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U.S. Department of the Interior

Water Resources Division
Natural Resource Program Center

Voyageurs National Park
Minnesota

Water Resources Management Plan

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 Management Plan

Voyageurs National Park

April 2005

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Table of Contents

List of Figures

List of Tables

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Boaters traveling through King Williams Narrows (top). Sunset over a marsh (bottom).

Special Note to Reader

Enclosed with this WRMP is a copy (hard copy report or CD) of the U.S. Geological Survey report, Aquatic Synthesis for Voyageurs National Park (Kallemeyn et al., 2003). This document presents over 20 years of collective information, gathered by Kallemeyn and others, regarding aquatic resources in the park. Much of the analysis in this WRMP is based on the findings presented in the U.S. Geological Survey report. The two documents were developed in a parallel process by design and so, are presented together. The synthesis is invaluable reference material to the WRMP and both should be read as complementary reports.

Voyageurs National Park's Water Resources Management Plan and NEPA

The National Environmental Policy Act (NEPA) mandates that federal agencies prepare a study of the impacts of major federal actions having a significant effect on the human environment and alternatives to those actions. The adoption of formal plans may be considered a major federal action requiring NEPA analysis if such plans contain decisions affecting resource use, examine options, commit resources or preclude future choices. Lacking these elements, VOYA's Water Resources Management Plan (WRMP) has no measurable impacts on the human environment and is categorically excluded from further NEPA analysis.

According to Director's Order (DO) #12 Handbook (section 3.4), water resources management plans normally will be covered by one or more of the following Categorical Exclusions:

- 3.4.B (1) Changes or amendments to an approved plan when such changes have no potential for environmental impact.
- 3.4.B (4) Plans, including priorities, justifications, and strategies, for non-manipulative research, monitoring, inventorying, and information gathering.
- 3.4.B (7) Adoption or approval of academic or research surveys, studies, reports and similar documents that do not contain and will not result in NPS recommendations.
- 3.4.E (2) Restoration of non-controversial native species into suitable habitats within their historic range.
- 3.4.E (4) Removal of non-historic materials and structures in order to restore natural conditions when the removal has no potential for environmental impacts, including impacts to cultural landscapes or archeological resources.
- 3.4.E (6) Non-destructive data collection, inventory, study, research, and monitoring activities.
- 3.4.E (7) Designation of environmental study areas and research natural areas, including those closed temporarily or permanently to the public, unless the potential for environmental (including socioeconomic) impact exists.

These Categorical Exclusions require that formal records be completed (Section 3.2, D0-12 Handbook) and placed in park files.

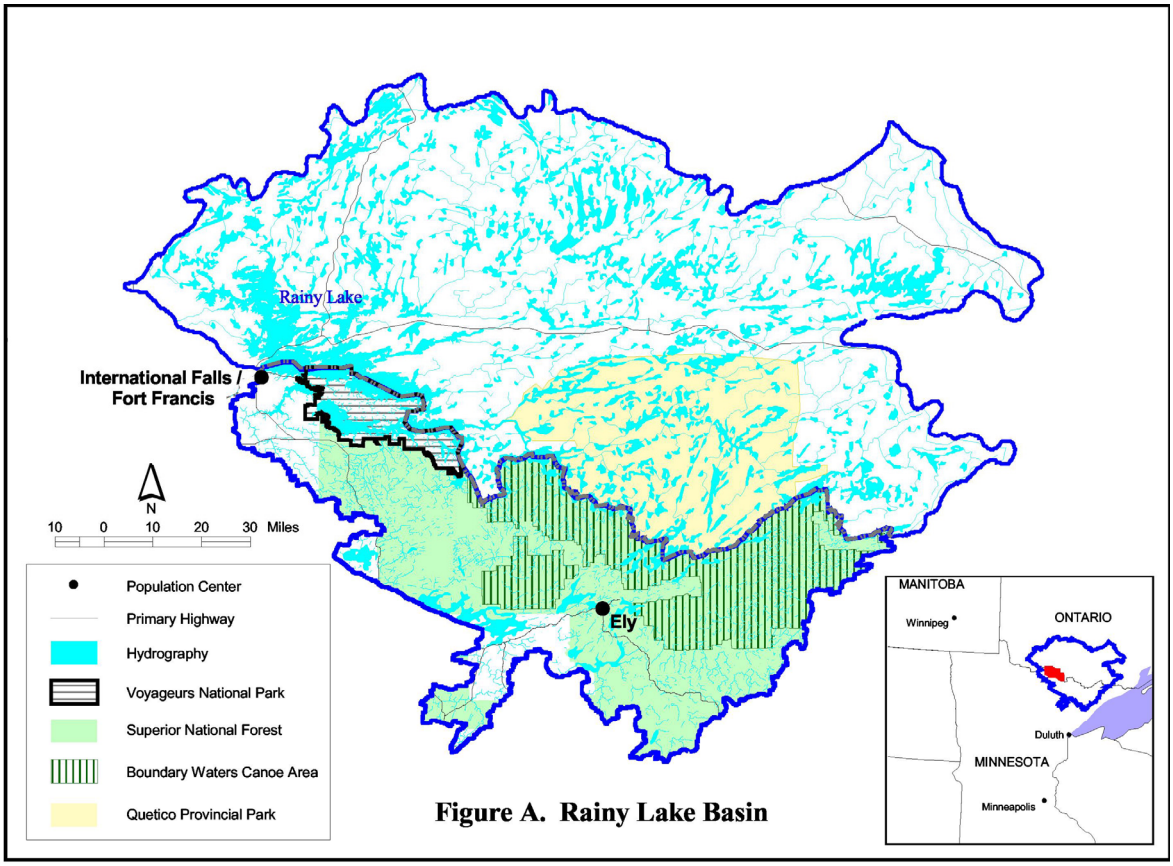


Figure A. Rainy Lake Basin

INTRODUCTION

BACKGROUND

Voyageurs National Park (Voyageurs) was established in 1975 and is in a hydrologically complex environment. Located along the Minnesota-Ontario border, Voyageurs is part of a 10,930 km^2 (4,219 mi^2) ecosystem, which includes the 4,856 km^2 (1,875 mi^2) Boundary Waters Canoe Area Wilderness and the 4,452 km^2 (1,719 mi^2) Quetico Provincial Park (Figures A and B). South of the park, national forest lands are largely checkered with state, Boise Paper Company and private lands. Boise Paper Company manages its lands primarily for pulpwood production. Private landowners manage their property for pulpwood production, agriculture (grains and cattle), residential use, or recreational activities (National Park Service 1994).

Voyageurs lies within the lower end of the 38,600 km^2 (14,900 mi^2) Rainy Lake drainage, which is part of the headwaters of the Hudson Bay watershed. The Rainy Lake basin contains a complex network of lakes, ponds and connecting rivers and streams (Figure A). Approximately 70% of the basin lies in Ontario with the remaining 30% in Minnesota. 38% of Voyageurs is covered by water with four major lakes (Kabetogama, Namakan, Rainy and Sand Point) comprising 96% of the park's total lake area (Kallemeyn et al.1993). The park's 26 interior lakes have a combined surface area of 1,278 ha (3,158 acre). Visitor use of the park is clearly water-oriented with paddling, boating, fishing, swimming, snowmobiling and cross-country skiing the primary visitor activities.

Lake levels in the park's four largest lakes are controlled by a dam crossing the Rainy Lake outlet at the international border between Fort Frances, Ontario and International Falls, Minnesota, as well as by small dams at Kettle Falls and Squirrel Falls on Namakan Lake. The Namakan Reservoir consists of Kabetogama, Namakan, Sand Point, and Crane, and Little Vermilion lakes. Originally, natural rock sills at the Kettle Falls and Squirrel Falls outlets of Namakan Lake controlled water levels for Namakan Reservoir. The lake levels have been artificially controlled for nearly 100 years. In 2000, a new rule curve for the Rainy and Namakan Reservoirs was put in place to approximate more natural water levels and fluctuations. Water management is and has been a very important issue in Voyageurs. There have been many contentious debates over water issues in the park. This can be attributed to: a large part of the park being covered by water; the park sharing a common boundary with Canada; surface water elevations being strictly regulated for anthropogenic needs (until recently); intense visitor use; and economic importance of the waters in the region (Weeks and Andrascik 1998).

Results of previous water quality studies indicate the park's waters are generally of high quality (Payne 1991, 2000). Although water quality is considered to be good, there are widespread and localized threats affecting the quality and quantity of park waters. There have been local instances of erosion, septic drainage and water contamination and widespread addition of petroleum byproducts and lead to park waters from snowmobiles and powerboats. Also, unnatural water level regimes have been shown to have significant

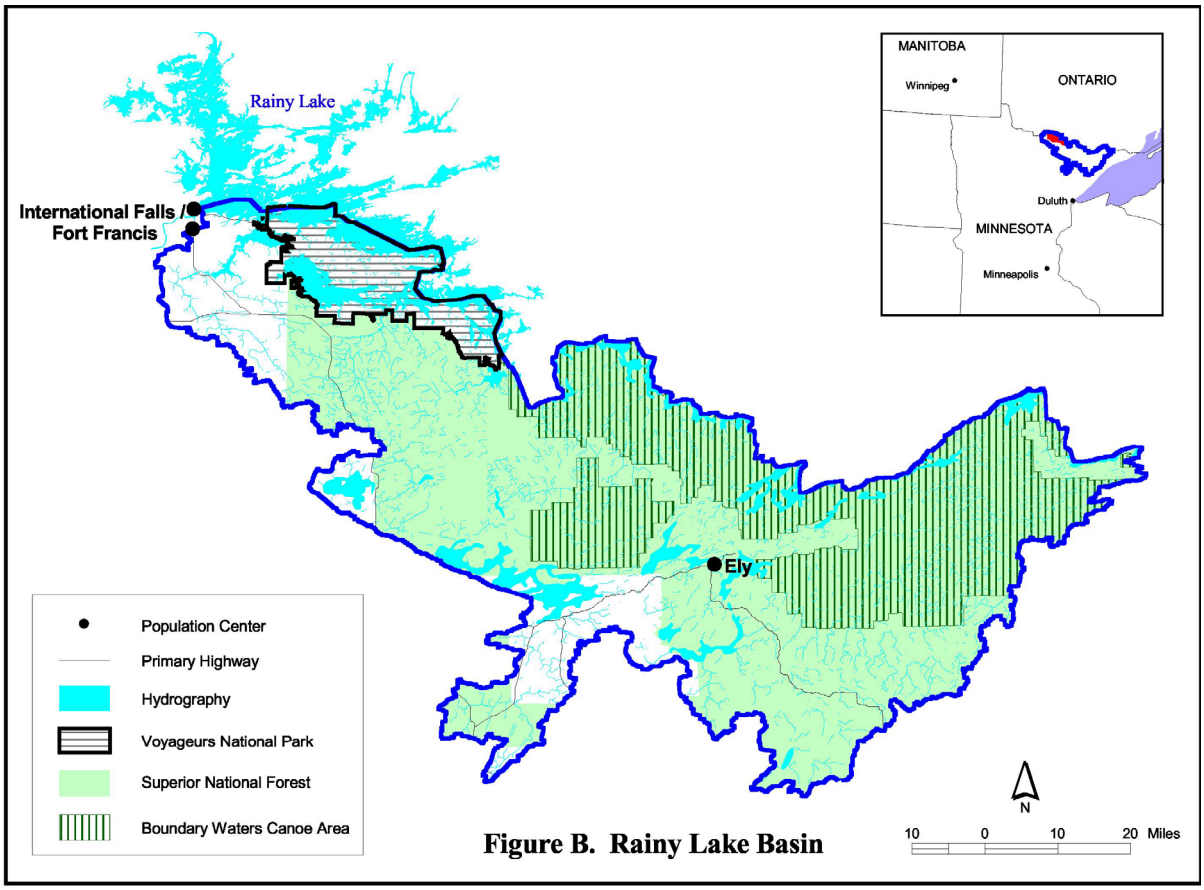


Figure B. Rainy Lake Basin

negative effects on the aquatic ecology of Voyageurs (see "Additional Analyses" section and Kallemeyn et al., 1993).

MANAGEMENT GOALS OF VOYAGEURS NATIONAL PARK

The objectives and goals of Voyageurs National Park for management of its water resources are listed below. These guide the issues addressed and actions recommended by this Water Resources Management Plan (WRMP).

Maintain or improve water quality through management actions, cooperation with adjoining land managers, partnerships, education and outreach programs

- Ensure water quality meets or exceeds standards for Outstanding State Resource Value Waters
- Participate in outreach and education forums to improve public understanding of water quality issues
- Cooperate with adjoining land managers, governments, and stakeholders for the maintenance or improvement of water quality
- Manage park operations to ensure water quality is not degraded
- Manage park waters to preserve scenic and experiential quality
- Engage the regulatory system to protect water quality from degradation

Manage aquatic habitats to maintain the highest level of ecological integrity within the confines of the park's authorizing legislation and the limits of managed lake levels

- Cooperate with governing bodies to ensure managed lake levels approximate a natural hydrologic regime
- Preserve or restore the function and structure of wetlands
- Protect native species from displacement by exotics
- Protect water clarity and limit nutrient loading by reducing erosion and sedimentation

Acquire sufficient information and understanding to support management decisions that protect water resources and aquatic systems from degradation

- Acquire baseline water chemistry information
- Acquire baseline aquatic communities information
- Monitor water quality and aquatic systems in relation to managed lake levels
- Understand contaminant bioaccumulation in aquatic organisms
- Understand the ecological effects of managed lake levels
- Understand the systemic relationship between wetlands, shoreline geomorphology and bathymetry

Shoreline at Voyageurs National Park, featuring exposed bedrock and White Pine (top). Red-necked Grebe nesting on Kabetogama Lake (bottom).

Purpose of the Plan

Thirty-eight percent of Voyageurs National Park is covered in water; the lakes, riparian zones, adjacent wetlands, and back channels are some of the primary resources of the park. Regulated lake levels, a common boundary with Canada, and intense water recreation make the management of Voyageurs water resources complex. Local and widespread threats could compromise Voyageurs' water quality, which could have broad impacts on the natural ecosystem and on the economic vitality of the region. A water resources management plan (WRMP) is needed to better understand the water and water-dependent resources of the park and to identify methods to protect those resources. The WRMP will supplement the park's Resource Management Plan with much greater detail specific to water related issues.

The WRMP provides an opportunity to synthesize all available information concerning the park's water resources, to identify gaps in information, and to develop project statements to work toward eliminating those gaps. The project statements become the vehicle through which funding is secured from special funding sources. Stakeholders are encouraged to participate before, during and after the development of WRMP. Many of the issues detailed in the project statements involve areas beyond park boundaries. Thus, multi-agency and international coordination is necessary for this plan to succeed.

Plan Development

The National Park Service (NPS) entered into a cooperative agreement with researchers from the University of Minnesota to develop this Plan. The general approach taken to develop the Plan was the following: send out 126 Water Resource Management Issues surveys (Appendix A) to the park community (government natural resource agencies, local businesses, non-government organizations, educators); present and use survey results to develop a top priority issues list at a scoping workshop with Voyageurs National Park stakeholders (agency managers, non-government organizations, and researchers); take the next 12 months to gather existing data and perform analyses; and use the remaining time to write and finalize the Plan including project statements to address top water resource issues, data gaps and mitigation strategies.

The results of the first workshop are discussed in detail later in the plan under "Water Resources Issues".

LEGISLATIVE AND REGULATORY RELATIONSHIPS

Federal Acts specific to the establishment of Voyageurs National Park

Voyageurs National Park was authorized in 1971 by Public Law 91-661 and established in 1975. As a unit of the National Park System, park management is committed to conserving the scenery and natural resources for the enjoyment of future generations (1916 NPS Organic Act).

> An Act to authorize the establishment of the Voyageurs National Park in the State of Minnesota, and for other purposes. (84 Stat. 1971)
> Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the purpose of this Act is to preserve, for the inspiration and enjoyment of present and future generations, the outstanding scenery, geological conditions and waterway system which constituted a part of the historic route of the Voyageurs who contributed significantly to the opening of the Northwestern United States.
>
> ESTABLISHMENT
>
> Sec. 101. In furtherance of the purpose of this Act, the Secretary of the Interior (hereinafter referred to as the "Secretary") is authorized to establish the Voyageurs National Park (hereinafter referred to as the "park") in the State of Minnesota, by publication of notice to that effect in the Federal Register at such time as the Secretary deems sufficient interests in lands or waters have been acquired for administration in accordance with the purposes of this Act: Provided, That the Secretary shall not establish the park until the lands owned by the State of Minnesota and any of its political subdivisions within the boundaries shall have been donated to the Secretary for the purposes of the park: Provided further, That the Secretary shall not acquire other lands by purchase for the park prior to such donation unless he finds that acquisition is necessary to prevent irreparable changes in their uses or character of such a nature as to make them unsuitable for park purposes and notifies the Committees on Interior and Insular Affairs of both the Senate and the House of Representatives of such findings at least thirty days prior to such acquisition.
>
> Sec. 102. The park shall include the lands and waters within the boundaries as generally depicted on the drawing entitled "A Proposed Voyageurs National Park, Minnesota," numbered LNPMW-VOYA-1001, dated February 1969, which shall be on file and available for public inspection in the offices of the National Park Service, Department of the Interior. Within one year after acquisition of the lands owned by the State of Minnesota and its political subdivisions within the boundaries of the park the Secretary shall affix to such drawing an exact legal description of said boundaries. The Secretary may revise the boundaries of the park from time to time by publishing in the Federal Register a revised drawing or other boundary description, but such revisions shall not increase the land acreage within the park by more than one thousand acres.

Interpretation staff leading park visitors on a North Canoe trip at Voyageurs National Park.

LAND ACQUISITION

Sec. 201. (a) The Secretary may acquire lands or interests therein within the boundaries of the park by donation, purchase with donated or appropriated funds, or exchange. When any tract of land is only partly within such boundaries, the Secretary may acquire all or any portion of the land outside of such boundaries in order to minimize the payment of severance costs. Land so acquired outside of the park boundaries may be exchanged by the Secretary for non-Federal lands within the park boundaries. Any portion of land acquired outside the park boundaries and not utilized for exchange shall be reported to the General Services Administration for disposal under the Federal Property and Administrative Services Act of 1949 (63 Stat. 377), as amended. Any Federal property located within the boundaries of the park may be transferred without consideration to the administrative jurisdiction of the Secretary for the purposes of the park. Lands within the boundaries of the park owned by the State of Minnesota, or any political subdivision thereof, may be acquired only by donation.

(b) In exercising his authority to acquire property under this section, the Secretary shall give immediate and careful consideration to any offer made by any individual owning property within the park area to sell such property to the Secretary. In considering such offer, the Secretary shall take into consideration any hardship to the owner which might result from any undue delay in acquiring his property.

Sec. 202. (a) Any owner or owners (hereinafter referred to as "owner") of improved property on the date of its acquisition by the Secretary may, if the Secretary determines that such improved property is not, at the time of its acquisition, required for the proper administration of the park, as a condition of such acquisition, retain for themselves and their successors or assigns a right of use and occupancy of the improved property for noncommercial residential purposes for a definite term not to exceed twenty-five years, or, in lieu thereof, for a term ending at the death of the owner, or the death of his spouse, whichever is later. The owner shall elect the term to be retained. The Secretary shall pay to the owner the fair market value of the property on the date of such acquisition less the fair market value on such date of the right retained by the owner.

(b) If the State of Minnesota donates to the United States any lands within the boundaries of the park subject to an outstanding lease on which the lessee began construction of a noncommercial or recreational residential dwelling prior to January 1, 1969, the Secretary may grant to such lessee a right of use and occupancy for such period of time as the Secretary, in his discretion, shall determine; Provided, That no such right of use and occupancy shall be granted, extended, or continue after ten years from the date of the establishment of the park.

(c) Any right of use and occupancy retained or granted pursuant to this section shall be subject to termination by the Secretary upon his determination that such use and occupancy is being exercised in a manner not consistent with the purposes of this Act, or upon his determination that the property is required for the proper administration of the park. The Secretary shall tender to the holder of the

right so terminated an amount equal to the fair market value of that portion which remains unexpired on the date of termination.

(d) The term "improved property", as used in this section, shall mean a detached, noncommercial residential dwelling, the construction of which was begun before January 1, 1969, together with so much of the land on which the dwelling is situated, the said land being in the same ownership as the dwelling, as the Secretary shall designate to be reasonably necessary for the enjoyment of the dwelling for the sole purpose of noncommercial residential use, together with any structures accessory to the dwelling which are situated on the land so designated.

Sec. 203. Notwithstanding any other provision of the law, the Secretary is authorized to negotiate and enter into concession contracts with former owners of commercial, recreational, resort, or similar properties located within the park boundaries for the provision of such services at their former location as he may deem necessary for the accommodation of visitors.

Sec. 204. The Secretary is authorized to pay a differential in value, as hereinafter set forth, to any owner of commercial timberlands within the park with whom the State of Minnesota has negotiated, for the purpose of conveyance to the United States, an exchange of lands for State lands outside the Park. Payment hereunder may be made when an exchange is based upon valuations for timber purposes only, and shall be the difference between the value of such lands for timber purposes, as agreeable to the State, the Secretary, and any owner, and the higher value, if any, of such lands for recreational purposes not attributable to establishment or authorization of the park: Provided, That any payment shall be made only at such time as fee title of lands so acquired within the boundaries is conveyed to the United States.

ADMINISTRATION

Sec. 301. (a) Except as hereinafter provided, the Secretary shall administer the lands acquired for the park, and after establishment shall administer the park, in accordance with the provisions of the Act of August 25, 1916 (39 Stat. 535) as amended and supplemented (16 U.S.C. 1-4).

(b) Within four years from the date of establishment, the Secretary of the Interior shall review the area within the Voyageurs National Park and shall report to the President, in accordance with subsections 3(c) and 3(d) of the Wilderness Act (78 Stat. 890; 16 U.S.C. 1132 (c) and (d)), his recommendation as to the suitability or nonsuitability of any area within the lakeshore for preservation as wilderness, and any designation of any such area as a wilderness may be accomplished in accordance with said subsections of the Wilderness Act.

(c) All mining and mineral activities and commercial water power development within the boundaries of the park shall be prohibited, and further, any conveyance from the State of Minnesota shall contain a covenant that the State of Minnesota, its licensees, permittees, lessees, assigns, or successors in interest shall not engage in or permit any mining activity nor water power development.

