Habitat Division Technical Report 93-2

Wetland Classification, Inventory, and Assessment Methods

An Alaska Guide to their Fish and Wildlife Application

Alaska Department of Fish and Game
Habitat Division
Juneau, Alaska

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Alaska Department of Fish and Game
Habitat Division
P. O. Box 240020
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Wetland Classification, Inventory, and Assessment Methods:

An Alaska Guide to their Fish and Wildlife Application

by Janet Hall Schempf

Alaska Department of Fish and Game
Habitat Division
Juneau, Alaska

October 1992

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Table of Contents

APPENDICES

List of Tables

List of Figures

Acknowledgements

This guide began with recognition of a need for Alaska biologists and others responsible for fish and wildlife habitat to be familiar with wetland classification, inventory, and functional assessment. The idea was submitted to the U.S. Environmental Protection Agency (EPA) as a grant application, and EPA agreed to fund a review of classification, inventory, and assessment methods that may be appropriate for use in an area as varied as Alaska.

Success of the project would not have been possible without the contribution of many interested offices and individuals. We would especially like to recognize the contributions of the following:

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Preface

The intent of this document is to help fish and wildlife agencies, and local governments responsible for developing the fish and wildlife elements of wetland planning efforts, understand the relative merits and limitations of various wetland classification, inventory. and assessment methods.

Alaska wetlands have been estimated to total between 130 and 300 million acres, but 170 million acres (Dahl 1990) is considered by some as the most credible approximation. These wetlands are highly variable and include intertidal areas; forested areas along the southeastern and southcentral coastlines; extensive river and stream drainages, including large river deltas and complexes of lakes and ponds known as "flats" in the Interior; extensive taiga; and poorly drained tundra.

These and other highly varied wetland types contribute to the mosaic of habitats so essential to Alaska's diverse and abundant fish and wildlife populations. Unlike other states, most of Alaska still supports the same basic complexes of plant and animal species that existed prior to European settlement. The state offers an exceptional opportunity to learn from several centuries of experience in the "Lower 48 States" and to ensure that wetlands are managed so that their functions and values can continue to be realized. This will be an increasing challenge as the pace and magnitude of human settlement, land subdivision, and natural resource development continue to increase.

Wetland functions that are of direct biological value to fish and wildlife include those such as living space, food supplies, refuge from predation, and opportunities for reproduction. Examples of functions and values that are at least indirectly important to fish and wildlife, as well as humans, are nutrient cycling, flood control, filtering and degradation of contaminants, and groundwater exchange.

The solution to wisely managing Alaska's wetlands for fish and wildlife, while recognizing the value to society of utilizing other natural resources, lies in careful land management planning. Similar to other types of land use planning, it is necessary to know what kinds of wetlands exist in an area, what functions these wetlands provide for fish and wildlife and other values important to human use, where and how extensive these wetland types are, their tolerances and sensitivities regarding human-induced disturbances, and the measures that can be taken to avoid, minimize, or otherwise mitigate against such disturbances.

This document can be thought of as a "buyer's guide" to wetland inventory and assessment methods, and it has been organized according to the criteria against which these methods can be comparatively evaluated. Some of these criteria are administrative, such as the relative costs of applying various wetland inventory or assessment methods. Others have more to do with the level of resolution at which a method will detect wetland functions and values important to fish or wildlife species.

Despite the availability of sophisticated satellite imagery and high altitude aerial photography, there may, for example, be no substitute for verifying the presence of coho salmon rearing habitat than to don one's rubber boots and slog through emergent wetland vegetation in search of darting juvenile fish. Whether this proves necessary will depend on the amount of detail needed for the level of planning undertaken.

Another criterion may be used to describe an inventory or assessment method's ability to reflect the land forms and habitat uses surrounding a wetland. It may, for instance, be important to know why one wetland habitat is utilized as swan nesting habitat when another, with apparently the same potential, is not. One wetland evaluation method may reveal that a nearby human activity or facility has inhibited nesting while another method may be insensitive to this disturbance.

Similarly, it may be important to pick a wetland evaluation method that is sensitive to the indirect as well as direct benefits that a wetland has for fish or wildlife. For example, although a particular black spruce bog may not be used by a wildlife species for foraging or rearing its young, it may provide an important indirect benefit as a movement corridor or as a buffer surrounding an area that is used for these purposes. Another indirect benefit of such a bog, at least in nonpermafrost areas, may be the effect it has in modulating extremely high or extremely low water flows in a nearby stream. By preventing severe torrents and droughts, the hydrologic stability necessary for the spawning and rearing of economically important salmon may be ensured. One method of analyzing wetland functions and values may do a very good job of revealing a wetland's benefits to a larger local ecosystem and another may not.

These then are the kinds of considerations that this guide is designed to help biologists and others take into account as they attempt to size up the relative usefulness of a variety of wetland inventory and assessment methods. In actual application, guide users are likely to encounter an iterative process in which major categories of wetlands need to be identified in order to begin analyzing their respective functions and values. As these functions and values become better understood, it may be necessary to refine the categories and identify subcategories to ensure a meaningful representation of wetland types.

And finally, the reader will find information in the appendices on matters such as sources of satellite imagery and aerial photographic coverage.

Some of the greatest values of Alaska's wetlands have to do with fish and wildlife populations, and it is important that those charged with representing the human use of these valuable resources be sufficiently informed to ensure that the biological elements of wetland inventory and assessment efforts are creditable. If this guide helps achieve this, it will be a success.

Bruce Baker
Former Deputy Director
Habitat Division
Alaska Department of Fish and Game

Preface

Figure

GENERALIZED \
OF ALA

LEGEND

Alpine Tundra

Moist Tundra

Wet Tundra

Muskeg

Freshwater Rivers, Lakes
and Riparian Habitat

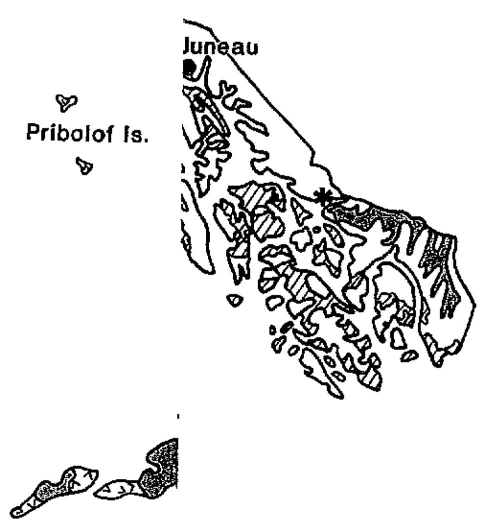
St. Lawr
Is.

Coastal Wetlands

Coastal Wetlands are located in many areas along Alaska's coastline.

St. Matthew
Island

from Quinlan et al. 1983 and Hall 1991.



Chapter I

Introduction: How to Use This Guide

A. BACKGROUND

Protection of important fish and wildlife wetland habitats requires that these habitats first be located and then evaluated. To succeed in wetland protection efforts, local, state and federal agencies must be able to assess the extent and nature of their wetlands. Management of these habitats can then be accomplished through a variety of jurisdictional means.

This guide has been written to provide guidance and direction for local and regional wetland inventory and assessment efforts and to facilitate consistency in wetland inventories and assessments statewide. The guide is intended primarily for use by biologists working in state and federal agencies, although local planners and other groups interested in wetland inventories may find it helpful.

The guide summarizes well known or widely used wetland inventory methods and related information sources, and compares and evaluates wetland assessment criteria and methods from the view of fish and wildlife habitat. The Department hopes the guide will foster a better understanding of various assessment techniques and their appropriate application and calibration in different Alaskan wetland types or physiographic regions, and for different planning or permitting purposes.

B. METHODOLOGY USED IN PREPARING THIS GUIDE

A search of wetland related literature was conducted to identify existing methods for classification and assessment of wetlands. The initial phase of the search was through the Western Library Network, Online Computer Library Center Network, and Dialog Information Services[1] with keyword search techniques. A personal outreach to individuals known to the Alaska Department of Fish and Game (ADF&G) to be familiar with wetland inventory and assessment, and with the Alaska situation, was then begun to gather unpublished literature. These contacts led to searches of the U.S. Fish and Wildlife Service grey literature data base and the "Wetland Functions and Values Data base" maintained by National Wetland Inventory for titles specific to Alaska.

The literature search identified review papers, books, conference proceedings, journal articles, and published bibliographies on wetland classification, inventory, and assessment. Although every effort was made to review each of these sources, some were simply unobtainable.

We sought specific methods that, under the varied conditions in Alaska, use biological and physical indicators or characteristics that identify which wetlands provide specific functions important to fish and wildlife. Some wetland functions are generally studied from a public health, welfare, and safety view; these functions often benefit fish and wildlife

[1]Dialog Information Services is a compilation of over 300 data bases. The following data bases were especially helpful: Environmental Bibliography, Enviroline, Life Sciences Collection, Waternet, NTIS (National Technical Information Services), Biosis, Scisearch, and CAB Abstracts (Commonwealth Agricultural Bureaux).

species and are included in our evaluation of the various assessment methods.

C. EXPLANATION OF REVIEW CRITERIA

Members of the Habitat Division selected 15 criteria for evaluating rapid assessment methods.

Applicability to Local Wetland Types: Alaska wetlands are varied. Estuarine, tidal freshwater, freshwater, permafrost underlain, and peatbog are some common wetland types. Inventory, classification, and assessment methods should be appropriate for the type of wetland being studied.

Applicability to Wetland Functions of Special Concern: Some communities may wish to emphasize habitat of a particular species or group of species. Classification and assessment methods chosen for this application should be designed for sensitivity to that habitat.

Duration of Time Required: Varying amounts of time may be available for a wetland study. The amount of time available interacts with size, complexity, and accessibility of study area, amount of data readily available and number of skilled personnel to commit to the study. Duration of time available will affect additional data collection and accuracy and detail of final products.

Personnel Required: The number of personnel required for a particular method can affect the overall cost as well as duration of time required to complete the project.

Skills and Proficiency Level Required: Some methods require particular skills; training is required or recommended for others. Data collection requires skills and proficiencies appropriate to the task.

Equipment Required: Some methods require simple field equipment such as binoculars, field notebook, rubber boots, and insect repellant. Others are more complicated, and may require sophisticated field and laboratory equipment. Equipment required for an application will vary with the amount and kind of data readily available, desired accuracy and detail of final products, the amount and kind of data which must be collected during the project, and available budget.

Data Required: Data requirements vary from very simple to very detailed and complex. At one end of the data scale is a species occurrence list, and at the other end detailed hydrologic and soils data.

Usefulness of Interim and Final Products: Usefulness of products relates to the purpose of the study. Maps must provide adequate information yet be readable. Interim products are related to organization of available data, identification of data gaps, and ground truthing. Final products are designed to meet the overall purpose of the project. Constraints on interim and final products relate to equipment requirements, production capabilities, kind of data that is to be presented and the best way to present that data, and available budget.

Accuracy: Accuracy is affected by study method, quality and quantity of data, and available budget.

Repeatability: Weak assumptions of a study method and the use of subjectivity rather than measurements decrease repeatability. Repeatability is enhanced in a method that is well based in scientific literature, field work, and accurate data collection and interpretation.

Ground Truthing: Ground truthing generally increases accuracy, which is desirable. Ground truthing can substantially increase the costs of a project, especially if a study area is large or access is difficult.

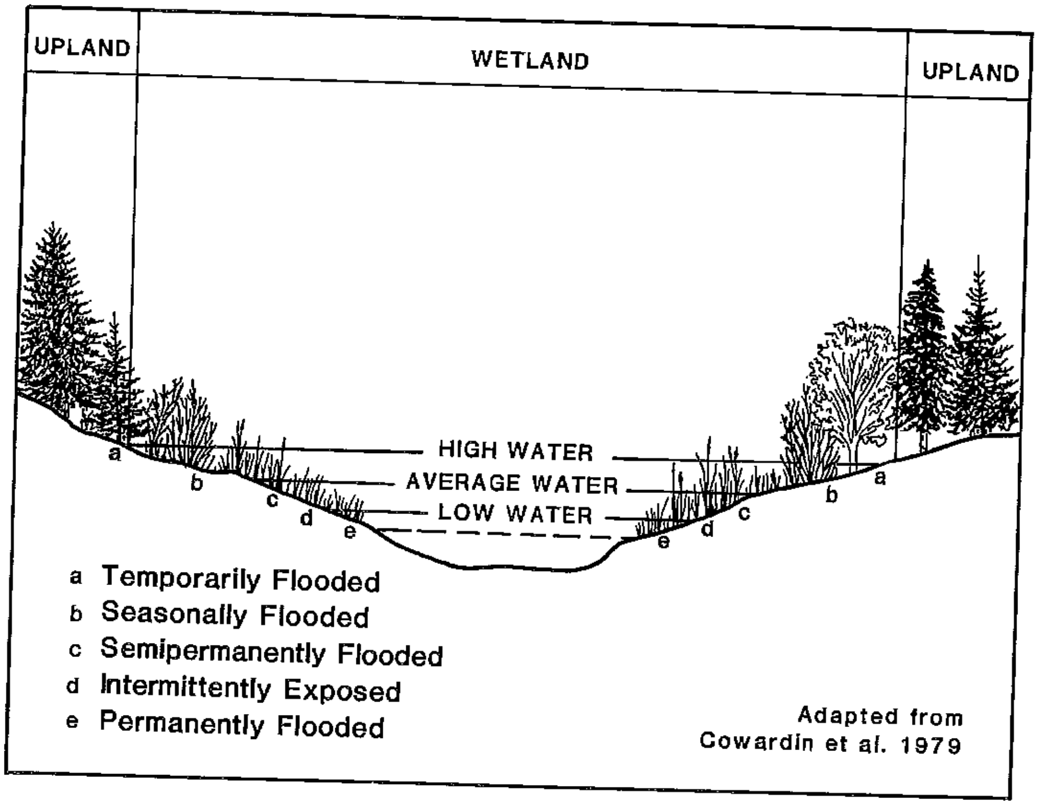
Relative Rating System: Some methods rank individual wetland functions, some generate an overall rank for a wetland, and others rank opportunity of a wetland to perform a function.

Cost: Cost can vary with study area size and accessibility, the amount of data available and the amount that is to be collected. Simpler methods, which may require only binoculars and bird species lists, are likely to be on the low end of the scale. More sophisticated or more thorough methods can cost many thousands of dollars.

Sensitivity to Ecosystem Considerations: Some methods classify or assess only the area delineated as wetlands. Other methods consider wetland placement in the watershed, connectivity to surface or ground water, nearby upland cover type, and other landscape features (Figure 2, Page 7).

Sensitivity to Fish and Wildlife Habitat Values: Some systems are sensitive to particular habitat requirements of certain species (for example, salmon spawning but not salmon rearing or waterfowl breeding).

Just as "there is no single, correct, indisputable, ecologically sound definition for wetlands" (Cowardin et al. 1992), this literature review indicates that there is no perfect classification system or assessment technique. Consequently, several examples of "regionalized" methods are included to inspire tailoring a technique to a local or regional situation. Our review includes several evaluation methods from glaciated eastern North America. These methods may have limited application to glaciated areas of Alaska (Figure 3, Page 8) but are included because they are well known methods. The following chapters are organized by general categories of "Wetland Inventory and Classification Systems" and "Wetland Assessment Methods." The appendices include additional information useful for planning a wetland inventory or assessment project.



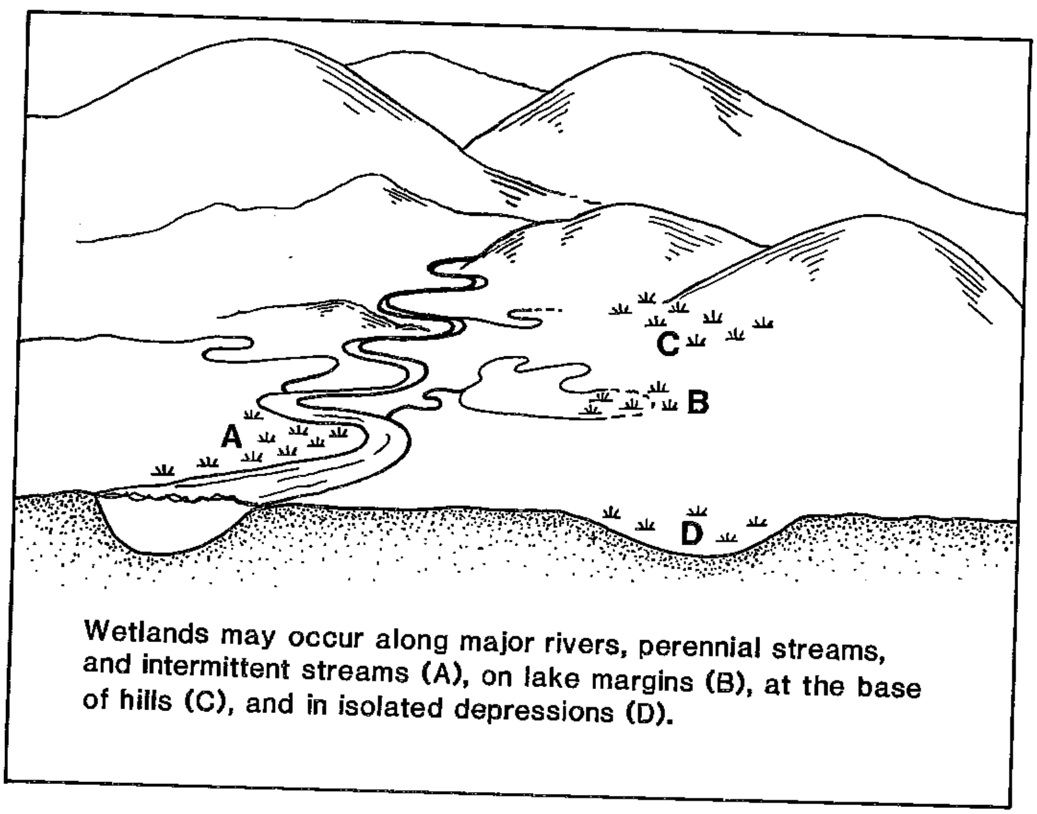


Figure 2. Some wetland assessment methods consider the changing nature of wetland conditions (top). Other assessment methods consider wetland position in the watershed (bottom).

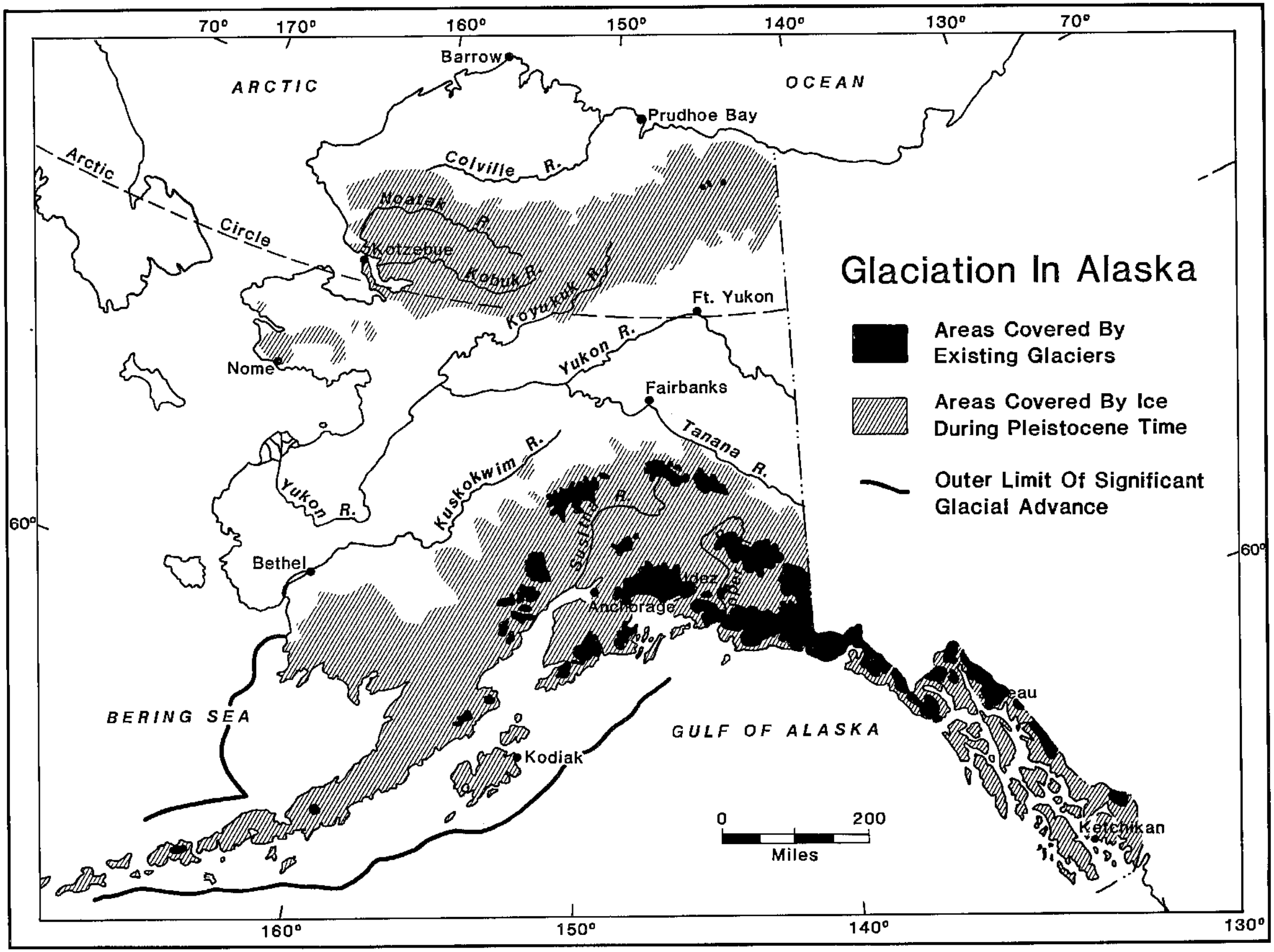


Figure 3. Glaciation in Alaska. Wetland inventory and assessment methods designed for use in the glaciated northeast may be adaptable to some Alaska sitr (Source: Hartman and Johnson 1978)

Chapter II

Wetland Inventory and Classification Systems

Wetland classification is not possible without first setting a definition of "what a wetland is" and establishing protocols for delineating wetland boundaries. While establishment of wetland boundaries (Figure 4, Page 10) is outside the scope of this publication, wetland definition is fundamental to a successful inventory and classification program.

A. WETLAND DEFINITIONS

The word *wetland* elicits various images and concepts. A person's experience largely defines that individual's answer to "What is a wetland?" Salt marshes and prairie potholes are common stereotypes of wetlands, but in reality, wetland types range from permafrost-underlain bogs in the Arctic to tropical mangrove swamps.

Wetlands have many names and many definitions. Names like *bog, fen, swamp, marsh, wet tundra*, or *muskeg* are familiar to wetland ecologists and the public at large. Often, these terms have different meanings for different people, and the variation in meaning can be subtle or substantial. Before wetlands can be delineated, classified, inventoried, or functionally evaluated, terminology must be established.

Alaskans use the terms *muskeg* and *tundra* for wetlands throughout much of the state. *Muskeg* is of Algonquin Indian origin (Dachnowski-Stokes 1941) and is applied "to natural and undisturbed areas covered

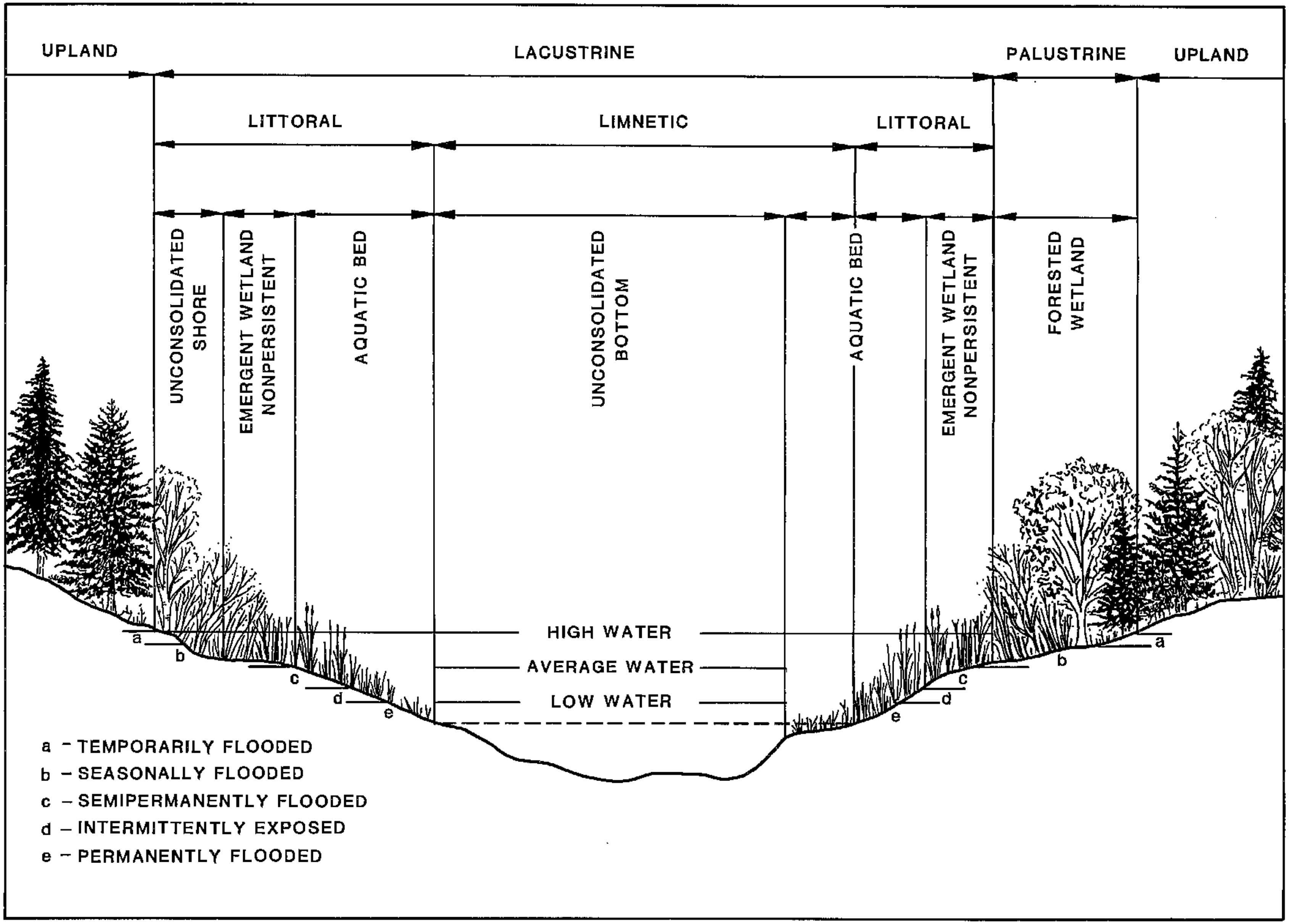


Figure 4. Wetland boundary delineation may be subject to local, state or federal regulation. Wetland inventory and assessment studies should use the U. S. Fish and Wildlife Service definition for the upland-wetland boundary. (Lacustrine example adapted from Cowardin et al. 1979)

more or less with *Sphagnum* mosses, tussocky sedges, and an open growth of scrubby trees." The glossary by Gabriel and Talbott (1984) includes three definitions for muskeg, each including the presence of *Sphagnum* and black spruce, two examples which illustrate the wide range of cover types described by the word muskeg. The term *tundra* is a little more restricted in its definition: "A level to undulating, treeless plain characteristic of arctic regions" (Agriculture Canada 1976, in National Wetlands Working Group 1988). Tundra conditions exist both in the Arctic and in alpine areas at lower latitudes. Gabriel and Talbott (1984) provide five definitions of tundra, all relating to a cold climate and a treeless landscape. More discussion of wetland types and terminology can be found in Maltby (1986) and Mitsch and Gosselink (1986). Information about types of wetlands occurring in Alaska can be found in Hall (1988) and Sigman et al. (1990).

Basically, *"wetland is a collective term for ecosystems whose formation has been dominated by water, and whose processes and characteristics are largely controlled by water. A wetland is a place that has been wet enough for a long enough time to develop specially adapted vegetation and other organisms"* (Maltby 1986). In its adoption of a wetlands defintion, the U.S. Fish and Wildlife Service has recognized that "there is no single, correct, indisputable, ecologically sound definition for wetlands, primarily because of the diversity of wetlands and because the demarcation between dry and wet environments lies along a continuum" (Cowardin et al. 1979). The Service defines *wetlands* as, *"lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water"* (Cowardin et al. 1979). This definition of wetlands recognizes the difficulty of exactly defining wetland hydrology (Tiner 1991) and is similar to definitions used by regulatory agencies for their differing administrative purposes. The Service definition provides regulatory agencies and wetland researchers a common definition that allows accurate identification and delineation of wetlands for resource management purposes (Tiner 1989).

B. WETLAND CLASSIFICATION

Organizing information or data about landforms as varied as wetlands requires a system or framework for that descriptive information or data. The term *classification* refers to methods that group wetlands according to similar physical characteristics (such as vegetation or hydrology) where wetland functions and values are not explicitly considered (EPA 1991). Over time, numerous classification systems have been developed; these range from the use of commonly recognized vegetation or cover types to systems based on hydrology, geomorphology, or some combination of the two. Researchers such as Brinson and Lee (1989) have found that some classification systems provide greater insight than others into factors responsible for the structure and dynamics of wetlands. Functionally based wetland classifications are helpful because the system or framework can simplify the concept of wetlands while recognizing the uniqueness of each wetland and the similarities of many wetlands.

Some wetland classification schemes are specific to a particular species or to a taxonomic group or class. Many studies of wetland habitats have been conducted in Alaska, but most are not described in the literature as wetland studies (for example: Albert and Shea 1986; Derksen et al.

1982). Instead, these studies are described as studies of a particular species, population, or life-phase.

Terminology of wetland classification can overlap with wetland definitions. Wetland scientists often use the terms *marine, estuarine, lacustrine, riverine, and palustrine* to distinguish types of wetlands. These terms are based on wetland location and chemistry and are often the names of *categories* used to organize, or *classify*, information about wetlands.

C. WETLAND INVENTORY

For the purposes of this guide, a wetland *inventory* is a systematically assembled collection of wetland related information. The kinds of information in an inventory will vary with the purpose of the inventory. For example, an inventory of waterfowl wetland habitats will not be the same as an inventory of moose wetland habitats. Likewise, an inventory of coho salmon habitat will be different from both the waterfowl and moose wetland habitat inventories.

