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Water Resources Division
Natural Resource Program Center

Technical Report NPS/NRWRD/NRTR-2005/341

WATER RESOURCES INFORMATION AND ISSUES OVERVIEW REPORT

DENALI NATIONAL PARK AND PRESERVE

ALASKA

The National Park Service Water Resources Division is responsible for providing water resources management policy and guidelines, planning, technical assistance, training, and operational support to units of the National Park System. Program areas include water rights, water resources planning, regulatory guidance and review, hydrology, water quality, watershed management, watershed studies, and aquatic ecology.

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Water Resources Information and Issues Overview Report

Denali National Park and Preserve
Alaska

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Technical Report NPS/NRWRD/NRTR- 2005/341

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WATER RESOURCES DIVISION

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ACRONYMS AND ABBREVIATIONS

ACWA	Alaska Clean Water Actions
ADEC	Alaska Department of Environmental Conservation
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
ADTPF	Alaska Department of Transportation and Public Facilities
ANCSA	Alaska Native Claims Settlement Act
ANILCA	Alaska National Interest Lands Conservation Act
AO	Arctic Oscillation
ARLIS	Alaska Resources Library and Information Services
AS	Alaska Statute
BLM	Bureau of Land Management
CASTNet	Clean Air Status and Trends Network
CAKN	Central Alaska Network
CBM	Coal-bed Methane
CFR	Code of Federal Regulations
CMC	Clean Mountain Can
CWA	Clean Water Act
DEM	Digital Elevation Model
DENA	Denali National Park and Preserve
DO	Director's Order
DOC	Dissolved Organic Carbon
DOI	U.S. Department of the Interior
EA	Environmental Assessment
EIS	Environmental Impact Statement
ENSO	El Niño/Southern Oscillation
FLPMA	Federal Land Policy and Management Act
FR	Federal Register
GAP	Gravel Acquisition Plan
GCM	General Circulation Models
GIS	Geographic Information System
GMP	General Management Plan
gpd	Gallons Per Day
HUC	Hydrologic Unit Code
IMPROVE	Interagency Monitoring of Protected Visual Environments Program
I&M	Inventory and Monitoring
IPCC	Intergovernmental Panel on Climate Change
LTEM	Long-term Ecological Monitoring
mg/L	Milligrams per Liter
MTBE	Methyl Tertiary Butyl Ether
N	Nitrogen
NAAQS	National Ambient Air Quality Standards
NADP/NTN	National Atmospheric Deposition Program/National Trends Network
NAO	North Atlantic Oscillation
NHD	National Hydrography Data

NPS	National Park Service
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric Turbidity Unit
OHV	Off-Highway Vehicle
PAH	Polycyclic Aromatic Hydrocarbon
PDO	Pacific Decadal Oscillation
PEL	Probable Effect Level
POP	Persistent Organic Pollutants
ppm	Parts per Million
RCRA	Resource Conservation and Recovery Act
RDI	Recordable Disclaimer of Interest
RMP	Resources Management Plan
ROD	Record of Decision
SOC	Semi-Volatile Organic Compounds
SOF	Statement of Findings
SWE	Snow Water Equivalent
USACE	United States Army Corps of Engineers
USC	United States Code
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UST	Underground Storage Tank
WRD	Water Resources Division

SECTION 1.0
EXECUTIVE SUMMARY

Denali National Park and Preserve (DENA) consists of approximately 6 million acres in the central interior of Alaska and features North America's highest mountain, Mount McKinley (elevation 20,320 feet). The park and preserve's water resources are diverse and extensive, including glaciers, icefields, large glacial and non-glacial river systems, groundwater, lakes and ponds, and wetlands. Prior to 1985, mining activities in the Kantishna Hills was the primary threat to water resources in the park. Currently, increasing development pressures within and adjacent to DENA is the primary threat. Development pressures include a proposal to construct a North Access Route to Kantishna, increased commercial development in the Kantishna area and South Side of the park, and proposed coal-bed methane development in Healy. Other potential threats associated with development include water rights and navigability conflicts between the park, State, and private interests.

The park's Water Resources Project Statement (Project Code: DENA-N-210) from the *Resources Management Plan* (NPS, 1998a) recommended development of a Water Resources Management Plan that would protect and preserve the park's high quality of surface and groundwater resources and correct current water quality degradation problems. Preliminary information was gathered in 1985 for preparation of a plan, but the plan was never written. As a result of this recommendation and accelerated development pressures within, and adjacent to the park, DENA developed a scope for a Water Resources Management Plan that would be achieved in two phases.

This Water Resources Information and Issues Overview Report is Phase I of the project, and provides 1) a description of the applicable Federal and State legislation and regulations, NPS management policies and Director's Orders (DOs), and park-specific planning documents that provide the mandates and foundation for management decisions related to water resources; 2) a general characterization of DENA's physical, biological, and socioeconomic resources in relation to water resources; 3) identification, prioritization, and analysis of water-related issues pertaining to water resources management at DENA; and 4) identification of the baseline inventory and monitoring needed to address each of the water-related issues identified. Information obtained for this report came from public sources, the DENA library and research files, and the Alaska Resources Library and Information Services (ARLIS).

The high priority water-related issues identified and discussed in this report include:

- Floodplain modification from existing and proposed development;
- NPS and commercial wastewater disposal, treatment, and discharge;
- Proposed North Access Route to Kantishna;
- Application of calcium chloride on Park Road for dust suppression;
- Introduction and spread of exotic species;
- Water quality and quantity impacts from CBM development in Healy;
- Alaska's gas license and lease procedure involving CBM development in Healy;

- Status of abandoned mine wastes and NPS reclamation efforts;
- Subsistence OHV use impacts on water resources;
- Impacts of sport fishing on fish populations;
- Status of navigable water determinations;
- Potential navigability determination impacts on DENA's water resources;
- Potential for water rights conflicts as a result of increased water demand and in-stream uses; and
- Climate change impacts on permafrost, shallow lakes, glaciers, ice formation and breakup, and soil biogeochemistry.

Arsenic in downtown Kantishna drinking water was also identified as a high priority issue but it is not discussed in this report due to a lack of available information on this subject.

Each of these issues affect DENA's water resources to some extent, although some are not under NPS control. Therefore, it is important to recognize that communication and coordination with other government agencies and private interest stakeholders are essential in the successful management of DENA's vast watersheds. The information provided in this report will be used in Phase II of the project to lay the framework for conducting public meetings and workshops with stakeholders and will serve as a foundation for addressing the park's water resources management needs.

SECTION 2.0
INTRODUCTION

Water is a particularly important and sensitive ecosystem component, and it plays a central role in the social, economic, environmental, and political mosaic of units of the national park system. Its physical availability and quality are critical determinants of a park's overall natural resource condition. Because of the important role of water in maintaining resource condition, it is the policy of the National Park Service (NPS) to maintain, rehabilitate, and perpetuate the inherent natural integrity of water resources and water-dependent environments occurring within the national park system.

Proper management of water resources within NPS units is becoming more complex and challenging as threats to this vital resource, within and outside park boundaries, increase. Planning is an essential step in understanding the hydrologic environment and addressing the complex water resource issues faced by many park units. DENA is faced with development pressures within, and adjacent to the park. The potential for large projects with resource-impact potential such as the proposed North Access Route to Kantishna and South Side Development Plan have accelerated over the past 5 years. As a result of these development pressures, there is a pressing need to identify the significant water resources of the park and the natural and anthropogenic processes affecting these resources.

2.1 SCOPE AND PURPOSE OF REPORT

The park's existing Water Resources Project Statement (NPS, 1998a) calls for the development of a Water Resources Management Plan to protect and preserve the high quality of surface and ground water resources, and correct current water quality degradation problems. As a result of this recommendation and the accelerated development pressures described above, the park developed a scope for a Water Resources Management Plan that would be achieved in two phases. Phase I would focus on producing a Water Resources Scoping Report, based on compilation of information from existing reports and water resource studies, legislation, planning directives and plans, and internal scoping. Phase II would result in a Water Resources Management Plan that would suggest specific action items, areas of concern, guidance for future management direction, and draft project statements for high-priority issues.

The title of the Water Resources Scoping Report was changed midway through the project to "Water Resources Information and Issues Overview Report" due to recent changes in the water resource planning framework described below; however, the general scope of Phase I remained unchanged.

The purpose of this report is to 1) identify applicable Federal, State, and NPS legislation and policy that affect the management of water resources, 2) identify interagency coordination on water resource programs/studies, 3) characterize the park's physical, biological, and socioeconomic resources in relation to water resources, using existing information, 4) identify and prioritize the major issues affecting the park's water resources through internal scoping, 5) provide a summary of existing information relevant to the park's water-related issues, and 6) identify the data gaps in the baseline inventory and monitoring data available for the park and what is still needed to sufficiently address the park's water-related issues.

Information obtained for this report came from public sources, the DENA library and research files, and ARLIS. The information provided in this report will be used in Phase II of the project to lay the framework for conducting public meetings and workshops with stakeholders and will serve as a foundation for addressing the park's water resources management needs.

2.2 WATER RESOURCES PLANNING FRAMEWORK

The NPS' Water Resources Division (WRD) initiated a program in 1991 that assists parks with their water resources planning needs. Recent changes in NPS general planning (new 2004 *Park Planning Program Standards*) and resources planning (draft *DO 2.1: Resource Stewardship Planning*) required programmatic revision to the existing NPS Water Resources Planning Program to assure that its products support the new NPS planning framework within which planning and decision-making are now accomplished. Within this new planning framework, six discrete elements of planning are in place that is captured in six planning-related documents (**Figure 2.2-1**).

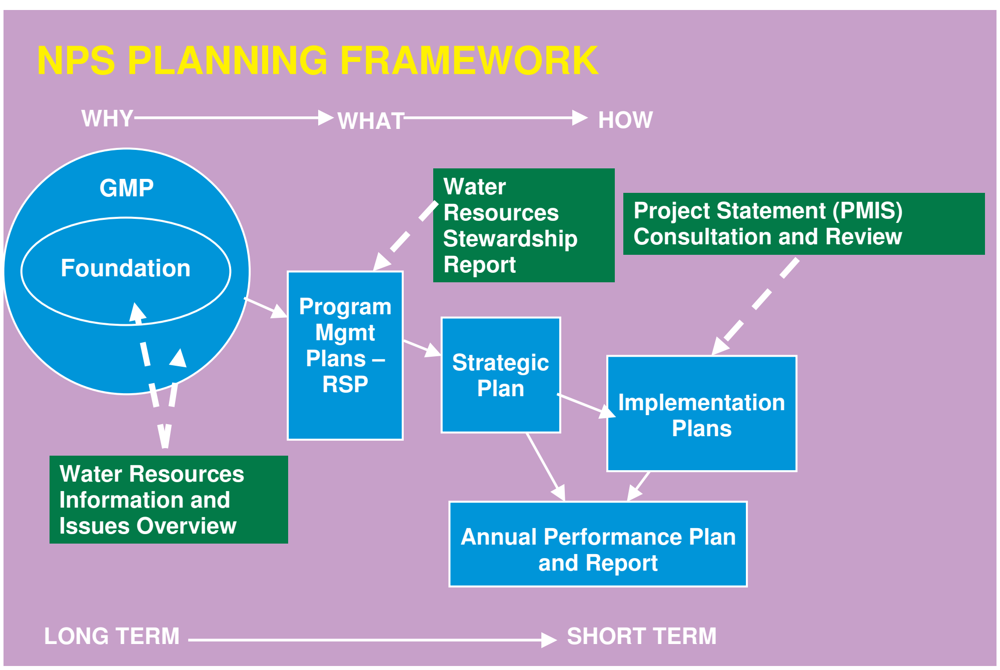

Figure 2.2-1. The 'New' NPS Framework for Planning and Decision-Making (blue boxes). Green boxes represent WRD's planning products or assistance. RSP = Resource Stewardship Plan.

The *Foundation for Planning and Management* defines the legal and policy requirements that mandate the park's basic management responsibilities, and identifies and analyzes the resources and values that are fundamental to achieving the park's purpose or otherwise important to park planning and management.

The _General Management Plan_ uses information from the *Foundation for Planning and Management* to define broad direction for resource preservation and visitor use in a park, and serves as the basic foundation for park decision-making, including long-term direction for d*esired conditions* of park resources and visitor experiences.

The _Program Management Plan_ tiers off the *General Management Plan* identifying and recommending the best strategies for achieving the desired resource conditions and visitor experiences presented in the *General Management Plan*. Program planning serves as a bridge to translate the qualitative statements of *desired conditions* established in the *General Management Plan* into measurable or objective indicators that can be monitored to assess the degree to which the *desired conditions* are being achieved. Based on information obtained through this analysis, comprehensive strategies are developed to achieve the *desired conditions*. The *Program Management Plan* component for natural and cultural resources is the *Resource Stewardship Plan* (**Figure 2.2-1**).

The _Strategic Plan_ tiers off the *Program Management Plan* identifying the highest-priority strategies, including measurable goals that work toward maintaining and/or restoring the park's *desired conditions* over the next 3 to 5 years.

Implementation Plans tier off the *Strategic Plan* describing in detail (including methods, cost estimates, and schedules) the high-priority actions that will be taken over the next several years to help achieve the *desired conditions* for the park.

The _Annual Performance Plan and Report_ measures the progress of projects from the *Implementation Plan* with objectives from the *Strategic Plan*.

The _Water Resources Information and Issues Overview_ and the _Water Resources Stewardship Report_ will support this new planning framework. The *Water Resources Information and Issues Overview* (**Figure 2.2-1**) addresses the needs of either the *Foundation for Planning and Management* document or phase one of the *General Management Plan*, but is flexible in design in order to serve other unique park needs, as warranted. The *Water Resources Stewardship Report* (**Figure 2.2-1**) is designed specifically to address the water resource needs in a park's *Resources Stewardship Plan*.

2.3 ORGANIZATION OF REPORT

This report is presented in four major sections:

- **Section 3.0, Legislation, Management, and Coordination**: Section 3 includes a description of the applicable Federal and State legislation and regulations, NPS management policies and DOs, and park-specific planning documents that provide the mandates and foundation for management decisions related to water resources.

- **<u>Section 4.0, Characterization of Water-Related Resources</u>**: Section 4 characterizes DENA's physical, biological, and socioeconomic resources in relation to water resources, and provides the reader with an overview of DENA's diverse environments.

- **<u>Section 5.0, Water Resources Issues</u>**: Section 5 identifies, prioritizes, and dicusses the water-related issues pertaining to water resources management at DENA.

- **<u>Section 6.0, Baseline Inventory and Monitoring</u>**: Section 6 identifies the baseline inventory and monitoring needed to address each of the water resources issues identified in Section 5.0.

SECTION 3.0
LEGISLATION, MANAGEMENT, AND COORDINATION

3.1 ALASKA NATIONAL INTEREST LANDS CONSERVATION ACT

In 1980, Congress passed the Alaska National Interest Lands Conservation Act (ANILCA), which enlarged and renamed Mount McKinley National Park as Denali National Park and Preserve. In 1917, Congress established Mount McKinley National Park as a "game refuge" to "set apart as a public park for the benefit and enjoyment of the people…for recreation purposes by the public and for the preservation of animals, birds, and fish and for the preservation of the natural curiosities and scenic beauties thereof…" (39 Statute 938). Section 101 of ANILCA describes the broad purposes of the new conservation system units throughout Alaska, including enlarged national parks and preserves such as DENA. These include the following:

- Preserve lands and waters for the benefit, use, education, and inspiration of present and future generations;
- Preserve unrivaled scenic and geological values associated with natural landscapes;
- Maintain sound populations of, and habitat for, wildlife species;
- Preserve extensive, unaltered ecosystems in their natural state;
- Protect resources related to subsistence needs;
- Protect historic and archeological sites;
- Preserve wilderness resource values and related recreational opportunities such as hiking, canoeing, fishing, and sport hunting;
- Maintain opportunities for scientific research in undisturbed ecosystems; and
- Provide the opportunity for rural residents to engage in a subsistence way of life.

Section 202 states that the new units of the enlarged Denali National Park and Preserve are to be managed for the following additional specific purposes:

- To protect and interpret the entire mountain massif and the additional scenic mountain peaks and formations;
- To protect habitat for, and populations of fish and wildlife including, but not limited to, brown/grizzly bears, moose, caribou, Dall sheep, wolves, swans, and other waterfowl; and
- To provide continued opportunities, including reasonable access, for mountain climbing, mountaineering, and other wilderness recreational activities.

Section 707 of ANILCA designates the "Denali Wilderness of approximately one million nine hundred thousand acres" under the Wilderness Act, including most of the former Mt. McKinley National Park. According to the Wilderness Act, these lands are to be:

> "administered for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness, and so as to provide for the protection of these areas, the preservation of their wilderness character, and for the gathering and dissemination of information regarding their use and enjoyment as wilderness."

Section 1313 of ANILCA addresses the purpose of national preserves created by the Act.

> "A National Preserve in Alaska shall be administered and managed as a unit of the National Park System … except that the taking of fish and wildlife for sport purposes and subsistence uses, and trapping shall be allowed in a national preserve under applicable State and Federal law and regulation."

ANILCA legislation not only established DENA, but also set into law the allowance of many activities that are not permitted in park units located in the lower-48 states. Consumptive uses of natural resources, such as subsistence use of fish, wildlife, and firewood in the national park and the allowance for subsistence and sport hunting in the preserve, offer a layer of complexity unique to Alaska parks.

3.2 FEDERAL LAWS AND REGULATIONS

Many Federal, State, and local agencies have an interest, mandated or otherwise, in the water resources at DENA. Protection of water resources requires an understanding of the various policy, regulatory, and management designations in order to facilitate coordination and cooperation among agencies and private landowners at DENA.

All Federal lands within the park and preserve boundary are under proprietary jurisdiction of the NPS. Both Federal and State agencies have authority for the enforcement of appropriate regulations. Water resource laws and regulations at the State and local levels are often patterned after Federal laws, or serve in response to Federal directives.

Federal legislation and executive orders that affect the management of DENA's water resources are presented in this section. For further information access the web pages for the U.S. Environmental Protection Agency (USEPA, www.epa.gov) and the U.S. Fish and Wildlife Service (USFWS, www.fws.gov).

National Park Service Organic Act of 1916

This Act established the NPS and mandated that it "shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of future generations."

General Authorities Act of 1970

This Act reinforced the 1916 Organic Act – all park lands are united by a common preservation purpose, regardless of title or designation. Hence, Federal law protects all water resources in the National Park System equally, and it is the fundamental duty of the NPS to protect those resources unless otherwise indicated by Congress.

Redwood National Park Act (1978)

This Act amended the General Authorities Act of 1970 to mandate that all park system units be managed and protected "in light of the high public value and integrity of the National Park System." Furthermore, no activities should be undertaken "in derogation of the values and purposes for which these various areas have been established", except where specifically authorized by law or as may have been or shall be directly and specifically provided for by Congress.

National Parks Omnibus Management Act of 1998

This Act attempts to improve the ability of the NPS to provide state-of-the-art management, protection, and interpretation of and research on the resources of the National Park System by:

- Assuring that management of units of the National Park System is enhanced by the availability and utilization of a broad program of the highest quality science and information;
- Authorizing the establishment of cooperative agreements with colleges and universities, including but not limited to land grant schools, in partnership with other Federal and State agencies, to establish cooperative study units to conduct multi-disciplinary research and develop integrated information products on the resources of the National Park System, or of the larger region of which parks are a part;
- Undertaking a program of inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources; and
- Taking such measures as are necessary to assure the full and proper utilization of the results of scientific study for park management decisions. In each case in which an action undertaken by the NPS may cause a significant adverse effect on a park resource, the administrative record shall reflect the manner in which unit resource studies have been considered. The trend in the condition of resources of the National Park System shall be a significant factor in the annual performance.

Park System Resource Protection Act

The Park System Resource Protection Act, 16 U.S.C. § 19jj, allows the NPS to seek compensation for injuries to park system resources and to use the funds recovered to restore, replace or acquire equivalent resources and to monitor and study such resources. Park system resources includes any living or non-living resource that is located within a park within the boundaries of a unit of the National Park System and is owned by the Federal Government. This is inclusive of natural resources, cultural resources, physical facilities and other resources that meet this definition.

Federal Land Policy and Management Act

This Act declares that all public lands will be retained in Federal ownership unless it is determined that a use other than public will better serve the interests of the nation. The Act requires that all public land be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, and environmental aspects of the land and that all public lands and their resources be inventoried periodically and systematically.

National Environmental Policy Act (NEPA) of 1969

This Act requires Federal agencies to evaluate the environmental impacts of their actions and to integrate such evaluations into their decision-making processes. NEPA's basic policy is to assure that all branches of government give proper consideration to the environment prior to undertaking any major Federal action that significantly affects the environment.

Clean Air Act of 1970

This Act, as amended, regulates airborne emissions of a variety of pollutants from area, stationary, and mobile sources; establishes a nationwide program for the prevention and control of air pollution; and establishes National Ambient Air Quality Standards (NAAQS). Under the Prevention of Significant Deterioration provisions, the Act requires Federal officials responsible for the management of Class I Areas (national parks and wilderness areas) to protect the air quality related values of each area and to consult with permitting authorities regarding possible adverse impacts from new or modified emitting facilities. The 1990 amendments to this Act were intended primarily to fill the gaps in the earlier regulations, such as acid rain, ground level ozone, stratospheric ozone depletion and air toxics. The amendments identify a list of 189 hazardous air pollutants. The USEPA must study these chemicals, identify their sources, determine if emissions standards are warranted, and promulgate appropriate regulations.

Clean Water Act (Federal Water Pollution Control Act)

The 1977 amended Clean Water Act (CWA) established the basic structure for regulating discharges of pollutants into the waters of the United States. It gave the USEPA the authority to implement pollution control programs, such as setting wastewater standards for industry, through best management practices and through water quality standards. Section 404 of the CWA requires that a permit be issued for discharge of dredged or fill materials into waters of the United States. The U.S. Army Corps of Engineers administers the Section 404 permit program. Section 402 of the CWA requires that all discharges to surface waters be permitted under the National Pollutant Discharge Elimination System (NPDES) permit program. The CWA intends for states to implement (to have primacy for) the NPDES program, with the USEPA acting in an oversight role. Forty-five states have primacy for the NPDES program; Alaska is one of the five remaining states that do not have NPDES primacy. Thus, the USEPA is the NPDES authority in Alaska. The ADEC, Wastewater Discharge Program, plays a secondary role certifying that

USEPA permits meet State water quality standards and issuing State permits for small discharges over which the USEPA does not claim jurisdiction.

Endangered Species Act of 1973

This Act requires the NPS to identify and promote the conservation of all federally listed endangered, threatened, or candidate species within any park unit boundary. This Act requires all entities using Federal funding to consult with the Secretary of Interior on activities that potentially impact endangered flora and fauna. It also requires agencies to protect endangered and threatened species, as well as designated critical habitats. While not required by legislation, it is NPS policy to also identify State and locally listed species of concern and support the preservation and restoration of those species and their habitats.

Executive Order 11990: Wetlands Protection

This executive order directs the NPS to 1) provide leadership and to take action to minimize the destruction, loss, or degradation of wetlands; 2) preserve and enhance the natural and beneficial values of wetlands; and 3) to avoid direct or indirect support of new construction in wetlands unless there are no practicable alternative to such construction and the proposed action includes all practicable measures to minimize harm to wetlands.

Executive Order 11988: Floodplain Management

This executive order requires all Federal agencies to take action to reduce the risk of flood loss, to restore and preserve the natural and beneficial values served by floodplains, and to minimize the impact of floods on human safety, health, and welfare. The objective of this executive order is "…to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is an practicable alternative." For non-repetitive actions, the executive order states that all proposed facilities must be located outside the limits of the 100-year floodplain. If there were no practicable alternative to construction within the floodplain, adverse impacts would be minimized during the design of the project.

Executive Order 13112: Invasive Species

This executive order requires the prevention of the introduction of invasive species and provides for their control and minimization of the economic, ecological, and human health impacts that invasive species cause. It complements and builds upon existing Federal authority to aid in the prevention and control of invasive species.

Executive Orders 11644 and 11989: Use of Off-Road Vehicles on Public Lands

These executive orders require Federal land managers to control off-highway vehicle (OHV) use on public lands. OHVs are defined as any motorized vehicle designed for or capable of cross-county travel on or immediately over land, water, sand, snow, etc. The definition excludes registered motorboats, emergency, military, and agency vehicles. Executive Order 1164 requires the designation of trails and areas, based on the protection of the natural resources of lands, safety of all users of the lands, and minimization of user conflicts, which are open or closed to OHVs. This executive order prohibits OHV routes in designated wilderness areas. Executive Order 11989 amends Executive Order 11644 and requires Federal agencies to close areas of OHV use if it is causing or will cause adverse effects on soil, vegetation, wildlife, habitat, cultural or historic resources.

3.3 STATE OF ALASKA LAWS AND REGULATIONS

Three State agencies regulate water-related resources in Alaska: Alaska Department of Environmental Conservation (ADEC), Alaska Department of Natural Resources (ADNR), and Alaska Department of Fish and Game (ADF&G).

ADEC administers Title 18 AAC Environmental Conservation, which regulates air quality, solid and hazardous waste management, water quality standards, wastewater disposal, underground storage tanks (UST), drinking water, and oil and hazardous substance pollution control. These regulations can be found at www.legis.state.ak.us. The department is currently organized into six divisions: Office of Commissioner, Air Quality, Environmental Health, Information and Administrative Services, Spill Prevention and Response, and Water. ADEC's Division of Water establishes standards for water cleanliness; regulates discharges to waters and wetlands; provides financial assistance for water and wastewater facility construction and waterbody assessment and remediation; trains, certifies, and assists water and wastewater system operators; and monitors and reports on water quality. The Division of Spill Prevention and Response prevents spills of oil and hazardous substances, prepares for when a spill occurs, and responds rapidly to protect human health and the environment.

On February 16, 2005, Alaska House Bill 153 and Alaska Senate Bill 110 were introduced in the State Legislature at the request of the Governor. If approved, the bills would direct the ADEC to seek and assume primacy for the NPDES program. There are six components to the NPDES permit program. It is proposed that the State assume responsibility for the first five.

1. *NPDES Permitting,* which amounts to developing, issuing, modifying, and renewing the permits.
2. *Stormwater Program,* which consists of permitting stormwater discharges from construction and industrial activities, as well as permitting the stormwater collected and discharged by large municipal storm sewer systems.
3. *Compliance and Enforcement,* which includes monitoring compliance with permit terms and conditions and taking enforcement action, when necessary.
4. *Federal Facilities,* which involves permitting of discharges from federally owned facilities, such as Department of Defense installations.
5. *Pre-treatment Program,* which consists of regulating highly toxic discharges into sewerage systems.
6. *Biosolids Management Program,* which regulates the disposal of sewage treatment byproducts, or "sludge."

ADNR administers Title 11 AAC Natural Resources, which regulates parks, recreation, and public use; oil and gas; agriculture; lands; trust land management; Alaska coastal management program; and protection of fish habitat. These regulations can be found at www.legis.state.ak.us. ADNR manages all State-owned land, water, and natural resources, except for fish and game. The department is currently organized into 7 divisions: Agriculture; Forestry; Geological and Geophysical Surveys; Mining, Land, and Water; Oil and Gas; Parks and Outdoor Recreation; and Support Services (ADNR, 2005b).

ADNR's Division of Mining, Land, and Water is the primary manager of Alaska's land holdings. Responsibilities include ensuring the State's title; preparing land use plans and easement atlases; classifying land; leasing and permitting State land for recreation; and commercial and industrial uses. It also manages 2.5 million acres in public use and recreational rivers like the Nenana River, and is responsible for land sales and conveyances to municipalities. The division also manages mineral (excluding oil & gas, coal-bed methane (CBM), and geothermal energy) and water resources. The division allocates and manages the State's water resources on all lands in Alaska, adjudicates water rights and withdrawals, provides technical hydrologic support, and assures dam safety (ADNR, 2005b).

ADNR's Division of Oil and Gas develops and manages the State's oil and gas leasing programs. The Division of Oil and Gas division staff identifies prospective lease areas; performs geologic, economic, environmental, and social analyses; develops a five-year leasing schedule; and conducts public review of proposed sales. The division conducts competitive oil and gas lease sales and monitors collection of all funds resulting from its programs. It is also responsible for the development of the State's geothermal and CBM resources (ADNR, 2005b).

Management of fisheries in Alaska is divided between the ADF&G and the USFWS. ADF&G is currently organized into four divisions (Subsistence, Sport Fish, Wildlife Conservation, and Commercial Fisheries), and administers Title 5 AAC Fish and Game, which regulates commercial and subsistence fishing, sport fishing and personal use fishery, game, protection of fish and game habitat, and subsistence hunting, fishing, and trapping. These regulations can be found at www.legis.state.ak.us (ADF&G, 2004). In 1999, the USFWS assumed responsibility for managing subsistence fisheries on Federal lands in Alaska (USFWS, 2005). The USFWS monitors harvest from commercial, sport, and subsistence fisheries and provides in-season recommendations to managers on the need to invoke harvest restrictions in order to meet subsistence needs. Federal fisheries regulations apply on all navigable and non-navigable waters within the 1980 ANILCA additions to DENA. The ADF&G manages commercial, sport, and personal use fisheries on all Alaskan waters. In addition, ADF&G cooperates with all Federal agencies in Alaska on aquatic invasive species.

The Alaska Clean Water Actions (ACWA), created through Administrative Order 200, directed these three Alaska resource agencies to work together to characterize Alaska's waters in a holistic manner; sharing data, expertise and other information. ACWA conducts an annual joint matched-solicitation for water quality projects using funds that are passed through from Federal monies. Projects include restoration; protection; or conservation of water quality, quantity, and aquatic habitat. Local governments, citizen groups, tribes, and education facilities are often recipients of these awards (ADEC, No date).

3.4 NATIONAL PARK SERVICE MANAGEMENT POLICIES AND DIRECTOR'S ORDERS (DO'S)

The NPS Management Policies (2001) provide broad policy guidance for the management of National Park System units. These NPS policies and guidelines broadly require management of natural resources of the National Park System to maintain, rehabilitate, and perpetuate the inherent integrity of aquatic resources. Section 4.6 of the NPS policy, specifically addresses water resource management including protection of surface waters and groundwater, water rights, water quality, floodplains, wetlands, and watershed and stream processes. It is NPS policy to determine the quality of park surface and ground water resources and avoid, whenever feasible, the pollution of park waters by human activities occurring within and outside of parks. Specifically, the NPS works with appropriate governmental bodies to: achieve the highest possible standards available under the CWA for protection of park waters; take all actions necessary to maintain or restore surface and ground water quality within the parks to be in compliance with the CWA and all applicable laws and regulations; and develop agreements with other governing bodies, where appropriate, to obtain their cooperation in maintaining or restoring the quality of park water resources. NPS Management Policies also direct the NPS to: manage watersheds as complete hydrologic systems; minimize human disturbance to natural upland processes that deliver water, sediment, and woody debris to streams; and manage streams to protect stream processes that create habitat features, including floodplains, riparian systems, woody debris accumulations, terraces, gravel bars, riffles, and pools.

In accordance with NPS Management Policies, the NPS will protect watershed and stream features mainly by avoiding impacts to watershed and riparian vegetation and allowing natural fluvial processes to proceed unimpeded. When conflicts between park infrastructure and stream processes are unavoidable, park managers will first consider relocating or redesigning infrastructure, instead of manipulating streams. However, where stream manipulation is inevitable, the NPS will use techniques that protect natural processes to the greatest extent practicable. In addition, the NPS will allow natural shoreline processes to continue without interference. Where human uses or infrastructure have altered the nature or rate of natural shoreline processes, the NPS will investigate alternatives for mitigating such effects.

DO-2, *Park Planning*, was incorporated into the 2001 NPS Management Policies and the DO elapsed in May 2002. In August 2004, replacement Park Planning Program Standards described under Section 2.2, *Water Resources Planning Framework*, became official. The NPS has a mandate in its Organic Act and other legislation to preserve resources unimpaired for the enjoyment of future generations. Park planning helps define what types of resource conditions, visitor uses, and management actions will best achieve that mandate. The NPS is to maintain an up-to-date General Management Plan (GMP) for each unit of the National Park System. The purpose of the GMP is to ensure that each park has a clearly defined direction for natural and cultural resource preservation and visitor use. DENA completed a GMP in 1986. A park's Resources Management Plan (RMP) describes the specific management actions needed to protect and manage the park's natural and cultural resources. DENA's RMP (1998) identifies existing resources and conditions, present actions, and identifies future needs consistent with legislative and administrative guidance, resource significance, and other park planning documents. Discipline-specific planning documents that complement the RMP (e.g., Fire

Management Plan, Water Resources Scoping Report, etc.) are prepared for NPS units when warranted. Based on these legislative mandates and NPS policies, the objectives for DENA's natural resources management are to:

- Conduct long-term ecological monitoring to assess park resource conditions, monitor regional and global changes, and detect impacts resulting from activities in the area;
- Through implementation of a fully developed subsistence management program, continue subsistence uses of wildlife, fish, and plants in the park additions and subsistence uses and sport hunting in the preserve without impairing natural and healthy populations;
- Encourage an ecosystem management approach and provide for outstanding visitor experiences within a wilderness setting while maintaining, restoring, or enhancing park resources and preserving natural processes;
- Develop visitor facilities that fit into the natural and cultural landscape and that do not significantly impair park resources. Provide opportunities for resource-based activities, and encourage development in areas least vulnerable to resource degradation;
- Design and develop visitor and administrative support facilities that are environmentally and economically sustainable; and
- Encourage and participate in efforts to acquire and analyze information to support the best possible management strategies for resource protection and visitor enjoyment.

3.4.1 Director's Orders (DOs) and Procedural Manuals

NPS DOs and procedural manuals describe the recommended procedures for implementing service-wide policy. Those DOs and procedural manuals that pertain most directly to water resources are described below.

DO #35A: Sale or Lease of Park Services, Resources, or Water in Support of Activities outside the Boundaries of National Park Areas

DO #35A establishes the operational policies, procedures, and requirements for the sale or lease of park resources, including water, for activities outside the park, including the conditional authorization of the sale or lease of water resources. In regards to water resources, when an application is for the use of water outside the park, the use of water will be in accordance with the laws and regulations governing ownership and use of water and water rights. In addition, when a park's future resource protection or visitor needs dictate, the NPS will terminate the sale or lease of park waters.

Reference Manual #77: Natural Resource Management

Reference Manual #77 offers comprehensive guidance to NPS employees responsible for managing, conserving, and protecting the natural resources found in National Park System units. The Manual serves as the primary guidance on implementing Service-wide natural resource management in units of the National Park System. Specific natural resources pertaining to water addressed in the manual include the management, protection, and use of: fish and fishery resources; freshwater resources; marine resources; nonnative species; shorelines; and marine, freshwater, and barrier island resources.

DO #77-1 and Procedural Manual #77-1: Wetland Protection

The purpose of DO #77-1 is to establish NPS policies, requirements, and standards for implementing Executive Order 11990, *Protection of Wetlands* (42 FR 26961). The NPS adopts a goal of "no net loss of wetlands." In addition, the NPS will strive to achieve a longer-term goal of net gain of wetlands service-wide. DO #77-1 directs NPS units to conduct park-wide wetland inventories to help assure proper planning with respect to management and protection of wetland resources and sets forth the standard for defining, classifying, and inventorying wetlands. For proposed new development or other new activities or programs that are either located in or otherwise have the potential for adverse impacts on wetlands, the NPS will employ a sequence of: 1) avoiding adverse wetland impacts to the extent practicable; 2) minimizing impacts that could not be avoided; and 3) compensating for remaining unavoidable adverse wetland impacts via restoration of degraded wetlands. Where natural wetland characteristics or functions have been degraded or lost due to previous or ongoing human activities, the NPS will, to the extent appropriate and practicable, restore them to pre-disturbance conditions. Where appropriate and practicable, the NPS will not simply protect, but will seek to enhance natural wetland values by using them for educational, recreational, scientific, and similar purposes that do not disrupt natural wetland functions. Procedural manual #77-1 provides more detailed procedures by which the NPS will implement DO #77-1

DO #77-2 and Procedural Manual #77-2: Floodplain Management

DO #77-2 applies to all NPS proposed actions, including the direct and indirect support of floodplain development, that could adversely affect the natural resources and functions of floodplains, including coastal floodplains, or increase flood risks. In compliance with Executive Order 11988, *Floodplain Management*, it is NPS policy to preserve floodplain values and minimize potentially hazardous conditions associated with flooding. Specifically, DO #77-2 directs the NPS to:

- Protect and preserve the natural resources and functions of floodplains;
- Avoid the long- and short-term environmental effects associated with the occupancy and modification of floodplains;
- Avoid support of floodplain development and actions that could adversely affect the natural resources and functions of floodplains or increase flood risks; and
- Restore, when practicable, natural floodplain values previously affected by land use activities within floodplains.

When it is not practicable to locate or relocate development or inappropriate human activities to a site outside and not affecting the floodplain, NPS will:

- Prepare and approve a Statement of Findings (SOF), in accordance with procedures described in Procedural Manual #77-2;
- Take all reasonable actions to minimize the impact to natural resources of floodplains;
- Use non-structural measures as much as practicable to reduce hazards to human life and property; and

- Ensure that structures and facilities are designed to be consistent with the intent of the standards and criteria of the National Flood Insurance Program (44 CFR Part 60).

Procedural manual #77-2 establishes NPS procedures for implementing floodplain protection and management actions National Park System units in accordance with DO #77-2. The manual defines regulatory floodplains and the information required to delineate floodplains; defines the information required to evaluate hazards associated with the modification or occupation of floodplains; and provides requirements for managing activities that impact floodplains.

3.5 PARK MANAGEMENT

The purpose of DENA has evolved since it was first established in 1917 by Congress as Mount McKinley National Park. Management of the park has also become more complex due to the different mandates that apply to the Old Park (the original Mount McKinley National Park), the national park and preserve additions (added by ANILCA), and the designated wilderness (covering most of the Old Park) (NPS, 2003e). Mount McKinley National Park was established as a "game refuge" to "set apart as a public park for the benefit and enjoyment of the people…for recreation purposes by the public and for the preservation of animals, birds, and fish and for the preservation of the natural curiosities and scenic beauties thereof…" (39 Statute 938). In 1980, Congress passed ANILCA, which enlarged and renamed the park as Denali National Park and Preserve. As described in Section 3.1 above, ANILCA (Section 101) describes the broad purposes of the new conservation system units throughout Alaska, including enlarged national parks and preserves, such as DENA. ANILCA (Section 202) also states that the enlarged Denali National Park and Preserve is to be managed for several additional specific purposes, as described in Section 3.1 above. In addition, the legislative history states that certain NPS units in Alaska, including the old park portion of DENA, "…are intended to be large sanctuaries where fish and wildlife may roam freely, developing their social structures and evolving over long periods of time as nearly as possible without the changes that extensive human activities would cause" (Report of the Senate Committee on Energy and Natural Resources, Report No. 96-413, p.137) (NPS, 2003e).

3.5.1 Park Management Plans

Several management and concept plans have been prepared for DENA, which guide and provide goals, objectives, and strategies for land management, visitor use, resource management, and development. These plans, from earliest to most recent, are described briefly below.

Mount McKinley National Park Backcountry Management Plan

This 1976 management plan outlined visitor use limits for designated units in the backcountry, established a quota system within the park's backcountry, and institutionalized the concepts of dispersed use, freedom, and self-reliance (NPS, 2003e).

Denali National Park and Preserve General Management Plan

The 1986 General Management Plan (GMP) provides comprehensive guidance for all aspects of park management. The purpose of this plan is to protect the ecosystems of DENA, while simultaneously accommodating recreation, subsistence, and other valid uses. The 1986 GMP zones the park, identifies resource management needs, summarizes interpretive objectives and the desired visitor experience, and determines the need and general locations for park development. The plan proposed a cooperative Federal/State venture to develop visitor facilities on the south side of DENA (see description of the South Side Denali Development Concept Plan below). The 1986 GMP also included the Land Protection Plan and Wilderness Suitability review. Virtually all areas of the park were found suitable for wilderness designation, except the entrance area, road corridor, and primary mining areas in the Kantishna District (NPS, 1986). The 1986 GMP will be amended by the revised *Denali National Park and Preserve Backcountry Management Plan, General Management Plan Amendment* (draft, February 2003), once finalized, as described below.

Final Environmental Impact Statement (EIS) for the Denali National Park and Preserve Wilderness Recommendation

The park's 1988 wilderness recommendation EIS, mandated by Section 1317 of ANILCA, adopted the wilderness suitability review described in the 1986 GMP. In 1998, the NPS proposed that the President recommend to Congress that all of the park be designated for wilderness, except for former mining districts in the Kantishna Hills, Stampede Mine, Dunkle Hills, and a few other areas along the south boundary and north of the Wolf Townships along the northeast boundary. None of the preserve areas were proposed for wilderness designation. The U.S. Department of Interior (DOI) did not forward the proposal to Congress (NPS, 2003e).

Statement for Management, Denali National Park and Preserve (1995)

The 1995 *Statement for Management* provides an overview of DENA's condition, including existing uses, regional context, and adjacent land considerations, and an analysis of its major management issues. The statement outlines objectives to achieve the park purpose, desired future conditions, preferred visitor experience, and compliance with legislation, regulation, and policy, and provides strategies to achieve those objectives. While this document does not prescribe major solutions to significant resource protection, visitor use management, or facility development problems, it provides a comprehensive strategy for the park and identifies short-term critical management needs (NPS, 1995a).

South Side Denali Development Concept Plan and Final EIS

The 1997 *South Side Denali Development Concept Plan* is a cooperative planning effort between the NPS, State of Alaska, Denali Borough, Matanuska-Susitna Borough, and two Native regional corporations to increase recreational and tourism opportunities on the south side of the Alaska Range through the development of visitor facilities and services. The plan proposes little development within the boundaries of DENA; visitor facilities will be developed in the Tokositna area near the end of the Petersville Road and along the George Parks Highway in

Denali State Park, at Chelatna Lake, and in the Dunkle Hills area. Key components of the plan call for:

- Upgrading the Petersville Road;
- Constructing up to a 5,000 square-foot visitor center overlooking the Tokositna River (with up to 50 primitive RV or tent campsites, picnic areas, up to 4 public use cabins, and short hiking trails);
- Additional visitor facilities (campgrounds, roadside exhibits, trails) along the George Parks Highway;
- Up to 5 primitive fly-in campsites, 2 public-use cabins, and a hiking trail at Chelatna Lake; and
- Public access from the Dunkle Hills road (NPS et al., 1997).

Entrance Area and Road Corridor Development Concept Plan and Final EIS

The 1997 *Entrance Area and Road Corridor Development Concept Plan* amended the 1986 GMP for the entrance area and road corridor ("frontcountry") of DENA to provide specific direction for road management and facility development proposals to meet the current and future needs of the public while ensuring resource protection. The frontcountry includes all non-wilderness areas along the George Parks Highway, the entrance and headquarters areas, and the Denali Park Road corridor to the Kantishna airstrip. This plan calls for a hostel and walk-in campsites in the vicinity of Kantishna, hiking trails along the road corridor, several visitor services developments in the entrance area of the park (including interpretive centers, parking areas, rest areas, and environmental education opportunities), and resource protection programs (NPS, 1997).

Resource Management Plan (1998)

The 1998 Resource Management Plan (RMP) describes DENA's resource management objectives and the actions necessary to achieve those objectives. The RMP documents information and status of DENA's natural, cultural, and subsistence resources; describes and evaluates current resource management activities; prescribes an action program; and identifies funding and personnel needs. The RMP identifies the number, type, and source of external threats and sets priorities for addressing those threats; develops project statements, which describe the mitigation actions that can be taken, for each external threat; and evaluates the status of threat mitigation actions. The plan also strives to evaluate threats in the context of the vast acreages of undeveloped resources that surround DENA. The Water Resources Management (Project Code: DENA-N-210) section of this document provides a brief description of the present condition of water resources, the current management actions and results for surface and ground water, and recommends specific planning, research, mitigation, monitoring, and interpretation actions (NPS, 1998a).

Denali National Park and Preserve Backcountry Management Plan, General Management Plan Amendment (Draft, February 2003; April 2005)

This plan, once finalized, will update and expand the 1976 Backcountry Management Plan and amend the 1986 GMP for DENA. This plan addresses management of all park and preserve areas not included in the Entrance Area and Road Corridor and South Side Development Concept Plans, including the designated wilderness in the former Mt. McKinley National Park, the national park additions, the northwest and southwest national preserve areas, and the Park Road corridor west of park headquarters during the winter season. The goal of this revised backcountry management plan is to describe how the NPS will act to provide future visitors with a variety of opportunities to experience DENA's backcountry, while protecting park wildlife and other resources. Specifically, actions described by this plan should:

- Protect and preserve the park's natural and cultural resources and values, and wilderness resource values, including natural soundscapes and intangible values such as solitude;
- Provide for the public's maximum freedom of use and enjoyment of the park's backcountry and wilderness in a manner that is consistent with park purposes and the protection of park resources and values;
- Define the recreational opportunities provided in DENA's backcountry in the context of a spectrum of recreational opportunities available on public lands in the Denali region;
- Ensure all NPS management practices and research in the backcountry are consistent with park purposes; and
- Provide for the means to achieve public understanding and support of backcountry and wilderness values (NPS, 2003e).

[Note: A revised draft Backcountry Management Plan and EIS were released for public comment at the conclusion of this report. Any new information or data provided in this revised draft Plan and EIS may not be reflected in this report.]

3.6 MINING LAWS AND MANAGEMENT

The Mining Law of 1872 (30 USC 21) allowed general mining claims on public domain lands; however, most national parks were closed to new mining claims by park enabling legislation, amendments to the 1916 NPS Organic Act, and the 1970 NPS General Authorities Act. The Mining in the Parks Act of 1976 (16 USC 1901) closed the last six park units that had remained open to new mining claims. Both patented and unpatented mining claims exist within the 1980 park and preserve additions (NPS, 1998a). Mining and Mining Claims 36 CFR 9.1 was established from 42 FR 4835 of January 26, 1977, and authorized the Secretary of the Interior to regulate activity associated with unpatented and patented mining claims within all NPS units. Regulatory requirements requiring NPS approval include mining plan of operations, reclamation plan, and performance bond.

The NPS Minerals Management Division of the Alaska Regional Support Office has responsibility for providing policy, technical, and programmatic oversight and expertise on all matters involving minerals management issues on NPS-administered lands in Alaska. In addition, the minerals management staff at DENA provide in-park expertise and consultation to operators and claimants; review and conduct analysis of plans of operations; evaluate the environmental impacts of plans of operations and mineral-related proposals as per NEPA (PL 91-190); monitor active mining operations; collect resource information on mining claims, access routes, and other sites of mining activity; coordinate, review, and comment on other agency or private mineral-related proposals; develop mineral management policies, regulations, and implementation guidelines; conduct reclamation activities; and conduct mineral examinations and claim validity determinations (NPS, 1993).

3.7 NAVIGABILITY

Coupled with the Alaska Statehood Act of 1958, the Submerged Lands Act of 1953 provides for State ownership of water and submerged lands where waters are determined to be navigable. Under Title IX of ANILCA, the Bureau of Land Management (BLM) makes navigability determinations, which are subject to judicial review, for the Department of the Interior for purposes of land conveyance to Native corporations. In 1980, the State of Alaska established a navigability program to respond to Federal land conveyances and land management activities under the Alaska Statehood Act, the Alaska Native Claims Settlement Act (ANCSA), and ANILCA. The basic purpose of the State's program is to protect the public rights associated with navigable waters, including the State's title to submerged lands. The Alaska Constitution establishes State duties and management constraints regarding State-owned land underlying navigable waters. The Alaska Constitution also contains principles, known as the public trust doctrine, requiring the State to ensure that the right of the public to use navigable waters for navigation, commerce, recreation, and related purposes is not substantially impaired. Article VIII, Sections 1, 2, 3, 6, 13, and 14 of the Alaska Constitution and Alaska Statues 38.05.127 and 38.05.128 are the legal basis for applying the public trust doctrine in the State.

3.8 WATER RIGHTS

Legislative authorities for NPS water rights in Alaska include the Alaska Water Use Act (Alaska Statute (AS) Title 46, Chapter 15), NPS Organic Act, ANILCA, and various park-specific enabling acts. The NPS will obtain and use water in accordance with these legal authorities. The NPS will consider authorities in Alaska law and Federal law on a case-by-case basis and will pursue those that are most appropriate to accomplish the purposes and protect water-related resources at DENA. While preserving its legal remedies, the NPS will work with State water administrators to protect park resources and, if conflicts amongst multiple water users arise, will seek their resolution through good faith negotiations.

The authority for the determination and adjudication of water rights is given to the ADNR by Section 46.15.010 of the Alaska Water Use Act, which issues water rights for various appropriations and for in-stream flow reservations. All surface and subsurface waters of Alaska are reserved to the people for the common use and are subject to appropriation pursuant to the Alaska Water Use Act (ADNR, 1981), excepting those specific waters that have been reserved pursuant to Section 46.15.145 of the Act or pursuant to a Federal reserved water right.
The NPS can hold each of the three different types of water rights in Alaska: State appropriative water rights, State in-stream flow or water level reservations, or Federal reserved water rights. These three types of water rights are described below, respectively.

3.8.1 State Appropriative Water Rights

The Water Use Act of Alaska enables the State to apply Prior Appropriation to both surface and subsurface waters: "Wherever occurring in a natural state, the water is reserved to the people for common use and is subject to appropriation and beneficial use and to reservation of in-stream flows and levels of water, as provided in this chapter" (AS 46.15.030).

A State appropriative water right is a legal right to use surface or ground water under the Alaska Water Use Act (AS 46.15). A State appropriative water right allows a specific amount of water from a specific water source, such as a river or aquifer, to be diverted, impounded, or withdrawn for a specific use. When a water right is granted, it becomes appurtenant to the land where the water is being used for as long as the water is being used. If the land is sold, the water right transfers with the land to the new owner, unless the conveyance document excludes water rights from the conveyance. The State uses the Prior Appropriation Doctrine to allocate water. This doctrine establishes a right to the use of water based upon "first in time, first in right." Water rights are given priority based upon the date of application.