Sec. 302. (a) The Secretary shall permit recreational fishing on lands and waters under his jurisdiction within the boundaries of the park in accordance with applicable laws of the United States and of the State of Minnesota, except that the

Secretary may designate zones where and establish periods when no fishing shall be permitted for reasons of public safety, administration, fish and wildlife management, or public use and enjoyment. Except in emergencies, any regulations of the Secretary pursuant to this section shall be put into effect only after consultation with the appropriate agency of the State of Minnesota.

(b) The seining of fish at Shoepack Lake by the State of Minnesota to secure eggs for propagation purposes shall be continued in accordance with plans mutually acceptable to the State and the Secretary.

Sec. 303. The Secretary may, when planning for development of the park, include appropriate provisions for (1) winter sports, including the use of snowmobiles, (2) use by seaplanes, and (3) recreational use by all types of watercraft, including houseboats, runabouts, canoes, sailboats, fishing boats and cabin cruisers.

Sec. 304. Nothing in this Act shall be construed to affect the provisions of any treaty now or hereafter in force between the United States and Great Britain relating to Canada or between the United States and Canada, or of any order or agreement made or entered into pursuant to any such treaty, which by its terms would be applicable to the lands and waters which may be acquired by the Secretary hereunder, including, without limitation on the generality of the foregoing, the Convention Between the United States and Canada on Emergency Regulation of the Level of Rainy and of Other Boundary Waters in the Rainy Lake Watershed, signed September 15, 1938, and any order issued pursuant thereto.

Sec. 305. The Secretary is authorized to make provision for such roads within the park as are, or will be, necessary to assure access from present and future State roads to public facilities within the park.

Federal Acts, Regulations and Policies specific to administration of National Park Units

There are several laws that constitute the primary authorities for administration of the National Park System.

National Park Service Organic Act (1916)

In 1916 Congress created the National Park Service in the Department of the Interior to:

"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 said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." (NPS organic act, 16 USC 1)

The basis for park management policies was specifically addressed for the first time by Secretary of the Interior Franklin K. Lane in a letter to the first director of the National Park Service, Stephen T. Mather, on May 13, 1918. Secretary Lane stated that administrative policy should be based on three broad principles:

"First, that the national parks must be maintained in absolutely unimpaired form for the use of future generations as well as those of our own time; second, that they are set apart for the use, observation, health, and pleasure of the people; and third, that the national interest must dictate all decisions affecting public or private enterprise in the parks."

General Authorities Act (1970)

The General Authorities Act of 1970 defines the national park system as including "any area of land and water now or hereafter administered by the Secretary of the Interior through the National Park Service for park, monument, historic, parkway, recreational, or other purposes" (16 USC lc(a)). It states that "each area within the national park system shall be administered in accordance with the provisions of any statute made specifically applicable to that area" (16 USC lc(b)) and in addition with the various authorities relating generally to NPS areas, providing the general legislation does not conflict with specific provisions.

Redwood National Park Act (1978)

In a 1978 act expanding Redwood National Park, NPS general authorities were further amended to add:

"The authorization of activities shall be construed and the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress." (16 USC la-l)

National Park Service Management Policies and Guidelines

The National Park Service Management Policies (2001) give broad policy guidance for the management of National Park System Units. Some of the topics included are: park planning, land protection, natural and cultural resource management, wilderness preservation and management, interpretation and education, special uses of the parks, park facilities design, and concessions management. Recommended procedures for the implementation of service-wide policy are described in the NPS Director's Orders series. Orders most directly related to actions affecting water resources include: 1) Order 2, for the Planning process, 2) Order 12, Environmental Impact Analysis, 3) Order 77, Natural Resource Protection (being developed, NPS-75, for Natural Resources Inventory and Monitoring and NPS-77, for Natural Resource Management still apply until it is finished), 5) Order 77-1, Wetlands protection and 6) Order 83, for Public Health Management.

Federal Acts relevant to federal land management

Clean Water Act

The Federal Water Pollution Control Act, more commonly known as the Clean Water Act, was first promulgated in 1972 and amended in 1977, 1987, and 1990. This law was designed to restore and maintain the integrity of the nation's water. Goals set by the act were swimmable and fishable waters by 1983 and no further discharge of pollutants into the nation's waterways by 1985. The two strategies for achieving these goals were a major grant program to assist in the construction of municipal sewage treatment facilities and a program of "effluent limitations" designed to limit the amount of pollutants that could be discharged.

As part of the act, Congress recognized the primary role of the states in managing and regulating the nation's water quality within the general framework developed by Congress. All federal agencies must comply with the requirements of state law for water quality management, regardless of other jurisdictional status or land ownership (section 313). States implement the protection of water quality under the authority granted by the Clean Water Act through best management practices and through water quality standards. Best management practices are defined by the U.S. Environmental Protection Agency (EPA) as methods, measures, or practices selected by an agency to meet its nonpoint control needs. These practices include but are not limited to structural and non-structural controls, operational procedures, and maintenance procedures. They can be applied before, during, and after pollution-producing activities to reduce or eliminate the introduction of pollutants into receiving waters (Code of Federal Regulations 1990). Water quality standards are composed of the designated use or uses made of a water body or segment, water quality criteria necessary to protect those uses, and an anti-degradation provision to protect the existing water quality.

Section 404 of the Clean Water Act further requires that a permit be issued for discharge of dredged or fill materials in waters of the United States including wetlands. The Army Corps of Engineers administers the Section 404 permit program with oversight and veto powers held by the EPA.

The Clean Water Act and regulations are generally implemented by the states with the EPA serving in an oversight role. A triennial review of a state's water quality regulatory program is conducted by each state's water quality agency to determine if its standards are adequate to meet federal requirements. These standards are then forwarded to the EPA for approval.

Executive Order* 11988: *Floodplain Management (1977)

The objective of this executive order is, "…to avoid to the extent possible the long- and short-term adverse impacts associated with occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative." For non-repetitive actions, the E.O. 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* 11990: *Wetlands Protection (1977)

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 alternatives to such construction and the proposed action includes all practicable measure to minimize harm to wetlands.

Endangered Species Act (1973)

This act provides for the conservation, protection, restoration, and propagation of biota including selected species of native fish, wildlife, and plants that are threatened with extinction. All federal agencies must consult with the Secretary of the Interior on activities that potentially affect endangered flora and fauna.

Section 7 outlines procedures for interagency cooperation to conserve federally listed species, species proposed for listing and for designated critical habitat and proposed critical habitat. Section 7(a)(1) requires federal agencies to use their authorities to further the conservation of listed species and section 7(a)(2) prohibits federal agencies from undertaking, funding, permitting or otherwise authorizing actions that are likely to jeopardize the continued existence of listed species or that would destroy or adversely modify critical habitat.

Water Quality Improvement Act (1970)

This act requires federally regulated activities to have state certification that they will not violate water quality standards.

Safe Drinking Water Act (1974) and Amendments (1986)

This act sets national minimum water quality standards and requires regular testing of drinking water for developed public drinking water supplies.

National Environmental Policy Act (1969)

This law requires a systematic analysis of federal actions with the potential to affect the human and natural environments. The analysis includes a consideration of reasonable alternatives and an analysis of short- and long-term irretrievable, irreversible, and unavoidable impacts. If a federal action may result in major impacts, an environmental impact statement is prepared. The EIS ensures evaluation of the impacts of proposed projects and facilitates public review.

Regulations implementing NEPA require consultation with other federal agencies and encourage the reduction of duplication through cooperation with state and local agencies including early efforts of joint planning, hearings and environmental assessments.

The narrows separating War Club and Locator Lakes on the Kabetogama Peninsula (top). Muskrats are common at Voyageurs National Park (bottom).

State water quality regulations relevant to Voyageurs National Park

The State of Minnesota (MPCA Ch. 7050.0180) has designated the waters of Voyageurs as "Outstanding Resource Value Waters" (ORVWs). ORVWs are waters whose characteristics (high quality, wilderness characterization, cultural significance, recreational and scientific value) warrant stringent protection from pollution. These regulations prohibit new or expanded discharge of any sewage, industrial waste, or other waste from point or nonpoint sources to Voyageurs' waters**.**

Water Rights

Minnesota administers water rights under the Riparian Doctrine (Waters and Water Rights, 1991 Volume 6). Riparian rights refer to legal rights the owner of the bank of a stream or lake has in regard to use of that water. These uses include access to the water, to build a wharf or pier, to use the water without transforming it, to consume the water, to acquire accretions (accretions are the gradual enlargement of land by fluvial processes such as the accumulation of sediment on a floodplain by stream action or the deposition of sand on a beach), and to own the bed of non-navigable streams and other private waters. In Minnesota, water is considered public water and administered by the State if it is considered navigable. The basis and limit of water use is governed by the reasonable use doctrine in Minnesota. Under this doctrine, each riparian owner is allowed to use a waterbody regardless of the effect on natural flows as long as each user does not adversely affect the equal right of another riparian owner to use the water (Waters and Water Rights, 1991 Volume 1). Permits are a method used by States to control the amount of water use and to vest the right of a user to continue that use (Sherk 1990). In Minnesota, a State permit is required for any consumptive use of more than 10,000 gallons per day or 1,000,000 gallons per year for surface or ground water (Waters and Water Rights, 1991 Volume 6). The surface water permits can be revoked if the diversion is harmful to other riparian water users (Sherk 1990). Minnesota acknowledges instream flow rights for such uses as fishing, navigation, and swimming.

In addition to riparian rights, the United States may have rights based upon Federal law to the minimum amount of water necessary to achieve the purposes for which Voyageurs National Park was created. A significant portion of the land comprising the park was never out of Federal ownership and these lands contain many lakes and streams. The Office of the Solicitor should be consulted to determine if federally reserved water rights apply to the park.

Water rights for Voyageurs are complicated by the fact that the park is located along an international boundary; approximately 78% of the 14,900 mi^2 Rainy Lake basin is located in Canada. Seventy-five percent of Rainy Lake (248 mi^2) and twenty-three percent of Namakan Reservoir (23 mi^2) are located in Canada. Since the early 1900s, Voyageurs' lake levels have been controlled by a dam crossing the Rainy Lake outlet at the international border between Fort Frances, Ontario and International Falls, Minnesota, as well as by small dams at Kettle Falls and Squirrel Falls on Namakan Lake. While these dams are privately owned, they are regulated by both the United States and Canada through the International Joint Commission (IJC). In 1949, the IJC issued its first Order for Rainy and Namakan Reservoirs and has

since added Supplementary Orders in 1957 and 1970. Because the dams resulted in larger-than-natural fluctuations on Namakan Reservoir and less-than-natural fluctuations on Rainy Lake, the National Park Service and others raised concerns regarding aquatic biota effects. Subsequent studies pointed to water regulations on Namakan Reservoir in particular as adversely affecting the ecosystem. On January 6, 2000 the IJC issued a supplementary order to adopt new rule curves for the lake levels, so as to more closely approximate natural levels. A more detailed discussion on lake level regulation, studies and effects can be found in the "Regulated Lake Levels" section of the Aquatic Synthesis for Voyageurs National Park (Kallemeyn et al. 2003).

LAND STATUS, USES AND PLANNING RELATIONSHIPS

Land status and use

This Water Resources Management Plan covers the federally administered lands of Voyageurs National Park. Located approximately 12 miles east of International Falls, Minnesota and sharing its northern boundary with Ontario, Voyageurs includes 655 miles of undeveloped shoreline and over 1000 islands. The park encompasses 218,054 acres, of which approximately 134,000 acres are forested woodlands and 84,000 acres are water. Over 90% of Voyageurs' lands are managed as proposed wilderness. There are 1,179 acres of privately owned land within Voyageurs.

The park is less than a mile from the boundary of the 1.2-million-acre Boundary Waters Canoe Area Wilderness (BWCAW) and approximately 10 miles from the boundary of the 1.1-million-acre Quetico Provincial Park. South of the park lie national forests, bounded by state, St. Louis and Koochiching County and Boise Paper Company lands and other private ownership. Land use outside the park is primarily pulpwood production south and west of the park, agriculture (i.e., grains and cattle), and recreation (U.S. National Park Service 1994) (Figure C). Minneapolis, Minnesota is approximately 300 miles south of the park.

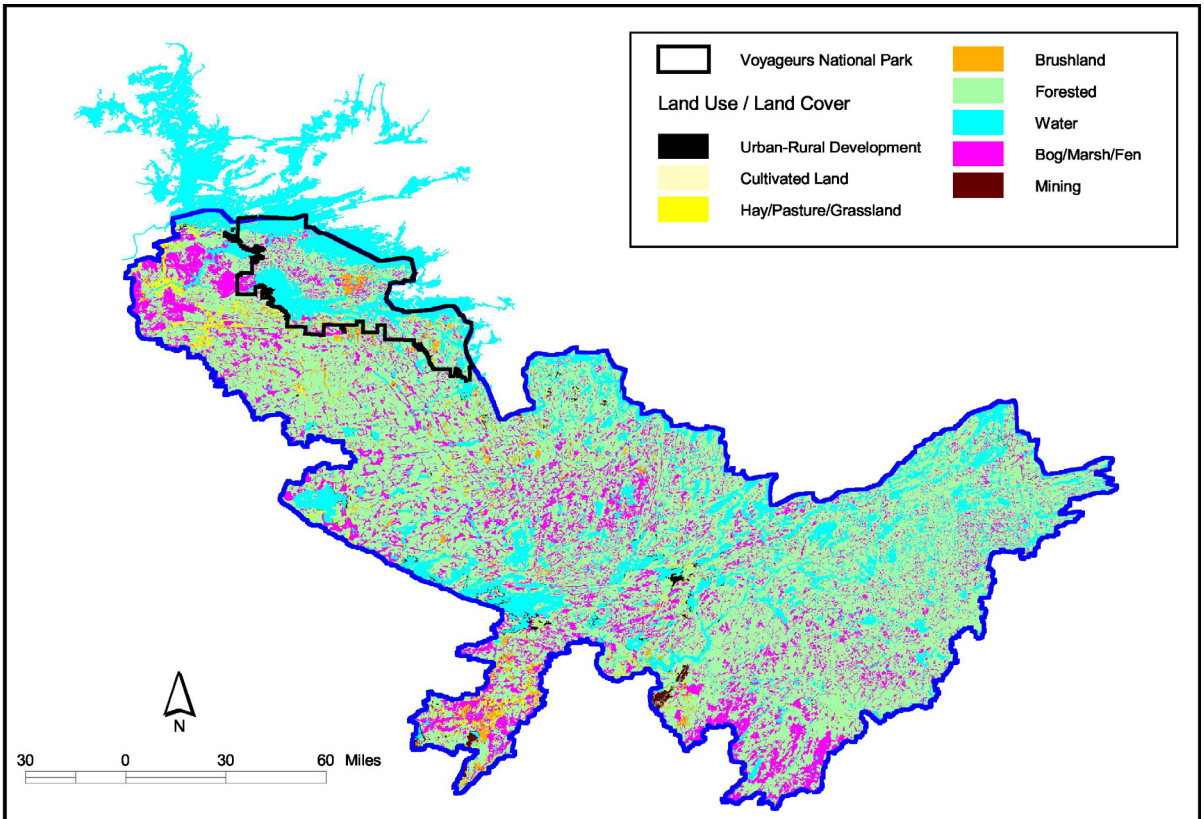


Figure C. Land Use / Land Cover of the Rainy Lake basin

Management Areas

The following section describes six different land and water management areas for the park. These areas differ from one another with respect to uses, facilities and degree of solitude offered. Note that motorized uses include motorboats, electric motors, fixed-wing aircraft, houseboats, and snowmobiles. Nonmotorized uses include canoeing, kayaking, paddleboating, rowboating, sailboating, skiing, snowshoeing, and hiking.

Land Management Areas

***Developed Area*:** Developed areas include visitor facilities (such as visitor centers, contact stations, or group campgrounds) and park operation facilities (such as administrative offices, maintenance facilities, or employee housing). Existing developed areas include the Rainy Lake, Kabetogama Lake and Ash River Visitor Centers and access roads, and the Kettle Falls Developed Area.

***Lakecountry Area*:** This area includes the shoreline and islands of the four major lakes, Rainy, Kabetogama, Namakan, Sand Point, that are within the park as well as the north shore of Crane Lake.

***Backcountry Trail Area*:** This area includes hiking, cross-country skiing, and snowshoe trail corridors, where visitors can enjoy the park's natural environment.

***Primitive Area*:** This area consists of the backcountry lands away from existing trails. Visitors can expect a "wild" experience, with few facilities. Most of the land of Voyageurs fits into this category.

Water Management Areas

***Integrated Use Area*:** This area includes the four major lakes, the special use zone on Kabetogama Lake, the Chain of Lakes on the Kabetogama Peninsula, and other interior lakes currently open to motorized uses.

***Nonmotorized Use Area*:** This management area includes interior lakes surrounded by primitive areas or proposed wilderness where motorized use is not appropriate.

Other Planning Efforts

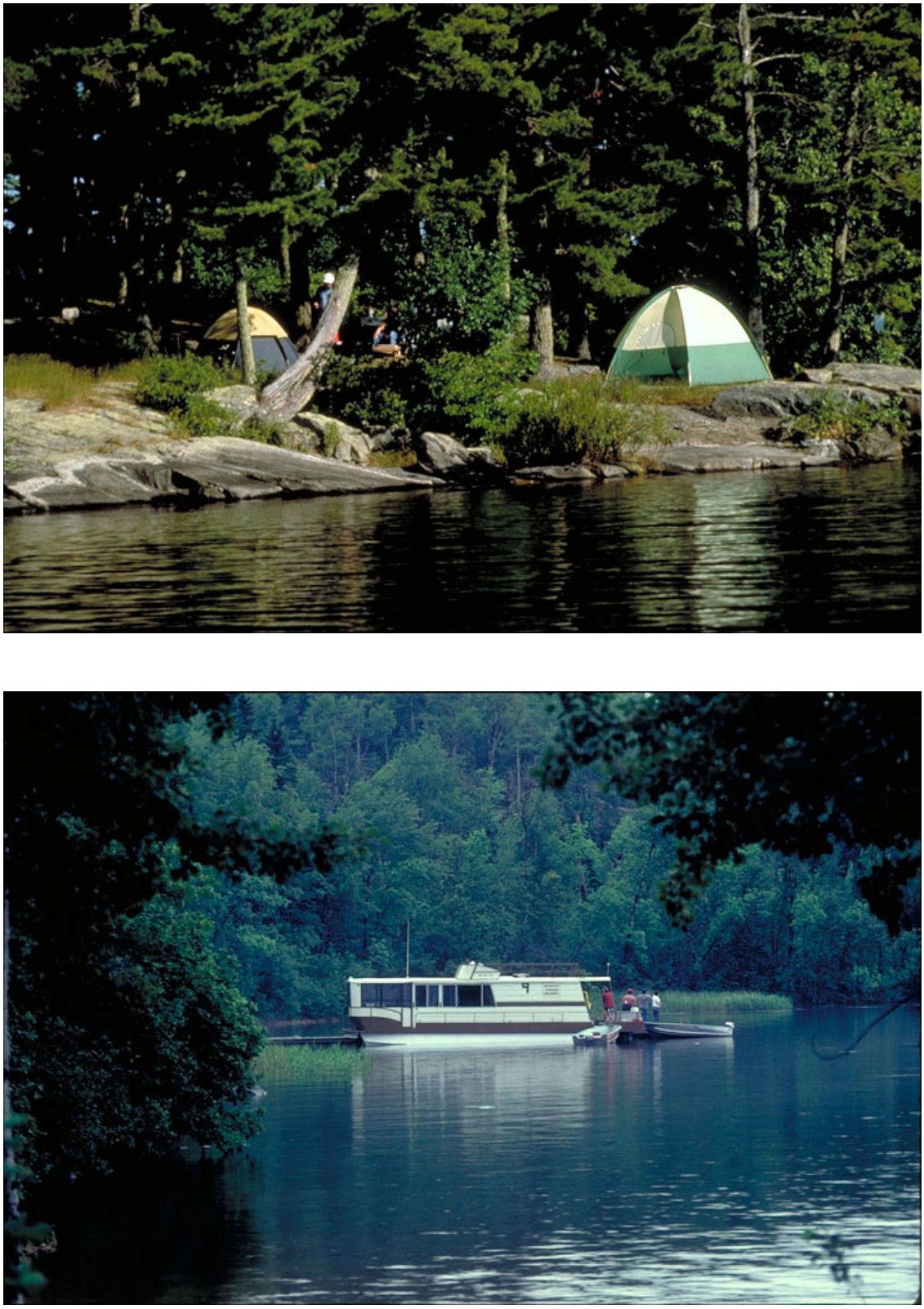
The park's current management document, the General Management Plan (GMP), was completed in 2001. The GMP provides a management concept for the park; identifies the park's role in regional trends and conservation plans; outlines recreation, economics, transportation and other regional issues; and outlines strategies toward resolving issues and meeting management goals. This WRMP, as its name implies, focuses on the water and water dependent resources of the park. While the GMP included substantial public involvement, the WRMP is primarily an internal document to guide the management of the water resources of the park. The WRMP will aid park managers in planning and decision-

making regarding water resource related actions. The WRMP will be updated regularly to reflect a dynamic and changing resource and to remain consistent with the park's GMP and Resource Management Plan (RMP).

Minnesota Statutes Chapter 84B.10 state that Minnesota will "cooperate to maintain in the park the highest standards relating to air, land, and water quality, whether these highest standards be state or federal, consistent with the lawful authority possessed by the State of Minnesota and the Secretary of the Interior in his administration of the National Park System to maintain air, land, and water in the park." As Voyageurs shares a common watershed with Canada, international coordination also is necessary. The International Joint Commission (IJC), was established under the Boundary Waters Treaty of 1909, to help prevent disputes regarding the use of boundary waters. The Ontario Ministry of Natural Resources (OMNR) determines fishing regulations within Canadian borders, which are next to waters shared with Voyageurs.

Voyageurs is involved with the U.S. Geological Survey (USGS)-Biological Resources Division (BRD) in a research partnership. This effort involves the long-term data collection of fish, aquatic invertebrates and water samples and the analyses of various parameters, resulting in many reports on the natural systems in the park. Voyageurs also is involved in various studies with the Minnesota Pollution Control Agency (MPCA), Minnesota Department of Natural Resources (MNDNR), other government agencies and tribes and various educational institutions and universities.

Other agencies besides Voyageurs involved in the greater Rainy Lake Basin area are the USGS-BRD and National Water Quality Assessment (NAWQA) (south and west of the park at Red River of the North; the Upper Mississippi River will be at a high intensity phase in 2004-2005), MPCA, MNDNR, OMNR and IJC. The MPCA completed on January 1, 2004, a Rainy River Basin Plan, also known as the Water Quality Plan. The plan, which was built from locally identified goals and strategies, documents water management activities in the basin for a five-year period. It includes input from residents, stakeholders, and local, state, and federal governments (including Voyageurs). A Basin Information Document previously completed by the MPCA served as a springboard for the overall plan.