Wetland habitat inventories are not possible without a *classification* structure to organize descriptive information and data. Numerous classification schemes exist; the purpose of the inventory will help determine which classification method is used. Of the many purposes of wetland classification and inventory efforts, three related to fish and wildlife and their habitats are:

1. Identifying and prioritizing wetland habitats for protection or acquisition.
2. Assessing specific wetland functions or values for use in land management planning or in the review of wetland related resource development projects.
3. Conducting research.

D. WETLAND RANKING AND CATEGORIZATION

Some rapid assessment methods *rank* wetlands based upon some consideration of their relative value. *Categorization*, a new term in wetlands literature, relates to a degree of regulatory protection afforded an individual wetland based on wetland functions or values perceived by society to be important, whereas *ranking* is based solely on knowledge or understanding of a wetland or a specific group of wetlands. Categorization also refers to the proposed ranking of wetlands for use in the Clean Water Act Section 404 regulatory program (EPA 1991).

E. WETLAND MAPPING

The products of wetland inventories usually include wetland maps. Some wetland inventory efforts involve sophisticated equipment, computers, and computer software. Others are more simple, and involve the use of hand drawn maps and mylar overlays.

The level of detail and the accuracy of final maps are dependent upon:

1. The scale and accuracy of reference information;

2. Wetland boundary delineation methods[2] and amount of field investigation;
3. The difference in scale between field maps[3] and final wetland inventory maps;
4. The technique used to transfer information from field and reference maps to final wetland inventory maps;
5. The minimum size of a mapping unit; and
6. The accuracy of the base map used for the final wetland inventory maps.

Because any map product can be expected to contain errors or omissions, the limitations of each wetland map must be understood by all map users. Each map should include a disclaimer as to the possible exclusion of wetlands and the approximate nature of boundaries.

Any data about the characteristics, functions, and values of wetlands must be viewed in the context of the thoroughness and accuracy of the methods used during the inventory.

F. STARTING YOUR PROJECT

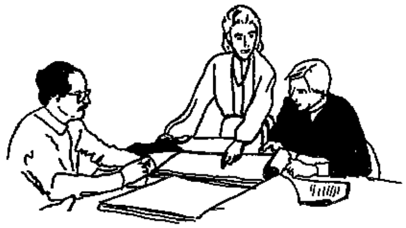
Developing a successful wetland inventory and assessment project requires careful planning (Figure 5, page 16). The study area boundaries

[2]Jurisdictional definitions of wetlands vary, and areas that function as a wetland should be mapped, even if they are not regulated. Although, the U.S. Fish and Wildlife Service wetland definition should be used for inventory and functional assessment efforts, this does not preclude the use of other definitions for management and regulation of wetlands.

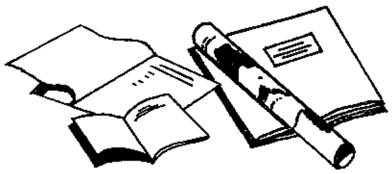
[3] Large map scales are recommended for field mapping.

FIGURE 5

PHASES OF A SUCCESSFUL INVENTORY AND FUNCTIONAL ASSESSMENT

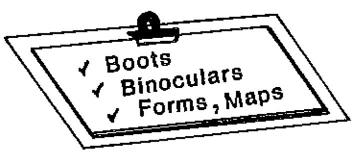


I. PLANNING

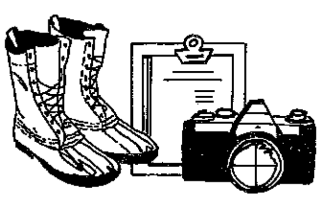


II. OFFICE INVENTORY: LITERATURE SEARCH AND ASSEMBLY OF EXISTING DATA

III. DATA GAP ANALYSIS

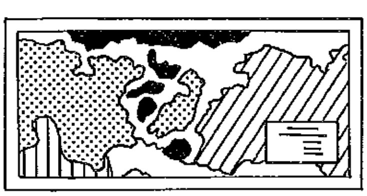


IV. FIELD WORK PREPARATION



V. FIELD WORK

VI. DATA ANALYSIS



VII. FINAL PRODUCTS

must be established and the goals and objectives of the study clearly stated. Available data should be assembled and evaluated so that gaps in the data can be identified. Budget planning should include field work, data analysis, and production of interim and final products. Compromises in level of detail and accuracy should be clearly understood, and all assumptions should be supported by technical liturature and data.

G. EARLY WETLAND CLASSIFICATION AND INVENTORY EFFORTS

"The purpose of classification is to group like elements into units that can be defined and characterized . . . Wetlands, being complex dynamic ecosystems, are difficult to categorize and classify" (Zoltai 1988).

The history of wetland classification and inventory dates at least as far back as 1692 when Gerard Boate classified several types of British bogs (Gorham 1957). Early classification systems separated wetlands in major groupings based on location (coastal or interior), type (fresh, saline, or alkaline), and permanence (permanent, semi-permanent, or temporary).

Several early wetland inventory efforts concerned peatlands of North America and Europe in the early 1900's (Davis 1907, in Mitsch and Gosselink 1986; Osvald 1925, in Zoltai 1988). The first national-scale attempt to inventory wetlands in the United States occurred in 1906, when Congress authorized the Department of Agriculture to collect data on the extent, character, and agriculture potential of inland wetlands east of the 115th meridian (Stegman 1975). The 1906 inventory followed the Swamp Land Acts of 1849, 1850, and 1860, which enabled fifteen states to "reclaim" wetlands through the construction of levees and drains and to implement programs to lessen the impacts of severe floods and to eliminate mosquito-breeding swamps (Shaw and Fredine 1956).

The Bureau of Agricultural Economics (U.S. Department of Agriculture) conducted the second wetland inventory with a national scope in 1922 (Stegman 1976). This inventory incorporated soil survey reports by the U.S. Bureau of Public Roads, topographic maps by the U.S. Geological Survey, drainage information, and other data. Estimates of reclaimable wetlands were made using this inventory until at least the 1970's.

1. CIRCULAR 39, *WETLANDS OF THE UNITED STATES*: WATERFOWL HABITAT

The third national wetland inventory considered waterfowl habitat, rather than reclaimable wetlands. In 1953, Martin et al. developed a classification system for the purpose of a national wetlands inventory to "determine the distribution, extent, and quality of the remaining wetlands in relation to their value as wildlife habitat." This classification system and the inventory results were published by the U.S. Fish and Wildlife Service as Circular 39, *Wetlands of the United States* (Shaw and Fredine 1956). This system provides for the inventory

Major Classification Categories of Circular 39:

Inland Fresh
Inland Saline
Coastal Freshwater
Coastal Saline

and classification of wetlands in terms of relative importance to wild game in general, and to waterfowl (and waterfowl management) in particular. The inventory is intended to show state and federal land management agencies the locations and relative importance of wetlands that should be preserved or improved for waterfowl as soil and water conservation programs are carried forward. The classification scheme uses water depth and permanence, water chemistry, vegetative life form, and dominant plant species as related to waterfowl habitat.

Circular 39, *Wetlands of the United States*, addresses only wildlife related values of wetlands, and especially waterfowl production. Inventory designers intended that the inventory would "have far-reaching effects on keeping waterfowl populations at a harvestable level" (Shaw and Fredine 1956). The Preface to this circular points out that wetlands have additional functions and values, including the storage of groundwater, retention of surface water for farm uses, stabilization of runoff, creation of firebreaks, provision of an outdoor laboratory for students and scientists and production of cash crops such as bait minnows, marsh hay, wild rice, blueberries, cranberries, and peat moss. Fish habitat is not included in the classification system, although the Preface includes the statement "Some wetlands provide good fishing."

The classification system by Martin et al. (1953) has been used widely by many federal and state agencies, universities, and private conservation groups. The system became the inventory and classification standard used by the U.S. Fish and Wildilfe Service, National Marine Fisheries Service, and the Soil Conservation Service. The system also formed the basis of many federal regulations and policies concerning preservation of wetlands (Stegman 1976).

The relatively simple classification system of Circular 39, *Wetlands of the United States*, relies primarily on vegetative life form and the depth of flooding for identification of wetland type. The need for a more widely applicable system of wetland classification led to other classification systems; the literature review of Brown at al. (1979) notes that 12 different wetland classification systems were published for either the entire United States or particular regions of the country in the 1970s. These efforts included *Classification of Natural Ponds and Lakes in the Glaciated Prairie Region* (Stewart and Kantrud 1971), *Classification of Freshwater Wetlands in the Glaciated Northeast* (Golet and Larson 1974), *Influences of Riparian Vegetation on Aquatic Ecosystems with Particular References to Salmonid Fishes and their Food Supply* (Meehan et al. 1977), and numerous others. Further evolution of wetland classification led to *Classification of Wetlands and Deepwater Habitats of the United States*, often referred to as the "Cowardin System" (Cowardin et al. 1979), to the National Wetlands Inventory, and to regionalization of the Cowardin System.

H. OTHER CLASSIFICATION SYSTEMS

Classifications have also been developed using hydrologic and geomorphologic features. These have included streams (Bisson et al. 1982, Craig and McCart 1975, Leopold et al. 1964, Paustian et al. 1992, Rosgen 1985); particular wetland types, such as riverine and forested wetlands (Brown et al. 1979, Mader 1991, Prance 1979), or mangroves

(Lugo and Snedaker 1974); particular places (Gosselink and Turner 1978; O'Brien and Motts 1980); or only hydrology (Gilvear et al. 1989, Hollands 1987, Novitzki 1978, Winter 1977). Tidal wetlands, which range from mostly fresh water to brackish water, have been classified by Brinson (1989), Odum et al. (1974, 1984), and Stone (1984). Recently, wetland classifications have begun to look beyond wetland boundaries to better understand the wetland. Kangas (1990), for example, uses landscape form and the role of water as an energy source for the basis of a classification system that can be applied to terrestrial systems as well as wetlands.

I. FOCUS OF THIS REPORT

This report highlights two classification systems: The "Cowardin System" (Cowardin et al. 1979) and its derivatives, and the Hydrogeomorphic (Brinson) System (Brinson 1992). The Cowardin System is the most widely used classification system in the United States, and the Hydrogeomorphic System is one that has drawn the interest of wetland scientists and land managers in the contiguous United States and Alaska.

1. THE COWARDIN SYSTEM: *CLASSIFICATION OF WETLANDS AND DEEPWATER HABITATS OF THE UNITED STATES*

The U.S. Fish and Wildlife Service generally discontinued use of *Circular 39* (Shaw and Fredine 1956) after the introduction of *Classification of Wetlands and Deepwater Habitat of the United States* (Cowardin et al. 1979).

The Cowardin System provides a framework for the description of ecological taxa and categorizes wetlands by plant types (hydrophytes), soil (hydric soils), and the frequency of flooding. The classification system includes a "deepwater habitat" category for deepwater areas not traditionally considered wetlands but which are, in fact, ecologically related.

The classification system is hierarchical. Five ecological "systems" form the highest level: Marine, Estuarine, Riverine, Lacustrine, and Palustrine. The Marine and Estuarine systems each have two "subsystems," Subtidal and Intertidal, to differentiate submerged and periodically inundated areas. The Riverine system has four subsystems, Tidal, Lower Perennial, Upper Perennial, and Intermittent; and the Lacustrine (lake) system has two subsystems, Littoral and Limnetic. The Palustrine system has no subsystem.

Subsystems are further divided into "classes" based on substrate material and flooding regime, or on the dominant vegetative life form. Figure 6, page 23, presents the hierarchy and shows that some classes are included in one or more classification categories.

The dominant life form defines the vegetation classes: Aquatic Bed, dominated by plants that grow principally on or below the surface of the water; Moss-Lichen Wetland, dominated by mosses or lichens; Emergent Wetland, dominated by emergent herbaceous angiosperms; Scrub-Shrub Wetland, dominated by shrubs or small trees; and Forested Wetland, dominated by large trees. Dominance type, the lowest level of the

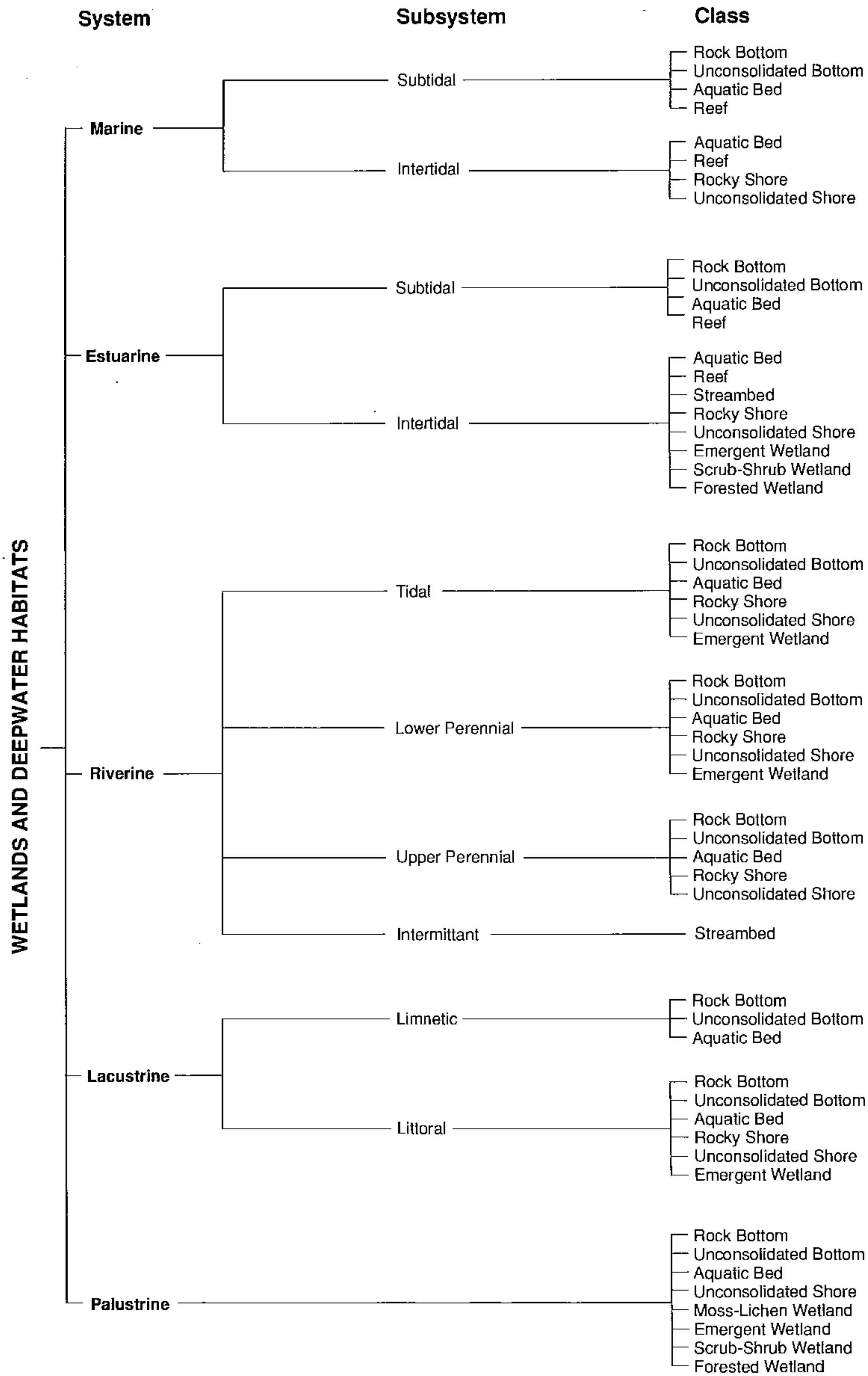


Figure 6. The Cowardin System. The classification hierarchy of wetlands and deepwater habitats developed by Cowardin et al. (1979) showing systems, subsystems, and classes. The Palustrine System does not include deepwater habitats. This classification scheme is used by the National Wetlands Inventory.

hierarchy, must be developed by a user during a particular application of the system. The dominance type level is named for the dominant plant or animal species or assemblage.

The Cowardin System uses "modifiers" to further separate the broad classification categories. The type and duration of tidal flooding, for example, are described by subtidal, irregularly exposed, regularly flooded, and irregularly flooded. Eight modifiers are used in nontidal areas: permanently flooded, intermittently exposed, semipermanently flooded, seasonally flooded, saturated, temporarily flooded, intermittently flooded, and artificially flooded. Additional modifiers describe water chemistry by salinity and pH, and soil modifiers provide information about soils. A set of "special modifiers" describe alterations such as excavated, impounded, diked, partly drained, farmed, and artificial.

Classification and mapping require the determination of boundaries for a wetland classification mapping unit. The Cowardin System designates the terrestrial limit of a wetland using three criteria: (1) the boundary between land with predominantly hydrophytic cover and land with predominantly mesophytic or xerophytic cover; (2) the boundary between soil that is predominantly hydric and soil that is predominantly nonhydric; or (3) in the case of wetlands without vegetation or soil, the boundary between land that is flooded or saturated at some time each year and land that is not.

The line distinguishing wetland and deepwater habitats in Marine and Estuarine categories is the elevation of the extreme low water of "spring" tide. Lands seaward of the extreme low water line (ELW) are permanently flooded and are considered deepwater habitats in the Marine and Estuarine categories. The division of wetland and deepwater habitat in the Riverine, Lacustrine, and Palustrine systems is determined by the 2-meter (6.6 feet) depth isobar; however, if emergent shrubs, or trees grow beyond this depth, the deepwater edge of this vegetation is the boundary.

Limitations of the Classification System: Data indicating highly detailed categories of the system often are not available, and a data gathering effort may be required before a classification project can be undertaken. The classification hierarchy restricts community definition at the dominant overstory species level. This can mask important differences in habitat use and community structure.

Adamus (1992) and Dethier (1990, 1992) identified several important indicators of function that are not included in this classification system. These include wetland gradient (shoreline and inlet-to-outlet), basin size and shape, water source and transport vector, wave and current exposure, interspersion of open water with vegetation, and position and condition relative to that of other wetlands, land uses, and landform types. Some of these limits can be mitigated by data sources specific to topography, hydrology, and land use.

Strengths of the Classification System: A strength of the classification hierarchy is that the system can be used at any of several levels. Colloquial terms like *bog, fen, swamp, marsh, muskeg,* and *shallow open water* are not used. The structure of the system appears to provide internal consistency and objectivity; this allows for a high level of accuracy and detail when sufficient data are available. The system is the basis of the National Wetland Inventory maps, the nation's largest source of wetlands mapping data.

Sensitivity to Fish and Wildlife Habitat Values: "Modifiers" used in the classification system can be interpreted to infer ecosystem processes and function. General distribution of some fish and wildlife species can be predicted by maps generated from the classified information, although predictions are more accurate for species with narrow habitat niches than for generalists. The Dominance classes allow individual users to further define categories to be sensitive to fish and wildlife species of special concern.

2. National Wetland Inventory

The U.S. Fish and Wildlife Service has used the classification system of Cowardin et al. (1979) and aerial photo interpretation for an ambitious effort to map wetlands of the United States, including Alaska. The Cowardin System was adapted for this National Wetland Inventory (NWI) with minor modifications. The NWI project maps wetlands to a minimum mapping size of 1-3 acres, depending upon the size of the area being mapped and the wetland types

Wetland Functions Inferred by NWI Mapping Attributes:

Flood Control
Food Chain Support
Nutrient/Sediment Retention
Fish Habitat
Wildlife Habitat
Ground Water Exchange
Recreational Use
Dissipation of Erosive Forces

present. Maps are produced at scales of 1:40,000 or 1:63,360. As of October 1, 1992, 24 percent of Alaska has been mapped.

Applicability to Local Wetland Types: The inventory has been used to successfully map wetlands in many areas of Alaska (see appendix, page 195).

Applicability to Wetland Functions of Special Concern: The inventory is not function oriented, but wetland functions can be inferred by mapping attributes.

Duration of Time Required: Varies with amount of wetlands in a study area, complexity, and ground truthing required. The mapping process generally takes two years to complete, including obtaining aerial photographs, ground truthing, photo-interpretation, draft map production, and final map production. An average project size is 15 to 20 maps at the 1:40,000 or 1:63,360 scales.

Personnel Required: One experienced biologist/photo-interpreter can complete field work and photo-interpretation for one USGS quad (1:63,360) in approximately three weeks. Cartographic production requires an additional three weeks.

Skills and Proficiency Level Required: Experienced photo-interpreter/biologists are required for photo-interpretation. Cartographic technicians are needed for map production.

Equipment Required: Stereoscopes, soil sampling equipment, salinity meter, and related field equipment; a helicopter is needed for ground truthing in remote areas.

Data Required: Aerial photography.

Usefulness of Interim and Final Products: Draft and final maps are available in mylar and paper form. The mylar maps allow overlay on a base map of the same scale, allowing NWI maps to be used in conjunction with other maps, such as Alaska Department of Fish and Game anadromous fish stream maps (ADF&G 1992a, 1992b, 1992c, 1992d, 1992e, 1992f). NWI maps are used widely by federal, state, and local agencies and the private sector.

Accuracy: Approximately 90 percent for wetlands greater than two acres in size.

Ground Truthing: Ground truthing is conducted on all maps. Representative wetland types are examined in the field by the photo-interpreter/biologist.

Relative Rating System: NWI does not rate wetlands.

Cost: NWI mapping averages $4,000 per 1:63,360 scale map area.

Sensitivity to Ecosystem Considerations: NWI mapping attributes and nine wetland functions and values have been correlated (Pitt *In prep.*). Predictors for flood control, food chain support, nutrient/sediment retention, groundwater exchange, and dissipation of erosive forces can be used to make inferences about the landscape and ecosystem functioning.

Sensitivity to Fish and Wildlife Habitat Values: Fish and wildlife habitat predictors are included in the correlation of NWI mapping attributes and wetland functions and values (Pitt 1992). Predictors for Fish Habitat include meanders (sinuosity), shoreline irregularity, stream order, stream width, barriers to anadromous fish, and shoreline vegetation. These predictors appear generally applicable to most salmonid wetland habitats. The Wildlife Habitat predictors are selected for sensitivity to waterfowl; these predictors include contingnuosity of wetlands, sinuosity and edge effect, wind fetch, stream order, wetland type, flooding, and shoreline vegetation.

3. *A Marine and Estuarine Habitat Classification System for Washington State:* Regionalization of the Cowardin System

Cowardin et al. (1979) recognize the need to regionalize the classification system and recommend seven regions for Alaska (Figure 7, page 30).

Cowardin et al. (1979) recommend the hierarchial system developed by Bailey (1976) in inland Alaska. This classification uses related climates and vegetation to separate ecoregions. Figure 1 illustrates the broad Polar and Humid Temperate Domains; the Tundra, Subarctic and Marine Divisions; and specific Provinces of Bailey's classification.

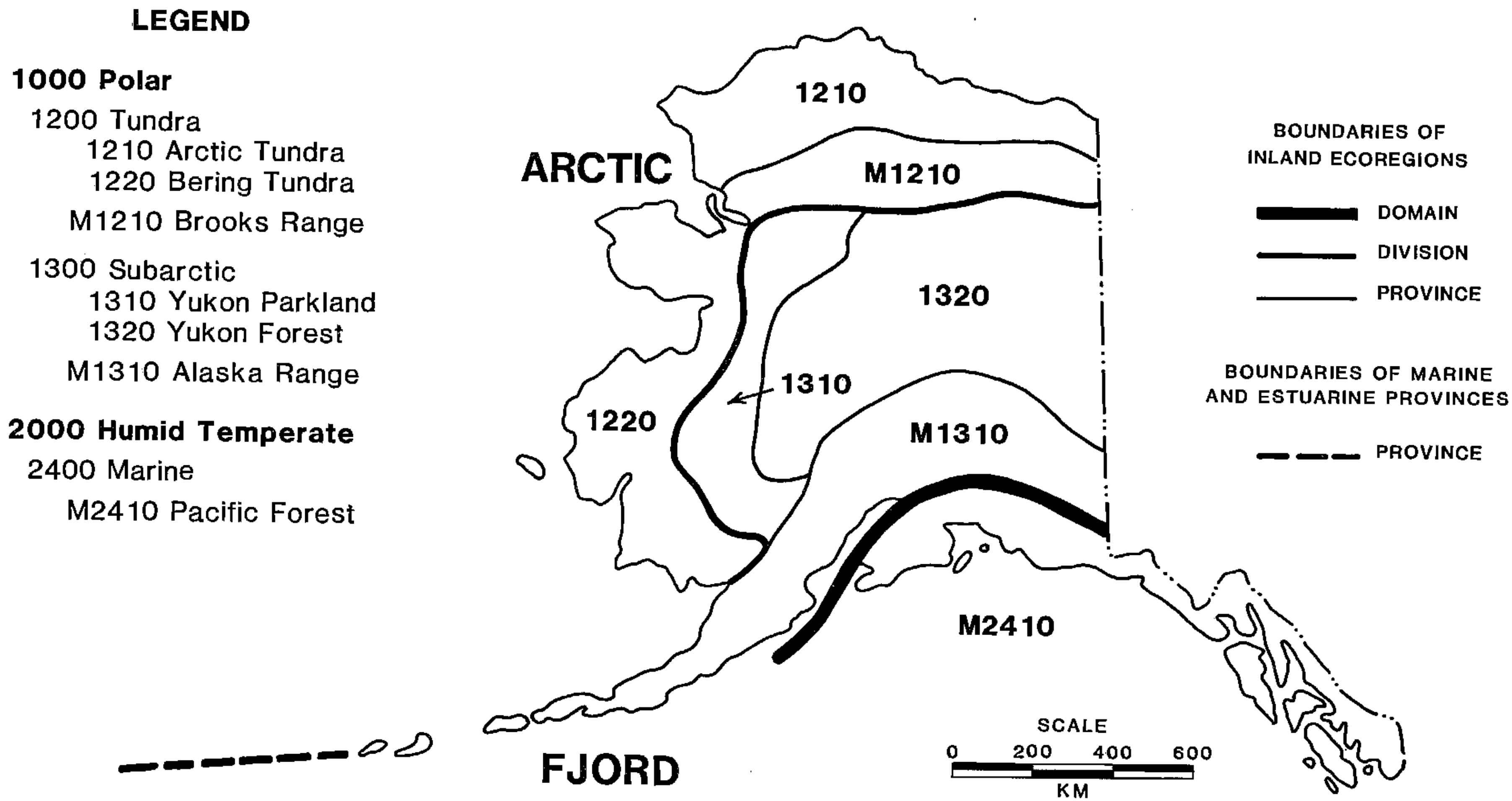


FIGURE 7. ECOREGIONS OF ALASKA RECOMMENDED BY COWARDIN ET AL. 1979

The Arctic Province extends along the Arctic Ocean and the Bering Sea. It is characterized by arctic biota, the 4-degree Celsius summer isotherm, and the southern extension of floating ice.

The Fjord Province extends along the Gulf of Alaska coast from southeastern Alaska to the tip of the Aleutian Islands. Precipitous mountains, deep estuaries, tidewater glaciers, and a heavily indented shoreline subject to winter icing are typical. The biota is boreal to sub-arctic. Aleutian and Japanese Currents influence the province, and the tidal range is large.

Our literature search did not find an example revision of the Cowardin System for use in Alaska. One example that could be useful in the Fjord Province (Figure 7) is a system used by the Washington Natural Heritage Program (Washington Department of Natural Resources) for organizing data describing marine and estuarine natural communities in Washington state (Dethier 1990, 1992). This system adds an "Energy" level to incorporate the critical importance of waves and currents in structuring marine communities and removes the "Aquatic Bed" categories from all classification levels, making substratum type one of the highest levels in the classification hierarchy. The Washington Natural Heritage Program uses the system for planning marine parks and sanctuaries, but the system could be used by land-use planners, resource managers, regulators, and other agency personnel needing information in greater detail than that provided by the National Wetland Inventory (NWI) maps.

The Cowardin System does not specifically include wave and current exposure in the classification hierarchy. This makes it inadequate when describing marine and estuarine habitats, because exposure to waves and currents is a critical factor limiting distribution of marine organisms. The Washington revisions to the Cowardin System classify marine and estuarine habitats by depth, substratum type, energy level, and a few additional modifiers for depth, salinity, and degree of disturbance or alteration. These physical habitat features, especially depth, stratum type and energy level, strongly constrain the distributions and interactions of marine plants and animals.

Table 1, page 34, shows an overview of the Washington additions to the Cowardin System. The Washington definitions follow Cowardin et al. (1979) with some slight refinement or clarification.

The Washington system provides mapping units, which can be used to create maps with uniform terminology describing nearshore habitat types on an ecological basis, and should facilitate collection, organization, and presentation of site-specific information describing characteristics of fish and wildlife habitat.

Sensitivity to Fish and Wildlife Habitat Values: The Washington revisions avoid the problem of restricting community definition at the dominant overstory species level, which can ignore important differences in understory layers or less common species. While the Washington classification system is potentially more precise than the Cowardin System, detailed information necessary to apply the extra layer of precision may not be available. Additional field surveys may be required to describe substrate, dominance types, and indicator species.

Additional Information: Washington Department of Ecology is now using a simplification of this system to assess sensitivity to oil spill impact, which is likely to correlate highly with these same physical parameters.

Table 1. A comparison of the classification system by Cowardin et al. (1979) and the system used by Washington Natural Heritage Program (WaNH) (after Dethier 1992). The additional detail further describes estuarine and marine habitats with greater accuracy and detail.

COWARDIN ET AL.		WANHP	
SYSTEM: Marine and Estuarine		**SYSTEM:** (same)	
SUBSYSTEM: Intertidal and Subtidal		**SUBSYSTEM:** (same)	
Class:	Rocky shore	**Class:**	Consolidated
	Unconsolidated shore		Unconsolidated
	Aquatic Bed		(no corresponding category)
	Reef		Reef
			Artificial
Subclass:	Bedrock	**Subclass:**	Bedrock
			Hardpan
	Rubble		Boulders
	Cobble-Gravel		Cobble
			Mixed-Coarse
			Gravel
	Sand		Sand
			Mixed-Fine
	Mud		Mud
	Organic		Organic
(no corresponding categories)		**Energy/Enclosure**	
Modifiers (salinity, depth, etc.)		**Modifiers**	
Dominance Types		**Characteristic Species**	

4. HYDROGEOMORPHIC (BRINSON) CLASSIFICATION

The Hydrogeomorphic (Brinson) Classification system is a functionally based scheme being considered by the U.S. Army Corps of Engineers for use throughout the United States. The system assumes that a geomorphologic classification simplifies the high degree of variability among wetlands. The level of simplification is a compromise between dealing with the uniqueness of each wetland on one hand, and ignoring such differences on the other (Brinson 1988). The State of Alaska is considering a pilot test of a preliminary version of the methodology with the ultimate goal of classifying wetlands. The Hydrogeomorphic Classification is not intended to replace or conflict with the NWI program.

