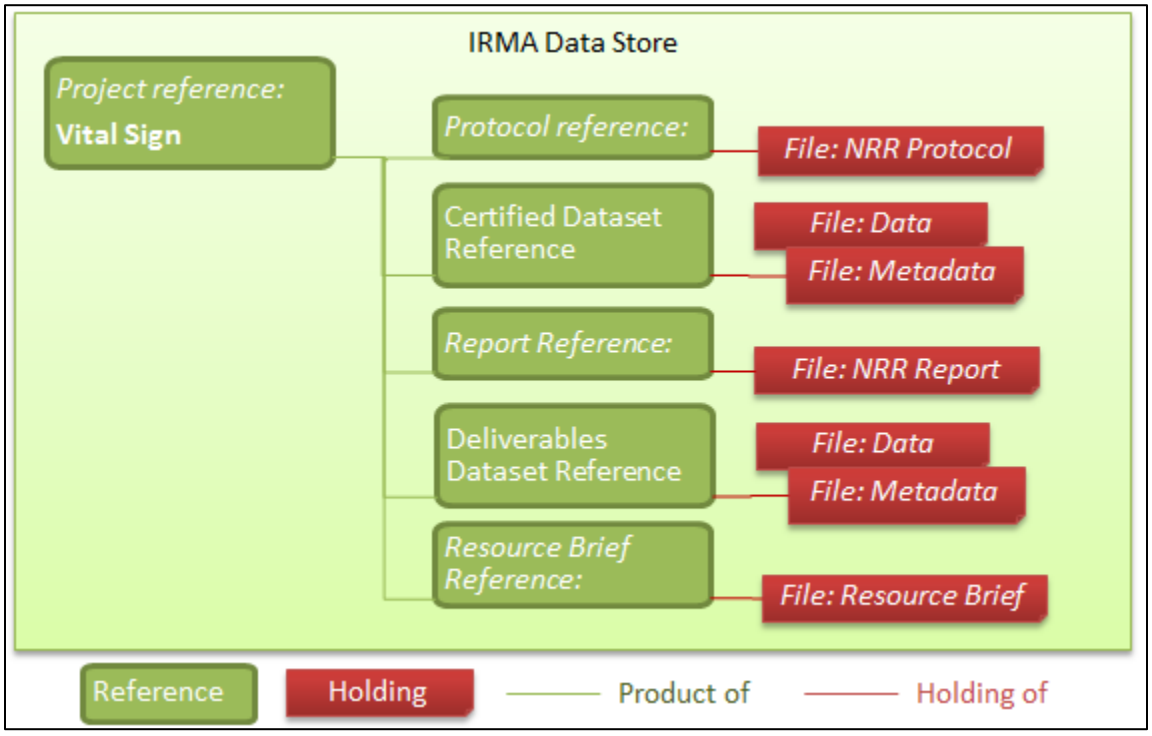


Figure 32. Architecture of products management system in the IRMA Data Store.

The public Vital Sign profile web page covering fire monitoring will display for download the releasable contents of the fire monitoring Project reference and its related products.

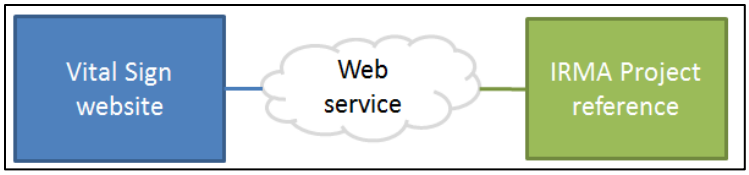


Figure 33. The fire extent and severity website is tightly integrated with the fire monitoring master Project reference in the IRMA Data Store. New products and information cascade directly from the Data Store to the fire monitoring profile page on the Arctic Network website.

It is the joint responsibility of the PI and the data manager to keep the system of related IRMA Data Store references up to date.

Data Deliverables

The fire monitoring program creates and maintains specific data deliverables. Each deliverable is disseminated directly from the IRMA Data Store, the single authoritative source for Network products. In the event that a data product ever diverges from that in the IRMA Data Store the latter version should be considered authoritative. Details on data deliverables schedule and file management for the Fire Extent, Frequency and Lightning portion of the fire monitoring program are provided in SOP 1.9. Details on data deliverables schedule and file management for the Burn Severity portion of the fire monitoring program are provided in SOP 2.8. Details on data deliverable schedule and fire management for the Fire Effects are provided in SOP 3.5.

Reports

Reports are published in the NPS Natural Resource Report publication series (http://nature.nps.gov/publications/nrpm/index.cfm) or professional journals. Reports and journal articles reporting analytical results will be published in tandem with the dataset that was used.

Natural Resource Reports are automatically tracked and announced to Network program managers and data managers but journal articles are not. The PI will create Data Store references for journal articles related to monitoring, link them to the Vital Sign's IRMA Project reference (Figure 32) and notify Network staff of their presence.

Data Publication

All reports providing statistical results will also publish the releasable portions of the data on which they were based. Metadata will be provided as well as a link to the certified original dataset (NPS, 2005). Data are made available through IRMA in machine readable formats according to Director's Order #11A and as mandated by the Federal Open Data Initiative (Executive Order No. 13642).