3.8.2 State In-Stream Flow Reservations

Private individuals, organizations, and government agencies may apply for a reservation of water for in-stream use under Alaska State law. A reservation of water for in-stream use is a water right that protects specific in-stream water uses, such as 1) protection of fish and wildlife habitat, migration, and propagation; 2) recreation and park purposes; 3) navigation and transportation; and 4) sanitary and water quality purposes (AS 46.15.145). In-stream flow includes the amount, timing and duration of water in streams and rivers, natural lakes, wetlands and riparian zones. The State may issue a certificate for a reservation of water for in-stream use if they find that: 1) the rights of prior appropriators will not be affected, 2) the applicant has demonstrated that a need exists, 3) there is unappropriated water in the stream or body of water sufficient for the reservation, and 4) the proposed reservation is in the public interest. The State must review each certificate issued at least once every 10 years, and may revoke or modify the certificate if it is considered in the best interest of the State.

3.8.3 Federal Reserved Water Rights

The Federal reserved water right is a judicially-created water right – the result of a series of United States Supreme Court opinions dating back to 1907. The United States Supreme Court has held that where water is needed to fulfill the purposes of a reservation of Federal land, Congress intended (often implied) to reserve that amount of water needed to fulfill the purpose of the reservation.[1] Such reservations of water have been recognized for national forests,[2] national parks,[3] and national recreation areas[4]. A reservation of water is implied to meet only the "primary" purposes of the reservation; water needed for "secondary" purposes should be obtained through a state's appropriative system.[5]

In order to fully assess the existence and nature of a Federal reserved water right associated with DENA, an examination of the legislation creating DENA would be necessary. If needed to

[1] *United States v. New Mexico*, 438 U.S. 696,701 (1978).
[2] *Arizona v. California*, 373 U.S. 546, 601 (1963).
[3] *United States v. New Mexico, supra; Cappaert v. United States*, 426 U.S. 128 (1976).
[4] *Arizona v. California*, at 601.
[5] *Id.*, at 716.

fulfill the purposes of the Federal reservation, a Federal reserved right may be either for consumptive purposes (e.g., involving diversion of water from the stream) or for non-consumptive purposes (e.g., involving in-stream uses of water). A Federal reserved right associated with these purposes would be limited to that amount needed to accomplish those purposes. The effective date of a Federal reserved water right is the date the reservation was made.[1] While a Federal reserved water right ordinarily comes into existence upon the reservation of Federal land for a specific purpose, its existence can be confirmed, and its exact contours (i.e., purpose, amount, timing, source) ascertained, only through adjudication. Until such adjudication, the existence and contours of a Federal reserved right are a matter of estimation.

In 1952, Congress passed the McCarran Amendment, which consented to the joining of the United States in state suits determining the water rights of all users in a watershed.[2] This allows Federal reserved water rights to be determined in conjunction with state water rights. Once adjudicated, Federal reserved rights are recognized and may be administered through the state's water rights administrative system. No adjudications have been initiated by the State within the vicinity of DENA.

[1] See *Cappaert v. United States*, 426 U.S. 128, 147 (1976).
[2] 43 U.S.C § 666.

SECTION 4.0
CHARACTERIZATION

4.1 PARK LOCATION AND DESCRIPTION

DENA consists of approximately 6 million acres of land in the central interior of Alaska, approximately two-thirds of which were added with the passage of the Alaska National Interest Lands Conservation Act (ANILCA) in 1980. DENA is located directly west of the Nenana and Chulitna Rivers, and includes portions of the Denali and Matanuska-Susitna boroughs. Lands to the west and north of the park fall within the Iditarod and Yukon-Koyukuk Census areas, respectively, which do not have organized borough governments.

The BLM and the State of Alaska administer the majority of lands surrounding the park. The Denali State Park abuts DENA on it southern border with a common border of roughly 48 miles. The entrance area to DENA is located about 235 miles north of Anchorage and approximately 120 miles south of Fairbanks along the George Parks Highway (Alaska Highway #3). Small towns border DENA, including Healy, Cantwell, and Minchumina (see **Figure 4.1-1**). Section 4.4.5, Land Ownership, below provides a detailed breakdown of land ownership within and surrounding DENA.

The park was established as Mt. McKinley National Park on February 26, 1917. In 1980, 4 million acres was added to the park, the original 2 million acres was designated wilderness, and the park's name was changed to Denali National Park and Preserve. In 1976, the park was designated an international biosphere reserve. DENA provides one of the few intact and naturally regulated subarctic ecosystems in the world because of its long history and substantial size. Landscape scale processes such as fire, succession, and outbreaks of disease have not been significantly altered by human intervention. These components and processes of the system are still responding naturally to other primary processes, such as weather or geologic events.

DENA features North America's highest mountain, 20,320-foot tall Mount McKinley. The Alaska Range also includes countless other spectacular mountains and many large glaciers. Permafrost underlies many areas of the park, where only a thin layer of topsoil is available to support life. After the continental glaciers retreated from most of the park 10,000 to 14,000 years ago, hundreds of years were required to begin building new soils and revegetating the landscape. The dynamic glaciated landscape provides large rivers, countless lakes and ponds, and unique landforms, which form the foundation of the ecosystems that thrive in DENA.

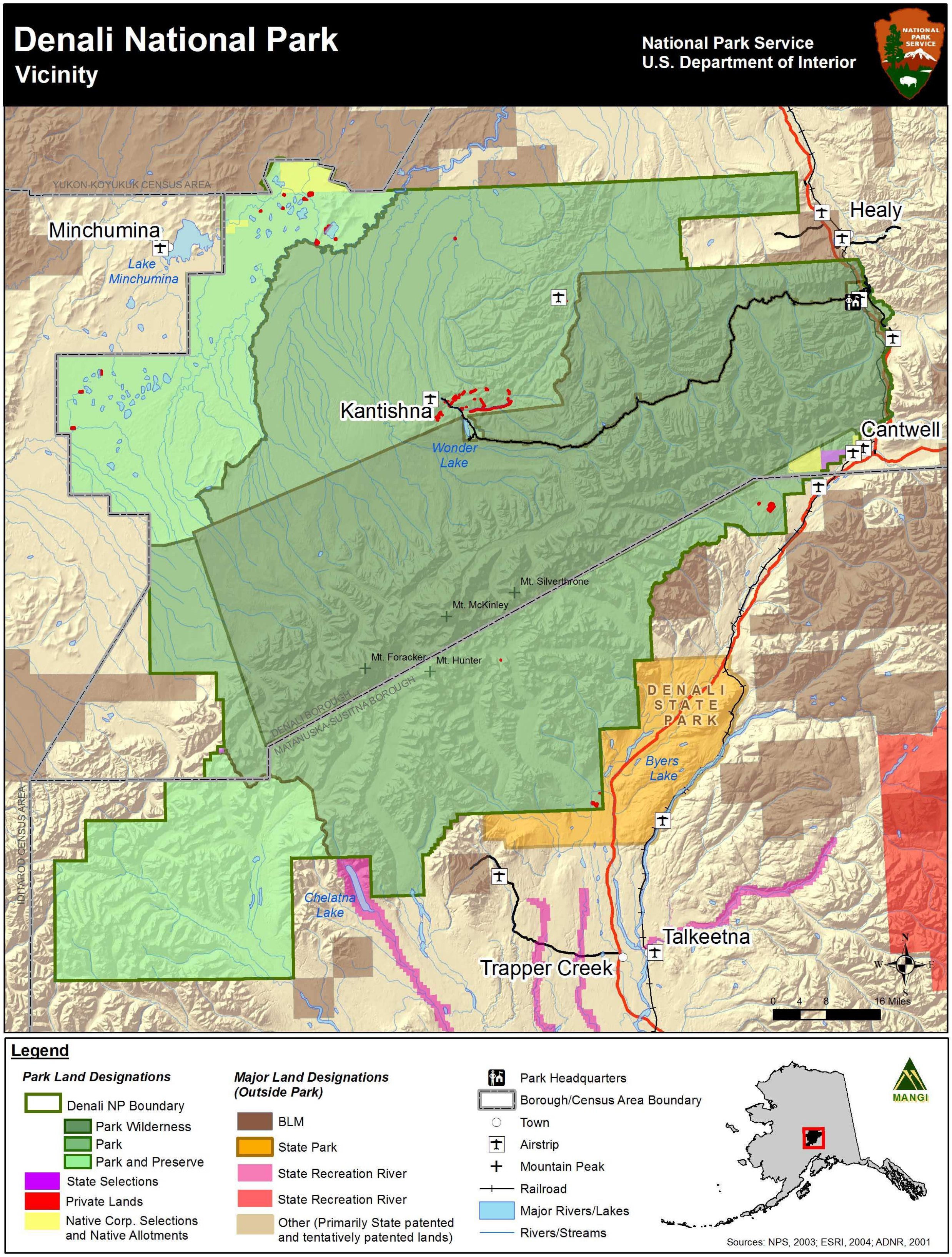

Figure 4.1-1. Denali National Park and Preserve Vicinity and Land Ownership

4.2 PHYSICAL RESOURCES

4.2.1 Climate

General Patterns

DENA straddles two major climatic zones of Alaska — the transitional maritime zone south of the Alaska Range and the continental zone in the Interior north of the range (NPS 2003e). The south side of the park falls within the transitional maritime climate zone. In this zone, climate is governed by the weather patterns of the Aleutian Low, moderating air temperatures and bringing considerable precipitation in the form of rain and snow to the south (windward) side of the Alaska Range. In contrast, climate conditions on the north side (leeward) of the Alaska Range support a continental interior climate regime, where temperature extremes are generally colder in winter and warmer in summer. The Alaska Range exerts a major influence on the climate of the Interior by blocking much of the moisture that sweeps inland from the Gulf of Alaska (Sousanes, 2002). The effect of the Alaska Range on climate (most notably precipitation) serves as a defining factor driving hydrologic conditions on the north and south sides of DENA.

Latitude and altitude are other major climatic forces in the park. Latitude plays a major role in climate conditions, since solar radiation fluctuates significantly between summer (with up to 21 hours of solar radiation) and winter (with only 4 hours of solar radiation). Latitude also affects seasonal changes in precipitation due to varying exposure to latitudinal belts of high and low pressure. A polar high pressure belt, known as the Arctic High, and Sub Polar low pressure belt, known as the Aleutian Low, shift south during winter and north during summer. These shifts provide much of the precipitation that falls on the north side park during the summer months (Sousanes, 2002). Changes in temperature, atmospheric moisture, precipitation, wind, pressure, and solar radiation also vary with elevation (Sousanes, 2002). DENA has a wide range of elevations ranging from low points of approximately 400 feet to over 20,000 feet at the peak of Mt. McKinley.

The following map (**Figure 4.2-1**) shows zones of equal annual precipitation in and around DENA. The map was prepared in 1994 as part of a flood frequency study of the streams and rivers of Alaska, and later published in GIS format (USGS, 1997). Precipitation values for each zone were set to equal the average value of their bounding lines of equal annual precipitation. Because the precipitation map was developed using a relatively small number of precipitation stations, has large intervals between contours of equal annual precipitation, and was originally prepared on a 1:2,000,000 scale, caution should be used when interpreting values. The map is presented here to provide graphic representation of the general precipitation patterns described above.

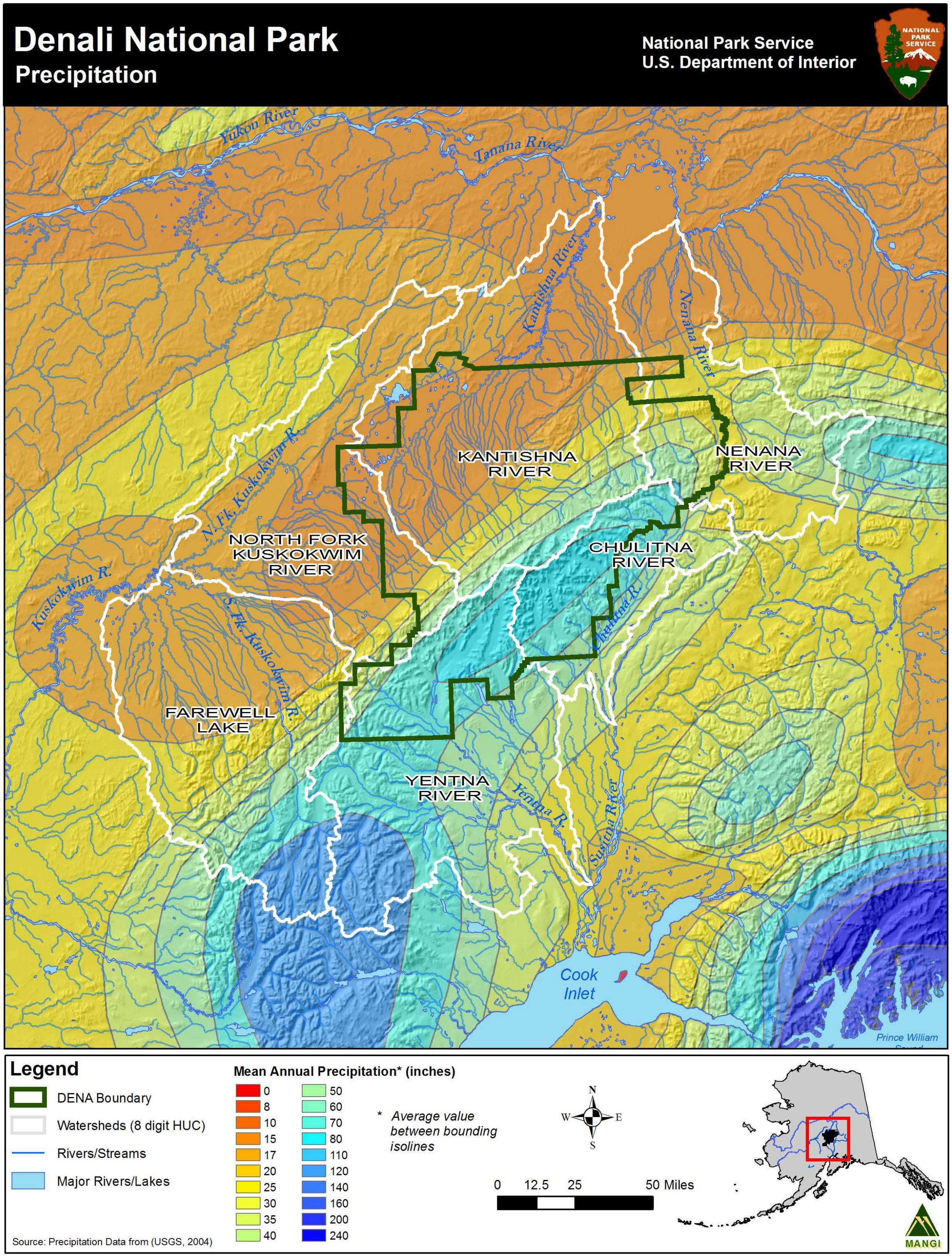

Figure 4.2-1. Precipitation Patterns at DENA

DENA Observations

Daily weather observations, including minimum and maximum temperature and precipitation amounts, have been recorded at park headquarters since 1923. Temperature extremes at this location range from 91ºF to –54º F. The average maximum temperatures at park headquarters are 11º F for January and 66º F for July. The average minimum temperatures for the same months are –7ºF and 43ºF, respectively. Temperatures generally decrease with increasing elevation, except in winter, when there are often temperature inversions with colder air flowing down the mountains and settling into valley bottoms (NPS, 2003e).

The average annual precipitation taken from the long-term climate station at park headquarters on the lee side of the Alaska Range is about 15 inches, including an average annual snowfall of 81 inches[1]. There are no long-term temperature or precipitation records for the park south of the Alaska Range. However, Talkeetna, roughly 100 miles southwest of park headquarters, has an average annual precipitation amount of 28 inches, with 120 inches of average annual snowfall. At higher elevations and on the windward slopes of the Alaska Range, precipitation amounts in both the summer and winter are greater. There are Natural Resource Conservation Service (NRCS) aerial snow markers immediately adjacent to the southern boundary of the park which have been surveyed since 1980. March 1 average snowfall depths for sites in the Tokositna Valley are 67 inches with 15.7 inches of Snow Water Equivalent (SWE) in the lower valley and 76 inches with 23 inches SWE at 3,000 feet.

4.2.2 Physiographic Regions

DENA falls within five major physiographic sections: the Interior Alaska Range, South Central Alaska Range, Cook Inlet Lowlands, Yukon-Kuskokwim Bottomlands, and the Kuskokwim Mountains (**Figure 4.2-2**). The Alaska Range (Interior and South Central) and Yukon-Kuskokwim Bottomlands ecoregions comprise most of the park. The Cook Inlet Lowlands occur along stream bottomlands in the Yentna and Chulitna River watersheds on the South Side of the Alaska Range. Small areas in the northwest corner of the park lie within the Kuskokwim Mountains ecoregion (Clark and Duffy, 2004).

The major physiographic elements of DENA are mountains and hills (the Alaska Range, Tokosha Mountains, Kichatna Mountains, Kantishna Hills, and Wyoming Hills) and lowland basins (the Toklat Basin and Yukon-Kuskokwim Bottomlands north of the Alaska Range, and the Cook Inlet lowlands south of the Alaska Range). The Alaska Range exerts strong influences on temperature, precipitation and wind patterns (and other climatic factors) throughout the region, which in turn strongly affect the physical environment for plants and the processes of mineral weathering that provide the substrate for plant life. Rivers and streams are common in the mountains and hills, such as the silt-laden glacial streams of the Alaska Range and non-glacial streams in the lower elevation hills. Permafrost is the defining element of the Toklat

[1] Snowfall is reported here as the sum of snowfall *depth* measurements. Snowfall samples are then melted and measured in liquid form to determine their precipitation equivalent (on average, 1” of snow derived precipitation is equal to 10” of measured snowfall depth). (NOAA, 1996)

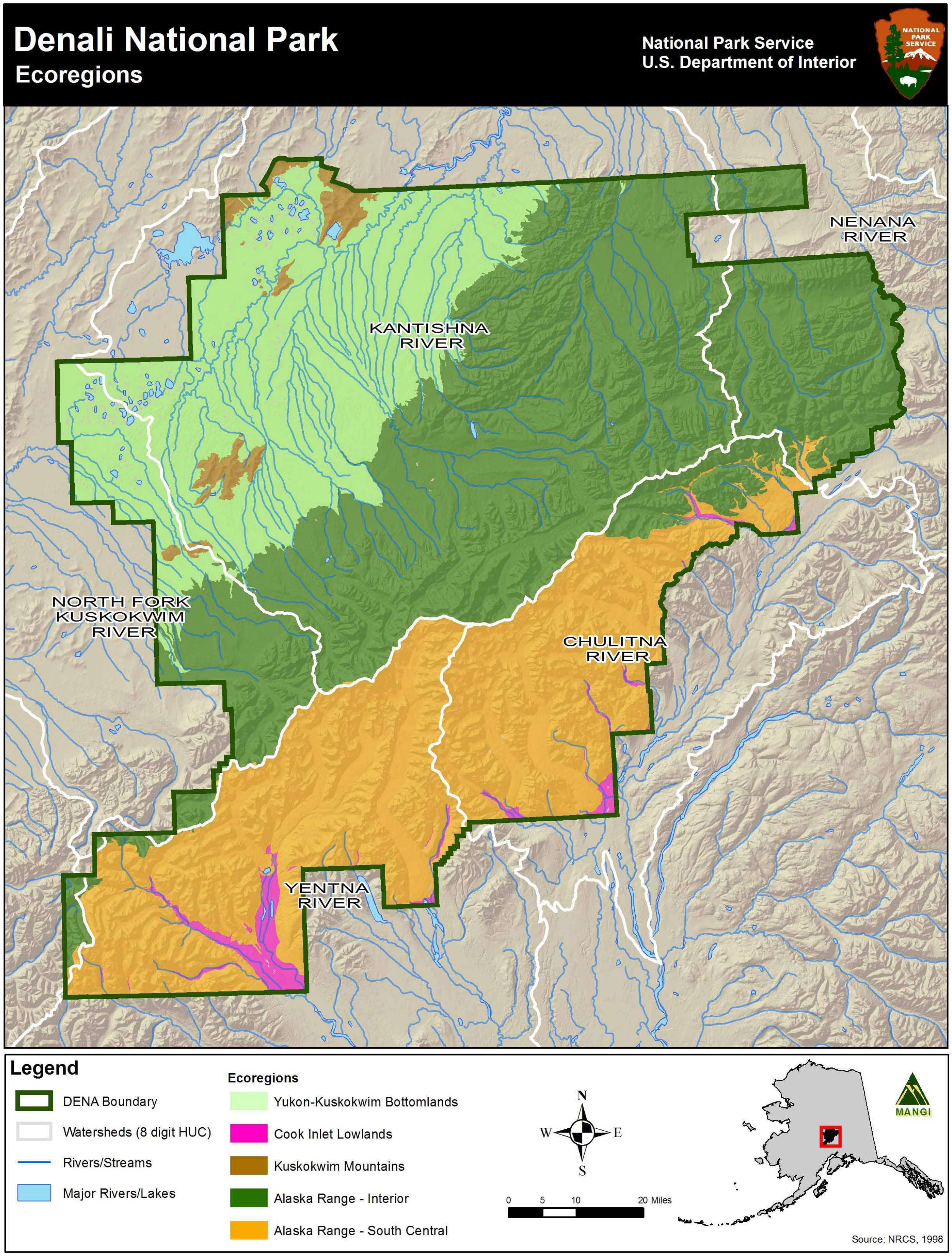

Figure 4.2-2 Major Ecoregions of DENA

Basin. The Minchumina Basin landscape is a mosaic of ponds, wetlands, and forested lowlands. Streams flowing off of the mountains crisscross the entire area and numerous small and shallow subarctic ponds dot the landscape of the Yukon-Kuskokwim lowlands. The Cook Inlet lowlands are dotted with wetlands and small lakes in kettles and other depressional features and old oxbows of rivers.

4.2.3 Geology

DENA consists of three rock provinces, which are closely associated with bedrock types and geochronology. The largest province, the Yukon-Tanana Terrane, includes most of the northern half of the park, where the oldest, most highly altered marine and volcanic rocks underlie smaller pods or veneers of Quaternary and Tertiary sediments (Clark and Duffy, 2004). These rocks formed from shallow sediments that were buried with volcanic flows and intrusions approximately 400 million years ago. Extended subjection to heat and pressure changed them into metamorphic rocks, such as schists, gneiss, and phyllites (NPS, No date [b]). The Pingston/McKinley Terranes are found along the Alaska Range Crest and are slightly younger and less altered marine sediments. They are pierced and covered in places by much younger granitic and volcanic rocks. Younger still is the Kahlitna Terrane that includes the majority of rocks in the southern half of the park, where the highest peak, Mt. McKinley and other mountains consisting of plutonic rocks, have intruded into shallow marine sediments (Clark and Duffy, 2004). This area of the park has undergone extensive glacial modification and is still largely occupied by large glacial systems (NPS, 1998a).

The Denali fault system bisects these rock provinces and separates the park into northwest and southeast halves. The southern half of the park, consisting of the crest of the Alaska Range and most of the highest elevations of the park, is a much younger terrane dominated by late Paleozoic to Mesozoic marine sediments and plutonic rocks. The Denali fault system runs along the north flank of the Alaska Range, which began to be uplifted approximately 35 to 65 million years ago. The relief to the north of the fault is not as rugged as that to the south, and the entire northwest portion of the park is dominated by Quaternary surficial deposits (NPS, 1990).

Sedimentary rocks exposed in the Alaska Range take the form of a syncline having Cretaceous rocks exposed near the center of the syncline. Faults related to the Denali fault system parallel the range. Coinciding with the start of the uplift of the Alaska Range, Tertiary sedimentary and/or volcanic rocks began to be deposited in the area; most of these rocks outcrop in the northeastern portion of the park. During this period, a series of granitic intrusions within the Alaska Range also began. Most of the mineral deposits in the park are related to this period of tectonic activity (NPS, 1990).

The Kantishna Hills area experienced a rapid uplift during the Quarternary period. The northeasterly trend of the region parallels the structural grain of basement metamorphic rocks. The Kantishna Hills lie several miles north of the Alaska Range and are separated from the higher terrain of the Alaska Range by the McKinley River and the Clearwater Fork of the Toklat River. Two of the most significant rock units in the Kantishna Hills are the Pre-Cambrian to early Paleozoic Birch Creek schist and the early Paleozoic Spruce sequence. The Birch Creek schist is exposed throughout most of the area and consists of variable amounts of quartzite, quartz-mica schist, marble, and greenstone. The Spruce Creek sequence is composed of chlorite and graphitic schist, marble, and metavolcanic rocks. Mineralized vein-faults are of variable size and can be divided into gold-, silver-, and stibnite (antimony)-dominant. Eighty percent of these vein deposits lie in the Spruce Creek sequence (NPS, 1990).

DENA is located in one of the most seismically active regions of Alaska and North America. This region is part of the larger seismically active arc called the Ring of Fire, which follows the coastline of the North Pacific. Seismic activity is caused by the collision of the Pacific tectonic plate into the North American Continental plate along the northern Pacific coastline. Numerous small faults occur on the south side of the Alaska Range as part of the Denali fault complex, which arcs east-west through the park, and through most of the State, for a total of 720 miles (NPS, 2003e). While these small faults may not cause major earthquake activity by themselves, they are susceptible to movement as a result of activity in other adjacent areas (NPS, 1986).

4.2.4 Soils

Soil types within DENA vary widely as a result of differing parent materials, topography, climate, and vegetative cover. The soils can be generally classified as mountain and tundra soils, bog soils, and forest soils (NPS, 1986). Mountain and tundra soils form directly from bedrock and the slow accumulation of organic matter. These soils can be highly undeveloped, and their sparseness is attributable to cold weather extremes and slope steepness. Bog soils, or histosols, are poorly drained organic soils formed in depressions or other low lying areas, and consist of plant material and peat layers that have accumulated through time over the moraine clay and glacial moraine parent material. Forested areas within the park range from undeveloped to well-developed, and are typically characterized by clay dominated soils covered with humus layers supporting mosses and lichens (NPS, 1986).

Figure 4.2-3 depicts the types and locations of permafrost, or perennially frozen ground, in DENA. Continuous, discontinuous, and sporadic permafrost is most prevalent in the Yukon-Kuskokwim Bottomlands, Alaska Range, and Kuskokwim Mountain ecoregions on the north side of the Alaska Range. Permafrost is extensive in these areas on loamy textured soils and occasionally occurs in gravelly alpine soils. In many places permafrost exists as small ice crystals, lenses, and seams in the soil, whereas in others, permafrost exists as massive ice features several meters thick (Clark and Duffy, 2004). The extent and thickness of permafrost is not known for the entire park; however, thicknesses of up to 100 feet have been recorded near the eastern park entrance.

Permafrost is highly sensitive to changes in thermal regime. Fires or other disturbances can remove insulating vegetation and result in warming of the permafrost and an increase in the thickness of the active layer - the surface that seasonally thaws. As the permafrost thaws, a large volume of water is liberated from the soil and either accumulates in local depressions or runs off through surface or subsurface drainage. Melting permafrost is especially susceptible to erosion, sagging, and other surface movement. The term “thermokarst” describes a landform developed when permafrost is partially or totally melted. The extent of thermokarst depends on soil texture,

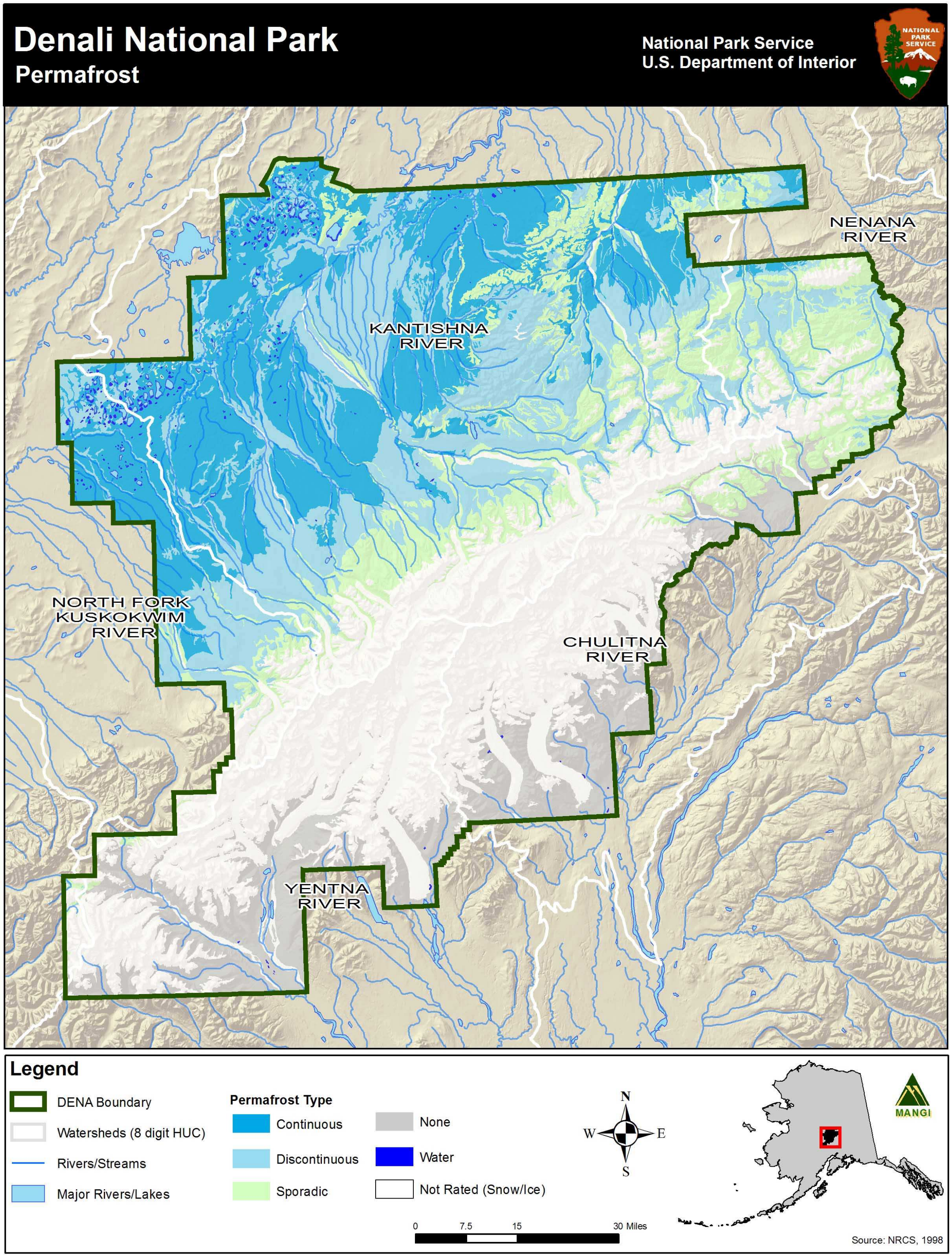

Figure 4.2-3. Permafrost at DENA

ice content, air and soil temperatures, and degree of disturbance. Thermokarst can be highly detrimental to buried cables and utility lines, paved surfaces, roadbed foundations, buildings, and other developments (NPS, 1998a).

4.2.5 Hydrology

Surface Water

Glaciers and Ice

Glaciers are an important water resource in Alaska because they are naturally regulated reservoirs that reduce runoff variability by increasing flow during hot, dry periods and by storing water as ice and snow during cool, wet periods (Fountain et al., 1997). Glaciers affect the hydrology of glacier-fed streams in DENA by controlling seasonal discharges and rates of flow. During peak melting of glaciers in early summer, streams become a torrent, often flooding the valley below, whereas in winter, discharge is reduced to a mere trickle or is locked solid (Weeks, 2003). Water impounded by glaciers present a potential flood hazard because water is often released catastrophically, flooding the valleys below without warning. The internal processes of glaciers that affect daily and seasonal variations in water storage and release are unclear, although it is known that subglacial water flow is coupled to glacier movement (Fountain, 2000). Glacier outflow and sediment characteristics appear to determine the overall productivity and structure of biological communities in glacier-fed streams. Changes in glaciers affecting outflow to streams can greatly influence the local and regional hydrologic regime (NPS, 1998a).

Glaciers cover approximately 17 percent, or 1 million acres of DENA, and exist on both sides of the Alaska Range in 2 different climate regimes. Glaciers flow away from the mountains from as high as 19,000 feet and descend to elevations as low as 800 feet above sea level. Hundreds of the glaciers in DENA are unnamed (NPS, No date [f]). A list of some of the major glaciers found on the north and south side of the Alaska Range in DENA is presented in **Table 4.2-1**. Glaciers tend to be larger and longer on the south side of the range than on the north (NPS, 1986). The Ruth, Kahiltna, and Muldrow Glaciers are the longest glaciers in the park. The 44-mile long Kahiltna Glacier is also the longest glacier in the entire Alaska Range within the park (NPS, No date [f]).

Table 4.2-1. Major Named Glaciers on North and South Side of Alaska Range

South Side	North Side
Dall Glacier	Chedotlothna Glacier
Yentna-Lacuna Glacier	Herron Glacier
Kahiltna Glacier	Foraker Glacier
Kanikula Glacier	Straightaway Glacier
Tokositna Glacier	Peters Glacier
Ruth Glacier	Muldrow Glacier
Buckskin Glacier	Traleika Glacier
Eldridge Glacier	Brooks Glacier
	Sunset Glacier
	Toklat Glacier
	Surprise Glacier

There are two major types of glaciers in DENA: those that exhibit long-term steady flow and those that undergo periodic surges. Both types are found on the south and north sides of the Alaska Range. Surge-type glaciers alternate between brief periods of rapid flow lasting 1 to 4 years and extended periods of quiescence, lasting 10 to 100 years. Surge-type glaciers in DENA include Muldrow, Peters, Tokositna, Straightaway, Lacuna-Yentna, Herron, West Fork Eldridge, and Chedotlothna (NPS, 1998a). The Muldrow Glacier last surged in 1956 and advanced nearly 2.5 miles (NPS 2004a). Glacier surges typically have a significant effect on flow, sediment load, and chemistry of receiving streams (NPS, 1998a) and can cause devastating floods by blocking and suddenly releasing large quantities of melt water (Meier, 1976).

Icing, or ‘aufeis,’ formations are another ice derived factor affecting hydrologic processes. Aufeis formations occur as a result of the successive freezing of sheets of water derived from groundwater discharge or from the upwelling of river water through contraction cracks in seasonal ice cover or behind ice dams. Icings often develop along high elevation streams when they freeze solid and block ground-water discharge into the channel. Eventually, incremental rises in the local water table result in discharge either through contraction cracks in the seasonal ice cover and/or along the river bank over the top of the previously formed ice. This process can result in aufeis formations several meters thick extending beyond the stream channel. Formations of this sort can affect ice breakup processes in the spring, displacing flood flows and altering breakup scour processes (Prowse and Culp, 2003). Icings in the Alaska Range have been noted as more numerous on the north flank of the Alaska Range, commonly occurring in finely braided floodplains and in shallow stream reaches (Dean, 1984; Reger et al., 2003).

Icings occurring on or near travelways such as the Park Road can significantly impact access and increase maintenance needs. In a recent study of icings on the park road, four icing locations were noted between 6.7 and 10.9 km of the intersection of the Park Road and Highway 3 resulting in maintenance problems and hindering access into the park (Vinson and Lofgren, 2003). These icings were derived from a combination of water sources including springs, groundwater seepage, and nearby streams.

Rivers and Streams

Rivers and streams at DENA can be broadly categorized as either glacially fed or non-glacially fed. The contribution of glaciers to runoff in Alaska is considerable, and even modest contributions of glacial runoff to stream flow markedly affect the channel dynamics and flow regimes of streams and rivers (Oswood, 1997). Streams of glacial origin are often characterized by shallow, swift flows over gravel beds, and are silty, braided, and have wide gravel floodplains filling mountain valleys (NPS, 2003e). Glacier-fed rivers generally have pronounced daily and seasonal stream flow fluctuations, with large year-to-year fluctuations in flow (**Figure 4.2-4**). Typical glacial stream and river discharge in winter is very low to absent, then flows begin to rise in early May with increased solar radiation and reach a summer peak at maximum glacier melt. Discharge declines following the onset of freeze-up in November and December (Milner and Petts, 1994; Milner et al., 1997). In contrast, non-glacial streams rise rapidly following ice breakup in early May, reaching a peak flow during breakup snowmelt by late May. An additional peak is often observed in these streams as a result of late summer storms (Milner and Petts, 1994; Milner et al., 1997). This latter non-glacial stream flow characteristic has been shown in studies of the Rock Creek watershed in DENA as part of the Long-Term Ecological Monitoring Program. Peak discharge often occurs in Rock Creek between early May and mid June, and represents melt of snowpack storage during a spring leafless period, before trees and shrubs begin to transpire. Frozen soils, combined with near maximum incoming solar radiation, induce the quick and flashy nature of the spring runoff. However, large precipitation events later in the summer, during the cool wet months of July and August, can also induce large flashy stream flow peaks (Karle and Sousanes, 2000). The hydrographs of Healy Creek (1998-2001) and Rock Creek (1998) show the peak of summer rain events exceeding snow melt discharge (**Figure 4.2-5**). On the north side of the Alaska Range, prominent non-glacial streams include Bearpaw River, Clearwater Fork, Moose Creek, Savage River, and the Sushana River which have extensive watersheds in the foothills of the Alaska Range. On the south side, non-glacial streams are limited to smaller headwater streams in the Alaska Range (NPS, 2003e).

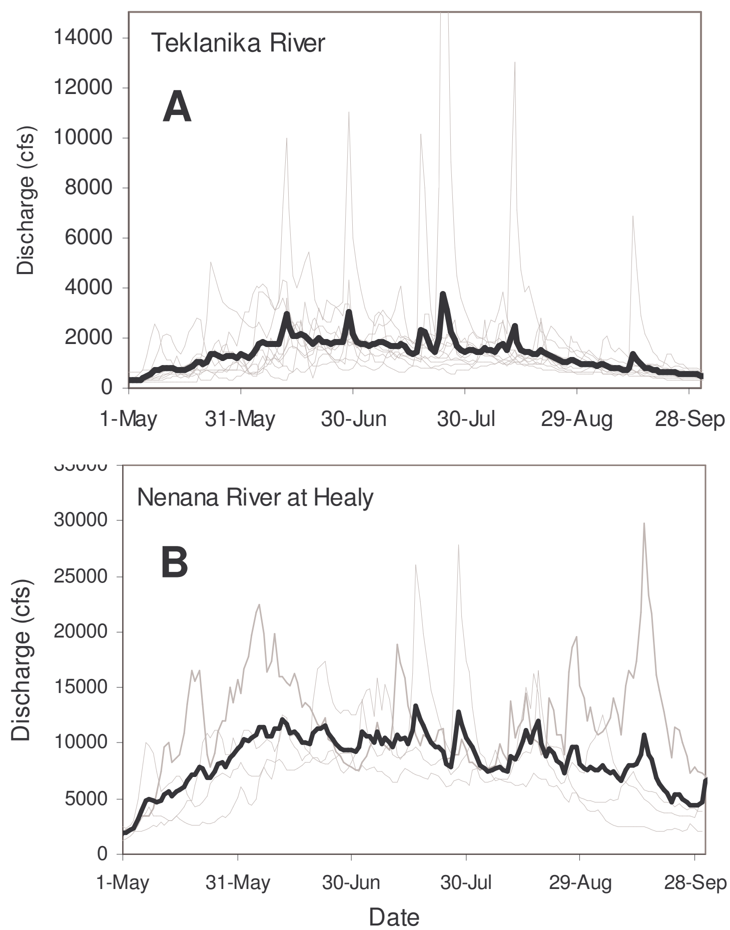

Figure 4.2-4. (**A**) May to October Hydrograph for the Teklanika River (1964 – 1974) (**B**) May to October Hydrograph for the Nenana River at Healy, AK (1990 - 1991, 2000 - 2001). Gray lines represent individual hydrographs. The average daily value is also presented (black line).

The relative proportion of rain or snow precipitation, as well as the persistence of snow throughout the year, has an effect on the seasonal flow regimes. Although these factors affect all streams, they have a dominant effect on clear streams, in which flows are more directly driven by precipitation. Like glaciers, snow serves as a reservoir of water that can be released throughout the summer warming months, and therefore, the release of this water is highly dependent on the energy supplied by solar radiation and air temperature. Most annual floods occur as a result of springtime melting of the winter snowpack. In clear streams farther from maritime influence, the fall peak is typically smaller and occurs earlier, and streams do not return to baseflow during the summer season due to a prolonged snowmelt season (Milner and Petts, 1994; Milner et al., 1997). Precipitation falling as rain typically occurs in the late summer, and since more water can often be produced in a one-day rain event as compared to an intense snowmelt event, the highest floods of records will most often be associated with extreme rainfall events (Yang et al., 2000).

Stream flows are also influenced by permafrost, which exists north of the Alaska Range in the Kantishna, Nenana, and North Fork Kuskokwim watersheds. Permafrost has a very low permeability and commonly acts as a barrier to infiltration, limits subsurface storage, and acts as a confining layer to aquifers. Summer precipitation falling on soils underlain by permafrost moves quickly through the unfrozen active layer and flows over permafrost to the stream; short-circuiting the groundwater portion of the hydrologic cycle. Because of this characteristic, streams draining permafrost areas typically exhibit a 'flashy' hydrograph in response to storms, and are therefore prone to flash flooding (Oswood, 1997; NPS, 2003e). Due to a limited ability to provide subsurface water storage, base flow levels between precipitation events are often lower in permafrost watersheds than in non-permafrost watersheds (Bolton et al., 2000). At the same time, the melting of the permafrost may increase recharge of aquifers, thus increasing base flow in streams. By increasing summer recharge, melting of permafrost can also decrease summer peak flows (Brabets et al., 2000). These effects are a concern when considering current trends in climate change (See Section 4.10, *Climate Change*).

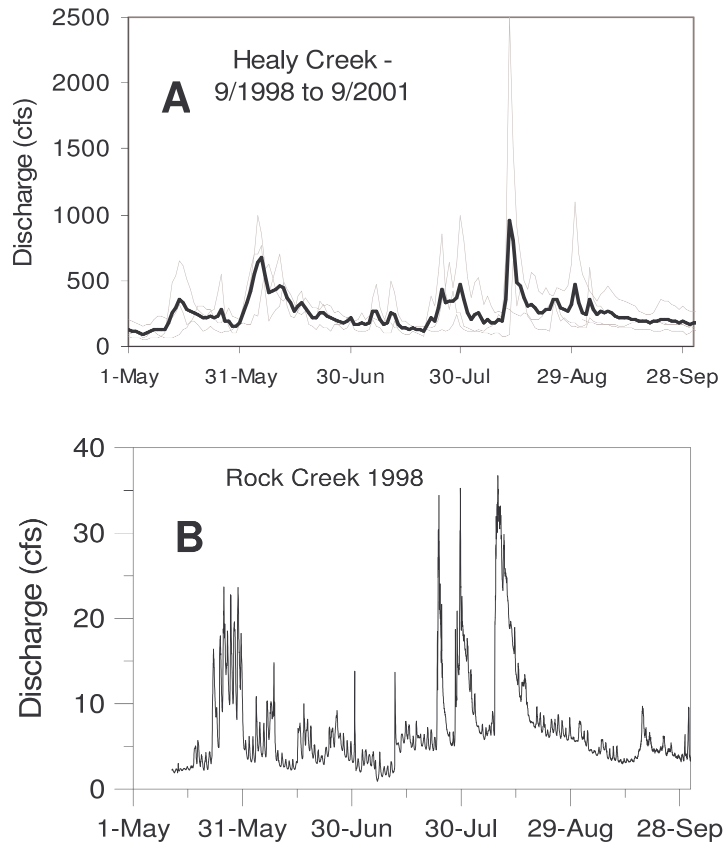

Figure 4.2-5. Hydrographs of Healy Creek for the years 1998 -2001 (**A**) and Rock Creek for 1998 (**B**). (USGS, 2005) and (Karle and Sousanes, 2000), respectively. (A) Gray lines represent individual hydrographs from 1998-2001. Black line represents the average daily flow for the period of record.

Lakes and Ponds

There are thousands of lakes in DENA, most of which are small, unnamed tundra ponds. Lakes and ponds are common in the lowland areas north of the Alaska Range, in the broad floodplains and valleys south of the Alaska Range, and at higher elevations often associated with glaciers. The highest concentrations of lakes and small ponds occur in the lowlands north of the Alaska Range in areas of continuous and discontinuous permafrost. The most recent available data (USGS, 2005a) suggests that there are over 12,000 lakes and ponds at DENA, with over 60 percent less than or equal to 2 acres in size and 30 percent between 2 and 10 acres in size. These numbers are likely underestimated due to the limitations in identifying smaller lakes and ponds at the 1:1,000,000 mapping scale. Large lakes are less common and are often formed by glacier scouring, oxbows, and landslides. Some of the major named lakes include Wonder Lake and Horseshoe Lake. Wonder Lake is a classic steep-sided glacial trough reaching a depth of 250 feet. The lake was once completely inundated by the Muldrow Glacier (Werner, 1990).

Lakes in the northern continuous and discontinuous permafrost are *thaw lakes*, formed where thermokarst processes melt ground ice and the overlying soil collapses below the water table. Water accumulates in the resulting depression and the warm water deepens the active layer under the pond or lake. These lakes are often small, typically shallow, and freeze to the bottom in the winter (Milner et al., 1997). Because of their unique sensitivity to climate and its associated changes in hydrology, inventory and monitoring efforts have recently been proposed to monitor shallow lakes in the Central Alaska Network (CAKN) (Larsen et al., 2004).

Lakes associated with glaciers are also common at DENA, and based on the most recent available data, are most common along glaciers on the south side of the Alaska Range. These lakes can be formed as a result of numerous glacial processes, and can form on the base of the glacier, be entrapped between the glacier and side of the glacier's valley, be formed in the valley of a tributary that becomes blocked by an advancing glacier, or occur in front of a glacier as a result of a damming feature preventing runoff movement downhill (such as a glacial moraine) (Gangadean, 2000). Periodic release of these lake waters is of particular concern, as many glacial lakes exhibit a cycle of filling and discharge, wherein the stage of the lake reaches a critical level that either initiates discharge over the top of the natural dam, or causes failure and a resulting breakout flood event that can create hazardous conditions for areas downstream (Gangadean, 2000).

Lakes receiving the highest use are Wonder Lake, located near Kantishna at the end of the Park Road, and Horseshoe and Triple Lakes, in the frontcountry near the park headquarters (NPS, 2003e). Several studies have been conducted at Wonder Lake on its bathymetry (Werner, 1990) and sediments (Werner, 1990; Child and Werner, 1993; Child and Werner, 1999), and water quality assessments are currently proposed (NPS, 2004f).

Wetlands

Wetlands are found extensively throughout DENA; however, there has been no park-wide wetland inventory or mapping project conducted to date. In general, Alaska has more wetlands – approximately 170 million acres – than the total area of wetlands in the other 49 States combined (USGS, 1996). U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) maps have only been completed for 27 of the 50 U.S. Geological Survey (USGS) quadrangles covering the park. **Table 4.2-2** below lists these quadrangles and their NWI status.

Table 4.2-2. NWI Status of DENA Quadrangles

Quad Name	Status of NWI	Quad Name	Status of NWI
HEALY A-5	Digital	MT MCKINLEY C-2	Digital
HEALY A-6	Digital	MT MCKINLEY C-3	Digital
HEALY B-4	Digital	MT MCKINLEY C-4	*None*
HEALY B-5	Digital	MT MCKINLEY C-5	*None*
HEALY B-6	Digital	MT MCKINLEY C-6	*None*
HEALY C-4	Digital	MT MCKINLEY D-1	Digital
HEALY C-5	Digital	MT MCKINLEY D-2	Digital
HEALY C-6	Digital	MT MCKINLEY D-3	*None*
HEALY D-4	Digital	MT MCKINLEY D-4	*None*
HEALY D-5	Digital	MT MCKINLEY D-5	*None*
HEALY D-6	Digital	TALKEETNA B-3	Digital
KANTISHNA RIVER A-3	Digital	TALKEETNA B-4	Digital
KANTISHNA RIVER A-4	*None*	TALKEETNA B-5	*None*

MT MCKINLEY A-1	*None*	TALKEETNA B-6	*None*
MT MCKINLEY A-2	*None*	TALKEETNA C-1	Digital
MT MCKINLEY A-3	*None*	TALKEETNA C-2	Digital
MT MCKINLEY A-4	*None*	TALKEETNA C-3	Digital
MT MCKINLEY A-5	*None*	TALKEETNA C-4	Digital
MT MCKINLEY B-1	Digital	TALKEETNA C-5	*None*
MT MCKINLEY B-2	Digital	TALKEETNA C-6	*None*
MT MCKINLEY B-3	Digital	TALKEETNA D-1	*None*
MT MCKINLEY B-4	*None*	TALKEETNA D-2	Mylar
MT MCKINLEY B-5	*None*	TALKEETNA D-3	*None*
MT MCKINLEY B-6	*None*	TALKEETNA D-4	*None*

Source: Noon, 2005

Seasonally flooded tall shrub wetlands can be found in association with glacial outwash drainages and fans. Willows and alders dominate these wetlands. Occasionally, small ponds and wet sedge meadows also can be found in alpine valleys. At lower elevations and in valley bottoms, scrub shrub and forested wetlands have developed where alluvial and loess deposits have accumulated (NPS, 2003e). Wetlands are sometimes underlain by permafrost, which helps form and maintain wetlands from retention of snowmelt and rain at the surface. Spring snowmelt supplies most of the annual water budget in most wetlands (USGS, 1996).

The scrub shrub wetlands in DENA are primarily composed of dwarf birch, willows, Labrador tea (*Ledum decumbens*), bog blueberry, mountain cranberry (*Vaccinium vitis-idaea*), and sphagnum moss. The forested wetlands are dominated by black spruce, dwarf birch, Labrador tea, blueberry, and sphagnum moss. Scrub shrub and forested wetlands are sensitive to disturbance because of concern over disrupting the underlying permafrost, changing the thermal regime and promoting the development of impoundments. The difficulty in traversing these areas because of their wetness, however, limits extensive human use of these areas. Tall shrub wetlands are less sensitive to activities that may damage vegetation (e.g., trampling associated with foot traffic and camping, snowmobiles) because they are adapted to a disturbance regime (seasonal flooding) (NPS, 2003e).