Wetland Features Classified by the Hydrogeomorphic (Brinson) Method:

Geomorphic Setting
Water Source
Hydrodynamics

The classification system is based on the hydrogeomorphic character of wetlands rather than vegetation or cover type. The system considers three general groupings that are sometimes redundant or highly intercorrelated: geomorphic setting of the subject wetland, water source and transport on a basin or wetland level, and hydrodynamics. These abiotic features are emphasized for their relative independence from the biogeographical distribution of species. Biotic information can be brought into the classification process as the Hydrogeomorphic System is applied locally or regionally. The system requires ground-level measurements to determine function, indicators, and spatial and temporal variability within a region. This information represents a theoretical "profile" of the subject wetland, from which the wetland's probable functions can be determined from literature and other sources.

Limitations of this Classification System: The Hydrogeomorphic System in its current, generic form does not have the resolution to discern the many types of wetlands that exist within a geographic region. This limitation is intentional, because the approach represents only a strategy for functional assessment that will require development for specific wetland type by geomorphic region.

Use of this classification system requires information usually not available in Alaska. The required ground-level measurements to determine function, indicators, and their spatial and temporal variability within a study area are expensive to obtain. Given the great variability of even similar wetlands, only very detailed information is necessary to initially assess the degree that this variability influences function.

Strengths of the Hydrogeomorphic (Brinson) Classification System: The classification system may be useful at a regional planning level as the approach is expected to distinguish broad classes of wetlands. At the local level, the system could highlight similarities, rather than differences among wetlands.

One attractive feature of the system is the establishment of reference wetland sites to use for comparison with a subject wetland. For the system to become a useful tool in practice, the reference wetlands must be representative of natural or quasi-natural wetlands that currently or previously existed in the region. Additional reference wetlands that have been impacted can serve as examples for illustrating how various impacts affect the functioning of a given wetland class.

Adamus' evaluation of the system (1992) notes that this functionally based, simple classification system is based on factors that may be important not only to predicting function, but to sustaining wetland function over time. The system is not a compromise between potentially important wetland functions and practical wetland identification and mapping considerations. The classification system can be modified as additional information about wetland functions and dynamics becomes available.

Applicability to Local Wetland Types: The Hydrogeomorphic System may be applied to inland and tidal wetlands. The classification is designed for application in riverine, depressional, fringe, and extensive peatlands. For the purposes of the Hydrogeomorphic System, *riverine* wetlands are those associated with steep to low gradient streams and are represented by floodplains; *depressional* wetlands may be connected to surface flows, or may be tightly or loosely connected to groundwater flows; *fringe* wetlands are those controlled by sea or lake level; and *extensive peatlands* occur where organic matter accumulation has greatly modified drainage and topography of the subpeat surfaces.

Applicability to Wetland Functions of Special Concern: In its current form, the method considers only hydrologic and water quality functions of wetlands and their watersheds. One goal is to relate hydrologic and water quality functions and properties to habitat condition and food web support. The Hydrogeomorphic Classification is an effort to logically connect these properties in a scientifically and defensible way.

Duration of Time Required: The amount of time needed to apply the Hydrogeomorphic approach will vary with the size, complexity, and accessibility of the study area, amount of data readily available, and desired level of accuracy and detail.

Personnel Required: Development of the classification system and initial pilot projects have involved numerous participants.

Skills and Proficiency Level Required: Members of the national technical teams developing the Hydrogeomorphic Classification are all noted experts in their fields. For the system to adequately reflect wetland characteristics important to Alaska fish and wildlife, there needs to be a high degree of involvement by biologists in its application.

Equipment Required: The method is yet evolving; field equipment typical to any wetland study is likely to be needed for an application.

Data Required: The ecological significance of the properties of geomorphic setting, water source, and hydrodynamics is described qualitatively and is further quantified if necessary data exist or can be gathered. If information is not available for the study area or a similar ecosystem, the significance is developed through logic. The system requires ground-level measurements.

Usefulness of Interim and Final Products: Interim products can be used for a gap analysis. Interim and final products can be the basis of further study. The establishment of reference wetlands and a library of wetland profiles will facilitate wetland management and study.

Accuracy: Accuracy will vary with quality and quantity of available data for any particular wetland type.

Repeatability: The system recommends the establishment and use of reference wetlands that represent the functions of a given wetland type as well as likely variations of these functions within a wetland type. These reference wetlands would provide a baseline against which study results may be measured. The degree to which a reference wetland matches the functional potential of a subject wetland will affect repeatability.

Ground Truthing: Reference sites that constitute populations of reference wetlands are the basis for ground truthing.

Relative Rating System: The classification system is not intended to judge or estimate value of any wetland function, and thus does not rank wetlands. The classification scheme is not intended to be used as primary means of assigning levels of protection or appropriate mitigation, but rather the system is intended to emphasize abiotic factors which have been documented for wetlands, and are assumed to control or influence ecosystem function. The system simply "indicates that some wetlands have certain functions, while others do not" (Adamus 1992).

Cost: Cost of applying the Hydrogeomorphic Classification in Alaska is likely to be very high, due to the absence of detailed hydrologic information in most of Alaska and the difficulties associated with obtaining basic or detailed data.

Sensitivity to Ecosystem Considerations: The Hydrogeomorphic System implicitly requires that factors beyond a wetland's boundaries be recognized and considered. Both geomorphic setting and water source recognize features beyond wetland boundaries.

Sensitivity to Fish and Wildlife Habitat Values: The system considers only abiotic features. Researchers involved in the development of the Hydrogeomorphic System stress that the focus of the system on abiotic features is not meant to minimize the role of life forms in the structure and function of wetland ecosystems. Rather, the hope is that application of the approach will lead to better understanding of the relationship between organisms and the physical environment, and that biological information will be gathered and superimposed on the hydrogeomorphic data base to come up with an adequate representation of biological characteristics.

Additional Information: The hydrogeomorphic approach is not an assessment technique, but it can be used to develop an assessment methodology. National technical teams are working with the Waterways Experiment Station (U.S. Army Corps of Engineers) to further develop the hydrogeomorphic method into a wetlands functional assessment tool (see Smith 1992). A goal of this methodology that will go beyond the capabilities of the Wetland Evaluation Technique (WET) (Adamus et al.

1987). Reference wetland profiles would be an important link between the hydrogeomorphic classification system and the evolving functional assessment methodology.

Once a classification project is complete, the reference wetlands would provide standards by which to evaluate anticipated impacts during a permit review, assessment of functions, new wetland construction, and restoration of degraded wetlands.

Chapter III
Wetland Assessment Methods

Studies related to wetland inventory and functional assessment should generally identify the location, quantity, type, condition, and functions of the study area wetlands. If applicable, such studies should also describe the causes and rate of wetland degradation or loss. Studies on a regional or statewide scale should also describe the specific areas where degradation and loss is concentrated.

Rapid assessment methods use indicators to evaluate selected wetland functions. Readily obtained information about site characteristics such as position in the watershed, soil permeability, and connection to surface water, rather than detailed hydrologic data, are examples of information used in a rapid assessment of the function "groundwater recharge."

Many rapid assessment methods have been developed for general or specific use. Nearly all differ in the number and type of functions assessed. Indicators used to estimate or predict wetland function also vary widely.

Rapid assessments can be used to answer wetland related questions when time, information, or budgetary constraints prevent detailed data gathering. Even so, rapid assessments all require certain basic information which may not be available for wetlands in Alaska.

Application of rapid assessment methods require the following information:

1. National Wetland Inventory maps: NWI maps assist determination of what types of wetlands are present and where these wetlands lie in a planning area; and
2. Soils maps: While there is no direct correlation between hydric soils and the functioning of wetlands, soils maps can be used to estimate general location and extent of wetlands;

Some methods also require:

3. Floodplain (FEMA) and/or "Swampbuster" maps: These often provide a finer level of detail to complement the NWI and soils maps;

To understand wetland functions, methods rely upon:

4. Existing scientific and technical literature: A review of the literature is necessary to understand the assumptions and limitations of any particular method; and
5. Consultation with experts: Experts can range from local residents to agency personnel or university researchers, whose expertise complements the available data and literature base.

When selecting an assessment method, consideration must be given to the inherent trade-offs between accuracy and detail, timeliness in obtaining results, and cost. Some methods provide very general results that may not provide the detail needed by a community or agency for decision-making. Other methods take longer and cost more money but provide finer accuracy and detail.

Whichever method is selected, the data collection methods must be scientifically defensible and repeatable. The assumptions should be well founded in the technical literature, and the need for subjective judgement should be restricted. Further, the method should be sensitive to the temporal nature of wetlands, and should account for changes in a wetland or a wetland system both seasonally and over time.

Wetland assessment is evolving. Currently, many consider a state-of-the-art to be the Wetland Evaluation Methodology (WET) prepared for the U.S. Federal Highway Administration (Adamus and Stockwell 1983) and the Army Corps of Engineers (Adamus et al. 1987). WET has been adapted for use in Juneau and Homer, Alaska, and Puget Sound, Washington. Users of WET have expressed a need for something beyond what WET is able to accomplish. An effort led by the Waterways Experiment Station (U.S. Army Corps of Engineers) is exploring a new system that would organize information for multidisciplinary uses (Smith 1992).

Fish and wildlife need food, escape from weather and floods, specialized reproductive habitat, and water for growth, survival and reproduction. Many abiotic wetland functions are closely related to the function "fish and wildlife habitat." Abiotic processes such as surface and subsurface water supply, flooding, and water quality influence composition and construction of the vegetation community and productivity, which in turn affect fish and wildlife distribution and abundance. Abiotic functions can

Figure 8.

Some Functions, Uses, and Values of Wetlands

Water supply - Wetlands are important sources of ground and surface waters.

Water quality - Wetlands contribute to improved water quality by removing excess nutrients and many chemical contaminants. Wetlands are sometimes used in treatment of sewage, storm run-off, and industrial wastes.

Flood conveyance - Riverine wetlands and adjacent floodplain lands often form natural floodways that convey flood waters from upstream to downstream points.

Flood storage - Inland wetlands may store water during floods and slowly release it to downstream areas, lowering flood peaks.

Barriers to waves and erosion - Coastal wetlands and those inland wetlands adjoining larger lakes and rivers reduce the impact of storm tides and waves before they reach upland areas.

Sediment control - Wetlands reduce flood flows and the velocity of flood waters, reducing erosion and enabling flood waters to release sediment.

Habitat for fish and shellfish - Wetlands are important spawning and nursery areas, and provide sources of nutrients supporting commercial and recreational finish and shellfish industries.

Habitat for waterfowl and other wildlife - Coastal and inland wetlands provide essential breeding, nesting, feeding, protection from strong currents, and predator escape habitats for many waterfowl, mammals, amphibians, and reptiles.

Habitat for rare and endangered species - Almost 35 percent of all rare and endangered animal species are dependent on wetlands, even though wetlands constitute only about 5 percent of the nation's lands.

Fishing, hunting and trapping - In the United States, almost half the saltwater catch is associated with wetlands. All freshwater recreational angling depends upon wetlands. Wetlands produce an abundance of furbearers and other game animals.

Recreation - Recreational activities, such as fishing, hunting, photography, and bird watching, often occur at wetland sites.

Education and research - Intertidal, coastal, and inland wetlands provide opportunities for nature observation and scientific study.

Timber and plant production - Many wetland plants are economically important. Wetlands produce some of the world's food staples, such as rice and oil palm. Wetlands are a major source of non-food plants (for example, reeds, palms, and willows). Forested wetlands can be an important source of timber (for example, bald cypress, black and Sitka spruce, western red cedar, and Western hemlock).

Historic and archaeological values - Eskimo, Aleut, and Indian settlements were often located in or near wetlands which provided subsistence harvest opportunities.

Open space and aesthetic values - Tidal and inland wetlands are areas of great diversity and beauty, and provide open space for recreational and visual enjoyment.

Source: Adapted from Kusler 1983 and Maltby 1986.

be related to specific habitat requirements of fish and wildlife. For example, "sediment control" can be related to the quality of salmon spawning gravels.

Measurements of water and other features of fish and wildlife habitat can exhaust limited time, money and personnel resources. Scientists and land managers without unlimited resources turn to rapid assessment methods for guidance in land management decisions. The following review addresses rapid assessment methods developed for use in the coterminous United States, rapid assessment methods developed for use in a particular area or region within the coterminous United States, and inventory and assessment methods specific to Alaska. Additional comparative matrices are provided at the end of this chapter (Tables 5, 6, 7, 8, and 9). Whenever possible, the review updates or supplements that of Adamus (1992).

A. RAPID ASSESSMENT METHODS DESIGNED FOR USE IN THE COTERMINOUS UNITED STATES

1. HAT: Habitat Assessment Technique

Functions and Values Addressed by the Habitat Assessment Technique:

Breeding Bird Habitat

The Habitat Assessment Technique (Cable et al. 1989) is based on the premise that species diversity and the uniqueness of species found in a wetland can be used to assess the quality of a wetland habitat. The technique uses birds as indicators of habitat quality. The method is a refinement of an earlier assessment method that combined birds and their habitats within Illinois (Graber and Graber 1976). The technique's design is intended to address criticisms of many existing wetlands assessment methods (Lonard et al. 1981) that wetland assessment methods should be tailored to an identified use, and that methods intended for regulatory actions should be quick, simple, and inexpensive to use.

The technique is based on the assumptions that (1) the presence of a greater number of species and the presence of unique species make an area more valuable, and (2) that birds serve as indicators of habitat quality. Comparisons of wetlands are made with a "faunal index" derived from bird presence and wetland size indicators. The index handicaps small or very large wetlands, as the authors assume a large habitat tract would be too expensive to study, and that a small habitat area would be "ecologically inferior" (Cable et al. 1989).

Strengths of HAT: HAT uses all available information on avian species occurring in a study wetland, and thus avoids the bias of indicator-species methods. Wetland studies can use HAT to supplement other, more extensive evaluation methods, especially when a large number of study wetlands must be assessed. HAT uses the "red flag" concept for endangered or rare or unusual species (accidentals excepted).

Limitations of HAT: Field study is required when bird breeding population estimates and other information are not available for study area wetlands. The index does not consider fluctuations in bird population levels. The short Alaska breeding period restricts field work to a brief, intense period.

Adamus (1992) notes that HAT is most likely to be useful in areas where breeding birds have been extensively inventoried, and where yearly bird populations are relatively stable. Few areas in Alaska meet these two parameters. Cable et al. (1989) report successful use of the system on Forested Palustrine and Emergent Estuarine wetlands in Delaware.

Applicability to Alaska Wetland Types: HAT can be used anywhere.

Applicability to Wetland Functions of Special Concern: HAT is specific to bird habitats but could be expanded for other terrestrial taxa.

Duration of Time Required: Field data collection can occur only during the period birds are breeding in the study area. This can be a severe constraint, as many migrant species occupy breeding habitats for a short period. In addition to the field work, time is required for literature search, consultation with knowledgeable persons, and index computation. The overall length of time required depends upon the number of species to be found and the size of the study area.

Personnel and Skills Required: At least one evaluator with advanced bird identification abilities is required for bird identification. Mathematical calculations (including log values) can be completed with a hand-held calculator.

Equipment Required: Binoculars, handheld calculator. If wetland area must be determined in the field, equipment appropriate for establishing wetland boundaries and measuring wetland size must also be used.

Data Required: HAT requires bird inventory data for the study area. Calculation of the area factor requires that wetland habitat type and area size be determined from aerial photographs, maps or field measurements. The authors recommend National Wetlands Inventory maps (the minimum one-acre mapping unit of NWI is compatible with the HAT procedure.)

Usefulness of Interim and Final Products: An interim product would be the results of a literature search and "office inventory." Final HAT products can be used on their own, or as a component of a larger, more complex wetland functional assessment.

Accuracy and Repeatability: If a substantial data base is not available, the index will reflect species diversity and abundance present only during field visits. The technique does not use transects. Differences in survey effort can be compensated using the method of Caughly (1965).

Ground Truthing: HAT is dependent upon field work.

Relative Rating System: HAT develops one score to reflect diversity and uniqueness of bird species present. This score can be logarithmically adjusted for site comparisons using the method of Caughly (1965), which is based on the assumption that additional species are found at a predictable logarithmically decreasing rate relative to the number of species initially observed.

Cost: The greatest expense of a HAT study may be the field work, especially in large, remote study areas.

Sensitivity to Ecosystem Considerations: Results of a HAT study can be used to make inferences about ecosystems, as birds can often be used as indicators of ecosystem health and functioning.

Sensitivity to Fish and Wildlife Habitat Values: Authors of HAT recommend using birds as indicators of habitat quality because, relative to other taxa, they are conspicuous, easy to identify, and occur in nearly every habitat type, thereby minimizing field time. A weakness of the technique is that species with narrow wetland habitat requirements are considered the same as generalist species. The index does not consider population level fluctuations.

Theoretically, the technique could be used with any taxa, but procedures already developed by Alaska Department of Fish and Game biologists to estimate particular fish and wildlife populations may be more useful in locations with sparse population data or estimates.

2. HEP: Habitat Evaluation Procedures

HEP is a technique used to document the quality and quantity of available habitat for *selected* fish and wildlife species. The U.S. Fish and

Wildlife Service has been developing this quantitative wildlife habitat rating system since the early 1970's (Schamberger et al. 1978). The system rates various components of a habitat type according to the component's ability to satisfy specifically identified or assumed requirements of individual wildlife species or groups of species. From these ratings, a *habitat suitability index* is calculated for each species in each habitat type within a defined area. One may then calculate a *suitability index* for each species and one for all species over the entire planning or project area. These *Habitat Evaluation Procedures* have been used by Fish and Wildlife Service and other agencies to assess the impacts of various development projects. The procedure measures habitat, not species presence. The degree of confidence is related to known habitat requirements and known features of the study area.

Application of HEP provides information for two general types of wildlife habitat comparisons: (1) the relative value of different areas at the same point in time; and (2) the relative value of the same area at future points in time. When the two types of comparisons are combined, HEP provides "a mechanism for estimating responses of faunal communities to perturbation" (Brinson and Lee 1989), and anticipated land and water changes on wildlife habitat can be quantified.

Applicability to Local Wetland Types: The procedure was designed for use in all types of inland wetland habitats in the United States.

HEP has been successfully applied in Alaska. An example of a successful application is the Bradley Lakes hydroelectric power project. The field portion of a 1987 HEP training course in Juneau was held in an estuarine wetland situated in the high to extreme high tide area. The results were variable and inconclusive.

Applicability to Wetland Functions of Special Concern: A HEP study can occur where five or more appropriate Habitat Suitability models have been developed. HEP only documents quality and quantity of available habitat: hydrologic, silvicultural, agricultural, and recreation functions of wetlands are not evaluated.

Duration of Time Required: The amount of time varies with wetland size, location (ease of access), number of cover types, number of evaluation species, and number and types of proposed impacts, and whether the "Full HEP" or abbreviated "Short HEP" version is used. A HEP application can be completed in several days, or only after several months of field investigations and data analysis.

Personnel Required: Both HEP versions require a team of at least three evaluators.

Skills and Proficiency Level Required: The evaluators should be trained in field biology; the U.S. Fish and Wildlife Service HEP training course probably increases the efficiency, accuracy, and repeatability of a HEP study. The U.S. Fish and Wildlife Service recommends the use of interdisciplinary planning teams for HEP applications.

Equipment Required: Computer software is optional for analysis of data.

Data Required: Usual data requirements include aerial photography, cover type analysis, water gauging station records, and topographic survey maps.

Usefulness of Interim and Final Products: The products of a HEP evaluation are a series of tables and evaluation forms which contain data required for deriving rating values.

Accuracy: A basic assumption of HEP is that a habitat for selected wildlife species can be described by the Habitat Suitability Index (HSI). "The reliability of HEP is directly dependent on the ability of the resource manager to assign a well-defined and accurate [HSI] to the selected evaluation species" (Lonard 1981). This may be a limitation when details of seasonal or life phase habitat requirements are poorly understood.

Repeatability: Some aspects of the technique are "unavoidably subjective" (Lonard 1981).

Ground Truthing: Ground truthing is recommended for any system dependent upon modeling.

Relative Rating System: HEP can be used to assess a single wetland area for baseline conditions or for comparisons of two or more areas. Rating may be weighted or unweighted, and allow a baseline comparison of a study area with itself or another study area (Ballard 1981).

Cost: The costs of a HEP study may be too great for small study areas, or for a project with an anticipated low impact.

Sensitivity to Ecosystem and Landscape Considerations: The study area is generally defined by purposes of the study. The study area could include areas adjacent to wetlands "where biological linkages with the wetland occur" (Lonard 1981). HEP may not technically be suited for small wetland sites (Lonard 1981).

Sensitivity to Fish and Wildlife Habitat Values: Habitat Suitability Models have been developed for use in particular areas of Alaska (For example, U.S. Forest Service 1991). The sensitivity of a HEP study to fish and wildlife is related to the quality and quantity of information and data describing habitat features of the study area and the accuracy of the Habitat Suitability Models.

3. Synoptic Approach for Wetland Cumulative Effects Analysis

Understanding the cumulative effect of multiple, seemingly small decisions has been made difficult by the absence of a standardized approach to cumulative impact assessment. Any cumulative impact assessment should evaluate the cumulative effects of the

General Functions Evaluated by the Synoptic Approach:

Hydrology
Water Quality
Life support

individual impacts occurring over the entire landscape and through time (Bedford and Preston 1988; Gosselink and Lee 1989).

The Synoptic Approach for Wetland Cummulative Effects Analysis is a procedure being developed by the Wetlands Research Program of the U.S. Environmental Protection Agency that would provide a standardized framework within the context of landscape sensitivity to cumulative wetland loss. An application of the synoptic approach produces maps of the study area.

The synoptic approach allows the assembly of generally available data into a scientific framework that maps and ranks watersheds or other landscape units according to the relative importance of wetland function and wetland loss. The procedure is designed for use in routine wetland evaluation and management work. The authors consider the synoptic approach to be a rapid, inexpensive technique for assessing the cumulative effects of wetland loss on landscape function. This rapid assessment technique is intended to complement site-specific information used in reviewing permit applications to use or alter wetlands. The synoptic approach does not indicate or predict the functions or values of a particular wetland.

The approach can be applied to a variety of geographic scales and regulatory situations, including wetland permitting and advance wetland planning at the regional or state scale, and prioritizing of watershed units where wetland restoration and creation efforts could be beneficial.

The synoptic approach was developed to provide a means of evaluating the cumulative effects of wetland loss in regulatory decisions that must be made quickly and with limited resources. The authors explain that the approach is a common sense logic structure based on many simplifying assumptions. The consequences of these assumptions are not fully understood.

The synoptic approach considers the aggregate impact of individually permitted activities that could cause significant degradation and damage to the environment, rather than the permit-by-permit view, which usually does not address any significant impact to the environment.

The approach evaluates three broad groups of wetland function. These are (1) Hydrology—the ability of wetlands to attenuate peak hydrologic flow, desynchronize floods, and stabilize shorelines; (2) Water Quality—the capability of wetlands to retain, remove, or detoxify pollutants; and (3) Habitat—the ability of wetlands to supply the required habitat and food chain support of wetland dependant biota. These functions are evaluated using indicators of wetland function. Indicators can include wetland acreage, hydric soils acreage, watershed acreage, annual precipitation, land cover, slope, main channel length, length of polluted streams, number of threatened/endangered species, and agricultural and population growth rates.

Data concerning each function are compiled by watershed or other landscape unit by an indicator category; these data may include wetland acreage, hydric soil acreage, watershed acreage, annual precipitation, land cover, slope, main channel length, length of polluted streams, number of threatened/endangered species, and agricultural and population growth rates. Data on other indicators may be compiled at the discretion of the user. A GIS is optional required for producing synthesis maps.

The synoptic approach has been applied to two pilot studies, Louisiana (Abbruzzese et al. 1990a) and Washington (Abbruzzese et al 1990b). Only the Washington case study was reviewed for this report. The Washington study was conducted to determine whether the synoptic approach could be used in the development of state water quality standards. Assumptions of the Washington pilot test include the following:

1. precipitation based processes determine hydrologic function;
2. data on polluted streams from state reports are valid indicators of pollutant loading rates;
3. the number of rare, threatened and endangered wetland dependant species present are representative of wetland biota most sensitive to habitat destruction;
4. wetland area is proportional to wetland capacity to process landscape inputs, regardless of location in the watershed;
5. hydric soils can be used to estimate past wetland losses;
6. recent trends in agricultural and population growth can be used to predict future wetland losses.

The study also tested the ranking of wetland "functional uses" at the watershed scale, identification of wetland resources that are ecologically important or sensitive to changes, and the application of the approach to wetland planning.

Limitations of the Synoptic Approach: After completion of the Washington and Louisiana pilot studies, Abbruzzese et al. (1990a and 1990b) concluded that the synoptic approach may be more appropriate for a state with a generalized set of water quality standards rather than a state which has specific surface water use categories. Currently, Alaska has specific surface water use categories similar to at least some of the categories used by the state of Louisiana.

The synoptic approach is a broad-scale study and does not provide adequate information for decisions regarding a particular wetlands site. Site-specific information on wetland value and function is still required for permitting purposes.

Abbruzzese et al. (1990b) found compromising data gaps in the Washington pilot study. They noted that the need for greater precision in the approach is accentuated in an area with highly variable landforms, soil associations, precipitation patterns, wetland densities, and data availability. Features of the Alaska landscape and the absence of basic data could make application of the synoptic approach in most of Alaska a frustrating experience.

Strengths of the Synoptic Approach: Preliminary results can be computed from existing data without a site visit. The disadvantage to this is that the final products are only as good as the data, which in much of Alaska may be scant. The availability of data, the preferred number of evaluation indicators, and the desired scale of results combine to determine the amount of time needed to use the synoptic approach. When the synoptic approach is applied to entire regions, states, or river basins, the amount of time per wetland is the least of the rapid assessment methods reviewed by Adamus (1992).

Most of the indicators used are resistant to major temporal change, so collection during all seasons or weather conditions may not be problematic.

The Washington pilot study has shown that the approach can be useful when identifying wetland areas where additional study is needed. Abbruzzese et al. (1990b) believe the assessment may be useful in regional planning and as a tool for nonpoint source pollution assessment.

Applicability to Local Wetland Types: The approach can be applied wherever enough data are available to make the effort worthwhile.

Applicability to Wetland Functions of Special Concern: The approach does not evaluate specific wetland functions.

Duration of Time Required: Application of the approach can require weeks to months, depending upon detail and complexity of the study. The greater the number of landscape units and indicators, the more time required.

Personnel Required: At least one evaluator is required.

Skills and Proficiency Level Required: Schooling in environmental sciences is recommended. GIS skills are required if a GIS is used.

Equipment Required: GIS is optional for mapping and analysis.

Data Required: Digital data are required for a GIS application. Data that can be used in a synoptic approach include wetlands acreage, hydric soil acreage, watershed acreage, annual precipitation, land cover, slope, main channel length, length of polluted streams, number of threatened or endangered species, and agricultural and human population growth rates.

Usefulness of Interim and Final Products: Output maps illustrate indicators of wetlands capacity, cumulative loss, and landscape input to wetlands. Watershed rankings can be used to identify sites for further study, or application of another wetland evaluation method.

Accuracy: Quality of the output maps depends upon detail and quality of the input data.

Repeatability: The procedure is repeatable.

Ground Truthing: The approach uses available data. No ground work is required. Accuracy is improved with ground truthing and field data collection.

Relative Rating System: The Synoptic Approach does not rank individual wetlands. Instead, landscape units may be ranked (1, 2, etc.) or categorized (high, low, etc.) as the user desires.

Cost: Cost of applying the Synoptic Approach will vary with size and complexity of study area, amount of readily available data, field work, and GIS use.

Sensitivity to Ecosystem Considerations: Landscape inputs are considered watershed or basin.

Sensitivity to Fish and Wildlife: The Synoptic Approach does not measure wetland functions. When used with a habitat oriented evaluation method, however, the approach can highlight loss of wetland habitats.

Additional Information: A manual for using the Synoptic Approach will be released in late 1992.

4. WET: WETLAND EVALUATION TECHNIQUE

Wetland Evaluation Technique, or WET, began as the assessment method developed for the Federal Highways Administration (Adamus and Stockwell 1983), and was later revised for the U.S. Army Corps of Engineers (Adamus et al. 1987). WET provides a rapid assessment procedure for screening functions and values of wetlands. WET can also be applied in a variety of other situations including: (1) comparison of different wetlands, (2) selection of priorities for wetland acquisition or

Functions and Values Addressed by the WET Method:

Groundwater Exchange
Floodwater Alteration
Sediment Stabilization
Sediment/Toxicant Removal
Nutrient Removal/Transformation
Production Export
Aquatic Diversity/Abundance
Wildlife Diversity/Abundance
Fish and Wildlife Habitat Suitability

detailed, site-specific research, (3) selection of priority wetlands for Advanced Identification, (4) identification of options for conditioning of permits, (5) determination of the effects of preproject or postproject activities on wetland functions and values, and (6) comparison of created or restored wetlands with reference to preimpact wetlands for mitigation purposes. WET is the most reviewed assessment method (for example, Doughtery 1989, Eargle 1991, Ford and Bedford 1987, Stuber and Sather 1984), and may be the most widely used in the United States.

WET evaluates functions and values in terms of social significance, effectiveness, and opportunity. *Social significance* assesses the value of a wetland to society in terms of its special designations, potential economic value, and strategic location. *Effectiveness* assesses the capability of a wetland to perform a function to its level of capability. Functions and values are evaluated by characterizing the wetland in terms of predictors. Predictors are simple or integrated variables that are believed to correlate with the physical, chemical, and biological characteristics of the wetland and its surroundings. Responses to questions concerning the predictors are analyzed in a series of interpretation keys that reflect the relationship between predictors and wetland functions or values as defined in the technical literature. Interpretation keys assign a qualitative probability rating of HIGH, MODERATE, or LOW to each function and value in terms of social significance, effectiveness, and opportunity.

