OPERATIONAL DRAFT

Guidebook for Reference Based Assessment Of The Functions Of Precipitation-Driven Wetlands on Discontinuous Permafrost in Interior Alaska

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This document to be cited as: State of Alaska Department of Environmental Conservation/U. S. Army Corps of Engineers Waterways Experiment Station Technical Report Number: WRP-DE-____1999. *Operational Draft Guidebook for Reference Based Assessment of the Functions of Precipitation-Driven Wetlands on Discontinuous Permafrost in Interior Alaska.* Anchorage, AK.

Disclaimer

This *Guidebook* was developed by the Alaska Department of Environmental Conservation (ADEC) to provide a basis for application of the hydrogeomorphic approach (HGM) to assessment of functions in Precipitation-Driven Wetlands on Discontinuous Permafrost in Interior Alaska. The steps taken to develop this operational draft have been consistent with (1) guidance provided in the *National Action Plan to Develop the Hydrogeomorphic Approach for Assessing Wetland Functions* (*Federal Register*, August 16, 1996 (Vol. 61, No. 160) pp. 42593-42603), (2) ADEC policies and procedures, and (3) standard field technical and analytical practices for collection and synthesis of data from ecological studies.

Consistent with the *National Action Plan to Develop the Hydrogeomorphic Approach for Assessing Wetland Functions* (*Federal Register*, August 16, 1996 (Vol. 61, No. 160) pp. 42593-42603), the following activities need to occur to bring this *Operational Draft Regional Guidebook* to final form:

Phase VII: Implement Draft Model Guidebook

A. Identify users of HGM functional assessment.
B. Train users in HGM classification and evaluation.
C. Provide Assistance to users.

Phase VIII: Review And Revise Draft Model Guidebook

A. Field test the operational draft Guidebook for two years. Solicit feedback from users.
B. “A” Team review of comments and suggestions.
C. Prepare and publish the final guidebook.

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Acknowledgments

Scientific studies are relatively unique in that they require extraordinary cooperation and coordination among many individuals with diverse skills and backgrounds. This study was no exception. Several people volunteered time, experience, and funding to make this project possible. These people worked hard to coordinate the funding and to provide the technical support that made development of this Guidebook possible. In particular, Mr. James Powell of the State of Alaska Department of Environmental Conservation, Mr. Theodore Rockwell of the U.S. EPA Region X, and Mr. Ellis Clairain of the U.S. Army Corps of Engineers Waterways Experiment Station were the principal agency staff persons responsible for the initiation of the project, development of the scope of work, and the contracting. They also provided valuable guidance and encouragement throughout the procedure. Our special thanks go to them; their patience is much appreciated.

A great deal of logistical and technical support was provided by various individuals. Without such support, this draft document could not have been completed. The members of the Assessment Team (A-Team), particularly Mr. Roger Post of the State of Alaska Department of Fish and Game, and Mr. Dan LaPlant and Mr. Mark Clark of the USDA Natural Resources Conservation Service, worked diligently to identify the priority subclass, to locate potential reference sites, and to work with the National and Technical Teams in the field. Other members of the A-Team and other regional professionals who provided critical technical support were Mr. Jon Hall of the U.S. Fish and Wildlife Service (National Wetlands Inventory), Mr. Torre Jorgenson of ABR Incorporated, Ms. Jacqueline LaPerriere of the University of Alaska Cooperative Fish and Wildlife Research Unit, and Mr. Charles Racine of the U.S. Army Corps of Engineers Cold Regions Research and Engineering Lab.

Finally, Ms. Paula Hunt-Higgins, Ms. Katharine Lee, Ms. Linda Ellis, Ms. Melissa Chaun, Ms. Karen Nakayama, Mr. Matthew Braun, Ms. Lisa Shaw and Ms. Liberty Jerentowski spent many hours providing logistics, entering, analyzing, and synthesizing data, and editing, formatting, and creating this document. Their assistance and their patience with the authors were invaluable.

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I. INTRODUCTION

A. Purpose Of The Guidebook

The state of Alaska includes 63% of the nation's wetland ecosystems (Hall *et al.* 1994). Activities in these wetlands and their associated waters (hereafter waters/wetlands) are regulated under several federal, state and local ordinances because these ecosystems have been shown to perform vital and valuable physical, chemical and biological functions. As a consequence of their functioning, Alaskan waters/wetlands help to support the State's diverse human, fish, and wildlife populations, water resources, and economy.

In addition to being valuable, Alaskan waters/wetlands are highly variable. They include salt and freshwater areas influenced by tides, temperate rain forests and slopes along the southeastern and south central coastlines, extensive rivers and streams, large river deltas, large and small complexes of lakes and ponds, and extensive areas of boreal forest and tundra.

To ensure that Alaskan waters/wetlands continue to be managed wisely, wetland professionals and policy-makers need regionally based, scientifically valid, consistent, and efficient, functional assessment tools. These assessment tools need to be developed in a manner that helps managers and users recognize and distinguish between naturally variable conditions and those changes in the functioning of Alaska's waters/wetlands that result from human activities. In addition to being able to detect changes in functioning, effective and properly structured assessment methods should include steps that ensure consistent technical and administrative approaches for completing assessments and documenting results. Such consistency provides the basis for scientifically-based assessments that, in turn, provide the technical input to ecosystem and watershed protection programs, and restoration projects.

To date, there have been no widely accepted methods developed for Alaska’s waters/wetlands that accurately and consistently provide a means to assess changes, both gains and losses, in ecosystem functions. In response to this need, the Alaska Department of Environmental Conservation (ADEC) with other cooperating state and federal agencies and organizations stepped forward and initiated a broad-based, statewide effort to develop a functional assessment approach for Alaska's waters/wetlands. It is called the Hydrogeomorphic Approach (HGM). HGM was selected by ADEC, the National Wetland Science Training Cooperative, and several other cooperating agencies and organizations because it offers a relatively rapid, efficient, and reference-based method of assessment that allows users to recognize human-induced changes in the functions of waters/wetlands ecosystems (Brinson 1993, Brinson *et al.* 1995) The HGM method departs from other functional assessment approaches in that it is based on (1) recognition of differences among waters/wetlands (*i.e.* classification) , (2) identification of functions performed by classes and subclasses of wetlands, and (3) regionally developed reference systems (Brinson 1996, Brinson 1995).

B. Interior Region Selected For The First Guidebook

The Delta Junction and Fairbanks areas in Interior Alaska include the highest proportion of cultivated lands in Alaska. These lands are used mostly for commodity crops, dairy production, and for domestic livestock grazing. Since the early 1980's, agricultural developers in Alaska have encountered regulation of their activities in waters/wetlands. Considering the vastness of Alaska's waters/wetlands compared to its sparse human population, many landowners have viewed these regulations as unnecessary infringements on their property rights. Residents have also been frustrated by what they perceive to be complex federal and state regulatory processes. To address this situation, and consistent with their national guidance (USDA NRCS 1994), the Natural Resources Conservation Service (NRCS) decided to use the HGM approach to provide technical input to the "Minimal Effects Process". Specifically, the Food Security Act of 1995 (USDA NRCS 1995) required that HGM be used in the Minimal Effects Process to assess the functions of waters/wetlands. Because of the reasons mentioned above, NRCS asked the agencies interested in developing HGM (ADEC, U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (USFWS) and the U.S. Army Corps of Engineers (Corps)) to consider the Interior Region a priority for developing HGM. Almost immediately, EPA agreed to fund the field activities and the majority of the office work that was necessary to develop the regional guidebook. ADEC, in cooperation with NRCS, USFWS, EPA, representatives from the private sector, and the University of Alaska, Fairbanks, decided to develop HGM for the Interior Region. This operational draft Guidebook is the result of this work

Three teams of wetland experts and other assisting personnel (Tables 1 and 2) developed this operational draft of the Guidebook, (hereinafter referred to as "The Guidebook" and the previous *Peer Review Draft Guidebook* (NWSTC 1997). The Guidebook will be used to assess wetland functions for two years. This interval will provide the opportunity for extensive field testing prior to further revision. The NRCS intends immediate use of this guidebook for Minimal Effects Determinations pursuant to the Food Security Act (USDA 1995).

Table 1. Teams and Members Who Developed the March 1997 Peer Review Guidebook.

TEAM	**TEAM MEMBERS AND AFFILIATION**
National Wetland Science Training Cooperative "National Team"	Mark Brinson, Garrett Hollands, Lyndon Lee, Wade Nutter, Dennis Whigham
Interior Alaska Assessment Team	Ellis Clairain, Army Corps of Engineers (Waterways Experiment Station); Mark Clark and Dan LaPlant, Natural Resources Conservation Service; Jon Hall, U.S. Fish and Wildlife Service (National Wetlands Inventory); Torre Jorgenson, ABR, Inc.; Jacqueline LaPerriere, University of Alaska (Cooperative Fish and Wildlife Research Unit); Roger Post, State of Alaska Department of Fish and Game; Jim Powell, State of Alaska Department of Environmental Conservation; Charles Racine, Army Corps of Engineers (Cold Regions Research and Engineering Lab); Theodore Rockwell, Environmental Protection Agency (Region X)
National Wetland Science Training Cooperative "Technical Team"	Mark Cable Rains, William Kleindl, Kai Coshow

Table 2. Personnel Who Contributed to Development of the Operational Draft Regional Guidebook by Providing Peer Review and Preliminary Field Testing

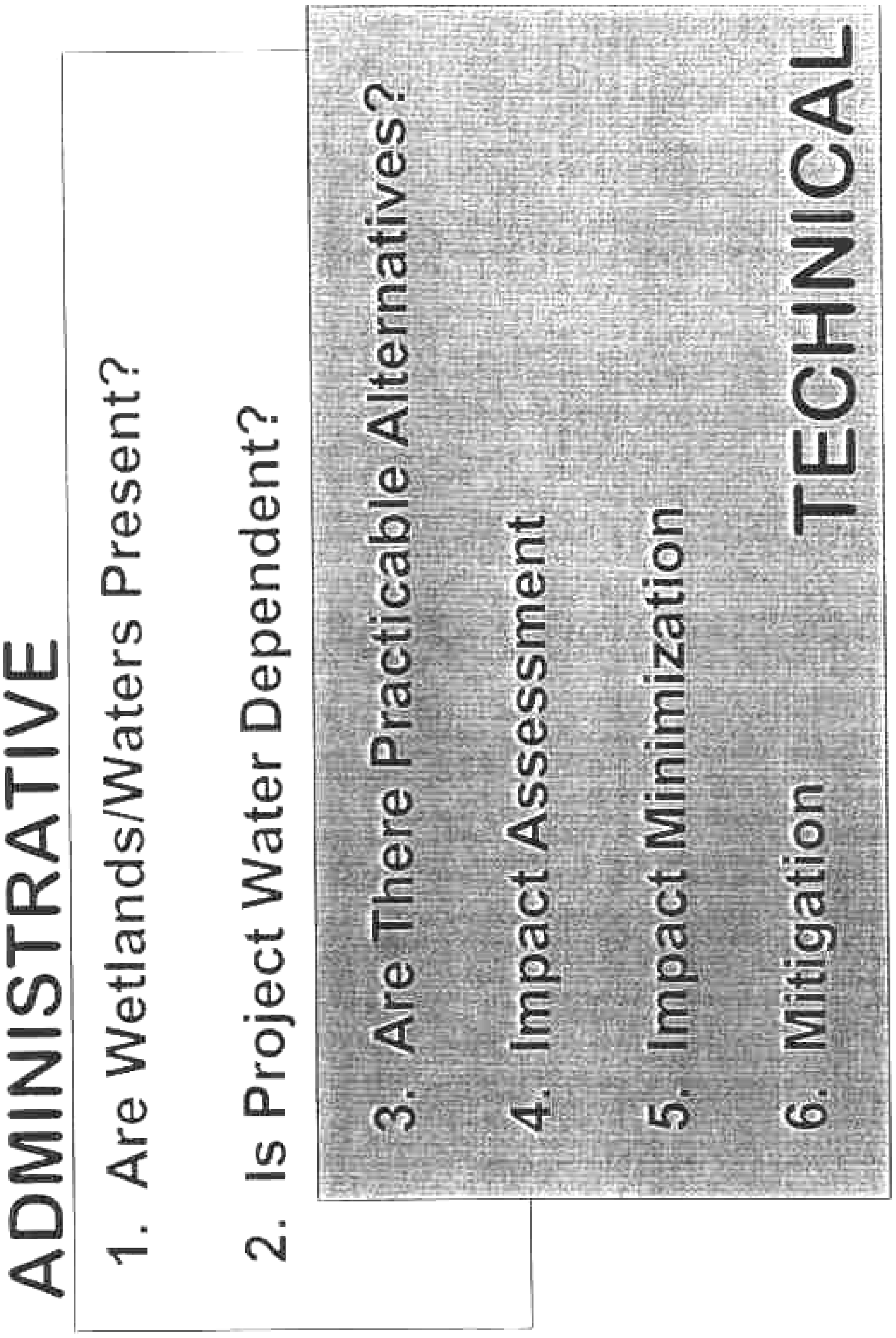
TEAM	**PEER REVIEWERS AND FIELD TEST PERSONNEL AND AFFILIATION**
National Team	Garrett Hollands and Lyndon Lee, National Wetland Science Training Cooperative
Interior Alaska Assessment Team	Ellis Clairain, Army Corps of Engineers (Waterways Experiment Station); Mark Clark and Dan LaPlant, Natural Resources Conservation Service; Jon Hall, U.S. Fish and Wildlife Service (National Wetlands Inventory); Jacqueline LaPerriere, University of Alaska (Cooperative Fish and Wildlife Research Unit); Roger Post, State of Alaska Department of Fish and Game; Jim Powell, State of Alaska Department of Environmental Conservation; Theodore Rockwell, Environmental Protection Agency (Region X)
Agency Personnel	Phyllis Weber-Scannell, State of Alaska Department of Fish and Game; Amy Ash, State of Alaska Department of Environmental Conservation; Erv McIntosh, U.S. Fish and Wildlife Service; Jim Helm, Dennis Mulligan, and Bill Daily, Natural Resources Conservation Service
Landowners	Frank Burris, Biologist, Eagle Ridge Ranch; Scott Schultz, Salcha-Big Bend Soil and Water Conservation District
Technical Team	Mark Cable Rains and William Kleindl, National Wetland Science Training Cooperative

C. Background On The National Initiative To Develop A Method For Assessment of Functions Of Waters/Wetlands Using the HGM Approach

The Clinton Administration's Wetlands Plan (1993) articulated the need for improvement of assessment techniques for waters/wetlands. The primary objective in the Clinton plan was to allow for scientifically valid and consistent consideration of ecosystem functions in the Clean Water Act (CWA) Section 404 process. The Section 404 Process as presented in 404(b)(1) Guidelines (40 CFR Part 232 and 233) is comprised of six essential steps: (1) Determination of the geographic extent of jurisdiction (2) determination of water dependency, (3) evaluation of practicable alternatives, (4) impact assessment, (5) impact minimization, and (6) mitigation (Figure 1). While all permit applications under Section 404 currently undergo some form of impact assessment, approximately 2%-5% of the 14,000 permit applications received annually require analyses of impacts that invoke rigorous, field-based functional assessments.

In the Federal Clean Water Act Section 404 Process, initial evaluations of practicable alternatives, impacts, etc., are completed (1) after "the geographic extent of waters of the U. S., including wetlands" have been delineated on a site, and (2) after "administrative" determinations of water dependency have been made. Specifically, HGM is designed to be used in the more

Figure 1. Administrative and Technical Steps of the 404 Process.



ADMINISTRATIVE

1. Are Wetlands/Waters Present?
2. Is Project Water Dependent?

3. Are There Practicable Alternatives?
4. Impact Assessment
5. Impact Minimization
6. Mitigation

TECHNICAL

Figure 1. Administrative and Technical Steps in the 404 Process

technically focused stages of the Section 404 process: practicable alternatives analyses; impact assessment; impact minimization; and mitigation (Figure 1).

In several types of federal, state or local regulatory processes, HGM can be used as an impact assessment and predictive tool that can help regulatory specialists and managers suggest, and/or examine, alternatives for projects involving waters/wetlands (Step 3 in Figure 1). Furthermore, HGM can be used in several types of waters/wetlands management or regulation processes and at several different scales (Figure 2). For example, facets of the HGM approach (*e.g.* classification, identification of functions by HGM class) lend themselves to reconnaissance-level inventories. Standard HGM approaches can and have been used to minimize project impacts, to develop and condition restoration project targets, and to trigger contingency measures when restoration project targets or standards are in jeopardy. Finally, a properly focused HGM effort can identify specific areas of concern in an impact assessment process, and thus target efforts for further study or restoration.

The strategy that federal agencies will follow to develop the HGM approach is described in the *National Action Plan to Develop the Hydrogeomorphic Approach for Assessing Wetland Functions (Federal Register: August 16, 1996 (Volume 61, Number 160, Pages 42593-42603); Federal Register: June 20, 1997 (Volume 62, Number 119, Pages 33607-33620).* The National Action Plan was developed by a National Interagency Implementation Team (NHIT) which consists of the Army Corps of Engineers (Corps), the Environmental Protection Agency (EPA), the NRCS, the Federal Highways Administration (FHWA), and the U. S. Fish & Wildlife Service (USFWS). The goal of the National Action Plan is to develop sufficient HGM assessment Guidebooks to address 80% of the Section 404 permit workload requiring functional assessments in waters/wetlands. To achieve this goal, the NHIT estimates that approximately 25 to 30 regional subclass models must be developed. Given the magnitude of the effort and the need for interdisciplinary expertise, development of the HGM approach will require participation from federal, state, tribal and local agencies, and from academia and the private sector.

Figure 2. HGM Assessment Levels

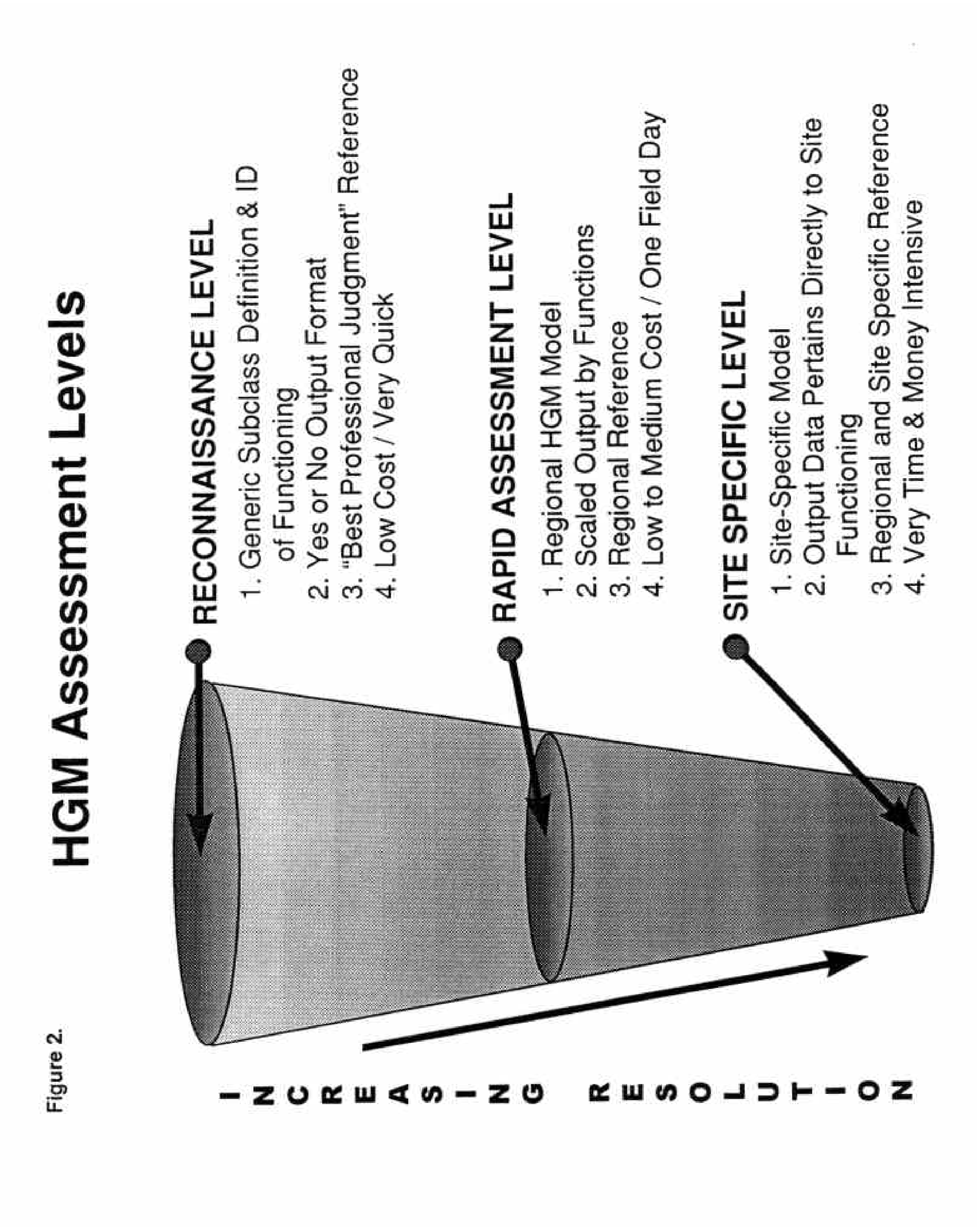


Figure 2.

HGM Assessment Levels

RECONNAISSANCE LEVEL

1. Generic Subclass Definition & ID of Functioning
2. Yes or No Output Format
3. "Best Professional Judgment" Reference
4. Low Cost / Very Quick

RAPID ASSESSMENT LEVEL

1. Regional HGM Model
2. Scaled Output by Functions
3. Regional Reference
4. Low to Medium Cost / One Field Day

SITE SPECIFIC LEVEL

1. Site-Specific Model
2. Output Data Pertains Directly to Site Functioning
3. Regional and Site Specific Reference
4. Very Time & Money Intensive

II. AN OVERVIEW OF THE HYDROGEOMORPHIC APPROACH TO THE ASSESSMENT OF THE FUNCTIONS OF WATERS/WETLANDS

A. Distinguishing Characteristics Of The Hydrogeomorphic Approach

There are three essential elements to the HGM approach to assessment of functions of waters/wetlands (Brinson 1993, Brinson 1995, Brinson 1996). The first is classification of waters/wetlands based on hydrogeomorphic factors. The second is identification, definition, and description of the functions for the subclass of waters/wetlands under consideration. The third is development of a reference system that includes descriptive information about the subclass and which describes the range of variation in structure and function observed within the subclass. Procedures for development of regional guidebooks which incorporate the essential elements of HGM and synthesize them into a standardized assessment approach for a particular subclass of waters/wetlands have been outlined by the EPA and Corps (*e.g.* Brinson 1993, Smith *et al.* 1995, U. S. Army Corps of Engineers 1997).

1. Hydrogeomorphic Classification

Classification of waters/wetlands based upon their position in the landscape, or geomorphic setting, dominant source of water, and flow and fluctuation of the water in the waters/wetlands is the first essential element of the HGM approach (Brinson 1993). Classification criteria are described in Brinson (1993). Seven hydrogeomorphic classes have been identified: riverine, depression, slope, mineral soil flats, organic soil flats, estuarine fringe, and lacustrine fringe. Each of these classes is defined in Table 3. Identification of subclasses of waters/wetlands logically follow (*e.g.* the Depression class can be subdivided into perched, shallow surface, and subsurface flow-through depressions.) The purpose of the HGM classification is to provide a mechanism to account for the natural variation inherent to waters/wetlands. This variation is often attributable to factors such as geomorphic setting, dominant water source and hydrodynamics (Brinson 1993).

Table 3. Seven HGM Classes of Wetlands.

CLASSIFICATION	DEFINITION
Riverine	Riverine waters/wetlands occur in floodplains and riparian corridors in association with stream channels. Dominant water sources are overbank flow from the channel or subsurface hydraulic connections between the stream channel and waters/wetlands. Additional water sources may include groundwater discharge from surficial aquifers, overland flow from adjacent uplands and tributaries and precipitation. Riverine waters/wetlands lose surface water by flow returning to the channel after flooding and saturation flow to the channel during precipitation events. They lose subsurface water by discharge to the channel, movement to deeper groundwater, and evapotranspiration. Examples: Bottomland Hardwood Floodplain Waters/Wetlands in the Southeastern U.S.; Riparian waters/wetlands in the annually flood prone area of Prairie rivers.
Depressional	Depressional waters/wetlands occur in topographic depressions on a variety of geomorphic surfaces. Dominant water sources are precipitation, groundwater discharge, and surface flow and interflow from adjacent uplands. The direction of flow is normally from surrounding non-wetland areas toward the center of the depression. Elevation contours are closed, allowing for the accumulation of surface water. Depressional waters/wetlands may have any combination of inlets and outlets or lack them completely. Dominant hydrodynamics are vertical fluctuations, primarily seasonal. Depressional waters/wetlands lose water through intermittent or perennial drainage from an outlet, evapotranspiration, or contribution to groundwater. Examples: Prairie Potholes; Vernal Pools in the California Central Valley; Depressions on valley alluvium in the Pacific Northwest
Slope	Slope waters/wetlands normally occur where there is a discharge of groundwater to the land surface. They usually exist on sloping land surfaces; from steep hillslopes to nearly level terrain. Slope waters/wetlands are usually incapable of depressional storage. Principal water sources are groundwater return flow and interflow from surrounding non-waters/wetlands as well as precipitation. Hydrodynamics are dominated by downslope unidirectional flow. Slope waters/wetlands can occur in nearly level landscapes if groundwater discharge is a dominant source to the waters/wetland surface. Slope waters/wetlands lose water by saturation subsurface and surface flows and by evapotranspiration. Channels may develop but serve only to convey water away from the waters/wetland. Examples: Fens; Swales in the California Central Valley; Forested wetlands on toeslopes adjacent to, but above floodprone areas of western streams.
Mineral Soil Flats	Mineral soil flats are most common on interfluves, extensive relic lake bottoms, or large floodplain terraces where the main source of water is

Table 3. Seven HGM Classes of Wetlands.

CLASSIFICATION	**DEFINITION**
	precipitation. They receive virtually no groundwater discharge, which distinguishes them from depressions and slopes. Dominant hydrodynamics are vertical fluctuations. They lose water by evapotranspiration, saturation overland flow, and seepage to underlying groundwater. They are distinguished from flat upland areas by their poor vertical drainage and low lateral drainage. Example: Pine Flatwoods of the Southeastern U.S.
Organic Soil Flats	Organic soil flats, or extensive peatlands, differ from mineral soil flats, in part, because their elevation and topography are controlled by vertical accretion of organic matter. They occur commonly on flat interfluves, but may also be located where depressions have become filled with peat to form a relatively large flat surface. Organic flats often expand beyond the areas where they started to form (usually depressions) to adjacent areas that were non-wetland or mineral soil flats. Water source is dominated by precipitation, while water loss is by saturation overland flow and seepage to underlying ground water. Raised bogs share many of these characteristics, but may be considered a separate class because of their convex upward form and distinct edaphic conditions for plants. Example: Pocosin wetlands in eastern North Carolina; Portions of the Everglades
Estuarine Fringe	Tidal fringe waters/wetlands occur along coasts and estuaries and are under the influence of sea level. They usually intergrade landward with riverine or slope waters/wetlands where tidal currents diminish and other sources of water (e.g. river flow; groundwater discharge) dominate. Tidal fringe waters/wetlands seldom dry for significant periods. They lose water by tidal exchange, by saturation overland flow to tidal creek channels, and by evapotranspiration. Organic matter normally accumulates in higher elevation marsh areas where flooding is less frequent and the are isolated from shoreline wave erosion by intervening areas of low marsh. Examples: Spartina alterniflora Salt Marshes
Lacustrine Fringe	Lacustrine fringe waters/wetlands occur adjacent to lakes where the water elevation of the lake maintains the water table in the water/wetland. In some cases, they consist of a floating mat attached to land. Additional sources of water are precipitation and groundwater discharge. Surface flow in bi-directional, usually controlled by water level fluctuations such as seiches in the adjoining lake. Lacustrine fringe waters/wetlands are indistinguishable from depressional waters/wetlands where the size of the lake becomes so small relative to fringe waters/wetlands that the lake is incapable of stabilizing water tables. Lacustrine waters/wetlands lose water by flow returning to the lake after flooding, by saturation surface flow, and by evapotranspiration. Organic matter normally accumulates in areas sufficiently protected from shoreline wave erosion.

Table 3. Seven HGM Classes of Wetlands.

CLASSIFICATION	DEFINITION
	Example: Great Lakes Marshes

2. *Identification, Definition and Description of Functions*

The second essential element of the HGM approach is identification, definition, and description of the functions of the waters/wetlands of concern. For the purposes of HGM, "functions" are defined as "processes that are necessary for the maintenance of an ecosystem such as primary production, nutrient cycling, decomposition, etc." In the context of HGM, the term "functions" is used primarily as a means to highlight the distinction of ecosystem functions from values. The term "values" is associated with society's perception of ecosystem functions. Functions occur in ecosystems regardless of whether or not they have value. Usually, HGM Guidebook authors choose to group functions according to logical sets such as (1) Hydrologic, (2) Biogeochemical, (3) Plant Community, and (4) Faunal Support/Habitat.

3. *Reference Systems*

The third component of the HGM approach is establishment and use of a reference system (NWSTC in prep., Brinson 1996; Brinson 1995). The structure of an HGM reference system is shown in Figure 3. To apply the use of reference systems in the context of HGM, it is important to understand the standard definitions presented in Table 4.

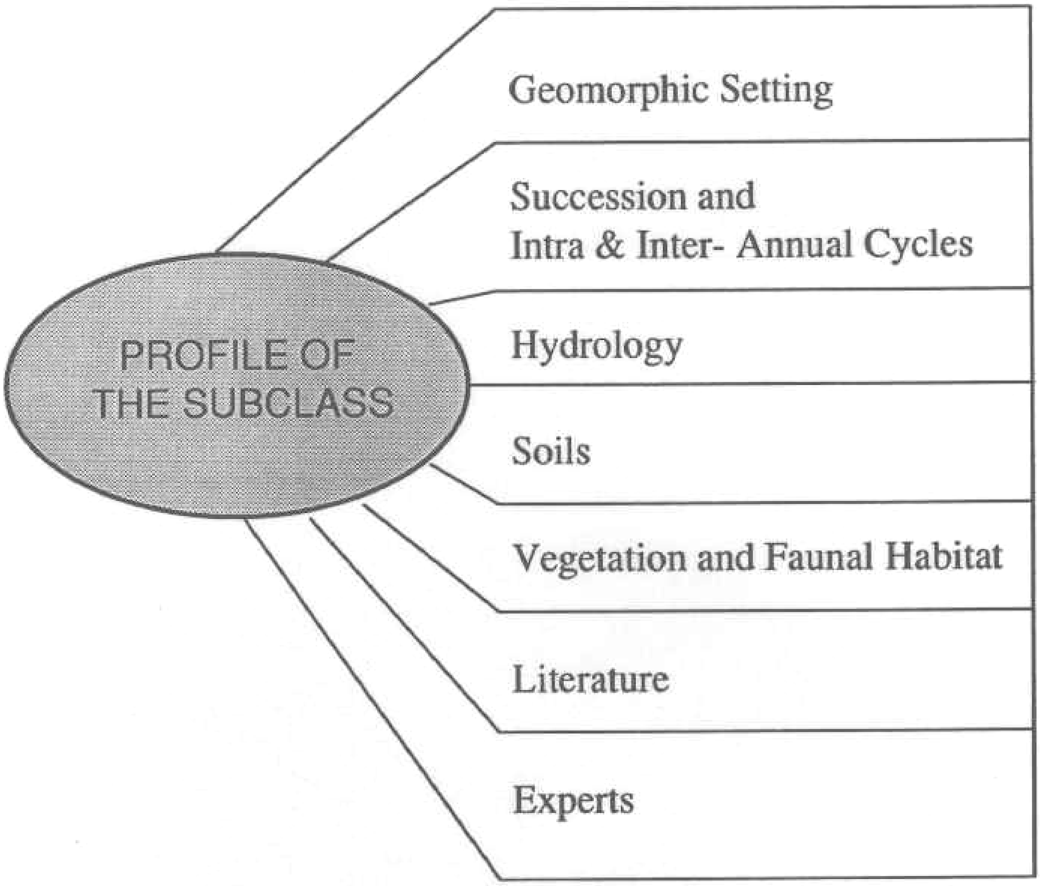
Table 4. HGM Reference System Definitions.

TERM	**DEFINITION**
Reference Domain	All wetlands within a defined geographic region that belong to a single hydrogeomorphic subclass.
Reference Sites	Sites within the reference domain that encompass the known variation of the regional subclass. Reference sites are used to establish the ranges of functions within the regional subclass, including functional changes resulting from site alteration (human-induced perturbation).
Reference Standard Sites	The sites within a reference wetland data set from which reference standards are developed. Among all reference wetlands, reference standard sites are judged by an interdisciplinary team to have the highest level of functioning.
Reference Standards	Conditions exhibited by a group of reference sites that correspond to the highest level of functioning (highest sustainable capacity) across the suite of functions of the subclass.
Site Potential	The highest level of functioning possible given local constraints of disturbance history, land use, and other factors. Site potential may be equal to or less than levels of functioning established by reference standards.
Subclass Profile	The highest organizational element of an HGM reference system and is defined as a narrative and quantitative description of at least, the subclass geomorphic setting, climate, hydrology, geology, soils and biotic communities.
Project Targets	The level of functioning identified or negotiated for a restoration or creation project. Must be based on reference standards and/or site potential and consistent with restoration or creation goals. Used to evaluate whether a project is developing toward reference standards and/or site potential.
Project Standards	Performance criteria and/or specifications used to guide the restoration or creation activities towards the project targets. Project standards should include and specify reasonable contingency measures if the project targets are not being achieved.

Figure 3. HGM Reference System Structure

Figure 3.

HGM REFERENCE SYSTEM STRUCTURE



National Wetland Science Training Cooperative 1996

As illustrated in Figure 3, the subclass profile is the highest organizational element of the HGM Reference System. Users of HGM reference systems commonly access information included in the subclass profile to establish standards for comparison among members of the subclass (*e.g.*, sites of the same subclass within the domain (Smith *et al.* 1995). Typically HGM users will use reference systems (1) to apply HGM models and thus detect changes in ecosystem functioning, (2) as design templates, and (3) to set monitoring targets and to specify contingency measures (Figure 4). The principle of reference in the context of HGM is useful because (1) everyone uses the same standard of comparison, and (2) relative rather than absolute measures allow efficiency in time and consistency in measurements.

Standards and details concerning development of HGM reference systems are given in the National Reference Guidebook (Whigham *et al.* in prep.) Basically, to develop an HGM reference system, an interdisciplinary team (or “A” team) visits reference sites in a range of conditions (*i.e.* relatively pristine to highly degraded) in the same domain and hydrogeomorphic subclass. At each site, the team collects data on physical, hydrologic, biogeochemical, plant community, and faunal support/habitat community attributes. When synthesized and interpreted, and combined with the best scientific judgment of the interdisciplinary team, these data help to indicate the range of ecosystem conditions, functions, and responses to perturbation witnessed by the team within the subclass.

In addition to developing a subclass profile, the “A” team uses best scientific judgment to determine whether each site is a “reference standard site.” Reference standard sites are those that are determined by the “A” team to be functioning at the highest level (*i.e.*, highest sustainable capacity) across the *suite* of functions exhibited within the subclass. “Reference standards” are articulated from the data collected at the reference standard sites. Reference standards are the conditions exhibited by the reference standard sites that correspond to the highest level of functioning. In the HGM approach, Reference standards are used to construct functional profiles of the waters/wetlands subclass, and to set the standards that allow development of HGM models.

Ideally, all of the waters/wetlands within a defined geographic region that belong to a single hydrogeomorphic subclass constitute the “reference domain.” Again, reference sites are selected to encompass the known range of variation within the potential reference domain. It is important to note that practical limitations of funding, personnel, and access do not usually allow sampling of all waters/wetlands within a region. Therefore, the reference domain is often envisioned as both the actual waters/wetlands sampled to build the reference system, and the geographic area within which reference sites for a regional waters/wetlands subclass have been sampled. Where sampling of additional references sites could reasonably be used to expand the (sampled) reference domain (*e.g.* within an ecoregion), one can infer a “potential reference domain.” The potential reference domain thus constitutes the sampled reference domain plus the pool from which additional reference sites might be selected to expand the sampled reference domain.

Figure 4. Use of the HGM Subclass Profile

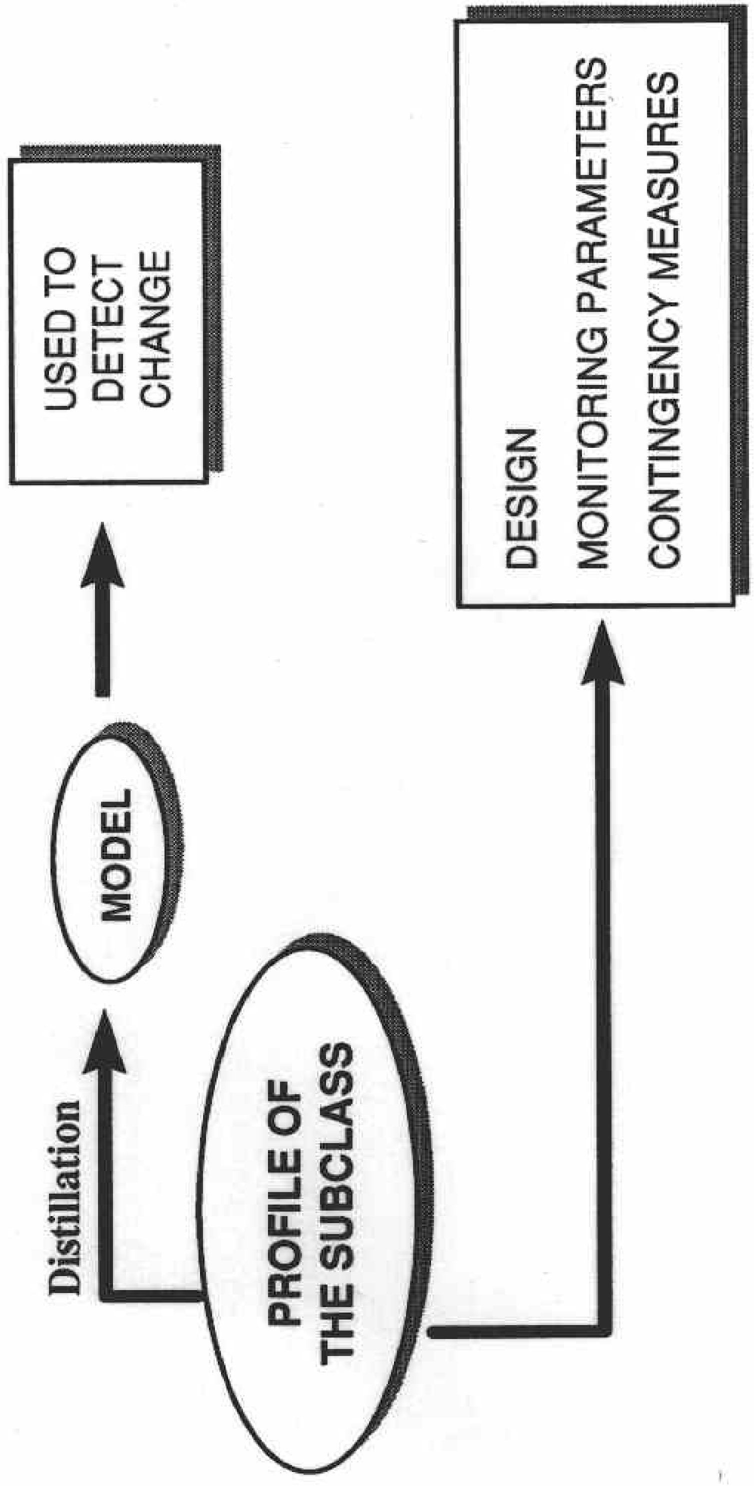


Figure 4.

USE OF THE HGM SUBCLASS PROFILE

HGM Assessment Models and Functional Indices.As discussed above, an important step in developing the HGM approach is the description of the functions that waters/wetlands within a subclass perform. In this, and most Guidebook(s), identification of functions is followed by development of assessment models and functional capacity indices that are estimates of the capacities of the waters/wetlands within a subclass to perform those functions (Smith *et al.* 1995, See Section VI).

It has long been recognized that some waters/wetlands perform certain functions better than others, not because they are impacted in some way, but because waters/wetlands are inherently different (Brinson 1993). For example, bottomland hardwood forests of the Southeastern United States support breeding habitat for neotropical migrant birds more intensively than forested wetlands on steep slopes throughout Southeast Alaska. These two extremes in breeding habitat differ so greatly due to many intrinsic properties that most comparisons between them become meaningless. The same logic applies to comparison of functions across classes, *e.g.*, between riverine and depressional waters/wetlands. To avoid assessment of functions that are inappropriate for a particular class of water/wetland, functions are described differently for each of the seven classes of waters/wetlands defined in Table 3. Even if the suite of functions overlap significantly between classes, which they often do, these functions are likely to be performed at different levels or intensities. Furthermore, the field indicators and variables used to assess each function would differ sufficiently to require separate treatment.

To develop assessment models for functions associated with a regional waters/wetlands subclass, “variables” must be identified, defined and scaled using data from the reference system. Variables are the attributes or characteristics of a waters/wetland ecosystem or the surrounding landscape that influence the capacity of a water/wetland to perform a function or a set of functions. For example, in Interior Alaska, macro and micro topographic complexity affect the hydrologic function “surface and near-surface water storage. " At each project assessment area, a variable may be operating or expressed to a greater or lesser degree, depending on land uses, degree of disturbance, etc. Hence, variables are usually observed to relate directly to the degree of anthropogenic perturbation extant on a particular site. In the field, variable conditions are either measured directly (*e.g.* tree stem density) or indirectly through the use of field indicators (*e.g.* microtopographic roughness = number of pits a certain size capable of storing ponded water). Specifically, field indicators are observable characteristics of the water/wetland that correspond to identifiable variable conditions in the water/wetland or in the surrounding landscape.

Finally, variables must be combined into assessment models. An HGM model for a particular function is usually expressed as a simple formula that combines variables in certain ways to yield estimate of a "functional capacity index" or FCI. In a well done Guidebook, the relationships among variables that are combined to develop an FCI have been established based on analyses of reference system data developed for the subclass (Figure 5). By definition, reference standard sites yield FCI’s of 1.0, and FCI values range from 1.0 to 0.0. Therefore, highly degraded waters/wetlands may yield FCI’s of 0.0 (*i.e.*, unrecoverable loss of function). Thus, an FCI is an

Figure 5. Structure of an HGM Model

estimate of the function performed by a water/wetland with respect to reference standard conditions.

4. Assessment Protocol

Authors of regional guidebooks must provide an assessment protocol for users of the HGM models included in a Guidebook. In fact, the assessment protocol is actually the fourth essential component of the HGM approach. The assessment protocol establishes criteria for the background information necessary to perform a functional assessment, and provides instructions for measurement of variables in the field and subsequent calculation of FCI's. Use of an assessment protocol sets minimum requirements for valid use of models and thus helps ensure their unbiased, consistent application. More details on the assessment protocol developed in the Guidebook are presented in the "Applications" section of this Guidebook (Section VII).

III. METHODS USED TO DEVELOP THIS OPERATIONAL DRAFT GUIDEBOOK

A. Consistency With National Guidance

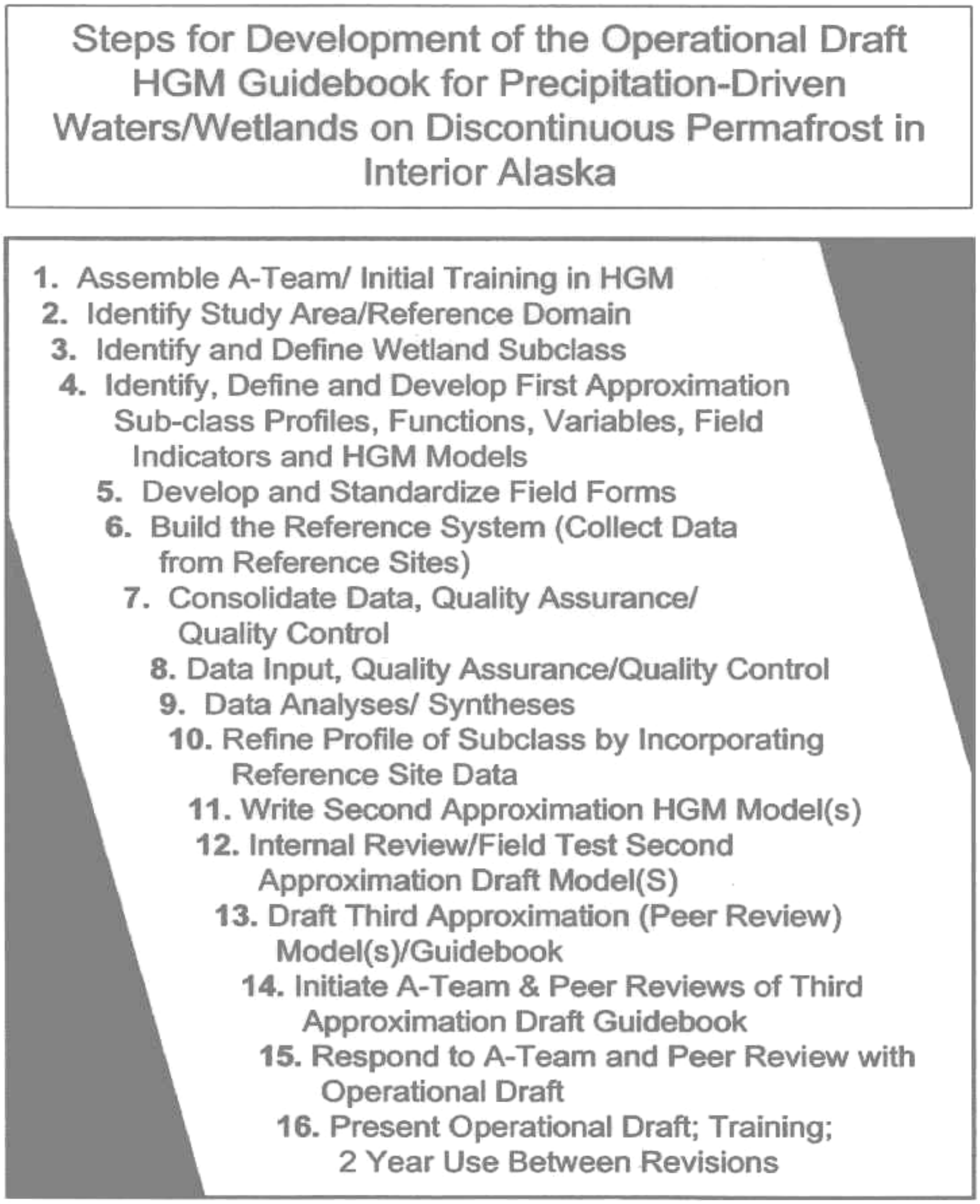
The authors of this Guidebook developed the document over a period of time when national guidance on HGM was being articulated and refined by the "National Hydrogeomorphic Implementation Team" (NHIT). The NHIT group consists of representatives from the Corps, EPA, USF&WS, NRCS, FHA, and National Marine Fisheries Service *(Federal Register: August 16, 1996 (Volume 61, Number 160, Pages 42593-42603); Federal Register: June 20, 1997 (Volume 62, Number 119, Pages 33607-33620)*. As of this writing, NHIT guidance on the development and implementation of HGM continues to be in flux. Thus, the sequence and timing of some tasks completed in development of this Guidebook differ from those outlined in current versions of national guidance (Table 5). Figure 6 offers a reasonably accurate summary of the principal steps that the Alaska Interior teams used to develop this operational draft Guidebook.

Table 5. Steps in Development of Model Guidebooks (Draft) (source: Federal Register 8/16/96)

Phase I: Organization of Regional Assessment Team:
A. Identify A-Team members
B. Train members in HGM classification and assessment
Phase II: Identification of Regional Wetland Assessment Needs:
A. Identify regional wetland subclasses
B. Prioritize regional wetland subclasses
C. Define reference domains
D. Initiate literature review
Phase III: Draft Model Development:
A. Review existing models of wetland functions
B. Identify reference wetland sites
C. Identify functions for each subclass
D. Identify variables and measures
E. Develop functional indices
Phase IV: Draft Regional Wetland Model Review:
A. Obtain peer-review of draft model
B. Conduct interagency and interdisciplinary workshop to critique model
C. Revise model to reflect recommendations from peer-review and workshop
D. Obtain second peer-review of draft model
Phase V: Model Scaling:
A. Collect data from reference wetland sites
B. Scale functional indices using reference wetland data
C. Field test accuracy and sensitivity of functional indices
Phase VI: Draft Model Guidebook Publication:
A. Develop draft model guidebook
B. Obtain peer-review of draft guidebook
C. Publish as an Operational Draft of the Regional Wetland Subclass HGM Functional Assessment
Guidebook to be used in the field
Phase VII: Implement Draft Model Guidebook:
A. Identify users of HGM Functional Assessment
B. Train users in HGM classification and evaluation
C. Provide assistance to users
Phase VIII: Review and Revise Draft Model Guidebook

Figure 6. Steps for Development of the Operational Draft HGM Guidebook for Precipitation-Driven Wetlands on Discontinuous Permafrost in Interior Alaska.

Figure 6.



Steps for Development of the Operational Draft HGM Guidebook for Precipitation-Driven Waters/Wetlands on Discontinuous Permafrost in Interior Alaska

1. Assemble A-Team/ Initial Training in HGM
2. Identify Study Area/Reference Domain
3. Identify and Define Wetland Subclass
4. Identify, Define and Develop First Approximation Sub-class Profiles, Functions, Variables, Field Indicators and HGM Models
5. Develop and Standardize Field Forms
6. Build the Reference System (Collect Data from Reference Sites)
7. Consolidate Data, Quality Assurance/ Quality Control
8. Data Input, Quality Assurance/Quality Control
9. Data Analyses/ Syntheses
10. Refine Profile of Subclass by Incorporating Reference Site Data
11. Write Second Approximation HGM Model(s)
12. Internal Review/Field Test Second Approximation Draft Model(S)
13. Draft Third Approximation (Peer Review) Model(s)/Guidebook
14. Initiate A-Team & Peer Reviews of Third Approximation Draft Guidebook
15. Respond to A-Team and Peer Review with Operational Draft
16. Present Operational Draft; Training; 2 Year Use Between Revisions

B. Nomenclature

It is important to note that because development of HGM nationally and in Alaska is a work in progress, HGM nomenclature used in this and preceding drafts of the Interior Regional Guidebook has undergone some changes. To the extent possible, the authors have updated HGM nomenclature used in this operational draft Guidebook to be consistent with developing national standards. However, the condition of an HGM nomenclature nationally remains uncertain and relatively inconsistent from region to region. Therefore, for the purposes of this Alaska effort, and in addition to updating nomenclature to developing national standards, the authors chose to present the operational draft using nomenclature that is as clear to users and as consistent with past drafts as possible.

C. Selection and Characterization Of The Regional Subclasses Of Waters/Wetlands

For precipitation-driven wetlands on discontinuous permafrost in Interior Alaska, Phases I and II listed in Table 5 were completed or substantially advanced during the interval from May 22 to 26, 1996. This effort included HGM training for the Interior Alaska Assessment Team (A-Team) personnel. This training was offered by the National Wetland Science Training Cooperative (NWSTC) "National HGM Technical Team" (Tables 1 and 2). With assistance from the NWSTC national scientists, the Interior A-Team identified priority and secondary subclasses of waters/wetland for the Interior based on extensive discussion of boreal ecosystem characteristics. Prior to initiating field work, the A-Team assembled information about the landscape within the reference domain. Topographic and geologic maps, soil surveys, National Wetland Inventory (NWI) maps, aerial photographs, species lists, climatic data, and historical information were analyzed. Members of the A-Team also identified potential reference sites and reference standard sites and developed initial working definitions of the subclasses to be sampled. In addition, the leader of the A-Team prepared a review of black spruce wetland ecology and functions (Post 1996) that was available to the National, Technical, and A-Team Teams in draft form. This draft contributed to substantial completion of Phase III (Table 5) prior to field work in the summer of 1996.

D. Field Verification Of The Subclass And Development Of First Approximation Assessment Models

The NWSTC National and A-Teams finalized subclass definitions and developed first approximation models for functions and draft subclass profiles during July 1996. At the same time, the team collected data at 55 reference sites from the priority subclass reference system. From the outset, the NWSTC and Interior "A" team undertook four major tasks:

> <u>Task 1 - Field Verification And Definition Of The Priority Subclass:</u> At the outset of this study, the combined Interior A and NWSTC teams conducted preliminary sampling of a variety of sites pre-selected by the A-Team. These sites were characteristic of Interior Alaska and were critical in the regulatory context. The combined teams engaged in extensive discussions of the characteristics of each site. The teams then collectively determined that most of the pre-selected sites were "precipitation-driven wetlands on discontinuous permafrost in Interior Alaska." This subclass was identified as the priority regional subclass. Groundwater-driven wetlands (*i.e.,* fens), which are less common than

precipitation-driven wetlands in the Interior, were identified as the secondary subclass and will be addressed elsewhere.

Task 2 - Definition Of First Approximation Functions, Variable, and Field Indicators: The second task that the combined teams completed was to identify functions, variables and field indicators for the priority subclass. First approximation models for functions potentially performed by the priority wetland subclass were refined. The teams also developed field data sheets to ensure consistent collection of reference site hydrology, soils, plant, habitat and land use data. The draft assessment models and data sheets continued to evolve throughout the sampling procedures. Examples of the sheets are provided in Appendix A.

Task 3 - Development Of The Reference System: Throughout the course of the field effort, the combined Interior A and NWSTC teams identified 55 reference sites in the priority waters/wetlands subclass for sampling. Reference sites were selected with great care. Such caution was warranted due to limited field time and the large size of the potential (geographic) domain. The teams recognized early that each reference site would have a great deal of influence on the final data sets that constitute the reference system. In selecting sites for sampling, the teams targeted the range of variation in the priority subclass.

In offering the operational draft Guidebook, the authors would like to emphasize that, by design, we chose to use our collective experience to develop data collection techniques at the 55 reference sites that would largely encompass procedures required for use in the assessment protocol developed in this Guidebook. Using this approach, we believe that (a) a large amount of our practical field experience is embedded in the assessment models, and (b) measurements stipulated in the assessment procedure developed in this Guidebook are as efficient and rapid as possible.

Task 4 - Refinement Of Draft HGM Models: Before leaving the field, the teams revisited critical functions and variables and refined the draft assessment models for use in a working draft guidebook. For the secondary subclass (fens), the teams also identified and described critical functions and suggested ways in which these fen ecosystems could be sampled and a regional guidebook developed for them. Thus, the teams completed Phase III (Table 5) of the protocol for development of regional guidebooks during their field efforts. Initial work on Phase IV.A. was subsumed in subsequent tasks (*e.g.,* Phase VI.B.) due to the sequence of development used for this regional guidebook.

E. Collection Of Reference System Data

As introduced above, the Interior A and NWSTC field teams collected quantitative and qualitative data on hydrology, soils, plant communities, and faunal/habitat features at each of 55 reference sites. This field data collection effort served to accomplish Phase V.A. (Table 5) of the protocol for development of regional guidebooks. Data were recorded on forms that were specifically tailored and standardized for the subclass (Appendix A). Most of the methods for collecting qualitative information are outlined on the data sheets. Methods for collecting quantitative data are described below. In addition, Figure 7 shows the standard plot layout.

1. Hydrologic Sampling

Field teams sampled two hydrologic characteristics at reference sites: (1) microtopographic variation, and (2) frequency of microtopographic and ponding features. Microtopographic variation was measured by stringing a measuring tape taught between two fixed points 30 feet (ft) (9.1 meters (m)) apart. The tape was leveled using a line level. The distance from the tape to the vegetative mat (*i.e.,* relative relief) was measured at 1.0-ft (30 centimeter (cm)) intervals. Ranges and standard deviations associated with these data were used as an estimate of microtopographic variation. The depth of the organic mat (*i.e.,* ground surface to mineral soil) was measured at 0.0 ft and at 30 ft (9.1 m) along the transect.

Field teams measured the frequency of microtopographic and ponding features at points along a 200 ft (61 m) transect, separate from the 30 ft (9.1 m) microtopographic-variation transect. The sampler walked along the transect and stopped every 20 ft (6.1 m) to describe the microtopographic surface (*e.g.,* plane, pit, hummock) percentage in each feature.

2. Soil Sampling

Field teams sampled soils using soil pits to identify and describe soil characteristics. Soil characteristics also yielded important information on site hydrology (*e.g.* thickness of the organic soil layers; depth to seasonal frost or to permafrost).

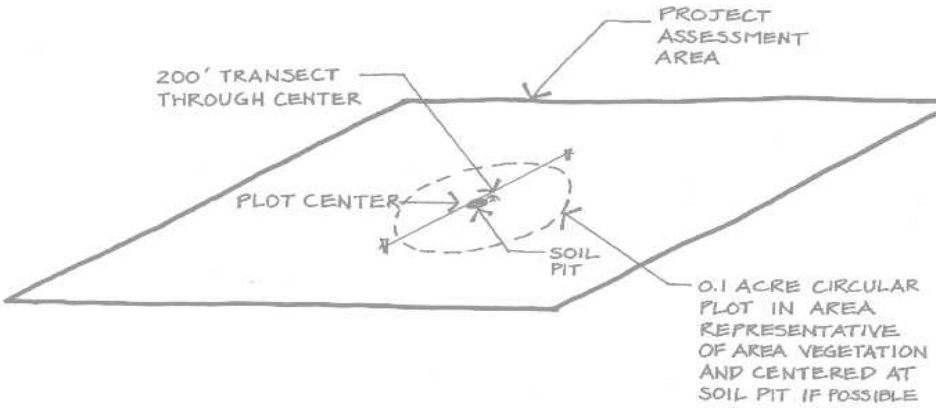
Soil pits were excavated to a depth of 6.6 ft (2.0 m) or to the depth of permafrost (substrates remaining frozen for ≥2 years), whichever was encountered first. The upper 1.6 ft (0.5 m) were excavated with a sharpshooter shovel. Below 1.6 ft (0.5 m), pits were usually excavated with a closed-bucket auger. At times, ice probes were used to determine depth of seasonal frost or depth to permafrost.

Field teams excavated at least one representative soil pit within each assessment area (Figure 7), and excavated and described two or more pits where two distinctly different landscape features were recognized. For example, at sites with high-centered polygonal ground, teams excavated pits in the troughs and on the mounds. Measurement protocols are described in detail in Section VI.

Identification, nomenclature, and description of soil horizons were consistent with guidance provided by the USDA Soil Conservation Service (SCS 1962; SCS 1990). Field teams measured

Figure 7. Standard Plot Layout and Location of Measurements In Relation To Project Assessment Area for Each Variable

Figure 7. Standard Plot Layout and Location of Measurements in Relation to Project Assessment Area for each Variable



Measurement Location	Variables
Soil Pit in Center of PAA*	- V_{AQUIC}, V_{OH}, V_{SLM}
100' Transect Bisecting Center of PAA	- V_{STRATA}
200" Transect Bisecting Center of PAA	- V_{TOPO}, V_{SURWAT}, $V_{SURFCON}$,
0.1 Acre Circular Plot in PAA	- V_{HERB}, $V_{MOSSLICH}$, V_{PRATIO}, V_{SHRUB}, V_{TREE}
Entire PAA	- V_{ASIGN}, $V_{AREAUSE}$, V_{CWD}
100' Surrounding Land around PAA	- V_{CONTIG}
1000' Surrounding Land around PAA	- V_{SURUSE}

* PAA = Project Assessment Area

.all depths from the top of the O horizon. Live vascular and non-vascular plant materials were **not** included in these depths. Soil colors were determined using a standard Munsell Soil Color Chart (Munsell 1992).

3. Vegetation/Habitat Sampling

Field teams sampled vegetation and habitat via species identification and measures of community structure. Vascular plants were identified to species level when possible. Mosses and lichens were identified as *Sphagnum* spp. mosses, non-*Sphagnum* spp. mosses, and fruticose lichens. Nomenclature was consistent with *Flora of Alaska and Neighboring Territories* by Eric Hultén (1974).

Most quantitative vegetation data were collected using circular 0.1 acre (0.04 hectare (ha)) plots (radius 37 ft (11.3 m)) and point center quarters (PCQ) (Mueller-Dombois and Ellenburg 1974) (Figure 7). For example, percent cover measurements were made within the 0.1 acre (0.04 ha) plots, while density, volume and basal areas were assessed using the PCQ protocol. Plots were located in areas of representative, homogenous vegetation. A method for estimating percent canopy cover for plant species is given in Section VI.

The number of vegetation strata within a given plant community was determined by sampling every 10 ft (3 m) on a 100 ft (30.5 m) transect. Field teams used a combination of air photos, site reconnaissance, and available cartography to estimate and record the size (area) of the community type represented by the 0.1 acre (0.04 ha) plot to reflect patch shape, size, distribution, and dynamics. The dominant land use of the project assessment area was identified and described by using standard classes (*e.g.* undisturbed, burned and recovering, cleared and recovering, clear and cultivated, etc.). If there was evidence of fire, field teams assigned a successional stage (Foote 1983) to the sampling area (*e.g.* 0-3 years, 4-15 years, 16 - 50 years, >50). Snags, coarse down and dead wood, and the presence and abundance of willow (*Salix* spp.) were counted at each site.

4. Faunal Community Sampling

At each site evidence of animal trails crossing a 200 ft (61 m) line transect were counted and recorded on standard data sheets (Appendix A). In addition the presence of animal signs (*e.g.* scat, fur, bedding, nests, etc.) was recorded.

F. Analyses Of Reference System Data

Following standard quality assurance and quality control steps, the combined Interior A and NWSTC teams analyzed field data from the reference sites. The team first sorted all sampled sites into "reference standard" and "non reference standard" categories. Following this initial split, sites were sorted according to community types.

Sorting of sites as described above allowed relatively fast characterizations of the reference system data. When possible, and to facilitate the variable scaling effort, qualitative data were converted to numeric ranks (*e.g.*, dominant leaf type was given a 1 to 4 rating). Other qualitative data were used to classify reference sites by reference class (*i.e.*, reference site or reference standard site), land use, years since natural burn, and other appropriate characteristics. Quantitative data (*e.g.* tree stem densities) were analyzed using standard statistical methods.

The team conducted multivariate analyses of some of the reference system data. For example, using vegetation data, detrended correspondence analysis (DCA) was used to ordinate sampled sites (Hill 1979; Hill and Gauch 1980; ter Braak 1987; Jongman *et al.* 1987). The authors emphasize that DCA was not necessarily used to scale vegetation variables. Rather, the Interior A and NWSTC teams found ordination approaches to be useful tools that facilitated our understanding of how altered sites and reference standard sites differed in terms of measured (*e.g.* vegetation community) traits. Using standard ordination techniques, some overlap among reference standard sites assigned to different community types is to be expected, given the wide range of perturbation histories associated with community types included within the subclass. Often, significant similarities existed between post-fire plant communities and anthropogenically altered plant communities. In addition, apparent outliers in the ordinations resulted from small sample sizes for some localized or rare types of site alteration. NWSTC used standard techniques for analyses of outliers in an effort to make the ordinations as meaningful as possible.

The combined Interior A and NWSTC team used several approaches to examine quantitative data in an attempt to determine trends. Standard statistical analyses were used to find ranges of values, means and standard deviations. (Zar 1984). Variable scaling based on quantitative field data included in the reference system generally used data ranges, means, and standard deviations as the "statistical" inputs. More advanced parametric or non-parametric methods were usually not needed or were not practicable, given low sample sizes for each community type.

In several instances, simple x, y plots or histograms were generated according to (1) reference condition (*e.g.*, reference standard, other reference sites), (2) land uses (*e.g.*, undisturbed, rural, urban), and/or (3) dominant plant community/disturbance history. The teams used these graphical summaries in their attempts to understand trends in the data and to offer assistance to users of the Guidebook. Some of these graphic summaries can provide a basis for development of restoration project targets and standards for wetlands within the subclass.

G. Scaling Of HGM Model Variables

After field sampling and before rigorous analyses of the reference system data, the combined Interior A and NWSTC Team reviewed and attempted to refine aspects of the first approximation HGM models developed at the outset of the project. Following analyses of the reference system data as described above, the team verified that certain variables in the first approximation models could be scaled using reference system data and used successfully to develop models of ecosystem functions. During this process, some first approximation variables were discarded because they were impractical. New variables were added as necessary. Often, new variables were either (a) Alaska Interior surrogates for variables published in other HGM guidebooks, or (b) chosen because of particular patterns observed in reference system data gathered for the subclass. Following the model refinement efforts explained above, all variables were scaled by the team using reference system data combined with best scientific judgment. The National and Technical teams used the scaled variables to develop second approximation HGM models, which were then incorporated into the working draft of the *Peer Review Draft Guidebook* (NWSTC 1996).

Consistent with the steps outlined in Figure 6, the combined Interior A and NWSTC Team completed an internal review of the *Peer Review Guidebook* in October 1996. Limited field testing was conducted. Review comments submitted by the combined team members were incorporated in a March 27, 1997, revision of the *Peer Review Guidebook (NWSTC 1997).* The revised *Peer Review Guidebook*, which incorporated analyses of reference data and a synthesis of relevant literature, was presented at an interdisciplinary peer review workshop conducted on April 1 - 2, 1997. This peer workshop step represented the completion of Phase IV.A-B. (Table 5) of the recommended national protocol for development of regional guidebooks. The authors consider this workshop to also represent partial completion of Phase V.B. because scaled variables were used in the March 24, 1997 *Peer Review Guidebook* (NWSTC 1997).

Members of the A-Team, with assistance from other agency personnel, conducted preliminary field tests of the March 1997 *Peer Review Guidebook* on June 25 - 27, 1997. This work completed Phase V.C (Table 5) of the recommended HGM development protocol. The A-Team recommended modification of certain aspects of the Guidebook based on the field tests. Subsequently, a core group of A-Team and NWSTC staff engaged in work sessions on March 30 - April 1 and August 3 - 5, 1998, to address peer review comments and field testing recommendations. By incorporating field test results, these meetings produced an October 1998 draft guidebook, equivalent to Phase VI.A. in Table 5. Subsequently, the combined Interior A and NWSTC team incorporated review comments to substantially revise the October 1998 draft Guidebook during the interval November, 1998 - April, 1999 and to produce this operational draft Guidebook. Thus, Phase VI.B. and Phase VI.C. (Table 5) of the protocol will be complete upon publication of this Guidebook. Phases VII and VIII require additional work, but the authors propose that it is most logical to subsume this work in the use of this operational draft Guidebook, which will require further revision following two years of field implementation.

IV. FUTURE DEVELOPMENT OF THE OPERATIONAL DRAFT REGIONAL GUIDEBOOK

As discussed in detail above, the authors have developed this operational draft Guidebook in a manner that is as consistent as possible with national guidance (U.S. Army Corps Of Engineers 1997). Future work will likely result in an expansion of the reference domain. The open structure of this document will allow assimilation of new information from the expanded reference set, and facilitate transforming technical information into tools for rapid HGM functional assessments.

As funding allows, the State of Alaska and participating federal agencies will offer training in the use of this operational draft Guidebook and provide continuing technical assistance. These technology transfer objectives represent Phase VII of the National Action Plan (Table 5). Initially, the NRCS will apply the Guidebook for Minimal Effects Determinations pursuant to the federal Food Security Act (USDA 1994, 1995). Application of the operational draft Guidebook by other agencies is highly encouraged.

V. PROFILE OF PRECIPITATION-DRIVEN WATERS/WETLANDS ON DISCONTINUOUS PERMAFROST IN INTERIOR ALASKA

A. Introduction And Overview

Approximately 44% of the land surface of Interior Alaska consists of waters/wetlands (Hall *et al.* 1994) and thus these ecosystems are among the dominant features of the regional landscape. Precipitation (*i.e.*, rainfall and snowmelt) drives the hydrologic characteristics of the majority of waters/wetlands in this landscape. Permafrost characterizes many sites in the reference domain, but is discontinuous and not essential for the formation of waters/wetlands. Permafrost commonly underlies landscapes insulated from warmer air by thick surface organic soil horizons and, to a lesser degree, by vegetation. Many sites within Interior Alaska cycle between a poorly drained, shallow-permafrost condition and a well-drained, ice-free state. Frequent anthropogenic alterations to precipitation-driven wetlands on discontinuous permafrost in Interior Alaska consist of land clearing operations for agricultural, commercial, or residential development. Agriculture probably accounts for the highest areal proportion of such clearing, but commercial and residential development around major population centers (*e.g.*, Fairbanks, Alaska) accounts for the majority of wetland regulatory activity. Thus, the authors developed this operational draft Guidebook with attention to the fact that the defined subclass was the most extensive and most frequently perturbed wetland type within the Interior Alaska region.

The following section of this draft operational Guidebook offers users of the Guidebook the entry to the reference system for precipitation-driven wetlands on discontinuous permafrost in Interior Alaska. In particular, the subclass profile developed herein focuses on the definition and description of the geologic, climatic, and landscape contexts in which the subclass exists in Interior Alaska. The profile also highlights (1) the HGM domain, (2) definition, identification and delineation of HGM class and subclass in the field, (3) characteristics of the subclass hydrology, soils, and vegetation, and (4) cyclic processes associated with the subclass. Throughout this subclass profile, frequent references are made to Appendix B data which are offered in an attempt to provide Guidebook users with a consistent data base and system of reference pertinent to the subclass. As discussed elsewhere in this Guidebook, depending on the questions Guidebook users may have regarding the subclass, the reference system can be used along with the assessment protocol as the basis for impact assessment, as a design template, or to develop monitoring programs and reasonable contingency measures.