Wetlands in Alaska have important hydrologic and water quality functions, including flow regulation, erosion control, sediment retention, nutrient uptake, and contaminant removal. Wetlands with seasonally or perennially frozen soils have limited flood control or water storage functions during snowmelt; however, they help reduce peak flows through detaining water behind hummocks and within depressions, ponds, and lakes, and decrease flow velocity through wetland vegetation. During higher summer temperatures, the thickness of permafrost decreases and the capacity of wetland soils to store water increases. In permafrost areas, wetland vegetation also reduces erosion by preventing the warming and thawing of ice-rich soils. Wetland vegetation in floodplains can help remove suspended sediment by slowing water velocities (USGS, 1996).

In August and September 2001, a wetland delineation was conducted on 11 potential gravel acquisition sites (New Teklanika Pit; Old Teklanika Pit; East Fork Cabin; Beaver Pond; Old Boundary; North Face Corner; Moose Creek Terrace 1, 2, and 3; Camp Ridge; and Kantishna Airstrip) along the corridor of the Park Road (NPS, 2002e). Wetland boundaries were delineated using the Routine Determination method specified in the U.S. Army Corps of Engineers (USACE) Wetland Delineation Manual. Wetland functional assessments were also conducted using the USACE's Reppert Method (1979). A total of approximately 19 acres of wetlands were estimated on the sites. Most of the wetlands were classified as palustrine scrub-shrub broad-leaved deciduous or mixed palustrine scrub-shrub and needle-leaved evergreen characterized by low and dwarf scrub vegetation types with no or relatively few trees. Dominant shrubs included birch, willow, and various members of the Ericaceae family. These wetlands are common throughout the park and appear to provide low to moderate functions, primarily because of their proximity to the Park Road (NPS, 2002e). In addition, based on Ken Karle's *End of Season Report* (Karle, 2000), two projects he participated in included USFWS wetlands mapping of transportation corridors and several USACE projects involving wetlands.

Major Watersheds

The United States is divided and sub-divided into successively smaller hydrologic units, which are classified into four levels: regions, sub-regions, accounting units, and cataloging units (also referred to as watersheds). The hydrologic units are arranged within each other, from the smallest (watersheds) to the largest (regions). Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to eight digits based on the four levels of classification in the hydrologic unit system (Seaber et al., 1987).

DENA falls within the Alaska Region, and covers three different hydrologic sub-regions: the Northwest Alaska, Southwest Alaska, and Yukon. Within these three hydrologic sub-regions there are six watersheds: Chulitna River, Nenana River, Kantishna River, Yentna River, North Fork Kuskokwim River, and Farewell Lake[1] (**Figures 4.2-6**). All six of these watersheds receive some portion of their drainage from the park, but do not exist entirely within the park's boundaries.

The Alaska Range serves as a major dividing line for the six watersheds, with many headwater drainages originating along its slopes. The Yentna and Chulitna River watersheds receive their headwater drainage from within park boundaries along the south side of the Alaska Range, drain southward into the Susitna River drainage, and empty into the Cook Inlet and the Gulf of Alaska. The North Fork Kuskokwim River and Farewell Lake watersheds receive headwater drainage from the north side of the Alaska Range along the southwest portion of the park, flow west into the Kuskokwim River drainage, and eventually drain into the Bering Sea. The headwaters of the Kantishna River watershed also begin along the north slope of the Alaska Range; however, drainage from this watershed first flows due north, joins with the Tanana River, and eventually flows into the Yukon River. The Nenana River watershed drains the easternmost portion of the park, and exists within a break in the Alaska Range. Drainage from the Nenana River watershed follows a fate similar to that of the Kantishna River, flowing north into the Tanana River and eventually flowing into the Yukon River Basin. From its confluence with the Tanana River, the

[1] The Farewell Lake Watershed drains only a very small fraction of the southwestern tip of the park (totaling 41 square miles). For this reason, detailed statistics and discussion for this watershed are not provided.

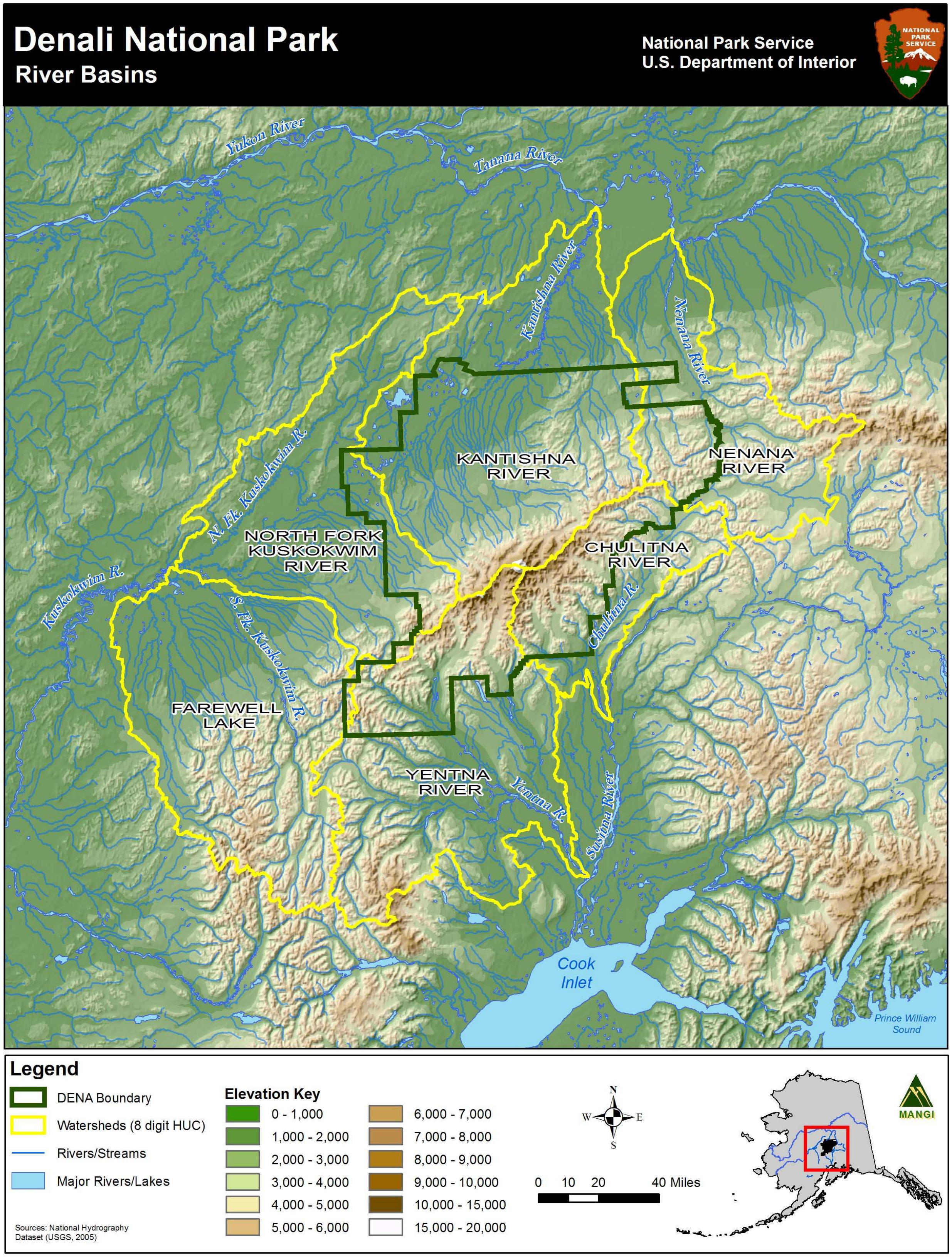

Figure 4.2-6. Watersheds of DENA

Yukon River flows west across Alaska, eventually draining into the Bering Sea roughly 175 miles northwest of the Kuskokwim River outflow.

The following watershed characteristics are derived from calculations using Geographic Information System (GIS)-based data layers, including the most recent draft of the National Hydrography Data (NHD) for watersheds within DENA (USGS, 2005a). The NHD is a comprehensive set of digital spatial data that contains information about surface water features, such as lakes, ponds, streams, rivers, springs, and wells. The NHD is based upon the content of USGS Digital Line Graph (DLG) hydrography data integrated with reach-related information from the United States Environmental Protection Agency (USEPA) Reach File Version 3 (RF3). It is primarily based on 1:100,000-scale data, and therefore, the following descriptions of stream mileage, glacier extent, and waterbody occurrence should be considered rough approximations. In addition to the NHD, draft ecoregion delineations, 60-meter Digital Elevation Model (DEM) data, and administrative boundaries provided by NPS staff were also used.

Nenana River Watershed

The Nenana River watershed (see **Figure 4.2-7**) drains the eastern most portion (9 percent) of DENA, and accounts for 963 miles of stream and river courses within the DENA boundary (roughly 8 percent). The Nenana River bisects the Alaska Range, with roughly three fourths of its drainage area within the Alaska Range, and the remaining area in the Yukon-Kuskokwim Bottomlands to the north. At its southwestern corner, Broad Pass differentiates waters of the Nenana flowing north to the Yukon, from those of the Chulitna flowing south to Cook Inlet.

Glaciers and ice account for only a small portion of the watershed (3 percent), the majority of which exist outside of the park in the southeast portion of the watershed at the headwaters of Yanert Fork, Wells Creek, and the Nenana River itself. Glacial rivers on NPS lands in the watershed are found primarily in the Teklanika River watershed on the western side. These glaciers account for only a small portion of the total ice cover in the watershed.

A mixture of sporadic, discontinuous, and continuous permafrost exists on NPS lands within the Nenana River watershed. A trend roughly similar to that observed in the Kantishna watershed occurs with increasing latitude. Together, continuous and discontinuous permafrost cover roughly 30 percent of NPS lands in the Nenana River watershed, with discontinuous permafrost accounting for the majority. Sporadic permafrost covers approximately half of the NPS lands within the watershed. Although a broader account of soil conditions for the basin suggest that the entire Nenana River watershed is underlain by discontinuous permafrost conditions (Long and Brabets, 2002), a similar mixture and distribution trend of sporadic, discontinuous, and small amounts of continuous permafrost would be anticipated for the rest of the basin.

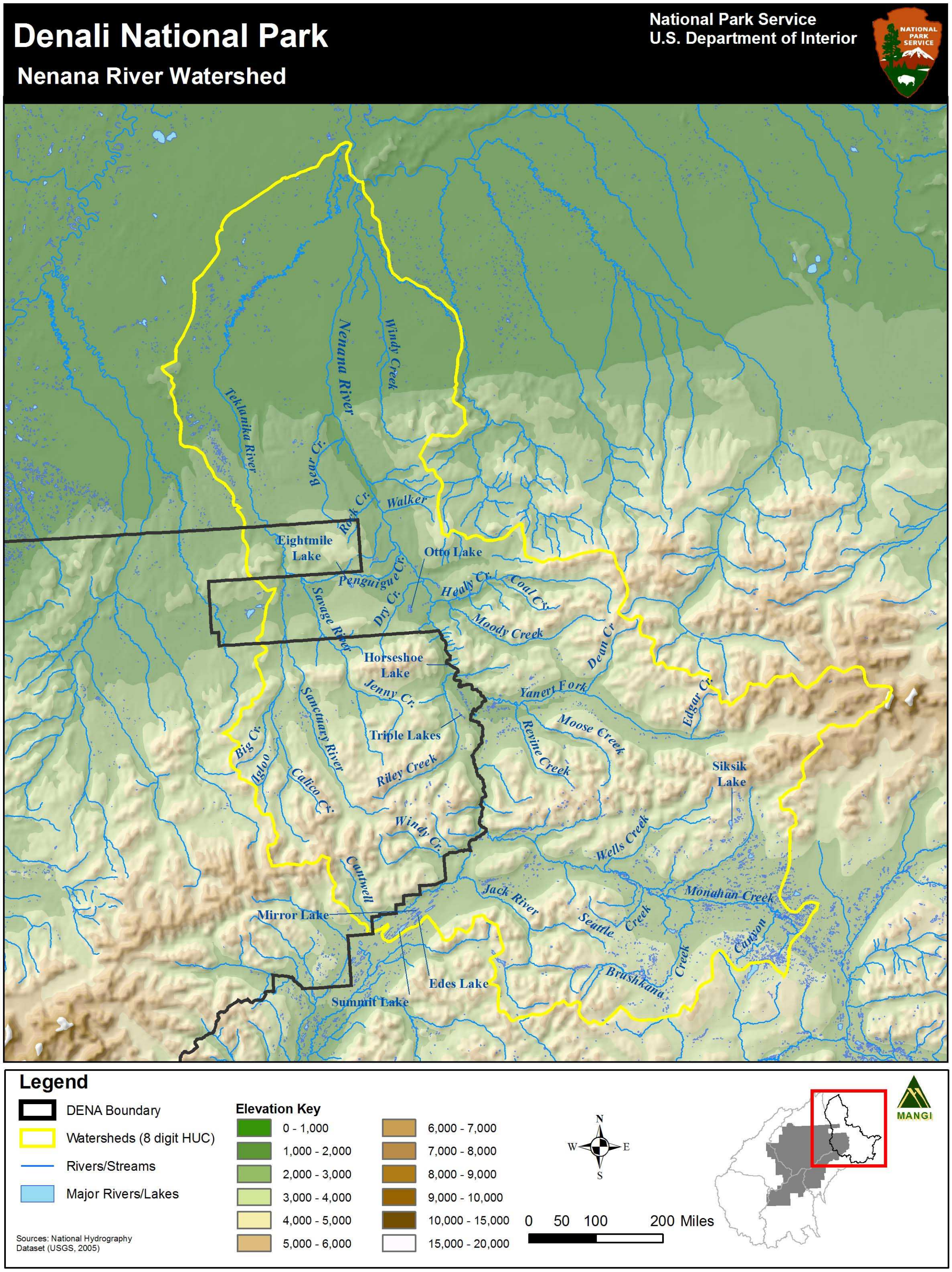

Figure 4.2-7. Nenana River Watershed

Table 4.2-3 provides the names, mileage on NPS lands, and type of streams greater than 10 miles in length in the Nenana River watershed.

Table 4.2-3. Streams in the Nenana River Watershed		
Name	**Length (Miles)**	**Type**
Teklanika River	37	Glacial*
Nenana River	37	Glacial**
Sanctuary River	28	Non-glacial
Riley Creek	26	Non-glacial
Savage River	23	Non-glacial
Windy Creek	16	Non-glacial
Cantwell Creek	13	Glacial
Jenny Creek	12	Non-glacial
Big Creek	12	Non-glacial
Igloo Creek	10	Non-glacial
* Gaged River – Discharge and peak flow measurements (1964 – 1974) ** Gaged River – Discharge and peak flow measurements have been taken at three locations on the Nenana River, including one upstream of its confluence with Jack River (discharge: 1950 -1973, peak flows: 1951 - 1981), and two near the town of Healy (discharge: 1950 – 1979 and 1990 – 2004, peak flows: 1951 – 1979 and 1990 – 2003)		

Few large lakes and ponds occur in the mountainous terrain of the Nenana River watershed. Larger waterbodies on NPS lands are primarily found in the Teklanika River, Sanctuary, and Riley Creek watersheds, as well as along the western floodplain of the Nenana River. Notable lakes on NPS lands include Horseshoe Lake and the Triple Lakes south of park headquarters in the Riley Creek watershed. Notable lakes in the Nenana River watershed outside of NPS lands include: Summit Lake, Siksik Lake, Otto Lake, Edes Lake, Mirror Lake, and Eight Mile Lake. The majority of these lakes are less than two acres in size.

As described previously, the number and total area of lakes is likely highly underestimated, due to the limitations in identifying smaller lakes and ponds at the 1: 1,000,000 scale. A more accurate inventory of these lakes is not currently available.

Kantishna River Watershed

The Kantishna River watershed (see **Figures 4.2-8** and **4.2-9**) drains 51 percent of DENA, and accounts for an estimated 67 percent of its stream mileage (an estimated 7,991 miles of stream and river courses). Glaciers on the north slope of the Alaska Range comprise roughly 7 percent of the NPS portion of the watershed, providing meltwater input to many of the watershed's headwaters. Many of the major non-glacial streams in the watershed originate in the Kantishna Hills region, where a long history of both placer and lode mining has disrupted floodplains in localized areas. **Table 4.2-4** provides the names, mileage on NPS lands, and type of streams greater than 25 miles in length in the Kantishna River watershed.

Table 4.2-4. Streams in the Kantishna River Watershed		
Name	**Length (Miles)**	**Type**
Birch Creek	99	Glacial (Lower and East Fork); Non-glacial (Upper and Middle Forks)
Bear Creek	74	Non-glacial
Herron River	72	Glacial
Foraker River	69	Glacial
McKinley River	67	Glacial
Moose Creek	64	Non-glacial
Slippery Creek	60	Glacial
Bearpaw River	55	Non-glacial
Toklat River	55	Glacial
Muddy River[1]	52	Non-glacial
Kantishna River	48	Glacial
White Creek	44	Glacial
East Fork Toklat River	41	Glacial
Flume Creek	34	Non-glacial
Hot Slough	32	Non-glacial
McLeod Creek	29	Glacial
Sushana River	28	Non-glacial
Wigand Creek	28	Non-glacial
Stony Creek	27	Non-glacial
Glacier Creek	27	Non-glacial
Clearwater Fork	26	Non-glacial
Wolf Creek	25	Non-glacial
Hult Creek	23	Non-glacial
Hauke Creek	23	Non-glacial
Otter Creek	23	Non-glacial
Clearwater Creek	23	Non-glacial
Caribou Creek	18	Non-glacial
Crooked Creek	17	Non-glacial
Iron Creek	16	Glacial
North Fork Moose Creek	15	Non-glacial
Muddy River[2]	15	Glacial
East Fork Clearwater Creek	13	Non-glacial
Rock Creek	13	Non-glacial*
Canyon Creek	12	Non-glacial
Chitsia Creek	10	Non-glacial
Flat Creek	10	Non-glacial
Carlson Creek	10	Non-glacial
Cache Creek	10	Non-glacial

[1] – Muddy River flowing from Lake Minchumina to Birch Creek before flowing into Kantishna River.

[2] – Muddy River beginning on the north side of the Alaska Range and flowing into the McKinley River

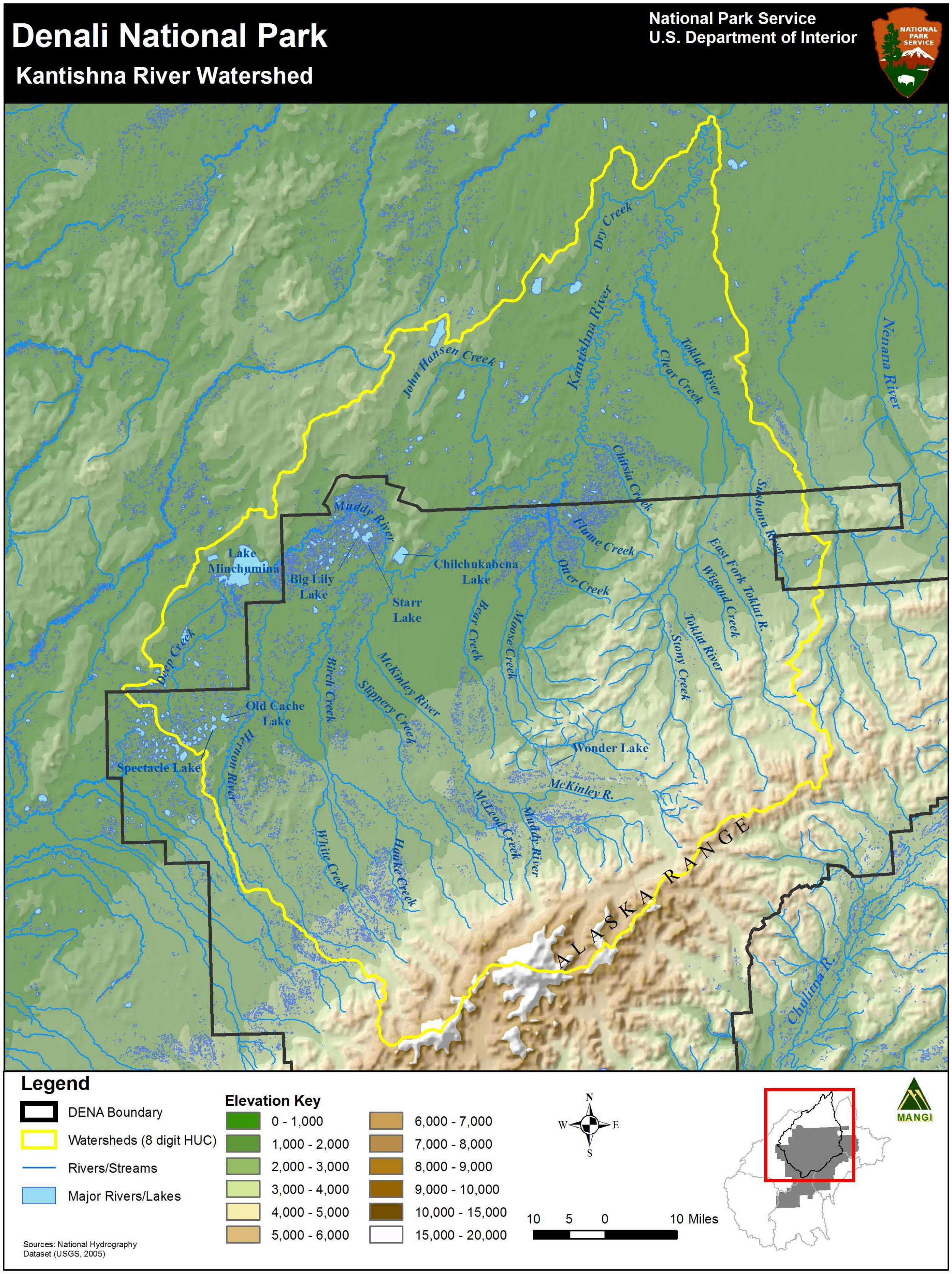

Figure 4.2-8. Kantishna River Watershed

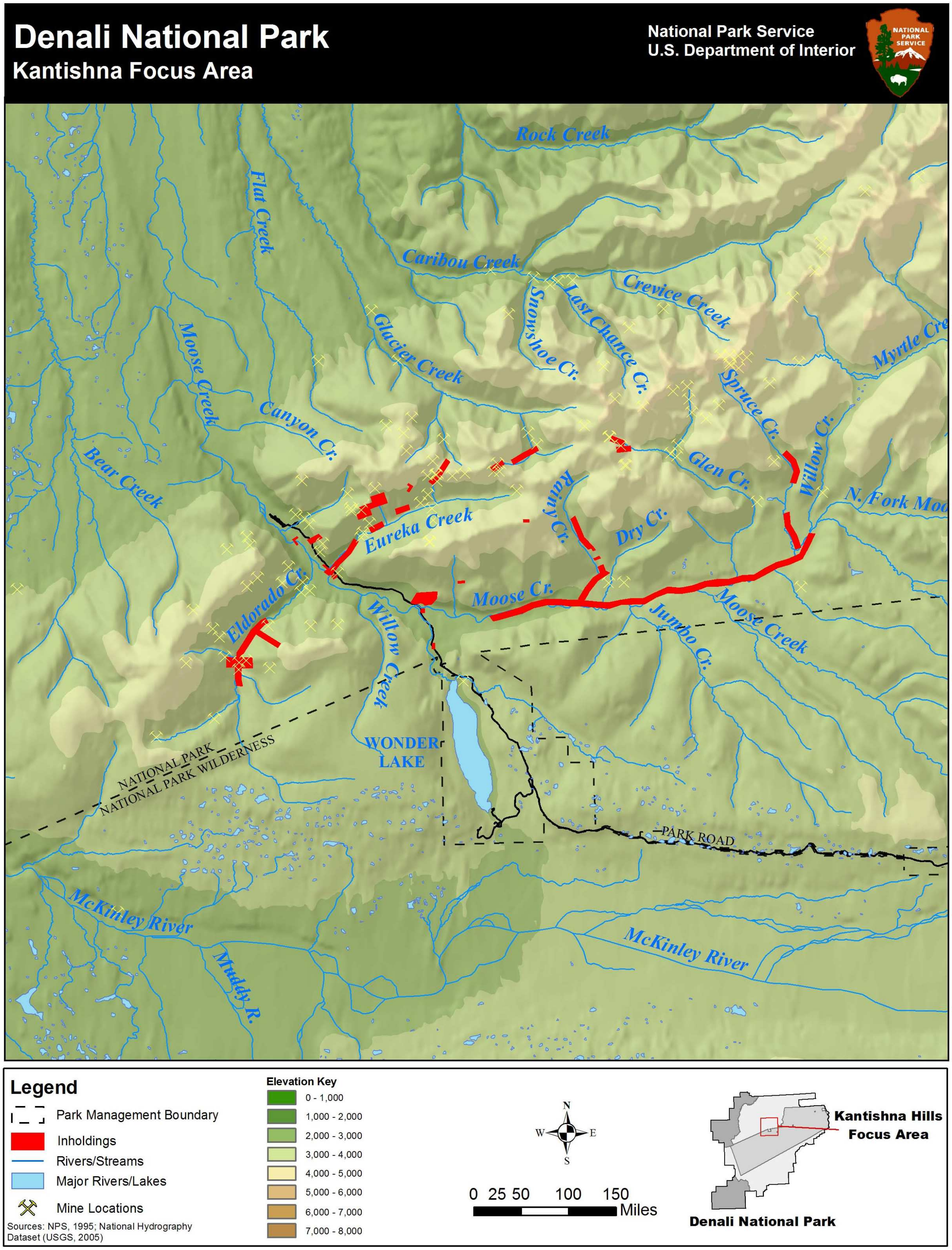

Figure 4.2-9. Detailed Map of the Kantishna Hills Area

Along the lower (non-ice covered), north-facing slopes of the Alaska Range, permafrost is sporadic. A rough band of discontinuous permafrost extends from the areas of sporadic permafrost northward roughly 5 to 15 miles from the base of the Alaska Range. This zone of discontinuous permafrost extends further into the interior boreal lowlands along major river floodplains, expanding into broader discontinuous permafrost zones in some areas. Continuous permafrost is primarily found north of the discontinuous permafrost zone in the areas between the major drainages. Together, continuous and discontinuous permafrost cover roughly 70 percent of NPS lands in the Kantishna watershed, with each occupying a nearly equal area.

Thousands of lakes and ponds occur in the northwestern lowlands found in the Kantishna watershed. Based on the information provided in the NHD, there are nearly 10,000 ponds and lakes, totaling roughly 82 square miles, on park lands in the Kantishna River watershed. This area is likely highly underestimated, due to the limitations in identifying smaller lakes and ponds at the 1:1,000,000 scale. Some of the notable larger lakes (greater than 500 acres) include Chilchukabena Lake, Starr Lake, Spectacle Lake, Old Cache Lake, Wonder Lake, and Big Lily Lake. The majority of lakes identified in the NHD data (approximately 60 percent) were less than 2 acres in size. A more accurate inventory of these lakes is not currently available.

North Fork Kuskokwim River Watershed

The North Fork Kuskokwim River watershed (see **Figure 4.2-10**) drains the western edge of DENA. The watershed portion that drains DENA begins along the north side of the Alaska Range, draining north and west through the Yukon-Kuskokwim Bottomlands. This watershed drains approximately 8 percent of the park lands and accounts for an estimated 11 percent of the park's total stream mileage (an estimated 1,361 miles of stream and river courses). Glaciers on the north slope of the Alaska Range comprise roughly 8 percent of the NPS portion of the watershed. Major rivers on park lands originate from glaciers on the Alaska Range, with non-glacial streams limited to smaller headwater tributaries feeding major glacial rivers. **Table 4.2-5** provides the names, mileage on NPS lands, and type of stream for named streams greater than 10 miles in length in the North Fork Kuskokwim River watershed.

Table 4.2-5. Streams in the North Fork Kuskokwim Watershed

Name	Length (miles)	Type
Highpower Creek	115	Glacial
Deep Creek	39	Non-glacial
Fish River	30	Non-glacial
Swift Fork	27	Glacial
Dry Creek	25	Non-glacial
Shisnona River	15	Non-glacial
Boulder Creek	15	Glacial
Somber Creek	13	Glacial
Lonestar Creek	12	Non-glacial
Jack Frost Creek	11	Non-glacial

Similar to the Kantishna River watershed, permafrost is sporadic, along the north facing slopes of the Alaska Range, transitioning to discontinuous 5 to 15 miles from the base of the Alaska Range, and finally continuous north of the discontinuous permafrost zone in the areas between

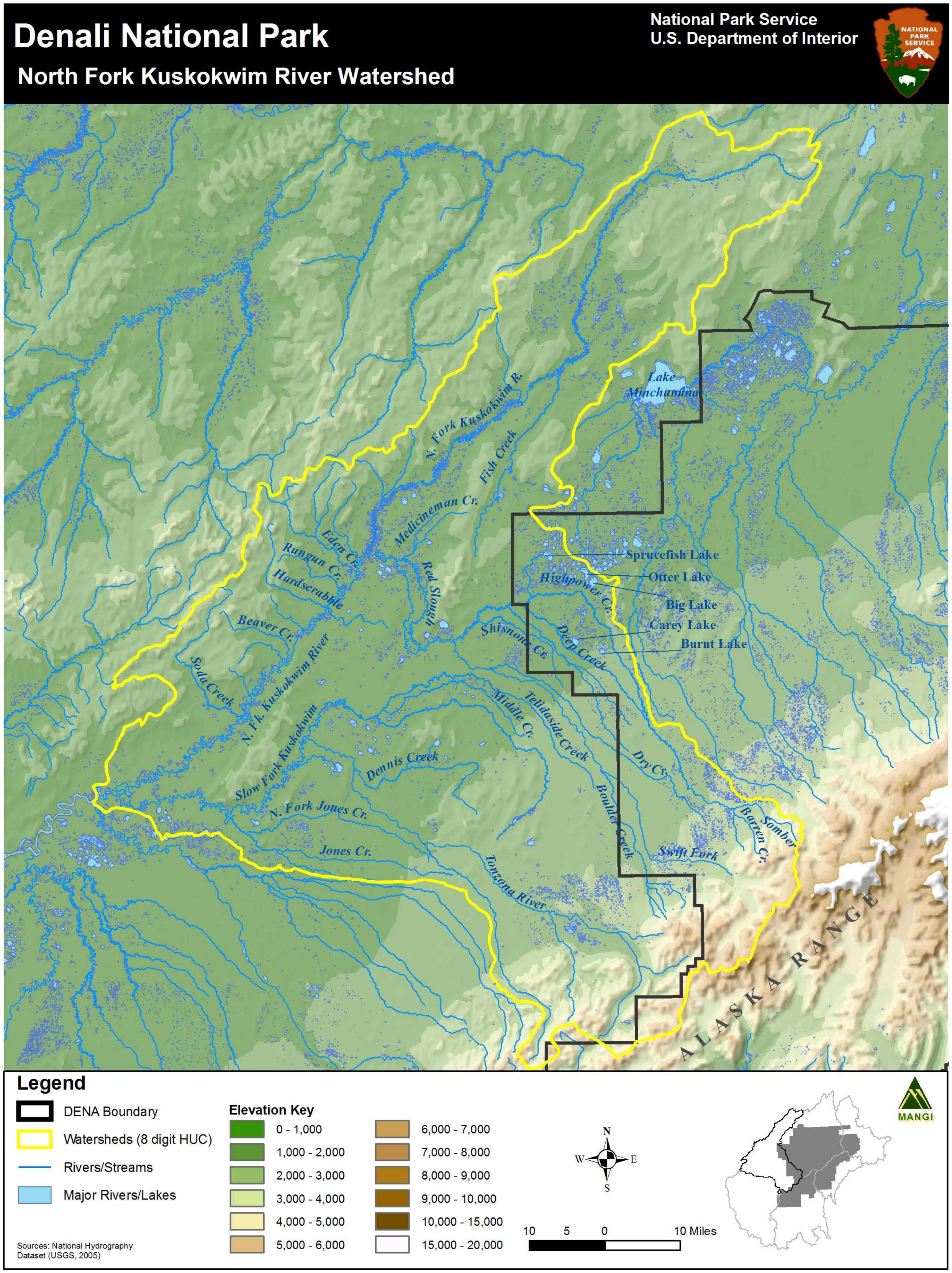

Figure 4.2-10. North Fork Kuskokwim River Watershed

the major drainages. Continuous and discontinuous permafrost cover roughly 68 percent of NPS lands in the watershed, with each occupying a nearly equal area.

Major ponds and lakes are frequent in the northwestern lowlands. Based on the information provided in the NHD, there are nearly 1,700 ponds and lakes, totaling roughly 20 square miles, on park lands in the North Fork Kuskokwim River watershed. As described above, this area is likely highly underestimated, due to the limitations in identifying smaller lakes and ponds at the 1:1,000,000 scale. Some of the notable larger lakes on park lands in the watershed include: Big Lake, Otter Lake, Sprucefish Lake, Carey Lake, and Burnt Lake.

Chulitna River Watershed

The Chulitna River watershed (see **Figure 4.2-11**), found on the on the south side of the Alaska Range, drains roughly 15 percent of DENA and accounts for an estimated 6 percent of its stream mileage (approximately 756 miles of stream and river courses). The northeast portion of the Chulitna watershed abuts the Nenana River watershed at its southwestern most point divided by Broad Pass. Glaciers and ice account for a large portion (37 percent) of NPS lands within the watershed. Major glaciers include the Ruth Glacier, Eldridge Glacier, Tokositna Glacier, Buckskin Glacier, and Kanikula Glacier. The majority of south side streams from the park are glacially fed, whereas the streams from the opposite side of the watershed (to the southeast) are non-glacially fed streams.

Table 4.2-6 provides the names, mileage on NPS lands, and type of streams greater than 10 miles in length in the Chulitna River watershed.

Table 4.2-6. Streams in the Chulitna River Watershed

Name	Length (miles)	Type
Bull River	22	Glacial
West Fork Chulitna River	18	Glacial
Costello Creek	18	Non-glacial
Alder Creek	18	Glacial
Colorado Creek	13	Non-glacial
Tokositna River	13	Glacial
Coffee River	12	Glacial
Ruth River	10	Glacial
Chulitna River	None on NPS lands	Glacial*
* Gaged River – Although the Chulitna River is not on NPS lands, it is a gaged river (discharge and peak flow measurements 1958 – 1986) that has immediate tributaries that drain portions of the south side of the park.		

Numerous small lakes and waterbodies are found in the Chulitna River watershed. The majority of these lakes exist outside of the park boundaries in the broad Chulitna River valley. Those found on park lands are generally at higher elevations associated with glaciers. Pirate Lake near the terminus of Ruth Glacier is one of the few large lakes on NPS lands, while several large lakes in the Chulitna River valley outside the park include Byers Lake, Swan Lake, Spink Lake,

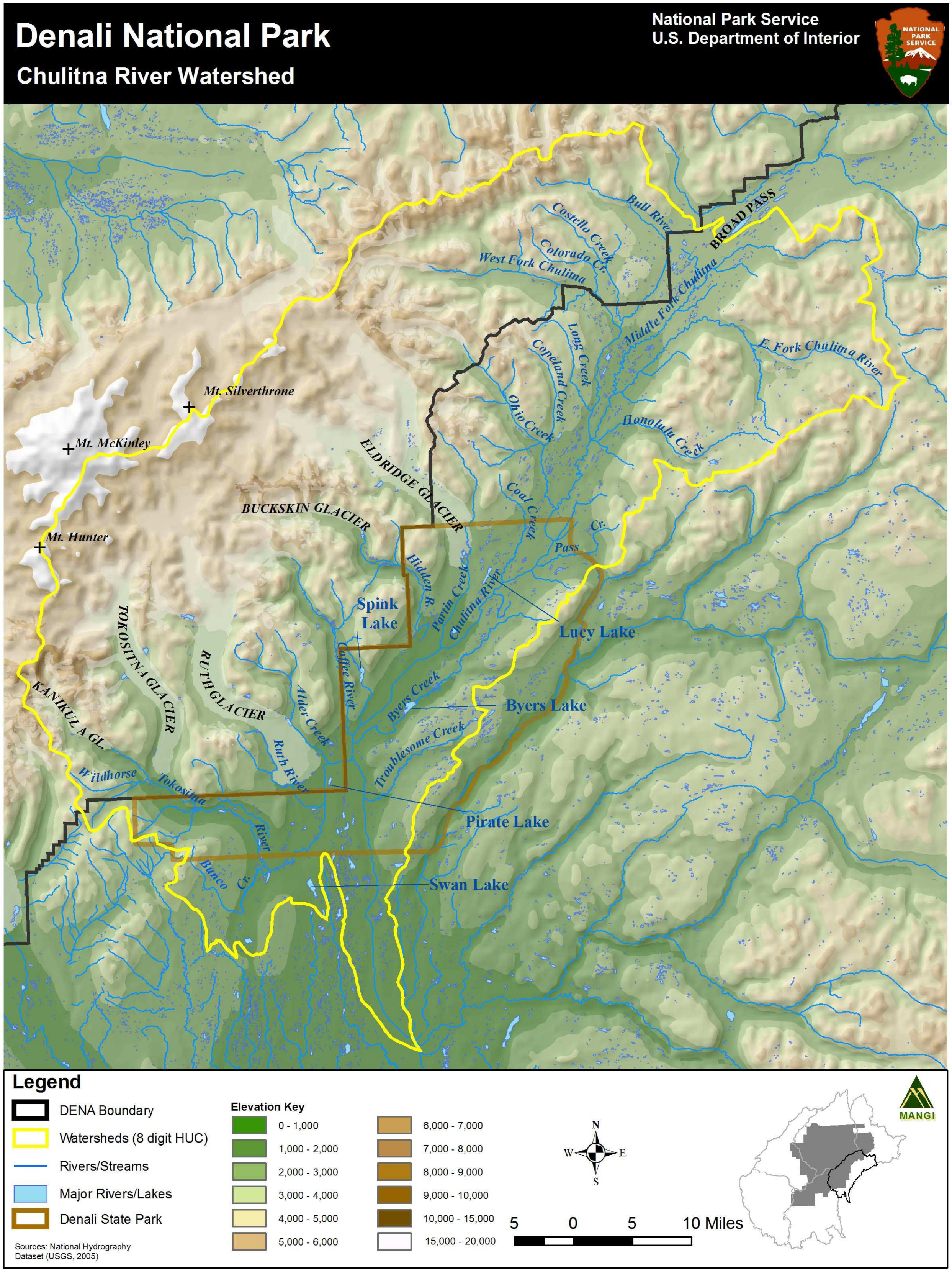

Figure 4.2-11. Chulitna River Watershed

and Lucy Lake. The majority (70 percent) of lakes and ponds in the Chulitna River watershed are less than 2 acres in size.

Yentna River Watershed

The Yentna River watershed (see **Figure 4.2-12**), on the south side of the Alaska Range, drains roughly 17 percent of DENA at its southeastern corner and accounts for an estimated 7 percent of its stream mileage (approximately 806 miles of stream and river courses). The Yentna River watershed drains the southeast corner of the park, and shares its western boundary with the Farewell Lake watershed, which drains a very small fraction of the park's southwest corner (41 square miles).

Glaciers and ice account for a large portion (38 percent) of the watershed on NPS lands and approximately 15 percent of the watershed as a whole. The majority of this ice cover exists inside the park boundary. The largest glaciers are found in the northeast portion of the watershed, and include the Kahiltna Glacier, Lacuna Glacier, Yentna Glacier, and the Dall Glacier. Nearly all of the streams originating in the Yentna River watershed from NPS lands are glacially fed.

Only four rivers on NPS lands in the Yentna River watershed are greater than 10 miles in length. **Table 4.2-7** provides the mileage on NPS lands and types for these four rivers.

Table 4.2-7. Streams in the Yenta River Watershed

Name	Length (miles)	Type
East Fork Yentna River	41	Glacial
West Fork Yentna River	26	Glacial
Fourth-of-July Creek	25	Glacial
Kichatna River	10	Glacial

Many small waterbodies are found in the Yentna River watershed, though the vast majority is found south of the DENA border, in the broad slopes of the Alaska Range Transitional zone. Those found on park lands are generally at higher elevations, and are either impounded by glaciers or formed at the terminus of the large glaciers. The Chelatna Lake, the largest lake in the Yentna River watershed (approximately 6 square miles, or 3,900 acres) exists just south of the park boundary.

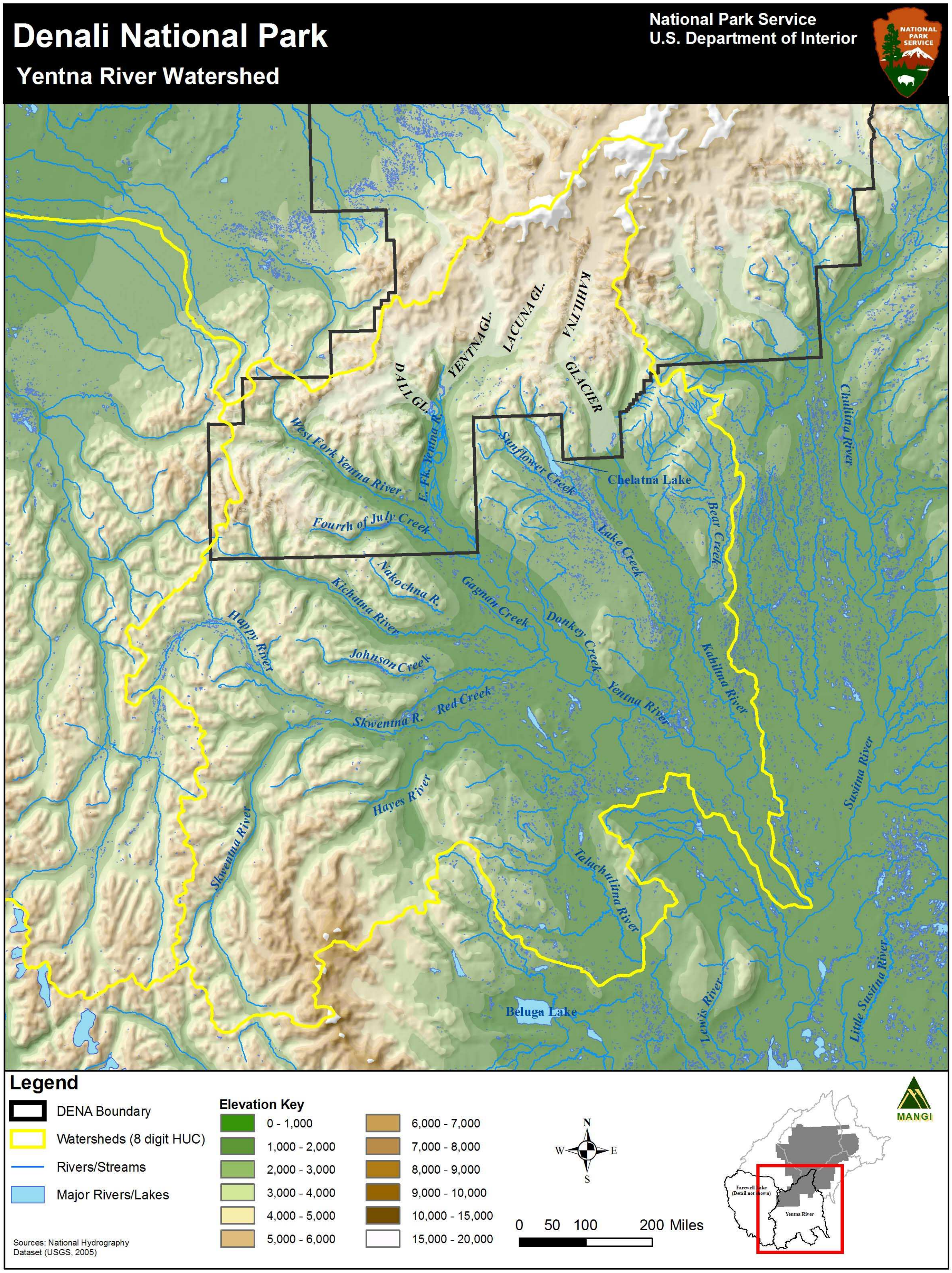

Figure 4.2-12. Yentna River Watershed

Table 4.2-8 provides a summary of the characteristics of each of the watersheds presented above.

Table 4.2-8. Summary Comparison of Watershed Characteristics Within DENA				
Watershed	**% of Park Drained by Watershed**	**Total Stream Miles within Park**	**% Glacier & Ice Cover within Park**	**Permafrost Cover within Park**
Kantishna River	51%	7,991	7%	Cont., discont., & sporadic
Yentna River	17%	806	38%	None
Chulitna River	15%	756	37%	Sparse
Nenana River	9%	963	3%	Discont. & sporadic
N. Fork Kuskokwim River	8%	1,361	8%	Cont., discont., & sporadic
Total	**100% ****	**11,906**	**-**	**-**
** A small proportion (less than 1%) of the park drains into the Farewell Lake Watershed (see Figure (4.2-6).				

Groundwater

In the USGS groundwater database, there are 6 sites in DENA that have been sampled for groundwater characteristics (USGS, 2005b). Of the 6, only 2 have long-term records, with the other 4 sampled only once between 1958 and 1971. The two long-term sampling records available are for the ground wells at park headquarters. Average groundwater depth at these sites over the last decade is roughly 97 feet (USGS Site No.634355148550501) and 103 feet (USGS Site No. 634359148545401)[1]. Groundwater levels at these sites are considered stable.

Recent studies in the Cook Inlet aquifer, which stretches to the Alaska Range along the Yentna and Chulitna Rivers, supports the conceptual model that groundwater on the South Side of the park is primarily from the infiltration of local precipitation and water from streams, rivers, lakes, and wetlands, rather than from deeper aquifers. Most of the wells used for water supply in the Cook Inlet aquifer are completed near the top of saturated glacial till, outwash, or alluvial deposits, and are anticipated to yield waters that were recharged within the last 25 years (Glass, 2002).

Several locations at DENA have been monitored for groundwater contamination by either NPS staff or by government contractors. These sites, and ongoing or proposed actions concerning their monitoring/rehabilitation, are listed below (Scholten, 2005a).

[1] Gauge datum 1,750.00 feet above sea level NGVD29

Contaminated Aquifers of DENA

Riley Creek Lagoon

Current Condition: Four monitoring wells have been installed down gradient of the percolation pond. Nitrate levels in the monitoring wells exceed the ADEC allowable limit of 5 mg/L in all wells. Some wells have concentrations as high as 25 mg/L.

Action: Correct treatment process and discharge method under a Compliance Order by Consent with ADEC.

Front Country Hotel Location

Current Condition: Existing water wells have been abandoned. Potable water is obtained from an up-gradient surface water source. In 2005, a consultant will try to model migration to groundwater for this contaminated site. Samples taken in 2004 of an abandoned well at the site had high levels of diesel range organics (DRO) contamination.

C-camp Residential Area West Side

Current Condition: One monitoring well within plume with DRO levels of 1.69 mg/L in 2004; all other constituents were below ADEC cleanup levels. Two monitoring wells that are located down-gradient between the plume and rock creek show no contamination.

Action: Will monitor bi-annually to determine if the plume may migrate to surface water.

C-camp Residential Area East Side

Current Condition: One monitoring well installed, but all contaminate levels were below ADEC cleanup levels. Several small spills along east side of C-camp, but no migration to groundwater.

Action: Will monitor bi-annually to determine if the plume may migrate to this location.

C-camp UST Site

Current Condition: One monitoring well is installed within UST plume. One down-gradient monitoring well was installed in 2004. Contaminate levels in down-gradient well were 1.5 mg/L for DRO, 0.0301 mg/L for benzene, and 2.05 mg/L for GRO.

Action: Will monitor bi-annually to determine plume migration. Future plan for 2007/2008 is to replace fueling system and excavate source contamination.

Headquarters at Buildings 51/54

Current Condition: Two monitoring wells have been installed in the known contamination area. Four down-gradient and one up-gradient monitoring wells have been installed. Floating product has been found on one plume well and one down-gradient well. Product recovery devices have been installed and are emptied periodically. All other wells have levels below cleanup requirements.

Action: Continue to remove product and monitor down gradient wells.

Toklat Road Camp

Current Condition: Seven groundwater monitoring wells have been installed and monitored since 2001. Contaminate levels have been below cleanup levels for the past two years. Site was closed with institutional controls.

4.2.6 Water Quality

Water quality of both surface and subsurface waters within DENA is generally considered to be of very high quality, with the exception of some localized impact areas (NPS, 1998a). Three major factors affect the water quality of streams and rivers in DENA: water source (glacial or non-glacial water), underlying geology (marine sedimentary, located primarily on the north side of the Alaska Range, or granitic, located primarily on the south side of the Alaska Range), and mining impacts (placer mined or unmined) (Edwards and Tranel, 1998).

Surface waters in DENA are concentrated with metal ions and very well buffered. Stream chemistry is dominated by calcium, magnesium, bicarbonate, and sulfate (Stottlemyer and McLoone, 1989). Specifically, calcium sulfate and magnesium sulfate are the dominant ion pairs present in most of the park's streams and rivers, regardless of their position relative to the Alaska Range and whether they are glacial or non-glacial fed (Edwards and Tranel, 1998). Overall, most pH values have been found to be in the 7.51 to 8 range. Streams found to be slightly acidic are almost strictly located on the south side of the park (Edwards and Tranel, 1998).

Glaciers have a profound effect on water quality, and can contribute large amounts of sediments to receiving streams, significantly increasing their turbidity. Streams and rivers in which glacial melt water contributes to streamflow are referred to as glacial waters. Glacial waters within DENA contain suspended sediment concentrations ranging from means of 100 to 1,400 milligrams per liter (mg/L) and turbidity ranging from means of 77 to 363 Nephelometric Turbidity Units (NTUs) (Edwards and Tranel, 1998). Most of the sediment load is carried during the summer months. In non-glacial streams, streams that are not influenced by glacial melt water, suspended sediment and turbidity can vary tremendously. DENA's non-glacial streams contain suspended sediment concentrations ranging from means of 2 to 48 mg/L and turbidity ranging from means of 2 to 29 NTUs (Edwards and Tranel, 1998).