The following functions are addressed by WET: groundwater exchange, floodflow alteration, sediment stabilization, sediment/toxicant removal, nutrient removal/transformation, production export, aquatic diversity/abundance, and wildlife diversity/abundance. Fish and wildlife habitat suitability is evaluated on a coarse scale.

Strengths of WET: WET is well-documented and can be adapted for local use. WET evaluations forms provide a record of how judgements of wetlands are made.

Limitations of WET: Ford and Bedford (1987) note that "Alaska's wetland resources are vast and the literature dealing directly with any given aspect of Alaskan hydrology is sparse" and that most wetland evaluation schemes, including WET, make several assumptions that are not valid for Alaska.

Applicability to Local Wetland Types: The method was designed for use in all wetland types in the 48 coterminous states. The method has been adapted for use in southeastern Alaska (Adamus Resource Assessment 1987).

Duration of Time Required for an Evaluation: Hours to days may be required, depending upon the availability of data, wetland size and accessibility, and the desired accuracy and precision of final products.

WET is the most comprehensive of all wetlands assessment methods; experienced evaluators can assess two to four wetlands daily.

Personnel and Skills Required: At least one evaluator is required. Training in WET is recommended.

Data Required: WET uses the wetland definition and classification system developed by Cowardin et al. (1979). The procedure can use "office-type" data, data from cursory field visits, and/or detailed data, with corresponding increase in the predictive validity. The office portion of the WET procedure utilizes maps, aerial photographs, and other information for the wetland to be evaluated as well as the area within a five-mile radius of the study wetland. If the study wetland occurs along a waterway, information about the area 20 miles downstream of the wetland is also recommended.

Accuracy: WET is based on published literature. The reliability, accuracy and appropriateness of the technique will vary regionally as well as from function to function, depending on available literature.

Repeatability: The functional ratings given by WET are repeatable. Better precision is gained when more data are available, and fewer subjective choices must be made. WET can be used in conjunction with expert opinion. The WET authors stress the need to fully document decisions and assumptions as part of evaluation results.

Relative Rating System: The assessment method is qualitative and not based on a series of weights and scores. It can be used to evaluate the importance of a single wetland or to compare several wetlands. The authors of WET provide guidelines and numerical values and overall probability ratings for different functions for an entire wetland, and stress that no satisfactory method exists to synthesize probability ratings of functions into an overall probability rating for the wetland.

Sensitivity to Ecosystem Considerations: WET differentiates the contributions of individual wetlands and their basins; the seasonal variability of wetlands is taken into account. WET cannot anticipate cumulative efforts on functions and values.

Sensitivity to Fish and Wildlife Habitat Values: WET evaluates fish and wildlife habitat for social significance, aquatic diversity/abundance, and wildlife diversity/abundance for effectiveness. These evaluations generate a measure of wetland-dependent bird diversity and abundance in the study wetland. WET assesses the suitability of wetland habitat for 14 waterfowl species groups, 4 freshwater fish species groups, 120 species of wetland-dependent birds, 133 species of saltwater fish and invertebrates, and 90 species of freshwater fish. WET does not assess the suitability of wetland habitats for many wildlife resources important to Alaskans (e.g., furbearers, game mammals), but other assessment methods can be used for these species to complement a WET study.

B. RAPID ASSESSMENT METHODS DEVELOPED FOR A SPECIFIC REGION, AREA, OR WETLAND TYPE IN THE COTERMINOUS UNITED STATES

1. LARSON/GOLET METHOD

The Larson/Golet method was the first method developed for rapid assessment of inland wetlands; it has been used extensively in Rhode Island.

Functions and Values Addressed by the Larson/Golet Method:

Wildlife Value
Groundwater Potential
Visual-Cultural Model

The method uses the "Golet" submodel to evaluate the wildlife value of a subject wetland. Groundwater potential is estimated by the "Heely-Motts" submodel, and visual-cultural value is estimated by the "Smardon-Fabos" submodel. These models were developed twenty years ago and have not been revised to incorporate advances of wetland science and the more recent increased understanding of wetland functions. Some important, easily observed functional indicators are not included in the models.

The Larson/Golet method is a scoring technique and is not suitable to evaluation of a single wetland. Instead, the system is intended for ranking a series of wetlands without placing them in specific categories such as high, moderate, or low. Literature citations do not support the weights assigned to various functional indicators.

Limitations of the Larson/Golet Method: The scoring technique combines indicators linearly. This approach may not reflect the nonlinear nature of wetland functions. The statistical method may not be valid (Smith and Theberge 1987). Preliminary results require a site visit.

Strengths of the Larson/Golet Method: Final scores are easily calculated. Adamus (1992) comments that this method is likely to be highly sensitive to differences among wetlands.

Sensitivity to Fish and Wildlife Habitat Values: The Smardon-Fabos submodel considers the proximity to users in the assessment of the visual-cultural and groundwater functions. Fish and wildlife related values are not likely to be reflected in such an analysis. The wildlife model may have limited use in the varied conditions of Alaska.

The Golet Submodel stresses "maximum wildlife diversity and production" as a standard for measurement of wetland values and is "designed primarily for those cases where an overall estimate of a wetland's wildlife value is needed" (Golet 1979). The system recognizes 18 life forms of vegetation that differ in their value as wildlife cover and classifies wetlands in terms of these dominant life forms, soils, and water regime.

Once the wetland or wetlands are classified by the Golet Submodel, they are then functionally evaluated and scored. The evaluation uses ten criteria, each of which is assigned a fixed weight (a significance coefficient). A subscore is calculated for each criterion by multiplying the rank given by the significance coefficients. Subscores are summed, and a total wetland score is obtained. This final score represents, in simple quantitative fashion, the wetland's relative wildlife value (Golet 1978).

Functions and Values Addressed by the Golet Submodel:

Wetland Class Richness
Dominant Wetland Class
Wetland Size

Golet and Larson (1974) present details of the criteria and their scientific basis. The system is designed "so that members of a town conservation commission, with little or no experience in wetland ecology, could employ the system at the local level" (Golet 1979). Golet recognizes that the complexity of an evaluation technique can be discouraging, and he goes on to mention that this evaluation and ranking system represents a compromise between "scientific sophistication and utility." The system has been used in local planning (Massachusetts, New Hampshire, and Rhode Island), county wetland inventory (New York), statewide inventory (Maryland), and in a study of potential salinity control program impacts in Colorado.

Golet (1979) mentions that less important criteria may be omitted to conduct a relatively quick evaluation of wetlands over a large area. Golet comments that using three of the ten criteria will produce a broad estimate of overall wildlife value with only aerial photograph interpretation.

2. Hollands-Magee Method

The Hollands-Magee Method (Hollands and Magee 1986) was developed in 1975 in response to requirements of the Massachusetts Protection Act and was an outgrowth of *Classification of Freshwater Wetlands in the Glaciated Northeast* by Larson and Golet (1974). The method is designed to accommodate regulations of several New England states and Wisconsin, and regulations implementing Section 404 of the Clean Water Act. It was extensively reviewed by the Wisconsin Department of Natural Resources and found to satisfy the requirements of NR 132, Wisconsin's wetland law relative to mining activities. The system applies only to freshwater wetlands and has been used throughout the United States.

Functions and Values Addressed by the Hollands-Magee Method:

Biological Function
Hydrologic Support
Groundwater Recharge
Storm and Floodwater Storage
Shoreline Protection
Water Quality Maintenance
Cultural and Economic Values
Recreational and Public Access Values
Aesthetics Values
Educational Values

Initially, the method was intended to determine the significance of seven functions of Massachusetts wetlands but was later revised to evaluate ten Wisconsin functions. These ten incorporate a range of biological, hydrologic and socio-cultural attributes of wetlands. The method is a field method and not a desk-top method.

The Hollands-Magee Method is sensitive to legislative designations of particular places: the method recognizes Wisconsin designated Aquatic

Study Areas, Sanctuaries or Refuges, Wildlife Management Areas, Fisheries Management Areas, Educational Study Areas, and Historical Areas, although other terms can be used instead of Wisconsin-specific designations. These designations do not contribute to any of the functional values models but indicate that the wetlands require additional consideration. The designations can also be used as preemptive elements.

The centerpiece of the Hollands-Magee assessment method is a wetland inventory. This inventory is prepared using an "inventory report form" to record information about a wetland's characteristics. These characteristics are physical, topographic, geologic, hydrologic, socio-economic, and biologic. The inventory form is organized by "element" and directs the researcher to select a condition which best describes the wetland from a multiple choice list. The data sheet is used for input into the wetland function models as a check list for consistency, as a permanent description of the wetland, and as a record of the inventory procedure. The data sheet provides a structure for quality control and becomes the most important part of the method. The inventory list can be modified to reflect the regional nature of wetland elements.

There are five steps to applying the Hollands and Magee Wetland assessment method. These are:

1. Define the wetland area to be assessed.
2. Inventory the wetland.

3. Generate a narrative of wetland function using the inventory form, personal (field) knowledge of the wetland, and qualitative professional opinion/ judgement.
4. Enter data into semi-quantitative models using the inventory sheet data.
5. Compare results of steps 3 and 4.

Sensitivity to Local Wetland Types: The Hollands-Magee Method may be applied to freshwater wetlands only. In its original form, this wetland assessment method is applicable to glaciated regions of the United States. The method can be adapted to any region of the U.S.A. and Canada when modified to reflect the regionality of wetland elements (Hollands pers. comm.).

Duration of Time Required: The amount of time needed complete the inventory and use the functional models will vary with the size and accessibility of the wetland, the availability of background data, and the desired level of accuracy and detail. Generally, the inventory form is completed by the field crew which delineates the wetland. Little additional field time is required once the inventory form is complete.

Personnel, Skills, and Proficiency Level Required: A two-person team is generally required for data collection and use of the method. One member of the team should be a geologist/hydrologist/soil scientist; the other a botanist/ecologist. Both should be experienced in wetland functional assessment.

Equipment Required: In addition to usual field equipment for data collection, a hand-held calculator is needed for data analysis. A personal computer is required to use a computerized modeling program, however, the program can easily be run by hand for a few wetlands.

Data Required: The "Ecological Element" requires information at the wetland subclass and dominant class levels. The ecological information is organized following the wetland classification system of Larson and Golet (*Classification of Freshwater Wetlands in the Glaciated Northeast,* 1974).

The "Topographic" and "Geological" elements require information describing topographic configuration, size, gradient, surrounding slopes, wetland position in the watershed, surfacial geologic material underlying both the study wetland and the watershed, bedrock type, and soil type and permeability. The "Hydrologic Element" considers information that maybe more difficult to acquire, such as the hydrologic position of the wetland, its groundwater relationship, and the transmissity of the aquifer. Some "Hydrologic Element" information is similar to that of the "Topographical Element," for example, hydrologic position of wetland, surface connections, percent of wetlands bordering open water or upland, amount of wind fetch, or depth of lake.

Information about any special legislative status of species or lands within the study area is used in the Ecological Element.

Usefulness of Interim and Final Products: Partial results are possible without a field visit, but method authors do not recommend using this method without a field visit.

Accuracy: Accuracy varies with amount of background data. Adamus (1992) reports that the method is highly sensitive to differences among wetlands. The field inventory sheets provide a record of accuracy.

Repeatability: The Wetland Inventory Report generated during each site visit enables some consistency from one wetland to another, or from one point in time to another, at the same wetland. The Wisconsin Department of Natural Resources has found the Holland and Magee Method to be highly reproducible between different assessment teams evaluating the same wetland.

Ground Truthing: The method requires that each "element" of the Wetland Inventory Form be evaluated in the field using actual measurements or observations.

Relative Rating System: Ranking involves scoring each wetland for each function. For context, scores for an individual wetland can be compared to a model mean or to actual scores for other wetlands in the area.

Assessment of functional value uses best professional judgement of the method authors, and weighting of elements in the biological, watershed, and socio-cultural functional models reflects the view of Hollands and

Magee that these elements are considered to be of greater importance than other elements of the models.

Cost: Costs of using the method are related to the expertise required to apply the system (a two person team consisting of a geologist/hydrogeologist/soil scientist and a botanist/ecologist) and field work. The field team conducts site visits to each wetland under study, and the method requires that each element in the inventory be evaluated in the field using actual measurements and observations whenever possible. The wetland delineation and assessment should be completed by the same field team during a single visit to reduce cost and time.

Sensitivity to Ecosystem Considerations: The system includes sensitivity to the landscape and classifies wetland location by four topographic features: closed basins, semi-closed basins, valleys, and hillsides. These categories could easily be modified to the hydrogeomorphic wetland types of the Hydrogeomorphic (Brinson) Classification.

Sensitivity to Fish and Wildlife Habitat Values: The Biological Function Model of the Hollands-Magee Method considers the presence or absence of "unique fisheries" and endangered or threatened species. Wetland class, surrounding habitat, cover, plant diversity and density, and other habitat features are used to evaluate habitat value. More information about habitats can be inferred from the "Topographical," "Geological," and "Hydrologic" elements of the Wetland Inventory Data. Other than these general features of the method, potential sensitivity of the method to Alaska fish and wildlife species and their habitats was not determined from the materials available during this review project.

Strengths of the Hollands-Magee Method: According to the authors of the method, the system is fast, cost-effective, and easily applied, although an experienced geologist/hydrologist and a botanist/ecologist are required. The authors believe the application results compare favorably with more complex methods such as WET (Adamus 1983). The authors indicate the method allows for adjustments to be made for regional differences in wetland function and for advances in scientific understanding or measurement of wetland functions.

Additional Comments: Both Hollands and Magee are part of a national technical group working with the Waterways Experiment Station in Vicksburg, Mississippi, to develop a national wetland assessment method based upon the Hydrogeomorphic (Brinson) Classification. The evolving new Federal method follows the same steps as the Hollands-McGee Method (definition/boundary first, inventory second, then assessment), and both use similar wetland elements as predictors for wetland functions (Hollands 1992). Magee expects that the Hollands-Magee Method will be replaced by the method developed by the national technical group (Magee 1992).

3. Connecticut/New Hampshire Method

The *Method for the Evaluation of Inland Wetlands In Connecticut: A Watershed Approach* (Ammann et al. 1991) evaluates 14 values or functions of nontidal wetlands in Connecticut and New Hampshire.

Functions and Values Evaluated by the Connecticut/New Hampshire Method:

Ecological Integrity
Wetlands Wildlife Habitat
Finfish Habitat
Educational Potential
Visual/Aesthetic Quality
Water-Based Recreation
Flood Control Potential
Groundwater Use Potential
Sediment Trapping
Nutrient Attenuation
Shoreline Anchoring
Urban Quality of Life
Historical Site Potential
Noteworthiness

The Connecticut/New Hampshire method is derived from the Hollands-Magee (Normandeau) Method. The Connecticut method emphasizes wetland assessment from a systematic view. The method is designed to be scientifically defensible, but simple enough to use so that it can be applied to all wetlands in a community. Application of the system has contributed to a data base of wetland information that can be used by government officials and educators.

Limitations of the Connecticut/New Hampshire Method: The method linearly combines functional indicators and produces a final score that is equal to the product of acreage multiplied by functional values. This approach is not likely to reflect the non-linear nature of wetland processes. Overall, the statistical methods may not be valid (Smith and Theberge 1987).

A field visit is required for preliminary results. A GIS is recommended for up-to-date base maps detailing location, classification, and delineation of wetlands.

Strengths of the Connecticut/New Hampshire Method: The system is intended for use by a community official, although some technical training is advised. For example, some evaluation questions require the ability to delineate a watershed. The manual is very well done; it is easy to understand and use.

Applicability to Local Wetland Types: The method was designed for nontidal wetlands in Connecticut and New Hampshire.

Applicability to Wetland Functions of Special Concern: Anadromous fish habitat is specifically included in the evaluation.

Duration of Time Required: Total time required to apply the method will vary from hours to days, depending upon wetland size, accessibility, and complexity; availability of background data; and desired level of accuracy and detail.

Personnel Required: At least one evaluator is required.

Skills and Proficiency Level Required: The method manual is intended for use by public officials and others who have some familiarity with wetlands, but who are not necessarily wetland scientists or other specialists.

Equipment Required: GIS is optional.

Data Required: Maps and information required include: Anadromous fish maps, soils surveys, geologic maps, topographic maps, flood insurance study reports, zoning maps, NWI maps, and aerial photographs.

Usefulness of Interim and Final Products: An office inventory prepares draft wetland delineation maps. Mylar overlays are included.

Accuracy: The method manual includes detailed instructions and data sheets. If directions are followed, the method is highly sensitive to differences among wetlands (Adamus 1992). The level of detail and accuracy will vary with amount of data used for evaluation.

Repeatability: The method manual includes detailed instructions and data sheets. The manual includes guidance for a defensible wetland assessment. If directions are followed, subjective choices should be limited.

Ground Truthing: The method requires ground truthing for final products.

Relative Rating System: The method has two sets of scoring criteria: one for "urban" wetlands and another for all other wetlands. In both cases, functional scores are optionally multiplied by acreage to generate overall wetland score for each function.

Cost: The cost of applying the Connecticut Method was not available during the review. Size and complexity of study area, amount of available data, use of GIS, and necessary field work will affect cost.

Sensitivity to Ecosystem Considerations: A few landscape-related factors are included in the evaluation. Relationship to landscape (i. e., other wetlands adjacent lands) are included.

Sensitivity to Fish and Wildlife Habitat Values: The method does not emphasize a particular species or group of species. Rather, the intent is to evaluate the suitability of wetlands as habitat for those wildlife species typically associated with wetlands and with a wetland edge. The method is one of three reviewed for this report that considers fish access between the ocean and the wetland being evaluated.

Fish habitat is evaluated two ways: rivers and streams, and lakes and ponds.

The wildlife habitat evaluation is partially based on the assumptions that larger wetlands provide more habitat, that open water is essential to some species, and that those wetlands which are the least degraded by human activity provide the highest quality habitat.

Additional Information: A similar evaluation method has been developed for New Hampshire (Amman and Stone 1991).

4. WEM: MINNESOTA WETLAND EVALUATION METHODOLOGY

The *Minnesota Wetland Evaluation Methodology for the North Central United States*, or WEM, is used in Minnesota for all freshwater wetland types. WEM is partially derived from WET (Wetland Evaluation Technique, Adamus and Stockwell 1983). WEM uses fewer functional indicators than does WET, omitting some important, easily observed indicators. The method is structured so that functions to be included in a wetland evaluation can be selected by the user.

Function and Value Components of the Minnesota Wetland Evaluation Method

Peak Flow Reduction
Sediment Trapping
Nutrient Trapping
Wildlife Diversity and Productivity
Warmwater Fish
Northern Pike Spawning Habitat
Shoreline Anchoring
Visual Variety
Visual Importance
Visual Integrity
Special Features

WEM evaluates 11 functions and values to assign scores (e.g., 1, 2, 3) to low, moderate and high categorical ratings, and assigns subjectively chosen weights to the individual functions. Multiplication of scores by the function weights produces an overall wetland score. These ratings are generally not statistically valid (Smith and Theberge 1987).

Limitations of WEM: Seasonal change is not considered by the evaluation questions or the data forms. The method requires a site visit before preliminary results can be derived.

If optional computer software is used to evaluate data, application of the entire evaluation system requires a computer with a math coprocessor.

Strengths of WEM: The system considers some landscape context and regional factors that contribute to wetland functions. The system gives extra consideration to wetlands upstream from some types of social/cultural features likely to benefit from those upstream wetlands.

Applicability to Local Wetland Types: WEM is designed for use with all types of wetlands found in Minnesota.

Applicability to Wetland Functions of Special Concern: Special attention is given northern pike habitat.

Duration of Time Required: WEM was developed with the intent that an evaluation would be completed in about 9 hours (not including travel time).

Personnel Required: At least two evaluators.

Skills and Proficiency Level Required: The WEM manual is designed for use by someone with a basic understanding of potential wetland functions and values, plant communities, regulation, and issues related to wetland delineation.

Equipment Required: A computer (IBM-compatible with a math co-processor chip and 360k of memory) is required for the inflow-outflow hydrographs.

Data Required: Topographic maps, soil survey, climatological data, wetland inventory maps, aerial photographs, and other similar information sources provide data required in a WEM evaluation.

Usefulness of Interim and Final Products: Interim products are the result of the office portion of the procedure. Final products are generated after a field visit.

Accuracy: The WEM manual stresses that if the methodology produces a rating that seems peculiar, a second source of information should be consulted or further study should be recommended.

Repeatability: Professional judgement and expertise are sometimes used to make modifications to arbitrary cut-off points or rating tables.

Ground Truthing: About one hour of field work at the wetland site is required.

Relative Rating System: WEM includes an option for the user to assign scores (e.g. 1, 2, 3) to categorical ratings. (The categorical ratings of low, moderate and high are generated the same way WET generates categorical individual wetland functions.) An overall wetlands score is produced by multiplying scores by function weights.

Cost: The cost of applying the Minnesota Method was not available to us during the review. Size and complexity of study area, amount of available data, and necessary field work will affect cost.

Sensitivity to Ecosystem Considerations: The method is tailored to Minnesota's ecoregions.

Sensitivity to Fish and Wildlife Habitat Values: WEM incorporates wildlife valuation methods developed by Golet (1978) and Adamus (1983). Golet criteria weights which are based on professional judgement in the New England area are not used in WEM.

Minnesota is similar to Alaska in that wetlands vary considerably across the state, consequently, prairie potholes, southern forest, and northern forest regions were established so that prairie potholes would not be categorically rated "low" on a scale designed to measure wildlife related values of all Minnesota wetlands. This "regionalization" applies to the general diversity/productivity section of WEM.

The WEM waterfowl evaluation is based on criteria proposed by Adamus (1983) for evaluating waterfowl nesting and summer habitats. The evaluation is sensitive to habitat and food required of different ducks, geese, and swans. WEM does not evaluate waterfowl wintering and migration values of wetlands. The fish evaluation portion of WEM is intended for use in the north central region of the United States. Of particular interest to some Alaska wetland studies is the evaluation criteria for northern pike spawning habitat. Trout and other cold water fish species are included in the "Special Features" portion of WEM.

5. ONTARIO METHOD

Functions and Values Addressed by the Ontario Method:

Flow Stabilization
Water Quality Improvement
Shoreline Erosion Control
Biological Productivity
Biological Diversity
Economically Valuable Products
Recreational Activities
Education and Public Awareness
Rarity/Scarcity
Special Habitat Features
Ecological Age
Size
Ownership
Proximity to Human Settlement
Landscape Aesthetics
Groundwater Exchange

Loss of wetland values, especially wildlife habitat, has been a concern in southern Ontario where regional wetland loss is estimated at 70 percent. Area officials recognized that the necessary first step for planning and management is an inventory in which the relative values of the remaining wetlands are assessed using a standard method. An evaluation system similar to the Hollands-Magee Method was prepared and field tested in 1981; a 1983 version of the evaluation method (Euler et al. 1984) has been under review over the last two years while a parallel method for northern Ontario has been under development. Subsequent modifications have improved the assessment method, and drafts of *A Wetland Evaluation System for Southern Ontario: Covering Hill's Site Regions 6 and 7 (Draft)* (Ontario Ministry of Natural Resources, 1992b) and *A Wetland Evaluation System for Northern Ontario: Covering Hills Site Regions 2 to 5* (Ontario Ministry of Natural Resources 1992a) have recently been released. The difference between the two evaluation systems reflect the differences in variables such as climate, geomorphology, and human uses. The southern Ontario method is a revision of Euler (1984), and specifically applies to areas south of the Precambrian Shield. The Ontario methods draw on earlier works (i.e., Jeglum et al. 1974, Golet 1976, Larson 1976, Gupta et al. 1976).

The Ontario method is a hierarchial system that measures or estimates a large number of values for all wetlands in the planning area. It is not suitable for assessing a single wetland, and it does not consider vulnerability to development pressures or management strategies.

The method generates scores in four component categories (biological, social, hydrologic, and special features) and in 65 subcomponents. The method is designed for use at the municipal, county, or regional levels of government, as well as the national planning level. The authors indicate that the method be applied only by trained individuals or evaluation teams.

Strengths of the Ontario Methods: Field test results indicate a high degree of repeatability. The evaluation questions consider regional factors and landscape inputs. The system is sensitive to the seasonal nature of wetland conditions: for example, the methods require a site visit to Palustrine wetlands during low water stage so that inflow and outflow may be accurately determined. The Ontario methods can be used for a preliminary biophysical inventory of a wetland.

Limitations of the Ontario Methods: Adamus (1992) reviewed *An Evaluation System for Wetlands of Ontario South of the Precambrian Shield* (Euler 1984), an earlier version of the southern Ontario method. Adamus noted that the statistical analyses are not likely to be valid, and thus the rankings should be used with caution. He also noted that literature citations were seldom used to support rationale for selected indicators or the weights assigned to indicators or functions. Both limitations appear to apply to the two recently released draft methods as well.

Applicability to Local Wetland Types: The Ontario Method may be used to evaluate all wetland types found in Ontario, except for brackish wetlands bordering Hudson and James Bay.

Applicability to Wetland Functions of Special Concern: The special features component highlights waterfowl staging or molting areas, provincially or regionally significant species, osprey, common loon and fish.

Duration of Time Required: Time required to assess a wetland will vary with wetland size, accessibility, and complexity; availability of background information, and desired accuracy and detail.

Personnel Required: At least one evaluator is required.

Skills and Proficiency Level Required: Authors of the Northern and Southern versions recommend the evaluation methods be used by individuals or teams with the following minimum experiences:

1. adequate knowledge and experience with wetland ecology to be able to correctly identify all wetland classes, their characteristic species, and unusual features;

2. knowledge of flora and fauna to the extent of being able to identify most wetland species and those in the adjacent upland areas as well as rare or significant species. Associated skills in the use of plant, bird, mammal and fish keys are also necessary;
3. knowledge of air photo interpretation, sufficient to interpret wetland vegetation and boundaries;
4. general knowledge of natural history and wildlife;
5. some understanding of hydrologic processes;
6. in the case where remote wetlands are to be evaluated, then some experience at wilderness survival and first aid.

Application of this system can be carried out only by persons who are certified by the Ministry of Natural Resources as having the necessary qualifications. Persons may be required by the Ministry to take a wetlands evaluation course and/or pass a plant and animal identification exam in order to gain the necessary certification.

Equipment Required: The draft manuals provide a list (presented here in Table 2, page 91) of equipment and supplies required for a wetland evaluation using the Ontario Method.

Data Required: Maps, air photos, wetland size, climate, land uses, species lists.

Usefulness of Interim and Final Products: Interim products are developed prior to field work from available background information and data.

Accuracy: The Ontario method has been field tested since 1981, when the 1984 version was being drafted (Euler 1984). The 1984 version was applied to some 2,500 wetlands across Southern Ontario (MNR 1992b) and to more than 100 in Northern Ontario (MNR 1992a).

Repeatability: The two draft manuals provide specific guidance for application of the evaluation procedure.

Ground Truthing: Field work is required for each wetland evaluation. The Ontario method is sensitive to the fact that wetland conditions vary with weather conditions and seasons; the manual stresses the goal of accurate, objective and complete work.

Relative Rating System: The Ontario method develops ratings for specific and overall wetland values.

Cost:

Sensitivity to Ecosystem Considerations: The Ontario evaluations consider diversity of surrounding habitat (i.e., utility corridor, clearcut, quarry, forest, pasture), proximity to other wetlands, wetland age, and wetland complexity.

Sensitivity to Fish and Wildlife Habitat Values: The method includes evaluation questions for beaver and beaver ponds. The presence of Northern pike and salmonids is considered in the fish habitat evaluation but fish access is not specifically evaluated. Glooshenko, Archbold, and Herman (1988) report that the Ontario Method highlights the relationship between particular wetland types and the occurrence of bird species. Evaluation questions consider various bird habitats and bird sightings, wildlife winter cover, fish habitat, and plants, however, most of Ontario's significant fish, reptile, and amphibian species are not known to occur in Alaska. The time of day, year, and weather conditions are also included in the analysis.

Additional Information: The Municipality of Anchorage has developed a modification of Euler (1984) for use in the Anchorage area. A shorter version based upon satellite imagery is being developed for use in the more remote areas of Ontario.

Table 2. Equipment and supplies required for the Ontario Method (from Ministry of Natural Resources 1992a and 1992b).

canoe & cartop canoe rack	sun hats
paddles	insect repellent
anchor and rope	ethanol (for cleaning air photos)
life jacket	soil probe or auger
waders, rubber boots	field guides and manuals
metre stick	aquatic vegetation survey forms
stereoscopic glasses, mirror stereoscope	clinometer
pH meter	Secchi disk
binoculars	plant press
camera (polaroid and/or 35 mm) and film	copy of Evaluation system procedures and data forms
plastic bags	clip boards
jackknife	field note books, pencils, fine acetate markers
water cooler	air photos with acetate overlays
first air kit	topographic maps
knapsack	rain gear

6. Ranking and Categorization: Adirondack Wetlands Inventory

One example of a wetland inventory and classification method designed for categorization use is that used in New York's Adirondack Park for regulatory and ecological purposes (Curran et al. 1989). The inventory and mapping components of the Adirondack Inventory use an adaptation of National Wetland Inventory procedures. These adaptations include mapping to one-acre units at 1:80,000, increased cover type resolution by use of large scale 1:24,000 backup photography, pre- and post-photography interpretation fieldwork.

Wetlands identified in the inventory are classified into categories intended to distinguish outstanding wetlands from less significant wetlands. The wetland categories, which range from most significant (I) to least significant (IV), are based on wetland functions and values considered important, and on natural processes and cover type (Table 3). Wetland functions and values considered by the classification are wildlife habitat, stream flow moderation, rare and endangered species habitat, energy flow and nutrient cycling, fisheries habitat, and aesthetics. Groundwater recharge, while recognized as an important natural process, is poorly understood in the planning area and is not currently used for determining value of a wetland.

Applicability to Local Wetland Types: Adirondack Park is large (six million acres) and relatively inaccessible, with highly variable climatic, geomorphic, and topographic conditions. The inventory and classification method applies to inland wetlands found in this setting.

Applicability to Wetland Functions of Special Concern: The method is very sensitive to any wetland providing habitat for rare, threatened, or endangered plants or animals, and any scarce habitat type.

Duration of Time Required: The more detailed mapping and field checking procedures require at least twice as much time as the usual NWI protocol.

Personnel Required: At least one evaluator.

Skills and Proficiency Level Required:

Equipment Required:

Data Required: 1:80,000 black and white quad-centered aerial photography.