Tent camping (top) and houseboating (bottom) are common visitor activities in the summer months at Voyageurs National Park.

WATER RESOURCES ISSUES

As part of the process for developing the Water Resources Management Plan for the park, we sent a survey entitled "Water Resource Management Issues for Voyageurs National Park" (Appendix A) to 126 Voyageurs National Park stakeholders in July 2000. The response rate to the survey was 75% (94 surveys received). Responses to the survey questions were tabulated; mean responses to each survey question are in Appendix B. In October 2000, key stakeholders (federal, state and local management agencies, educational institutions, NGO's and First Nations) were brought together at a workshop to identify the major issues affecting the park. Participants included park management team members and other federal, Canadian, state and local government agency representatives (NPS, OMNR, MDNR, MPCA, Superior National Forest, USGS, Koochiching County Environmental Services, Koochiching SWCD), members from non-government organizations (Rainy River First Nations, Voyageurs Regional National Park Association, Rainy Lake Conservancy, Boise Paper Company) and researchers from an educational institution (University of Minnesota) (For a list of attendees see Appendix C).

Results of the survey were presented and workshop participants were asked to prioritize the most significant issues for Voyageurs. Top issues were discussed in detail, asking why and how each should be addressed. The issues rated as top priority and their resulting project statement reference are in Table 1. These top issues served as the basis for project statements included in the WRMP. In several cases, issues of similar subject matter were combined under a single project title. The workshop resulted in the following Project Statement titles:

1. Water Quality Information for Decision Making
2. Scoping Issues for a Cooperative Fisheries Strategy
3. Ecosystem effects of Rule Curve Changes
4. Aquatic Invasive Strategy
5. Ecological Implications of Contaminants
6. Waste Management
7. Education
8. Monitoring Ecosystem Integrity
9. Graywater Investigation
10. Communication Strategy
11. Ways to Address Regional Impacts

Because of the similarity of content, projects 1,3, and 8 were combined into one. We determined that a separate project statement on Purple Loosestrife was necessary due to the severity and complexity of the threat. Further, due to current and planned projects in the park on mercury and petroleum fuel byproducts, it was apparent that contaminant issues already were sufficiently addressed within the park. Topical areas in titles 10 and 11 are beyond the scope of this WRMP. Voyageurs National Park and the Minnesota Department of Natural Resources are currently modifying an existing general agreement which may include strategies for fisheries management. This will likely involve project number two, and therefore, fisheries are not addressed explicitly in this plan.

The following table lists the top stakeholder issues and how each is addressed.

Table 1. The Top Issues Prioritized by Stakeholders

Issue	Subject	Issue	How Issue will be Addressed
1	Water Quality	Having enough information to determine if water quality is degrading	Project Statement 1, 2, 7 Current: Fish and aquatic assessment (USGS), water quality large lakes (USGS and DNR), reservoir effects on and trophic-state indicators (educational institutions), contaminants in remote lakes (educ. inst.), Effects of snowmobile use on aquatics (USGS)
2	Fisheries Strategy	Development of a fisheries strategy (i.e., how the agencies would work together with the communities to develop, express and implement an interagency management plan)	Future Fisheries Management Plan Current: Large lake smelt research (USGS), fish harvest data large lakes (DNR) and small lakes (NPS). Sports fish monitoring large and small lakes (DNR). Fish and aquatic assessment (USGS)
3	Monitoring	Careful monitoring of ecosystem effects of water level impacts of the recent rule curve changes	Project Statement 1 Current: reservoir effects on wetlands and trophic-state indicators (educational institutions), water quality large lakes (USGS, DNR, and MPCA)
4	Exotics Management	Development of an aquatic non-native species strategy	Project Statement 2,3 Current: Integrated Pest Management - zebra mussels/rusty crayfish (USGS) Purple loosestrife management effects: (NPS)
5	Contaminants	Further investigation into the consistent and increasing detections of contaminants (particularly mercury) in fish and other components of the park's aquatic ecosystem	Project Statement 7. Current: Mercury in fish (various educational institutions and USGS), mercury in interior lake water and in soils (USGS). Effects of snowmobile use on aquatics (USGS). Ecological contaminants in eagle plasma (educ. inst.), contaminants in remote lakes (educ. inst.)
6	Waste Management	Finding a solution to overloaded septic systems leaking wastes into the lakes	Project Statement 5
7	Education	Educating the community and visitors about water-related issues and impacts in the park	Project Statement 6
8	Graywater	Assessing impacts of graywater discharge on water quality	Project Statement 4
9	Septic Tanks	Reviewing and improving septic tank management	Project Statement 5
10	Regulated Lake Levels	Studying the impacts of regulated lake levels on flora and fauna	Project Statement 1 Current: reservoir effects on wetlands and trophic-state indicators (educational institutions), effects of lake levels on loons, benthos, muskrats, wetland vegetation, and fish (starting 2004)
11	Food Chain	Determining the health of each level of the food chain (algae, insects, frogs, crayfish and mussels, fish) so that we can understand impact, population limits and production	Project Statement 1 Current: reservoir effects on wetlands and trophic-state indicators, Fish and aquatic assessment (USGS, MDNR)

ADDITIONAL ANALYSES

As part of developing this WRMP, we analyzed data on acid deposition that had been previously collected but not yet analyzed; those data are in the water chemistry section of the attached synthesis (Kallemeyn et. al., 2003). We also analyzed existing data in an attempt to examine the effects of observed changes in dam discharge in the 1990's. The following results are based on that analysis.

Analyses of Existing Data and New Rule Curve

In the late 1980's, multiple studies were conducted in Voyageurs National Park to determine the effects of water level regulation on selected species and communities. These studies were in response to concerns that the rule curve at that time was negatively impacting the biotic communities of the park. Researchers were asked to consider the effects, if any, of a rule curve approximating more natural conditions (i.e., less annual water level fluctuation, less winter drawdown, higher spring levels, lower late-summer levels).

Using a total phosphorus (TP) mass-balance model, Kepner and Stottlemyer (1988) determined that peak spring TP levels in Kabetogama Lake would be reduced. This was attributed to a reduction in bottom areas exposed by drawdown and accompanying sediment-water interactions, reduced littoral macrophyte die-off and the accompanying nutrient inputs and reduced nutrient concentration effects from volume changes.

Phosphorus is thought to be a limiting nutrient in most lakes. Therefore based on their model results for TP in Kabetogama Lake, Kepner and Stottlemyer (1988) also predicted a reduction in phytoplankton biomass and primary production if the rule curve was changed to reflect more natural conditions.

Various studies have shown a positive relationship between the abundance of young of the year (YOY) walleye and northern pike and spring lake levels (Johnson et al.1966, Chevalier 1977, Kallemeyn 1987a & b) in the park. According to these studies, preferred spawning habitats occurred at relatively high elevations because of stable lake levels maintained throughout the summer and early fall. Therefore, considerable rise in lake levels is required in early spring to make these areas available for spawning. Researchers concluded that a return to more natural conditions, allowing for a summer drawdown and earlier rise in the spring, would increase the area of available spawning habitat (Kallemeyn et al., 1993).

From our analysis of existing data, we have found additional relationships that support these findings. From 1991 to 1999 (the new rule curve was put in place in 2000), Namakan annual water level fluctuation was significantly reduced (i.e., 2.4 m [1981-1990] to 2.0 m [$p = 0.001$]) (Fig. D). The 2.0m fluctuations are within the new 2000 rule curve requirements for the Namakan Reservoir. Also, Namakan Reservoir water levels were significantly($p<0.05$) higher in the spring than the previous ten years and late summer levels were significantly ($p<0.05$) lower. Overall average daily Namakan Reservoir stage height has increased significantly during the last 9 years ($p=0.0002$). All of the previous findings indicate 1990-1999 hydrological conditions were more similar to natural conditions than they were the

previous ten years, and also were similar to what the 2000 rule curve requires. We also found a small decrease in discharge but this appears to be a regional effect (Lac La Croix, which is just upstream from Namakan Reservoir, also had a small decrease in discharge). Management agencies, including the park, have been asked to gather information to be able to identify impacts of the new rule curves on the aquatic communities. Because of this and because the annual fluctuation of the past nine years was within the new rule curve's requirements, we took the opportunity to analyze the changes in water level fluctuation. This analysis provides a starting point in identifying any effects the new rule curves will have on biotic communities in the park.

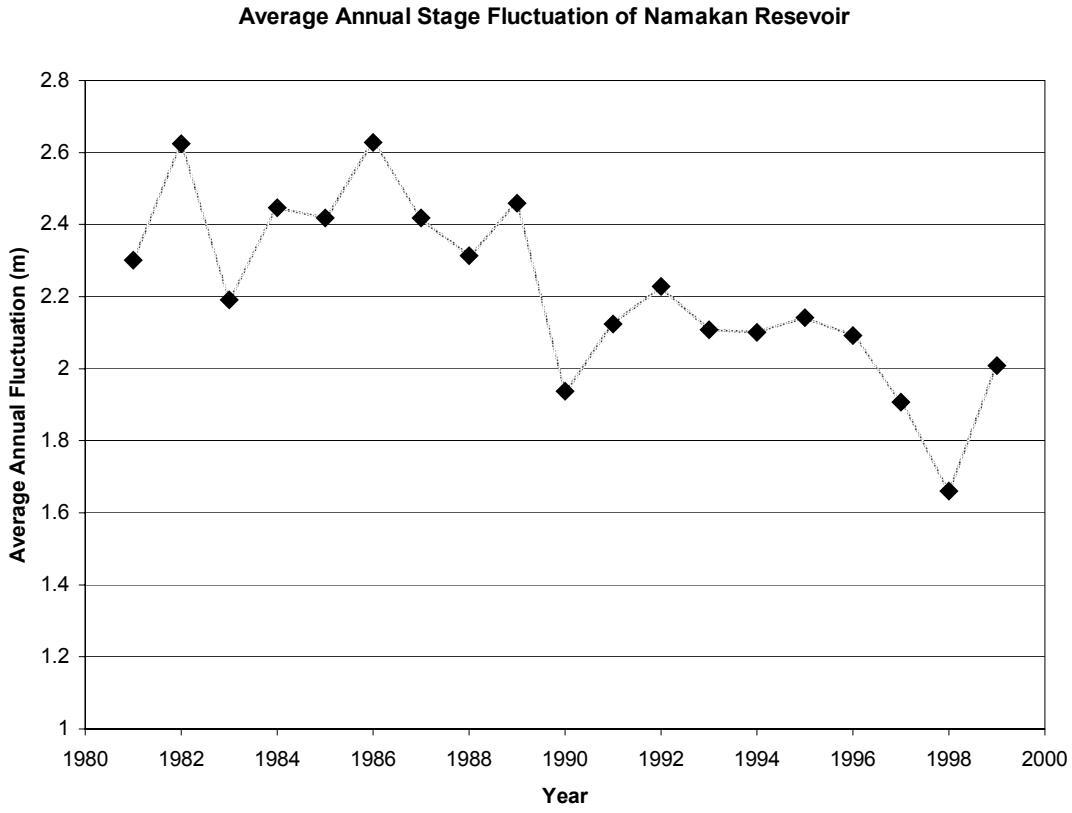


Figure D. Average annual stage fluctuation of Namakan Reservoir. Data from Kettle Falls dam daily stage averages.

Our analysis (based on data from Voyageurs/USGS and MNDNR unpublished) found a strong relationship ($r^2 = 0.37 – 0.70$) between annual mid-summer chlorophyll *a* (Chl *a*) concentrations and June-August water level fluctuation in all lakes except Rainy. We also found annual mid-summer Chl *a* concentrations increased with increasing annual water level fluctuation and annual mid-summer phosphorus concentrations increased with increasing annual coefficient of variation (CV) of water levels in Kabetogama Lake. Combining all lake water quality data and using lake as a covariate, we found a significant positive relationship between Chl *a* and Namakan Reservoir/Rainy Lake average annual water level fluctuation and a negative relationship with Namakan Reservoir/Rainy Lake average annual discharge. These relationships suggest that a decrease in annual water level fluctuation would result in a decrease in phosphorus and Chl *a* concentrations, especially in Kabetogama Lake. We found a negative relationship between average monthly Secchi disk depth (May – Sept.) and both average monthly water level fluctuation and discharge in all of the lakes except Kabetogama. The negative relationship with discharge suggests that water clarity is also dependent on turbidity, not just phytoplankton. As might be expected from those relationships, Chl *a* levels in Kabetogama Lake significantly decreased in the 9 years after 1990 (from 21 to 9 μg/L). We also found a highly significant (p=0.01- 0.0001) increase in Secchi disk depth in all lakes except Namakan Lake after 1990. These relationships support the prediction of Kepner and Stottlemyer (1988) that phosphorus and Chl *a* would decrease in Kabetogama Lake with a return to more natural water level fluctuations. Our findings show that Chl *a* has decreased significantly in Kabetogama Lake and water clarity has improved in all the lakes (significantly in all except Namakan Lake) since the post 1990 decrease in water level fluctuation. Since Kabetogama Lake has a significantly higher trophic status than the other lakes, it stands to reason that a change in Chl *a* would be easier to detect in it than in the other lakes.

Through analyses of fish data obtained from Voyageurs, we found further support for the Kallemeyn et al. (1993) assertions that a change to more natural levels and fluctuations would positively affect communities in the park. For example, we found significant negative relationships between water level fluctuation for June, July and August and walleye, darter, log perch, white sucker and yellow perch YOY catches in Kabetogama Lake. From back-calculated fish scale data for northern pike, sauger and walleye, we found significant negative relationships between Age 1 –3 sauger and walleye growth and Namakan Reservoir/ Rainy Lake annual water level fluctuation in all lakes except Kabetogama Lake. This suggests that decreased fluctuation would have a positive effect on growth of these species. This benefit may be from increases in macroinvertebrate food sources and ramifications throughout the food web, all resulting from decreased macroinvertebrate mortality from winter drawdown. It is not surprising that Kabetogama Lake was not affected the same way as the other lakes since it has different trophic dynamics than the other three. Density of benthic invertebrates was shown to be 2.7 times higher in Kabetogama Lake than the other three lakes (Kraft 1988), so the fish in Kabetogama Lake would likely be less impacted by the winter macroinvertebrate mortalities. We also found significant negative relationships between Age 1 –3 sauger and walleye growth and Namakan Reservoir/Rainy Lake annual discharge in all of the lakes. The effect of discharge on water temperature is the most likely cause of this. These relationships were strengthened when data for ages 1-4 were combined with age as a covariate ($r^2 = 0.8 – 0.9$ for most). As would be expected from those

relationships, the 9-year period after 1990 had significantly higher sauger growth for ages 1,2, and 3 than the previous 10-year period. Namakan, Rainy and Sand Point Lakes all had significantly higher sauger growth after 1990 when age was used as a covariate. These findings complement what Kallemeyn et al. (1993) observed with relation to YOY success and spring water levels. Fish growth and year class strength both appear to be affected by water level fluctuation and discharge. For example, during a 9-year period with reduced water level fluctuation and increased stage height, there was increased growth for sauger, as these relationships would predict.

The changes in hydrology for the period of 1990-1999 were similar to what we expect from the new 2000 rule curve. Based on the preliminary results shown here, it appears that the changes seen in the last nine years have reduced primary production in Kabetogama Lake and increased fish year class strength and growth of some species in Namakan, Rainy and Sand Point lakes. These trends should continue under the 2000 rule curve.

WATER RESOURCES MANAGEMENT PROGRAM

Voyageurs National Park is located in an area of exceptional beauty and expansive waters. Over 200,000 people visit Voyageurs every year to enjoy its many cultural and natural resources and recreational opportunities. The large lakes of Voyageurs have been given a state Outstanding Resource Value Waters designation and must be managed to maintain this designation. However, numerous internal and external factors may threaten Voyageurs' water resources. Additionally, the park's common border with Canada and controlled lake levels complicates management. Providing park managers with current information about Voyageurs' water resources and accurate assessment of impacts on those resources is critical for informed decision-making. A management program is needed to ensure that all aspects of managing Voyageurs water resources are supported.

Voyageur's National Park water resources management program contains four components:

Baseline Resource Information (Inventory and Monitoring)
Threat/Impact Assessment
Impact Mitigation or Avoidance
Staff and Support Needs

The third component (to mitigate or avoid impacts) is the main goal of the management program. The other three components feed into this component and give the data, assessment and resources needed to attain all of the goals of the park.

Many winter visitors take advantage of the snow at Voyageurs National Park by snowmobiling (top) or cross country skiing (bottom).

We developed seven project proposals that would support the management program beyond the work presently going on and planned in the park. Those proposals are presented as *project statements*, standard National Park Service programming documents. Each project statement includes background about the park, a description of the issue being addressed, actions for resolution of the issue and a required budget. Project statements are intended to be the basis for proposals that would assist in acquiring support beyond present funding and staff.

Most of the proposed projects fall within the first two components of the management plan and many support more than one program component. They focus on gathering more information about park resources and threats to those resources, including long-term monitoring to determine trends and chronic impacts and short-term sampling to determine immediate threats. These projects are the ones apparent today; others will be needed to support the "impact mitigation or avoidance" management component that follows research.

Program Element 1: Baseline Resource Information

The purpose of this component is to:

Acquire sufficient information and understanding to support management decisions that protect water resources and aquatic systems from degradation.

- *Acquire baseline water chemistry information*
- *Acquire baseline aquatic communities information*
- *Monitor water quality and aquatic systems in relation to managed lake levels*
- *Understand the relationship anthropogenic pollutants play in bioaccumulation in aquatic organisms*
- *Understand the systemic relationship between wetlands, shoreline geomorphology and bathymetry*

In order to fulfill the charge to "promote and regulate the use of the Federal areas known as national parks . . . and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (NPS organic act, 16 USC1) the park needs baseline information about its water resources (including biota, habitat and processes). In order to protect the park's resources, we must acquire knowledge of the water resources and their contribution to the integrity of the overall natural functioning of the ecosystem. This information allows the park to determine changes and trends in its resources, which may indicate an impact. The park has some existing consistent monitoring of baseline information, however much of the data collection in the park has been inconsistent or insufficient either in frequency (e.g., once/year) or location (e.g., large lakes only) or both, and is for a limited set of parameters (e.g., fish or water quality).

The Minnesota Department of Natural Resources has been collecting water quality samples from one station and fish from multiple stations annually on each of the four large lakes in Voyageurs since 1983. Voyageurs/USGS staff have consistently taken basic bi-weekly chemical and physical measurements from May through September on the four large lakes since the early 1980's.

USGS-Water Resources BRD staff sampled ion chemistry in the four large lakes and many of the interior lakes in the late 1970s and early 1980s and repeated their sampling in 1999. USGS sampled again during 2001-2003. That sampling included primary productivity, nutrient enrichment, and major-ion chemistry.

As part of an EPA funded program dealing with the effects of acid rain, researchers sampled four interior lakes (Locator, Quill, Shoepack and Cruiser) intensively at least two or three times a year from the late 1970s to the mid-1990s.

The following project statements support consistent, thorough baseline information acquisition:

- Monitoring Ecosystem Integrity
- Aquatic Invasive Strategy
- Purple Loosestrife Management
- Graywater Investigation
- Investigation of Polycyclic Aromatic Hydrocarbons

Voyageurs is currently involved (with others) in several other projects that also support baseline information acquisition. Those include:

- Mercury levels in fish, water and soils in Voyageurs' interior and large lakes (USGS, MPCA, UMD, UW Lacrosse)
- Impacts of snowmobile use on aquatics (USGS)
- Rainbow smelt research on large lakes (USGS)
- Effects of reservoir operations on trophic-state indicators (USGS)
- Zebra mussel/rusty crayfish detection (USGS)
- Purple loosestrife management effects
- Fish and aquatic invertebrate assessments in large lakes (USGS, MNDNR, OMNR)
- Water temperature/oxygen monitoring in large lakes (USGS)
- Effects of lake levels on loon productivity (USGS, MNDNR, OMNR, Northland College, BioDiversity Research Institute)
- Dispersal/interaction of fish in interior ponds (University of North Dakota)
- Reservoir effects on wetlands (Northland College)
- Ecological contaminants in eagle plasma (Clemson University)
- Fish surveying and monitoring (USGS, OMNR, MNDNR)
- Macroinvertebrate and zooplankton surveys (USGS, University of Minnesota, and North Dakota State University)
- Fire effects on mercury (USGS)
- Sturgeon movement and habitat assessment (USGS, OMNR, MNDNR)

Voyageurs has recently completed (with others) two projects that support baseline information acquisition. These are:

- Muskellunge study on Shoepack Lake (USGS, Iowa State University)
- Sturgeon movement and habitat assessment in Rainy Lake (USGS, OMNR, MNDNR)

Program Element 2: Threat/Impact Assessment

The purpose of this component is to:

Manage aquatic habitats to maintain the highest level of ecological integrity within the confines of the park's authorizing legislation and the limits of managed lake levels.

- *Cooperate with governing bodies to ensure managed lake levels approximate a natural hydrologic regime*
- *Assess if aquatic systems are degraded by managed lake levels*
- *Preserve or restore the function and structure of wetlands*
- *Protect native species from displacement by exotics*
- *Protect water clarity and limit nutrient loading by reducing erosion and sedimentation*

Threat assessment is a dynamic component and addresses specific issues of Voyageurs. As part of the development of this plan, stakeholders identified and prioritized issues of the park (Appendix C). The project statements in this plan address the most significant issues identified by those stakeholders and the park. Most of the issues fall under the general topics of human impacts and species of special concern. The most pressing issue presently facing the park is monitoring regulated lake level effects. This is due to an IJC mandate that affected natural resource agencies, including Voyageurs, must monitor effects of the 2000 rule curve change.

The issues addressed by this component will change as new issues arise and priorities change. A routine reassessment of the most significant issues at Voyageurs will be needed in the future and should be part of the threat/impact component. The following project statements address the current major issues in the park:

- Monitoring Ecosystem Integrity
- Aquatic Invasive Strategy
- Purple Loosestrife Management
- Investigation of Polycyclic Aromatic Hydrocarbons
- Graywater Investigation

Voyageurs is currently involved (with others) in several projects that also support threat/impact assessment:

- Effects of reservoir operations on trophic-state indicators
- Zebra mussel/rusty crayfish detection
- Beast Lake apex predator reestablishment

- Purple loosestrife management effects
- Fish and aquatic invertebrate assessments in large lakes
- Rainbow smelt research at large lakes
- Effects of lake levels on loon productivity
- Reservoir effects on wetlands
- Fish surveying and monitoring
- Macroinvertebrate and zooplankton surveys

Program Element 3: Impact Mitigation or Avoidance

The purpose of this component is to:

Maintain or improve water quality through management actions, cooperation with adjoining land managers, partnerships, education and outreach programs.