Water quality parameters other than suspended sediment and turbidity appear to be affected more by headwater geology than glacial water sources. Runoff from marine sedimentary terrains, which dominate the bedrock in the north side of the park (north of the Alaska Range), has higher pH, alkalinity, electrical conductivity, dissolved ions, and dissolved organic carbon (DOC) compared to runoff from the granitic terrains, which dominate the south side of the park (Edwards and Tranel, 1998; Edwards et al., 2000). These results were determined to be independent of whether the streams were glacial or non-glacial fed. **Table 4.2-9** presents the general surface water quality characteristics of streams studied on the north and south side of the park.

Table 4.2-9. General Surface Water Characteristics Grouped by Headwater Geology

Parameter	North Side Streams	South Side Streams
pH	> 7.51 (mean of 7.77)	< 7.5 (mean of 7.00)
Mean Alkalinity (mg CaCO3/L)	112.74	22.75
Electrical Conductivity (mS/cm)	250-500	< 250
Mean Dissolved Ion (Analyte) Concentrations for Glacially Fed Streams and Rivers (mg/L)	Chloride 1.39	Chloride 0.10
	Nitrate 0.52	Nitrate 0.33
	Sulfate 119.77	Sulfate 10.64
	Calcium 49.60	Calcium 7.49
	Magnesium 17.92	Magnesium 1.35
	Sodium 6.57	Sodium 0.80
	Potassium 1.45	Potassium 0.61
	DOC 5.34	DOC 1.45

Source: Edwards and Tranel, 1998; Edwards et al., 2000

In the Kantishna Hills, many streams originate in highly mineralized areas and have very different water chemistries than those that originate in tundra. Water containing greater than 180 parts per million (ppm) calcium carbonate is considered to be “hard,” and waters in Kantishna Hills often range from 500 to 900 ppm calcium carbonate hardness (Hanneman, 1993).

Mining and mining related activities prior to 1985, specifically in the Kantishna Hills area, have led to the localized deterioration of several water quality parameters, including turbidity, suspended solids, and heavy metals contamination. Two streams in this area, Caribou Creek and Slate Creek, remain currently listed on the ADEC’s 303(d) list of impaired water bodies (ADEC, 2003a). As a result of mining, stream channels have been straightened, resulting in accelerated erosion of the stream beds, and hundreds of acres of floodplain and riparian areas have been destroyed or significantly altered. Since 1985, however, there has been minimal mining activity in the park, and recent monitoring in the Kantishna Hills area found few differences between mined and unmined streams, suggesting substantial recovery of water quality (Edwards and Tranel, 1998).

Over 16 miles of Caribou Creek are listed as impaired due to turbidity caused by past mining activity in the Kantishna mining district. In 1997, the NPS conducted a helicopter reconnaissance tour of Caribou Creek and determined that the stream had lost sinuosity along segments in the upper half of the watershed. The NPS plans to draft a waterbody recovery plan for Caribou Creek after it completes obtaining the titles to private mining claims in the area. Over 2 miles of Slate Creek are also listed as impaired due to turbidity caused by past mining activity in the Kantishna mining district. A waterbody recovery plan was drafted for Slate Creek and plan implementation began in 1997. The recovery plan includes restoration objectives for 4 acres of disturbed upland and stream channel areas in the vicinity of the old antimony mine site. Restoration objectives include placement of fill over the exposed antimony ore body, reconfiguration of the stream channel, increasing the pH of acidic soils, and revegetation of disturbed soils with willow and alder seedlings. Review of the recovery plan by the State of Alaska is required prior to de-listing of Slate Creek as an impaired waterbody (ADEC, 2003a).

NPS reclamation and restoration efforts of Slate Creek and Caribou Creek are described under Section 5.3, *Mining-Related Issues*.

Little information exists regarding the presence, quality, or extent of subsurface aquifers in DENA (NPS, 2003e). Much of DENA is underlain by discontinuous permafrost, which limits the availability of groundwater (NPS, 1998a). Water supply for developed areas along the Park Road is generally provided by surface and shallow groundwater well sources due to the dense silt/clay soils and permafrost along areas of the road which inhibit subsurface water flow. Surface water and shallow groundwater sources are predicted to continue to provide primary water supplies to developed areas in the park (NPS, 1998a). Chlorination serves as the primary treatment for most of the park's potable water needs. However, the park is gradually shifting to subsurface groundwater (well) sources to meet current State and Federal drinking water quality standards with minimal pretreatment. There are no plans to tap subsurface aquifers in the backcountry (NPS, 2003e).

Baseline Water Quality Inventory and Analysis

In 1995, NPS published a *Baseline Water Quality Inventory and Analysis Report* for the DENA study area, which is a compendium of surface water quality data retrieved from 5 of the USEPA's national databases generated between 1955 and 1985. Much of the data included in the report was originally included in previously published studies (Deschu, 1985a; 1986; West and Deschu, 1984; Deschu and Kavanagh, 1986). The inventory and analysis data included 4,136 distinct analysis results for 120 different water quality parameters collected by the USEPA and USGS at 89 monitoring stations (NPS, 1995b). The analysis results found that 10 water quality parameters exceeded screening criteria at least once within the study area. Arsenic, cadmium, copper, lead, zinc, antimony, and mercury exceeded their respective USEPA acute criteria for the protection of freshwater aquatic life, while arsenic, cadmium, chromium, lead, nickel, antimony, and mercury exceeded their respective USEPA drinking water criteria. In addition, turbidity exceeded the NPS Water Resources Division's screening limit for the protection of aquatic life 21 times (NPS, 1995b). The primary waterbody sampling points that exceeded national water quality standards are summarized in **Table 4.2-10.**

Table 4.2-10. Selected Data from Baseline Water Quality Inventory and Analysis Report

Waterbody Sampling Point	General Waterbody Location	Water Quality Parameter with Concentration Exceeding Standards	Associated Activity in Area	Year Data Collected
Eldorado Creek, below Slate Creek (Station 12)	Kantishna Hills; Tanana River System	arsenic, copper, lead, antimony mercury, turbidity	Mining	1983
Glen Creek (Station 24)	Tanana River System	arsenic, cadmium, copper, lead, zinc, antimony, turbidity	Mining	1983
Moose Creek, 50m below Eureka Creek (Station 25)	Kantishna Hills; Tanana River System	lead, zinc, antimony, turbidity	Mining	1983

Eureka Creek Intake Pond, Banni Mining (Station 29)	Tanana River System	arsenic, turbidity	Mining	1984
Friday Creek (Station 42)	Tanana River System	arsenic, cadmium, chromium, copper, lead, nickel, zinc, antimony, mercury, turbidity	Mining	1983
Moose Creek, 50m below Friday Creek (Station 43)	Kantishna Hills; Tanana River System	lead, zinc, antimony, turbidity	Mining	1983
Glacier Creek (Station 65)	Kantishna Hills; Tanana River System	arsenic, cadmium, copper, lead, zinc, antimony	Mining	1983
Caribou Creek (Station 68)	Kantishna Hills; Tanana River System	cadmium, copper, lead, zinc, antimony, turbidity	Mining	1983
Placer Creek (Station 76)	Tanana River System	arsenic, turbidity	Mining	1984
Moose Creek, 0.6km above Diamond (Station 87)	Kantishna Hills; Tanana River System	cadmium, lead, zinc, antimony, turbidity	Mining	1983
Bearpaw River, 1.5km below Diamond (Station 88)	Kantishna Hills; Tanana River System	lead, zinc, antimony, turbidity	35km downstream of mining	1983

Source: NPS, 1995b

4.2.7 Air Quality

The NPS is responsible for preserving, protecting, and enhancing air quality and related values of the National Park System units under both the Organic Act (16 USC 1, 1a-1) and the Clean Air Act. DENA is designated a Class I airshed under the Clean Air Act, which requires the prevention of significant deterioration of air quality over baseline conditions. DENA is the only national park in Alaska that is designated a mandatory Class I airshed.

In respect to water resources, air quality is a concern because air pollutants in the atmosphere can settle to the ground or surface waters, potentially contributing to water quality degradation. In general, air quality within DENA is very good to excellent, with the notable exceptions of haze and smoke from wildland fires in summer, local fugitive dust from the Park Road, and the measurable presence of airborne contaminants from international industrial sources (NPS, 2003a). On average, the peak concentrations of international contaminants occur in the late winter and spring, and naturally-occurring wildfire smoke is the primary contributor to air quality degradation in the summer (NPS, 2003c). Stationary and area source emissions at DENA include: space and water heating equipment, generators, fuel storage tanks, woodstoves/ fireplaces, campfires, wildland and prescribed fires, and miscellaneous area sources. Mobile source emissions at DENA include visitor vehicles, tour buses, Federal personnel vehicles, snowmobiles, off-road vehicles, the Alaska Railroad, and aircraft (NPS, 2003a).

In addition to sources at DENA, the Golden Valley Electric Association operates a 25MW coal-burning power plant (the Healy Power Plant, Standard Industrial Classification Code 4911), located adjacent to the Usibelli Coal Mine in Healy. ADEC issued a Title V operating permit (Permit No. 173TVP01) for this facility on November 14, 2003, which expires on December 13, 2008. Air pollutants regulated under the permit include nitrogen oxides, sulfur dioxide, carbon monoxide, particular matter/particulate matter less than 10 microns (PM_{10}), volatile organic compounds (VOCs), lead, asbestos, formaldehyde, beryllium, mercury, benzene, toluene, and xylene. A summary of the potential to emit[1] Clean Air Act criteria pollutants, as indicated in the modified application from the Healy Power Plant, is shown below in tons per year (ADEC, 2003b):

Nitrogen Oxides	Carbon Monoxide	Pm_{10}	Sulfur Dioxide	VOCs	Total
1,526	944	239	749	21	3,479

In addition, the Alaska Industrial Development and Export Authority constructed the 50MW Healy Clean Coal Power Plant in 1998. Although not yet commercially operational due to equipment concerns (Bradner, 2002), compliance testing conducted at the plant in 1998 showed sulfur and nitrogen oxide emissions below the permit requirements for the facility (DOE, 1998). However, there is the potential for control technology retrofit (the type of which is currently unknown) at this facility in the future, which may produce higher emission levels.

Air Quality Monitoring Programs

DENA participates in four national air quality monitoring/sampling programs. These programs and their monitoring results are summarized below.

NPS Ozone Monitoring Program

This program monitors gaseous pollutants nation-wide. At DENA, only ozone and meteorology are monitored under this program, and sampled levels are evaluated for compliance with the National Ambient Air Quality Standards (NAAQS). Ozone has been monitored with a continuous analyzer from 1987-present at a sampling site near park headquarters in DENA (USEPA Site ID 02-290-0003), and in 1995, a passive ozone sampler was also used. No exceedances of the NAAQS have been documented at this sampling station (NPS, 2003a; 2002a; 2001a; 2000a). However, the 1990 to 2002 trend data indicate that ozone is increasing in DENA for both the 1-hour and 8-hour ozone standards, but concentrations and doses are still well below levels that cause injury to vegetation (NPS, 2004g; 2003a).

National Atmospheric Deposition Program/National Trends Network (NADP/NTN)

This program has monitored wet deposition in DENA from 1980 to the present (site ID AK03). Atmospheric deposition of nitrogen and sulfur can cause adverse ecological effects, such as surface water acidification, nutrient enrichment of estuaries, declines in forest health, and

[1] *Potential to Emit* means the maximum quantity of a release of an air contaminant, considering a facility's physical or operational design, based on continual operation of all sources within the facility for 24 hours a day, 365 days a year, reduced by the effect of pollution control equipment and approved state or federal limitations on the capacity of the facility's sources or the facility to emit an air contaminant, including limitations such as restrictions on hours or rates of operation and type or amount of material combusted, stored, or processed as defined in AS 46.14.990(21), effective 1/18/97 (ADEC, 2003b).

nutrient leaching from soils. The purpose of the network is to collect precipitation chemistry data to evaluate the geographic distribution and long-term trends of air pollutants. The program monitors concentrations and trends in calcium, magnesium, potassium, sodium, ammonium, sulfate, nitrate, chlorine, and pH at the park (NADP/NTN, No date). DENA experiences some of the lowest values of nitrogen and sulfur deposition measured in the NADP network. Deposition of nitrogen and sulfur both peak in the summer due to high precipitation. The most recent 10 years of data show no trends in ammonium and sulfate concentrations in precipitation; however, concentrations of nitrate have increased slightly ($p<=0.15$). Concentrations of nitrate, ammonium, and sulfate in precipitation all peak in the spring.

Alaska State and Local Air Monitoring System (SLAMS) and Interagency Monitoring of Protected Visual Environments (IMPROVE) Program

These programs monitor aerosols at DENA to calculate and track visibility conditions (1988 to present) in accordance with the USEPA's Regional Haze Regulations. ADEC operated one SLAMS background monitoring site at DENA (AIRS ID 02-290-0003), which was located uphill of the park headquarters and contained two monitors. The site was located on the regional haze IMPROVE monitoring shelter near the Rock Creek Water Treatment Plant, which is operated by the NPS. ADEC monitored $PM_{2.5}$ at this site until July 2003, comparing data collected by this method with data collected under the NPS' IMPROVE program. Data from this monitoring site indicated that the park's visibility was occasionally impaired by human-caused pollution (ADEC, 2001).

In addition, a digital web camera documents visibility conditions at DENA during summer months (www2.nature.nps.gov/air/webcams/index.cfm). IMPROVE aerosol monitoring is also conducted at Trapper Creek, which is located about 36 kilometers south of the DENA boundary (2001-present) (NPS, 2004g).

Clean Air Status and Trends Network (CASTNet)

This program (1998 to present) measures weekly concentrations of sulfur and nitrogen compounds at DENA. There is one CASTNet monitoring site at DENA (site DEN417). Two additional CASTNet sites operated in the vicinity of the park: the Poker Flat Research Range to the north (1998 to 2004) and the Trapper Creek site to the south (1998 to 2001) (NPS, 2004g; 2003b). Data from all three monitoring sites show low dry nitrogen and sulfur concentrations, with DENA being the lowest. Long-term trends from CASTNet are not available. Particulate sulfate concentrations tend to be highest in the winter/spring; sulfur dioxide concentrations are consistently higher during mid-fall and winter (November through March); and particulate ammonium concentrations are highest during spring and summer. Particulate nitrate concentrations show no seasonal trend and are low throughout the year. Nitric acid concentrations at DENA are generally low, with somewhat elevated levels in winter and summer (NPS, 2003b).

Western Airborne Contaminants Assessment Project

The NPS initiated the Western Airborne Contaminants Assessment Project in 2002 to determine the risk to ecosystems and food webs in western national parks from the long-range transport of airborne contaminants. It has been designed and implemented by the NPS' Air Resources Division in cooperation with national parks, USEPA, USGS, and several universities. The contaminants of concern are compounds known as semi-volatile organic compounds (SOCs). This group contains a variety of persistent organic pollutants (POPs), such as PCB and DDT, as well as elements such as mercury (Hg). Persistent organic pollutants (POPs) and other toxic airborne contaminants are a growing concern throughout the arctic and subarctic (NPS, 2004h). Arctic environments are sensitive indicators of climate change and atmospheric deposition. Materials transported through the atmosphere can have specific properties, such as cold fractionation, that facilitate their accumulation in cold areas. Watersheds within DENA can be particularly affected by global-scale atmospheric transport and deposition of toxic metals or changes in precipitation chemistry (NPS, 2004f). SOCs are direct or indirect products of human industrial activity and can be transported thousands of miles in the atmosphere (NPS, 2004h). In March 2003, sampling for this 6-year, multi-park project began in DENA. Snow samples were collected at Wonder and McLeod Lakes, and will be analyzed for an array of toxic airborne contaminants. Ecosystem indicators, including fish, lichens, willow bark, lake water, lake sediments, and moose tissue, were sampled at the two watersheds in August 2004 (NPS, 2004h). Preliminary results indicate that mercury concentrations in snowpack in DENA are roughly comparable to that in the 6 Western Airborne Contaminants Assessment Project parks in the lower 48 states (Blett, 2005.).

4.3 BIOLOGICAL RESOURCES

Water resources are important to the success of DENA's flora and fauna. Biological resources can serve as a tool for better understanding hydrological systems. For example, botanical evidence can assist with determining recent history of glaciers. Biological integrity can indicate environmental condition and ecological health of water resources. The following two sections provide background information on park biological resources that are influenced by water resources.

4.3.1 Flora

DENA preserves 6 million acres (2.4 million hectare (ha)) of intact subarctic ecosystems. The vegetation of DENA is a mosaic of taiga and tundra ecosystems that are controlled by the interaction of climate, topography, substrate, and site history (Roland, 2004). These determining factors vary considerably across the landscape of the park. The shape of the land – slope, aspect, elevation – exerts important influences on habitat attributes for plants, and how they vary and interact affects all of the major physical drivers for plant growth, including temperature, amount and distribution of solar energy, moisture, and other soil attributes.

DENA is located between 62 and 64 degrees north latitude. This forested portion of this region is considered taiga, or northern boreal forest biome. As such, DENA is predominantly forested below elevations of about 763 meters (2,500 feet), although local treeline varies with topography and location. Subalpine and alpine vegetation communities occur above treeline. In the subalpine zone (generally located between 2,500 ft (763 m) and 3,500 ft (1,068 m)), scrub vegetation, consisting mainly of tall shrubs interspersed with open white spruce (*Picea glauca*) woodland, dominates. In the alpine zone, tundra is found. The alpine zone occurs above 3,500 ft (1,068 m) and extends upwards to the polar zone, beginning at about 7,500 ft (2,288 m), where the limits of plant life are met.

A reconnaissance inventory of the vascular plant flora of DENA was conducted from 1998-2001 (Roland, 2004). With the results of this inventory, the number of species vouchered for the park flora reached 753 (816 taxa, including subspecies and varieties). This represents about 49 percent of the total number of species in the vascular flora of Alaska. The 753 resident species are members of 250 separate genera, representing 74 families of vascular plants. The Alaska Natural Heritage Program's database of existing species in Alaska National Parks is 1,309 species for DENA (Lenz et al., 2001). This discrepancy includes species that are probably present and unconfirmed.

Roland (2004) also characterized the growth forms of DENA vegetation. The largest growth-form class in the park flora is the herbaceous forbs, almost all of which are perennial species. Sixty percent of the vascular plant species that occur in the park are forbs (448 species). Graminoids (or grass-like plants) represent about a quarter of the park's vascular plant species (24 percent, or 178 species). Eleven percent of the vascular plant species have woody growth forms (85 species, including trees, shrubs, and dwarf shrubs). The remaining 5 percent of the vascular plant species that occur in the park are ferns and fern allies (25 species, or 3 percent of the total), clubmosses (11 species) and horsetails (7 species) (Roland, 2004).

In addition, non-vascular plant species new to DENA have been identified in an on-going examination of plant specimens collected from permanent vegetation monitoring plots. As of March 2004, 22 species of lichens, 10 species of mosses, and 5 species of liverworts have been added to DENA's non-vascular plant list since this work began (NPS, 2004a).

Also as part of the reconnaissance inventory of the vascular plant flora, Roland (2004) divided the park into nine separate floristic regions by grouping together areas with relatively similar ecological and floristic attributes. To simplify the discussion here, these nine regions are generally described below in three categories: lowland/forested zone, subalpine zone, and alpine zone according to NPS (2003e).

<u>Lowlands/Forested Zone</u>

Black spruce (*Picea mariana*) forest and woodland occupies areas underlain by permafrost, mostly north of the Alaska Range. The cold soil temperatures and impeded drainage found in these sites result in relatively low annual productivity and slow growth. Common understory shrubs in these areas include alder (*Alnus crispa*), dwarf birch (*Betula glandulosa*), and several species of willow (*Salix* spp.).

River corridors and upland areas with better drainage support more productive forest types than sites with permafrost because of higher soil temperatures and increased nutrient availability.

White spruce forest occupies uplands, sometimes mixed with paper birch (*Betula papyrifera*) on hillsides. Birch occupies early successional sites in relatively moist areas, while aspen (*Populus tremuloides*) is locally abundant in very dry or more xeric early successional sites.

In southerly aspects, spruce forest is gradually replaced by aspen woodland with increasing slope. Aspen forest is characteristic of warm, relatively steep slopes in the Interior and is much less common on the south side of the Alaska Range, where balsam poplar (*Populus balsamifera*) more commonly occupies warmer slopes in the forest. The very warmest and driest sites in the forest zone of the Interior are occupied by dry meadow and steppe-like vegetation dominated by grasses, scattered shrubs of juniper (*Juniperus communis*), and a variety of herbaceous perennials of the genera *Arabis*, *Erigeron*, *Pulsatilla*, and *Solidago*. Equivalent slopes to the south of the Alaska Range are more likely to support lush graminoid-forb meadows as a result of the moister growing conditions and historical factors.

Terraces along the major rivers support colonial herbs in newly abandoned channels, grading into thickets of alder and willow. Older surfaces support mature balsam poplar forests, grading into closed white spruce forests. Black spruce and mixed black-and-white spruce forests occupy areas where permafrost has developed and drainage is impeded.

Interspersed within the forested zone on both sides of the Alaska Range are numerous wetland and riparian areas dominated by herbaceous taxa, including sedges, rushes, grasses, forbs, and mosses. Wetlands in these areas occupy topographic depressions, thaw features, and sites with impeded drainage. Numerous ponds and wetlands dot large areas underlain by glacial till and represent relicts of kettlehole ponds formed as glacial ice retreated.

Subalpine Zone

In the subalpine zone, scrub vegetation dominated by dwarf birch, alder, and willow alternates with open spruce woodland and meadow sites. As the upper elevational limit of trees is approached, spruce woodland becomes very open and has higher relative cover of tundra shrubs, such as blueberry (*Vaccinium uliginosum*), dwarf birch, Rhododenron (*Rhododendron lapponicum*), and willows. The subalpine zone south of the Alaska Range crest, particularly in the Kahiltna and Yentna River drainages, is dominated by dense thickets of alder, devil’s club (*Echinopanax horridum*), and other shrubs of more coastal distribution. The vegetation in these areas is considerably denser than equivalent sites north of the Alaska Range.

Alpine Zone

The alpine vegetation of the park is most often dominated by dwarf shrubs of the families Rosaceae and Ericaceae, as well as graminoids and forbs. Due to the large amount of geomorphic activity and the relatively young age of many of the surfaces in the alpine zone, many slopes are essentially barren, supporting only a few scattered cushion plants. The upper limit of plant growth is about 7,500 feet, and elevations above 8,000 feet are mostly heavily blanketed by glacial ice.

In rivulet areas and more gravelly and disturbed snowbed sites, several saxifrages (*Saxifraga calycina*, *S. nelsoniana*, *S. nivalis*, *S. oppositifolia*, and *S. rivularis*) are very common throughout the park, particularly in high elevations. The distribution of these spatially limited snowbed communities on the landscape is controlled by late lying snow, which is determined by local topography and wind patterns that redistribute the snowpack. Accumulation zones in the lee of exposed slopes and topographic depressions are areas commonly associated with snowbed plant communities.

Dwarf scrub-sedge alpine tundra associations occupy mesic topographic positions in the park. These associations occur in more insolated sites than snowbeds and north-facing heath tundra. Dwarf-scrub-lichen tundra occurs on windswept ridges, sometimes with relatively sparse vascular plant cover of *Dryas* spp. and graminoids and abundant lichen.

Threatened and Endangered Species

No threatened or endangered plants are known to occur in DENA; however, one plant species is considered a Federal species of concern (former Candidate 2 species). The pink dandelion (*Taraxacum carneocoloratum*) is found on alpine slopes and coarse, well-drained substrates of the Alaska Range and has been documented on the north side of the park in gravelly areas and scree slopes (NPS, 2003e). Fifty-three vascular plant taxa that are considered rare in Alaska by the Alaska Natural Heritage Program (ranked S3 or lower) are known to occur in DENA (Roland, 2004). Fourteen of these taxa are considered globally imperiled (i.e., they have a global rank of G3 or lower).

Exotic Plant Species

No exotic species are known to occur in intact native plant communities in DENA (NPS, No date [c]). The relative scarcity of roads and other developed land has limited these outside invaders to only small and tenuous footholds around human settlements. Roland (2004) noted that more than 20 exotic vascular plant taxa have become established in developed areas and in the road shoulders within the park, but were never observed in native plant communities (even those adjacent to the Park Road).

An exotic plant survey along the Park Road found that most exotic plants were the common species of recent and continuing human disturbances, including pineapple weed (*Matricaria discoidea*), shepherd's purse (*Capsella bursa-pastoris*), and lambs quarters (*Chenopodium album*). White sweetclover (*Melilotus alba*) presents a larger problem, as it repeatedly invades the area and is capable of expanding along the Park Road via continuous introduction on vehicle tires. Narrowleaf hawksbeard (*Crepis tectorum*) has invaded and spread rapidly in the last several years. Common dandelion (*Taraxacum officinale*) is the only species that was found to spread along the Park Road beyond the developed areas at the east and west ends of the road (Densmore et al., 2001).

4.3.2 Fauna

DENA is well-known for its wildlife. There are 39 species of mammals, 167 species of birds, 22 species of fish, 26 species of benthic macroinvertebrates, and 1 species of amphibian, which are discussed below. Year-round residents include all the mammals, fish, about 25 species of birds, and the amphibian.

Fish

DENA has relatively low fish species composition and abundance compared to other regions of Alaska. This is largely due to the glacial character of many of the streams, which carry high loads of suspended sediment from glacial melt-water, the high altitude, and the fact that most streams are the headwaters of much larger drainages (Miller, 1981). The glacial rivers also generally contain few pools or slow-moving sections that would provide suitable rearing habitat for fish (NPS, 2003a). Lakes and non-glacial streams originating from headwaters of mountainous areas without glaciers and from small watersheds in moraines and lowlands provide much of the good habitat for fish (Miller, 1981). All five species of Pacific salmon (*Oncorhynchus tshawytscha*) and at least six other species of freshwater fish commonly harvested for subsistence and sport inhabit streams and lakes in various areas of DENA (NPS, 2003e; Markis et al., 2004). In addition, blackfish (*Dallia pectoralis*), longnose sucker (*Catostomus catostomus catostomus*), slimy sculpin (*Cottus cognatus*), and Arctic lamprey (*Lethenteron camtschaticum*) inhabit park waters. The five species of salmon, Dolly Varden (*Salvelinus malma malma*), several species of whitefish (*Coregonus nelsoni*), and lamprey are anadromous species that migrate from salt water to freshwater to spawn. Depending on the species, juveniles remain in freshwater-rearing habitats for varying periods before migrating to salt water. Resident species, such as grayling (*Thymallus arcticus arcticus*), sheefish (*Stenodus leucichthys*), rainbow trout (*Oncorhynchus mykiss*), lake trout (*Salvelinus namaycush*), blackfish, suckers, and sculpins, live in freshwater habitats year-round, although some undertake extensive seasonal migrations. Waters used by anadromous species receive high levels of protection because of the value of these species for subsistence, commercial, and sport harvest.

Fish species reported in some of the larger lakes, such as Wonder Lake, Chilchukabena Lake, Sprucefish Lake, and Blackfish Lake, include the northern pike (*Esox lucius*), broad whitefish (*Coregonus nasus*), blackfish, burbot (*Lota lota*), and sculpin. However, no comprehensive inventory of fish, or evaluation of its importance to the local environment, exists. In addition, lake trout occupy Wonder Lake and its outlet, Lake Creek. However, this is believed to be an isolated population and, as a popular sport fish in DENA, may be susceptible to overfishing (NPS, 1998a).

Arctic grayling, the most common resident species of gamefish in the park, inhabit many streams throughout DENA, including several streams near the Park Road corridor, such as Caribou, Hogan, Igloo and Little Stony Creeks (NPS, 2003e). Grayling have also been found in the Kantishna River (sloughs/springs) and Bearpaw River (Cleary, 2004). Grayling prefer non-glacial, cold, gravel-bottomed streams, and do not tolerate the silt-laden flows of glacial rivers during the summer months. Arctic grayling spawn early in the summer, from mid-May to June. Rainbow trout spawn in the spring, mainly between mid-April and late June. Other resident species spawn at different times of the year: northern pike in early spring (coinciding with spring breakup); lake trout in September and October; whitefish and ciscos in late September and October; and burbot from December through February (NPS, 2003e).

Salmon and other anadromous species use freshwater habitats for migration, spawning, and rearing of young. These species spawn in park streams, such as the Bearpaw, Toklat, McKinley, Foraker, and West Fork of the Yentna River. Adult salmon produced from these streams are important to subsistence and commercial fisheries located downstream. The Kantishna, Nenana, Yentna, Tokositna, Chulitna, and Susitna Rivers are major drainages outside the park that receive park waters and support anadromous fish (NPS, 1998a). Spawning seasons differ among species, and there are often multiple spawning runs involving different species of salmon in some drainages. Coho salmon (*Oncorhynchus kisutch*) generally spawn from midsummer to early winter at the head of riffle areas in narrow side channels and tributaries of mainstream rivers. Pink salmon (*O. gorbuscha*) usually enter natal streams from late June to September. Sockeye salmon (*O. nerka*) spawn during the summer and fall from July to October (sometimes as late as December), primarily in streams connected to lakes and along lake shorelines. Chinook salmon (*O. tshawytscha*) spawn from July to early September. Most chum salmon (*O. keta*) spawn in August and September. Dolly Varden char spawn between the end of July and the beginning of December, with most occurring in September and October. The amount of time spent in freshwater habitats by juveniles of the anadromous species is highly variable, depending on the species; some migrate downstream from spawning areas within a few months of hatching, whereas others may spend several years in freshwater before migrating to the ocean (NPS, 2003e).

In the Kantishna River watershed, chum salmon, Arctic grayling, round whitefish (*Prosopium cylindraceum*) and slimy sculpin are known to inhabit Moose Creek in the vicinity of the bridge. Grayling have also been found in the Kantishna River (sloughs/springs) and Bearpaw River (Cleary, 2004). Chinook and coho salmon and northern pike inhabit areas of Moose Creek further downstream. Salmon migrating up Moose Creek generally reach the vicinity of the bridge by mid- to late August (NPS 2003a).

In 1999, the Alaska Department of Fish and Game (ADF&G) initiated a fall chum and coho salmon stock assessment study in the Kantishna and Toklat Rivers. In 2000, DENA entered into a partnership with the ADF&G in this study. ADF&G operates a live capture fish wheel in the lower Kantishna River, where salmon are captured, tagged, and released. The ADF&G also operates two live capture recovery fish wheels on the Toklat River, and DENA operates a live capture recovery fish wheel in the Kantishna River. These fish wheels operate 24 hours per day from August 15 through October 5 (NPS, 2004i).

In 2004, a fall chum salmon stock assessment was conducted on the Tanana and Kantishna Rivers. Data from this assessment was used to estimate fall chum abundance for these rivers. Preliminary fall chum abundance at 119,898 (SEM ± 10,712) for the Tanana River and 64,950 (SEM ± 3,195) for the Kantishna River was the second highest estimate since the project was initiated (NPS, 2004j). In addition, an October 2004 survey for fall chum salmon was conducted of the upper Kantishna River drainage streams. This survey found chum salmon in the Bearpaw River (mouth of Bearpaw to about 1 mile above Diamond), Moose Creek (from upper Moose

Creek near Kantishna to Moose Creek confluence with the Bearpaw River), McKinley River (lower 15 to 20 miles of the River until its confluence with the Kantishna River), and Hult Creek (from outlet to about 0.5 miles above its confluence with White Creek. No salmon were detected in Hot Slough or in the two sloughs/springs near John Hansen Lake on the Kantishna River (Cleary, 2004).

Also in 2004, fall chum salmon escapement was estimated on the Delta and Toklat Rivers. The Delta River has a biological escapement goal of 6,000 to 13,000 fall chum salmon. In 2004, escapement on the Delta River was estimated at 25,073 salmon. The Toklat River in the Kantishna River drainage has a biological escapement goal of 15,000 to 33,000 fall chum salmon. The Toklat River escapement was 35,480 fall chum salmon in 2004 (NPS, 2004j).

On the south side of DENA, Peters Creek and its major tributaries are rated the seventh most important waterway system in the Susitna Basin by the ADF&G (NPS, 2003e). Chelatna Lake contains important salmon spawning habitat. The Susitna River and its tributaries support the largest stock of king salmon in the Cook Inlet drainage, which is thought to be the fourth largest stock in Alaska. The Susitna River also supports the largest coho salmon stock in northern Cook Inlet. Fishing is generally permitted throughout the south side; however, the Tokositna River drainage and Byers Creek are closed to chinook salmon fishing. The species harvested for subsistence include chinook, sockeye, and coho salmon; lake and rainbow trout; Arctic grayling; and burbot.

Benthic Macroinvertebrates

Macroinvertebrates are good indicators of aquatic health and reflect the health of a waterbody over a relatively long period of time. Species populations can be an effective measurement of environmental changes since certain species respond differently to various stresses in the environment (e.g., pH fluctuations, increases in contaminants). Several long-term aquatic macroinvertebrate studies have been conducted in DENA, both as part of a specific study (i.e., stream reclamation study by Karle and Densmore, 1994; the effects of mining by Mangum, 1986 and Oswood et al., 1990), or as a component of a long-term ecological monitoring program (Milner and Gabrielson, 1993).

Taxa diversity of the macroinvertebrate community in DENA as throughout many areas of Alaska is markedly low when compared to temperate areas of North America. This is attributable to several factors relating to the latitude- and climate- extremes that affect the region. Many insect species reach the northern limits of their range in Alaska (Conn, 1998). Their expansion northwards is limited by the effects of low temperatures, as manifested by physiological ability to withstand freezing, behavioral adaptations to avoid freezing, and ability to grow and reproduce under these conditions. Despite the low numbers of taxa found, densities of macroinvertebrates in Alaskan streams have been found to be similar to those described for temperate systems (Conn, 1998).

Benthic macroinvertebrates were studied in numerous streams throughout DENA in 1994 and 1995. Based on the results of the data, streams within the park were classified into six distinct groups which can be described as:

1. *Glacially fed rivers* – have unstable channels and support a low abundance and diversity of macroinvertebrates, but diversity and density increase with increasing distance from the glacier.
2. *Non-glacially fed rivers* – small rivers with stable channels and riparian zones with abundant growth of willow and alder.
3. *Spring-fed creeks* – small creeks with stable channels, a close riparian border, and much of the channel is shaded.
4. *Kantishna rivers* – located in Kantishna and the north-western area of the park, these rivers have a well-developed riparian zone and support the greatest diversity of benthic macroinvertebrates in DENA.
5. *Large rivers* – some with slight glacial meltwater influence.
6. *Small unstable creeks* – high gradients, actively migrating channels, and respond rapidly to summer precipitation events (Conn, 1998).

The benthic macroinvertebrate communities of each of the six groups were significantly different in terms of diversity and the degree of inter and intra seasonal variation (Conn, 1998). The most important variables separating the groups from each other were channel stability, water temperature, nitrate concentration, and turbidity (Conn, 1998). Temperature is considered to be the dominant variable influencing invertebrate community structure in glacial rivers (Milner and Petts, 1994). In DENA the variation in benthic macroinvertebrate fauna is very large between watersheds, but relatively homogeneous within a watershed.

Conn (1998) identified 26 taxa of benthic macroinvertebrates, including 6 families of Diptera, 6 genera of mayflies, 7 stonefly genera, and 6 Trichoptera genera. The only non-insects found were Oligochatae worms. Many of the glacier-fed rivers located on the north side of the Alaska Range contained very low numbers of Diptera and no other taxa were found. Sites located in the Kantishna area commonly had over 15 taxa of macroinvertebrates with very high densities (Conn, 1998). The lowest abundance and diversity of benthic macroinvertebrates were found in glacier-fed rivers and in Rock Creek in the Kantishna area.

Overall, the benthic macroinvertebrate studies in DENA have revealed that species diversity is low while the population density is high, particularly in more stable non-glacial streams (Conn, 1998). Abundance of benthic macroinvertebrates has been shown to vary markedly from year to year (Milner et al., submitted), and certain taxa may not be found at all in some streams in all years. Such variability in macroinvertebrate abundance is likely due to channel stability, flow variability, and climatic conditions, such as snowfall. Generally, however, undisturbed streams show less variability in macroinvertebrate communities over time than streams with unstable channels.

Amphibians

The wood frog (*Rana sylvatica*) is the only species of amphibian that occurs in DENA (NPS, No date [c]). The wood frog spends its life in the woodlands and vegetated wetlands across Alaska and occurs in DENA at lower elevations. It hibernates through the winter in shallow depressions in the upper layer of the previous year's dead vegetation and breeds in spring in seasonal ponds primarily in forested areas. Results from a preliminary survey suggest that wood frogs are relatively widespread across DENA and that populations are relatively dense across the landscape (NPS, 2004a).

Mammals

Thirty-nine species of mammals have been documented in DENA and range in size from the 1,200-pound moose to a 1.5-gram shrew (NPS, 2002d). Wetlands and riparian areas are important habitats for large and small mammals such as moose (*Alces alces*), caribou (*Rangifer tarandus*), bear, beaver (*Castor canadensis*), river otter (*Lutra canadensis*), and muskrat (*Ondatra zibethica*).

Moose are abundant throughout the year in and near the numerous drainages. During calving from late May through June, cows seek areas in their home range that provide low predator densities (islands in rivers) or improved visibility (open muskeg areas) (NPS, 2003e). Post-calving moose generally move to higher elevations. Fall rutting and post-rutting concentrations occur in subalpine habitats, with moose moving down from these areas in winter as snow depths increase. Moose depend on wetlands and riparian corridors for forage and spend much of the year in these habitats. Riparian willow stands provide a large part of winter forage, and upland coniferous forests provide thermal cover and shallower snow depths.

Before the 1990s, moose were abundant in the broad drainages on the south side of the Alaska Range, particularly in the Tokositna, Ruth, and upper Yentna drainages. The Yentna drainage alone supported approximately 300 moose. During a 1996 survey, park staff observed only 202 moose in the Yentna River drainage within the preserve boundary. Since that survey, there has been a 50 percent or greater decline in moose numbers throughout the southern slope of the Alaska Range, likely due to deep snow winters and increasing predator numbers (NPS, 2003e).

Caribou are migratory herd animals that use varying habitats for wintering, calving (late May to early June), summer range, and rutting (September and October). The Denali Caribou Herd currently numbers approximately 2,000 caribou and ranges over approximately 10,000 square kilometers, including most of DENA north of the Alaska Range, and areas south of the range and east of Mount McKinley. During breeding season in mid-September, caribou aggregate into rutting herds. These rutting groups can be found from the foothills of Mount McKinley, north through the Upper Moose Creek drainages, and into the Toklat, East Fork, and Sushana River drainages (NPS, 2003e).

Both brown (grizzly, *Ursus arctos*) and black (*Euarctos americanus*) bears inhabit DENA where habitats provide abundant foods as well as denning areas. Brown bears range throughout the park, but generally prefer high-elevation tall shrub, low shrub, and alpine tundra communities. In contrast to brown bears, black bears prefer upland forest and floodplain forest communities below elevations of 2,000 feet. Black bears are known to be present in relatively large numbers in the lowland forests of the Chulitna, Ruth, and Tokositna Rivers; however, their home ranges often extend out of these forests well up into the open tundra vegetation of the higher foothills. They are present from the lower end of the Ruth Glacier down to the Tokositna River, in the

Chelatna Lake area, and on south facing slopes of the Hidden River, Coffee River, and Tokositna River.

Beavers, muskrat, and river otters live in areas dominated by ponds, lakes, and streams. Beavers play a major role in diverting water and creating small-to-large ponds. Beavers have a considerable influence on the distribution of wetlands through the impounding of streams, particularly in the forested lowlands of the Yentna, Susitna, Kantishna, and Kuskokwim River basins (NPS, 2003e). Beavers physically alter habitats by cutting down trees, building dams, digging canals, and building lodges. When beavers dam a stream, they slow the movement of water and form a pond of still water behind the dam. This pond is then colonized by plants and animals that typically live in lakes rather than streams. Organisms dependent on fast moving water either die out in the pond or move to parts of the stream where the flow of water has not been slowed by the dam. After a beaver dam has been in place for 10 years or more, the pond it created typically has an abundance of submerged and emergent vegetation, along with the many animals that live in such vegetation. Other effects of beaver ponds include changes in surrounding tree species compositions, flooding of tree roots with subsequent death of trees, and alteration of wildlife distribution and abundance, including that of fish, invertebrates, birds and amphibians (Haemig, 2005).

Birds

DENA supports a cosmopolitan avian fauna with 167 documented species (NPS, 2003e; NPS, No date [c]). All of the major groups of birds (waterfowl, raptors, grouse, shorebirds, near-passerines, and passerines) found in Interior Alaska are found at DENA. At least 119 bird species breed in DENA. The rich avifauna is supported by a diversity of habitats, with the distribution of avian species being a function of habitat and elevation. Except for approximately 25 resident species, most birds are migratory and occur in DENA only during the breeding season (April to October).

The Minchumina basin, in the northwestern portion of the park, supports the highest densities of breeding waterfowl in DENA. Except for a few species, waterfowl distribution on the south side is limited to the wetlands, lakes, and ponds along the southern park boundary, and lands south of the park boundary contain more waterfowl habitat. Of the 20 species of migratory waterfowl that breed in DENA, trumpeter swans (*Cygnus buccinator*), harlequin ducks (*Histrionicus histrionicus*), and Tule greater white-fronted geese (*Anser albifrons gambelli*) are of particular interest on a nationwide basis (NPS, 2003e).

Breeding and staging trumpeter swans occur on the south side of the Alaska Range, particularly in the Yenta and Tokositna drainages, and in the Minchumina basin on the north side of the Alaska Range. However, there is limited swan habitat within the boundaries of DENA on the south side of the Alaska Range. Wetlands and waterways from the Yenta River drainage east to the Ruth River drainage contain large numbers of breeding swans, with the highest concentrations of swans in the Minchumina basin, and large flocks of staging swans in the Chulitna River area, especially between the Tokositna drainage and West Fork of the Chulitna River (NPS, 2003e).

Harlequin ducks are designated as species of concern by the USFWS because they winter in coastal areas that are threatened by habitat degradation. Harlequin ducks occur in fast-moving non-glacial streams and rivers in the Alaska Range, including at DENA. Although population surveys have not been conducted in the park, Moose Creek in the Kantishna area and other non-glacial streams probably support breeding harlequin ducks (NPS, 2003e).

The Tule greater white-fronted goose, a subspecies of the greater white-fronted goose (*Anser albifrons*), is considered "at risk" by the International Waterfowl Research Bureau, although it is not listed federally or by the State. They nest at very low densities from the Yenta River drainage to the Tokositna River drainage within and adjacent to DENA's boundaries (NPS, 2003e).

In autumn, tens of thousands of sandhill cranes (*Grus canadensis*), Canada geese (*Branta canadensis*), greater white-fronted geese, trumpeter and tundra swans (*Cygnus columbianus*), and other waterfowl migrate through the area, especially along the north side of the Alaska Range, the Wonder Lake and eastern Kantishna Hills areas, and the northern additions. Many of these species also use wetlands and tundra areas for feeding and resting during migration. In spring, migratory waterfowl are often forced to congregate in relatively small areas of open water. For instance, flocks of white-winged scoters (*Melanitta fusca*) numbering in the hundreds often stage at the south end of Wonder Lake in spring (NPS, 2003e).

Raptors are well represented in the avifauna of DENA, and include eagles (bald [*Haliaeetus leucocephalus*] and golden [*Aquila chrysaetos*]), falcons (gyrfalcons [*Falco rusticolus*] and peregrine [*F. peregrinus*]), merlins (*F. columbarius*) and kestrels (*F. sparverius*), accipiters (northern goshawk [*Accipiter gentilis*] and sharp-shinned hawk [*Accipiter striatus*]), northern harriers (*Circus cyaneus*), and owls (great gray [*Strix nebulosa*], short-eared [*Asio flammeus*], northern hawk [*Surnia ulula*], boreal [*Aegolius funereus*], great horned [*Bubo virginianus*], and snowy [*Nyctea scandiaca*]). Until recently, most quantitative data on raptor abundance, distribution, and habitat preferences in DENA were restricted to studies on the north side of the park on a few species: golden eagles, gyrfalcons, merlins, and northern hawk owls (NPS, 2003e). Ospreys (*Pandion haliaetus*) have been observed south of DENA, with at least one pair nesting in the Trappers Creek area, and are occasionally seen in the Wonder Lake area.

Shorebird species nest in subalpine and alpine habitats (whimbrel [*Numenius phaeopus*], upland sandpiper [*Bartramia longicauda*], surfbird [*Aphriza virgata*], semipalmated plover [*Charadrius mongolus*]) and wetland and riparian areas (yellowlegs [*Tringa* spp.], common snipe [*Gallinago gallinago*], solitary sandpiper [*Tringa solitaria*], wandering tattler [*Heteroscelus incanus*]). DENA provides important summer breeding grounds for two species that winter at sea: Arctic tern (*Sterna paradisaea*) and long-tailed jaeger (*Stercorarius longicaudus*). The numerous lakes and ponds at lower elevations provide important breeding habitats for the Arctic tern, and longtailed jaegers breed in subalpine and alpine areas of the park.

The olive-sided flycatcher (*Contopus borealis*), also a Federal species of concern, nests in open coniferous forests with bog ponds and marshy streams and in woodland/dwarf forest, usually in black spruce trees located near drainages (NPS, 2003e). This species has been recorded annually on point counts and Breeding Bird Surveys on the north and south sides of the Alaska Range and has been found breeding on the north side near Moose Creek.

Currently, 11 bird species dependent on boreal forest wetlands have been listed as species of concern by the North American Bird Conservation Initiative (2004) because of their declining populations. All of these bird species are found in wetlands throughout the Central Alaska Network (CAKN), and all are found in DENA. These species include the greater (*Aythya marila*) and lesser (*Aythya affinis*) scaups; white-winged, black (*Melanitta nigra*), and surf (*Melanitta perspicillata*) scoters; short-eared owl; rusty blackbird (*Euphagus carolinus*); olive-sided flycatcher; blackpoll warbler (*Dendroica striata*); Lincoln’s sparrow (*Melospiza lincolnii*); and horned grebe (*Podiceps auritus*) (Larsen et al., 2004).

4.4 SOCIOECONOMIC RESOURCES

4.4.1 Recreation

In 2003, DENA reported 359,840 recreational visitors, compared to 353,560 in 2002, and 360,218 in 2001 (NPS, 2004a). The vast majority of visitation occurs during the months of June, July, August, and September (NPS, 1986). Visitation of all types is anticipated to increase over the next 10 to 15 years (NPS, 2004d).

The entrance area of DENA houses many visitor facilities and services for users of the park. The Visitor Access Center is located in this area, along with NPS interpretive programs, dog kennels, the staging area for bus and shuttle tours, a campground, and trail network. A new visitor center, food court, and bookstore are currently under construction on the site of the former Denali Park Station Hotel, and are expected to open in 2005. The new Murie Science and Learning Center will also host a winter visitor contact center (NPS, 2004d).

The Eielson Visitor Center is located at Mile 65 of the Park Road and is the main stop and turnaround site for the park’s shuttle bus system. Due to overcrowding and undersized facilities at this visitor center, this facility is scheduled to be replaced, with construction commencing in 2005 and ending in 2006. Two temporary structures will be situated at the Toklat Rest Stop at Mile 53 to provide visitor services during construction (NPS, 2004e).

Numerous recreational activities are offered at DENA. Summer activities include day hiking, backpacking, cycling, camping, fishing, nature walks, mountaineering, kennel visits, and photography/wildlife viewing. Winter activities include cross-country skiing, dog mushing, snowshoeing, photography, and snowmobiling. Visitors are permitted to bike all 90 miles of the Park Road. Off-road biking and biking on trails are prohibited (NPS, No date [a]). The only designated picnic area in DENA is near the Riley Creek Campground. The Stony Overlook pullout at Mile 62 of the Park Road includes picnic tables, but no restroom facilities (NPS, 2003e)

Water-related recreation at DENA includes boating (kayaking, canoeing, rafting, floating), powerboating, swimming, water skiing, and sport fishing. All areas are open to launching of boats, swimming, and water skiing, with no permits required. There are also no restrictions on vessel size or on activities such as snorkeling or scuba diving (NPS, 2004b). Surface waters at DENA believed to receive the heaviest use are the Nenana River, Moose Creek (in the Kantishna area), Horseshoe and Triple Lakes, and Wonder Lake (NPS, 2003e). The Nenana River is thought to receive the most recreational use, and represents one of the premier recreational rivers in Alaska. Recreational opportunities on this river include rafting (commercial and private), canoeing, kayaking, powerboating, and fishing (NPS, 1998a).

While most streams and lakes in DENA are not prime sport fishing areas, some fishing opportunities are available at the park. Moose Creek and Wonder Lake in the Kantishna area offer opportunities for Arctic grayling and lake trout fishing. The NPS estimates that recreational fishing on Moose Creek upstream of North Face Lodge is minimal (about 1 person or less per day, or less than 90 fishing days per year). Approximately 10 to 15 fishers use Moose Creek below North Face Lodge each day of the season (or about 900 fishing days per season). However, no catch data are available. Anecdotal information indicates that sport fisheries use in the Moose Creek drainage and Wonder Lake by park visitors is increasing. Other popular fishing areas at DENA include the Triple Lakes and Caribou Creek. Recreational fishing activity in other areas of DENA are not well known; however, fishing is known to be a popular activity on the south side of the Alaska Range near the park boundary (NPS, 2003e).

There are currently 11 maintained hiking trails within DENA (see **Table 4.4-1**); however, visitors are allowed to hike almost everywhere in the park. No permits are required for day hiking in the park.

Table 4.4-1. Maintained Hiking/Walking Trails within DENA

Trail	Approx. Distance	Location
Horseshoe Lake Hike	0.7 miles one way	Park entrance area (starts on the Taiga Loop Trail and joins the Horseshoe Lake Trail at the railroad tracks)
Mount Healy Overlook Trail	2.2 miles one way	Park entrance area
Taiga Trail	1.3 miles	Park entrance area
Roadside Trail	1.8 miles one way	Park entrance area
Rock Creek Trail	2.3 miles one way	Park entrance area
Savage River Trail	2 miles round trip	Savage River Canyon
Savage River Bar Trail	0.2-mile loop	West side of Savage River
Savage Cabin Interpretative Trail	0.3 miles	Savage River
Eielson Stroll	45-minute loop	Vicinity of Eielson Visitor Center
McKinley Bar Trail	4.4 miles (round-trip)	Trail starts at the Wonder Lake Campground and continues south towards the McKinley River
Jonesville Trail	0.4 miles	Park entrance area; leads to the business district outside the park

Source: NPS, No date [a]

Table 4.4-2 lists the campgrounds available at DENA, along with their locations, uses, availability, and the facilities they provide.