Usefulness of Interim and Final Products: Interim products include interpreted photography, overlays of wetland boundaries, orthophoto quadrangle sheets, rectified wetland base maps, and final wetlands maps. Wetland boundaries are plotted onto suitable base maps so that land owners can be determined.

The one-acre mapping unit is related to jurisdictional size; smaller wetlands are mapped with a dot, and dashes indicate wetlands along waterbodies.

Accuracy: Use of the wetland maps has shown that the maps are accurate.

Repeatability: The Adirondack Wetland Inventory uses procedures developed within the framework of applicable state law.

Ground Truthing: The Adirondack Inventory uses ground truthing before and after photo interpretation to increase the reliability of the photo interpretation. Field check sites are selected by accessibility, and about two quads can be ground truthed in one working day.

Relative Rating System: The Adirondack Wetland Inventory categorizes wetlands based on cover type and selected wetland functions and values.

Costs: The cost of applying the Airondack procedure was not available during the review. Cost will be affected by size, complexity, and accessibility of study area, and required field work.

Sensitivity to Ecosystem Considerations: The permitting review component of the Adirondack Inventory draws in a wider view than the footprint of a proposed project. Adjacent area permits are evaluated, in part, by Category rating.

Sensitivity to Fish and Wildlife Habitat Values: Category I Wetlands include habitats for rare, threatened or endangered plants or animals. Scare habitats are also included in Category I. Category II and

III Wetlands are the most common wetlands and have a range of functions and values.

The planning area includes a few Category IV Wetlands. These wetlands "provide limited benefits" and have "no other special value" (Curran et al. 1989). An example of this category would be a wet meadow maintained in agricultural use as a pasture or hayfield.

Additional Information: Categorization as applied by the Adirondack Inventory differs from the EPA proposal in the area of compensation. Adirondack wetlands are generally considered undevelopable and have limited market or taxable value. The EPA proposal would consider any limitation of use to be a regulatory taking that requires compensatory action.

Table 3. A comparison of the cover type categories used by National Wetland Inventory (Cowardin et al. 1979) and the Adirondack Inventory (from Curran et al. 1989).

COWARDIN ET AL.	ADIRONDACK INVENTORY
Forested, needle-leaved, deciduous or evergreen	Coniferous swamp
Forested, broad-leaved, deciduous	Deciduous swamp
Scrub-shrub	Shrub swamp
Emergent, persistent, seasonally flooded	Wet meadow
Emergent, persistent or nonpersistent, semipermanently flooded	Emergent marsh
Aquatic bed	Deepwater marsh

C. EXAMPLES OF WETLAND INVENTORY AND ASSESSMENT METHODS USED IN ALASKA

Statewide: The only extensive wetland inventory effort is the National Wetland Inventory, or NWI, conducted by the U.S. Fish and Wildlife Service. The NWI was initiated nationwide in 1975, and in Alaska in 1978. The NWI procedure involves interpretation of high-altitude (1:80,000) color infrared aerial photographs. Wetland areas are delineated and classified based on vegetation, visible hydrology, and geological information from the aerial photographs. Draft maps are confirmed by field studies. This inventory only provides information. The NWI does not rank or score wetlands, nor does it evaluate any wetland function.

Local: Alaska Coastal Management Program: Four Alaska communities have prepared wetland inventories of selected wetland areas within their jurisdictions. These are Sitka, Juneau, Homer, and Anchorage. As this guide goes to print, a study of some Fairbanks area wetlands is being planned. These studies have been components of Coastal Zone Management or federal Clean Water Act programs.

Local: EPA Advanced Identification of Areas Suitable for Development: The U.S. Environmental Protection Agency program "Advanced Identification" has completed two studies of wetlands. These studies focused on wetlands in the Homer and Juneau areas. A third study of the Colville area was completed by not adopted by regulatory agencies. EPA also conducted a test of a waterfowl habitat classification scheme at Kuparuk. The EPA advanced identification studies rank wetlands as "suitable" or "unsuitable" for fill, based upon ecological considerations only. The EPA studies are a component of that agency's program to implement Section 404 of the Federal Clean Water Act.

1. ANCHORAGE RAPID ASSESSMENT METHOD

The Municipality of Anchorage has recently completed the *Anchorage Wetlands Assessment Methodology* (Tobish 1992). This method considers wetland functions related to hydrology, fish and wildlife habitat, and plant, fish and wildlife occurrence, as well as societal uses and values of wetlands. The method was developed over a period of four years.

Functions and Values Addressed by the Anchorage Method:

Floodflow Stabilization
Fish and Wildlife Habitat
Plant, Fish and Wildlife Occurrence/Scarcity
Recreation/Education Value
Ownership/Accessibility

The method is modelled after the Ontario method (Euler 1984), and draws heavily on earlier work done in the general Anchorage area (for example, Hogan and Tande 1983, Elliot and Finn 1984, Ertic Northwest 1981, Murphy et al. 1984, Rosenberg 1986, and Lensink and Derksen 1986) and in Minnesota and Wisconsin (for example, Brown and Stark 1989, Hindau 1975, Novitski 1978).

The paucity of data and the difficulty of measuring some predictors of wetland function required that some questions of the Ontario method be dropped from the Anchorage method and that best professional judgement be used instead of data. Authors of the Anchorage method recognize that the resulting level of detail is potentially superficial, and that the methods assignments of values may similarity be flawed.

The Anchorage method generates high, moderate, and low ratings for individual functions of a wetland or a group of wetlands. These ratings will be used in a future wetlands management plan revision for Anchorage wetlands. Wetland function ratings will be combined with societal features (such as zoning, presence of infrastructure) to generate a score to be used in categorizing a wetland range of categories between "developable" and "preservation."

Applicability to Local Wetland Types: The Anchorage method is intended for use throughout the municipality of Anchorage (Anchorage Bowl, Eagle-River-Chugiak, Turnagain Arm).

Applicability to Wetland Functions of Special Concern: Fish and wildlife habitat and species occupance are important components of the assessment portion of the Anchorage method.

Duration of Time Required: The methodology has been developed over a four year period. An application requires one day per single site visit if adequate data or knowledge is available.

Personnel Required: State, federal, and local government staff contributed to the project. An application of the Anchorage method requires a single evaluator.

Skills and Proficiency Level Required: All participants involved with developing the methodology have at least a basic understanding of wetland functions.

Equipment Required: An application requires a TOS meter.

Data Required: NWI maps, aerial photographs, USGS 1:63,360 topographic maps, wetland size.

Usefulness of Interim and Final Products: Interim map products can identify fish and wildlife habitats and plants considered significant.

Accuracy:

Repeatability: The method relies on best professional judgement and field data when verifiable data is absent.

Ground Truthing: The method was ground truthed on 269 wetland sites within the municipality.

Relative Rating System: The Anchorage assessment method scores wetland functions into high, medium, and low value rankings. A future management plan will use these scores in conjunction with ownership and zoning information to generate a management category.

Cost: The cost of developing or applying the Anchorage methodology were not available during this review. The municipality's expense was related to staff time only.

Sensitivity to Ecosystem Considerations: The methodology considers wetland position in the water shed, land use for 1/2 mile below the watershed, general land use. The method does not consider cumulative loss.

Sensitivity to Fish and Wildlife Habitat Values: The method considers wetland plant community structure and diversity, local climate effects, contiguity and other physical features of fish and wildlife habitat. A "rarity and/or scarcity" component considers endangered, threatened, or rare plants and breeding, feeding, spawning or rearing habitat for significant bird or anadromous fish species. The consideration given to ownership, accessibility, and zoning is not greater than the consideration given wetland functions and values, such as fish and wildlife habitat.

2. Homer Wetland Inventory and Ranking

The Homer wetlands study area included lakes, streams, tidelands and wetlands within the city limits of Homer, excluding the Homer Spit and the top of the bluff. Site descriptions with hydrologic, pedologic, and vegetative characteristics of 25 wetland sites were completed. Sites were classified into 14 major wetland types, 13 physiognomic vegetation types, and 26 National Wetland Inventory classes. Wetland mapping and a

Wetland Functions and Values Evaluated by the Homer Wetland Study:

Wildlife Use
Water Quality
Foodchain Productivity
Shoreline Protection
Subsistence and Personal Use
Recreational Use
Local or Regional Uniqueness

limited functional assessment were later used for an EPA Advanced Identification study which categorized wetlands as "high value" or "low value" and to support issuance of a general permit for development in certain wetlands. The City of Homer believed that by working with developers, planners, and resource agencies greater protection would be available to important wetlands.

Functions and values of Homer wetlands considered by the functional assessment were: bird, mammal and fish use; water quality; shoreline protection; subsistence and personal use; recreational use; and local or regional uniqueness. These functions were generally evaluated by the presence or absence of the use or activity. Some evaluation questions are derived from Adamus and Stockwell (1983) and a 1983 version of Euler et al. (1984).

Applicability to Local Wetland Types: The Homer study evaluated estuarine and freshwater wetlands.

Applicability to Wetland Functions of Special Concern: Wetlands of special concern in the study area provide critical moose winter habitat, shorebird staging and feeding areas, and Aleutian tern nesting habitat.

Duration of Time Required: The mapping phase required six weeks; the ranking phase was a public process spanning six months.

Personnel Required: The wetland inventory phase, including wetland delineation, was done by a private contractor using specifications provided by the U.S. Army Corps of Engineers (Jorgenson and Berg, 1987). Wetland boundaries were later verified by the Corps to ensure the delineations conformed with the then current Corps' definition of wetland.

During the ranking phase, an interagency study group consisting of representatives from the Corps, the Environmental Protection Agency, the U.S. Fish and Wildlife Service, and the Alaska Department of Fish and Game ranked wetlands based on their functions and values and designated them "low" or "high."

Skills and Proficiency Level Required: All agency participants had expertise in some wetland functions or values. The mapping phase was completed by a private consultant. The ranking phase relied heavily on a local biologist's knowledge of moose numbers and distribution. Maps depicting moose habitat were already available to the wetland study, as was previous work on Aleutian terns (Rosenberg 1986).

Equipment Required: The mapping phase required stereoscopic photography.

Data Required: Aerial photography, fish and wildlife data, National Wetlands Inventory maps, and Soil Conservation Service soil classifications of the area.

Usefulness of Interim and Final Products: Interim products included a report "Wetlands of Homer" (Jorgenson and Berg 1987). This report describes wetlands in the study area, and incorporates some work previously done on the Kenai Peninsula (for example, Imamura 1976, Ritchie et al. 1981, Rosenberg 1986).

Final products are large scale orthophoto maps (1" = 100') for two major areas of the city, and maps identifying high and low value wetlands within the city limits.

Accuracy: Presumed high, but based on limited knowledge of some functions; e.g., water quality and food chain productivity.

Repeatability: The method is repeatable, given the assumptions and project parameters.

Ground Truthing: The mapping phase required a limited amount of field verification.

Relative Rating System: Generally, high scores for a combination of evaluated functions and values are required for a wetland to be considered "high value" in this study.

The study placed wetlands in the "low value" category if relatively few important functions or values were found for those wetlands. The "low value" wetlands are the same wetlands considered suitable for fill by the EPA Advanced Identification study and by the COE General Permit issued to the City of Homer for residential, commercial, and industrial development.

Cost: The wetland mapping phase cost less than $20,000 for private contractor (this does not include Corps of Engineer personnel).

Total cost of the wetland ranking phase has not been estimated due to the numerous contributions of agencies and agency personnel.

Sensitivity to Ecosystem Considerations: The Homer wetland study and subsequent ranking is not ecosystem sensitive, nor are cumulative effects of wetlands loss.

Sensitivity to Fish and Wildlife Habitat Values: A wetland was ranked "high value" if it supported moose, Aleutian terns, or shore birds. Except for the intertidal area, anadromous fish do not occur in the area. The study area supports few waterfowl. Some nesting and overwintering bald eagles occur in the area.

3. RAPID ASSESSMENT METHOD FOR SOUTHEAST ALASKA: JUNEAU WETLANDS STUDY

During a study of selected wetlands within the City and Borough of Juneau, Adamus Resource Assessment, Inc. in consultation with state and federal agencies, adapted the wetland evaluation technique (WET) developed in the lower 48 states (Adamus and Stockwell 1983). The customized method was successfully used for field work in the Mendenhall River and Lemon Creek valleys, the Juneau International Airport, and the Mendenhall Wetlands State Game Refuge. Later, the rapid assessment method was extended to cover other non-alpine wetland situations which might occur elsewhere in southeast Alaska.

Functions and Values Addressed by the Rapid Assessment Method for Southeast Alaska:

Ground Water Exchange
Surface Hydrologic Control
Bank or Shoreline Sensitivity
Sediment/Toxicant Retention
Nutrient Removal and Transformation
Salmonid Habitat: Coho/Cutthroat Rearing
Production Export
General Wildlife Diversity/Abundance
Riparian Support
Downslope Beneficiary Sites

Use of the method yields a preliminary, qualitative estimate of the functional values of a particular wetland. The method does not score wetlands, but gives ratings of high, moderate, or low for *effectiveness, significance,* and, where appropriate, *opportunity* for particular wetland functions. The rapid assessment technique can be used to evaluate a single wetland or a group of wetlands.

Limitations of the Southeast Alaska Methodology: The rapid assessment methodology has not been tested outside of the Juneau study area. The author notes that research on wetlands elsewhere in southeast Alaska is needed to improve the accuracy of rapid assessment methods for wetland functions in the region.

Strengths of the Southeast Alaska Methodology: Southeast Alaska and other Gulf Coast areas of the state have several similarities and with a few refinements, the system may be useful in Prince William Sound or the Kodiak Archipelago.

Sensitivity to Fish and Wildlife Habitat Values: The Juneau Wetland Study used representative wetlands to calibrate the function assessment criteria. These criteria were then applied to all study wetlands. Results of Salmonid Rearing and Wildlife Diversity/Abundance evaluations generally matched "best professional judgements" of biologists who work with wetlands in the Juneau study area.

4. Colville River Delta Bird Habitat Study

The Colville River delta is Alaska's largest arctic river delta (Figure 9, page 107). The delta supports outstanding bird resources, and is also an area with high potential for oil and gas related development. Recognizing the need for identification of important habitats prior to development, the U.S. Environmental Protection Agency (EPA) funded a study of relative values of wetlands to waterbirds. The study compiled existing information on wetlands and waterbirds in a map based system that portrays waterbird-related resource values (Meehan and Jennings 1988). The EPA planned to use study results for advanced identification of areas suitable or unsuitable for fill (40 CFR, Sec. 230.80).

The Colville habitat classification separates emergent vegetation adjacent to lakes as a distinct class. The wetland classification developed by Bergman et al. (1977) treats lakes and other types of wetlands as complete units.

The Colville classification does not comprehensively address surface or landforms integral to a geobotanical classification (Walker 1983 or Troy 1985).

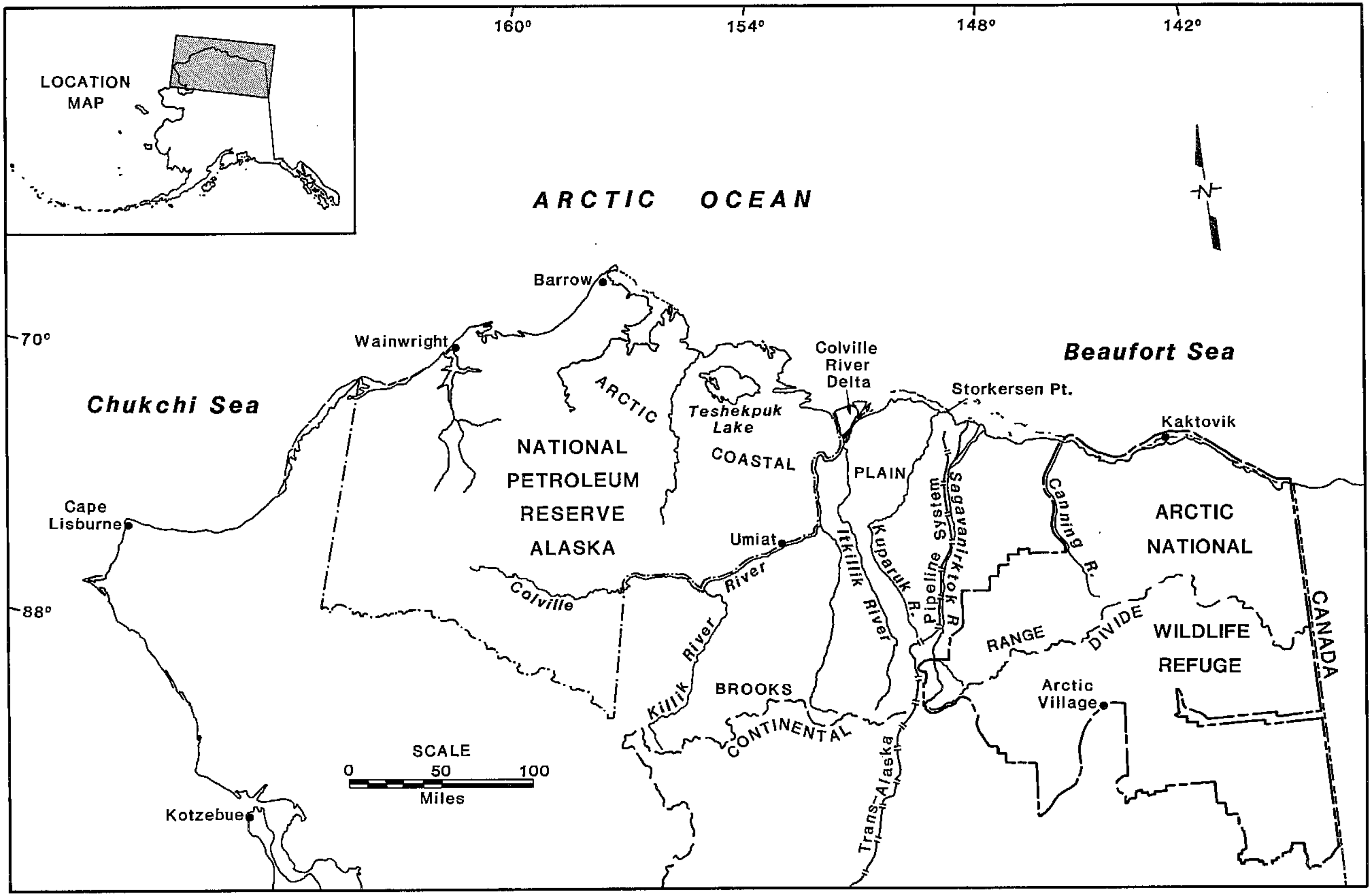


Figure 9. Alaska's North Slope, including Teshekpuk Lake, Colville River Delta, and Kuparuk River. (Adapted from Meehan and Jennings 1988)

The Colville classification and value ranking are intended for area-wide planning. Site specific information is not particularly included. In addition to the Colville being Alaska's largest arctic river delta, researchers have found that the numerous and varied wetland types on the delta make it the most productive on Alaska's North Slope (Gilliam and Lent 1982, Divoky 1983).

The study derived waterbird habitat categories from a cover type system developed by Markon (1980). Specifically for the delta using the classification method of Viereck et al. (1981).

Applicability to Local Wetland Types: Colville delta wetlands include many types common on adjacent tundra areas; some delta habitats are unique to the delta. Many features of the delta are typical of most river deltas, but the presence of permafrost creates some differences in river discharge, bank erosion, and delta modification. Geomorphic features such as ice-wedges, pingos, and frost mounds also occur.

Applicability to Wetland Functions of Special Concern: The study focused on waterbird habitats, especially habitats important to Tundra swans, Greater White-fronted Geese, and Pacific and Yellow-billed loons. The habitat values rankings are specific to the study area.

Duration of Time Required: Field work was completed during July 1-25, 1982 and July 20-26, 1987. The final project report was issued in June 1988.

Personnel Required: Two-person field team.

Skills and Proficiency Level Required: Bird and plant identification skills.

Equipment Required: A GIS was used to organize and draw relationships between bird distribution and covertype maps.

Data Required: NWI mapping; color-infrared (CIR) and black and white (B&W) panchromatic aerial photos.

Usefulness of Interim and Final Products: A preliminary covertype map was produced prior to field work for planning and orientation.

Accuracy: Cover type map accuracy of the entire Colville study area was 62 percent with most of the errors due to confusion between similar cover types. Accuracy errors of the cover type map are not repeated in the value ranked map, thus the value ranked map is likely to be more accurate.

Repeatability: The project appears repeatable, within constraints of cover type errors.

Ground Truthing: The preliminary covertype map was field checked for accuracy and completeness. Data collected during field work included cover type present, dominant plant species, and interpretation of any special color, texture, or physical characteristic (flooding, brackish water, high tide marks or debris). Field work was designed for statistical analysis using recommendations of Hay (1979).

Relative Rating System: The wetland ranking system developed in this project applies on to waterbird habitats. The study developed an index formula that uses each species, habitat, and species density or occurrence.

Costs: The estimate of project costs was not available during this review.

Sensitivity to Ecosystem Considerations: The Colville covertype map covers the entire delta.

Sensitivity to Fish and Wildlife Habitat Values: The Colville habitat rankings reflect the suitability of wetland habitats for waterbirds, especially tundra swans, greater white-fronted geese, and Pacific and yellow-billed loons.

5. TAGS: TRANS-ALASKA GAS SYSTEM WETLAND EVALUATION TECHNIQUE

Yukon Pacific Incorporated (YPI) has proposed the Trans Alaska Gas System (TAGS) comprised of a 798.5 mile, 42 inch diameter gas pipeline from Prudhoe Bay to Anderson Bay near Valdez. Prior to the grant of right-of-way, an Environmental Impact Statement (EIS) for the TAGS project was prepared in 1988 by the BLM and the U.S. Army Corps of Engineers to fulfill their requirements under the National Environmental

Policy Act. The EIS projected that 51 percent of the TAGS route would involve wetlands.

A comprehensive environmental analysis of the TAGS alignment requires a thorough study of the wetland resources in the pipeline corridor. A Wetlands Evaluation Working Group (WEWG) was formed to develop a wetland evaluation technique and to evaluate wetlands potentially impacted by the project. The WEWG consists of representatives from Federal and State agencies, and YPI. The U.S. Fish and Wildlife Service's NWI mapping technique was reviewed by the WEWG and deemed acceptable for use in the wetlands study.

In a cooperatively funded project between the NWI and YPI, the NWI agreed to complete the wetlands mapping along the proposed route of the gas pipeline. Although a major portion of the route had already been mapped, an additional 28 quads (1:63,360 scale) needed to be inventoried. These map areas are located between the northern foothills of the Brooks Range and Fairbanks.

Wetlands mapping was completed using standard NWI photo-interpretation and cartographic conventions. Aerial photography (1:60,000 scale) available through the Alaska High Altitude Program was the primary data source. The photo-interpreters spent ten days in the field examining representative wetland sites in the project area. Wetlands along the gas pipeline corridor were delineated on the aerial photographs to a minimum size of one to three acres, depending on the types of wetlands being identified. This process was completed approximately eight months after the field investigations. Cartographic production of the maps was finished six months later.

Following completion of the standard NWI maps, YPI digitized the wetlands information in a two mile wide corridor along the entire length of the proposed pipeline route. Conversion of the information into a digital data base facilitates planning and allows for the automated evaluation of wetlands functions. Using wetland characteristics shown on the maps, a wetland evaluation system was designed that resulted in the ranking of wetlands according to their importance as fish and wildlife habitat. Map features that form the basis of the ranking system include hydrologic connection, water regime, tidal influence, extent of open water, interspersion, vegetation life form, and wetland scarcity.

The wetland evaluation technique developed for use along the Trans-Alaska Gas System (Wetlands Evaluation Working Group, 1992) combines wetland evaluation, ranking, and fish and wildlife habitat documentation for the purposes of planning a pipeline project through an area rich in wetlands and fish and wildlife resources.

Relative wetland values are determined by scoring drainage and spatial characteristics of planning area wetlands. A point system was developed to define the relative importance of each wetland and to categorize wetland polygons into higher and lower value groupings. The actual wetland values found varied from 60 to 180 points. The WEWG decided that an area must receive a minimum of 140 points in order to be considered as higher value. This evaluation technique will facilitate planning for wetland construction of the pipeline, as required in both the

Federal right-of-way grant; the state conditional lease; and other government permitting responsibilities.

One objective of the TAGS method is to direct mitigation priorities (including avoidance) of construction related impacts from the pipeline and ancillary facilities to higher value wetlands.

Applicability to Local Wetland Types: The TAGS method is used to evaluate tidal and non-tidal wetlands. NWI mapping has identified over 100 wetland types in the study area. TAGS groups these 100 wetland types into 26 types. Marine, Estuarine, Palustrine, Lacustrine and Riverine wetlands are included in this inventory.

Applicability to Wetland Functions of Special Concern: The technique primarily assesses fish and wildlife habitat functions of wetlands along the proposed gas pipeline corridor.

Duration of Time Required: The technique was developed over a period of two years. Application to a particular site will vary with size of site and amount of available data.

Personnel Required: Over 30 people were involved in the overall project, including photo-interpreters field work, cartographic technicians, computer specialists, resource managers, and fish and wildlife biologists. A single evaluator is needed for data entry.

Skills and Proficiency Level Required: Participants all have at least a basic understanding of habitat requirements of fish and wildlife resources as related to wetland functions and values. Basic knowledge of computers is needed for data entry.

Equipment Required: Stereoscopes, cartographic equipment, helicopter for ground truthing, and computer equipment (GIS) for digitizing maps and data analysis.

Data Required: 1:60,000 scale color infra-red aerial photography, digitized NWI maps of pipeline corridor with a one-acre minimum mapping unit, and ground truthing data. Maps documenting important fish and wildlife habitats, if available.

Usefulness of Interim and Final Products: Interim maps depict NWI wetland types for each polygon, as well as a computer assigned value based on the wetland evaluation characteristics (see Relative Rating System, below). Final products identify higher value wetlands and documented fish and wildlife habitats. The final products are intended for project planning and to facilitate permitting pipeline construction in wetlands.

Accuracy: The TAGS method was field tested at three sample quads. Relative value ratings appear consistent with values identified in review literature. Wetland identification and mapping is approximately 90 percent accurate for wetlands greater than two acres in size.

Repeatability: Because a computer develops the overall wetland rating (see Relative Rating System, below) subjectivity is limited to basic assumptions. The NWI portion of the project is a component of the statewide NWI program which prepares hard-copy and digital wetland data for priority areas throughout Alaska. Although the TAGS wetland evaluation scheme is specific to the gas pipeline corridor, a similar system could be developed for other areas.

Ground Truthing: Ground truthing was conducted on all map areas along the gas pipeline corridor. Field trips were taken in order to train the photo-interpreters and to check draft map accuracy. Application of the TAGS wetland evaluation technique does not require additional field work except in instances when drainage characteristics are not obvious on the maps and when a proposed facility conflicts with higher value wetlands.

Relative Rating System: The TAGS wetland evaluation technique uses a point system to rank the relative importance of each wetland. Wetland polygons receive an overall rating, which is the sum of factors assigned to drainage, extent of open water, edge (complexity and interspersion), water regime, vegetation life form, and scarcity.

Cost: Cost of developing the TAGS technique is unknown. The total cost of field work, mapping, digitizing and wetland evaluation was approximately $500,000 for the 80 maps covering the gas pipeline corridor. Application cost will vary with amount of available data and size of project.

Sensitivity to Ecosystem Considerations: The project considers only the pipeline corridor. The inventory and evaluation were designed to assess the impact of the proposed pipeline project on fish and wildlife habitats within that corridor.

Sensitivity to Fish and Wildlife Habitat Values: The inventory and evaluation resulted in the ranking of wetlands according to their importance as fish and wildlife habitat. The TAGS method is specifically designed for sensitivity to habitat requirements of fish and wildlife. Higher value habitats are those used for fish spawning, rearing, or overwintering, bird nesting, moose or caribou calving areas, mineral licks, and core wildlife wintering areas. Additional evaluation can be conducted in the higher value wetlands.

D. OTHER WETLAND HABITAT STUDIES

1. SITKA WETLAND INVENTORY

In the early 1980's the State of Alaska supported managing wetlands appropriate to their resource values, rather than establishing a boundary having little or no relationship to the functions and values which are or should be protected (Akins 1982). The state supported regulation of wetlands pursuant to section 404 of the Clean Water Act but sought improvements in the administration of the program to address particular problems that have occurred from time to time. The desired improvements also reflect the reality that despite the large extent of wetlands in Alaska, development is generally centered in specific locations. The state's approach at that time was to complete intense "classifications" of wetland resources in these specific areas, followed by a wetlands management plan adopted as part of the comprehensive plan of the involved city or borough.

The Sitka Coastal Management Program was the first coastal district program to inventory coastal habitats including wetlands. These inventories identified coastal habitats within the City and Borough of Sitka at a scale useful to implementation of the Sitka District Program (Logan 1979).

Applicability to Local Wetland Types: The Sitka wetland inventory identified estuarine and freshwater wetlands in Sitka Sound.

Applicability to Wetland Functions of Special Concern: The inventory documented migratory and overwintering bird use of study area wetlands.

Duration of Time Required: Data on bird species' use of wetlands and adjacent waters were gathered over a one-year period.

Personnel Required: One evaluator.

Skills and Proficiency Level Required: Skills in plant and bird identification and use of transects were required. The evaluator had access to numerous agency personnel and their expertise.

Equipment Required: Boat and aircraft for surveys.

Data Required: Topographic maps, tide tables, aerial photographs, and orthophotos.

Usefulness of Interim and Final Products: Final product is a report (Watson, 1981) that includes vegetation maps of individual wetlands in the study area. Coastal habitats are mapped at the scale of 1:250,000 for the City and Borough of Sitka and on a larger scale for the urban area.

Accuracy: The use of transects for developing site maps improves accuracy.

Repeatability: High.

Ground Truthing: The project required substantial field work for bird and vegetation surveys, and for mapping the individual wetland areas.

Relative Rating System: The Sitka inventory does not rate wetlands.

Cost: Total costs of the Sitka Inventory have not been tallied. Many agencies contributed equipment or personnel.

Sensitivity to Ecosystem Considerations: Landscape features beyond the wetland boundary are often included in the final wetland maps (Watson 1981).

Sensitivity to Fish and Wildlife Habitat Values: The inventory principally concerns bird habitats. Inferences about fish and other wildlife may be drawn from the individual wetland maps included in the final report (Watson 1981).

Additional Information: The Sitka wetland study was one component of habitat work completed during Phase I of the Sitka Coastal Management District Program (see Sundberg 1981, Liepitz and Sundberg 1981) and was completed in 1981. Soon after, the Corps of Engineers issued five general permits based on the detailed habitat inventories. The original five general permits and the current three general permits conditionally allow certain activities in particular places.