- *Ensure water quality meets or exceeds standards for Outstanding State Resource Value Waters*
- *Participate in outreach and education forums to improve public understanding of water quality issues*
- *Cooperate with adjoining land managers, governments and stakeholders to maintain or improve water quality*
- *Manage park operations to ensure water quality is not degraded*
- *Manage park waters to preserve scenic and experiential quality*
- *Engage the regulatory system to protect water quality from degradation*

This component is the action step to protect Voyageurs' waters from adverse impacts. Potential impacts to Voyageurs are determined from monitoring or are predicted from threat assessment. The function of this component is to take actions to avoid or mitigate the adverse impacts. Project statements are only one way to accomplish this. Degradation is avoided through the park's review of permits for construction of roads and docks and regulation of visitor activities. Since many of the threats to Voyageurs' waters are outside its borders, effort is and will be expended working cooperatively with the appropriate agency to address and correct those threats, including pollutants and exotics.

As described in the Aquatic Synthesis for Voyageurs National Park (Kallemeyn et al. 2003), in the 1980's and 1990's the park was instrumental in determining the adverse impacts of the 1970 rule curves on the aquatic ecosystem of the park. In a 2000 Supplementary Order, the park was an active participant in getting rule curves changed to a more natural regime. The park and other natural resource management agencies have been charged with collecting data that may indicate the effect of the changes to the 2000 Order. Those data must be available for review 15 years after the Order change (i.e., by 2015). The park presently considers this charge one of the main factors of this element

This component is also dynamic. As more threats are identified, additional mitigating actions will need to be developed and implemented; additional project statements may be

required. The following project statements are actions that will lead to the avoidance or amelioration of presently known or potential threats to Voyageurs waters:

- Monitoring Ecosystem Integrity
- Graywater Investigation
- Purple loosestrife Management
- Wastewater Management
- Education

Voyageurs is currently involved (with others) in several projects that also support impact mitigation or avoidance:

- Purple loosestrife management effects
- Effects of reservoir operations on trophic-state indicators
- Effects of lake levels on loon productivity
- Reservoir effects on wetlands
- Investigation of relationship between reservoir operations and mercury accumulation in fish

Program Element 4: Staff and Support Needs

Current Staffing and Workload

The current natural resources team consists of ten permanent positions, one seasonal position, and one term position. In addition to the Chief of Resource Management, the division includes a Biologist, a Biological Science Technician, a Fire Ecologist, a Fire Technician, a Fire Management Officer, a Fire Program Assistant, a GIS Specialist, a Cultural Resource Specialist, a part-time Museum Technician, a seasonal Biologist, and a term Aquatic Ecologist. The resource management team is responsible for the park's natural and cultural resource management, fire management, and geographic information system. A USGS aquatic biologist is also stationed at Voyageurs.

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PROJECT STATEMENTS

Project Statement

Title: MONITORING ECOSYSTEM INTEGRITY

Problem Statement

Abstract:
There has been limited long-term monitoring of the Voyageurs National Park aquatic ecosystem. Recent changes (i.e., rule curve changes; non-degradation standards for water quality; localized and widespread threats such as exotics, contaminants and septic drainage) are compelling circumstances that demand that the park achieve more complete monitoring of its water resources. WRMP stakeholders ranked "having adequate information to determine if water quality is degrading" as the top priority and ranked "monitoring ecosystem health" among the top ten priorities for water resource issues. Voyageurs' complex environment makes it imperative that accurate and thorough data of the park's water resources be consistently updated. Only then will the park be able to assess the magnitude of threats, evaluate degradation/improvement to its waters and be able to address those threats and opportunities with defendable management strategies.

Background:

Voyageurs National Park (Voyageurs) was established in 1975 and is in a hydrologically complex environment. Located along the Minnesota-Ontario border, Voyageurs is part of a relatively undisturbed ecosystem of 10,930 km^2 (4,219 mi^2), which includes the 4,856 km^2 (1,875 mi^2) Boundary Waters Canoe Area Wilderness and the 4,452 km^2 (1,719 mi^2) Quetico Provincial Park. South of the park, Kabetogama State Forest and Superior National Forest lands are largely checkered with Boise Paper Company and private lands. Boise Paper Company manages its lands primarily for pulpwood production. Private landowners manage their property for pulpwood production, agriculture (grains and cattle), residential use, or recreational activities (National Park Service 1994).

Voyageurs lies within the lower end of the 38,600 km^2 (14,900 mi^2) Rainy Lake drainage, which is part of the headwaters of the Hudson Bay watershed. The Rainy Lake basin contains a complex network of lakes, ponds and connecting rivers and streams. Approximately 70% of the basin lies in Ontario with the remaining 30% in Minnesota. 38% of Voyageurs is covered by water with four major lakes (Kabetogama, Namakan, Rainy and Sand Point) comprising 96% of the park's total lake area (Kallemeyn et. al., 2003). The park's 26 interior lakes have a combined surface area of 1,278 ha (3,158 acre). Visitor use of the park is clearly water-oriented with paddling, boating, fishing, swimming, snowmobiling and cross-country skiing the primary visitor activities.

Lake levels in the park's four largest lakes are controlled by a hydroelectric dam crossing the Rainy Lake outlet at the international border between Fort Frances, Ontario and International Falls, Minnesota, and two stop-log dams at Kettle Falls and Squirrel Falls on Namakan Lake. The Namakan Reservoir consists of Kabetogama, Namakan, Sand Point and Crane, and Little

Vermilion lakes. Originally, natural rock sills at the Kettle Falls and Squirrel Falls outlets of Namakan Lake controlled water levels for Namakan Reservoir. The lake levels have been artificially controlled for nearly 100 years. In 2000, a new rule curve for the Rainy and Namakan Reservoirs was put in place to approximate more natural water levels and fluctuations.

The State of Minnesota (MPCA Ch. 7050.0180) has designated the waters of Voyageurs as "Outstanding Resource Value Waters" (ORVWs). ORVWs are to be managed to prevent any degradation of their quality. Results of previous water quality studies indicate the park's waters are generally of high quality (Payne 1991, 2000). Although water quality is considered to be good, there are widespread and localized threats affecting the quality and quantity of the park's waters. There have been local instances of erosion, septic drainage and water contamination and widespread addition of petroleum byproducts and lead to park waters from snowmobiles and powerboats. Also, unnatural water level regimes have been shown to have significant negative effects on the aquatic ecology of Voyageurs (Kallemeyn et al., 1993, NPS 2003).

Description of Problem:

Annual fish and water quality samples and a few basic bi-weekly summer chemical and physical measurements have been taken consistently since the early 1980's. Otherwise there has been no consistent monitoring of any water quality, aquatic community or habitat variable in the park. There have been studies on various parts of the aquatic ecosystem, but most studies were done as one-time projects for a few years. Data from the 1990's are especially sparse. Analyses of the few variables that provide adequate data indicate a significant change in the 90's in water quality and growth of some species of fish in the major lakes. However, there are no or insufficient data for nutrients, macrophytes, invertebrates and habitat to substantiate if or how such a change occurred. Several exotic species (purple loosestrife, rainbow smelt) have invaded the park and more (e.g., rusty crayfish, zebra mussel, spiny waterflea) are likely to invade. Present monitoring efforts are insufficient to determine if management efforts are working and if the new exotic species have entered the park.

The park conducted a project, which ended in 2003, to "document changes in primary productivity, nutrient enrichment, and major-ion chemistry in the Rainy-Namakan Reservoir system due to changes in reservoir operation" (NPS 2000). This project does not address most of the aquatic communities and habitats in the park.

The International Joint Commission (IJC), an organization established by treaty to help prevent and resolve disputes over the use of waters along the U.S.-Canada border, issued a supplementary order for the management of Rainy Lake and Namakan Reservoir in 2000. The order sets rule curves to more closely approximate natural conditions. The IJC 2000 order stated, "monitoring programs will be implemented by the resource management agencies to enable the impacts of the new rule curves on the biological and aquatic communities to be identified, and to provide an adequate source of information for future reviews". The IJC requested the assistance of the U. S. Geological Survey's Biological

Resources Division (BRD) to facilitate the development of a monitoring program. The BRD proposed that a facilitated workshop be held, the goals of which would be to: 1) define the scope of the monitoring program; 2) develop monitoring protocols for fisheries and other major components of the aquatic communities; and 3) identify possible funding mechanisms for implementation of the monitoring protocols. The workshop was held in International Falls, MN in January 2000. The results from the workshop were written up in *Proceedings of the Rainy Lake – Namakan Reservoir Ecological Monitoring Workshop*, 2000. Approximately 60 scientists and resource managers from United States and Canadian universities, First Nations, private industry and government agencies attended the workshop. One of the top conclusions from the participants was the need for a joint United States-Canada coordinating committee for the monitoring program (Kallemeyn, 2000). A committee was established in 2002. The IJC also asked BRD to write up a monitoring plan based on the results of the workshop. This was completed by Larry Kallemeyn (USGS) in April, 2002. The IJC order also included a review of the monitoring information collected after 15 years to look at the effect of the changes contained in the supplementary order. Thus, if there is not sufficient evidence of improvement from the changes in the 2000 order, the order could be reversed.

In July 2000, University of Minnesota researchers sent a survey "Water Resource Management Issues for Voyageurs National Park" to 126 Voyageurs National Park stakeholders. They asked participants to rank issues in the park based on importance. As part of the process for developing the Water Resources Management Plan for the park, the researchers also brought stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) together to identify the major issues affecting the park (October 2000). Both the survey participants and these stakeholders ranked "having adequate information to determine if water quality is degrading" as the top priority and workshop stakeholders ranked "monitoring ecosystem health" among the top ten priorities. The park also has as specific management objectives to "acquire sufficient information and understanding to support management decisions that protect water resources and aquatic systems from degradation, acquire baseline water chemistry information, acquire baseline aquatic communities information, and monitor water quality and aquatic systems in relation to managed lake levels."

Availability of adequate data about the park's water resources is very important to the park and its community.

There are pressing and compelling circumstances that demand that the park begin more complete monitoring of its water resources. In order to address the issues of non-degradation standards for water quality, exotic species, localized and widespread threats, the IJC 2000 rule curve changes and a complex and politically sensitive environment, it is imperative that accurate and thorough data of the park's water resources be consistently updated. Only then will the park be able to assess the magnitude of threats and degradation/improvement to its waters and be able to address these threats with defendable management strategies that will hold up in public and legal opinion. The IJC has supported the initial phases of a coordinated monitoring program and the MNDNR and OMNR have expressed interest in starting a coordinated long-term monitoring program, however the next steps may take years.

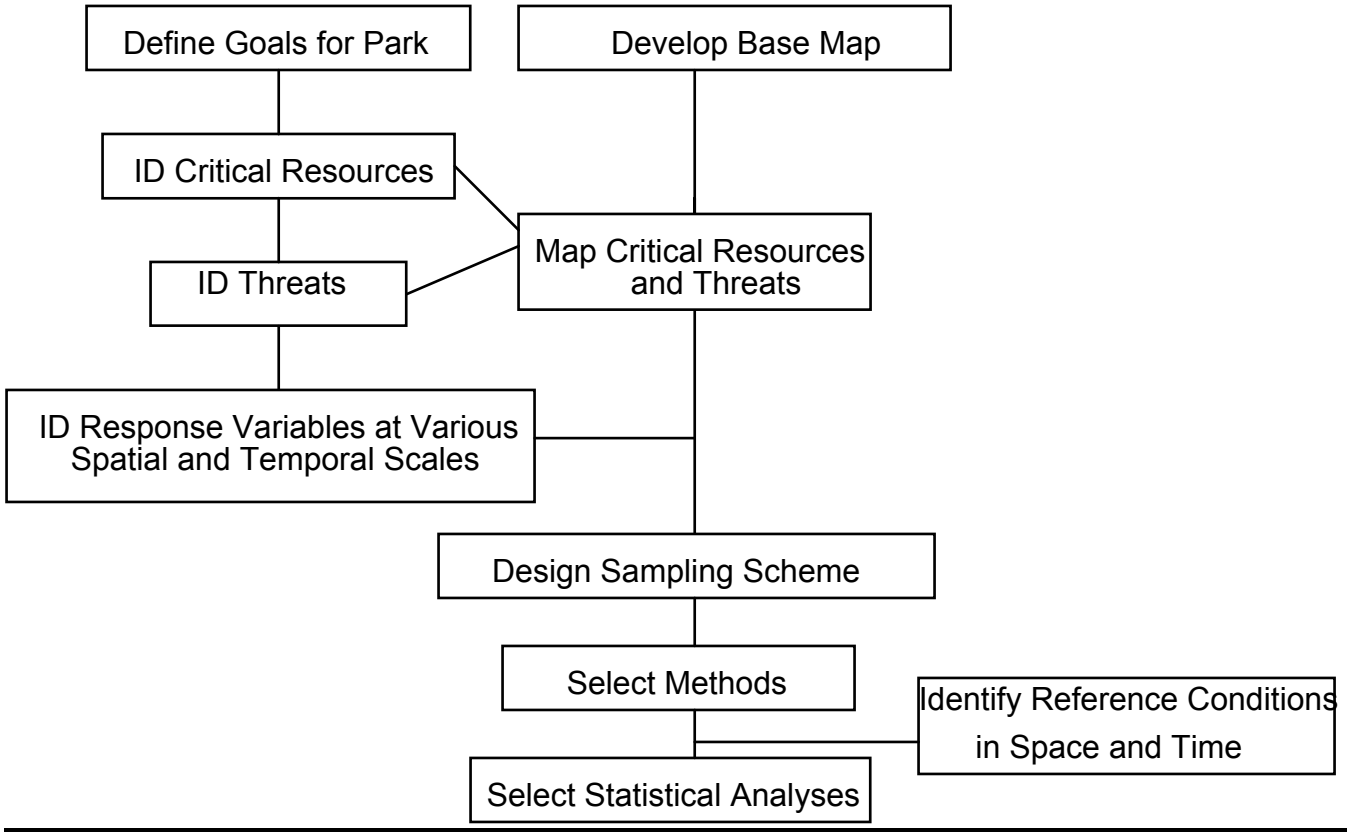
Kallemeyn (2002) states: "They (the agencies) have continued their existing fish monitoring programs …. Expansion of their programs into new areas, however, has been limited by a lack of financial resources and in some cases, expertise. Unless these agencies, which have invested over 20 years and significant resources into this issue, meet the IJC's charge, ecological values are unlikely to play a significant role in the assessment of the 2000 Order. Failure to act now may also limit opportunities to have meaningful input into future decisions regarding this or similar issues. To prevent this, either one or more of the agencies need to step forward and assume a leadership role or they need to decide to once again coordinate their involvement, an approach they successfully used in the past". Also from Kallemeyn 2002, "Unless action is taken quickly, … the opportunity to assess the effects and learn from the rehabilitative components of the 2000 Order will be lost. The longer the implementation of monitoring and/or assessment programs is delayed, the more difficult it will be to discern the cause-effect linkages that must be considered in a rigorous evaluation of the impacts of habitat manipulations (Jones et al.1996)". To ensure accurate assessment of the rule curve changes that occurred in 2000, the park needs an immediate increase in monitoring critical components of its water resources until a more permanent, international, interagency monitoring program is established.

Project Purpose and Objectives:

The primary purpose of this project is to start a comprehensive interim water resource monitoring program while laying the ground work for a long-term monitoring program, so as not to miss changes that may have occurred or may be occurring from local impacts, widespread impacts and rule curve changes. This will allow time for a more permanent, interagency monitoring program to be established while still gathering pertinent information to allow assessment of rule curve change effects. The recommended methods have included results of the BRD 2000 monitoring workshop, Larry Kallemeyn's (USGS) report to the IJC Establishment of an Assessment Program to Evaluate the Long-term Effects of Changes in the Water Management Program for Rainy Lake and Namakan Reservoir and NPS water quality vital signs monitoring guidelines. All recommended actions (with the exception of #1) should be tied into and combined with efforts of other groups monitoring natural resources in the basin.

Specific objectives are to: lay ground work for long-term monitoring with detailed maps of the littoral zone and classification of habitats, identify park's critical resources and threats to those resources, start assessing changes to water resources by sampling indicators and habitats related to identified resources and threats (i.e., erosion and septic failures, exotic species invasion, addition of petroleum byproducts and lead, water level timing and fluctuation).

Recommended Action



Sequential Steps:

1. **Define goals for park.** The following will be used as a starting point to be revised during implementation of the project. Table 1 lists the goals and objectives defined by the Water Resources Management Plan (2005). The second goal speaks of ecological integrity. Karr defines ecological integrity: the "biota is a balanced, integrated, adaptive system having the full range of elements and processes that are expected in the region's natural environment. Adopting integrity as a management goal means aiming for a system that resembles this evolved state as much as possible" (Karr, 1999).
2. **Identify critical resources.** This will allow for efficiency of effort and focusing on water resources that are most important to the park. We chose these based on park goals, monitoring questions presented in Kallemeyn (2002), importance to ecosystem integrity and importance to humans (recreational, economical, health). We suggest: water quality, fish, benthic invertebrates, plankton, aquatic habitats for fish and invertebrates (spawning habitat, macrophytes beds, woody debris, wetlands), and aesthetics.
3. **Identify threats** (see Table 2). We will obtain these from past occurrences (erosion problem areas, septic failures, heavy human usage, contaminants, draw downs) or

present issues from the WRMP Scoping Report (Weeks and Andrascik, 1998), WRMP scoping workshop, area resource managers or the public (fish population declines, changes in water clarity, smell, taste, exotics, rule curve changes).

4. **Map critical resources and threats.** This will provide a base-line for all future monitoring to assess changes in habitats, allow resource managers to locate a resource of interest and enable managers/researchers to identify and use common sites for consistency/comparison. With the use of satellite imagery, aerial photography, existing maps and surveying with GPS, we will map critical resources from step 2, threats from step 3, monitoring/research sites, land use/development, sewage networks, tributaries, businesses, municipalities, visitor sites, etc. into a GIS.
5. **Select indicators.** Following the format in table 2, we will select spatially and temporally appropriate indicators. Based on IJC/Great Lakes Water Quality Board (1991), SOLEC (1998), Kallemeyn (2002), and others (Messer et al.1991, Niemi et al. 2000, etc.), we will select indicators to address each critical resource and threat. Examples of indicators are turbidity, nutrients, productivity, contaminants, available habitat, invertebrate abundance and composition.
6. **Design sampling scheme**. Sampling scheme will include site selection and sampling frequency and will be done in consultation with a professional statistician.
    a. Selection of sites. We will select sites to address each critical resource and threat while trying to duplicate sites from previous studies/ monitoring as much as possible. We will take duplicates randomly for 10% of the samples for statistical accuracy and quality assurance.
    b. We will select sampling frequency to represent a balance between the temporal and spatial scale at which a particular indicator responds and rational costs of sampling efficiency.
    c. The design team will select statistical analyses of the elements based on its best professional judgment after consulting a statistician.
7. **Select methods.** We will use methods and sites from previous lake level studies (Kepner and Stottlemyer 1988, Wilcox and Meeker 1991, Kraft 1988, Payne 1991, 2000 etc.) as much as possible for consistency and comparison purposes, however we will incorporate updated methods and techniques to ensure the highest level of accuracy and statistical relevance.
8. **Collect samples from field and analyze**. We will collect samples based on steps 6 and 7 above and will analyze either in the field or laboratory.
9. **Identify reference conditions.** These will be from historical data (i.e., before a certain change or threat was introduced) or reference lakes (i.e., Lac La Croix).
10. **Select statistical analyses.** We will consult a professional statistician to determine the analyses most statistically appropriate to detect resource trends or responses to threats; we also will examine monitoring projects similar to this one for analytical tools. If historical data are used as a reference for analyzing a certain threat or change, we will examine changes in weather patterns, deposition rates, etc. to distinguish between water management related effects and natural processes.

Measurable Outcomes:

This project will produce detailed maps of the park's littoral zone, classified habitats, critical resources and threats to those resources. It will also establish sampling sites and methods that are or will be part of long-term monitoring. This will give statistically valid and comparable data for use in assessing any changes in the state of the park's waters and what may be causing those changes.