B. Reference Domain - Definition And Geographic Extent

The authors developed this operational draft Guidebook and the associated reference system from data collected on 55 reference wetland sites throughout Interior Alaska. By definition, these 55 reference sites are the reference domain for the Guidebook (Table 4). The geographic extent of the 55 reference sites extends from the Tanana Flats south of Fairbanks southeastward to the agricultural area beyond Delta Junction, and extends northward and northeastward from Fairbanks along the Elliott, James Dalton, and Steese highways toward the Yukon River and Circle (Figures 8 and 9). By encompassing both alluvial lowlands of the Tanana River valley

Figure 8. Approximate Locations of Reference Sampling Sites

Figure 8. Approximate Location of Reference Sampling Sites

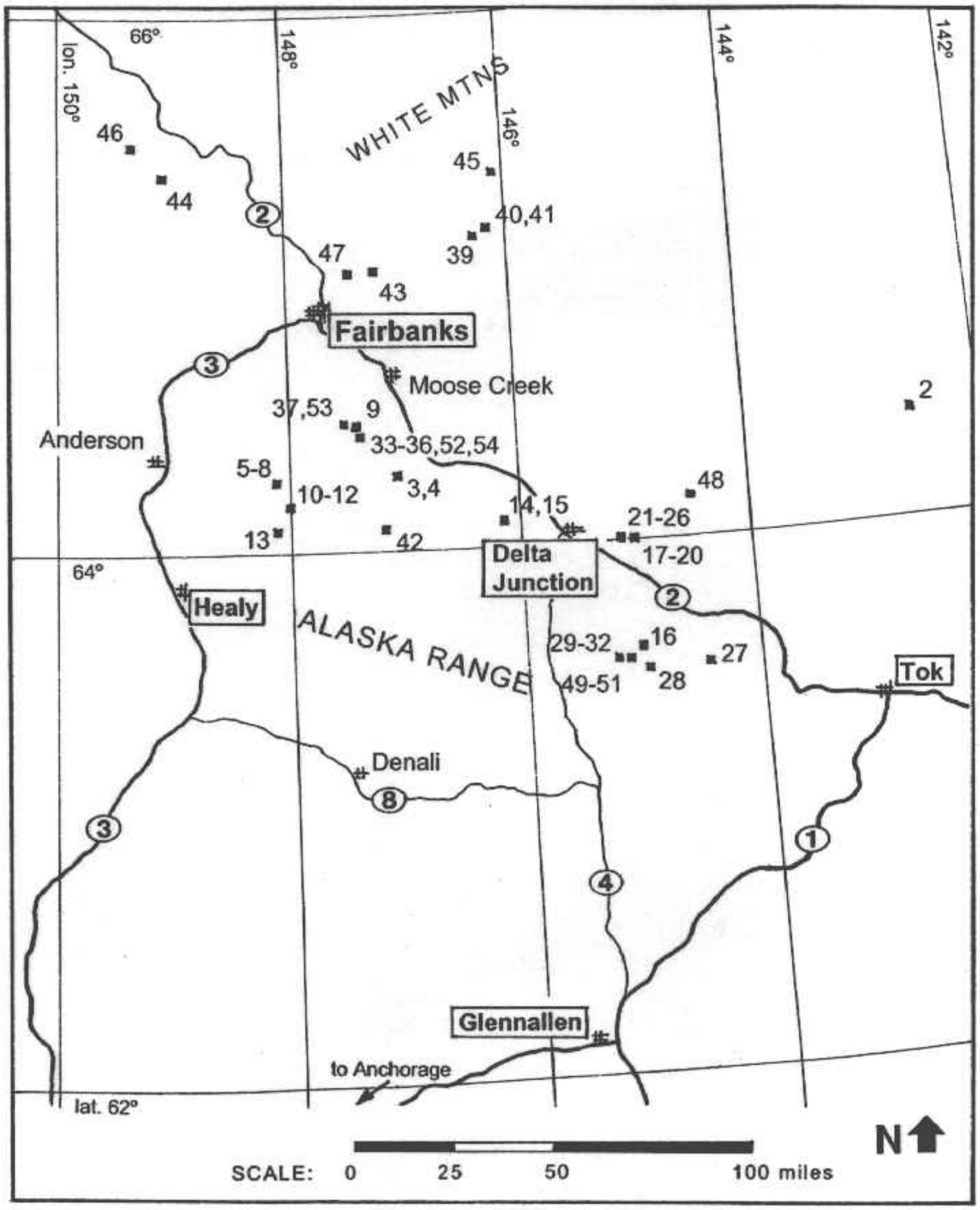


Figure 9. Approximate Extent of Reference Domain

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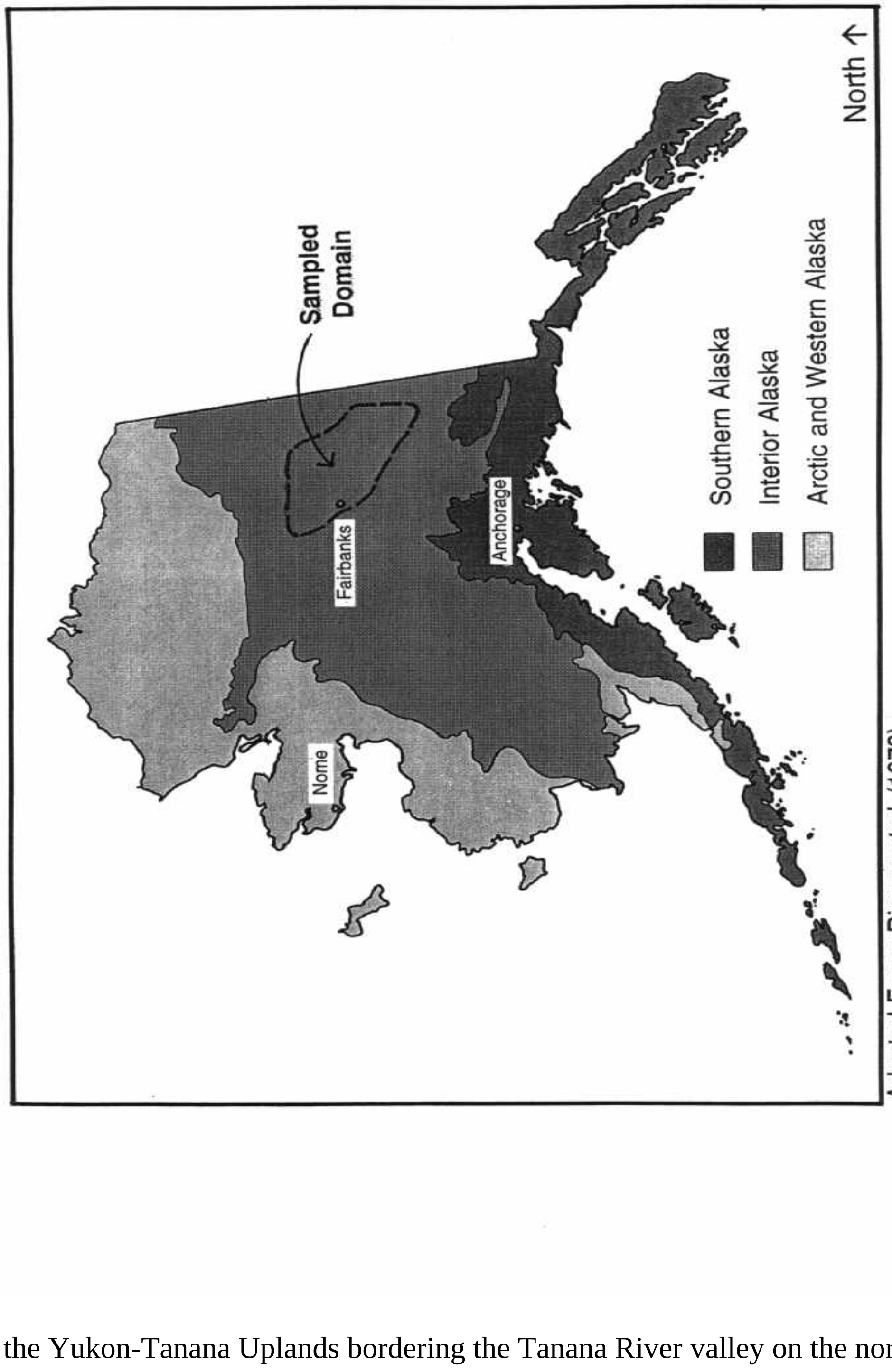


Adapted From: Rieger *et al.* (1979)

and portions of the Yukon-Tanana Uplands bordering the Tanana River valley on the north, the sampled reference domain captures representative variation in precipitation-driven wetlands of Interior Alaska's boreal forest.

C. Geographic Extent Of The Potential Reference Domain and Applicability Of This Guidebook To Similar Regions

The geographic extent of the potential reference domain for this Guidebook extends beyond the sampled reference domain and throughout the interior region of Alaska, as defined by Hall *et al.* (1994) (Figure 10). Boreal forest ecosystems of Alaska's Interior share strong similarities in hydrologic and geomorphic characteristics, as well as in typical biotic communities. These similarities make applicability of the assessment models in the operational draft Guidebook to much of the potential reference domain likely. However, the operational draft Guidebook should not be used outside the sampled reference domain until regional experts (*e.g.*, the A-Team) collect additional reference data throughout the potential reference domain and revise the profile and assessment models accordingly.

D. Summary Of The Climate Within Geographic Extent Of The Reference Domain

A continental climate characterizes the reference domain (Figure 9) with extreme variations in temperature. July mean temperature is approximately 63°F (17.1C), and January mean temperature is approximately -12°F (-24.4C) (Haugen *et al.* 1982). The mean annual air temperature in Interior Alaska is approximately 27°F (-2.7C) (U.S. Dept. of Commerce 1992), which allows formation of permafrost at sites with specific microclimates.

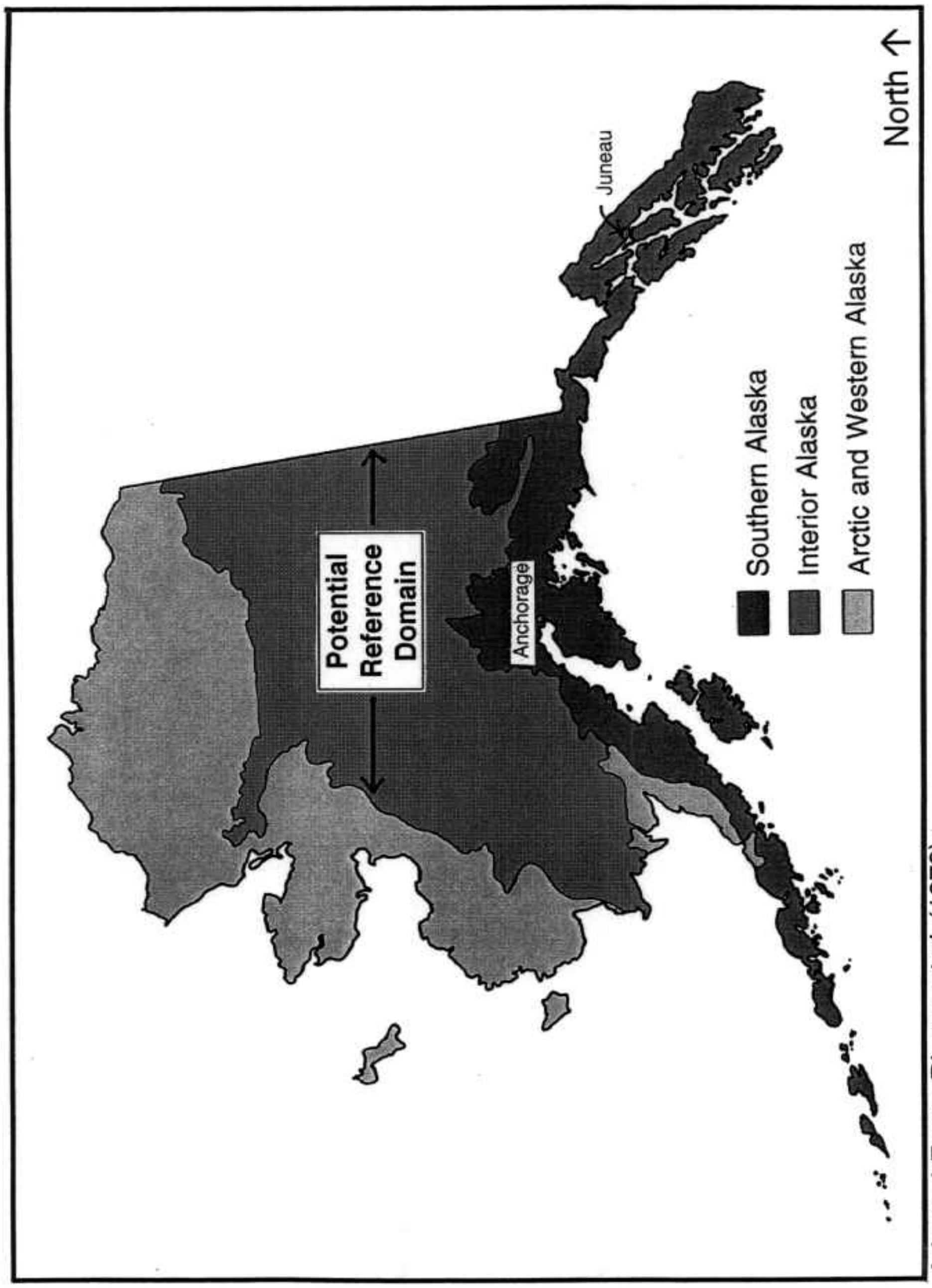
Total precipitation averages approximately 11.2 inches (28.4 cm) in the Fairbanks area (Ping 1987) and ranges from 10 to 20 inches (25 to 51 cm) in Interior Alaska. One-third of the precipitation comes in the form of snow (Post 1996) and is released during spring snowmelt, becoming available to saturate precipitation-driven wetlands on discontinuous permafrost. Where permafrost, thick seasonal frost, or soils with low hydraulic conductivity are present, snowmelt and rainfall are stored as surface and shallow subsurface water. Relatively low evapotranspiration rates are characteristic of Interior Alaska (Patric and Black 1968 *in* Slaughter and Viereck 1986), and an 89 to 90 day frost-free growing season (Ping 1987), coupled with subsurface restrictive layers, creates conditions that provide for the existence of precipitation-driven wetlands.

E. An Overview Of The Geologic And Landscape Settings Within The Geographic Extent Of the Reference Domain

The geographic extent of the reference domain is comprised of intermontane uplands and lowlands located within the Tanana-Kuskokwim Lowlands, and the Yukon-Tanana Uplands (Figure 9). Level to gently undulating plains characterize the Tanana-Kuskokwim Lowlands, while gently rolling hills characterize the Yukon-Tanana Uplands (Péwé 1975).

Figure 10. Approximate Extent of Potential Reference Domain

Figure 10. Extent of Potential Reference Domain



Adapted From: Rieger *et al.* (1979)

.Glaciofluvial Outwash Fans

Glaciofluvial outwash from the Alaska Range has deposited interbedded gravels, sands, and silts in the Tanana Basin (Hopkins *et al.* 1995). The depth of these deposits is not known, but depths of 325 - 1950 ft. (100 to 600 m) have been reported (Hopkins *et al.* 1955, Racine and Walters 1994). Thus, the Tanana-Kuskokwim Lowlands are situated primarily on stratified glaciofluvial outwash from Pliocene, Pleistocene, and Holocene times (Figure 11). Areas of drift exist south of Delta Junction (Péwé 1975).

The glaciofluvial outwash fans (Figures 12 and 13) are almost entirely covered with a silty or loamy mantle composed of loess and fluvial overbank fines (Péwé 1975, Jorgenson *et al.* 1996). Where the silty or loamy mantle is approximately 20 inches (51 cm) or greater in depth, permafrost may form and result in episaturation of the soil profile. Low relief, deep organic layers, and deep silty or loamy mantles characterize interfluves, which frequently have permafrost in the upper part of the soil profile. Abandoned channels primarily function as linear depressions, and unidirectional flows are infrequent. Some abandoned channels are covered with medium- to coarse-grained alluvial deposits that are well drained to excessively drained. The areas with these drainage classes are not wetlands in their unperturbed state and, by definition, are not within the regional HGM wetland classes and subclass addressed in this Guidebook.

Areas influenced by groundwater discharge occur within the Interior region, but the geomorphology of the groundwater-discharge systems is not well known. These systems generally are linear basins of varying shape with areas of open water and floating mats (Figure 14) of vascular and non-vascular plants, dominated by sedges (Racine and Walters 1994). Floating-mat fens are groundwater-driven wetlands, and, by definition, are not within the range of the regional HGM wetland classes and subclass addressed in this Guidebook.

Proximate to these groundwater discharge systems are thermokarst ridges and non-thermokarst interfluves that have low relief, deep organic layers, and deep silty or loamy mantles. These sites often have permafrost in the upper part of the soil profile. These interfluves may have small thermokarst features such as sinkholes, cracks, and edges that are often slumped into the groundwater discharge basins (Figure 14). Such thermokarst ridges and interfluves are within the bounds of the regional class and subclass addressed in this Guidebook.

Collapse scar bogs, perhaps originating as thermokarst pits (Figure 14), are thawed treeless areas within permafrost plateaus. Hydrologic input is primarily precipitation. Because small collapse scar bogs constitute part of the morphology of precipitation-driven wetlands on discontinuous permafrost in Interior Alaska, they are included within the regional HGM wetland classes and subclass addressed in this Guidebook. Accumulation of peat in stable collapse scar bogs may allow them to redevelop shallow permafrost and elevate soil surfaces to a level supporting growth of black spruce. Several authors have hypothesized that a long-term cycle of inflation and collapse occurs in some permafrost wetlands (Drury 1956, Viereck 1970, Zoltai 1993). Collapse scar bogs may grow with continuing permafrost degradation, intersect groundwater-driven wetlands, and move out of the organic soil flats HGM class into the slope class.

Figure 11. Idealized Geological Cross Section of the Tanana Basin

Figure 11. Idealized Geological Cross Section of the Tanana Basin

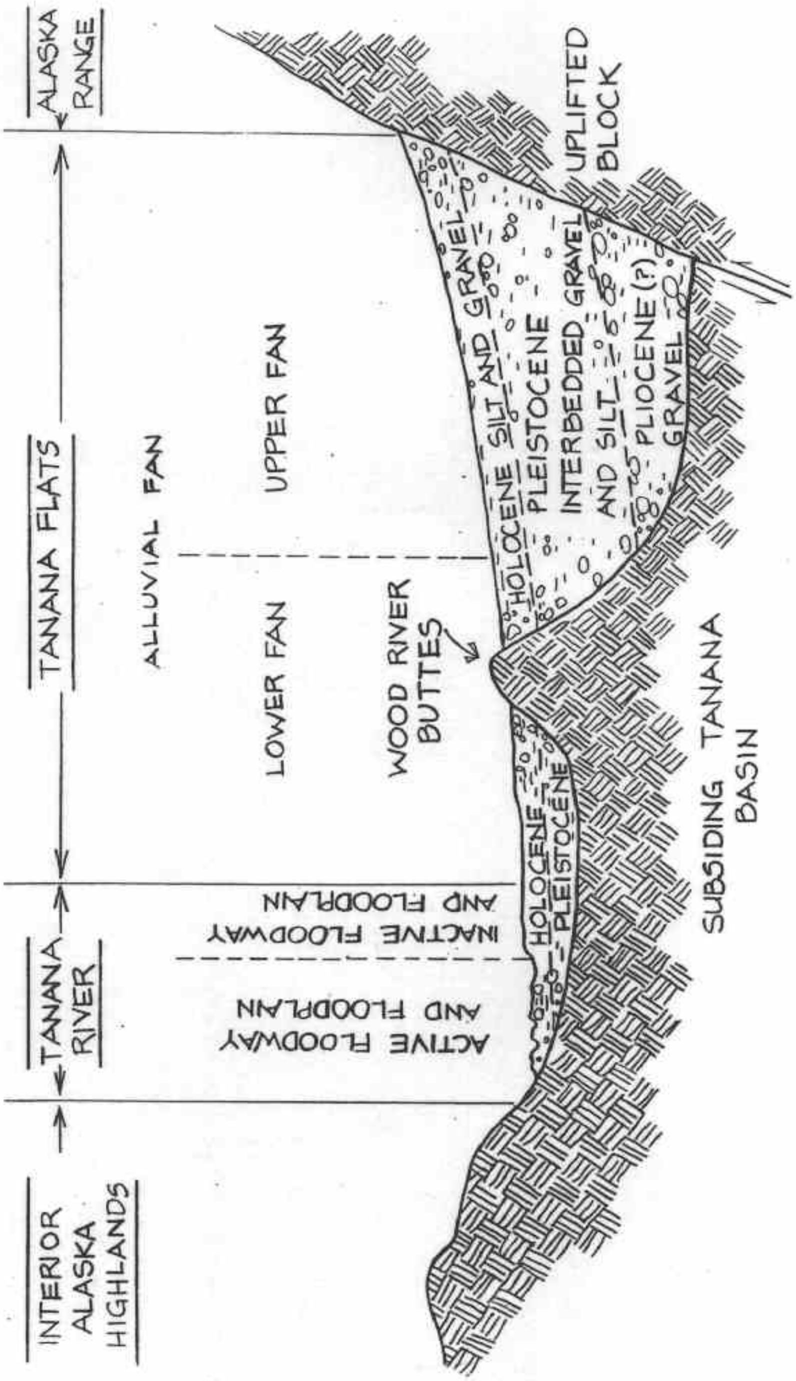


Figure 12. Idealized Cross Section of Upper Alluvial Fan

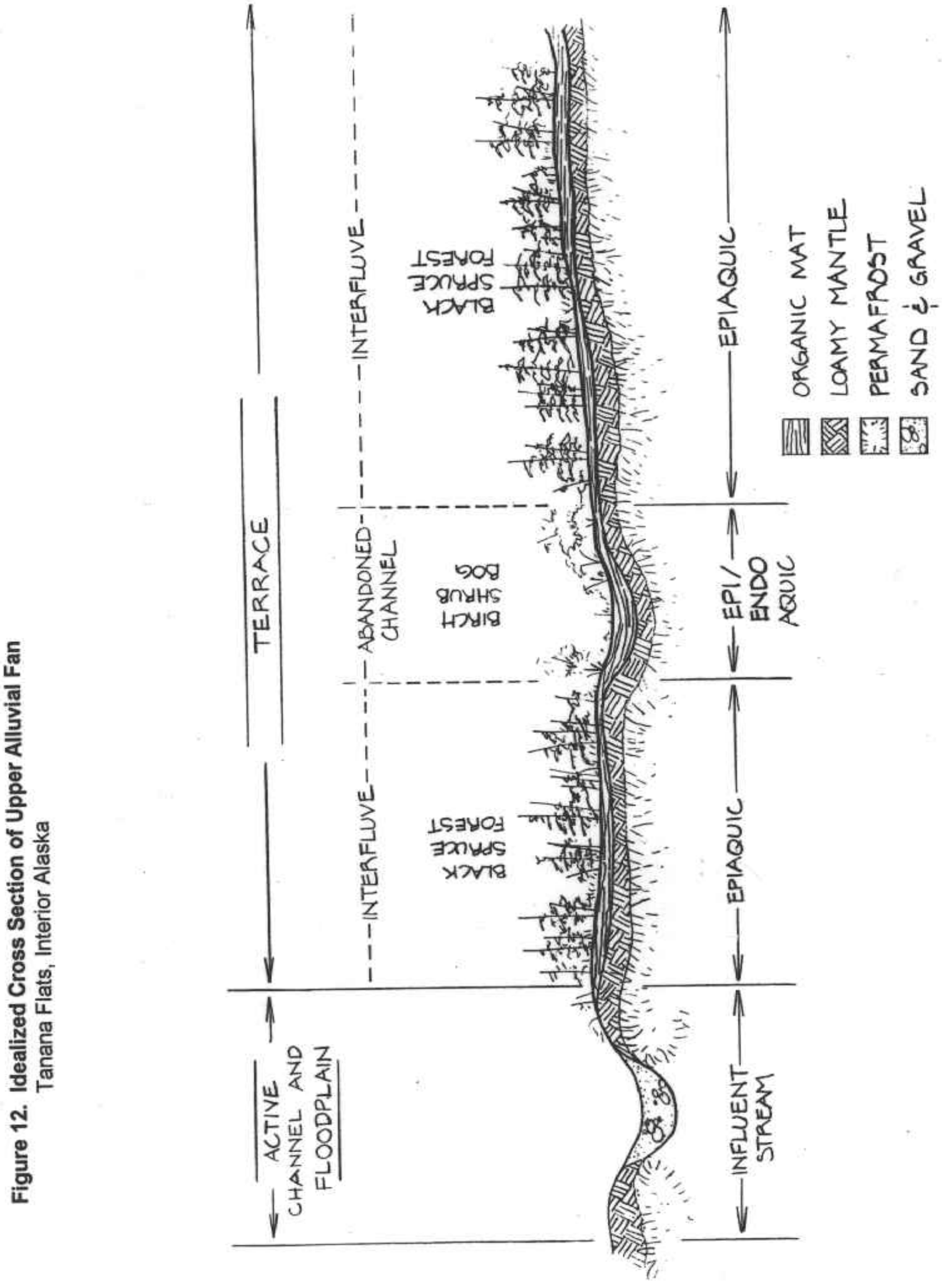


Figure 13. Idealized Cross Section of Abandoned Fluvial Channels on Lower Alluvial Fan

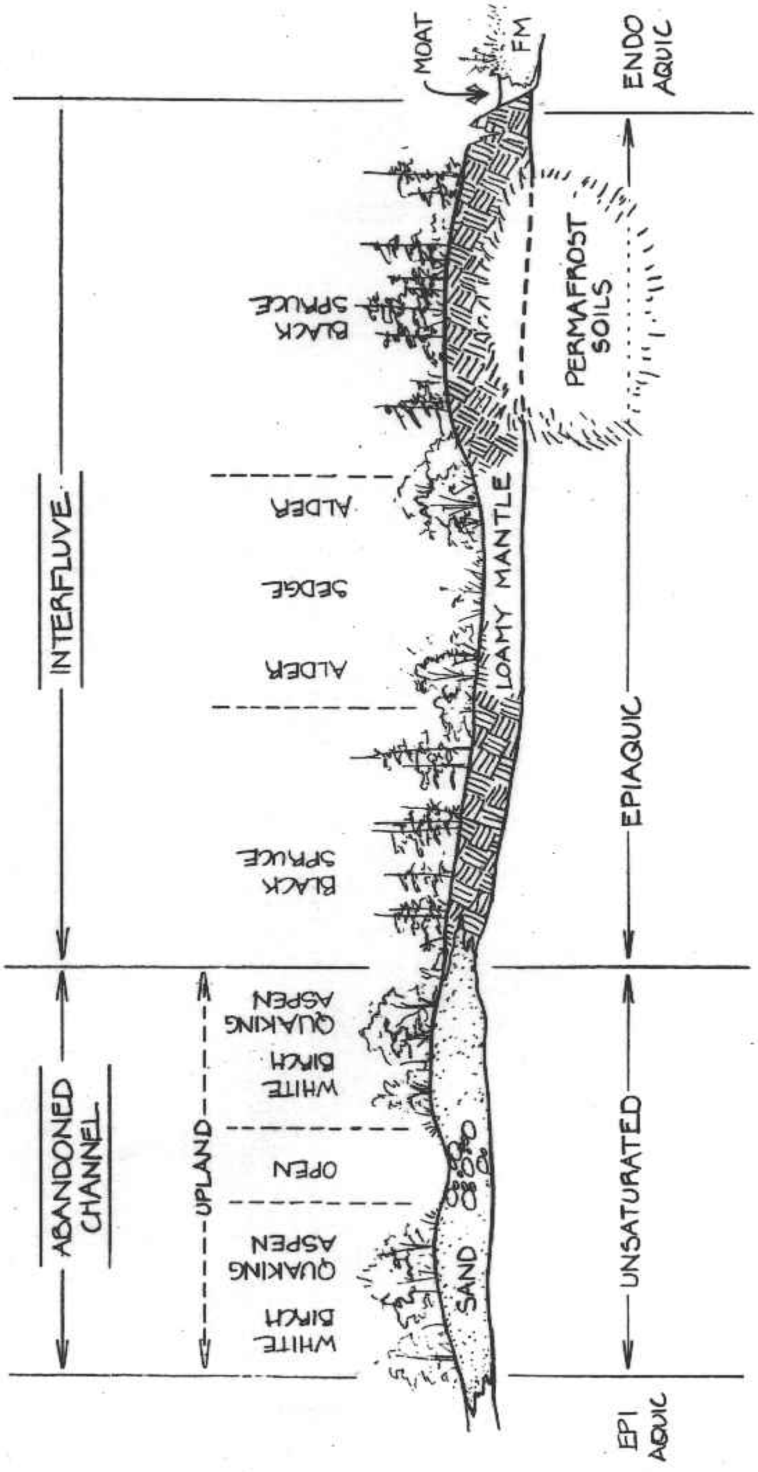


Figure 13. Idealized Cross Section of Abandoned Fluvial Channels on Lower Alluvial Fan
Tanana Flats, Interior Alaska

Figure 14. Idealized Cross Section of Thermokarst Topography with Collapse Scar Complex

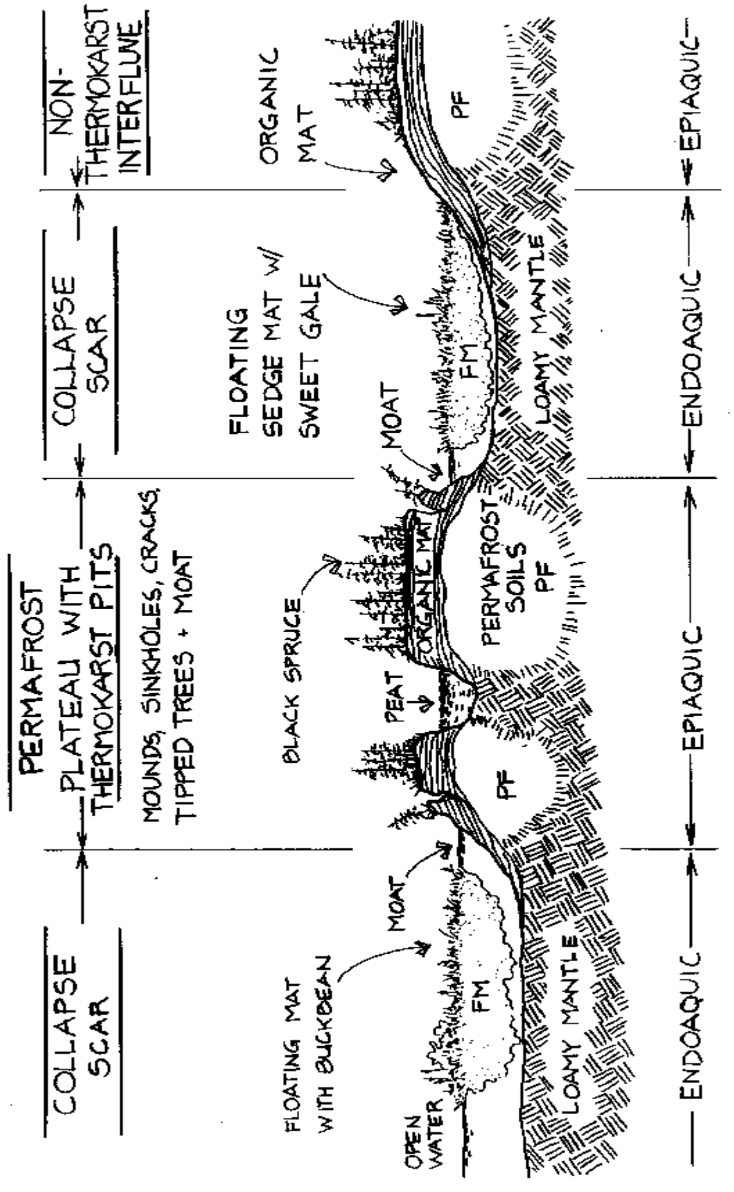


Figure 14. Idealized Cross Section of Thermokarst Topography with Collapse Scar Complex
Lower Fan, Tanana Flats, Interior Alaska

5. *.Active Floodplains and Abandoned Alluvial Plains*

Active floodplains and terraces are adjacent to the active riverine ecosystems (Figure 15). Nutrient-rich inputs into the active floodplains influence many of the physical, chemical, and biological processes (Van Cleve *et al.* 1991) within these areas. Since these areas are flooded and precipitation is not the dominant hydrologic input, active floodplains are not within the range of the regional HGM wetland class and subclass addressed in this Guidebook.

The abandoned alluvial plains can be quite similar to the glaciofluvial fans in that they have little relief, deep organic layers, and deep, silty or loamy mantles. Permafrost may form in these landforms, but is less common than in other landforms. Permafrost absence may be due to groundwater influence, since the water table is closer to the surface in these regional lows (Hopkins *et al.* 1955, Williams 1970). Therefore endosaturation is common, but episaturation may develop where patches of permafrost are present or, where the low permeability silty or loamy mantle is present. These areas are included within the bounds of the regional HGM wetland class and subclass addressed in this Guidebook.

6. *Uplands*

The bedrock of the Yukon-Tanana Uplands consists of well-jointed micaceous schist and isolated masses of granite and basalt. The buttes that are exposed above the glaciofluvial outwash fans and the alluvial plains in the lowlands are composed of similar materials (Hopkins *et al.* 1955). Loess mantles much of the uplands, and the depths vary in thickness from 0 to 100 ft (30.5 m) (Hopkins *et al.* 1955, Péwé 1975). These landforms contain precipitation-driven wetlands, particularly on northern aspects where permafrost may be coupled with massive ice wedges (Figure 16). At elevations above 1,640 ft (500 m) and/or on slopes >20% the thickness of the loess mantle is usually insufficient to support permafrost. In these areas it is typical to see a soil profile comprised of a deep, fibric organic horizon on top of weathered bedrock (Figure 16). These areas are non-wetlands in their unperturbed state, and, by definition, are not within the bounds of the regional HGM wetland classes and subclass addressed in this Guidebook.

F. HGM Classifications And Definitions

1. *HGM Class*

Given the discussions of geomorphic and landscape settings offered above, it should be evident that the landscape of interior Alaska includes several classes of HGM waters/wetlands. The most frequently occurring classes are riverine, slope, mineral and organic flats, lacustrine fringe, and depressional waters/wetlands. Each of these classes are defined in Table 3. For the purposes of this draft operational Guidebook, precipitation-driven wetlands on discontinuous permafrost in Interior Alaska can be most consistently classified into either the organic flat or slope classes as defined in Table 3. In relatively mature successional states, precipitation driven wetlands on discontinuous permafrost in Interior Alaska most closely resemble organic soil flats. However, as defined in this Guidebook, these wetlands can occur on relatively gentle

Figure 15. Idealized Cross Section of the Alluvial Plain

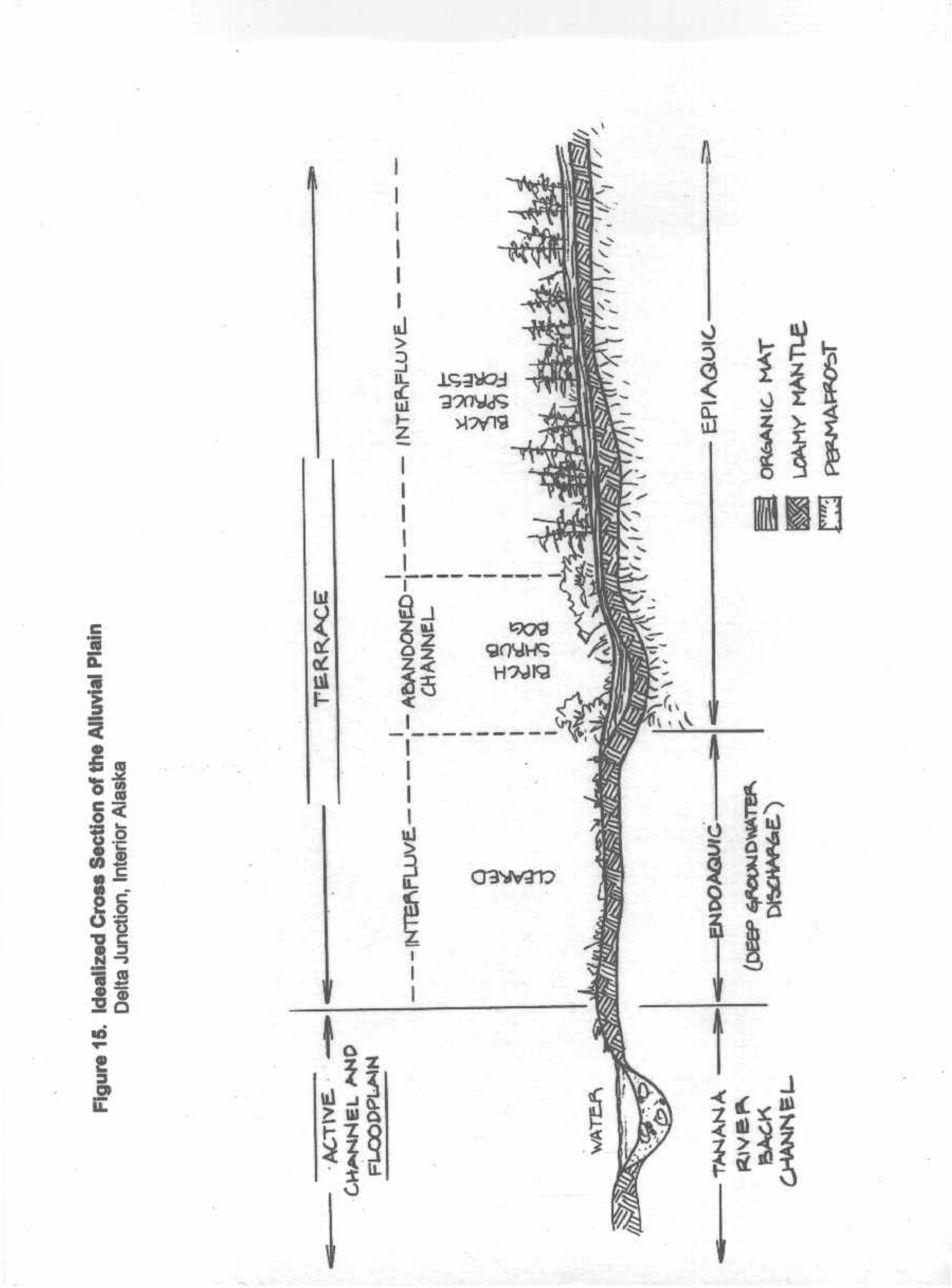
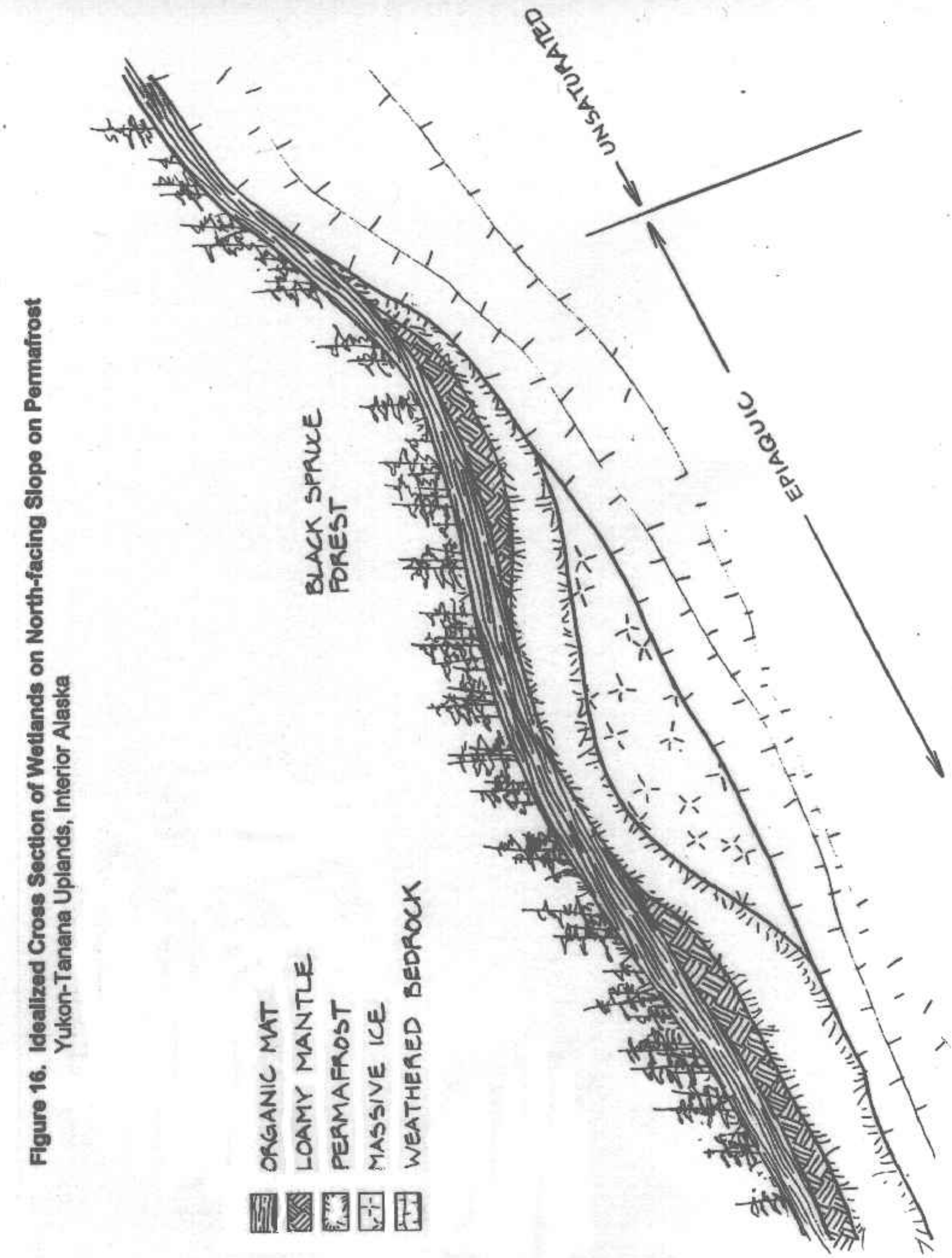


Figure 16. Idealized Cross-Section of Wetlands, North-Facing Slope On Permafrost



to moderate slopes up to 20% in steepness. In relatively undisturbed conditions and without significant human alteration, the dominant hydrodynamics are vertical, even on relatively gentle to moderate slopes (*i.e.* slopes < 20%). Specifically, the main hydrologic input to wetlands within the organic soil flat and gentle to moderate slope classes in interior Alaska is precipitation. The primary hydrologic output is evapotranspiration. Thus, precipitation and poor internal drainage maintain these wetlands. If perturbed by clearing and filling activities, wetlands within the organic soil flats and slope classes may change to resemble non-wetlands, mineral soil flats, depressions, or, in the most perturbed situations, riverine waters/wetlands.

The organic soil flats and gentle to moderate slope classes of waters/wetlands are extensive in interior Alaska. Therefore, for the purposes of developing this Guidebook, it was necessary to refine the relatively broad HGM class distinctions to the subclass level of the HGM classification. This refinement is offered below.

2. HGM Subclass Definition

Precipitation driven wetlands on discontinuous permafrost in Interior Alaska occur on a variety of landforms that range from nearly level organic soil flats to moderate slopes (≤ 20% steepness) (Photographs 1 and 2). These wetlands support forest, scrub, and sedge tussock vegetation communities that undergo cyclic succession due to periodic fire. Landforms on which these wetlands occur include abandoned alluvial plains, glaciofluvial outwash fans, footslopes and toeslopes with re-transported deposits, and low hills with bedrock cores. Precipitation-driven wetlands in the subclass addressed by this operational draft Guidebook develop largely as a result of either restricting permafrost or loamy mantle layers that perch water at or near the surface during the summer months. As discussed above at the class level of the HGM classification, in relatively undisturbed conditions and without significant human alteration, the dominant hydrodynamics in these wetlands are vertical, even on relatively gentle to moderate slopes. The main hydrologic input to these wetlands is precipitation. The primary hydrologic output is evapotranspiration. Thus, precipitation and poor internal drainage maintain these wetlands.

3. Characteristics For Identification Of the Subclass In The Field

As introduced above, there are two major subclass boundaries that define precipitation-driven wetlands on discontinuous permafrost in Interior Alaska. First, the subclass does not include sites on active floodplains within reach of periodic flooding (*i.e.* flooding every year or at least 50% of the years within a specified interval). These are riverine waters/wetlands. Second, and by definition, the subclass does not include sites that occur on slopes ≥ 20% in steepness. Wetlands that occur on slopes > 20% in steepness would be classified as slope wetlands. In addition to the two major subclass boundaries, several characteristics can be combined to aid positive identification of the subclass in the field. A summary of these characteristics follows:

Photograph 1. Typical Precipitation-Driven Forested Wetland (<100 Years Old) of Interior Alaska Lowland

Photograph 2. Typical Precipitation-Driven Wetland of Interior Alaska Upland

a. Permafrost And/Or Loamy Mantle

Permafrost characterizes most sites in the regional subclass, but permafrost is not essential for the formation of wetlands within the subclass. It can be discontinuous. Specifically, the presence of a thick silty or loamy mantle with low hydraulic conductivity and persistent annual frost is typical of the subclass. These mantles can support processes and ecosystem functions that mimic the presence of permafrost.

b. Cyclic Succession Due To Fire

Permafrost commonly underlies landscapes insulated from warm summer air by thick surface organic soil horizons and, to a lesser degree, shaded by vegetation. As a result of wildfires and post-fire succession in plant communities, many sites within the subclass cycle between a poorly drained, shallow-permafrost (wetland) condition, and a well-drained, ice-free, non-wetland state. Permafrost, deep organic horizons, and black spruce (*Picea mariana*) forests or woodlands up to 250+ years old characterize the majority of ecologically mature sites within this subclass. An extensive discussion of the cyclic processes associated with these wetlands is offered below (Section V).

c. Slopes ≤ 20% Define Upper (Up Slope) Boundaries Of The Subclass

For the purposes of this draft operational Guidebook, the authors chose to include wetlands on gentle to moderate slopes (*i.e.* slopes with a steepness of ≤20%) within the subclass. Interflow or shallow, subsurface flow over bedrock, frozen loess, or frozen colluvium is quite evident on steep slopes, which can often, but do not always meet wetland criteria as stipulated in the Corps delineation manual (Environmental Laboratory 1987). On the other hand, topographically flat sites have little or no interflow because they have very subtle hydraulic gradients. Both steep and low-gradient sites receive water as precipitation that infiltrates soil surfaces and percolates through organic soils. Where relatively pronounced negative hydraulic gradients exist, water in the zone of saturation moves generally downslope. This movement is rapid only when the water table is within organic soils with sufficient hydraulic conductivity to allow rapid water movement (*e.g.* Kane *et al.* 1978). Such conditions occur during snowmelt and during prolonged periods of high precipitation on significant topographic gradients. During drier periods, interflow is much reduced because mineral soil horizons have relatively low hydraulic conductivities. Under these conditions, water is supplied to the rooting zone of vascular plants by precipitation, not interflow. The nonvascular component of the forest floor, being directly dependent on atmospheric input of moisture and nutrients, is not supplied by interflow in any case.

The authors recognize that within the conterminous 48 states, waters/wetland sites located on hillslopes are often considered to be within the slope HGM class. The authors further recognize that the choice of slope steepness as a criteria for delineating the subclass boundary between flats and slopes is a matter of definition, opinion, and best scientific judgment. It begs detailed research on the relationships between topographic gradients and wetland functions in the Interior Alaska reference domain. It is the authors' opinion, however, that the degree and importance of interflow to site functioning is likely a continuous variable in the slope components of the defined subclass. Therefore, for the purposes of this draft operational Guidebook, it is the authors' convention that sites which occur on slopes ≤ 20% in steepness and which may exhibit intermittent interflow or shallow subsurface flow characteristics have no obvious differences in function from associated organic soil flats. Consequently, these slope sites are included within the reference domain.

d. Summary Of Dominant Features

As discussed above, precipitation-driven wetlands on discontinuous permafrost in Interior Alaska exhibit a wide range of variation with respect to their appearance (*e.g.*, presence or absence of trees). Nevertheless, these wetlands share certain dominant features that may be used to help identify the regional subclass (Table 6).

Table 6. Dominant Features Of Precipitation-Driven Wetlands On Discontinuous Permafrost In Interior Alaska.

FEATURE	**DESCRIPTION OR EXAMPLE**
Vegetation	Spruce and dwarf spruce forest/woodland and associated fire stages, bog birch shrub, closed-sheath cotton grass wet meadow.
Landforms	Stream terraces, alluvial fans, footslope and toeslope positions on hills.
Slopes	0% to ≤ 20%
Near Surface and Parent Materials	Silty or loamy surface mantle (≥20” thick) consisting of loess, stratified sandy and silty alluvium, and an admixture of loess and colluvium. Parent materials that commonly underlie the silty or loamy surface mantle include sandy and gravelly glacial outwash, gravelly colluvium, and bedrock.
Soil Organic Horizons	Commonly 5” to 30” thick (measured from the top of the surface (usually Oi horizon)).
Depth to Permafrost or Impervious Layer (Loamy Mantle)	From near the surface to 40” deep.
Depth to Water Table	Water table is usually perched over permafrost and/or seasonally frozen loamy mantle, and is within about 20” of the soil surface. In closed-sheath cotton grass wet meadow types (tussocks), ponding is common in depressions between tussocks.

4. Inclusions Of Other Waters/Wetlands Within The Subclass; Associated Waters/Wetlands

a. Waters/Wetlands Inclusions

Permafrost processes produce topographic relief on precipitation-driven surfaces. These processes can create wetlands of minor extent that fall within the subclass, such as collapse scar bogs (Photograph 3). These are small depressions where disturbance has caused melting of

Photograph 3. Collapse Scar Bog: A Minor Wetland Type Included Within the Precipitation-Driven Wetlands on Discontinuous Permafrost in Interior Alaska Subclass.

underlying ice-rich permafrost and subsequent localized subsidence. These areas are usually colonized by ericaceous shrubs, sedges, and mosses, particularly *Sphagnum* mosses, that tolerate extended periods of inundation or flooding. Peat accumulation and growth of *Sphagnum* mosses eventually may increase the surface elevation in these collapse scar bogs and support permafrost aggradation. At the scale of individual small features, low areas such as collapse scar bogs might be considered to function as depressions. When considered in the context of the surrounding wetland landscape, however, such small features can be viewed as part of the topography of precipitation-driven wetlands. Larger low-lying features in precipitation-driven wetlands, at some size, must be viewed as discrete entities deserving recognition as one or more separate subclasses. The authors have chosen 40 acres (16 ha) as the subclass boundary condition for low-lying areas entirely embedded within other precipitation-driven wetlands on discontinuous permafrost in Interior Alaska. This size is based on best scientific judgment for a relatively pristine, largely wetland landscape and is not necessarily appropriate to other domains.

Other wetlands of minor extent exhibit similar processes and ecosystem functions and thus are included within the regional subclass (Table 7). One such wetland type occurs on portions of low stream terraces with thick silty or loamy soil mantles and persistent annual frost. Some of the wetlands in the reference set for precipitation-driven wetlands on discontinuous permafrost in Interior Alaska occurred in thawed soils on abandoned floodplains near the Tanana River. These sites overlie a large aquifer and have high water tables. In many cases, land clearing or fire has thawed thin permafrost layers between the aquifer and the surface. Sites closer to points of aquifer discharge may be thawed in their unperturbed state. These sites obviously lie on or near class boundaries between HGM flats and slopes. Nevertheless, ecological communities present on these thawed sites, if unaltered, are the same as, or very similar to, those on permafrost sites without groundwater influence. Upward groundwater head gradients appear insufficient to overpower the influences of precipitation and lingering seasonal frost layers in these boundary wetlands. The nonvascular mat and root zone in these sites appear to be predominantly influenced by precipitation. For this reason, the authors chose to include them in the precipitation-driven regional subclass.

Table 7. Water/Wetland Types of Minor Extent That Are Included In The Regional Subclass.

WATER/WETLAND TYPE OR DESCRIPTION
Thawed terraces with deep groundwater discharge but precipitation-driven surface characteristics.
Low terrace positions adjacent to floodplains (rarely flooded).
Sites with a thick silty or loamy mantle but with only sporadic permafrost.
Sites with no apparent permafrost within 60 inches of the surface.
Dwarf spruce forest/woodland vegetation on shallow permafrost.
Collapse scar bogs <40 acres in size (thermokarst feature).
Subsidence features resulting from melting of massive ground ice (thermokarst feature).
Sphagnum bogs or shrub-sphagnum bogs, often in collapse scar landforms.

The authors considered forming two regional subclasses to separate sites on abandoned alluvial plains, some of which showed influence of groundwater discharge and differing responses to perturbation, from those on other landforms. However, lacking adequate criteria for separating sites on abandoned alluvium, this operational draft Guidebook includes precipitation-driven wetlands on all sampled landforms in the subclass with slopes ≤20%. The Interior A-Team must revisit this classification following two years of field application of the operational draft Guidebook to ensure that the assessment models are accurate for the range of landforms currently included in the regional subclass.

b. Associated Waters/Wetlands

In addition to the two major subclass boundaries listed above, low-gradient wetlands belonging to the depression HGM class and some low-gradient members of the slope HGM class are associated with, but distinct from, precipitation-driven wetlands on discontinuous permafrost in Interior Alaska. Tables 8, 9 and 10 provide indicators for identifying associated wetlands that fall outside the subclass boundaries.

Table 8. Indicators For Associated Riverine Wetlands That May Be Confused With Precipitation-Driven Wetlands On Discontinuous Permafrost In Interior Alaska.

INDICATOR OR DESCRIPTOR
The site is located within an active (primarily unvegetated) floodplain or within the vegetated flood-prone area adjacent to a channel.
Stratified mineral and organic layers are observed near the surface, within or directly below the organic surface horizon.
No histic epipedon is present.
The upper mineral horizons are slightly acidic to moderately alkaline.
Permafrost is not present.
Moss, lichen, and liverwort cover is sparse and highly discontinuous.
Mature willow (*Salix* spp.), alder (*Alnus tenuifolia*), and/or balsam poplar (*Populus balsamifera*) are prevalent.
The site supports a productive white spruce (*Picea glauca*) forest.

Table 9. Indicators For Associated Depressional Wetlands That May Be Confused With Precipitation-Driven Wetlands On Discontinuous Permafrost In Interior Alaska.

INDICATOR OR DESCRIPTOR
Site occurs in a broad depression normally >40 acres in size
Site has sphagnum bog, shrub-sphagnum bog, or closed-sheath sedge wet meadow
Permafrost is not present

Table 10. Indicators For Associated Low-Gradient Slope Wetlands That May Be Confused With Precipitation-Driven Wetlands on Discontinuous Permafrost In Interior Alaska.

INDICATOR OR DESCRIPTOR
Site occurs as a linear feature, including a cutoff meander not connected to a riverine system (oxbow) or a broad groundwater-discharge wetland with a continuous floating mat.
Site has fen vegetation including sedge wet meadow, buckbean (*Menyanthes trifoliata*) herbaceous wet meadow, or sweetgale (*Myrica gale*) shrub vegetation.
Soil is slightly acid to moderately alkaline
Permafrost is not present

Riverine sites (Photographs 4 and 5) are characterized by sediment and nutrient inputs that influence many physical, chemical, and biological processes. For example, sites on floodplains tend to be nutrient rich, which substantially influences nutrient cycling and/or export processes (Van Cleve *et al.* 1991). The transition from abandoned river terraces to active floodplains is often gradual and indistinct. It requires judgment in the field and use of several indicators to identify the subclass boundary (Table 8).

Slopes with a steepness >20% (Photograph 6) exhibit a number of differences in ecosystem processes and functions as compared to organic soil flats or low to moderately sloping sites. As originally suggested by NRCS (Mark Clark pers. comm.), and generally confirmed during field reconnaissance, slopes greater than 20% often have insufficient loess deposits to support saturated permafrost. Such slopes typically have a folist-like soil profile with a deep, fibric organic horizon on top of weathered bedrock. In those situations where loess is present on steep slopes, water may be observed to flow at the mineral soil surface beneath the organic horizon. Downslope discharge may appear as small fans or radial deposits of loamy material on top of the organic layer (Photograph 7). The discharge phenomenon from high-gradient slopes appears to be the result of high moisture content at the interface between organic and mineral soil. During cold winters with low snowfall, moisture appearing at the organic/mineral interface may freeze and form ice lenses that push up and rupture the organic mat. During thaw, these ice lenses degrade quickly and release the water/mineral soil slurry which flows down-gradient and surfaces through the ruptures in the organic surface horizon, hence the small fans of loamy material on top of the organic surface layer.

Groundwater discharge is a characteristic of the slope class. Although classic groundwater-discharge wetlands are not common in discontinuous permafrost landscapes, areas of thawed soils and low topographic gradients adjacent to riverine systems, or areas of large-scale discharge from subpermafrost aquifers support wetlands of the slope class. Slope wetlands in the domain can occur near the edges of river valleys, often in old, infilling, isolated river channels or sloughs with groundwater flow. In addition, relatively unique floating-mat fens (Photograph 8) occur in discrete areas north of the Alaska Range in a mosaic with permafrost black spruce wetlands. Indicators may be necessary to identify subclass boundaries with adjacent groundwater-driven wetlands (Table 10).

Photograph 4. Landscape View of Active Glacial River Floodplain and Adjacent Forest

Photograph 5. Site Influenced by Floodplain Processes

Photograph 6.	Landscape View of Slope >20%

G. Natural And Anthropogenic Perturbation And The Range Of Variation Within The Subclass

Wildfires are the most significant periodic disturbance in interior Alaska and precipitation-driven wetlands on discontinuous permafrost in Interior Alaska are subject to cyclic succession related to fire. Soils of post-burn sites frequently drain deeper into the profile and pass through a dry stage. Successional processes gradually restore typical vegetation and long-duration seasonal frost or permafrost, and eventually restore hydrologic characteristics of mature sites. Under anthropogenic disturbance regimes, the cycle of disturbance, permafrost degradation and recovery differs, and in some cases, the cycle does not occur.

1. Fire Disturbance and the Reference Standard Cycle

a. Effects of Fire on Precipitation Driven Wetlands on Discontinuous Permafrost in Interior Alaska

As a result of periodic fires and vegetative succession following fires (Figure 17), extensive areas of permafrost soils in the zone of discontinuous permafrost (Pewe 1969) may cycle between a poorly drained, shallow permafrost state and a well-drained, ice-free condition (*e.g.*, Ping *et al.* 1992). Burning of tree, shrub and/or herb canopies, and especially burning of the moss layer and organic soil horizons, removes insulating layers over the soil and increases the amount of incident solar radiation reaching the soil surface. Mean soil temperatures increase following fire, which can result in thawing of permafrost, a deepening of the active layer (*i.e.*, zone of annual thaw above permafrost (Gabriel and Talbot 1984)), or earlier thawing of seasonal frost (Viereck 1982). Increasing the depth to permafrost or decreasing the duration of seasonal frost in effect removes shallow impermeable layers, and can increase soil drainage and change hydrologic regimes.

A variety of surface drainage conditions can occur following disturbance. In the area of discontinuous permafrost, fires tend to affect hydrologic regimes in four general ways. First, areas which are underlain by highly permeable, coarse textured soils can become moderately well-drained to well-drained once permafrost layers thaw following disturbance. For example, soils of sites on glaciofluvial outwash fans and low hills may thaw and drain following disturbance because the soils are coarse textured gravel, sands or sandy loams, or surface and subsurface drainage outlets are present. These sites can cycle between hydric soils in the upper part when permafrost is shallow, to non-hydric soils when soils have warmed and permafrost is deep.

Second, sites with fine textured silts, silt loams or peats located in abandoned channels (*i.e.*, paleochannels), in depressions, or low areas on flats, may collect surface and shallow subsurface water despite thawing or deepening of the permafrost layer following disturbance. Areas which are underlain by poorly drained to very poorly drained fine-textured soils or peat, remain saturated following thawing of permafrost because of impermeable, or very slowly permeable soils. Soils of these areas continue to be hydric after fire disturbance and these areas continue to meet wetland criteria after disturbance.

Photograph 7. Sediment-Discharge Phenomenon Associated with Non-Wetland Slopes

Photograph 8. Floating-Mat Groundwater-Discharge Fen: A Member of the Slopes HGM Class.

Figure 17. Generalized Processes of Fire-Induced Cyclic Succession in Wetlands on Discontinuous Permafrost in Alaska

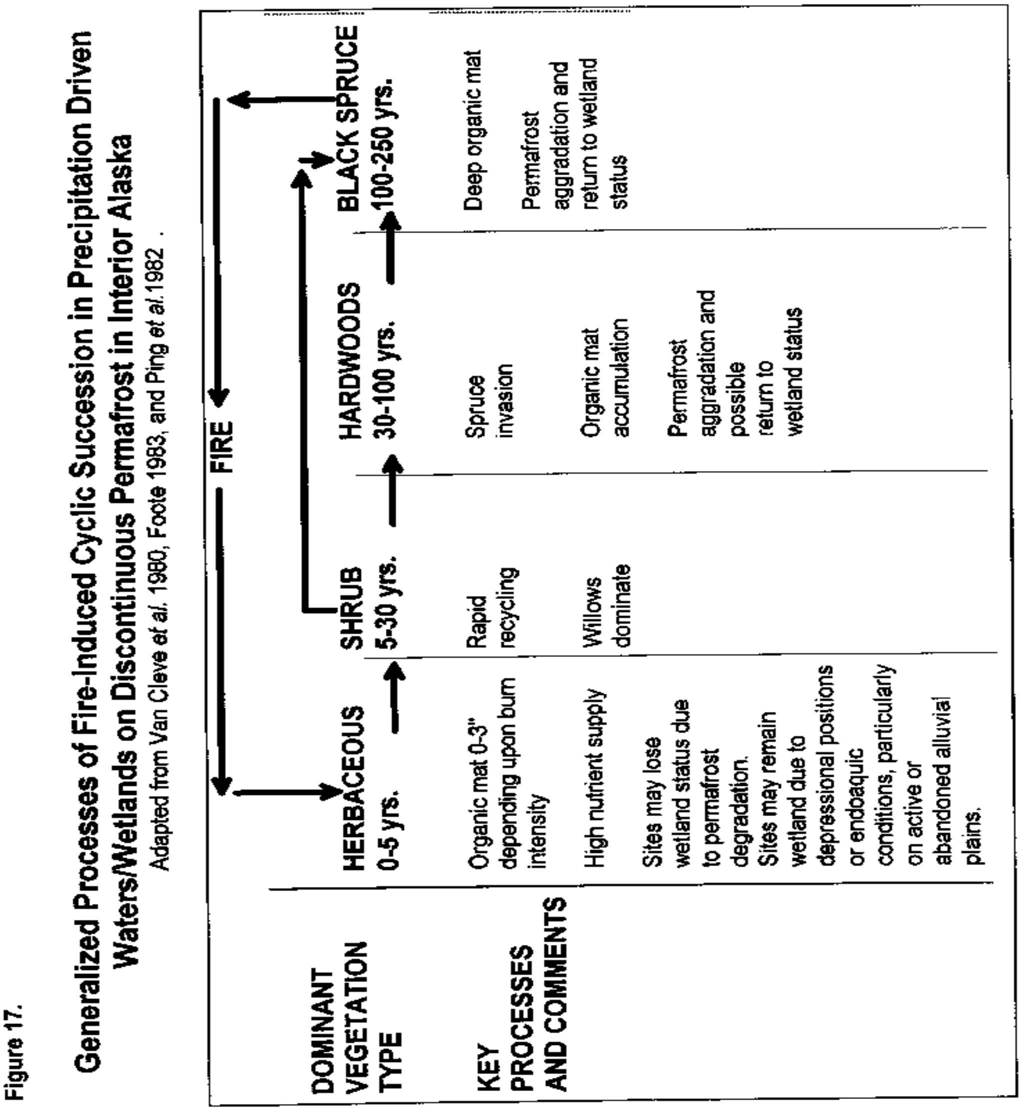


Figure 17.

Generalized Processes of Fire-Induced Cyclic Succession in Precipitation Driven Waters/Wetlands on Discontinuous Permafrost in Interior Alaska

Adapted from Van Cleve *et al.* 1980, Foote 1983, and Ping *et al.* 1982 .

DOMINANT VEGETATION TYPE	HERBACEOUS 0-5 yrs.	SHRUB 5-30 yrs.	HARDWOODS 30-100 yrs.	BLACK SPRUCE 100-250 yrs.
KEY PROCESSES AND COMMENTS	Organic mat 0-3" depending upon burn intensity High nutrient supply Sites may lose wetland status due to permafrost degradation. Sites may remain wetland due to depressional positions or endoaquic conditions, particularly on active or abandoned alluvial plains.	Rapid recycling Willows dominate	Spruce invasion Organic mat accumulation Permafrost aggradation and possible return to wetland status	Deep organic mat Permafrost aggradation and return to wetland status

Third, other areas may experience changes in surface microrelief as massive ice features melt, and the ground surface subsides and creates small water-filled depressions, such as collapse scar bogs (Photograph 3 and Figure 14). Because ice-rich permafrost subsides when it thaws, surfaces of collapse scar bogs are lower than surrounding permafrost plateaus. It is likely that the surrounding permafrost black spruce wetlands contribute some suprapermafrost drainage to the collapse scar bogs, but the low hydraulic gradient of the surrounding lowland terrain should limit the magnitude of such flow. Supra-permafrost flow primarily occurs in the organic soil horizons surrounding the bog because the underlying silty or loamy mantle has low hydraulic conductivity. The dominant direction of water movement in collapse scar bogs is vertical with precipitation dominating inputs and evapotranspiration dominating outputs. Collapse scar bogs with no underlying permafrost layers may also recharge groundwater. As a result of increased inundation following fire, these areas are colonized by *Sphagnum* mosses, sedges and shrubs in a process known as paludification.

Collapse scar bogs that become sufficiently large through thermokarst processes can intersect groundwater-driven wetlands that occur in the same landscape. Once dominated by groundwater, these wetlands are no longer in the precipitation driven subclass.

Finally, in some areas, a pre-disturbance regime dominated by a water table perched over permafrost with hydric soils (*i.e.,* episaturation), following disturbance and thawing of permafrost, may be dominated by an artesian water table (*i.e.*, endosaturation) and hydric soils. This is particularly true on floodplains and terraces where regional groundwater is expressed (Hopkins *et al.* 1955, Williams 1970). All of these variations are considered within the range of characteristics of the subclass.

b. Recovery from Fire: Vegetation Succession and Effects on Permafrost

In most cases, re-invasion or aggradation of permafrost to pre-disturbance conditions occurs as part of the process of post-fire vegetation succession. However, the time required to reach pre-burn permafrost conditions (*i.e.,* depth to permafrost) is not well documented. Permafrost recovery depends, in part, on the intensity of the fire. Fire intensity affects the extent to which the insulating moss layer or organic soil horizons are degraded or removed (Dyrness and Norum 1983), and therefore the extent to which permafrost will be degraded, the depth of thaw, and the time required to re-establish permafrost conditions. Low intensity burns leave more of the organic soil horizon and moss layer intact. Therefore, post-burn soil temperatures do not increase as much and thawing of permafrost is not as great as with high intensity fires. Fire intensity also affects the rate of revegetation by influencing the number of seeds and vegetative plant parts available to initiate regeneration of the plant community (Viereck and Schandelmeier 1980). Recovery of the vegetation, especially the tree canopy, occurs much more rapidly after low intensity burns.

As the new vegetation canopy develops after a fire, the amount of solar radiation reaching the ground decreases, and mean soil temperatures decrease as well. Most importantly, as mosses and organic soil horizons thicken, there is more insulation at the soil surface, further decreasing soil warming during spring and summer. As soil temperatures decrease, the permafrost level gradually rises, and/or the duration of seasonal frost increases. As the depth to permafrost decreases, drainage is impeded, restoring perched water tables and saturated soils in the upper part. In black spruce wetlands in Interior Alaska, tree canopy cover, moss layer and organic soil horizon thickness, and depth to permafrost, generally return to pre-burn conditions within 50 to 70 years following fire (Viereck 1973, Foote 1976).

There is no universal successional sequence of vegetation following fire (Viereck 1983), but general successional patterns have been described for black spruce wetlands in Interior Alaska (*e.g.,* Van Cleve *et al.* 1980, Foote 1983, Ping *et al.* 1992). On sites which become better-drained following fire, the following general sequence occurs. Immediately following fire (*i.e.*, 0-5 yr.) most sites are dominated by herbaceous vegetation. These sites are characterized by a much reduced cover of trees and shrubs, an absence of mosses or a thin patchy moss layer, a shallow organic soil horizon, and a herbaceous stratum which can range from sparse to very thick (Photograph 9). Most of the plant species colonizing a site immediately after fire, especially after intense fires, are wind-dispersed, fast growing annuals, such as fireweed (*Epilobium angustifolium*).

In years 6 to 30, shrubs such as alders (*Alnus* spp.), willows (*Salix* spp.), and shrub birches (*Betula* spp.) dominate sites (Photograph 10). Towards the middle of this period, hardwoods and conifers which typically occur on warmer, somewhat well-drained to well-drained soils, such as paper birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), and white spruce (*Picea glauca*) become more common. Sites drained by permafrost degradation remain better drained throughout this period. Black spruce begins to re-invade most sites and become more common during the 6 to 30 year post-fire period. If these sites are burned frequently, the shrub/small tree community typical of the 6 to 30 year old communities may persist indefinitely. Finally, in years 31 to 100 (Photograph 11), the moss layer becomes re-established, and organic soil horizons accumulate as tree and shrub abundance increases and the canopy becomes more closed. At this time also, permafrost may aggrade, the active layer becomes shallower and perched water tables develop, returning sites to wetland status. Development of tree cover, thick moss layers, deep organic soil horizons and sufficient aggradation of permafrost to re-establish pre-burn conditions can occur as early as 40 to 60 years following fire (Zoltai 1975, Van Cleve and Viereck 1983). Deep organic soil horizons, shallow permafrost, and black spruce forest (Photograph 12) usually characterize sites from 101 to 250+ years following fire.

On sites where thawing of permafrost following fire does not result in better drained soils, the successional sequence progresses from shrub or sedge dominated communities immediately following fire, to black spruce communities. These sites can remain dominated for long periods of time by shrub or sedge communities if fire frequency, or duration of inundation prevents tree re-colonization. On sites that become much wetter following fire (*e.g.*, collapse scar bogs) the immediate post fire community is dominated by sedges (*Carex* spp., *Eriophorum* spp.) and grasses. There is a gradual increase in shrubs over time, especially ericaceous species such as the Labrador teas, cranberries and blueberries (*Vaccinium* spp.). Mosses, especially *Sphagnum* spp., are common within 5 to 10 years following fire (Foote 1983, Viereck et al. 1992). Because these sites are usually too wet for tree regeneration, they can remain dominated by shrubs for long periods of time. In some sites, the accumulation of mosses and organic soil horizons becomes great enough within 30 to 50 years following fire to raise the surface elevation to the point that tree growth is supported and black spruce will eventually re-invade these sites.

Photograph 9. Typical Precipitation-Driven Wetland 0 to 5 Years Following Fire

Photograph 10. Typical Precipitation-Driven Wetland 6 to 30 Years Following Fire

Photograph 11. Typical Precipitation-Driven Wetland 31 to 100 Years Following Fire surface

Photograph 12. Typical Precipitation-Driven Wetland 101 to 250+ Years Following Fire elevation to the point that tree growth is supported and black spruce will eventually re-invade these sites

The nature of these successional cycles are influenced by several characteristics of fire disturbance regimes. Natural fires are patchy and have a wide range of intensities. On a landscape level, this results in a patchwork of communities in different stages of post-fire succession. Therefore, there are sources of propagules from mature communities nearby for recolonizing recently burned sites. In addition, animals which require mature plant communities as habitat can persist in an area after fire if there are patches of mature communities nearby. Low intensity fires leave thin organic horizons, snags and downed woody debris, which provide materials and substrates for re-building soils and continuing nutrient cycling processes which support microbial, plant and animal food webs. On-site propagules, such as roots and seeds survive all but the most intense fires, and can rapidly regenerate the native plant community characteristic of unaltered sites.

2. *Effects of Anthropogenic Disturbance on Precipitation Driven Wetlands on Discontinuous Permafrost in Interior Alaska*

The most frequent anthropogenic alteration to precipitation-driven wetlands on discontinuous permafrost in Interior Alaska is land clearing for agricultural, commercial, or residential development. Agriculture probably accounts for the highest areal proportion of such clearing, but commercial and residential development around major population centers (*e.g.,* Fairbanks, Alaska) accounts for the majority of wetland regulatory actions. Clearing promotes permafrost degradation and altered hydrology within the soil profile with consequent loss of wetland hydrology. Although many cleared sites, especially those in agricultural land use, retain the potential to return to wetland status through successional pathways, fill placement, frequently associated with urban development, may permanently remove other sites from such trajectories.