2. REMOTE SENSING: DUCKS UNLIMITED WATERFOWL WETLAND HABITAT INVENTORY AND CLASSIFICATION

Ducks Unlimited (DU), an international conservation organization, has undertaken a large-scale assessment of North American wetlands important to waterfowl. In Alaska, DU has joined the Bureau of Land Management (BLM) to inventory wetlands on BLM lands in interior Alaska.

The inventory utilizes a DU modified version of image processing software designed by NASA called Earth Resources Laboratory Application Software (ELAS) to extract wetland information from satellite data marketed by EOSAT, a private corporation. Analysis of satellite scenes can identify wetland areas and classify them into various wetland habitat types, calculate acreage, and assess the condition of each wetland shown on the computer image (Figure 10, page 121). The DU inventory can be used to assess nesting cover and water levels; satellite scenes from different years or seasons allow monitoring of habitat change over time. The inventory can use satellite imagery from at least two consecutive seasons to determine water levels and upland cover type.

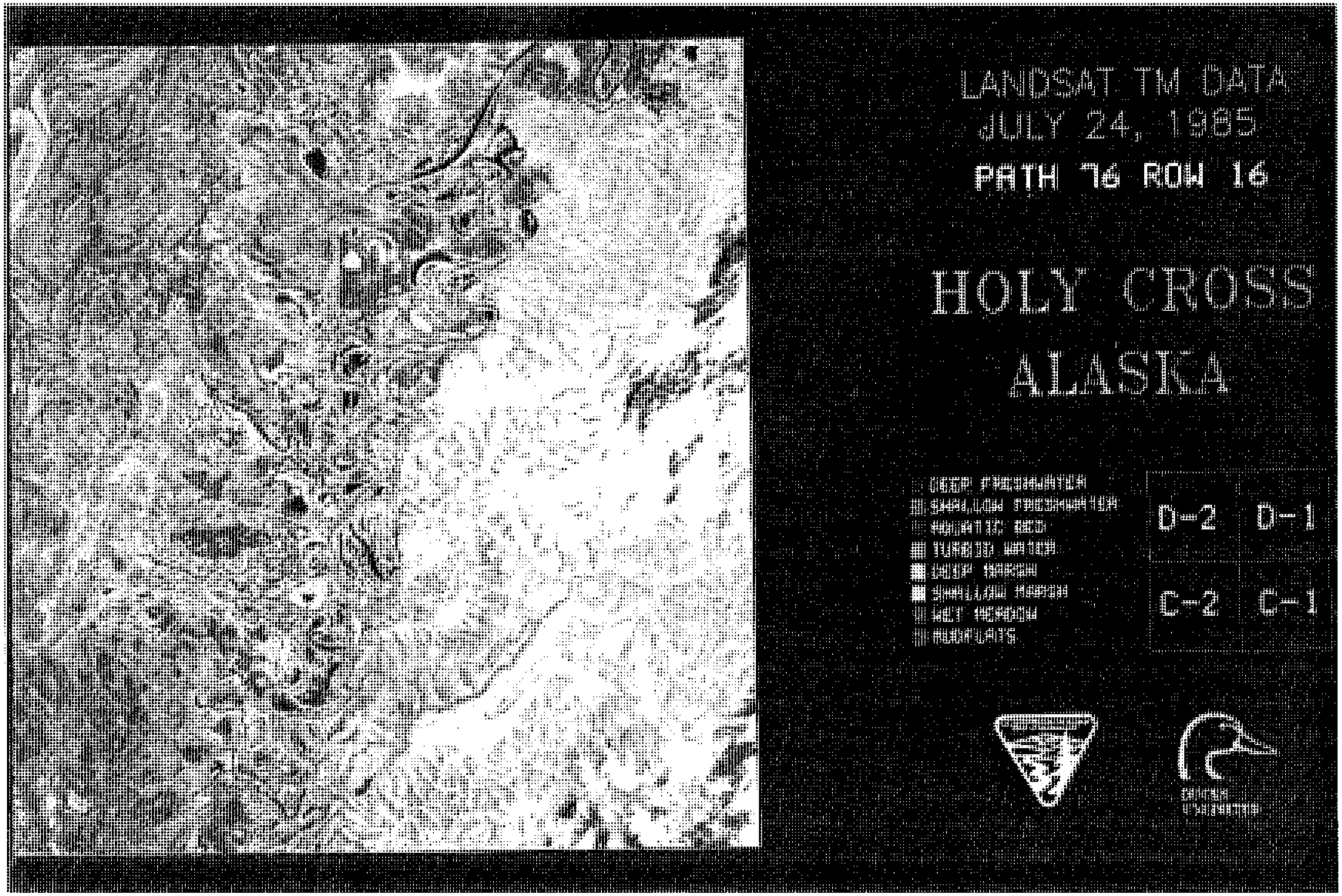


Figure 10. Sattelite scenes can be used to identify and classify wetlands. This photograph is an example of Landsat™ data interpreted by Ducks Unlimited, Inc.

The DU inventory uses a classification system based on waterfowl habitats. Wetland categories are *open water, deep marsh*, and *shallow marsh*. For the purposes of this inventory, *deep marsh* is characterized by emergent wetland vegetation growing in areas of persistent surface water, and the *shallow marsh* category represents vegetation commonly growing in areas with very shallow temporary surface water.

Applicability to Local Wetland Types: The DU inventory can be applied anywhere satellite imagery is available.

Applicability to Wetland Function of Special Concerns: The classification and inventory are specific to waterfowl habitat.

Duration of Time Required: Variable, depends on staff availability and priority of work.

Personnel Required: Minimum of two, variable depending on size of project.

Skills and Proficiency Levels Required: Image processing specialist (full professional level), and habitat biologist (full professional level).

Equipment Required: Image processing computer and software.

Data Required: Satellite TM imagery, digitized NWI mapping, and topographic; field notes are useful for high quality product.

Usefulness of Interim and Final Products: DU's inventory program develops a variety of maps and data sheets that are helpful prior to field truthing or additional data gathering. Full-color Landsat scenes can identify various habitat types and land uses. When used together, computer generated overlay maps depicting wetland categories (open water, deep marsh, and shallow marsh), topographic maps, and wetland basin identification numbers enable a better understanding of wetland locations, types, sizes, and the adjacent landscape. The product can be incorporated into a GIS for additional analysis such as land use planning. Wetland statistic files can be exported to statistical packages for analysis.

Accuracy: The DU method provides correction of satellite imagery for a very high accuracy rate. Landsat TM data and NWI digital data have been compared in the Gulkana area (Ritter 1990).

Repeatability: The DU method is repeatable.

Ground Truthing: The Alaska inventory uses field visits to representative wetlands for supervision of image classification and calibration and editing final maps.

Relative Rating System: The inventory does not rate or rank wetlands. The inventory provides information about wetlands and waterfowl habitat and their juxtaposition on the landscape.

Cost: About $4,000 for 8 million TM images (prices from EOSAT subject to change), personnel, and ground truthing. The total cost is variable, depending of effort and accuracy desired for specific effort.

Sensitivity to Ecosystem Considerations: The use of Landsat imagery and wetland basin information allows inferences to be made about wetlands and the adjoining landscape. Procedures have been developed to identify upland waterfowl nesting cover and other habitat types from computer-generated satellite images.

Sensitivity to Fish and Wildlife: The inventory is designed to identify wetlands and habitats important to waterfowl. These wetland habitats are not always the same wetland habitats used by fish and other wildlife species. This inventory can be an important component of a wetlands functional assessment when used in conjunction with other habitat information.

Additional Information: Wetland inventories derived from Landsat thematic mapper data are underway in the Yukon and Innoko Rivers floodplain (Jacobson 1990).

3. TESHEKPUK LAKE HABITAT STUDY

One area of the arctic coast supports unusual concentrations of molting brant and other geese (Figure 9, page 107). In an effort to better understand the factors determining why the Teshekpuk Lake Special Area is such an important area for molting brant, Derksen et al. (1988, 1990) have compared vegetation communities between lakes of similar size and configuration relative to their use by brant; determined which vegetational zones and plant assemblages are favored by brant within lakes; and examined shoreline configuration contributing to high habitat values for brant. To facilitate the brant habitat study, a cover type classification system was developed (Derksen et al. 1988). The classification scheme first separates basins according to waterfowl population data. Shorelines were grouped by slope, and vegetation was grouped according to life form. The vegetation classes were initially derived from work by Walker (1983) as modified by Tande and Jennings (1986) and Meehan and Jennings (1988). Ground interpretation allowed the development of more appropriate categories: Peat; Moss *species*, Grasses, such as *Deschampsia* and *Dupontia*; Sedges and carices, such as *Eriophorum* and *Carex aquatilis*; Forbs; Shrubs, such as *Salix spp.*; and Lichens.

4. Alaska Arctic Coastal Plain Wetland Study: Kuparuk

A multiphase project was initiated by EPA to provide detailed mapping of arctic plant communities in a portion of the Kuparuk management area (Figure 9, page 107). The project identified waterfowl habitats and ranked these habitats in order to determine areas suitable for development. The products developed for this project were a Habitat Management Classification (HMC) scheme and aerial photographic interpretation keys. These tools enable EPA to evaluate large inaccessible areas of the arctic coastal plain and to efficiently identify waterfowl habitats at a scale needed for Section 404 permit reviews.

Chapter III

Development of the Habitat Management Classification (HMC) system was the first phase of the project. The HMC is composed of eight classes, and is based on geobotanical characteristics that reflect waterfowl use of wetland habitat types, as described in Roe and Ayers (1954 in Williams et al. 1988) and Anderson et al. (1976).

The aerial photo interpretation key was prepared to aid analysis of color infrared (CIR) aerial photographs at a scale of 1:18,000. Three stereopairs were selected from the July 1983 Kuparuk photography based upon accessibility of the sites for field checking and presence of all HMC classes.

The study area was mapped using the HMC from 1:66,000 color infrared aerial photographs (which are available for the entire North Slope of Alaska Arctic coastal plain). An interpretation key for signatures unique to the high-altitude photographs was developed during phase two of the project. The interpretation was transferred to enlargement of the high-altitude photographs for comparison with the phase one interpretations. The comparison showed that the HMC could be applied to the high altitude photographs.

GIS software was used in phase three to determine the classification agreement between the two HMC maps. The resulting classification agreement between the two map products averaged 85 percent, and indicates that the HMC can be utilized to interpret waterfowl habitat from the high-altitude imagery of the entire North Slope.

ARC/INFO overlay algorithms were used to correlate the HMC maps with National Wetland Inventory classification maps to determine if the NWI classification maps could potentially be used to assess waterfowl habitat at a level of detail necessary for permit reviews.

The comparison found that certain NWI classes were present within two HMC classes and certain HMC classes were present within two NWI classes, but overall agreement of polygons averaged 45 percent for the NWI classes within the study area. Further study of the similarities of the NWI and HMC classification systems is necessary.

5. Bird Habitat Classification for Alaska

The University of Alaska Museum, Fairbanks has developed a classification scheme describing the predictable relationship between the occurrence of a bird species and its characteristic habitat niche in Alaska (Kessel 1979). This scheme is largely based on the interactions of vegetation, water, topography, and substrate type. It is not a vegetation or landform classification system, but one describing habitat used by birds. Kessel comments that with minor modification, the classification may be applicable to other terrestrial taxa.

Categories of the classification scheme are presented in Table 4, page 130. The broad habitat units of the classification scheme can be further subdivided to accommodate more detailed habitat analysis or regional studies of bird habitat use. Some of the categories reflect the continuum of a moisture gradient from deep water to uplands, and are likely to be useful when evaluating bird habitats of a particular wetland or a group of wetlands.

6. Copper River Delta Vegetation Classification

The U.S. Forest Service and the Alaska Natural Heritage Program have begun a two-year study of plant community types on the Copper River Delta. The project will collect vegetation and site information that will enable a description of community types and their successful trends on the Copper River Delta. Among the project's specific objectives, four relate to wetland classification inventory and functional assessment:

Information Categories for Copper River Delta Plant Community Type Classification:

Successful Trends
Distribution
Landform
Vegetation Description
Soils
Wildlife
Other Studies

1. Develop a preliminary community type classification.
2. Predict a potential natural vegetation of each community type.
3. Describe resource opportunities for each community type for such species as dusky Canada geese, trumpeter swans, and moose.
4. Develop a preliminary list of plants derived from the classification data base.

The study includes a literature review which will emphasize classification literature for the Copper River Delta. The principal product of the study will be a preliminary community type classification for the Copper River Delta. Wildlife managers and others will be interested in descriptions of plant communities of limited extent or having special resource opportunities for major wildlife species of the Copper River Delta.

Table 4. The Alaska avian habitat classification scheme proposed by Kessel (1979). Names of habitat categories are capitalized.

I. Fresh or brackish waters
- a. LACUSTRINE WATERS AND SHORELINES
- b. FLUVIATILE WATERS AND SHORELINES

II. Marine waters
- a. NEAR SHORE WATERS
- b. INSHORE WATERS
- c. OFFSHORE WATERS
  - 1. MID-CONTINENTAL SHELF
  - 2. OUTER CONTINENTAL SHELF
  - 3. SHELF BREAK
  - 4. OCEANIC WATERS
- d. SEA ICE EDGE

III. Unvegetated substrates
- a. ROCKY SHORES AND REEFS
- b. BEACHES AND TIDAL FLATS
- c. BARRIER ISLANDS (sometimes)
- d. ALLUVIA AND MORAINES
- e. CLIFFS AND BLOCK-FIELDS
- f. SUBTERRANEAN SOIL

VI. Meadows
- a. WET MEADOW
- b. DWARF SHRUB MEADOW
- c. GRASS MEADOW
- d. SALT GRASS MEADOW
- e. TALL FORB MEADOW

V. Shrubbery
- a. DWARF SHRUB MAT
- b. LOW SHRUB THICKET
- c. MEDIUM SHRUB THICKET
- d. TALL SHRUB THICKET

VI. Forests and woodlands
- a. DECIDUOUS FOREST
- b. CONIFEROUS FOREST
- c. MIXED DECIDUOUS-CONIFEROUS FOREST
- d. SCATTERED WOODLAND AND DWARF FOREST

VII. ARTIFICIAL HABITATS

Conclusion

Criteria used to inventory, classify and evaluate wetlands should include their value as wildlife habitat, hydrologic features, and importance in regional ecology. Evaluation methods that provide a comparative analysis of wetlands within a region should include an index by which to assess individual wetlands or particular wetland functions or values. Compiling a data base for developing an index may not be feasible due to time, cost, and absence of basic data required for an index.

The application of evaluation criteria can help ensure potential habitat impacts are identified and appropriate mitigation can be anticipated. In those instances when wetland losses or alterations need to be mitigated, thorough wetland classification, inventory, and assessment can set the stage for providing a diversity of habitats suitable for a variety of species. Description and evaluation of the hydrologic functions of Alaskan wetlands is sparse; what information does exist is geographically concentrated and usually does not directly relate to hydrologic functions (Ford and Bedford 1987).

Basic planning tools (i.e., large scale topographic maps, soils maps, aerial photographs, and tide tables) are often not available for Alaskan study areas. Accessibility to sites can be difficult and expensive due to remoteness, absence of facilities, and weather conditions.

A great deal of research must be completed before wetland hydrologic function, specific fish and wildlife habitat locations, and role of individual wetlands in a regional ecosystem or watershed is understood. In the meantime, the regional tailoring illustrated by the Homer, Juneau, and the TAGS projects will meet immediate needs for wetland identification and evaluation. The regional approach is needed because no one single wetland assessment method will be appropriate for an area as large as Alaska (Figure 11, page 133) or as varied (Figures 2 and 12, pages 7 and 134).

Future development of wetland functional assessment methods should stress clarity and rigor in the formulation of criteria measurements and the multicriteria evaluation models (Smith and Theberge 1987).. Assessment methods should not obscure important issues or conceal subjective judgements. Assumptions should be clearly stated and rationalized in terms of the data and areas being compared.

Figure 11. Size of Alaska. No single wetland assessment method will be appropriate for an area as large and varied as Alaska. (Source: Hartman and Johnson (1978))

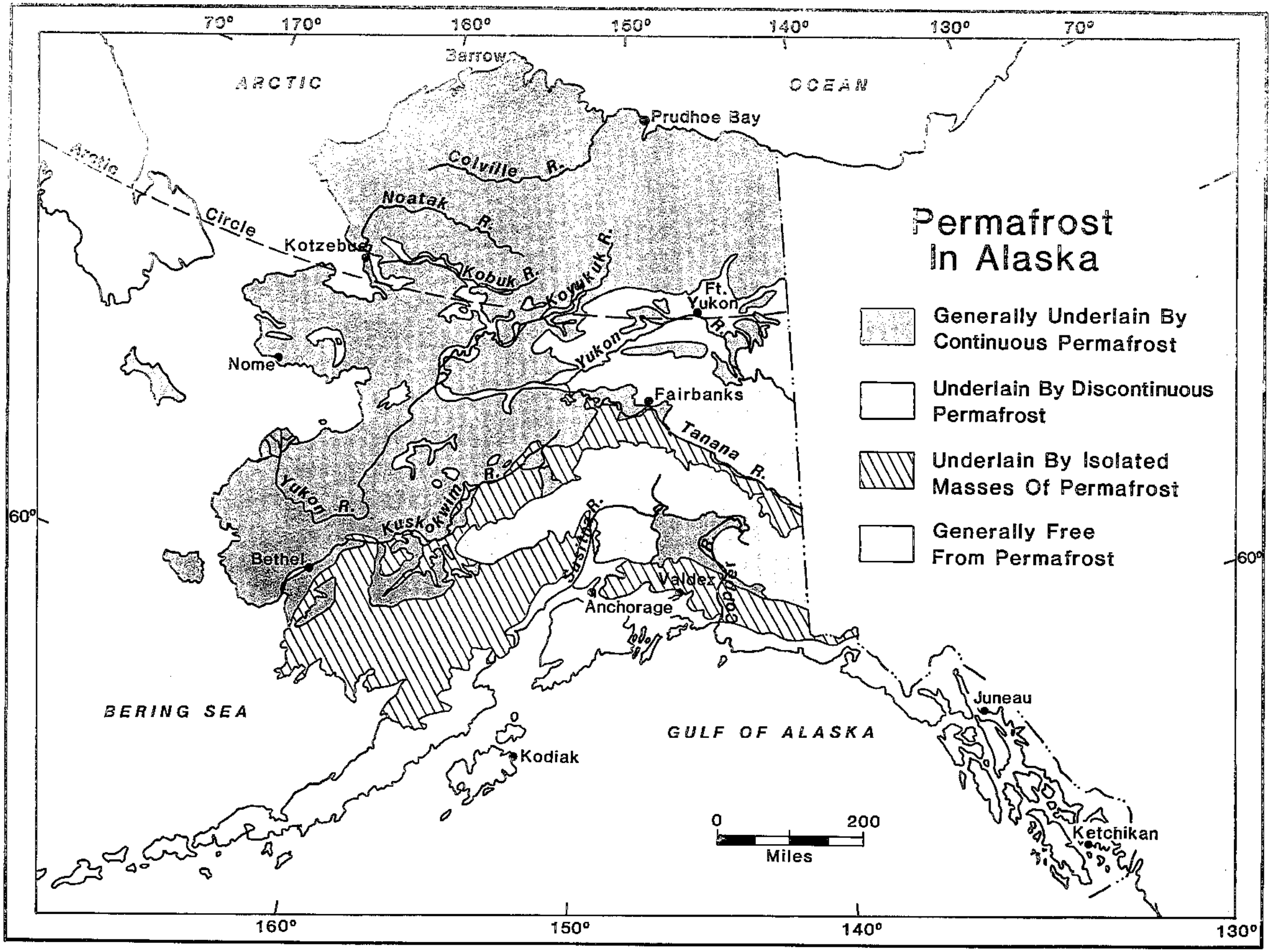


Figure 12. Permafrost in Alaska. Basic assumptions of wetland assessment methods used in permafrost underlain areas must be sensitive to the permafrost condition. (Source: Hartman and Johnson (1978))

Tables

The following tables compare function and value indicators of selected wetland assessment methods. These comparisons should be used with caution, as definition, weight, or measurement of a function or value may differ among assessment methods.

These tables are largely derived from the work of Adamus (1992), especially for assessment methods designed for use in the contiguous United States or a particular region or wetland type within the contiguous United States.

Method names are abbreviated as follows:

Key:

WET	=	Wetlands Evaluation Technique
SeAK	=	Rapid Assessment for Southeast Alaska
CT	=	Connecticut Method
H-M	=	Holland-Magee Method
L-G	=	Larson-Golet Method
WEM	=	Minnesota Wetlands Evaluation Method
Ont	=	Ontario Wetlands Evaluation System
Anc	=	Anchorage
Synop	=	Synoptic Approach for Wetlands
NY	=	New York Freshwater Wetlands Act

Table 5. **Comparison of Ranking and Rating Features of Selected Wetland Assessment Methods**

Ranking and Rating Criteria	**Assessment Methods**									
	WET	SeAK	Homer	CT	H-M	L-G	WEM	Ont	Anc	Synop*
Method applicable to individual wetlands	yes	yes	yes	no	no	no	yes	no	yes	yes
Method applicable to groups of wetlands	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Rank wetland functions by high, medium, or low category	yes	yes	no	no	no	no	yes	no	yes	3
Rank wetland by an overall high, medium, or low category	yes	yes	yes	no	no	no	yes	no	no	3
Accuracy of ranking	1	1		N/A		2		2	2	N/A
Rank wetland functions by numerical score	no	no	no	yes	no	yes	yes	yes	yes	no
Rank wetland by a single numerical score	no	no	no	no	yes	yes	yes	yes	yes	no
Accuracy of numerical score	N/A	N/A	N/A	2	2	2	2	2	2	N/A

Key:

1 = confidence levels of ratings provided by method documentation

2 = computation of scores may be questionable (Adamus 1992)

3 = The Synoptic Approach ranks and categorizes watersheds rather than individual wetlands

N/A = Not applicable

Table 6. **Application Requirements of Selected Wetland Assessment Methods.**

Application Requirements	**Methods**												
	HAT	HEP	WET	SeAK	Homer	CT	H-M	L-G	WEM	Ont	Anc	Synop*	NY
Data Bird Abundance, Diversity	X			R							X		
Habitat Suitability Models		X											
NWI maps					X	X			X		X	R	
USGS topographic maps						X			X		X	R	
FWS hydric soils list				X									
FEMA maps						X						R	
Soils maps					X	X			X		X	R	
Aerial photos					X				X		X		
Tidal data				X								R	
Site visit for data collection or result verification	X			X	X		X					R	
Storm hydrograph				X									
Hardiness zone											X		
Anadromous fish maps				X		X					X		
GIS (computer and software)						R					O	O	
Data analysis w/ IBM compatible personal computer with a math coprocessor chip	O		O						O			O	

Key:

X = Required

R = Recommended

O = Optional

Table 7. **Comparison of Aquatic Habitat Indicators of Selected Wetlands Assessment Methods**

Aquatic Habitat Indicators	**Assessment Method**										
	WET	SeAK	Homer	CT	H-M	L-G	WEM	Ont	Anc	Synop*	NY
fish access, general	X						X				
fish access, anadromous fish	X	X		X					X		
lotic/lentic	X			X			X				
presence of inlets/outlets	X	X									
water chemistry/quality	X	X		X			X		X		
turbidity		X									
salinity	X	X									
temperature	X	X					X				
channel width or stream order	X			X							
minimum depth		X									
mean depth	X										
maximum depth	X						X				
velocity		X									
cover % (wood, banks, etc.)	X	X		X							
dominant vegetation form	X	X									
submerged aquatic veg. %	X	X		X							
shade %	X	X		X							
meandering/channelized %	X	X		X							
wetland acreage	X			X					X		
daily water level flux	X	X									
open water % (% veg. cover)	X						X	X			
open water interspersion (open water edge complexity)	X										
seasonally flooded	X	X									
seasonally flooded duration	X						X				
flood recurrence interval (annual hydroperiod)	X						X				
duration of freezing	X	X									
streambottom not sand	X										
upslope land use (nearby)	X	X									
aquatic invertebrate density	X	X									
known presence of fish	X	X		X			X				
known lack of fish kills				X							
known spawning area		X						X	X		
presence of undesirable fish	X										
fish standing crop (biomass)											
endangered, threatened, rare species	X	X		X					X	X	
large organic debris		X									
upwelling		X									

Table 8. **Comparison of Wildlife Habitat Indicators of Selected Wetlands Assessment Methods**

Wildlife Habitat Indicators	**Assessment Method**										
	WET	SeAK	Homer	CT/NH	H-M	L-G	WEM	Ont	Anc	Synop*	NY
wetland size	X	X		X	X	X	X	X	X		
dominant vegetation form	X	X			X	X	X	X	X		
vegetation form richness	X			X	X	X	X	X	X		
vegetation form interspersion	X	X		X	X	X	X				
vegetation overstory %											
vegetation group cover %											
vegetation understory %											
seasonally flooded %	X										
seasonally flooded duration	X	X							X		
flood recurrence interval (annual hydroperiod)	X				X						
daily water level flux	X										
diversity of hydroperiods (distance to topographic change)											
open water % (% vegetation cover)	X				X	X		X			
open water: permanent, shallow				X					X		
open water size									X		
open water interspersion (open water edge complexity)	X	X		X	X	X	X	X	X		
islands & upland inclusions	X	X		X							
duration of freezing	X	X									
distance to another wetland (local wetland density)	X			X	X	X	X	X			
corridor to other undeveloped wetlands	X	X		X							
human visitation disturbance	X			X							
upland land cover (nearby)	X	X		X	X	X	X				
upland land cover richness					X			X			
local wetland type richness (complex diversity)	X	X					X	X			
preferred wildlife foods	X	X			X						
distance to preferred foods											
pH or acidity	X	X				X	X				
expected contamination	X			X							
presence of inlet/outlet (surface water connection)	X	X		X		X					
groundwater connection					X						
very large trees	X	X									
trees younger than 30 years		X									
dead trees (snags)	X	X									
tidally influenced	X	X									
regional position	X	X							X		
slope angle		X									
endangered, threatened, rare species	X	X			X	X				X	

Table 9. **Comparison of Ecological Integrity and Cultural/Aesthetic Indicators of Selected Wetland Assessment Methods.**

Ecological Integrity and Cultural/Aesthetic Indicators	**Assessment Method**										
	WET	Jnu	Homer	CT	H-M	L-G	WEM	Ont	Anc	Synop*	NY
education/research use/proximity	X			X		X		X	X		
species habitats: endang., threat., rare species	X			X	X	X	X	X	X		X
plant community regionally rare	X			X		X			X		
Natural Heritage Site or other special habitat area	X			X	X						
colonial water bird rookery	X			X				X	X		
significant spawning area		X		X				X	X		
other nationally/regionally significant spp./habitat	X			X		X	X	X	X		X
difficult-to-replace wetland type (ecological age, etc.)								X			
unusual geologic features								X			
dedicated conservation use	X					X					
prior public investment	X								X		
buffers adjoining sensitive site											
corridor to other undeveloped wetlands											
historic/archaeological site	X			X		X					
regional wetland loss rate	X									X	
recent human population trends										X	
dominant vegetation form				X	X	X					X
vegetation form richness				X	X	X	X				
open water (% veg. cover)				X	X		X				
open water interspersion (open water edge complexity)						X	X				
upland land use type		X		X		X	X	X			
upland land cover richness						X					
wetland contrast with upland				X		X	X	X	X		
wetland position (focal point)						X	X		X		
wetland acreage	X				X	X	X		X		X
distance to another wetland (local wetland density)					X						
presence of inlet, outlet (surface water connection)											X
noise, odors, pollution	X						X				
unaltered/pristine wetland	X								X		
undesirable plant species											
autumn colors/flowering plants				X							
legal access	X				X	X	X		X		
easy physical access to open water					X	X	X				

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Literature Cited

Glossary

Key to References:

A = Adamus et al. 1987
B = Brinson 1992
C = National Wetlands Working Group 1988
F = Finlayson and Moser 1991

Abiotic Not living. An example of an abiotic process is deposition of suspended sediments on floodplains. (B)

Advanced Identification of Areas Suitable for Development (ADID) A program of the U.S. EPA which identifies wetlands as suitable or unsuitable for development.

Anadromous fish Fish that migrate from the sea into rivers or into coastal water to spawn. (F)

Arctic The area extending north from the most northward extension of trees, with lichen-moss-heath or barren landscapes and permafrost conditions. (C)

Biota Animal and plant life. (F)

Biotic Refers to living processes or entities. (B)

Bog A peatland that is nutrient poor because it lacks access to substantial quantities on minerotrophic water. (B) A wetland with poor drainage generally characterized by extensive peat deposits and acidic waters. Vegetation may include sedges, sphagnum moss, shrubs, and trees.

Bottomland General term referring to floodplain wetlands. (B) In usage however, the term seems to refer to southern U.S. wetlands.

Brackish Water containing salt; usually a mixture of fresh water and sea water. (B) In the Cowardin System, Marine and Estuarine waters with mixohaline salinity.

Categorize To separate into similar groupings.

Categorization A wetland management technique that often combines wetland inventory, assessment, ranking, or mitigation.

Class The taxonomic unit used in the Cowardin System that describes the general appearance of the habitat in terms of dominant vegetation or some other feature. (A)

Classification A system for separating wetland features into categories or similar groupings.

Cowardin System A hierarchial wetland classification system developed by Cowardin et al. (1979).

Cumulative effects The combined environmental impacts that accrue over time and space from a series of similar or related individual actions, contaminants or projects. Although each action may seem to have a negligible impact, the combined effect can be severe.

Depressional In the Hydrogeomorphic (Brinson) Classification, a wetland type that occurs in depressions, often with minimal or negligible surface flows, and so, by definition, occur in headwater setting. (B)

Depressional wetland In the Hydrogeomorphic (Brinson) Classification, a wetland located in a depression in the landscape so that the catchment area for surface runoff is generally small. (B)

Ecosystem A community of living things interacting with one another and with their physical environment, such as a rain forest, pond, or estuary. An ecosystem can be thought of as a single complex system, and damage to any part may affect the whole. An ecosystem can also be thought of as the sum of many interconnected ecosystems such as the rivers, wetlands, and bays. Ecosystem is thus a concept applied to various scales of living communities and signifying the interrelationships that must be considered.