Table 4.4-2. Campgrounds at DENA

Name	Location	Use	Open	Facilities
Riley Creek Campground	1/4 mile west of Alaska Hwy. #3	150 sites for RVs and tents	Year-round	Flush toilets, water, (limited facilities Sept.-May)
Morino Backpacker	Mile 1.9	60 Tent	May - Sept. (weather dependent)	Pit toilets, water
Savage River Campground	Mile 13	33 sites for RVs and tents	May - Sept. (weather dependent)	Flush toilets, water
Savage Group Campground	Mile 13	3 tent sites for large groups	May - Sept. (weather dependent)	Flush toilets, water
Sanctuary River Campground	Mile 23	7 sites, tents only (no vehicles), bus	May - Sept. (weather dependent)	Chemical toilets, no water
Teklanika River Campground	Mile 29	53 sites for RVs and tents (closed to tents until further notice, hardside campers only)	May - Sept. (weather dependent)	Flush toilets, water
Igloo Creek Campground (currently closed until further notice due to wildlife activity)	Mile 34	7 tent sites	May - Sept. (weather dependent)	Pit toilets, water
Wonder Lake Campground	Mile 85	28 sites, tents only (no vehicles), bus	June - Sept. (weather dependent)	Flush toilets, water

Source: NPS, No date [a]

The 6 million acres of DENA is divided into 87 separate backcountry units, 41 of which have a limit on the number of individual people that can camp in each unit per night. With the exception of day hiking, permits are required for all backcountry uses except on the South Side, including camping, skiing, mountaineering, and snowshoeing. Neither pit nor chemical toilets are available in the backcountry (NPS, No date [a]).

Mountaineering is a popular recreational activity at DENA. Although Mount McKinley and Mount Foraker are popular attractions, the majority of use occurs on three peaks: Scott, Pendleton, and Brooks (NPS, No date [a]). The NPS keeps annual counts of the number of Mt. McKinley and Mt. Foraker climbers and expeditions. In 2004, 1,275 climbers attempted Mt. McKinley and 16 attempted Mt. Foraker (NPS, 2004c). In 2003, climbers totaled 1,179 and 34, respectively, compared with 1,232 and 36, respectively, in 2002, and 1,305 and 40, respectively, in 2001 (NPS, 2001b; 2002c; 2003f).

Winter trails in the park that are commonly used by mushers and skijorers are located along the Park Road corridor and the Stampede Road corridor. The Park Road corridor includes three trail areas: Headquarters to Savage Campground, Savage Campground to East Fork, and the Toklat

Loop, a 100-mile loop from Park Headquarters to Toklat, then downstream to the Stampede Trail. The Stampede Road corridor follows Stampede Road to the Sushana River (NPS, No date [a]).

Snowmobile use is not allowed in the portion of the park formally known as Mt. McKinley National Park, but is permitted for subsistence and traditional activities in all the 1980 additions to DENA, providing there is adequate snow cover. Off-highway vehicle (OHV) use is allowed only on designated trails to access those areas where they have been traditionally employed for subsistence purposes. The recreational use of OHVs off established roads, parking areas, or designated routes in DENA is prohibited. Currently, there are no designated OHV routes or areas at DENA (NPS, 2004b).

Three NPS-permitted concessionaires operate out of the Kantishna area, located at the end of the Park Road: Denali Backcountry Lodge, Denali National Park Wilderness Centers (Camp Denali and North Face Lodge), Kantishna Roadhouse, and Kantishna Air Taxi. All of these are wilderness lodges that offer a variety of recreational/visitor activities, including hiking, cycling, recreational gold panning, boating, horseback riding, and flightseeing (NPS, 2003e).

Denali Sightseeing Safaris, a commercial outfitter, gives backcountry sightseeing tours to visitors in large-tire "monster" trucks. This tour transports visitors along a 100-foot-wide State-owned right-of-way (called the Colorado-Bull River Road) to locations inside DENA in the Dunkle Hills area. This 30-mile round-trip tour travels along a former mining access route, and crosses several streams, including Bull River and the braided West Fork of the Chulitina River. Bridges formerly crossed these rivers, but no bridges exist today (NPS, 2003e; Phillips, 2001). Other "monster truck" trips have started up in other areas adjacent to DENA. No such trips are commercially allowed on NPS lands within DENA boundaries, and all trips are currently on State land or State selected Federal land that is generally downstream of the park (Adema, 2005b).

4.4.2 Infrastructure

Facilities/Development

Development within DENA's boundaries is concentrated in the frontcountry, including the park entrance and headquarters area, along the 92-mile Park Road, and in the Kantishna area at the end of the Park Road. Developed facilities near the park entrance and headquarters areas and along the Park Road corridor include the Visitor Access Center, parking areas, campgrounds, railroad depot, airstrip, visitor accommodations, rest areas, employee housing, various maintenance shops, administrative buildings, and utilities (NPS, 2003e; 1998a). Recreational facilities and services in the frontcountry, including campgrounds and visitor centers, are described in detail in Section 4.4.1, *Recreation*. Rest areas (Teklanika, Polychrome, Toklat) are located at nearly every major node along the Park Road corridor, and range in development from portable toilets to comfort stations (NPS, 2003e). In addition, the Salvage River Check Station is located at Mile 14.8 of the Park Road, where the road changes from paved to gravel.

Three NPS-permitted concessionaires operate out of the Kantishna area, located at the terminus of the Park Road. The Denali Backcountry Lodge includes a vacation lodge and 30 cedar cabins. The Denali National Park Wilderness Centers owns and operates two facilities, Camp Denali and North Face Lodge, both of which include a wilderness lodge. Camp Denali also includes 17 guest cabins. The Kantishna Roadhouse Company operates a wilderness lodge and associated cabins. All three of the Kantishna area businesses are located on private inholdings and operate from late-May through mid-September (NPS, 2003e). These businesses are concentrated along a 3-mile stretch of Moose Creek (NPS, 1998a).

The Eielson Visitor Center is located at Mile 65 of the Park Road and is the main stop and turnaround site for the park's shuttle bus system. Among other features, the building contains sales and exhibit rooms, restrooms, and drinking water. While used primarily for visitor services, the building also serves management and administrative functions (NPS, 2003e). Due to overcrowding and undersized facilities, the visitor center is scheduled to be replaced, with construction commencing in 2005 and ending in 2006. Two temporary structures will be situated at the Toklat Rest Stop at Mile 53 to provide visitor services during construction. The proposed Eielson Visitor Center development calls for replacing the existing visitor center with an approximately 9,000 square-foot facility, enlarging the existing parking lot to accommodate 9 permanent bus spaces and 10 private and administrative parking spaces, replacement of the existing septic system and leach field, and installation of a small hydro power plant structure and associated water piping and power lines. Proposed development at the Toklat Rest Stop includes parking for 15 buses and 10 cars, 3 large vault toilets, a new visitor and staff office facility, and associated utilities (NPS, 2004e).

In addition to changes to the Eielson Visitor Center, the *Entrance Area and Road Corridor Development Concept Plan* (NPS, 1997) proposes several new developments in the frontcountry of DENA. These include construction of additional parking areas, visitor buildings, entrance station, offices, and other facilities in the park entrance area; construction of a comfort station, parking area, package sewage treatment plant, emergency medical service/search and rescue station, and additional administrative space in the park headquarters/C-Camp area; construction of a Savage River Rest Stop; upgrades to housing within the vicinity of the Toklat Rest Stop; and rehabilitation of the Ranger Station and housing in the Wonder Lake area (NPS, 1997).

The *South Side Denali Development Concept Plan* (NPS et al., 1997) provides for resource-based destination experiences on the south side of the Alaska Range. The proposed development includes development of a visitor center and other visitor facilities in the Tokositna area and along the George Parks Highway, as well as improved access to the Dunkle Hills area. The majority of the proposed development is located outside the DENA boundary (NPS et al., 1997).

Several additional commercial lodging, camping, and other developed operations exist outside the park in the vicinity of the entrance area along the George Parks Highway, as well as to the south of the park within or near Denali State Park. Recent community developments in the Healy area near the park entrance include auto services, hotels, bed and breakfast establishments, campgrounds, eating facilities, commercial flightseeing, horseback riding, and river rafting services (NPS, 2003e). In addition, over the past two decades, an extremely concentrated area of development has arisen between Mile 238 and 239 of the George Parks Highway, just to the north of the park's entrance. This development is located in a narrow band along the highway, much of which is sandwiched between the highway and the Nenana River, and consists of a wide range of businesses, including hotels, restaurants, campgrounds, recreational outfitters, and bus parking and maintenance facilities (NPS, 1998a).

Water Supply Systems and Wastewater

Potable Water

Water supply systems, consisting mainly of deep and shallow wells and three surface water systems, are located as to provide high quality water while being as close as possible to the park infrastructure requiring water. Chlorination and filtration serve as the primary treatment for the park's fresh water needs. The parks' drinking water monitoring and treatment program is implemented by the U.S. Public Health Service to insure that drinking water quality standards are met. Deep wells serve the potable water needs of the headquarters area, Visitor Access Center, and several campgrounds. Shallow wells formerly served the Sanctuary and Igloo campgrounds, but they did not meet U.S. Public Health Service requirements and were closed in 1993. A beaver pond serves as the water source for the Wonder Lake Ranger Station. Surface water is also used as a water source for the Eielson Visitor Center. In addition to potable water supplies, water is also drafted from surface water sources for various maintenance and construction operations (NPS, 1998a).

NPS Wastewater Facilities

In 2002, DENA contracted HDR Alaska. Inc. to conduct a study of the parks' wastewater facilities. The park owns and operates an aerated sewage lagoon followed by a percolation basin near the entrance to the park, which were designed and constructed in the early 1970s. Wastewater is treated in the aerated lagoon and the effluent flows through a manhole into the percolation basin which allows for percolation of the effluent into the ground. The lagoon and percolation basin each hold approximately 2.7 million gallons. Approximately 20 inches or 470,000 gallons of sludge was removed from the aerated lagoon in 1989 prior to replacement of the lagoon's liner. The sludge was buried in a monofill near the percolation pond. In 2003, approximately 12 inches of sludge was removed and was treated and hauled offsite by a contractor (HDR Alaska, 2004).

The original design flow for the wastewater treatment system is 144,000 gallons per day with design Biochemical Oxygen Demand (BOD) of 450 pounds per day in the summer based on contributions solely from the old hotel, dormitory, service station, railroad depot, and Riley Creek campground. Currently all wastewater from these facilities enters the lagoon during the summer months between mid-May and mid-September. Additional truck hauled waste originating from 11 facilities with septic tanks, and 15 facilities with sewage holding tanks, chemical toilets, and sweet smelling toilets along the Park Road is discharged into the piped collection system through a manhole upstream from the aerated lagoon during this same summer period (HDR Alaska, 2004).

The Headquarters and C-Camp areas do not contribute wastewater to the aerated lagoon. These facilities are served by on-site wastewater disposal systems consisting of septic tanks and leachfields (HDR Alaska, 2004).

The gravity flow sewage collection system consists of 8,500 linear feet of wood stave, cast iron, and HDPE pipe. Since the system is gravity flow, there are no lift stations to operate or maintain. Wastewater sources connected to the piped system are operated year round (with the exception of the old Visitors Center and the Riley Creek Campground), with flows decreasing significantly in the winter. Septic tanks are typically pumped in the fall when the Park Road is closed and sludge is discharged into the aerated lagoon. Sweet smelling toilets and sewage holding tanks are emptied twice a year and chemical toilets are pumped approximately every other day during the summer months. The aerated lagoon is shut down in the winter and the lagoon freezes over (HDR Alaska, 2004).

During the winter months and shoulder season, wastewater from the collection system is diverted through a 11,000-gallon septic tank into a separate percolation basin rather than being conveyed to the lagoon. During these periods wastewater is mainly contributed by employees (HDR Alaska, 2004).

Commercial and Industrial Wastewater Facilities

The NPS has no information on the types of wastewater treatment processes used by the Kantishna area businesses (NPS, 1998a); however, information is available on wastewater systems serving businesses within the Nenana River corridor. **Table 4.4-3** provides a summary of all the currently permitted commercial and industrial discharges within or near DENA. All of these permitted discharges are located on or adjacent to the Nenana River, and use the river as their receiving waterbody.

Domestic wastewater discharges to land or waters of the State are authorized in Alaska under either ADEC Wastewater General Permits or under ADEC Individual Permits for large discharges. General Permits cover secondary treated domestic wastewater (discharged 2 times per year) from community operated lagoons in communities with population of less than 1,000 residents, which generate less than 250,000 gpd of domestic wastewater influent; secondary treated domestic wastewater discharges up to 25,000 gpd; and gray water disposals of up to 5,000 gpd,. It is not currently known whether discharges authorized under ADEC General Permits are potentially affecting waters adjacent to or within DENA (NPS, 1998a).

Table 4.4-3. Current Permitted Wastewater Discharges Adjacent to DENA				
Facility Name	**Type of Permit**	**System Description**	**Discharge Amount (gallons per day)**	**Waterbody or Surface Discharged to**
Denali Rainbow Village & RV Park (located at 238.6 Parks Hwy)	ADEC Individual Permit	Sewage treated through a series of septic tanks and soil absorption fields	6,000 gpd	Subsurface discharge through a leachfield
Denali Princess Lodge Wastewater Treatment Facility (located at 238.5 Parks Hwy)	USEPA NPDES Permit	Sewage treated with chlorine in extended aeration facility	145,000 gpd	Nenana River
Denali Riverside RV Park Wastewater Treatment Facility (located at 240 Parks Hwy)	USEPA NPDES Permit	Sewage treated with chlorine in extended aeration facility	8,000 gpd	Nenana River
Grande Denali Hotel Wastewater Treatment Facility (located at 238.3 Parks Hwy)	USEPA NPDES Permit	Sewage treated with chlorine in fixed film with aeration facility	30,000 gpd	Nenana River
Healy Power Plant Ash Pond	ADEC Individual Permit	Wastewater containing fly ash and bottom ash discharged into a fly ash pond followed by a percolation field	479,000 gpd	Ash Pond near the Nenana River

Source: ADEC, 2005

Solid and Hazardous Waste

Solid and hazardous wastes generated within the park are currently disposed of in permitted landfills located outside the park. DENA has a conditionally exempt Small Quantity hazardous waste generator status, and the park's Maintenance Division keeps an inventory, updated annually, of hazardous materials stored at the park. The park has established a six-month limit on storage of hazardous materials awaiting disposal, and the storage area is inspected weekly to ensure integrity of the containers (NPS, 1998a).

Two landfills were operated in the past by the NPS to dispose of park-generated solid waste. These landfills were closed in 1988 and will remain inactive (NPS, 1998a). One landfill is located at Mile 234 of the George Parks Highway and the other is located at Mile 5 of the Park Road. Hazardous materials, such as paints, solvents, and household chemicals, were suspected of having been disposed of in these landfills, but there are no records documenting disposal. These sites were reported in 1991 to the CERCLIS Federal Facilities Docket and a Preliminary Assessment (PA) was conducted at each site in 1992. The PA's concluded that there was no evidence of hazardous substances disposal or environmental contamination and that no further action was necessary (Stromquist, 2005). Solid waste disposal is currently handled through a contractor who hauls waste to area landfills outside the park (NPS, 1998a).

There are currently two CERCLA sites listed by USEPA in DENA: Banjo Mine and Stampede Mine. These mines are located above Friday Creek and along Stampede Creek, respectively, in the Kantishna Hills. The Banjo Mine is awaiting site inspection and the Stampede Mine has most recently undergone site reassessment in 2000. Cleanup of the Stampede Mine is being lead by the State. Two additional CERCLA sites listed in DENA (Red Top Mine and Mile 237 George Parks Hwy) have been archived and no further remedial action is planned (USEPA, 2005a).

Hazardous waste generating facilities currently being operated within or adjacent to DENA include: Stampede Airstrip; NPS facilities in Kantishna (at Mile 90 of the Park Road), the park entrance and visitor center, and the park headquarters, where an autoshop is located; Weaver Brothers Incorporated (located at Mile 236.5 of Parks Highway); Golden Valley Electric Association operating at the Healy Power Plant; Usibelli Coal Mine in Healy; Denali Mine in Cantwell; and U.S. Air Force Clear Air Station (USEPA, 2005b).

Twenty-five underground storage tanks (USTs) have been inventoried within the park. A UST monitoring program conducted by NPS includes precision tightness testing of tanks and piping, planning for in-tank monitoring, upgrading regulated tanks, and disposal and replacement of older unregulated tanks. Also within the park, the Kantishna Airstrip, McKinley Park Airstrip, and the park boiler plant each have fuel tanks exceeding 1,320 gallons fuel capacity, and are required to have Spill Prevention, Control and Countermeasure Plans (NPS, 1998a).

The Alaska Federal/State Preparedness Plan for Response to Oil and Hazardous Substance Discharges/Releases (Alaska Unified Plan) provides a spill response plan framework for the park. A memorandum of understanding between the DOI, USEPA, and ADEC has been developed as part of the Unified Plan to define the spill response roles of each agency (NPS, 1998a). The Unified Plan summarizes area spill response resources, including information on different categories of hazardous materials. Additionally, Park specific plans are required under the Unified Plan to address specific park facilities and hazardous waste management. DENA has developed a Spill Prevention, Control and Countermeasure Plans (SPCC) for the park.

Roads/Vehicular Transportation

The park entrance is located off the George Parks Highway (Alaska Highway #3), which is a 40-foot-wide primary highway connecting Anchorage and Fairbanks (NPS, 1994). The George Parks Highway follows the eastern boundary of DENA and enters the park for a 7-mile stretch. This highway has a right-of-way easement of 300 feet for this 7-mile stretch (NPS, 1998a).

Visitors and staff enter DENA at Mile 237.3 of the George Parks Highway and transition to the 28-foot-wide DENA Park Road (NPS, 1994). The 92-mile Park Road connects the park entrance area to Kantishna, and is the primary access route to the interior of the Old Park (NPS, 2003e). Two other routes lead from the George Parks Highway into the park. The first route leads from Mile 187 to the now inactive Dunkle Mine area. The Dunkle Mine was historically accessed by a road from the railroad village of Colorado and along the West Fork of the Chulitna River. This road is currently in disrepair and only passable by four-wheel-drive vehicles. The portion of the road that diverges southwest across the West Fork of the Chulitna River to the Golden Zone area was improved for access to the Golden Zone mine outside the park, southwest of the Dunkle

Mine area (NPS, 1994). While the State of Alaska has a 100-foot-wide right-of-way easement for 7 miles of this Golden Zone/Dunkle Road (NPS, 1998a), the road is currently closed to public use (NPS, 1994).

The second route into the park leads into the Stampede area of the park, northwest of the park entrance. This Stampede Road is passable by most vehicles for the first 8 miles and then deteriorates into a four-wheel-drive negotiable road and then further deteriorates into a trail. The trail enters the park at about mile 30 of its total 56-mile length (NPS, 1994). For a number of years, construction of a new North Access route to the interior of DENA was a topic of consideration. This access route would follow or parallel the Stampede Road corridor from the George Parks Highway just north of Healy to the Stampede airstrip (where the existing corridor ends), then would continue to the Kantishna/ Wonder Lake area (NPS, 2003g). The NPS conducted a Feasibility Study on a potential North Access route in 2003 (NPS, 2003g).

Park Road

The first 15 miles of the Park Road (to the Savage River) are paved and are open to all traffic. NPS traffic statistics indicate that vehicle use of this paved portion of the Park Road is increasing steadily from spring through fall, with as many as 500 vehicles per day driving to the Savage River Bridge during peak season (NPS, 2003e).

Beyond Mile 15, the road is gravel and travel is restricted to tour and shuttle buses, vehicles used to access private inholdings (including Kantishna businesses), administrative traffic, campers driving to the Teklanika Campground, and occasional special permitted uses (NPS, 2003e). The 1986 GMP established a seasonal limit of 10,512 vehicles allowed to travel on the restricted part of the Park Road during the core visitation period from May 26 through September 13; this limit was codified in NPS regulations published in June 2000. Aside from daily bus limits, no limits have been established for use of the Park Road during the two shoulder seasons (May 15-25 and September 14 until road closure). During the first shoulder season, private vehicles and tour buses are permitted to drive as far as the Teklanika Rest Stop, pending weather and road conditions. After the shuttle bus system ceases operation in September, a lottery system limits the number of private vehicles allowed on the Park Road (NPS, 2003e).

The park's shuttle bus system is operated by a park concessionaire, who is responsible for maintaining vehicles and operating the system according to the terms of the NPS contract. Bus parking and maintenance areas are located in the park near the concessionaire housing and administration area. In addition, "camper buses" provide visitor transportation to campgrounds or backcountry starting points along the Park Road. All buses load and unload at the visitor center for the trip into the park interior. Camper buses also load at the Riley Creek Campground bus stop. Parking in the entrance area is available at several locations, with the largest capacity parking lots at the Visitor Access Center, Riley Creek overflow lot adjacent to the campground, and former hotel area (NPS, 2003e).

A *Road System Evaluation*, which details the physical conditions along all segments of the Park Road, was conducted in 1994; no more recent report exists. In addition, Appendix A of the

Gravel Acquisition Plan Environmental Assessment (2003) provides the most up-to-date breakdown of projected road maintenance needs for the Park Road by segment.

The *Denali National Park and Preserve Transportation Study, Entrance Area and Road Corridor Development to Savage River* was prepared in June 2000 to better accommodate the growing number of park visitors, while minimizing impacts to the natural and wilderness environments. Among other items, this study recommended several improvements to the Park Road in the entrance area, including widening portions of the road, provision of additional parking areas, and increasing lane width in this area (NPS, 2000c).

Access to Inholdings and Other Right-of-Way (ROW) Easements

Access is guaranteed under ANILCA to non-Federal lands, subsurface rights, and valid mining claims, but any such access is subject to reasonable regulation to protect the values of the public lands that are crossed (ANILCA, sections 1110 and 1111). Existing regulations (43 CFR 36.10) govern access to inholdings. Under these regulations, concessionaires and their visitors in the Kantishna area are guaranteed reasonable right to access their property, and as such, they do not require a concession permit to travel on the Park Road. However, there are limits to the number of road trips that can be taken by the Kantishna lodges (Sisson, 2005).

In addition, access to or across park and preserve lands may include the Alaska Native Claims Settlement Act (ANCSA) Section 17(b) public access easements, as well as R.S. 2477 routes asserted by the State of Alaska. The NPS at DENA is responsible for management of three ANCSA 17(b) easements:

1. The former cat-trail beginning near the Cantwell Airstrip to the park boundary (25 feet wide);
2. A 5-mile easement from near the junction of Highpower Creek and Swift Fork River to the preserve boundary (25 feet wide); and
3. A 1-acre overnight camping site on an unnamed lake north of the Muddy River (NPS, 2003e).

The validity and limitation of any R.S. 2477 rights-of-way asserted by the State of Alaska across DENA lands would be determined on a case-by-case basis (NPS, 2003e).

In addition to the ROW easements discussed above, the 4.5-mile Kantishna section of the Park Road (from Mile 87.9 to Mile 92.1) is held under a 200-foot-wide ROW easement by the Alaska Department of Transportation and Public Facilities (ADTPF). ADTPF performs minimal maintenance on this segment of the Park Road, and their practice of grading material over the fill slope has over-steepened and destabilized the slope. In addition, the road fords two streams within this segment (NPS, 1994).

Motorized vehicles access the Moose Creek drainage in the Kantishna area using a four-wheel-drive road that crosses Moose Creek and the North Fork of Moose Creek. Fourteen ford-type crossings occur below the Moose Creek and North Fork confluence, and an additional 10 fords occur above the North Fork. This road formerly provided access to the placer mines operating in this drainage. Current use of the road is for occasional NPS management activities and by the owners of properties in the drainage (Marshall, 1998).

In 2002, two applicants requested right-of-way permits for access to a pair of one-acre inholdings on Spruce Creek in the Kantishna Hills area of DENA (a former mining site). These applicants each sought a permit to use 9.7 miles of primitive gravel road along Moose and Spruce Creeks and a dirt airstrip near Glen Creek to access their properties for personal use. Existing travel along the gravel road requires crossing Moose and Spruce Creeks at 38 locations, in addition to 1,600 feet of in-stream travel. The NPS has issued a 5-year permit to these applicants, renewable every 5 years. The permit grants access both by vehicle along the gravel road from Mile 88 of the Park Road to the inholdings and by airplanes to the airstrip near lower Glen Creek. In addition, the applicants will make improvements to the primitive 9.7-mile mining access road along the segment by Spruce Creek to avoid in-stream travel, as well as fund or restore directly at least 0.37 acres of wetlands at the direction of the NPS (NPS, 2002f).

Maintenance

Beginning in early September, the park maintenance crew concentrates on final inspection of culverts and ditches and placing culvert markers before the Park Road is closed due to snow conditions. Routine snow removal operations, consisting of plowing and sanding, occur throughout the winter up to the headquarters area (Mile 3.4) and access is provided to the airstrip, select service roads, headquarters, administrative areas, and the C-Camp (NPS, 1994).

In March, snow removal begins from headquarters west down the Park Road. Ice build-ups are removed, as necessary, in six locations between headquarters and the Toklat River, and culverts are thawed with portable steamers (NPS, 1994).

Summer road maintenance operations for the Park Road include:

- Major road failure repairs and work orders;
- Cleaning, replacing, and realigning culverts and ditches;
- Grading potholes and washboards in the gravel segment (5 graders run 7 days/week so that the entire gravel portion is regarded biweekly);
- Resurfacing bare areas with gravel;
- Filling slump sections and repairing shoulder slope failures;
- Repairing storm washouts, landslides/mudslides, and shear sections/slope failures;
- Brushing roadsides to provide adequate sight distance and vehicle clearance;
- Crack sealing and pavement patching;
- Grading and maintaining shoulders on the paved section of the Park Road;
- Sweeping bridge decks and intersection;
- Maintaining and installing signs or gates; and
- Sweeping, patching, and maintaining all parking lots and secondary roads.

Gravel is extracted from river floodplains at DENA to provide gravel for frequent and recurrent maintenance of the 92-mile long Park Road. NPS Special Directive 91-6, *Field Guide on Implementing the NPS Management Policies Re: Administrative Use to In-Park Barrow*

Material, determined that it is economically infeasible to obtain gravel for road maintenance from outside the park and must be obtained from sources within the Denali Park Road corridor (NPS, 1999). The 1992 Gravel Acquisition Plan (GAP) identifies two gravel sources within the Park Road corridor that meet specific natural resource criteria and NPS Special Directive 91-6: the Teklanika pit and Toklat River floodplain. The plan restricts excavation of gravel to 10,000 cubic yards per year and restricts use for routine Park Road maintenance (NPS, 1994).

The 2003 GAP and EA identifies gravel sources that meet the administrative needs for park construction projects along the Park Road and maintenance of the Park Road for at least the next 10 years. The 1992 GAP was determined to be inadequate to meet these needs and does not address mineral materials necessary for park road reconstruction and new facility construction associated with the 1997 *Entrance Area and Road Corridor Development Concept Plan*. The new plan identifies 10 sites that remain in the final site inventory for consideration for future material source sites along the Park Road corridor because they meet specific plan criteria and are thought to be capable of providing sufficient quantities and quality of mineral materials for park projects over the next 10 years. Of these 10 sites, 3 are located within a floodplain. The East Fork Toklat River and Downtown Kantishna sites are new potential sites and the Toklat River is a currently operating site. The plan proposes to increase gravel excavation from the Toklat River floodplain to 11,100 cubic yards per year; excavate a maximum average of 5,400 cubic yards per year from the East Fork Toklat River; and produce up to 59,000 cubic yards per year from Downtown Kantishna as a byproduct of part of mining site reclamation (NPS, 2003h).

The road prism and surface condition of the Park Road vary considerably from the Savage River Bridge to the Kantishna Airstrip. Calcium chloride, a dust palliative, is applied to the Park Road from the Savage River Bridge at Mile 14.9 to the Teklanika River Bridge at Mile 31.2 to reduce fugitive dust and help retain fines on the road surface. This, in turn, helps reduce the loss of gravel material and the rate of wear and tear on the road. In summer 2002, the NPS tested the application of calcium chloride to the Park Road between Mile 72 and 74. The dust palliative may be applied to additional segments of the Park Road after environmental testing and monitoring is instituted (NPS, 2003h).

Maintained Airstrips and Other Landing Sites

Much of DENA remains accessible primarily by air transport (NPS, 2003e). Four general categories of aircraft use occur at DENA: private, commercial, military, and administrative. All of these uses have occurred at DENA for many years, and are clearly showing an increasing trend in all categories (NPS, 1998a). The NPS has regulatory authority over aircraft landings within the management boundaries of DENA, excluding private or other inholdings (NPS, 2003e). Fixed-wing aircraft may be landed and operated on lands and waters within the park and preserve assuming that no vegetative or terrain alterations are made, and except where such use is prohibited or otherwise restricted by the superintendent pursuant to 36 CFR 1.5 and 13.30 and 43 CFR 36.11(f) and (h) (NPS, 1998a; 1986). Fixed-wing aircraft land on gravel bars and tundra ridges in DENA, and there are a sufficient number of these natural aircraft landing sites in the park to accommodate public access. These natural landing sites do not require any form of maintenance or improvement (NPS, 1986). Helicopters, however, are prohibited from landing anywhere in DENA unless a permit is obtained. There are two designated helicopter landing areas within DENA: Kantishna Airstrip and Toklat Road Camp. Helicopter landings within the park and preserve are not allowed except for administrative purposes or emergencies (NPS, 2003e). The 1986 GMP calls for an inventory of airstrips for fixed-wing aircraft for the purposes of identifying which strips should be maintained for public use, as well as for the potential designation of helicopter landing sites. An inventory of landing sites was partially completed to this end, identifying 121 informal landing sites on the south side of the park. However, completion of this inventory has not been possible due to funding limitations, leaving much of the north side of the park unsurveyed (Paynter, 2005).

While there are only two maintained landing strips within DENA, the McKinley Airstrip at the park entrance and the Kantishna Airstrip at the west end of the Park Road, there are former constructed airstrips (such as Stampede and Dunkle Mines and the Glen Creek airstrip) and other undeveloped areas, such as gravel bars on braided rivers and dry ridgetops, which provide suitable landing sites for small aircraft equipped with large tundra tires. Most developed airstrips in DENA were originally constructed to support mining operations, particularly in the Kantishna and Peters Hills. Ski-equipped aircraft can land throughout much of DENA during the winter and on glaciers during the summer when snow conditions allow. Private aircraft are permitted to land on any lakes or ponds within the park's northern additions. Designated backcountry landing strips may be maintained as needed with nonmotorized hand tools by people using these areas. Any other maintenance requires a permit from the superintendent. Outside designated landing areas, no alteration of vegetation or terrain is authorized for landings and takeoffs, except in emergencies (NPS, 2003e).

In addition to airstrips on NPS-administered lands, there are two maintained airstrips on non-Federal inholdings within DENA boundaries in the vicinity of Cantwell (see **Figure 1.2-1**). Other maintained airstrips are located outside, but adjacent to, DENA boundaries, including in the vicinity of Healy, Summit, Petersville, Curry, Purkeypile, and Lake Minchumina.

There are 8 concession permittees authorized to land on glaciers in the southern park additions, and 14 holders of incidental business permits to land in the northern additions east of the Toklat River and west of the McKinley River. No commercial landings are permitted in the Old Park. Air taxi services at DENA transport visitors for a variety of backcountry recreational uses, the majority of which are for mountaineering. The Kahiltna Base Camp received a steady number of about 800 landings per year from 1999-2001, which the Ruth Amphitheater and Pika Glacier has 216 and 74, respectively. The Eldridge Glacier, Tokositna Glacier, and Ruth Gorge generally have 10 or more landings a year, while another 31 sites have occasional use (NPS, 2003e).

Scenic air tours also occur in DENA, and typically land in the same areas as air taxi flights. Scenic tours concentrate their landings in three main areas: Ruth Glacier (1,892 landings in 2001), Kahiltna Base Camp (198 landings), and Pika Glacier (170 landings). However, the number of landings at each location is increasing. In addition, preliminary data collected in 2000 on the Ruth Glacier found that there had been illegal commercial landings by non-concessionaire flight services (NPS, 2003e).

4.4.3 Subsistence Uses

ANILCA recognizes the important connection between local rural subsistence users and the land, and provides the opportunity for local, rural residents engaged in a subsistence way of life to continue to do so on Federal public lands. In DENA, as long as fish and wildlife resources and their habitats are maintained in a natural and healthy state, traditional subsistence hunting, trapping, and fishing are allowed in the ANILCA additions to DENA, with the area within the former boundaries of Mt. McKinley National Park not open to subsistence uses. Many native and non-native local rural residents engage in, and depend upon, resources from the park and preserve for personal consumption, cultural identity, and to maintain a subsistence way of life.

Subsistence uses are allowed by qualified subsistence users, currently subject to Federal subsistence regulations. Users engaged in subsistence activities in the park additions either live in the resident zone or have been issued a subsistence use permit based on a demonstrated history of using park resources before 1980. A local rural resident qualifying by a Federal customary and traditional use determination is eligible to hunt in the preserve. The communities of Cantwell, Lake Minchumina, Nikolai, and Telida are recognized as subsistence resident zones for DENA. Based on 2000 U.S. Census Bureau data for DENA's resident zone communities, there are approximately 357 local rural residents eligible to engage in subsistence use activities in DENA. In addition, 15 other local rural families with subsistence use permits do not live in one of these designated resident zone communities, but have traditionally engaged in subsistence activities in the park (NPS, 2003e).

Federal subsistence regulations, with which eligible subsistence users must comply, guide hunting, trapping, and fishing seasons of take, harvest limits, and methods and means of harvest, and identify which communities and areas have customary and traditional use of wildlife species on park and preserve lands or fish stocks for subsistence purposes (NPS, No date [e]). DENA has two areas designated as National Preserves. Both Federal subsistence and State of Alaska hunting and trapping are permitted in the preserves. State harvests are regulated by State game laws passed by the Alaska Board of Game. Federal subsistence harvests are regulated by Federal regulations passed by the Federal Subsistence Board.

Subsistence activities are dynamic and diverse, with hunting usually occurring in the fall and winter months. Fishing is concentrated during summer and fall, and trapping efforts occur in the mid to late winter months when snow cover is adequate for travel and fur is prime. Berry picking and use of plant greens occur in the summer and fall months. Timber harvest typically occurs in the winter, when frozen rivers and lakes and snow cover make access and transportation more efficient.

The different means and methods of subsistence access and the seasonal timing of their use are critical for harvest. Common methods of access include hiking, skiing, snowshoeing, dog sled teams, horses, snowmobiles, motorboats or canoes, and in some cases, such as near Cantwell and in the Kantishna Hills, the use of off-highway vehicles (OHVs). Along the eastern region of the park, subsistence users from McKinley Village, and more recently some individuals from Cantwell, use motor vehicles for driving the Park Road to access the Kantishna Hills (NPS, 1998a). There is no known use of airplanes by local rural subsistence users to access preserve lands for the taking of subsistence fish or wildlife.

Subsistence community profile studies were conducted for most rural communities in the Denali area in the early to mid-1980s. Studies indicate a dependence primarily on moose, caribou, rock (*Lagopus mutus*) and willow ptarmigan (*Lagopus lagopus*), spruce grouse (*Dendragapus canadensis*), hare (*Lepus* spp.), ducks, geese, salmon, and a few species of freshwater fish. Black bear, brown bear, and Dall sheep (*Ovis dalli*) are less frequently used. Large mammals account for 70 percent of the resources used, and fish account for 21 percent. The remaining 9 percent include freshwater fish, furbearers, plants, and berries. Freshwater fish include burbot, Dolly Varden char, grayling, lake trout, northern pike, rainbow trout, and whitefish. Important fur animals include marten (*Martes americana*), mink (*Mustela vison*), red fox (*Vulpes vulpes*), wolf (*Canis lupus*), lynx (*Lynx canadensis*), weasel (*Mustela nivalis*), wolverine (*Gulo gulo*), land otter (*Lutra canadensis*), beaver, muskrat, and coyote (Canis latrans). Subsistence use of plant materials include spruce and birch trees for shelters, structures, and firewood. Willow, spruce burls, birch (*Betula* spp.), and cottonwood (*Populus deltoides*) are used for making furniture and other hand crafted items. Commonly used berries include blueberries, lingonberries (*Vaccinium vitis-idaea*), and raspberries (*Rubus* spp.). Wild greens include fireweed (*Chamerion* spp.), lambsquarter (*Chenopodium album*), and ferns (NPS, 1998a).

Most subsistence activities in DENA currently occur in the north park and preserve additions, and the southeastern park addition near Cantwell. Moose, caribou, and fish constitute the major subsistence resources used by Cantwell residents. Few households in Cantwell trap furbearers in the park. Trapping is a significant subsistence use activity in the north park and preserve additions. Lake Minchumina traplines extend to the Castle Rock Lakes, Birch Creek, Muddy River, Kantishna River, and Slippery Creek areas. Other qualified subsistence users in Healy, Nenana, and Tanana trap into the Stampede, Bearpaw, and McKinley River areas (NPS, 2003e).

Most of the locations for contemporary subsistence hunting and trapping by the people of Nikolai are outside (west) of the park and preserve. The residents of Telida do some trapping near Sprucefish Lake in the preserve and some hunting in the park near the Swift Fork River. They also use the area south of the preserve and west of the park for hunting and trapping (NPS, 2003e). Residents of the Skwentna community hunt moose and trap in the Upper Yentna River drainages in the preserve.

4.4.4 Mining

The only recorded productions of minerals in DENA have occurred in the Kantishna Hills mining district, the Dunkle Mine area, and the Yentna district within the Kantishna, Chulitna, and Yentna River basins, respectively. Minerals mined included antimony, arsenic, coal, copper, gold, lead, molybdenum, silver, tin, tungsten, and zinc. Beyond the deposits in these basins, minerals occur in other areas of the park, including deposits of coal, clay, limestone, and perlite, which are primarily related to faults, veins, contact zones, or volcanic rocks (NPS, 1990).

In 1903, James Wickersham discovered gold in the stream gravels of Chitsia Creek in the northern Kantishna Hills, following a failed attempt to make the first ascent of Mount McKinley.

His discovery prompted others to prospect in the central Alaska Range foothills and in the Toklat River Basin. The first commercial discoveries of gold in the Kantishna Hills occurred in 1904 in Friday and Eureka Creeks. A stampede of several thousand placer miners followed, but most stampeders had left by 1910, as it became evident that only a few streams carried profitable quantities of gold. Prospecting for lode deposits continued, and reached a peak in 1916, when numerous lode prospects were located along a 40-mile corridor stretching from Slate Creek to Stampede Creek (NPS, 1990).

In 1905, placer mining activity began in the Yentna mining district, which encompasses part of the Tokositna River drainage. However, mining claims along the Tokositna River were soon abandoned due to the remoteness of the area and the difficulties associated with milling the ore.

The historic Dunkle Mine area arose when the Dunkle coal deposit was discovered on Costello Creek in 1915. The Dunkle Mine Township on the east side of the park is part of the Chulitna/ Yentna mining district. Metals mined from the area include copper, arsenic, gold, silver, tin, molybdenum, lead, and zinc. The Golden Zone Mine in the headwaters of the West Fork of the Chulitna River produced gold, copper, and silver in the 1930s. The abandoned Dunkle Mine produced 64,000 tons of coal from underground mining operations during the period from 1940 until 1954. Coal reserves of up to 8 million tons are estimated to still exist in the Costello, Colorado, and Camp Creek basins (NPS, 2003e).

The 1930s were considered the golden era for mining in the Kantishna mining district. The Stampede Mine began producing antimony ore in 1936, and by 1941, was the largest antimony producing mine in Alaska. The Banjo Mine on Wickersham Dome began producing lode gold in 1939, and became the largest lode gold producer in the Kantishna mining district's history. Large-scale placer mining was successfully re-introduced in the district in the late 1930s, when firms such as Caribou Mines began operating mechanical draglines on Caribou Creek. Annual gold production in the district reached an all time high of 7,000 ounces of gold in 1940 (NPS, 1990).

Following World War II and the eventual deregulation of the price of gold in 1972, placer mining activity resurged in the area. By 1983, total mineral production in Kantishna was estimated at 85,000 ounces of gold, 265,000 ounces of silver, 504,000 pounds of lead, 4,400,000 pounds of antimony, and several million pounds of combined lead and zinc (Thornsberry et al., 1984). Economically, placer gold is the most important mineral extracted from the Kantishna Hills, and accounts for over 75 percent of the total dollar value of past production. Historically, the Kantishna Hills mining district has been one of Alaska's consistent mineral producing areas (NPS, 1990).

In 1980, after ANILCA was passed, the Kantishna mining district was incorporated into DENA. Placer mining continued until the end of the 1985 season, when a lawsuit forced a moratorium on all mining until an Environmental Impact Statement (EIS) could be prepared to document and evaluate the cumulative effects of mining in DENA. In 1990, the EIS and its Record of Decision (ROD) was completed and the moratorium on mining was lifted. Since that time, and as part of the ROD, claimants have been required to submit Plans of Operations for evaluation prior to resuming mining operations. Concurrently, an NPS land acquisition program has been undertaken to acquire Federal ownership of all mining claims within DENA (NPS, 1998a).

Since the 1990 ROD, DENA has received a total of 19 proposals for Plans of Operations. Environmental Assessments (EAs) have been conducted by the park on Plans of Operations that were considered for further evaluation. Only one Plan of Operations has been approved as a result of its EA findings; however, a permit has not been issued to the operator due to lack of a reclamation costs security deposit (NPS, 1998a).

Although there are no valid mining claims within the pre-1980 park boundaries, both patented and unpatented mining claims exist within the 1980 park and preserve additions (NPS, 1998a). Unpatented claims give the right for a claimant to extract minerals, but no surface ownership rights are given. Patented claims generally result in full ownership rights to the minerals and surface estate (NPS, 1993). The approximate acreages of patented and unpatented mining claims in DENA are presented in **Table 4.4-4** in the following section.

Regional metals mining and prospecting outside the boundaries of DENA continues, although the extent to which it continues is not clear. Most of the drainages affected by current metals mining appear to be located outside park boundaries. Coal mining occurs adjacent to the park where the northern park boundary encompasses the westernmost portion of the Nenana coalfield. Coal production began in the Healy area in 1920, and in 1943, the Usibelli Coal Mine was founded in Healy. Today's mine production from the Usibelli Coal Mine averages approximately 1.5 million tons annually (Fried and Windisch-Cole, 2001). Coal was once mined on a small scale near Riley Creek within the Nenana River Basin to supply park facilities, such as heating (NPS, 2003e).

4.4.5 Land Ownership

Land Ownership within DENA

DENA encompasses approximately 6,059,263 acres. This acreage includes 2,108,041 acres from the former Mount McKinley National Park (the Old Park), plus 2,616,604 acres of new park land and 1,334,618 acres of preserve land added in 1980 under ANILCA (NPS, 1998a). The significant enlargement of DENA by the passage of ANILCA resulted in a complex pattern of non-Federal land ownership within DENA's boundaries, including patented and unpatented mining claims, Native Corporation selections and allotments, selected State lands, and private inholdings, as shown in **Table 4.4-4** and in **Figure 4.1-1**. In addition, 4 major right-of-way easements exist within the park, including the Alaska Railroad, the George Parks Highway (Alaska Highway #3), the 4.5-mile Kantishna section of the Park Road, and 7 miles of the Golden Zone/Dunkle Road. Submerged lands under existing navigable

Table 4.4-4. Non-Federal Lands within DENA's Boundaries

Type of Inholding	Approx. Acreage
Patented Mining Claims	2,443
Unpatented Mining Claims	2,556
Native Corporation Selections	38,266
State Selections	5,663
Native Allotments	910
Private*	131
TOTAL	49,969

Source: NPS, 1998a
*Acreage available only from Tokositna area

waterways for which a navigability determination has been made total an estimated 417.5 acres and are owned by the State of Alaska (NPS, 1998a).

The Land Protection Plan for DENA establishes NPS land acquisition priorities and addresses certain types of adjacent land uses; however, the Land Protection Plan has not been updated since its original publication in 1986 with the GMP. Issues and land status within and adjacent to the park have changed since preparation of the plan and updates to the plan are required(NPS, 1995a).

Patented and Unpatented Mining Claims

New mining claims are not allowed on lands added to the park with the passage of ANILCA. However, valid, pre-existing claims may continue to be operated under existing laws. The majority of existing mining claims are located within the Kantishna area (NPS, 1995a). As discussed in Section 4.4.4, *Mining*, above, the 1990 EIS and ROD on mining operations called for NPS acquisition of all mining claims within DENA, and the NPS subsequently developed a land acquisition program for this purpose. Since that time, 29 patented claims, 7.5 unpatented claims, and significant portions of 4 other patented claims have been purchased through this program. An additional 20 to 30 unpatented claims have been abandoned for failure to pay rental fees or declared null and void for failure to prove validity (discovery) (NPS, 1998a).

Native Corporation Selections

Native corporation selections are located in two areas of DENA. Doyon, Ltd. has selected 25,251 acres near Lake Minchumina. Selection of 3,185 acres by a group identifying itself as Minchumina Natives, Inc. is under court challenge. The Cantwell Village Corporation and AHTNA, Inc. have selected 9,720 acres on the west-facing slopes above Cantwell Creek (NPS, 1998a).

Native Allotments

Twelve separate Alaska Native Claims Settlement Act (ANCSA) Native allotments, totaling 910 acres, are located in the northwest preserve (NPS, 1998a).

State of Alaska Selections

The State owns one section of land within the southwest preserve boundary. In addition, the State has selected 5,663 acres southwest of Cantwell (NPS, 1998a).

Private Inholdings

Four private inholdings totaling 131 acres are located near the Tokositna River. These inholdings are located within an area that received approval in 1990 for a land exchange with the State (NPS, 1998a). Additional small private inholdings are scattered throughout DENA in the Kantishna area, at Diamond (north of Kantishna), the Stampede Mine area, Ruth Amphitheater, Pirate Lake, and the Muddy River area (NPS, 2003e). The uses of these inholdings include a mountaineer staging camp, homesteads, cabin sites, subsistence activities, and recreational lodges in the Kantishna area (NPS, 1986). There are four major lodges on private inholdings in the Kantishna area that are used for seasonal recreational purposes only; there are no year-round residents in the area (NPS, 2003e).

Surrounding Land Ownership

DENA is surrounded by mostly undeveloped public land, the majority of which is owned by the State of Alaska and was granted under the Alaska Statehood Act. The State lands surrounding DENA are heavily used for dispersed recreation. A large portion of the south boundary of DENA abuts Denali State Park, which includes campgrounds, picnic areas, public use cabins, a boat launch at Byers Lake, developed trails, and scenic and interpretive waysides along the George Parks Highway. Other major public lands surrounding DENA are owned by the boroughs (parcels that were selected from the State lands) (NPS, 1995a). The Denali Borough is entitled to 50,000 acres from State lands as part of its incorporation. Much of the land selected is in the Wolf Township (NPS, 1998a).

There are major areas of Federal land to the east and northwest of DENA that are under the administration of the Bureau of Land Management (BLM). Significant parcels of land to the east and west are owned by Native corporations, including the Cook Inlet Region, Inc.; Ahtna, Inc.; and Doyon, Ltd (NPS, 1995a).

Other relatively small, but significant parcels of private land exist adjacent to the park, including lands along the George Parks Highway east of DENA that are being extensively developed for commercial facilities to support park visitors. The small community of Healy offers the nearest year-round visitor services to the park entrance. Other communities near the east and south sides of the park include Cantwell, Trapper Creek, and Talkeetna (NPS, 1995a).

SECTION 5.0
WATER RESOURCE ISSUES

The park's water-related issues presented in this section were identified in November 2004 by NPS staff during a 2-day kickoff meeting at DENA and the Alaska Regional Support Office in Anchorage, Alaska. Additional issues were identified through the review of literature and discussions with NPS staff during production of this report. These issues were prioritized as follows during an internal NPS scoping meeting held on May 19, 2005:

• Climate change impacts on permafrost, shallow lakes, glaciers, ice formation and breakup, and soil biogeochemistry	5-52 through 5-55
• Arsenic in downtown Kantishna drinking water	Not discussed, no data available

<u>Moderate Priority Issues</u>	**<u>Page(s) Discussed</u>**
• Effects of transportation infrastructure on fisheries and aquatic resources	5-13
• Hydrologic impacts of gravel extraction and processing	5-27
• Water quality impacts of past mining in Dunkle Hills	5-28
• Impacts of past mining on fisheries and aquatic resources	5-29
• Impacts of water-related recreational use (e.g., boating, fishing, swimming) on water resources	5-40
• Impacts of snowmobile use on water resources	5-42

<u>Low Priority Issues</u>	**<u>Page(s) Discussed</u>**
• Solid and hazardous waste disposal and management	5-15
• Lack of road inventories, assessments, and monitoring	5-16
• Hydrologic and water quality impacts of road system	5-16
• Water quality impacts of aircraft landing sites	5-18
• Glacial surge and glacial lake outburst floods	5-19
• Flood hazards to infrastructure, property, and visitor safety	5-20
• Mass movement hazards	5-21
• Hydrologic impacts of past placer mining in Kantishna Hills	5-31
• Water quality impacts of past mining in Kantishna Hills	5-32
• Subsistence fishing impacts on fish populations	5-37
• Impacts of litter and human waste on water resources	5-44
• Impacts of trail use and construction on water resources	5-46

These water-related issues are grouped by resource area and bulleted in order of priority within each resource area for discussion below.