Effects of anthropogenic disturbances can be similar to natural fire disturbance, but anthropogenic disturbances can differ in fundamental ways that influence recovery from disturbance. For example, fire decreases organic surface horizon thickness, but anthropogenic perturbation generally removes the organic horizon completely (Figure 18). Removal degrades the permafrost, drains supra-permafrost groundwater, and reduces shallow subsurface storage of water. Surface storage of water also is reduced because topographic features and microtopography are frequently leveled or homogenized by anthropogenic disturbance. The decrease in microtopographic roughness with human-induced disturbance (Figure 19) strongly influences hydrologic functions of wetlands within the regional subclass. Alternatively, some types of anthropogenic disturbances have effects similar to fire, and sites altered in this way may follow a disturbance cycle and successional sequence similar to that described above. Clearing for agricultural fields, logging, or other purposes, such as a power line or road right of ways, can also cause rapid subsidence of permafrost, often with a loss of saturated soil conditions. Once active management of these areas has ended (*e.g.*, in abandoned agricultural fields), successional sequences similar to the reference standard cycle can occur, eventually re-establishing pre-disturbance soil, hydrology and vegetation conditions. However, the time required for these systems to return to pre-disturbance conditions, and the extent to which the system can recover, depends on the intensity and extent of the disturbance. The time necessary to return to pre-disturbance depth to permafrost, soil moisture levels and vegetation following anthropogenic disturbance in Interior Alaska has not been well-documented.

Figure 18 Organic Mat Mean Depth by Land Use

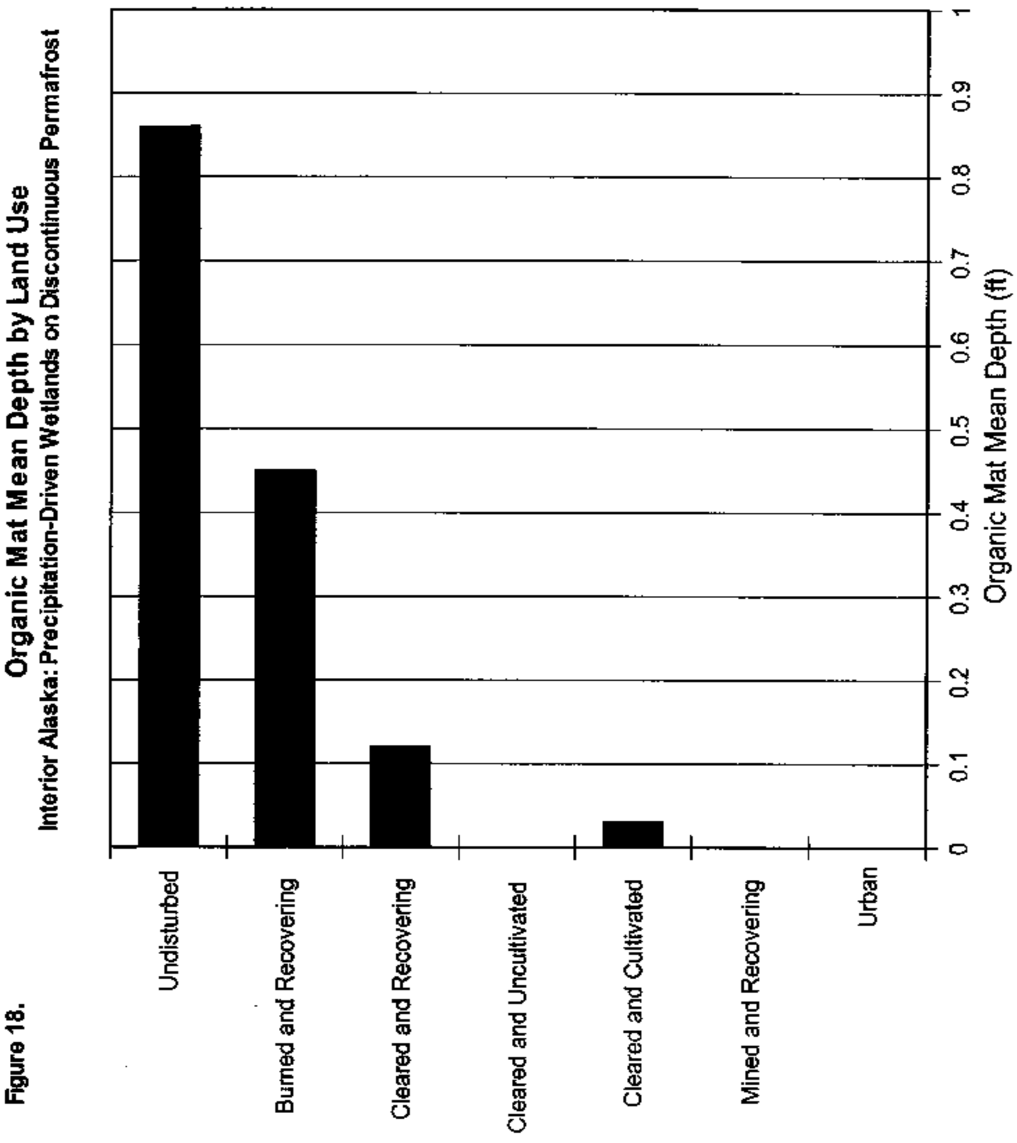
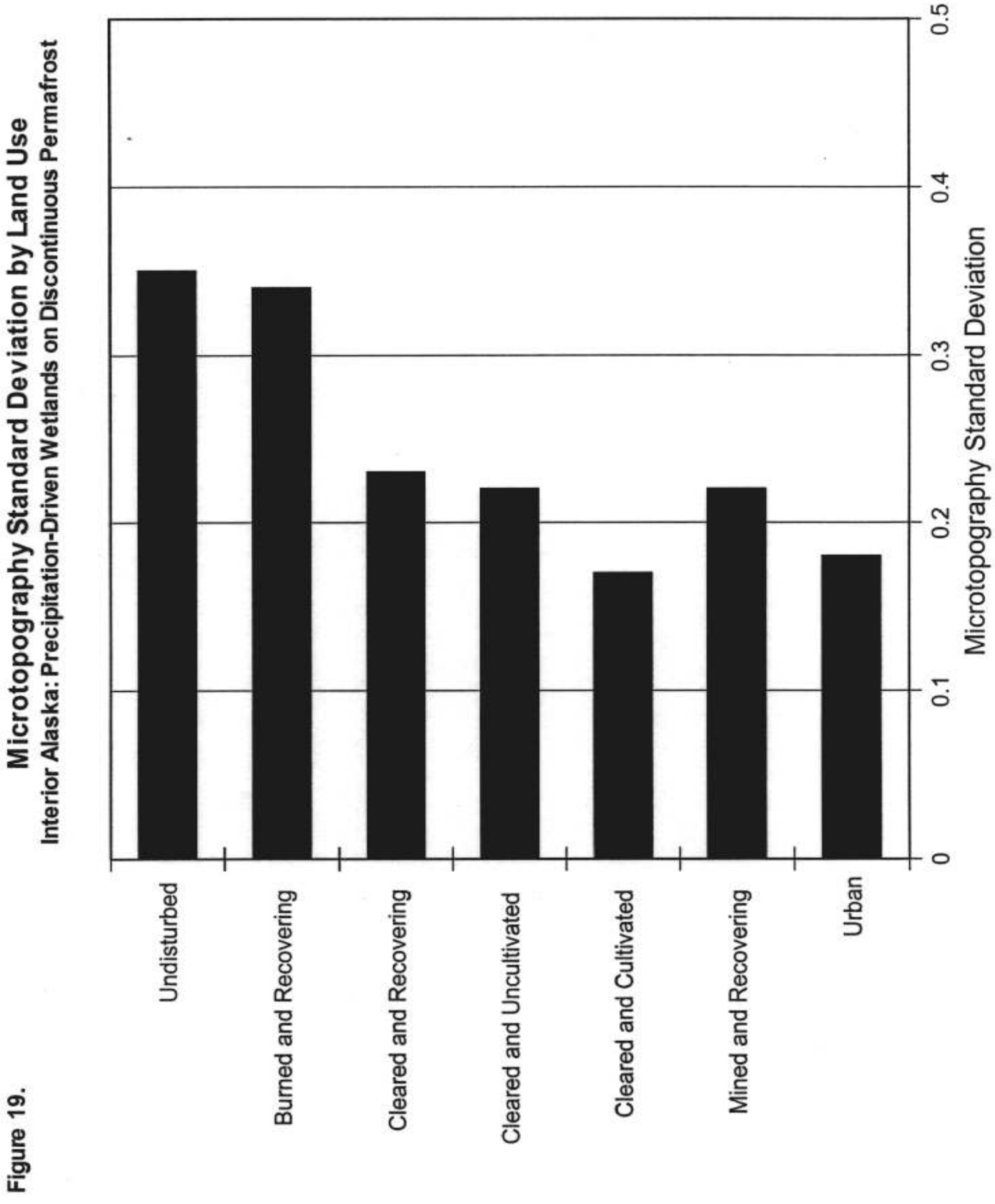


Figure 19. Microtopography Standard Deviation by Land Use



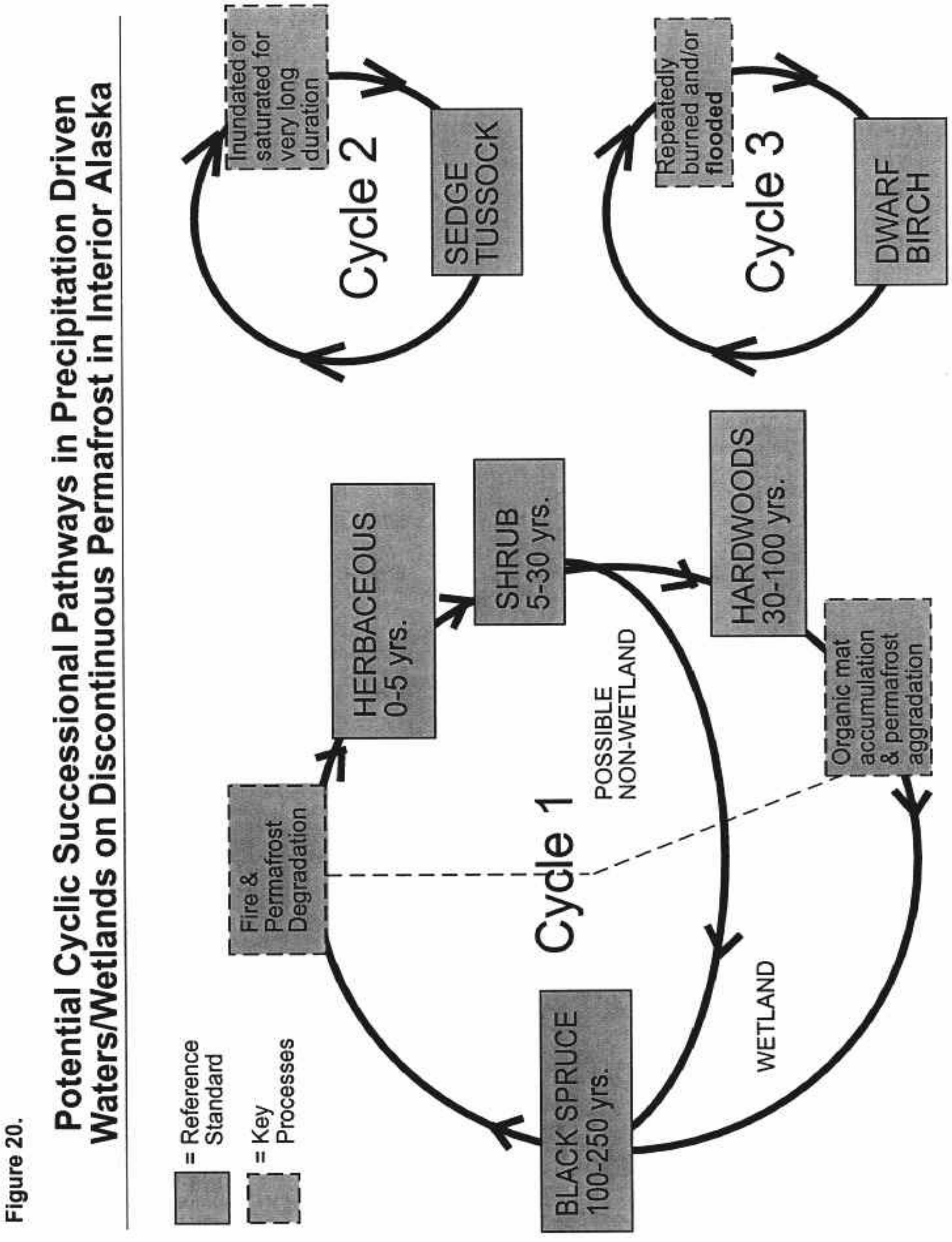
Severely disturbed or extensively altered sites do not follow the natural successional cycle. Anthropogenic clearing generally uniformly removes above and sometimes below-ground vegetation, organic soil horizons, and detrital biomass such as coarse woody debris, over large contiguous areas. Native vegetation is often replaced by non-native vegetation or non-vegetated surfaces. These sites lack on-site propagules for regeneration and off-site propagules are less likely to reach the site due to the larger scale and uniform nature of anthropogenic disturbance. Thermal, resting, hiding, feeding and escape cover for animals is less likely to exist near enough for animal populations to persist because anthropogenic disturbances are rarely patchy. These on-site and off-site characteristics of severe anthropogenic disturbances make it far less likely that these can naturally re-establish pre-disturbance hydrology, soils, vegetation, or faunal community conditions.

H. Selection of Community Type for Model Entry

The regional subclass was defined to be inclusive of this disturbance related range of variation, to encompass temporal, as well as spatial, characteristics of precipitation-driven wetlands on discontinuous permafrost in Interior Alaska. Rather than developing a model for a single reference standard condition (*e.g.,* old growth forest on HGM slope wetlands in Southeast Alaska), the authors established multiple reference standard conditions within a reference standard burn cycle. Five major community types, based on seral stage, cyclic processes, and dominant vegetation occur in precipitation-driven wetlands and have associated reference standards: 0 to 5 yr. old forested, 6 to 30 yr. old forested, >30 yr. old forested, shrub, and sedge tussock. Sites undergoing perturbation by natural processes such as fire or paludification follow successional trajectories leading them to fall into different community types depending on successional stage (Figure 20). Importantly, an anthropogenically unaltered site can be a reference standard site as long as it is anywhere on one of these natural successional pathways. The authors intend users to identify the community types present in a project assessment area and apply the appropriate assessment models provided in the operational draft Guidebook, as outlined in the assessment protocol (Section VII).

Stand age can be used as a rough generalization to subdivide post-fire community types of the subclass. Site-specific conditions will cause a range of variation in the characteristics of same-age stands. In addition, stand age is a continuous quantity, and no clear breaks will occur at temporal boundaries between community types following fire. The authors chose time since fire as an easily measurable trait (*e.g.,* tree ring counts, local or agency knowledge of fire history) for most potentially forested or woodland sites. Ideally, for a very large reference standard set (*e.g.,* hundreds of sites), more refined subdivisions of the set could be made. The 33 reference standard sites in the existing set will not support additional refinement, however. For example, the reference standard set for the >30 yr. old forested community type contains one or more stands dominated by paper birch, but most wetland stands in the community type are dominated by black spruce. The present reference set is not sufficiently large to establish separate reference standards for paper birch stands >30 years old. Thus, stand age seems a reasonable subdivision of unaltered post-fire seres in the subclass at this time. With the addition of more reference standard sites, future iterations of the model for precipitation-driven wetlands on discontinuous

Figure 20. Potential Cyclic Successional Pathways in Precipitation-Driven Wetlands on Discontinuous Permafrost in Interior Alaska



permafrost in Interior Alaska may provide an improved method of accounting for subclass variability.

For assessing anthropogenically and legally altered sites (*i.e.*, sites where it may not be possible to establish community or stand age, or pre-disturbance condition), the authors have developed an alternative method for subdivision of the subclass based on stand structure (*e.g.,* dominance and cover of vegetative strata). Table 11 presents a dichotomous key for choosing an entry point to the assessment models for precipitation-driven wetlands on discontinuous permafrost in Interior Alaska. The scheme avoids some of the difficulties associated with determining site history and acknowledges partial functional parallels between certain altered sites and natural post-fire community types, as discussed in the following paragraphs. In using the dichotomous key it is important to remember that the key is not intended to define community types, but to direct initial users of the Guidebook to the appropriate model to use for assessing wetland functions.

Field testing of the peer review draft Guidebook (*Peer Review Draft Guidebook.* March 1997) showed that anthropogenically disturbed sites have natural analogs in the successional stages that follow natural disturbance. Altered sites dominated by the herbaceous stratum (*e.g.,* hay fields) can be considered equivalent to the 0 to 5 yr. old forested community type. Sites dominated by shrub and small tree strata (*e.g.,* former agricultural land allowed to undergo succession) can be considered to be equivalent to the 6 to 30 yr. old forested community type, and sites dominated by trees are equivalent to the >30 yr. old forested community type. The authors believe that existing legally altered sites should be assessed using the ecologically equivalent natural community type as the “without project” condition. Of course, with- and without project functional assessments must be based on the same entry point (community type) to the assessment models so that changes in FCI’s can be fairly calculated.

Table 11. Key To Community Types Precipitation-Driven Wetlands on Discontinuous Permafrost in Interior Alaska

1a Project assessment area (PAA) shows evidence of anthropogenic alteration…………………….……**7**

1b PAA shows no evidence of anthropogenic alteration.

  2a Canopy cover of trees (*i.e.,* single-stem, woody vegetation ≥10 ft [3 m] tall) and small trees (*i.e.,* single-stem, woody vegetation >3 to <10 ft [0.9 to 3 m] tall) combined <10……………..……**4**

  2b Canopy cover of trees and small trees combined ≥10%

    3a Stand age **>**30 yr…………………………………. **>30-yr-old Forested Community Type** (*e.g.,* black spruce forest or woodland, paper birch forest or woodland, mixed forest or woodland).

    3b Stand age ≤30 yr ………………………………**6 to 30-yr-old Forested Community Type** (*e.g.,* regenerating black spruce forest or woodland, paper birch forest or woodland, mixed forest or woodland).

  4a Shrub cover <50%……………………………………………………………………………..**6**

  4b Shrub cover ≥50%

Table 11. Key to Community Types (con't)

5a Canopy cover of mosses, lichens and liverworts ≥50% **and** canopy cover of closed-sheath sedge (cotton grass) <50%; few prominent tussocks and intertussock depressions ………… **………………………………Shrub Community Type** (*e.g.*, *Betula glandulosa* community)

5b Canopy cover of mosses, lichens and liverworts <50% **and** cover of closed-sheath sedge (cotton grass) ≥50%; prominent tussocks and intertussock depressions ……………………… **……………………Sedge Tussock Community Type** (*e.g.*, *Eriophorum* spp. community)

6a Canopy cover of mosses, lichens and liverworts <50% **and** closed-sheath sedge (cotton grass) canopy cove ≥50%; prominent tussocks and intertussock depressions ..……………..……………. **……………………Sedge Tussock Community Type** (*e.g.*, *Eriophorum* spp. community)

6b Canopy cover of mosses, lichens and liverworts ≥50% **and** closed-sheath sedge (cotton grass) canopy cover <50%; few prominent tussocks and intertussock depressions………………………. **……………………………Shrub Community Type** (*e.g.*, *Betula glandulosa* community).

7a PAA is too wet to support tree regeneration (*i.e.*, soils not sufficiently drained; if alteration in land use were discontinued); soil has peraquic conditions…………………………………………………**9**

7b PAA sufficiently well drained to support tree regeneration, if alteration in current land use(s), including fire, were discontinued

8a Dominant and/or co-dominant trees and/or small trees >30 years old (e.g., site altered by partial removal of trees, post-clearing or post-fire community type)……………………… …………………………….…..……………… **>30-yr-old Forested Community Type**

8b Dominant and/or co-dominant trees and/or small trees 6 - 30 years old (e.g., site altered by partial removal of trees, post-clearing or post-fire community type)……………………… ………………………………………….……**6 - 30-yr-old Forested Community Type**

8c Dominant and/or co-dominant trees and/or small trees <6 years old(e.g., site altered by partial removal of trees, post-clearing or post-fire community type)……………………… …………………………………………..………. **<6-yr-old Forested Community Type**

9a Shrub cover ≥10%………………………………………………………..**10**

9b Shrub cover <10%; bare mineral soil or herbaceous dominant……………………… ………..…………………………………………**Sedge Tussock Community Type**

10a Surrounding area or other evidence (*e.g.*, documentation of condition prior to legal alteration) indicates shrub cover could reach ≥50% if the altering land use were, or has been, discontinued ……………….….. ………………………… …… ………………………**Shrub Community Type** (*e.g.*, post-clearing sere).

10b Surrounding area or other evidence (*e.g.*, pre-alteration documentation) indicates potential shrub cover <50% if the altering land use were, or has been, discontinued…………..………………………………………………………… **……………………………………Sedge Tussock Community Type**

I. Water Sources and Hydrodynamics

As introduced and discussed above, precipitation is the main hydrologic input to sites within the regional subclass, and evapotranspiration is the dominant mode for water movement out of these wetlands. Soils frozen during the winter may not thaw until late in the summer season. Some sites, with specific combinations of aspect, slope, vegetation, thermal properties of the parent material, and insulation properties of the vegetation and organic surface horizon(s), may remain frozen at depth for ≥2 yr as permafrost (Péwé 1982). Frost, whether seasonal or permafrost, forms an impermeable zone in the soil profile and perches water (Post 1996), as evidenced by ponding. As seasonal frost melts, the saturated soil zone increases in depth. Complete melting of the impermeable frost layer may not occur until well into the growing season on some sites. Where permafrost exists, supra-permafrost groundwater occupies the zone of annual thaw (*i.e.*, active layer). Permafrost and seasonal frost strongly influence hydrologic functions of precipitation-driven wetlands on discontinuous permafrost in Interior Alaska. Hydrologic functions are tightly coupled to soil properties and vegetation as a function of their effects on the soil thermal regime and permafrost processes.

J. Soils

Soils of the regional subclass cycle between a poorly drained permafrost-rich state and a well-drained to poorly drained ice-free state initiated by wildfire or other perturbation and post-fire vegetation succession. The basic soil stratigraphic relations in precipitation-driven wetlands on discontinuous permafrost in Interior Alaska are based on observations of soils in unperturbed and perturbed states (Tables 12 through 15). A perturbed site may return to a permafrost-rich condition if it has silty or loamy surface materials ≥20 inches (51 cm) thick, topographic slopes generally ≤20%, and is not subject to significant flooding. Thus, the integrity of the soil profile, through linkages with the thermal regime of the soil and site hydrology, exerts strong controls on ecosystem processes (*i.e.*, wetland functions), including processes affecting nutrient cycles and storage. A more complete description of thermal properties, drainage characteristics, and range of variation within the subclass appear in following sections.

Table 12. Soil taxa, stratigraphic relationships, and indicators in unperturbed precipitation-driven wetlands located on alluvial terraces and glaciofluvial outwash fans.

INDICATORS AND CHARACTERISTICS OF SOILS OF THE REGIONAL SUBCLASS	
Common Soil Taxa (Great group Level)	Cryaquepts, Cryaquents, Aquiturbels, Histoturbels, and Cryofibrist-Histel complexes .
Organic Soil Horizons	Moderate to great thickness (5 to >30 inches (13 to >76 cm) thick).
Silty or Loamy Mantle	Silty loess **or** stratified sandy and silty alluvium (≥20 inches (51 cm) thick).
Substratum	Stratified sandy and silty alluvium **or** sand and gravel.
Permafrost State	Ice-rich permafrost (when present) ≤3 ft (91 cm) from surface.
Soil Moisture	Episaturation occurs above permafrost.
Indicators of Prolonged Saturation	1. Complex patterns of redox depletions and concentrations in the mineral soil **or** greenish-gray (gleyed) substratum color (redoximorphic features), and

INDICATORS AND CHARACTERISTICS OF SOILS OF THE REGIONAL SUBCLASS	
	2. An over-thickened surface organic layer (histic epipedon).
Vegetation Indicators of Unperturbed State	Mature Forested (black spruce or dwarf black spruce), Shrub (low birch), or Sedge Tussock (closed-sheath sedge wet meadow) community types.

Table 13. Soil stratigraphic relationships in unperturbed precipitation-driven wetlands located in footslope and toeslope positions on hills with topographic slopes ≤20%.

INDICATORS AND CHARACTERISTICS OF SOILS OF THE REGIONAL SUBCLASS	
Common Soil Taxa	Fibristels, Aquiturbels, Histoturbels, and Cryochrepts,
Organic Soil Horizons	Moderate thickness (5 to 18 inches (13 to 46 cm) thick).
Silty or Loamy Mantle	Silty loess **or** loamy colluvium (≥20 inches (51 cm) thick).
Substratum	Silty loess, loamy colluvium, or bedrock.
Permafrost State	Ice-rich permafrost present ≤3 ft (91 cm) from surface.
Soil Moisture	Episaturation occurs above permafrost.
Indicators of Prolonged Saturation	1. Complex pattern of redox depletions and concentrations in the mineral soil (redoximorphic features), and 2. An over-thickened surface organic layer (histic epipedon).
Vegetation Indicators of Unperturbed State	Mature Forested (black spruce or dwarf black spruce), Shrub (low birch), or Sedge Tussock (closed-sheath sedge wet meadow) community types.

Table 14. Soil stratigraphic relationships in burned (unaltered) precipitation-driven wetlands located on alluvial terraces and glaciofluvial outwash fans <u>or</u> located in footslope and toeslope positions on hills with topographic slopes ≤20%.

INDICATORS AND CHARACTERISTICS OF SOILS OF THE REGIONAL SUBCLASS	
Organic Soil Horizons	Variable thickness (1 to 30 inches (3 to 76 cm) thick).
Silty or Loamy Mantle	Same as unburned condition (≥20 inches (51 cm) thick).
Substratum	Same as unburned condition.
Permafrost State	Absent or intermittent and, if present, is associated with areas of thick organic horizons.
Indicators of Prolonged Saturation or Loss of Saturation	***<u>In plane or convex positions</u>*** Evidence of redox depletions and concentrations throughout the upper part of the silty or loamy mantle (relict redoximorphic features) is present. ***<u>In depressions</u>*** (1) An apparent water table is present within 5 ft (1.5 m) of the surface, but permafrost is absent; **<u>OR</u>** (2) No water table is observed, but evidence of redox depletions and concentrations throughout the upper part of the silty or loamy mantle (redoximorphic features) is

INDICATORS AND CHARACTERISTICS OF SOILS OF THE REGIONAL SUBCLASS	
	present.
Vegetation Indicators of Post-Fire Successional State	Mosaic of vegetation types on aerial photography, charred trees, or charcoal in organic soil horizons or at the surface of mineral soil.

Table 15. Soil stratigraphic relationships in anthropogenically perturbed precipitation-driven wetlands located on alluvial terraces and glaciofluvial outwash fans <u>or</u> located in footslope and toeslope positions on hills with topographic slopes ≤20%.

INDICATORS AND CHARACTERISTICS OF SOILS OF THE REGIONAL SUBCLASS	
Organic Soil Horizons	Generally absent as a result of mechanical clearing and stripping.
Silty or Loamy Mantle	Generally the same as the unperturbed condition (≥20 inches (51 cm) thick).
Substratum	Same as unperturbed condition.
Permafrost State	Absent.
Indicators of Prolonged Saturation or Loss of Saturation	***In plane or convex positions*** a perched water table is absent, and evidence of redox depletions and concentrations throughout the silty or loamy mantle (relict redoximorphic features) is present. ***In depressions*** (1) a water table may be temporarily perched over seasonal frost during late spring as evidenced by presence of black mucky surface textures ≥2 inches (5 cm) thick over strongly contrasting redox depletions and concentrations (active redoximorphic features); **OR** (2) a water table (endosaturation) and prolonged saturation may persist as evidenced by an apparent water table ≤5 ft (1.5 m) from the surface and a predominance of greenish-gray (gleyed) mineral soil color (active redoximorphic features) ≤ 20 inches (51 cm) from the surface.
Vegetation Indicators of Anthropogenic Perturbation	Vegetation absent, non-native vegetation dominant, or early successional community of mixed non-native and native vegetation present.

1. *Soil Thermal Properties*

Permafrost in Interior Alaska occurs in a discontinuous pattern across the landscape depending on site and soil conditions, including thickness of organic soil horizons, soil texture, local hydrology, aspect, and exposure. In Interior Alaska, permafrost is most common in soils formed in deep organic deposits or soils with thick organic horizons underlain by silty or loamy mineral soil layers (Figure 21) such as stratified sandy and silty alluvium, silty eolian deposits, and silty or loamy colluvium. Permafrost primarily is maintained by the insulating properties of the

Figure 21. Generalized Cross Section of the Formation of Permafrost

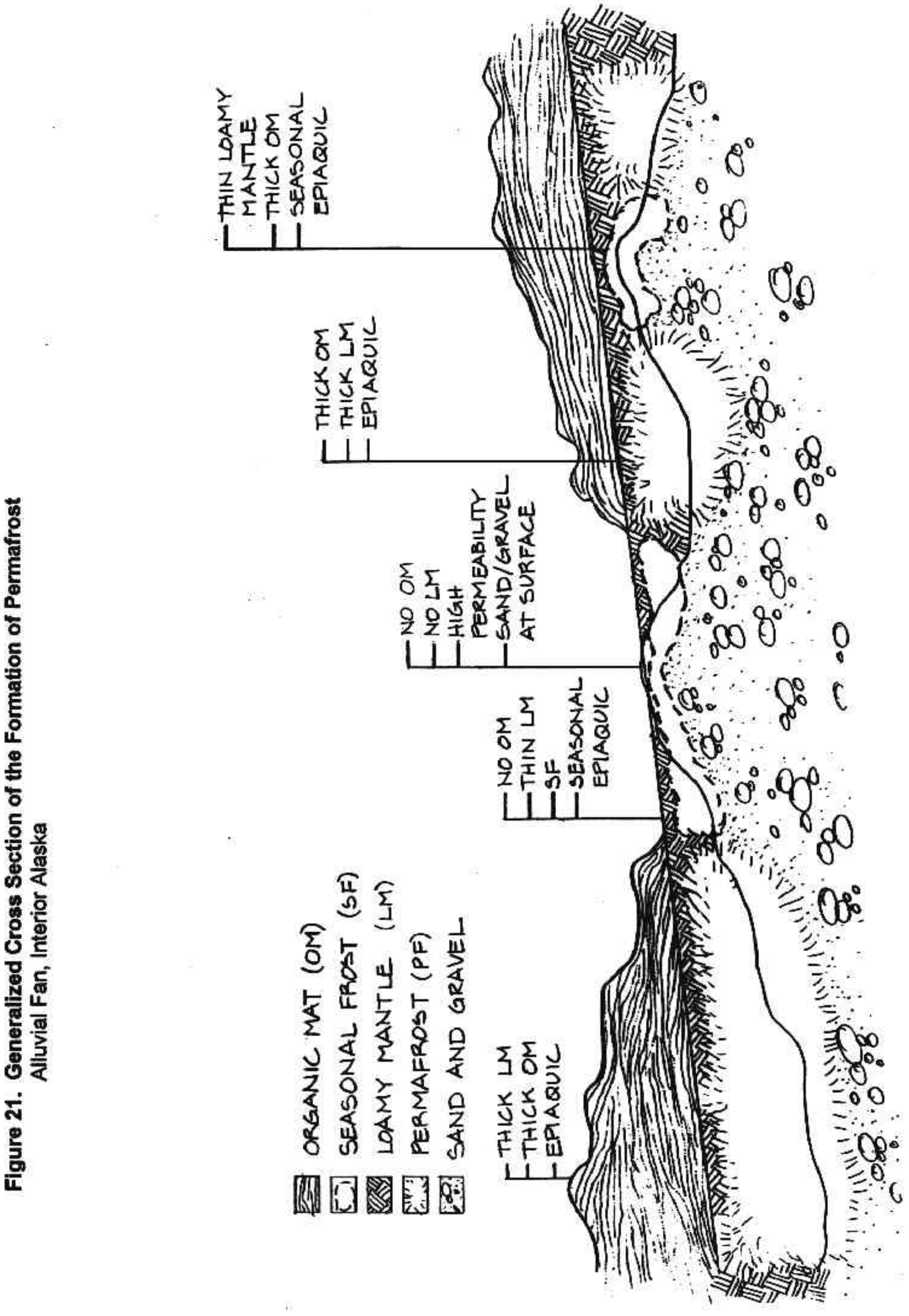


Figure 21. Generalized Cross Section of the Formation of Permafrost
Alluvial Fan, Interior Alaska

surface organic horizon (Ping *et al.* 1992). Soil temperatures warm slowly and remain low during the summer months due to inefficient heat exchange from the atmosphere to the soil materials, and this favors permafrost establishment and maintenance. Where the organic surface horizon(s) is perturbed by natural or anthropogenic means, the insulating properties are diminished or lost and permafrost may degrade. As the organic horizon(s) recovers, the unperturbed thermal regime may return and permafrost may be re-established.

Permafrost occurs infrequently in soils with thick organic surface horizon(s) over coarse-textured materials because these soils typically have warm summer temperatures, a property favoring slow rates of organic matter accumulation. Thermal conductivity and diffusivity are relatively low in moist organic materials and moist mineral soils with loamy or finer texture (Jury 1991) and higher in coarse-textured materials (Baver 1972). Therefore, heat is more efficiently transferred from the atmosphere to coarse-textured soils, and frost cannot persist throughout the summer months. In addition, organic materials accumulate slowly in warm soils because the rate of decomposition is high. Because the return interval for fire averages 100 to 200 years in interior Alaska, there is rarely sufficient time for the formation of thick organic horizons or permafrost in these coarse textured soils. These sites are not extensive and are not considered within the range of the subclass.

Seasonal freezing and thawing may extend to ≥1 m below the mineral soil surface. Seasonal frost can strongly influence soil horizon arrangement and microtopography. Surface-down freezing during the winter traps bodies of unfrozen soil between the seasonal frost and the permafrost. Water expands as it freezes; therefore, ice formation confines unfrozen water and reduces the free energy of the water. The resulting cryosuction causes water to migrate to the freezing zone (Williams and Smith 1989). In a progressively freezing soil, especially one that is saturated, high hydrostatic pressures develop because ice occupies about 9% more volume than water. Cryoturbation, or the fracturing and mixing of soil horizons by differential freezing, occurs where soil layer(s) under increasing and differential pressure is mixed and distorted. The degree to which this occurs is dependent on water content and the subsequent ice content of the active layer. Differential freezing and frost heave generates surface microrelief features such as hummocks, frost boils, and patterned ground features (Washburn 1979).

Although permafrost is characteristic of most sites, it is not essential for inclusion in the regional subclass. The subclass is characterized by a thick organic surface horizon(s), episaturation caused by permafrost or low permeability soils, and relatively low summer soil temperatures in the upper 20 inches (51 cm). Permafrost-rich and permafrost-free soils both have relatively low summer temperatures in the upper 20 inches (51 cm) of the soil: permafrost-rich soils with thick organic surface horizon(s), thick silty or loamy surface mantles, and episaturation have summer soil temperatures ranging from 1° to 4° C (34° to 39° F), while similar permafrost-free soils have summer soil temperatures ranging from 4° to 9° C (39° to 48° F) (Ping, Univ. of Alaska, unpubl. data).

2. *Soil Drainage Properties in a Landscape Subject to Cyclic Processes*

Landscape position, thermal regime, the fire cycle, and anthropogenic disturbance are primary determinants of drainage class in these soils. In particular, the fire cycle (Figures 17 and 20) may cause soils to cycle between poorly drained, shallow-permafrost states, well-drained, ice-free states, and back to poorly drained, shallow-permafrost states (Ping *et al.* 1992). The potential for a site to cycle between a permafrost-rich condition and an ice-free, well- drained state is dependent upon landscape position. In the Yukon-Tanana Uplands and the Tanana-Kuskokwim Lowlands, soils with thick silty or loamy surface mantles are found in several locations. Along the floodplains of the Tanana River and on the alluvial fans (Figure 13) that originate in the Alaska Range, the silty or loamy mantle occurs as thick vertical accretion deposits of stratified sandy and silty deposits that have accumulated from overbank flooding (Ruhe 1975). Generally, these deposits are thicker on higher surfaces and back channels. In bar and channel positions more proximal to the river, and occasionally on high interfluves on alluvial fans, the thick silty or loamy sediments are thin or absent.

In the Yukon-Tanana Uplands, thick loamy deposits occur as loess or loess-influenced colluvium with textures that are primarily silt or silt loam. These materials are thickest on slopes facing the Tanana River and on footslopes, toeslopes, and valley bottom positions. Sites that have either a thin silty or loamy mantle or coarse textured materials in the silty or loamy mantle will tend toward a better-drained state if permafrost is degraded by fire or anthropogenic disturbance.

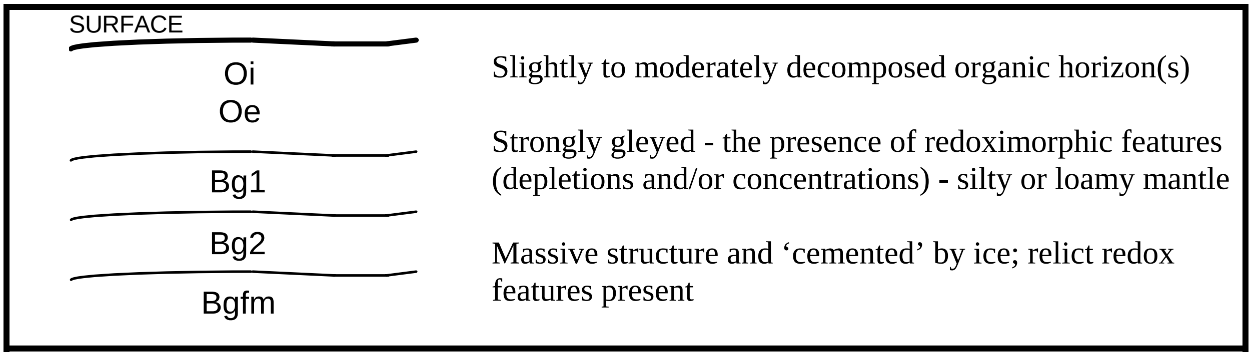
Sites located in abandoned channels or in collapse scar bogs on glaciofluvial outwash fans may remain poorly drained by virtue of being in low landscape positions. Sites located in abandoned channels on the terraces, particularly along the Delta and Tanana Rivers, may remain poorly drained because of regional groundwater discharge (Hopkins *et al.* 1955, Williams 1970). These sites may receive more water early in the growing season following fire or anthropogenic disturbance as adjacent interfluves drain via surface and shallow subsurface flow to the lower landscape positions.

3. Range of Variation Within Soils of the Regional Subclass

Soil profiles vary in their specific properties, but generalizations can be developed that assist in the identification, or deviations from, reference standard conditions. All reference standard sites, including those that have recently burned, have an organic horizon and a silty or loamy mantle >20 inches (51 cm) in depth. General profiles are outlined in Figures 22 - 30. These soil profiles are generalizations; specifics can be found in the soils data arrays (Appendix B).

Organic soil horizons are ubiquitous within the regional subclass, including at sites where fire has recently occurred (Table 14). Histosols, such as Pergelic cryofibrists and Pergelic cryohemists, (see Table 16 for the current NRCS taxa for pergelic, *i.e.*, permafrost soils) occur primarily in depressions and regional lows that are saturated for long or very long duration during the growing season (Ping *et al.* 1992). Histosols were found in linear depressions formed in abandoned channels, in collapse scar bogs, in troughs in high-centered polygonal ground, and on toeslopes in valley bottom positions adjacent to streams. Permafrost in the organic layer was observed wherever deep, organic deposits were found except in collapse scar bogs. Organic horizons also occur outside of depressions and regional lows, but horizon depths were not sufficient for Histosol classification. Depths were frequently sufficient, however, to identify the surface organic horizon as a Histic epipedon.

Figure 22. Ruptic Histoturbels occurring in Abandoned Floodplains and Alluvial Terraces

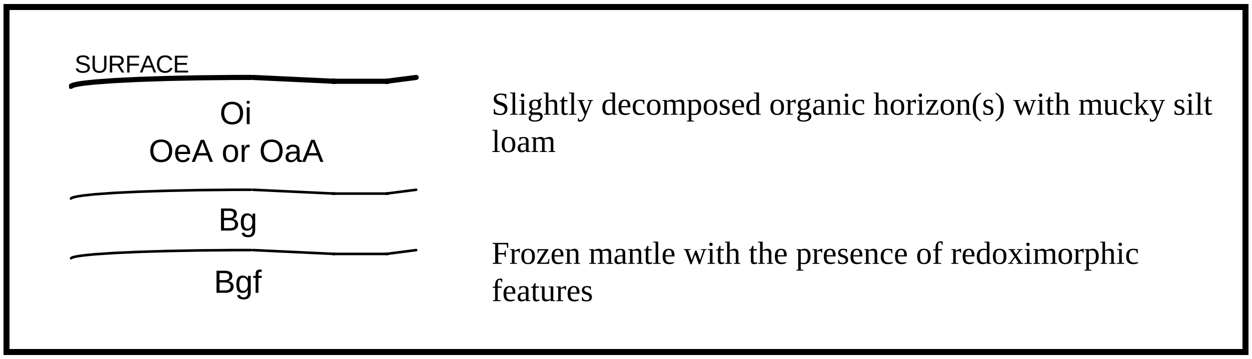


Slightly to moderately decomposed organic horizon(s)

Strongly gleyed - the presence of redoximorphic features (depletions and/or concentrations) - silty or loamy mantle

Massive structure and 'cemented' by ice; relict redox features present

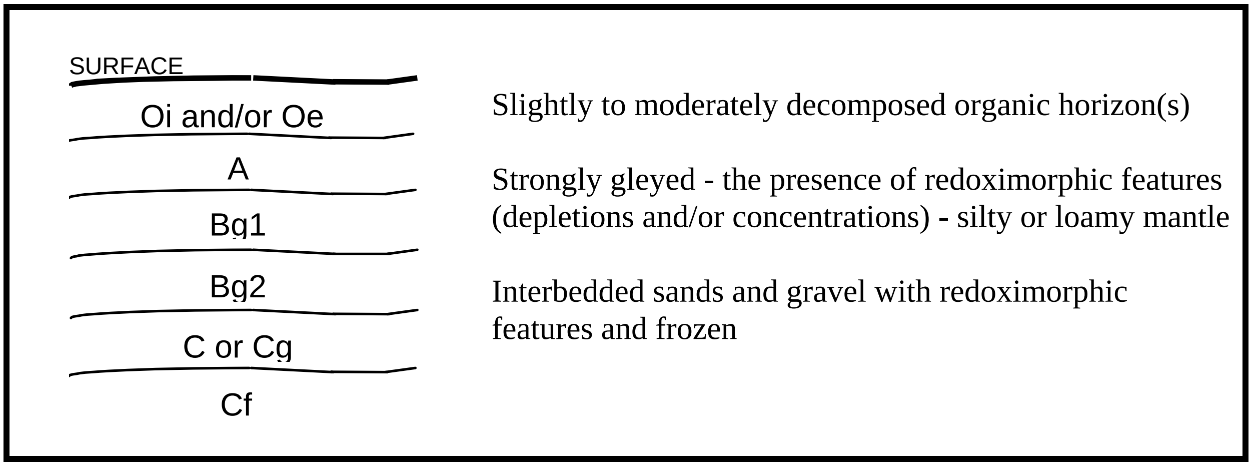
Figure 23. Typic Histoturbels occurring in Abandoned Floodplains and Alluvial Terraces



Slightly decomposed organic horizon(s) with mucky silt loam

Frozen mantle with the presence of redoximorphic features

Figure 24. Typic Aquiturbels occurring in Abandoned Floodplains and Alluvial Terraces

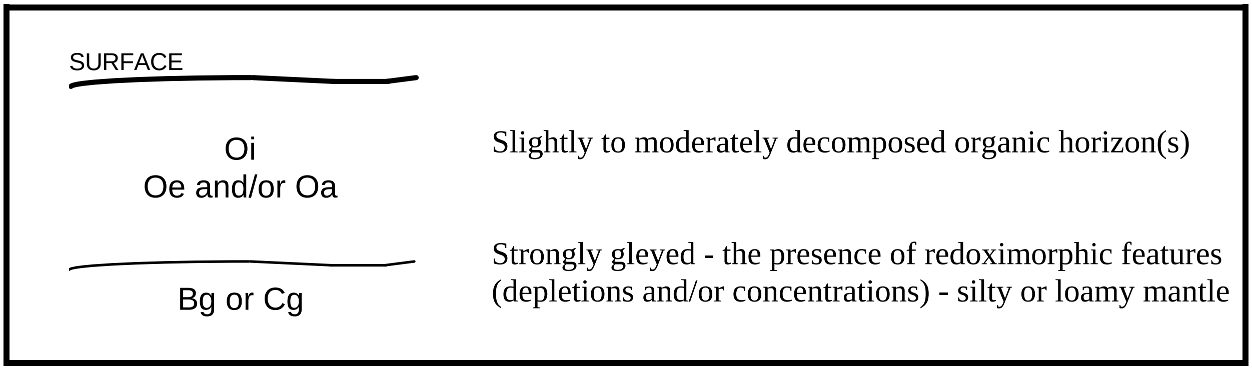


Slightly to moderately decomposed organic horizon(s)

Strongly gleyed - the presence of redoximorphic features (depletions and/or concentrations) - silty or loamy mantle

Interbedded sands and gravel with redoximorphic features and frozen

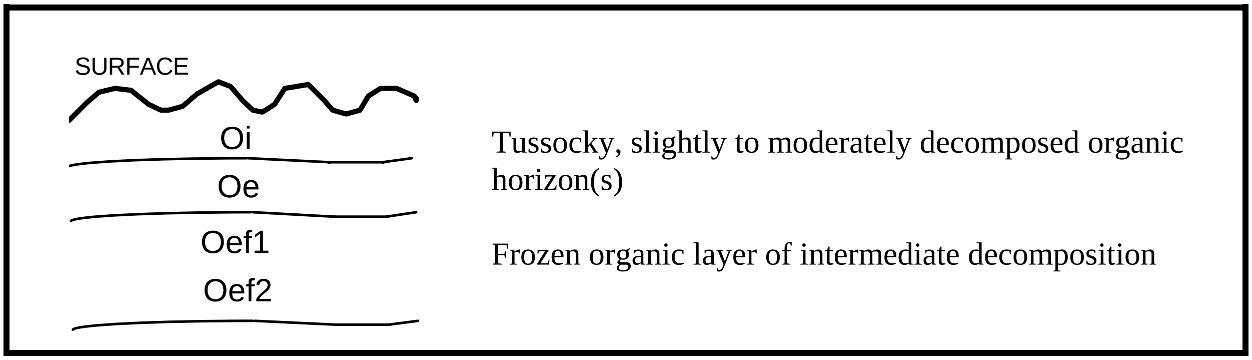
Figure 25. Terric Cryofists occurring in Depressions on Alluvial Flats, Floodplains and Terraces



Slightly to moderately decomposed organic horizon(s)

Strongly gleyed - the presence of redoximorphic features (depletions and/or concentrations) - silty or loamy mantle

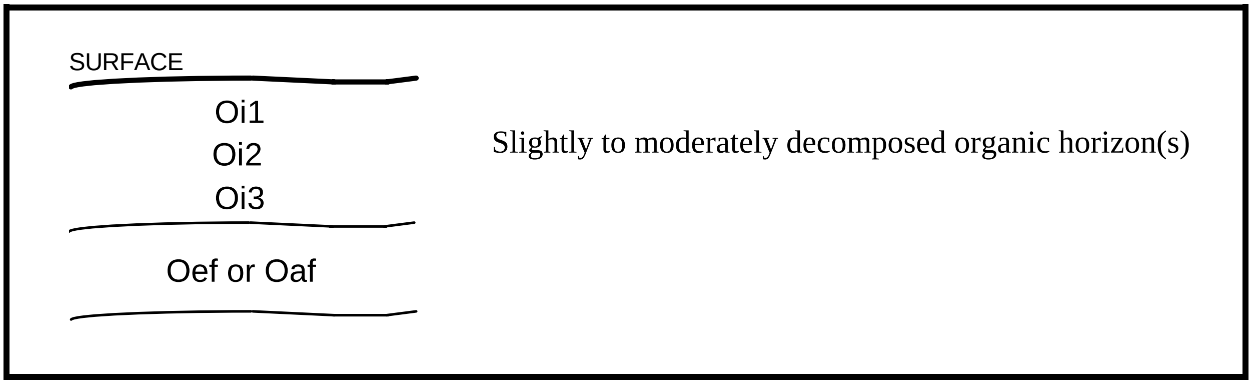
Figure 26. Typic Hemistels occurring in Depressions on Alluvial Flats, Floodplains and Terraces



Tussocky, slightly to moderately decomposed organic horizon(s)

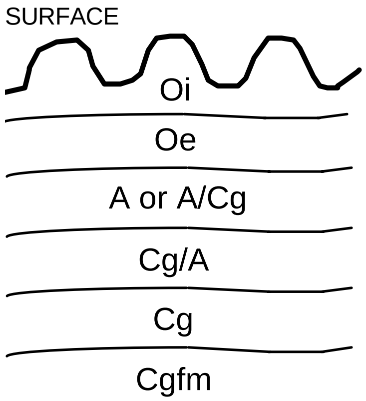
Frozen organic layer of intermediate decomposition

Figure 27. Typic Fibristels occurring in Depressions on Alluvial Flats, Floodplains and Terraces



Slightly to moderately decomposed organic horizon(s)

Figure 28. Typic Aquiturbels occurring in Terraces and Lower Slopes of Hills

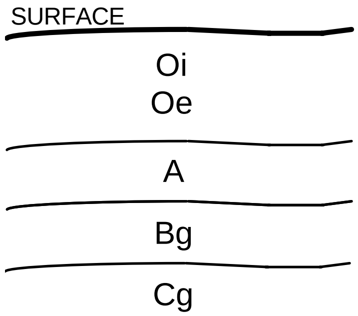


Slightly to moderately decomposed organic horizon(s)

Strongly gleyed - the presence of redoximorphic features (depletions and/or concentrations) - silty or loamy mantle

Interbedded sands and gravel with redoximorphic features and frozen

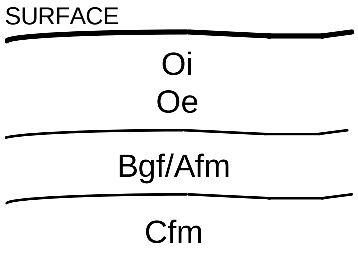
Figure 29. Histic Cryaquepts occurring in Terraces and Lower Slopes of Hills



Slightly to moderately decomposed organic horizon(s)

Strongly gleyed - the presence of redoximorphic features (depletions and/or concentrations) - silty or loamy mantle

Figure 30. Typic Histoturbels occurring in Middle and Lower Positions of North Slopes



Slightly to moderately decomposed organic horizon(s)

Frozen horizon with components of the surface (A) and subsurface (B) horizons mixed by freeze thaw processes. Massice texture - cemented by ice

Table 16. Translation of old taxonomic terms (USDA/NRCS Keys to Soil Taxonomy,

seventh edition 1996) to new taxa equivalent (USDA/NRCS Keys to Soil Taxonomy, eighth edition 1998) incorporating the new Gelisol (permafrost soils) soil order.

OLD TAXA: SUBGROUP LEVEL	**NEW TAXA: SUBGROUP LEVEL**
Histic Pergelic Cryaquepts	Typic Histoturbels (frozen mineral soil)
Pergelic Cryaquepts	Typic Aquiturbels (frozen mineral soil)
Pergelic Cryohemists	Typic Hemistels (frozen organic soil)
Pergelic Cryofibrists	Typic Fibristels (frozen organic soil)

The presence of a silty or loamy surface mantle, requisite for this subclass, consists of soil materials with a composite texture that is loamy or finer and ≥20 inches (51 cm) thick (Tables 12 to 15). The origins of the silty or loamy surface materials are varied and include windblown sediments (*i.e.*, eolian sediments), alluvium, and colluvium. Eolian materials in Interior Alaska were deposited during Pleistocene through early Holocene time when extensive, sparsely vegetated, braided river systems originating in the Alaska Range provided source materials. Strong winds associated with the periglacial environment transported large clouds of fine sand through silt-sized particles (0.02 to 0.00008 inch (0.500 to 0.002 mm)) from the river systems to the surrounding uplands and lowlands. The thickness of the surficial eolian materials and their particle size generally decreases with distance from the source areas (Péwé 1975). The thickness of these deposits ranges from a few millimeters to >60 m (~0.1 inch to >197 ft) (Péwé 1975). The most commonly observed eolian materials consist of silt-sized particles and are referred to as loess.

Silty or loamy alluvial surficial deposits, are more heterogeneous in nature than eolian deposits and are extensive in Interior Alaska. Alluvial deposits occur on active floodplains, terraces, and glaciofluvial and fluvial outwash fans. Silty or loamy alluvial materials occur as thick, vertically accreted deposits of stratified sandy and silty deposits that have accumulated as a result of overbank flooding. Gradual degradation of the riverine system often results in these materials being located above current flood levels. Surface deposits of silty or loamy alluvium range from very thin or nonexistent to many meters thick, with variable depth over very short distances. Silty or loamy material also occurs as colluvium derived from predominantly loess materials along footslope and toeslope positions.

Regardless of origin, the silty or loamy mantle is frequently characterized by either a weak platy structure due to horizontal ice lens formation, or a massive structure due to lack of rooting activity and a low clay content. The small particle size and lack of soil structure results in low hydraulic conductivity causing snowmelt and/or precipitation to permeate slowly through these materials. Soil moisture content remains high in these materials and saturation is frequently observed, particularly during and following snowmelt in spring.

Soil profiles in Interior Alaska frequently contain two or more materials of contrasting texture and origin. Interbedded gravels, sands, and silts of fluvial or glaciofluvial origin underlie the silty or loamy surface mantle on terraces, glaciofluvial outwash fans, and some footslopes and toeslopes. Backslope, footslope, and toeslope positions on landforms that are shallow to bedrock, have loess and colluvial material underlain by weathered bedrock.

K. Vegetation

1. Reference Standard Sites, Forested, Shrub And Sedge Tussock Communities

Interior Alaska lies within the taiga, or northern boreal forest, region (Bailey 1998). Northern boreal forest forms the belt of needleleaf forest and open lichen woodland that extends across the subarctic from Alaska and Canada to Siberia. The vegetation of Interior Alaska is dominated by closed to open canopy forests and woodlands, but also includes large areas of shrub and herbaceous vegetation (Viereck *et al.* 1992). Three reference standard plant community types were defined on the basis of the reference sampling for precipitation driven wetlands in Interior Alaska: (1) forested; (2) shrub; and (3) sedge tussock (Photographs 13 - 16). In addition, the forested community type was subdivided into three burn-cycle stages to capture the range of variation found in forested communities as a result of periodic disturbance by fires, and post-fire successional sequences. The reference standard forested community types are defined by community age, or time since the last burn: (1) > 30 yr. old forested communities have stand ages of at least 30 years and include includes sites that show no sign of having been burned within the last 30 years; (2) 6 to 30 yr. old stands; and (3) 0 to 5 yr. old stands. Plant communities profoundly influence nearly all processes occurring in precipitation-driven wetlands on discontinuous permafrost in Interior Alaska, including development of soil profiles and maintenance of characteristic soil thermal regimes, nutrient cycling, biomass production, and maintenance of habitat/faunal support functions.

a. Forested Community

Forest types in Interior Alaska can be divided into two major groups, white spruce forests and black spruce forests (Foote 1983, Viereck *et al.* 1992). White spruce forests are not typically the dominant vegetation in precipitation driven wetlands on discontinuous permafrost, however, they do occur on some sites as a stage in the burn cycle and will be described further below. Black spruce (*Picea mariana*) forests occur in areas with poor drainage, characterized by cool, wet soils. In precipitation driven wetlands in Interior Alaska, the cool, wet soils are the result of impeded drainage and/or a perched water table due to shallow, ice-rich permafrost, or very long duration seasonal frost. Black spruce forests can be closed or open canopy forests or woodlands, and are often characterized by very high densities of small trees (Dyrness *et al.* 1986). White spruce, paper birch, green alder and Larch (*Larix laricina*) may be minor components of the tree or small tree strata. Black spruce forests typically have dense shrub layers dominated by ericaceous shrubs such as narrow-leaf Labrador tea (*Ledum decumbens*), Labrador tea (*L. groenlandicum*), mountain cranberry (*Vaccinium vitis-idaea*), bog blueberry (*V. uliginosum*), crowberry (*Empetrum nigrum*), and leatherleaf (*Chamaedaphne calyculata*), as well as dwarf birch (*Betula nana*). The herbaceous layer tends to be sparse and includes sedges (*Carex* spp.), cottongrass (*Eriophorum vaginatum*), cloudberry (*Rubus chamaemorus*), and bog cranberry (*Vaccinium oxycoccus*). A conspicuous feature of black spruce forests is the thick moss layer which covers most of the forest floor. The moss layer can be up to 1 m thick, includes living

Photograph 13. Typical High-Density, Mature, Precipitation-Driven Forested Wetland

Photograph 14. Typical Low-Density, Mature, Precipitation-Driven Forested (Woodland) Wetland

Photograph 15. Typical Precipitation-Driven Shrub Wetland

Photograph 16. Typical Precipitation-Driven Sedge Tussock Wetland

mosses and lichens as well as moss peat, and is dominated by *Sphagnum* mosses. Common additional mosses include the mosses *Hylocomium splendens*, *Pleurozium schreberi*, *Drepanocladus uncinatus*, *Polytrichum* spp. and *Dicranum* spp. Lichens, especially, *Cladonia* spp. and *Peltigera* spp. occur frequently on top of the moss layer.

b. Shrub Reference Standard Sites

Shrub communities in precipitation driven wetlands in Interior Alaska occur on sites that are saturated or inundated for long or very long duration. Shrub communities typically occur in collapse scar bogs, in thermokarst complexes and on flats where the water table is at or near the surface. Sites that have been repeatedly burned and/or flooded may develop shrub plant communities as stages in the reference standard cycle (Figure 31 and Table 17). Reference standard sites are dominated by shrubs which provide between 50% and 80% cover. Trees and small trees are absent or scattered. Frequently encountered shrubs include dwarf birch (*Betula nana)*, bog birch (*B. glandulosa*), lingonberry (*Vaccinium vitis-idaea*), alpine blueberry (*V. uliginosum*), leatherleaf (*Chamaedaphne calyculata)*, Labrador tea (*Ledum groenlandicum*), and shrubby cinquefoil (*Potentilla fruticosa).* Trees and small trees together have < 10% cover. Black spruce is the most common tree, with an average percent cover of about 3%. Common small trees include black spruce and white spruce *(Picea glauca)*. The average small tree cover in reference standard sites is about 7%. Cover of the herbaceous layer averages 31%, and common species include cotton grasses (*Eriophorum* spp.) and sedges (*Carex* spp.). Mosses, lichens, and liverworts are important components of reference standard shrub communities, with a total cover of about 67%. The dominant mosses are *Sphagnum* spp., with about 25% cover. Sample size (n = 4) for reference standard sites in this community type is therefore small and is unlikely to encompass the range of variation for this community type.

c. Sedge Tussock Reference Standard Sites

Sites that have been inundated or saturated for very long duration may develop sedge tussock plant communities (Figure 32 and Table 17). These sites are characterized by a hummock-hollow microtopography, with tussock sedges forming elevated mounds or hummocks surrounded by a network of low hollows which frequently contain ponded water. This plant community can represent a variant of the reference standard cycle. Cover of the herbaceous layer averages 80%-90%, and this layer is dominated by cotton grasses, particularly *Eriorphorum vaginatum* (70% cover). *Carex* spp., particularly *Carex bigelowii*, are also common, with about 20% cover. Average shrub cover is 34%, commonly including leatherleaf (*Chamaedaphne calyculata*), dwarf birch *(Betula nana)*, bog birch (*B. glandulosa*), Labrador tea (*Ledum groenlandicum*), lingonberry (*Vaccinium vitis-idaea*), alpine blueberry (*V. uliginosum*), cloudberry (*Rubus chamaemorus*), willows (*Salix* spp.), and shrubby cinquefoil (*Potentilla fruticosa*). Moss, lichen, and liverwort cover is 31%, about 13% of which is *Sphagnum* spp. Trees contribute very little cover (*i.e.*, <1% cover) to this community. Seedling and small tree cover each average about 5%. Trees and small trees are most commonly black spruce and where present these occur on local topographic highs. Sample size (n = 3) for reference standard sites in this community type is small and is unlikely to encompass the range of variation for this community.

Figure 31. Vegetation Percent Cover: Shrub Reference Standard Sites

Table 17. All Reference Sites: Density and Cover

	REFERENCE STANDARD SITES			**OTHER**
VARIABLE	**Forest**	**Shrub**	**Sedge-Tussock**	**SITES**
Density (Number per Acre)				
Tree Density	1,042	39	2	197
Small Tree Density	1,278	194	146	868
Seedling Density	1,923	126	178	3,394
Snag Density	261	28	0	4
Total Tree Percent Cover	24	4	0	5
Betula papyrifera	4	0	0	1
Larix laricina	1	1	0	0
Picea glauca	1	0	0	0
Picea mariana	19	3	3	3
Populus tremuloides	0	0	0	1
Total Small Tree Percent Cover	18	7	9	12
Betula papyrifera	1	0	0	2
Picea glauca	1	4	0	0
Picea mariana	15	3	5	5
Populus tremuloides	0	0	0	2
Total Seedling Percent Cover	7	1	5	8
Betula papyrifera	0	0	1	1
Picea glauca	0	1	1	1
Picea mariana	6	0	0	4
Populus tremuloides	0	0	0	1
Total Shrub Percent Cover	45	74	34	39
Alnus crispa	1	0	0	0
Betula glandulosa	10	52	7	11
Betula nana	0	0	13	0
Chamaedaphne calyculata	0	10	14	0
Ledum groenlandicum	22	9	10	10
Rosa acicularis	2	0	0	1
Rubus Chamaemorus	6	0	7	3
Salix spp.	4	1	4	22
Vaccinium uliginosum	9	12	7	7
Vaccinium vitis-idaea	17	17	7	4
Total Herbaceaous Percent Cover	26	31	86	53
Agrostis scabra	0	0	0	5
Calamagrostis canadensis	6	5	5	16
Carex spp.	0	1	21	5
Deschampsia spp.	0	0	0	4
Epilobium angustifolium	3	0	0	3
Equisetum arvense	5	1	0	8
Eriophorum spp.	5	3	71	2
Petasides frigidus	0	3	0	0
Potentilla fruticosa	1	3	4	1
Unknown graminoids	3	10	0	10
Non-vascular Plant Cover	76	67	31	25

	REFERENCE STANDARD SITES			OTHER
VARIABLE	**Forest**	**Shrub**	**Sedge-Tussock**	**SITES**
Ceratodon purpurea	1	0	0	1
Fruticose lichens	10	0	0	2
Liverworts	3	0	0	0
Non-spagnum moss	37	21	7	14
Spagnum moss	8	25	14	11

Figure 32. Vegetation Percent Cover: Sedge Tussock Reference Standard Sites

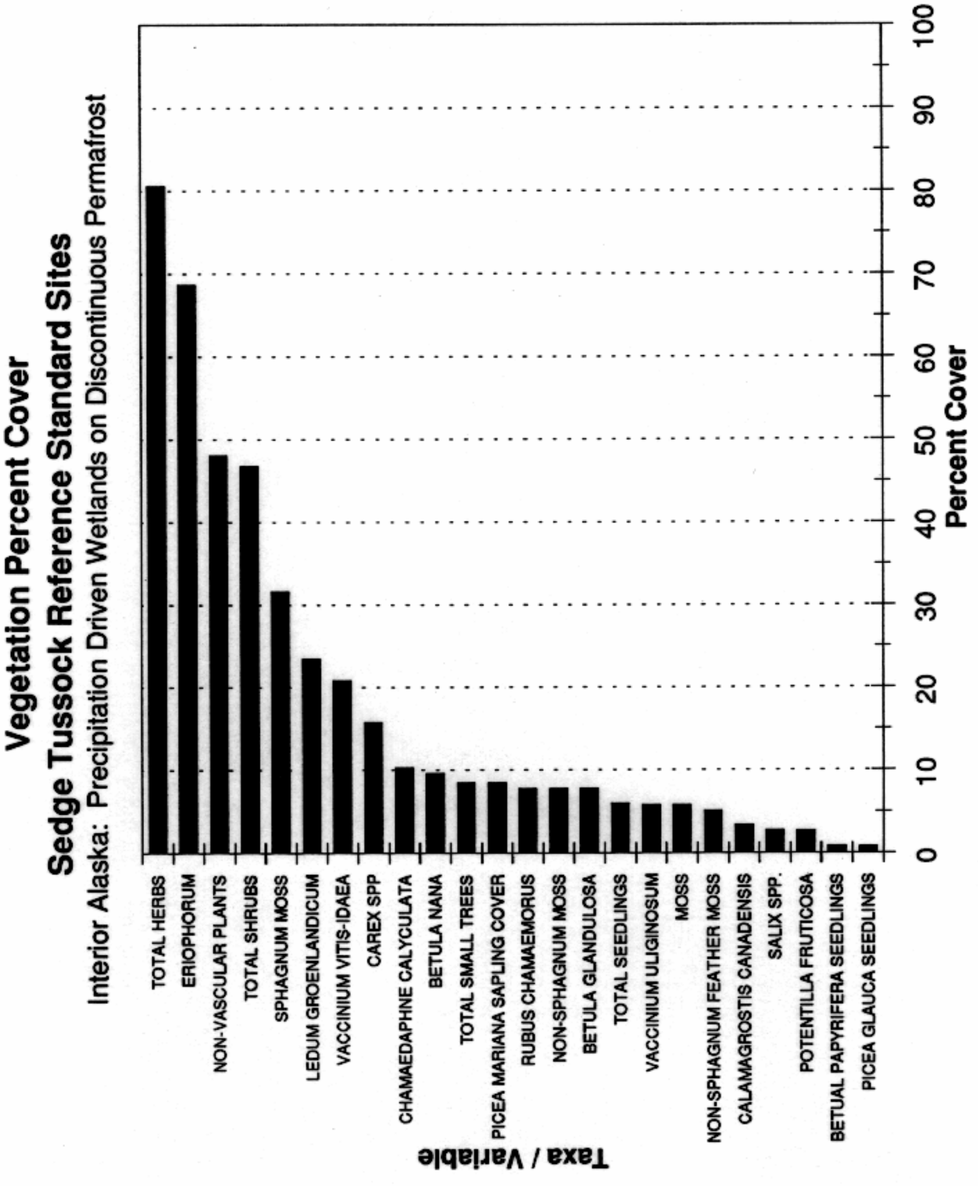


Figure 32.

2. *Fire disturbance and reference standard stages in the burn cycle*

Fires are frequent in the taiga ecoregion, and fire is the most important source of periodic natural disturbance to biotic communities in this part of Interior Alaska (Foote 1983, Dyrness *et al.* 1986). On a landscape level, the frequency of fire disturbance and the variation in fire intensity results in a spatial and temporal mosaic of plant communities in different stages within the fire disturbance cycle.

Wildfires in Interior Alaska tend to be high intensity crown fires that typically kill entire stands (Viereck and Schandelmeier 1980). The effects of fires in general are to open up and expose the site to increased insulation and heat exchange at the ground surface. Fires reduce or completely remove the vegetation canopy (*i.e.,* trees and shrubs) thus reducing shade at the ground surface. In addition, fires reduce the depth and/or cover of the organic matter layer on the forest floor (*e.g.,* herbs and graminoids, moss, lichen and liverwort layer, leaf litter, peat and/or organic soils). High intensity fires expose mineral soils, which are usually darker and absorb more heat than the organic layer. As a result, with more sunlight reaching the ground surface, exposure of mineral soils, and loss of the insulating organic layer, the soil surface receives and absorbs more solar radiation. Mean soil temperatures increase, which can result in thawing of permafrost, a deepening of the active layer, or earlier thawing of seasonal frost (Viereck 1982). Because permafrost and seasonal frost can act as impermeable layers, decreasing the duration of seasonal frost or increasing the depth to permafrost can increase infiltration and soil drainage, and change hydrologic regimes.

Forested community types exhibit the following general post-fire successional pattern. An herb-dominated community develops on previously forested sites immediately after a burn. Wind-dispersed species, including fireweed (*Epilobium angustifolium)* and various grasses, are among the most common plants up to 30 years after a burn. In reference standard sites the percent cover of fireweed peaked at 26% during the first 5 years, dropped to 3% at sites 6 to 30 years post burn, and was <1% at sites >30 years post burn. The percent cover of graminoids and the moss, *Ceratodon purpureus,* peaks at 6 to 30 years post burn, before dropping off sharply in the >30-yr group. Willows (*Salix* spp.) are the most common shrub 0 to 5 years post burn (11% cover) and, while they are no longer the most common shrub 6 to 30 years post burn, they still are common (6% cover). Willow cover drops to 3% in the >30 yr. post-burn communities. Conifer regeneration becomes apparent at 6 to 30 years post burn, and black spruce is the most common tree >30 years post burn. Mosses other than *Ceratodon purpureus* begin to colonize sites during the 6 to 30 year post burn period and at sites more than 30 years post burn, mosses form a thick, continuous mat over the forest floor.

a. *Forested sites 0 to 5 years after burn*

The herb stratum dominates forested reference standard sites at this early seral stage at 49% cover (Figure 33 and Table 18). Common species include fireweed, bluejoint reedgrass (*Calamagrostis canadensis),* unknown grasses, marsh fivefinger *(Potentilla palustris),* tansy mustard *(Descurainia sophioides),* Gmelini’s buttercup *(Ranunculus Gmelini),* willow weed

Figure 33. Vegetation Percent Cover: Forested Reference Standard Sites 0 to 5 Years Since the Last Fire

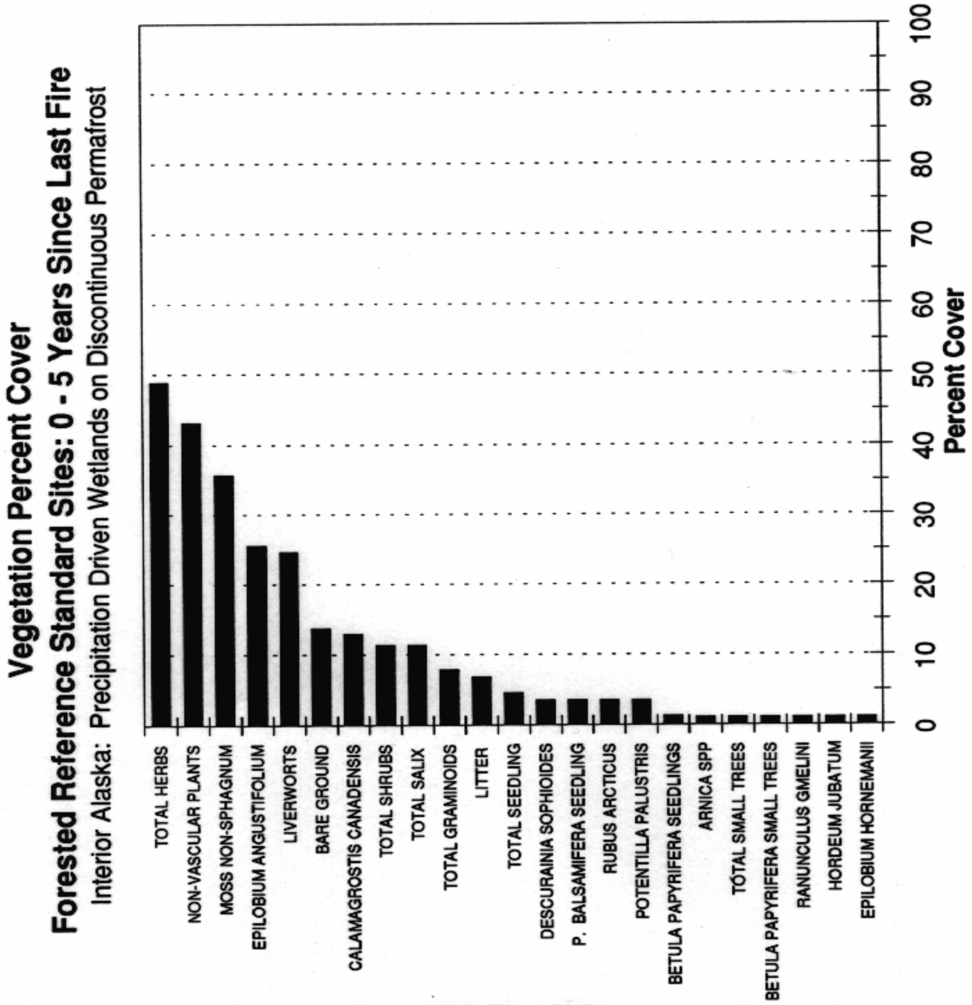


Figure 33.