Table 1. Water Related Purpose/Goals of Voyageurs National Park

1. Maintain or improve water quality through management actions, cooperation with adjoining land managers, partnerships, education and outreach programs a. Ensure water quality meets or exceeds standards for Outstanding State Resource Value Waters b. Participate in outreach and education forums to improve public understanding of water quality issues c. Cooperate with adjoining land managers, governments and stakeholders for the maintenance or improvement of water quality d. Manage park operations to ensure water quality is not degraded e. Manage park waters to preserve scenic and experiential quality f. Engage the regulatory system to protect water quality from degradation
2. Manage aquatic habitats to maintain the highest level of ecological integrity within the confines of the park's authorizing legislation and the limits of managed lake levels a. Cooperate with governing bodies to ensure managed lake levels approximate a natural hydrologic regime b. Ensure aquatic systems are not degraded by managed lake levels c. Preserve or restore the function and structure of wetlands d. Protect native species from displacement by exotics e. Protect water clarity and limit nutrient loading by reducing erosion and sedimentation
3. Acquire sufficient information and understanding to support management decisions that protect water resources and aquatic systems from degradation a. Acquire baseline water chemistry information b. Acquire baseline aquatic communities information c. Monitor water quality and aquatic systems in relation to managed lake levels d. Understand the relationship anthropogenic pollutants play in bioaccumulation in aquatic organisms e. Understand the systemic relationship between wetlands, shoreline geomorphology and bathymetry

Table 2. Examples of Critical Resources, Threats to those Resources and Threat Indicators

Scale	Critical Resources	Threats	Water Resource Indicators
Patch (10-100 m^2)	Water quality Phytoplankton Macrophyte bed	(Visitor use) Erosion	Increased Turbidity, Decreased productivity Decreased productivity
Shoreline (100 – 1,000 m^2)	Phytoplankton Water quality Aesthetics	Septic drainage	Increased productivity, blue-green Increased nutrients, bacteria Decreased water clarity, unpleasant smell
Bay (1,000-10,000 m^2)	Water quality Phytoplankton	Local land use change	Increased nutrients, sedimentation Change in productivity
Arm (100-300 km^2)	Water quality Habitat	Outboard motors and snowmobile use	Increased contaminants in water Loss of shoreline from erosion
Lake (100's km^2)	Habitat Fish/ Macroinvertebrate Phytoplankton	Change in regulated water levels	Increased/decreased spawning habitat, Invertebrate abundance, composition Nutrients/productivity
Watershed (20,000-50,000 km^2)	Water quality Aesthetics	Deforestation Development	Increased variance and concentrations of runoff, sediment, nutrients Decreased water clarity
Region (1×10^7-3×10^7 km^2)	Water quality Water quantity	Global Change Long range transport of contaminants	Change in water temperature Change in precipitation patterns Contaminants in fish

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Budget

	Source	Item	Action #	Item Cost
Year 1:		GIS TECH 6 mo. @ $40k	#4	20,000
		RES 6mo. @ $40k	#2,3,5,6,7,9	20,000
		RES 6 mo. @ $40k	#8	20,000
		2 TECH 6 mo. @ $20K	#8	20,000
		Contract	#10	500
		RES 3 mo. @ 40k	#10	10,000
		Supplies (sampling devices and accessories)	#8	20,000
		Sample analysis	#8	10,000
		Transportation (truck and Boat)	#8	4,000
Year 2:				
		RES 6 mo. @ $40k	#8	20,000
		2 TECH 6 mo. @ $20K	#8	20,000
		RES 3 mo. @ 40k	#10	10,000
		Supplies (sampling devices and accessories)	#8	3,000
		Sample analysis	#8	10,000
		Transportation (truck and Boat)	#8	4,000

	Source	Item	Action #	Item Cost
Year 3:				
		RES 6 mo. @ $40k	#8	20,000
		2 TECH 6 mo. @ $20K	#8	20,000
		RES 3 mo. @ 40k	#10	10,000
		Supplies (sampling devices and accessories)	#8	3,000
		Sample analysis	#8	10,000
		Transportation (truck and Boat)	#8	4,000
			==========	==========
			Total:	$258,500

Project Statement

Title: EXOTICS MANAGEMENT

Problem Statement

Abstract:
Several exotic plants and animals have invaded Voyageurs and many more are poised to do so. Plants such as purple loosestrife and fish such as rainbow smelt have changed Voyageurs' environment, while other exotic species such as rusty crayfish and Eurasian watermilfoil could easily invade from neighboring counties. Exotics can displace native species by competition or predation and can dramatically alter the structure of the food web. They are incompatible with Voyageurs' purpose which is "to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." The park needs an aggressive management strategy to both anticipate and combat exotics.

Background:

Voyageurs National Park (Voyageurs) was established in 1975 and is in a hydrologically complex environment. Located along the Minnesota-Ontario border, Voyageurs is part of a relatively undisturbed ecosystem of 10,930 km^2 (4,219 mi^2), which includes the 4,856 km^2 (1,875 mi^2) Boundary Waters Canoe Area Wilderness and the 4,452 km^2 (1,719 mi^2) Quetico Provincial Park. South of the park, Kabetogama State Forest and Superior National Forest lands are largely checkered with Boise Paper Company and private lands. Boise Paper Company manages its lands primarily for pulpwood production. Private landowners manage their property for pulpwood production, agriculture (grains and cattle), residential use, or recreational activities (National Park Service 1994).

Voyageurs lies within the lower end of the 38,600 km^2 (14,900 mi^2) Rainy Lake drainage, which is part of the headwaters of the Hudson Bay watershed. The Rainy Lake basin contains a complex network of lakes, ponds and connecting rivers and streams. Approximately 70% of the basin lies in Ontario with the remaining 30% in Minnesota. 38% of Voyageurs is covered by water with four major lakes (Kabetogama, Namakan, Rainy and Sand Point) comprising 96% of the park's total lake area (Kallemeyn et al., 2003). The park's 26 interior lakes have a combined surface area of 1,278 ha (3,158 acre). Visitor use of the park is clearly water-oriented with paddling, boating, fishing, swimming, snowmobiling and cross-country skiing the primary visitor activities.

Lake levels in the park's four largest lakes are controlled by a hydroelectric dam crossing the Rainy Lake outlet at the international border between Fort Frances, Ontario and International

Falls, Minnesota, and two stop-log dams at Kettle Falls and Squirrel Falls on Namakan Lake. The Namakan Reservoir consists of Kabetogama, Namakan, Sand Point and Crane, and Little Vermilion lakes. Originally, natural rock sills at the Kettle Falls and Squirrel Falls outlets of Namakan Lake controlled water levels for Namakan Reservoir. The lake levels have been artificially controlled for nearly 100 years. In 2000, a new rule curve for the Rainy and Namakan Reservoirs was put in place to approximate more natural water levels and fluctuations.

The State of Minnesota (MPCA Ch. 7050.0180) has designated the waters of Voyageurs as "Outstanding Resource Value Waters" (ORVWs). ORVWs are to be managed to prevent any degradation of their quality. Results of previous water quality studies indicate the park's waters are generally of high quality (Payne 1991, 2000). Although water quality is considered to be good, there are widespread and localized threats affecting the quality and quantity of the park's waters. There have been local instances of erosion, septic drainage and water contamination and widespread addition of petroleum byproducts and lead to park waters from snowmobiles and powerboats. Also, unnatural water level regimes have been shown to have significant negative effects on the aquatic ecology of Voyageurs (Kallemeyn et al., 1993, NPS 2005).

Description of Problem:

The National Park Service (NSP) defines exotic species as those that occur in a given place as the result of direct or indirect, deliberate or accidental action by humans (NPS-77, chapter 2). Exotic species are non-native and can disrupt and threaten natural ecosystems. The park lacks a comprehensive list of exotic species. At least seventy-one exotic species have invaded the park (NPS 2001). Long-term monitoring for prevention and control of exotics is vitally important to the health of Voyageurs' ecosystem.

Purple loosestrife (*Lythrum salicaria)* has invaded less than 100 acres of Voyageurs thus far. A wetland native of Europe and Asia, purple loosestrife can rapidly overtake marshes and crowd out vegetation such as cattails, bulrushes, reeds and sedges (see Thompson et al.1983, as cited in Purple Loosestrife Control Plan 1989). Loosestrife is very compact, is poor shelter for wildlife and has very little forage value. While the impact loosestrife has on wild rice is uncertain, wild rice grows in environments ideal for loosestrife germination. Eradication is difficult because of the large amount of seeds purple loosestrife produces and its ability to re-sprout from its roots. Recommended actions to address the purple loosestrife infestation are being addressed in a separate project statement.

While several fish species are controversial as to their designation as an exotic, rainbow smelt is clearly an exotic. Rainbow smelt (*Osmerus mordax*) can dramatically impact aquatic ecosystems, particularly the cool and cold water fish components (Evans and Loftus, 1987). First introduced by humans in the upper Rainy Lake watershed (Franzin et. al., 1994), rainbow smelt were first found in Rainy and Namakan lakes in 1990. Due to its intermediate trophic position as consumers and as prey, the species has the potential to impact the ecosystem both directly and indirectly. There is some evidence that the rate of mercury accumulation in predators such as walleye (*Stizostedion vitreum*) and northern pike (*Esox*

lucius) accelerates when they switch to a diet of smelt (Mathers and Johansen 1985). Accurate methods to measure the population of rainbow smelt are lacking. Traditional sampling methods such as gill nets, seines, trap nets and electrofishing boom shocker are not effective for sampling primarily pelagic fish such as rainbow smelt. The park is presently cooperating in a five-agency study to examine the impact of rainbow smelt on the ecology of park lakes. The study is using the experimental combination of acoustic and mid-water trawling sampling methods, hoping to not only increase what is known about rainbow smelt ecology but also to develop and refine methods to sample and study this fish. It is estimated that the final report on the project will be done by fall of 2005. This study should go far in helping to model and predict the impact of rainbow smelt on the park's aquatic resources.

Several other exotics of great concern that have not yet been found in Voyageurs, but could be easily introduced as they are present elsewhere in the state and in some cases in neighboring counties, include the rusty crayfish (*Orconectes rusticus*), zebra mussel (*Dreissena polymorpha*), Eurasian watermilfoil (*Myriophyllum spicatum)* and the spiny waterflea (*Bythotrephes cederstroemi)*. The rusty crayfish displaces native crayfish and consumes the eggs of native fish as well as vast amounts of lake and stream vegetation (Helgen 1990). The MNDNR collected one rusty crayfish from Crane Lake in 2002 and has also collected specimens from Johnson and Vermilion lakes, both of which drain into the park (Kallemeyn et al., 2003). Eurasian watermilfoil forms thick underwater stands of tangled stems and large mats of vegetation on the water surface that crowd out native species and interfere with water recreation. The nearest known infestation is in Itasca County. The park is also monitoring for the arrival of the spiny waterflea, which competes with young fish for food, as well as the exotic zebra mussel, which in addition to clogging intakes of water pipes and outboard boat engines, can completely eliminate native mussel species. Because of the serious consequences the invasion of these species could have on the park's ecosystem and their presence in neighboring counties, a proactive strategy needs to be taken. Assessment of the probability of success of these exotics in the Voyageurs ecosystem is needed to determine where resources for monitoring would be most wisely invested.

As part of the process for developing the Water Resources Management Plan for the park, University of Minnesota researchers brought stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) together to identify the major issues affecting the park (October 2000). These stakeholders ranked having an aquatic invasive strategy in the top five priorities for the park. Two park goals specific to exotics are (NPS 2005):

Manage aquatic habitats to maintain the highest level of ecological integrity within the confines of the park's authorizing legislation and the limits of managed lake levels

- *Preserve or restore the function and structure of wetlands*
- *Protect native species from displacement by exotics*

Acquire sufficient information and understanding to support management decisions that protect water resources and aquatic systems from degradation

- *Acquire baseline aquatic communities information*

Having an aquatic invasive management strategy is obviously very important to the park and its community.

The introduction of several new exotics (especially rusty crayfish and spiny waterflea) to the park is imminent. If they are able to establish, these exotics could have major impacts on the aquatic ecosystem as well. An early detection, education and action strategy is essential to minimizing damage from potential invaders.

Project Purpose and Objectives:

The purpose of the project is to develop a pro-active strategy for dealing with potential introductions of exotics into the park. This will allow the park to actively reduce the chance of introduction of a particular exotic and facilitate early detection and control if an exotic is able to invade the park.

Specific objectives are to: determine which exotics have the greatest potential for introduction and establishment in the park, take actions to prevent the introduction of these exotics, which will include both education and enforcement, and develop plans for immediate action if an exotic does invade the park.

Recommended Action

Pro-active Strategy

A pro-active, aggressive program must be a key ingredient of Voyageurs' exotic plant management strategy. Education and monitoring are the best ways to prevent exotics from becoming introduced and/or established. There are many ways exotics can be introduced into the park and once populations are established, eradication is expensive and difficult. Voyageurs needs to identify and educate the public on potentially harmful exotics that may invade the park, and predict pathways that are likely to bring new harmful species into the park, such as drainages or boats being trailered from infested waters. Following this, a strategy must be developed and implemented to reduce possible introduction and spread of exotics. For example, boat checks conducted by the MNDNR throughout Minnesota found 20% of all inspected boats had aquatic vegetation on or in them (watermilfoil and spiny waterflea are easily spread this way).

Actions:

1. Determine which exotics are most likely to be introduced into the park based on presence in surrounding areas and mode of introduction. The most obvious presently are rusty crayfish, zebra mussel, Eurasian watermilfoil, and spiny waterflea.
2. Gather an information base on each exotic from 1. above. Information will include what critical components are necessary for the exotic to invade and establish (i.e., water chemistry, nutrient concentrations, habitat, host) and what methods of control have been used, which methods have proven to be most effective and what the variables are for effectiveness.

3. For each exotic determine the potential for invasion and extent of invasion in the park based on whether the critical components identified in 2. and the mode of introduction exist in the park (live bait and floatplane landings are a big concern). Rank potential exotics on probability for greatest impact to the park.
4. Develop and implement a monitoring plan for potential exotics focusing the most resources and effort on exotics identified in 3. that pose the greatest threat of invading and establishing. For example, if Eurasian watermilfoil were determined to be the greatest threat, monitoring efforts would be focused on boat checks and surveys around boat landings and lakes with higher nutrients. Monitoring efforts will be coordinated with other resource agencies (MDNR, OMNR, counties, etc) to maximize resources.
5. Develop a strategy for immediate action if a new exotic is detected in the park. Clear steps including chemical, biological or physical controls will be laid out based on information gathered from 2.

Education

Education is vital in the effort to avoid exotic arrival in Voyageurs. Boats can easily introduce exotics such as spiny waterflea and water milfoil; rusty crayfish is often used as bait; illegal stocking of fish is harmful; purple loosestrife is often used as an ornamental plant. The park's Interpretive and Resources Management Divisions can be used to further educate visitors, employees and nearby residents about the current and potential exotics. Distributing pamphlets, placing posters at visitor centers, airing TV and radio ads in cooperation with MNDNR and other agencies and NGO's are also very effective.

Actions:

1. Develop list of key facts about the negative impacts, mode of introduction and spread and identifying characteristics of various exotics from information gathered in action 2 of the Pro-active Strategy component of this project statement. Efforts should focus on exotics that pose the greatest threat for impact identified in action 3 of the Pro-active Strategy component.
2. Create signs, posters, fact sheets and ads with key facts from 1. above and distribute through boat launches, visitor centers, bait shops, mailings, radio and TV.
3. Hold mandatory seminars with information from 1. above for all park personnel, inviting other resource agency and NGO staff to attend as well.
4. Develop a list of other entities that conduct fieldwork in the park or surrounding areas and request to educate their personnel about exotics.

Measurable Results:

This project will produce an information database of all exotics that have the potential to invade the park, ranked list of the exotics from greatest to least threat, signs, posters, fact sheets and ads with key facts about exotics threatening the park and a management strategy for immediate implementation if an exotic is found in the park. The project will also result in a reduction or delay of exotic invasions and in all park employees being able to identify potential exotics.

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Budget

Source	Item	Action #	Item Cost
Strategy Year 1:	RES 3 mo. @ 40k	1,2,3,5	10,000
	*RES 3 mo. @ 40k	4	10,000
	*TECH 4 mo. @20k	4	6,666
	*Supplies (sampling devices and accessories)	4	1,000
	*Transportation (truck and boat)	4	1,000
Education Year 1:	RES 2 mo. @ 40k	1,2,3,4	6,666
	Supplies (printing)	2	1,000
Strategy Year 2:	*RES 3 mo. @ 40k	4	10,000
	*TECH 4 mo. @20k	4	6,666
	*Supplies (sampling devices and accessories)	4	1,000
	*Transportation (truck and boat)	4	1,000
Education Year 2:	Supplies (printing)	2	1,000
		==========	==========
		Total:	$55,998

*Note: If a long-term monitoring program is funded, these items should be addressed in that program

Project Statement

Title: PURPLE LOOSESTRIFE MANAGEMENT

Problem Statement

Abstract:
Purple loosestrife (*Lythrum salicaria)* has invaded less than 100 acres of Voyageurs thus far. A wetland native of Europe and Asia, purple loosestrife can rapidly overtake marshes and crowd out vegetation such as cattails, bulrushes, reeds and sedges (see Thompson et al.1983, as cited in Purple Loosestrife Control Plan 1989), negatively impacting birds, aquatic animals and fish. The park has had good success in controlling loosestrife in the past, with continued effort through a combination of methods the park stands an excellent chance of containing the plant. Without sustained effort to detect and control it, loosestrife will spread, making it a serious threat to wetland plant and animal species in the park.

Background:

Voyageurs National Park (Voyageurs) was established in 1975 and is in a hydrologically complex environment. Located along the Minnesota-Ontario border, Voyageurs is part of a relatively undisturbed ecosystem of 10,930 km^2 (4,219 mi^2), which includes the 4,856 km^2 (1,875 mi^2) Boundary Waters Canoe Area Wilderness and the 4,452 km^2 (1,719 mi^2) Quetico Provincial Park. South of the park, Kabetogama State Forest and Superior National Forest lands are largely checkered with Boise Paper Company and private lands. Boise Paper Company manages its lands primarily for pulpwood production. Private landowners manage their property for pulpwood production, agriculture (grains and cattle), residential use, or recreational activities (National Park Service 1994).

Voyageurs lies within the lower end of the 38,600 km^2 (14,900 mi^2) Rainy Lake drainage, which is part of the headwaters of the Hudson Bay watershed. The Rainy Lake basin contains a complex network of lakes, ponds and connecting rivers and streams. Approximately 70% of the basin lies in Ontario with the remaining 30% in Minnesota. 38% of Voyageurs is covered by water with four major lakes (Kabetogama, Namakan, Rainy and Sand Point) comprising 96% of the park's total lake area (Kallemeyn et al., 2003). The park's 26 interior lakes have a combined surface area of 1,278 ha (3,158 acre). Visitor use of the park is clearly water-oriented with paddling, boating, fishing, swimming, snowmobiling and cross-country skiing the primary visitor activities.

Lake levels in the park's four largest lakes are controlled by a hydroelectric dam crossing the Rainy Lake outlet at the international border between Fort Frances, Ontario and International Falls, Minnesota, and two stop-log dams at Kettle Falls and Squirrel Falls on Namakan Lake. The Namakan Reservoir consists of Kabetogama, Namakan, Sand Point, Crane, and Little

Vermilion lakes. Originally, natural rock sills at the Kettle Falls and Squirrel Falls outlets of Namakan Lake controlled water levels for Namakan Reservoir. The lake levels have been artificially controlled for nearly 100 years. In 2000, a new rule curve for the Rainy and Namakan Reservoirs was put in place to approximate more natural water levels and fluctuations.

The State of Minnesota (MPCA Ch. 7050.0180) has designated the waters of Voyageurs as "Outstanding Resource Value Waters" (ORVWs). ORVWs are to be managed to prevent any degradation of their quality. Results of previous water quality studies indicate the park's waters are generally of high quality (Payne 1991, 2000). Although water quality is considered to be good, there are widespread and localized threats affecting the quality and quantity of the park's waters. There have been local instances of erosion, septic drainage and water contamination and widespread addition of petroleum byproducts and lead to park waters from snowmobiles and powerboats. Also, unnatural water level regimes have been shown to have significant negative effects on the aquatic ecology of Voyageurs (Kallemeyn et al., 1993, NPS 2003).

Description of Problem:

The National Park Service (NSP) defines exotic species as those that occur in a given place as the result of direct or indirect, deliberate or accidental action by humans (Olkowski et al.1983). Exotic species are non-native and can disrupt and threaten natural ecosystems. Long-term monitoring for prevention and control of exotics is vitally important to the health of Voyageurs' ecosystem.

Purple loosestrife (*Lythrum salicaria)* has invaded less than 100 acres of Voyageurs thus far with 230 adjacent acres at risk for invasion or re-invasion in the next 3-5 years (Szymanski, VOYA, per. comm. 2002). Purple loosestrife, a wetland native of Europe and Asia, can rapidly overtake marshes and crowd out vegetation by both direct competition and stealing pollinators from native plants such as sedges (NPS 1989). Loosestrife is very compact, is poor shelter for wildlife and has very little forage value. It is unsuitable for shorebird nest sites, its seed is a poor source of food for songbirds, waterfowl avoid it leading to decreased duckling productivity, and muskrats lose needed cattail for food and shelter. Several fish species are adversely affected by loosestrife, in particular northern pike which require specific wetland vegetation for egg attachment. While the impact loosestrife has on wild rice is uncertain, wild rice grows in environments ideal for loosestrife germination. It is difficult to eradicate loosestrife because of the large amount of seeds it produces and its ability to re-sprout from its roots.

The park's Purple Loosestrife Control Plan was implemented in 1988 and has been successful by using a broad spectrum of tools (cutting and burning, herbicide use), killing at least 95% of the plants in the first 3 years. In some areas the loosestrife has been successfully eradicated. However, these efforts have been hampered recently by a lack of personnel and resources. In 1997, for example, only four of thirteen known loosestrife locations were monitored (Grim, 1998 as cited in Project Statement Voyageurs N 004.001, NPS 1999). The above-mentioned techniques are effective if the loosestrife is caught before

it has been able to establish well. For high-density areas however, these techniques are not very practical or effective.

Biological control may be the best method for long-term loosestrife control. MNDNR successfully introduced beetles to sites in Minnesota between 1992 and 1999 – at nearly half of these sites, the loosestrife was 90-100% defoliated. This release occurred only after years of testing to make sure the insects were purple loosestrife specific and would not damage native plants or agricultural crops. This method is most effective on areas with well-established populations. Voyageurs, in collaboration with MNDNR, started a biological control program in 1998 at sites with higher densities of loosestrife. The two loosestrife leaf-eating beetles, *Galerucella calmariensis* and *G. pusilla* were collected from nearby public lands, cultivated, and released at five known loosestrife locations in the park, and subsequently monitored by park staff (Larsen 1998 as cited in Project Statement Voyageurs N 004.001, NPS 1999). Since then the park has been working together with others adjacent to the park (resorts and Boise Paper Company) to expand biological control to ten sites in the park and either areas adjacent to the park or drainages into the park. Monitoring of these sites showed that the beetles have been successful in decreasing loosestrife densities. Eventually the beetles and the plants will reach an equilibrium at reduced densities, but will not completely eradicate the loosestrife.

Currently, loosestrife is widespread outside of the park, including several drainages into the park. Careful monitoring is needed to keep on top of new infestations especially with well-established populations so close to the park. Of troubling note, in 2000 park employees found loosestrife at several locations where it had not been noted for several years.

As part of the process for developing the Water Resources Management Plan for the park, University of Minnesota researchers brought stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) together to identify the major issues affecting the park (October 2000). These stakeholders ranked aquatic invasives in the top five priorities for the park. The park's Water Resources Management Plan (2005) states as two of its goals:

Manage aquatic habitats to maintain the highest level of ecological integrity within the confines of the park's authorizing legislation and the limits of managed lake levels

- *Preserve or restore the function and structure of wetlands*
- *Protect native species from displacement by exotics*

Acquire sufficient information and understanding to support management decisions that protect water resources and aquatic systems from degradation

- *Acquire baseline aquatic communities information*

Preventing and minimizing aquatic invasive impacts is very important to the park and its community. The park will continue to map and monitor the locations where biological control is underway. With continued effort the park stands an excellent chance to contain the plant and a good chance to keep it at very low levels. But without annual efforts to detect and control loosestrife, it will spread, making it a serious threat to wetland plant and animal

species in the park. All of the park's marshes, those that border lakes and those on the margins of over 1000 beaver ponds are at risk.

Project Purpose and Objectives:

The purpose of this project is to reduce purple loosestrife populations and keep them at low to non-existent levels in the park.

Specific objectives are to contain and reduce loosestrife by a combination of manual, chemical and biological control methods and to build a long-term monitoring program.