5.1 INFRASTRUCTURE AND DEVELOPMENT-RELATED ISSUES

As discussed in Section 4.4.2, *Infrastructure*, most development at DENA is concentrated in the park entrance and headquarters areas, along the Park Road corridor, and in the Kantishna area. In addition, there is a concentrated area of development immediately outside the park, near the park entrance along the Nenana River. The NPS has proposed upgrades to existing facilities and several new developments in the frontcountry of DENA (NPS, 1997). These include upgrades to the Eielson Visitor Center, construction of additional parking areas, visitor buildings, administrative offices, and other facilities in the park entrance area, and construction of a Savage River Rest Stop; upgrades to housing within the vicinity of the Toklat Rest Stop; and rehabilitation of the Ranger Station and housing in the Wonder Lake area (NPS, 1997). A greater area covered with hardened parking lots, sidewalks, and buildings would likely lead to an increase in surface water flow from storms and spring melt; however, surface runoff from the new parking areas and other areas above the Visitor Center complex would be intercepted with bio-filtration swales. Surface water runoff from the depot expansion would be dispersed in the forest east of the airstrip and not reach any water channels. Adverse impacts to surface water from the proposed project, such as siltation or hydrocarbon pollution to nearby streams, would be minimal, assuming adequate design and engineering controls are implemented (NPS, 1997). These projects would be implemented in full compliance with the National Environmental Policy Act and would address and mitigate impacts to water resources.

In addition to future NPS developments, there is concern about future development on non-NPS administered lands within and adjacent to DENA, including private inholdings (in the vicinity of Wonder Lake, Upper Moose Creek, Spruce Creek, and Rainy Creek), Native Corporation lands, and the Wolf Township. The *South Side Denali Development Concept Plan* (NPS et al., 1997) provides for resource-based destination experiences on the south side of the Alaska Range. The proposed development includes development of a visitor center and other visitor facilities in the Tokositna area and along the George Parks Highway, as well as improved access to the Dunkle Hills area. The majority of the proposed development is located outside the DENA boundary; however, development on these lands has the potential to impact downstream water quality and quantity within DENA.

Areas of concentrated development can cause non-point source pollution to nearby waterbodies. Development increases paved (impervious) and compacted areas, which can alter flow patterns and lead to greater water yield to waterbodies. Stormwater runoff from these surfaces may carry petroleum products and other pollutants to nearby streams, leading to a degradation of water quality in these streams. Non-point source pollutants from such developed areas may include oil, gasoline, and other organics; sediment; heavy metals; nutrients; and microbal agents. This non-point source pollution is neither regulated nor monitored. Many of the impacts caused by concentrated developed areas are subtle and incremental, and can have multiple implications throughout the ecosystem. These impacts are further compounded by the high level of visitor use concentrated in the developed areas (NPS, 1998a). Point sources of pollution associated with development, such as wastewater disposal, are also a concern. Siting and construction of proposed new facilities could impact water resources by increasing sedimentation and turbidity, altering stream flow, and contaminating water of nearby streams. Proposed building and roadway developments can impact the free flow of water by reducing connections between wetland areas or changing existing water flow patterns and sediment transport.

- ***Issue (High Priority): Floodplain modification from existing and proposed developments***

A major water resource concern at DENA is impacts associated with floodplain modification from existing and proposed developments. Both NPS and private developments exist or are proposed within known and potential floodplains of the Teklanika River, Moose Creek, Nenana River, and Toklat River. The Park Road corridor crosses several large streams and rivers, including the Savage River, Sanctuary River, Teklanika River, East Fork Toklat River, Toklat River, and Stony Creek. The McKinley River flows generally parallel to the road corridor toward the west end near Wonder Lake (NPS, 2003h). In addition to potential risk from flood damage, developments along glacier-fed braided rivers, such as the Sanctuary, Toklat, East Fork Toklat, Teklanika, and McKinley Rivers, are also at risk from encroachment of river bank erosion. The Toklat heliport was destroyed by this type of erosion in 1992 (NPS, 1998a). Braided rivers contain numerous active and abandoned shallow channels, which crisscross a wide gravel bed. The unstable and poorly defined banks of braided rivers are subject to large annual rates of erosion, even during periods of smaller discharges, which can cause more damage than flooding (Karle et al., 2000). Streams fed predominantly by snowmelt, such as Moose Creek in the Kantishna Hills, have much narrower and more confined floodplains (NPS, 2003h).

The *Entrance Area and Road Corridor Development Concept Plan, Denali National Park and Preserve, Alaska* (NPS, 1997), which amends the 1986 GMP, proposes visitor facilities and services along the Park Road that have the potential to impact floodplains. The plan noted that an SOF for Executive Order 11988, *Floodplain Management*, may be required for the following projects proposed in the plan:

- Teklanika River gravel source;
- Riley Creek bridge on relocated Triple Lakes trail;
- Savage River 2-mile loop trail;
- Toklat rest stop, with river protection (see discussion above);
- Relocation of Toklat gravel crushing operation, with river protection; and
- Gravel acquisition from Kantishna area (NPS, 1997)

A campground and rest area are located along the Teklanika River off the Park Road. The Teklanika Campground may be located within the river's floodplain. Four lodges and a campground are located along a 3-mile reach of Moose Creek in the Kantishna Hills. The Denali Backcountry Lodge, a privately owned commercial facility, is located within the Moose Creek floodplain. The lodge has attempted to install flood control structures and DENA is concerned that it could affect adjacent NPS lands (NPS, 1998a).

The Nenana River corridor along the eastern boundary of the park is undergoing increased commercial development due to the premier recreational opportunities the river offers (see Section 4.4.2, *Infrastructure*). The NPS owns and manages 36 miles of upland frontage along the river (Whittaker, 1991). Most of the commercial development is occurring along river frontage opposite NPS lands just to the north of the park's main entrance. DENA is also concerned about flood control and bank stabilization structures installed on private lands along the Nenana River and their effects on adjacent NPS lands.

The Toklat River is a major braided glacial stream, with an active floodplain almost 2,000 feet across (NPS, 2004e). Developments within the river's floodplain include parts of the Toklat road camp, including the autoshop, leach field, propane storage tank, and refuse piles (NPS 1998a). In 2003, the NPS installed steel sheet pile for bank stabilization just above the east Toklat bridge to protect the new gravel processing area downstream of the road camp. This action may be in conflict with NPS DO and Procedural Manual #77-2. Replacement of the Eielson Visitor Center at Mile 65 of the Park Road is scheduled to begin in spring of 2005. In addition to replacing the old visitor center with a new facility, the project will include bank stabilization of the Toklat River to protect the visitor and administrative facilities downstream of the west Toklat River bridge; installation of a small hydro power plant, and construction of a new Rest Stop 200 feet downstream of the west Toklat bridge. Sheet pile bank stabilization would not impact existing floodplain acreage and would be designed to prevent the river from increasing in velocity as it courses next to the sheet pile. The hydro plant would remove water from 2 small creeks and return it a few hundred feet downstream. Collection boxes would be dug into the creek beds and associated utilities would be buried under ground. During dry conditions, the collection boxes would be closed to preserve in-stream flow. A Floodplain Statement of Findings (SOF) was prepared to evaluate impacts to floodplains from construction of the Rest Stop, which is located within the 100-year floodplain of the Toklat River. The SOF found that there were no practicable alternatives to disturbing the floodplain and impacts would be minimized through mitigation measures. Mitigation plans for stream flow and debris flow will be incorporated in the construction of the Rest Stop through the use of structural flood control measures. The NPS also acknowledged that some natural localized floodplain processes of erosion, deposition, and channelization would be altered by the project and that the Rest Stop would face some risk of damage by flooding (NPS, 2004e).

- ***Issue (High Priority): Lack of floodplain delineations and identification of flood hazard zones***

Executive Order 11988, *Floodplain Management*, directs Federal agencies to avoid impacts associated with floodplain modification to the greatest extent practicable. NPS DO and Procedural Manual #77-2 also direct the NPS to protect, preserve, and restore floodplain values and functions. NPS Special Directive 93-4 floodplain guidelines require identification of the floodplain areas within the park and an inventory of the existing and proposed structures and facilities. Floodplain delineations have not been conducted for streams and rivers in DENA except for the Toklat and Teklanika Rivers. In addition, the characteristics of braided rivers in DENA make floodplain delineation difficult.

Karle et al. (2000) developed a method for floodplain delineation for braided rivers that takes into account the predicted rates and most likely locations of bank erosion. The study areas included the Toklat and Teklanika Rivers in the greater Kantishna and Nenana River watersheds, respectively (see **Figures 4.2-8** and **4.2-7**). The following year, floodplain delineations of select reaches of the Teklanika and Toklat Rivers were completed in a report entitled, *Floodplain Delineation and Development of Management Recommendations for Flood Hazard Zones in Denali National Park and Preserve, Final Report* (2001). The report includes the following data and documentation: literature review, physical stream channel and floodplain survey data; discharge calculations, inventory of existing structures and facilities; USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS) generated data and cross-sections, floodplain assessment and methodology, 100- and 500-year floodplain delineation maps, and recommendations. The report recommends performing a risk analysis for flood hazard zones to determine high, moderate, or low risk areas to allow DENA personnel to make informed decisions concerning floodplain management (Schalk et al., 2001).

- ***Issue (High Priority). Noncompliance of park's current wastewater system with ADEC regulations***

The park's existing aerated lagoon system is currently operating without a wastewater discharge permit as required by ADEC (18 AAC 72.010) and is not in regulatory compliance due to elevated levels of nitrate detected in groundwater monitoring wells and the absence of regular monitoring of the aerated lagoon effluent and groundwater for various wastewater constituents. In addition, the park's winter wastewater system does not meet ADEC requirements and the Public Health Service has cited concerns with the system. Groundwater nitrate concentrations cannot exceed the ADEC standard level of 5 mg/L. In 1998 five groundwater monitoring wells were installed near the percolation basin. These wells were sampled for nitrate from 2001 to 2003 (see **Table 5.1-1**). Exceedance levels are highlighted in bold.

Table 5.1-1. Nitrate Levels in Groundwater Monitoring Wells (units in mg/L)					
Year	**MW-1**	**MW-2**	**MW-3**	**MW-4**	**MW-5**
2001	1.1	0.9	0.89	**17.22**	No sample
2002	0.84	0.41	**11.7**	**18.6**	No sample
2003	<MRL	<MRL	**25**	**17**	**25**
MRL – Method Reporting Limit					

Source: HDR Alaska, 2004

A total of 6 samples from three of the five monitoring wells exceeded nitrate standards by up to 5 times the allowable level of 5 mg/L. To determine background levels of nitrates, other groundwater monitoring wells within the area were sampled for comparison. Samples from the Horseshoe and Riley Creek drinking water wells had concentrations of 0.36 and 0.24 mg/L, respectively. These low levels suggest that the aerated lagoon and percolation basin system is contributing to increased nitrate levels in groundwater.

The NPS has entered into a bi-lateral compliance agreement with ADEC to implement a plan of action to achieve compliance and avoid the issuance of a Notice of Violation by ADEC. The waste stream study conducted in 2004 was the first step of this plan of action.

- ***Issue (High Priority). Adequacy of the park's wastewater system in meeting current and future demands***

As part of the wastewater stream study, HDR Alaska, Inc. monitored existing sewage collection and truck hauled flows to the aerated lagoon from July to September 2004. The average daily amount of wastewater discharged from the sewage collection system was approximately 16,805 gpd and the average amount of hauled wastewater was approximately 1,975 gpd. During the peak month of July (greatest number of Park visitors), combined average daily flow rates of both collection system and hauled wastewater was approximately 22,500 gpd. These flow rates are significantly lower than the original design flow of 144, 000 gpd and other past estimates. This difference is most likely due to the closing of the park hotel in 2001. In addition, facilities in the summer of 2004 were only operating at 50 percent of full capacity. The estimated full capacity daily flow rate is 42,700 gpd. Twenty-year projected flows were developed based on full build out of the park's *Entrance Area and Road Corridor Development Concept Plan.* The future 20-

year design flow rate was estimated at approximately 78,320 gpd for the summer and 14,675 gpd for the winter. These 20-year estimates are still under the original design flow of 144,000 gpd.

Projected 20-year design wastewater flow rates were also estimated for the Headquarters and C-Camp areas since these areas may be connected to the sewer collection system in the future. Both the summer and winter rates were each estimated at 7,600 gpd since all wastewater contributions are from park employees and are not influenced by the number of park visitors. According to the *Entrance Area and Road Corridor Development Concept Plan* the septic tanks and leachfield currently serving these areas will be replaced by a single package sewage treatment plant with a capacity of 25,000 gpd. An alternative to the package plant is to connect these areas with the existing sewer collection system. As part of this same plan, the NPS (1997) proposes to upgrade and/or rehabilitate other wastewater systems at several other park facilities. These include:

- Rehabilitation of entrance and headquarters area sewer systems;
- Installation of a septic tank and leachfield in the entrance area to provide for year-round use of portions of the environmental education and science center and the visitor services building;
- Upgrading of the water system at the Sanctuary and Igloo Campgrounds by installing grey water disposal system at each campground;
- Construction of an on-site wastewater disposal system for the Toklat rest area (underway);
- Upgrading of the Wonder Lake Ranger Station water system; and
- Provision of minimal sewage facilities (pit toilets) for the Yanert Overlook and Kantishna area backpacker campgrounds (NPS, 1997).

In addition, the Eielson Visitor Center on the Park Road is scheduled to be replaced, which would include the replacement of the existing septic system and leach field. The existing leach field was installed in 1985, and has a life expectancy of 20 years. The replacement leach field site is parallel to, and immediately downhill of, the existing leach field (NPS, 2004e).

Wastewater constituents were also analyzed as part of the waste stream study to obtain an accurate characterization of the waste discharged into the aerated lagoon. Sampling found that the composition of untreated domestic wastewater (i.e., BOD, COD, TSS, ammonia, TKN, and total phosphorous) from the gravity sewer system was on the high strength side of "normal" likely due to the very short collection system leading to minimal degradation in route. Samples taken from septic tanks were also higher than typical values with the exception of ammonia. Samples taken from hauled chemical toilet, sweet smelling toilet, and septic tank waste were extremely high strength waste as expected. Although the truck hauled waste contributes to only 9 percent of the average daily flow rate, it comprises up to 83 percent of the total daily organic load, acting as a "shock" load on the system (see **Table 5.1-2**).

Table 5.1-2. Daily Organic Loading on Aerated Lagoon		
	Gravity Collection System	**Truck Hauled Waste**
Average Daily Flow Rate (gpd)[1] Percentage of Total	20,500 91%	2,000 9%
Daily BOD loading (lbs/day)[2] Percentage of Total	62 20%	250 80%
Daily COD loading (lbs/day)[3] Percentage of Total	171 17%	834 83%
Daily TKN loading (lbs/day)[4] Percentage of Total	14 38%	23 62%

[1] Daily flow rates obtained from gravity collection flow monitoring and truck haul documentation from summer 2004

[2] Average strength of BOD assumed to be 360 mg/L for gravity collection wastewater and 15,000 mg/L for truck hauled waste based on average of 2004 sampling results

[3] Average strength of COD assumed to be 1,000 mg/L for gravity collection wastewater and 50,000 mg/L for truck hauled waste based on average of 2004 sampling results

[4] Average strength of TKN assumed to be 80 mg/L for gravity collection wastewater and 1,350 mg/L for truck hauled waste based on average of 2004 sampling results

Source: HDR Alaska, 2004

- ***Issue (High Priority). Improper infiltration of the aerated lagoon effluent in the percolation basin***

The NPS has determined that the percolation basin may not be meeting ADEC's requirement of 6 feet of vertical separation from the bottom of the percolation basin to the confining layer. A confining layer is defined as bedrock, clay, or other impermeable strata with an expected percolation rate greater than 120 minutes per inch (HDR Alaska, 2004).

During the 1998 drilling of the groundwater monitoring wells around the aerated lagoon and percolation basin, a silt-clay layer with very low hydraulic conductivity was found in four or the five wells, ranging between 13 and 15 feet below ground surface. Groundwater was reached between 9.5 and 19 feet below ground surface. Two additional soil borings were drilled in 2004 near the percolation basin. Some bore logs indicated a confining layer as little as 4 feet from the bottom of the percolation pond. Wastewater effluent percolating down to this silt-clay confining layer would begin to travel horizontally rather than continuing to percolate down preventing adequate treatment of the wastewater before its contact with the groundwater. It is also possible that once the effluent hits the confining layer it flows horizontally towards and eventually discharges into the Nenana River via a perched water table (HDR Alaska, 2004).

- ***Issue (High Priority). Increased wastewater discharge as a result of increased commercial development***

Substantial development has occurred and continues to occur along the Parks Highway or U.S. Route 3 located just north of the park entrance. This development includes hotels, restaurants, campgrounds, rafting outfitters, bus parking, and maintenance facilities. The Nenana River runs parallel to the highway, and although the State monitors permitted individual wastewater discharges into the Nenana River, potential downstream cumulative effects from both point and non-point source discharges could potentially degrade water quality. Cumulative effects of discharges into the Nenana River could include increased biochemical oxygen demand (and lower dissolved oxygen), suspended solids, and fecal coliform bacteria and changes to water pH (NPS, 1998a).

Commercial development also poses a potential threat to the water quality of Moose Creek in the Kantishna Hills, where four major lodges currently operate (NPS, 2003e). DENA does not currently have any information on the amount of discharge or the types of wastewater treatment used by the businesses operating in this area. None of the discharges are individually permitted by the State (ADEC, 2005), and no sampling has been conducted to date to determine if water quality degradation is occurring in Moose Creek as a result of wastewater effluent discharge (NPS, 1998a).

- ***Issue (High Priority): Proposed North Access Route to Kantishna***

Construction of a new North Access Route from the Parks Highway near Healy to the Wonder Lake area of DENA has been under consideration by the State of Alaska for several years. The approximately 90-mile route would traverse 1980 ANILCA additions to DENA that were included to ensure protection of wilderness recreation and ecosystem values (NPS, 2004l), and would bisect the Toklat Basin area along or adjacent to the old Stampede road and trail (HMM, 2005). In 1997, the NPS completed a feasibility study for the proposed North Access Route to Kantishna, as directed by Public Law 104-134. Based on this preliminary evaluation of the transportation corridor, at least 17 streams were found to cross the corridor (NPS, 2003g; 2004k).

Five major river systems bisect the proposed road/rail corridor, and include the Toklat River, East Fork River, Sushana River, Wigand Creek, and Clearwater Fork. One of the unique features of several rivers along the north side of the Alaska Range is the presence of numerous warm springs, which provide critical habitat for salmon spawning, rearing, and over-wintering (NPS, 2004l).

In addition to impacts on wildlife habitat and populations, the proposed North Access Route could have numerous effects on waterbodies, aquatic habitat, and wetlands, including disturbance to wet tundra and riparian habitat and effects on hydrology and water quality (e.g., turbidity, suspended solids, and heavy metals contamination). In addition, standard construction practice for Interior and Arctic Alaska requires a massive amount of gravel for the roadbed, which is anticipated to be at least 28 feet wide and 80 miles long for the proposed North Access Route. River beds and terraces provide the largest deposits of clean gravel, and as such, major gravel extraction could be expected to occur on the river systems that bisect the proposed transportation corridor (NPS, 2004l; HMM, 2005).

Most of the drainages along the proposed corridor have never been inventoried for stream water quality, physical hydrology, or fisheries resources, with the exception of the streams in the Kantishna area (Miller, 1981; Meyer and Kavanagh, 1983; NPS, 2004l). This basic and severe lack of baseline water resources information threatens the NPS' ability to analyze, manage, and protect water resources along the corridor; evaluate the environmental impacts of gravel extraction for the proposed new transportation route and construction and use of the route; and subsequently mitigate impacts if road construction were to occur (NPS, 2004l; HMM, 2005). As a result, the NPS is currently undertaking a comprehensive two-year study to determine baseline water quality and physical hydrology information along the proposed North Access Route. This study is being conducted in two phases. Phase I includes a comprehensive water resource assessment report for the proposed corridor. A draft report, *Water Resources Assessment of the Toklat Basin in the Vicinity of the Stampede Road Alignment* (HMM, 2005), has recently been completed under Phase I. This report includes a hydrologic inventory of the five major watersheds along the corridor; flood-flow statistics, including magnitude and flow duration and magnitude; water quality analysis; aerial survey of the Toklat springs; channel geometry analysis of the Toklat River; and air photo analysis of flood-prone areas on the Toklat and East Fork Rivers (HMM, 2005).

Phase II of the study will produce an evaluation of the physical hydrology characteristics from an engineering and development standpoint, culminating with an impact assessment of the proposed development. Phase II will also expand upon information provided by Phase I of the study, and will include water chemistry data for springs identified during Phase I; channel geometry analysis of the East Fork River, Sushana River, Wigand Creek, and Clearwater Fork; and air photo analysis of the Sushana River, Wigand Creek, and Clearwater Fork (NPS, 2004l).

- ***Issue (High Priority): Application of calcium chloride on Park Road for dust suppression***

Fugitive dust generated from use of the 72 unpaved miles of the Park Road under dry conditions may alter natural resources in the immediate vicinity of the road. Potential water resources impacts include increased concentrations of heavy metals in nearby soils, which can enter streams through runoff and changes in soil pH and chemistry, restriction of photosynthesis by roadside plants, and gaseous diffusion and transpiration in vegetation (NPS, 1998a; Furbish, 1996), all of which can affect vegetation growth in the vicinity of roadways and subsequently alter soil stability. Alterations to permafrost may also occur (NPS, 1998a). A study to measure dust accumulation from the Park Road in the Teklanika area found that these effects are greatest within the first 5 meters from the road, and decline rapidly as distance from the road increases until about 50 meters from the road, where conditions are nearly indistinguishable from background dust deposition levels (Furbish, 1996). To reduce fugitive dust and help retain gravel on the road surface, calcium chloride, a dust palliative, is applied to the Park Road from the Savage River Bridge at Mile 14.9 to the Teklanika River Bridge at Mile 31.2. In summer 2002, the NPS tested the application of calcium chloride to the Park Road between Mile 72 and 74. The dust palliative may be applied to additional segments of the Park Road after environmental testing and monitoring is instituted (NPS, 2003h). Calcium chloride has been determined to be the most effective suppressant at controlling dust along the Park Road that has been tested (Marshall, 1997a; 1997b).

Calcium chloride has been found to be harmful to the roadside environment when used as a de-icing salt, and numerous studies document these effects (see Marshall, 1997a). However, there are few studies on the effects of the use of calcium chloride as a dust suppressant (Marshall, 1997a; 1997b). While application as a dust suppressant is more dilute and less frequent than de-icing applications, there is a concern regarding the build-up of salt in the roadside soils and water over years of use as a suppressant (Marshall, 1997b). Salt can move from the road surface by dissolving in water and leaving the road through runoff, being directly removed during maintenance (e.g., grading) activities, or from movement caused by vehicle tires (Marshall, 1997a).

A five-year study to monitor the effects of road dust, test the effectiveness of dust suppressants, and assess the resultant effects of suppressants on the roadside environment along the Park Road began in 1994 (Furbish 1996; Marshall, 1997b). A 1997 report from this study (Marshall, 1997a) documented the results of samples of roadbed material, roadside soil, runoff, and ditch water tested adjacent to sections of the Park Road treated with calcium chloride before and after application, as well as from a control section of the road. An analysis of the roadbed material, roadside soil, runoff, and roadside ditch water found that electrical conductivity, salinity, and chloride levels were elevated after calcium chloride treatment in most areas, and these areas showed some recovery with time after treatment. The analysis of soil and roadside ditch water were most variable, with some evidence of flushing that removed the salt. In addition, pH values for roadbed material and runoff were reduced post-treatment. Effects on pH in roadside ditch water and soils were less dramatic, since these areas were affected only after runoff transported calcium chloride from the roadbed to the sides of the road (Marshall, 1997a; 1997b).

The concern with lower pH in road material post-treatment is the increased potential for heavy metals to move from sediments into solution. Heavy metals, including lead, zinc, and copper, originate from vehicle exhaust and tires. These metals are mobilized in waters and soils with lower pH values. Samples of soil taken from the Park Road in areas not treated with calcium chloride showed no elevated levels of these metals; however, tests for changes in metal concentrations in soils after treatment with calcium chloride have not been conducted (Marshall, 1997a).

Chloride in the roadbed, runoff, and ditch water are all sources of and means for movement of chlorides entering roadside soils. As such, chlorine levels of roadside soils are the best indicators of the potential for environmental damage following calcium chloride treatments (Marshall, 1997a).

There is a concern that, with continued application of calcium chloride or any other palliative that contains materials of potential concern, even small amounts of contaminants could accumulate to amounts of concern over years of application (Marshall, 1997b). Existing testing and monitoring of dust suppressant use is not sufficient for long-term determinations of the effects of palliative use. Marshall (1997a) noted the need for additional studies to determine the amount of chlorides that are likely to accumulate with repeated years of calcium chloride application, and the levels of chlorides that can be applied without adverse effects. The NPS is developing a monitoring plan to address this concern and to assess and monitor the possible effects on soil, water, and vegetation of applying calcium chloride as a dust palliative on the Park Road. The goals for this monitoring program are to:

1. Synthesize and analyze all existing data on this issue (including where dust palliatives have been applied and in what years);
2. Complete a comprehensive review of the literature concerning the environmental attributes and effects of calcium chloride applications as a dust palliative;

3. Perform targeted field sampling to determine existing park conditions (including control areas that have not been treated with calcium chloride); and
4. Use the information derived from #1 through #3 above to develop an affordable, logistically sustainable, and effective long-term monitoring protocol for dust palliative application on the Park Road (NPS, 2004a).

- ***Issue (High Priority): Introduction and spread of exotic species***

Vehicle traffic accounts for the largest proportion of exotic plant seed introduced at DENA (Densmore, 2005). Vehicles entering the park can carry seeds from many exotic plant species. Of special concern is white sweetclover (*Melilotus alba*), which was seeded along the Parks Highway roadsides north of DENA. This is the only exotic species found in DENA that prefers riparian habitats. Every time the Park Road crosses a river or stream, there is potential for seed carried by vehicle tires to disperse into riparian areas.

Construction is another problematic activity for dispersal of exotic plants (Densmore, 2005). Construction equipment often transports exotic plant seeds picked up at previous work sites, and exotic seeds can often be brought in with fill material. These vectors of dispersal can have serious consequences on water resources when construction activities occur around stream crossings. Contracts for construction work should, if they do not already, specify that equipment must be washed clean before entering the park and that fill must be weed free (Densmore, 2005).

Despite the many various dispersal vectors, exotic plants have only been observed in developed areas and along road shoulders (Densmore, 2005; Roland, 2004). Exotic plants have not been found in riparian areas, wetlands, or other natural communities, and surveys of aquatic vegetation have not revealed any exotics in water bodies (Roland, 2004). Densmore (2005) hypothesized that many riparian, wetland, and other exotic species that have become problematic in Southeast Alaska have not established in DENA because it is located too far north to provide adequate growing conditions.

At present, exotic plant species control at DENA consists only of manual control (i.e., hand pulling) (Densmore, 2005). This control technique does not pose a threat to water resources. Herbicide use, which is not taking place currently, is the control method most obviously associated with impacts to water resources.

Hays (2005) identified one exotic species whose control could become an issue in the future. White sweetclover (*Melilotus alba*) grows in riparian areas and has become established on the banks of the Nenana River north of the park. Although this species is not yet found along the Nenana in the park, Hays (2005) believes it is only a matter of time before it reaches the park. White sweetclover is found every year along the Park Road; however, as soon as a plant is located it is pulled. The method targeted for long-term control of white sweetclover is hand pulling; however, if manual control in large infestations proves to be ineffective, such as could be the case in riparian areas, the park will need to resort to control using herbicides. Since white sweetclover grows near water, use of herbicides would be near water, as well. Appropriate herbicides labeled as safe for aquatic use would need to be employed and all precautions would need to be taken to minimize entry of herbicides into surface and ground water. Other exotic species that occur at DENA do not currently or in the foreseeable future need herbicide control.

- ***Issue (Moderate Priority): Effects of transportation infrastructure on fisheries and aquatic resources***

Infrastructure development and use can have dramatic effects on river, stream, and lake ecosystems. Primary infrastructure effects on aquatic communities and habitats at DENA are concerned with roads, road crossings, other impervious surfaces and their effects on riparian areas, water quality, hydrology, and aquatic species movements in fish-bearing streams (primarily non-glacial).   These effects may be *direct*, such as those associated with localized alterations in stream flow and spawning or foraging habitats, or *indirect*, such as those associated with altered upstream-downstream habitat connectivity or floodplain stream interactions (Forman et al., 2003).

Several studies have been conducted at DENA that directly assess fisheries and macroinvertebrate communities in the park; however, the majority of these studies focused on impacts associated with past mining operations (for additional discussion of these impacts, see Section 5.3, *Mining-Related Issues*). Although a recent freshwater fish inventory was conducted (Markis et al., 2004) no recent field studies have specifically addressed the effects of DENA roads or infrastructure on aquatic communities. A few studies, primarily from the early 1980s, provided limited accounts of road-related impacts on freshwater fisheries (Miller, 1981; Meyer and Kavanagh, 1983). No specific impacts associated with salmon use relative to infrastructure were noted. Information provided in site-specific project planning documents has provided some additional localized reporting of potential infrastructure impacts on aquatic species and habitats (NPS, 1981; NPS, 2002f).

Culverts, and their condition and effects on aquatic species movements, have been specifically identified as a concern for future fisheries management planning (NPS, 1998a). Poorly designed culverts can reduce or completely restrict aquatic organism movement and migration within stream systems. Undersized culverts can constrict flows, increasing flow velocities beyond that passable by many smaller fish (Forman et al., 2003; NPS, 1981). Culverts can also completely block upstream fish movements if blocked by sediment and/or debris, or, if situated above the surface level of the stream, by creating plunge pool conditions at the culvert outflow. Of the 26 streams surveyed by Miller (1981), culverts were used to channel 7 with confirmed or potential fish populations above the culvert, and 2 specific culvert-associated impacts to fish passage noted (Miller, 1981).

Transportation evaluations can also provide insight into potential infrastructure impacts on aquatic communities and habitats. In a road system evaluation of the Park Road prepared in 1994 (NPS, 1994), 9 of 12 segments of the road were considered to have drainage problems. Major drainage problems were noted from Mile 31.3 to the end of the Park Road, including: "difficult drainage conditions," poor ditches, washouts, and localized flooding. Major non-glacial streams crossing the Park Road include Jenny Creek and its tributaries, Igloo Creek, Caribou Creek, Little Stony Creek, Hogan Creek, and tributaries to the Sanctuary, East Fork, Toklat, and Teklanika Rivers (NPS, 1994).

Poorly designed and maintained culverts can also degrade aquatic habitats through erosion and delivery of sediment to streams. Undersized culverts or flow blockages can cause downstream scour holes and upstream channel aggradation, as particles settle and are trapped in sluggish backwater zones. When blockage is complete, flow may be redirected across or along the road, resulting in significant damage to the road surface, and often dramatic sediment delivery to nearby streams (Forman et al., 2003). Similar drainage conditions were noted along the Park Road from Eielson Visitor Center to Grassy Pass, resulting in the gully erosion (NPS, 1994). There was some major work done in 2003 at Grassy Pass that may have addressed the problem. High sediment levels and turbidity have been noted as a major factor affecting macroinvertebrate populations and community structures (Conn, 1998), and fish surveys in the Kantishna area observed a correlation with reduced or absent grayling and high sediment levels (Meyer and Kavanagh, 1983). Slimy sculpin, another common species of non-glacial streams, were more tolerant of higher sediment levels (Meyer and Kavanagh, 1983; Miller, 1981).

Many roads or historic access routes exist adjacent to, or even within, streams at DENA (NPS, 2002f; Oswood et al., 1990). Roads that encroach upon or isolate floodplains can compromise their function by preventing the natural flooding of these areas during high flows. This condition can result in flow velocities that induce increased erosion of the roadbed itself or transfer erosive forces to other areas in the channel. Similar potential for these effects exists along the Park Road, where it parallels streams for long stretches, for example, along its 6.5-mile path through Igloo Canyon and along the 7-mile stretch from the Toklat River to Stony Creek Bridge (NPS, 1994). The potential for in-stream effects from vehicular traffic primarily occurs in the Kantishna Hills area, where historic mining roads abut or are completely within the banks of some streams (NPS, 2002f). Meyer and Kavanagh (1983) noted that no fish were collected from stream channels used as roads.

Stream fords result in direct and indirect disturbance to aquatic habitats through disruption of the stream bed, destabilization of the stream banks and riparian areas, and increased sediment input. The detrimental effects of excessive sediment on aquatic habitat and fish are well documented. Sediment input into streams can cover streambeds and fill interstitial gravel spaces, decreased dissolved oxygen, impede egg development, reduce fry size and impede fry emergence, cover food sources, decrease productivity of plants and invertebrate, slow fish growth rates, abrade the gills of fish, and cause species avoidance of affected waters. In addition, high sediment levels in waterbodies can decrease the size of pools, disrupt spawning areas, and cause hydrologic changes (ADEC, 1990).

A 9.7-mile primitive gravel access route to 2 private land inholdings with 32 stream crossings was recently permitted for non-commercial use. The permit allowed the 2 private landowners to the use 9.7 miles of an existing access route, make improvements to portions of the access route (including 6 ford locations), and use the lower Glenn Creek landing strip. As a result of the use and improvement of this access, approximately 2,350 feet of aquatic habitat in Moose Creek and its tributaries will experience reduced habitat quality from many of the above described processes, such as road bed effects on floodplain function and chronic sediment inputs from bank and bed destabilization. The above described primitive road conditions (unimproved stream crossings, destabilized banks, damaged riparian areas, etc.) are noted in several areas around Kantishna as a result of its past mining history (Meyer and Kavanagh, 1983). Vegetative cover estimates showed that about one quarter of the streamside areas crossed by access routes in Kantishna have exposed soil, compared to no exposed soil in undisturbed sites (NPS, 1998a).

Where heavy metals are present, heavy metals adhere to sediments and are introduced into streams with the addition of sediments, resulting in a higher concentration of heavy metals in fish tissue and a higher potential for cell abnormalities (West and Deschu, 1984). As described in detail in Section 5.1, *Infrastructure and Development-Related Issues*, Marshall (1998) studied the effects of vehicle crossings in Moose Creek on stream turbidity/sediment. Motorized vehicles access the Moose Creek drainage in the Kantishna area using this 4-wheel-drive road, which crosses Moose Creek and the North Fork of Moose Creek via 24 separate fords. Data from the study indicated that vehicle traffic in Moose Creek causes temporary increases in turbidity. Sediment was highest within the first 5 to 15 meters of each creek crossing tested, and by 50 meters downstream of the crossings, sediment was noted to be partially, or in some cases fully, dispersed in the stream flow or settled to the streambed. This indicates that, for each of the 24 fords crossing Moose Creek, a stream length of approximately 50 meters is affected by increased sediment deposition from vehicle crossings (Marshall, 1998). Given this area's mining history, impacts on fish from reduced habitat quality and sediment inputs could be compounded by the presence of heavy metals from historic mining.

In general, bridges are less likely to have adverse impacts on stream flows, fish movements, and aquatic habitat quality than culverts and fords. However, bridges can constrain stream channels from migrating or changing as they would naturally, and lead to channel instability and sedimentation effects (Forman et al., 2003). Bridge replacements/realignments have occurred in the past (NPS, 1981; NPS, 1994); however, information concerning current bridge repair and replacement effects on aquatic communities was not identified.

In addition to effects associated with sedimentation, fish passage, and stream bed disturbances, roads and other developed surfaces have the potential to convey chemicals from accidental spills or asphalt surfaces to streams in runoff. These chemicals can affect fish and aquatic communities, for example, polycyclic aromatic hydrocarbons (PAHs) in asphalt can cause cancer in laboratory animals, and oil in water can coat fish gills and increase biochemical oxygen demand, killing fish and aquatic invertebrates. Moreover, chemicals derived from roads and paved surfaces can often be persistent in streambed sediments, and have long-term effects. No studies at DENA were identified that addressed potential effects on aquatic species related to PAHs in road runoff or other chemicals derived from roads or other paved surfaces of the park road, rest stops, or parking areas (NPS et al., 1997).

- ***Issue (Low Priority): Solid and hazardous waste disposal and management***

A few incidents of UST leakage and subsequent contamination have occurred within the park. Fuel oil spills have been identified in areas, such as the hotel powerhouse, the headquarters steam plant, and the C Camp fueling area. In 1972, a rail car with 10,000 gallons of fuel was spilled on park grounds. About 50 feet of fuel product was found in an unused well in the vicinity of the spill and was treated in 1991 by pumping the product in a barrel and burning it in a waste-oil generator (NPS, 1998a; Scholten, 2005b). In 2004, significant efforts were put towards cleaning up old contaminated sites where fuel spills have occurred (NPS, 2005b).

Planned activities associated with hazardous waste removal in the park include the removal and replacement of two old 10,000-gallon heating oil tanks, which the park feels have a significant risk of leaking (NPS, 1998a). Additionally, the park plans to replace single-wall fuel piping with double-wall piping in USTs. In 2004, single-wall fuel tanks in the Headquarters area and the Talkeetna Helo Pad were replaced with double-wall tanks to reduce spill potential (NPS, 2005b). Soils and water found contaminated during UST monitoring activities will be treated either on-site or in nearby treatment facilities. In addition, in 2003, NPS work crews installed underground propane tanks and heaters at the roadside cabins, Toklat Road Camp, and in C-Camp. The NPS believes this effort will significantly reduce the hazards associated with fuel spills (NPS, 2003c).

Hazardous waste materials most often requiring mitigation measures are generally located in the Kantishna Hills (NPS, 1998a). A discussion of wastes associated with mining activities that may pose a potential threat to water quality is included in Section 5.3, *Mining-Related Issues*. Although most hazardous materials have been removed following their identification, remaining materials "still pose a threat to backcountry visitors, aquatic systems, and biotic organisms in the Kantishna area." In addition to the Kantishna area, other developed areas within the park may present hazardous materials or waste management problems not yet addressed (NPS, 1998a). The NPS is also concerned about hazardous materials being transported on the Alaska Railroad through the park, and the potential for accidental spills of those materials. However, no information is available regarding a Spill Plan or response procedures for the Alaska Railroad.

- ***Issue (Low Priority): Lack of road inventories, assessments, and monitoring***

While several studies of the Park Road corridor have been conducted over the past 10 years, road corridor baseline information is still incomplete, corridor management planning is unaddressed, dust palliative studies are incomplete, and impact monitoring studies are unfinished (NPS, 1998a). The effects of road construction, use, and maintenance activities on water resources have been described and documented in numerous reports and studies. However, there are very few studies relating to road effects on water resources at DENA. In addition to formal, maintained roads, there are numerous smaller, lesser-used roads (such as old mining access roads) scattered throughout DENA. Although many of these roads are concentrated around old mine sites in the Kantishna and Stampede mine areas, a comprehensive inventory of these old mining and other access roads is not available.

- ***Issue (Low Priority): Hydrologic and water quality impacts of road system***

Both the George Parks Highway and the Park Road, along with the several historic, gravel mining roads, cross streams and rivers, or follow courses parallel and immediately adjacent to waterways. In some cases, stream courses have been modified to accommodate surface transportation (NPS, 1998a). As discussed in Section 4.4.2, *Infrastructure*, in 2002, two applicants requested ROW permits for access along 9.7 miles of primitive gravel road along Moose and Spruce Creeks to a pair of inholdings and a dirt airstrip near Glen Creek in the Kantishna Hills area of DENA. At the time of the permit request, travel along the gravel road required crossing Moose and Spruce Creeks at 38 locations, in addition to 1,600 feet of in-stream travel. The NPS has issued a 5-year permit to these applicants, renewable every 5 years. As part of the permit requirements, the applicants will make improvements to the access road that will replace all in-stream (streambed) travel of Spruce Creek with six shorter crossings (fords), and reduce the total number of stream crossings to 32 (24 on Moose Creek, 1 on Jumbo Creek [2 braids], and 1 on Glen Creek) (NPS, 2002f). These improvements should reduce existing impacts to the stream channels and water quality, although use of the remaining crossings would continue to impact these streams.

A *Road System Evaluation* was conducted for the Park Road in 1994 (NPS, 1994). No evaluation has been conducted since then. This evaluation noted several problems at various locations along the road that could be contributing to water resource degradation. These include:

- Foundation and drainage problems, consisting of wet soft spots, frost heaves, subsidence, fatigue failure, difficult drainage conditions, poor ditches, washouts, shear failure across slopes, localized flooding, and some landslides;
- Drainage problems at lower-grade road segments, leading to road flooding and subsequent erosion or ice build-up;
- Eroded gullies;
- Fill slope erosion along the East Fork River, which has required repair with sheet piling;
- Lack of surface material;
- Steep grades and other sections threatened by extensive mass slope failure; and
- Two stream fords in the AKDPF-maintained section of the road near Kantishna (NPS, 1994).

These identified road problems are a recurrent maintenance issue and are likely affecting water resources in the vicinity of the Park Road corridor, particularly where the road crosses streams. These effects may include increased sediment loading to streams from eroded gullies, washboarding, and slope failures; channelization of surface runoff; and inputs of contaminants (e.g., fuels, motor oils) to streams from flooding and improper drainage. In addition, the NPS at DENA uses sand during winter months to provide traction after plowing (NPS, 1994). Sand in runoff during snowmelt can enter nearby waters along the Park Road, increasing sediment loads in affected streams. However, there is no monitoring data available to assess the actual occurrence or extent of these impacts.

Marshall (1998) conducted a study to determine if vehicle traffic on a road located in the Moose Creek watershed causes fine sediments to be added to the creek and if there is additional movement of fine sediments in the stream. The road is used by 4-wheel-drive vehicles to access the Moose Creek drainage in the Kantishna area. The road fords Moose Creek and the North Fork of Moose Creek 24 times. Previous studies of Moose Creek primarily focused on effects of mining activities in cooperation with the EIS Cumulative Impacts of Mining (NPS, 1990). Moose Creek is particularly susceptible to sedimentation due to its low gradient.

Marshall (1998) measured turbidity (as a substitute for sediment) before, during, and after vehicles of varying weights drove the road through Moose Creek. Three sources of sediment were observed: 1) sediments from the stream bank loosened by tire action and introduced into the stream by the tires and water splashing on the bank during the crossing; 2) sediment adhering to the vehicle from travel on a dusty or muddy (weather-dependent) road that were washed off the vehicle during crossing; and 3) sediment on the bottom of the creek that was disturbed by the action of the tires during crossing, which subsequently became suspended in the water column. The first two sources added sediment to the stream, and the third source contributed sediment for re-suspension and movement downstream. Data from the study indicated that vehicle traffic in Moose Creek causes temporary increases in turbidity. Sediment was highest within the first 5 to 15 meters of each creek crossing tested, and by 50 meters downstream of the crossings, sediment was noted to be partially, or in some cases fully, dispersed in the stream flow or settled to the streambed. This indicates that, for each of the 24 fords crossing Moose Creek, a stream length of approximately 50 meters is affected by increased sediment deposition from vehicle crossings. In addition, the heaviest vehicles (crew cab and dump truck) most often caused turbidity to increase above the State standards for Moose Creek, and also caused the elevated turbidity levels to last for longer periods of time. However, the natural variability of turbidity was noted to be a complicating factor in analyzing turbidity during the study (Marshall, 1998). Friday, Eureka, and Spruce Creeks are also known to have fords. However, no other studies have been conducted on the effects of vehicles crossing streams in other areas of DENA.

- ***Issue (Low Priority): Water quality impacts of aircraft landing sites***

Very few fixed-wing aircraft landings occur within the DENA wilderness area; however, use in some non-wilderness backcountry areas is common. A recent inventory of landing sites identified 121 informal landing sites on the South Side of the park. Surveys of the North Side of the park were not completed due to funding limitations (Paynter, 2005).

Aviation fuels can be a major resource protection concern if handled improperly. The two maintained airstrips (the McKinley and Kantishna Airstrips) in DENA contain fuel storage facilities that require scheduled maintenance and monitoring to minimize water quality threats to surface and ground waters in the immediate area. In 1998, fueling systems at both airstrips were noted to be in good order. Recent steps have been taken to improve the handling procedures for barrel fuel (NPS, 1998a).

No other information exists on potential water resource-related effects of aircraft landing sites in DENA. While regulations exist regarding vegetation or terrain impacts at undesignated landing areas, no monitoring of these areas occurs. Several former constructed airstrips (such as Stampede and Dunkle Mines) exist at DENA, and it is possible that use of these airstrips is impacting water quality in the area. In addition, many aircraft land on gravel bars in braided rivers and on dry ridgetops. Private aircraft are permitted to land on any lakes or ponds within the park's northern additions. The location of many of these landing sites within or adjacent to waterbodies increases the potential for fuel or oil leaks/spills to contaminate water quality. No information is available on landing areas on snow-covered glaciers (such as Ruth Amphitheater, Pika Glacier, southwest fork of the Kahiltna Glacier, Eldridge Glacier, and Cul-de-sac Glacier) at DENA.

5.2 HYDROLOGIC HAZARD-RELATED ISSUES

The park provides a range of unique landscape types that present different hazards associated with hydrological processes. Seasonal flooding, glacial outburst floods (jökulhlaup), mass movements (i.e., mudslides and landslides), and advancing glacial systems are considered hazards in the park and preserve that threaten property, transportation links, and human life.

- ***Issue (Low Priority): Glacial surge and glacial lake outburst floods***

Of very limited concern is the possibility of glacial outburst flooding (or jökulhlaup), where a glacier-dammed lake can be formed then released suddenly, causing catastrophic flood damage to facilities many miles downstream. Most of the major glaciers on the south side of the park (e.g., Eldridge, Buckskin, Ruth, Tokositna, Kahiltna, and Yentna-Dall) pose some threat of jökulhlaup development, and some perhaps on the north side (e.g., Toklat, Muldrow), as well. In general, the possibility of glacial outburst flooding affecting park facilities is considered minimal. Moreover, outburst water volumes are difficult to estimate, and are frequently in remote locations, where effects to man-made facilities located many miles downstream are difficult to perceive. Some privately owned properties or cabins on the south side of the park may be at some risk to jökulhlaups (NPS, 1998a).

The Peters and the Muldrow Glaciers on the north side of Mt. McKinley are known to be surge-type glaciers. The Muldrow Glacier last surged in 1956-1957, extending its terminus approximately 2.5 miles. Surges may occur at 50-year intervals, meaning that another surge is anticipated within a few years of 2007 (NPS, 2004a). The Peters Glacier surged in 1986. These surges are known to last 1 to 2 years, and may result in an advance of a glacier's terminus by several miles. Most recently, in 2000, surges occurred on the Tokositna Glacier (NPS, No date [f]). During major glacial surge events, significant increases in flow can occur and cause devastating floods by blocking and suddenly releasing large quantities of melt water (Meier, 1976).

DENA staff has monitored ice elevations and flow rates of the Muldrow Glacier since 1992. Monitoring efforts will continue in order to describe the quiescent glacier between surges so that the data can be compared to information collected during and after the next surge. Ice surface flow rate markers will be surveyed on various points of the Muldrow Glacier, as well as its two largest tributary glaciers (Traleika and Brooks), to detect flow rate changes that might signal the start of a surge. The following items will be measured or sampled:

- Elevations of the main ice streams and moraine crests, using longitudinal and cross-section surveys;
- Levels of the water table in moulins (stream caverns in glaciers) and other slow-flow subsurface ice pools;
- Temperature and stage of water flowing at the terminus; and
- Surface ablation (melting and evaporation) and the position of the terminus ice front (NPS, 2004a).

In August 1996, a program of annual aerial reconnaissance and photography over glaciers in Denali was initiated. This monitoring effort will provide a photographic record of glacier conditions and will allow the detection and monitoring of developing glacier surges, ice-dammed lakes that may produce outburst floods, and landslides that have deposited debris on glaciers, which can be tracked for glacier movement (NPS, 1998a).

DENA has identified the need for determining glacial outburst flood potentials in the park, average minimum and maximum flow conditions, and the evaluation of flood potentials for streams emanating glaciers, which have produced, or may produce, outburst floods. In cooperation with the USGS, the NPS would like to establish stream flow gauging stations below these glaciers and develop a predictive capability for these events (NPS, 1998a).

- ***Issue (Low Priority): Flood hazards to infrastructure, property, and visitor safety***

The magnitude, duration, and frequency of floods on large and small streams at DENA are not well known because streamflow records are short or periodic, and there are few gauging stations. In general, floods commonly occur in spring from snowmelt or in mid-summer from rain and glacial runoff. The most severe floods typically occur from rain concurrent with high elevation snowmelt during late summer. Floods during the early spring can be aggravated by ice-jamming (NPS, 2003c). The severity of these floods depends on the antecedent conditions of ice thickness, snowpack, air temperature, and quantity of water and ice released when ice jams upstream break free. On the Nenana River after the late/spring early summer floods, which are generally associated with low elevation snow melt, flows become more dependant on glacier melt and snow events. Floods during the middle of the summer rarely exceed snowmelt floods, but they still can be bankfull (Whittaker, 1991).

Both glacial and non-glacial rivers cause flooding and stream bank erosion problems at numerous areas in the park where NPS or private facilities are located. High energy water flows and slow to rapid meandering conditions on the Toklat River threaten the Park Road on the east side of the bridge and at the Toklat Camp, where bank erosion has made it necessary to relocate the fuel cache facility and destroyed helipad (NPS, 1998a). Flooding has also been identified as a concern along other portions of the Park Road in the *Road System Evaluation* (NPS, 1994). In addition, flooding and bank erosion threaten two of the privately owned lodges within Kantishna (NPS, 1998a).

Floodplain erosion and bank stability of braided rivers are a noted hydrologic hazard concern at DENA. Braided rivers have high rates of lateral erosion during both flood events and normal flows. Floodplain delineation and identification of the zone of greatest potential hydrologic hazard is problematic for large braided rivers (Schalk et al., 2001). Studies have been conducted on the Toklat and Teklanika Rivers at DENA to address this concern and develop methods for delineation of large braided rivers (Karle et al., 2000). For specific instances of floodplain development hazards at DENA, see Section 5.1, *Infrastructure and Development-Related Issues.*

Another important concern relating to flooding at DENA is recreation and visitor safety. Floods may pose safety hazards to hikers crossing rivers; campground users from erosion and inundation; campers using gravel and sandbars as campsites; boaters, canoeists and kayakers from dangerous rapids in flood-swollen streams and rivers; and to winter recreational use on rivers from overflow ice and break-up.

The National Weather Service River Forecast Center in Anchorage is responsible for issuing flood warnings for inhabited areas of the State. It also monitors spring ice breakups on the major rivers, principally the Kuskokwim and the Yukon that are particularly subject to ice dam flooding (Lamke, 1989). The Federal Emergency Management Agency has not developed floodplain boundaries for DENA rivers and streams (NPS, 2003e).