Table 18. Forested reference standard sites: Density and Cover.

VARIABLE **Years Since Last Burn**	**>30 Years**	**6-30 Years**	**0-5 Years**
Density (Number per Acre)			
Tree Density	1,386	218	1
Small Tree Density	1,597	1,316	13
Seedling Density	2,098	1,254	3,079
Snag Density	97	1,309	11
Percent Cover of Representative Species			
Total Tree Cover	30.5	10.4	0.0
Betula papyrifera	4.8	3.4	0.0
Larix laricina	1.3	0.0	0.0
Picea mariana	24.3	5.9	0.0
Total Small Tree Cover	21.2	21.6	1.0
Betula papyrifera	0.2	2.8	1.0
Larix laricina	0.6	0.0	0.0
Picea glauca	1.1	0.0	0.0
Picea mariana	19.0	17.3	0.0
Total Seedling Cover	9.6	5.4	4.7
Betula papyrifera	0.1	0.4	1.2
Larix laricina	0.5	0.0	0.0
Picea mariana	8.0	5.4	0.0
Populus balsamifera	0.5	0.0	3.5
Total Shrub Cover	44.2	69.3	11.3
Alnus crispa	1.1	2.6	0.0
Betula glandulosa	7.8	25.3	0.0
Ledum groenlandicum	22.6	31.5	0.0
Rosa acicularis	1.5	3.4	0.0
Rubus arcticus	0.1	0.0	3.5
Rubus Chamaemorus	2.6	31.5	0.0
Salix spp.	2.4	6.0	11.3
Vaccinium uliginosum	8.1	21.0	0.0
Vaccinium vitis-idaea	14.2	39.8	0.0
Total Herbaceous Cover	22.5	19.3	48.8
Calamagrostis canadensis	4.0	12.9	12.8
Descurainia sophioides	0.0	0.0	3.5
Epilobium angustifolium	0.0	2.9	25.5
Eriophium spp.	4.1	1.5	0.0
Equisetum arvense	6.6	0.3	0.2
Unidentified Graminoids	2.0	5.3	7.8
Potentilla fruticosa	1.1	0.0	0.0
Potentilla palustris	0.1	0.0	3.5

VARIABLE Years Since Last Burn	>30 Years	6-30 Years	0-5 Years
Non-Vascular Plant Cover	82.5	64.9	43.0
Ceratodon purpurea	0.0	9.5	0.0
Foliose Lichen	0.0	5.1	0.0
Fruticose Lichen	9.0	22.1	0.0
Liverworts	0.0	0.0	24.7
Non-spagnum Moss	39.5	26.8	35.7
Spagnum Moss	7.0	14.6	0.0

(Epilobium hornemanii), and Arnica (*Arnica* spp.). There was no overstory at these sites. The seedlings and small trees are composed mainly of balsam poplar *(Populus balsamifera*, 3.5% cover) and paper birch *(Betula papyrifera*, 1% cover). The dominant shrubs (11% cover) are willows and dwarf nagoonberry *(Rubus arcticus)*. Sample size (n = 3) for reference standard sites in this community type is small and is unlikely to encompass the range of variation for all burn intensities.

b. Forested sites 6 to 30 years after burn

Total tree cover averages 10% on forested reference standard sites during this period (Figure 34 and Table 18). The most common tree is black spruce (5% cover), which also is the dominant (5% cover) species of tree seedling (single-stem, woody species ≤3-ft (0.9-m) tall). The shrub cover (69% cover) is mainly composed of lingonberry *(Vaccinium vitis-idaea)*, bog Labrador tea (*Ledum groenlandicum)*, cloudberry *(Rubus chamaemorus)*, shrub birch (*Betula glandulosa)*, alpine blueberry *(Vaccinium uliginosum)*, willows, prickly rose *(Rosa acicularis)*, and kinnikinnick *(Arctostaphylos uva-ursi)*. The herb layer is 19% cover (reduced from 49% cover in the 0 to 5 years post-burn group) and is composed mainly of bluejoint reedgrass, fireweed, tall bluebells *(Mertensia paniculata)*, and/or common yarrow *(Achillea millefolium)*. Sample size (n = 4) for reference standard sites in this community type is small and is unlikely to encompass the range of variation for all burn intensities and stand ages.

White spruce/mixed hardwood forests are not usually found in wetlands in Interior Alaska, however, these forests can be the dominant vegetation in precipitation driven wetlands at this stage in the reference standard burn cycle. Closed to open forests of white spruce (*Picea glauca*), often with a mixture of aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*), occur on uplands, floodplains, river terraces, and slopes with a south or southeast aspect. White spruce communities occur in sites that have relatively warm, well-drained soils in which permafrost is absent or very deep, or with seasonal frost that melts early in the growing season, by May or early June (Foote 1983, Viereck *et al.* 1992, Post 1996). These communities also form successional stages in the burn cycle on sites where removal of insulating vegetation and organic mats has resulted in thawing of permafrost, draining of the soil and a change from hydric to non-hydric soil conditions. Minor tree or small tree components are green alder (*Alnus crispa*), balsam poplar (*Populus balsamifera*) and willows (*Salix* spp.). Common shrubs are prickly rose (*Rosa acicularis*) and highbush cranberry (*Viburnum edule*). The herb layer is composed of scattered plants, predominantly twin-flower (*Linnaea borealis*), bunchberry (*Cornus canadensis*), horsetail (*Equisetum arvense*), fireweed (*Epilobium angustifolium*) and bluejoint reedgrass (*Calamagrostis canadensis*). Mosses, particularly the feathermoss *Hylocomium splendens*, and lichens, particularly *Cladonia* spp., occur but are not common, and do not form thick layers on the forest floor (Foote 1983). Typically, forest floors are covered by a thin layer of leaf litter (Foote 1983).

Figure 34 Vegetation Percent Cover: Forested Reference Standard Sites 6 to 30 Years Since the Last Fire

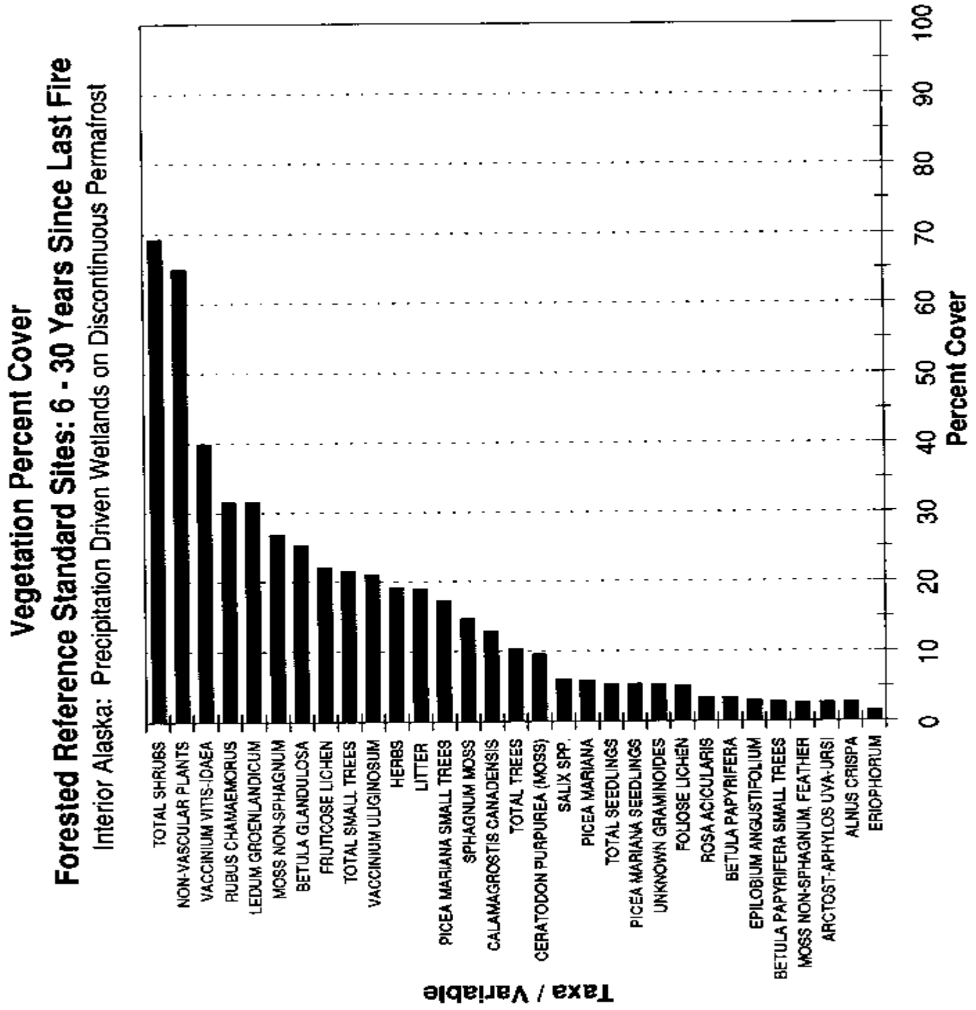


Figure 34.

Towards the end of this stage, black spruce begins to increase in abundance, the moss layer begins accumulating, reducing soil temperatures and beginning the process of permafrost aggradation. As the permafrost layer becomes shallower and the soil becomes more poorly drained, black spruce becomes more dominant and white spruce and hardwoods, such as paper birch and aspen, are not replaced as older trees die.

c. Forested sites >30 years after burn

Trees, primarily black spruce, contribute an average of 31% cover to forested reference standard sites after >30 years since the last fire (Figure 35 and Table 18). The average total cover of small trees is 19% and of seedlings is 8%, virtually all of which is due to black spruce regeneration. The shrub layer (43% cover) commonly is composed of bog Labrador tea, lingonberry, shrub birch, alpine blueberry, cloudberry, willows, and/or crowberry (*Empetrum nigrum)*. There is an average of 21% total herb cover. Common constituents include field horsetail *(Equisetum arvense)*, cotton grasses (*Eriophorum* spp.), unknown grasses, and bluejoint reedgrass. Mosses, lichens, and liverworts contribute the largest percent cover to this community (82%), 10% of which is fruticose lichens, and 4% of which is *Sphagnum* spp. Sample size (n = 19) for reference standard sites in this community type is moderate and is likely to represent much of the range of variation for past burn intensities and stand ages.

d. Shrub communities

Communities dominated by shrubs are one major variant within the forested burn cycle described above. Shrub communities form under two kinds of conditions: (1) under repeated burning, especially with short intervals between burns; and (2) with conditions of increased flooding, or higher water tables which result from thawing of permafrost and subsidence of the ground surface. Under these conditions, shrub communities may persist for very long periods of time without undergoing succession to forest.

Where fires occur repeatedly, and especially where the interval between burns is short, shrub communities dominate sites because there is not enough time between burns for trees to establish. Dominant shrubs immediately following fire tend to be fast growing species that can rapidly colonize newly disturbed areas such as willows (*Salix* spp.) and alders (*Alnus* spp.). In interior Alaska, many of the ericaceous shrubs, such as Labrador tea (*Ledum groenlandicum*) and narrow leaf Labrador tea (*L. decumbens*) also rapidly colonize recently burned sites. Shrub communities with a high frequency of fires usually have a cover of mosses, lichens and liverworts that is similar to that in the 6 to 30 year old forested community, and a herbaceous layer comprised mostly of sedges and cottongrasses.

Where increased flooding has resulted from thawing of permafrost, for example in collapse scar bogs, the shrub community is dominated by ericads such as lingonberry, bog blueberry, leatherleaf, Labrador tea, and dwarf and bog birches. Cottongrasses and sedges dominate the herb layer and mosses form a thick layer. These shrub communities most closely resemble the shrub reference standard sites. These communities may progress to black spruce forests over

Figure 35. Vegetation Percent Cover: Forested Reference Standard Sites >30 Years Since the Last Fire

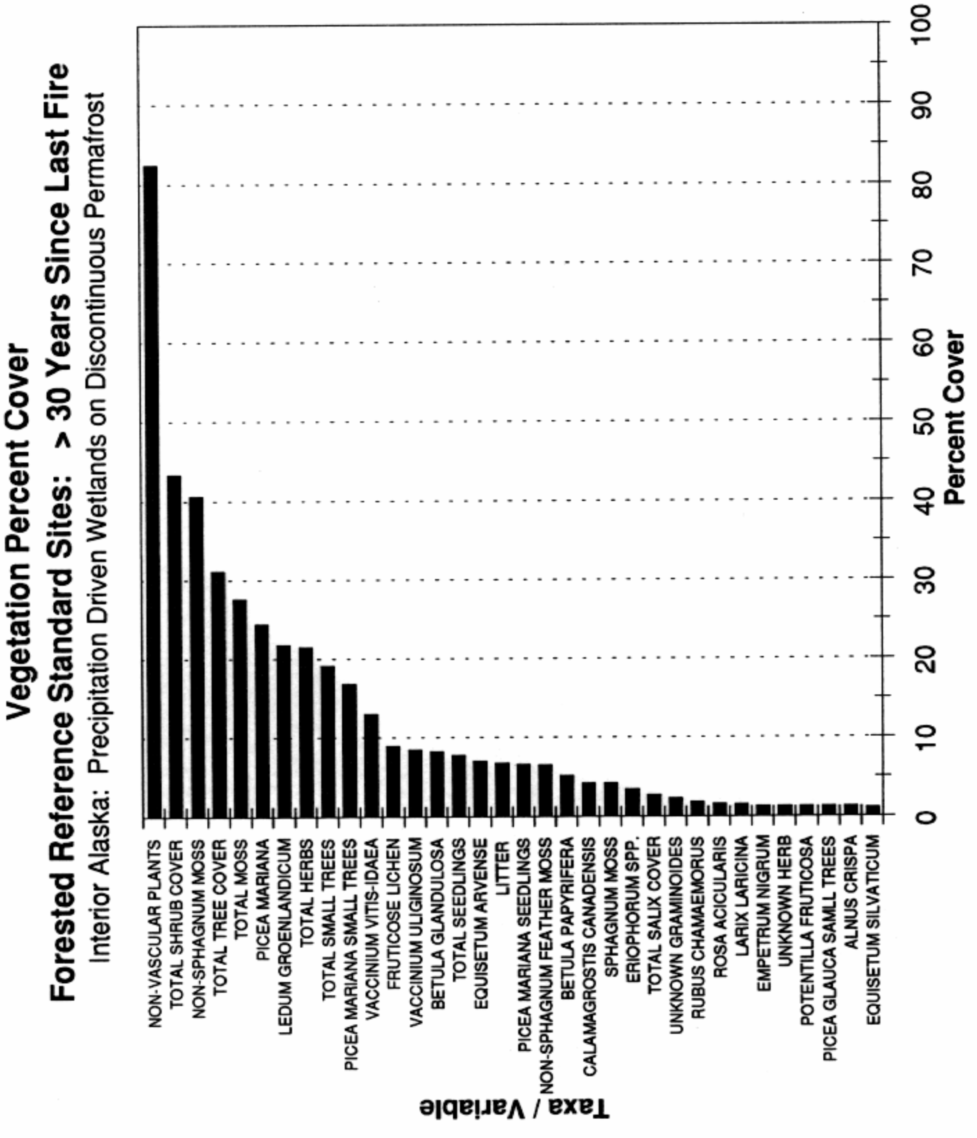


Figure 35.

time as the accumulation of mosses and organic soil horizons raises the surface elevation to the point that conditions are drier and tree regeneration is possible.

e. Sedge tussock communities

Sedge tussock communities form within the burn cycle in areas where inundation is increased as a result of fire and subsequent thawing of permafrost, so that these sites become inundated or saturated for long or very long duration (*e.g.,* ≥30 days during the growing season). These sites become too wet for tree growth and especially for tree regeneration. Shrubs and sedges dominate these communities immediately after a burn, with the herbaceous strata, composed mostly of sedges, becoming more and more dominant over time (Foote 1983). Once sedge tussock communities become established, they may persist for long periods.

3. Other reference sites

This discussion profiles all sites that had evidence of anthropogenic alteration (*i.e.,* "other" reference sites: the portion of the reference set that did not meet reference standard criteria). Most of these sites were probably forested communities prior to disturbance or alteration, but the authors do not exclude the possibility that one or more of the reference sites were shrub or sedge tussock community types before alteration (Figure 36 and Table 17). In altered sites, herbs are the dominant strata, followed by shrubs. Other reference sites typically lack a forested component, with an average tree cover of 4%. Trees when present are primarily black spruce. In these sites seedlings and small trees are also rare or absent, with a combined average cover of seedling/small tree strata of 14%. In the seedling/small tree strata, paper birch and quaking aspen *(Populus tremuloides)* had the highest cover values (4% each), followed by black spruce (3%) and white spruce (1%). Willow species (24%), shrub birch (12%), alpine blueberry (7%), and bog Labrador tea (7%) dominated shrub layer cover (37% total). Cover of the herb layer (57% total) predominately was composed of bluejoint reedgrass (17%), field horsetail (8%), unknown graminoids (11%), wood horsetail (*Equisetum silvaticum* (6%)), and winter bentgrass (*Agrostis scabra,* (5%)). Mosses, lichens, and liverworts provided 20% cover, *Sphagnum* mosses were lacking and the dominant moss was *Ceratodon purpureus,* which colonizes disturbed mineral soils. Sample size (n = 22) for other (altered) reference sites is moderate and provides a gradient of alteration intensities representative of land uses in the reference domain.

4. Comparison of vegetation across a disturbance and alteration gradient

The Technical Team grouped the sampling sites according to the following combined disturbance (natural processes) and alteration (anthropogenic processes) gradient: (1) no disturbance (undisturbed), (2) burned and recovering, (3) cleared and recovering, (4) cleared and uncultivated, (5) cleared and cultivated, (6) mined and recovering, and (7) urban. The vegetation structures of land-use groups 2 through 7 were compared with the vegetation structures of the unperturbed sites (reference standard sites that showed no evidence of burn). This comparison is presented below on a stratum-by-stratum basis.

Unperturbed sites had the highest average values among all sites for tree percent cover and tree density (Figures 37 and 38). The only other land-uses with an overstory were "burned and

Figure 36. Vegetation Percent Cover: Other Reference Sites

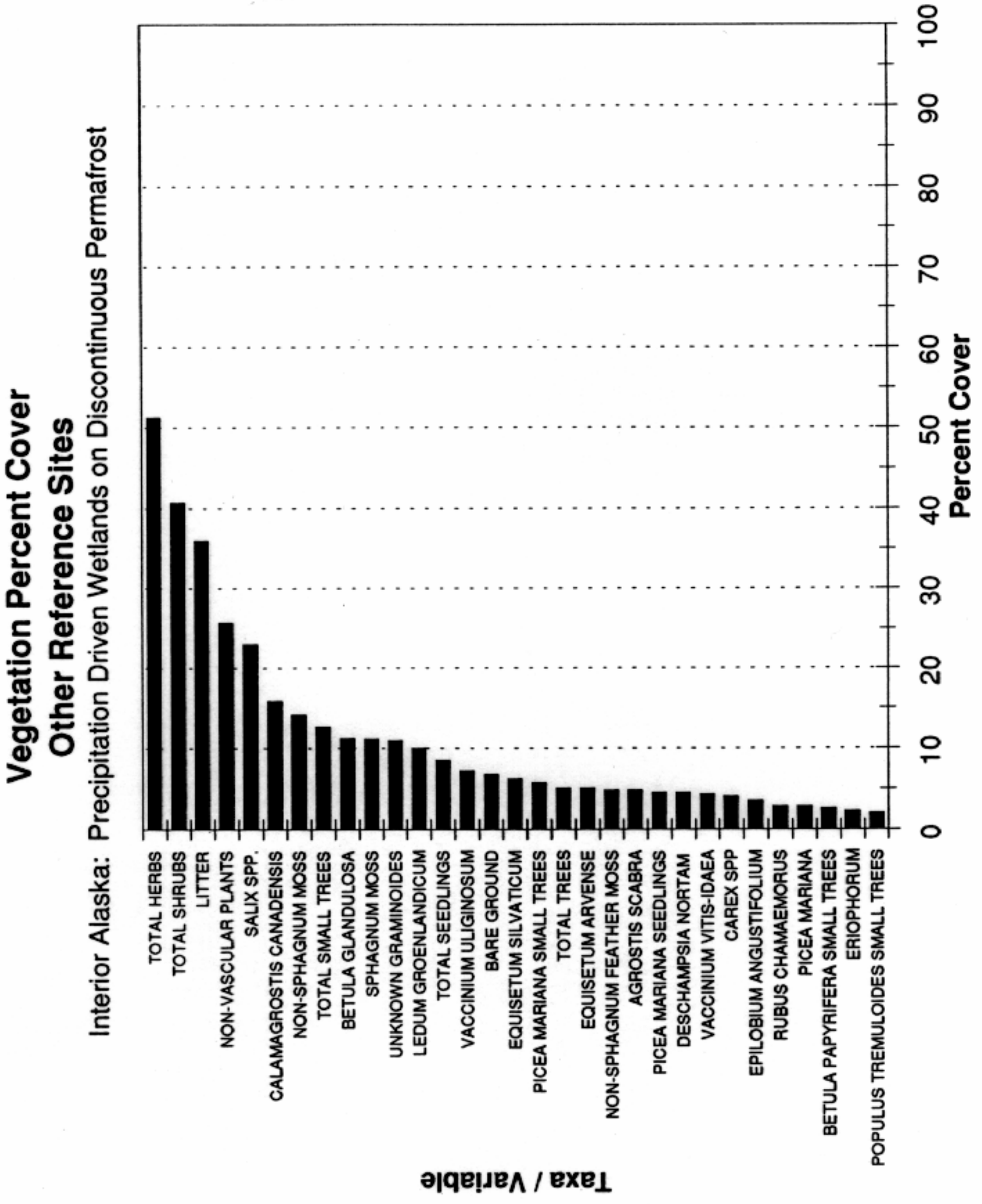


Figure 36.

Figure 37. Tree Percent Cover by Land Use

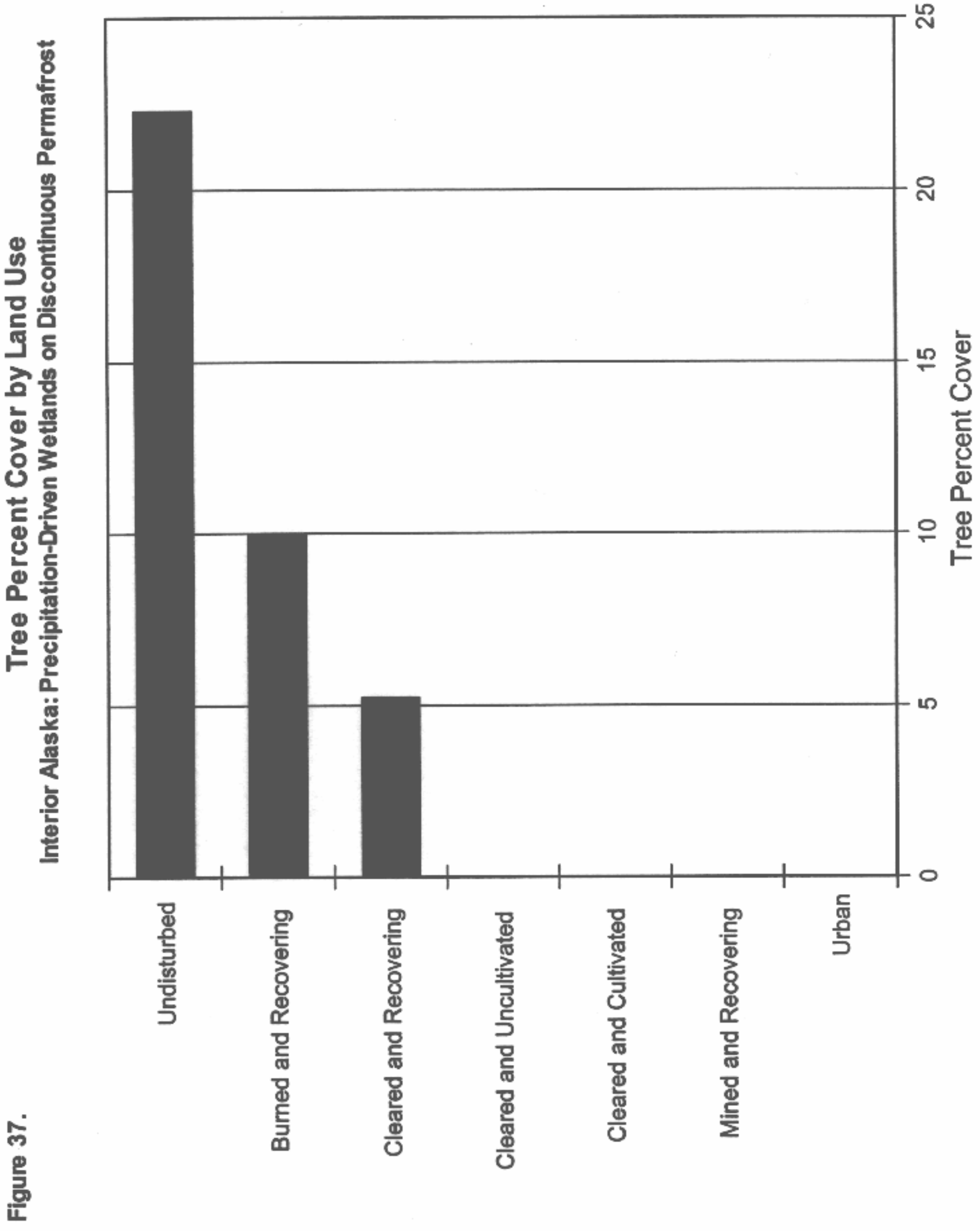
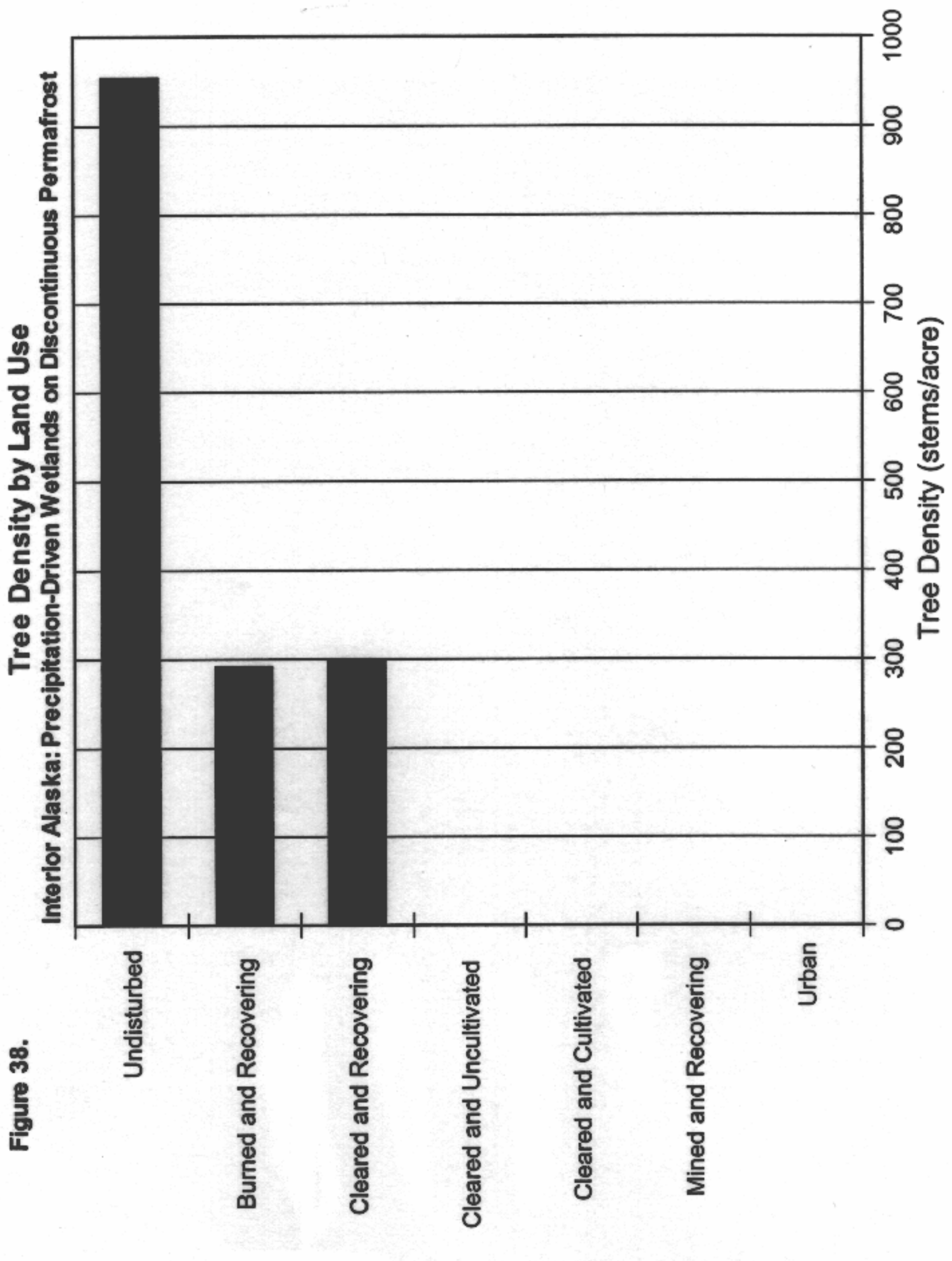


Figure 38. Tree Density by Land Use



recovering" and "cleared and recovering." Unlike clearing operations, many fires do not kill all the trees in an area, and this fact is reflected in higher tree values for the "burned and recovering" sites than for the "cleared and recovering" sites.

Tree regeneration (small trees and seedlings) is evident in the undisturbed "burned and recovering," and "cleared and recovering" land-use groups (Figures 39 and 40). In particular, "cleared and recovering" sites have similar or greater values than the "undisturbed" sites for small tree and seedling densities. There was no evidence of trees or tree regeneration in the "cleared and uncultivated," "cleared and cultivated," "mined and recovering," or "urban" sites. "Cleared and uncultivated" and "cleared and cultivated" sites are cleared frequently and "urban" sites commonly are inhospitable to tree species (*e.g.,* asphalt, clearing operations). Field teams sampled the "mined and recovering" sites in the data set <8 yr. after mining operations had ceased, but trees likely will establish on these sites in the future. Mining operations significantly alter soils and deplete natural seed banks, both of which prolong time necessary for overstory regeneration.

Shrub cover values of "burned and recovering" (41%), "cleared and recovering" (56%), and "undisturbed" sites (52%) are similar (Figure 41). However, average shrub species composition of the "cleared and recovering" sites is dissimilar to that of the "burned and recovering" and "undisturbed" groups. For example, willow species have an average of 51% cover in the "cleared and recovering" sites, 7% in the "burned and recovering" sites, and 3% in the "undisturbed" sites (Table 19).

Snags and coarse wood are present on "undisturbed" sites and are particularly abundant in "burned and recovering" sites (Figures 42 and 43, Table 19). Neither the urban sites nor those that had been cleared contained a significant amount of coarse wood or snags. The coarse wood present in the "mined and recovering" sites was in the form of a pile of brush that had been pushed into a corner of one mining area. Regularly distributed coarse wood was not a common feature in the mining areas visited during this study.

5. *Vegetation Ordination*

The Technical Team ordinated vegetation data from the reference sites (Figure 44) using the DCA (Hill 1979) option in CANOCO (ter Braak 1987). DCA Axis 1 (eigenvalue = 0.53) explains 12% of the cumulative variance in the data. A lack of trees, small trees, and snags, and few mosses, lichens, or liverworts, and an abundance of native and non-native weedy herbaceous species characterize sites that are high on the axis; most are not reference standard sites. One reference standard site, Site 8, is high on this axis. Site 8 is a large collapse scar bog that had no trees or small trees, probably because the site was extremely wet. Abundant small trees and seedlings characterize sites that are in the middle of this axis. The reference standard sites in this range are predominantly post-fire forested, shrub, and sedge tussock community types. Abundant trees, small trees, snags, and mosses, lichens, and liverworts characterize sites that are low on the axis; most are reference standard sites. Black spruce and white spruce are prevalent at these sites. The only site low on the axis that is not a reference standard site, Site 55, would have been a reference standard site were it not surrounded by urban land uses.

Figure 39. Small Tree Density by Land Use

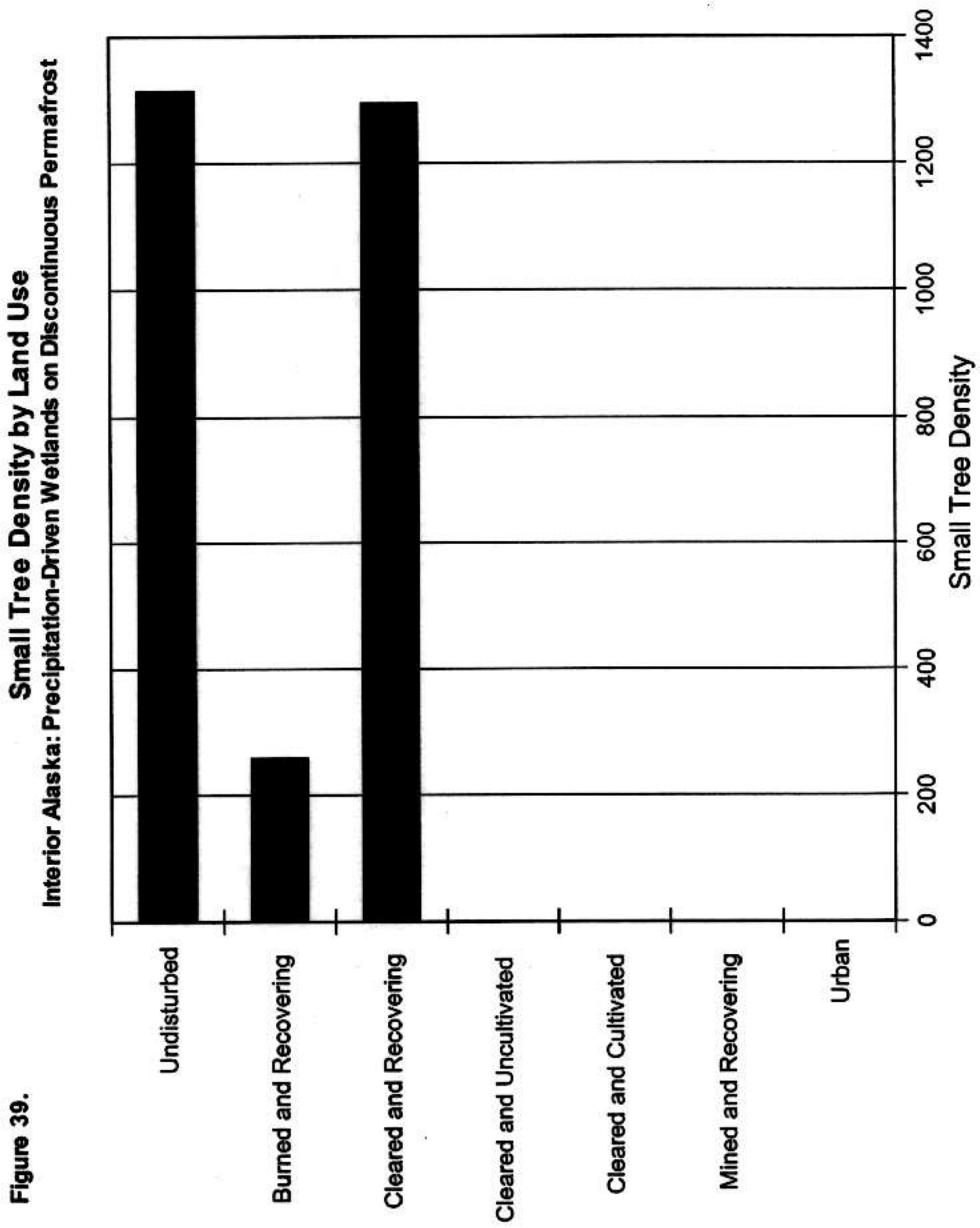


Figure 40. Seedling Percent Cover by Land Use

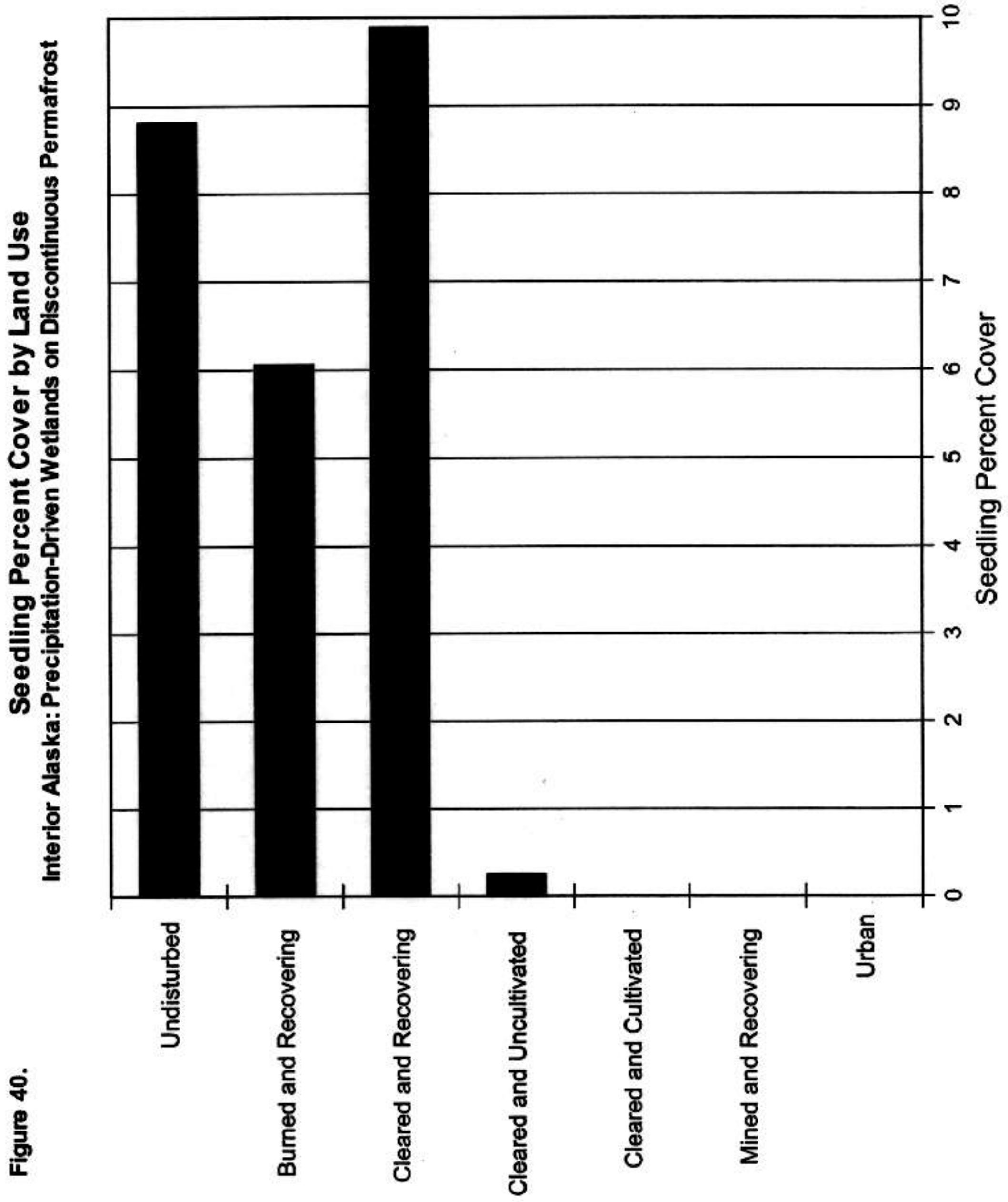


Figure 41. Shrub Percent Cover by Land Use

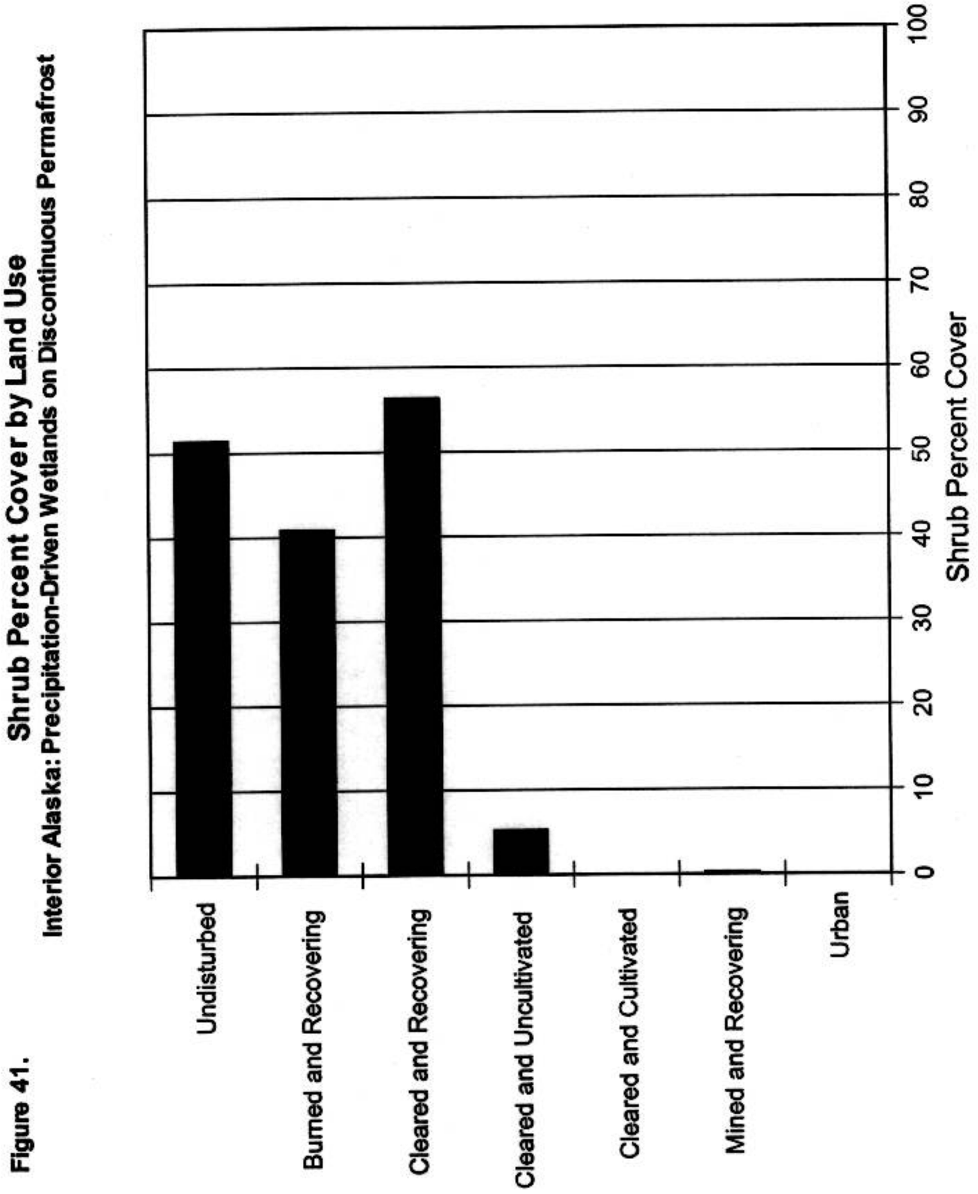


Table 19. Comparison of vegetation across a disturbance gradient.

Variable	**Undisturbed**	**Burned & Recovering**	**Cleared & Recovering**	**Cleared & Uncultivated**	**Cleared & Cultivated**	**Mined & Recovering**	**Urban**
	Density (Number per Acre)						
Tree Density	954	291	298	0	0	0	0
Sapling Density	1,436	258	1,295	0	0	0	0
Seedling Density	1,916	1,502	6,867	5	0	0	0
Shrub Density	731	659	0	0	0	0	0
Snag Density	69	678	0	0	0	0	0
	Percent Cover of Representative Species						
	Tree Percent Cover						
Total Tree Percent Cover	22	10	5	0	0	0	0
Betula papyrifera	3	2	3	0	0	0	0
Picea glauce	0	0	0	0	0	0	0
Picea mariana	18	9	0	0	0	0	0
Populus tremuloides	0	0	2	0	0	0	0
	Small Tree Percent Cover						
Total Small Tree Percent Cover	19	9	17	0	0	0	0
Betula papyrifera	0	2	6	0	0	0	0
Picea glauce	1	1	0	0	0	0	0
Picea mariana	18	5	0	0	0	0	0
Populus tremuloides	0	0	5	0	0	0	0
	Seedling Percent Cover						
Total Seedling Percent Cover	9	6	10	0	0	0	0
Betula papyrifera	0	1	3	0	0	0	0
Picea glauce	1	0	2	0	0	0	0
Picea mariana	7	5	0	0	0	0	0
Populus tremuloides	0	0	4	0	0	0	0
	Shrub Percent Cover						
Total Shrub Percent Cover	51	41	56	5	0	0	0
Alnus crispa	0	4	0	0	0	0	0
Betula glandulosa	16	5	14	0	0	0	0
Chamaedaphne calyculata	3	0	0	0	0	0	0
Ledum groenlandicum	23	19	2	0	0	0	0
Rosa acicularis	1	3	1	0	0	0	0
Rubus chamaemorus	8	0	0	0	0	0	0
Salix spp.	3	7	51	6	0	0	0
Vaccinium uliginosum	10	9	2	0	0	0	0
Vaccinium vitis-idaea	19	8	2	0	0	0	0
	Herbaceous Percent Cover						
Total Herbaceous Percent Cover	31	33	69	98	86	3	33
Agrostis scabra	0	0	0	33	0	0	19
Calamagrostis canadensis	4	10	24	11	29	0	0
Carex spp.	2	0	7	11	7	0	0
Deschampsia spp.	0	0	0	0	33	0	0
Epilobium angustifolium	0	11	3	5	0	0	19
Equisetum arvense	5	0	8	32	13	0	0

Variable	**Undisturbed**	**Burned & Recovering**	**Cleared & Recovering**	**Cleared & Uncultivated**	**Cleared & Cultivated**	**Mined & Recovering**	**Urban**
Equisetum silvaticum	0	1	11	10	4	0	0
Eriophorum spp.	13	1	2	0	0	0	0
Polygonum persicaria	0	0	0	10	7	0	0
Unknown graminoids	2	11	16	0	33	0	0
	Cryptogram Percent Cover						
Total Cryptogram Percent Cover	76	61	14	2	13	0	12
Ceratodon purpurea	0	5	2	0	0	0	0
Foliose Lichen	0	3	0	0	0	0	0
Fruticose Lichen	6	16	0	0	0	0	0
Spagnum Moss	18	0	0	0	0	0	0
Non-spagnum Moss	30	40	14	2	13	0	12
	Other Percent Cover						
Litter Percent Cover	9	3	65	43	13	0	33
Bare Ground Percent Cover	0	5	1	2	7	0	62

Figure 42. Snag Density by Land Use

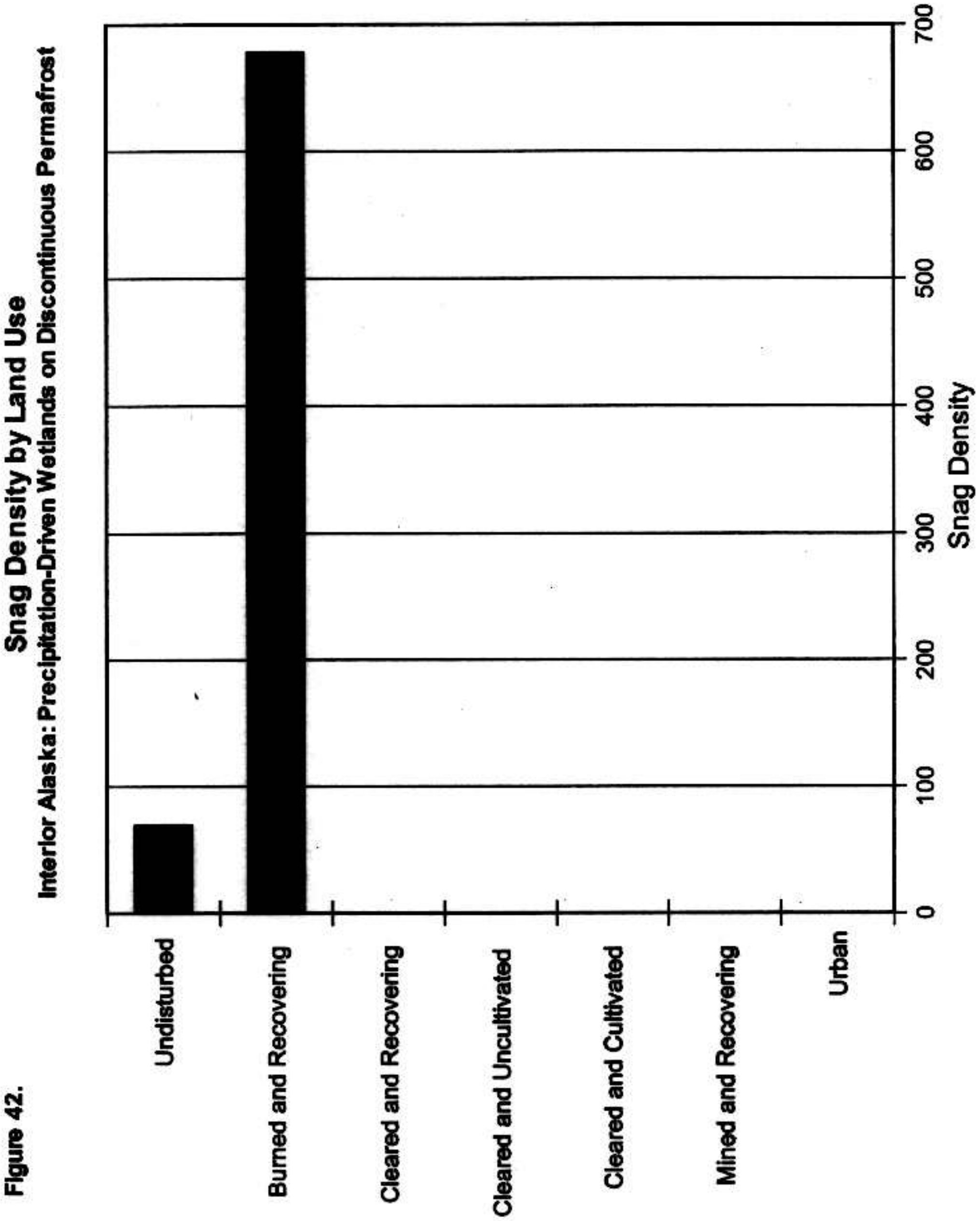


Figure 42.

Snag Density by Land Use

Interior Alaska: Precipitation-Driven Wetlands on Discontinuous Permafrost

Figure 43. Coarse Wood Pieces/Acre by Land Use

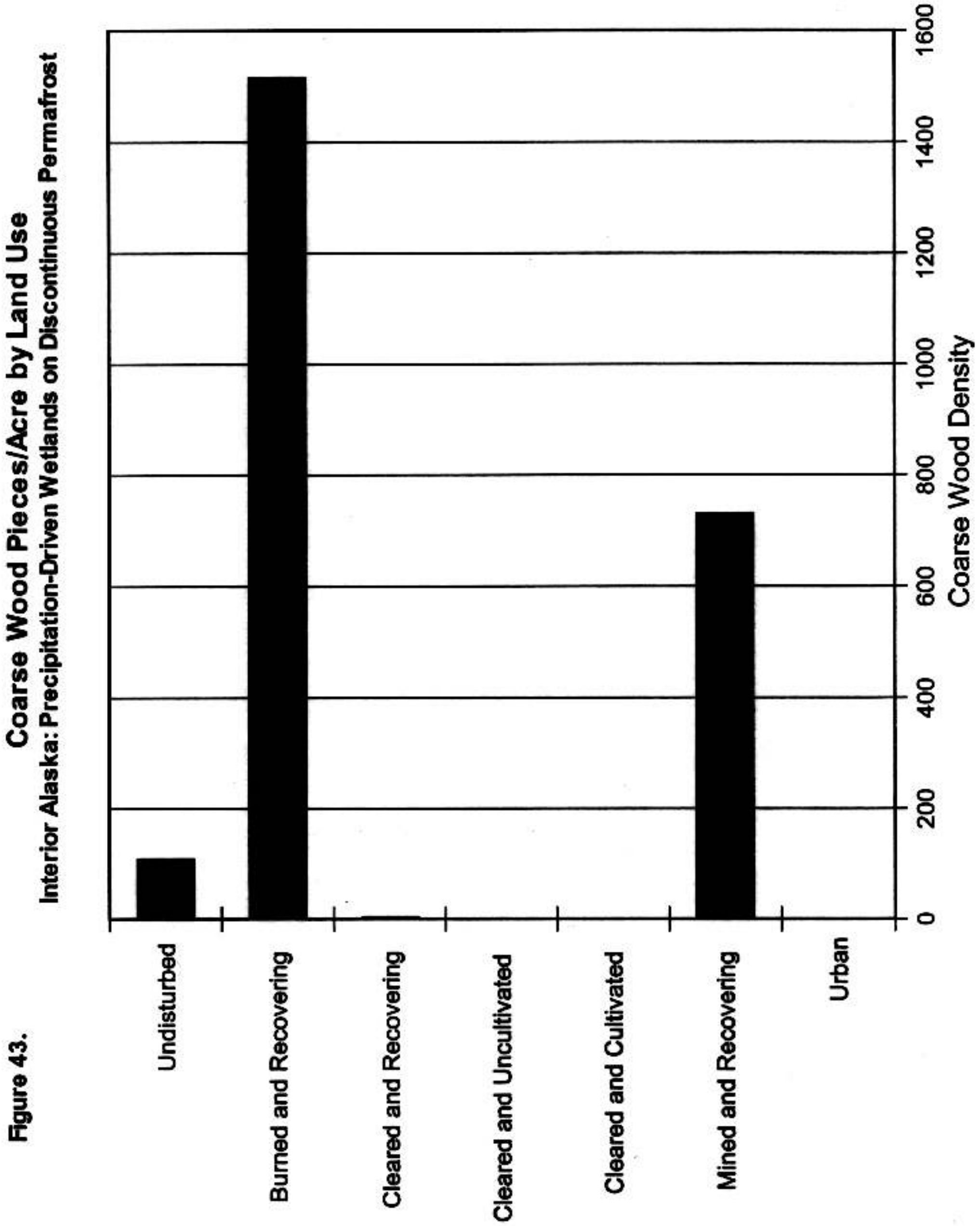


Figure 44. Vegetation DCA: Precipitation-Driven Wetlands on Discontinuous Permafrost in Interior Alaska

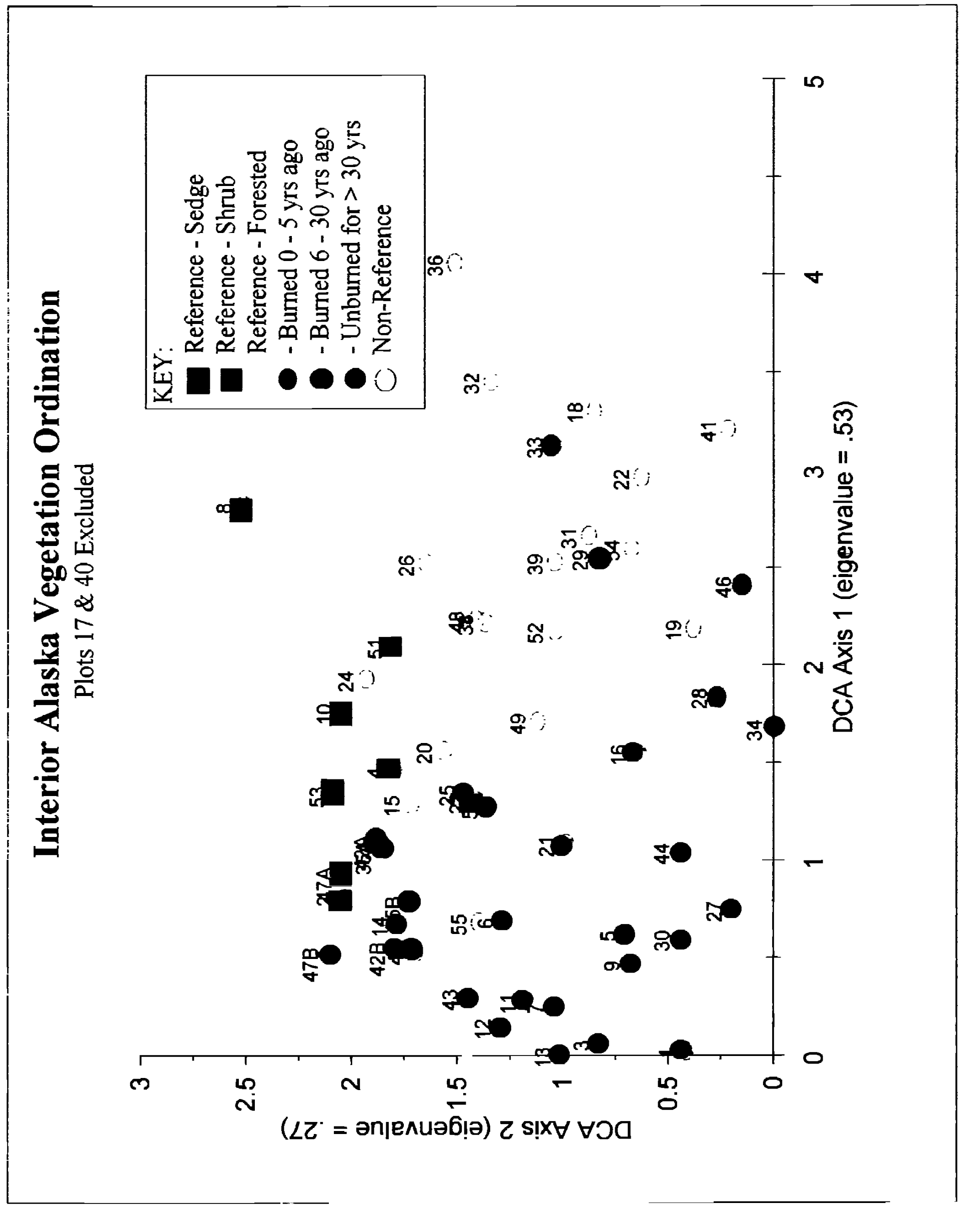


Figure 44.

DCA Axis 2 (eigenvalue = 0.27) explains an additional 7% of the cumulative variance in the data. Sites high on this axis are the wettest sites and are mostly reference standard sedge tussock or shrub communities. These sites are characterized by sedge tussock species such as cottongrass, bog buckbean (*Menyanthes trifoliata*), *Carex bigelowii*, or by ericaceous shrub species such as lingonberry, bog blueberry, leatherleaf, crowberry, and the presence of Larch (*Larix laricina*). Sites low on this axis are characterized by abundant moss cover, higher densities of black spruce trees and low herb cover. Most of these sites are reference standard forested communities burned more than 30 years ago. Sites in the middle of this axis are characterized by presence of white spruce, and paper birch and are either reference standard sites burned 6 to 30 years ago or are other reference sites (*i.e.*, impacted sites).

L. Faunal Support/Habitat

The authors recognized important components of faunal habitat from ecosystem attributes and by referring to associated literature (*e.g.*, Post 1996). Habitat components include those aspects of vegetation structure and species composition, microtopography, and hydrologic conditions that are suitable for supporting animal populations. These components provide potential resting, hiding, feeding, escape and reproductive sites for vertebrates and invertebrates; regulate and moderate fluctuations in temperature; and provide habitat heterogeneity that supports a diverse assemblage of organisms. Although all ecosystem attributes are important for maintenance of habitat integrity, plant community structure largely determines habitat quality for resident and nonresident animals. Thus, plant communities of significant structural complexity often support taxa-rich animal assemblages.

Precipitation-driven wetlands on discontinuous permafrost in Interior Alaska are relatively unproductive faunal habitats, especially on mature sites where mammalian and avian species generally exist at low densities. Wetlands driven by precipitation tend to be nutrient poor and support stress-adapted, slow-growing, evergreen woody plants (*e.g.*, black spruce and bog Labrador tea) that contain antiherbivory compounds unpalatable to vertebrate herbivores (Bryant and Kuropat 1980, Bryant 1984). Nevertheless, the great expanse of heterogeneous, unimpacted habitat of Interior Alaska, much of it wetland of the regional subclass, supports significant animal populations (Post 1996). Animal populations influence plant communities and other wetland functions through herbivory, seed dispersal, short-circuiting nutrient cycles, and influencing site microtopography.

1. Characteristic Amphibian, Avian, and Mammalian Fauna and Their Habitats

Interior Alaska has no reptiles and only one species of amphibian, the wood frog (*Rana sylvatica*)(Hodge 1976). A large number of avian species at least occasionally use precipitation-driven wetlands on discontinuous permafrost in Interior Alaska (Post 1996), but only a handful of those species, mainly birds of prey and songbirds, find these wetlands optimal foraging or breeding habitat (Table 20). A diversity of carnivores and their small rodent and lagomorph prey account for most characteristic mammals of wetlands of the regional subclass (Table 20). As with birds, additional mammalian species use these wetlands to some extent but are less strongly associated with the subclass than with other habitats, have limited distributions within the potential reference domain, or occur at very low densities (Post 1996).

Wood frogs breed in ponds, bogs, and fens after overwintering in hibernacula in leaf litter (Kirton 1974). Post-breeding habitats include moist wooded areas, frequently far from water. Habitat use by wood frogs is not well documented in Alaska, but use of the regional subclass, especially areas of standing water for breeding and transit of, or foraging in, surrounding wetland habitat, is probable (Post 1996).

Table 20. Avian and Mammalian Species Associated with Precipitation-Driven Wetlands on Discontinuous Permafrost in Interior Alaska (*after* Post 1996).

AVIAN SPECIES	
Waterbirds, Cranes, and Shorebirds	
Mew Gull (*Larus canus*)	Lesser Yellowlegs (*Tringa flavipes*)
Sandhill Crane (*Grus canadensis*)	Common Snipe (*Gallinago gallinago*)
Raptors	
Northern Harrier (*Circus cyaneus*)	Great Gray Owl (*Strix nebulosa*)
American Peregrine Falcon (*Falco peregrinus anatum*)	Short-Eared Owl (*Asio flammeus*)
Great Horned Owl (*Bubo virginianus*)	Boreal Owl (*Aegolius funereus*)
Northern Hawk Owl (*Surnia ulula*)	
Game Birds	
Spruce Grouse (*Dendragapus canadensis*)	
Passerine Birds	
Gray Jay (*Perisoreus canadensis*)	Yellow-Rumped Warbler (*Dendroica petechia*)
Ruby-Crowned Kinglet (Regulus calendula)	Savannah Sparrow (*Passerculus sandwichensis*)
Gray-Cheeked Thrush (Catharus minimus)	White-Crowned Sparrow (*Zonotrichia leucophrys*)
Swainsons's Thrush (*Catharus ustulatus*)	Dark-Eyed Junco (*Junco hyemalis*)
American Robin (*Turdus migratorius*)	Common Redpoll (*Carduelis flammea*)
Bohemian Waxwing (*Bombycilla garrulus*)	
MAMMALIAN SPECIES	
Insectivores	
Common Shrew (*Sorex cinereus*)	Dusky Shrew (*Sorex monticolus*)
Rodents and Lagomorphs	
Red squirrel (*Tamiasciurus hudsonicus*)	Yellow-Cheeked Vole (*Microtus xanthognathus*)
Northern Red-Backed Vole (*Clethrionomys rutilus*)	Snowshoe Hare (*Lepus americanus*)
Meadow Vole (*Microtus pennsylvanicus*)	

Table 20 Species (con't)

Carnivores	
Wolf (*Canis lupus*)	Marten (*Martes americana*)
Red Fox (*Vulpes vulpes*)	Ermine (*Mustela erminea*)
Lynx (*Lynx canadensis*)	Black Bear (*Ursus americanus*)
Ungulates[1]	
Moose (*Alces alces*)	Barren Ground Caribou (*Rangifer tarandus granti*)

1. Moose and caribou use wetlands of the regional subclass; however, use differs substantially between community types. Most community types of the subclass are not optimal habitats for ungulates.

Among the avifauna, raptors, mainly owls, strongly associated with the regional subclass key on abundant small mammals occupying the forest floor. Other raptors, moderately likely to forage in these wetlands (Post 1996), prey on birds as well as small mammals. Mew gulls (*Larus canus*), waterbirds, often nest in black spruce trees. Sandhill cranes (*Grus canadensis*) breed and forage in open bog and shrub wetlands within the regional subclass. Lesser yellowlegs (*Tringa flavipes*) breed and forage in sparsely treed wetlands. Spruce grouse (*Dendragapus canadensis*) forage on insects and plants, including spruce needles and alpine blueberries, and roost in spruce trees. Passerines feed on seeds and the abundant insect fauna associated with black spruce (Werner 1983) and the forest floor. Multiple vegetative strata in the forested community type provide habitat diversity for avian species adapted to use of differing layers within the plant community. Trees and snags provide habitat for nesting and perching, but only the largest trees provide suitable habitat for species that require cavities for nesting.

With respect to mammals, the herbaceous stratum and moss ground cover of wetlands of the regional subclass provide optimal cover for shrews (*Sorex* spp.) and microtine rodents. Several shrubs (*e.g., Vaccinium* spp.) provide seeds and fruits for rodents, as well. Dense tree and shrub cover affords snowshoe hares (*Lepus americanus*) important refuge from predators as well as forage. Small carnivores such as ermine (*Mustela erminea*) and marten (*Martes americana*) forage on the forest floor and in trees in search of birds, voles, hares, and red squirrels (*Tamiasciurus hudsonicus*). Ermine and marten use post-burn vegetation, although marten are strongly associated with mature forests as well. Intermediate carnivores, such as lynx (*Lynx canadensis*) search for hares and other prey in forest and shrub habitats, but avoid recently burned areas. Large carnivores such as the wolf (*Canis lupus*) range widely in large territories in search of, primarily, large ungulate prey. The black bear (*Ursus americanus*) regularly uses precipitation-driven wetlands for foraging on succulent shoots of herbaceous plants and on berries. Moose (*Alces alces*) and barren-ground caribou (*Rangifer tarandus granti*) use wetlands of the regional subclass to the extent that preferred forage species are present. Willows are particularly important to moose and, along with hardwood regeneration, are likely to occur in the 6 to 30 yr. old forested community type. Likewise, fruticose lichens and cotton grass important to caribou occur in the >30 yr. old forested and sedge tussock community types, respectively. More complete discussion of fauna and habitats associated with precipitation-driven wetlands on discontinuous permafrost in Interior Alaska can be found in Post (1996).

2. *Range of Variation in Faunal Support/Habitat Structure and Use*

Structure of the plant community types included within the regional subclass varied as discussed in the preceding vegetation section (Figures 31 - 43 and Tables 17 - 19). Faunal species composition and use may be expected to vary between community types due to differences in plant community structure and plant species composition. For example, the post-fire forested community types are particularly important for faunal species adapted to successional vegetation (e.g. moose). Likewise, tree density is a major structural component of faunal habitat that varies widely, even within the >30 yr. old forested community type. Tree density likely affects the local distribution of tree-foraging or -nesting birds, effectiveness of predator-escape cover for small mammals, and small mammal distribution. Although simple inferences about distribution of animal use among the community types used in this regional guidebook are possible, habitat-specific distribution information, especially for shrub and sedge tussock community types, is not well documented in the literature by community type. A thorough review of the literature for species known to occur in the reference domain would provide additional information on expected animal use by community type.

Field teams also counted snags, coarse down and dead wood, the presence and abundance of willow, various evidence of animal use, and number of trails crossing a 200 ft (61 m) transect at each site. Specific indicators of animal use included red squirrel middens, small (≤4 inches (10 cm) wide) animal trails, large (>4 inches (10 cm) wide) animal trails, animal bedding sites, plant browsing, bark gnawing, scat, bird nests or nest cavities, tracks, fur, bark clawing, dirt scrapes, and tree rubs. The number of different indicators found at reference sites showed that animal use is prevalent throughout the gradient of land uses, except at heavily altered urban sites (Figure 45). The implication of these data is that fauna continue to use altered sites at some level (perhaps reduced) of intensity as long as forage and cover requirements are still present to some degree. Practical experience shows that moose as well as smaller carnivores and herbivores do use urban, suburban, and rural areas throughout the year for forage and as corridors to other habitats.

Frequency of animal use can be inferred from development and maintenance of animal trails, which, for large mammal traffic, deepen over time and become less vegetated if frequently used. Data from reference sites (Figure 46) suggest that the number of trails crossing a 200 ft (61 m) transect may be a slightly more sensitive measure of faunal use at some sites than summed indicators of faunal use. As the intensity and frequency of anthropogenic disturbance increased, the number of trails decreased or they were absent. Again, impacted sites were not usually devoid of animal use, rather animals avoided frequent use of such areas.