Recommended Actions

REDUCE SEED SOURCES

Work with MN DOT and the county extension agents to control loosestrife that is growing in the ditches on roads leading to the park.

CONTAIN AND REDUCE

The most effective strategy to combat purple loosestrife is a combination of chemical and biological control. The use of herbicides is good for the short-term to reduce the possibility of seed dispersal by water to downstream lakes. Herbicide control is most successful when used on small, recently established populations. The most effective herbicide is Rodeo or glyphosate. Due to its toxicity to native plants, Rodeo is applied by backpack sprayer as a spot treatment to individual loosestrife plants. A more selective but less effective alternative is 2,4-D. Renovate, or triclopyr, will be the best herbicide treatment for loosestrife if Renovate is registered for aquatic use in the U.S. Renovate is less expensive than Rodeo, is less harmful to native plants, and is very effective at loosestrife control.

In areas of severe purple loosestrife infestation, manual and chemical control efforts are ineffective and may in fact contribute to the problem. In areas of high loosestrife density, biological control has been shown to be an effective tool. Five species of beetles have received approval for release in North America. *Galerucella pusilla* and *G. calmariensis* are leaf-eating beetles which seriously affect growth and seed production by feeding on the leaves and new shoot growth of purple loosestrife plants. *Hylobius transversovittatus* is a root-boring weevil that deposits its eggs in the lower stem of purple loosestrife plants. Once hatched, the larvae feed on the root tissue, destroying the plant's nutrient source for leaf development, which in turn leads to the complete destruction of mature plants. Finally, two flower-eating beetles, *Nanophyes breves* and *N. marmoratus*, severely reduce seed production of purple loosestrife. Park staff have already successfully introduced biological control insects *Galerucella calmariensis* and *G. pusilla* to at least ten sites in and around the park.

1. For high to medium density sites, we will introduce biological control invertebrates each year.
2. For medium to low density sites, we will use a combination of digging and hand pulling, cutting and chemical control to reduce and ultimately eradicate loosestrife in the park. We will establish monitoring plots in control areas and measure before and five years after control actions. We will pay special attention to the establishment of other aggressive or invasive plants—reed canary grass, narrow-leaved cattail, and eastern reed.
3. We will continue monitoring, mapping and control annually to keep existing infestations from expanding and to prevent new infestations from establishing.

Measurable Outcomes:

This project will result in reduction of loosestrife in and around the park.

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Budget

	Source	Item	Action #	Item Cost
Year 1:		RES 1 mo. @ 40k	1	3,333
		TECH 1 mo. @20k	1	1,666
		RES 2 mo. @ 40k	2	6,666
		4 TECH 1 mo. @20k	2	6,666
		Supplies (equipment and chemicals)	2	1,500
		Transportation (truck and boat)	1,2	1,000
Year 2:		RES 1 mo. @ 40k	1	3,333
		TECH 1 mo. @20k	1	1,666
		RES 2 mo. @ 40k	2	6,666
		2 TECH 2 mo. @20k	2	6,666
		Supplies (equipment and chemicals)	2	800
		Transportation (truck and boat)	1,2	1,000
			==========	==========
			Total:	$40,962

Project Statement

Title: GRAYWATER INVESTIGATION

Problem Statement

Abstract:

Graywater, non-toilet waste, is being discharged into Voyageurs' waters from an unknown number of houseboats and cruisers. Voyageurs is a water-oriented park with heavy boat use; the environmental impact from the detergents, soaps and solid kitchen waste found in graywater is unknown. The metamorphic and granitic rock underlying the park has a very limited ability to host ground water. The health of the surface water, therefore, is very important, as it is the area's primary water source. It is necessary to investigate graywater's effect on water quality, aquatic life and the natural limnological processes of the lakes in order to understand the issues regarding graywater discharge in the park.

Background:

Voyageurs National Park (Voyageurs) was established in 1975 and is in a hydrologically complex environment. Located along the Minnesota-Ontario border, Voyageurs is part of a relatively undisturbed ecosystem of 10,930 km^2 (4,219 mi^2), which includes the 4,856 km^2 (1,875 mi^2) Boundary Waters Canoe Area Wilderness and the 4,452 km^2 (1,719 mi^2) Quetico Provincial Park. South of the park, Kabetogama State Forest and Superior National Forest lands are largely checkered with Boise Paper Company and private lands. Boise Paper Company manages its lands primarily for pulpwood production. Private landowners manage their property for pulpwood production, agriculture (grains and cattle), residential use, or recreational activities (National Park Service 1994).

Voyageurs lies within the lower end of the 38,600 km^2 (14,900 mi^2) Rainy Lake drainage, which is part of the headwaters of the Hudson Bay watershed. The Rainy Lake basin contains a complex network of lakes, ponds and connecting rivers and streams. Approximately 70% of the basin lies in Ontario with the remaining 30% in Minnesota. 38% of Voyageurs is covered by water with four major lakes (Kabetogama, Namakan, Rainy and Sand Point) comprising 96% of the park's total lake area (Kallemeyn et al., 2003). The park's 26 interior lakes have a combined surface area of 1,278 ha (3,158 acre). Visitor use of the park is clearly water-oriented with paddling, boating, fishing, swimming, snowmobiling and cross-country skiing the primary visitor activities.

Lake levels in the park's four largest lakes are controlled by a hydroelectric dam crossing the Rainy Lake outlet at the international border between Fort Frances, Ontario and International Falls, Minnesota, and two stop-log dams at Kettle Falls and Squirrel Falls on Namakan Lake.

The Namakan Reservoir consists of Kabetogama, Namakan, Sand Point, Crane, and Little Vermilion lakes. Originally, natural rock sills at the Kettle Falls and Squirrel Falls outlets of Namakan Lake controlled water levels for Namakan Reservoir. The lake levels have been artificially controlled for nearly 100 years. In 2000, a new rule curve for the Rainy and Namakan Reservoirs was put in place to approximate more natural water levels and fluctuations.

The State of Minnesota (MPCA Ch. 7050.0180) has designated the waters of Voyageurs as "Outstanding Resource Value Waters" (ORVWs). ORVWs are to be managed to prevent any degradation of their quality. Results of previous water quality studies indicate the park's waters are generally of high quality (Payne 1991, 2000). Although water quality is considered to be good, there are widespread and localized threats affecting the quality and quantity of the park's waters. There have been local instances of erosion, septic drainage and water contamination and widespread addition of petroleum byproducts and lead to park waters from snowmobiles and powerboats. Also, unnatural water level regimes have been shown to have significant negative effects on the aquatic ecology of Voyageurs (Kallemeyn et al., 1993, NPS 2003).

Description of Problem:

Graywater is untreated (kitchen, bath, shower, etc) wastewater that has not come into contact with toilet water (blackwater) (Jenkins 1999). Graywater is typically separated from blackwater for several reasons. Graywater contains less than one-tenth the amount of nitrogen found in blackwater, it contains fewer pathogens, and it breaks down much faster (ninety percent of its biological oxygen demand (BOD) is used in the first five days) (http://greywater.com). While blackwater disposal is strictly regulated, the regulation of graywater is in question; many boats, in particular houseboats, release detergents, soaps, solid kitchen waste and ensuing oil, grease, ammonia, nitrogen, and phosphates directly into Voyageurs' waters. Alkylphenol polyethoxylates, which are common in detergents and personal hygiene items, "are notorious for the toxicity, persistence and hormone-mimicking properties of their biodegradation products, specifically alkylphenols. White et al.(1994) illustrated that alkylphenols including octyl and nonylphenols were estrogenic in fish, birds, and mammals. Ahel et al.(1993) were able to illustrate the bioaccumulation of nonylphenol and nonylphenol mono- and di-ethoxylates in algae and fish in the surface waters of Glatt Valley, Switzerland" (Xia and Bhandari 1999). In addition to contaminants, graywater's rapid breakdown rate may stimulate rapid plant or algae growth, resulting in increased biochemical and chemical oxygen demand. In phase one of the development of uniform national discharge standards (UNDS) for Armed Forces vessels, graywater Nature of Discharge Report concluded that "Graywater has the potential to cause adverse environmental effects because measured concentrations and estimated loadings of nutrients and oxygen-demanding substances are significant" (Nature of Discharge Report, Graywater, http://unds.bah.com/Nod/Graywatr.pdf).

We do not know the effects of unchecked graywater disposal on Voyageurs' ecosystem. Riparian graywater impacts at sources such as established campgrounds, backcountry camping areas and cabins at the small lots dotting the parks large lakes are also unknown.

Due to the area's geology and lack of groundwater, surface water is the primary water source for industrial and domestic needs as well as being a vital part of the entire area's ecosystem health. While graywater at other areas such as the oligotrophic Lake Powell (pers. comm., Mark VanMouwerik NPS 2001) may not pose much of a threat, there is a wide range in trophic status among Voyageurs' water bodies, and its more eutrophic waters, particularly at Kabetogama and Black Bay, could increase the potential hazards of graywater.

Voyageurs will develop a Houseboat Management Plan (HMP) if funding and staff are available (General Management Plan 2001 pg I-58). Park resource managers would like information on the presence and possible environmental impacts of graywater. This effort is hampered by a lack of literature on the actual amount of graywater discharge by houseboats as well as information on the graywater effects at Voyageurs. The potential for harmful effects from houseboat graywater has been magnified by the addition of dishwashers and washing machines to some houseboats (pers. comm., Dan Helwig MPCA 2002). Approximately 92 houseboats currently serve the Rainy and Namakan basins (as of the summer of 2003, the number may be as high as 146; pers. comm., Hablett 2003). Each houseboat produces up to an estimated 60-80 gallons (230-307 liters) of graywater per day. Taking into account all houseboats, approximately 216,000 to 288,000 gallons (830,000 to 1.1 million liters) of graywater is released into the Namakan basin and approximately 228,000 to 304,000 gallons (877,000 to 1.17 million liters) is released into Rainy Lake (NPS 2001 pg I-193). As both lakes have volumes in the billions of gallons, this amount is a small fraction, however, graywater contains nutrients and suspended solids that could build up in the calm shallow bays where most houseboats moor. Current policy allows two houseboats to moor at any of the park's 78 developed sites, and they may moor for several days. The park has no information on whether there is degradation of water quality, particularly oxygen levels. While the park has not collected water samples at sites where houseboats moor, park staff have observed graywater discharges, and visitors have lodged inquiries and complaints (park staff, pers. comm. Nov 1999, NPS 2001 I-215). Houseboat use is expected to increase; the Rainy Lake Basin has seen an increase of 87% in houseboat use since 1996 (NPS 2001 pg I-158).

As part of the process for developing the Water Resources Management Plan for the park, University of Minnesota researchers brought stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) together to identify the major issues affecting the park (October 2000). These stakeholders ranked "Assessing impacts of gray water discharge on water quality" in the top ten priorities for the park. The Water Resources Management Plan (2005) states as two of its goals:

Maintain or improve water quality through management actions, cooperation with adjoining land managers, partnerships, education and outreach programs

- *Ensure water quality meets or exceeds standards for Outstanding State Resource Value Waters*
- *Participate in outreach and education forums to improve public understanding of water quality issues*
- *Cooperate with adjoining land managers, governments and stakeholders for the maintenance or improvement of water quality*

- *Manage park operations to ensure water quality is not degraded*
- *Manage park waters to preserve scenic and experiential quality*
- *Engage the regulatory system to protect water quality from degradation*

Acquire sufficient information and understanding to support management decisions that protect water resources and aquatic systems from degradation

- *Acquire baseline water chemistry information*
- *Understand the relationship anthropogenic pollutants play in bioaccumulation in aquatic organisms*

Graywater's potential to threaten Voyageurs' aquatic ecosystem is a serious concern to the Voyageurs community. To meet the goals of the park, graywater impacts to water quality must be assessed. The park needs to know if graywater is affecting the aquatic environment presently and if it may be a potential threat in the future. With this knowledge Voyageurs can make recommendations as to disposal and limits for graywater in order to mitigate and avoid impacts.

Project Purpose and Objectives:

The purpose of this project is to determine if graywater disposal into the waters of Voyageurs has a potential to threaten or impact the aquatic ecosystem. Objectives are to measure any differences between sites with high graywater disposal and control sites, and determine whether those differences are a threat to the immediate area.

Recommended Action

Ideas for these actions are mostly based on recommendations proposed by Mark VanMouwerik, WRD/Research Associate, Colorado State University, in a Trip Report to Voyageurs. The purpose of the trip was to answer a technical assistance request from Voyageurs to help develop a study or monitoring program to measure contamination of park water from releases of graywater from houseboats. Also, if data collected in Phase one of developing uniform national discharge standards (UNDS) for vessels of the Armed Forces were examined, it may shed some light on whether graywater could pose a threat to Voyageurs. There may be some way to extrapolate the graywater constituents data from the Armed Forces vessels to houseboats in Voyageurs (see Graywater Nature of Discharge Report, Table 2 & 3 (http://unds.bah.com/Nod/Graywatr.pdf).

1. Site set up. We will set up monitoring sites at several undeveloped sites with no boat activity and at worst-case scenario sites such as a shallow, calm bay with high houseboat use and/or high campground use, and areas with high cabin density such as along Crane, Sand Point and Kabetogama lakes. We will take samples throughout the water column at least monthly, preferably more often and during high use times, such as the Fourth of July.

2. Measure parameters. One concern is graywater's possible effect on dissolved oxygen (DO) and on aquatic ecology (e.g. algal blooms, changes in macroinvertebrate or fish

populations). Therefore, we will measure algae (chlorophyll *a*) and DO as well as turbidity, Secchi depth, nutrients (total phosphorus, inorganic nitrogen, and dissolved silica), total and suspended solids, biochemical oxygen demand, macroinvertebrates and bacteria (rates of hypolimnetic oxygen depletion). Most importantly, we will measure surfactants from detergents, as this will be the easiest way to demonstrate graywater as the probable source and will indicate the presence of estrogenic compounds. One possible method described by Chemetrics (http://www.chemetrics.com/analytes/deterg.html), the methylene blue active substances (MBAS) method is used in a 3-minute procedure to measure anionic detergents in the 0-3 ppm (mg/L) range. This procedure features a unique extraction/sampling technique that eliminates several steps required in other test procedures-and provides increased sensitivity. Anionic detergents react with methylene blue to form a blue colored complex that is extracted into an immiscible organic solvent. GC/MS (gas chromatography/mass spectrometry) and HPLC (high-performance liquid chromatography) could also be used to for specific determination of surfactants including alkylphenols. We will also measure heavy metals as they have been found in analysis of graywater from Armed Forces vessels (Nature of Discharge Report, http://unds.bah.com/Nod/Graywatr.pdf).

3. Analyze data. We will analyze the data collected to determine differences between high use and control sites and to identify areas of concern with respect to BOD, nutrient and contaminant (i.e., surfactants) concentrations. We will compare levels to toxicity tests to determine possible adverse impact to the aquatic ecosystem in these areas.

4. Recommend further action. Based on the results of the study, we will recommend further actions to eliminate and mitigate graywater threats (long-term monitoring, required holding tanks on houseboats, phosphate limits on detergents etc.)

Measurable Results:

Results will show whether sites with heaviest graywater discharge are being impacted compared to control sites. If adverse impacts are occurring, an outline of future actions to mitigate these impacts will be produced.

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Budget

	Source	Item	Action #	Item Cost
Year 1:		RES 4 mo. @ 40k	1,2,3,4	13,333
		TECH 3 mo. @20k	2	5,000
		Supplies (sampling devices and accessories)	2	500
		Sample processing	2	5,000
		Transportation (truck and boat)	2	500
Year 2:		RES 3 mo. @ 40k	1,2,3,4	13,333
		TECH 3 mo. @20k	2	5,000
		Supplies (sampling devices and accessories)	2	500
		Sample processing	2	5,000
		Transportation (truck and boat)	2	500
			==========	==========
			Total:	$48,666

Project Statement

Title: WASTE MANAGEMENT

Problem Statement

Abstract:

Waste management in and around Voyageurs National Park is a serious issue due to the natural system's dependence on surface water. The thin soil regolith coupled with inadequate and failing septic systems pose a threat to Voyageurs' ecosystem health. The addition of nutrients to the ecosystem accelerates lake aging, encourages excessive growth of invasive and opportunistic plants, and causes algal blooms. Additionally, contaminants from household wastes and detergents stress the environment. Local efforts by property owners at complying with state regulations are hampered by cost and difficulty. Lake country pit toilets are being converted to vault systems within the park. The park needs to support neighboring counties' on-going efforts toward improving waste disposal systems in order to ensure park goals are met.

Background:

Voyageurs National Park (Voyageurs) was established in 1975 and is in a hydrologically complex environment. Located along the Minnesota-Ontario border, Voyageurs is part of a relatively undisturbed ecosystem of 10,930 km^2 (4,219 mi^2), which includes the 4,856 km^2 (1,875 mi^2) Boundary Waters Canoe Area Wilderness and the 4,452 km^2 (1,719 mi^2) Quetico Provincial Park. South of the park, Kabetogama State Forest and Superior National Forest lands are largely checkered with Boise Paper Company and private lands. Boise Paper Company manages its lands primarily for pulpwood production. Private landowners manage their property for pulpwood production, agriculture (grains and cattle), residential use, or recreational activities (National Park Service 1994).

Voyageurs lies within the lower end of the 38,600 km^2 (14,900 mi^2) Rainy Lake drainage, which is part of the headwaters of the Hudson Bay watershed. The Rainy Lake basin contains a complex network of lakes, ponds and connecting rivers and streams. Approximately 70% of the basin lies in Ontario with the remaining 30% in Minnesota. 38% of Voyageurs is covered by water with four major lakes (Kabetogama, Namakan, Rainy and Sand Point) comprising 96% of the park's total lake area (Kallemeyn et al., 2003). The park's 26 interior lakes have a combined surface area of 1,278 ha (3,158 acre). Visitor use of the park is clearly water-oriented with paddling, boating, fishing, swimming, snowmobiling and cross-country skiing the primary visitor activities.

Lake levels in the park's four largest lakes are controlled by a hydroelectric dam crossing the Rainy Lake outlet at the international border between Fort Frances, Ontario and International Falls, Minnesota, and two stop-log dams at Kettle Falls and Squirrel Falls on Namakan Lake. The Namakan Reservoir consists of Kabetogama, Namakan, Sand Point, Crane, and Little Vermilion lakes. Originally, natural rock sills at the Kettle Falls and Squirrel Falls outlets of Namakan Lake controlled water levels for Namakan Reservoir. The lake levels have been artificially controlled for nearly 100 years. In 2000, a new rule curve for the Rainy and Namakan Reservoirs was put in place to approximate more natural water levels and fluctuations.

The State of Minnesota (MPCA Ch. 7050.0180) has designated the waters of Voyageurs as "Outstanding Resource Value Waters" (ORVWs). ORVWs are to be managed to prevent any degradation of their quality. Results of previous water quality studies indicate the park's waters are generally of high quality (Payne 1991, 2000). Although water quality is considered to be good, there are widespread and localized threats affecting the quality and quantity of the park's waters. There have been local instances of erosion, septic drainage and water contamination and widespread addition of petroleum byproducts and lead to park waters from snowmobiles and powerboats. Also, unnatural water level regimes have been shown to have significant negative effects on the aquatic ecology of Voyageurs (Kallemeyn et al., 1993, NPS 2003).

Description of Problem:

Problem Statement:

Waste management within Voyageurs' watershed is complex due to soil and bedrock conditions. The metamorphic and granitic rock underlying the park has a very limited ability to host ground water. The health of the surface water, therefore, is very important, as it is the area's primary water source. Most current septic systems do not take into account this unique geological situation. Traditional septic system designs in the area, which include underground leach fields, do not adequately treat waste due to the thin soil regolith and/or soil composition. Human wastes from developed and undeveloped shoreline properties are sometimes washed in the lakes. Developed campsites, pit toilets, and inadequate septic systems at some residences and resorts all take a toll on Voyageurs' fragile environment.

Voyageurs has several waste concerns within its boundaries. Toilet paper rings on land at some houseboat mooring sites have raised questions about potential adverse effects on water quality. Additionally, the park would like to have a system to verify that all houseboats have adequate blackwater containment. While visitors use vault toilets at developed campsites, camping at undeveloped areas is permitted and may result in human waste problems. Not surprisingly, a study at nearby Boundary Waters Canoe Area (King and Mace 1974, as cited in Weeks and Andrascik 1998) found that coliform bacteria counts in water at canoe campsites were higher than in reference sites. Voyageurs is working to convert pit toilets at lake country sites to vault systems, where a barge can pump out human wastes (Andrascik, pers. comm., Weeks and Andrascik 1998). A serious concern within the watershed is failing sewage systems adjacent to the park.

Septic failures are thought to be common in the area for several reasons: the soil is too sandy or too rocky for bacterial action to properly treat wastes, the bedrock is located too close to the surface and/or the land includes wetlands. At Crane, Sand Point, Kabetogama and Rainy lakes, seasonal cabins were built on small lots; upgrades in electricity and pressurized water systems have not been accompanied by upgrades in waste treatment systems (Weeks and Andrascik, 1998). Failures along Kabetogama Lake are especially worrisome due to its relative shallowness and tendency toward eutrophy. Thirty resorts and many houses with insufficient leachfields are located along Kabetogama Lake (Jim Schaberl, pers. comm.). In addition, many residences are situated along Ash River that flows into the park at Sullivan Bay, an area that has exceeded standards for several nutrients (Payne 1991). The area urgently needs effective sewage systems less reliant on soil absorption. However, the costs to upgrade systems are significant.

In 1970, Minnesota adopted rule 7080, which requires that counties establish a program to upgrade non-complying septic systems within shoreline areas. The regulations state that the size of septic systems be based on water use. Additionally, the rule requires a separation of at least three feet of native soil between the bottom of the septic system and the bedrock or the seasonal saturation zone. Small lots, homes on islands and wetlands, and thin soil regolith make both regulations very difficult to achieve. In the case of mound systems, the regulations allow one foot of native soil. Even so, the vast majority of lots require fill to achieve even this standard, and fill is allowed only for experimental systems.