- ***Issue (Low Priority): Mass movement hazards***

Numerous large to small mass movements are known to occur throughout DENA, and there are topographic indicators of historic or prehistoric mass movements in various locations. Some of these phenomena not only directly threaten existing facilities, but may also threaten land use areas indirectly by altering stream courses and creating erosion or flooding hazards (NPS, 1998a).

Almost all DENA terrain is subject to mass soil movements (landslides/mudslides), which can be slow to very rapid (mass slumping or shear failure) and are highly unpredictable (NPS, 1994). Landslides reaching streams can introduce large volumes of rock, soil, and debris. In some cases, a debris torrent can result, wherein a mass of material is flushed downstream. Debris torrents can carry large amounts of sediment, as well as larger material and debris, and can cause rapid changes in stream morphology, substrates and habitat (ADEC, 1990).

Over half of the park is comprised of foothills and interior lowlands, frequently veneered with fine-grained glacial and/or eolian materials, which tend to be areas of ice-rich ground. These materials are highly absorptive, which enhances erosion when the permafrost soils are disturbed. These fine-grained materials also are highly susceptible to mass movement (landslides, slumps, mud and debris flows, or soil creep). Periods of high precipitation often mobilize these surface materials, releasing mass movements at numerous locations simultaneously along the Park Road (NPS, 1998a). The *Road System Evaluation* (1994) of the Park Road identifies several segments along the road in which movements are occurring (NPS, 1994).

The primary method of inventorying and understanding geologic hazards within the park, whether mass movements or other hazards, is by bedrock and surficial geologic mapping. Fault zones, landslides, slumps, avalanches and areas susceptible to subsidence are most frequently identified by geo-surficial mapping. Numerous locations within the park demonstrate obvious slope stability problem areas, and additional geo-surficial information would expand the knowledge of these principal and potential risk areas. No systematic evaluation of slope stability or landslide risk potential has been attempted in DENA. Additionally, no known formal risk assessment has been made of rock and icefall areas on any travel routes (roads, trails, backcountry, or climbing routes) within DENA. The following section itemizes the areas of known mass failure incidents in the park.

Mass Failure Incidents at DENA

Identified historic or prehistoric slides on the north side of DENA include large block slides or debris flows at Quake/Berg Lake, Drunken Forest, and along the Parks Highway south of the park entrance. Numerous smaller slumps and debris flows occur in various drainages in the northern foothills of the Alaska Range, and many are noticeable along the Park Road. Active slopes have been identified along Hines Creek, Teklanika River, Igloo Creek, the Wyoming Hills vicinity, and the Toklat and Thoroughfare Rivers (NPS, 1998a).

Historic or prehistoric mass movements on the south side of the park include block glides and debris flows at Hidden River, Coffee Creek, and Slide Creek. In the southwest corner of the park, movements have occurred at Shellabarger Pass, the headwaters of Diffinger River, and a large slump block complex near the terminus of Shadows Glacier (NPS, 1998a).

Several potentially large-scale movements currently occur along the Park Road. The slope failure at Mile 20 of the Park Road, which occurred in 1992, was caused by the liquefaction of fine grained sediments beneath the road, resulting in fracturing and subsidence at the road surface. The Mile 43 failure concerns an outer shoulder fracture due, at least in part, to unloading of a buttress slope by the East Fork River. This failure was first detected in 1988, has been drilled, and monitoring continues while the movement appears to have slowed or ceased (NPS, 1998a).

The Mile 45 failure (or Bear Cave Slump) along the Park Road, which consists of a multiple slump terrace surface of nearly an acre in size, was first noticed to be active (or reactivated) in the summer of 1990. Four or 5 scarps, approximately 7 to 10 feet high, were identified on the primary terrace surface, along with numerous fractures in a pressure ridge that is forming at the bluff edge which overlooks the East Fork River. This movement is a classic rotational slump with a headwall scarp, subsiding basins, pressure ridges and fractures, and flow features. The uppermost scarp is within 35 horizontal feet of the Park Road where, in 1990, a relief culvert outlet was feeding water to the movement almost directly. Although this culvert was relocated shortly after discovery of the problem, the headwall of this scarp continues to erode toward the Park Road (NPS, 1998a). In 1993, a survey net of more than 30 stations was established to characterize the movement and monitor the encroachment of the Mile 45 landslide (NPS, 2003c). Generally, the degree of displacement has diminished in recent years of survey. However, increased rates of precipitation or concentrated periods of precipitation could reactivate the landslide. Annual monitoring of the horizontal and vertical movement of the landslide using approximately 50 stations will continue so staff can watch sustained or increased rates of movement. Resurvey occurred during the 2003 field survey season, but the results and interpretation have not yet been completed (NPS, 2004a).

Numerous smaller slumps and debris flows occur along the Park Road on an intermittent basis, particularly during periods of heavy or concentrated rainfall. On August 28, 1990, during such a period of continued rainfall, several mass movements at or near the park resulted in rockslides and earthflows that partially or completely blocked the Park Road. These sites, located at Mile 34, 36, and 37 in Igloo Canyon, and at Mile 46 on Polychrome Pass, as well as several sites at Stony Dome, Thorofare Pass, and Eielson Bluffs, require continued maintenance and monitoring (NPS, 1998a).

Although only one NPS structure has been damaged by subsidence, several problem areas on the Park Road (areas of subsidence, grade sags, and other movement) are known or suspected to be at least partially caused by permafrost degradation or fine grained soil compression. Slow deformational subsidence has been identified at Miles 4, 49, and 74, with occasional subsidence symptoms noticeable in other sections of the road. Additionally, the Wonder Lake Ranger Station, constructed in the 1930s, has continued to subside on the outer perimeter walls of the foundation due to fine grained soils compression or possibly permafrost conditions (NPS, 1998a).

5.3 MINING-RELATED ISSUES

- ***Issue (High Priority): Water quality and quantity impacts from Coal-bed Methane (CBM) development in Healy***

Conventional production scenarios for CBM entail the pumping of groundwater overlying and within the coal beds to reduce the hydraulic head so that the methane gas released from the coal can be captured by production wells. Produced water is typically discharged into surface drainages, which may adversely impact the quality of park surface waters and the hydraulic integrity of the park's stream channels. The quality of water associated with CBM is generally more saline than the receiving surface waters. This has the potential to alter the structure of aquatic floral and faunal communities. From a water quantity standpoint, there have been several instances noted where the hydraulic capacity of the receiving drainages is not sufficient to convey the large volumes of water associated with CBM production. This can lead to massive erosion and bank failures in the receiving channels, and cause localized flooding. With these potential impacts in mind, the NPS' Geologic Resources, Water Resources, and Air Resources Divisions, recommend that the State issue NPDES permits under the Clean Water Act for individual discharges that could occur during the exploration phase and would likely occur during the production phase (NPS, 2005d).

Also, the NPS is concerned about the potential impacts to the natural streamflow in the areas should groundwater draw-downs migrate to the point of intercepting baseflow that feeds the streams in the area. Reduced baseflows could severely impact the park's natural aquatic communities. The NPS, therefore, recommends that the State require a groundwater right or permit be obtained for the wells that produce groundwater (NPS, 2005d).

- ***Issue (High Priority): Alaska's gas license and lease procedure involving CBM development in Healy***

Exploration and development of oil and gas on State-owned lands in Alaska is governed by the Article 06 of the Alaska Lands Act, *Oil and Gas Exploration Licenses; Leases.* Under Article 06, either the commissioner [of natural resources] initiates the licensing process, or an applicant submits a proposal to the commissioner (§38.05.132). After publishing notice of the proposal and receiving comments, the commissioner will make a finding on the submitted proposals. The standard under which the commissioner will determine whether a proposals is accepted or rejected is whether the "State's best interests would be served by issuing an exploration license"

(§ 38.05.133(f)). The criteria the commissioner will use to make a best interest finding are found at §38.05.035(g). In the finding, the commissioner must discuss facts that are (NPS, 2005d):

> "(A) material to issues that were raised during the period allowed for receipt of public comment, whether or not material to a matter set out in (B) of this paragraph, and within the scope of the administrative review established by the director under (e)(1) of this section; or
>
> (B) material to the following matters:
>
> (i) property descriptions and locations;
> (ii) the petroleum potential of the sale area, in general terms;
> (iii) fish and wildlife species and their habitats in the area;
> (iv) the current and projected uses in the area, including uses and value of fish and wildlife;
> (v) the governmental powers to regulate the exploration, development, production, and transportation of oil and gas or of gas only;
> (vi) the reasonably foreseeable cumulative effects of exploration, development, production, and transportation for oil and gas or for gas only on the sale area, including effects on subsistence uses, fish and wildlife habitat and populations and their uses, and historic and cultural resources;
> (vii) lease stipulations and mitigation measures, including any measures to prevent and mitigate releases of oil and hazardous substances, to be included in the leases, and a discussion of the protections offered by these measures;
> (viii) the method or methods most likely to be used to transport oil or gas from the lease sale area, and the advantages, disadvantages, and relative risks of each;
> (ix) the reasonably foreseeable fiscal effects of the lease sale and the subsequent activity on the state and affected municipalities and communities, including the explicit and implicit subsidies associated with the lease sale, if any;
> (x) the reasonably foreseeable effects of exploration, development, production, and transportation involving oil and gas or gas only on municipalities and communities within or adjacent to the lease sale area; and
> (xi) the bidding method or methods adopted by the commissioner under AS 38.05.180; and
>
> (2) the basis for the director's preliminary or final finding, as applicable, that, on balance, leasing the area would be in the state's best interest."

Once an exploration license is issued, the licensee must post a bond with the State, and it then has the exclusive right to explore for a term not to exceed 10 years (NPS, 2005d).

Upon fulfillment of the "work commitment" contained in the exploration license, the licensee has the option to covert the exploration license into an oil and gas lease (§38.05.132(b)(1) and (2)). The licensee's work commitment is expressed in dollars of direct exploration expenditures. The licensee must complete certain phases of its work commitment within the time frames specified under the statute (§38.05.132(c)). If the licensee does not meet the requirements of the work commitment, the license can be terminated, or the acreage available for exploration may be reduced (§ 38.05.132(d)).

If the licensee has fulfilled its work commitment, the commissioner shall convert the license to a lease on all or part of the area covered under the exploration license. The lease is subject to a royalty, annual rental, and "other conditions and obligations that are specified in the lease" (see §38.05.134).

Under the State's process the licensee's only truly substantive condition precedent to obtaining a lease is fulfillment of the work commitment. Through expenditure of exploration dollars and meeting certain timelines, the licensee can meet that commitment. Based on NPS review of the State process, there does not appear to be an opportunity to object to the issuance of a lease. Hence, now is the time to put all possible concerns with the potential impacts that can result from the issuance of an exploration permit. As noted above, the commissioner's finding that supports the issuance of a license must discuss the reasonably foreseeable effects of exploration, development, production on lands adjacent to the lease sale area, and must also discuss lease stipulations and mitigation measures (NPS, 2005d).

Through substantive comments submitted at this time, the NPS will be engaged in the license/lease process early on and have the best opportunity to affect development scenarios in the future. Further, if the NPS wanted to appeal or request a reconsideration of the commissioner's finding, state regulations at §38.05.035(i) limit who is eligible to file such an appeal to those persons who "(1) meaningfully participated in the process set out in this chapter for receipt of public comment by submitting written comment during the period for receipt of public comment; or present[ed] oral testimony at a public hearing…" (NPS, 2005d).

It is for these reasons that the NPS recommend the park take a hard look at the likely impacts of CBM development during this comment period, identify those areas of high risk to the park, and submit comments to seek ways to avoid impacts to the park (NPS, 2005d).

- ***Issue (High Priority): Status of abandoned mine wastes and NPS reclamation efforts***

The NPS has acquired numerous mining claim lands since 1990, where mine wastes, such as hazardous materials drums and lead-acid batteries, have been abandoned. These hazardous materials pose a risk of entering both surface and subsurface soils if left to corrode on-site (NPS, 1998a).

In 1993 and 1994, Alaska Support Office (AKSO) staff conducted drum and barrel removal projects from these abandoned mine areas in the Kantishna Hills. Approximately 200 drums containing hazardous waste and other materials were removed from the Stampede Mine and Crooked Creek areas. Hazardous materials were also removed from Friday Creek, Eureka Creek, and the lower portion of Glen Creek. Specific hazardous wastes disposed of included waste petroleum products, automotive grease and solvents, used glycol, adsorbents, and abandoned explosives. Hazardous substances existing on mining claims scheduled for acquisition by the NPS have been surveyed in detail; however, former mining claims acquired through claim abandonment, land donation, or litigation outside of Kantishna Hills may not be fully surveyed and may present hazardous materials or waste management problems not yet addressed (NPS, 1998a). Unrecorded hazardous materials may be very difficult to survey and reclaim, as materials may be partially or completely obscured by revegetation.

The upper portion of Glen Creek has recently reverted to NPS ownership, and contains a significant amount of abandoned mining debris and equipment, such as barrels and other fuel containers, scrap metal, and structures. Past mining has also resulted in substantial soil contamination and aquatic and riparian impacts on approximately 240 acres of land, along roughly 7 miles of the creek. Miscellaneous mining debris and equipment are also located within patented claims currently undergoing NPS acquisition negotiations on Spruce Creek, and hazardous materials are known to occur on Rainy Creek on claims not yet acquired by the NPS (NPS, 2004a).

As the NPS continues to acquire former mining claims at DENA where substantial environmental disturbance has occurred, well-planned and comprehensive reclamation efforts are needed. Past studies have indicated that, due to the extensive disturbances to riparian areas caused by mining, including vegetation and topsoil removal and/or floodplain and streambed excavations, riparian ecosystem recovery through natural processes can be significantly hindered (Karle and Densmore, 1992). In 1988, the NPS began conducting comprehensive research on methods to promote and facilitate riparian ecosystem recovery from the effects of mining (NPS, 2001c). The lower portion of Glen Creek was the flagship for NPS floodplain restoration techniques for 10 years (NPS, 2004a). Testing of stream restoration techniques was conducted in 1991 and 1992 along two reaches of Glen Creek. The Karle and Densmore study, *Stream and Floodplain Restoration in Glen Creek, Denali National Park and Preserve* (1994), documents the results of these tests (Karle and Densmore, 1994).

Subsequent NPS reclamation efforts have included:

- 1997 Slate Creek: Stibnite ore had been extracted on lode claims on Slate Creek. The small excavated open pit was draining highly acidic water into the stream and several settling ponds. Twenty-five tons of limestone rock and geotextiles were installed to provide an anoxic drain to intercept groundwater flow and buffer the acid drainage. Approximately 15,000 cubic yards of tailings were used for floodplain reconstruction (NPS, 2004a).

- 1998, 1999, and 2000 Lower Eureka Creek: Preliminary work included an inventory of all mining equipment and debris and a hazardous waste assessment. Over 20 tons of mining debris, including abandoned bulldozers, trailers, and outbuildings, and 17 barrels of hazardous waste were removed from lower Eureka Creek. Acid mine drainage from an abandoned adit, a horizontal mine opening, was treated by installation of a limestone drain at the Red Top mill site. Contaminated soils were capped with a 3-foot layer of topsoil and 500 feet of floodplain and stream channel were reconstructed, with streambanks reinforced and stabilized (Karle and Griffiths, 1999; NPS, 2004a). In 2000, volunteers helped install biologs to stabilize new stream banks until vegetation could reestablish. Willow cuttings were also planted in the floodplains and on the new banks (Karle, 2000).

- 1993, 1999, and 2000 Red Top Mine: High-grade silver-lead ore was mined for several years at Red Top Mine, located near Friday Creek. Debris and barrel cleanup of the site occurred in 1993. Reclamation efforts began in 1999, which included tailing pile stabilization, treatment of acid mine drainage from the adit, or mine tunnel opening, and capping of contaminated soils with a 3- to 4-foot layer of topsoil (Karle, 1999). In 2000, volunteers helped plant willow cuttings on the stabilized slope (Karle, 2000).

- 2001, 2002, and 2003 Caribou Creek: Five former claim areas underwent creek channel and floodplain reconstruction. The reconstructed areas were revegetated to promote floodplain stability and create habitat. The last few miles of the access road to Caribou Creek was to be scarified and revegetated once the stream restoration work was completed (NPS, 2004a).

- In 2001, the NPS published an EA on a proposed 10-year plan to reclaim and restore approximately 517 acres of floodplain and wetlands disturbed by mining in each of the 10 drainages in the Kantishna Hills area. Drainages proposed for reclamation included Eldorado Creek, Moose Creek, Spruce Creek, Rainy Creek, Glacier Creek, Friday Creek, Crooked Creek, and Quigley Ridge. Reclamation efforts would include reconstructing floodplains and channels to restore natural functions (NPS, 2001c).

- 2004 Bear Creek: Abandoned barrels were removed from a Bear Creek area mine (NPS, 2005b).

- In 2004, the NPS conducted reclamation work on Glen Creek in the Kantishna Hills, which consisted of reconstructing over 100 feet of floodplain and hauling out 15 tons of scrap steel from the site. The on-site inventory included remaining equipment, barrels, debris, and soil contamination (NPS, 2005b). In June 2005, the NPS issued a contract to an environmental engineering firm to remove hazardous containers (primarily old 55-gallon drums of fuels) and contaminated soils from the former Gold King placer mining claims on Glen Creek. This work will be conducted in Summer 2005 (estimated completion by September 2005) (NPS, 2005c). Additional work on the site could include recontouring tailings piles and reinforcing stream banks (NPS, 2004a).

Although reclamation efforts result in varied intensities of streambed disturbances and water quality impairments during and immediately following reclamation activities, stream conditions have been found to stabilize within just a few years after restoration based on both stream morphometry and benthic macroinvertebrate communities (Edwards and Tranel, 1998).

- ***Issue (Moderate Priority): Hydrologic impacts of gravel extraction and processing***

Gravel extraction from rivers is considered mining a renewable resource (Emmett et al., 1996). The impact of gravel mining is closely related to the role played by the coarser fraction of bed load in controlling and stabilizing channel patterns and bed forms. Removal of this coarser fraction can lead to erosion and loss of this control (Lagasse et al., 1980). The USFWS conducted a study in 1980 on the effects of gravel extraction on braided streams in subarctic

Alaska. Observed effects included changes in channel configuration, hydraulic geometry, sedimentation, ice characteristics, and hydrology. Details of these effects can be found in the EA prepared for the 2003 Gravel Acquisition Plan (GAP) (NPS, 2003h).

Gravel extraction has impacted the Toklat River floodplain since park road construction began in the 1930s, although documentation of extraction and processing operations did not begin until the 1970s. The original park gravel crusher was set up in 1986 in the alluvial fan near the west Toklat River bridge and processed gravel excavated from the fan and Toklat River until the late 1990s. This site is no longer a gravel acquisition site and has not been restored. Minor stockpiles of processed gravel still remain at this site (NPS, 2004e).

Since 1992, gravel has been extracted from the active floodplain of the Toklat River near the road camp (NPS, 1999). The 1992 GAP established the Toklat River floodplain as a gravel excavation site; however, it did not establish a gravel processing site. A collaborative program between NPS and USGS enabled a study of the replenishment rate of desired gravel (bedload-transport rates of particular particle sizes) and the accompanying river hydraulics of the Toklat River. Movement of bed material in the Toklat River was monitored during melt-water high flows of July through September, 1988 and 1989, by measuring transport rates with a bedload sampler and by tracking and locating coarse sediment using radio transmitters (Emmett et al., 1996). Information from this study allowed DENA managers to make informed decisions regarding gravel extraction operations.

In 1999, the NPS proposed to replace the original gravel crusher site and develop a new gravel processing and storage area north of the Toklat Road Camp in the Toklat River floodplain. The EA and Floodplain SOF prepared for the project evaluates impacts to 4.77 acres of previously disturbed floodplain. The SOF concluded that the continued annual excavation of 7,500 cubic yards of gravel from the Toklat River floodplain represents less than 5 percent of the total bedload discharge and would be replenished by the natural action of the stream within 1 to 5 years. Placement of the gravel crusher and gravel stockpiles would permanently impact 4.77 acres of floodplain (NPS, 1999).

In 2000, Ken Karle reported having arranged for a new study by the original authors William Emmett and Robert Burrows discussing their analysis, observations, and recommendations for increasing the annual excavation of gravel from the Toklat River. This study was used in the 2003 GAP (Karle, 2000) and concluded that 11,100 cubic yards could be extracted each year from the Toklat River without affecting the channel (NPS, 2003h). The 2003 GAP proposes to increase gravel excavation from the Toklat River floodplain by 3,600 cubic yards per year.

[Note: The Teklanika pit does not affect floodplains.]

- ***Issue (Moderate Priority): Water quality impacts of past mining in Dunkle Hills***

In 1998, the USGS sampled and tested the biological and chemical characteristics of two streams that drain DENA land – Costello and Colorado Creeks – to provide the NPS with baseline information on water quality (Frenzel and Dorava, 1999). Both creeks are tributaries to the west fork of the Chulitna River on the south side of DENA, and were selected because they represent a currently undisturbed area where historical mining has occurred. Several SOCs, compounds that are typically associated with coal tar or coal gas, were detected in the creeks. One compound, dibenzothiophene, was detected above the minimum reporting limit of 50 micrograms per kilogram (µm/kg). This compound was detected at Costello Creek at a concentration of 85 µm/kg (Frenzel and Dorava, 1999). Additionally, both Costello and Colorado Creeks tested relatively high for their respective concentrations of trace-elements, such as arsenic, chromium, and nickel. Samples taken from streambed sediments in Colorado Creek were found to have the highest concentrations of arsenic, chromium, and nickel of any of the waterbodies sampled as part of a related USGS study (Frenzel, 2000). The arsenic and chromium concentrations exceeded the PEL (probable effect level to aquatic life) in samples from both Colorado and Costello Creeks.

From 1999 through 2000, the USGS sampled several streams on the south side of DENA, including Camp and Costello Creeks, as part of a cooperative study with the NPS (Brabets and Whitman, 2002). Both Camp and Costello Creeks have the potential to receive runoff from the Dunkle Mine, an abandoned lignite coal mine that was active primarily from 1940 to 1954. One of the goals of the study was to assess whether the Dunkle Mine had affected the water quality of the creeks. The USGS concluded through chemical and physical analysis of the water column and bed sediment, evaluation of the macroinvertebrate populations, and analysis of trace element concentrations in fish, that there were no effects on water quality from the Dunkle Mine (Brabets and Whitman, 2002).

- ***Issue (Moderate Priority): Impacts of past mining on fisheries and aquatic resources***

Stream reaches in the Kantishna Hills area with extensive disturbance from mining activities have generally been found to contain the lowest quality fish habitat (NPS, 2001c). In 1982, Meyer and Kavanagh (1983) surveyed 45 streams in the Kantishna Hills area to assess the aquatic habitat quality of streams affected by mining activities. Placer mining "extensively altered" large areas of riparian vegetation and aquatic habitat on at least 15 of the streams surveyed. Streams with the greatest extent of alterations include Eureka, Glen, Friday, Spruce, Rainy, Eldorado, Yellow, and Caribou Creeks. The abundance of artic grayling was found to be consistently low in altered sections of these streams. Habitat alterations included removal of riparian vegetation, stream channelization, channel diversion, increased sedimentation and turbidity, construction of roads and settling ponds in streams, and other barriers to fish movement. Intensive mining has altered habitat along 88 percent of the length of some streams and has increased turbidity in up to 100 percent of some streams (Meyer and Kavanagh, 1983). Increased turbidity and decreased light penetration in the Kantishna area has ultimately reduced the primary production of benthic algae and larger plants attached to the stream bottom, resulting in a subsequent reduction in fish production (NPS, 1998a).

Dissolved oxygen has been observed to remain high in both unmined and mined streams in DENA due to the turbulence and velocity of most streams (Deschu and Kavanagh, 1986). The low temperatures in the region also help retain oxygen in the water. The high oxygen levels and low water temperatures of streams in DENA minimize the amount of stress that fish in these systems experience related to these physical water parameters (Deschu and Kavanagh, 1986). The high pH and hardness concentrations of streams in DENA also maintain mobile heavy metal concentrations at low levels where they are not toxic to fish and pose a decreased risk of bioaccumulation (Deschu and Kavanagh, 1986).

In 1982, artic grayling and slimy sculpin were found to be the most abundant fish species of a total of eight species observed in the Kantishna Hills streams. In most cases, artic grayling abundance in individual streams was found to be much greater where a minimum amount of aquatic habitat alteration had occurred from mining activities. Furthermore, the recovery rates of aquatic habitat in streams were found to depend on the nature and the extent of the mining activity that occurred (Meyer and Kavanagh, 1983). Without extensive reclamation work in stream systems that have undergone a large amount of aquatic habitat alteration as a result of mining activities, permanent decreases in the biological productivity of these streams may occur. In 1984, artic grayling sampled from mined streams in the Kantishna Hills were found to generally exhibit higher metals concentrations than those collected from control streams; however, levels did not present a health hazard for human consumption (West and Deschu, 1984).

Slimy sculpins are nonmigratory and bottom-feeding omnivores, making them good indicators of contamination. Deschu (1985) sampled sculpins and tested them for elevated arsenic levels in select streams located in the Kantishna Hills in an effort to investigate the potential effects of mining on fish. Mean arsenic concentrations in sculpin livers were found to be higher in mined streams than in unmined streams. Additionally, Deschu (1985) found that the mean length and weight of sculpins were significantly lower in mined streams than in unmined streams. Decreased light penetration, decreased food availability and visibility, and metal-induced physiological stress were identified as possible explanations for these differences in growth (Deschu, 1985a).

In 1998, the USGS investigated the concentrations of organochlorines, SOCs, and trace elements found in stream sediments and fish tissues from 15 sites located in the Cook Inlet Basin of south central Alaska, including Costello Creek and Colorado Creek (Frenzel, 2000). Both Costello Creek and Colorado Creek are located in the south side of DENA within the Susitna River Basin. Sculpins sampled from Costello Creek had elevated concentrations of arsenic, cadmium, chromium, copper, nickel, selenium, and zinc, but no SOCs or organochlorine compounds were detected. No fish were sampled from Colorado Creek. Elevated concentrations of arsenic, cadmium, chromium, copper, nickel, selenium, and zinc, along with 7 SOC compounds, were detected in streambed sediments from Costello Creek. Similarly, elevated concentrations of arsenic, cadmium, chromium, copper, nickel, selenium, and zinc were detected in streambed sediments from Colorado Creek, along with 10 SOC compounds. Streambed sediments sampled from Colorado Creek were found to have the highest concentrations of arsenic, chromium, and nickel of all the waterbodies sampled as part of the study (Frenzel, 2000). Arsenic and chromium concentrations exceeded the Probable Effect Level in samples from both the Colorado and Costello Creeks.

SOCs found in the environment, such as polycyclic aromatic hydrocarbons (PAHs), result from anthropogenic sources, such as incomplete combustion of fossil fuels, or from natural sources, such as wetlands and coal deposits. Fish tissues concentrate both organic compounds and trace elements, and when present, can indicate long-term environmental exposure levels. Trace elements are derived from natural sources, but may be redistributed in the environment by human activities, such as mining and urbanization (Frenzel, 2000). Some trace elements are essential micronutrients, yet at elevated concentrations may be harmful to exposed organisms.

- ***Issue (Low Priority): Hydrologic impacts of past placer mining in Kantishna Hills***

Changes to channel morphology from placer mining can include changes in slope, velocity, discharge, depth and width, scouring, stream length, pool-riffle ratio, and stream bottom material (Madison, 1981). This is the case in the Kantishna Hills, where mining up until 1985 altered the stream morphology of 12 drainages in the Kantishna Hills, including Caribou Creek, Glen Creek, Glacier Creek, Yellow Creek, Slate Creek, Eldorado Creek, Spruce Creek, Rainy Creek, Eureka Creek, Friday Creek, Moose Creek, and the Bearpaw River (NPS, 1990). Up to 90 percent of some streams have been disturbed (NPS, 1990). Alterations included straightening and diverting of stream channels, erosion of stream beds and banks, accumulation of sediments, and destruction and alteration of riparian areas and floodplains. Documented effects on channel morphology include increased gradient, average width, floodplain icing, and braiding; and reduced stream length (NPS, 1998a). Glen Creek is typical of many placer mined streams in the Kantishna Hills and is characterized by significant stream channel adjustments, disfunctioning riparian zones, unstable or excessively confined steambeds, and over-steep floodplains (Karle and Densmore, 1992).

At the request of the NPS, the USGS collected data on streamflow characteristics, channel morphology, and streambed composition at 14 stream reaches in the Kantishna Hills area in September 1982 and in June, July, August, and September of 1983 and 1984 to assess the effects of placer mining. Streams studied included Caribou Creek, Glacier Creek, Bearpaw River, Moose Creek, North Fork Moose Creek, Glen Creek, Rainy Creek, and Jumbo Creek. No significant differences between stream channel configurations in mined and unmined streams were observed, with the exception of the Rainy Creek reach. The Rainy Creek reach had been diverted from its natural channel by abandoned settling ponds and a new channel had formed, resulting in considerable soil erosion and damage to vegetation. Other observations included: 1) average mean particle size tended to be finer in mined drainage basins compared to non-mined basins; 2) variations in particle-size distribution between surface and subsurface layers in the streambed; and 3) bed material within mined study reaches had greater average silt-clay and sand content (Van Maanen and Solin, 1988).

The 1984 *Final Environmental Impact Statement, Kantishna Hills/Dunkle Mine Study Report* primarily focused its analysis of water resource impacts from implementation of a mineral leasing program (preferred alternative) on water quality and did not address impacts to stream hydrology (NPS, 1984).

In 1982 and 1984, the NPS conducted helicopter surveys to determine the extent of placer mining disturbance in the Kantishna Hills. The report concluded the following: 1) Caribou Creek had sustained the most riparian and stream habitat loss and natural regeneration of vegetation had occurred on some of the tailing piles from 1939; 2) the extent of mine-disturbed areas increased greatly from 1982 to 1984, particularly on Caribou and Glacier Creeks; and 3) stream bottom and channel disturbance was caused by staging operations, road and airstrip construction, backhoe work, pond and dam construction, and tailing deposition (Deschu, 1986).

In 1989, William Jackson from NPS Water Resources Division toured placer mining sites on Glen, Moose, Caribou, and Friday Creeks in the Kantishna Hills. At the time, all sites except the active mine site on Glen Creek had impacts mitigated, in part, either by more careful mining practices (Caribou Creek), or prescribed recontouring of tailings (Glen, Friday, and Caribou Creeks). All sites were characterized by poor revegetation and significant stream channel adjustments. None of the placer-mined streams had established proper channel capacity (width, depth, gradient, and roughness), sinuosity, or floodplain function. It appeared this was the result of bed instability from replacement of the native streambed with mine tailings, channel incision and widening, or placement of tailings in floodplains creating overly steep floodplains. Over-steep floodplains were evident on the Glen Creek NPS rehabilitation site, and channel incision and widening was evident at Friday Creek (Jackson, 1989).

In 1994 to 1997, streams in the Kantishna Hills were sampled to determine the level of recovery that may have occurred since placer mining ceased in 1985. Average turbidity and suspended sediment levels were low in most cases, and were very similar for both mined and unmined streams. Turbidity levels recorded for these same streams in 1979, 1982, and 1983 studies were considerably greater, indicating substantial water quality recovery from mining impacts. This recovery is likely due to the lack of mining activity and regrowth of vegetation in these drainages (Edwards and Tranel, 1998).

Karle and Densmore (1992) observed that in placer mined watersheds that have undergone significant hydrologic regime disturbance, riparian ecosystem recovery through natural processes is significantly hindered and requires restoration of stream channels and floodplains for recovery to take place. Jackson (1989) recommended rehabilitating placer-mined streams by recreating conditions that favor natural stream function (i.e., approximate ultimate channel capacity, shape, and floodplain function). He also stresses the importance of Rosgen stream classification because it provides for stratification criteria for inventory and monitoring studies and general design criteria for rehabilitation.

Reclamation of placer mined areas in the Kantishna Hills began in 1988 with the study of stream and floodplain restoration in lower Glen Creek (Karle and Densmore, 1994). Reclamation efforts are discussed above under *Abandoned Mine Wastes and Reclamation Efforts*.

- ***Issue (Low Priority): Water quality impacts of past mining in Kantishna Hills***

Localized mining impacts in the Kantishna Hills area has caused increased turbidity and suspended sediment loads in streams, as well as heavy metals contaminations (NPS, 2003g). The effects of mining have been visible on over 1,555 acres of land covering 10 drainages in the Kantishna Hills area alone (NPS, 2001c). Major stream systems that drain mining claim areas located in the north side of the park include the Kantishna, Toklat, and Nenana Rivers, which flow north, contributing to the Yukon River Basin. Streams along the east side of the Kantishna Hills mining district flow into the Toklat River (NPS, 1998a). The major stream system that drains mining claim areas from the south side of the park is the Chulitna River, which flows south and contributes to the Susitna River Basin.

In 1983, actively mined areas were observed to determine what effect mining operations were having on water quality (Deschu and Kavanagh, 1986). Sediments and turbidity were found to be a major problem in all of the actively mined streams in Kantishna Hills. Sediment runoff from mining-related road construction adversely affected several Kantishna streams, most notably Glacier, Friday, and Eureka Creeks. The wastewaters generated from road work related to mine access were generally found to have higher concentrations of sediment and levels of turbidity than wastewaters generated directly from mining activities, including backhoe and sluicing efforts (Deschu and Kavanagh, 1986).

Meyer and Kavanagh (1983) examined 34 streams or stream reaches in the Kantishna Hills area and found that turbidity measurements were dramatically lower in streams that had never been mined when compared to streams that had undergone mining in the early 1980s. Sediment accumulation from placer mining was observed to be greatest in lower-gradient stream reaches, such as the lower reaches of Moose, Spruce, Glen, Eldorado, and Glacier Creeks (Meyer and Kavanagh, 1983).

Deschu (1985) found that rainfall influences the concentration of heavy metals in streams in the Kantishna Hills. In some cases, an increase in metals was observed due to increased dissolution of metals, whereas in other cases, metal concentrations decreased due to dilution from the increased water flow. In either case, the alkalinity levels in Kantishna Hills streams have been found to be high enough to effectively precipitate metals, in effect preventing high concentrations of dissolved metals to persist in the stream systems following rainfall events (Deschu, 1985a).

Arsenic and mercury have historically been the two metals of greatest concern associated with mining activities in the Kantishna Hills. Arsenic is extremely mobile in water and appears to be associated with pyrite deposits and placer gold. The underlying geologic structure of an area plays a major role in determining the concentration of dissolved arsenic in streams and arsenic burdens in stream sediments (Deschu, 1985a).

In 1992, a study of heavy metals in Rock Creek, located within the Nenana River Basin, concluded that the source of the heavy metals found in the creek were most likely the result of weathering of the watershed’s natural rocks, which consist of metavolcanic quartz schist, marble, and glacial deposits (Hanneman, 1993). Rock Creek has no history of mining activity, but can be used as a baseline for unmined streams, particularly when compared to heavy metals in DENA’s historically mined streams. Heavy metal concentrations in surface waters are directly related to water pH and hardness (Hanneman, 1993). Both alkaline and hard waters, which are typical of waters in the north side of DENA, will generally precipitate metals out of solution, thereby decreasing the dissolved metal concentrations in the water. Specifically, in hard waters with high alkalinity and pH, metals are often co-precipitated and/or sorbed into sediments, thus removing them from occurring in a dissolved state and potentially affecting fish or other aquatic life. Sorption generally increases as pH increases.

Oswood et al. (1990) examined the impacts of placer mining on primary productivity and macroinvertebrate communities of streams within the Kantishna area. They found that primary productivity and macroinvertebrate densities were significantly lower in streams that had been heavily mined when compared to unmined streams (Oswood et al., 1990).

As a result of the studies conducted in the 1980s (Deschu, 1985a; 1986; West and Deschu, 1984; Deschu and Kavanagh, 1986; Meyer and Kavanagh, 1983; West, 1982), streams in the Kantishna Hills area were determined to have naturally high levels of heavy metals upstream of mining disturbances, many of which exceeded State and Federal water quality standards. Areas disturbed by past mining activities were found to contribute metals to streams at a higher level than undisturbed streams through precipitation runoff as sediment loads increased (West and Deschu, 1984). West and Deschu (1984) found that metal concentrations were "usually found to be substantially higher below active mining operations than above operations," and "runoff from abandoned mines had metal input into the streams, but was not as great as that sampled from active mines." Additionally, sediments and turbidity were found to be a major problem in all of the actively mined streams in Kantishna Hills (Deschu and Kavanagh, 1986). However, a study conducted by Edwards and Tranel (1998) suggested that, based on data comparing unmined streams to mined streams within DENA, "the long-term effects of mining disturbance anticipated in studies conducted during the early 1980s did not develop" (Edwards and Tranel, 1998).

Edwards and Tranel (1998) characterized streams as either non-glacial or glacially fed, and historically mined or unmined, for accurate comparison. Turbidity levels of previously mined streams were found to have markedly decreased in 1994 to 1996 observations, when compared to turbidity data from 1979 to 1983. Additional signs of substantial recovery of several Kantishna watersheds were observed, including regrowth of riparian vegetation. In this same study, watersheds outside the Kantishna Hills area that experienced historic mining, including Long Creek, Camp Creek, Costello Creek, Slippery Creek, Colorado Creek, and Bear Creek, were also sampled for various water chemistry parameters, turbidity, and suspended sediments. Results from these sampling data indicate that these previously mined streams are very similar to undisturbed watersheds where mining has never occurred (Edwards and Tranel, 1998).

Edwards and Tranel (1998) also noted that elevated concentrations of metals, ions, and other potential impairments to water quality found in previously mined streams within DENA may be due to past mining disturbances, or they may be attributable to the geologic characteristics of the areas that were selected for mining, as these areas would "possess geologic and edaphic features more conducive to weathering and erosion than areas that would have been excluded from mining" (Edwards and Tranel, 1998).

5.4 SUBSISTENCE USE-RELATED ISSUES

- ***Issue (High Priority): Subsistence OHV use impacts on water resources***

Impacts on water resources associated with subsistence uses are primarily related to the method used to access park resources. In general, the majority of access methods have limited impacts on water resources. However, off-highway vehicle (OHV) use has been linked to several instances of resource damage.

The NPS at DENA has established a policy for allowing OHV use in the park and preserve where OHVs have been traditionally employed for subsistence purposes. OHV use may only occur on designated trails where it has been determined that such use will not adversely affect the natural, aesthetic, or scenic values of the park. Currently, there are no designated OHV routes or areas at DENA (NPS, 2004b). Park staff and the Subsistence Resource Commission are currently working with subsistence users in Cantwell to evaluate traditional use of OHVs for access to important hunting areas near Cantwell. In July 2005, the NPS issued a draft determination on the traditional use of OHVs for federally qualified subsistence users in the Cantwell area, which concludes that adequate evidence exists to support a conclusion that OHVs were traditionally used for access for subsistence purposes by residents of Cantwell prior to 1980. If this draft determination is approved, the 1980 park additions between the Bull River and Cantwell will be opened to the use of OHVs by federally qualified Cantwell residents for subsistence harvest. In order to allow for reasonable access to subsistence resources and to protect sensitive park resources from adverse impacts by OHV use, the NPS proposes to implement a management program and promulgate permanent regulations over the next year (NPS, 2005e).

On the south side of DENA near Cantwell, subsistence users employ OHVs on park land to access hunting areas. This OHV use is not legally authorized. This off-road use finds subsistence users traveling into riparian areas and drainages. There are no creek crossings associated with this mode of access. Park managers have encountered some resource impacts to wetlands and marshes, such as vegetation damage and soil disturbance (Twitchell, 2005). Cantwell subsistence users claim that the use of OHVs was a traditional means of access and that they were free roaming in larger geographic areas and not just confined to road beds. NPS is currently looking into this issue to determine if OHV use was a traditional means of access. If NPS finds that it was, and if OHV use is allowed in the future, park management would need to put in place prescriptions that mitigate this use so as to prevent resource damage.

The Upper Moose Creek Road is a road in the Kantishna Hills area, which was constructed by mining interests. This road became an access road for the public when mining was shut down and many of the claims were sold. The miners have been replaced by recreational private inholders, who have built cabins, and subsistence users. One to 6 subsistence users per year hunt in this area; however, the road is used more by the recreational users than the subsistence users. This road traverses over and through streams many times, including a section of road from Kantishna to Spruce Creek, which crosses the creek 36 times in 15 miles (Twitchell, 2005). Potential impacts as a result of these crossings could include: reduced aquatic species habitat quality, floodplain disturbance, and chronic sediment inputs.

In 2003, two incidents of resource damage occurred as a result of OHV use. These incidents occurred during the fall subsistence hunt. OHVs in the Bull River area caused resource damage to more than four miles in the park additions. The second incident of resource damage took place in Kantishna when a subsistence hunter drove a pickup truck off the Moose Creek Road to retrieve a moose carcass in a sensitive area, causing considerable damage (NPS, 2003c).

Currently, the only authorized subsistence access into the park out of Cantwell are two existing roads. The Windy Creek Trail was used in the past to access mining claims, and the Old Road coming out of Cantwell was used to access the airport. As in Kantishna, subsistence users did not develop these roads, but they are using them now for hunting moose and caribou. Recreational users also use the old roads, especially the Windy Creek Trail, but opposite of Kantishna, there are more subsistence users than recreational users here. Although there could be potential for impacts on water resources with this road use, none have been identified at present.

Rivers and streams in the northwest part of DENA, such as the Muddy, Kantishna, and Bear Paw Rivers, are used for travel by subsistence and non-subsistence users. People travel from village to village, sport hunters travel to access hunting areas, recreational users boat on these waterways, and subsistence users travel to access harvest areas. Both motor boats and non-motorized vessels are used. Possible impacts could include pollution from fuel and oil leaks, disturbance of wildlife, and shoreline degradation, such as soil compaction or erosion and vegetation trampling where people stop on shore. No comprehensive survey or inventory of these effects has been conducted.

No studies of the effects of OHV use have been conducted at DENA. However, numerous past and ongoing studies have been conducted on the topic at Wrangell-St. Elias National Park and Preserve and other nearby areas. In addition to concerns about oils and gasoline pollution from OHV use, which can directly impact water resources if such pollution enters nearby waters, studies have indicated that OHV use can cause many other types of adverse resource impacts, which can directly or indirectly affect water resources. Some of the findings include:

- OHV use causes shifts in plant species composition, decreased frequency and cover of plant species (herbaceous compression and shrub breakage), thermokarsting, soil erosion and compaction, soil displacement surface depression/rutting, increased trail width (NPS, 2003d; Weeks, 2003; USFS, 2002).
- Indirect impacts of OHV use include hydraulic changes (e.g., disruption of surface water flow), reductions in infiltration and percolation, surface ponding, and the loss of water-holding capacity of soils (USFS, 2002).
- OHV route impacts are largely controlled by the level of use, vegetation, soils, and terrain characteristics (NPS, 2003d; Sparrow et al., 1978). Mesic herbaceous communities and low shrub vegetation typically exhibit the greatest number of route braids, route widths, ponding, and thaw depth. Cold and wet permafrost soils are most susceptible to churning and displacement of vegetation and organic matter from OHV use. On the contrary, open forests with well drained soils and dryas and tall willow communities have been shown to exhibit less severe OHV resource impacts (NPS, 2003d).
- Resource damage increases significantly with increased use of the trail. At a low number of passes (10 passes/year), little or no change in surface ponding or soil exposure was noted; however, as passage increased, surface depressions, soil exposure standing water, and other impacts increased (NPS, 2003d; Weeks, 2003). Moderate OHV use (50 to 100 passes/year) results in the most damage to vegetation and soils; at high use (greater than

100 passes/year) in sensitive vegetation types, routes become impassable, resulting in the spread of the route area (NPS, 2003d).

- Of particular concern are areas where OHV trails traverse wetlands, permafrost soils, and steep slopes. The wettest areas have been noted to be the most disturbed portions of trails, especially when subjected to heavier use (Sparrow et al., 1978).
- OHV trail degradation typically results in either surface erosion or surface failure. Surface erosion is typical ion steep terrain or on sandy soils. Surface failure (i.e., when the trail surface degrades into muddy tracks with deep muck holes) typically occurs on flat areas with organic or finely textured soils (USFS, 2002).
- OHV use throughout Wrangell-St. Elias National Park and Preserve has damaged lands with underlying permafrost, causing streams to be diverted from their natural course into subsided motor vehicle trail areas. Vehicle use appears to upset the freeze/thaw balance in the underlying permafrost layers by removing the insulating vegetative cover, promoting changes in hydrological conditions. OHV use along stream channels or banks increases sedimentation of rivers and streams, damaging important riparian vegetation and altering stream structure (Weeks, 2003).
- Research in other arctic areas has indicated that sites can continue to degrade if the organic mat has been destroyed, even if OHV use ceases (Sparrow et al., 1978; Weeks, 2003).
- Trail degradation leads to wider trails, as users avoid degraded sections, and to trail abandonment, resulting in new routes being formed on adjacent soils. This process is called trail braiding, which dramatically increases the area of impacts associated with trail use (USFS, 2002).

The majority of NPS units have indicated that most of their OHV-related monitoring and management activities are done collaterally to other duties, such as backcountry patrols, overflights, and law enforcement. These monitoring efforts tend to produce only subjective, qualitative data and do not provide an accurate assessment of change over time (NPS, 2003d). In Summer 2005, DENA began a project to GPS OHV trails in the Cantwell area. However, additional baseline data on OHV routes, usage, and monitoring efforts are needed in other areas of DENA to determine the extent of OHV use and the need for route mitigation or rehabilitation efforts.

- ***Issue (Low Priority): Subsistence fishing impacts on fish populations***

Overall, NPS assesses that the degree of adverse impacts from subsistence on fish resources is low (NPS, 1998a). A cooperative study between NPS and ADF&G has been underway at DENA for four years to assess salmon runs on the Tanana and Kantishna Rivers. The 2004 fall chum salmon run was the largest number of salmon documented since the inception of the project (NPS, 2004j). However, collapsing salmon runs in the Yukon River system has caused major concerns to State and Federal resource managers, subsistence users, and the Canadian Government. The Kantishna and Toklat Rivers, tributaries to the Tanana and Yukon drainage, have failed to meet their biological escapement goals into these river systems for spawning purposes since 1995. Recently, the Alaska Board of Fisheries listed the Toklat fall chum salmon fishery as a Major Stock of Concern NPS, 2004a; 2004i). Conservation and restoration efforts are underway to restore basic escapement numbers into these river systems, and resource protection and monitoring, including collection of timely and accurate biological information, is crucial for recovery of this fishery. To aid in this effort, the NPS recently submitted a proposal for the construction and operation of a second NPS recapture fish wheel in the upper Kantishna River drainage in the vicinity of Moose Creek and Bearpaw Creek (NPS, 2004i).

According to Hollis Twitchell (2005), Subsistence Specialist at DENA, little subsistence fishing occurs inside the boundaries of the park; most harvest is outside and adjacent to the park. Fish are a major commodity for most local subsistence users and they rely heavily on it. Since fish travel across the park boundaries, fishing pressures from outside of the park is of as much concern to fish populations as from inside the park. On the south side of DENA, subsistence use of anadromous fish only accounts for a small proportion of all subsistence fishing around DENA. Resident fish are used more than anadromous fish, especially on Lake Minchumina, which is used for subsistence year-round. At one time, pike were harvested in large number at Lake Minchumina; however, over-fishing of pike led to a decrease in numbers. Today, the population seems to rebounding (Twitchell, 2005). Currently, whitefish is the most commonly fished species at Lake Minchumina. Although the magnitude and level of subsistence use was probably greater historically than it is now, the use and relative importance of certain species is similar today (NPS, 1998a). One reason for this is that harvest levels of fish at Lake Minchumina were higher in the past due to the higher numbers of dog teams that needed to be fed. These harvest levels have recently decreased with fewer dog teams in the area and less personal use.

5.5 RECREATION-RELATED ISSUES

- ***Issue (High Priority): Impacts of sport fishing on fish populations***

In comparison to other areas of the State, overall sport fishing levels are low at DENA (Owen, 2005). However, sport fishing is still more common inside the park than subsistence fishing (Twitchell, 2005). The greatest proportion of sport fishing is for Arctic grayling. Fly-fishing is popular at Wonder Lake, Moose Creek, Savage River, and Teklanika River (Owen, 2005). Horseshoe Lake is very accessible for Arctic grayling, but still does not receive a large amount of pressure. Caribou Creek receives more pressure, where many people fish for grayling near the Savage River bridge. The Savage and Sanctuary rivers receive more use than many other areas because they are along the Park Road and provide easy access. The Moose Creek drainage also receives a good amount of pressure for grayling by local residents and guests and staff at the lodges. Wonder Lake receives a large proportion of recreational fishing by staff and campgrounders fishing for lake trout. The small ponds near Wonder Lake contain Arctic char, but very few people fish there. Elsewhere in the park there is less fishing because of the high glacial silt content in lakes and rivers, resulting in poor fish habitat, and because of the remoteness and difficulty in accessing other non-glacial rivers and lakes.

Given its importance to sport fishing and fly fishing, the small populations of Arctic grayling in DENA may be vulnerable to even a moderate level of use by anglers. Arctic grayling are delicately balanced to their environment, and cannot cope well with human encroachment. Their slow growth and ease of capture make them susceptible to local extirpation, particularly in such exposed sites as streams bordering roads and highways (NPS, 1998a).

For sport fishing in the park, NPS regulations have been put in place for fish possession limits because of concern over impacts to fish populations. In the “old park,” the catch limit per person per day is 10 fish, and the catch shall not exceed a total of 10 pounds. The catch limit for lake trout per person per day is 2 fish, including those hooked and released (NPS, No date [d]). The lower limit on lake trout takes into account the slow growing rates of this species and possible population impacts if more fish are harvested. Even with possession limits in place and relatively low amounts of sport fishing occurring at DENA, park management should be aware of fish population impacts and the potential for over harvesting.

Anecdotal information indicates that sport fishing in the Moose Creek drainage and Wonder Lake by Kantishna Lodge guests and park visitors may be increasing. Lake trout found in low productivity, high altitude, Alaskan lakes (such as Wonder Lake) are generally very slow growing and prone to overharvest from even limited fishing pressure. Another stream that receives sport fishing use is Caribou Creek, a tributary of the Savage River. All of these areas are within easy access to visitors, since they are located along the Park Road corridor. Recreational fishing pressure on other park and preserve areas is not well known. No formal study has been done to determine fisheries use and no monitoring program currently exists (NPS, 1998a).