The authors conclude that evidence of animal use, while useful, is subject to large uncertainties related to timing and duration of site visits, cyclic fluctuations of animal populations characteristic of the boreal environment, and skill of observers in recognizing signs of animal use. In this regard, the structure and composition of the plant community may be a good proxy for animal use (*i.e.*, habitat potential), although it still cannot account for characteristics of the physical (*e.g.*, climate) or trophic (*e.g.*, predator density) environment that also control the

Figure 45. Average Number of Different Signs of Animal Use

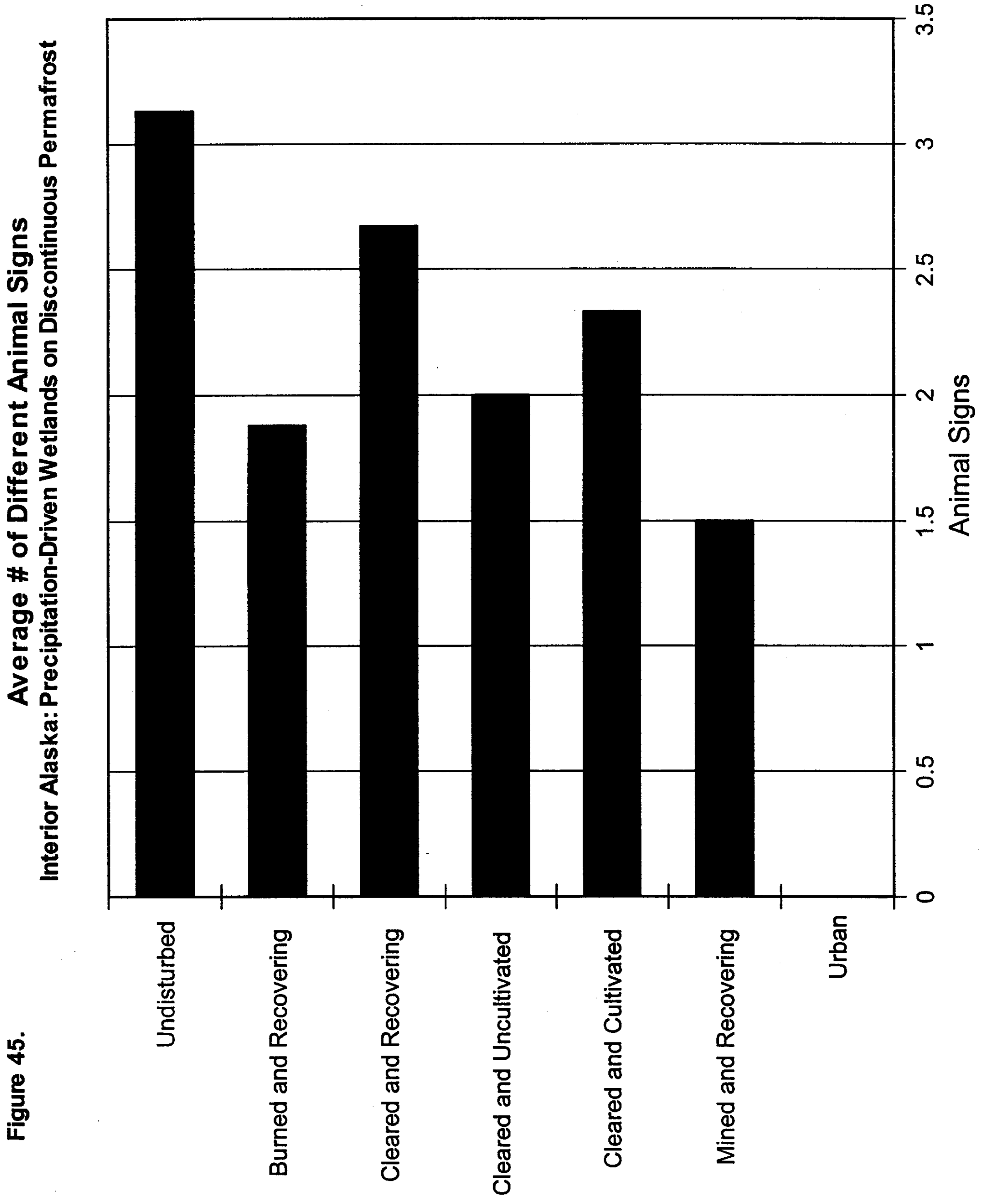
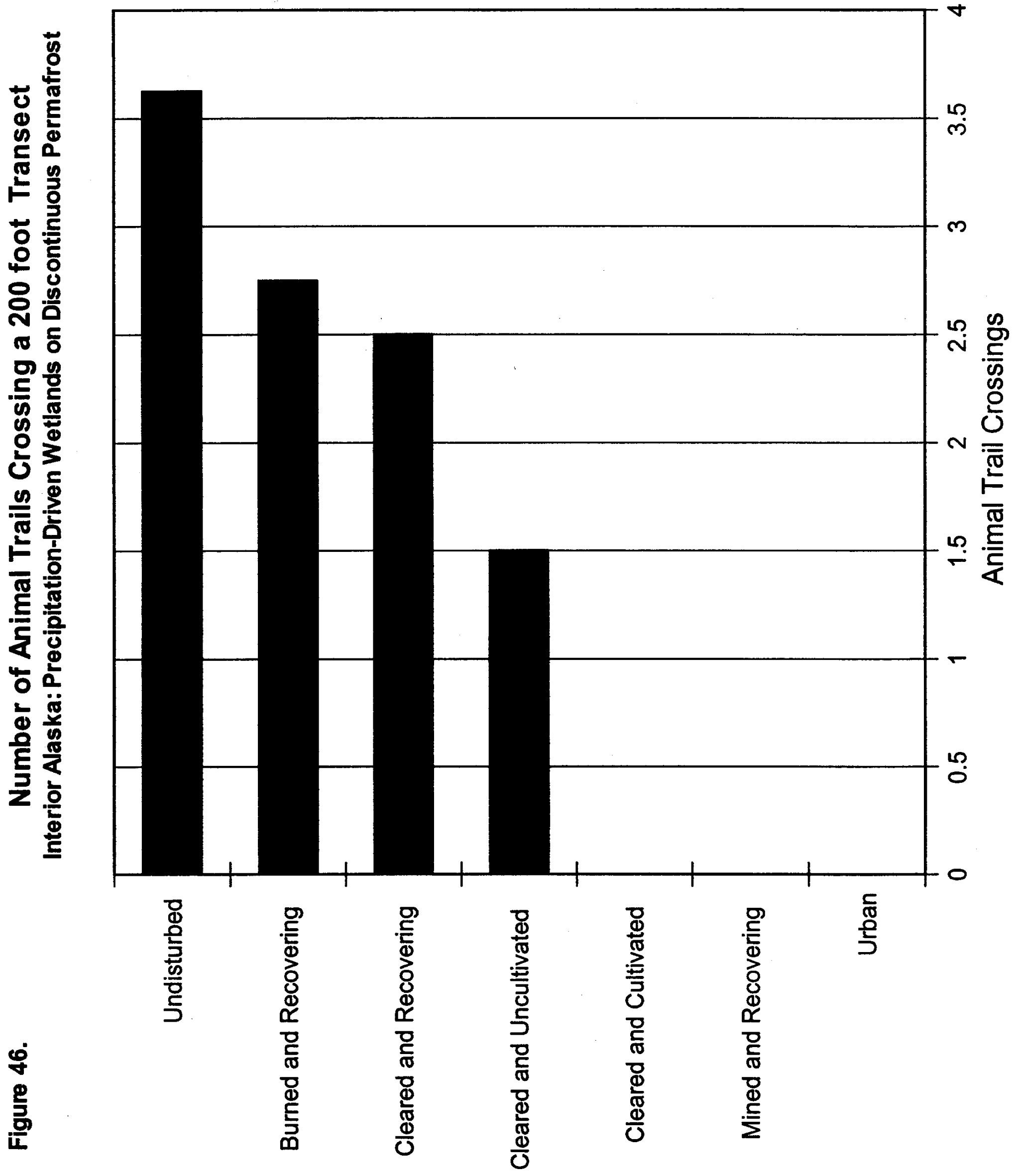


Figure 46. Average Number of Animal Trails Crossing a 200-ft (61-m) Transect



distribution and abundance of animal populations. It should be clear that faunal support/habitat results reported herein are not intended to replace more intensive studies of wildlife and animal communities, such as HEP (U.S. Fish and Wildlife Service 1980) or complete and repeated faunal surveys of parcel over a period of years.

VI. WETLAND FUNCTIONS AND ASSESSMENT MODELS FOR PRECIPITATION-DRIVEN WETLANDS ON DISCONTINUOUS PERMAFROST IN INTERIOR ALASKA

A. Overview

The National, Technical, and A-Team teams identified eight functions performed by precipitation-driven wetlands on discontinuous permafrost in Interior Alaska . These functions fall into four logical groups: hydrology, biogeochemistry, plant community, and faunal support/ habitat (Table 21) All but one of these functions are performed at some level at all sites within the subclass. The exception is, organic carbon export from sedge tussock wetlands. This function is performed only at selected sites in the sedge tussock community type, as discussed in the descriptions of functions that follow.

A total of 17 variables are used to describe each of the eight functions discussed in this Guidebook (Table 22). The authors considered additional variables during model development, but these variables were not included in the operational draft Guidebook because (1) they were not characteristic to all sites, or (2) reference system data associated with the variable did not show a trend that could be used to predict ecosystem functioning. Variables representing a given function sometimes differ among the five community types found in the regional subclass. These changes in the variables used are the author's attempts to account for the unique characteristics of each community type. For each function, the authors used data from reference standard sites (Appendix C), stratified by community type, to determine reference standard conditions (Table 23) . Following establishment of the reference standard conditions, data from other reference sites (non-reference standard sites), were stratified by community type and used to scale variables.

Each of the eight wetland functions (Table 21) and each of the 17 variables (Table 22) are fully described in the following sections. Descriptions of functions include (1) a definition, (2) a rationale for the function in precipitation-driven wetlands on discontinuous permafrost in Interior Alaska, (3) a discussion of characteristics and processes that influence the function, and (4) a description of the variables used to assess the function, (5) rationale for selection of the variables, and (6) a description of the rationale and formulae used to estimate the appropriate functional capacity indices. These formulae are also listed in Table 24.

Descriptions of each of the 17 variables include the following information:

(1) Definition
(2) Rationale for selection of the variable
(3) A protocol for measuring the variable in the field
(4) Location of reference system data in appendices
(5) Scaling rationale - a description of how reference system data were used to scale the variable
(6) Confidence - a description of the author's confidence that reasonable logic and/or data support scaling .

(7) Scaling - the authors provide a rationale for use of a variable each time it is called by a function.

Table 21. List of Functions By Category.

CATEGORIES OF FUNCTIONS	
HYDROLOGIC 1. Soil Profile Integrity 2. Characteristic Soil Thermal Regime 3. Surface and Near Surface Water Storage	**PLANT COMMUNITY** 6. Plant Community
BIOGEOCHEMICAL 4. Cycling of Elements and Compounds 5. Organic Carbon Export	**FAUNAL SUPPORT/HABITAT** 7. Faunal Habitat Components 8. Interspersion and Connectivity

Table 22. Definition of Variables for Precipitation-Driven Wetlands on Discontinuous Permafrost in Interior Alaska

V_{ASIGN} :	**Animal Sign.** Number of observations of use of the project assessment area by animals.
V_{AQUIC} :	**Aquic Moisture Regime.** Degree to which soils currently experience continuous or periodic saturation and reduction.
$V_{AREAUSE}$	**Assessment Area Use.** Predominant land use within the project assessment area.
V_{CWD} :	**Coarse Woody Debris.** Density (#/acre) and/or volume (ft^3/acre) of coarse woody debris (diameter >2") within the project assessment area. Coarse woody debris includes down wood <45° from horizontal, but not standing snags.
V_{CONTIG} :	**Contiguous Native Plant Communities.** Extent to which the project assessment area is contiguous with, and surrounded by, native plant communities
V_{HERB} :	**Herbs.** Percent canopy cover of herbaceous vegetation including forbs, graminoids, ferns, and fern allies within the project assessment area.
V_{TOPO} :	**Macro/Micro Topographic Complexity.** The degree to which macrotopologic features (e.g., paleo-channels and interfluves) and microtopologic features (e.g., pit-and-mound and hummock-and-hollow patterns) exist on the landscape.
$V_{MOSSLICH}$:	**Mosses, Lichens, and Liverworts**. Percent canopy cover of mosses, lichens, and liverworts within the project assessment area.
V_{OH} :	**Organic Horizons.** The thickness and condition of the surface organic horizon(s) (i.e., Oi and/or Oe and/or Oa horizons) in modal soils within the project assessment area.
V_{VRATIO} :	**Ratio of Native to Non-Native Plant Species.** Percent of the dominant taxa within the project assessment area that are native species.
V_{SHRUB} :	**Shrubs.** Percent canopy cover of shrubs (i.e., multiple stem, woody species) within the project assessment area.
V_{SLM} :	**Silty or Loamy Mantle.** Presence and condition of a silty or loamy mantle (usually $\geq$20 inches thick) within the soil profile in the project assessment area.
V_{SURWAT} :	**Static Surface Water Storage.** Surface water ponding (i.e., static surface and shallow subsurface storage).

$V_{SURFCON}$:	**Surface Connections**. Estimate of the presence of surface and shallow subsurface hydrologic flow and thus, hydrologic connection(s) between the assessment area waters/wetlands and down-gradient waters/wetlands.
V_{SURUSE} :	**Surrounding Land Use.** The dominant land use or condition within 1,000 ft of the perimeter of the project assessment area.
V_{TREE} :	**Trees.** Percent canopy cover of trees (single-stem, woody species ≥10 ft tall) and small trees (single-stem, woody species ≥3 ft and ≤10 ft tall) within the project assessment area.
$V_{VSTRATA}$:	**Vegetative Strata.** The average number of vegetation strata present within the project assessment area. Vegetation strata were defined as follows: trees (single-stem, woody species ≥10 ft tall); small trees (single-stem, woody species ≥3 ft and ≤10 ft tall); shrubs (multiple-stem, woody species); herbs, including forbs, graminoids, ferns and fern allies; and mosses, lichens, and liverworts.

Table 23. Reference Standard Conditions for Precipitation-Driven Wetlands on Discontinuous Permafrost in Interior Alaska

Variable	Reference Standard Condition
V_{AQUIC}:	Direct observation of aquic soil conditions and/or evidence of aquic conditions from morphological characteristics indicative of saturated soils in the modal soil profile. Aquic conditions have not been altered by human-induced disruption of the soil profile or thermal regime.
$V_{AREAUSE}$:	Site undisturbed. No significant human-induced alterations.
V_{CONTIG}:	Assessment area is connected to adjacent areas through contiguous native plant communities along 100% of its perimeter. Plant communities must extend at least 100 feet beyond the assessment area boundary.
V_{CWD}:	**Forested Community Type:** Burned 0 - 5 years ago: > 3023 pieces/acre (density) and/or > 1781 cu. ft./acre (volume) Burned 6 - 30 years ago: ≥ 545 pieces/acre (density) and/or > 90 cu. ft./acre (volume)
V_{HERB}:	**Forested Community Types:** Burned 0-5 years ago: >26% CC **and/or** Site unaltered by humans and dominated by native plant species Burned 6-30 years ago: >26% and < 75% CC **and/or** Site unaltered by humans and dominated by native plant species Burned >30 years ago or if no evidence of burn: ≤50% CC an/or site unaltered by humans and dominated by native plant species **Shrub Community Type:** 6-75% CC **and/or** site unaltered by humans and dominated by native plant species **Sedge Tussock Community Type:** >50% CC **and/or** site unaltered by humans and dominated by native plant species
V_{LM}:	Mantle is undisturbed **OR** permafrost exists in the organic mat.
$V_{MOSSLICH}$:	**Forested Community Types:** Burned 0-5 years ago: Depending on fire intensity and time since burn, canopy coverage of moss, lichen and liverworts can vary significantly (*e.g.* from 0% CC to 98% CC). For this reason, the Vmosslich variable is not used for this community type age class. Burned 6-30 years ago: ≥26% CC **and/or** site unaltered by humans and dominated

Variable	Reference Standard Condition
	by native plant species Burned >30 years ago or if no evidence of burn: ≥54% CC **and/or** site unaltered by humans and dominated by native plant species **Shrub Community Type:** ≥37% CC **and/or** site unaltered by humans and dominated by native plant species **Sedge Tussock Community Type:** >10% CC **and/or** site unaltered by humans and dominated by native plant species
V_{OH}:	Surface organic soil horizons are present **and** are undisturbed by human activities. Average thickness of all organic layers combined varies from 5 to >20 inches for mature sites and from 2 **-** >8 inches for post-fire seres <60 years old.
V_{PRATIO}:	100% of dominant species are native.
V_{SHRUB}:	**Forested Community Types:** Burned 6-30 years ago: >26% Canopy cover **and/or** site unaltered by humans and dominated by native plant species Burned > 30 years ago, or if no evidence of burn: >26% Canopy cover **and/or** site unaltered by humans and dominated by native plant species **Shrub Community Type:** >75% Canopy cover **and/or** site unaltered by humans and dominated by native plant species. **Sedge Tussock Community Type:** Canopy cover of shrubs highly variable and usually < 75% (*e.g.* 0 **-** 63% CC was observed at reference standard sites). Site unaltered by humans and dominated by native plant species.
V_{SIGN}:	One or more types of animal sign exist. [Note: Direct observation of animal use = 1 type of animal sign. Do not double count direct sign with fresh tracks, scat, etc.].
$V_{SURFCON}$:	Project assessment area and areas between the project assessment area and adjacent riparian corridor(s) are undisturbed, and no human-induced impediments to surface and shallow subsurface connections or flows exist.
V_{SURUSE}:	Site undisturbed. No significant human-induced alterations.
V_{SURWAT}:	Observation or evidence of surface water ponding (*i.e.*, static storage) **and** the project assessment area is unaltered by human activities.
V_{TOPO}:	The entire project assessment area (100%) is characterized by complex macro and micro topographic relief (*e.g.* Paleo channels, interfluves, pit, hummocks, etc.) and/or the site is unaltered by human activity.
V_{TREE}:	**Forested Community Types 6-30 years old and >30 years old:** Tree and/or small tree canopy coverage ≥ 10%. Site unaltered by humans and dominated by native plant species.

Table 24. Indices of Functions for Precipitation-Driven Wetlands on Discontinuous Permafrost in Interior Alaska

Function 1. Maintenance of Soil Profile Integrity:

Forested Community Types:

If burned 0 to 5 years ago, then
$=(V_{OH} + V_{SLM} + (V_{HERB} + V_{CWD})/2)/3$

If burned 6 to 30 years ago, then
$=(V_{OH} + V_{SLM} + (V_{TREE} + V_{SHRUB} + V_{HERB})/3)/3$

If burned > 30 years ago, or if no evidence of burn, then
$=(V_{OH} + V_{SLM} + V_{AQUIC} + (V_{TREE} + V_{SHRUB} + V_{HERB})/3)/4$

Shrub Community Types:

$=(V_{OH} + V_{SLM} + V_{AQUIC} + (V_{SHRUB} + V_{HERB})/2)/4$

Sedge Tussock Community Types:

$=(V_{OH} + V_{SLM} + V_{AQUIC} + (V_{SHRUB} + V_{HERB})/2)/4$

Function 2. Maintenance of Characteristic Thermal Regime:

Forested Community Types:

If burned in the last 0 to 5 years, then
$=(V_{OH} + V_{HERB} + V_{SLM})/3$

If burned in the last 6 to 30 years, then
$=(V_{OH} + (V_{TREE} + V_{SHRUB})/2 + V_{SLM})/3$

If burned > 30 years ago or if no evidence of burn, then
$=(V_{OH} + V_{TREE} + V_{SLM})/3$

Shrub Community Types:

$=(V_{OH} + (V_{SHRUB} + V_{HERB})/2 + V_{SLM})/3$

Sedge Tussock Community Types:

$=(V_{OH} + (V_{SHRUB} + V_{HERB})/2 + V_{SLM})/3$

Function 3. Surface and Near Surface Water Storage:

Forested Community Types:

If burned in the last 0 to 5 years, then
$=(V_{MTOPO} + V_{OH} + V_{SLM})/3$

If burned in the last 6 to 30 years, then
$=(V_{MTOPO} + V_{OH} + V_{SLM})/3$

If burned > 30 years ago or if no evidence of burn, then
$=((V_{MTOPO} + V_{SURWAT})/2 + V_{OH} + V_{SLM}+ V_{AQUIC})/4$

Shrub Community Types:

$=((V_{MTOPO} + V_{SURWAT})/2 + V_{OH} + V_{SLM} + V_{AQUIC})/4$

Sedge Tussock Community Types:

$=((V_{MTOPO} + V_{SURWAT})/2 + V_{OH} + V_{SLM}+ V_{AQUIC})/4$

Function 4. Maintain Cycling of Elements and Compounds:

Forested Community Types:

If burned 0 to 5 years ago, then
$=((V_{OH} + V_{HERB} + V_{CWD})/3 + V_{SLM})/2$

If burned 6 to 30 years ago , then
$=((V_{OH} + V_{TREE} + V_{SHRUB} + V_{CWD})/4 + V_{SLM})/2$

If burned > 30 years ago, or if no evidence of burn, then
$=((V_{OH} + V_{TREE} + V_{SHRUB})/3 + V_{SLM} + V_{AQUIC})/3$

Shrub Community Types:

$=((V_{OH} + V_{SHRUB} + V_{HERB})/3 + V_{SLM} + V_{AQUIC})/3$

Sedge Tussock Community Types:

$=((V_{OH} + V_{SHRUB} + V_{HERB})/3 + V_{SLM} + V_{AQUIC})/3$

Function 5. Organic Carbon Export:

Sedge Tussock Community Types:

$=(V_{SURFCON} \text{ x } ((V_{SHRUB} + V_{HERB})/2 + V_{OH} + V_{AQUIC})/3)^{1/2}$

Function 6. Maintain Characteristic Plant Community:

Forested Community Types:

If burned in the last 0 to 5 years, then
$=(V_{HERB} + V_{PRATIO})/2$

If burned in the last 6 to 30 years, then
$=((V_{TREE} + V_{SHRUB} + V_{HERB} + V_{MOSSLICH})/4 + V_{PRATIO})/2$

If burned > 30 years ago or if no evidence of burn, then
$=((V_{TREE} + V_{SHRUB} + V_{HERB} + V_{MOSSLICH})/4 + V_{PRATIO})/2$

Shrub Community Types:

$=((V_{SHRUB} + V_{HERB} + V_{MOSSLICH})/3 + V_{PRATIO})/2$

Sedge Tussock Community Types:

$=(V_{SHRUB} + V_{HERB} + V_{MOSSLICH})/3 + V_{PRATIO})/2$

Function 7. Maintain Faunal Habitat Components:

Forested Community Types:

If burned in the last 0 to 5 years, then
$=(V_{ASIGN} \text{ x } (V_{MTOPO} + V_{OH} + V_{VSTRATA} + V_{CWD})/4)^{1/2}$

If burned in the last 6 to 30 years, then
$=(V_{ASIGN} \text{ x } (V_{MTOPO} + V_{OH} + V_{VSTRATA} + V_{CWD})/4)^{1/2}$

If burned > 30 years ago or if no evidence of burn, then
$=(V_{ASIGN} \text{ x } (V_{MTOPO} + V_{SURWAT} + V_{OH} + V_{VSTRATA})/4)^{1/2}$

Shrub Community Types:

$=(V_{ASIGN} \text{ x } (V_{MTOPO} + V_{SURWAT} + V_{OH} + V_{VSTRATA})/4)^{1/2}$

Sedge Tussock Community Types:

$=(V_{ASIGN} \text{ x } (V_{MTOPO} + V_{SURWAT} + V_{OH} + V_{VSTRATA})/4)^{1/2}$

Function 8. Maintain Interspersion and Connectivity:

Any Community Type:

$=(V_{AREAUSE} + V_{SURUSE} + V_{CONTIG})/3$

B. Definition of Functions

1. Hydrologic Functions

a. Soil Profile Integrity

1) Definition

This function represents the presence of intact horizons within the soil profile. Soil profiles characteristic of precipitation-driven wetlands on discontinuous permafrost in Interior Alaska have organic horizons and deep silty or loamy mantles. Independent, quantitative measures of this function are the daily temperature (C), moisture (%), and reduction-oxidation potentials (Eh) of the soil with depth, all integrated over one year.

2) Rationale for the Function

Within the regional wetland subclass, soil profile conditions (*i.e.*, intact soil horizons) strongly affect soil thermal, moisture, and redox regimes, and support pedogenic processes. Intact soil horizons are necessary for wetland hydrology and associated processes at many sites within the regional subclass. In addition, pore space within the organic and mineral soil horizons provides subsurface storage of water. The soil profile provides substrates for, and strongly influences, biogeochemical processes that, transform, cycle, and store elements and compounds. The soil profile provides substrates for establishment and maintenance of plant communities. Off-site effects of intact soil horizons include diminished water runoff, element and nutrient export, and diminished sediment transport to adjacent areas.

3) Characteristics and Processes that Influence Soil Profile Integrity

An organic horizon and a deep silty or loamy mantle characterize soil profiles in precipitation-driven wetlands on discontinuous permafrost in Interior Alaska. The organic horizon and deep silty or loamy mantle combine to buffer fluctuations in Characteristic Soil Thermal Regime. Under reference standard conditions in mature community types of the regional subclass, the characteristic soil profile often maintains permafrost near the soil surface.

Organic horizons are ubiquitous within the regional wetland subclass, including at sites where fire has recently occurred. Histosols, such as Pergelic Cryofibrists and Pergelic Cryohemists (See Table 16, for current NRCS taxonomic nomenclature), occur primarily in depressions and regional lows that are saturated for long or very long duration during the growing season (Ping *et al.* 1992). These taxa occur in linear depressions formed in abandoned channels, collapse scar bogs, troughs in high-centered polygonal ground, and on toeslopes in valley bottom positions adjacent to streams. Permafrost generally exists in the organic layer wherever these deep organic deposits are found, except in collapse scar bogs that form by thermokarst processes. The insulating properties of the surface organic horizon primarily maintain permafrost (Ping *et al.* 1992). Organic horizons also occur outside of depressions and regional lows, but depths often are not sufficient to classify such soils as Histosols or Histels. Depths often are sufficient, however, to identify surface organic horizons as histic epipedons (*e.g.*, Histic Cryaquepts).

Typically, the silty or loamy mantle consists of silt size (0.00008 to 0.002 inch (0.002 to 0.05 mm)), or a mixture of sand (0.002 to 0.08 inch (0.05 to 2.0 mm)) and silt size particles of mixed origin. Common sources of these materials include eolian, alluvial and colluvial deposition. A weak platy structure in predominantly silty materials (an effect of horizontal ice lens formation), weak blocky structure, or massive structure (due to lack of significant rooting activity and low clay content) often characterize the silty or loamy mantle. These soils lack significant pore space and structure; thus, hydraulic conductivity is low and the movement of water is very slow. These soils remain saturated or wet for long periods following spring break-up and significant rainfall events.

Important processes affecting, and mediated by, the soil profile include oxidation/reduction (*i.e.*, redox) reactions. These reactions are driven by carbon and are microbially mediated. Saturation and the onset of anaerobic conditions in soils initiates a series of chemical reactions that are a function of the new redox regime. Diffusion of oxygen into a saturated soil is on the order of four magnitudes lower than in aerated soils (Gambrell and Patrick 1978). Many microorganisms prefer oxygen as the terminal electron acceptor in metabolic processes due to a higher energy yield, which makes aerobic systems more efficient than anaerobic systems in organic matter decomposition (Ponnamperuma 1972). As oxygen becomes limiting, both facultative and obligate anaerobic organisms begin to utilize components such as nitrate, oxides of manganese and iron, and sulfates, as terminal electron acceptors. The reduced species of these compounds are the more mobile forms within the soil solution. Denitrification is an important function of wet soils and occurs by the reduction of the nitrate/nitrite solid phase to the gas phase which allows diffusion of nitrogen from the soil system to the atmosphere.

Wetland alteration within the regional subclass usually involves disruption of the characteristic soil profile. This disruption frequently includes complete removal of organic soil horizons, for example during land clearing for agriculture. Because organic horizons account for much of the soil influence on ecosystem processes such as permafrost formation and wetland hydrology, Soil Profile Integrity is an important function. Although disrupted profiles can recover over periods on the order of 100 to 250 years with redevelopment of moss cover and restoration of pedogenic processes, such disruption frequently results in the loss of wetland functions in the near term and as long as the native plant community is suppressed.

4) Description of Variables Used to Assess Soil Profile Integrity

Variables associated with performance of the Soil Profile Integrity function focus on the physical state and soil moisture status of the observed soil profile and potential contribution of vegetation to maintenance of the soil profile. These variables, as described in the following section, are Aquic Moisture Regime (V_{AQUIC}), Coarse Woody Debris (V_{CWD}), Herbs (V_{HERB}), Organic Horizons (V_{OH}), Shrubs (V_{SHRUB}), Silty or Loamy Mantle (V_{SLM}), and Trees (V_{TREE}).

5) Rationale for Selection of the Variables

Aquic Moisture Regime (V_{AQUIC}): Variables associated with Soil Profile Integrity focus on the physical, chemical and hydrologic status of the soil profile and the contribution of vegetation to the maintenance of the soil profile. Mature sites within the regional subclass have aquic soil conditions under reference standard conditions. Disruption of the soil profile affects soil moisture and thermal regimes, often by causing permafrost to thaw with consequent drainage of soil horizons and loss of hydric conditions. Alternatively, shifts from episaturation to endosaturation may occur following anthropogenic perturbation in areas of shallow groundwater over permafrost. Perturbed sites can regain aquic soil conditions with successional development of vegetative cover and an insulating moss layer that promotes development of permafrost and wetland hydrology. Thus, Aquic Moisture Regime is an important component for assessing Soil Profile Integrity in the >30-yr-old Forested, Shrub, and Sedge Tussock community types of the regional wetland subclass.

Coarse Woody Debris (V_{CWD}): Coarse Woody Debris is incorporated in the soil profile as it undergoes decomposition. A change in Coarse Woody Debris therefore can alter soil-building processes. Alterations in soil processes can change characteristics of the soil profile (Daubenmire 1974). Furthermore, the presence of coarse down and dead wood can help stabilize the soil and prevent erosion, as well as provide a substrate for growth of mosses and lichens that also contribute to pedogenic processes. Early post-fire seres characteristically contain large amounts of coarse wood under reference standard conditions, but such wood is much less common in mature post-fire seres and largely absent from Shrub and Sedge Tussock community types. Altered sites frequently have no coarse wood because the wood is stripped along with the organic soil horizons during clearing. This situation contrasts with natural perturbation from fire, which generates large amounts of coarse wood. Coarse Woody Debris thus is an important component for assessing Soil Profile Integrity in the 0- to 5-yr-old Forested Community Type of the regional wetland subclass.

Herbs (V_{HERBS}): A change in vegetative structure can change microclimate and soil-plant interactions and thereby alter soil-building processes. These alterations in soil processes can change characteristics of the soil profile (Daubenmire 1974). For example, root production of herbaceous vegetation adds organic C and tilth to the profile, as does decomposition of aboveground herbaceous litter. Furthermore, live and senescent herb cover help stabilize the soil and prevent erosion. Altered sites sometimes have no herbaceous cover (*e.g.,* agricultural tillage, fills). This situation contrasts with natural perturbation from fire, which produces abundant herbaceous cover by native plants in early post-fire seres. Significant herbaceous cover also characterizes mature Shrub and Sedge Tussock community types. The Herbs variable thus is an important component for assessing Soil Profile Integrity in all community types of the regional wetland subclass.

Organic Horizons (V_{OH}): Reference standard sites from mature seral stages have thick organic soil horizons, and associated soils often are classified as Histosols or Histels. Post-fire seres generally retain organic soil horizons as well; therefore, all profiles in the reference standard condition have organic soil horizons.

Changes in the thickness of organic soil horizons directly represent changes in the soil profile. In addition, intact surface organic soil horizons maintain soil thermal and hydrologic properties (*e.g.,* Dyrness 1982, Woo 1986) whereas decreased thickness or loss of surface organic soil horizons can degrade permafrost (Dyrness 1982, Viereck 1982) and decrease the capacity for surface and near-surface water storage(Kane *et al.* 1981, Roulet 1987). Altered sites of the regional subclass (*e.g.,* land cleared for agriculture) frequently are stripped of organic soil horizons and do not regain them while under intensive land uses (*e.g.,* agricultural tillage). Organic material and associated soil profiles can recover as moss cover and litter accumulate over the 100- to 250-yr fire cycle on sites allowed to re-enter natural successional pathways. Thus, Organic Horizons is an important component for assessing Soil Profile Integrity in all community types of the regional wetland subclass.

Shrubs: A change in vegetative structure can change microclimate and soil-plant interactions and thereby alter soil-building processes. These alterations in soil processes can change characteristics of the soil profile (Daubenmire 1974). Shrubs occur in all community types in the regional subclass and are significant in all but the earliest post-fire seres: average shrub canopy coverages in Sedge Tussock and Shrub community types were 34% and 80%. Shrub biomass turns over at rates of 34 to 43% annually (Chapin 1983) at sites representative of the regional subclass, which adds substantial litter to the surface for decompositional incorporation into organic soil horizons. Furthermore, the root mass of shrubs and their fine woody litter help stabilize the soil and prevent erosion.

Altered sites sometimes have no shrub cover (*e.g.,* agricultural tillage, pasture, hay fields). This situation contrasts with natural perturbation from fire, which produces abundant cover by native shrubs in post-fire seres >5 yr. old. Significant shrub cover also characterizes mature Shrub and Sedge Tussock community types. The Shrubs variable thus is an important component for assessing Soil Profile Integrity in the 6- to 30-yr-old and >30-yr-old Forested community types and in the Shrub and Sedge Tussock community types of the regional wetland subclass.

Silty or Loamy Mantle (V_{SLM}): All soil profiles in the reference standard condition have a deep silty or loamy mantle. Undisturbed silty or loamy mantles often are abrupt textural changes and/or low permeability layers within the soil profile. These mantles tend to be seasonally saturated and/or perch water within the soil profile. Intact finer-grained mantles have lower thermal and hydraulic conductivities, and diffusivities, than coarse-textured soil (Baver 1972, Jury 1991) and thus act to preserve permafrost layers and consequent wetland hydrology.

Altered sites within the regional subclass frequently have disrupted mantles from land clearing or agricultural tillage. Disruption of the mantle represents direct disturbance of the soil profile, and affects site thermal and hydrologic regimes with subsequent deterioration of permafrost. Sites with thin mantles tend toward a long-term or permanent well-drained (nonwetland) state, if permafrost is degraded by fire or anthropogenic disturbance. The degree of disruption or loss of the mantle at anthropogenically modified sites thus affects the potential of the site to recover or maintain wetland hydrology. Where only the surface of the mineral soil is disturbed (*e.g.,* tillage), and the bulk of the fine-grained mantle remains intact, at least partial recovery of thermal and hydrologic characteristics can occur with the cessation of disturbance and progression of ecological succession on the site. Thus, Silty or Loamy Mantle is an important component for assessing Soil Profile Integrity in all community types of the regional wetland subclass.

Trees (V_{TREE}): Tree cover characterizes 6- to 30-yr-old and >30-yr-old Forested community types but is sparse or absent in the other community types within the regional wetland subclass.

A change in the vegetative structure can change microclimate and soil-plant interactions and thereby alter soil-building processes. These alterations in soil processes can change the characteristics of the soil profile (Daubenmire 1974). Specifically, removal of the tree stratum affects site microclimate because unperturbed black spruce canopies intercept incoming short-wave solar radiation and reduce incident radiation reaching forest floors (Petzold 1981, Slaughter 1983), as well as reduce air movement within stands. In addition, a substantial portion of the aboveground net primary production of black spruce (*e.g.*, ~1,000 kilograms (kg) ha^{-1} yr^{-1} (Viereck *et al.* 1983)) eventually returns to the forest floor for decompositional incorporation into soil profiles. Furthermore, trees help stabilize the soil and prevent erosion.

Altered sites (*e.g.,* agricultural lands, cleared rights-of-way, fills) within the regional wetland subclass frequently are devoid of trees. Successional redevelopment of tree cover is rapid upon cessation of site manipulation, however. Over the 100-yr to 250-yr fire cycle, altered sites can return to reference standard condition. The Trees variable thus is an important component for assessing Soil Profile Integrity in the 6- to 30-yr-old and >30-yr-old Forested community types of the regional wetland subclass.

6) Functional Capacity Index

The assessment models for Soil Profile Integrity differ by community type (Table 25). The models use individual variables to represent the current condition of the soil profile: Organic Horizons (V_{OH})and Silty or Loamy Mantle (V_{SLM}) are used in each community type, but Aquic Moisture Regime (V_{AQUIC}) appears only in the models for >30-yr-old Forested, Shrub, and Sedge Tussock community types because aquic soil conditions are often absent from young post-burn sites. Organic Horizons and Silty or Loamy Mantle represent physical components of the soil profile and thus are tightly linked to the Soil Profile Integrity. Aquic Moisture Regime usually accompanies undisturbed conditions of V_{OH} and V_{SLM} on mature sites and thus provides additional information on the function.

The models use an arithmetic average of some or all of the plant community structural variables Herbs, Shrubs, Trees, and Coarse Woody Debris, depending on the specific conditions characteristic of each community type, to represent the average influence of vegetation on soil-building processes. Specifically, 0- to 5-yr-old Forested, Shrub, and Sedge Tussock community types do not support (or have not yet developed) trees and thus V_{TREE} is not used in the models for these types. Likewise, shrub cover is not dominant in the 0- to 5-yr-old Forested community type, but Coarse Woody Debris is characteristic in the type, and thus V_{CWD} is used in place of V_{SHRUB} in the model for the type.

The assessment models average individual variables representing soil profile condition and moisture with the mean value for plant community variables to yield the FCI. This procedure gives greater weighting to the variables representing current condition of the soil profile than to the plant community variables representing pedogenic processes and potential future condition of the profile. Plant community variables can recover relatively quickly with cessation of site manipulation, but disrupted soil horizons and loss of hydric conditions take longer to recover, another reason to weight soil variables more heavily in the models.

Table 25. Assessment models for calculating Functional Capacity Indices (FCI's) for Soil Profile Integrity by community type.

COMMUNITY TYPE	ASSESSMENT MODEL
Forested	
0- to 5-yr-old	$FCI = (V_{OH} + V_{SLM} + (V_{HERB} + V_{CWD})/2)/3$
6- to 30-yr-old	$FCI = (V_{OH} + V_{SLM} + (V_{TREE} + V_{SHRUB} + V_{HERB})/3)/3$
>30-yr-old	$FCI = (V_{OH} + V_{SLM} + V_{AQUIC} + (V_{TREE} + V_{HERB} + V_{SHRUB})/3)/4$
Shrub	$FCI = (V_{OH} + V_{SLM} + V_{AQUIC} + (V_{SHRUB} + V_{HERB})/2)/4$
Sedge Tussock	$FCI = (V_{OH} + V_{SLM} + V_{AQUIC} + (V_{SHRUB} + V_{HERB})/2)/4$

b. Characteristic Soil Thermal Regime

1) Definition

This function represents the capacity of the wetland to maintain or return to the characteristic soil thermal conditions of Interior Alaska within a period of time determined by climate and landscape position. Low soil temperatures and permafrost soils often characterize late seral stages of precipitation-driven wetlands on discontinuous permafrost in Interior Alaska. An independent, quantitative measure of this function is the daily distribution of soil temperatures (° C) with depth within the soil profile and integrated over the annual cycle.

2) Rationale for the Function

Within precipitation-driven wetlands on discontinuous permafrost in Interior Alaska, soil thermal regimes modify hydrology by changing flow vectors through aggradational or degradational permafrost processes. At many sites within the regional subclass, wetland hydrology directly depends on Characteristic Soil Thermal Regime. In addition, soil temperature regimes control decomposition rates and nutrient mineralization and cycling. Low decomposition rates characteristic of cold, mature sites produce nutrient-poor environments, especially with respect to nitrogen. This is a limitation to primary production, which, in turn, changes plant community composition to species adapted to nutrient stress (*e.g.,* black spruce, ericaceous shrubs). Faunal species requiring highly productive forage (*e.g.,* moose) tend not to be found in cold, wet, low-nutrient sites but frequent early post-fire seres. Off-site effects of Characteristic Soil Thermal Regime include modifying the hydrology of adjacent wetlands by surface runoff and/or shallow subsurface flow and/or groundwater flow to adjacent wetlands.

3) Characteristics and Processes that Influence Soil Thermal Regime

The mean annual air temperature near Fairbanks, Alaska is 26.7°F (-2.94C) (U.S. Dept. of Commerce 1992). When mean annual air temperature is below 32°F, frozen ground may not thaw until well into the summer season (seasonal frost). At the lower mean annual air temperatures (Brown and Péwé 1973, Ping *et al.* 1992) typical of the Interior, the combination of aspect, slope, vegetation, and the thermal properties of the soil parent material may be such that the ground will remain frozen for ≥2 yr. and form permafrost (Péwé 1982). Thus, the reference domain lies within the Zone of Discontinuous Permafrost (Péwé 1975, Ping *et al.* 1992). The transition from continuous to discontinuous-permafrost roughly coincides with the Brooks

Range. The extent of permafrost declines southward to the Alaska Range and the south side of the Copper River Basin. Permafrost is widespread, particularly in valleys and north-facing slopes (Péwé 1986). Permafrost may occur as layers of frozen sand and silt intercalated with unfrozen beds of gravel, or as massive ice in the form of large sheets and wedges. Areas that do not contain permafrost generally consist of coarse textured parent material, or are on hilltops or moderate to steep south-facing slopes. These areas may remain frozen with annual frost into June or July.

Insulating properties of the surface organic horizon primarily maintains permafrost (Ping *et al.* 1992). Low thermal diffusivities of dry surface organic matter limit heat flow into the soil profile, and the higher thermal diffusivities of wet organic materials allow evaporative cooling of the soil surface following precipitation. Both mechanisms act to maintain permafrost in the summer (Riseborough and Burn 1988). In winter, saturated, frozen organic soils conduct heat from the ground to the atmosphere (Brown and Péwé 1973). Where organic soil horizons are thin or partially destroyed by fire, the insulating properties are lost, and permafrost may degrade (*e.g.,* following a fire or human-induced clearing). As the plant community recovers under natural conditions, thermal properties of the soil community return (Péwé 1983, Ping *et al.* 1992), and Characteristic Soil Thermal Regime is re-established.

A thick silty or loamy mantle with low hydraulic conductivity facilitates development of wet-frozen permafrost. Wet-frozen permafrost forms an impermeable layer that perches water, and, therefore, may support episaturation (Ping *et al.* 1992). Furthermore, where the silty or loamy mantle is thin, cross-bedded gravels, sands, and silts, or weathered bedrock, are near the soil surface and may result in a well-drained to excessively drained soil. The silty or loamy mantle has significant influence on soil thermal properties and the potential for permafrost formation. Measured values for soil thermal conductivity and diffusivity are lower in soils with loamy or finer textures, as compared to more coarse materials (Jury 1991). Loamy or finer-textured soils have less heat transferred from the atmosphere and thus maintain lower soil temperatures during the summer than more coarse textured soils. These low soil temperatures favor rapid accumulation of organic materials, establishment of mosses and lichens, and soil acidification. Eventually, significant organic accumulation depresses summer soil temperatures to the point of permafrost formation.

Soils with a thin silty or loamy mantle over sand and gravel warm rapidly during summer due to greater thermal conductivity and diffusivity within the soil profile. Warmer summer soil temperature facilitates rapid organic turnover. Therefore, at these sites organic accumulation is slow and permafrost is rare. Since the most common recurrence period for fire ranges from about 100 to 200 yr. in Interior Alaska (*e.g.,* Viereck 1983), sufficient time for establishment of thick organic soil horizons and permafrost is rarely achieved in soils with thin silty or loamy mantles over coarse-textured materials.

Altered wetlands of the regional subclass frequently experience increased soil temperatures. Mean annual ground temperatures in anthropogenically perturbed terrain within Interior Alaska can be 6.5°F (3.6C) warmer than mean annual air temperatures (Haugen *et al.* 1983). In areas with mean annual air temperatures of ~27°F (~-3C), a 6.5°F (3.6C) temperature differential (increase) facilitates permafrost degradation. Characteristic Soil Thermal Regime can recover through successional processes within the 100- to 250-yr fire cycle. As detailed in Chapter III, increasing development of vegetation and moss cover eventually lowers soil temperature and facilitates permafrost aggradation and subsequent recovery of wetland hydrology.

4) Description of Variables Used to Assess Characteristic Soil Thermal Regime

Variables for Characteristic Soil Thermal Regime address the biotic and abiotic conditions that influence and maintain spatial and temporal distributions of soil and air temperature in precipitation-driven wetlands on discontinuous permafrost in Interior Alaska. These variables are Herbs (V_{HERB}), Organic Horizons (V_{OH}), Shrubs (V_{SHRUB}), Silty or Loamy Mantle (V_{SLM}), and Trees (V_{TREE}).

5) Rationale for Selection of the Variables

Herbs: Variables for Characteristic Soil Thermal Regime address the biotic and abiotic conditions that influence and maintain spatial and temporal distributions of soil and air temperatures in the regional wetland subclass. Herbaceous vegetation is prominent in the 0- to 5-yr-old Forested, Shrub, and Sedge Tussock community types. Vegetation shades soil surfaces and influences evapotranspiration rates with consequent thermal effects on the soil and near-surface air temperatures. Senescent herbs provide insulative litter cover for the soil surface.

Altered sites sometimes have no herbaceous cover (*e.g.*, agricultural tillage, fills). This situation contrasts with natural perturbation from fire, which produces abundant herbaceous cover by native plants in early post-fire seres, and contrasts with nonforested, mature community types, which also support significant herbaceous cover. Reduction of vegetative cover increases the depth of thaw in permafrost soils (*e.g.,* Brown 1963). Recovery of vegetation following perturbation can decrease the depth of thaw in such soils (Heilman 1966, Viereck 1983). The Herbs variable thus is an important component for assessing Characteristic Soil Thermal Regime in the 0-to 5-yr-old Forested, Shrub, and Sedge Tussock community types of the regional wetland subclass.

Organic Horizons: Variables for Characteristic Soil Thermal Regime address the biotic and abiotic conditions that influence and maintain spatial and temporal distributions of soil and air temperatures in the regional wetland subclass. Reference standard sites from mature seral stages have thick organic soil horizons, and associated soils often are classified as Histosols or Gelisols. Post-fire sites generally retain organic soil horizons; therefore, all profiles in the reference standard condition have such horizons. Organic soil horizons provide the primary insulating properties of characteristic soils in precipitation-driven wetlands on discontinuous permafrost in Interior Alaska; thus, intact organic horizons maintain soil thermal properties (Dyrness 1982). Reduction in thickness of organic soil horizons can result in an increase in depth of thaw in permafrost soils (Viereck and Foote 1979).

Altered sites of the regional subclass (*e.g.,* land cleared for agriculture) frequently are stripped of organic soil horizons and do not regain them while under intensive land uses (*e.g.,* agricultural tillage). Organic material and associated soil profiles can recover as moss and litter accumulate over the 100- to 250-yr fire cycle on sites allowed to re-enter natural successional pathways.

Increased thickness of organic soil horizons associated with recovery from site perturbation or late seral stages can reduce soil temperatures (Heilman 1966, Viereck 1983). The Organic Horizons variable thus is an important component for assessing Characteristic Soil Thermal Regime in all community types of the regional wetland subclass.

Shrubs: Variables for Characteristic Soil Thermal Regime address the biotic and abiotic conditions that influence and maintain spatial and temporal distributions of soil and air temperatures in the regional wetland subclass. Shrubs occur in all community types in the regional subclass and are significant in all but the earliest post-fire seres: average shrub canopy coverages in Sedge Tussock and Shrub community types were 34% and 80%. Shrub cover is important in >30-yr-old Forested Community Type but, there, its effects on soil temperature are overshadowed by those of the tree stratum. Shrubs shade soil surfaces and affect evapotranspiration rates with consequent thermal effects on the soil and near-surface air temperatures. Reduced vegetative cover increases depth of thaw in permafrost soils (Brown 1963).

Altered sites sometimes have no shrub cover (*e.g.*, agricultural tillage, pasture, hay fields). This situation contrasts with natural perturbation from fire, which produces abundant cover by native shrubs in post-fire seres >5 yr.-old. Altered sites can re-establish shrub cover if allowed to enter natural successional pathways. Such recovery following perturbation can decrease the depth of thaw (Viereck 1983) as soil temperatures decline. The Shrubs variable thus is an important component for assessing Characteristic Soil Thermal Regime in the 6- to 30-yr-old Forested, Shrub, and Sedge Tussock community types of the regional wetland subclass.

Silty or Loamy Mantle: Variables for Characteristic Soil Thermal Regime address the biotic and abiotic conditions that influence and maintain spatial and temporal distributions of soil and air temperatures in the regional wetland subclass. Silty or Loamy Mantle, which represents the thickness and condition of the mineral soil immediately beneath organic horizons is a critical abiotic variable related to soil temperature. Measured values for thermal conductivity and diffusivity are relatively low in moist mineral soils with loamy or finer texture (Jury 1991). Conversely, higher thermal conductivity and diffusivity values have been reported in more coarse-textured materials (Baver 1972). The fine-grained mantle thus has low thermal and hydraulic conductivity that facilitates the formation of wet-frozen soils.

Altered sites within the regional subclass frequently have disrupted mantles as a result of land clearing or agricultural tillage. A disrupted mantle can affect soil thermal regimes with consequent deterioration of permafrost and the potential loss of wetland hydrology. Sites with thin mantles tend toward long-term or permanent better-drained (nonwetland) states, if the permafrost is degraded by fire or anthropogenic disturbance. The degree of disruption or loss of the mantle at anthropogenically modified sites thus affects the potential of the site to recover cold thermal regimes supporting permafrost aggradation and wetland hydrology. Where only the surface of the mineral soil is disturbed (*e.g.,* tillage), and the bulk of the fine-grained mantle remains intact, partial recovery of its characteristics can occur with the cessation of disturbance and the subsequent progression of ecological succession on the site. Thus, Silty or Loamy Mantle is an important component for assessing Characteristic Soil Thermal Regime in all community types of the regional wetland subclass.

Trees: Variables for Characteristic Soil Thermal Regime address the biotic and abiotic conditions that influence and maintain spatial and temporal distributions of soil and air temperatures in the regional wetland subclass. The Trees variable represents thermal effects of the tree stratum in 6- to 30-yr-old and >30-yr-old Forested community types, which have significant tree cover. Trees are sparse or absent in other community types within the regional wetland subclass. Where present, trees shade soil surfaces and affect evapotranspiration rates with consequent thermal effects on the soil and near-surface air temperatures. A change in the vegetative structure can change microclimate, and reduction of vegetative cover increases the depth of thaw in permafrost soils (*e.g.,* Brown 1963). Specifically, removal of the tree stratum affects site microclimate because unperturbed black spruce canopies intercept incoming short-wave solar radiation and reduce incident radiation reaching forest floors (Petzold 1981, Slaughter 1983), as well as reduce air movement within stands.

Altered sites (*e.g.*, agricultural lands, cleared rights-of-way, fills) within the regional wetland subclass frequently are devoid of trees. Successional redevelopment of tree cover is rapid upon cessation of site manipulation, however. Over the 100-yr to 250-yr fire cycle, altered sites can return to reference standard condition. Recovery of vegetation following perturbation reduces soil temperatures and can decrease the depth of thaw (Viereck 1983). The Trees variable thus is an important component for assessing Characteristic Soil Thermal Regime in the 6- to 30-yr-old and >30-yr-old Forested community types of the regional wetland subclass.

6) Functional Capacity Index

The assessment models for Characteristic Soil Thermal Regime differ by community type (Table 26). Each model has two abiotic variables representing soil characteristics and one or two biotic variables representing dominant or co-dominant vegetation strata. Organic Horizons (V_{OH}) and Silty or Loamy Mantle (V_{SLM}) account for the low thermal diffusivity and conductivity of moist, fine-grained mineral horizons and organic soil horizons and represent soil profile conditions necessary to support low soil temperatures characteristic of most unperturbed sites within the regional wetland subclass.

Herbs (V_{HERB}), Shrubs (V_{SHRUB}), and Trees (V_{TREE}) account for shade and evapotranspiration effects of dominant or co-dominant strata. The vegetation subpart of the assessment models uses only V_{HERB} in the 0- to 5-yr-old Forested Community Type, which is not treed; uses V_{SHRUB} and V_{TREE} in the 6- to 30-yr-old Forested Community Type, in which either shrubs or trees may be dominant; uses only V_{TREE} in the >30-yr-old Forested Community Type, where trees dominate; and uses V_{HERB} and V_{SHRUB} together for Shrub and Sedge Tussock community types, in which a mix of dominant strata potentially are present. Biotic variables, as a group, receive the same weighting as each of the individual abiotic variables, V_{OH} and V_{SLM}, to reflect the role of vegetation as a third factor generally necessary to support cold soil temperatures.

The assessment models average plant community variable subindices to produce a mean value representing the contribution of vegetative cover to Characteristic Soil Temperature Regime. The models then average the biotic mean value with individual subindices for V_{OH} and V_{SLM} to yield the FCI for Characteristic Soil Thermal Regime. This procedure accounts for thermal effects of soils and vegetation on characteristic soil temperature distributions in precipitation-driven wetlands on discontinuous permafrost in Interior Alaska.

Table 26. Assessment models for calculating Functional Capacity Indices (FCI's) for Characteristic Soil Thermal Regime by community type.

COMMUNITY TYPE	ASSESSMENT MODEL
Forested	
0- to 5-yr-old	$FCI = (V_{OH} + V_{SLM} + V_{HERB})/3$
6- to 30-yr-old	$FCI = (V_{OH} + V_{SLM} + (V_{TREE} + V_{SHRUB})/2)/3$
>30-yr-old	$FCI = (V_{OH} + V_{SLM} + V_{TREE})/3$
Shrub	$FCI = (V_{OH} + V_{SLM} + (V_{SHRUB} + V_{HERB})/2)/3$
Sedge Tussock	$FCI = (V_{OH} + V_{SLM} + (V_{SHRUB} + V_{HERB})/2)/3$

c. Surface and Near-Surface Water Storage

1) Definition

This function represents the capability of a wetland to temporarily store (retain) surface and shallow subsurface water. Precipitation-driven wetlands on discontinuous permafrost in Interior Alaska characteristically store surface and near-surface water within surface relief features, organic soil horizons, and silty or loamy mineral horizons. An independent, quantitative measure of this function is to calculate storage magnitude and duration (inches day^{-1} (cm day^{-1})) as part of an annual water budget for the wetland. Measured quantities include precipitation input (inches (cm)), supra-permafrost lateral flow input ($ft^3\ ft^{-1}$ ($m^3\ m^{-1}$)), supra-permafrost lateral flow output ($ft^3\ ft^{-1}$ ($m^3\ m^{-1}$)), evapotranspiration output (including snow sublimation) (inches (cm)), and runoff output on permafrost sites (inches (cm)). Groundwater input and output would dominate over supra-permafrost input and output, on thawed sites. Measurements of input and output quantities must be frequent enough to characterize water movement through wetland storage compartments and residence times therein.

2) Rationale for the Function

Precipitation-driven wetlands on discontinuous permafrost in Interior Alaska store surface and shallow subsurface water, the amounts of which are dependent on the position of the water table, permafrost, and/or other restrictive layers. Small short-term regulation of flow is also observed in these systems (Post 1996). Surface and Near-Surface Water Storage replenishes supra-permafrost soil moisture during snowmelt and precipitation events and provides a variety of functions such as: sediment removal, nutrient and elemental cycling, the maintenance of vegetative composition and diversity along moisture gradients, the maintenance of habitat for growth and reproduction of invertebrates, and the maintenance of water sources for vertebrate fauna. Off-site implications of Surface and Near-Surface Water Storage include improvement of water quality, and surficial groundwater recharge.

3) Characteristics and Processes that Influence Surface and Near-Surface Water Storage

The potential for storage of water at or near the wetland surface is a function of the soil profile, micro and macrotopographic relief, the presence of permafrost, and existing hydrology. The silty or loamy mantle and organic soil horizons characteristic of precipitation-driven wetlands on discontinuous permafrost in Interior Alaska provide the pore space that is available for water storage. In addition, topographic relief over several scales provides surface roughness and complexity that serve as water storage compartments within Interior wetlands.

Processes influencing Surface and Near-Surface Water Storage include formation or thawing of permafrost as a result of site seral characteristics and patterns of perturbation. When the mean annual air temperature is less than ~28 to 30°F (-1 to -2C), ground frozen during the winter may not thaw until well into the growing season (annual frost) or, under certain conditions, may remain frozen for ≥2 years (permafrost) (Brown and Péwé 1963, Péwé 1982, Ping *et al.* 1992). Mean annual air temperature of the reference domain is ~27°F (-2.8C) (U.S. Dept. of Commerce 1992); therefore, permafrost is common in precipitation-driven wetlands.

Surface organic soil horizons desiccate during winter as soil water vapor moves into the snowpack in response to temperature gradients (Slaughter and Kane 1979, Kane *et al.* 1981, Slaughter and Benson 1986, Woo 1986). Consequently, the organic horizon, which has low bulk density (Kane *et al.* 1981) and moisture content becomes a sink for snowmelt. Underlying frozen mineral soils with high moisture content and higher bulk density, are impermeable and snowmelt moves through the surface organic horizon(s) on the permafrost sites (Kane *et al.* 1981). Throughout the growing season and into September, the layer of soil above the permafrost (active layer) thaws and the seasonal frost layer recedes deeper into the profile. The zone of saturation generally follows the seasonal frost layer. Thus, depending upon antecedent precipitation (Roulet 1987) and evapotranspiration, the active layer can receive and store water from precipitation events. The capacity of the active layer to store water influences the plant community, biogeochemical cycling, and hydrologic processes that occur within the regional wetland subclass.

Anthropogenic perturbation of precipitation-driven wetlands often reduces their topographic complexity and removes organic soil horizons. The capacity of the soil profile to store water may decrease from such perturbation. For example, wetlands of the regional subclass that have been cleared for agriculture exhibit highly altered runoff characteristics. Snowmelt quickly moves over frozen mineral surfaces in the absence of organic soil horizons that would promote storage and diminish water energy. Paleochannels on abandoned alluvial plains receive runoff and function as depressions, until conditions are such that they return to reference standard conditions. Altered paleochannels and other macrotopographic features can provide short-term surface water storage, however. On altered alluvial plains, ponded water infiltrates into the soil profile following the thaw of annual frost. Non-permafrost upland sites with dry, frozen mineral soil have high infiltration rates (Kane and Stein 1983).

4) Description of Variables Used to Assess Surface and Near-Surface Water Storage

Soil characteristics, topographic relief, and the presence of water in the active (thawed) layer are used to assess Surface and Near-Surface Water Storage. Variables representing these characteristics are Aquic Moisture Regime (V_{AQUIC}), Macro/Microtopographic Complexity (V_{MTOPO}), Organic Horizons (V_{OH}), Silty or Loamy Mantle (V_{SLM}), and Static Surface Water (V_{SURWAT}).

5) Rationale for Selection of Variables

Aquic: Aquic Moisture Regime indicates the presence of water in the active layer. Post-fire sites typically have diminished permafrost layers, better drainage, and generally do not exhibit aquic soil conditions outside of topographic lows with thick seasonal frost. Mature community types of the regional wetland subclass generally are underlain by permafrost under reference standard conditions, and exhibit episaturation.

Disruption of the soil profile affects soil moisture regimes, often by causing permafrost to thaw with consequent better drainage within the soil profile and loss of hydric conditions. Permafrost thaw can also cause shifts from episaturation to endosaturation in areas where shallow groundwater aquifers are capped by thin permafrost. Water table position and near-surface storage capacity can, therefore, change on altered sites. Some altered sites that have shifted to endosaturation may remain sufficiently wet as to be unusable for the purposes (*e.g.,* agriculture) for which they were originally altered. Perturbed sites that have thawed and developed better drainage can regain aquic soil conditions with successional development of vegetative cover and moss layers that insulate and, subsequently, promote development of permafrost and wetland hydrology. Aquic Moisture Regime thus is an important component for assessing Surface and Near-Surface Water Storage in the >30-yr-old Forested, Shrub, and Sedge Tussock community types of the regional wetland subclass.

Macro/Micro Topographic Complexity: Topographic relief provides surface roughness and complexity to wetland systems. Roughness and complexity form features that can store or retain water in precipitation-driven wetlands. For example, depression and detention storage can occur on permafrost slopes (Woo 1986). Flow of snowmelt within the organic horizons of the active layer (Kane *et al.* 1978) further illustrates the potential for depression and detention storage in precipitation-driven wetlands. All community types showed topographic complexity under reference standard conditions. Macrotopography reflects the landscape setting and overall landform of a wetland and is not necessarily lost with site alteration.

Anthropogenically perturbed reference sites with relatively intensive land uses (*e.g.,* tilled agricultural fields, fills) generally lost microtopographic relief whereas sites with less intensive uses (*e.g.,* utility rights-of-way) retained surface roughness because of the lack of significant disturbance. Altered sites can re-enter natural successional pathways and recover surface roughness with redevelopment of moss cover and accumulation of litter. Macro/Microtopographic Complexity thus is an important component for assessing Surface and Near-Surface Water Storage in all community types of the regional wetland subclass.

Organic Horizons: Reference standard sites from mature seral stages have thick organic soil horizons, and associated soils often are classified as Histosols or Histels. Post-fire sites generally retain organic soil horizons as well; therefore, all profiles in the reference standard condition have organic soil horizons. Organic soil horizons provide pore space for storage of near-surface water. Temperature-driven gradients of vapor pressure result in the movement of soil moisture from the organic layer into the overlying snowpack during winter (Slaughter and Kane 1979). The low-density, desiccated surface organic soil horizons store a portion of the water generated during spring snowmelt (Kane *et al.* 1981). Unsaturated portions of the active layer, including organic horizons, have more capacity for water storage during summer when active layer thickness increases and supra-permafrost water tables subside. Runoff and overland flow occur when water tables reach the surface (Woo 1986).

Intact surface organic soil horizons maintain soil hydrologic properties (Woo 1986) whereas decreased thickness or loss of surface organic soil horizons can degrade permafrost (Dyrness 1982, Viereck 1982) and decrease the capacity to store water at, or near, the surface (Kane *et al.* 1981, Roulet 1987). Altered sites of the regional subclass (*e.g.*, land cleared for agriculture) frequently are stripped of organic soil horizons and do not regain them while under intensive land use (*e.g.*, agricultural tillage). Organic horizons and other parts of the soil profile can recover as moss cover and litter accumulate over the 100- to 250-yr fire cycle on sites that have returned to natural successional pathways. Therefore, Organic Horizons is an important component for assessing Surface and Near-Surface Water Storage in all community types of the regional wetland subclass.

Silty or Loamy Mantle: Silty or Loamy Mantle represents the thickness and condition of fine-grained mineral soil beneath the organic soil horizon(s). Silty or loamy soil horizons provide pore space for storage of water. Undisturbed mantles often are abrupt textural changes and/or low permeability layers that tend to saturate seasonally and/or perch water within soil profiles. The low hydraulic conductivity of fine-grained soils reduces the lateral flow of soil water. Intact fine-grained mantles also have lower thermal conductivities and diffusivities than coarse-textured soil (Baver 1972, Jury 1991) and thus act to preserve permafrost layers and consequent wetland hydrology. All soil profiles in the reference standard condition have a deep silty or loamy mantle.

Altered sites within the regional subclass frequently have disrupted mantles from land clearing or agricultural tillage. Disruption of the mantle affects site thermal regimes, with consequent deterioration of permafrost and altered hydrology. Sites with thin mantles tend toward a long-term or permanent better-drained (non-wetland) state. The degree of disruption or loss of the mantle at anthropogenically modified sites thus affects the potential of the site to store water near, or at, the surface. Where only the surface of the mineral soil is disturbed (*e.g.*, tillage), and the bulk of the fine-grained mantle remains intact, partial recovery of its characteristics can occur with cessation of disturbance and the progression of ecological succession on the site. Silty or Loamy Mantle thus is an important component for assessing Surface and Near-Surface Water Storage in all community types of the regional wetland subclass.

Static Surface Water: Static Surface Water indicates the presence of a water table at or above the wetland surface (ponding) during a portion of the year. For example, depression storage (ponding) can occur on permafrost slopes (Woo 1986). Typically, only mature community types exhibit evidence of ponding under reference standard conditions. Younger post-fire sites are frequently better drained due to thawing of the underlying permafrost, while isolated paleochannels on alluvial plains can retain wetland hydrology even after losing shallow permafrost. Ponding on mature sites generally results from supra-permafrost water tables.

The evidence of ponding varied substantially among reference standard sites, but anthropogenic perturbation nearly always eliminated ponding on the remaining reference sites. The exceptions were sites where alteration thawed thin permafrost overlying shallow aquifers which created consequent endosaturation and ponding. Effects of leveling, smoothing, and/or the placement of fill include, increased surface runoff and, decreased evapotranspiration (Post 1996). These effects have a direct bearing on hydrologic and biogeochemical functions. Static Surface Water thus is an important component for assessing Surface and Near-Surface Water Storage in the >30-yr-old Forested, Shrub, and Sedge Tussock community types of the regional wetland subclass.

6) Functional Capacity Index

The assessment models for Surface and Near-Surface Water Storage differ by community type (Table 27). The more complex model used in the >30-yr-old Forested, Shrub, and Sedge Tussock community types has a subpart that represents the physical complexity of site surface topography (Macro/Microtopographic Complexity (V_{MTOPO})) and evidence of ponding (Static Surface Water (V_{SURWAT})). The model averages subindices for V_{MTOPO} and V_{SURWAT} to yield a mean value representing actual and potential storage of water within surface roughness.

Individual subindices for Organic Horizons (V_{OH}) and Silty or Loamy Mantle (V_{SLM}) represent potential capacity of pore space to store water within the soil profile and Aquic Moisture Regime (V_{AQUIC}) provides evidence that such storage actually occurs. The model averages the mean value of V_{MTOPO} and V_{SURWAT} with the preceding individual variables to yield the FCI for Surface and Near-Surface Water Storage. Soil variables thus receive greater weighting than do the two surface storage variables in the model for mature community types.

The assessment model for the 0- to 5-yr-old and 6- to 30-yr-old Forested community types is a simple average of V_{MTOPO}, V_{OH}, and V_{SLM}. These community types typically do not have evidence of ponding and may not have aquic soil conditions in the reference standard condition; therefore, V_{SURWAT} and V_{AQUIC} are deleted from the model.

Table 27. Assessment models for calculating Functional Capacity Indices (FCI's) for Surface and Near-Surface Water Storage by community type.

COMMUNITY TYPE	ASSESSMENT MODEL
Forested	
0- to 5-yr-old	$FCI = (V_{MTOPO} + V_{SLM} + V_{OH})/3$
6- to 30-yr-old	$FCI = (V_{MTOPO} + V_{SLM} + V_{OH})/3$
>30-yr-old	$FCI = ((V_{MTOPO} + V_{SURWAT})/2 + V_{OH} + V_{SLM} + V_{AQUIC})/4$
Shrub	$FCI = ((V_{MTOPO} + V_{SURWAT})/2 + V_{OH} + V_{SLM} + V_{AQUIC})/4$
Sedge Tussock	$FCI = ((V_{MTOPO} + V_{SURWAT})/2 + V_{OH} + V_{SLM} + V_{AQUIC})/4$

2. Biogeochemical Functions

a. Cycling of Elements and Compounds

1) Definition

This function represents short- and long-term transformation of elements and compounds through abiotic and biotic processes that convert chemical species (*e.g.,* nutrients and metals) from one form, or valence, to another. Elemental transformations are a function of the redox environment and are reversible (*i.e.*, cyclical) processes. An independent, quantitative measure of this function is an annual budget (kg ha^{-1}) for all major nutrients (*e.g.,* nitrogen (N), phosphorus (P), carbon (C), sulfur (S)) and metals (*e.g.,* potassium (K), sodium (Na), calcium (Ca), iron (Fe), manganese (Mn)) occurring within the wetland. Measurements of gas-, solid-, and liquid-phase inputs and outputs; element/compound pool sizes; and element/compound turnover rates (*e.g.*, nitrate (NO_3), ammonium (NH_4), methane (CH_4), carbon dioxide (CO_2)) are necessary. Sampling frequency must be sufficient to measure species movement between compartments within the wetland and to quantify exchanges with water and atmosphere, including seasonal changes in turnover rates and pool sizes.

2) Rationale for the Function

Cycling of nutrients, mediated by biotic and abiotic variables, is a fundamental ecosystem process. Net primary productivity, in which nutrients are taken up by plants, and detritus turnover, in which nutrients are released for renewed uptake by plants and microbes, comprise biotic components of elemental cycling. Abiotic components are inextricably linked to the microbially mediated (biogeochemical) processes that drive the oxidation-reduction reactions that alter elements and compounds. Sources of these abiotic components are, the soil profile, eolian processes that input nutrients and particulates, and (rarely in this subclass) flood processes that input nutrients and particulates to the system. Net effects of elemental cycling are balanced between gains through import processes, and losses through hydrologic export, efflux to the atmosphere, and long-term retention in sediments and persistent biomass. Retention of elements and compounds on site decreases the probability of their export to down-gradient aquatic ecosystems and diminishes nutrient loading. Elements and compounds retained on site also contribute to both thermal and water-holding properties of wetlands adjacent to the assessment area.

Precipitation-driven wetlands on discontinuous permafrost in Interior Alaska facilitate nutrient cycling, but such cycles typically access only a small proportion of the total nutrient pool due to lower decomposition rates of organic matter in cold, wet soils (Post 1996). Forest floor biomass is about 25% greater than tree biomass in black spruce stands, but limiting nutrient concentrations (*e.g.*, N and P) in the forest floor exceed those in trees by factors of ~3 to ~5 (Van Cleve *et al.* 1983), which suggests a concentration of some macro and micro nutrients within the non-oxidized organic matter of the forest floor. Cycling of Elements and Compounds in wetlands of the regional subclass thus occurs in a distinctive manner.

3) Characteristics and Processes that Influence Cycling of Elements and Compounds

Nutrient cycling in black spruce wetland systems affects only a small portion of the total nutrient pool due to reduced rates of organic matter decomposition (Post 1996). Elements and compounds become available for biological uptake through mineralization. However, this availability may be brief due to uptake by plant and microbial communities and retention in the tissues (immobilization) of herbs, shrubs, trees, and microbes. Nutrients can also be lost from the system by leaching or volatilization. Contributions to the system occur via photosynthesis (*i.e.*, carbohydrate synthesis) and atmospheric additions of gas and particulate (solid-phase) elements and compounds. Nutrients immobilized by flora are retained in this form until plant material is consumed, or senesces and returns to detrital storage. Biomass turnover rates differ between strata in precipitation-driven wetlands. Black spruce retains nutrients efficiently, with little litterfall (Van Cleve *et al.* 1983). In contrast, an annual biomass turnover of 34 to 43% has been recorded for the shrub stratum (Chapin 1983).

Regardless of vegetation type, the forest floor is most important compartment for nutrient retention and cycling in the Subarctic (Van Cleve *et al.* 1981). The rooting structure of plant communities within this subclass helps to explain these nutrient retention and cycling characteristics. In these poorly drained, permafrost-dominated soils, root systems concentrate in the humus layers and upper few inches of mineral soil. Soil temperatures below 41° F (5C) during the growing season (Ping *et al.* 1992), and saturated conditions, probably restrict rooting depth. The organic surface compartment exhibits nutrient residence times as much as an order of magnitude longer than the aboveground tree component. The shortest residence times of nutrients in coniferous vegetation are 8 to 20 yr. for N, P, and K; 11 to 15 yr. for Mg; and 28 to 34 yr. for Ca. In contrast, residence times for most of these elements in the forest floor ranged from ~40 to 212 yr. (Van Cleve *et al.* 1981). Rates of N mineralization are low, with residence times on the order of 61 years (Van Cleve *et al.* 1983). The mosses are particularly effective nutrient sinks within these wetlands (Oechel and Van Cleve 1986). For example, Weber and Van Cleve (1981) determined that the feathermoss layer of a permafrost-dominated black spruce ecosystem retained over 90% of ^{15}N isotope 28 months after application.

Periodic fire is a dominant influence driving rate-limiting processes for Cycling of Elements and Compounds in precipitation-driven wetlands. Fire not only mineralizes or volatilizes substantial amounts of stored nutrients but also strongly changes Characteristic Soil Thermal Regimes and initiates seral changes in litter quality (*i.e.*, nutrient content, resistance to decomposition). Widely recognized effects on soils as a result of burning include increased base saturation of the soil surface, and a subsequent increase in soil pH. Improved soil P and NO_3 availability following fire is usually attributed to this increase in pH (Heilman 1966). Fire removes low-density, low-N moss layers; redistributes N to the soil surface, which is the warmest portion of the soil profile; and greatly improves N availability and productivity. As discussed in Chapter III, soils on newly burned sites warm and may become drier with thawing and recession of the permafrost table. Post-fire herbaceous vegetation rapidly takes up nutrients released by burning and annually returns senesced tissue to the ground surface. Warmer, drier soils and higher litter quality of early seres imply rapid nutrient cycling as compared to mature sites.

Thickening of the organic horizon diminishes the availability of nutrients within the upper portion of the soil profile. Elements at low concentrations and, therefore, potentially limiting, such as N, P, and K, are cycled by vegetation and dispersed throughout an increasingly thick organic layer (Heilman 1966 1968). Thickening organic horizons result in reduced soil temperatures and rates of N mineralization. This undoubtedly reduces the availability of N for uptake by plants and microbes and, subsequently, the return of N to the soil as litter. Percolation from major rainfall events only slightly affects this relatively immobile N within the organic mat (Weber and Van Cleve 1981). At the same time, decreased active layer thickness immobilizes nutrients and reduces effective rooting depth at which plants may extract nutrients. Grigal (1979) found the only element immobilized to any degree by permafrost was Ca. However, Heilman (1968) did not find Ca to be deficient in the successional seres of stands he studied. Declining soil temperature, increasing soil moisture, and declining litter quality (*e.g.,* shift to dominance by evergreen, nutrient-conserving species and high-resin content litterfall) imply reduced nutrient turnover rates in later seral stages.