Effectiveness Effectiveness assess the capability of a wetland to perform a function due to its physical, chemical, and biological attributes. Effectiveness does not estimate the magnitude at which a function is performed, only the probability that a wetland will perform the function.

EOSAT Earth Observation Satellite Company, a private company that sells Landsat data in digital and photographic forms.

Estuary An inlet of the sea reaching a river valley as far as the upper limit of tidal rise (Fairbridge 1980). (C) A confined coastal water body where fresh and salt waters meet and tides occur.

Estuarine Tidal wetlands usually semienclosed by land but with partly obstructed or sporadic access to the open ocean. Salinities are usually greater than 0.5 parts per thousand. (A) In the Cowardin Classification System, those wetlands washed or inundated with brackish or saline waters.

Fauna A collective term for animal life.

FEMA Flood Emergency Management Agency, a federal agency that produces flood way and flood plain maps.

Fen A peatland that is fed by groundwater. (B)

Floodplain The land beside a waterway that receives overbank flooding when discharge exceeds channel capacity. (B)

Flora A collective term for plant life.

Flow, groundwater Water that flows below the surface in a saturated condition in a porous medium. (B)

Flow, near-surface Flow that occurs just below the surface of a wetland in a layer that is often more permeable than the more consolidated sediments just below. (B)

Flow, surface Non-channelized flow that occurs above the surface. (B)

Forested A wetland class characterized by vegetation that is 6 m or taller. (A)

Fringe wetland In the Hydrogeomorphic (Brinson) Classification system, a wetland that is located near a large body of water, most typically the ocean, and receives frequent 2-way flow from tides.

Functional profile In the Hydrogeomophic (Brinson) Classification system, the narrative or quantitative information on a wetland being assessed which describes the wetland properties, such as water source. (B)

Function A physical, chemical, and biological process or attribute of a wetland without regard to its importance to society. (A)

In the Hydrogeomorphic (Brinson) Classification system, *ecosystem functions* are processes necessary for the self-maintenance of an ecosystem, such as primary production, nutrient cycling, and decomposition. Here again, the term is used primarily to distinguish itself from *values*, a term associated with society's perception of ecosystem functions. **Functions occur in ecosystems regardless of whether or not they have values.** (B)

Geographic Information System (GIS) A computerized system that can manipulate multiple layers of data.

Geomorphic A term that refers to the shape of the land surface. (B)

Geomorphic setting In the Hydrogeomophic (Brinson) Classification system, the location in a landscape, such as stream headwater locations, valley bottom depression, and coastal position. (B)

GIS Geographic Information System

Glaciated Currently or formerly covered by a glacier.

Ground water Underground water supplies, also called aquifers. Aquifers are created by rain which soaks into the ground and flows down until it is collected at a point where the ground is not permeable. Ground water then usually flows laterally toward a river or lake or the ocean.

Groundwater discharge Flow originating from the groundwater aquifer which flows to the surface. (B)

Groundwater inflows In the Hydrogeomophic (B) Classification system, flow of water received by a wetland or some other area as a result of groundwater discharge. (B)

Groundwater recharge Flow of water from an area that contributes to the groundwater aquifer. Most upland areas contribute to groundwater recharge. (B)

Habitat The specific area or environment in which a particular type of plant or animal lives. An organism's habitat should provide all of the basic requirements for life and be free of harmful contaminants for that organism to be successful.

Halophyte Vegetation that grows naturally in soils having a high content of various salts (Agriculture Canada 1976). (C) Plants that are tolerant of salty water. (B)

HAT Habitat Assessment Technique (Cable et al. 1989).

Hydrodynamics In the Hydrogeomophic (Brinson) Classification system, the motion of water that generally corresponds to its capacity to do work such as transport sediments, erode soils, flush pore waters in sediments, fluctuate vertically, etc. Velocities can vary within each of three flow types: primarily vertical, primarily bidirectional and horizontal, and primarily unidirectional and horizontal. Vertical fluxes are evapotranspiration, precipitation, bidirectional are astronomic tides or wind driven seiches, and unidirectional are downslope flow that occurs from seeps and on floodplains. (B)

Hydrogeomorphic (Brinson) Classification System A wetland classification system based on abiotic features.

Hydrologic Dealing with the field of hydrology or the distribution and movement of water.

Hydrologic cycle The continual cycling of water between the land, the sea, and the atmosphere through evaporation, condensation, precipitation, absorption into the soil, and stream runoff.

Hydroperiod In the Hydrogeomophic (Brinson) Classification system, the depth, duration, seasonality, and frequency of flooding. Often it refers simply to the time period of inundation of the land surface. (B)

Hydrophyte Vegetation that grows naturally in water or in saturated soil conditions. Synonym: hydrophilic vegetation. (C) Adjective: hydrophytic.

Indicators (of function) In the Hydrogeomorphic (Brinson) Classification, water chemistry, species composition, soil type, or some other feature that allows one to infer or predict certain ecosystem functions or other conditions. (B)

Intertidal area The area between high and low tide levels. The alternate wetting and drying of this area makes it a transition between land and water organisms and creates unique environmental conditions.

Interspersion The degree of intermingling of different cover types, regardless of the number of types or their relative proportions. (A)

Inundation Flooding or covering by water, usually on a seasonal or periodic basis. (C) The condition of water occurring above the surface, i.e., flooding. (B)

Lacustrine In the Cowardin System, wetlands and deep water habitats which generally are situated in a topographic depression or a dammed river channel, lack trees, shrubs, persistent emergents, emergent mosses or lichens, and have a total area greater than eight acres.

Landsat Satellite data of the Landsat series, 1972 to present.

Landscape Gross features of the land surface, including but not limited to slope, aspect, topographic variation, and position relative to other land forms. (B)

Limnetic In the Cowardin System, all deep water habitats within the Lacustrine System.

Littoral In the Cowardin System, all wetland habitats in the Lacustrine System. The Littoral subsystem extends from the shoreward boundary of the Lacustrine category to a depth of two meters (6.6 feet) below low water or to the maximum extent of nonpersistent emergents, if these grow at depths greater than two meters.

Marine Tidal, with salinities greater than 30 parts per thousand and erect vegetation absent. (A)

Marsh A wetland where the dominant vegetation is non-woody plants such as grasses and sedges, emergent, herbaceous vegetation, as opposed to a swamp where the dominant vegetation is woody plants like trees. (B)

Meandering Winding or bending in river beds; usually erosion occurs on the outer bend, while sediment is deposited on the inner bend. This can lead to the meander being cut off and the river changing its channel. (F)

Mire A general English term embracing all kinds of peatlands and all kinds of peatland vegetation. (C)

Moss-Lichen The wetland class in which mosses or lichens cover substrates other than rock and where emergents, shrubs, or trees make up less than 30% of the areal coverage. (A)

Muskeg A North American term frequently employed for peatland. The word is of Algonquin Indian origin and is applied in ordinary speech to natural and undisturbed areas covered more or less with *Sphagnum* mosses, tussocky sedges, and an open growth of scrubby trees (Stanek 1977). (C)

National Wetland Inventory A program of the Fish and Wildlife Service that maps and inventories wetlands of the United States. The categories used are those developed in the *Classification of Wetlands and Deep Water Habitats of the United States.* (Cowardin et al. 1979)

Nonpoint source Normally used to distinguish a source of nutrients or contaminants from point sources that are discharged from a pipe. These are diffuse sources, often from agricultural and urbanizing landscapes. (B)

NWI National Wetland Inventory, a U.S. Fish and Wildlife Service project to map wetlands throughout the United States.

Open wetland A wetland generally with a surface free of trees. (C)

Opportunity Opportunity assesses the chance or opportunity a wetland has to perform a function. For example, a wetland may possess the physical attributes required to perform floodflow alteration, but unless the wetland is positioned in the watershed where it will receive floodflows it will not have the opportunity to preform the floodflow alteration function. (A)

Palustrine Nontidal wetlands dominated by trees, shrubs, persistent emergents, or emergent mosses and lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 ppt. (A) Nontidal wetlands where the salinity from ocean derived salts in less than 5 ppt. Further modifiers are used by the National Wetland Inventory. (B)

Peat Dead plant material that has accumulated for a long time. It forms where the natural cycle of plant production and decomposition is disrupted under waterlogged conditions. (F)

Peatland A generic term including all types of peat-covered terrain. Many peatlands are a complex of swamps, bogs, and fens, sometimes called a "mire complex." (C)

Permafrost Ground (soil and/or rock) that remains at or below 0° C for at least two years. (C)

Photo-interpretation A technical process of understanding, analyzing and correcting satellite imagery.

Polygon A type of pattered ground consisting of a closed, roughly equidimensional figure bounded by more or less straight sides. Some or all of the sides may be irregularly curved. (C)

Pond A general term for an open water body of a seasonal to permanent nature, held in an impoundment or natural basin. A pond usually implies a transitional form between a lake and a wetland. (C)

Prairie pothole Depressional wetlands in the upper Midwestern states and the plains provinces of Canada. (B)

Predictor Simple, or integrated variables that directly, or indirectly, measure the physical, chemical, and biological processes of characteristics of the wetland. (A)

Profile, wetland In the Hydrogeomophic (Brinson) Classification system, a descriptive or quantitative depiction of a wetland that, in the case of the hydrogeomorphic classification, emphasized the physical characteristics such as water source, hydrodynamics, and geomorphic setting. (B)

Probability Rating A measure of the potential of a wetland to perform a function. A probability rating is not a direct estimate of magnitude of a function or value, rather it is na estimate of the probability that a function or value will exist or occur in a wetland to an unspecified degree. (A)

Ranking A comparison of the relative importance of wetlands functions and values.

Rating A low, high, or medium value given to a wetland or wetland function.

Recharge The process by which water is added to the zone of saturation as in an aquifer (Soil Conservation Society of America 1982). In the case of ponds, recharge refers to outflow basins where surface water seeps downwards or outwards to a water table. (C)

Recharge, groundwater Addition to the storage component of an aquifer. (B)

Reference wetland In the Hydrogeomophic (Brinson) Classification system, a site or one of a group of sites within a relatively homogeneous biogeographical region that represents typical, representative, or common examples of a particular hydrogeomorphic type. (B)

Reference wetland population In the Hydrogeomophic (Brinson) Classification system, a group of wetlands of the same hydrogeomorphic type that represent the variation that occurs within the type. (B)

Region An area (e.g., Corps District, river basin, state, EPA region, advance identification region, flyway) for which quantitative data are compiled and available for types of wetlands and their loss rates. Ideally, the area will be of relatively homogenous topography usually with a single landscape pattern. Choose the most geographically restricted area available that is larger than "locality," and favor the use of hydrologic criteria over geopolitical criteria. (A)

Riparian Pertaining to the boundary between water and land. Normally represents the streamside zone and the zone of influence of the stream toward the upland. (B)

Riverine Flowing fresh waters (salinity less than 0.5 ppt) with less than 30% persistent vegetation cover. (A) Situated beside a river; or of a river. (F)

Run-off, Overland flow of water following rain or irrigation events (F)

Salinity A measure of the quantity of dissolved salts such as in seawater.

Salmonid A fish of the salmon family, Salmonidae. Fish in this family include salmon and trout. Many Alaska salmonids are anadromous.

Salt marsh Marsh forms affected by the daily or seasonal influence of brackish to saline waters, generally in coastal and dry prairie conditions. (C)

Scrub-shrub The wetland class dominated by woody vegetation less than 6 m. (A)

Seepage A site where groundwater discharges to the surface, as often happens at the toe of a slope. (B)

Setting, geomorphic In the Hydrogeomophic (Brinson) Classification system, see geomorphic setting. (B)

Smolt An anadromous trout or salmon that is making its first descent to the sea from the fresh waters where it was born.

Social Significance A nonstatistical measure of the importance society (locally or nationally) may attach to a wetland due to the official recognition of its natural features, economic value attributable to the wetland, strategic location of the wetland, or other factors. (A)

Source, nonpoint See nonpoint source. (B)

SPOT Systèmes Probatoire Pour l'Observation de la Terre. A satellite platform for remote sensing used since 1986. Used for mapping at scales of 1:50,000 to 1:25,000.

Subarctic An area where open-canopied coniferous woodlands are the dominant vegetation from with or without outliers of treeless tundra. (C)

Subclass A subdivision of a class as used in the Cowardin et al. (1979) wetland classification system. Classes are based on substrate material and flooding regime, or on vegetative life form. (A)

Swamp A wetland where the dominant vegetation is composed of emergent woody plants like trees, as opposed to a marsh where the dominant vegetation is non-woody plants like grasses.

Synoptic Approach The Synoptic Approach for Wetland Cumulative Effects Analysis is a developing technique in development by the U.S. EPA (Abbruzzese et al. 1990).

Tidal marshes, irregularly flooded Marshes located in a tidal region, but too isolated to be inundated by all tides. (B)

Tidal marshes, regularly flooded Marshes located in a tidal regime with elevations low enough to be flooded by nearly all tides. (B)

Topographic A term referring to the slope and elevation of land. (B)

Tundra A level to undulating, treeless plain characteristic of arctic regions (Agriculture Canada 1976). (C)

Valuation The process of ascribing values. (B)

Values Wetland processes or attributes that are valuable or beneficial to society. (A) The rules that determine what people consider important. It can be measured by what motivates people into activity. (B)

Water quality The condition of water, usually in reference to the physical, chemical, and biological properties, often from a human perspective. (B)

Water table The upper surface of ground water or the level below which the soil is saturated with water.

Weighting The practice of adjusting wetland ratings for scoring or management categories.

Wetland(s) Habitats where the influence of surface or ground water has resulted in development of plant or animal communities adapted to such aquatic or intermittently wet conditions. Wetlands are those areas that inundate or saturate at a frequency to support, and normally do support, plants in a saturated environment. Wetlands includes tidal flats, shallow subtidal areas, swamps, marshes, wet meadows, bogs, peatlands and similar areas.

Wetland System This refers to a category of wetlands that share the influence of similar hydrologic, geomorphologic, chemical, or biological factors. Wetland systems recognized in the FWS wetland classification system (Cowardin et al. 1979) include: Marine, Estuarine, Riverine, Lacustrine, and Palustrine.

WET Wetland Evaluation Technique, developed by Adamus and others (Adamus and Stockwell 1983, Adamus et al. 1987).

Wildlife habitat The sum total of environmental conditions of a specific place that is occupied by an organism, population, or community, Habitat refers to a species distributional response to environmental factors at different points in the landscape. It is a recognizable living space including interacting physical and biological factors which furnish the minimal conditions for an individual or species population to survive and reproduce. (C)

Contact List

The following list of contacts is generally organized following the Table of Contents.

The Cowardin System and the National Wetland Inventory

For information about the wetland classification system developed by Cowardin et al. (1979) and for information about National Wetland Inventory projects in Alaska, contact:

Jon Hall
Regional Coordinator
National Wetlands Inventory
U.S. Fish and Wildlife Service
1011 East Tudor Road
Anchorage, AK 99503
(907) 786-3403

For information about training in the use of the Cowardin System, contact:

National Wetlands Inventory
U.S. Fish and Wildlife Service
9720 Executive Center Drive
Monroe Building, Suite 101
St. Petersburg, FL 33702

The Hydrogeomorphic (Brinson) Classification:

A manual for the Hydrogeomorphic System may be available in early 1993. For further information, contact:

E. Clairain or R.D. Smith
U.S. Army Corps of Engineers
Waterways Experiment Station
WESER-W
Vicksburg, MS 39180

HAT: Habitat Assessment Technique

For information about the HAT procedure, contact:

Dr. Ted T. Cable
Department of Forestry—Call Hall
Kansas State University
Manhattan, KS 66505
(913) 532-6011

HEP: Habitat Evaluation Procedures

For HEP training, contact:

U.S. Fish and Wildlife Service
Office of Training and Education
4401 North Fairfax Drive, Room 741
Arlington, VA 22203

For a copy of the HEP manual (102ESM), contact:

U.S. Fish and Wildlife Service
1849 C Street, NW
Mail Stop 725, Arlington Square
Washington, DC 20240

Synoptic Approach for Wetlands Cumulative Effects Analysis

Scott Leibowitz
U.S. EPA Environmental Research
Laboratory
200 S.W. 35th Street
Corvallis, OR 97333
(503) 757-4666

Synoptic Approach contacts (continued):

Brooke Abbruzzese
ManTech Environmental Technology, Inc.
U.S. EPA Environmental Research
Laboratory
200 S.W. 35th Street
Corvallis, OR 97333
(503) 757-4666

WET: Wetland Evaluation Technique

For a copy of the optional computer program, contact:

Dan Smith
Waterways Experiment Station-W
P.O. Box 631
Vicksburg, MS 39180

For a copy of the 1987 manual, sent $27.50 to:

National Technical Information Service
Springfield, VA 22161

Ask for report ADA 189968 (paper).

Larson/Golet Method

For a copy of *Models for Assessment of Freshwater Wetlands*, contact:

Water Resources Research Center
University of Massachusetts
Amherst, MA 01003
(413) 545-2842

Hollands-Magee Method

For information on procedures and intent of the Hollands-Magee method, contact:

Dennis Magee
Normandeau Associates
25 Nashua Road
Bedford, NH 03102-5999
(603) 472-5191

Connecticut Method

For a copy of the Connecticut method manual, send $12.25 to:

Connecticut Department of
Environmental Protection
Natural Resources Center
Publication Sales, Room 555
165 Capitol Avenue
Hartford, CT 06106
(203) 566-7719

Any questions regarding procedures or intent should be directed to:

Connecticut Department of
Environmental Protection
National Resources Center
165 Capitol Avenue, Rom 553
Hartford, CT 06106
(203) 566-3540

WEM: The Minnesota Wetland Evaluation Methodology for the North Central United States

For a copy of the manual, contact:

U.S. Army Corps of Engineers
St. Paul District
1135 U.S. Post Office and Custom House
St. Paul, MN 55101
(612) 220-0376

For questions or comments on WEM procedures or intent, contact:

John R. Wells
Minnesota Environmental
Quality Board
300 Centennial Building
658 Cedar Street
St. Paul, MN 55155

or

WEM contacts (continued):

Bruce Gerbig
Minnesota Department of
Natural Resources
Division of Waters
500 Lafayette Road
St. Paul, MN 55155
(612) 296-0515

For a copy of optional computer program, contact:

Bruce Gerbig
Minnesota Department of
Natural Resources
Division of Waters
500 Lafayette Road
St. Paul, MN 55155
(612) 296-0515

Ontario Method

Margaret McLaren
Wetland Habitat Coordinator
Wildlife Policy Branch
ICI House
90 Sheppard Ave. East, 6th Floor
North York, Ontario M2N 3A1
CANADA

Adirondack Wetlands Inventory

For information about procedures used to inventory and categorize wetlands in the Adirondack Park, contact:

Dr. Raymond P. Curran
National Resources Analysis Unit
Adirondack Park Agency
P.O. Box 99
Ray Brook, NY 12977
(518) 891-4050

Anchorage Method

For information on procedures and intent of the Anchorage inventory, assessment, and categorization, contact:

Thede Tobish
Senior Planner
Department of Economic Development
and Planning
Municipality of Anchorage
Anchorage, AK 99519
(907) 343-4984

Rapid Assessment Method for Southeast Alaska

For a copy of the *Rapid Assessment Method for Southeast Alaska* or for information on the Juneau Wetlands Study, contact:

City and Borough of Juneau
Department of Community Development
155 South Seward Street
Juneau, AK 99801
(907) 586-5235

Rapid Assessment Method for Southeast Alaska (continued)

For information on procedures and intent of the rapid assessment method, contact:

Dr. Paul A. Adamus
ManTech Environmental Technology, Inc.
200 Southwest 35th Street
Corvallis, OR 97333
(503) 754-4600

TAGS: Trans Alaska Gas System

For information about the wetland inventory completed in the pipeline corridor, contact:

Jon Hall
Regional Coordinator
National Wetlands Inventory
U.S. Fish and Wildlife Service
1011 East Tudor Road
Anchorage, AK 99503
(907) 786-3403

For information about the wetland assessment technique used within the corridor, contact:

Wetlands Evaluation Working Group
Joint Pipeline Office
411 West Fourth Avenue
Anchorage, AK

Sitka Wetland Inventory

For questions or comments of the habitat inventory procedures or intent, contact:

Kimbal A. Sundberg
Alaska Department of Fish and Game
Habitat Division
333 Raspberry Road
Anchorage, AK 99518
(907) 344-0541

For questions about the Sitka Coastal Management Program, contact:

Marlene Campbell or Richard Smith
City and Borough of Sitka
304 Lake Street, Room 104
Sitka, AK 99835
(907) 747-3294

Ducks Unlimited Wetland Habitat Inventory and Classification

For information about Ducks Unlimited wetland inventory projects, contact:

Ducks Unlimited
One Waterfowl Way
Long Grove, IL 60047
(708) 438-4300

For information about the Alaska Ducks Unlimited/Bureau of Land Management project, contact:

Craig Altop
Division of Lands and Renewable
Resources
Alaska State Office
Bureau of Land Management
Anchorage, AK
(907) 271-5477

North Slope Studies

For information on wetland studies on Alaska North Slope, contact:

U.S. Fish and Wildlife Service
Alaska Fish and Wildlife
Research Center
1011 E. Tudor Road
Anchorage, AK 99503

and

U.S. Fish and Wildlife Service
Alaska Investigations: Branch of
Wetlands and Marine Ecology
1011 E. Tudor Road
Anchorage, AK 99503

Bird Habitat Classification for Alaska

For information on intent, use, or modification of this classification scheme, contact:

Brina Kessel
University of Alaska Museum
907 Yukon Drive
Fairbanks, AK 99775
(907) 474-7359

Copper River

For information on the Copper River vegetation classification project and other activities of the Alaska Natural Heritage Program, contact:

The Alaska Natural Heritage Program
707 A Street, Suite 208
Anchorage, AK 99501
(907) 279-4549

Alaska Wetlands Plant List

The U.S. Fish and Wildlife Service publishes a plant list that is used for wetland inventory in Alaska titled *National List of Plant Species that Occur in Wetlands: Alaska (Region A)* (Reed 1988). This wetland plant list is a listing of plants associated with wetlands, as defined by the U.S. Fish and Wildlife Services' wetland definition and classification system (Cowardin et al. 1979). Scientific and common names of plants, distribution, and regional indicator status of almost 6,700 plant species are included in the wetland plant list. These plants have demonstrated an ability to grow to maturity and reproduce in places where all or portions of the soil around the roots becomes saturated or inundated, periodically or continuously, during the growing season.

The list separates plants into four indicator categories according to the plants' occurrence in wetlands. The categories range from always found to seldom found:

(1) obligate (always found) - these plants are found in wetlands more than 99% of the time.

(2) facultative wet (usually found) - these plants are found in wetlands 66 - 99% of the time.

(3) facultative (sometimes found) - these plants are found in wetlands 33 - 66% of the time.

(4) facultative upland (seldom found) - these plants are found in wetlands less than 33% if the time.

Wetland Plant List Category	Descriptive Rate of Occurrence	Statistical Rate of Occurrence
Obligate	Always	>99%
Facultative Wet	Usually	66-99%
Facultative	Sometimes	33-66%
Facultative Upland	Seldom Found	<33%

The Regional List publication includes additional explanatory information. The wetland plants data base is updated as additional information is received.

Fish and Wildlife Service's Office of Training and Education currently offers computer-based tutorial courses for each of the 13 regional subdivisions of the United States. For information about this course, contact:

U.S. Fish and Wildlife Service
Office of Training and Education
2201 North Fairfax Drive, Room 741
Arlington, VA 22203

Reference:

Reed, P.B. 1988. National list of plant/species that occur in wetlands: Alaska (Region A). Biological Report 88(26.11). U.S. Fish and Wildlife Service, Washington, D.C. 87 pp.

Soil Surveys in Alaska

Soil Conservation Service records indicate the earliest soil surveys in Alaska were made in 1914 as part of a study of possible routes for the Alaska Railroad. The next soil survey was a reconnaissance of soils within and adjacent to the Chugach National Forest (Kenai Peninsula region). Apparently, no detailed soil surveys were made until 1939 and 1940 when part of the Matanuska Valley was mapped. Additional surveys were later completed in the principal farming and ranching areas of the Tanana Valley, the Cook Inlet-Susitna lowland, Kodiak Island, and several smaller areas throughout the state. The U.S. Forest Service completed soil surveys in parts of National Forest lands in southcentral and southeastern Alaska.

A statewide general soil survey was begun in 1967 and completed in 1973. This survey is often incorrectly referenced as a tool for hydric soils determinations. However, field mapping for this general survey was done at a scale of 1:500,000 and final maps were produced at 1:1,000,000. The map units represent "an association of soils arranged in a consistent pattern" (Rieger 1979). Map units are about a million acres in size (LaPlant 1992) an indicate only that a hydric soil may be found within an appropriate map unit.

A soil survey is an on-going effort, updated as information is available. Soil surveys published prior to 1980 do not describe hydric soils, however, the U.S. Soil Conservation Service has hydric soils information on file at local offices.

References:

LaPlant, D. 1992. Wetland identification in Alaska. 7 pp. *In:* Statewide Coastal District Conference, Division of Governmental Coordination, Juneau, Alaska, unpublished manuscript.

Rieger, S., D.B. Schoephorster, and C.E. Furbush. 1979. Exploratory soil survey of Alaska. U.S. Department of Agriculture, Soil Conservation Service, Washington, D.C. 213 pp.

Soil Conservation Service. 1985. Hydric soils of the State of Alaska 1985. USDA Soil Conservation Service, Washington, DC. 10 pp.

NWI Mapping in Alaska

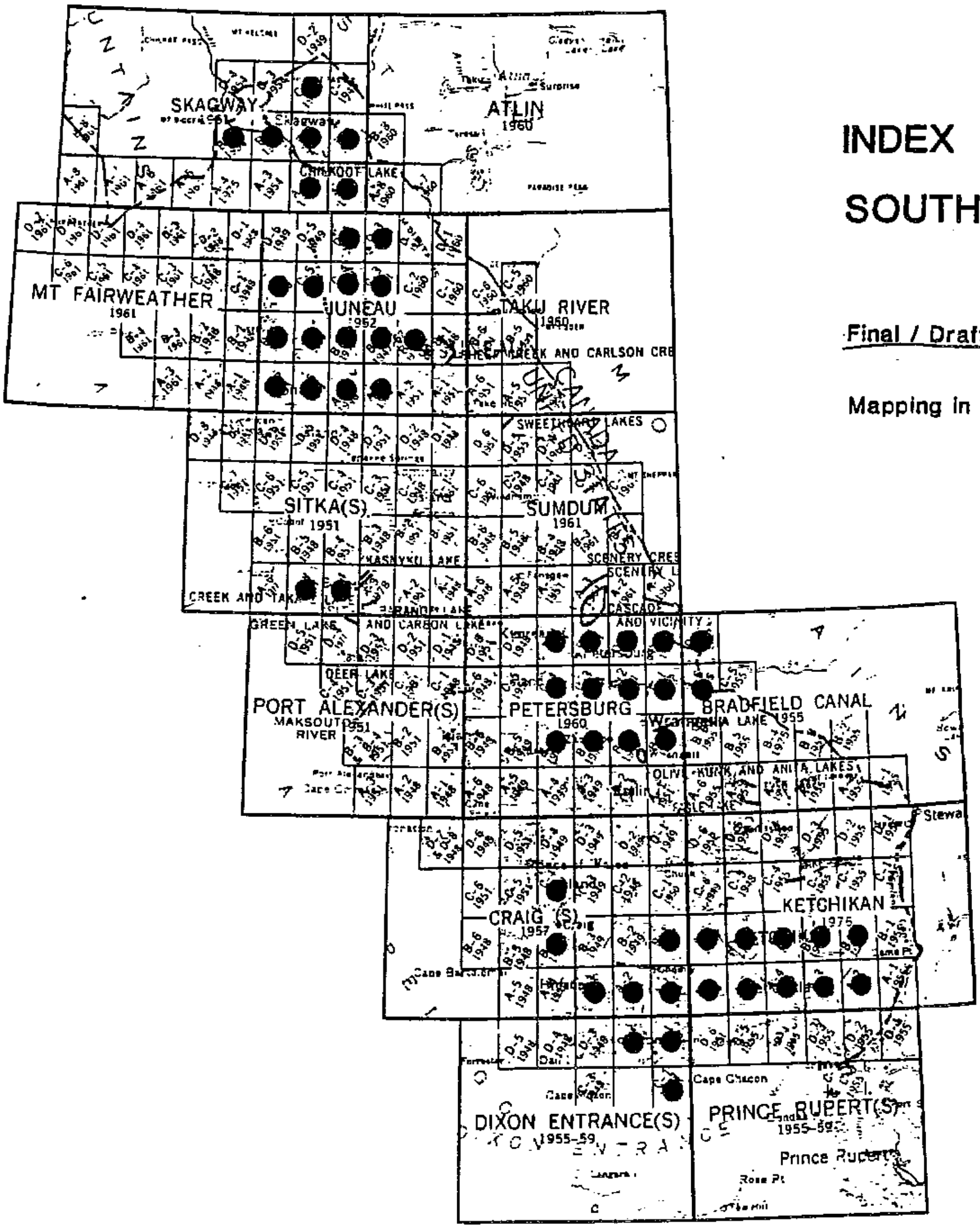
Status of National Wetlands Inventory - Alaska

October 1, 1991

The following index maps identify the wetland map products prepared by the National Wetlands Inventory (NWI) that are now available for distribution. The maps are at a scale of 1:63,360, unless otherwise noted. Wetlands are classified according to the U.S. Fish and Wildlife Service's "Classification of Wetlands and Deepwater Habitats of the United States."