- ***Issue (High Priority): Introduction and spread of exotic species by recreational use***

Hikers can introduce exotic plant seeds into the park at any location. People come from all over to visit DENA, and seeds lodged on boots or clothing can be easily dispersed. Many visitors enjoy walking along river banks and most backcountry use takes place along river corridors with such activities as camping and gathering of water. People can also bring their own canoes and kayaks to Wonder Lake, although this is not often done. Wetland areas are also subject to exotic species dispersal; one main hiking trail traverses wetlands from Wonder Lake to the McKinley River (Hays, 2005).

Boating and rafting activities on the Nenana River have the potential to spread exotic species into riparian areas, especially white sweetclover. Other exotics, such as vetch (*Vicia craca*) and toadflax (*Linaria vulgaris*), can also establish on river banks in exposed soils (Hays, 2005). The Nenana River, from where it enters the park to where it exits, is monitored for infestation of white sweetclover. Densmore (2005) hypothesized that this exotic has not been found yet in the river corridor, since the seed source for white sweetclover is to the north of the park and raft trips start from the south.

Other activities that have the potential to spread exotic plants, but are not considered current threats, are OHV use and the use of float planes, which can land in the preserve at numerous lakes.

In regards to aquatic invasive species, Alaska is relatively uninvaded due to its harsh climate, low human populations, and low amounts of disturbance. According to Dr. Bob Piorkowski, Invasive Species Program Coordinator with the ADF&G, DENA is currently almost completely devoid of aquatic invasive species. While there are no known documented cases of aquatic invasive species in DENA, there may be some northern pike in drainages on the south side of

DENA, where they are non-indigenous. Northern pike are indigenous north of the Alaska Range, where the majority of DENA is located. The potential for several other aquatic invasive species to occur at DENA, such as Atlantic salmon (*Salmo salar*), zebra mussels (*Dreissena polymorpha*), or New Zealand mud snails (*Poltamopyrgus antipodarum*), is very low. There are presently no documented freshwater invasive aquatic weed populations in Alaska (Piorkowski, 2005).

- ***Issue (Moderate Priority): Impacts of water-related recreational use (e.g., boating, fishing, swimming) on water resources***

The majority of surface waters in the backcountry receive little recreational use due to difficult access, challenging boating conditions, or lack of fisheries (NPS, 2003e). This lack of opportunity for recreation on most of the park's surface waters focuses such use on the few rivers, streams, and lakes that are accessible and floatable, such as the Nenana, Tokositna, and Yentna Rivers; Moose Creek, and Wonder Lake. No water quality impairments attributable to use impacts were detected on the Nenana River or on Moose Creek as of 1995 (NPS, 2003e). However, as visitation to the park increases, potential impacts on these rivers from water-related recreation could increase (NPS, 1998a). No recent monitoring data for recreation use impacts on these rivers are available.

Wonder Lake and Moose Creek experience some light recreational use from campground users and Kantishna area lodge guests, although specific impacts to water resources from this use have not been noted to date (NPS, 1998a). Currently, there is only one campground located at Wonder Lake. Data from 2001 to 2003 indicate that the campground is fully occupied from opening day to the last day of the season and that there is a demand for more campgrounds in the area. The NPS is concerned that additional campgrounds and a corresponding increase in visitation could put additional stresses on Wonder Lake from waste disposal, riparian area trampling, and habitat degradation. This resource degradation can be attributed to activities such as fishing, swimming, wading, canoeing, camping, and hiking in sensitive areas (e.g., along shorelines). While a limited limnology study of Wonder Lake was conducted in 1976, there is no current limnology or water quality data that indicates whether Wonder Lake has been impacted by campground use, and the NPS does not have a sense of what effects additional campground areas could have on the water quality of the Lake. The NPS has proposed a study to sample and analyze water quality and other parameters at Wonder Lake between fiscal year (FY) 2005 and FY 2007. The findings from the study should indicate the effects of current and projected campground use on the Lake, which could be used to predict impacts of recreational use on other waterbodies in other areas of the park (NPS, 2004f).

Private boaters inside the park are not regulated by the NPS, but the NPS controls commercial boating activities within the park boundaries. Currently, there are 5 businesses authorized to provide river trip guide services in the park. Incidental business permit restrictions for 2 of these businesses allow boating only in limited areas of the preserve; the other 3 businesses are lodge operators in Kantishna, which are authorized to conduct raft trips on Moose Creek. Commercial boating operators using the Nenana and Tokositna Rivers are not required to receive NPS authorization, provided that they do not launch, stop, or land on park lands during float trips. The State of Alaska has jurisdiction over these rivers up to the ordinary high water mark, and as such, the NPS conducts very limited monitoring of these boating operations (NPS, 1998a). As of 1991, over 21,000 people were estimated to take floating trips along the Nenana River each year, and another 6,000 people were estimated to take upper river powerboat trips (Whittaker, 1991). In recent years, the Nenana River has supported approximately 30,000 to 35,000 visitors each summer on commercial rafting tours (NPS, 2003e). No public agency collects use information on the Nenana River as a whole (NPS, 1998a).

Several impacts of recreational river use have been noted, including litter, social trail development, and vegetative trampling. Social trails can lead to decreased vegetative cover, and subsequent increases in soil erosion, surface water runoff, and sedimentation; these impacts increase with increased proximity to nearby waterbodies. Social trails have developed at popular access points along the Nenana River. One such trail exists near Riley Creek, where there is access for kayakers and rafters from the Parks Highway to the river. The Nenana River bridge area north of the park entrance also receives heavy use from boaters during summer months, with multiple launchings and pull-outs along the banks. Vehicle parking along the bridge approach also presents some problems, especially during the annual kayak (whitewater) races held in July (NPS, 1998a). These access points may be resulting in adverse impacts on riparian zones, water quality, channel stability, and fisheries.

Boating (e.g., powerboat, motorboat, and jet boat use) is one of the primary river recreation-related concerns for water resources at DENA (NPS, 2003e). Limited use of motorboats occurs in DENA, primarily on the south side on the Tokositna and Yentna Rivers. Motorized use also occurs frequently on the Nenana River. Noted impacts from this use include increased erosion rates, fish mortality due to spawning bed disturbance and physical contact with propellers or jet units, loss of fish habitat due to channel morphology changes, and deterioration of water quality due to gasoline and oil pollution of water (NPS, 1998a).

Most motorboats use two-cycle engines, which may discharge as much as 30 percent of the unburned fuel/lubricating oil used by the engines into surrounding waters. The primary pollutants from unburned fuel include methyl tertiary butyl ether (MTBE) and polycyclic aromatic hydrocarbons (PAHs) (NPS, 2003e). No studies or monitoring programs have occurred to investigate this situation or evaluate specific impacts from powerboats in DENA (NPS, 1998a). However, studies of lakes in general elsewhere receiving high motorboat use have found PAH concentrations at levels considered detrimental to aquatic organisms, as well as to human health from drinking water or fish consumption. Even very low concentrations (in the parts per trillion range) were observed to cause adverse effects on aquatic organisms. In contrast, aquatic ecologic communities did not appear to be threatened by observed concentrations of MTBE in lakes with heavy motorboat use, but more research is needed to reinforce this conclusion (VanMouwerik and Hagemann, 2000c).

In a study of environmental impacts from boat use in Alaska, Hill et al. (2002) also noted hydrodynamic impacts, such as wake-induced shoreline erosion and turbulent prop wash, as potential concerns. Turbulence produced by prop wash can increase the mortality rate of fish eggs and re-suspend bottom sediments, potentially leading to erosion, internal nutrient loading, or elevated levels of turbidity and heavy metals in the water column. Their study, which measured boat wake height, near-bank turbidity, and near-bed water velocity induced by boat passage, found that:

- Boat wakes are capable of dislodging sediments from stream banks.
- Wakes increase in amplitude with an increase in boat size.
- Keeping boats “on-plane” reduces overall wake heights at the banks.
- Comparisons of streamflow and boat wake shear stress indicate that wakes can exert a larger shear stress than streamflow.

A recent follow-on study concerning the biological impacts of hydraulic disturbances associated with jet boats utilized a laboratory environment to simulate hydraulic stresses on salmon fry (Hill and Younkin, 2005). The results of this study suggested that although the presence of turbulence can reduce the growth rate of juvenile salmon, different magnitudes of turbulence did not result in varying levels of inhibitive effect. Future studies will be needed to more appropriately extrapolate the results of this lab-based study to natural river conditions.

Recreational use of DENA has been increasing, and is anticipated to continue to increase. Recreational use of rivers on the south side of DENA, including commercial trips, is believed to be increasing significantly, the main focus of which is on the Tokositna and Yentna Rivers (NPS, 1998a). As recreational use increases, motorboat use would also likely increase, which could increase the potential for water pollution effects on boatable rivers, such as the Nenana, Tokositna, Kantishna, Bearpaw, Yentna, and Muddy Rivers. In addition, there is a concern of increasing jet boat use on DENA streams, particularly on Windy Creek, south side rivers (e.g., Yentna, Chilintna), and in the northwest area of the park. However, there is no data available regarding jet boat use or environmental damage caused by such use at DENA. Increasing jet boat use is a concern because jet boats can operate in less water depth (as little as two to three inches of water) than other types of boats, and therefore, can increase the number of streams that can be impacted by boat use.

- ***Issue (Moderate Priority): Impacts of snowmobile use on water resources***

In February, March, and April, snowmobiles are the most common form of off-road surface transportation for DENA park visitors, and is the most common winter use activity in the south slope area (including Preserve additions) (NPS, 1998a). Prior to 1980, Mt. McKinley National Park was closed to snowmobile use. The 1980 passage of ANILCA authorized snowmobile use throughout the entire DENA for “traditional activities,” but did not define which activities are considered “traditional.” On June 19, 2000, final special regulations for DENA were published in the Federal Register (65 FR 37863), which established a definition for “traditional activity” that applied only to the former Mt. McKinley National Park area of DENA. The rule determined that, prior to the enactment of ANILCA, no traditional activities occurred in the former Mt. McKinley National Park area for which snowmobiles may now be used. As a result, the rule implemented closure of the former Mt. McKinley National Park portion of DENA to snowmobile use (NPS, 2003e). Winter access by snowmobiles is still permitted for subsistence and traditional activities in all the 1980 additions to DENA, provided there is adequate snow cover. However, there remains uncertainty about appropriate reasons for snowmobile use, and “traditional activities” remain undefined (Loeb, 2005).

Snowmobile use throughout the State has increased substantially over the last decade. At DENA, the highest concentration of use occurs on the south side of the Alaska Range, as evidenced by aerial surveys (NPS, 2004a). The number of jump-off points along plowed roads to the south and east of DENA makes accurate estimates of users difficult. The NPS estimated that, during March and April of 1999, there were 1,500 to 2,000 snowmobile users along the Parks Highway, primarily in the area from Cantwell to the West Fork of the Chulitna River and the Tokositna River (NPS, 2003e). Other areas of high snowmobile use at DENA include:

- Broad Pass area, near Cantwell Creek and the Dunkle Hills;
- Yentna River corridor;
- Along Cache and Peters Creeks in the Dutch Hills and Peters Hills;
- Tokositna River drainage to the base of the Tokositna and Kanikula Glaciers;
- Along Dutch and Bear Creeks;
- Fairview Mountain;
- Chelatna Lake;
- Along Snowslide Creek, in the Kahiltna River drainage;
- Near the plowed end of Petersville Road (Kroto Creek and around Forks Roadhouse);
- Ruth Amphitheater; and
- Stampede trail alignment (north side of park) (NPS, 2003e; 2004a; Adema, 2005a).

Snowmobile use is expanding in DENA to areas that were previously inaccessible, and such use has also been observed in the Old Park (Mt. McKinley National Park) near Cantwell Creek and Bull River, where snowmobile use is not permitted (NPS, 2003e).

Snowmobiles are considered a potential source of water pollution and a potential threat to aquatic ecosystems from gasoline and oil pollution. Snowmobiles can also affect water resources indirectly by soil compaction and associated increased surface water runoff, reduced infiltration, and impeded root growth. These effects are most prominent in areas that can become snow-free during certain times in the winter or that have a thin snow layer that can be further reduced by snowmobile passes (such as along mountain passes and exposures and areas with steep slopes) (NPS, 2003e). These impacts are also greatest in high-use areas, and can be expected to increase as unregulated use increases.

Of particular concern are snowmobile emissions containing significant quantities of PAHs, which are known to have a wide variety of adverse biological effects and can be photo-activated by sunlight. Once emitted from snowmobiles, PAHs are removed from air by vapor phase sorption on exposed surfaces and by wet and dry deposition. In low temperature situations, PAH residue are largely immobilized; however, as temperatures increase during spring and summer, the mobility of PAH residues increases, potentially resulting in pollution problems in park streams and lakes. As a result of these concerns, a recent, joint study to assess the presence and potential impacts of PAHs resulting from recreational snowmobile use in DENA was conducted by the DENA and Columbia Environmental Research Center. Semi-permeable membrane devices were deployed on the park in Camp Creek, Bull River, and Cantwell Creek in the vicinity of Cantwell. No quantifiable PAH residues or PAH-related hydrocarbon degradation products were found at the sample sites, and no evidence of any significant contamination was found (Petty et al., 2003). No known studies have been conducted in other areas of the park to monitor snowmobile effects on water quality or aquatic ecosystems.

Several other projects designed to assess the effects of snowmobile use are currently in progress at DENA. A snowpack characterization study focuses on measuring the characteristics of the snowpack that allow adequate support of snowmobile travel without causing adverse impacts to vegetation and soils. Snow depth and density are monitored at several fixed survey sites located in different vegetation types, as well as areas of special concern to park management, throughout the winter season (December through May). In addition, the snowmobile activity patterns and route maps study uses aerial and ground surveys to produce maps showing where visitors use snowmobiles the most within the park (NPS, 2004a). Once adopted, the new Backcountry Management Plan will set forth standards and goals for resource conditions in various areas of the backcountry, including goals for the amount of snowmobile use allowed to ensure protection of resources (Loeb, 2005).

Traditionally, park visitation is relatively low during the winter season (September through April). However, as the State's population grows and winter recreation is increasingly promoted State-wide, visitation to DENA during the "off season" continues to grow. Little is known of the potential resource impacts from this type of use; resource impact studies tend to focus on summer activities, including trail and road use and development. During the winter, ranger and resource management staff levels are significantly reduced, and impacts and problems associated with winter recreation may not be adequately planned for, monitored or mitigated (NPS, 1998a).

- ***Issue (Low Priority): Impacts of litter and human waste on water resources***

Backcountry user and mountain climber trash and human waste disposal are major concerns in DENA. However, the majority of available information on this problem focuses on mountain climber waste. Increased sewage and garbage disposal has the potential to increase nutrient loads in naturally nutrient-poor ecosystems. This could substantially affect existing water quality and ecosystem equilibrium.

Since 1977, a "pack in-pack out" policy (Leave No Trace) has been enforced at DENA requiring mountain climbers and backcountry users to remove all their garbage from the Alaska Range. Citations are issued for violations of this policy. A pit toilet was established in 1977 at the 7,200-foot basecamp on Mt. McKinley; another pit toilet was installed at the 14,200-foot camp in 1982. In 1989, a toilet was installed at 17,200 feet using a removable box that could be dumped in a crevasse for disposal. Even with these improvements in waste disposal, a large amount of garbage was still being left on Mt. McKinley, and improper disposal of feces at the camps continued. In 1997, one mountaineering patrol cleaned up more than 700 pounds of garbage from the 14,200-foot camp alone (NPS, 2000b). A 2000 climbing season study on trash at DENA found that more than 37,000 pounds of food and potential trash are hauled into DENA each year by climbing expeditions (NPS, 2003e).

As a result of trash concerns, the NPS began a pilot study in 2000 to determine the amount of trash generated per person per user day that should be returned by a climbing party. This study involved a mandatory waste bag weighing and numbering system that made climbers more accountable for their garbage and human waste (NPS, 2000b). It was found that, on average, expeditions generate about one-third of a pound of trash per person per day (NPS, 2001b). The study resulted in improved trash return rates, partially due to the increased attention paid to resource management by the NPS, and a significant decrease in garbage found in the popular camps. The study provided valuable baseline information upon which to build an education and enforcement program for future seasons (NPS, 2000b).

While the problem of trash accumulation on the mountain is improving, the most frequently reported problem by climbers is improper disposal of human waste (NPS, 2001b). Therefore, the recent primary focus of the Leave No Trace program is on the removal of human waste, which has become an issue for water quality in the park. Park regulations for disposal of human waste during mountaineering require that latrines be used at elevations of 7,200 feet and 14,200 feet and Clean Mountain Cans (CMCs) be used above 14,200 feet; in other areas or when CMCs or pits are not available, visitors are to use biodegradable bags and crevasse human waste. In 2000, CMCs were introduced at DENA, and the NPS now requires that all human waste be removed from the 17,200-foot high camp on Mount McKinley using CMCs. CMCs are issued to expeditions at the Kahiltna Basecamp for the West Buttress and at the Talkeetna Ranger Station for other parts of the range prior to departure; upon returning to the base, CMCs are returned to the NPS, who arranges for proper disposal and disinfection. The use of the CMC remains a high priority for other glacier fly-in basecamp operations throughout the park (NPS, 2005a). The CMC program was used successfully during the 2002, 2003, and 2004 seasons (NPS, 2002c; 2003f; 2004c), and is continuing to be implemented and improved on the park. In 2003, almost every climber ascending to the 17,200-foot high camp on the West Buttress removed their waste using CMCs, and the human impact at this camp has significantly improved (NPS, 2003f).

Even with all of the NPS programs and requirements regarding disposal of trash and human waste, with growing numbers of climbers, the NPS is still noting occasional abandonment of caches and improper human waste disposal. There is also a concern regarding the leachate from these toilets draining down the mountain and impairing water quality, particularly during snowmelt (Twitchell, 2005). In addition, since all drinking water for mountain climbers is obtained from snowmelt, there is the potential for climbers to consume snowmelt contaminated from improper human waste disposal on the mountain. Human waste can contaminate water resources with fecal coliform and *Giardia lamblia* and alter plant and animal communities by increasing nutrient loads and dissolved oxygen demand (NPS, 1998a). The long-term effects of human waste deposition on surface water or groundwater resources at the park are unknown.

Giardia lamblia has always been a concern at DENA. Although *Giardia lamblia* is thought to exist naturally in surface waters of the park, baseline conditions are not well established and the contamination of DENA's watersheds by *Giardia* cysts may also be a result of recreation use. If humans are infected with Giardiasis and defecate near a water source, surface storm runoff can carry the cysts from the location of deposit to the water source (NPS, 1998a). *Giardia* has been found in watersheds on the South Side of DENA (NPS, 1996a), and in beaver ponds associated with Jenny Creek, which originates east of the Savage River and joins the Savage River several miles above the beaver ponds (Saltonstall, 1988). While the NPS warns park users of the potential risks of *Giaridia* infection, only limited studies have been conducted in the park to investigate the extent and methods of transmission of *Giardia lamblia* (NPS, 1998a; Saltonstall, 1988).

There is no visitor registration system in place for the south side area of DENA, and there are no regular park patrols in the area. Consequently, information pertaining to issues such as proper trash management and sanitation practices are not communicated to visitors. Past observations in the area indicate that some visitors only dig shallow holes to dispose of human waste, leading to the waste melting out later in the season and increasing water quality concerns. Better information is needed for popular locations on the south side of DENA, such as the Ruth Glacier area, where many types of visitor use are occurring, increasing the potential for resource impacts (Valentine et al., 2000).

- ***Issue (Low Priority): Impacts of trail use and construction on water resources***

Some visitor use areas in the frontcountry receive heavy and consistent visitor use during the summer season and are subject to severe soil compaction and associated increased surface water runoff. Under the right conditions, the increased sediment yields from trail use can enter a waterbody and degrade water quality through increased turbidity and total dissolved solids, and degrade aquatic habitat by covering the natural substrate through increased sediment deposition. In addition, these areas are subject to multiple tread, informal trails, which could increase the potential for water resource impacts. Even areas that receive relatively low use could be prone to the development of multiple tread trails, particularly at popular departure points for hiking into the backcountry (NPS, 1998a).

The NPS has noted that it has insufficient funding for trail maintenance at DENA, which is leading to erosion and development of social (user-created) trails off main trails (NPS, 1998a). The proximity of these social trails and erosional problems to nearby waterbodies may be posing additional water quality problems. These problems may be exasperated by an increase in trail development. Several user-created social trails are known in the vicinity of the Eielson Visitor Center, including one social trail that leads to the spring providing water to the visitor center and two trails leading downhill to Gorge Creek (NPS, 2004e).

DENA began a comprehensive trails and nodes (areas of non-linear impact) monitoring program in 1995, which was designed to provide information necessary to assess the impact of trails and nodes on the park. The purposes of this monitoring program are to: detect unknown impact areas through surveys for new trail-node formation; quickly and accurately establish the current impact status of trail-nodes through qualitative evaluation; and track conditions at certain problem areas or sensitive sites to quantitative monitoring (NPS, 1998a). The initial scope of this project includes only named social trails (foot trails and nodes) along the Park Road (excluding the Kantishna area) that are not designated or maintained by the park. Although visitors in these areas are encouraged to disperse when hiking, a number of social trails have become established. Similar trails and nodes likely exist along Highway 3 within the park, in the Kantishna area, along river banks near roads, etc. The monitoring program may eventually be expanded to include all social trails and nodes in all areas of the park (Furbish, 1997).

The last available progress report on the program presents the results of the 1995 and 1996 qualitative evaluations for some trail segments identified during those years. Sixty-two trails were identified during 1995-1996, the majority of which are social trails that were created in various ways, such as old stock or vehicle roads and well-established game trails, but which were perpetuated by foot traffic from park visitors. Historic information was found for 48 of the 62 trails; historic information had not been found for 14 of the identified trails. Of the 62 trails identified, the progress report presents qualitative evaluation data for 23 trails. Data presented includes several resource impact parameters, such as degree of erosion, level of humus layer impact, average trail width, amount of exposed mineral soil and vegetation coverage, amount of human litter observed, and number of collateral trails. One of the parameters not identified by the study is the proximity of trails to water resources, which would be crucial to evaluate the effects of these trails on water resources. Five of the trails evaluated had segments rating high or severe for erosion. Seventeen monitored trails had segments rating high (layer nearly gone) or severe (layer gone) for humus layer condition and root exposure. In addition, 18 trails had segments rating high to severe for mineral soil exposure and vegetation coverage. Ratings for these trails were determined by evaluating mineral soil and vegetation cover on the trail surface and comparing coverage to surrounding off-trail conditions; the greater the difference in coverage, the more severe the rating (Furbish, 1997).

In addition to the established trails listed in **Table 4.4-1** in Section 4.4.1, *Recreation*, several new trails are being planned for development at and around DENA. A new 1.3-mile long multi-purpose (hiking and cycling) trail in the entrance area of the park is being planned, which would connect users of the Parks Highway (Alaska Highway 3) and the new pedestrian trail leading from the gateway area ½-mile north of the park entrance to the new park visitor center (NPS, 2004d). Also planned is the construction of a 4 ¼-mile Springtime Dogsled/Ski Trail (Spring Trail) in the vicinity of the Park Road from park headquarters at mile 3.4 to mile 7.63. This trail would accommodate non-motorized over-snow travel by skiers, snowshoers, and sled dog teams (NPS, 2002b). In addition, as part of the South Side Development Concept Plan, two hiking/interpretive trails are being planned that would link areas of Denali State Park to DENA, providing additional visitor access to DENA. These trails are proposed from the Tokositna visitor center area and the Chelatna Lake area in Denali State Park (NPS et al., 1997). Trail development can result in adverse impacts to affected water resources, particularly sensitive wetland communities. The cumulative effects of these impacts increase if multiple trails are constructed in close proximity to each other.

Development of additional trails from Denali State Park to DENA, and increased access provided by these trails, could increase unauthorized snowmobile and OHV use in DENA. If unrestricted snowmobile/OHV use is allowed on State lands, problems could arise where trails cross Federal land boundaries, where such use is prohibited except for traditional or subsistence purposes. Increases in resource damage and water quality impacts could result.

5.6 NAVIGABLE WATERS-RELATED ISSUES

- ***Issue (High Priority): Status of navigable water determinations***

A definitive Federal list of navigable waters in Alaska does not exist. The State has indicated thousands of rivers, streams, and lakes are potentially navigable. However, since statehood in 1959, the Federal courts have determined navigability of less than a dozen unreserved rivers, streams, and lakes in Alaska. This litigation process is both expensive and time consuming to the State and Federal governments.

The criteria for navigability takes into account geography, economy, historical use, customary modes of water-based transportation, and the particular physical characteristics of the waterbody (ADNR, 2004). The BLM determined four miles of the Tokositna River inside the south part of the park as navigable, and the navigability of portions of the Muddy and Kantishna Rivers are reportedly in adjudication. Other waterbodies may be determined navigable in the future (NPS, 1986).

In August 1991, the ADNR, Division of Water signed a finding that Moose Creek in DENA is "navigable in fact" downstream of its confluence with Rainy Creek to its confluence with the Bearpaw River. A draft report on Moose Creek's boatability was prepared for the NPS in order to review Moose Creek's navigability and consequent stream bed ownership issues (Shelby, 1992). The State's determination of navigability of Moose Creek was later withdrawn, in part due to the loss of flow into the thickening gravels of Moose Creek about 20 miles south of Kantishna (Carwile, 2005).

The State of Alaska is using the recordable disclaimer of interest (RDI) process to help confirm the State's ownership of navigable waters in Alaska. Section 315 of the Federal Land Policy and Management Act (FLPMA) and 43 CFR 1864 allows the Secretary of the Interior, under certain conditions, to issue an RDI where the disclaimer will help remove a cloud on the title of such lands. The goal of the disclaimer is to eliminate the necessity for court action or private legislation in those instances where the United States asserts no ownership or record interest, based on a determination by the BLM that there is a cloud on the title to the lands, attributable to the United States, and that an interest of the United States has terminated by operation of law or is otherwise invalid (BLM, 2004). An RDI issued by BLM releases any possible Federal interest in the river beds; those beds are then clearly subject to State statutes, regulations, and policy (Adema, 2005c). In all likelihood, the State of Alaska will initially file RDI applications on approximately 200 rivers that it identified in 1992 when it filed notice of intent to sue for quiet title to the beds of the identified waterbodies (BLM, 2004). Of these 200 rivers, those within DENA include portions of the Muddy, McKinley, Kantishna, Tokositna, Nenana (ending northeast of Healy), and Teklanika (ending north of the park boundary) Rivers (BLM, 2004; ADNR, 1992). Currently, the NPS is organizing a team to investigate, review, and make an assessment of navigability on upcoming State applications for RDI on the Kantishna River (downstream from the confluence of Birch Creek and McKinley River, about 15 miles of which is in DENA) and Muddy River (from Lake Minchumina downstream to Birch Creek, about 24 miles of which is in DENA), among other rivers on NPS lands in the State (Adema, 2005c).

- ***Issue (High Priority): Navigable water criteria disputes between State and Federal government***

Since State, Federal, and native land units blanket the State, navigability questions have arisen for Alaskan rivers, lakes, and streams. While the navigability of many of these waterbodies for conveyance purposes has already been established, navigability for title has not been determined for most waterbodies. Navigability determinations are required to determine whether the State or the Federal government owns the submerged lands. State ownership of the beds of navigable waters is an inherent attribute of State sovereignty protected by the U.S. Constitution (ADNR, 2004). However, it is the position of the Federal government that waters and submerged lands within the boundaries of NPS units created prior to Alaska statehood are federally owned (Weeks, 2003; DOI, 1998).

A major goal of the State's navigability program is to identify the proper criteria for determining title navigability in Alaska and to gather sufficient information about the uses and physical characteristics of individual water bodies so that accurate navigability determination can be made. The greatest hurdle to overcome in identifying and managing navigable waters in Alaska has been the differences of opinion between the State and Federal government regarding the criteria for determining title navigability. As a result of these criteria disputes, many waterbodies considered navigable by the State have been determined non-navigable by the Federal government. Final court decisions in Alaska are still needed to provide legal guidance for accurate navigability determinations (ADNR, 2004).

- ***Issue (High Priority): Potential navigability determination impacts on DENA's water resources***

In 1992, the Secretary of the Interior directed the NPS, USFWS, and BLM to assume responsibility for navigability research for quiet title through negotiation and litigation. However, no additional funding has been allocated for the Bureaus to accomplish this work. As a result, there may be an undue loss of submerged lands to State ownership if research and documentation are inadequate. In addition, land management issues are raised when the navigability of a waterbody is in question. Unresolved title navigability results in uncertainty for law enforcement personnel and the public. For the public, there is uncertainty about securing permits for guiding operations or resource development. Where submerged lands belong to the State, there are conflicting opinions regarding management of the streambed versus uplands. In addition, there are issues related to development within submerged lands that may be incompatible with the purposes of federally reserved lands (DOI, 1998), such as the potential for placer and gravel mining and other in-stream uses.

The U.S. DOI recognizes that interagency coordination is essential to providing efficient and effective research regarding navigability and the development of consistent policy for navigability work. In addition to projects needed to solve interagency coordination needs, the DOI has identified several projects to solve current information needs regarding navigability. These projects include:

- Including navigability data needs in the prioritization of index gauging stations;
- Collecting channel and drainage basin characteristics and stream discharge data, if necessary, needed for navigability reports and litigation;
- Accelerating navigability research to gather information needed for navigability reports and potential litigation;
- Creating agency databases of navigability-related information;
- Investigating and, if feasible, implementing an Internet function to link DOI navigability databases; and
- Developing Geographic Information System (GIS) coverage to display on maps the navigability status of waterbodies on DOI lands (DOI, 1998).

5.7 WATER RIGHTS-RELATED ISSUES

The DENA GMP (1986) states that the Park will:

> "Quantify and inform the State of Alaska of its existing water uses and those future water needs necessary to carry out the purposes of the [Federal] reservation. When the reserve doctrine or other Federal law is not applicable, water rights will be applied to in accordance with Alaska laws and regulations."

Water rights, whether Federal reserved rights or state law-based, are needed by the Park to meet the water needs of Park personnel and visitors, and to protect the Park's water or its water-dependent resources. Because the Park is located at the headwaters of drainage basins, the risk to resources from private water development in or adjacent to the Park is low. However, in some areas, the risk to Park water and water-dependent resources associated with private water development is likely to increase, rather than decline, in the future. There are increasing risks of private development of water resources both within and adjacent to the Park, such as the potential drilling of CBM in and around Healy (see Section 5.3, *Mining-Related Issues*). Consequently, it is important for the Park to ascertain its water resource needs, and to ensure support for those needs with the necessary water rights. This support can be achieved through combinations of Federal reserved rights and state appropriative or reservation rights for both consumptive and in-stream purposes.

While the NPS could not view a State reservation as a substitute for a Federal reserved water right which is considered Federal property, there is merit in collaborating to avoid litigation and bring more clarity to water management issues. However, the data collection requirements necessary to quantify Alaska reservations are considerable and this expense, coupled with a general lack of water use conflicts in DENA, has caused such an effort to receive a low priority. Specific areas where development may spark water rights conflicts are identified below.

- ***Issue (High Priority): Potential for water rights conflicts as a result of increased water demand and in-stream uses***

At present, the Park does not hold any State appropriative rights for consumptive use or State in-stream reservations. Park consumptive uses and in-stream needs are presently supported by Federal reserved rights (ADNR, 2005a). (As discussed in Section 3.8.3, Federal reserved rights are created when Federal lands are reserved for a specific purpose and arise as of the date of the reservation.) These rights have not yet been described and confirmed in adjudication proceedings. In addition, State water law affords additional means to meet park needs, for both consumptive and in-stream purposes. Denali area residents and park visitors have used surface water resources to meet personal and commercial needs: historically the Nenana River and Moose Creek are the most heavily used. However, visitor use and commercial development have increased dramatically, resulting in greater demands on water resources. This increased demand could cause conflicts over water rights between the park and private interests. The greatest water demands come from tourism (commercial lodge operations and service industries), recreation (commercial outfitters and RV parks), placer and coal mining, and power industries. In addition, there is concern about the conversion of patented mining claims within the park to other uses, and the development of private inholdings such as Kantishna Hills. In addition to consumptive uses, the Park is also concerned about in-stream flow needs. High quality surface water resources are necessary to support wildlife and botanical communities, and to insure compatibility with the cultural and natural landscapes.

- ***Issue (High Priority): Data collection needed to support applications for water rights***

Data regarding stream flows is necessary to support applications for State reservation rights and to support the adjudication of Federal reserved water rights. In addition, such data is necessary to evaluate the nature of any threats to park water resources brought about by private development. Consequently, the ongoing collection of stream flow data is critical to obtaining and enforcing water rights to meet park consumptive needs and protect park water resources. For in-stream flow applications, ADNR recommends five years of stream flow gauging information, and requires biological, recreational, or water quality data to justify the need for in-stream flow water rights. A similar understanding of the flow regime and park needs is also needed to support assertions of Federal reserved rights. Consequently, as funding is available, NPS should prioritize data collection efforts, including stream gauge installation.

5.8 CLIMATE CHANGE-RELATED ISSUES

Climate change in high latitude regions over the past few hundred years was dominated by the generally cool Little Ice Age, and subsequent warming of up to several degrees has marked the termination of this cold period. General Circulation Models (GCMs) of future climatic response to increasing anthropogenic emissions of “greenhouse gases” in the atmosphere have predicted that high latitude regions, such as Alaska, will experience greater warming relative to lower latitudes (Dowdeswell et al., 1997). Small changes in temperature can reduce the amount of snow and ice coverage in these regions and increase the amount of sunlight reaching ground and ocean surfaces. Snow and ice reflect solar radiation, whereas ground and ocean surfaces absorb solar radiation, which in turn produces slightly warmer temperatures (Papineau, unpublished; ARAG, 1999). Climate trends in Alaska over the last three decades have shown considerable warming, with a rise in average temperature of about 5°F (3°C) in winter (ARAG, 1999). The winter of 2000 to 2001 was one of the warmest on record in Alaska (Papineau, unpublished). In addition to warming trends, the Alaskan climate has shown strong multi-year cycles, which are coupled to large-scale climate oscillations: the 2- to 5-year El Niño/Southern Oscillation (ENSO) in the Pacific, and the interdecadal (approx. 15-year) Arctic Oscillation (AO), of which the Pacific Decadal Oscillation (PDO) and the North Atlantic Oscillation (NAO) are part. The ENSO, AO, NAO, and PDO influence climate, but they cannot explain observed climate trends (ARAG, 1999).

The mean annual temperature of much of Alaska, including DENA, is close to the melting point of ice and a relatively small warming of the climate can affect the hydrological regime of DENA through thawing of permafrost, drying up of shallow lakes, melting of glaciers, and later freeze-up and earlier breakup of river and lake ice. Warming also has an affect on soil biogeochemistry, which impacts water chemistry and aquatic habitats. Basic research and long-term monitoring are needed to compliment on-going regional and global efforts to better understand the causes and consequences of climate change.

DENA has a network of six automated weather stations in the Rock Creek watershed adjacent to park headquarters, a single manual weather station at park headquarters, two weather stations at Eielson Visitor Center and Wonder Lake Ranger Station, and four remote automated weather stations at Wonder Lake, McKinley River, Lake Minchumina, and Ruth Glacier. New climate stations are being installed in the park as part of the NPS Central Alaska Network (CAKN) Inventory and Monitoring Program. Data from the climate stations are available on the internet at http://www.wrcc.dri.edu/ and from annual park reports. The park headquarters weather station has been operating since the fall of 1923 and is the only station in DENA with historical temperature records. Temperatures at park headquarters for the winter months of January through March 2001 were above average, with temperatures in January being among the five warmest on record since 1923 (Sousanes, 2002).

The primary goal of the CAKN Inventory and Monitoring Program is to build a holistic picture of change across the ecosystems of the network through monitoring of ecosystems and detection of change in the relationships among ecological components. Global climate change is a broad-scale concern for all parks in the network (MacCluskie and Oakley, 2002). Information on this program and published reports is available on the internet at http://www1.nature.nps.gov/im/units/cakn/Index.cfm.

In addition, in a joint international project to evaluate and synthesize knowledge on climate variability, climate change, and increased ultraviolet radiation and their consequences, the Arctic Council and the International Arctic Science Committee (IASC) released the results of their assessment at the ACIA International Scientific Symposium held in Reykjavik, Iceland in November 2004. The results of their study, the *Arctic Climate Impact Assessment*, are also available on the internet at http://amap.no/acia/.

- ***Issue (High Priority): Climate change impacts on permafrost***

The Intergovernmental Panel on Climate Change (IPCC) predicts a disappearance of most of the ice-rich discontinuous permafrost in Alaska over a century-long time span (ARAG, 1999). Permafrost plays an important role in the hydrology of watersheds by not readily allowing water from snowmelt or rain to infiltrate the ground surface, resulting in increased response time to precipitation events, higher peak flows, limited subsurface storage, and lower base flows compared to permafrost-free areas (Bolton et al., 2000). Permafrost also creates conditions which favor the formation of extensive wetlands (USGS, 1996). As permafrost decreases in thickness and extent, the interaction of surface and sub-permafrost groundwater processes become more important, either by contributing groundwater to streamflow, or allowing surface water to drain. Climate warming causes degradation of permafrost, impacting hydrologic processes, including increased winter stream flows, decreased summer peak flows, changes in water chemistry, and other fluvial geomorphological processes. As permafrost thaws, thermokarst topography forms. The dynamic processes involved in thermokarsting include thaw, ponding, surface and subsurface drainage, surface subsidence, and related erosion. These processes can be rapid and can cause extensive modification of the landscape (Hinzman et al., 2001).

- ***Issue (High Priority): Climate change impacts on shallow lakes***

Shallow lakes, which are a major wetland feature in Alaska, including DENA, are particularly sensitive to climate change because their hydrologic cycle is tied to seasonal snow cover and permafrost. Over the past 20 years, much concern has been expressed by scientists, native elders, and local people who have observed a decline in water level in shallow lake ecosystems throughout the Central Alaska parks (Larsen et al., 2004). Several studies have linked lake drying with permafrost degradation. Studies of thermokarst ponds in Council and Seward, Alaska, indicate that climatic warming has caused thermokarst ponds to drain and dry up by allowing sub-surface drainage to occur throughout the year. Regions over thin permafrost (less than 20 meters) are more at risk of pond loss depending on hydrologic gradients (i.e., groundwater upwelling or downwelling) (Hinzman et al., 2001). Aerial photographs taken of shallow lakes in the Yukon Flats National Wildlife Refuge from the 1950s to 2000 show significant reduction in lake surface water levels (Larsen et al., 2004). Overall, climatic changes that influence the availability of water in shallow lakes and other wetland systems will dramatically affect the structure and function of these systems.

In 2004, the CAKN Inventory and Monitoring Program developed a shallow lake limnology monitoring protocol to assess the effects of climate change on these ecosystems. Four parameters were selected to assess the condition of shallow lake ecosystems: 1) water quantity, 2) water chemistry, 3) vegetation, and 4) macroinvertebrate communities (Larsen et al., 2004). As part of this program, funding has also been requested to develop a protocol to measure the number and size of shallow lakes in CAKN and develop a strategy for monitoring lake area and ice and surface water dynamics over time using radar satellite imagery (NWA-CESU, 2004).

- ***Issue (High Priority): Climate change impacts on glaciers***

Glaciers are recognized as sensitive indicators of climate change because their size changes in accordance with variations in mass gain or loss (mass balance) (Fountain et al., 1997). The negative mass balance of most arctic glaciers, including Alaska glaciers, may be a response to recent warming trends (Dowdeswell et al., 1997).

The USGS operates a long-term glacier monitoring program to document changes in climate, glacier geometry, glacier mass balance, glacier motion, and stream runoff. The mass balance of a glacier is evaluated by measuring the addition to and loss of snow and ice mass at points on the glacier surface and estimating the gain or loss of mass within the glacier, which is caused by freezing of water or melting of ice, respectively (Fountain et al., 1997). Long-term glacier mass balance monitoring programs have been established at three benchmark glaciers in widely spaced glacier basins in the U.S. (USGS, 2004). These basins include Gulkana and Wolverine Glaciers in Alaska and South Cascade Glacier in Washington. Gulkana Glacier is a south-facing branched valley glacier on the southern flank of the Alaska Range, roughly 100 miles to the east of DENA. Over four decades, the cumulative mass balance trend of the Gulkana Glacier has been negative, but with rate-change inflection points that coincide with the interdecadal climate-regime shifts in the North Pacific indices. Since 1989, the trends of the glaciers in Alaska have been strongly negative with the highest rates of loss on record. These strongly negative trends during the 1990s agree with climate studies that suggest that the period since the 1989 regime shift has been unusual (Trabant et al., 2003).

A 1997 paper by Dowdeswell and others discussed the links between glacier mass balance and recent climate change in the Arctic. In Alaska, almost all glaciers observed are either in a state of negative mass balance or have mass balances close to zero based on 20 to 40 years of data. The Worthington Glacier in the central Chugach Mountains, the McCall Glacier in the Brooks Range of northern Alaska, and the Gulkana Glacier in the central Alaska Range have experienced a generally negative mass balance since the 1950s with a trend toward more negative values in the 1990s. The Wolverine Glacier in the Kenai Mountains in southern Alaska has a variable annual mass balance, which is statistically indistinguishable from zero. Detailed analysis between glacier mass balance and meteorological parameters were made based on winter precipitation accumulation and on summer melting. The winter balance, affected mainly by solid precipitation, was relatively consistent from year to year, whereas the summer mass losses were variable. This implies that variations in summer melting are most significant in influencing the net mass balance and its variability. Although glacier mass balance data does not suggest a correlation between negative balance conditions and anthropogenically induced global warming, it may be hidden within the noise of summer variability in mass balance records (Dowdeswell et al., 1997).

DENA began a formal glacier monitoring program in 1991 as part of the NPS' Long-term Ecological Monitoring Program, in cooperation with the USGS and the Geophysical Institute at the University of Alaska-Fairbanks (Adema et al., 2003). Long-term glacier monitoring sites were installed on Kahiltna and Traleika Glaciers to compare the mass balance and flow changes of glaciers on the north and south side of the Alaska Range. Based on 11 years of monitoring, the Kahiltna Glacier flows approximately 660 feet per year, while the Traleika Glacier flows approximately 165 feet per year. The Kahiltna Glacier has lost mass balance (approximately 13 feet of water-equivalent), while the Traleika Glacier has gained mass balance (approximately 7 feet of water-equivalent). In 2002 and 2003, estimates of glacier thickness through the use of radar soundings were made on the Traleika, Muldrow, Toklat, and Kahiltna Glaciers. This data will allow the NPS to document any changes in thickness of ice (NPS, 2004a).

- ***Issue (High Priority): Climate change impacts on ice formation and breakup***

River and lake ice formation and breakup has been recorded for the Tanana River in interior Alaska since the 1920s. Records show that river and ice formation is occurring later in fall and breakup is occurring earlier in spring, leading to shorter ice-covered periods (ARAG, 1999) and alteration of seasonal stream flows.

- ***Issue (High Priority): Climate change impacts on soil biogeochemistry***

In 1998, USGS Global Change program funded research for a network of Long-term Reference Ecosystems initially established in national parks and funded by the NPS. The network includes Asik watershed in Noatak National Preserve, Alaska. The Asik watershed is at the northern extent (treeline) of the boreal biome in North America. The research goal is to gain a basic understanding of ecosystem structure and function and the response to change in atmospheric inputs and climate. Soil warming and change in available nitrogen (N) can increase production and export of dissolved organic forms of carbon (DOC) and nitrogen (DON) to aquatic ecosystems (streams, lakes, and ponds), which will likely alter aquatic ecosystem production by altering the depth of the photic zone, which in turn can modify the base of the food web from primary production to bacteria-based production. The importance of such change will likely be most evident in northern ecosystems, such as the Arctik Asik watershed, where soil carbon and N reservoirs are especially large, moisture is not limiting, and climate warming is most pronounced. Research at the Asik watershed focuses on soil responses to change in climate and hydrology to better explain the high ecosystem N export where atmospheric inputs are low (Stottlemyer et al., 2002).

SECTION 6.0
BASELINE INVENTORY AND MONITORING (I&M)

"Data gaps" in water-related baseline inventory and monitoring were identified during preparation of this report through the identification and synthesis of available water resources information. Resource inventory and monitoring data was often inadequate to fully analyze or address the water-related issues identified and prioritized in Section 5 of this report. **Table 6-1** below lists the issues in order of priority and identifies the general inventory and monitoring data needed to analyze and address these issues for future planning and management purposes.

Table 6-1. Baseline I&M Needed By Issue

Issue	Baseline I&M Needed
High Priority Issues	
Floodplain modification from existing and proposed development	• Delineation of 100 and 500 year floodplains for rivers and streams associated with existing or proposed development • Mapping and risk assessment of flood hazard zones
NPS and commercial wastewater disposal, treatment, and discharge	• Complete second part of DENA wastewater facilities study • Conduct water quality sampling in Nenana River and Moose Creek to determine if wastewater effluent discharge is impairing water quality
Proposed North Access Route to Kantishna	• NPS is currently undertaking a comprehensive two-phased study to determine baseline water quality and physical hydrology conditions of water resources along the proposed route
Application of calcium chloride on Park Road for dust suppression	• Additional studies to determine long-term effects of calcium chloride application
Introduction and spread of exotic species	• Monitor spread of white sweetclover (*Melilotus alba*)
Water quality and quantity impacts from CBM development in Healy	• Collect baseline water quality and physical hydrology data on water resources at DENA potentially affected by CBM production
Alaska's gas license and lease procedure involving CBM development in Healy	• Identify areas of high risk from CBM impacts in the park and determine ways to avoid and mitigate these impacts
Status of abandoned mine wastes and NPS reclamation efforts	• Continue comprehensive planning and restoration of former mining claims acquired by DENA
Subsistence OHV use impacts on water resources	• Identify OHV routes and usage and monitor to determine extent of OHV use and need for route mitigation or rehabilitation efforts
Impacts of sport fishing on fish populations	• Determine extent of sport fishing in DENA and monitor fish populations prone to overharvest
Status of navigable water determinations	• Investigate, review, and assess navigability on upcoming State applications for RDI on the Kantishna, Muddy, McKinley, Tokositna, Teklanika, and Nenana Rivers.

Table 6-1. Baseline I&M Needed By Issue	
Issue	**Baseline I&M Needed**
Potential navigability determination impacts on DENA's water resources	• Collect channel and drainage basin characteristics and stream discharge data; create interagency database of navigability-related information; and develop GIS coverage to map the navigability status of waterbodies on DOI lands
Potential for water rights conflicts as a result of increased water demand and in-stream uses	• Install stream gages and collect 5 years of flow data in support of NPS application for water rights • Collect biological, recreational, or water quality data to justify need for in-stream flow water rights
Climate change impacts on permafrost, shallow lakes, glaciers, ice formation and breakup, and soil biogeochemistry	• Monitor permafrost degradation in DENA • Inventory shallow lakes in DENA using CAKN's developing strategy • Monitor shallow lakes using 2004 CAKN shallow lake limnology monitoring protocol • Continue DENA's long-term glacier monitoring program • Monitor trends in seasonality of ice formation and breakup and alteration of seasonal stream flows • Research soil responses to change in climate and hydrology
Arsenic in downtown Kantishna drinking water	• Monitor drinking water wells for arsenic and determine scope of problem
Moderate Priority Issues	
Effects of transportation infrastructure on fisheries and aquatic resources	• Conduct roads inventory in DENA • Conduct studies on road-related impacts on freshwater fisheries such as increased sedimentation, stream bed disturbances, floodplain alteration, and obstructed fish passage. Focus on Park Road and old mining roads.
Hydrologic impacts of gravel extraction and processing	• Continue to monitor movement of bed load material in Toklat River to determine replenishment rate of gravel and sustainability of gravel extraction volumes
Impacts of past mining on fisheries and aquatic resources	• Monitor stream sediments and fish tissues for concentrations of SOCs, organochlorines, and heavy metals
Water quality impacts of past mining in Dunkle Hills	• Monitor SOCs and heavy metals concentrations in Dunkle Hills streams (Costello and Colorado Creeks)
Impacts of snowmobile use on water resources	• Continue to monitor snowmobile activity patterns and produce maps identifying areas of use. • Monitor impacts of adoption of snowmobile standards and goals set forth in Backcountry Management Plan
Impacts of water-related recreational use on water resources	• NPS proposed study to sample and analyze water quality and other parameters at Wonder Lake between FY 2005 and 2007 to determine effects of current and projected campground use on the lake • Determine extent of jet boat use and adverse impacts to water resources
Low Priority Issues	
Solid and hazardous waste disposal and management	• Continue cleanup of old contaminated sites where fuel spills have occurred • Complete inventory and reclamation of hazardous waste materials associated with old mines in Kantishna Hills

Table 6-1. Baseline I&M Needed By Issue	
Issue	**Baseline I&M Needed**
Hydrologic and water quality impacts of park road system	• Conduct evaluation of road system and monitor problem areas
Impacts of aircraft landing sites	• Complete recent inventory of aircraft landing sites for North Side of park
Glacial surge and glacial lake outburst floods	• Continue monitoring of glacier conditions • Establish stream flow gauging stations below stream emanating glaciers and develop a predictive capacity for surge and outburst flood events
Flood hazards to infrastructure, property, and visitor safety	• Establish stream flow gauging stations on glacial and non-glacial rivers where flooding and stream bank erosion is a concern
Mass movement hazards	• Evaluate slope stability or landslide risk potential in DENA
Hydrologic impacts of past placer mining	• Continue mine reclamation efforts
Water quality impacts of past mining in Kantishna Hills	• Continue to monitor the concentrations of heavy metals in Kantishna Hills streams
Subsistence fishing impacts on fish populations	• Continue to monitor and restore chum salmon fishery in Toklat and Kantishna Rivers
Impacts of litter and human waste on water resources	• Continue Leave No Trace Program and enforcement • Monitor *Giardia lamblia* in areas of high risk to park users
Impacts of trail use and construction on water resources	• Continue trail monitoring program

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As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.