Anthropogenic perturbations that remove organic soil horizons, such as land clearing operations, also initiate seral changes in the absence of continuing perturbation. Fewer nutrients are available on sites with stripped organic horizons than on naturally burned sites, but nutrient pools should increase with time if such sites are allowed to re-enter the successional cycle. Continuing site manipulation, such as agriculture, generally limits the accumulation of nutrients, although turnover rates may be high in the warm, dry soils characteristic of better-quality tilled land.

4) Description of Variables Used to Assess Cycling of Elements and Compounds

Variables used to assess Cycling of Elements and Compounds represent biotic and abiotic components of the ecosystem that are involved in biological and geochemical processes. The following variables represent biotic ecosystem components: Coarse Woody Debris (V_{CWD}), Herbs (V_{HERB}), Shrubs (V_{SHRUB}), and Trees (V_{TREE}). Aquic Moisture Regime (V_{AQUIC}) and Silty or Loamy Mantle (V_{SLM}) represent abiotic ecosystem components. Both biotic and abiotic processes occur within nonliving organic material represented by Organic Horizons (V_{OH}).

5) Rationale for Selection of Variables

Coarse Woody Debris: The biotic components of wetland ecosystems cycle nutrients through (1) soil and water nutrient uptake, (2) biomass accumulation, and (3) litter production. Coarse Woody Debris is a biotic variable representing return of elements and compounds stored in the tree stratum to the forest floor by litterfall and mortality of whole trees. Fire sufficiently intense to kill most or all trees in a precipitation-driven wetland is a major factor in this process. Trees may topple immediately following fires sufficiently intense to burn supporting roots or may remain standing for many years following cooler fires that leave roots largely intact. Paludification, competition, defoliation, and decadence can return trees to the forest floor at low rates between fires. Under reference standard conditions, coarse wood is most apparent in early post-fire seres by virtue of large input over to the forest floor over relatively short periods of time compared to the length of the 100- to 250-yr fire cycle. Coarse wood is largely absent in Shrub and Sedge Tussock community types.

Coarse wood reaching the forest floor undergoes slow decomposition and releases stored elements and compounds for uptake by the plant community. Some components of wood resist decomposition and may enter the pool of stored carbon (peat) in the wetland. A change in characteristic input of coarse wood therefore can alter nutrient cycles. This is an important discriminant between natural post-fire succession with large amounts of coarse wood and land-clearing operations where all coarse wood is pushed into berms and often later burned. Coarse Woody Debris thus is an important component for assessing Cycling of Elements and Compounds in the 0- to 5-yr-old and 6- to 30-yr-old Forested community types of the regional wetland subclass.

Herbs: The biotic components of wetland ecosystems cycle nutrients through (1) soil and water nutrient uptake, (2) biomass accumulation, and (3) litter production. The herbaceous stratum of precipitation-driven wetlands on discontinuous permafrost in Interior Alaska, most prominent in early post-fire seres and Shrub and Sedge Tussock community types, produces new growth and senesces annually. Characteristic graminoids allocate a large proportion of production to below ground biomass, have high root surface-to-volume ratios, low optimum temperatures for root growth, and high capacity for P absorption (Chapin 1974, Chapin *et al.* 1980), and herbaceous litter decomposes more readily than woody plant litter. The herbaceous stratum thus is adapted for rapid turnover of biomass and associated nutrients. Finally, herbaceous cover interacts with nutrient cycling through effects on soil temperature and moisture.

Altered sites sometimes have no herbaceous cover (*e.g.*, agricultural tillage, fills). This situation contrasts with natural perturbation from fire, which produces abundant herbaceous cover by native plants. Altered sites with less intense land uses (*e.g.*, pasturing and hay production) often support non-native herbaceous cover capable of nutrient uptake and release. Upon cessation of active land uses, altered sites can re-enter natural successional pathways and move toward reference standard conditions, although rapid shrub and tree invasion will quickly reduce herbaceous dominance. The Herbs variable thus is an important component for assessing Cycling of Elements and Compounds in the 0- to 5-yr-old Forested, Shrub, and Sedge Tussock community types of the regional wetland subclass.

Shrubs: The biotic components of wetland ecosystems cycle nutrients through (1) soil and water nutrient uptake, (2) biomass accumulation, and (3) litter production. Shrubs occur in all community types in the regional subclass and are significant in all but the earliest post-fire seres: average shrub canopy coverages in Sedge Tussock and Shrub community types were 34% and 80%. Shrub biomass turns over at rates of 34 to 43% annually (Chapin 1983) at sites representative of the regional subclass, which adds substantial litter to the surface for decomposition. Nutrient cycling by shrubs in wetlands of the regional subclass is particularly effective in that tissue nutrient pools are high in proportion to biomass. Shrubs also can account for a significant proportion of annual production (*e.g.*, 16%) by vascular plants in black spruce wetlands (Chapin 1983). In addition, shrub cover interacts with nutrient cycling through the effects of cover on soil temperature and moisture.

Altered sites sometimes have no shrub cover (*e.g.*, agricultural tillage, pasture, hay fields). This situation contrasts with natural perturbation from fire, which produces abundant cover by native shrubs in post-fire seres >5 yr. old. Perturbation of shrub cover in precipitation-driven wetlands affects biomass accumulation, litter production, and soil temperature. Altered sites quickly recover shrub cover upon cessation of manipulation and can re-enter natural successional pathways toward reference standard conditions over the 100- to 250-yr fire cycle. The Shrubs variable thus is an important component for assessing Cycling of Elements and Compounds in 6- to 30-yr-old and >30-yr-old Forested community types and in Shrub and Sedge Tussock community types of the regional wetland subclass.

Trees: The biotic components of wetland ecosystems cycle nutrients through (1) soil and water nutrient uptake, (2) biomass accumulation, and (3) litter production. Tree cover characterizes 6- to 30-yr-old and >30-yr-old Forested community types but is sparse or absent in the other community types within the regional wetland subclass. Deciduous trees, often present in early- to mid-seral stages of precipitation-driven wetlands on discontinuous permafrost in Interior Alaska, have higher nutrient requirements than evergreens (Van Cleve *et al.* 1983). Conversely, black spruce has low nutrient requirements and efficiently retains nutrients in its tissues. Therefore, elements entering tree stratum nutrient pools should turn over more slowly with stand age. A substantial portion of the aboveground net primary production of black spruce (*e.g.,* ~1,000 kg ha^{-1} yr^{-1} (Viereck *et al.* 1983)) eventually returns to the forest floor for decomposition, however. In addition, trees provide shade with consequent effects on soil temperature (Brown 1963) and moisture and accompanying effects on rates of production and decomposition.

Altered sites (*e.g.,* agricultural lands, cleared rights-of-way, fills) within the regional wetland subclass frequently are devoid of trees. Perturbation of characteristically treed wetlands may remove stored elements and compounds and cause rates of nutrient cycling to increase as soils warm and potentially drain. Successional redevelopment of tree cover is rapid upon cessation of site manipulation, however. Over the 100-yr to 250-yr fire cycle, altered sites can return to reference standard conditions. The Trees variable thus is an important component for assessing Cycling of Elements and Compounds in the 6- to 30-yr-old and >30-yr-old Forested community types of the regional wetland subclass.

Aquic: Aquic Moisture Regime is an abiotic ecosystem component that indicates the presence of water in the active layer. Saturated soils containing sufficient carbon and heat to support microbial activity become reduced. Characteristic redox potentials of these soils affect elements, compounds, and chemical reactions of these species within the soil profile. Reduction and oxidation processes biogeochemically cycle elements and compounds (*e.g.,* N, S, C, Mn, Fe,) between different forms (valence states). For example, P co-precipitates with Mn and Fe oxides under oxidizing conditions but becomes soluble under reducing conditions. Mature community types of precipitation-driven wetlands on discontinuous permafrost in Interior Alaska exhibit at least periodically reduced soils, despite soil temperatures only slightly above 32°F (0C) near the permafrost table. Post-fire sites may undergo permafrost degradation, a change of drainage class, and alteration of nutrient cycling until successional processes restore wetland standard reference site conditions.

Altered sites (*e.g.,* land cleared for agricultural, fill placement) frequently lose saturated conditions in the upper part of the soil profile. Loss of saturation shifts the redox state from reducing to oxidizing with consequent effects on element transformations. With cessation of the disturbance, altered sites can re-enter natural successional pathways. Development of vegetation and moss cover eventually can aggrade permafrost and restore episaturation. When this occurs, the reference standard redox conditions characteristic of mature sites are restored. Aquic Moisture Regime thus is an important component for assessing Cycling of Elements and

Compounds in the >30-yr-old Forested, Shrub, and Sedge Tussock community types of the regional wetland subclass.

Silty or Loamy Mantle: Abiotic ecosystem components facilitate the microbially mediated (biogeochemical) processes of reduction and oxidation that are responsible for the cycling of elements and compounds (*e.g.,* N, S, C, Mn, Fe). All soil profiles of precipitation-driven wetlands on discontinuous permafrost in Interior Alaska have a deep Silty or Loamy Mantle with low hydraulic conductivity that results in the saturation of soils in the reference standard condition. These soils often remain reduced near the base of the active layer and frequently are gleyed (Figure 31). Abiotic processes occurring in these reduced soils include chemical transformations of nutrients in response to redox potentials. Fine-grained mantles also strongly influence soil temperature and moisture with consequent effects on microbial activity and redox potentials.

Altered sites within the regional subclass frequently have disrupted mantles from land clearing or agricultural tillage. The degree of mantle disruption affects site thermal regimes and hydrology with potential loss of reducing conditions, which, in turn, affects the types of element transformations that can occur. Where only the surface of the mineral soil is disturbed (*e.g.,* tillage), and the bulk of the mantle remains intact, at least partial recovery of its characteristics can occur with cessation of disturbance and progression of ecological succession on the site. Development of vegetation and moss cover can restore wet-frozen conditions in the mantle and reducing conditions in the lower part of the active layer. Silty or Loamy Mantle thus is an important component for assessing Cycling of Elements and Compounds in all community types of the regional wetland subclass.

Organic Horizons: Organic soil horizons support both biotic and abiotic processes and occur in all community types under reference standard conditions. Biotic processes occurring in organic soil horizons include root production and litter decomposition. In addition, *Sphagnum* spp. provide ion exchange surfaces that preferentially adsorbed cations and release H^+, which produces acidic conditions. Cotton grass (*Eriophorum* spp.) tussocks produce high levels of reactive C compounds, such as carbohydrates, fulvic acid, and hydrophilic neutrals (Michaelson and Ping 1997). Abiotic processes occurring in organic soil horizons include chemical transformations of nutrients in response to redox potentials. These redox transformations biogeochemically cycle elements and compounds (*e.g.,* N, S, C, Mn, Fe, in various valence states). In addition, organic soil horizons strongly influence soil temperature and moisture with consequent effects on microbial activity and redox potentials.

Alteration of sites within the regional wetland subclass frequently removes organic soil horizons (*e.g.,* agricultural land clearing, burial under fill). On altered sites, decreased thickness or loss of surface organic soil horizons affects the rates and volumes of import, *in-situ* cycling, storage, and export of nutrients and organic matter (*e.g.*, Whigham and Bailey 1979, Flanagan and Van Cleve 1983, Van Cleve *et al.* 1983, Moore 1987). In general, altered sites with minimal organic soil horizons are warmer and drier than mature reference standard sites and more likely to experience oxidizing conditions and higher rates of decomposition for remaining organic matter. Altered sites can re-enter natural successional pathways and regain organic soil horizons with development of vegetation and moss cover over the 100- to 250-yr fire cycle. Organic Horizons thus is an important component for assessing Cycling of Elements and Compounds in all community types.

6) Functional Capacity Index

The assessment models for Cycling of Elements and Compounds differ by community type (Table 28). The models all have a subpart representing biotic processes for nutrient cycling and one or more individual variables representing abiotic processes. Organic Horizons (V_{OH}) appears in the biotic subpart of the equations, although organic soil horizons also are sites of abiotic processes. Other variables in the biotic subpart are Coarse Woody Debris (V_{CWD}), Herbs (V_{HERB}), Shrubs (V_{SHRUB}), and Trees (V_{TREE}). Coarse wood is not significant in >30-yr-old Forested, Shrub, or Sedge Tussock community types. Trees are not dominant in 0- to 5-yr-old Forested, Shrub, or Sedge Tussock community types. Herbs are not dominant in 6- to 30-yr-old and >30-yr-old Forested community types. The models average sub-indices for vegetation and coarse wood variables appropriate to each community type to reflect mean biotic contributions to Cycling of Elements and Compounds.

The abiotic variables are Silty or Loamy Mantle (V_{SLM}) and Aquic Moisture Regime (V_{AQUIC}). Fine-grained mineral soil horizons characterize all community types in precipitation-driven wetlands on discontinuous permafrost in Interior Alaska, and V_{SLM} appears in each model. Aquic soil conditions characterize mature Forested, Shrub, and Sedge Tussock community types; therefore, V_{AQUIC} is not used in the models for the two earliest seral stages in the Forested Community Type.

In all cases, the assessment models average the mean value from the biotic subpart with subindices of individual abiotic variables to yield FCI's for Cycling of Elements and Compounds. This procedure accounts for nutrient uptake, storage, and mineralization by biotic communities and for chemical transformations taking place in the soil.

Table 28. Assessment models for calculating Functional Capacity Index (FCI) for Cycling of Elements and Compounds by community type.

COMMUNITY TYPE	ASSESSMENT MODEL
Forested	
0- to 5-yr-old	$FCI = ((V_{OH} + V_{HERB} + V_{CWD})/3 + V_{SLM})/2$
6- to 30-yr-old	$FCI = ((V_{OH} + V_{TREE} + V_{SHRUB} + V_{CWD})/4 + V_{SLM})/2$
>30-yr-old	$FCI = ((V_{OH} + V_{TREE} + V_{SHRUB})/3 + V_{SLM} + V_{AQUIC})/3$
Shrub	$FCI = ((V_{OH} + V_{SHRUB} + V_{HERB})/3 + V_{SLM} + V_{AQUIC})/3$
Sedge Tussock	$FCI = ((V_{OH} + V_{SHRUB} + V_{HERB})/3 + V_{SLM} + V_{AQUIC})/3$

b. *Organic Carbon Export from Sedge Tussock Wetlands*

1) Definition

This function represents export of dissolved and particulate organic carbon (OC) from Sedge Tussock wetlands. Export mechanisms include leaching, displacement, and erosion. An independent, quantitative measure of this function is to calculate a mass per unit wetland area for OC export (kg C ha^{-1} yr^{-1}). Hourly measurements of water output volume (surface and subsurface) from the wetland and associated concentrations of OC, integrated over one year, would yield an estimate of waterborne OC export.

2) Rationale for the Function

Wetlands export OC at higher rates per unit area than terrestrial ecosystems (Mulholland and Kuenzler 1979), in part because surface water has greater contact time with organic matter in litter and surface soil. While the molecular structure of most organic matter is not well known because of its chemical complexity (Stumm and Morgan 1981), organic matter, nevertheless, plays important roles in geochemical and food web dynamics. For example, OC complexes (chelates) with a number of relatively immobile metallic ions, which facilitates their transport in soil (Schiff *et al.* 1990). Organic carbon is a primary source of energy for microbial food webs (Edwards 1987, Edwards and Meyer 1986), which form the base of the detrital food web in aquatic ecosystems. These factors, in combination with the proximity of wetlands to aquatic ecosystems, make wetlands critical sites for supplying both dissolved and particulate OC (Brinson *et al.* 1995).

Many low-gradient, precipitation-driven wetlands on discontinuous permafrost in Interior Alaska do not export OC. Water movement in these wetlands is primarily vertical: precipitation input and evapotranspiration output. Constructed wastewater treatment wetlands, conceivably located in wetlands of the regional subclass, export OC because they generally receive greater loadings of water than they can evapotranspire, but treatment wetlands do not represent reference standard conditions. Nevertheless, reference standard wetlands of the regional subclass can export OC if they (1) are located on toeslopes or in valley bottom positions, (2) are proximal to streams and have hydraulic gradients that direct surface and subsurface flow to the streams, 3) have vegetation dominated by the Sedge Tussock Community Type, and 4) have peraquic conditions (*i.e.*, groundwater always at or very close to the ground surface) during much of the growing season.

3) Characteristics and Processes that Influence Organic Carbon Export from Sedge Tussock Wetlands

Research in OC transport largely has focused on arctic ecosystems, but similar export pathways are expected in subarctic ecosystems. Interior Alaska, like the Arctic, is underlain by permafrost and supports similar understory vegetation. The following summary of carbon transport in the Arctic is relevant to OC export by precipitation-driven wetlands on discontinuous permafrost in Interior Alaska.

Terrain, soil, porosity, and permafrost-active layer depth control the lateral pathway of hydrologic carbon transfer in Arctic ecosystems (Kane *et al.* 1992). Although as much as 95% of dissolved organic matter (DOM) entering mineral soil may be removed before water reaches streams in arctic and subarctic systems (Qualls and Haines 1992), relatively large quantities of carbon in both organic and mineral forms are transferred to aquatic systems in the Arctic (Peterson *et al.* 1986, Kling *et al.* 1991). In Arctic systems, DOM moves to aquatic systems by a different pathway, which is controlled by thaw depth, permafrost table, and porosity-water conductivity boundaries between organic and mineral layers (Hinzman *et al.* 1993). This vertically constrained pathway for DOM causes runoff water to move primarily through the upper organic layer for most of the summer season. Runoff water often does not interact with mineral soil layers, except in late summer (Michaelson and Ping 1997).

Two peak periods of surface water recharge and OC export are apparent in areas underlain by permafrost in Interior Alaska. The first peak occurs in late April or early May when meltwater from the winter's accumulation of snow is released into the system. The DOM composition of these waters is high in carbohydrate fractions that are readily available to soil organisms (Schimel and Cline 1996); however, low microbial activity is expected since runoff waters are cold, and anchor ice persists through the spring in many stream systems. The second recharge peak, less consistent from year to year than the spring peak, is from a pattern of increased precipitation typical of late summer or from localized, high-intensity summer thunderstorms common in Interior Alaska.

Export of OC is closely tied to vegetation type and form. In precipitation-driven wetlands with ericaceous shrub/moss understories, permafrost vertically constrains water movement and surface or subsurface hydrologic connections are few. Therefore, water movement is confined primarily to the upper organic soil horizons of the active layer. Low hydraulic conductivities restrict lateral movement, and most of DOM is removed before water enters streams. These vegetation types and forms do not export appreciable of carbon to adjacent ecosystems.

Precipitation-driven wetlands supporting closed-sheath sedge (cotton grass) wet meadow (the Sedge Tussock Community Type) have surface microrelief formed by a network of connected intertussock depressions. These depressions form channels for movement of surface water through the site. Not only do Sedge Tussock areas appear to contribute significant amounts of exported OC during peak discharge periods, but the DOM is generally of high quality in terms of reactivity and CO_2 evolution (G.J. Michaelson, pers. comm.).

Sites that perform this function are 1) on toeslopes or valley bottom positions, 2) are proximal to streams and have hydraulic gradients that direct surface and subsurface flow to streams, 3) have vegetation dominated by the Sedge Tussock Community Type, and 4) have peraquic conditions during much of the growing season. These systems export particulate and dissolved OC when surface and shallow subsurface water flows above the permafrost and through the organic mat (Dingman 1973). Surface water moves readily through the interconnected pattern of depressions between tussocks. Periods of maximum discharge are during spring snowmelt and again during heavy rainfall episodes more common in late summer. Organic Carbon Export from Sedge Tussock Wetlands is not performed during late spring and early summer when discharge from adjacent landscapes and rainfall is low and intertussock depressions are free of water. During these dry periods, the suprapermafrost water table recedes to within less permeable loamy materials, which impedes flow. Water thus tends to remain static during such periods.

Some anthropogenic perturbations of Sedge Tussock wetlands could largely eliminate sources of OC (*e.g.,* land-clearing operations that strip vegetation and organic soil horizons) or destroy hydrologic connections with adjacent aquatic systems. Conversely, ditching and drainage might increase rates of decomposition (Post 1996) and provide flow paths that at least temporarily increase OC export (Moore 1987) over the unaltered state of the wetland. Perturbations that alter wetland thermal regimes (*e.g.,* land-clearing) and degrade permafrost may change flow paths by fostering internal drainage of saturated soils and microbial oxidation of carbon on site. Description of Variables Used to Assess Organic Carbon Export from Sedge Tussock Wetlands

4) Description of Variables

Variables used to assess Organic Carbon Export from Sedge Tussock Wetlands represent sources of particulate and dissolved OC and the hydrologic processes that export OC from Sedge Tussock wetlands. The variables, as described in the following section, are Aquic Moisture Regime (V_{AQUIC}), Herbs (V_{HERB}), Organic Horizons (V_{OH}), Shrubs (V_{SHRUB}), and Surface Connections ($V_{SURFCON}$).

5) Rationale for Selection of Variables

Aquic: Aquic Moisture Regime represents hydrologic characteristics suitable for OC export. Peraquic conditions (*i.e.,* groundwater always at or very close to the ground surface) during much of the growing season are necessary to support export of OC because the water table must occur within or above organic soil horizons to support significant flow from a precipitation-driven wetland. Aquic Moisture Regime indicates periodic presence of water in the active layer. Dissolved and particulate OC in organic soil horizons, along with dissolved OC stored in fine-grained mineral soil horizons, will leave the system via surface and shallow subsurface water flow.

Altered wetlands (*e.g.,* ditched or stripped) of the Sedge Tussock Community Type could lose characteristic peraquic conditions, increase in temperature, and promote on-site microbial oxidation of carbon. Presumably, altered sites that had not been drained by extensive ditching could re-enter natural successional pathways upon cessation of disturbance, undergo permafrost aggradation, and eventually regain peraquic conditions. Aquic Moisture Regime is an important component for assessing Organic Carbon Export from Sedge Tussock Wetlands (community type) of the regional wetland subclass at peraquic sites on toeslope or valley bottom positions proximal to streams.

Herbs: The herbaceous and shrub strata (Figure 41, Table 15) co-dominate the Sedge Tussock Community Type; therefore, the Herbs variable represents an important part of the community for fixation of OC and its storage in living and dead plant tissues. Stored OC ultimately becomes available for export through decomposition, leaching, and transport processes. Herbaceous species annually senesce and return litter to the soil surface. Herbaceous litter decomposes relatively rapidly and becomes available for export from the system as particulate and dissolved OC.

Anthropogenic removal of herbaceous vegetation (*e.g.,* land clearing) removes a major carbon source from Sedge Tussock wetlands. Vegetation removal alters thermal regimes and could degrade permafrost leading to internal soil drainage and microbial oxidation of carbon on site. Presumably, altered sites can re-enter natural successional pathways and regain native herbaceous vegetation (*e.g.,* cotton grasses) with aggradation of permafrost and restoration of peraquic conditions. The Herbs variable thus is an important component for assessing Organic

Carbon Export from Sedge Tussock Wetlands (community type) of the regional wetland subclass for peraquic sites on toeslopes or valley bottom positions proximal to streams and with hydraulic gradients that direct surface and subsurface flow to streams.

Organic Horizons: The Organic Horizons variable represents the major source of OC within the soil profile that is available for export. Plant roots and litterfall provide OC to organic soil horizons. For example, cotton grass (*Eriophorum* spp.) tussocks produce high levels of reactive C compounds, such as carbohydrates, fulvic acid, and hydrophilic neutrals (Michaelson and Ping 1997). Litter decomposes in organic soil horizons and releases dissolved and particulate OC for export under appropriate site conditions.

The Sedge Tussock Community Type has somewhat variable organic soil horizons, typically thicker beneath tussocks and thinner or absent in intertussock depressions (Figure 31). Speculatively, the typical tussock configuration may enhance movement of OC from subtussock organic soil horizons to adjacent intertussock depressions. The tussock configuration and variable thickness of organic soil horizons in Sedge Tussock wetlands define interconnected intertussock depressions that form flow paths for export of OC.

Altered sites (*e.g.,* cleared land) frequently are stripped of organic soil horizons, which leads to thawing and better drainage of the soil profile. Under these condition, the major reservoir of OC available for decomposition and/or export is lost, as is the mechanism for export. At such sites, on-site microbial oxidation of OC within mineral soils is likely. Altered sites can re-enter natural successional pathways with the cessation of disturbance. Organic soil horizons can redevelop if permafrost aggrades and restores peraquic conditions that supports native vegetation and subsequent accumulation of organic matter. The Organic Horizons variable thus is an important component for assessing Organic Carbon Export from Sedge Tussock Wetlands (community type) of the regional wetland subclass for peraquic sites on toeslope or valley bottom positions proximal to streams.

Shrubs: The herbaceous and shrub strata are co-dominant in precipitation-driven Sedge Tussock wetlands (Figure 41). The Shrubs variable therefore represents fixation of OC by the shrub stratum and storage of OC as living and dead plant tissue. Shrubs store OC for longer periods than herbs, but Chapin (1983) recorded annual biomass turnover rates of 34 to 43% for shrubs in black spruce wetlands. Shrubs also can account for a significant proportion of annual production (*e.g.,* 16%) by vascular plants in black spruce wetlands (Chapin 1983). Similar production and turnover rates may occur in the Sedge Tussock Community Type, which largely share shrub species composition with other community types of the regional wetland subclass. As litterfall from the shrub stratum decomposes, particulate and dissolved OC become available for export from the system.

Altered sites frequently do not have shrub cover as a result of on-going land uses. Loss of shrub cover potentially interacts with export of OC by increasing soil temperature, causing permafrost degradation, loss of peraquic conditions, and allowing on-site microbial oxidation of carbon. Altered sites can rapidly redevelop shrub cover with cessation of disturbance and can re-enter natural successional pathways. The Shrubs variable thus is an important component for assessing Organic Carbon Export from Sedge Tussock Wetlands (community type) of the regional wetland subclass for peraquic sites on toeslopes or valley bottom positions proximal to streams.

Surface Connections: Surface Connections represents the surface and shallow subsurface hydraulic connections between the project assessment area and aquatic systems. Export of dissolved and particulate OC can only occur if flow paths are present to transport OC to aquatic ecosystems. Wetlands supporting closed-sheath sedge (cotton grass) wet meadow (*i.e.,* the Sedge Tussock Community Type) have surface microrelief formed by a network of connected tussock depressions. These depressions form channels for movement of surface water through the site. Continuous surface and shallow subsurface flow paths must reach from the Sedge Tussock wetland to a riparian zone in order for OC to reach aquatic ecosystems. Intervening features of the natural landscape may isolate some Sedge Tussock wetlands from aquatic systems, however.

Anthropogenic perturbation of the Sedge Tussock Community Type can disrupt flow paths and eliminate export of OC. Altered sites frequently are stripped and graded and may be filled. Such actions may eliminate flow paths to riparian zones or may cause internal drainage of the site following permafrost degradation. Where site alteration does not topographically block flow paths to adjacent aquatic ecosystems, sites can redevelop flow to those ecosystems with aggradation of permafrost. Such aggradation can result from allowing sites to re-enter natural successional pathways. Surface Connections thus is a controlling component for Organic Carbon Export from Sedge Tussock Wetlands (community type) of the regional wetland subclass for peraquic sites on toeslopes or valley bottom positions proximal to streams and with hydraulic gradients that direct surface and subsurface flow to streams.

6) Functional Capacity Index

The single assessment model for Organic Carbon Export from Sedge Tussock Wetlands appears in Table 29. The model has a subpart representing aboveground organic carbon production by the plant community (Herbs (V_{HERB}) and Shrubs (V_{SHRUB})) nested within a larger subpart that includes root production and litter decomposition (Organic Horizons (V_{OH})) and peraquic conditions sufficient for surface and shallow subsurface flow (Aquic Moisture Regime (V_{AQUIC})). A single variable, Surface Connections ($V_{SURFCON}$), represents flow paths for export of OC, without which the function does not occur.

The assessment model averages subindices for V_{HERB} and V_{SHRUB} to yield a mean. This mean is then averaged with subindices for V_{OH} and V_{AQUIC} to yield a grand arithmetic mean representing overall potential for within-site production and transport of OC. The model subsequently multiplies the grand mean by the subindex for $V_{SURFCON}$ and raises the entire quantity to the 0.5 power to yield a geometric mean as the FCI. This operation drives the FCI to 0.0 in the event that a flow path for carbon export to aquatic ecosystems does not exist and the function cannot logically occur. The FCI thus captures both the potential of the Sedge Tussock Community Type to produce OC and transport it within the site and the potential of surrounding landscape to support surface and shallow subsurface flow to riparian corridors.

Table 29. Assessment model for calculating a Functional Capacity Index (FCI) for

Organic Carbon Export from Sedge Tussock Wetlands.

COMMUNITY TYPE	**ASSESSMENT MODEL**
Sedge Tussock	FCI = $\{V_{SURFCON} \mathbf{x} ((V_{SHRUB} + V_{HERB})/2 + V_{OH} + V_{AQUIC})/3\}^{1/2}$

3. *Plant Community*

a. *a. Characteristic Plant Community*

1) Definition

This function represents the species composition and physical characteristics of living plants typically found in precipitation-driven wetlands. The emphasis is on the dynamics and structure of the plant communities as evidenced by the presence of trees, shrubs, herbs, mosses, lichens, and liverworts, and by the physical characteristics of the vegetation. An independent, quantitative measure of this function is to inventory all plant species present in the community and to measure the stem density (stems m^{-2} or stems ha^{-1}) and cover (%) of each species. Point-frame sampling for cover and total stem counts for density in replicated sample plots might be used to quantify these characteristics for smaller species. Cover and stem density of large species might be measured digitally from aerial photography. In general, the quantitative measure of Characteristic Plant Community is to improve the accuracy and precision of the rapid assessment techniques used in this model.

2) Rationale for the Function

Plants convert solar radiation and carbon dioxide into complex organic compounds that provide energy to drive microbial food webs, provide corridors (*e.g.* migratory pathways) between habitats, and provide structural complexity that forms feeding, resting, thermal cover habitat, and food for migratory and resident animals. Plants also provide seeds and other propagules for regeneration and succession following fire or anthropogenic alteration and thus account for the sustainability of precipitation-driven wetlands.

Off site, propagules generated in wetlands of the regional subclass maintain species composition and/or structure of adjacent wetlands and allow colonization of nearby degraded systems. In addition, plant communities and nonliving organic material derived from plant communities act through soil temperature and permafrost effects to profoundly affect other wetland functions. These effects include influencing oxidation and reduction processes and nutrient cycling, supplying a consistent source of nutrients to the wetland, driving hydrologic systems to produce aquic moisture regimes, regulating thermal conditions, and mediating soil chemical characteristics, all of which feed back to determine plant community assemblages.

3) Characteristics and Processes that Influence Characteristic Plant Community

Three types of palustrine wetlands (Cowardin *et al.* 1979) are in the subclass and are widespread in Interior Alaska: scrub/shrub, forested, and emergent herb-dominated wetlands (Hall *et al.* 1994). Species diversity is low in these Alaskan wetland communities compared to wetlands in more temperate regions, especially forested wetlands. Nevertheless, spatial variability in community composition in Alaskan palustrine wetlands is large due to landscape heterogeneity, frequency of disturbance, and permafrost processes. Much of the variability within and between different wetlands has been described in the classification system for Alaska vegetation (Viereck *et al.* 1992).

Spatial variability in plant community composition in precipitation-driven wetlands on discontinuous permafrost in Interior Alaska affects wetland functions. For example, the sedge tussock community type creates surface microrelief (*e.g.*, intertussock depressions) that promotes water movement and export of OC from uplands into riverine systems, a function not significant in other community types. Sedge tussock sites also produce a higher percentage of dissolved organic matter than do forested community types characterized by moss and ericaceous vegetation.

Disturbance, particularly fire, is common in Interior Alaska and has an important impact on vegetation dynamics (Van Cleve *et al.* 1991, Walker *et al.* 1986), as well as upon other functional characteristics of precipitation-driven wetlands. For example, accumulation of litter and establishment of moss promotes acidification of the soil surface resulting in rapid thickening of organic mat soil horizons during post-fire succession.

Continuous human-induced perturbation will impact community composition of Interior Alaska wetlands. For example, conversion of wetlands of the regional subclass to agricultural use replaces diverse natural communities with row crop or grass monocultures. Cleared lands often retain their ability to re-enter natural successional pathways upon cessation of active anthropogenic manipulation. Given sufficient time, altered sites can return to wetland conditions, a process assisted by redevelopment of natural plant communities and permafrost aggradation. Characteristic Plant Community measures the response of a wetland to anthropogenic disturbance.

4) Description of Variables Used to Assess Characteristic Plant Community

Variables used to assess Characteristic Plant Community represent characteristic cover percentages by vegetation strata observed in Interior Alaska, as determined from reference standards, and the presence of a native plant community. Variables, discussed in the following section, are Herbs (V_{HERB}); Mosses, Lichens, and Liverworts ($V_{MOSSLICH}$); Ratio of Native to Non-Native Plant Species (V_{PRATIO}); Shrubs (V_{SHRUB}); and Trees (V_{TREE}).

5) Rationale for Selection of Variables

Herb: The Herbs variable represents herbaceous stratum cover in precipitation-driven wetlands on discontinuous permafrost in Interior Alaska varies. Herbaceous cover varies by community type (Tables 17) and perturbation history (Table 19). The condition and extent of the herbaceous stratum affects soil temperature and moisture, pedogenesis, nutrient cycling, faunal support/habitat, and other processes occurring in wetlands of the regional subclass.

Some types of anthropogenic perturbation (*e.g.*, conversion to agricultural pasture, hay, or row crop production) of such wetlands maintain a herbaceous stratum. More severe disruption of precipitation-driven wetlands (*e.g.*, mining, fills) may remove or greatly reduce cover provided by the herbaceous stratum and leave a substrate not conducive to establishment of vegetation. Canopy coverage by the herbaceous stratum thus is a sensitive indicator of site alteration, particularly in treeless community types. The Herbs variable thus is an important component for assessing Characteristic Plant Community in all community types of the regional wetland subclass.

Moss: The Mosses, Lichens, and Liverworts variable represents the dominant ground cover stratum of many community types within precipitation-driven wetlands on discontinuous permafrost in Interior Alaska. Mosses, in particular, exert a strong thermal influence on the regional wetland subclass by facilitating development of permafrost and wetland hydrology on many sites. Moss cover tends to increase with successional maturity of the wetland; therefore, characteristic coverage varies by stand age in the forested community type (Table 18). Shrub and sedge tussock community types also support significant coverage by mosses (Table 17). At present, the authors have insufficient data to use Mosses, Lichens, and Liverworts in the 0- to -5-yr-old Forested Community Type; sampled sites varied from 3 to 63% cover.

Mosses contribute significantly to overall carbon production by these plan communities. production (*e.g.*, 1,257 kg ha^{-1} yr^{-1}) can exceed aboveground tree production in black spruce wetlands (Oechel and Van Cleve 1986). Mosses intercept precipitation-borne nutrients and contaminants before they reach the root zone of vascular plants (Oechel and Van Cleve 1986). By virtue of their rapid uptake and slow decomposition, mosses are nutrient sinks. Permafrost formation within organic soil horizons, a process mediated by the thermal effects of mosses, further immobilizes elements. Mosses provide important cover for some microtine rodents. Lichens and liverworts are less abundant than mosses in reference standard wetlands but share with mosses the stratum cloaking the soil surface. In addition, certain fruticose lichens are important foods for barren-ground caribou that frequent boreal forest winter ranges (Post 1996).

Altered sites *(e.g.*, tilled agricultural fields, fill) frequently have no ground cover from mosses. Such cover may be present on less intensively used sites (*e.g.*, cleared rights-of-way). Moss cover represented by the variable can redevelop on altered sites allowed to re-enter natural successional pathways with cessation of manipulation. The Mosses, Lichens, and Liverworts variable thus is an important component for assessing Characteristic Plant Community in the 6- to 30-yr-old and >30-yr-old forested community types and in the shrub and sedge tussock community types of the regional wetland subclass.

Ratio of Native to Non-Native Plant Species: Reference standard sites have plant communities with a high percentage of native plants, as measured by Ratio of Native to Non-Native Plant Species. Non-native plant species are rare or absent in unaltered precipitation-driven wetlands on discontinuous permafrost in Interior Alaska. Plant species composition is an important influence on other wetland functions. For example, herbivorous animals with specific feeding preferences may not use a plant community with altered species composition, even if the community has retained a physical structure comparable to that of a reference standard community. In addition, altered species composition may influence nutrient cycling (*e.g.*, differing nutrient-uptake capability and litter quality), soil temperature and moisture (*e.g.*, amount of shade and transpiration rate), and cover or reproductive habitat for animals. Anthropogenic perturbation of precipitation-driven wetlands frequently is accompanied by a change in plant species composition (Figure 36). For example, agricultural row crops or pasture support primarily non-native species. If perturbed systems undergo continuing manipulation, invasive native and non-native species can outcompete sensitive native species. In the absence of such manipulation, rapid colonization by native shrubs and trees can place altered wetlands on natural successional pathways leading to re-establishment of native plant communities. In time, trees and shrubs produce conditions (*e.g.*, cold, wet, low-nutrient status) less favorable to exotic species, and most or all non-native species presumably could not persist in mature sites. The Ratio of Native to Non-Native Plant Species thus is an important component for assessing Characteristic Plant Community in all community types of the regional wetland subclass.

Shrubs: The Shrubs variable represents cover of the shrub stratum. Shrubs occur in all community types of precipitation-driven wetlands on discontinuous permafrost in Interior Alaska and are significant in all but the 0- to- 5-yr-old forested community type. Cover varies by community type (Tables17) and perturbation history (Table 19): average reference standard shrub coverages in sedge tussock and shrub community types were 34% and 80%. Shrubs can turn over biomass at annual rates of 34 to 43% and account for a significant proportion of annual production (*e.g.*, 16%) by vascular plants (Chapin 1983) at sites representative of the regional subclass. The condition and extent of the shrub stratum affects soil temperature and moisture, nutrient cycling, faunal support/habitat, and other processes occurring in precipitation-driven wetlands.

Some types of anthropogenic perturbation (*e.g.*, power line rights of way, tree cutting) of wetlands in the regional subclass do not remove the shrub stratum. More severe alteration (*e.g.*, mining, agricultural tillage, fill) of sites within the regional subclass may remove or greatly reduce cover provided by the shrub stratum. Altered sites can re-enter natural successional pathways with cessation of manipulation and rapidly re-establish shrub cover. The Shrubs variable thus is an important component for assessing Characteristic Plant Community in the 6- to 30-yr-old and >30-yr-old Forested community types and in the Shrub and Sedge Tussock community types of the regional wetland subclass.

Trees: The Trees variable represents cover of the tree and small tree stratum. Significant tree cover occurs only in 6- to 30-yr-old and >30-yr-old Forested community types of precipitation-driven wetlands on discontinuous permafrost in Interior Alaska. Percent cover of trees varies between the referenced Forested community types (Table 18) and with perturbation history (Table 19). The condition and extent of the tree coverage affects soil temperature and moisture, nutrient cycling, faunal support/habitat, and other processes occurring in precipitation-driven wetlands.

Some types of anthropogenic perturbation (*e.g.*, removal of individual trees, grazing) of the Forested Community Type maintain some tree cover. More severe alteration (*e.g.*, land clearing, power line rights of way) may greatly reduce or remove tree cover. Altered sites can re-enter natural successional pathways with cessation of manipulation, and development of tree cover occurs relatively soon thereafter. The Trees variable thus is an important component for assessing Characteristic Plant Community in the 6- to 30-yr-old and >30-yr-old Forested community types of the regional wetland subclass.

6) Functional Capacity Index

The assessment models for Characteristic Plant Community differ by community type (Table 30). Each model averages subindices for one, three, or four of the vegetation strata variables appropriate to the community type (Mosses, Lichens, and Liverworts ($V_{MOSSLICH}$); Herbs (V_{HERB}); Shrubs (V_{SHRUB}); and Trees (V_{TREE})) to yield a mean value representing overall vegetation strata coverage. The coverage subpart of the models for 6- to 30-yr-old and >30-yr-old Forested community types includes V_{HERB}, V_{SHRUB}, V_{TREE}, and $V_{MOSSLICH}$. The V_{TREE} variable is deleted for Shrub and Sedge Tussock community types because they do not have significant tree cover. Only the variable V_{HERB} appears in the coverage subpart of the assessment model for the 0- to 5-yr-old Forested Community Type because early post-fire seres are dominated by herbaceous plants. The models then average mean strata coverage with the subindex for the single variable representing healthy community species composition, Ratio of Native to Non-Native Plant Species (V_{PRATIO}), to yield the FCI for Characteristic Plant Community. This procedure accounts for community structure and composition, which receive equal weighting.

Table 30. Assessment models for calculating Functional Capacity Indices (FCI's) for Characteristic Plant Community by community type.

COMMUNITY TYPE	ASSESSMENT MODEL
Forested	
0- to 5-yr-old	$FCI = (V_{HERB} + V_{PRATIO})/2$
6- to 30-yr-old	$FCI = ((V_{TREE} + V_{SHRUB} + V_{HERB} + V_{MOSSLICH})/4 + V_{PRATIO})/2$
>30-yr-old	$FCI = ((V_{TREE} + V_{SHRUB} + V_{HERB} + V_{MOSSLICH})/4 + V_{PRATIO})/2$
Shrub	$FCI = ((V_{SHRUB} + V_{HERB} + V_{MOSSLICH})/3 + V_{PRATIO})/2$
Sedge Tussock	$FCI = ((V_{SHRUB} + V_{HERB} + V_{MOSSLICH})/3 + V_{PRATIO})/2$

4. Faunal Support/Habitat

a. Faunal Support/Habitat Components

1) Definition

This function represents the capacity of a wetland to support animal populations and guilds by providing heterogeneous habitats. An independent, quantitative measure of this function is to identify all animal species potentially occurring within the reference domain (to any specified level of phylogenetic complexity), identify each species' multidimensional habitat requirements, and sample the assessment area sufficiently to determine the set of species whose multidimensional habitat requirements are supplied by the site. More realistically, repeated sampling of faunal species present (to any specified level of phylogenetic complexity) on seasonal, annual, and decadal scales is necessary to fairly characterize faunal use in the Subarctic, which is characterized by variable animal populations in response to cyclic and stochastic environmental events.

2) Rationale for the Function

Faunal Support/Habitat Components evaluates the suitability of vegetation structure, microtopography, and hydrologic conditions for sustaining characteristic animal populations of precipitation-driven wetlands on discontinuous permafrost in Interior Alaska. Life history activities supported by habitat components for vertebrates and invertebrates include predator escape, food, resting, and reproduction. Other habitat components serve as potential movement zones for wide-ranging and migratory animals, corridors for gene flow between separated populations, and avenues for progeny to exploit new areas. Habitat components also regulate and moderate fluctuations in temperature and other aspects of the physical environment impinging on faunal populations and provide habitat heterogeneity to support a diverse assemblage of organisms. Since structure is an important habitat component for resident and nonresident animals, communities possessing greater structural complexity often are more diverse and species rich. In addition, faunal metabolism and activities affect all ecosystem processes.

Faunal Support/Habitat Components is meant to be used as part of a rapid wetland functional assessment technique. The function is not meant to replace more detailed procedures or long-term habitat studies. If intensive studies of wildlife and animal communities are needed and justified, the more time-consuming Habitat Evaluation Procedure (HEP) should be used (U.S. Fish and Wildlife Service 1980).

3) Characteristics and Processes that Influence Faunal Support/Habitat Components

Precipitation-driven wetlands on discontinuous permafrost in Interior Alaska have highly variable structure. For example, the >30-yr-old Forested Community Type has a wide range of tree heights, coverages, and densities. Factors such as stand age, site aspect and slope, permafrost table, soil moisture, and soil profile affect tree growth and produce noted variation. Plant species composition (*e.g.,* presence or absence of willow) can vary from site to site within a community type, but overall species composition for the regional wetland subclass is relatively constant. These wetlands support invertebrate and vertebrate fauna ranging from microarthropods to moose. Animal use of wetlands within the regional subclass varies with site maturity and with plant community composition and structure but otherwise is difficult to generalize.

Faunal species characteristic of early successional sites and deciduous forest are most abundant in the 0- to 5-yr-old and 6- to 30-yr-old Forested community types. Species favoring coniferous forest will be most abundant in the >30-yr-old Forested Community Type. The Shrub and Sedge Tussock community types share Faunal Support/Habitat Components with both early and late stages of forest succession: the shrub stratum and graminoid component of herbaceous cover is structurally comparable to that of young post-fire sites but the moss component of the ground cover shares characteristics with mature forested sites.

Cyclic processes associated with fire, described in Chapter III of this ODRG, create the habitat mosaic typifying landscapes of the Interior Region. These processes affect most aspects of faunal Support/Habitat and establish a range of conditions allowing a variety of organisms to exist across the fire mosaic. Early post-fire seres generally will be warmer, drier, higher-nutrient sites with more herbaceous cover than later seres. Microtine rodent habitat and hunting habitat for raptors is abundant in such seres. Mid-successional stages supporting young deciduous trees and shrubs are important for moose, ruffed grouse, and deciduous-nesting passerine birds. Mature forest supports species such as snowshoe hare, red squirrel, spruce grouse, carnivorous furbearers, and coniferous-nesting passerine birds (Post 1996).

Anthropogenic alteration of precipitation-driven wetlands disrupts Faunal Support/Habitat Components by removing plant community structure and changing species composition. Alteration may occur over a range of intensities ranging from disturbance of a single stratum to removal of all vegetation and organic soil horizons. Effects of habitat alteration on faunal species are most severe for sites lacking vegetation and organic soil. Altered sites may re-enter successional pathways upon cessation of manipulation. These pathways ultimately may converge with those of natural cyclic processes, at which time Faunal Support/Habitat Components should return to natural conditions.

4) Description of Variables Used to Assess Faunal Support/Habitat Components

Variables used to assess Faunal Support/Habitat Components represent both direct animal use of a site and site potential to support characteristic fauna of precipitation-driven wetlands on discontinuous permafrost in Interior Alaska. The six variables, described in the following section, are Animal Sign (V_{ASIGN}), Coarse Woody Debris (V_{CWD}), Macro/Microtopographic Complexity (V_{MTOPO}), Organic Horizons (V_{OH}), Static Surface Water (V_{SURWAT}), and Vegetative Strata ($V_{VSTRATA}$).

5) Rationale for Selection of the Variables

Animal Sign: The strongest indication that a wetland possesses adequate Faunal Support/Habitat Components is evidence of use by animals, and Animal Sign represents such use. The prevalence of evidence for animal use is characteristic of a healthy system. Unfortunately, the amount of evidence for animal use at any given site is controlled by a large number of factors, not least of which are the time of day, season, or even year of the site assessment. Animal populations in the Subarctic undergo large natural fluctuations on a cyclic or stochastic basis. Such fluctuations strongly affect the probability of observing evidence of animal use during a given site visit. In addition, landscape-level or even regional patterns (*e.g.*, migration routes) can concentrate evidence for animal use in some wetlands but leave little in otherwise similar wetlands in the same landscape.

Interior Alaska sustains a rich faunal community, which demonstrates a range of tolerances to human-induced perturbations, and altered sites frequently support at least some continued faunal use if the degree of alteration is not severe. Even in degraded landscapes, animal movements between remaining patches of natural habitat can leave sign in sub-optimal habitats. Altered sites can re-enter natural successional pathways upon cessation of manipulation. Evidence of animal use should increase to levels characteristic of reference standard conditions over the 100- to 250-yr fire cycle. Animal Sign thus is an important variable for assessing Faunal Support/Habitat Components in all community types of the regional wetland subclass.

Coarse Woody Debris: Coarse Woody Debris represents site potential to support fauna that use dead and down wood. For example, coarse wood supplies cover and reproductive habitat for both vertebrates (*e.g.,* microtine rodents) and invertebrates (*e.g.,* carpenter ants), as well as adds microrelief to the forest floor. Tangles of down wood can create sufficient relief to provide sites for black bear denning. Coarse wood is a substrate for moss and lichen development that adds to community production, food web support, and nutrient cycling (*e.g.,* N fixation by cyanobacteria associated with lichens). Coarse wood is most abundant in the 0- to 5-yr-old Forested Community Type under reference standard conditions, diminishes in abundance in older post-fire seres, and is largely absent from Shrub and Sedge Tussock community types.

Altered sites frequently have little or no coarse wood. Land-clearing operations where all trees (potential coarse wood) and coarse wood is pushed into berms and often later burned removes a component of faunal support/habitat. Altered sites can re-enter natural successional pathways with cessation of manipulation. Redevelopment of significant coarse wood would not occur until completion of the 100- to 250-yr fire cycle and return of mature boles to the forest floor. Coarse Woody Debris thus is an important variable for assessing Faunal Support/Habitat Components in the 0- to 5-yr-old and 6- to 30-yr-old Forested community types of the regional wetland subclass.

Macro/Microtopographic Complexity: Macro/Microtopographic represents the surface roughness and topographic complexity of wetland systems that give rise to a variety of faunal support/habitat components. For example, topographic complexity establishes a variety of ecozones and ecotones that provide the habitat needs (*e.g.,* soil moisture conditions) of wetland plant and animal species. Roughness and complexity also form compartments that store water in precipitation-driven wetlands. All community types of the regional wetland subclass show topographic complexity under reference standard conditions.

Anthropogenic alteration generally removes microtopographic relief. On-going manipulation of altered sites (*e.g.,* agricultural tillage) usually ensures continued absence of microtopographic relief and may gradually reduce macrotopographic relief (*e.g.,* filling of paleochannels with repeated tilling). With cessation of manipulation, altered sites can re-enter successional pathways that restore microtopography through development of moss ground cover and gradual increase in complexity. Increasing complexity provides additional niches for faunal species. Macro/Microtopographic Complexity thus is an important variable for assessing Faunal Support/Habitat Components in all community types of the regional wetland class.

Organic Horizons: Organic Horizons represents the upper part of the soil profile occupied by soil invertebrates and used by small mammals. Organic soil horizons, which occur in all community types of the regional wetland subclass, provide cover and reproductive habitat for both vertebrates (*e.g.,* yellow-cheeked vole) and invertebrates. These horizons support most rooting by vascular plants in mature community types. To the extent that roots provide food chain support to other organisms, organic soil horizons are a food source for vertebrates and invertebrates. Many invertebrates overwinter beneath organic litter on the forest floor, as well. The low bulk densities characteristic of fibric and hemic organic layers facilitate faunal burrowing and formation of runways. In addition, fibric organic matter has insulative properties favorable for nest building and thermal shelter.

Altered sites (*e.g.*, agricultural land, fills) frequently have degraded or minimal organic soil horizons. Exposed mineral soils on such sites have much higher bulk densities and less favorable thermal properties for fauna that do organic soil horizons. Altered sites can re-enter natural successional pathways upon cessation of manipulation and rebuild organic soil horizons as the sites converge with natural wetland cycles. Development of moss cover and consequent gradual thickening of organic soil horizons are characteristic of site maturity. Organic Horizons thus is an important variable for assessing Faunal Support/Habitat Components in all community types of the regional wetland subclass.

Static Surface Water: Static Surface Water indicates the presence of a water table at or above the wetland surface (ponding) during a portion of the year and thus the potential for supporting characteristic water-dependent fauna. Although ponding generally is absent in early seral stages, unperturbed, mature sites frequently pond water. Ponded water provides important habitat components for aquatic invertebrates (*e.g., Typulidae, Chironomidae*) and a consistent supply of water for terrestrial vertebrate and invertebrate species. Ponded water also contributes to a diversity of plant species that may support a more diverse faunal assemblage than would occur on a site without ponding.

Sites that have undergone anthropogenic alteration can drain internally as permafrost degrades and thus lose the ability to pond water. Land clearing often removes relief and/or organic soil horizons that contribute to water storage. Altered sites can re-enter natural successional pathways upon cessation of manipulation and, with development of organic soil horizons and other late seral characteristics, regain the capability to pond water. Static Surface Water thus is an important component for assessing Faunal Support/Habitat Components in the >30-yr-old Forested, Shrub, and Sedge Tussock community types of the regional wetland subclass.

6) Functional Capacity Index

The assessment models for Faunal Support/Habitat Components differ by community type (Table 31). The models have two subparts: one represents structural components of faunal support/habitat and the other represents evidence that vertebrate fauna actually frequent the project assessment area. The variables Macro/Microtopographic Complexity (V_{MTOPO}), Organic Horizons (V_{OH}), Vegetative Strata ($V_{VSTRATA}$), and Coarse Woody Debris (V_{CWD}) are used in the structural components subpart of the models for 0- to 5-yr-old and 6- to 30-yr-old Forested community types. For >30-yr-old Forested, Shrub, and Sedge Tussock community types, Static Surface Water (V_{SURWAT}) replaces V_{CWD} in the structural subpart of the models. This replacement reflects the scarcity of coarse wood in successionally mature community types and the lack of ponding in early post-fire seres. The assessment models for all community types use Animal Sign (V_{ASIGN}) for evidence of faunal use.

In all cases, the models average subindices for structural components of faunal support/habitat to yield a mean structural value. The mean structural value is then multiplied by the subindex for V_{ASIGN} and the result raised to the 0.5 power to yield a geometric mean as the FCI. This procedure drives the FCI for Faunal Support/Habitat Components to 0.0 in the absence of evidence for animal use.

Table 31. Assessment models for calculating Functional Capacity Indices (FCI's) for Faunal Support/Habitat Components by community type.

COMMUNITY TYPE	ASSESSMENT MODEL
Forested	
0- to 5-yr-old	$FCI = (V_{ASIGN} \times (V_{MTOPO} + V_{OH} + V_{VSTRATA} + V_{CWD})/4)^{1/2}$
6- to 30-yr-old	$FCI = (V_{ASIGN} \times (V_{MTOPO} + V_{OH} + V_{VSTRATA} + V_{CWD})/4)^{1/2}$
>30-yr-old	$FCI = (V_{ASIGN} \times (V_{MTOPO} + V_{OH} + V_{VSTRATA} + V_{SURWAT})/4)^{1/2}$
Shrub	$FCI = (V_{ASIGN} \times (V_{MTOPO} + V_{OH} + V_{VSTRATA} + V_{SURWAT})/4)^{1/2}$
Sedge Tussock	$FCI = (V_{ASIGN} \times (V_{MTOPO} + V_{OH} + V_{VSTRATA} + V_{SURWAT})/4)^{1/2}$

b. *Interspersion and Connectivity*

1) Definition

This function represents characteristic juxtaposition and contiguous corridors of native plant communities necessary to meet life history requirements of organisms, including movements to and from the wetland. An independent, quantitative measure of Interspersion and Connectivity is to construct habitat maps of the landscape surrounding the wetland, perhaps extending to regional mapping to capture habitat interspersion and connections for large, wide-ranging or migratory species. Such maps would have to be evaluated in relation to data on characteristic juxtaposition of habitat types at several scales. In addition, species-specific research establishing minimum values for habitat connections would be necessary to evaluate the effectiveness of connections in the mapped landscapes or regions.

2) Rationale for the Function

Vertebrates and invertebrates extensively use precipitation-driven wetlands on discontinuous permafrost in Interior Alaska to complete life history activities including feeding, reproduction, resting, thermal cover, and predator avoidance (Post 1996). Adequate habitat corridors are required for connecting wetlands to other ecosystems (Brinson *et al.* 1995) and to provide refugia for plants and animals. For example, wide-ranging megafauna (*e.g.*, moose, brown/grizzly bear (*Ursus arctos*)) feed in wetlands of the regional subclass, riparian wetlands, fens, and uplands. Uninterrupted corridors facilitate movement within these large home-ranges. Smaller, less mobile faunal species frequently require juxtaposition of habitat components or resources on scales consistent with their smaller home ranges. Habitat connections and interspersion of resources contribute to dispersal of plants and animals between habitats and faunal access to resource requirements for completion of life cycles.

Alteration of wetlands and their isolation by incompatible surrounding land uses frequently accompanies increasing human population densities and economic activities. Studies of such habitat fragmentation show reduced faunal species richness as patch sizes decrease. Connections between habitats help maintain higher animal and plant diversity across the landscape (Brinson *et al.* 1995). Interspersion and Connectivity thus characterizes wetlands within their landscape settings.

3) Characteristics and Processes that Influence Interspersion and Connectivity

Habitat requirements of an animal species may encompass a number of plant communities or hydrogeomorphic contexts. Interspersion of native plant communities on a scale appropriate to the mobility and home range size of a given faunal species can juxtapose resources needed for the species to exist. Such interspersion of habitats must occur at the appropriate scale over sufficient area to support not just one individual but a population of sufficient size to be viable for extended periods of time. Connectivity between areas with sufficient resources to support individual animals must exist for viable populations to occur. Likewise, connections between areas occupied by viable populations must exist to ensure long-term occupation of available habitat through recolonization of habitat patches following local extinctions.

The chief natural process influencing Interspersion and Connectivity in Interior Alaska is fire. Fire produces a mosaic of plant communities on the landscape. The fire mosaic thus produces an interspersion of habitats, some of which are in a continual state of seral change. In the absence of anthropogenic perturbation, native species compose the mosaic of plant communities. Indigenous fauna presumably have evolved to thrive within the natural mosaic.

Anthropogenic perturbation of Interior landscapes, including wetlands of the regional subclass, often fragments faunal habitats and shifts the distribution of community types. For example, although agricultural fields are, to some extent, structurally similar to early post-fire seres, they do not undergo succession to shrub or forest while under cultivation. Neither do fields have the non-uniform plant community and successional distribution across the landscape characteristic of a fire mosaic. For a given geographic area, the extent of agricultural analogs to early post-fire seres can be much greater in the landscape, when integrated over time, than the extent of natural post-fire seres would have been. As a result, unaltered habitat patches may be entirely surrounded by non-native vegetation maintained in a barren or herbaceous state. precipitation-driven wetlands on discontinuous permafrost in Interior Alaska that lose a mosaic of native plant communities and lose connections with other wetlands may suffer reduced faunal species richness, in addition to reduced populations of remaining species as a result of decreased wetland habitat.

4) Description of Variables Used to Assess Interspersion and Connectivity

Variables used to assess Interspersion and Connectivity describe land use within and surrounding the project assessment area and describe the extent of contiguous native vegetation. These variables, discussed in the following section, are Assessment Area Use ($V_{AREAUSE}$), Contiguous Native Plant Communities (V_{CONTIG}), and Surrounding Land Use (V_{SURUSE}).

5) Rationale for Selection of Variables

Assessment Area Use: Assessment Area Use represents land uses within the assessment area. Uninterrupted corridors are critical for movement of animals within and between discontinuous permafrost wetlands. The integrity of these corridors may be disturbed through human-induced perturbations both within and around the assessment area. Land uses within the project assessment area largely determine the degree of alteration to native plant communities and the extent to which non-native analogs to native plant communities may still exist on site. For example, some activities (*e.g.,* tree removal, light grazing) may leave a portion of the native vegetation intact, which may allow cover for faunal movement within the site. Other activities (*e.g.,* agricultural hay or improved pasture production) may replace native vegetation with non-native vegetation but still provide cover for animal movement (*e.g.,* microtine rodents in the herbaceous stratum).

Altered sites can return to reference standard conditions over the 100- to 250-yr fire cycle by re-entering natural successional pathways upon cessation of manipulation. Such sites can recover characteristic native vegetation suitable for supporting faunal use and movement. Assessment Area Use thus is an important component for assessing Interspersion and Connectivity in all community types of the regional wetland subclass.

Contiguous Native Plant Communities: Contiguous Native Plant Communities represents the primary level of habitat connection between an assessment area and its surroundings. Contiguous vegetation cover provides corridors necessary for animal movement and migration in and out of wetland systems. For example, small mammals may have low likelihood of encountering a relatively sheltered dispersal corridor that has only a small connection to the wetland. In contrast, corridors connecting to the majority of the site perimeter may be encountered readily by small fauna. Corridors of native vegetation support plant and animal dispersal, genetic interaction between otherwise isolated populations, and recolonization of wetlands where local plant or animal populations have perished due to adverse environmental conditions or predation. The ideal situation for plant dispersal and animal movements is the unaltered context of natural wetlands within native plant communities.

Anthropogenic perturbation that removes native vegetation around a wetland reduces the freedom of animal movement in appropriate cover and reduces opportunities for dispersal of propagules of native vegetation. Altered sites and their surrounding buffer zones can re-enter natural successional pathways with cessation of manipulation. Redevelopment of native plant communities around recovering sites can restore reference standard conditions for the variable. Contiguous Native Plant Communities thus is an important component of Interspersion and Connectivity in all community types of the regional wetland subclass.

Surrounding Land Use: Surrounding Land Use represents the secondary-level connections (*i.e.,* out to 1,000 ft (305 m)) between an assessment area and its landscape context. Uninterrupted corridors are critical for movement of animals within and between precipitation-driven wetlands on discontinuous permafrost in Interior Alaska. The integrity of these corridors may be disturbed through human-induced perturbations both within and around the assessment area. Land uses occurring in the landscape surrounding a wetland largely determine the degree of alteration to native plant communities and the extent to which non-native analogs to native plant communities may still exist in the landscape. These native and non-native plant communities act as corridors leading between wetlands and other sites necessary for faunal life history activities and or plant dispersal.

Some land-use activities (*e.g.,* tree removal, light grazing) may leave a portion of the native vegetation intact, which may allow cover for faunal movement between wetlands. Other activities (*e.g.*, agricultural hay or improved pasture production) may replace native vegetation with non-native vegetation but still provide cover for animal movement (*e.g.*, microtine rodents in a herbaceous stratum). Finally, the most intensive land uses of landscapes surrounding wetlands may remove or suppress all suitable food and cover for animal movements or remove appropriate substrates plant reproduction and dispersal. Surrounding Land Use thus is an important component for assessing the Interspersion and Connectivity function in all community types of the regional wetland subclass.

6) Functional Capacity Index

The assessment model for Interspersion and Connectivity is used for all community types (Table 32). The model contains three land use or condition variables: Assessment Area Use ($V_{AREAUSE}$), Contiguous Native Plant Communities (V_{CONTIG}), and Surrounding Land Use (V_{SURUSE}). These variables respectively represent conditions within the assessment area, within the 100-ft (30.5-m) buffer around the site perimeter, and within the zone within 1,000 ft (305 m) of the site perimeter with respect to their capacities to support animal movements and life history activities, as well as plant and animal dispersal. The assessment model averages the variable subindices to yield a FCI for Interspersion and Connectivity. Conditions within the wetland, its immediate buffer, and the surrounding landscape thus are weighted equally.

Table 32. Assessment model for calculating the Functional Capacity Index (FCI) for Interspersion and Connectivity in all community types.

COMMUNITY TYPE	ASSESSMENT MODEL
All	$FCI = (V_{AREAUSE} + V_{CONTIG} + V_{SURUSE})/3$

C. Definition of Variables

Variable: Animal Sign (V_{ASIGN})

Definition: The number of observations of use of the project assessment area by animals. Observation include direct (*e.g.*, visual observation of animals) and indirect (*e.g.*, tracks) evidence of animal use of the area.

Rationale for Selection of the Variable: Variables used to assess faunal habitat components represent both direct animal use of a site, and site potential to support characteristic fauna of precipitation-driven wetlands on discontinuous permafrost in Interior Alaska.

Measurement Protocol: Field teams complete random walks within the project assessment area and count the number of different signs of animal use (Figure 47). Categories for sign include direct visual or aural observation of animals, tracks, trails ≤4” (10 cm) wide, trails >4” (10 cm) wide, evidence of feeding, middens, scat, nests or nest cavities, bedding, fur or hair, scrapes or rubs, and “other sign as specified.” In addition, field teams also count the number of animal trails encountered within a 200-ft (61-m) line transect through the project assessment area.

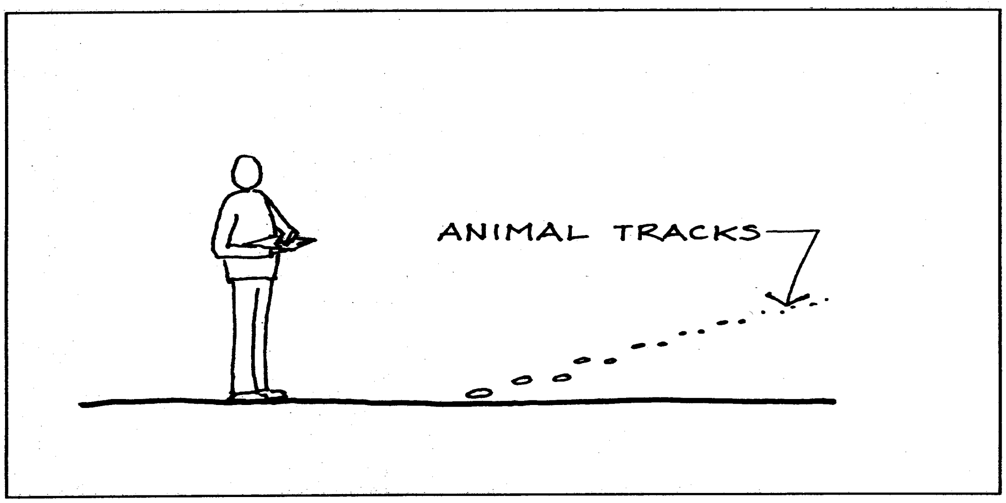
Data: Located in Appendix B. Summary graphs are in Appendix C.

Scaling Rationale: Field teams recorded evidence of animal use at 55 reference sites (Appendix B). Direct observations of animals were infrequent. Field observation of indirect evidence was the most reliable indicator of animal use. However, the correlation of evidence of animal use with other factors such as site condition, stand age, or land use was low. Therefore, best scientific judgment was used to scale this variable. The authors encourage basic and applied research on habitat features associated with the range of land uses that occur within precipitation-driven wetlands. Results of such research could improve scaling associated with measurements or conditions for the animal sign variable and/or the faunal habitat components function.

Confidence: The author's confidence that reasonable logic and/or data support scaling is Low to No Confidence.

Figure 47. Measurement Protocol for the Animal Sign Variable (V_{ASIGN})

Figure 47. Measurement Protocol for the Animal Sign Variable (V_{ASIGN})



Scaling: FOR ALL COMMUNITY TYPES

Measurement or Condition for V_{ASIGN}	**Index**
One or more signs of animal use exist. (Note: Direct observation of animal use = 1 type of animal sign. Do not double count direct sign with fresh tracks, scat, etc.).	1.0
No data to support this condition.	0.75
No data to support this condition.	0.5
No data to support this condition.	0.25
No evidence of animal use exists on the site. However, habitat is recoverable and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
No direct or indirect evidence of animal use exists on the site. The habitat on the site is neither recoverable nor sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

Variable Name: Aquic Moisture Regime (V_{AQUIC})

Definition: This variable is a measure of the degree to which soils currently experience continuous or periodic saturation and reduction. The presence of these conditions is indicated by redoximorphic features and can be verified, except in artificially drained soils, by measuring saturation and reduction.

Rationale for Selection of the Variable: Soils within the aquic moisture regime have morphological characteristics which indicate long term saturation (epi- and/or endo) and the presence of anaerobic conditions that reflect important biogeochemical processes such as elemental cycling and carbon export.

Measurement Protocol: Field teams directly observe aquic soil conditions in a soil pit located at the center point of the project assessment area and excavated to a depth of approximately 6 ft (2 m) by shovel and bucket auger, or to the depth of permafrost, whichever is encountered first (Figure 48). Indicators of aquic soil conditions on unperturbed sites include the following: (a) a complex pattern of faint grayish and reddish colors (redox depletions and concentrations, respectively) in the mineral soil (active redoximorphic features), (b) a greenish-gray (gleyed) substratum color, and an over-thickened surface organic layer (histic epipedon).

Burned sites and altered sites may exhibit evidence of faint grayish and reddish patterns (redox depletions and concentrations, respectively) throughout the upper part of the silty or loamy mantle (relict redoximorphic features). Burned, but unaltered, sites in depressions sometimes exhibit the following condition: an apparent water table is present within 5 ft (1.5 m) of the surface, but permafrost is absent.

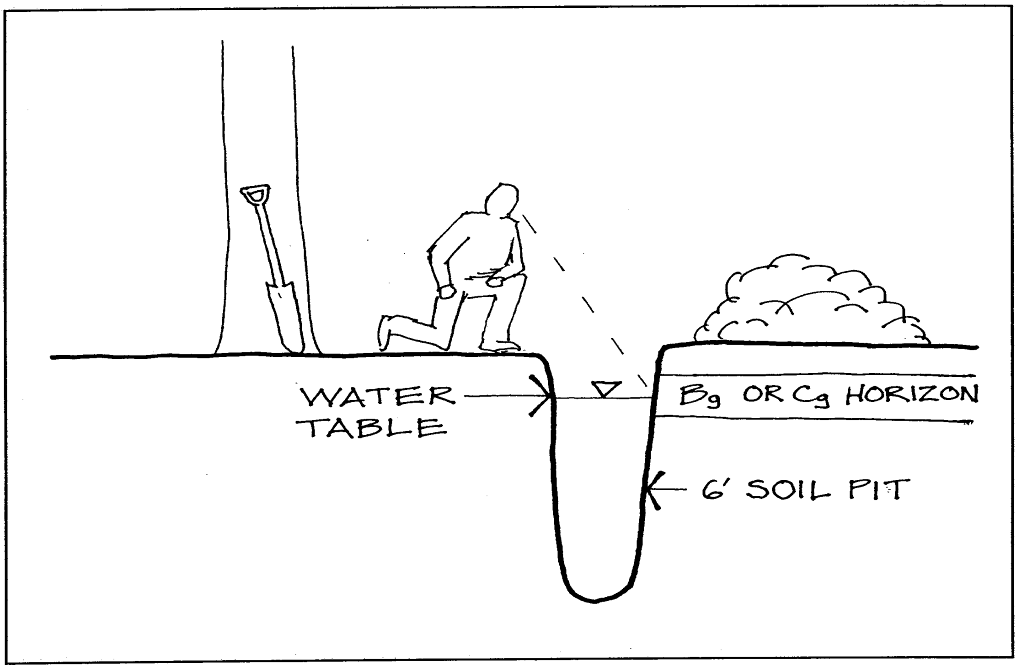
Altered sites in depressions sometimes exhibit the following indicators of aquic soil conditions: a water table may be temporarily perched over seasonal frost during late spring as evidenced by presence of black mucky surface textures ≥2 inches (5 cm) thick over a strongly contrasting gray and red mottled color pattern (active redoximorphic depletions and concentrations), a water table (endosaturation) and prolonged saturation may persist as evidenced by an apparent water table ≤5 ft (1.5 m) from the surface and a predominance of greenish-gray (gleyed) mineral soil color ≤ 20 inches (51 cm) from the surface.

Field teams should use current *Alaska Hydric Soil Indicators* and *Soil Taxonomy* (Soil Survey Staff 1990) for further guidance.

Data: Located in Appendix B. Summary graphs are in Appendix C.

Figure 48. Measurement Protocol for the Aquic Moisture Regime Variable (V_{AQUIC})

Figure 48. Measurement Protocol for the Aquic Moisture Regime Variable (V_{AQUIC})



Scaling Rationale: The authors scaled aquic moisture regime using empirical field data from 55 reference sites (Appendix B) and best scientific judgment. Reference standard sites representing mature seral stages of precipitation-driven wetlands on discontinuous permafrost in Interior Alaska exhibit aquic soil conditions, but severely disturbed sites often do not. Well-established relationships exist between perturbation of vegetation and surface soil horizons and the response of soil thermal regimes, which leads to altered site hydrology (Viereck 1982, Ping 1987). The authors suggest that the large discontinuity in scale from 0.75 to 0.25 is justified because it represents a binary response of the variable to loss of aquic conditions in the soil.

Confidence: The authors' confidence in the variable scaling is Medium High.