For wetland maps and specific information about the National Wetlands Inventory, please contact:

Jonathan Hall, Regional Coordinator
National Wetlands Inventory
U.S. Fish and Wildlife Service
1011 East Tudor Road
Anchorage, Alaska 99503
Phone (907) 786-3403

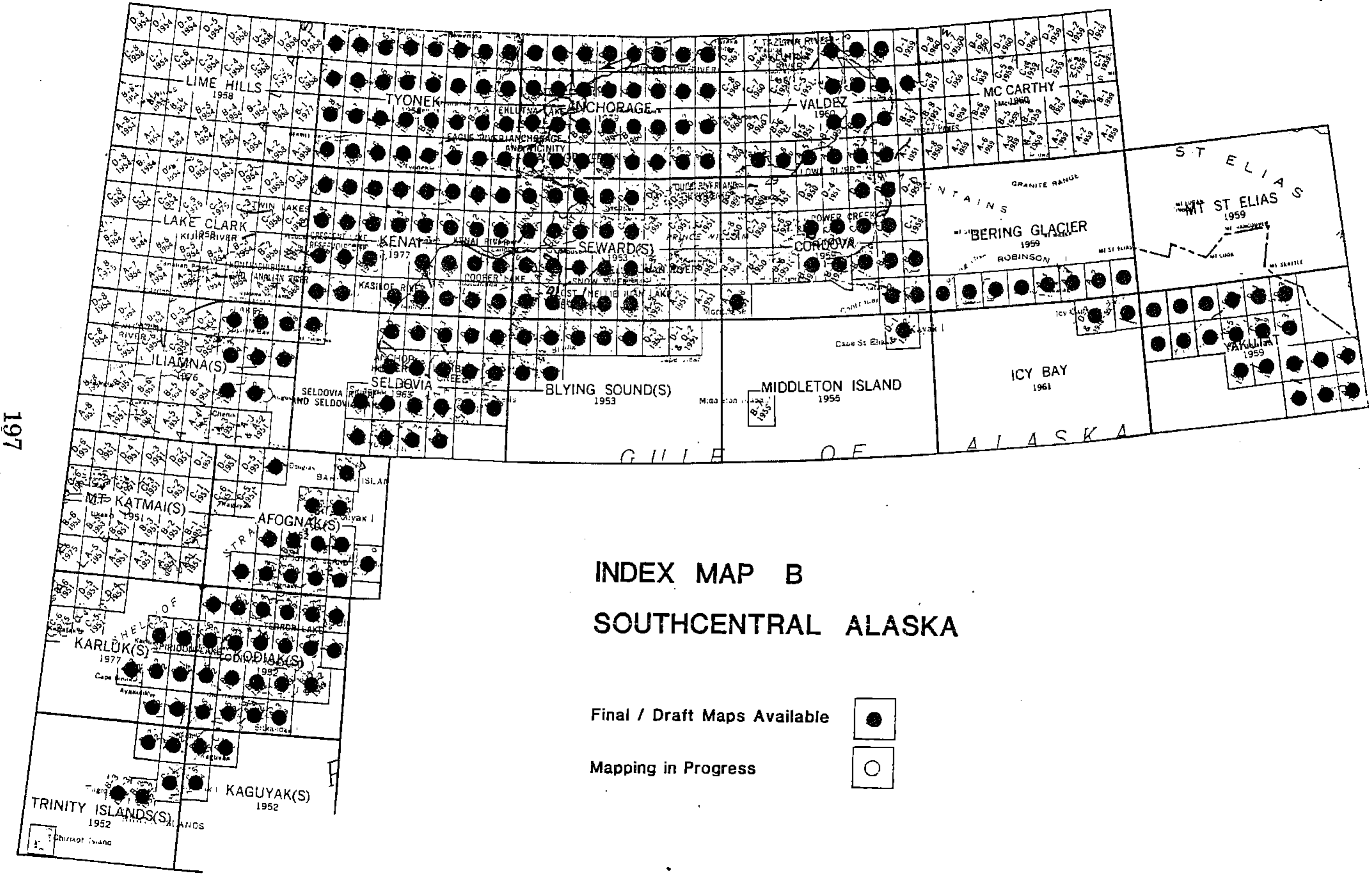


INDEX MAP A

SOUTHEAST ALASKA

Final / Draft Maps Available ●

Mapping in Progress ○



INDEX MAP B

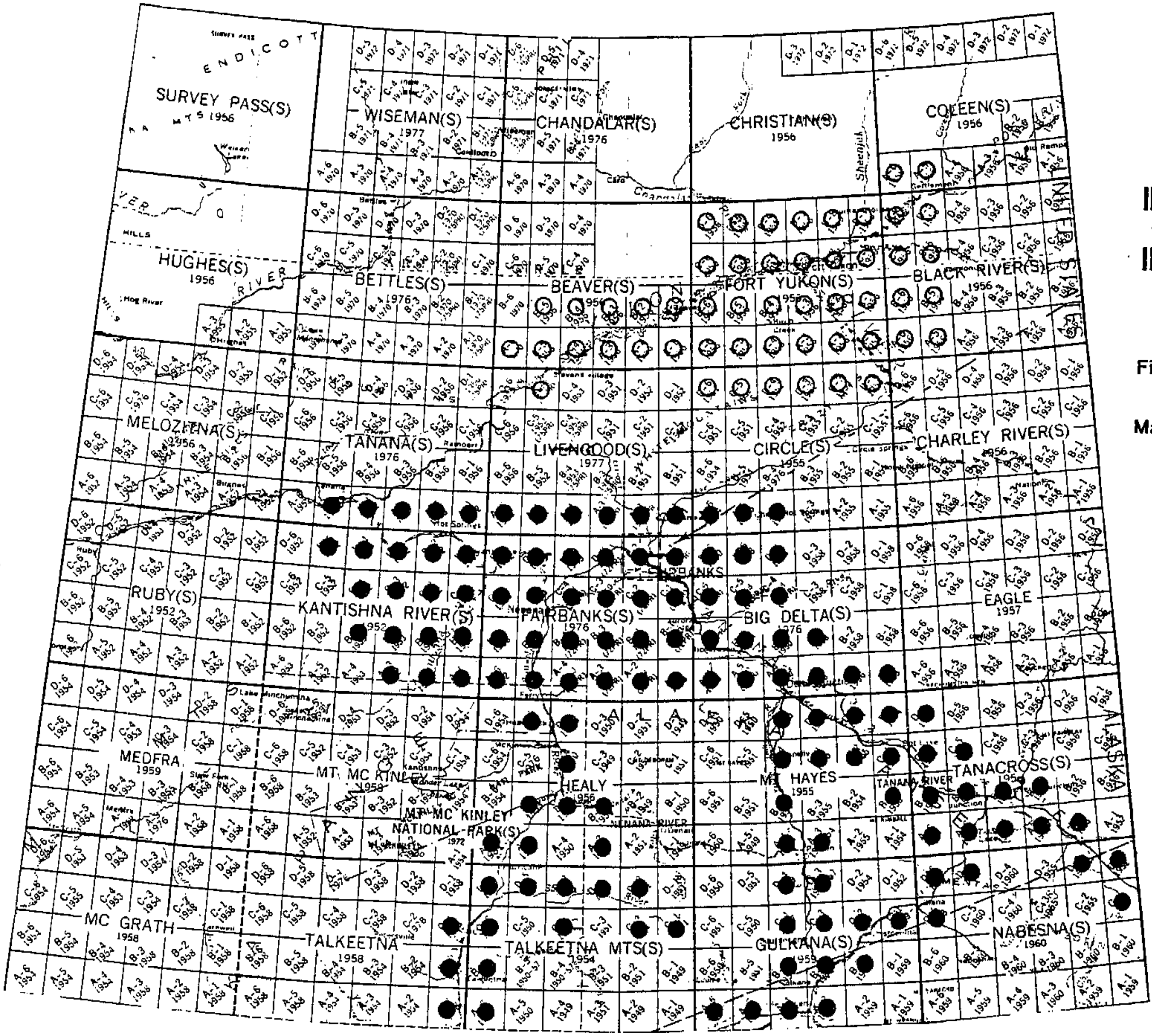
SOUTHCENTRAL ALASKA

Final / Draft Maps Available ●

Mapping in Progress ○

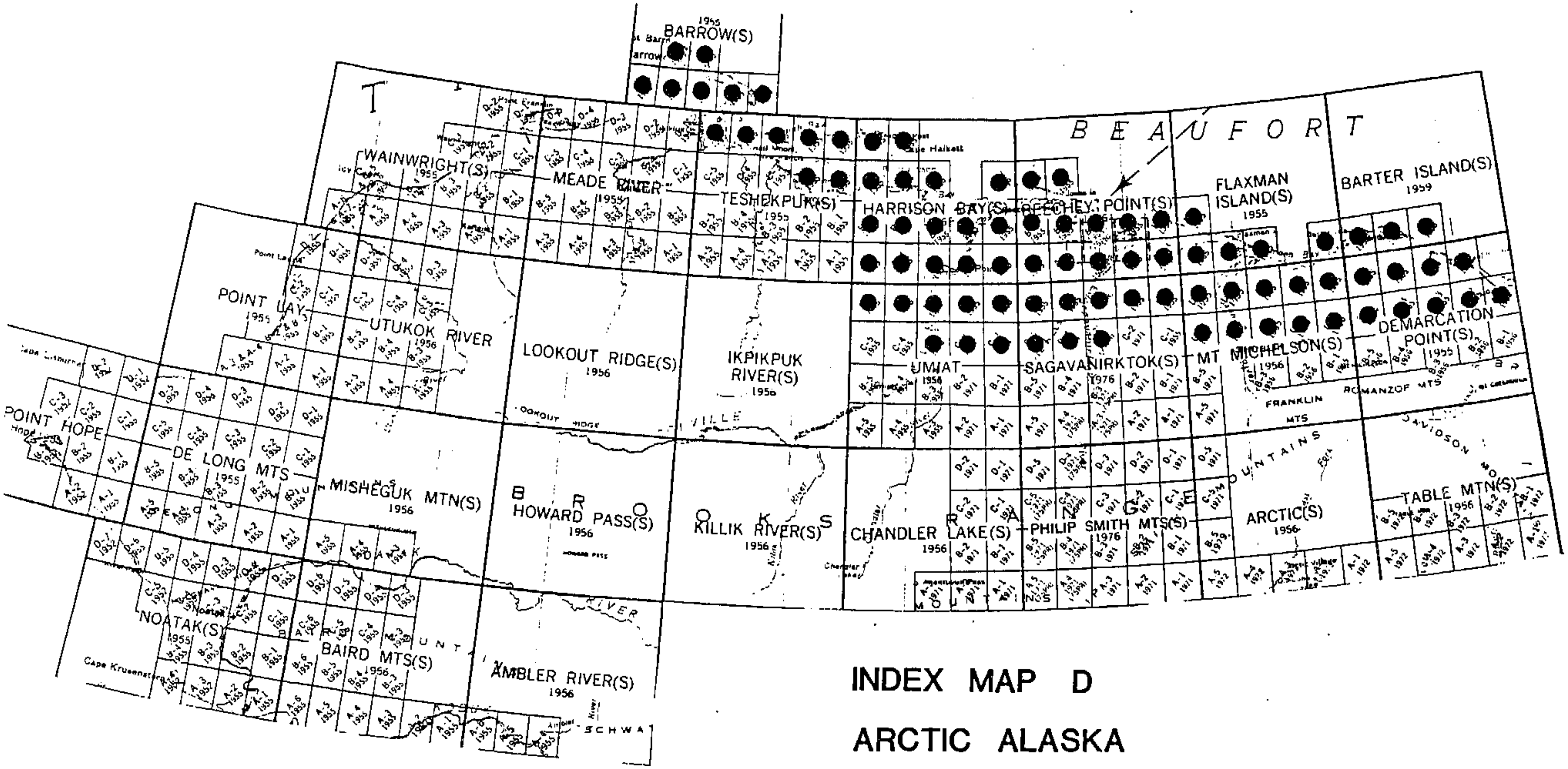
INDEX MAP C

INTERIOR ALASKA



● Final / Draft Maps Available

○ Mapping in Progress



INDEX MAP D

ARCTIC ALASKA

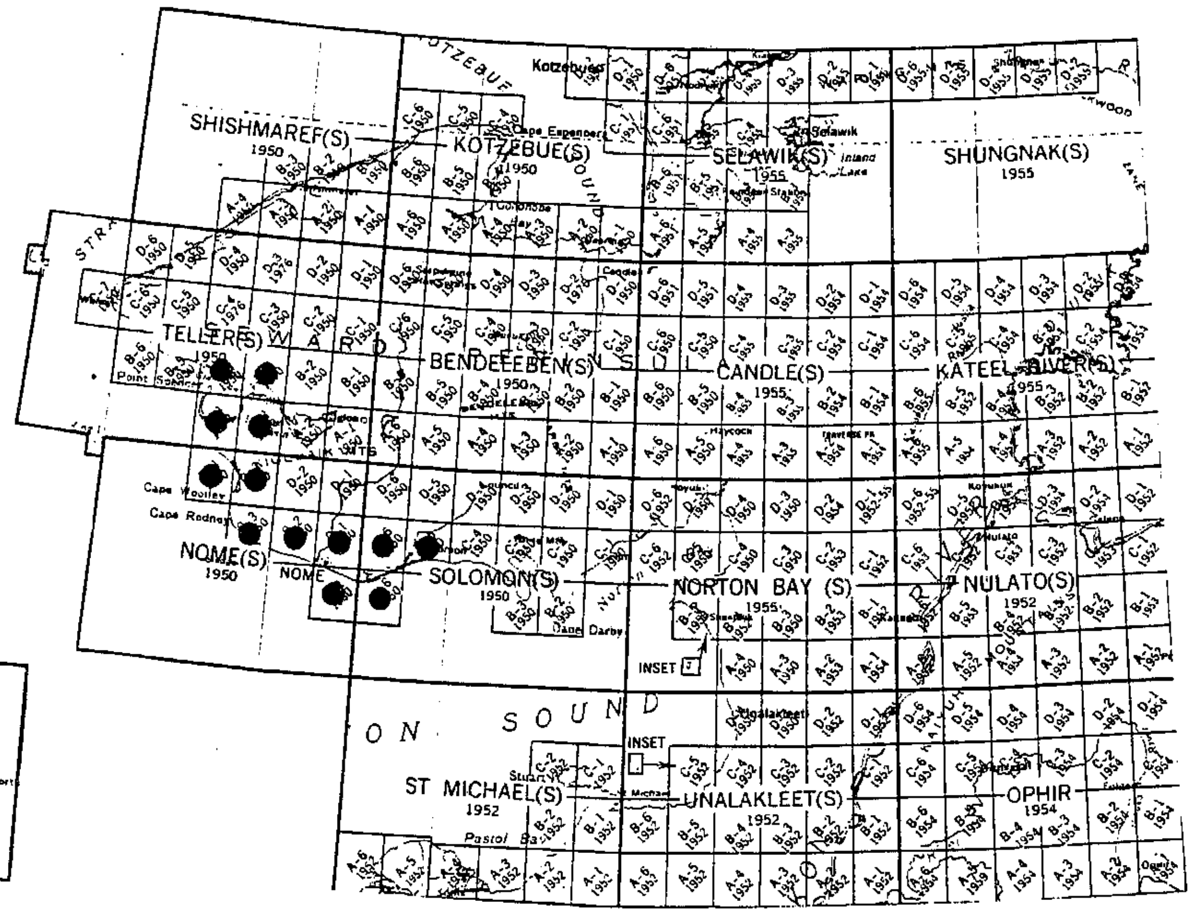
Final / Draft Maps Available	●
Mapping in Progress	○

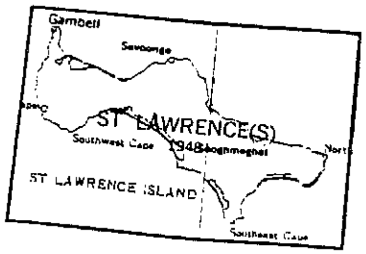
INDEX MAP E

NORTHWEST ALASKA

Final / Draft Maps Available ●

Mapping in Progress ○



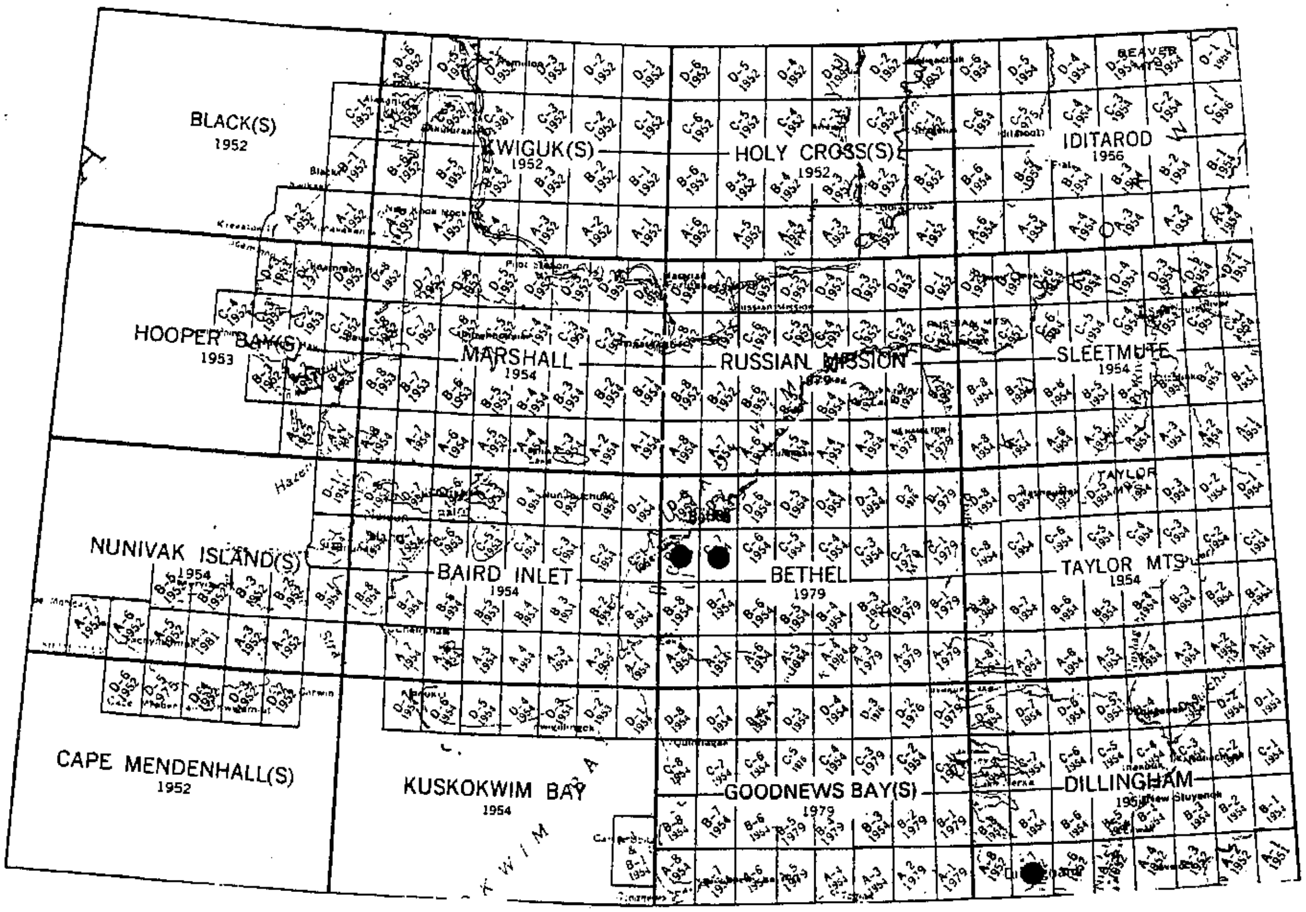


INDEX MAP F

WESTERN ALASKA

Final / Draft Maps Available ●

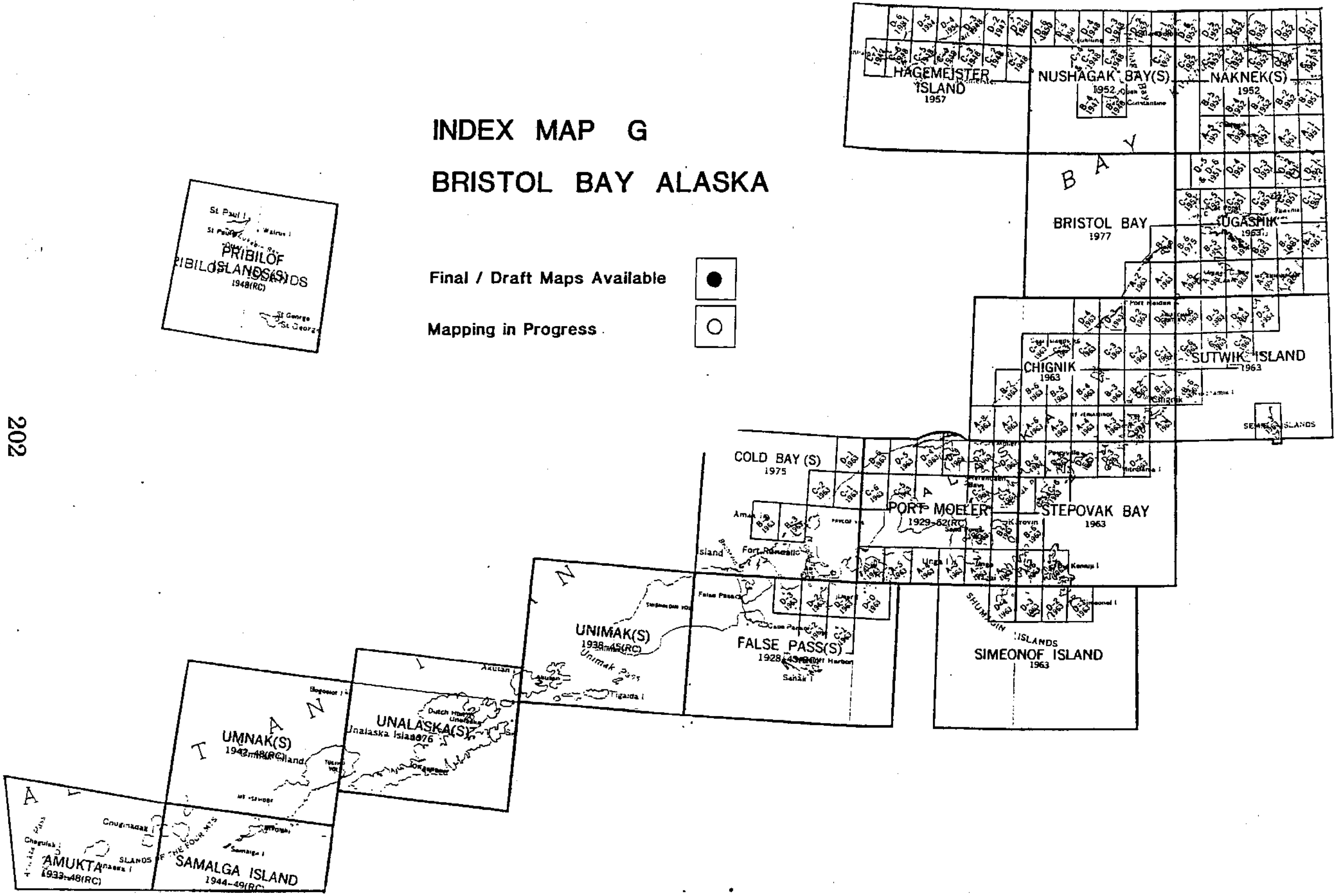
Mapping in Progress ○



INDEX MAP G
BRISTOL BAY ALASKA

Final / Draft Maps Available ●

Mapping in Progress ○

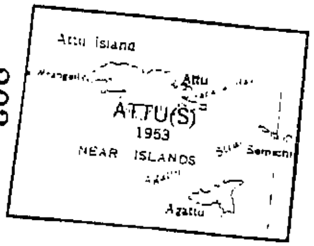


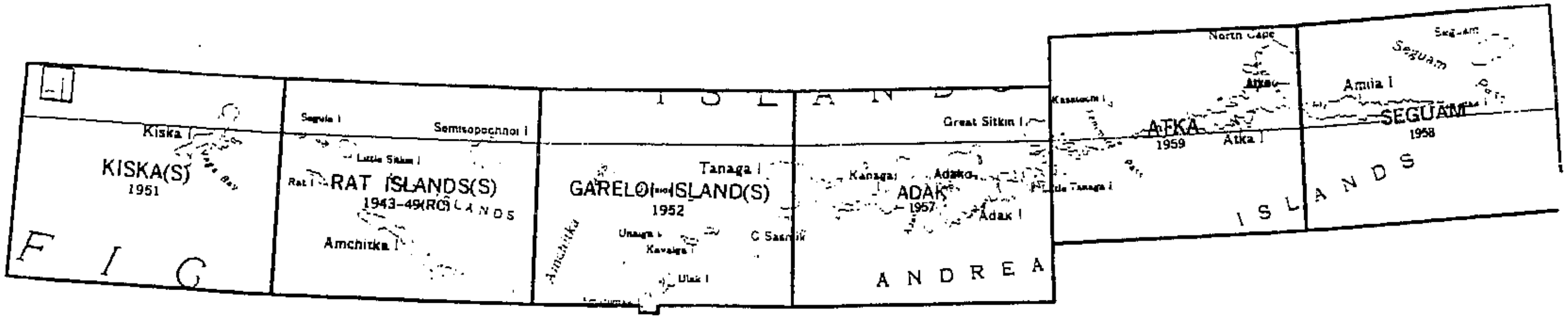
INDEX MAP H

ALEUTIAN ISLANDS ALASKA

Final / Draft Maps Available ●

Mapping in Progress ○





List of Equipment Useful for Field Work

Flagging

Compass

Shovel

Drop Dispenser Bottle (60 ml Capacity)

Waterproof field Notebook ("Rite-in-the Rain" or similar)

Munsell Soil Charts

Supplemental Gley Pages

Clip Board

Steel Tape 6"

Abney Level

Engineer Ruler (6')

Acreage and Photo-Coordinate Grid

Work Vest

English Basal Area Factor (BAF) 10 Prism

36 Tube Kit (Soil Auger)

Hand Pruner

Hand Lens/Pocket Magnifier 7X

Aerial Photo Covers

Pocket or belt knife

Backpack

First Aid Kit

Loggers Tape (100' combination)

Flashlight

Chrome-clad 76" Diameter Tape

Such equipment is available from suppliers such as Forestry Suppliers, Inc, and Ben Meadows. Mention of individual suppliers does not necessarily indicate endorsement by the Alaska Department of Fish and Game.

Additional Field Equipment That Potentially Can Be Useful in Making Wetland Determinations

Plastic Bags

Pencils and Sharpener

Camera

Binoculars

Data Sheets

Ferric Iron Test Kit*

20 X 30 cm Quadrat Frame

16 Penny Nail Soil Horizon Markers

Bucket Auger 3" diameter

Increment Borer (10")

HELPFUL REFERENCE MATERIAL

Pertinent Floras, Taxonomic Guides & Ecological Reports/Texts

NWI Wetland Plant List (regional & state)

Topographic Maps (USGS)

Pertinent Hydrologic Data (USGS, Corps of Engineers, State Sources)

Pertinent Soil Surveys (SCS)

Aerial Photos (NASA, USGS, DOT, aerial survey companies)

NWI Wetlands Maps

FEMA Flood Hazard Maps

*Available from William H. Patrick, Jr., Louisiana State University, Baton Rouge, Louisiana, 70083-7511, (504) 388-8810.

Wetland Inventory and Monitoring with Remote Sensing

"Remote sensing" refers to data collection through satellite imagery and aerial photographs.

Remote sensing platforms, particularly aircraft at various altitudes and satellites, are effective means of gathering data for large scale wetland studies. Remote sensing information can be used for single point-in-time inventories, for multiple points in time for better understanding a study area during different seasons, or for monitoring changes in wetlands over a period of years.

The choice of what type of remote sensing to use will be affected by required resolution, size or complexity of area to be covered, and available budget. Low-altitude aircraft surveys provide a fairly effective, relatively inexpensive way to survey small study areas. High-altitude aircraft can cover a greater area and may be less expensive per unit area than low-altitude photography when photo-interpretation is included in the cost. Aircraft photography is available from private companies and EROS, the Earth Resources Observation Systems operated by the U.S. Geological Survey.

Commercial sources of aerial photographs should be consulted for quality and scale of available photography.

The following are examples of sources based in Alaska:

Air Photo Tech	258-7435
Aeromap US Inc.	272-4495
Alaska Helicopters Inc.	243-3404
Frank Flavin Photographer	561-1606
Ken Graham	561-5531
R & M Engineering, Inc.	780-6060
Walker Alaska Aerial Surveys, Inc.	563-4104

EROS: Earth Resources Observation Systems

Remote sensing products and services are available from the U.S. Geological Survey:

Customer Services
EROS Data Center
Sioux Falls, SD 57198-0001
(605) 594-6151

or

Anchorage Earth Science
Information Center
Room 101
4230 University Drive
Anchorage, AK 99508
(907) 786-7011

Currently available products are described in the "Information Update," which follows. The "Aerial Photography Inquiry Form" will help you plan your purchase and help identify what photography may not be available for your study area.

Satellite imagery has been available since 1972, when LANDSAT satellites were launched. Satellite imagery can allow study of remote and vast areas, although some areas may have little or no satellite coverage.

Wetland inventories use color-infrared photography because wetland vegetation can be identified by its unique color combination, or "signature." Remote sensing does not replace field work, as interpretation of the satellite data must be tied to known ground features.

Landsat and SPOT are satellites equipped with multispectral scanners. Landsat and SPOT data are frequently used to map wetlands, although considerable interpretive skill is needed. Landsat data is available through EOSAT, and SPOT through the SPOT Image Corporation.

EOSAT: Earth Observation Satellite Company

EOSAT provides Landsat satellite data in digital or photographic form. Landsat sensors acquire imagery by measuring energy from the Earth's surface in seven discrete bands of electromagnetic spectrum, ranging from the visible to the thermal infrared.

For information about EOSAT products and current prices, contact:

Earth Observation Satellite Company
4300 Forbes Boulevard
Landham, MD 20706-9954
(800) 344-9933

EOSAT publications include a description of available products and current prices.

SPOT: Systémes Probatoire Pour l'Observation de la Terre

SPOT satellites are operated by the French Centre Nationales d'Ètudes Spatiales. The program began in 1986 and can provide a detailed narrow swath, stereo pairs of images, and a 2.5 day repeat interval.

Information on SPOT products and prices is available through:

SPOT Image Corporation
1897 Preston White Drive
Reston, VA 22091-4368
(703) 620-2200

Information about SPOT products, services, and prices are detailed in a brochure and the current product fee schedule.

References:

Earth Observation Satellite Company. n.d. EOSAT purchasing guide. EOSAT, Landham, Maryland. 11 pp.

Earth Observation Satellite Company. n.d. EOSAT catalog of products and services. EOSAT, Landham, Maryland. 18 pp.

Mason, R. 1991. Satellite remote sensing of polar regions: applicability, limitations, and data availability. Lewis Publishers, Boca Raton, Florida. 307 pp.

SPOT Image Corporation. 1992. SPOT products fee schedule. SPOT Image Corporation, Reston, Virginia. 2 pp.