The fire Vital Sign will have a single public dataset reference in the IRMA Data Store to which certified data will be published (Figure 32). This reference will be the only authoritative data source available to the public.

Resource Brief

The I&M resource brief is the primary outreach document for the fire monitoring program. The principal investigator will revise any existing resource brief after new findings to reflect current

understanding of the resource's trend and implications for park management. Resource briefs are made available on the Network web site through an IRMA Data Store Resource Brief product reference that is attached as a product of the main Vital Sign Project reference (Figure 32).

Products Publication

Reports, datasets and other monitoring products are published through the Arctic Network and related Inventory and Monitoring websites. Authoritative products will only be distributed through the IRMA Data Store (Figure 32).

Metadata

All project datasets, including spatial and non-spatial data, are archived in the IRMA data store with metadata. The mandate for adequate metadata comes from Director's Order #11A (NPS, 2005): *"All NPS data systems will develop data dictionaries and conform to available NPS organization-wide dictionaries. Geographic Information and Metadata must meet all Federal standards, DOI standards and NPS standards."* Acceptable standards include Federal Geographic Data Committee (FGDC) format and Ecological Metadata Language (KNB, 2017).

Line of Sight

Line of sight is the informal name given to the I&M program's philosophy that every datum should be inextricably linked in a traversable way to the standard operating procedure and protocol version that guided its collection (Figure 34). A data consumer will be reliably able to access a data record and discover the standard operating procedure version that defined its collection and processing.

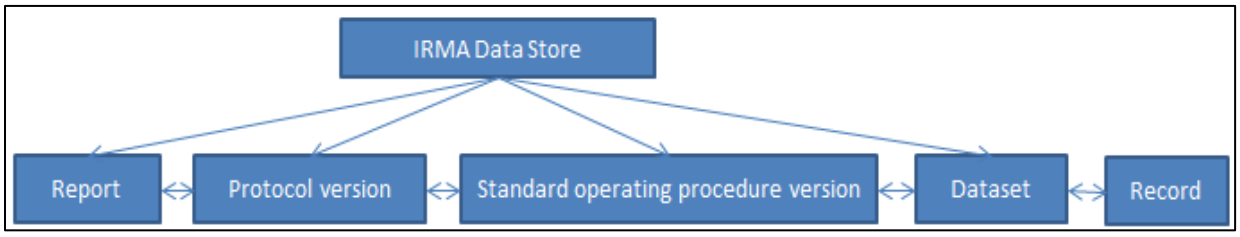


Figure 34. Each informational component informs and is informed by other components. Discovery of one component leads to discovery of all other components in a formalized data management chain of custody.

Data and Information Security

The fire monitoring program files are maintained on a network file share located in the Fairbanks Administrative Center (FAC) in Fairbanks, Alaska. Data and products are backed up to off-site storage. In the event of catastrophe at one site, the original data may be restored from the other. Finished products are uploaded to the IRMA Data Store. The Data Store has an industry standard security and disaster recovery framework.

5.7. Closeout

Closeout is the part of the fire monitoring data management life cycle through which seasonal data collection deliverables (SOPs 1.9, 2.8, and 3.5) are archived in the IRMA Data Store. Closeout happens after a remeasurement cycle when data files have been collected, processed and integrated

into the main monitoring database. After field data are integrated with the master monitoring database they are archived as holdings of private IRMA Dataset References (Figure 31). Closeout is complete when the IRMA Dataset's holdings match the archival specifications of the deliverables schedule in SOPs 1.9, 2.8 and 3.5. The closeout method described above will ensure that all data objects collected during a remeasurement cycle are accounted for, documented and available for perpetuity should the need arise to re-use or revisit the data.

5.8. Certification

Certification is the phase of the fire monitoring data management life cycle where the principal investigator formally attests that the Vital Sign's dataset is ready for analysis. A snapshot of the certified portions of the fire monitoring dataset are documented and uploaded to the authoritative certified Dataset reference for the Vital Sign in the IRMA Data Store (Figures 31 and 32). Certification affirms the integrity of the scientific, administrative and technical support structure of the fire monitoring program. Certification indicates:

- The protocol and standard operating procedures are current. All technical changes are up to date and documented.
- Raw and intermediate data deliverables have been processed via quality control procedures, have been integrated with the vital sign's database or data management system and have been archived and documented in the IRMA Data Store.
- Each data record is traceable to the protocol version and SOP version that guided its collection.
- All closeout activities have been performed.
- The certified database or data files have been published to the Vital Sign's public Dataset reference in the IRMA Data Store.
- The Vital Sign's IRMA Data Store references and cross-links are complete.

The Fire Extent and Severity monitoring program will certify datasets according to the standard Arctic Network dataset certification procedures describe in ARCN/CAKN DMSOP-1 *Product Archival, Seasonal Closeout and Dataset Certification Procedures for the Arctic and Central Alaska Inventory and Monitoring Networks* (Miller 2017).

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The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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