Scaling: FOR ALL COMMUNITY TYPES

Measurement or Condition for V_{AQUIC}	**Index**
Direct observation of aquic soil conditions and/or evidence of aquic soil conditions within the project assessment area, from morphological characteristics indicative of saturated soils in the modal soil profile. Aquic soil conditions have not been altered by human-induced disruption of the soil profile or soil hydrologic or thermal regimes.	1.0
Direct observation of aquic soil conditions and/or evidence of aquic soil conditions within the project assessment area, from morphological characteristics indicative of saturated soils in the modal soil profile. Evidence of altered hydrology (*i.e.*, episaturation to endosaturation) initiated through human-induced disruption of the soil profile or, soil hydrologic or thermal regimes. (*e.g.*, organic mat removal), which **may** result in permafrost degradation. Permafrost degradation can result in: (a) change from episaturation to endosaturation, **or** (b) increased depth of thaw with maintenance of episaturation.	0.75
No standard for this score.	0.5
Aquic soil conditions are absent due to discontinued land use practices or activities within the project assessment area, that have led to removal of the organic surface horizon(s) and altered surface and subsurface hydrology. Removal of the organic horizon can initiate permafrost degradation. The variable is recoverable to aquic conditions and sustainable through natural processes if the existing land use is discontinued and no restoration measures are applied.	0.25
Aquic soil conditions are absent due to ongoing land use practices within the project assessment area, that induce removal of the organic horizon(s) and alteration of surface and subsurface hydrology, initiating permafrost degradation (*e.g.*, agricultural or peat mining). Aquic soil conditions have potential toward recovery (*e.g.*, organic horizon is forming/reforming) through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
Aquic conditions are absent within the project assessment area due to removal or burial of organic horizon(s) and silty or loamy mantle (*e.g.*, urbanization or placer mining), and alteration of hydrology. The variable is neither recoverable to aquic soil conditions nor sustainable through natural processes (within the 100- to 250-yr fire cycle) if the existing land use is discontinued and no restoration measures are applied.	0.0

Variable: Assessment Area Use ($V_{AREAUSE}$)

Definition: Predominant land use within the project assessment area.

Rationale for Selection of the Variable: Predominant land use affects the condition (*i.e.*, more or less disturbed) of the project assessment area and the ability of the site to support native plant communities. In addition, land uses strongly influence the ability of the site to support functions and/or attributes, such as interspersion and connectivity with surrounding habitats, habitat patch size, and the extent of contiguous native vegetation.

Measurement Protocol: Field teams estimate the predominant land use category of the project assessment area (Figure 49). Predominant land use is the land use category that fits more than 50% of the area. Land use categories include information on time since site alteration; type of alteration; current successional state of site; if manipulation has ceased; whether dominant vegetation is native or non-native; permanence (*e.g.*, perennial or annual) of non-native vegetation cover; and nature of on-going anthropogenic activities.

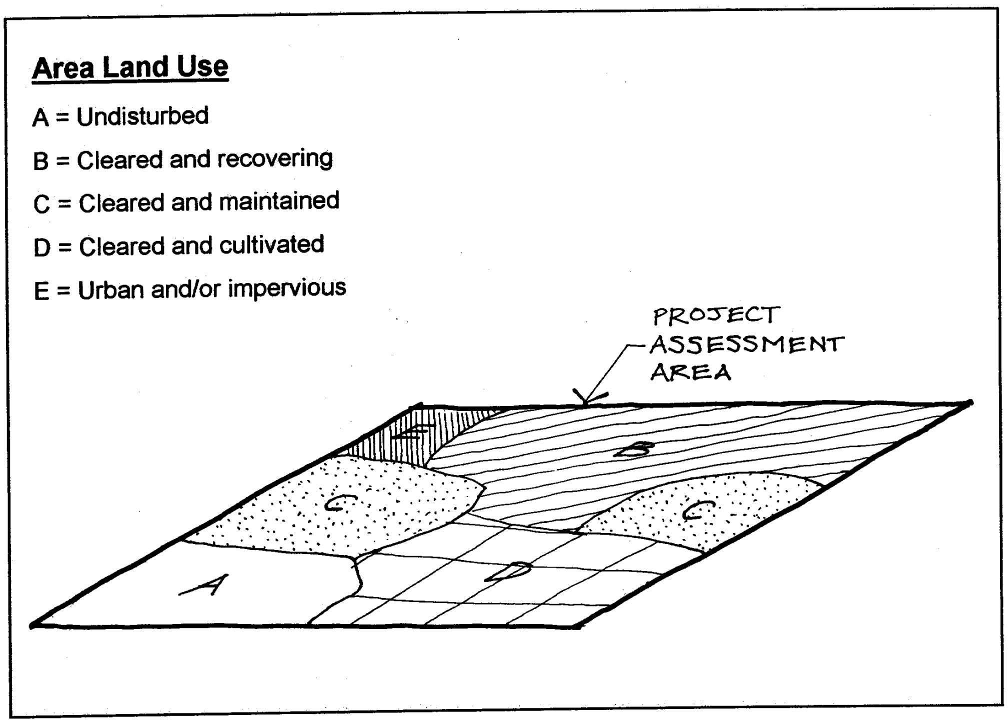
Data: Located in Appendix B. Summary graphs are in Appendix C.

Scaling Rationale: Field teams collected land use data at 55 reference sites (Appendix _, Matrices of Measured Attribute). The variable was scaled using reference data, field observations, and best scientific judgment. $V_{AREAUSE}$ was scaled according to a disturbance scale, ranging from unaltered reference standard conditions dominated by native vegetation to permanent alteration of the native communities and replacement with non-native vegetation or anthropogenic surfaces (*i.e.*, buildings, roads). The disturbance scale was developed by the interdisciplinary team based upon field observation and best scientific judgement.

Confidence: The authors' confidence that reasonable logic and/or data support scaling is Medium High.

Figure 49. Measurement Protocol for the Assessment Area Use Variable ($V_{AREAUSE}$)

Figure 49. Measurement Protocol for the Assessment Area Use Variable ($V_{AREAUSE}$)



Area Land Use

A = Undisturbed

B = Cleared and recovering

C = Cleared and maintained

D = Cleared and cultivated

E = Urban and/or impervious

Scaling: FOR ALL COMMUNITY TYPES

Measurement or Condition for $V_{AREAUSE}$	**Index**
Predominant Land Use of PAA is undisturbed. No significant human-induced alteration.	1.0
Predominant Land Use of PAA is cleared and/or altered >5 years before present. Site is dominated by native species and is recovering through natural successional processes.	0.75
Predominant Land Use of PAA is cleared of all large woody vegetation (trees and shrubs >3 ft (0.9 m) tall); regular maintenance prevents regeneration of woody vegetation (*e.g.*, mowed rights-of-way). Site is dominated by native species.	0.5
Predominant Land Use of PAA is cleared of all native vegetation. Herbaceous vegetation layer intact and dominated by cultivars or non-native adventive species. Permanent vegetative cover maintained (*e.g.*, hay land, pasture land, CRP land). **OR** Predominant Land Use of PAA is cleared ≤5 years before present. Site is dominated by native species and is recovering through natural successional processes.	0.25
Predominant Land Use of PAA is cleared and cultivated for annual cropping **or** cleared and maintained essentially free of vegetative ground cover. The variable is recoverable and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
Predominant Land Use of PAA is urban fill and/or impervious surface (*e.g.,* pavement, buildings, roofs). The variable is neither recoverable nor sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

Variable: Coarse Woody Debris (V_{CWD})

Definition: The density (# /acre (#/ha)) and/or volume (ft^3/acre (m^3/ha)) of coarse woody debris (diameter >2" (5 cm)) within the project assessment area. Coarse woody debris includes down wood, but not standing snags.

Rationale for Selection of the Variable: Amount of coarse woody debris characteristic of reference standard conditions is representative of the ability of the site to support native plant communities, as well as to provide habitat/faunal support functions.

Measurement Protocol: Field teams estimate density and volume of coarse woody debris using a point-center quarter (PCQ) method (Figure 50). The plot center is located adjacent to the main soil pit for the plot. In each quarter, field teams record the distance from plot center to the middle of the nearest piece of coarse down and dead wood. Then, the overall length and diameter of the piece is measured and recorded. Diameter is measured at the middle of the piece. On long pieces that taper to <2" (5 cm) diameter, only that portion of the piece that is ≥2" (5 cm) diameter is measured. If the piece spans quarter boundaries (*e.g.*, spans the NE - SE quarter boundary), only that portion of the coarse wood within the quarter is measured. If a quarter does not contain coarse woody debris, the PCQ method cannot be used. In these cases, field teams record the number of pieces of coarse down and dead wood within a 0.1-acre (0.04-ha) to calculate density. Lengths and diameters of all pieces of coarse wood are recorded and used to calculate volumes. Densities and volumes on a per acre basis are calculated from the plot data.

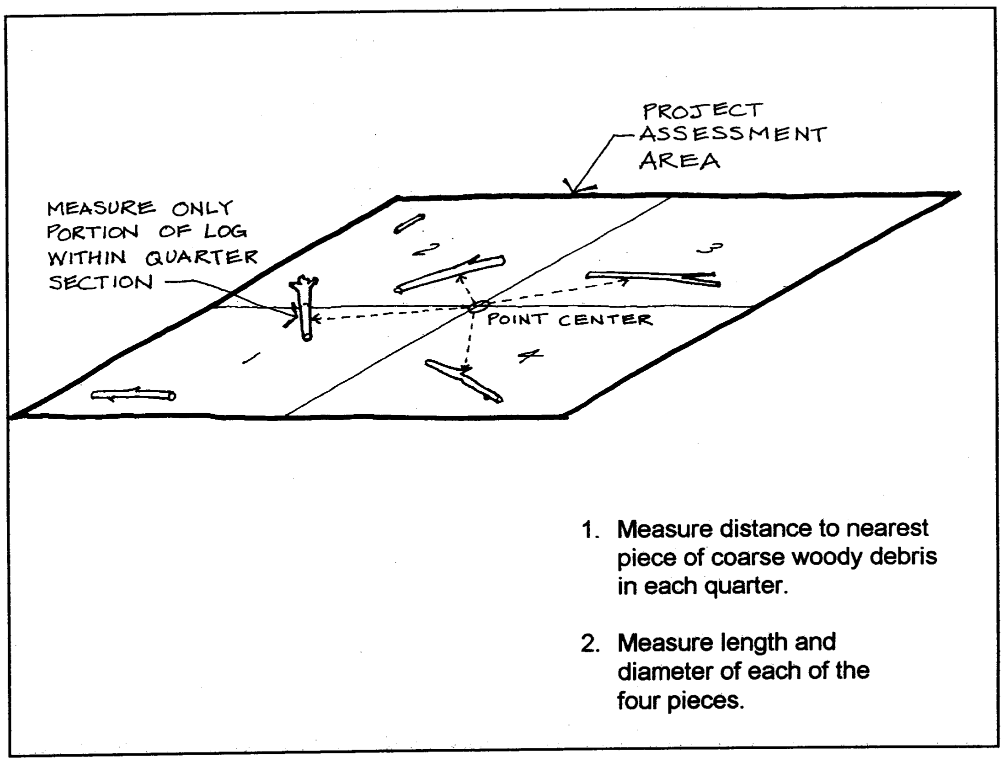
Data: Located in Appendix B. Summary graphs are in Appendix C

Scaling Rationale: This variable was scaled using reference data, field observations and best scientific judgement. V_{CWD} was scaled according to a disturbance scale. The disturbance scale was developed by the interdisciplinary team based upon field observations and best scientific judgement. Reference standard conditions were first defined from the reference data. Then, on a scale of increasing disturbance relative to the reference standard, the variable was scaled as 90%, 75%, 50% and 25% of the reference standard condition.

Variation in CWD was high in >30 yr. old forested communities. Coarse wood density ranged from 0 to 1,910 pieces/acre (4,718 pieces/ha) and volumes from 0 to 741 ft^3/acre (51.8 m^3/ha). Coarse wood was absent in the sedge tussock community type, and was rare (*i.e.*, present in only one site) in the shrub community type. Therefore coarse woody debris was not used to model any functions for these community types.

Figure 50. Measurement Protocol for the Coarse Woody Debris Variable (V_{CWD})

Figure 50. Measurement Protocol for the Coarse Woody Debris Variable (V_{CWD})



1. Measure distance to nearest piece of coarse woody debris in each quarter.
2. Measure length and diameter of each of the four pieces.

Confidence: The author's confidence that reasonable logic and/or data support scaling of Coarse Woody Debris is Medium.

Scaling:

FORESTED COMMUNITY TYPES

Forested Community: 0-5 yr. old

Measurement or Condition for V_{CWD}	**Index**
CWD density ≥3,023 pieces/acre (≥7,467 pieces/ha) **and/or** CWD volume ≥1,781 ft^3/acre (≥124.6 m^3/ha).	1.0
CWD density ≥2,015 to <3,023 pieces/acre (≥4,977 to <7,467 pieces/ha) **and/or** CWD volume ≥1,188 to <1,781 ft^3/acre (≥83.1 to <124.5 m^3/ha).	0.75
CWD density ≥1,008 to <2,015 pieces/acre (≥2,490 to <4,977 pieces/ha) **and/or** CWD volume ≥594 to 1,188 ft^3/acre (≥41.6 to <83.1 m^3/ha).	0.5
CWD density ≥403 to <1,008 pieces/acre (≥995 to <2,490 pieces/ha) **and/or** CWD volume ≥238 to <594 ft^3/acre (≥16.6 to <41.6 m^3/ha).	0.25
CWD density <403 pieces/acre (<995 pieces/ha) **and/or** CWD volume <238 ft^3/acre (<16.6 m^3/ha). Variable is recoverable and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
CWD density <403 pieces/acre (<995 pieces/ha) **and/or** CWD volume <238 ft^3/acre (<16.6 m^3/ha). The variable is neither recoverable nor sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

Forested Community: 6-30 yr. old

Measurement or Condition for V_{CWD}	**Index**
CWD density ≥545 pieces/acre (≥1,346 pieces/ha) **and/or** CWD volume ≥90 ft^3/acre (≥6.3 m^3/ha).	1.0
CWD density ≥363 to <545 pieces/acre (≥897 to <1,346 pieces/ha) **and/or** CWD volume ≥60 to <90 ft^3/acre (≥4.2 to <6.3 m^3/ha).	0.75
CWD density ≥182 to <363 pieces/acre (≥450 to <897 pieces/ha) **and/or** CWD volume ≥30 to <60 ft^3/acre (2.1 to 4.2 m^3/ha).	0.5
CWD density ≥73 to <182 pieces/acre (≥180 to 450 pieces/ha) **and/or** CWD volume ≥12 to <30 ft^3/acre (≥0.8 to 2.1 m^3/ha).	0.25
CWD density <73 pieces/acre (<180 pieces/ha) **and/or** CWD volume <12 ft^3/acre (<0.8 m^3/ha). Variable is recoverable and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
CWD density <73 pieces/acre **and/or** CWD volume ≤12 ft^3/acre. The variable is neither recoverable nor sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

Variable: Contiguous Native Plant Communities (V_{CONTIG})

Definition: The extent to which the project assessment area is contiguous with, and surrounded by, native plant communities.

Rationale for Selection of the Variable: Habitat patch size and edge/interior ratios are important factors affecting maintenance of characteristic native plant and animal communities, as well as influencing physical parameters within the assessment area, such as microclimate, soil temperature, depth of permafrost, and duration of snowpack. Patch size and contiguity is important in maintaining native plant communities and faunal habitat (Harris 1987). Habitat fragmentation reduces the amount of habitat available for some species, isolates populations within fragments, and increases the amount of edge habitat (Saunders *et al.* 1991). Results of these changes are an increased likelihood of population-level extinctions and a reduction in regional species diversity (Lande 1988, Simberloff *et al.* 1988).

Measurement Protocol: Field teams use current aerial photographs or imagery and/or reconnaissance of the project assessment area and surrounding areas to estimate the percent (%) of the project assessment buffer area covered by native plant communities (Figure 51). The buffer is the area that completely surrounds the project assessment area and is at least 100 ft (30.5 m) wide along the entire perimeter of the assessment area.

Data: Located in Appendix B. Summary graphs are in Appendix C.

Scaling Rationale: The variable was scaled using reference data, field observation, published literature, and best scientific judgment. For all reference standard sites, 100% of the buffer area consisted of native plant communities. Perturbed reference sites consistently exhibited some degree of fragmentation of the buffer, either by constructed surfaces or areas dominated by non-native plant species. The V_{CONTIG} variable was scored according to a disturbance scale, which ranged from the reference standard condition (*e.g.*, an unaltered buffer of native plant communities), to highly degraded conditions (*e.g.*, the absence of native plant communities). The disturbance scale was developed by the interdisciplinary team and is based upon field observations and best professional judgement.

Confidence: The authors' confidence that reasonable logic and/or data support scaling is Medium High.

Figure 51. Measurement Protocol for the Contiguous Native Plant Communities Variable (V_{CONTIG})

Figure 51. Measurement Protocol for the Contiguous Native Plant Communities Variable (V_{CONTIG})

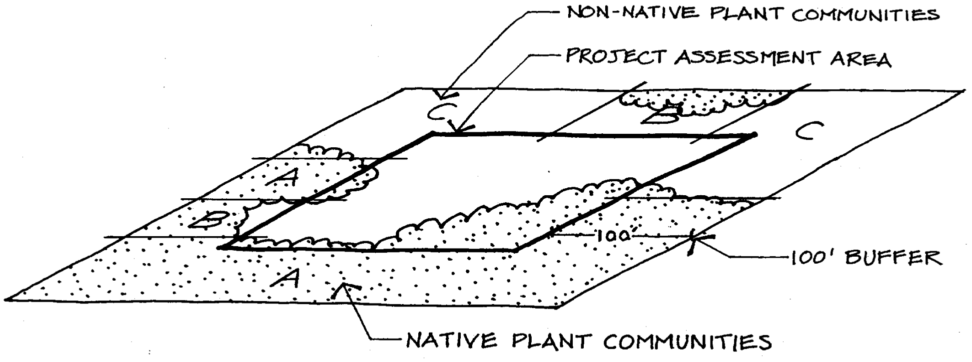
Buffer Area Sections:

A = Area of native plant communities that are contiguous over entire section of 100' buffer

B = Area of native plant communities that are not contiguous over entire section of 100' buffer

C = Area of buffer without native plant communities

% of Buffer Area w/ Contiguous Native Plant Communities = Section A / Entire Buffer Area



Scaling: FOR ALL COMMUNITY TYPES

Measurement or Condition for V_{CONTIG}	**Index**
100% of the buffer area is covered by native plant species.	1.0
75% of the buffer area is covered by native plant species.	0.75
≥25% and <75% of the buffer is covered by native plant species.	0.5
≥1% and <25% of the buffer is covered by native plant species.	0.25
<1% of the buffer is covered by native plant species. The variable is recoverable to reference standard conditions and sustainable through natural processes (within the 100-250 yr. fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
<1% of the buffer is covered by native plant species. Native plant communities must extend at least 100 ft (30.5 m) beyond the assessment area boundary. The variable is neither recoverable to reference standard conditions nor sustainable through natural processes (within the 100-250 yr. fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

Variable: Herbs (V_{HERB})

Definition: Percent canopy cover of herbaceous vegetation including forbs, graminoids, ferns, and fern allies within the project assessment area.

Rationale for Selection of the Variable: Cover of herbaceous vegetation typical of reference standard sites in a range of successional stages reflects presence and maintenance of native plant communities. Herbaceous cover typical of various stages in the fire disturbance cycle for each community type indicates maintenance of disturbance dynamics and successional processes characteristic of reference standard conditions.

Measurement Protocol: Field teams visually estimate percent canopy coverage of forbs, graminoids, ferns, and fern allies within circular 0.1-acre (0.04-ha) plots (Figure 52). At times, nested microplots within the 0.1-acre (0.04-ha) main plot may be useful to maintain consistent estimates of canopy coverage of relatively small undergrowth species.

Data: Located in Appendix B. Summary graphs are in Appendix C.

Scaling Rationale: The variable was scaled using reference data, field observation, published literature, and best scientific judgement. Appendix C shows herb canopy cover for all reference sites stratified by community types. Sample sizes were too small to allow scaling of V_{HERB} directly from the data for all community types. Therefore, the variable was scored according to a disturbance scale ranging from reference standard conditions to highly degraded conditions. Reference standard conditions and highly degraded conditions were used to establish the end points for variable scaling. Conditions intermediate to these end points were then scaled using standard proportions (1.00, 0.75, 0.50, 0.25, 0.10, and 0.00), consistent with national guidance (Brinson 1995, U. S. Army Corps of Engineers 1997). The disturbance scale was developed by the interdisciplinary team and is based upon field observations and best scientific judgement.

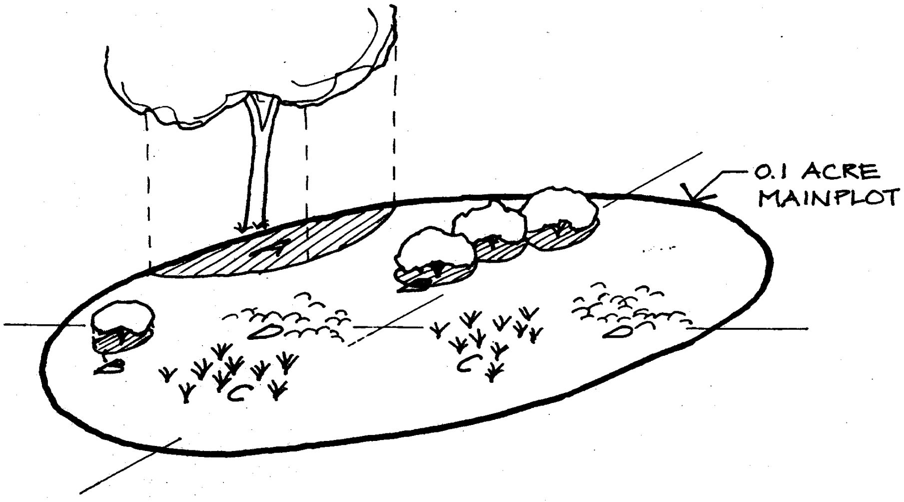
Due to the variation in herb cover in reference standard sites, two approaches were used to describe reference standard conditions. In cases where variation was high but sample sizes were not extremely small, the mean, plus or minus one standard deviation (SD), was used to define the reference standard condition. This established a lower and an upper bound for canopy cover estimates (Table 33). If data were highly variable (*e.g.*, SD greater than the mean) and if sample size was low (*e.g.*, 3 or 4 reference standard sites), the mean was used as the reference standard condition.

Figure 52. Measurement Protocol for the Herb Variable (V_{HERB})

Figure 52. Measurement Protocol for the Herb Variable (V_{HERB})

Types of Canopy Cover:

A = Area of tree canopy cover
B = Area of shrub canopy cover
C = Area of herb canopy cover
D = Area of mosses, lichens and liverworts canopy cover



Percentage of Herbaceous Vegetation Canopy Cover = C / 0.1 acres

Scaling of V_{HERB} using the disturbance scale was not adequately supported by data for all variable conditions. In these cases, no standard for the variable condition is given (*e.g.*, the 0.25 index for the 0- to 5-yr-old community type). Because the herb data was highly variable, site conditions with examples were articulated where possible to augment scaling using canopy coverage estimates alone. Therefore, the scaling for V_{HERB}, uses a combination of data-supported estimates of canopy coverage and descriptions of site condition. Table 34 provides an example of the entire process of variable scaling for the 0- to 5-yr-old forested community type.

Table 33. Mean and standard deviation for canopy cover of herbaceous plants for reference standard sites.

COMMUNITY TYPE	**SAMPLE SIZE (#)**	**% CANOPY COVER** **Mean, SD, Range (Mean ± One SD)**
Forested		
0- to 5-yr-old	3	49 ± 25 = 24 to 74
6- to 30-yr-old	4	19 ± 29 = 0 to 48
>30-yr-old	19	21 ± 25 = 0 to 46
Shrub	4	30 ± 25 = 5 to 55
Sedge Tussock	3	86 ± 20 = 66 to 100

Table 34. Example of scaling V_{HERB}: 0- to 5-yr-old Forested Community Type.

PROPORTION OF THE REFERENCE STANDARD CONDITION (≥24% CC)	**ADJUSTED SCALING USING STANDARD COVER CLASS BOUNDS (% CC)**	**FINAL DATA-BASED VARIABLE CONDITION SCALE (% CC)**	**INDEX**
1.00 x 24 = 24	≥26	≥26	1.00
0.75 x 24 = 18	16 - 25	16 - 25	0.75
0.50 x 24 = 12	10 - 15	6 - 15	0.50
0.25 x 24 = 6.0	6 - 10	No standard for this score	0.25
0.10 x 24 = 2.4	≤5	≤5	0.10
0.00 x 24 = 0.0	≤5	≤5	0.00

Confidence: The authors' confidence that reasonable logic and/or data support scaling differs depending on community type. Confidence estimates for V_{HERB} are given in Table 35.

Table 35. Confidence estimates in scaling of V_{HERB} by community type.

COMMUNITY TYPE	**CONFIDENCE ESTIMATE**
Forested	
0- to 5-yr-old	Medium
6- to 30-yr-old	Medium

COMMUNITY TYPE	**CONFIDENCE ESTIMATE**
>30-yr-old	Medium
Shrub	Medium
Sedge Tussock	Medium Low

FORESTED COMMUNITY TYPES

Forested Community: 0-5 yr. old

Measurement or Condition for V_{HERB}	**Index**
Herb canopy cover ≥26% and dominated by native plant species; **or** Site unaltered by human activity and dominated by native plant species.	1.0
Herb canopy cover ≥16%, **and** Site altered by human activity but dominated by native plant species.	0.75
Herb canopy cover ≥6% and ≤15%, **or** annually cropped agricultural land that can reasonably be expected to develop herb canopy cover of ≥6% and ≤15% sometime during the growing season (*e.g.*, barley field).	0.5
No standard for this condition.	0.25
Herb canopy cover ≤5% **and** site altered by human activity. The variable is recoverable to reference standard conditions and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
Herb canopy cover ≤5% **and** site altered by human activity. The variable is neither recoverable to reference standard conditions nor sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

Forested Community: 6-30 yr. old

Measurement or Condition for V_{HERB}	**Index**
Herb canopy cover ≥26% and ≤75%, and vegetation dominated by native plant species; **and/or** Site unaltered by human activity and vegetation dominated by native plant species.	1.0
Herb canopy cover ≥16% **and** site altered by human activity but dominated by perennial native plant species (*e.g.*, discontinued agricultural operation, cleared power line right-of-way dominated by shrubs).	0.75
Herb canopy cover ≥6% and ≤15% **and** site altered by humans but dominated by perennial native or non-native plant species (*e.g.*, discontinued agricultural operation, cleared power line right-of-way dominated by shrubs).	0.5
No standard for this condition.	0.25
Herb canopy cover ≤5% and site altered by human activity. The variable is recoverable to reference standard conditions and sustainable through natural processes (within the 100 to 250 yr. fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
Herb canopy cover ≤5% and site altered by human activity. The variable is neither	0.0

recoverable to reference standard conditions nor sustainable through natural processes (within the 100 to 250 yr. fire cycle), if the existing land use is discontinued and no restoration measures are applied.	

Forested Community: >30 yr. old

Measurement or Condition for V_{HERB}	**Index**
Herb canopy cover ≤50% and vegetation dominated by native plant species; **and** Site unaltered by human activity.	1.0
Herb canopy cover ≥6% and ≤50% **and** site altered by human activity but dominated by perennial native plant species (*e.g.*, right -of-way clearing, selective removal of trees for fuel wood).	0.75
Herb canopy cover ≥51 and ≤75% **and** site altered by human activity but dominated by perennial native or non-native plant species (*e.g.*, right -of-way clearing, selective removal of trees for fuel wood).	0.5
Herb canopy cover ≥76% **and** site altered by humans and dominated by non-native plant species (*e.g.*, spruce bark beetle-killed stand with some salvage logging for fuel wood).	0.25
Herb canopy cover ≤5% **and** site altered by human activity. The variable is recoverable to reference standard conditions and sustainable through natural processes (within the 100 to 250 yr. fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
Herb canopy cover ≤5% **and** site altered by human activity. The variable is neither recoverable to reference standard conditions nor sustainable through natural processes (within the 100 to 250 yr. fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

SHRUB COMMUNITY TYPE

Measurement or Condition for V_{HERB}	**Index**
Herb canopy cover ≥6% and ≤75% and vegetation dominated by native plant species; **and/or** Site unaltered by human activity and vegetation dominated by native plant species.	1.0
Herb canopy cover ≥6% and ≤75% **and** site altered by human activity but dominated by perennial native plant species (*e.g.*, light to moderate grazing by domestic livestock, light to moderate vehicular traffic).	0.75
Herb canopy cover ≥76% **and** site altered by humans but dominated by perennial native or non-native plant species.	0.5
No standard for this condition	0.25
Herb canopy cover ≤5% **and** site altered by human activity. The variable is recoverable to reference standard conditions and sustainable through natural processes (within the 100 to 250 yr. fire cycle), if the existing land use is discontinued and no restoration measures are applied (*e.g.* livestock trampling that removes the herbaceous strata, heavy ATV use).	0.1
Herb canopy cover ≤5% **and** site altered by human activity. The variable is neither recoverable to reference standard conditions nor sustainable through natural processes	0.0

(within the 100 to 250 yr. fire cycle), if the existing land use is discontinued and no restoration measures are applied.	

SEDGE TUSSOCK COMMUNITY TYPE

Measurement or Condition for V_{HERB}	**Index**
Herb canopy cover ≥50% and vegetation dominated by native plant species; **and/or** Site unaltered by human activity and vegetation dominated by native plant species.	1.0
Herb canopy cover ≥50%; **and** Site altered by human activity but vegetation dominated by native plant species.	0.75
Herb canopy cover ≥25% and <50% **and** site altered by human activity but vegetation dominated by native plant species.	0.5
Herb canopy cover ≥16% to <25% **and** site altered by human activity but dominated by non-native plant species.	0.25
Herb canopy cover ≤15% **and** site altered by human activity. The variable is recoverable to reference standard conditions and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
Herb canopy cover ≤15% and site altered by human activity. The variable is neither recoverable to reference standard conditions nor sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

Variable Name: Macro/Micro Topographic Complexity (V_{TOPO})

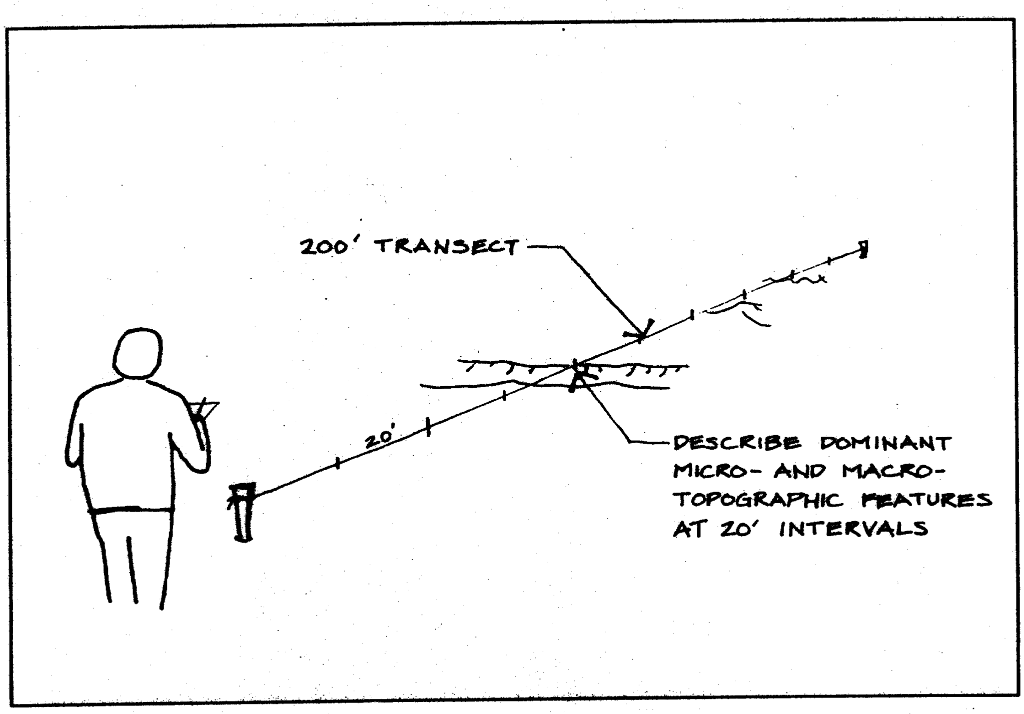
Definition: This variable is a measure of the degree to which macrotopographic (large scale) features (*e.g.*, paleo-channels and interfluves) and microtopographic (small scale) features (*e.g.*, pit-and-mound and hummock-and-hollow patterns) exist on the landscape.

Rationale for Selection of the Variable: Roughness imparted to sites by macro and microtopographic features contributes to surface water ponding, short and long term storage of surface and shallow subsurface water, and the reduction of surface and shallow subsurface flow-energy. Storage of surface and shallow subsurface water facilitates the increase of organic surface horizons, elemental cycling, and substrates for the establishment of different vegetation communities.

Measurement Protocol: Macro and microtopographic features were assessed along a line transect (Figure 53). One 200 foot line transect was established across a representative area through and in the immediate vicinity of the main plot. This transect was sampled at 20ft intervals. The dominant micro- and macrotopographic features should be described at 20ft intervals. The transect should be centered at the approximate center point of the project assessment area and oriented generally along the direction of flow through the site. For macrotopography: maps, air photos and field observations of landscape position,

Figure 53. Measurement Protocol for the Macro/Micro Topographic Complexity Variable (V_{TOPO})

Figure 53. Measurement Protocol for the Macro/Micro Topographic Complexity Variable (V_{MTOPO})



landform, and shape were recorded in standard categories for each plot to reflect the relationship of the plot to surrounding landscape features.

Data: Located in Appendix B. Summary graphs are in Appendix C.

Scaling Rationale: Human alteration of river proximal and slope/flat complex wetlands in the Alaskan Interior tends to simplify complex topography and impart planar features to the wetland surface. The authors scaled topographic complexity using empirical field data from 55 reference sites, linear interpolation between the reference standard condition (*e.g.*, micro and macrotopographic relief distributed over the entire surface of an unaltered site) and highly degraded conditions (*e.g.*, an entirely stripped and leveled surface with no evidence of macro/microtopographic relief), and best scientific judgment.

Confidence: The authors' confidence that reasonable logic and/or data support variable scaling is Medium High.

SCALING: ALL COMMUNITY TYPES

Measurement or Condition for V_{TOPO}	**Index**
The project assessment area is characterized by complex macro- and microtopographic relief (*e.g.*, paleo-channels, interfluves, pits, hummocks, sedge tussocks, etc.). ≥ 80% of the observed features are non-planar **and** the site is unaltered by human activity	1.0
The project assessment area is characterized by complex macro- and microtopographic relief (*e.g.*, paleo-channels, interfluves, pits, hummocks, sedge tussocks, etc.) but consists of a mix of natural and human-induced non-planar features. ≥ 60-80% of the observed features are natural non-planar features. 20-40% of the observed features are planar **or** are non-planar features caused by human activity (*e.g.*, vehicular traffic, rill erosion, clearing, etc,).	0.75
The project assessment area is characterized by the presence of moderately complex macro- and microtopographic features (*e.g.*, paleo-channels, interfluves, pits, hummocks, sedge tussocks, etc.), but the predominant condition (*i.e.* >50%) is relatively homogeneous surfaces that lack macro- and microtopographic relief (*i.e.*, do not provide features that pond water or otherwise provide complex microenvironments). 40-50% of the site microtopographic features are planar features, **or** are non-planar features caused by human activity (*e.g.*, vehicular traffic, rill erosion, clearing, etc,).	0.5
The project assessment area is characterized by the presence of macro- and microtopographic relief (*e.g.*, paleo-channels, interfluves, pits, hummocks, sedge tussocks, etc.), but the predominant condition (*i.e.* >50%) is relatively homogeneous surfaces that lack macro- and microtopographic relief (*i.e.*, do not provide features that pond water or otherwise provide complex microenvironments). Arrangement of any microtopographic features is generally uniform and a mixture of natural and human induced features. 60-90% of the site microtopographic features are planar features, **or** are non-planar features caused by human activity (*e.g.*, vehicular traffic, rill erosion, clearing, etc,).	0.25

The project assessment area is characterized by relatively homogeneous surfaces that lack macro- and microtopographic relief (*e.g.*, paleo-channels, interfluves, pits, hummocks, sedge tussocks, etc.) and do not pond water. Arrangement of any microtopographic features is generally uniform and a mixture of natural and human induced features. 90-100% of the site microtopographic features are planar features, **or** are non-planar features caused by human activity (*e.g.*, vehicular traffic, rill erosion, clearing, etc,). The variable is recoverable to reference standard conditions and sustainable through natural processes, if the existing land use is discontinued and no restoration measures are applied.	0.1
The project assessment area is characterized by homogeneous surfaces that lack macro- and microtopographic relief (*e.g.*, paleo-channels, interfluves, pits, hummocks, sedge tussocks, etc.) and do not pond water. However, slope surfaces may include rills, gullies, small scale sediment fans, etc. 90-100% of the microtopographic features are planar (*e.g.*, paved surfaces, graded fill, etc.). The variable is neither recoverable to reference standard conditions nor sustainable through natural processes, if the existing land use is discontinued and no restoration measures are applied.	0.0

Variable: Mosses, Lichens, and Liverworts ($V_{MOSSLICH}$)

Definition: Percent canopy cover of mosses, lichens, and liverworts within the project assessment area.

Rationale for Selection of the Variable: Characteristic cover of mosses, lichens and liverworts indicates ability of site to maintain characteristic soil thermal regime, and support native plant communities, as well as typifying stages within the fire disturbance cycles. In particular, moss/lichen cover affects soil temperatures, and therefore depth of permafrost, and site hydrology.

Measurement Protocol: Field teams visually estimate percent cover of mosses, lichens, and liverworts within circular 0.1-acre (0.04-ha) plots (Figure 54). Nested 0.01-acre (0.004-ha) microplots within a 0.1-acre (0.04-ha) main plot can be used to maintain consistent estimates of canopy coverage.

Data: Located in Appendix B. Summary graphs are in Appendix C.

Scaling Rationale: The variable was scaled using reference data, field observations, published literature and best scientific judgement.

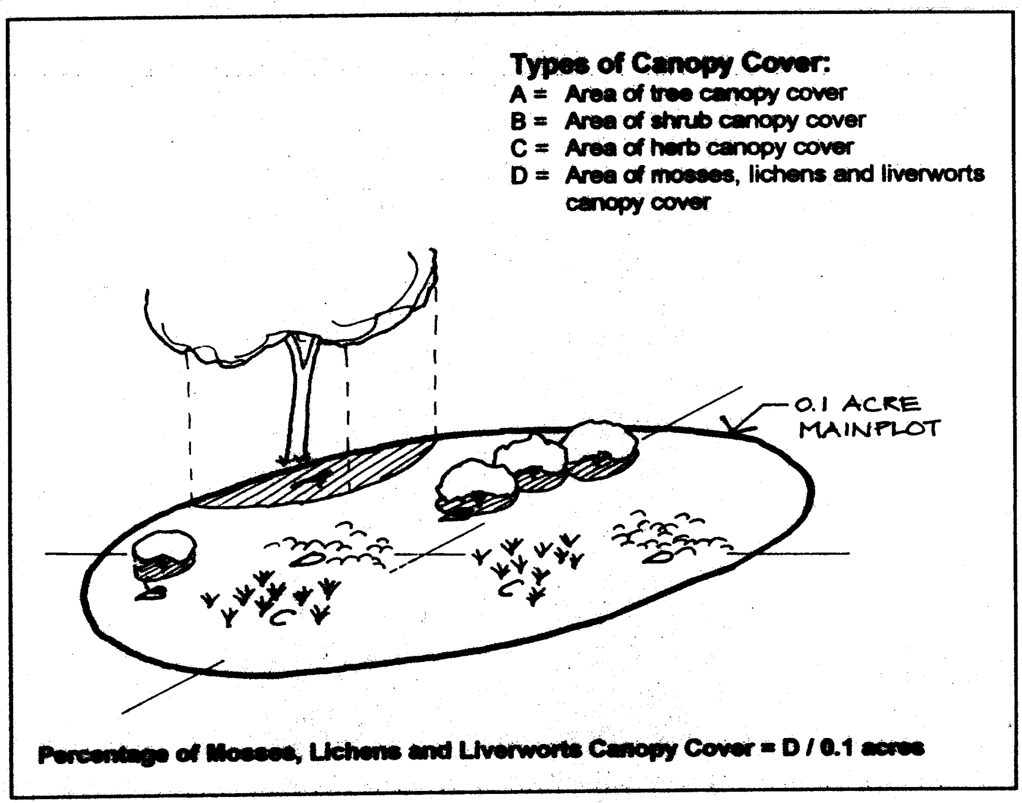
Sample sizes in the reference data set were too small to allow scaling of $V_{MOSSLICH}$ directly from the data for all community types. Reference standard means, and standard deviations (SD) for the community types are shown in Table 36. $V_{MOSSLICH}$ was scaled according to a disturbance gradient, which ranged from reference standard conditions to highly degraded conditions. The disturbance scale was developed by the interdisciplinary team and is based upon field observations and best scientific judgement. In addition, scaling using the disturbance scale is consistent with national guidance on scaling HGM variables (Brinson 1995, U.S. Army Corps of Engineers 1997).

The variation in moss, lichen and liverwort cover was high under reference standard conditions in most community types. Therefore, the mean plus or minus one standard deviation (SD) was used to define the range of reference standard conditions for each community type. If data were highly variable (*i.e.*, SD near or equal to the mean) and sample size was low (*e.g.*, 3 or 4 reference plots), the lowest moss/lichen/liverwort cover recorded at a reference standard site for a particular community type was used to set the reference standard condition. Finally, in reference standard sites that have been recently burned (*i.e.*, 0-5 yr. old sites), moss/lichen/liverwort cover was extremely variable, ranging from 0% to 98% cover. Variation in moss/lichen/liverwort cover depends on fire intensity, and time since burn. Therefore, $V_{MOSSLICH}$ could not be reliably scaled, or used in the models for the 0-5 yr. old forested community type.

Sites with anthropogenic disturbance, but which lacked any significant effects of this disturbance on the moss, lichen, and liverwort community component were scored as 0.75. Next, 25% incremental reductions in the 0.75 condition were used as the basis for scaling the variable according the disturbance scale, as shown in Table 37.

Figure 54. Measurement Protocol for the Mosses, Lichens, and Liverworts Variable ($V_{MOSSLICH}$)

Figure 54. Measurement Protocol for the Mosses, Lichens, and Liverworts Variable ($V_{MOSSLICH}$)



Types of Canopy Cover:

A = Area of tree canopy cover
B = Area of shrub canopy cover
C = Area of herb canopy cover
D = Area of mosses, lichens and liverworts canopy cover

Percentage of Mosses, Lichens and Liverworts Canopy Cover = D / 0.1 acres

Table 36. Percent cover ranges and lower bounds used to define reference standard conditions for mosses, lichens, and liverworts by community type, determined by mean ± one standard deviation (SD).

COMMUNITY TYPE	% COVER MOSS/LICHEN/ LIVERWORT (MEAN ± 1 SD)	% COVER LOWER BOUND (= MEAN – 1 SD)
Forested		
0- to 5-yr-old	Insufficient Data	Insufficient Data
6- to 30-yr-old	65 ± 31	34
>30-yr-old	83 ± 25	58
Shrub	67 ± 34	33
Sedge Tussock	31 ± 28	10 (Defined by Data Range Only)

Table 37. Example of scaling $V_{MOSSLICH}$ in the 6- to 30-yr-old Forested Community Type.

INDEX	INCREMENTAL REDUCTION CALCULATION	% CANOPY COVER BOUNDS	SITE CONDITION
1.00	None	≥34	Unaltered
0.75	None	≥34	Altered
0.50	34% x 0.75 = 25.5%	≥26 and <34	Altered
0.25	34% x 0.50 = 17.0%	≥17 and <26	Altered
0.10	34% x 0.25 = 8.5%	<17	Altered

Confidence: The authors' confidence that reasonable logic and/or data support scaling differs by community type. Confidence estimates for $V_{MOSSLICH}$ are given in Table 38.

Table 38. Confidence that reasonable logic and/or data support scaling for Mosses, Lichens, and Liverworts by community type.

COMMUNITY TYPE	CONFIDENCE IN SCALING
Forested (all successional stages)	Medium
Shrub	Medium
Sedge Tussock	Medium Low

SCALING:

FORESTED COMMUNITY TYPES

Forested Community: 0-5 yr. (no scaling)

Forested Community: 6-30 yr.

Measurement or Condition for $V_{MOSSLICH}$	**Index**
Canopy cover of mosses, lichens, and liverworts ≥34% and site dominated by native vascular plant species; **Or** Site unaltered by human activity and dominated by native vascular plant species.	1.0
Canopy cover of mosses, lichens, and liverworts ≥34%, **and** site altered by human activity but dominated by perennial native or non-native vascular plant species (*e.g.*, discontinued agricultural operation, cleared power line right-of-way dominated by shrubs).	0.75
Canopy cover of mosses, lichens, and liverworts ≥26 to <34%, **and** site altered by human activity but dominated by perennial native or non-native vascular plant species (*e.g.* discontinued agricultural operation, cleared power line right-of-way dominated by shrubs).	0.5
Canopy cover of mosses, lichens, and liverworts ≥17 to <26%, **and** site altered by human activity but dominated by perennial native or non-native vascular plant species (*e.g.* discontinued agricultural operation, cleared power line right-of-way dominated by shrubs).	0.25
Canopy cover of mosses, lichens, and liverworts <17%, **and** site altered by human activity. The variable is recoverable to reference standard conditions and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
Canopy cover of mosses, lichens, and liverworts <17%, **and** site altered by human activity. The variable is neither recoverable to reference standard conditions nor sustainable through natural processes (within the 100-250 year fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

Forested Community: >30 yr.

Measurement or Condition for $V_{MOSSLICH}$	**Index**
Canopy cover of Mosses, lichens, and liverworts ≥58% and site dominated by native vascular plant species; **OR** Site unaltered by human activity and dominated by native vascular plant species.	1.0
Canopy cover of mosses, lichens, and liverworts ≥58%, **and** site altered by human activity but dominated by perennial native vascular plant species (*e.g.*, right -of-way clearing, selective removal of trees for fuel wood).	0.75
Canopy cover of mosses, lichens, and liverworts ≥44% to <58%, **and** site altered by human activity but dominated by perennial native or non-native vascular plant species (*e.g.*, discontinued agricultural operation, cleared power line right-of-way dominated by shrubs).	0.5
Canopy cover of mosses, lichens, and liverworts ≥29% to <44%, **and** site altered by human activity but dominated by perennial native or non-native vascular plant species (*e.g.*, spruce bark beetle-killed stand with some salvage logging for fuel wood).	0.25
Canopy cover of mosses, lichens, and liverworts <29%, **and** site altered by human activity. The variable is recoverable to reference standard conditions and sustainable through natural	0.1

Measurement or Condition for $V_{MOSSLICH}$	**Index**
processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	
Canopy cover of mosses, lichens, and liverworts <29%, **and** site altered by human activity. The variable is neither recoverable to reference standard conditions nor sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

SCALING FOR SHRUB COMMUNITY TYPE

Measurement or Condition for $V_{MOSSLICH}$	**Index**
Canopy cover of mosses, lichens, and liverworts ≥33% and site dominated by native vascular plant species; **OR** Site unaltered by human activity and dominated by native vascular plant species.	1.0
Canopy cover of mosses, lichens, and liverworts ≥33%, **and** site altered by human activity but dominated by perennial native or non-native vascular plant (*e.g.* light to moderate grazing by domestic livestock, light to moderate vehicular traffic).	0.75
Canopy cover of mosses, lichens, and liverworts ≥25% and <33%, **and** site altered by human activity but dominated by perennial native or non-native vascular plant species (*e.g.,* discontinued agricultural operation; cleared power line right-of-way dominated by shrubs).	0.5
Canopy cover of mosses, lichens, and liverworts ≥17% and <25%, **and** site altered by human activity but dominated by perennial native or non-native vascular plant species (*e.g.,* discontinued agricultural operation, cleared power line right-of-way dominated by shrubs).	0.25
Canopy cover of mosses, lichens, and liverworts <17%, **and** site altered by human activity (*e.g.,* livestock trampling that removes ground cover, heavy ATV use). The variable is recoverable to reference standard conditions and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
Canopy cover of mosses, lichens, and liverworts <17%, **and** site altered by human activity. The variable is neither recoverable to reference standard conditions nor sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

SCALING FOR SEDGE TUSSOCK COMMUNITY TYPE

Measurement or Condition for $V_{MOSSLICH}$	**Index**
Canopy cover of mosses, lichens, and liverworts ≥10% and site dominated by native vascular plant species; **OR** Site unaltered by human activity and dominated by native vascular plant species.	1.0
Canopy cover of mosses, lichens, and liverworts ≥10%, **and** site altered by human activity and dominated by native vascular plant species.	0.75
Canopy cover of mosses, lichens, and liverworts <10%, **and** site altered by human activity but dominated by native vascular plant species.	0.5
No data to support this condition.	0.25
Canopy cover of mosses, lichens, and liverworts <10%, **and** surface of soil altered by human activity in a manner that eliminates mosses, lichens, and liverworts (*e.g.,* site cleared	0.1

Measurement or Condition for $V_{MOSSLICH}$	**Index**
for agriculture). The variable is recoverable to reference standard conditions and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	
Canopy cover of mosses, lichens, and liverworts <10%, **and** surface of soil altered by human activity in a manner that eliminates mosses, lichens and liverworts (*e.g.*, site cleared for agriculture). The variable is neither recoverable to reference standard conditions nor sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

Variable Name: Organic Horizons (V_{OH})

Definition: This variable is a measure of the thickness and condition of the surface organic horizon(s) (*i.e.*, Oi and/or Oe and/or Oa horizons) in modal soils within the project assessment area.

Rationale for Selection of the Variable: Soils with thick organic horizons on discontinuous permafrost help to maintain hydrologic, biogeochemical, and physical functions. Organic surface horizons provide an insulating cover (where permafrost is present), surface/near surface water storage (episaturation), energy reduction of surface and shallow subsurface water, elemental cycling, and establishment and maintenance of plant communities.

Measurement Protocol: Field teams excavate soil pits at the center of the project assessment area to a depth of approximately 6 ft (2 m), or to the depth of permafrost, whichever is encountered first, using shovel and auger (Figure 55). Identification, nomenclature, and description of soil horizons should be consistent with guidance provided by the USDA Soil Conservation Service (SCS 1962, SCS 1990). All depths are measured from the top of the surface (usually Oi) horizon. Live vascular and non-vascular plant materials are **not** included in these depths. Soil colors are determined with a Munsell Soil Color Chart (Munsell 1992).

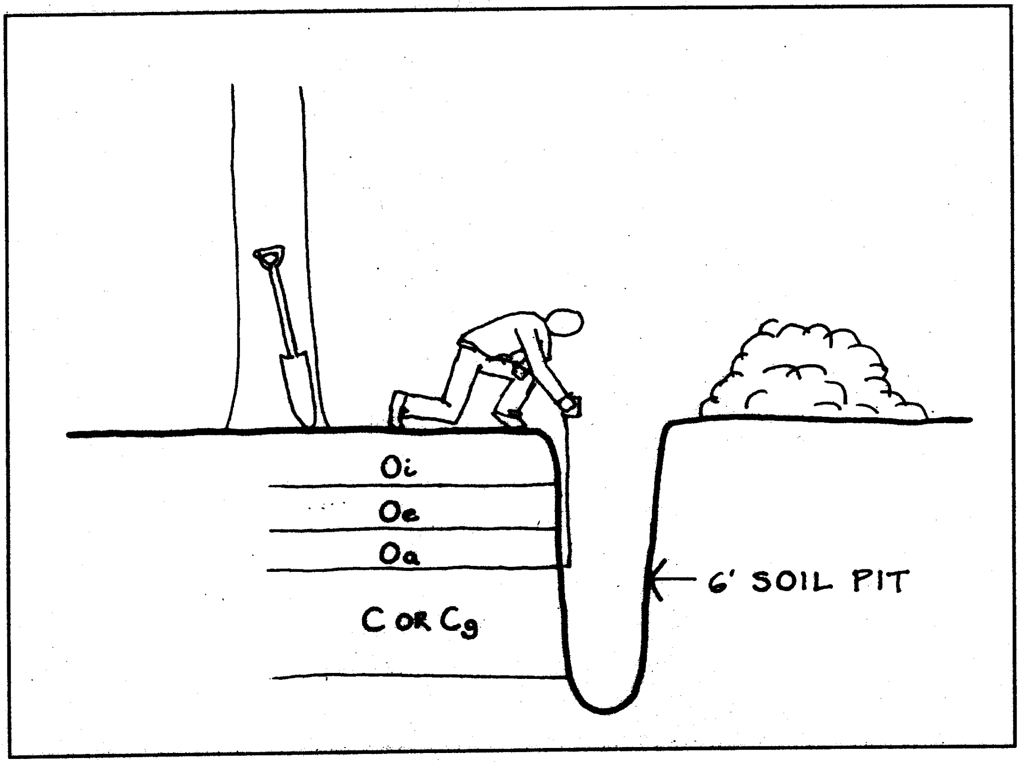
Data: Located in Appendix B. Summary graphs are in Appendix C.

Scaling Rationale: Both empirical field data from 55 reference sites and best scientific judgment drive scaling of organic horizons. Reference standard sites in the >30-yr-old forested, shrub, and sedge tussock community types had organic soil horizon(s) ≥5 inches (13 cm) in all but three instances. Two >30-yr-old forested sites had organic soil horizons of 1 inch (3 cm) and 4 inches (10 cm), respectively, but both sites were ≤60-yr-old and showed evidence of past fire. One shrub site (n = 4) had a 2-inch (3-cm) organic layer, but was in a river proximal landform that showed evidence of occasional flooding (mineral layers in organic mat) and probably represents a regional subclass boundary condition. Other reference standard sites in the shrub community type had ≥8 inches (20 cm) of organic soil horizons. In the 0- to 5-yr-old forested community type (n = 3), no reference standard site had <2 inches (5 cm) of organic soil horizons, and the one site had ≥15 inches (38 cm) of organic soil horizon. Similarly, no reference standard site in the 6- to 30-yr-old forested community type (n = 4) had <2 inches (5 cm) of organic soil horizons.

The authors chose to scale the Organic Horizons Variable by interpolation between the subindex 0.75 condition [*e.g.*, 5 to >30 inches (13 to >76 cm) for altered mature sites and 2 to >8 inches (5 to >20 cm) for post-fire seres <60-yr-old] and highly degraded conditions (*e.g.*, surface organic soil horizons absent) using abbreviated standard proportions (0.50, 0.25, 0.10, and 0.00), consistent with

Figure 55. Measurement Protocol for the Organic Horizons Variable (V_{OH})

Figure 55. Measurement Protocol for the Organic Horizons Variable (V_{OH})



National Guidance (Brinson 1995, U. S. Army Corps of Engineers 1997). Because reference standard sites have widely variable thickness of organic soil horizons, the authors supplemented quantitative thickness conditions with alternative conditions based on percent reduction of organic soil horizon thickness from reference standard conditions, which might be determined from adjacent unaltered sites or "with-" and "without-project."

Confidence: The authors' confidence that reasonable logic and/or data support scaling of Organic Horizons is Medium-High to High.

SCALING: FOR ALL COMMUNITY TYPES

Measurement or Condition for V_{OH}	**Index**
Within the project assessment area, surface organic soil horizons are present **and** are undisturbed by human activities. Average thickness of all organic horizons combined typically varies from 5 to >20 inches (13 to >51 cm) for mature sites and from 2 to >8 inches (5 to >20 cm) for post-fire seres <60-yr- old.	1.0
Within the project assessment area, surface organic soil horizons are present and intact, **but** human-induced activities (*e.g.*, vegetation removal) have occurred within the project assessment area. Average thickness of all organic layers combined typically varies from 5 to >20 inches (13 to >51 cm) for mature sites and from 2 to >8 inches (5 to >20 cm) for post-fire seres <60-yr-old.	0.75
Within the project assessment area, Surface organic soil horizons are present but are perturbed by human activities (*e.g.*, stripped by peat mining, or agricultural, commercial, or residential land clearing operations on thawed soils). Average thickness of the combined organic horizons has been reduced to 2.5 to <5 inches (6 to <13 cm) at mature sites, and to 1.0 to <2 inches (2.5 to 5 cm) for post-fire seres <60-yr-old. **If** a greater reduction in the thickness of the organic horizon has occurred, the reduction is <50% from reference standard conditions (*i.e.*, original unaltered site condition, see above).	0.5
Within the project assessment area, surface organic soil horizons are present but are perturbed by human activities (*e.g.*, stripped by peat mining, agricultural, commercial, or residential land clearing operations that occur on thawed or frozen soils, but result in removal of a substantial portion of the surface organic horizons). Average thickness of the combined organic horizons has been reduced to 1.0 to <2.5 inches (2.5 to <6 cm) at mature sites, and to 0 to <1.0 inches (0 to <2.5 cm) for post-fire seres <60-yr-old. **If** a greater reduction in the thickness of the organic horizon has occurred, the reduction is 50 to <75% from reference standard conditions (*i.e.*, original unaltered site condition, see above).	0.25
Within the project assessment area, "Minimal" to no surface soil organic horizon(s) are present, the dominant land use condition of the assessment area is cleared, and the native plant community is suppressed (*e.g.*, tilled field). Average thickness of the combined organic horizon has been reduced to <1.0 inch (<2.5 cm) in any community type or stand age. **If** a greater reduction in the thickness of the organic horizon has occurred, the reduction is 75 to <100% from the reference standard condition (*i.e.*, original unaltered site condition). Organic soil horizons are recoverable and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
Within the project assessment area, surface organic soil horizons are absent due to human-	0.0

Measurement or Condition for V_{OH}	**Index**
induced disturbances (*e.g.*, site preparation activities associated with hard rock or placer mining, building site preparation, parking lots, etc.). Organic soil horizons are neither recoverable nor sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	

Variable: Ratio of Native to Non-Native Plant Species (V_{PRATIO})

Definition: Percent of the dominant taxa within the project assessment area that are native species.

Rationale for Selection of the Variable: Percent native taxa characteristic of reference standard conditions indicate the presence of characteristic native plant communities. Percent native taxa is a measure of the degree to which native plant communities have been altered by anthropogenic activities.

Measurement Protocol: Field teams visually estimate canopy cover for all plant species by strata within a 0.1-acre (0.04-ha) plot (Figure 56). When necessary, nested microplots 0.01 acre (0.004 ha) in size are used to increase resolution of the canopy cover estimates (Daubenmire 1969). Cover estimates are used to construct a list of dominant taxa by strata. Dominant taxa are defined as follows. When ranked in descending order of abundance and totaled, dominants are the most abundant species that exceed 50% of the total canopy coverage for a stratum, plus any additional species that comprise ≥20% of the total canopy coverage (U.S. Army Corps of Engineers 1987). Dominant taxa are assigned native or non-native status using a combination of references (Kartesz 1994, Hultén 1968, Reed 1985, Viereck and Little 1972). Field teams then calculate the percent of native species among dominant taxa in each strata. In addition, the number of strata in which most of the dominant taxa are non-native was recorded and the percent of strata dominated by non-natives was calculated.

Data: Located in Appendix B. Summary graphs are in Appendix C.

Scaling Rationale: The variable was scaled using reference data, field observation, published literature and best scientific judgement. V_{PRATIO} was scaled according to a disturbance scale, ranging from the reference standard condition with 100% native taxa in all strata, to the most degraded condition, in which all vegetation is absent and/or there is no potential for recovery of native vegetation. The disturbance scale was developed by the interdisciplinary team and is based upon field observations and best scientific judgement.

Confidence: The authors' confidence that reasonable logic and/or data support scaling is High.

Figure 56. Measurement Protocol for the Ratio of Natives to Non-Natives Variable (V_{PRATIO})

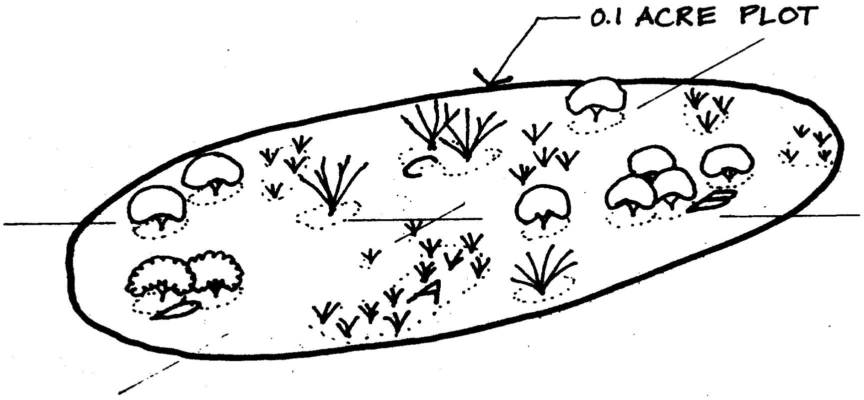
Figure 56. Measurement Protocol for the Ratio of Native Plants to Non-native Species Variable (V_{PRATIO})

Plant Sp. A (Native) = 12% Canopy Coverage

Plant Sp. B (Native) = 9% Canopy Coverage

Plant Sp. C (Non-native) = 5% Canopy Coverage

Plant Sp. D (Non-native) = 7% Canopy Coverage



Ratio of Native Plants to Non-Natives =
% Canopy Coverage of A and B / % Canopy Coverage of C and D

Scaling: **FOR ALL COMMUNITY TYPES**

Measurement or Condition for all Community Types	**Index**
100% of dominant species are native.	1.0
≥75% and 100% of dominant species are native, **and** no stratum is dominated by non-native species.	0.75
≥50% and <75% of the dominant species are native, **and/or** up to 25% of the strata present are dominated by non-native species.	0.5
≥25% and <50% of the dominant species are native, **and/or** up to 50% of the strata present are dominated by non-native species.	0.25
<25% of the dominant species are native, **and/or** up to 75% of the strata present are dominated by non-native species, **or** all vegetation is absent. The variable is recoverable to reference standard conditions and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
All vegetation is absent. The variable is neither recoverable to reference standard conditions nor sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

Variable: Shrubs (V_{SHRUB})

Definition: Percent canopy cover of shrubs (*i.e.*, multiple-stem, woody species) within the project assessment area.

Rationale for Selection of the Variable: Cover of shrubs characteristic of reference standard conditions reflects maintenance of native plant communities. Shrub cover characteristic of stages in the natural fire cycle reflect maintenance of successional processes typical of reference standard conditions.

Measurement Protocol: Field teams visually estimate the percent canopy cover of shrubs within the project assessment area within circular 0.1-acre (0.04-ha) plots (Figure 57).

Scaling Rationale: The variable was scaled using reference data, published literature, field observations, and best scientific judgment. Within the reference data set, sample sizes were too small and variance too high to allow scaling of V_{SHRUB} directly from the data alone. For example, canopy cover estimates for the shrub stratum in reference standard sites ranged from 11% to 86% for the >30-yr-old forested community type, and 0% to 63% for the sedge tussock community type. Due to this high variation, reference standard conditions were defined as follows for each community type. The lower limit from the range of shrub cover data was used, but this lower limit was adjusted upwards to the nearest lower bound for a standard canopy cover class (Table 39). After defining reference standard conditions in this manner, the variable was scaled according to degree of disturbance. The disturbance gradient was defined by the interdisciplinary team

Figure 57. Measurement Protocol for the Shrub Variable (V_{SHRUB})

Figure 57. Measurement Protocol for the Shrubs Variable (V_{SHRUB})

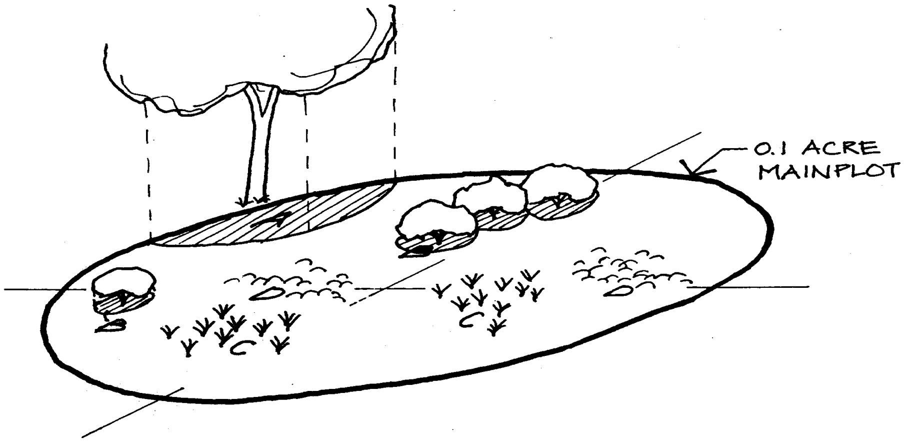
Types of Canopy Cover:

A = Area of tree canopy cover

B = Area of shrub canopy cover

C = Area of herb canopy cover

D = Area of mosses, lichens and liverworts canopy cover



Percentage of Shrub Canopy Cover = B / 0.1 acres

and was based upon field observations and best scientific judgement. In summary, V_{SHRUB} was scaled according to a disturbance scale, using shrub cover data augmented by information on site conditions and examples to complete the scaling.

Table 39. Rationale for scaling V_{SHRUB} by community type.

COMMUNITY TYPE	SCALING METHOD
Forested **6- to 30-yr-old**	Lower bound for reference standard condition estimated from data range (21 to 86%) and adjusted upward to the nearest lower bound for a standard canopy cover class (26%).
>30-yr-old	Lower bound for reference standard condition estimated from mean canopy cover minus one standard deviation (45% - 23% = 22%) and adjusted upward to the nearest lower bound for a standard canopy cover class (26%).
Shrub	Lower bound for reference standard condition estimated from mean canopy cover minus one standard deviation (80% - 11% = 69%) and adjusted upward to the nearest lower bound for a standard canopy cover class (76%).
Sedge Tussock	Upper bound for the reference standard condition estimated from the data range (0 to 63%) and adjusted upward to the nearest upper bound for a standard canopy cover class (75%). The authors also used percentage change in shrub canopy cover resulting from human perturbation to scale V_{SHRUB} because of small sample size and wide range of canopy-cover estimates.

Confidence: The authors' confidence that reasonable logic and/or data support the scaling varies by community type. Confidence estimates for V_{SHRUB} scaling are given in Table 40.

Table 40. Confidence estimates and sample size for scaling V_{SHRUB} by community type.

COMMUNITY TYPE	SAMPLE SIZE	CONFIDENCE ESTIMATE
Forested		
6- to 30-yr-old	4	Low
>30-yr-old	19	High
Shrub	4	Medium
Sedge Tussock	3	Low

SCALING:

FORESTED COMMUNITY TYPES

Measurement or Condition for the 6- to 30-yr-old and >30-yr-old Forested Community Types	Index
Shrub canopy cover ≥26%, **and/or** site unaltered by human activity **and** dominated by native plant species.	1.0

Measurement or Condition for the 6- to 30-yr-old and >30-yr-old Forested Community Types	**Index**
Shrub canopy cover ≥26%, **and** site altered by human activity but dominated by perennial native or non-native plant species (*e.g.*, discontinued agricultural operation; cleared power line right-of-way).	0.75
Shrub canopy cover ≥16% to <26%, **and** site altered by human activity but dominated by perennial native or non-native plant species (*e.g.*, discontinued agricultural operation, cleared power line right-of-way).	0.5
Shrub canopy cover ≥6% to ≤15%, **and** site altered by human activity but dominated by perennial native or non-native plant species (*e.g.*, discontinued agricultural operation, cleared power line right-of-way).	0.25
Shrub canopy cover ≤5%, **and** the site is significantly altered by human activity. The variable is recoverable to reference standard conditions and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
Shrub canopy cover ≤5%, **and** the site is significantly altered by human activity. The variable is neither recoverable to reference standard conditions nor sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

SHRUB COMMUNITY

Measurement or Condition for the Shrub Community Type	**Index**
Shrub canopy cover >75%, **and/or** site unaltered by human activity **and** dominated by native plant species.	1.0
Shrub canopy cover >75%, **and** site altered by human activity but dominated by perennial native or non-native plant species (*e.g.*, discontinued agricultural operation, cleared power line right-of-way dominated by shrubs).	0.75
Shrub canopy cover 51 to 75%, **and** site altered by human activity but dominated by perennial native or non-native plant species (*e.g.*, discontinued agricultural operation, cleared power line right-of-way dominated by shrubs).	0.5
Shrub canopy cover 26% to 50%, **and** site altered by humans but dominated by perennial native or non-native plant species (*e.g.*, discontinued agricultural operation, cleared power line right-of-way).	0.25
Shrub canopy cover ≤25%, **and** site altered by human activity. The variable is recoverable to reference standard conditions and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
Shrub canopy cover ≤25, **and** site altered by human activity. The variable is neither recoverable to reference standard conditions nor sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

SEDGE TUSSOCK COMMUNITY TYPE

Measurement or Condition for the Sedge Tussock Community Type	**Index**
Shrub canopy cover highly variable but usually ≤75% (*e.g.*, 0 to 63% canopy cover was observed at reference standard sites), **and/or** site is unaltered by human activity **and** dominated by native plant species.	1.0
Shrub canopy cover highly variable, **and** site is altered by human activity to produce shrub canopy cover >75% and/or a <25% reduction of shrub cover. Site dominated by perennial native or non-native plant species (*e.g.*, light to moderate grazing by domestic livestock, partial clearing, cleared power line right-of-way).	0.75
Shrub canopy cover highly variable, **and** site is altered by human activity to produce a ≥25 to <50% reduction of shrub canopy cover. Site dominated by perennial native or non-native plant species (*e.g.*, moderate to heavy grazing by domestic livestock, partial clearing, cleared power line right-of-way).	0.5
Shrub canopy cover highly variable, **and** site is altered by human activity to produce a ≥50% to <75% reduction of shrub canopy cover. Site dominated by perennial native or non-native plant species (*e.g.* heavy grazing by domestic livestock, clearing for agriculture within the last 5 years, cleared power line right-of-way).	0.25
Shrub canopy coverage highly variable, **and** site is significantly altered by human activity to produce a ≥75% reduction of shrub canopy cover. The variable is recoverable to reference standard conditions and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
Shrub canopy coverage highly variable, **and** site is significantly altered by human activity to produce a ≥75% reduction of shrub canopy cover. The variable is neither recoverable to reference standard conditions nor sustainable through natural processes (within the 100- to 250-yr year fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

Variable Name: Silty or Loamy Mantle (V_{SLM})

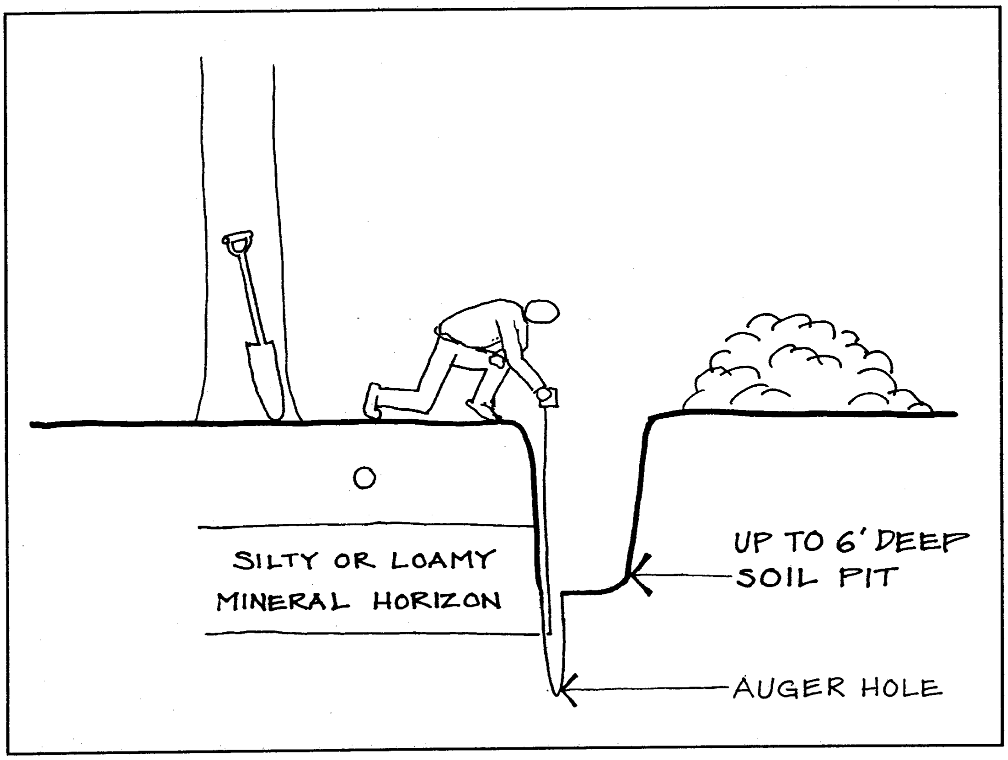
Definition: This variable is a measure of the presence and condition of a silty or loamy mantle (usually ≥20 inches (51 cm) thick) within the soil profile in the project assessment area.