In 1994, St. Louis County formed the Crane Lake Water and Sanitary District and worked with the University of Minnesota to address waste management problems in the area. All businesses and residences in the area were served by individual sewage treatment systems at that time. The St. Louis County Health Department determined that many of these septic systems were failing (MPCA 2001). Systems were not meeting Minnesota Rule 7080 for reasons such as an improper design or inadequate drainfield, and for insufficient separation between the drainfield and the seasonal high ground water level. Poor receiving soils and failing wastewater treatment have resulted in environmental health concerns and have limited development (MPCA 2001). High priority areas included areas with high-density development and small lots, areas with poor soils and high water table, and any failing septic systems within one quarter mile of any wellhead protection site. Due to the area's abundance of lakes and bays, a centralized sewage system for the entire area is impractical. The District therefore separated the area into Western and Eastern Service Areas. The Western Service Area is now serviced by a municipal wastewater treatment facility. The facility includes a recirculating sand filter facility and a phosphorus removal system (see RLK Kuusisto Ltd. Facility Plan Update 2001). The Eastern Service Area will continue to use on-site sewage systems; however, the District is planning to upgrade systems and, in some cases, to create cluster systems.

The St. Louis County Water Plan (2000) also identified sewer system problem areas at Ash River Trail, Crane Lake, and Kabetogama Lake. In 1996, Koochiching County created the Rainy On-site Sewage Solution (ROSS) Project to investigate effective, cost-productive ways for shoreline property owners to comply with Minnesota Rule 7080. The county chose Rainy

Lake due to the area's soil conditions, the shallow depth of the bedrock, the age of the septic systems, development density, and the area's dependence on lake water for their water supply. The ROSS report (1997) recommended a feasibility study for a centralized sewage system and possible on-site solutions such as holding tanks, experimental mound systems, constructed soil treatment areas or performance-based systems such as Alascan. The report voiced concerns that the cost of upgrades will be too much of a burden for some property owners, that funding sources are drying up, and that any approved sewage treatment system will encourage development. Current plans in the ROSS area involve extending sewage service from the East Koochiching Sanitation District to the Jackfish Bay area on Rainy Lake, an area that encompasses about half of the total dwellings in the ROSS area. The multi-million dollar project has recently been approved for a $3.69 million Minnesota state grant and a $500,000 grant from the United States Corps of Engineers' 569 grant program (Richard Lehtinen, Koochiching County Environmental Services, pers. comm.). The Environmental Assessment for the project has been completed and approved by the Minnesota Pollution Control Agency. The County will proceed with the required land easements, and construction of the sewer collection system is tentatively planned to begin in the Jackfish Bay area during summer 2005. The remaining portion of the ROSS area, the islands and the area east of Tilson Creek, will not get sewage service and will require on-site sewage solutions. The county and state worked on a performance code for this area as well as for unsewered areas in the rest of the county. They are also exploring the possibility of forming a water quality cooperative to manage septic systems. As of June 3, 2002 property owners are required to get compliance inspections for any additions.

These upgrades are very costly and will take many years to implement. Without proper sewage treatment, nitrogen, ammonia, phosphorus, chloride, bacteria, and Volatile Organic Compounds (VOCs) are sometimes deposited into water, all of which are serious ecological threats. Even small concentrations of phosphorus can lead to algal blooms, which impact the recreational value of a lake. In addition, decomposing algae reduces available oxygen for fish and other wildlife. Nitrates in water are a concern particularly to infants under 6 months old, as they can lead to methemoglobinemia ("blue baby syndrome") whereby blood's capacity to deliver oxygen to tissue is reduced (Minnesota Planning 2001). Bacteria, viruses, and parasites in wastewater can spread diseases such as hepatitis and dysentery (Univ. MN, 2002). Flies and mosquitoes attracted to wastewater may also spread disease. Fecal coliform bacteria make drinking, swimming and handling fish a concern.

As part of the process for developing the Water Resources Management Plan for the park, University of Minnesota researchers brought stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) together to identify the major issues affecting the park (October 2000). These stakeholders ranked finding a solution to overloaded sewers spilling wastes into the lakes in the top ten priorities for the park. The park has several goal objectives related to waste management (NPS 2005):

Maintain or improve water quality through management actions, cooperation with adjoining land managers, partnerships, education and outreach programs

- *Ensure water quality meets or exceeds standards for Outstanding State Resource Value Waters*

- *Participate in outreach and education forums to improve public understanding of water quality issues*
- *Cooperate with adjoining land managers, governments and stakeholders for the maintenance or improvement of water quality*
- *Manage park operations to ensure water quality is not degraded*
- *Manage park waters to preserve scenic and experiential quality*
- *Engage the regulatory system to protect water quality from degradation*

Failing and inadequate septic systems pose a clear risk to meeting these objectives.

Project Purpose and Objectives:

The purpose of this project is to help reduce the threat to park water quality posed by overloaded/insufficient septic systems in and adjacent to the park.

Objectives are a reduction of sewage contamination to park waters.

Recommended Action:

1. Support neighboring counties' efforts to upgrade septic systems. On site systems can cost up to $15,000-20,000 per resident. When geography permits, a centralized sewage system is the best option, although initial costs are quite high. Assistance to counties would also help to build bridges to the community.

2. Partner with responsible agencies to support remediation in any way possible (e.g. participate in the U.S. Rainy Basin planning effort and emphasize wastewater problem areas, inquire about wastewater efforts in Ontario and participate where possible).

3. Monitor local water quality of potential "hot spots" and/or areas that have received complaints or observations of possible contamination. Monitor parameters such as nitrates, phosphates, fecal coliform bacteria, dissolved oxygen, color, chlorophyll *a* and surfactants at high use areas.

4. Continue converting pit toilets to vault systems within the park.

5. Educate park visitors on proper waste disposal while camping, especially at lakecountry sites.

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Project Statement

Title: EDUCATION

Problem Statement

Abstract:

Voyageurs National Park is dominated by water; it is an ideal classroom for teaching visitors about water resources. However, current educational opportunities are limited. This project would develop an interactive computer system whereby visitors or students would be initially drawn to input observations and get a response (i.e., input fish length and get age estimate). This system would open opportunities to further educate the user about current issues and impacts in the park through questions and statements related to the initial topic.

Background:

Voyageurs National Park (Voyageurs) was established in 1975 and is in a hydrologically complex environment. Located along the Minnesota-Ontario border, Voyageurs is part of a relatively undisturbed ecosystem of 10,930 km^2 (4,219 mi^2), which includes the 4,856 km^2 (1,875 mi^2) Boundary Waters Canoe Area Wilderness and the 4,452 km^2 (1,719 mi^2) Quetico Provincial Park. South of the park, Kabetogama State Forest and Superior National Forest lands are largely checkered with Boise Paper Company and private lands. Boise Paper Company manages its lands primarily for pulpwood production. Private landowners manage their property for pulpwood production, agriculture (grains and cattle), residential use, or recreational activities (National Park Service 1994).

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Namakan Reservoirs was put in place to approximate more natural water levels and fluctuations.

The State of Minnesota (MPCA Ch. 7050.0180) has designated the waters of Voyageurs as "Outstanding Resource Value Waters" (ORVWs). ORVWs are to be managed to prevent any degradation of their quality. Results of previous water quality studies indicate the park's waters are generally of high quality (Payne 1991, 2000). Although water quality is considered to be good, there are widespread and localized threats affecting the quality and quantity of the park's waters. There have been local instances of erosion, septic drainage and water contamination and widespread addition of petroleum byproducts and lead to park waters from snowmobiles and powerboats. Also, unnatural water level regimes have been shown to have significant negative effects on the aquatic ecology of Voyageurs (Kallemeyn et al., 1993, NPS 2003).

Description of Problem:

Voyageurs has three visitor centers – two seasonal visitor centers at Ash River and Kabetogama Lake, and one year round at Rainy Lake. The Crane Lake Ranger Station functions primarily as a ranger station, although visitor use in the area is high. The park's visitor contacts are mainly through visitor centers and bulletin boards at entry points. The park offers interpretive programs at all of the visitor centers and at the Minnesota Department of Natural Resources' State Forest campground, Woodenfrog, on Kabetogama Lake. The park offers information on voyageurs history, voyageurs reenactments during North Canoe rides, naturalist guides on tour boats, as well as other ranger programs. The park also conducts school programs for a variety of grade levels on Voyageurs history, habitats, snowshoeing, wolves, tracking (both on site and off-site), and pre-visit information, and has a website at www.nps.gov/voya. Further attempts to expand education across the park boundaries and foster a resource protection ethic have been hampered by lack of staffing. Park support has been sporadic and insufficient (NPS 2001).

Currently, Voyageurs has no displays on water quality and no written water education program (pers. comm. Schoewe, VOYA, July 2002). Water quality education is limited to fourth grade environmental education trips to a beaver pond in which students test for various parameters such as pH and clarity. However, the vast majority of visitors at Voyageurs have no opportunity for a hands-on experience in water education. Such a program would help to foster resource awareness and more communication between the local population and park personnel, a critical need at Voyageurs. It might also aid tourism and businesses in the gateway communities.

Educational opportunities pertaining to water are abundant at Voyageurs. The clear water is ideal for measuring parameters such as lake transparency. The differences in lakes could easily teach visitors about biological oxygen demand, phosphorus and chlorophyll and humans impact on their levels. Additionally, the high level of fishing in Voyageurs would make measuring fish age a fun activity and an ideal opportunity for aquatic resource education.

As part of the process for developing the Water Resources Management Plan for the park, University of Minnesota researchers brought stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) together to identify the major issues affecting the park (October 2000). These stakeholders ranked education in the top ten priorities for the park. Education is an important part of the park's water management goals also. The park's Water Resources Management Plan (2005) states as one of its goals:

Maintain or improve water quality through management actions, cooperation with adjoining land managers, partnerships, education and outreach programs

- *Participate in outreach and education forums to improve public understanding of water quality issues*

The park's Interim Resource Management Plan (NPS 2000) also includes education in two of its goals (pg 66):

Recognize that visitors need a variety of experiences – recreational, educational, intellectual, contemplative, and restorative – to make a meaningful connection with the park mission.

Visitors are well informed of the susceptibility of the park's resources to damage and comply with regulations to ensure resource preservation and a quality visitor experience.

Education is a high priority to the park and its community. The lack of water resource education programs puts the park at risk of not meeting its goals and does not support the park's purpose.

Project Purpose and Objectives:

The purpose of this project is to offer interactive educational opportunities for people who come in contact with the park either at visitor centers or through the internet. Specific objectives are to establish an interactive educational program that can be accessed through computer kiosks at visitor centers or through the internet. The education program will give the public opportunities to collect water resource data from the park, enter it into the computer program and get an interpretation of their data.

Recommended Action:

This project would set up an interactive computerized system that gives immediate feedback when visitors and/or students in classrooms input data they have collected in the park (i.e., input fish length and get age estimate). This system would open opportunities to further educate the user about current issues and impacts (e.g. mercury) in the park through questions and statements related to the initial topic. It is an ideal venue for Voyageurs because a computer kiosk does not take up much space and managing the program does not necessarily require additional staffing, both of which are limited at Voyageurs.

1. Establish kiosks at one or more visitor centers. Each kiosk would have easy-to-follow instructions for data entry, similar to the data entry process for the Corporation of Public Broadcasting's Journey North program (http://www.learner.org/north) and the University of Minnesota's Monarch Lab program (http://www.monarchlab.umn.edu). Participants would be able to enter their own data and compare data from other observers. Ideally, the system would be connected to the Internet so that it could be accessed off site (e.g., by classrooms or the general public). We suggest two initial topics to start with:

    A. As over 70% of Voyageurs visitors engage in fishing, fishing is an ideal area to involve education. Estimating age from fish length would be an interesting and logistically simple thing to do. A measuring tape would be mounted outside the center where visitors could measure their fish. They would enter the data into the computer program, which would determine the relationship of fish length to age by species. After getting an age estimate of their fish, participants could compare their data to that of other participants. Interesting facts about the ecology of their fish (age and size range, reproduction and eating habits, etc) would also be part of the result.

    B. Secchi disk measurement of water transparency is also an easy and visible way to engage visitors in data collection. Visitors or students could check out a Secchi disk (8 in (20 cm) with black and white quadrants) attached to a cord at least 5 meters long from a visitor center. Anticipated Secchi readings would be 4 m at Namakan and Rainy Lakes, 3.4 m at Sand Point Lakes, 2.4 m at Kabetogama, and 1.5 m at Black Bay and Sullivan Bay. Participants could enter their data at the computer or on line and get a trophic state index or trophic classification of the lake they measured.

2. When visitors receive feedback from their entries, it will be couched within educational material about issues and impacts related to their topic. Examples include how regulated lake levels affect fish reproduction, growth and mercury bioaccumulation; how nutrient and sediment inputs affect water transparency; and why the different lakes have different transparencies. Information on ways to reduce impacts would also be included. The computer would also be an ideal area to link to Weekly News at the Park, naturalist-led programs, information on waste management, water conservation, geology of the area (lack of available groundwater), and the importance of clean lakes. Educating visitors would have an added benefit of perhaps enhancing appreciation of park personnel's efforts to protect the environment and its resources.

Measurable Outcomes:

The completion of this project would result in an educational kiosk set up at one or two visitor centers and the ability to access the education program through the internet. This would lead to expanded educational opportunities to park visitors and internet users about park water resources, issues and impacts.

Literature Cited:

Kallemeyn, L. W., K. L. Holmberg, J. A. Perry, and B. Y. Odde. 2003. Aquatic synthesis for Voyageurs National Park. U. S. Geological Survey Information and Technology Report 2003-0001.

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Payne, G.A. 2000. Water quality of lakes in Voyageurs National Park, northern Minnesota, 1999. U.S. Geological Survey Water-Resources Investigations Report 004281.

Budget

	Source	Item	Action #	Item Cost
Year 1:		Equipment (kiosk & website) (including hardware, software programming) (sampling equipment)	1 & 2	32,000
		RES 3 mo. @ 40k	2	10,000
			Total:	42,000

Project Statement

Title: INVESTIGATION OF POLYCYCLIC AROMATIC HYDROCARBONS IN VOYAGEURS NATIONAL PARK

Problem Statement

Abstract:

Snowmobiles and motorboats are the principal means of transportation within the park. Two-stroke engines typically discharge 10-20%, and as much as 40%, of their fuel into the environment (Hammitt and Cole 1987). Polycyclic aromatic hydrocarbons (PAHs), a group of about 100 different chemicals, are a by-product of fuel and are associated with fish deformities, fin erosion, lesions, tumors and anomalies, decreased fish weight, reproductive difficulties and decreased number of fish species (Eisler 2000). Many PAHs accumulate in tissues and can cause cancer, mutations and birth defects. Even the presence of low concentrations (parts-per-trillion range) can adversely affect fish and zooplankton through phototoxicity, whereby when PAHs become exposed to sunlight they become thousands of times more toxic (VanMouwerik 2000). To date, there has been only one small-scale investigation (USGS) into PAH contamination in Voyageurs (Alvarez and Little 2003). Extensive motorboat and snowmobile use combined with fish and water consumption in Voyageurs creates a very strong need for assessment of hydrocarbon (especially PAH) presence in the parks aquatic environment.

Background:

Voyageurs National Park (Voyageurs) was established in 1975 and is in a hydrologically complex environment. Located along the Minnesota-Ontario border, Voyageurs is part of a relatively undisturbed ecosystem of 10,930 km^2 (4,219 mi^2), which includes the 4,856 km^2 (1,875 mi^2) Boundary Waters Canoe Area Wilderness and the 4,452 km^2 (1,719 mi^2) Quetico Provincial Park. South of the park, Kabetogama State Forest and Superior National Forest lands are largely checkered with Boise Paper Company and private lands. Boise Paper Company manages its lands primarily for pulpwood production. Private landowners manage their property for pulpwood production, agriculture (grains and cattle), residential use, or recreational activities (National Park Service 1994).

Voyageurs lies within the lower end of the 38,600 km^2 (14,900 mi^2) Rainy Lake drainage, which is part of the headwaters of the Hudson Bay watershed. The Rainy Lake basin contains a complex network of lakes, ponds and connecting rivers and streams. Approximately 70% of the basin lies in Ontario with the remaining 30% in Minnesota. 38% of Voyageurs is covered by water with four major lakes (Kabetogama, Namakan, Rainy and Sand Point) comprising 96% of the park's total lake area (Kallemeyn et al., 2003). The park's 26 interior lakes have a combined surface area of 1,278 ha (3,158 acre). Visitor use of

the park is clearly water-oriented with paddling, boating, fishing, swimming, snowmobiling and cross-country skiing the primary visitor activities.

Lake levels in the park's four largest lakes are controlled by a hydroelectric dam crossing the Rainy Lake outlet at the international border between Fort Frances, Ontario and International Falls, Minnesota, and two stop-log dams at Kettle Falls and Squirrel Falls on Namakan Lake. The Namakan Reservoir consists of Kabetogama, Namakan, Sand Point, Crane, and Little Vermilion lakes. Originally, natural rock sills at the Kettle Falls and Squirrel Falls outlets of Namakan Lake controlled water levels for Namakan Reservoir. The lake levels have been artificially controlled for nearly 100 years. In 2000, a new rule curve for the Rainy and Namakan Reservoirs was put in place to approximate more natural water levels and fluctuations.

The State of Minnesota (MPCA Ch. 7050.0180) has designated the waters of Voyageurs as "Outstanding Resource Value Waters" (ORVWs). ORVWs are to be managed to prevent any degradation of their quality. Results of previous water quality studies indicate the park's waters are generally of high quality (Payne 1991, 2000). Although water quality is considered to be good, there are widespread and localized threats affecting the quality and quantity of the park's waters. There have been local instances of erosion, septic drainage and water contamination and widespread addition of petroleum byproducts and lead to park waters from snowmobiles and powerboats. Also, unnatural water level regimes have been shown to have significant negative effects on the aquatic ecology of Voyageurs (Kallemeyn et al., 1993, NPS 2003).

Description of Problem:

Fuel contamination at Voyageurs has not been well investigated, if at all. Polycyclic aromatic hydrocarbons (PAHs), a group of about 100 different chemicals, are a by-product of fuel and are associated with fish deformities, fin erosion, lesions, tumors and anomalies, decreased fish weight, reproductive difficulties and decreased number of fish species (Eisler 2000). Many PAHs accumulate in tissues and can cause cancer, mutations and birth defects. Even the presence of low concentrations (parts-per-trillion range) can adversely affect fish and zooplankton through phototoxicity, whereby when PAHs become exposed to sunlight they become thousands of times more toxic (VanMouwerik 2000). Effects on humans are of highest concern where lakes are used as drinking water and lake fish are eaten, both of which are true at Voyageurs. Also of concern are the effects hydrocarbons have on insect populations and subsequently fish populations. Hydrocarbons collect at the uppermost layer of water, a region critical to reproduction of many insect and fish species and to feeding for many birds, fish, and marine mammals.

Snowmobiles and motorboats are the principal means of transportation within the park. Two-stroke engines typically discharge 10-20%, and as much as 40%, of their fuel into the environment (Hammitt and Cole 1987). Voyageurs 1999 watercraft use is estimated at approximately 180,000 hours on Namakan, 188,000 hours on Kabetogama, and 70,000 hours on Sand Point Lake (NPS 2001, pg I-215). It has been estimated that 76,000 gallons (287,000 liters) of hydrocarbons (gas-oil mixtures) are expelled into the U.S. side of Rainy

Lake per year by motorboats and houseboats. As boats convert to four-stroke or fuel-injected engines, it is estimated that hydrocarbon emissions will be reduced to 60,000 gallons (232,000 liters) in 10 years. However, over a twenty-year period, motorboat engines would emit approximately 1.35 million gallons (5.1 million liters) into Rainy Lake. And while the newer engines reduce the amount of unburned fuel released, they do not reduce the amount of PAHs released from combustion of fuel. The 29,000 snowmobiles used in Voyageurs during the 1995-1998 seasons emitted roughly 380 tons of hydrocarbons and 1,050 tons of carbon monoxide. A USGS/NPS study on snowmobile exhaust, which includes PAH analyses, is being conducted. However this study is extremely limited as it involves only one contaminant pond and one control pond (Alvarez and Little 2003). There have been no investigations into motorboat exhaust and the presence of PAHs in sediments, fish and benthic invertebrates at Voyageurs (NPS 2001, pg I-191). A total of about 40 fueling stations on Rainy Lake, Ash River and Kabetogama Lake, including 6 park stations, exist. There are no on-going programs to monitor potential hydrocarbon leaks and spills at these fueling stations. Extensive motorboat and snowmobile use combined with fish and water consumption in Voyageurs creates a very strong need for assessment of hydrocarbon (especially PAH) presence in the parks aquatic environment.

As part of the process for developing the Water Resources Management Plan for the park, University of Minnesota researchers brought stakeholders (managers, researchers and citizen group representatives from a variety of agencies and institutions) together to identify the major issues affecting the park (October 2000). These stakeholders ranked ecological implications of contaminants as one of the top 5 issues for the park. The park's Water Resources Management Plan (2005) includes the following in its statement of goals:

Manage aquatic habitats to maintain the highest level of ecological integrity within the confines of the park's authorizing legislation and the limits of managed lake levels

Acquire sufficient information and understanding to support management decisions that protect water resources and aquatic systems from degradation

- *Acquire baseline water chemistry information*
- *Acquire baseline aquatic communities information*
- *Understand the relationship anthropogenic pollutants play in bioaccumulation in aquatic organisms*

Assessing the presence and extent of PAHs in Voyageurs' aquatic environment is essential to meeting the goals of the park and protecting the park from further contamination.

Purpose and Objectives

The purpose of this project is to determine if polycyclic aromatic hydrocarbons pose a threat to the aquatic ecology in Voyageurs.

The objective is to determine if there are significant levels of PAHs in the most likely contaminated areas of Voyageurs.

Recommended Action:

1. Determine what areas are most likely to have the highest PAH contamination. This will be determined by finding the lakes with the highest snowmobile and motorboat use and finding where sediment accumulation in the lakes is highest (generally steep, deep parts of a lake).

2. Once likely contamination areas are identified, sediment core samples will be taken and analyzed for PAH presence and concentrations. PAH concentrations will be compared to established criteria (e.g. TEL (Threshold Effect Level) and PEL (Probable Effect Level)) to determine if they are a potential threat (USEPA 1996, Cubbage and Batts 1997, Di Toro and McGrath 2000).

3. Results of the study will be analyzed. If PAHs are determined to be a potential threat to the parks aquatic environment, we will produce a report outlining the need and the steps for a more thorough and intensive investigation of this contaminant throughout the aquatic ecosystem. If appropriate, we will recommend actions to reduce and/or eliminate further impacts.

Measurable Outcomes:

With the completion of this project, the park will know if PAHs are a threat to its aquatic resources and will have a document summarizing results and outlining further steps to be taken to address this issue if needed.

Literature Cited:

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Cubbage, J. and D. Batts. 1997. Creation and Analysis of Freshwater Sediment Quality Values in Washington State. Washington State Department of Ecology. Publication number 97-323a.

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National Park Service, U.S. Department of the Interior. 2005. Voyageur National Park Water Resources Management Plan. Voyageurs National Park, MN.