Rationale for Selection of Variable: Soils with silty or loamy textured horizons help to maintain hydrologic, biogeochemical, and physical function due to texture(s) that help establish or re-establish permafrost, and facilitate surface and/or near surface water storage. Surface and near surface water storage helps maintain and increase surface organic horizons, surface insulation, and associated biogeochemical functions such as carbon export and elemental cycling.

Measurement Protocol: Field teams excavate soil pits at the center of the project assessment area to a depth of approximately 6 ft (2 m), or to the depth of permafrost, whichever is encountered first (Figure 58). Shovels are used and closed-bucket augers may be used below approximately 1.6 ft (0.5 m). Identification,

Figure 58. Measurement Protocol for the Silty or Loamy Mantle Variable (V_{SLM})

Figure 58. Measurement Protocol for the Silty or Loamy Mantle Variable (V_{SLM})



nomenclature, and description of soil horizons should be consistent with guidance provided by the USDA Soil Conservation Service (SCS 1962; SCS 1990). All depths are measured from the top of the surface (usually Oi) horizon. Live vascular and non-vascular plant materials are **not** included in these depths. Soil colors are determined consistent with a Munsell Soil Color Chart (Munsell 1992).

Data: Located in Appendix B. Summary graphs are in Appendix C.

Scaling Rationale: Under reference standard conditions, the mantle is protected from degradation by a thick organic horizon and frequently is frozen as well. Mantles on highly degraded sites may be greatly reduced, absent, or buried. The scaling is based on the degree of mantle disruption that has occurred from direct manipulation (*e.g.,* leveled construction sites) or eventually may occur from long-term exposure (*e.g.,* agricultural tillage) of the erosive, silty mantle to wind, water, or additional disturbances.

Confidence: The authors' confidence that reasonable logic and/or data support variable scaling is Medium-High.

Scaling: **FOR ALL COMMUNITY TYPES**

Measurement or Condition for V_{SLM}	**Index**
Within the project assessment area, the mantle is typically >20 inches thick (51cm), entirely undisturbed, and has an organic horizon overlying it **or** permafrost exists in the overlying organic horizon.	1.0
Within the project assessment area, the organic horizon is removed or slightly altered (e.g., Ap horizon) by human-induced activities, but the mantle is typically intact, >20inches (51cm) thick, and stabilized by an intact permanent native or non-native plant community that may be mowed but is not "regularly" tilled (*e.g.,* tilled every 7 to 10 yr.).	0.75
Within the project assessment area, the organic horizon is removed by human-induced activities, but the mantle is typically >20 inches (51cm) thick and stabilized by vegetation most of the time as part of a conservation cropping system (*e.g.,* tillage every 1 to 3 yr.) or similar land management practice.	0.5
Within the project assessment area, the organic horizon is removed by human-induced activities, and the mantle is typically >20 inches (51cm) thick, exposed, and subject to erosion most of the time (*e.g.,* repeatedly tilled fallow field, construction site)	0.25
Within the project assessment area, the mantle is exposed, partially removed (*e.g.,* decreased in thickness) and highly subject to deterioration through erosion. The mantle is often ≥20 inches (51cm) thick and thus, its insulating properties are recoverable and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
Within the project assessment area, the mantle is buried by human-induced activities, or absent due to removal. The mantle is usually <20 inches in thickness and is neither recoverable nor sustainable through natural processes (within the 100 to 250 yr. fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

Variable Name: Static Surface Water Storage (V_{SURWAT})

Definition: This variable is a measure of surface water ponding (*i.e.*, static surface and shallow subsurface storage).

Rationale for Selection of the Variable: Surface water ponding, and short and long term storage of surface and shallow subsurface water facilitates the establishment and augmentation of surface organic horizons, and helps establish a variety of substrates for different vegetation communities. Exchange of water between surface and shallow subsurface compartments facilitates biogeochemical processes associated with elemental cycling and organic carbon export.

Measurement Protocol: The presence or evidence of ponding and/or static surface water was assessed along a 200 foot line transect and described at 20 foot intervals (i.e., between 0 and 20 feet, between 20 and 40 feet, etc.) (Figure 59). The transect should be centered at the approximate center point of the project assessment area.

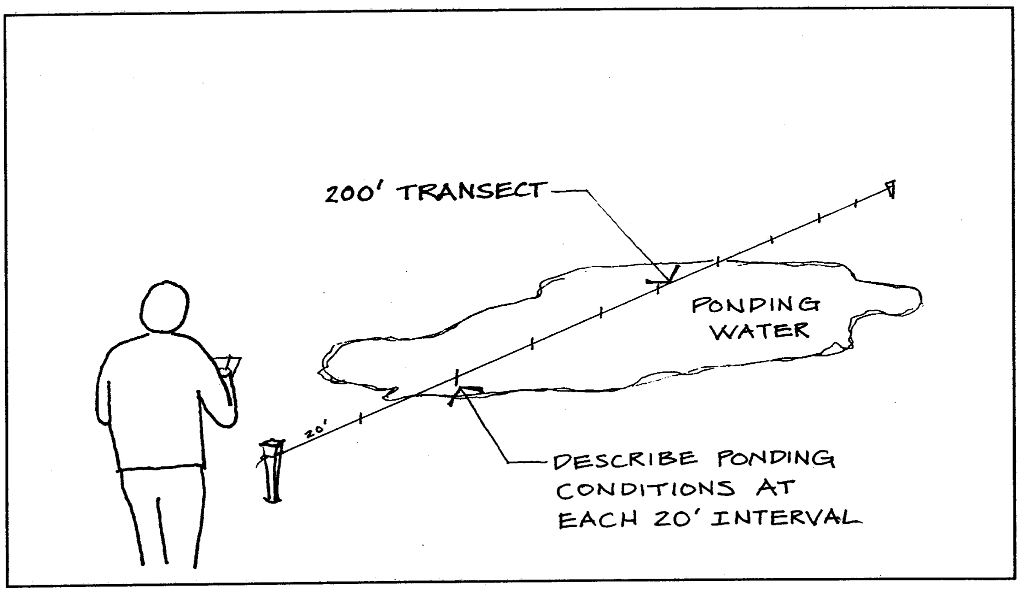
Data: Located in Appendix B. Summary graphs are in Appendix C.

Scaling Rationale: Human alteration of river proximal and slope/flat complex wetlands in the Tanana flats tends to simplify complex topography and impart planar features to the wetland surface such that it will no longer pond water and provide the associated wetland functions. The authors scaled surface water presence against topographic modification using empirical field data from 55 reference sites and best scientific judgment.

Confidence: The authors' confidence that reasonable logic and/or data support variable scaling is Medium High.

Figure 59. Measurement Protocol for the Static Surface Water Storage Variable (V_{SURWAT})

Figure 59. Measurement Protocol for the Static Surface Water Storage Variable (V_{SURWAT})



DESCRIBE PONDING CONDITIONS AT EACH 20' INTERVAL

Scaling: FOR ALL COMMUNITY TYPES

Measurement or Condition for V_{SURWAT}	**Index**
Observation or evidence of surface water ponding (*i.e.*, static water storage) in significant portions of the project assessment area. ≥ 80% of the observed topographic features are natural non-planar features capable of ponding water **and** the project assessment area is unaltered by human activities.	1.0
Observation or evidence of surface water ponding (*i.e.*, static water storage) in significant portions of the project assessment area. ≥ 60-80% of the observed topographic features are natural non-planar features capable of ponding water. The project assessment area assessment area is slightly disturbed by human-induced activities (*e.g.*, vegetation clearing, topographic modifications etc.).	0.75
Observation or evidence of surface water ponding (*i.e.*, static water storage) in portions of the project assessment area. 40-60% of the observed topographic features are natural or non-natural non-planar features capable of ponding water. The project assessment area is predominantly disturbed by human-induced activities (*e.g.*, vegetation clearing, topographic modifications etc.).	0.5
Project assessment area is greatly diminished in soil-surface features that could pond water. 10-40% of the observed topographic features are natural or non-natural non-planar features capable of ponding water. The project assessment area is predominantly disturbed by human-induced activities (*e.g.*, vegetation clearing, topographic modifications etc.,).	0.25
Project assessment area provides no soil-surface features that could pond water. The variable is recoverable to reference standard conditions and sustainable through natural processes, if the existing land use is discontinued and no restoration measures are applied.	0.1
Project assessment area provides no soil-surface features that could pond water. The variable is not recoverable to reference standard conditions nor sustainable through natural processes, if the existing land use is discontinued and no restoration measures are applied	0.0

Variable Name: Surface Connections ($V_{SURFCON}$)

Definition: This variable is an estimate of the presence of surface and shallow subsurface hydrologic flow and thus, hydrologic connection(s) between the assessment area waters/wetlands and down-gradient waters/wetlands.

Rationale for Selection of the Variable: Human induced disturbances can disrupt longitudinal connections such as channels, swales, and intact soil profiles that provide pathways for surface and shallow subsurface flow of water and organic carbon to down-gradient waters/wetlands. Hydrologic connections also facilitate biogeochemical processes associated with elemental cycling, organic carbon export, and vegetation establishment.

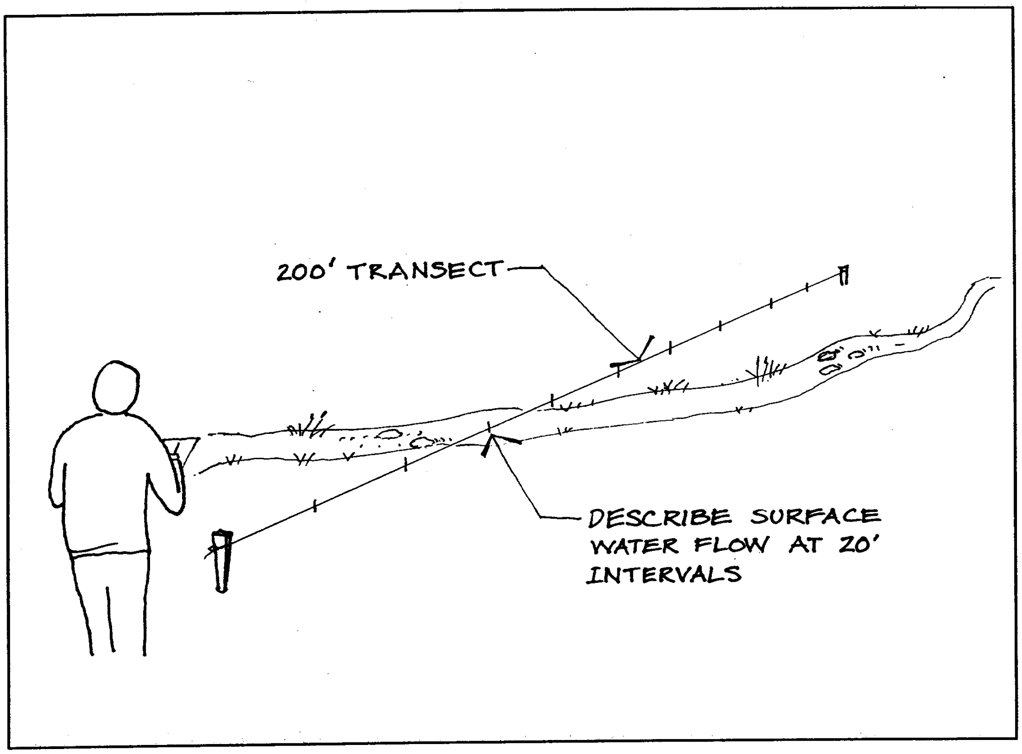
Measurement Protocol: The presence or evidence of surface water flows and connections was assessed along a 200 foot line transect and described at 20 foot intervals (Figure 60). The transect should be centered at the approximate center point of the project assessment area. In addition aerial photography should be used to assess hydrologic connective features along the 200ft transect.

Data: Located in Appendix B. Summary graphs are in Appendix C.

Scaling Rationale: The predominant use and condition of the longitudinal connective features to down-gradient waters/wetlands was scaled according to human-induced disturbance. The authors scaled the disturbance of the connective features using field observations from 55 reference sites (Appendix __, Matrices of Measured Attributes), and best scientific judgment.

Figure 60. Measurement Protocol for the Surface Connections Variable ($V_{SURFCON}$)

Figure 60. Measurement Protocol for the Surface Connections Variable ($V_{SURFCON}$)



Confidence: The authors' confidence that reasonable logic and/or data support variable scaling is Medium.

Scaling: **FOR SEDGE TUSSOCK COMMUNITY TYPES**

Measurement or Condition for $V_{SURFCON}$	**Index**
Project assessment area and the areas between the assessment area and down-gradient waters/wetlands are undisturbed (*i.e.*, unaltered by human activity) and no impediments to surface and shallow subsurface flow exist. The project assessment area is characterized by intact soil profiles, intact longitudinal connective features and vegetation communities, and discharge of surface and shallow subsurface water to down-gradient riparian corridor.	1.0
The longitudinal hydrologic connection(s) are predominantly undisturbed and are characterized by an intact soil profile and land use conditions that do not restrict discharge of surface and shallow subsurface flows from the project assessment area to down-gradient waters/wetlands. Land use condition might include: (a) cleared vegetation, or (b) foot or vehicle paths (not entrenched) or (c) footings for bridges, elevated boardwalks, powerlines, etc.	0.75
The longitudinal hydrologic connection(s) within the project assessment area has human-induced features that act to impede surface and shallow subsurface flow. The longitudinal connection(s) have minor constrictions, interruptions or diversions (*i.e.*, <50% of the width of the connection) and are characterized by disturbed soil profiles and vegetation communities, and land use conditions that restrict, redirect or interrupt surface and shallow subsurface flows such as: (a) through-fill roads with well designed and maintained culverts, or (b) entrenched foot or vehicle paths, or (c) shallow ditches, etc. The remainder of the hydrologic connection is intact.	0.5
The longitudinal hydrologic connection(s) within the project assessment area have human-induced features that act to impede surface and shallow subsurface flow. The longitudinal connection(s) have major constrictions, interruptions or diversions (*i.e.*, >50% of the width of the connection) and are characterized by highly disturbed soil profiles and vegetation communities, and land use conditions that restrict, redirect or interrupt surface and shallow subsurface flows such as: (a) through-fill roads with poorly designed and maintained culverts, or (b) large building pads, or (c) deep ditches, etc.	0.25
There is an obvious human-induced break or discontinuity that acts to block surface and shallow subsurface discharge (*e.g.*, through-fill road without culverts, urban fill, etc.) from the project assessment area to down-gradient waters/wetlands. The variable is recoverable to reference standard conditions and sustainable through natural processes, if the existing land use is discontinued and no restoration measures are applied.	0.1
There is an obvious human-induced break or discontinuity that acts to block surface and shallow subsurface discharge (*e.g.*, through-fill road without culverts, urban fill, etc.) from the project assessment area to down-gradient waters/wetlands. The variable is neither recoverable to reference standard conditions nor sustainable through natural processes, if the existing land use is discontinued and no restoration measures are applied.	0.0

Variable: Surrounding Land Use (V_{SURUSE})

Definition: The dominant land use or condition within 1,000 ft (305 m) of the perimeter of the project assessment area.

Rational for Selection of the Variable: Land use or condition surrounding the project assessment area reflects interspersion and connectivity, the extent of contiguous native vegetation, and habitat patch sizes. Land use conditions were ranked to reflect suitability for supporting animal movement to and from the project assessment area, based on the degree and permanence of native vegetative cover under various land use practices.

Measurement Protocol: Field teams categorize the surrounding area within 1,000 ft (305 m) of the perimeter of the project assessment area into land-use or condition categories ranging from undisturbed to urban (Figure 61). Teams develop a cartographic, air photo, and/or visual estimate of the percent of the area within 1,000 ft (305 m) of the perimeter of the project assessment area occupied by each of the land uses. The dominant land use category (*i.e.*, category covering >50% of the area) is recorded as V_{SURUSE}.

Data: Located in Appendix B. Summary graphs are in Appendix C.

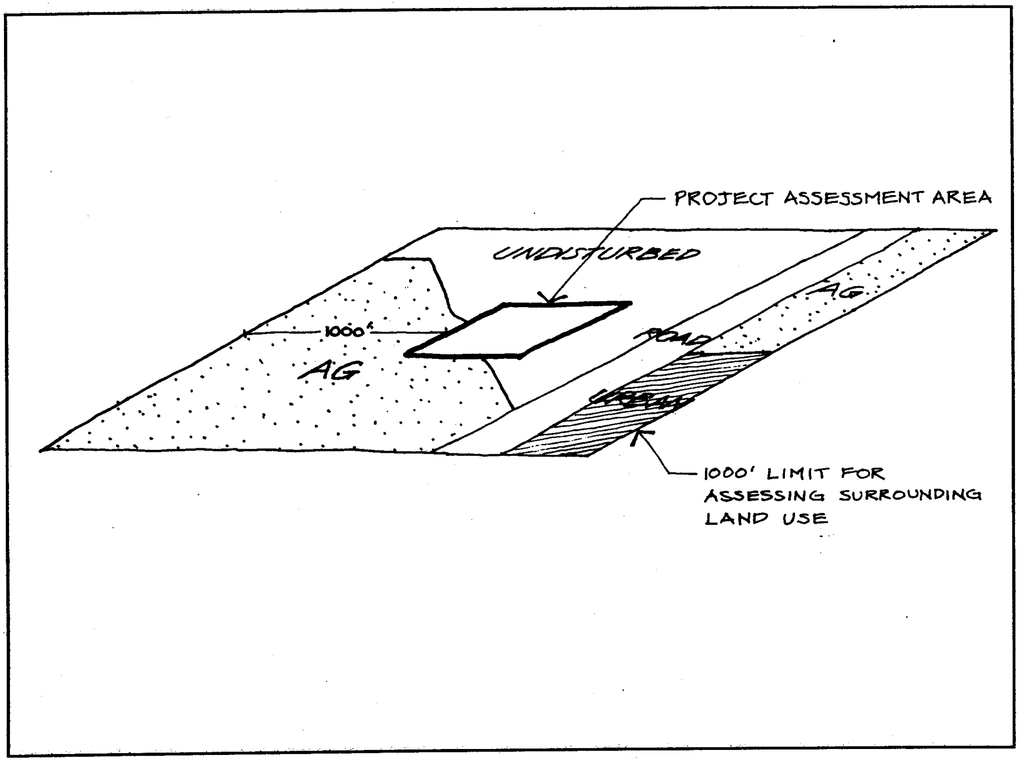
Scaling Rationale: The variable was scale using reference data and best scientific judgment to describe existing site land uses and conditions. The variable was scaled according to a disturbance scale. The disturbance scale was developed by the interdisciplinary team based upon field observations and best scientific judgement.

Scaling: **FOR ALL COMMUNITY TYPES**

Measurement or Condition for all Community Types	**Index**
Dominant land use is undisturbed. No evidence of significant human-induced perturbation of surrounding area.	1.00
Dominant land use in surrounding area: cleared >5 years before present **and** area is dominated by native species, **and** is recovering through natural successional processes.	0.75
Dominant land use of surrounding area: cleared of all large woody vegetation (*e.g.*, trees and shrubs >3 ft (0.9 m) tall) **and** regular maintenance prevents regeneration of woody vegetation (*e.g.*, mowed rights-of-way) but area is dominated by native plant species.	0.50
Dominant land use of surrounding area: cleared of all native vegetation **and** under cultivation. Herbaceous vegetation layer is intact **and** dominated by non-native adventive species maintained as permanent vegetative cover (*e.g.*, hay land, pasture land, CRP land).	0.25
Dominant land use of surrounding area cleared **and** cultivated for annual cropping with seasonal clearing, or cleared and maintained essentially free of vegetation.	0.10
Dominant land use of surrounding area is urban fill **and/or** impervious surface (*e.g.*, pavement, buildings, roofs).	0.00

Figure 61. Measurement Protocol for the Surrounding Land Use Variable (V_{SURUSE})

Figure 61. Measurement Protocol for the Surrounding Land Use Variable (V_{SURUSE})



Variable: Trees (V_{TREE})

Definition: Percent canopy cover of trees (single-stem, woody species ≥10 ft ([m] tall) and small trees (single-stem, woody species >3 to <10 ft [>0.9 to <3 m] tall) within the project assessment area.

Rationale for Selection of the Variable: Canopy cover of trees and small trees is an indicator of the ability of the site to support native plant communities and faunal habitat.

Tree and small tree canopy cover were combined in the variable V_{TREE}. These two strata were combined because in black spruce ecosystems mature trees are often stunted, and the small tree category as defined in this guidebook can include both young trees or saplings, and mature trees which have been dwarfed or stunted in response to stress (*e.g.,* very wet site conditions or very low nutrients). Therefore, it is not practical to distinguish in the field between stunted trees and saplings.

Canopy cover was used in the models rather than other measures of tree abundance, such as density or basal area, for the following reasons.

(1)Boreal forests within the reference domain dominated by black spruce typically have highly variable tree and small tree densities. These densities vary in response to gradients in fire intensity, depth to permafrost, site aspect, site water balance, land-use history, and other factors. Variation in densities and in particular, variation in response to multiple factors limits the usefulness of tree density as a variable in the models.

(2)Because black spruce stands typically have very high densities (*e.g.,* up to 6,900 stems/acre) of small diameter trees, accurate estimates of basal area are difficult and time-consuming.

Measurement Protocol: Field teams visually estimate percent canopy cover for the tree and small tree strata within circular 0.1-acre (0.04-ha) plots (Figure 62). Estimates are recorded as mid-points of standard canopy-cover classes.

Data: Located in Appendix B. Summary graphs are in Appendix C.

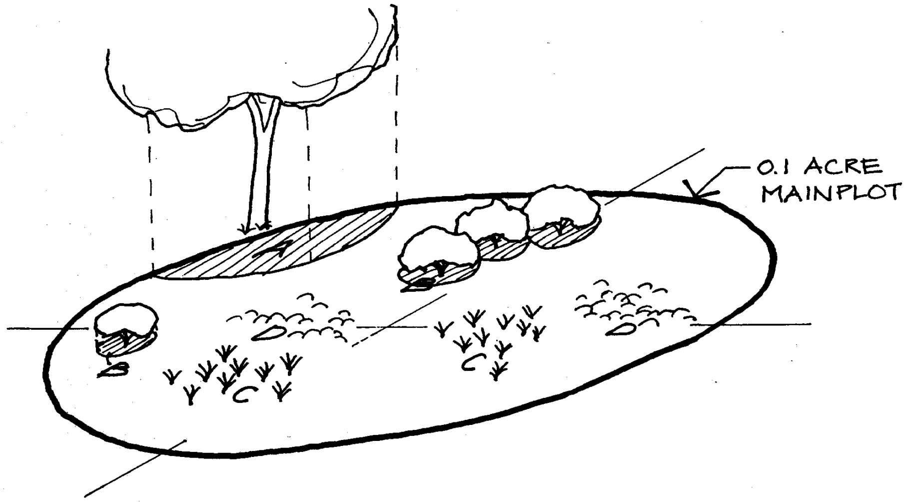
Scaling Rationale: Canopy cover estimates for trees ranged from 10% to 98% over the range of reference standard sites. Given this variation and generally small sample sizes V_{TREE} could not be scaled using data alone. The variable was scaled according to a disturbance scale. The disturbance scale was developed by the interdisciplinary team and is based upon field observations and best scientific judgement. V_{TREE} was not scaled for 0-5 yr. old Forested Communities or for Shrub and Sedge Tussock Communities.

Figure 62. Measurement Protocol for the Trees Variable (V_{TREE})

Figure 62. Measurement Protocol for the Trees Variable (V_{TREE})

Types of Canopy Cover:

A = Area of tree canopy cover
B = Area of shrub canopy cover
C = Area of herb canopy cover
D = Area of mosses, lichens and liverworts canopy cover



Percentage of Tree Canopy Cover = A / 0.1 acres

Confidence: The authors' confidence that reasonable logic and/or data support variable scaling is High.

Scaling:

FORESTED COMMUNITY TYPE

Forested Community Type: 0-5 yr. old (no scaling)

Forested Community Type: 6-30 yr. old and > 30 yr. old

Measurement or Condition for 6- to 30-yr-old and >30-yr-old Forested Community Types	**Index**
Tree/small tree canopy cover ≥10% and site dominated by native plant species; **and** site unaltered by human activity.	1.0
Tree/small tree canopy cover ≥10% **and** site altered by humans. Minimal disturbance to the tree and/or small tree canopy (*e.g.,* <25% reduction of the canopy or increased stem density due to alteration of soil) by human activity. Site dominated by native plant species.	0.75
Tree/small tree canopy cover ≥10%, **and** tree/small tree canopy significantly altered (*e.g.,* ≥25% and <50% reduction of the canopy) by human activity. Site dominated by native or non-native plant species (*e.g.,* light to moderate grazing by domestic livestock, cleared power line right-of-way dominated by shrubs).	0.5
Tree/small tree canopy cover ≥10%, **and** tree/ small tree canopy significantly altered (*e.g.,* ≥50% and <75% reduction of the canopy) by humans. Site dominated by native or non-native plant species (*e.g.,* moderate to seasonally heavy grazing by domestic livestock, fuel wood logging).	0.25
Tree/small tree canopy cover <10% due to disturbance to the tree/small tree canopy (*e.g.,* ≥75% reduction of the canopy) by human activity. The variable is recoverable to reference standard conditions and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
Tree/small tree canopy cover <10% due to disturbance to the tree/small tree canopy (*e.g.,* ≥75% reduction of the canopy) by human activity. The variable is neither recoverable to reference standard conditions nor sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

Variable: Vegetation Strata ($V_{VSTRATA}$)

Definition: The average number of vegetation strata present within the project assessment area.

Vegetation strata were defined as follows:

1. trees (single-stem, woody species ≥10-ft tall),
2. small trees [single-stem, woody species >3 to <10 ft (>1 to <3 m) tall],
3. shrubs (multiple-stem, woody species),
4. herbs, including forbs, graminoids, ferns and fern allies, and
5. mosses, lichens, and liverworts.

Rationale for Selection of the Variable: The number of strata characteristic of reference standard conditions is an indicator of the development and maintenance of native plant communities. In addition, number of strata represent the presence of the habitat structure and complexity necessary to support typical faunal assemblages. Similarly, the numbers and types of vegetation strata represent the diversity of habitat niches, as well as the types and amount of food and cover resources available.

Measurement Protocol: Field teams record the number of vegetation strata present at 10-ft (3-m) intervals along a 100-ft (30.5-m) transect in the project assessment area (Figure 63). The average number of strata is calculated for the transect, and rounded to the nearest integer to yield an estimate for the project assessment area.

Data: Located in Appendix B. Summary graphs are in Appendix C.

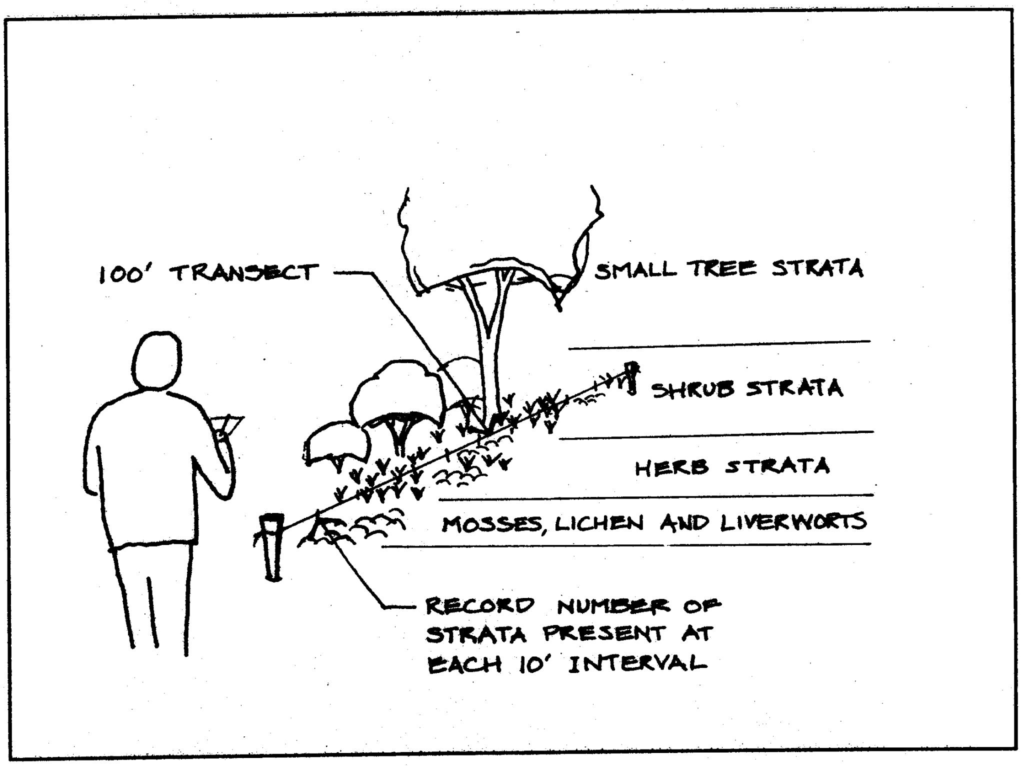
Scaling Rationale: The variable was scaled using reference data, field observations, and best scientific judgment. $V_{VSTRATA}$ was scaled according to a disturbance scale. The disturbance scale was developed by the interdisciplinary team based upon field observations and best scientific judgement.

Confidence: The authors' confidence that reasonable logic and/or data support scaling is Medium.

Scaling:

Figure 63. Measurement Protocol for the Vegetative Strata Variable (V_{STRATA})

Figure 63. Measurement Protocol for the Vegetative Strata Variable (V_{STRATA})



FORESTED COMMUNITY TYPE

Forested Community: 0-5 yr. old

Measurement or Condition for the 0- to 5-yr-old Forested Community Type	**Index**
One stratum present, **and** site unaltered by human activity and dominated by native plant species.	1.0
One stratum present, **and** site altered by human activity but dominated by **perennial native** plant species (*e.g.*, hydroaxed power line right-of-way).	0.75
One stratum present, **and** site altered by human activity but dominated by **perennial non-native** plant species (*e.g.*, grazed pasture, golf course fairway).	0.5
One stratum present, **and** site altered by human activity but dominated by **annual** native or non-native plant species (*e.g.*, row crop monoculture).	0.25
Zero strata present, **and** site altered by human activity (*e.g.*, recent land clearing or cultivation for agricultural production). The variable is recoverable to reference standard conditions and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
Zero strata present, **and** site altered by human activity (*e.g.*, parking lots, urban development). The variable is neither recoverable to reference standard conditions nor sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied	0.0

Forested Community: 6-30 yr. old and >30 yr. old

Measurement or Condition for 6- to 30-yr-old Forested, >30-yr-old Forested, Shrub, and Sedge Tussock Community Types	**Index**
Two or more strata present, **and** site unaltered by human activity and dominated by native plant species.	1.0
Two or more strata present, **and** site altered by human activity but dominated by **perennial native** plant species (*e.g.*, discontinued agricultural operation or cleared power line right-of-way dominated by shrubs).	0.75
One stratum present, **and** site altered by human activity but dominated by **perennial** native or non-native plant species (*e.g.*, agricultural hay field or improved pasture).	0.5
One stratum present, **and** site altered by humans but dominated by **annual** native or non-native plant species (*e.g.*, row crop monoculture).	0.25
Zero strata present, **and** site altered by human activity applied (*e.g.*, recent land clearing operation and/or cultivation). The variable is recoverable to reference standard conditions and sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.1
Zero strata present, **and** site altered by human activity (*e.g.*, parking lots, urban development). The variable is neither recoverable to reference standard conditions nor sustainable through natural processes (within the 100- to 250-yr fire cycle), if the existing land use is discontinued and no restoration measures are applied.	0.0

VII. APPLICATION AND USE OF HGM GUIDEBOOKS AND MODELS

A. Overview

As discussed in the introductory sections of this operational draft Guidebook, the HGM approach to assessing the functions of waters/wetlands is a useful tool that is designed specifically for a broad array of tasks related to project planning, design, implementation, and monitoring. Commonly, the HGM approach is used as the basis for (1) impact assessment, (2) restoration design, and (3) development of monitoring protocols and contingency measures (Brinson 1993, Brinson *et al.* 1995, NWSTC 1996).

The subclass profile and supporting appendices in the operational draft Guidebook (Sections V. Appendices B and C) offer a wealth of useful information concerning the geologic, hydrologic, soil, vegetation and habitat/faunal characteristics of precipitation driven wetlands on discontinuous permafrost in Interior Alaska. As discussed elsewhere in this operational draft Guidebook, this information can be used as design templates for restorations or to structure monitoring efforts and contingency measures for several different types of projects.

With particular respect to the assessment of changes in functions in Interior Alaska wetlands on discontinuous permafrost, application of the HGM approach offered in this operational draft Guidebook should be accomplished in a manner that is consistent with standard interpretations of operational draft HGM model logic, terminology and administrative procedures. Consistency requires articulation of conventions for field observations, field measurements, and documentation of assessment results. This section of the draft operational Guidebook provides guidance on how to run HGM models and develop an acceptable assessment report. The steps and required documentation for these procedures are summarized in Table 41, Parts a, b, and c, and are detailed below.

It should be emphasized that the documentation required in each of the steps discussed below constitute the MINIMUM SUBMITTALS of information required for an HGM assessment in Interior Alaska. Failure to complete the minimum submittals will be grounds for agency and/or peer rejection of an HGM assessment report, due to incomplete documentation.

Table 41. Part a. Recommended Steps and Procedures for Performing HGM Functional Assessments

Part a. Office Preparation

Step 1. Collect and review background information relevant to the project assessment area (PAA) and the proposed project(s). This includes, but is not limited to:

- a. Relevant U.S. Geological Survey, State, Borough, and other maps at several scales (*e.g.* 1:24,000, 1:250,000)
- b. Air photos and other imagery
- c. Relevant geological, geotechnical, hydrology, soils, or environmental reports
- d. Correspondence, construction plans and specifications, etc. on the proposed project
- e. Relevant published literature on the project assessment area, proposed activity, watershed, etc.

Step 2. Bound and stratify the PAA using maps, air photos, etc. At the same map scales:

- a. Define and complete a preliminary delineation of the PAA
- b. Estimate the geographic extent of waters/wetlands within the PAA
- c. Estimate the proportion of waters/wetlands that fall into the subclass of waters/wetlands addressed by and not addressed by this draft operational Guidebook (*i.e.*, precipitation driven wetlands on discontinuous permafrost).
- d. Complete a preliminary stratification of the PAA into community types using the Dichotomous Key to community types (Table 42). Consult the appropriate NRCS Soil Survey to determine the area soil types.
- e. Estimate the geographic extent and type of proposed project impact(s).

Step 3. Identify, verify, and document the rationale used for recognizing HGM classes and subclasses within the PAA.
a. Show/explain why the PAA or parts of the PAA are covered by the Guidebook

Step 4. Coordinate gear. Complete a preliminary assembly of field and safety equipment and field data sheets (Table 43).

Part b. Field Work

Step 1. Complete assembly and final checks of field and safety equipment and field data sheets

Step 2. Complete a thorough reconnaissance of the PAA and vicinity. Take particular note of geologic, landscape, hydrologic, soil, plant community, and faunal support/habitat conditions.

Step 3. Bound, stratify and complete mapping of the PAA . Confirm and refine all preliminary mapping in the field (*i.e.*, Office Step 3 above). This includes confirmation of the following:

- a. Delineation of the (PAA) boundaries
- b. Estimate the geographic extent of waters/wetlands within the PAA
- c. Estimate the proportion of waters/wetlands that fall into the subclass of waters/wetlands addressed by and not addressed by this draft operational Guidebook (*i.e.* Precipitation driven wetlands on discontinuous permafrost).

d. Complete a preliminary stratification of the PAA into community types using the Dichotomous Key (Table 42). Consult the appropriate NRCS Soil Survey to determine the area soil types.
e. Estimate the geographic extent and type of proposed project impact(s).

Step 4. Identify, verify, and document the rationale used for recognizing HGM classes and subclasses within the PAA.
a. Show/explain why the PAA or parts of the PAA are covered by the operational draft Guidebook

Step 5. Develop and refine a general description of existing conditions within the PAA (geologic and landscape contexts, hydrology, soils, vegetation, faunal support/habitat, historic and current land uses, etc.)

Step 6. Score the variables using standards for each variable presented in the Guidebook, based on:
a. Existing conditions
b. With proposed project conditions (or alternatives 1,2,3, etc.)

Step 7. Calculate the indices of function (FCIs) in the field, based on:
a. Existing conditions
b. With proposed project conditions (or alternatives 1,2,3, etc.)

Step 8. Review the results of the all FCI calculations <u>IN THE FIELD</u> to ensure accuracy.

Part c. Preparation of an Assessment Report - Recommended Table Of Contents

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List Of Appendices

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        2. Anticipated changes to:
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            - b. Soils
            - c. Vegetation
            - d. Faunal Support/Habitat

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Table 42. Dichotomous Key To Community Types Precipitation-Driven Wetlands on Discontinuous Permafrost in Interior Alaska

1a Project assessment area (PAA) shows evidence of anthropogenic alteration……………………..…**7**

1b PAA shows no evidence of anthropogenic alteration.

  2a Canopy cover of trees (*i.e.,* single-stem, woody vegetation ≥10 ft [3 m] tall) and small trees (*i.e.,* single-stem, woody vegetation >3 to <10 ft [0.9 to 3 m] tall) combined <10% ……………..……**4**

  2b Canopy cover of trees and small trees combined ≥10%

    3a Stand age **>**30 yr……………………………………. **>30-yr-old Forested Community Type** (*e.g.,* black spruce forest or woodland, paper birch forest or woodland, mixed forest or woodland).

    3b Stand age **=**30 yr ………………………………**6 to 30-yr-old Forested Community Type** (*e.g.*, regenerating black spruce forest or woodland, paper birch forest or woodland, mixed forest or woodland).

  4a Shrub cover <50% ……………………………………………………………………………..**6**

  4b Shrub cover ≥50%

    5a Canopy cover of mosses, lichens and liverworts ≥50% **and** canopy cover of closed-sheath sedge (cotton grass) <50%; few prominent tussocks and intertussock depressions ………

    Shrub Community Type (*e.g., Betula glandulosa* community)

    5b Canopy cover of mosses, lichens and liverworts <50% **and** cover of closed-sheath sedge (cotton grass) ≥50%; prominent tussocks and intertussock depressions …… .... ………**Sedge**

    Tussock Community Type (*e.g., Eriophorum* spp. community)

  6a Canopy cover of mosses, lichens and liverworts <50% **and** closed-sheath sedge (cotton grass) canopy cove ≥50%; prominent tussocks and intertussock depressions ..…………………..……**Sedge**

  Tussock Community Type (*e.g., Eriophorum* spp. community)

  6b Canopy cover of mosses, lichens and liverworts ≥50% **and** closed-sheath sedge (cotton grass) canopy cover <50%; few prominent tussocks and intertussock depressions……………..**Shrub Community Type** (*e.g., Betula glandulosa* community).

7a PAA is too wet to support tree regeneration (*i.e.,* soils not sufficiently drained; if alteration in landuse were discontinued); soil has peraquic conditions…………………………………………………………11

7b PAA sufficiently well drained to support tree regeneration, if alteration in current land use(s) were discontinued

8a Canopy cover of trees ≥10% ……………………….. **>30-yr-old Forested Community Type** (*e.g.*, site altered by partial removal of trees, post-clearing sere following cessation of tillage).

8b Canopy cover of trees <10%

9a Canopy cover of small trees ≥10%……… **6- to 30-yr-old Forested Community Type** (*e.g.*, post-clearing sere, tree removal).

9b Canopy cover of small trees <10%.

10a Shrub cover ≥10% ………………… **6- to 30-yr-old Forested Community Type** (*e.g.*, post-clearing sere, tree removal)

10b Shrub cover <10%; site typically barren or dominated by herbaceous vegetation ………………………………………..**0- to 5-yr-old Forested Community Type** (*e.g.*, early post-clearing community, freshly tilled agricultural land, annual grain crop, pasture, hay field, golf course, parking lot)

11a Shrub cover ≥10%……………………………………………………………………..**12**

11b Shrub cover <10%; bare mineral soil or herbaceous cover dominant…………… **Sedge Tussock Community Type**

12a Surrounding area or other evidence (*e.g.,* documentation of condition prior to legal alteration) indicates shrub cover could reach ≥50% if the altering land use were, or has been, discontinued……………………………………….. **Shrub Community Type** (*e.g.*, post-clearing sere).

12b Surrounding area or other evidence (*e.g.,* pre-alteration documentation) indicates potential shrub cover <50% if the altering land use were, or has been, discontinued

……………………………………………………..**Sedge Tussock Community Type**

Table 43. Recommended Gear List for Running the Operational Draft Guidebook for Assessment of the Functions of Precipitation-Driven Waters/Wetlands on Discontinuous Permafrost in Interior Alaska

I. Essential Gear
A. Minimum Safety Gear
1. Water
2. Foil blanket
3. Power Bars or equivalent
4. Signal Flares, mirror, etc.
5. Radios/cell phone
6. Matches/fire blocks
B. Pertinent NRCS soil surveys
C. Air photos and other imagery
D. USGS, State, Borough and other maps (at various scales)

E. Shovel(s), auger(s), and frost probe(s)
F. 300+ foot measuring tape(s)
G. 100 foot Spencer tape(s)
H. 25 foot Stanley measuring tape(s)
I. Abney level &/or clinometer
J. Line (bubble) level
K. Clipboard
L. Ruler(s) (metric and English)
M. Camera & film
N. Flora of Alaska (Hulten)
O. Plastic bags (for unknown plants, soil samples, etc.)
P. Permanent markers (*e.g.* Sharpies), pencils, etc.
Q. Calculator
R. Variable and Functional Score Field Forms
II. Desirable/Optional Gear
A. GPS
B. Laser level system (including tripod, rod, and target)
C. Laptop computer programmed to calculate functional capacity indices

B. Required Steps For Performing HGM Functional Assessments

1. *Office Preparation*

Office Preparation - Step #1: Collect and review background information relevant to the project assessment area (PAA) and the proposed project(s). This includes, but is not limited to:

a. Relevant U.S. Geological Survey, State, Borough, and other maps at several scales (*e.g.* 1:24,000, 1:250,000)
b. Air photos and other imagery
c. Relevant geological, geotechnical, hydrology, soils, or environmental reports
d. Correspondence, construction plans and specifications, etc. on the proposed project
e. Relevant published literature on the project assessment area, proposed activity, watershed, etc.

HGM functional assessments cannot be performed without a thorough review of the project assessment area (PAA) and its landscape context (a) in the office, and (b) in the field. While elements of the HGM approach can be used to structure preliminary discussions of ecosystem functions and impacts, an HGM functional assessment is not completed until a site review is performed and the minimum submittals identified in this draft operation Guidebook are organized into an assessment report. The requirement for both office review and a field visit to complete an HGM assessment is due to the fact that many of the variables require field measurement, and remote techniques lack the precision and accuracy that is required for useful data. The exception to the rule about making a field assessment only occurs in review of proposed designs for development, or enhancement, restoration, or creation projects. In these situations, HGM functional assessments can be performed on data collected or synthesized from design documents, specifications, etc.

Any field effort requires advance preparation. Prior to performing a field or design document review, it is important to collect information that is relevant to the assessment site. Aerial photographs, topographic maps, geologic maps, soil surveys, NWI maps, jurisdictional delineation documents, and other relevant information should be compiled and reviewed to provide a firm base of knowledge. During this review, particular attention should be paid to the geomorphic setting of the PAA. Understanding the geomorphic setting will facilitate the functional assessment by providing geomorphic boundaries to the assessment area(s). For instance, information may be compiled that suggests the existence of precipitation-driven wetlands and riverine waters/wetlands, and these will need to be assessed separately (see below).

Also, attention should be given to the land-use history and landscape context of the PAA, as these factors may affect the boundaries of the assessment area(s), community types within the PAA, or variable scores. For example, a proposed PAA may be 10 acres in size, with 8 acres of undisturbed forest and 2 acres of naturally or anthropogenically cleared land. Such conditions will have bearing on HGM assessment model results. The 8 and 2 acre community types should be individually assessed.

MINIMUM SUBMITTAL FOR OFFICE PREPARATION - STEP 1: WORKSHEET 1 (APPENDIX E)

Office Preparation - Step 2: Bound and stratify the PAA using maps, air photos, etc. at the same map scales:

a. Define and complete a preliminary delineation of the (PAA)
b. Estimate the geographic extent of waters/wetlands within the PAA
c. Estimate the proportion of waters/wetlands that fall into the subclass of waters/wetlands addressed by and not addressed by this draft operational Guidebook (*i.e.* Precipitation driven wetlands on discontinuous permafrost).
d. Complete a preliminary stratification of the PAA into community types using the Dichotomous Key (Table 42). Consult the appropriate NRCS Soil Survey to determine the area soil types.
e. Estimate the geographic extent and type of proposed project impact(s).

One of the most important steps in any HGM assessment is to bound and stratify the PAA. Bounding and stratification is best accomplished in a two-step process that encompasses (a) preliminary office delineations, and (b) confirmation and refinement of preliminary boundaries in the field. The authors strongly recommend that all cartography developed for HGM assessments be registered to the same map/photo scales. This technique allow overlays of various maps and facilitates project planning, implementation, and overall communication of assessment results. With respect to mapping scales, it is useful to know that planning scale documents for a proposed project have to be developed at mapping scales that are relevant to the activity being proposed. For example, a project of approximately 200 acres (*e.g.*, a golf course or campus) should be developed for planning purposes at a scale of 1:100. Construction scales for the same project , especially in areas where activities will be within or near waters/wetlands are routinely 1:20. In addition to consistent scale, the Authors strongly recommend that every map layer needs to have all of the elements listed in Table 44.

Table 44. Top Ten Essential Elements of a Waters/Wetlands Map

1. Title
2. Legend that includes:
    a. Scale (not to exceed 1”:300’)
    b. North arrow
    c. Site location (longitude/latitude or appropriate coordinate system)
    d. Average site elevation
    e. Attribute identifications (prominent landmarks, features, etc.)
3. Other background information that includes:
    a. Names of cartographers, delineation crew, etc.
    b. If pertinent, waters/wetland delineation methodology used (’87,’89, Other)
    c. If pertinent, definition of waters (33 CFR 328.3 (A)(1-8), or other)
    d. If pertinent, name and address of survey company/crew
    e. Review/revision blocks
    f. Agency approval signature block(s)
4. Topographic contours [2 foot intervals recommended (scale dependent)]
5. Property or PAA boundaries/limit(s) of work (according to legal description of property (meets and bounds or survey bearings)
6. Waters/wetlands boundaries (areas within boundaries highlighted or stippled to be cartographically distinct)
    a. All waters/wetlands individually numbered or lettered
7. Location of:
    a. All sample sites
    b. All control points
8. Location of any other significant landmarks/features (to aid in orientation while on site - (*e.g.*, roads, culverts, powerlines, etc.)
9. For waters/wetlands delineation maps - a separate table that includes:
    a. All waters/wetland loop numbers and respective area (ft.^{2} &/or acreage)
    b. All buffer/easement numbers and respective area (ft.^{2}/acreage), if applicable (see below)
10. Optional layers:
    a. Location and numbering of any buffer or easement boundaries (areas should be highlighted or stippled)
    b. If applicable, location of project footprint(s) for alternatives A, B, C, etc.

For the purposes of Step 2, item c, it is important to note that all lands in Interior Alaska are certainly not waters/wetlands. Neither are all lands within the domain addressed by this operational draft Guidebook. A proposed project may not impact waters/wetlands, or it may impact several classes or subclasses of waters/wetlands that may not be "precipitation driven wetlands on discontinuous permafrost". An important office step, therefore, is to estimate the proportion of waters/wetlands in the PAA that exist within the subclass of the wetlands addressed by this Guidebook. The areas of waters/wetland that do not qualify for treatment using the Guidebook is also important information.

The Dichotomous Key to community types (Table 42) provides a convenient model for stratification of the PAA into vegetation community types (see Section V). These community types relate directly to the HGM models included in this draft operational Guidebook. Finally, it is usually necessary in the context of an HGM assessment, to superimpose the proposed project impacts onto base cartography. If pertinent, the types of proposed project impacts should be clearly indicated and cartographically distinct.

MINIMUM SUBMITTAL FOR OFFICE PREPARATION - STEP 2: WORKSHEET 2 (APPENDIX E)

Office Preparation - Step 3: Identify, verify, and document the rationale used for recognizing HGM classes and subclasses within the PAA.

a. Show/explain why the PAA or parts of the PAA are covered by the Guidebook.

An important and essential part of the office preparation for an HGM assessment is to demonstrate clearly why certain parts or all of the PAA qualifies as a part of the subclass addressed by this draft operational Guidebook (*i.e.*, precipitation-driven waters/wetlands on discontinuous permafrost). It is not acceptable to simply offer maps or air photos with lines on them and assert that part or all of the PAA does or does not fall into the subclass. Narrative descriptions of the rationale and/or criteria used by the assessment team to recognize HGM classes and subclasses on maps and photos are necessary to establish the assessment report and findings as credible.

MINIMUM SUBMITTAL FOR OFFICE PREPARATION - STEP 3: WORKSHEET 3 (APPENDIX E)

Office Preparation - Step 4: Coordinate gear. Complete a preliminary assembly of field and safety equipment, and field data sheets (Appendix D).

Part of any office background work for an HGM assessment includes careful preparation of field and safety equipment, and necessary field data sheets. Table 43 lists all recommended sampling gear and minimal safety gear necessary to conduct an HGM assessment using this Guidebook. Appendix D includes blank, copy ready of all data and documentation forms necessary for an HGM assessment.

2. Field Work

Field Work - Step 1: Complete assembly and final checks of field and safety equipment and field data sheets

Please refer to Table 43.

Field Work - Step 2: Complete a thorough reconnaissance of the PAA and vicinity. Take particular note of geologic, landscape, hydrologic, soil, plant community, and faunal support/habitat conditions.

Time is rarely wasted in field reconnaissance. In fact, it is reckless to run an HGM assessment using this draft operational Guidebook without first conducting a thorough reconnaissance of the entire PAA and vicinity. Walk completely around the site. Walk through the site, several times. If the site is big, fly it first. Even if the site is medium sized or small, fly if it is at all possible. Take pictures. After an aerial reconnaissance, walk through the site with photos in hand. Walk along organized transects, and then randomly, generally bisecting the organized transects. Cover the ground. Understand how water flows into, through, and away from the site. Look for animal use. Age trees. Dig holes. Stop and listen for birds, mammals, etc. If possible, visit the site at dawn and dusk. Work diligently to orient yourself and any helpers to the PAA. Register information necessary to improve preliminary maps of the assessment area boundaries and its landscape context. Make sure to observe (1) the range of variation of variable conditions that exist on the site, and (2) landscape context and condition. If possible, note the watershed boundaries and waters/wetlands boundaries. All these areas should be reviewed carefully, particularly those that appear to be distinct from each other during office preparation.

**MINIMUM SUBMITTAL FOR FIELD WORK - STEP 2:
WORKSHEET 4 (APPENDIX E)**

Field Work - Step 3: Bound, stratify and complete mapping of the PAA . Confirm and refine all preliminary mapping in the field (*i.e.,* Office Step 3 above). This includes confirmation of the following:

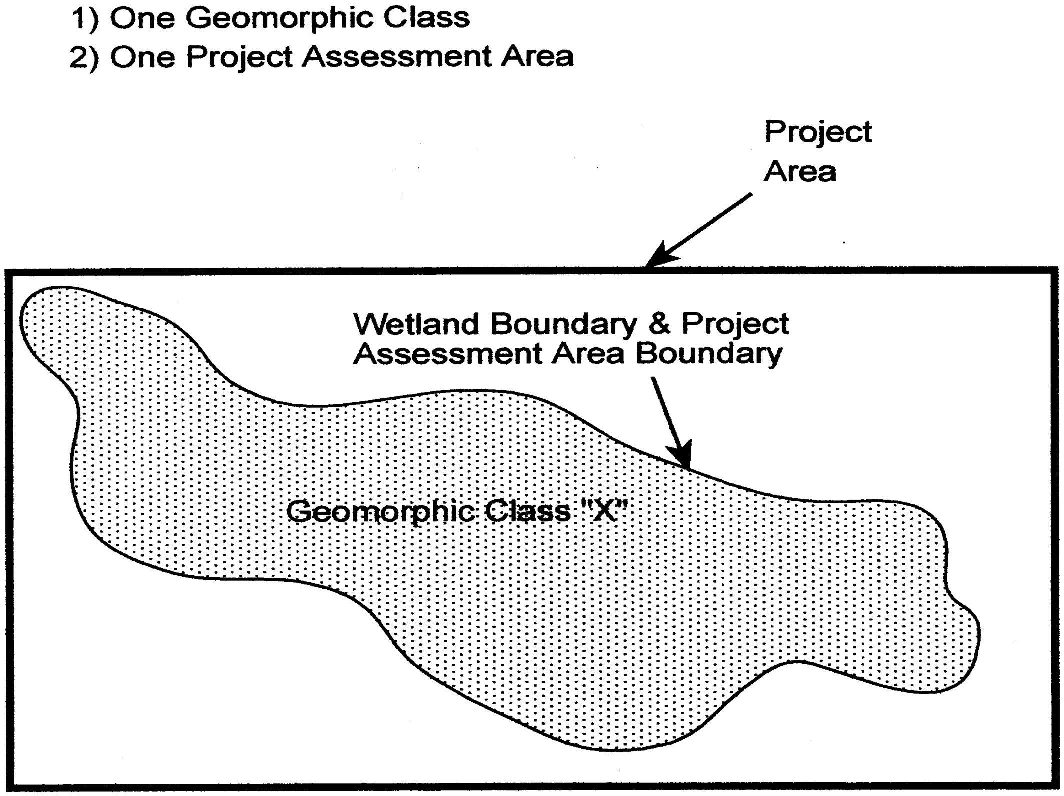
a. Delineation of the (PAA) boundaries
b. Estimate the geographic extent of waters/wetlands within the PAA
c. Estimate the proportion of waters/wetlands that fall into the subclass of waters/wetlands addressed by and not addressed by this draft operational Guidebook (*i.e.,* Precipitation-driven wetlands on discontinuous permafrost).
d. Complete a preliminary stratification of the PAA into community types using the Dichotomous Key (Table 42). Consult the appropriate NRCS Soil Survey to determine the area soil types.
e. Estimate the geographic extent and type of proposed project impact(s).

It is critical that the PAA(s) be bounded and delineated correctly for three reasons:

First, and as introduced above, if the PAA includes uplands and waters/wetlands, then the PAA must be bounded such that only the portion that is part of the waters/wetland subclasses treated by this Guidebook is included in the assessment (Figure 64). Specifically, only precipitation-driven wetlands on discontinuous permafrost in Interior Alaska should be included in the PAA

Figure 64. HGM Assessment Bounding: One Geomorphic Class and One Project Assessment Area

Figure 64. HGM Assessment Bounding: One Geomorphic Class and One Project Assessment Area



used for HGM functional assessments. Recall, however, that sites that are not currently waters/wetlands due to natural or anthropogenic disturbance may still be part of the regional wetland subclass based on cyclic processes that may return them to reference standard conditions (see discussion of cyclic processes presented in Section V. of this Guidebook).

Second, if several HGM subclasses exist on the same project site, then separate HGM models must be used in the functional assessments of these areas. For Interior Alaska, only one Guidebook exists. For example, where precipitation-driven wetlands on discontinuous permafrost in Interior Alaska (*e.g.*, flat interfluves) occur adjacent to riverine waters/wetlands (*e.g.*, active channels and floodplains along the Tanana River), each waters/wetland should be assessed using a separate Guidebook and associated HGM models.

Third, if different stages of development and/or different disturbance regimes exist on the same project site, then separate functional assessments may need to be performed for each area (Figures 65, 66, and 67). For example, consider a project site that contains a wetland of a single subclass (*e.g.*, precipitation-driven waters/wetlands). A portion of this wetland is undisturbed, while another portion has been cleared. These areas may need to be separated into two assessment areas.

In addition to bounding the PAA, Step 3 also requires confirmation of mapping for waters/wetlands (Step 3, b), HGM subclasses (Step 3, c), vegetation community and/or soils types (Step 3, d), and project impacts (Step 3, e).

MINIMUM SUBMITTAL FOR FIELD WORK - STEP 3: WORKSHEET 5 (APPENDIX E)

Field Work - Step 4. Identify, verify, and document the rationale used for recognizing HGM classes and subclasses within the PAA.

a. Show/explain why the PAA or parts of the PAA are covered by the Guidebook.

An essential part of the field work for an HGM assessment is to build upon Office Preparation Step 3 to clearly demonstrate why certain parts or all of the PAA qualifies as a part of the subclass addressed by this draft operational Guidebook (*i.e.*, precipitation-driven waters/wetlands on discontinuous permafrost). Again, it is not acceptable to simply offer maps or air photos with lines on them and assert that part or all of the PAA does or does not fall into the subclass. The assessment team should use the descriptions of cartographic and field observations to develop rationale and/or criteria in order to recognize HGM classes and subclasses (a) on maps and photos, and (b) in the field. This process is necessary to establish the assessment report and findings as credible.

MINIMUM SUBMITTAL FOR FIELD WORK - STEP 4: WORKSHEET 6 (APPENDIX E)

Field Work - Step 5: Develop and refine a general description of existing conditions within the PAA. The description should include a discussion of geologic and landscape contexts, hydrology, soils, vegetation, faunal support/habitat, historic and current land uses, etc.

This step requires field observations and syntheses of existing conditions within the PAA with respect to geologic and landscape contexts, hydrology, soils, vegetation, faunal support/habitat, historic and current land uses, etc. In a sense, this part of the field work allows the assessment team the opportunity to profile the PAA and describe its condition with respect to the subclass profile and reference standard conditions developed in this operational draft Guidebook.

MINIMUM SUBMITTAL FOR FIELD WORK - STEP 5: WORKSHEET 7 (APPENDIX E)

Field Work - Step 6. Score the variables using criteria presented in the Guidebook. The variables should be scored, based on the following circumstances:

- a. Existing conditions
- b. Proposed project conditions (or alternatives 1,2,3, etc.)

The HGM models in this draft Guidebook rely on the use of several variables that are combined in a variety of ways in the calculation of the indices of function. Most of the variables are used in several indices. In order to streamline the functional assessment for a particular waters/wetland in a given condition (*e.g.*, current condition), each of the variables called by an individual model should be scored once and tabulated on a variable score field form (Appendix D). If future conditions (*e.g.*, anthropogenic disturbance) need to be assessed, each of the variables called by the model will need to be scored again, on separate forms that identify the assessment effort as being for the "with project" alternative(s).

On the variable score field forms, (Appendix D) the variables are arranged in alphabetical order. To perform an HGM assessment, each of these variables must be scored according to the measurement protocols detailed in the models.

Do not estimate variable conditions if measurements are required.
This will result in significant errors.

Record the measurement result, the associated variable score, and the team’s rationale in selecting the variable score on the variable score field form. Please note that the field forms include space for recording rationale or making comments on the decision to score a variable in a certain way. The author's intent is to provide model users with an opportunity to make notes on each variable score and to facilitate meaningful discussions at a later date. Use the comment/rationale column every time to document your team decision structure.

Figure 65. HGM Assessment Bounding: One Geomorphic Class, Two or More Assessment Areas

Figure 65. HGM Assessment Bounding: One Geomorphic Class and Two (or More) Project Assessment Areas

1) One Geomorphic Class
2) Two (or more) Project Assessment Areas

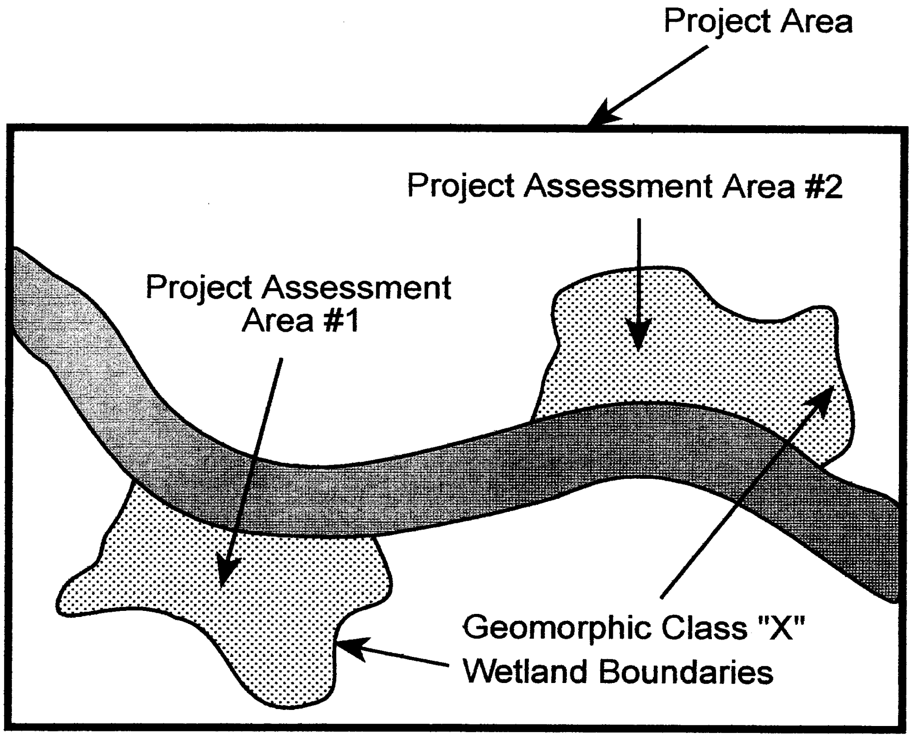


Figure 66. HGM Assessment Bounding: One Geomorphic Class, Two Project Assessment Areas - Example A

Figure 66. HGM Assessment Bounding: One Geomorphic Class and Two Project Assessment Areas - Example A

1) One Geomorphic Class
2) Two Project Assessment Areas

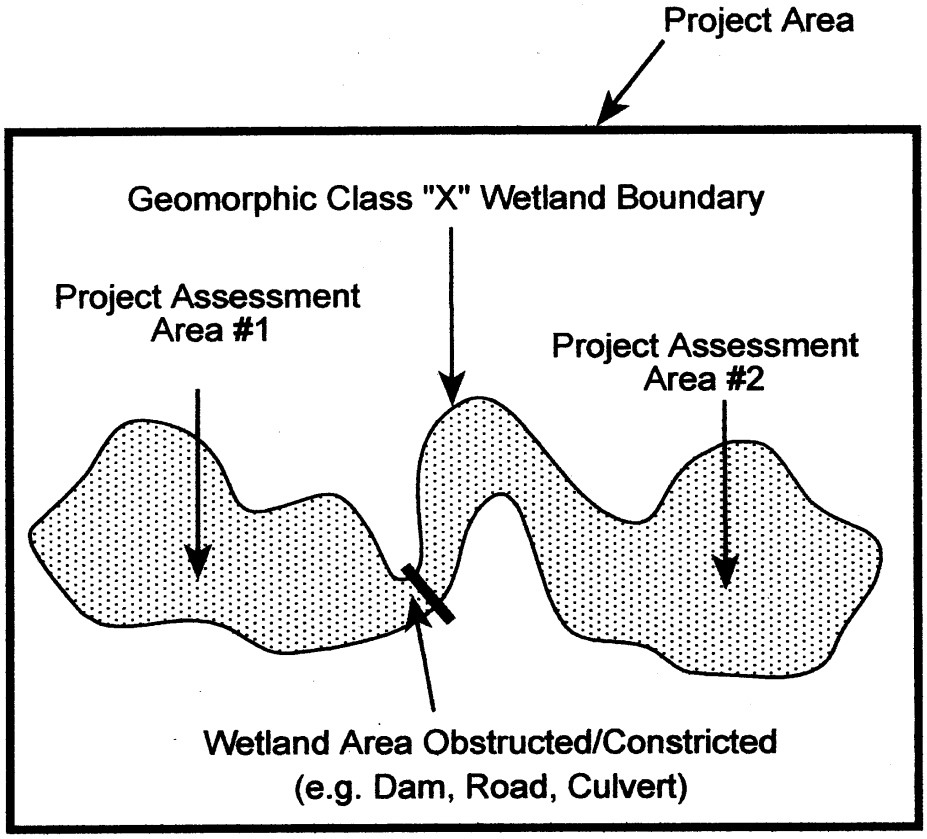
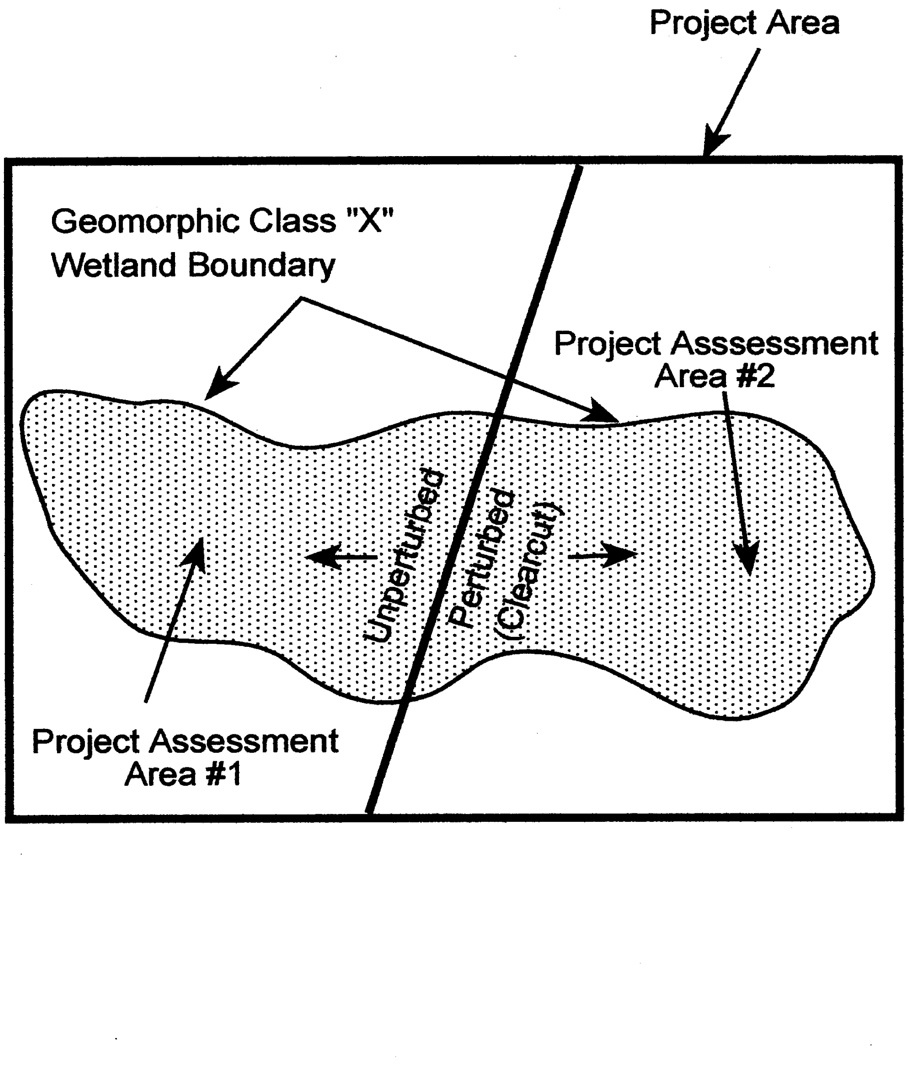


Figure 67. HGM Assessment Bounding: One Geomorphic Class, Two Project Assessment Areas - Example B

Figure 67. HGM Assessment Bounding: One Geomorphic Class and Two Project Assessment Areas - Example B.

1) One Geomorphic Class
2) Two Project Assessment Areas



Groups of variables require different ranges or scales of observation within the assessment area. For example, the variable V_{OH} requires observations of soil conditions within the waters/wetland; the variable V_{CONTIG} requires observation of the plant communities in a 100 foot buffer surrounding the project assessment area. The variable V_{SURUSE} requires observations within 1,000 feet of the PAA. Figure 7 summarizes the scale at which each variable should be observed.

MINIMUM SUBMITTAL FOR FIELD WORK - STEP 6:
WORKSHEET 8 (APPENDIX E)

Field Work - Step 7. Calculate the indices of function (FCIs) <u>in the field</u>. FCI calculations should be completed based on the following circumstances:

  a. Existing site conditions
  b. Proposed project conditions (or alternatives 1,2,3, etc.)

In order to streamline the functional assessment process, the functions and their corresponding functional capacity indices are summarized in functional score field forms. The calculations and review of the preliminary assessment results should be reviewed by the assessment team members **<u>in the field</u>,** not in the office.

Again, the functional score field forms include space for recording rationale or making comments on the decision with the intent of facilitating meaningful discussions at a later date. If the functional assessment is conducted based on proposed project conditions, the rationale/comment section should include any assumptions that were made.

MINIMUM SUBMITTAL FOR FIELD WORK - STEP 7:
WORKSHEET 9 (APPENDIX E)

3. Preparation of an HGM Assessment Report

Consistent with the guidance offered in Table 41, a written report of all HGM assessment results should be prepared by the assessment team. As shown in this table, the assessment report should include:

1. **Introduction:** This section shows the location of the site and describes the proposed activity and anticipated types of activity. This section should include maps of the site and documentation of the proposed activity (*e.g.*, construction plans), is available.
2. **Assessment report objectives:** This sections states the purpose for conducting the functional assessment and discusses how the results will be applied to the proposed project.
3. **Description of the project assessment area:** This section should include a detailed description of the site conditions and relevant landscape context, and should be based on the preliminary profile that was developed in Field Step 5.
4. **Methods:** This section discusses the methods that were used throughout the assessment process, including (a) the HGM approach, (b) functional assessment of waters/wetlands, and (c) application of the results to the proposed project.
5. **Results:** This section presents the results of the functional assessment based on (a) existing conditions in the PAA, and (b) proposed project conditions.

6. **Conclusions:** This section provides a synthesis and interpretation of assessment results.
7. **Literature Cited:** Discussions throughout the report should be bolstered with citations from current literature. All citations should be listed in the Literature Cited section.
8. **Appendices:** The appendix section should include (a) multiple photographs of the site, (b) copies of the assessment data sheets, (c) calculations of FCU's, and (d) resumes of the assessment team members.

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