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VanMouwerik, M. 2000. *Water quality concerns related to personal watercraft usage. Natural Resource Year in Review--1999;* published by the National Park Service, U.S. Department of the Interior, August 2000 (publication D-1406) http://www.aqd.nps.gov/pubs/yir/yir99/pages/05risks/03vanmouwerik_pwc.htm

Budget

	Source	Item	Action #	Cost
Year 1:		RES 6 mo. @ 40k	1,2,3	20,000
		2 TECH 3 mo. @20k	2	10,000
		Supplies (sampling devices and accessories)	2	5,000
		Sample processing (20 samples)	2	10,000
		Transportation (truck and boat)	2	1,500
			==========	==========
			Total:	$46,500

Appendix A

Water Resource Management Issues Survey

Survey #_____

Water Resource Management Issues for Voyageurs National Park

Listed inside are water resource issues for Voyageurs National Park that have been identified from stakeholder input. Please indicate how important you feel each issue is to park management. If you have additional issues you feel are important, please add those at the end of the survey. *(Please circle one response for each issue)*

	Extremely Important	Very Important	Important	Somewhat Important	Not Important
Water Quality					
For Voyageurs National Park, how important is…….					
a. Having enough information to determine if water quality is degrading	1	2	3	4	5
b. Investigating the surface water quality parameters that have exceeded EPA criteria for freshwater aquatic life protection	1	2	3	4	5
Fisheries					
For Voyageurs National Park, how important is…….					
a. Knowing what limits fish production	1	2	3	4	5
b. Assessing the long term health of walleye populations	1	2	3	4	5
c. Assessing Lake Sturgeon populations (Sturgeon are a state and federal species of concern).	1	2	3	4	5
d. Having enough information about fish populations to set harvest limits that allow maximum take without endangering the population	1	2	3	4	5
e. Determining if deteriorating water quality is influencing fisheries	1	2	3	4	5
f. Having fisheries data from Canada in order to know what is going on with fish populations in the border lakes	1	2	3	4	5
g. Determining the health of each level of the food chain (algae, insects, frogs, crayfish & mussels, fish) so that we can understand impact, population limits and production	1	2	3	4	5
Exotics					
For Voyageurs National Park, how important is…….					
a. Finding out if rainbow smelt introductions are displacing native species	1	2	3	4	5
b. Determining if some bays are being filled in by purple loosestrife infestations	1	2	3	4	5
c. Examining the potential for spiny water flea invasion	1	2	3	4	5
d. Determining the potential for zebra mussel invasion	1	2	3	4	5

	Extremely Important	Very Important	Important	Somewhat Important	Not Important
Exotics (continued)					
For Voyageurs National Park, how important is…….					
e. Examining the potential impacts from a rusty crayfish invasion	1	2	3	4	5
f. Determining the potential for Eurasian watermilfoil invasion	1	2	3	4	5

Impacts *For Voyageurs National Park, how important is……..*					
a. Further investigation into the consistent and increasing detections of contaminants (particularly mercury) in fish and other components of the Park's aquatic ecosystem	1	2	3	4	5
b. Investigating whether Canadian refineries and dischargers are impacting the resources within the Park	1	2	3	4	5
c. Looking into the deformities in dragonfly and frog populations	1	2	3	4	5
d. Careful monitoring of ecosystem effects of water level changes due to the recent rule curve changes	1	2	3	4	5
e. Studying the impacts of regulated lake levels on the flora and fauna	1	2	3	4	5
f. Determining if some roads may be cutting off flow from one water body to another	1	2	3	4	5
g. Examining effects of global climate change	1	2	3	4	5
h. Studying impacts associated with motorboat or snowmobile use on water quality and the aquatic ecosystem	1	2	3	4	5
i. Assessing the potential water quality impacts of the Park's fire management program	1	2	3	4	5
Waste issues *For Voyageurs National Park, how important is……..*					
a. Determining the extent of gray water discharge into the lakes	1	2	3	4	5
b. Assessing impacts of gray water discharge on water quality	1	2	3	4	5
c. Finding a solution to overloaded sewers spilling wastes into the lakes	1	2	3	4	5
d. Reviewing and improving septic tank management	1	2	3	4	5
e. Finding alternatives to soil-based wastewater treatment systems	1	2	3	4	5
	Extremely Important	**Very Important**	**Important**	**Somewhat Important**	**Not Important**
Coordination *For Voyageurs National Park, how important is……..*					
a. Seeking to resolve inconsistencies in guidelines and regulations between US and Canada resource management	1	2	3	4	5
b. Studying the influence that waters coming from Canada have on the waters in the Park (70% of Park waters come from Canada)	1	2	3	4	5
c. Ensuring county interests are represented in Park management	1	2	3	4	5
d. Educating the community and visitors about issues and impacts in the Park	1	2	3	4	5
e. Involvement of Park in water basin planning efforts	1	2	3	4	5
Additional issues (specify):					

	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5

In addition to the information from this survey, we are interested in speaking with you and other stakeholders to gather more detailed information about water resource issues for Voyageurs National Park. Would you be willing to talk with someone in more detail about park management issues (approximately 5-10 minutes of your time)?

No _____

Yes _____ When would be a good time to reach you? _____

Phone Number to reach you: _____

Thank you for your help!

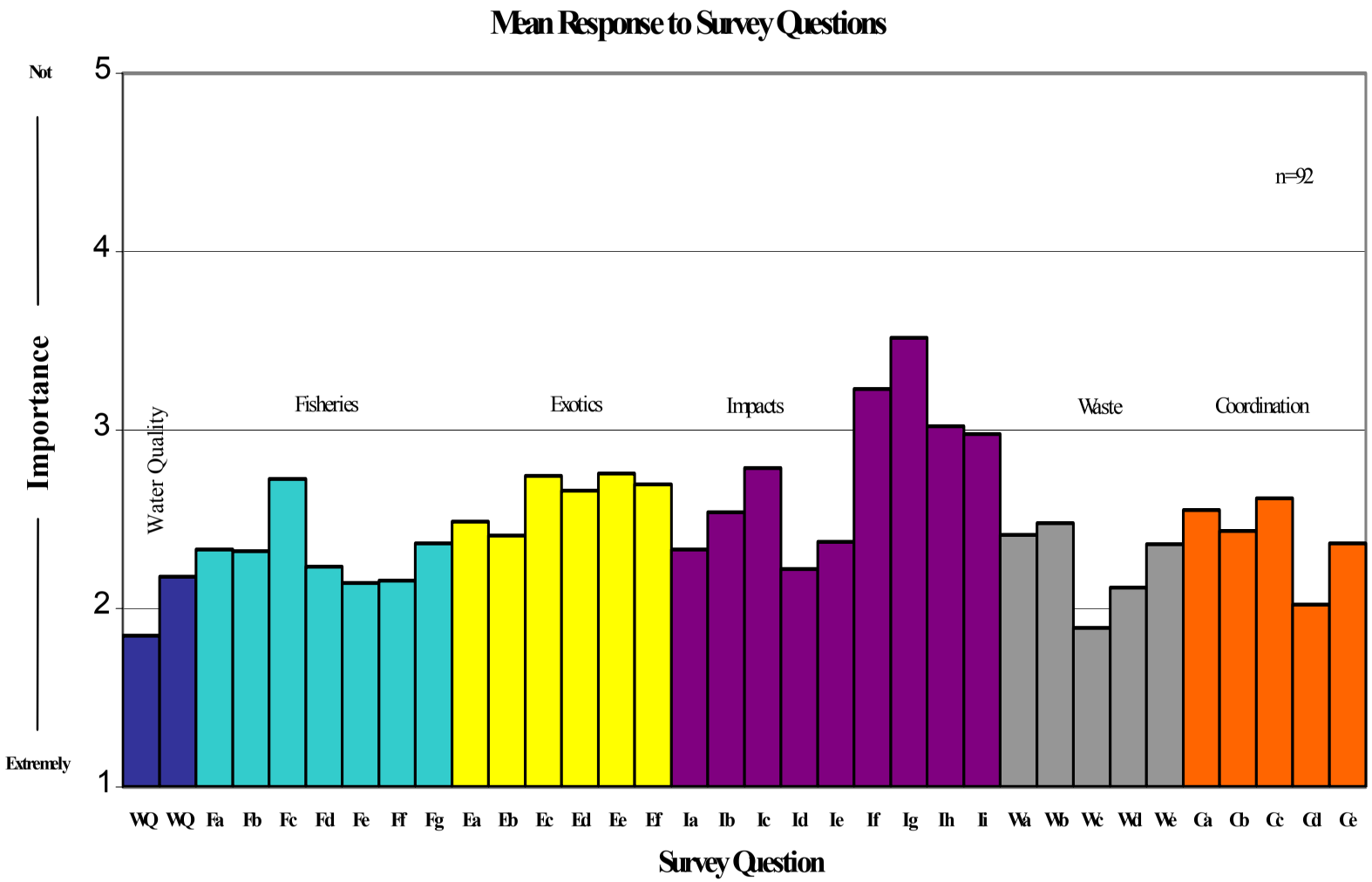
Please return this survey using the prepaid, self-addressed envelope provided

If you want more information about this project, contact Kerry Holmberg, University of Minnesota, 115 Green Hall, 1530 Cleveland Avenue North, St. Paul, MN 55108, 612-624-3722

Appendix B

Mean Survey response by question

Note: Please refer to Appendix A for questions. 1= Extremely Important, 2=Very Important, 3= Important, 4=Somewhat Important, 5= Not Important



Appendix C

Scoping workshop participants

Participants in NPS Voyageurs National Park Scoping Workshop
October 18-19, 2000

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October 18-19, 2000

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Appendix D

Data Sources List for Voyageurs National Park

Data Source/ Literature	Contact	Type/Format/ # Pages	Period of Record	Site Location	Main Data Fields	Other Data Fields
Minnesota Department of Natural Resources Fish Data. See separate table following this one.	Alan Anderson MN Department of Natural Resources 392 Highway 11 East International Falls, MN 56649 alan.anderson@dnr.state.mn.us	hard copy and digital reports, spreadsheets, 1992- on .dbf	See separate table following this one.	See separate table following this one.	See separate table following this one.	
Minnesota Department of Natural Resources Annual Water Quality Data. 1983- present.	Alan Anderson MN Department of Natural Resources 392 Highway 11 East International Falls, MN 56649 alan.anderson@dnr.state.mn.us	digital database	1983-present	Rainy and Kabetogama	Basic water quality	
Mercury in Water Research - Interior Lakes. Mark Brigham/Jeff Jeremiason	Mark Brigham US Geological Survey 2280 Woodale Dr. Moundsview , MN 55112 mbrigham@usgs.gov	digital spreadsheet	2000-2002	About 12 interior lakes	Aqueous mercury species and gaseous fluxes	
Factors Influencing the Distribution, Abundance, and Reproductive Success of Ospreys in Voyageurs National Park, Minnesota. 1988. Francesca Cuthbert and Arlene Rothstein	Francesca Cuthbert University of Minnesota St Paul, MN 55108	hard copy report, possible digital 42 pages	1985-1986	Rainy, Kabetogama and Sand Point	Reproductive and fledgling success	
Interior Lake Water Chemistry Data. Gary Glass	Gary Glass University of Minnesota-Duluth 10 University Drive Duluth, MN 55812 gglass@d.umn.edu.	digital database	1978-1983	Four interior lakes	Detailed water chemistry	
Baseline Water Quality Data Inventory and Analysis - Voyageurs National Park. 1995. National Park Service	Chris Holbeck Voyageurs National Park 3131 Highway 53 International Falls, MN 56649 Chris_Holbeck@nps.gov	hard copy, .DBF database format report 366 pages + appendices	1967-1984	98 Stations within the Park study area	Water chemistry, hydrologic parameters, some biological parameters	location, collecting agency, discharger locations, many others

Data Source/ Literature	Contact	Type/Format/ # Pages	Period of Record	Site Location	Main Data Fields	Other Data Fields
Ecological Analysis of the Plankton Communities of Voyageurs National Park, Completion Report. 1981. Jack R. Hargis, *et al.*	Larry W Kallemeyn US Geological Survey - International Falls Biological Station 3131 Hwy 53 International Falls, MN 56649 larry_kallemeyn@usgs.gov	hard copy report 27 pages + appendices	1979	Rainy, Kabetogama, Namakan, Sand Point, Crane & interior Lakes	Basic water chemistry, nutrients, Chlorophyll, zooplankton	
Evaluation of the Effects of Invasions or Introductions of Exotic Fish Species on Voyageurs National Park's Native Fish Community and other Components of the Aquatic Food Web. 1995.	Larry W Kallemeyn US Geological Survey - International Falls Biological Station 3131 Hwy 53 International Falls, MN 56649 larry_kallemeyn@usgs.gov	in press report	1996-2002	Rainy	Hg in smelt, growth of smelt and predators, food habits	
USGS/Voyageurs Water Quality Data.	See above	digital/hardcopy spreadsheet/field sheets	1981-present	Rainy, Kabetogama, Namakan, Sand Point	Basic water quality	
USGS/Voyageurs Interior Lake Water Quality Data.	See above	hardcopy field sheets	1981-1984	Many interior lakes	Basic water quality	
Opossum shrimp sampling (*Mysis relicta*).	See above	Hard copy/digital Some spreadsheet	1996-present	Primarily Rainy Lake	bi-weekly counts, age, size and sex	
Physical and Chemical Factors Affecting Primary Production in the Voyageurs National Park Lake System. 1988. Raymond L. Kepner, *et al.*	Ray Kepner Marist College Donnelly Hall 290 North Road Poughkeepsie, NY 12601 ray.kepner@marist.edu	digital report and spreadsheet 115 pages +	1985-86	Rainy, Kabetogama, Namakan, Sand Point Lakes	Basic water chemistry, nutrients, major ions, primary productivity	Phytoplankton
Effect of Increased Winter Drawdown on Benthic Macroinvertebrates in Namakan Reservoir, Voyageurs National Park. 1989. Kenneth J. Kraft	Kenneth Kraft Michigan Tech University Houghton, MI 49931	hard copy report, possible digital 76 pages	1983-86	Rainy and Namakan Lakes	Benthic invertebrates, sediments	

Data Source/ Literature	Contact	Type/Format/ # Pages	Period of Record	Site Location	Main Data Fields	Other Data Fields
A Comparison of Aquatic Macrophyte Communities in Regulated and Non-Regulated Lakes, Voyageurs National Park and Boundary Waters Canoe Area. 1989. James E. Meeker, *et al.*	James Meeker Northland College, Ashland, WI 54806	hard copy report, possible digital 39 pages	1987	Rainy, Namakan and Lac La Croix Lakes	Species importance	
The Summer Sportfishery in Voyageurs National Park and Surrounding Waters for 1977 and 1978. 1980. D. Ernst & T.C. Osborn	Minnesota Department of Natural Resources 500 Lafayette Rd N St Paul, MN 55155	hard copy report 37 pages	1977 and 1978	Rainy, Kabetogama, Namakan, Sand Point, & Crane Lakes		
An Analysis of the Effects of Fluctuating Water Levels on Littoral Zone Macrophytes in the Namakan Reservoir / Rainy Lake System, Voyageurs National Park. 1986. Paul H. Monson	Paul Monson University of MN, Duluth, MN	hard copy report, possible digital 273 pages	1982-83	Rainy, Kabetogama, Namakan & Sand point Lakes	species, biomass, site physical characteristics	
Water Quality of Lakes in Voyageurs National Park, Northern Minnesota, 1999. 1999. G.A. Payne	USGS-Water Resources Division 2280 Woodale Dr Mounds View, MN 55112 greg.payne@usgs.gov	database report and Storet 12 pages	1999	VNP 4 big lakes	Basic water chemistry, nutrients, trace metals, trophic status	
Water Quality of Lakes and Streams in Voyageurs National Park, Northern Minnesota, 1977 - 84. 1991. G.A. Payne	USGS-Water Resources Division 2280 Woodale Dr Mounds View, MN 55112 greg.payne@usgs.gov	database report and Storet 95 pages	1977-1984	VNP 4 big lakes, 19 interior lakes, Ash and Namakan River	Basic water chemistry, nutrients, trace metals, trophic status	
The effect of regulated lake levels on muskrats, *Odatra zibethicus*, in Voyageurs National Park, Minnesota. 1988. J.M. Thurber and R.O. Peterson	Rolf Peterson Michigan Tech University Houghton, MI 49931	hard copy report, possible digital 27 pages	1984-1987	Rainy and Kabetogama	Population, densities, standard body measurements, house counts	

Data Source/ Literature	Contact	Type/Format/ # Pages	Period of Record	Site Location	Main Data Fields	Other Data Fields
The Effects of Regulated Lake Levels on Beavers in Voyageurs National Park. 1988. Douglas W. Smith and Rolf O. Peterson	Rolf Peterson Michigan Tech University Houghton, MI 49931	hard copy report, possible digital 84 pages	1984-1987	Rainy, Namakan and Kabetogama	Population and standard body measurements	Movement, growth weights and over-winter weight loss from recaptures
Distribution and Abundance of River Otter in Voyageurs National Park, Minnesota. 1988. William T. Route and Rolf O. Peterson	Rolf Peterson Michigan Tech University Houghton, MI 49931	hard copy report, possible digital 62 pages	1985-1987	Rainy and Namakan Lakes	Population, productivity and home ranges	Prey based on scat analysis
Effects of Regulated Lake Levels on the Reproductive Success, Distribution and Abundance of the Aquatic bird Community in Voyageurs National Park. 1988. M. Hildegard Reiser	M Hildegard Reiser Northern Arizona University . Flagstaff, AZ 86011 .	hard copy report, possible digital 67 pages	1983-1986	Four big lakes and some interior	Population, territories, reproductive parameters of loons and red-necked grebes	some information on other shorebirds
The effect of exotic rainbow smelt (Osmerus mordax) on nutrient/trophic pathways and mercury contaminant uptake in the aquatic food web of Voyageurs National Park. 2001. J. Sorensen, G. Rapp Jr. and G.E. Glass	John Sorensen University of Minnesota-Duluth 10 University Drive Duluth, MN 55812 jsorense@D.umn.edu.	hard copy report possible digital	1996-1998	Rainy and Namakan Lakes	stable isotope ratios of carbon and nitrogen in aquatic plants and animals	
Trophic Ecology of Largemouth Bass and Northern Pike in Allopatric and Sympatric Assemblages in Northern Boreal Lakes. 2000. Craig A. Soupir, Michael L. Brown, Larry W. Kallemeyn	Craig Soupir South Dakota State University South Dakota State University Brookings, SD 57007 csoupir@hotmail.com	journal article possible digital 8	1996-1997	Six interior lakes	Food habits of largemouth bass and northern pike	
Interior Lake Water Chemisty Data. Kathleen Webster	Kathleen Webster Wisconsin Department of Natural Resources 1350 Femrite Dr. Monona, WI 53716 WebstK@mail01.dnr.state.wi.us	digital database	1983-1995	Four interior lakes	Detailed water chemistry	

Data Source/ Literature	Contact	Type/Format/ # Pages	Period of Record	Site Location	Main Data Fields	Other Data Fields
Mercury in Fish Research - Interior Lakes. Jim Wiener, Knights, Helwig, Kallemeyn	Jim Wiener University of Wisconsin Cowley Hall, Room 4032 La Crosse, WI 54601 wiener.jame@uwlax.edu	digital spreadsheet	2000-2003	About 12 interior lakes	Mercury concentration, length, weight and age of 1-year-old perch	
Mercury in Soils Research - Interior Lakes. Laurel Woodruff/Bill Cannon	Laurel Woodruff US Geological Survey 2280 Woodale Dr. Moundsview , MN 55112 woodruff@usgs.gov	digital spreadsheet	2000-2002	About 12 interior lakes	Mercury in soils, rocks and wetlands in watershed	
Status and Trends of Selected Inland Lakes of the Great Lakes Cluster National Parks. Whitman et al.	Richard Whitman USGS-GLSC-LMES 1100 N. Mineral Springs Rd Porter, IN 46304	Hardcopy	1997-1999	Locator and Mukooda lakes	Water chemistry, zooplankton, phytoplankton, benthos	

Lakes Routinely Sampled by MN Department of Natural Resources in Voyageurs National Park

Survey Rotation	Initial	Last																																			
Lake Name	(years)	Survey	Assmt.	Pre-1970 Invest.	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02
Agnes	20	1971	1999			SU								SP																			SU			
Beast	15	1970	2001		IS				PA				PA			PA?																			SU	
Cruiser	10	1983	1995		IS													PA												PA						
Ek	10	1972	1996				IS							PA																	SU					
Kabetogama	1	1946	2002	IS 46, PA 66	PA			PA				PA			PA			LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS
Locator	10	1983	2000		IS													SU																SU			
Loiten	10	1989	2001		IS													SU						PA			PA	PA							SU		
Mukooda	5	1983	2002	IS 69														SU				PA				PA			PA			SU					PA
Namakan	1	1962	2002	IS 62, SU 63, 66				PA		PA			PA			PA		PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA
O'Leary	15	1972	2001	SU 60										PA																					SU		
Oslo	15	1971	1983	SU 60		SU												SU																			
Peary	15	1971	1983	SU 60		SU												SU																			
Quill	10	1983	2002		IS													SU									PA	PA									SU
Rainy	1	1959	2002	IS 59, PA 58, 63, 65, 67	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS
Ryan	15	1973	1973	SU 60				SU																													
Sand Point	1	1970	2002	IS 70	PA			PA						PA			PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA	PA
Shoepack	15	1983	1999		IS													SU															SU			
Shoepack, Little	15	1983	1999		IS													SU															PA			
Trout, Little	5	1983	1999	PA 69				SP										SU								PA			PA				SU			
War Club	10	1983	2000		IS													SU																SU			

IS = initial survey, **SU** = survey (includes fish community indices, water chemistry, aquatic macrophyte surveys, watershed characteristics, fish disease investigations, tissue contaminant levels, spawning habitat surveys, inlets/outlets and water level surveys) **PA** = population assessment (includes population indices)
LS = large lake survey (includes various netting techniques, night electrofishing, shoreline seining throughout the summer, biweekly temp/D.O. profile monitoring, and on Rainy, open water angler creel surveys, small mesh gill netting for rainbow smelt and trap netting for black crappie.
ALSO: Creel surveys on Kabetogama, Namakan and Sand Point Lakes are conducted two consecutive years out of every six, and angler creel surveys were conducted on Mukooda and Little Trout Lakes during the winter of 2002.

APPENDIX E

Aquatic Synthesis for Voyageurs National Park –
included as a separate document and in compact disc format

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.

VOYA D-148, April 2005